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SHALE GAS EXTRACTION AND WATER CONSUMPTION IN NORTH CAROLINA: A PRIMER

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ABSTRACT

About 25,000 acres of area underlying the Deep and Dan River Basins in North Carolina has been identified to contain large shale gas reservoirs that could be used for the natural gas production. This study attempted to quantify the impact of potential hydraulic fracturing (or fracking) activities in the existing water resources of North Carolina. Supply and demand analysis was conducted using a water balance approach. Availability of surface water resources was quantified using the streamflow monitoring data of the surrounding area. A general assessment of the water demand for fracking was done using existing literature data and assumptions. Finally, a comparison was made between the water demand due to fracking and the water availability from nearby water sources. The preliminary analysis concluded that the surface water resources of North Caroline will not be affected at all as far as water quantity is concerned. However, whether extracting the shale gas of North Carolina is a good decision or not depends on the complete evaluation of the shale reservoirs and how well environmental impacts can be addressed.

Keywords: Fracking, Surface Water, North Carolina

1. INTRODUCTION

Shale gas is an extraordinary uprising source of energy since the advances in horizontal drilling and hydraulic fracturing allowed large scale production that made the shale gas extraction economically viable. The importance and growth of natural gas have been increased dramatically since the horizontal wells allow extracting the gas inside the shale rocks. The hydraulic fracture is the propagation of fractures in rock layers induced by a pressurized fluid. It can happen naturally; however, induced hydraulic fracture, more known as fracking, is achieved by drilling a wellbore into rock formations to release petroleum, natural gas or other substances.

Currently, natural gas is the fuel source for 21% of electricity production and for 24% of the total energy demand in the United States (EIA, 2011). The fastest growing source of natural gas is shale gas, which is projected to be the largest contributor to growth in natural gas production in the United States for the next 25 years (**Fig. 1**; EIA, 2011).

In 2009, the North Carolina Geological Survey (NCGS) published a report on the existence of shale in North Carolina that extends across ~25,000 acres at depths less than 3,000 feet in the Sanford sub-basin, Lee and Chatham counties (Reid and Taylor, 2009). This entire area is underlying the Deep and Dan River Basins in twelve North Carolina counties. The large scale production of natural gas, if permitted for extraction, has potential to positively impact the economy. However, North Carolina law currently prohibits both horizontal drilling and the injection of waste into wells (Plikunas *et al*., 2012).

This study does not take a position supporting or denying hydraulic fracturing. Instead, it focuses on the impact that shale gas extraction would have in the water resources of North Carolina. Hydraulic fracturing uses water first for the drilling and later for the fracturing of each well.

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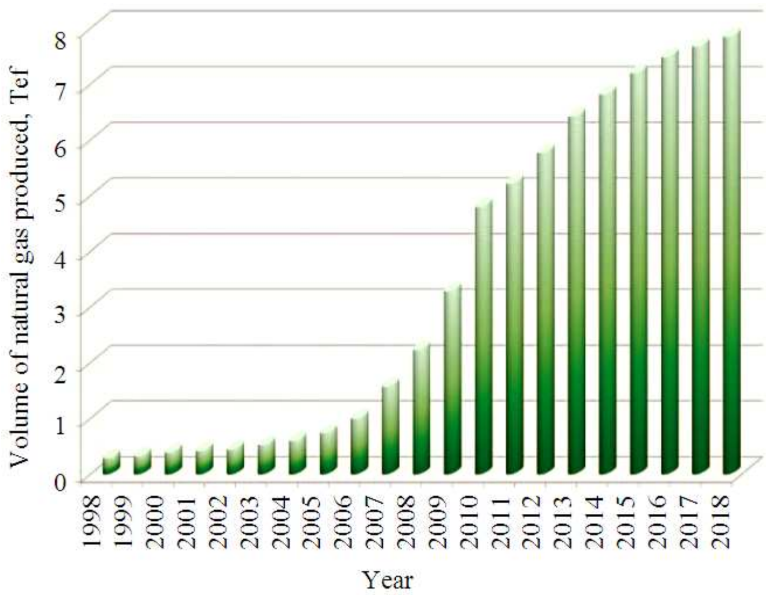

Fig. 1. Actual and projected production of natural gas from shale in the United States in trillions of cubic feet (Tcf) (adapted from EIA, 2011)

The volume of water required depends on the type of geologic formation and depth and lateral length of the well. Some wells use significantly more water than others and may vary from two to four million gallons of water for each well drilled (DOE, 2009). This amount could be significant and a limiting factor for gas production in water deficient areas. North Carolina is a relatively water-rich state, but the amount of water needed to fracture a well in the Deep or Dan River Basins was not yet known.

