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April 25, 2012

Senator Tony Avella
Senate Public Forum on Fracking
NY Legislative Office Building
Hearing Room B
Albany, New York 12248

RE: Hydrogeologic Justification for Banning Hydraulic Fracturing throughout New York State and the Delaware River Basin (Testimony provided at the Senate Democratic Conference Public Hearing on Fracking Legislation in Albany, New York on April 25, 2012)

Dear Senator Avella,

HydroQuest and Mid-Hudson Geosciences, two professional hydrogeologic consulting firms, hereby provide testimony on behalf of the Delaware Riverkeeper Network (925 Canal St.; 7th Floor, Suite 3701; Bristol, PA 19007; 215-369-1188; drn@delawareriverkeeper.org) in support of draft NYS legislation designed to protect New York State's groundwater and freshwater resources. Delaware Riverkeeper Network is a nonprofit membership organization dedicated to the Delaware River watershed, working to protect and restore the Delaware River, its tributaries, habitats and communities. Part of the Delaware River watershed lies within NYS.

Today's gas field technology is not capable of isolating our freshwater aquifers from gas field contaminants. For this reason, there are no hydrofracking procedures which can assure protection of our finite and valuable water resources now or into the future. As a result, toxic and carcinogenic contaminants are already and will continue to move with our groundwater flow systems to our most prolific valley bottom aquifers and rivers. The enormous magnitude of planned gas well installations (i.e., thousands) will result in large-scale and widespread water contamination that cannot be remediated. As aptly stated by Cyla Allison, Ph.D. of the Eight Rivers Council, WV: "*The damage may not show up for years, the ruination of our water may at first be invisible and in the end irreparable.*"

The <u>only</u> viable means of protecting our groundwater and surface water resources now and for future generations is to immediately institute a New York State and Delaware River watershed ban on hydraulic fracturing. Perhaps sometime in the future alternate sealant technologies and non-toxic means of fracturing geologic formations will be developed. Only at that time should consideration be given to permitting hydraulic fracturing for gas and oil extraction. At this time, the only justifiable and scientifically defensible means of protecting New York State's water resources is by enacting S4220A-2011 which prohibits the use of hydraulic fracturing in the extraction of oil and gas.

The extraction of natural gas and oil reserves using hydraulic fracturing presents significant risk to the environment (S4220A-2011). Our testimony today targets, but is not limited to support of, the following draft NYS legislative bills:

S4220A-2011: Prohibits the use of hydraulic fracturing in the extraction of oil and gas

S6261-2011: Suspends hydraulic fracturing for the extraction of natural gas or oil

S1230-2011: Establishes a moratorium on the issuance of permits for the drilling of wells and prohibits drilling within two miles of the New York City water supply infrastructure

S1234-2011: Relates to the regulation of the drilling of natural gas resources [this bill includes provisions to prohibit drilling within the NYC and Delaware River watersheds]

S2697A-2011: Relates to natural gas development using hydraulic fracturing

S5592-2011: Suspends hydraulic fracturing for the extraction of natural gas or oil [only provides for suspension until June 1, 2012; this date would need to be increased]

Herein, we provide a synopsis of many of the key hydrogeologic justifications that individually and collectively support a permanent ban on hydraulic fracturing throughout New York State, the Delaware River basin, and beyond. All citations are herewith incorporated by reference:

- **The durability and mechanical properties of gas well sealant materials, primarily cement and steel, are not sufficiently advanced such that freshwater aquifers will be safely protected for even as long as 100 years, much less the hundreds of thousands of years required**. Failure of cement sheaths (i.e., the cement designed to seal well casing to bedrock) due to shrinkage, debonding, cracking, corrosion, and other mechanisms are well documented throughout gas industry literature[1]. The aquifers we enjoy today took about a million years to form. Without unnatural alteration from gas drilling activities, they should be capable of providing potable water for future generations for another one million plus years. Industry documentation establishes that, under the best of circumstances, cement and steel used to effect zonal isolation may last up to 100 years and 80 years, respectively – often far less. Recognized sealant failure mechanisms, inclusive of corrosive gases, will degrade "protective" surface casings regardless of whether there is only one or nine. The lack of a durable sealant technology should single handedly be recognized as sufficient rationale to immediately halt all hydraulic fracturing activity and gas well drilling permits throughout all of New York State and the Delaware River basin;

