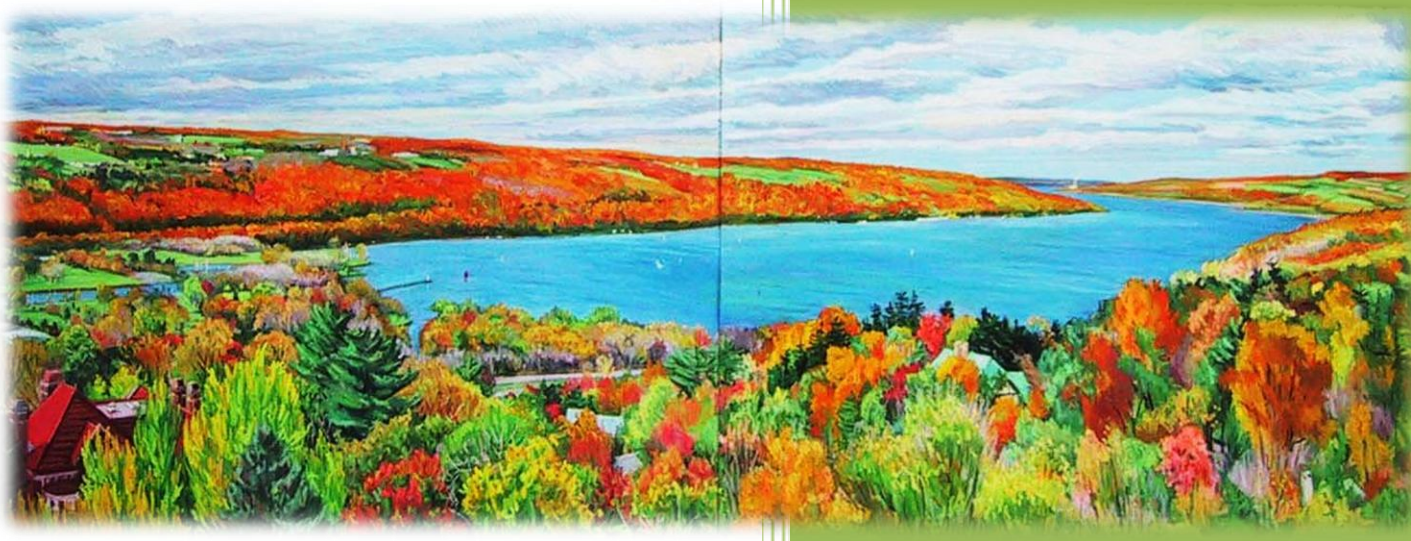
CRP 5072

Hydraulic Fracturing – Effects on Water Quality



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City and Regional Planning

CRP 5072

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I. INTRODUCTION

The United States is currently on a push to decrease their dependence on foreign energy supplies as well as pushing to decrease the use of fossil fuels. After discovering the abundance of natural gas that is available from our own natural resources, including the Marcellus and other shale formations, it would seem that our wish to utilize more local natural resources while reducing carbon emissions has come true.

Although, yes, it would seem that we have come across a way to supply ourselves with over half a century's supply of natural gas[1], recent occurrences including the BP oil spill in the Gulf of Mexico in late April of this year and the contamination cases in Dimock, Pennsylvania in 2009, many people have taken the view that either no drilling should be allowed or at the very least that risk mitigation should be in place prior to drilling in the New York state area. These risks arise not because citizens feel that drilling for natural supplies is wrong, but because unplanned releases into the environment have caused significant damage in addition to the fact that other components of the drilling process have not been conducted with the quality that the drilling companies had promised.

The sponsors of the new legislation are also concerned because drilling is being proposed near many suburban and urban areas. A small problem could be catastrophic. According to Senator Bob Casey (D-PA), who is one of the sponsors of the legislation, stated the following:

> *"Drilling for natural gas in the Marcellus Shale across much of Pennsylvania is part of our future. I believe that we have an obligation to develop that natural gas responsibly to safeguard the drinking water wells used by 3 million Pennsylvanians. We already have private wells contaminated by gas and fluids used in hydraulic fracturing. We need to make sure that this doesn't become a state-wide problem over the next few decades as we extract natural gas."*[2]

Hydraulic Fracturing development has the potential to impact the quality and quantity of water supply through land disturbance, toxic chemical usage near ground water supplies, disruption of groundwater flow pathways, increased water consumption, waste generation, release of methane pockets, and other possible negative risks. The overall goal of this project is to identify the potential threats to the groundwater and surface water supplies in the New York state area.

