# Delaware River Basin Commission (DRBC) Consolidated Administrative Hearing on Grandfathered Exploration Wells

*Prepared for:*

**Delaware Riverkeeper Network**
**and**
**Damascus Citizens for Sustainability**

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# 1. Executive Summary

Demicco & Associates, LLC has been retained by the Delaware Riverkeeper Network and Damascus Citizens for Sustainability to provide expert review and opinion on the Delaware River Basin Commission's (DRBC) decision to exclude 11 Pennsylvania state permitted wells from DRBC review of exploratory wells under its June 12, 2010 and July 23, 2010 Supplemental Determinations. The decision to exclude the 11 wells has resulted in the Consolidated Administrative Hearings on actions of the DRBC relative to exploration wells being drilled into the Marcellus Shale. Specifically the Hearing will address DRBC decisions to:

- Regulate so-called "exploratory wells" and subject them to DRBC's temporary moratorium (challenge brought by Northern Wayne County Property Owners' Alliance, joined by Newfield and Hess Corporation as interested parties)
- Exclude certain state-permitted wells from DRBC review of exploratory wells, (challenge brought by the Delaware Riverkeeper Network (DRN) and the Damascus Citizens for Sustainability (DCS))

The findings in this report are based on the material provided by DRN and DCS included within the references presented at the end of the report. Should additional materials and reports be disclosed as part of the Hearing process the findings and conclusions in this report are subject to revision.

### Conclusion 1 - Grandfathering

In our opinion, the 11 wells listed as grandfathered exploration wells do not meet the DRBC criteria of exploration well due to the lack of an appropriate certification of Intent by Well Operator to Plug the Well. The Marcellus Shale in sections of Wayne County, PA may exceed the average thickness of the shale unit throughout much of the rest of the state and vertical wells can expose a significant volume of Marcellus shale for gas production. True exploration wells would be sealed and decommissioned immediately upon completion.

### Conclusion 2 – Exploratory Drilling Impacts

Drilling of exploratory holes can, with lack of regulatory oversight, cause as much if not more harm to the water resources of the Delaware River Basin than a properly permitted and installed nontraditional horizontal well. Specific problems with exploratory drilling are the apparent dominance of air rotary drilling techniques to increase speed of drilling and decrease the cost of drilling. Air rotary drilling uses generally uses either naturally occurring ground water or a source of potable water and compressed air to remove the rock cuttings from the borehole as well as cooling the compression air hammer drill bit. When extensive fractures are encountered during air rotary drilling, large volumes of ground water approaching 1000 gpm can be blown from the borehole. Extensive fracturing will also cause problems with borehole stability and resulting problems with achieving a proper grout seal. Grout seals are the single most important element to protecting ground water resources from contamination as presented within this report.

### Conclusion 3 – Water Resource Impacts

Damage to ground water resources can occur through both negative impacts on quantity and quality. The month long process of drilling may exceed the 100,000 gallons per day (gpd), 3.1 million gallon per month (mgm) threshold for an allocation permit if numerous fractures are encountered during air rotary drilling. Again, adequate and complete grouting of the gas well from the principal fresh water aquifers is critical to protect the water resources. Leakage along the grout wall can promote vertical upward movement of low quality water if over pressure from deeper zones in the well creates an upward gradient. Large movement of gas and deep brine fluids into shallow zones will have negative water quality impacts on both water resource wells and streams. However, vertical downward leakage of freshwater into newly exposed and opened fracture zones from air rotary drilling can remove fresh water from the shallow aquifer zones. Loss of fresh water to deeper portions of the aquifer would diminish summer base flow to headwater streams. The increased runoff from site construction and road construction will also have a negative impact on the quantity summer base flow by decreasing the amount of rainfall that would normally reach the ground water.

## Conclusion 4 – Exploratory Well and Grouting Efficiency

The drilling of the stated "exploratory" hole is done predominantly by air rotary methods based on the examined documents obtained to date. This results in an underbalanced borehole at depth where formation pressure exceeds borehole pressure. When formation pressure exceeds borehole pressure water, petroleum and gas, if present in the formation enter into the borehole and are brought up to the surface. The result is even greater strain on the borehole increasing the importance of properly grouting the well. Regulatory changes are currently being proposed in Pennsylvania indicating the inadequacies of the current regulatory procedures. Air rotary drilled wells, if drilled quicklywithout maintaining directionality, will potentially drift off vertical. The rapidly varying rock types encountered in Pennsylvania will create an uneven borehole with a wide borehole where soft shale is easily removed and a narrower borehole when passing through hard sandstones. Both the verticality (i.e. deviations from a purely vertical bore) and uneven borehole width will have negative impacts on the efficiency of the grout installation. It should be noted that State of Pennsylvania requires only a 1 inch grout diameter, whereas the State of New Jersey, where gas wells are not being drilled, requires a two inch diameter grout seal on any borehole annulus (eg. water, oil, geothermal, water, etc.).