- **Upward hydraulic gradients in failed wellbores will provide contaminant pathways.** When failure of protective cement sheaths and casing material does occur in 100 years or far less (see above), breached confining beds that now naturally serve to separate and protect our freshwater aquifers will result in long-term contamination by naturally-occurring deep chemicals and gases, toxic hydrofracking chemicals, and saline water. In some hydrogeologic settings, upward hydraulic gradients will force contaminants into overlying aquifers via failed wellbores. A crack in a cement sheath of only 0.001 inch is sufficient to allow upward gas migration;

- **Gas production wells placed within seismically active regions where ground shaking/motion will damage the integrity of cement seals will significantly increase the risk of contaminant dispersal upward into overlying aquifers.** While assessment is warranted to establish acceptable threshold values, appropriate maximum values for Richter magnitude and modified Mercalli shaking-vibration intensity may be on the order of 3.0 (III) or less for both. Philadelphia, PA, for example, recently experienced structural damage to buildings from an earthquake some 200 miles to the SW. Clearly, if

the related earthquake intensity of 4.7 could damage buildings, it was also likely to result in damage to the integrity of cement sheaths, especially with repeated seismic events through time. Seismic hazard risk must be evaluated over the duration of the life of aquifers – 1,000,000 plus years. Much of New York State is seismically active. For example, HydroQuest used a USGS model to assess earthquake probability for Howes Cave, NY[2]. Earthquake probabilities for a 5.0 magnitude earthquake were found to be 2-3%, 10-12%, 15-20%, 60-80%, and 80-90% for 100 year, 500 year, 1,000 year, 5,000 year, and 10,000 year time periods respectively. A similar assessment was conducted for Philadelphia[3&4]. Thus, if sealant material doesn't fail from the mechanisms discussed in the first bulleted item above, ground shaking from earhquakes will assuredly result in grout failure (e.g., cracking) in a relatively short period of time, followed by contamination of freshwater resources;

- **Repeated hydrofracking episodes in gas wells will also result in cracking and failure of cement sheaths that are intended to protect our freshwater aquifers.** Repeated stress from multiple fracking episodes per well, as well as from fracking in nearby wells, has a high likelihood of degrading the integrity of cement sheaths used to isolate freshwater aquifers. Once cracked, cement sheaths will provide a contaminant transport pathway into overlying aquifers;

- **"Protective" setback distances between gas wells and water resources, as proposed in state regulations, do not allow for groundwater flow, the migration of contaminants in groundwater, and ARE NOT based on any empirically-based data.** Furthermore, setback distances are erroneously established from individual vertical wellbores vs. from the outer boundary of horizontal wellbore arrays[5]. If groundwater flow was accounted for in statewide regulatory documents, there could not be any setback distance that would be protective of down gradient contaminant receptors. The concept of setback distance is inappropriate hydrologically[7]. However, because regulators seem to insist on allowing the injection of toxic contaminants into our groundwater flow systems, it is of some use to provide scientifically-based setback distance numbers. To date, HydroQuest has provided the only empirically based value for setback distance[5]. Pumping tests can be used to establish hydraulic interconnections along bedrock fractures[4&6]. Two large-scale aquifer tests were analyzed to conservatively estimate potential regulatory setback distances, both within the Delaware River basin in NYS locations. One test was conducted in the Fleischmanns area and the other in Deerpark[8]. Minimum fracture interconnection distances of 2,100 feet and 4,300 feet, respectively were documented. These tests show that homeowner wells connected via bedrock fractures to gas production wells will have a high likelihood of groundwater quality degradation when well sealant materials fail in gas producing wells. Based on these analyses, regulatory based setback distances from gas production well arrays should be greater than 4,300 feet from water bodies (e.g., reservoirs, lakes, rivers, streams, wetlands), dams, pipelines, homeowner wells, and other vulnerable features. Based on aquifer test results in NYS, lesser gas well setback distances, inclusive of all horizontal projections, have a high probability of degrading groundwater, wells, and surface water bodies from natural gas and Light Non-Aqueous Phase Liquid (LNAPLs) excursions along fracture and borehole pathways. Hydraulic fracturing should not be permitted in the absence of empirically-based setback distances from gas well horizontal arrays;