North Carolina’s potential shale gas resources are primarily located within the fastest-growing region of the state where water demands are rapidly increasing (NC DENR, 2009). This study attempted to predict the amount of water that would be needed to extract the shale gas under the counties of Granville, Durham, Orange, Wake, Chatham, Lee, Moore, Montgomery, Anson, Richmond and Union. A supply-demand comparison was conducted to quantify the impact of shale gas production on the existing water resources of the region.

2. REVIEW OF THE ENVIRONMENTAL CONCERNS

There are many concerns of drilling down to 2000 m vertically and 1000m horizontally to fracture rocks with pressurized water solutions that contain hazardous chemicals. Although this study focus just in the water consumption need to perform the fracturing, it may be interesting to slightly review the major environmental concerns of fracking.

It seems easy to understand how hydraulic fracturing can induce seismic phenomenon but evidence suggests that earthquakes are not a serious concern. A recent report published by the National Research Council (NRC) on energy and seismic activity reported only two registered minor tremors associated with fracking despite the large scale of activity (NRC, 2013). However, this report does warrant the potential environmental impacts of the underground injection of wastewater produced by hydraulic fracturing.

Carbon dioxide emissions may seem a problem because of the diesel motors required in hydraulic fracturing; however, the real problems about the air quality in hydraulic fracturing are “escaping gases”, especially methane which is a very pernicious greenhouse gas. According to the study conducted by Howarth *et al*. (2011), 3.6 to 7.9% of the methane from shale-gas production escapes to the atmosphere in venting and leaks over the lifetime of a well. This amount is expected to be at least 30% and perhaps even 100% more than from conventional gas production. However, a follow-up commentary by Cahles *et al*. (2012) contradicted the published results by responding with their assessment. They argued that the assessment was “seriously flawed” because it significantly overestimated the fugitive emissions associated with unconventional gas extraction and undervalued the contribution of green technologies to reducing those emissions to a level approaching that of conventional gas.

Radionuclides are associated with hydraulic fracturing in two main ways: Injection of man-made radioactive tracers (along with other substances in the fluid) and unsuitable location of fractures which may release naturally occurring heavy metals and radioactive materials from shale deposits. These substances return to the surface with flowback, also referred to as wastewater. Flowback of the fracturing fluid occurs over a few days to a few weeks following hydraulic fracturing (USEPA, 2011).

In addition to these substances, wastewater contains very high concentrations of Total Dissolved Solids (TDS) return to the surface. The TDS concentration in the flowback wastewater can reach five times the concentration of sea water (Kargbo *et al*., 2010). The composition of the flowback water changes as a function of the time the water was in contact with the formation. Minerals and organic constituents present in the formation dissolve into the fracturing water, creating a brine solution that includes high concentrations of salts, metals, oils, greases and soluble organic compounds, both volatile and semi-volatile (Kargbo *et al*., 2010). The flowback water is typically impounded at the surface for subsequent disposal, treatment, or reuse. Due to the large water volume, the high concentration of dissolved solids and the complex physicochemical composition of the flowback water, there is growing public concern about management of this water because of the potential for human health and environmental impacts associated with an accidental release of flowback water into the environment (Gregory *et al*., 2011). Treatment technologies and management strategies for flowback water are based on constraints established by governments, economics, technology performance and the appropriateness of a technology for particular water (Kargbo *et al*., 2010).

Another important concern is the water consumption in the fracking process. Water is used in two ways for hydraulic fracturing, first for drilling and after that for the fracturing of each well. The Groundwater Protection Council, a non-profit association of state groundwater regulators, estimates that drilling and hydraulic fracturing of a single well requires between two and four million gallons of water (DOE, 2009). Pennsylvania’s Marcellus Shale Advisory Commission found that a single well may use more than five million gallons per fracturing well (Soeder and Kappel, 2009). The volume of water required varies with the geologic formation, depth and lateral length of the well and the number of times it is fractured. As a result, some wells use significantly more water than others. Natural gas producers frequently draw water for drilling and hydraulic fracturing from nearby surface waters, including rivers and lakes. This leads to a general concern about the availability of water supply in the region for gas production. Some drilling operations also take water directly from groundwater or municipal water supplies. Others reuse wastewater from previous drilling operations for at least a portion of their water supply, though the quality of the produced water limits its reusability as a source of fracturing fluid.