Scope of the Study

The first phase of the study will briefly describe the process of High-Volume Slickwater Horizontal Hydraulic Fracturing, which will be the foundation for our study on hydraulic fracturing's effects on water quality. After analyzing the process of hydraulic fracturing, we will describe how this process can potentially impact two important areas of interest in this state: effects on water quality and quantity. Like Pennsylvania, New York State's residents and business owners alike have a strong belief of preservation for their land and as such, a study of the risks is essential before drilling may begin. For this reason, there is currently a moratorium placed on drilling in the state of New York until May 15, 2011 (or until EPA, who is conducting a similar study, has completed its investigations and regulation amendments). There has also been a stop to new leases of state forest land in Pennsylvania for this same reason[3].

Following our analysis of possible risks associated with hydraulic fracturing, aka fracing, we will dive further into the issues of water quality and water quantity and what is currently being done in order to mitigate these risks. We will introduce you to growing trends in recycling of the flowback water and introduce a few companies who are currently implementing these technologies.

Lastly, we will analyze the costs associated with this process in order to determine what the future has in store for the feasibility of producing this natural gas. We will also offer our suggestions in regards to regulation for New York, implementations that should be set in

place, possible ways to avoid certain risks, and our overall conclusion on the process of High-Volume Slick Water Horizontal Hydraulic Fracturing in the great state of New York.

II. WATER'S ROLE IN HYDRAULIC FRACTURING

Hydraulic fracturing uses highly pressurized water and chemical additives to crack the shale. Natural gas trapped in the shale is able to flow through these fissures into the gas well. This process requires around 3 to 7 million gallons of water per well.

The water for hydraulic fracturing can be taken from a variety of sources. In Marcellus Shale areas of northern Pennsylvania most of the water originates from rivers with the Susquehanna River watershed. Water withdrawal sites are set up on a river bank and water is pumped out of the river into tanker trucks. Drilling companies usually build their own withdrawal sites and use the water for multiple wells in the area. Separate companies also build withdrawal sites and sell the water to a number of different drilling companies.

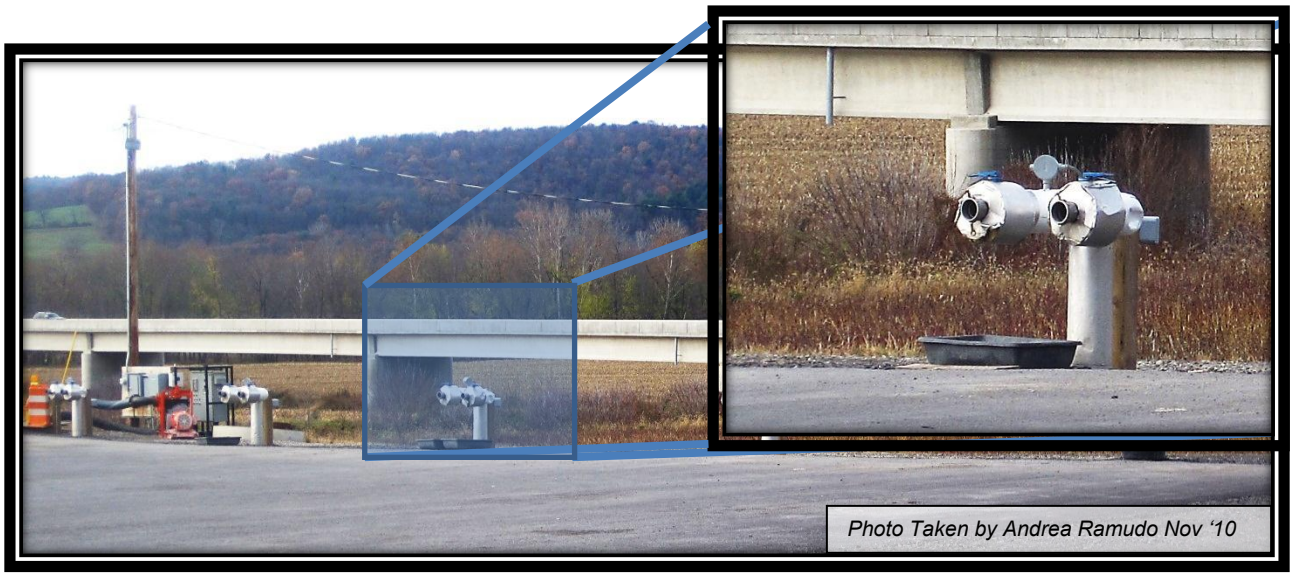

Figure 1: Water Withdrawal Site (Approximately 500' From Susquehanna River)