- **Toxic fracking fluid contaminants, when injected into gas wells, move within the deep basin hydrologic flow system that ultimately discharges upward into our major river valleys (i.e., where our major groundwater aquifers are used by large population centers).** Even if dilution of contaminants occurs during flow, population centers are likely to experience low level chronic exposure to toxic chemicals. The concept of knowingly and intentionally permitting the subsurface discharge of a chemical soup of toxic contaminants into deep and shallow groundwater flow that will become drinking water and surface waters defies all logic. Hydrofracking is analogous to running a

slowly leaking hose from an oil drum onto the ground near a drinking water well. It's not a question of whether contaminants will degrade well water, but rather one of when and in what concentration. The cumulative impact of injecting millions of gallons of toxic chemicals from thousands of gas wells into deep and shallow groundwater flow systems that will surface in our valley bottom aquifers is cause enough to pass S4220A-2011 which seeks to prohibit the use of hydraulic fracturing in the extraction of oil and gas;

- **The interconnection of gas-rich fractures, some of which connect with the same fracture sets tapped by homeowner wells, has resulted in exacerbated and increased natural gas release in homeowner wells – often far in excess of natural background conditions.** The physical process of hydraulic fracturing successfully interconnects numerous pre-existing joint sets and faults over great distances. Gas migration along fracture pathways has resulted in significant health and safety concerns, including explosive risk. This situation is exacerbated as cement sheaths and casing material degrade[9&10]. In turn, increased fracture interconnection with homeowner wells provides contaminant transport vectors that were not formerly present[11];

- **All New York State aquifers are not afforded equal protection. Until NYS aquifers are regulated equally, a statewide ban on hydraulic fracturing should be maintained.** For example, the revised draft SGEIS gas drilling regulations seek to provide rationale for providing greater protection for NYC and Syracuse watersheds, as well as for high-yielding primary aquifers. The extra protection for the New York City watershed is not enough and needs to be expanded to all of New York based on the great similarity in bedrock lithology, as well as groundwater and surface flow characteristics. Groundwater protection sought for primary aquifers and other portions of watersheds must adequately take into account the simple hydrogeologic fact that the surrounding watershed areas up-gradient of primary aquifers all drain down-gradient to these primary aquifers, as well as reservoirs. Simply put, if gas drilling methods are indeed safe – ALL New York State watersheds and aquifers should be treated equally;

- **Hydraulic fracturing should be banned because tracer addition to all fracking waters is not mandated, resulting in no sound protection for adversely impacted homeowners. Tracers must be required.** The costly burden of legal, chemical, and hydrogeologic proof incumbent upon adversely impacted homeowners is onerous and overwhelming. This situation must be remedied BEFORE any additional gas drilling is permitted in NYS. An effective remedy can be accomplished by simply requiring the use of tracers in all fluids unique to the specific gas company drilling, fracking, and producing from gas wells. Non-naturally occurring tracers **must** be added to all gas field drilling and hydraulic fracturing fluids so that contaminant excursions can reliably and immediately be assigned to gas companies, or not, without extensive cost and litigation to homeowners. This measure will afford homeowners one key environmental protection the NYSDEC is charged with providing and will provide assurance of rapid connection to alternate water supplies by gas companies should their actions result in groundwater contamination. There is absolutely no reason to not fully institute this mandatory regulation immediately. Tracer selection, concentrations and required detection limits should be determined by an independent panel of tracer experts. Failure to adopt this recommended regulation essentially leaves adversely impacted homeowners with no financially viable and time-effective recourse and, thus, should provide scientific and legal cause to both discard the revised draft SGEIS entirely and advance S4220A-2011 which seeks to prohibit the use of hydraulic fracturing in the extraction of oil and gas;