3. RESULTS

3.1. Water Availability

Figure 2 shows the stream network in North Carolina and the location of shale reservoirs that can potentially be tapped into for the production of natural gas. Also indicated on the map are USGS gage locations where surface water data were obtained to estimate the amount of water available. **Figure 2** identifies multiple streams that go around and across the gas reservoirs. It can be implied that not all drilling units will be using water from only one source/storage but multiple water storages can be established along the gas reservoirs.

For the analysis of total water availability, nine USGS stations surrounding the shale reservoirs were selected. Surface water data in terms of average monthly discharge were obtained from the USGS website. It was assumed that only surface water will be used in the fracking operation. **Table 1** details the station information and **Table 2** provides the monthly streamflow discharge at gaging locations in cubic feet per second (ft^3/s) unit. Monthly averages were calculated based on the total daily data at the stations.

3.2. Water Need or Water Consumption

Amount of water needed was calculated by measuring the area of the shale reservoirs to be exploited and the number of drilling units that can be installed.

Basic assumptions in the calculation:

- Each drilling unit will need an average of 5 million gallons of water
- Each drilling unit will cover an area of 1.4 km^2
- Life span of a shale gas well varies from 15 to 30 years

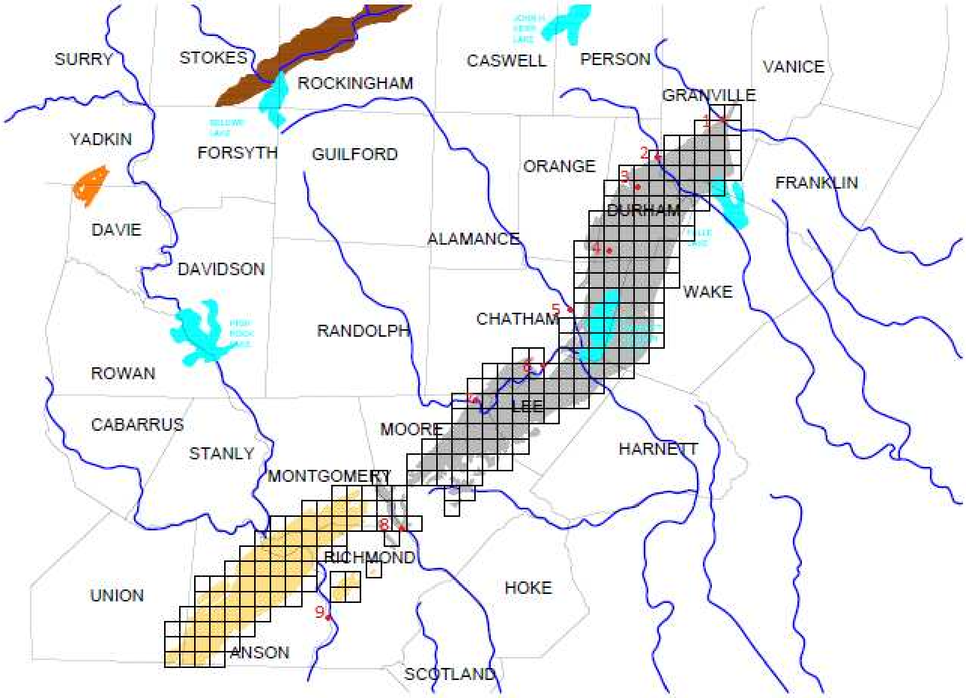

Fig. 2. Location of the river network, shale reservoirs and USGS surface water monitoring stations in North Carolina (USGS stations are numbered from 1 through 9)

Table 1. USGS gaging sites used in the calculation of surface water availability

Site	USGS Station #	County	Latitude	Longitude	Drainage area (mi^2)
1	2081500	Granville	36°11'39"	78°34'59"	167.0
2	2086624	Granville	36°07'40"	78°47'55"	43.0
3	2085249	Durham	36°06'48"	78°51'35"	98.9
4	2097314	Durham	35°53'06"	78°57'55"	75.9
5	2096960	Chatham	35°45'55"	79°08'09"	1,275.0
6	2102000	Lee	35°37'37"	79°06'58"	1,434.0
7	2101066	Moore	35°29'20"	79°25'15"	859.0
8	2133500	Richmond	35°03'40"	79°29'38"	183.0
9	2129000	Richmond	34°56'45"	79°52'11"	6,863.0