Figure 2: Trucks Using Water Withdrawal Facility

The amount of water that can be withdrawn per day is regulated by the Susquehanna River Basin Commission (please refer to Figure 3). The SRBC is an agency set up by the states of New York, Pennsylvania, and Maryland and the federal government called a federal-interstate compact agency. It was created to protect water quality, create flood mitigation projects, and regulate water withdrawals, among other things. The SRBC has authority over much of the Marcellus Shay area in New York and northern and central Pennsylvania. The SRBC monitors the water levels of the river and its tributaries and has the authority to temporarily stop withdrawals if the water level drops too low. The Delaware River basis has similar authority over Marcellus shale areas in eastern New York.[13]

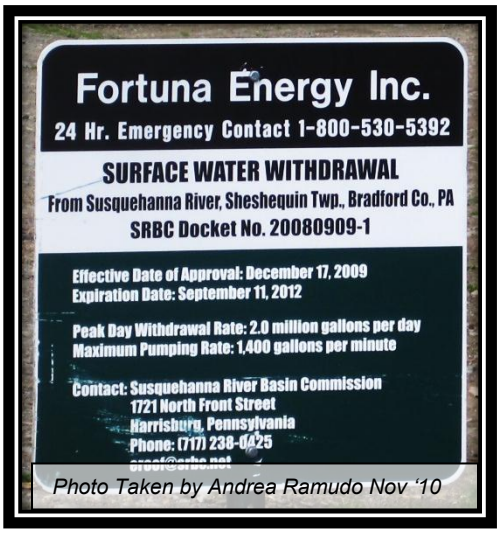

Figure 3: Regulation Sign Detailing Water Withdrawal Restrictions

After water has been taken out of the river, trucks take the water either to the well pad or to a water containment pond near one or more well pads. Temporary pipes run from the water containment ponds to the one or more well pads in the area. If the well pad is not able to be reached by temporary piping, the water is brought in by truck. In these cases most of the 900 to 1,200 truck trips to the well pads during drilling and hydrofracing are water trucks.

The first use for the water is for the actual drilling of the well. This uses a relatively small amount of water as compared to the rest of the fracing process. The drilling process uses a water-based fluid called drilling mud. Drilling mud serves several functions. It acts as a lubricant and a coolant for the drill bit. It also suspends the drill cuttings and carries them to the surface as it circulates through the well. The mud also acts as a barrier along the bore walls until the casing is put in place.[14]

Once the site has been determined work begins on building the pad. An area of 3-4 acres[4] is leveled. Water runoff and erosion protection is established using silt fencing, riprap, and grass seeding. No direct runoff is allowed from the well pad. Well pads are constructed with geotextile fabric covered in gravel (please refer to the figure below). Once the pad is built and inspected, the drilling can begin.

Figure 4: Gravel Road Leading to Site (Ponding Shows Retention of Runoff)

A bit drills a bore below the groundwater (most Pennsylvania aquifers are at most 250 feet below ground.)[15] The drill is removed and a steel casing is placed in the bore hole and concrete is forced down to the end of the hole and up the outside of the casing. The drill is put back down the hole and the drilling continues. Some drilling companies add an intermediate casing to prevent the lower quality gas at shallower depths from entering the well during the drilling process. This casing extends to the surface and acts as another layer between the well and the groundwater. Once the drill has reached a certain depth the drill reaches the drill is removed and second drill is installed which is able to gradually curve the bore into a horizontal well. The drill is removed and a casing is installed in the entire length of the well and cement is again forced down to the end of the bore hole and along the outside of the casing along the length of the horizontal portion.[6]

A device is lowered down to the end of the horizontal bore. It contains small directed charges which are ignited and punch small holes in the casing. During fracing the pressurized fracing fluids are forced through these holes and into the shale. After these holes have been made, the device is removed and the hydrofracing can begin.[16]

The first stage of the fracing process is the acid stage. A relatively small amount of water is mixed with 15% hydrochloric or muriatic acid and is pumped down the well. The acid dissolves minerals, sand and loose cement. The purpose of this stage is clear the openings in the casing and dissolve impurities which opens fissures in the shale.