The four issues described above result in an overall summary conclusion. It is my opinion, given with a reasonable degree of scientific certainty, that the grandfathering of these so-called exploratory wells is not protective of the Special Protection Waters of the

Delaware River Basin due to lack of regulatory review by DRBC, reliance on outdated and inadequate drilling regulations that are currently undergoing modification, and uncertainty in proper development of grout seals with the use of air rotary exploration drilling into an over-pressurized geologic zone.

# 2. Introduction

The primary topic of this expert report focuses on water resource issues, specifically possible water usage and water resource contamination which can occur during exploratory drilling operations. Mr. Peter Demicco is the author of this report and has over 28 years in ground water resource development including water well design, water resource and allocation permitting, ground water recharge wells, and deep geothermal wells. Part of his experience includes several years of appointment to the New Jersey Well Drillers Licensing Board for the New Jersey Department of Environmental Protection. Mr. Demicco is also a registered geologist in the State Of Pennsylvania. His curriculum vita is attached to this report (Exhibit 1).

## *2.1 Discussion of Drilling Techniques*

The first topic of the presentation will include a discussion of drilling techniques including background experience in both mud and air rotary drilling. Volumes of water needed vary based on drilling techniques and conditions encountered during drilling. In addition, air rotary drilling can result in large volumes of water production when fracture zones are encountered along with borehole stability issues. The quality of this water will vary with depth of materials encountered with naturally occurring contaminants and radionuclides increasing with depth.

## *2.2 Discussion of Well Grouting*

The second topic is the potential long term impacts that can occur if casing or grout failure occurs from unexpected drilling conditions or improper grouting. Grout and casing failure are jointly caused by rock shearing and pressure changes in the formation. These impacts range from casing deformation to breakdown of the grout seal, both often occur together. The breakdown of the grout seal potentially leads to migration of water from one aquifer zone to another, vertical upward movement of naturally occurring non-potable water into potable zones and vertical downward movement of aquifer water into a non-potable zone. The latter condition would potentially result in diminished aquifer resources and potentially have a negative effect on stream base flow. In addition, migration of water even within potable aquifer zones can have negative consequences. The most common example of this is migration of water with dissolved oxygen into an anoxic zone containing specific minerals, most notably pyrite. With the introduction of oxygen into such zones, dissolution of pyrite will result in water with low pH and high iron and either elevated sulfate or sulfide concentrations. Arsenic contamination can occur as arsenic is known to be a secondary element in iron pyrite.

Multiple reports and publications were reviewed for this opinion. The documents most germane to this report are presented as exhibits attached to this report. Several background documents also reviewed for this report include the followings:

- PaDEP's existing Chapter 78 Oil and Gas Well Regulations
- PaDEP's proposed amendments to Chapter 78 Oil and Gas Regulations in the Pa Bulletin (July 10, 2010)
- DRBC's May 19, 2009 Executive Director Determination (EDD)
- DRBC's June 14, 2010 Supplemental Executive Director Determination (SEDD)
- DRBC's July 23,2010 Amendment to Supplemental Executive Director Determination
- DRBC's Delaware River Basin Code: 18 CFR Part 410

# 3.0 Background Geology

A cursory overview of the geology of Wayne County is needed in the context of drilling. The background overview of the geology has been obtained from "Ground water in Northeastern Pennsylvania" by S. W. Lohman. (1937; 2nd printing, 1957). Exhibit 2 presents an updated review of the stratigraphy of northeastern Pennsylvania from Frank Fletcher. Generally, the Upper Devonian rocks of the Catskill Continental Group are the dominant bedrock unit below any glacial deposits. The Catskill Group consists of various non-marine sandstone, shale and conglomerate units. These rock units were largely deposited in fluvial (i.e. riverine) environments. The rocks exhibit the fining upward characteristics of the classic fluvial sequence. The fining upward sequence starts with coarse sandstones and some conglomerates channel deposits at the base with finer grained river overbank siltstone and shale at the top of the sequence. These cycles repeat throughout most of the sequence of unit.

Wells drilled into the Catskill Group produces abundant water for nearly all domestic needs (Lohman, 1957). This geologic group is the most important water bearing unit in Wayne County and provides not only domestic and other human needs, but provides a large part of the base flow to local surface waters along with flows from surficial glacial deposits. The sandstones form the largest water bearing group of sediments. The Catskill Group can range in thickness from 1,800 feet thick in Susquehanna County in the north to over 6,000 feet in Carbon County (see Lohman, 1957).