- **Existing maximum contaminant levels (MCLs) are not sufficient and must be amended to reflect all gas field contaminants. Failure to promulgate drinking water standards that take into account ALL fracking chemicals injected underground should be cause to advance S4220A-2011 which seeks to prohibit the use of hydraulic fracturing in the extraction of oil and gas.** The original MCLs for drinking water were not formulated with consideration given to massive underground injection of millions of gallons of toxic chemicals throughout most of New York State. Furthermore, they cannot be formulated for unknown proprietary, non-disclosed, and potentially toxic, chemicals that existing and draft regulations would allow. The concept of knowingly and intentionally discharging unknown toxic chemicals into our finite state water resources with full legal and regulatory approval is mindboggling. Adequate drinking water protection cannot be assumed based solely on dated and limited MCLs. The gas drilling regulations in New York State should not be contemplated as complete until such time as toxicologists have fully reviewed **all** gas field chemicals and worked with State Health Department experts to revise and upgrade MCL drinking water standards;

- **Hydraulic fracking fluids are not designated as point source discharges to aquifers. The failure of hydraulic fracturing regulations to adopt this definition provides a lack of acknowledgement that each gas well IS a significant groundwater contaminant source.** Chemical additives in drilling mud and hydrofracking fluid that are forced into geologic formations via gas wells are NOT, but should be, officially designated as point source discharges. Some of these chemicals will migrate into freshwater aquifers, homeowner water supplies and surface waters;

- **Pre-existing networks of fractures, faults, and joints are present in bedrock and are potential pathways for migration of toxic fracking fluids and gas from gas wells to near surface bedrock and unconsolidated overburden aquifers.** The mere presence of natural fracture networks is reason enough to ban fracking. Long before development of the petroleum industry, thousands of openings existed in subsurface bedrock from rock formations 10,000 feet or deeper to near surface outcrops. Professor Robert Jacobi [12] at the University of Buffalo has been studying fractures in New York State over a period of 36 years. He has made maps which look like a black mass of lines everywhere on the southern tier of New York. He has found that methane measurements in soils indicate the presence or absence of vertical fractures. The background concentration of methane is about 4 ppm where no fractures have been detected. Higher concentrations ranging from 40 to 1000^{+} ppm have been found over bedrock fractures buried beneath the soil. Thus, there is already a system of fractures developed from bedrock to the land surface in potential drilling areas before drilling and fracking begin;

- **Another pre-existing pathway for contaminant flow is through the boreholes of old abandoned wells.** Many wells were drilled along the southern tier of New York long before drilling permits were required. Many of the old wells were not properly plugged when abandoned. DEC has a program to find and plug old wells, but the success of that program is unknown because the total number and locations of individual wells are unknown. Until knowledge that all old wells are properly plugged is available, fracking must be banned.

- **The process of hydrofracking increases the interconnectivity of the network of potential pathways for fluid transmissivity through bedrock.** Spreading contaminated fracking fluids through such natural and manmade fractures is obviously a reason to ban fracking. The fracking process increases the density of contaminant pathways by exerting forces on the order of 10,000 pounds per square inch on the fluids and rock material, by introducing 4 to 5 million gallons of toxic fracking fluid into thin bedrock openings, which can transmit contaminants from gas wells to near surface aquifers. When pressure declines in gas producing wells, another hydrofrack treatment is used

to revitalize gas flow. Increasing the pressure inside the wellbore and out into geologic formations can only force fluid and gas upward through pathways of least resistance;