In the second stage, called the *pad stage*, water mixed with friction reducers such as polyacrylamide, potassium chloride or mineral oil. It also includes biocides such as bromide or glutaraldehyde. The first fluid of this stage also includes surfactants and scale inhibiters. This combination is called slickwater. This slickwater mixture is forced down the well at 5,000 to 8,000 pounds-per-square-inch (PSI). The force creates minute cracks in the shale formation surrounding the well.

The *prop sequence stage* uses the most water. It begins with very fine particles of sand suspended in water being pumped into the newly formed cracks in the formation. This is

done multiple times gradually using large grains of sand are added until the all the fissures are propped open. The last stage is the *flushing stage*. Water is pumped down the well to flush out any extra sand. Once this water is pumped out the natural gas has open channels to flow up the well.[17] There are different additives added during these stages to aid in the hydraulic fracturing process. The types of chemicals used and their concentrations vary from company to company and from one well site to another. However the basic ingredients are the same. Please refer to the following table to see what these chemicals are.

Table 1: Breakdown of Additives[18]

Additive Type	Main Compound	Purpose
Diluted acid (15%)	Hydrochloric acid *	Dissolve mineral/sand initiates cracks in rock
Biocide	Glutaraldehyde	Bacterial control
Corrosion inhibitor	N,n-dimethylformamide	Prevents corrosion
Breaker	Ammonium persulfate	Delays breakdown of gel polymers
Crosslinker	Borate salts	Maintains fluid viscosity at high temperature
Friction reducers	Polyacrylamide *	Minimize friction between the fluid and the pipe
	Potassium chloride	
	Mineral oil	
Gel	Guar gum or Hydroxyethylcellulose *	Thickens water to suspend the sand
Iron Control	Citric Acid	Prevent precipitation of metal oxides
Oxygen scavenger	Ammonium bisulfite **	Remove oxygen from fluid to reduce pipe corrosion
pH adjusters	Potassium or sodium carbonate	Maintains effectiveness of other compounds (e.g. crosslinker)
Proppant	Silica quartz sand	Keeps fractures open
Scale inhibitor	Ethylene glycol	Reduced deposition on pipe
Surfactant	Isopropanol	Increase viscosity of fluid
* indicates degree of health hazard in concentrated form		

The well is not hydraulic fraced all at once. Instead the process is repeated 4 to 20 times beginning at the "end" of the well.[19] After the first piece of the well has been fraced the area is plugged and the next section is blasted and then goes through the four stages of hydraulic fracturing. Then this section is plugged and so on. Once all the areas of in the well along the

shale have been fraced the plugs are drilled out. The natural gas is naturally pressurized had there is a strong initial surge of gas that is forced up the well. It brings with a significant amount of the fracing water and its additives. This water is contains some combination of the fracing additives as well as a large amount of dissolved solids such as salts, calcium and chloride.[20]

Separation Process

After the hydraulic fracturing is completed, the natural gas is separated from the flowback or produced water by a separator. The natural gas is then flowed through a meter and out through a transmission line (figure below refers to a transmission line where disturbed area around it has been mitigated and restored).

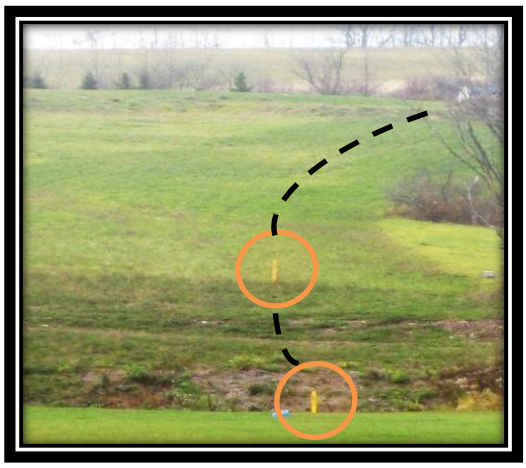

Figure 5: Transmission Line (Shown in Orange Circle)

The flowback or produced water is transferred to steel tanks or trucks for transport to either a deep injection well, wastewater treatment facility, or for treatment and re-use on the pad for a new well. It once was common for companies to temporarily store the flowback or produced water in lined "lagoons" or storage ponds, but due to the increasing amounts of incidents with liners breaking and in turn, seepage into the ground water supplies, most companies do not choose this option.