Beneath the Catskill Group non-marine units are marginal marine units of the Portage Group dominated in this area by the Trimmers Rock Formation. These marine units contain typically coarsening upward deposits of off shore deltaic deposition. Soft shale from deep water environments forms the basal units and, as the delta builds out into the shallow seas, coarser and cleaner sandstones are deposited near the top of the sequence. This Group is not considered an aquifer in Wayne County due to depth, probable salt and hydrogen sulfate concentrations. This Group, as with the Catskill Group will exhibit rapidly varying drilling conditions. The unit is roughly 1,500 feet thick in the eastern part of northeast Pennsylvania thickening to 3,000 feet westward into Luzerne County (see Lohman, 1957).

The Hamilton Group, which includes the upper Hamilton Formation (see Lohman, 1957 for an in depth discussion of stratigraphy) and lower Marcellus Shale, underlies the Portage Group. The Hamilton Formation represents shallower marine waters than the depositional environment of the Marcellus Shale. In the Hamilton Formation, beds of fossiliferous olive-gray to dark grey sandy shale and sandstone with locally thin beds of calcareous shale to coral limestone and coquinite can be found (see Lohman, 1957). This unit is on the order of 1,100 to 1,600 feet thick (see Lohman, 1957). The Marcellus Shale is a gray to black shale with some fine sand in locations and contains pyrite indicative of the anoxic environment that resulted in the formation of natural gas. The thickness of the Marcellus Shale is on the order of 700 to 900 feet in the eastern counties of northeast Pennsylvania, including Wayne County) decreasing to 400 feet in the western counties of northeastern Pennsylvania (see Lohman, 1957).

The Onondaga Formation, a cherty limestone, underlies the Marcellus Shale in the northeastern portion of Pennsylvania. This formation has been listed as the target formation by some drilling operations presumably to ensure that the full thickness of the Marcellus Shale has been penetrated.

Each of the 11 grandfathered wells will have to be drilled through this highly variable geologic column. The amount of the Catskill Group penetrated will vary the most depending on location of the well.

# 4.0 Well Permits

Several well permits and related documents were reviewed including the Docket NO. D-2009-18-1 on the Stone Energy Corporation Matoushek 1 Well (Exhibit 3). Only this Docket provided any details on the actual drilling of an gas well into the Marcellus Shale. The other exploratory well permits reviewed had some details on specific aspects of the drilling including the MSDS sheets for material to be brought on-site, the "Preparedness, Prevention, and Contingency Plan, Wayne County Field, Wayne County, Pennsylvania" report, and site construction details. (see Exhibit 4, Woodland Mgmt Partners 11: Exhibit, 5 HL Rutledge 11; and Exhibit 6, VE Crum 11). However, the permits were completely silent on the actual drilling methods, well construction methods and the critically important grouting methods. It is important to note that the materials and grouting techniques will not vary greatly from an exploratory hole to a production well.

The Stone Energy Corporation, Matoushek 1 well was reported in the Docket (Exhibit 3) to be drilled by air rotary methods to the top of the Marcellus Shale, and then the Marcellus Shale was cored using a 3 percent potassium chloride solution. Air rotary drilling is different than mud rotary drilling in that air and chemicals are used as the fluid to cool the drilling bit, lift the cuttings from the hole, and lubricate the drill column. Usually foaming agents are used with air rotary drilling. The borehole should be underbalanced in this process, in other words the pressure of water and gas in the formation should be greater than the pressure created by the air compressor. As a result, oil, gas and brine ground waters will be pulled up to the ground surface during this type of drilling. Air drilling should be significantly faster than mud rotary through the use of air hammer drilling bits and with less deterioration and damage to the drill bit. However, there is a greater risk of well blowout if overpressurized (i.e. greater than atmospheric pressure at the depth of the overpressure area) zones are encountered as the borehole is advanced.

As stated above, the other permits (the grandfathered exploratory well permits) were silent on drilling method(s), so there is no information available to evaluate the risks associated with the drilling technique that will be used on these wells. A discussion of drilling methods should be mandatory in these permits. -. Typically, mud rotary drilling would be used to drill through the gas producing Marcellus shale.

Several other significant differences with air rotary drilling versus mud rotary exist. The compressed air injected during drilling also lifts the water encountered in borehole and surrounding fractures to the surface. Air drilled wells can remove significant volumes of water during the drilling process. Exhibit 7 presents a set of e-mails discussing the volume of discharge to the Valley Joint Sewerage Authority. Significant volumes of water are reported to have been removed during drilling of the Matoushek well.