- **In a recently published paper, through the use of computer simulation, Tom Myers[13] has estimated that pressure after fracking takes about 300 days to return to pre-injection levels.** The high pressures and injection of fluid upsets the hydraulic equilibrium of the fluid-gas-rock system and it takes about 3 to 6 years for the system to reach a new equilibrium. During periods of such variable semi-unstable conditions, pressurized fluids not only rise up the wellbore, but they will rise up any other opening in the vicinity of the well. Myers estimates that contaminant fluids and gas can rise up from fracked wells to aquifers in less than 10 years. However, by the time such contamination is discovered, aquifers will be irreparably damaged. Remediation of gas field contaminated groundwater is impossible. A fracking ban will eliminate large scale pollution of water resources resulting from the hydraulic fracturing processes.

Conclusion

The risk and assured contamination of ground and surface water supplies is the reason to ban hydrofracturing in New York State and the Delaware River basin. The use of fracking fluids containing contaminants and the fact that the petroleum industry is exempt from hazardous waste regulations are potential high risk factors contrary to the protection of public health in New York State. The frequency of natural and pressure-induced fracture networks and abandoned wells increase the likelihood of vertical migration of contaminants upward from gas wells to aquifers. Multiple fracking treatments for each well increases the time of pressurization of the reservoir and the potential for movement of fracking fluids to higher levels in bedrock. Seismic events (earthquakes) have been documented in injection wells as induced by over-pressurization, which can also result in additional interconnections between natural and frack-induced fractures. Inherently the fracking process has the potential to damage the cement sheath around well casings and therefore allow leakage of well fluids. All of these factors indicate that fracking has the capability of creating openings in rock which will help in gas production, but can also conduct contaminants upward with potential discharge to aquifers and surface waters. The use of toxic chemicals in fracking fluids and the potential for upward flow and contamination of aquifers and surface waters are reasons to ban hydrofracking in New York. To allow the petroleum industry to destroy our precious water resources is imprudent. Once contamination is discovered and documented, the profits of the industry will be long gone. Remediation will be impossible. As citizens of New York, we implore the Legislature to protect the water resources of the people of the State.

Respectfully Submitted,

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Reference testimony may be viewed at: http://hydroquest.com/Hydrofracking/ except where noted:

[1]: HydroQuest DRBC Draft Regulations Comment Report 4-09-11. [Includes April 9, 2011 DRBC Comment Report Figures (Folder includes 21 figures & 2 addenda)]
[2]: HydroQuest – Schoharie Valley Watch NYS dSGEIS Comment Report 1-10-12. Found at: http://hydroquest.com/Schoharie/ (see folder titled: Earthquake Probability Figures/)
[3]: Seismic Hazard Expert Fact Sheet Front 9-4-11
[4]: Seismic Hazard Expert Fact Sheet Back 9-4-11
[5]: HydroQuest – Schoharie Valley Watch NYS dSGEIS Comment Report 1-10-12. Found at: http://hydroquest.com/Schoharie/ (see folder titled: Setback Distance from Gas Well Laterals)
[6&4]: HydroQuest – Schoharie Valley Watch NYS dSGEIS Comment Report 1-10-12. Found at: http://hydroquest.com/Schoharie/ (see folder titled: Fracture Pumping Test Schematic)
[7]: Palmer – Potential Contaminant Paths from Hydraulic Fracturing of Shale Gas Reservoirs [This white paper is very important and should be read by all]
[8]: Fracture Interconnections (Deerpark)
[9]: Aquifer Protection Expert Fact Sheet Front 9-2-11
[10]: Aquifer Protection Expert Fact Sheet Back 9-2-11
[11]: Graphic Figure – Gas-Contaminant Migration Pathways
[12] Jacobi, R.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. Fakundiny, R. Jacobi, and C. Lewis (eds.): Tectonophysics, v. 353, page 75-113.
[13] Myers, T., 2012, Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers, Ground Water, National Ground Water Association, preprint, accepted for publication February 2012.