Once Water is separated from Natural Gas

If the water is to be transported, it will primarily go to one of the following locations: a deep injection well nearby, a wastewater treatment plant, or a privately owned and operated recycling facility. A few examples of these recycling facilities include AquaPure (Williamsport, PA), FracPure (Harrisburg, PA), and EcoSphere (Lafayette Hill, PA), which are classified as private for-profit companies. Many of these facilities use an evaporation process, which essentially takes the water through a two-step procedure. This first is to pretreat the water to a certain standard. The second step is to basically boil the water, which results in both brine and distilled water via steam. (Please refer to the figure below to see the results observed at Aqua Pure's Williamsport Treatment Facility.) On average, about 80% of the incoming fluid is being recycled, which greatly aids in reuse causing a reduction in water consumption.[7]

Figure 6: Aqua Pure's Resulting Water (From Left to Right: Pretreated Water, Brine, Distilled Water)

In regards to how much water is left in the ground after hydraulic fracturing occurs, it varies for a number of reasons including size of the well, how much water was required for fracing, the rate at which it returns, and how porous the particular shale was. According to industry sources, about 18% of the fracing fluid returns to the surface[4]. This causes great concern to

the people of New York who depend greatly on the water supplies of the Finger Lakes for instance. This leads us into our next topic of discussion: effects on water resources.

Effect on Water Resources

A great issue of concern is ensuring that water withdrawals for the drilling operations do not sacrifice the water supplies needed for daily life and other industries in the area. Intensive natural gas well development without regulation of water withdrawal could greatly increase the risk of drought. According to Josh Brown from Chesapeake Energy, the water consumption per year for all uses and industries in Pennsylvania amounts to about 3.6 trillion gallons. Of that, the natural gas industry uses about 0.19% of this water in withdrawals for the hydraulic fracturing process[4].

Although the withdrawals represent a small portion of overall watershed use, withdrawals for hydraulic fracturing could significantly impact commitments for water supply and habitat protection during periods of drought, if not closely regulated and monitored. The severity of impacts will depend on the amount and timing of withdrawals. If these withdrawals occur while reservoirs are overflowing, they would not have a large impact. However, as the DEP claims, "Withdrawals during dry periods could increase the duration of drought watch, warning, or emergency conditions."[8]

If natural gas development utilizing high-volume hydraulic fracturing does occur in New York, the New York State Department of Environmental Conservation may need to implement mitigation measures to reduce the risks to the water supply. Nevertheless, the risks associated with natural gas well development cannot be eliminated.

Effective mitigation of cumulative water withdrawal impacts on system operations, supply reliability and in-stream habitat would require the development of appropriate monitoring, enforcement, and diversion permitting or other control mechanisms to curtail withdrawals during low flow conditions or when such withdrawals adversely impact existing uses. In principle, diversion permits should be based on an analysis of long-term stream flow data, in-stream habitat requirements, pre-existing consumptive withdrawals, and other pertinent

parameters. Each stream should be considered individually to determine the allowable level of additional consumptive withdrawals while avoiding adverse impacts. Currently, Pennsylvania has placed restrictions on water withdrawals, as can be seen in the following figure. However, it is not certain how closely regulated this is.

In New York, the SGEIS[9] has proposed the following regulation:

> *"Water Consumption: Companies will not only have to follow Susquehanna River Basin Commission and Delaware River Basin Commission protocols for water withdrawal where applicable, but also must complete a more stringent and protective streamflow analysis in regards to water withdrawal plans – whether inside or outside the Susquehanna or Delaware basins".*[9]

In conclusion, if water withdrawals are monitored both during normal and drought conditions, water quantity should not be a major issue in the New York state area. This is, of course, based upon proper regulation from the agencies. In an article by Heading Out[10] about comments made by Albert F. Appleton who is a consultant on infrastructure and the environment and a former Director of the New York City Water and Sewer System, the following points were made:

> *"… There are also concerns that there are not enough regulators to ensure compliance with the regulations, and that water withdrawal may have severe and negative impact on communities."*[10]

So in addition to making sure regulations are set in place, there also needs to be enough personnel to monitor these regulations and enforce them. Regulations are not enough if there are not enough personnel to enforce them.

III. EFFECTS ON WATER QUALITY

Hydraulic fracturing, itself, has very limited effects on water quality if done properly. In this portion of the report, we will be analyzing what happens or could happen to the water when hydraulic fracturing is done properly and also when something goes wrong. The water on this earth is a special commodity, just as natural gas, so we should ensure that while trying to capitalize on one, we should aim to also protect the other.