Where large fractures are encountered, borehole collapse can occur further enhancing the water flow and slowing drilling. A mud cake is not formed on the borehole of an air drilled well to diminish water movement into or out of fracture zones. As a result air drilling allows for greater movement of water between fracture zones during drilling. On occasion, I have observed drillers of geothermal wells stop and grout up sections of failing rock before drilling deeper. Conventional wisdom was that very few high water yielding fractures existed below 500 feet. Again, I have seen yields close to 800 gpm being blown from fractures zones below 1000 feet deep. Bottom line, during the month long drilling process using air rotary, the potential exists to withdraw more than 100,000 gallons per day on average, or 3.1 million gallons for the month.

It is not unusual for air drilled wells to have significant deviation from the vertical in areas of nearly flat lying to slightly dipping bedrock (Dr. Greg Herman, New Jersey Geological Survey, 2005). Dip is the angle from the horizontal of the bedding plane of the rock. Typically, the drill bit may follow the near vertical (but not completely vertical) fractures in the rock mass. This is also a concern when rocks of very different characteristics are adjacent to one another as is the case in Wayne County, PA. Typically, a very ragged borehole will result with zones of collapsed fractured sandstone.

Problems with the verticality and variability of the borehole will potentially result in grouting difficulties. Questions on the integrity of the grout seal arise when the casing to be grouted may lie up against one side of the borehole. Centralizers may not align the well properly in a rough borehole. In addition, Pennsylvania requires only 1 inch diameter of grout whereas New Jersey requires 2 inches of grout. Since details on well drilling and construction are absent in the permit papers, how is the issue of the casing grout going to be reviewed and documented during drilling? The PaDEP regulations do not appear to require disclosure of drilling method on the permit application. However, DRBC has not required this information on any of the 11 exploratory well sites to know potential drilling risks at the 11 sites and have a better inventory of chemicals stored at these sites to conduct mud rotary drilling before allowing these 11 "grandfathered" wells to proceed. In my opinion, these data are necessary to evaluate potential impacts to the water resources of the basin.

Grouting at the depth of the production casing occurs with only 1¼ inch of grout on either side of the casing. This assumes that the casing is centered, the hole is truly vertical and the drill bit drilling the 8-inch borehole had not been worn down significantly. The potentially rapidly varying casing pressures that occur if test fracking or test gas production occurs may shear the grout and even the casing (Dusseault, et al, 2001). If grout failure occurs at this interval, high pressure gas and fluids could reach up to the surface and conductor casings via the ungrouted portion of the borehole. At the shallower depths, the higher pressures could damage the surface and conductor casings allowing further upward migration of gas and fluids into the aquifer zones above.

The significant issue with these wells is the pressures placed on the grout seals and casings. Experience even in the water industry has led to field observations of grout mixtures that have excess water to improve pumping characteristics. The result is a grout subject to shrinkage, a situation that could prove disastrous in high and overpressured environments such as the Marcellus shale in the Delaware River Basin. Skimping on the grout seal may be an inevitable problem that has been the cause of well blowouts. Again, the result is vertical upward migration of gas and fluids into the area of the surface and conductor casings and eventually into the aquifers above.

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In summary, in my opinion, water use and resource losses can be an issue with exploratory wells. Drilling and grouting plans for any well must be fully developed prior to any drilling activities and, because these 11 exploratory wells are going unregulated by the DRBC, there is no review of these plans and procedures and no basis for any conclusion by the executive director of DRBC that the drilling of these exploratory wells will not have a substantial effect on the water resources in the Special Protection Waters of the Delaware River Basin.

The opinions expressed in this report are stated to a reasonable degree of scientific and professional certainty.

# 5. References

Dusseault, M. B., Gray, M. N., and Nawrocki, P. A., 2000, Why oil wells leak: Cement behavior and long-term consequences: SPE International Oil and Gas Conference and Exhibition; Bejing, China, November, 2000.

Dusseault, M. B., Bruno, M. S., and Barrera, John., 2001, Casing shear; casues, cases, cures: SPE Drilling and Completion, March, 2001, pages 98 – 107.

Herman, G. C., 2005, Joints and veins in the Newark basin, New Jersey, in regional tectonic perspective: in Gates, A. E., editor, Newark Basin – View from the 21st Century, 22nd Annual Meeting of the Geological Association of New Jersey, College of New Jersey, Ewing, New Jersey, p. 75-116.

Lohman, S. W., 1957, Ground water in northeastern Pennsylvania: Pennsylvania Topographic and Geologic Survey Bulletin W 4, Harrisburg, Pennsylvania, 2nd printing, 312 pages.