Currently, the rule in Pennsylvania is that if water is found to be contaminated within 1,000 feet of a well, with high methane levels for instance, then the drilling company will automatically be "guilty until proven innocent"[4]. This is the exact opposite from our normal judicial system for criminal law, which states that a party is "innocent until proven guilty". For this reason many companies are performing testing of any water wells, surface water bodies, etc. in order to determine what the state of the water is prior to drilling. This way, if water is found to be contaminated, the company can show whether it already was or was not, and to what extent. It is interesting to note that 1in 3 private well sample test results in Bradford County have indicated that there were already high levels of methane already present prior to drilling[4], which is probably due to the fact that private well drilling is not currently regulated in any way.

One key requirement that the SGEIS[9] will implement in NY is to require the testing of private and public water supplies to the minimum 1,000 foot radius or even extend it. Per the SGEIS[9], "Prior to drilling, private wells within 1,000 feet of the drill site will be tested to provide baseline information and allow for ongoing monitoring. If there are no wells within 1,000 feet, the survey area will extend to 2,000 feet." This could help in not only mitigating future law suits, but may also shed light on what the current standards and regulations should be for private well drilling. It will also ensure companies will maintain proper procedures in order to reduce the chances of litigation.

Hydraulic Fracturing's Effect on Water Quality

In 2004, research was conducted on the impacts of hydraulic fracturing of coalbed methane on underground sources of drinking water. EPA concluded that it could find no confirmed cases that could link hydraulic fracturing to drinking water well contamination. This study was used by the Bush Administration and Congress to justify legislation exempting hydraulic fracturing from oversight of the Safe Drinking Water Act. The new EPA study currently underway should add insight into the hydraulic fracturing debate. Unlike the 2004 study, the 2010 version will address natural gas drilling in shale formations. Unfortunately, the EPA effort is just beginning, and definitive results will probably not be available for one or two years.

Effects on Water Quality (When Something Goes Wrong)

There are numerous occasions when water quality can be affected by the process of hydraulic fracturing, if precautions are not made to ensure that proper methods and materials are being utilized. This section will cover the major possibilities that could occur to lead to contamination of water.

Preparation of the Drilling Pad

If proper attention is not made to the placement of the liner under the drilling pad, this could lead to a number of issues in relation to water quality. Some of these issues could include a spill of the additives used during the mixing of the fracturing fluid, spillage from a faulty backflow preventer, or spillage of the collected flowback or produced water when transferring it to storage containers, which would all lead to seepage of the fracking fluid and/or natural gas into the ground, contaminating the ground water supply. Logically, this would seem to be an easy implementation and thus there would not be much concern here.

Unfortunately, not every drilling company pays as close attention to this risk as they should. For example, Cabot Oil and Gas has shown that spills can and do occur on well sites and that this risk can cause many to suffer. On one well site alone, Cabot had three isolated spills in Dimock, Pennsylvania last year. The contaminants had seeped into a nearby creek, where a

fish kill was reported by the state Department of Environmental Protection. Well water was also reported for containing metals and methane gas that state officials determined leaked underground from Cabot wells. These incidents are the latest in a series of environmental problems connected to Cabot's drilling in the Dimock area[11]. Given cases like these, careful attention needs to be made in order to help mitigate and diminish these occurrences.

Additionally, proper attention needs to be made when creating the stormwater and pollution prevention plan, SWPP to ensure that if indeed a spill occurs, that the Best Management Practices in place will ensure that no runoff of fracing fluids, flowback or produced water, or natural gas will occur to neighboring unlined areas. This may have prevented the extensive environmental damage and costly litigation that Cabot was presented with after the spills.

Construction of the Well

- **Casing:** When the structural casing is being formed, proper attention needs to be made to the strength and integrity of the structural casing in order to ensure that it will hold during the hydraulic fracturing process. According to the SGEIS[9], the piping must be either new API graded pipe with a minimum internal yield pressure of 1,800 psi or reconditioned pipe that has been tested internally to a minimum of 2,700 psi. Excessive pressure in the annulus between the surface casing and intermediate or production casing could break down the formation at the shoe of the surface casing and result in the potential creation of subsurface pathways outside the surface casing. Excessive pressure could occur if gas infiltrates the annulus because of insufficient production casing cement and the annulus is not vented in accordance with the required casing and cementing practices. Hence, proper testing should be conducted to ensure that the integrity of the casing is in fact there.

- **Cementing Around the Casing:** In addition, proper attention needs to be made when cementing the structural casing and subsequently the intermediate casing in place in order to ensure that there is, in fact, a proper seal between the ground water supply and the well. Inadequate cement in the annular space around the surface casing could cause leakage to the groundwater supply by gas channeling or insufficient cement setting time.

Another possibility is that gas channeling may occur as a result of naturally occurring shallow gas or from installing a long string of surface casing that would put the potable water supplies and shallow gas behind the same pipe. A way to remedy this situation is by the use of centralizers. Centralizers need to be used in order to ensure a proper thickness is achieved uniformly around the casing.

According to the SGEIS[9] 7.1.4, current casing and cementing practices attached as conditions to all oil and gas drilling permits require use of centralizers on all casing strings and specify adequate hole diameters and spacing for their use. Furthermore, centralizers are required every 120 feet on surface casing, but no fewer than two may be run.

According to SGEIS[9], the following stringent requirements will be implemented in the New York Marcellus Shale areas:

- Minimum of 50% of excess cement is to be pumped, with appropriate lost circulation materials
- Squeezing or grouting will need to be conducted, from the surface or through perforations, if proper circulation is not achieved
- Remedial action will be needed prior to drilling out of and below the surface casing if there is any evidence or indication of flow behind the surface casing.
- If intermediate casing is not installed, then production casing must be fully cemented to the surface. If it is installed, then it must be fully cemented to the surface and the production casing cement must be tied into the intermediate casing string with at least 300 feet of cement.
- In any event, the top of the cement on the production casing must be at least 500 feet above the casing shoe or tied into the previous casing string with at least 300 feet of cement.
- The operator must run a cement bond log to verify the cement bond on the intermediate casing, if any and the production casing.
- Remedial cementing shall be required if the cement bond is not adequate to isolate hydraulic fracturing operations.

An important note is that prior to surface casing cementing for any well, prior notice and notification will need to be made so that the DEC staff will have the opportunity to witness the operations to ensure compliance.

- **Depth:** Lastly, inadequate depth and integrity of surface casing would prevent the isolation of the potable fresh water supplies from deeper gas-bearing formations. For this reason, proper length of structural casing needs to be achieved. According to the SGEIS[9], surface casing must extend at least 100 feet below the deepest fresh water zone and at least 100 feet into bedrock.

If any of these measures are not properly done, seepage of fracing fluids, flowback and produced water, and natural gas could occur, which would contaminate the groundwater supply. Casing failures in Pennsylvania, for example, have resulted in contamination of drinking water wells with methane, causing explosions and flaming tap water. The reasoning for this can be found below in a news release by a Pennsylvania news source in regards to a company, Cabot, who did not properly cement their casing:

> *"The consent order and agreement caps a DEP investigation that began early this year when numerous Dimock area residents reported evidence of natural gas in their water supplies. DEP inspectors discovered that the well casings on some of Cabot's natural gas wells were cemented improperly or insufficiently, allowing natural gas to migrate to groundwater."*[12]

According to SGEIS[9] 7.1.4.2, the Supplementary Permit Conditions will require submission of a Pre-Frac Checklist and Certification Form at least 48 hours prior to commencement of high-volume hydraulic fracturing operations. Regarding the surface casing hole, the pre-frac form will attest to well construction having been performed in accordance with the well permit or approved revisions. This will also list the depth and estimated flow rates where fresh water, brine, oil and/or gas were encountered or circulation was lost during drilling operations, and includes information about how any lost circulation zones were addressed.

Hydraulic fracturing will not be authorized to proceed without the above information and certifications.

After Construction and Prior to Hydraulic Fracturing

Before perforating the casing and pumping fracturing fluid into the well, the operator will need to pump fresh water or drilling mud to test the production casing. Test pumping needs to be performed to at least the maximum anticipated treatment pressure, which is maintained for a period of time while the operator monitors the pressure gauges. Currently, most companies test their casing prior to hydraulic fracturing, although it is not currently required in Pennsylvania[4, 5]. Given that the process of hydraulic fracturing causes a pressure of about 5,000-9,000 psi[4] testing should be done for pressures up to about 13,000 psi. The companies who test their casing are doing this type of conservative testing, but not all companies test. This should be an item to enforce given that it is very likely than accident could occur through a mistake in the casing.

If this testing is not done, or not done properly, then there is a risk that that the casing will not successfully hold the pressure and contain the fluids, which could cause a leakage into the groundwater supply.

During Drilling

If proper attention is not made during the permitting and drilling process, cross communication can occur with adjacent wells causing penetration and subsequent groundwater contamination if proper casing has not been installed yet. During the permitting process, the proposed wells should show that they do not intersect with any existing wells.

Storage

Lined pits are being used less and less for storage of the flowback water. However, if they are used, possible contamination of ground water and surface is possible. For instance, if there is a flood there is a possibility for contamination to other surface waters or the ground water supply. For this reason, the SGEIS[9] has put in place many regulations in regards to

holding ponds. For instance, according to the SGEIS[9]: "**Floodplains:** On-site reserve pits are banned in floodplains – closed-loop tank systems are required instead to protect against potential spills."

During Transport

After the flowback and/or produced water has been extracted from the well and collected into storage tanks, this fluid is transported to either to a wastewater treatment plant, recycling facility, or to a deep injection well for disposal or treatment. On route, it is imperative that precautions be made to ensure a safe delivery. If an accident were to occur, groundwater would be susceptible to contamination if runoff of these fluids were to penetrate into the ground or runoff into adjacent bodies of water. Contingencies should be set in place to ensure that a plan is in place should this occur.

Improper Treatment

If the flowback/produced water is not treated properly and released into the environment, contamination to water supplies could occur. This is very unlikely, however, given the regulation standards needed to adhere to for any dumping into natural water bodies.

Findings

If proper precautions are taken and regulations upheld, as described above, there should be no effects to the water quality. As mentioned above, there have been no reports of contamination caused by the hydraulic fracturing itself, with the cases reported relating to some error made by the drilling companies during development of the wells.

It is difficult to say at this point whether or not contamination to the groundwater supplies will occur simply due to hydraulic fracturing itself. Given that it would take many years for this to occur due to the fact that the produced water is injected more than 4,000 feet beneath the surface of the earth, research including modeling and studies of the specific formations should be conducted in order to determine this risk. If these studies are not conducted, it may be too late in 50 years when methane levels begin to rise in our groundwater supplies.

IV. CONCLUSION

> *"For many of us, water simply flows from a faucet, and we think little about it beyond this point of contact. We have lost a sense of respect for the wild river, for the complex workings of a wetland, for the intricate web of life that water supports."* - Sandra Postel, Last Oasis: Facing Water Scarcity, 2003. [12]

The quote above describes the purpose for this report perfectly. At times, it is easy to take for granted our resources. But, as Benjamin Franklin once said, “When the well's dry, we know the worth of water." Hydraulic fracturing itself has not proven to cause any negative effects to water quality, but when mistakes have occurred, the results have been disastrous. In order to prevent these mistakes from happening in New York, strict regulations should be implemented and, most importantly, enforced.

Thankfully, there are companies out there that have learned to take seriously the important role of regulations in hydraulic fracturing. But not every company is as diligent in making sure that procedure is followed. For this reason, regulation and enforcement should be a number one priority before allowing the moratorium to be lifted. If the DEC does not have the ability to increase the amount of personnel necessary to oversee every drilling rig, then phasing should be implemented, with a maximum number of wells to be drilled in a certain area at any one time, to allow for the process to be closely monitored and quality insured. Additionally, further investigation needs to be conducted in order to determine whether the process of hydraulic fracturing can, in fact, cause detrimental results to our ground water supplies. It would be catastrophic to simply sit back and wait until something occurs.

Also, water consumption is another area to pay close attention to. The SRBC has maintained tight control in Pennsylvania and the same should be implemented in NY. It is recommended that statewide water withdrawal regulations be implemented along the lines of the SRBC to ensure that Tompkins and Cortland Counties and other areas outside both the SRBC and Delaware basins are protected. Another way to regulate water consumption is by utilizing the treatment options that are available and continually expanding for cleaning the flowback and produced

water. This will ensure that as much water as possible is returned to the environment or at least recycled.

Lastly, natural gas is a limited resource. Sooner rather than later, our society needs to move away from these limited resources, and move diligently towards renewable resources. This world simply should not procrastinate until our resources are depleted. In the meantime, it is understandable that our society would like to utilize its domestic resources. However, in the process of doing so, the environment and the quality of the nation's water should not be sacrificed.

V. WORKS CITED

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