Table 2. Monthly discharge data (ft^3/s) at gaging stations

	Streamflow in ft3/s											
USGS gage #	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2081500	236	256	367	210	94	71	56	54	85	52	107	165
2086624	56	56	94	55	31	18	21	15	10	15	29	41
2085249	74	106	154	109	40	24	16	15	81	19	45	78
2097314	131	166	185	136	81	46	46	42	69	47	81	87
2096960	1,640	1,870	2,320	1,700	918	853	653	554	763	636	877	1,190
2102000	2,050	2,360	2,882	1,760	913	718	579	602	682	704	934	1,250
2101066	1,270	1,510	1,520	610	332	701	366	310	708	491	675	423
2133500	293	311	335	267	167	129	125	149	144	175	205	239
2129000	10,500	11,000	13,300	10,000	6,760	5,650	4,440	4,410	4,180	4,930	5,540	7,610
Total	16,250	17,635	21,157	14,847	9,336	8,210	6,302	6,151	6,722	7,069	8,493	11,083

Table 3. Estimates of water requirement by the fracking system

Life span	30 years	20 years	10 years	5 years
Total (MG)	1690.0000	1690.0000	1690.000	1690.000
MG/Month	4.6900	7.0350	14.070	28.140
MG/Day	0.1564	0.2345	0.469	0.938
Gallons/hour	6519.0000	9770.0000	19540.000	39008.000
Gallons/second	1.8100	2.7100	5.420	10.840
ft^3/second	0.2420	0.3623	0.725	1.450

We considered the worst-case scenario by assuming the upper limit of water consumption for each drill. Area covered by each drilling unit was not set arbitrary but estimated based on the assumption of the well spacing requirement of 140 ha. This requirement is not set yet for North Carolina. However, its value varies from 40 to 360 acre in New York, Pennsylvania, West Virginia and Ohio, according to the report published by the National Park Service (NPS, 2008).

The total area of the shale reservoir is calculated using the graphical method as shows in **Fig. 2**. The entire area was found to be about 473 km^2 or 116,880 acres. That would give us a total of 338 drilling units (= 473/1.4).

If each drilling unit uses 5 million gallons, the total water consumption by 338 drilling units will be 1,690 million gallons of water, consumed in its lifetime. The life of a shale gas well is also variable and usually goes from the 15 to the 30 years. Four different time frames including 5, 10, 20 and 30 were considered for evaluating the water consumption. Considering about this problem as a Supply-Demand problem, the supply in a monthly basis has been established (**Table 3**).

4. DISCUSSION

Total potential water consumption of the fracking system and total water availability from nearby surface water sources close to the shale gas reservoirs were analyzed for comparison. It can be seen that even at the lowest life span assumption of the drilling unit; the water demand (1.45 ft^3/s) is significantly lower than the water availability (August has the lowest demand of 6,151 ft3/s when adding from all sources). Although when a water demand such as 1,690 million gallons (under assumed condition for a 30-years drilling system) is a very big volume of water and could be a problem in certain areas, the results identified that it would not be like that in the case of North Carolina. It is very clear that the surface water supplies of North Carolina will not be affected at all by the fracking activities. Nonetheless, environmental concerns may be the limiting factor.

It is remarkable to notice that the water is available from more than one source. Having different sources of water all along the shale gas reservoirs would allow to avoid the intense water withdrawal from only one source, making the water usage even more sustainable. The availability of multiple streams alongside would potentially reduce the cost because there would be no need to pump water to long distances.

This study was born with the idea of having a bigger scope of the possible environmental concerns that could appear in the case of exploiting the North Carolina shale gas reservoirs. A main difficulty was found as soon as the study began was the lack of available information. Fracturing fluids remain an absolute secret and it was impossible to get some valuable and certified information about it. Fracking companies were contacted but answers were never given. Again, lack of information of the condition of the shale gas reservoirs makes it impossible to make a more precise calculations of the water needed.

5. CONCLUSION

In 2009, the North Carolina Geological Survey (NCGS) published a report on the existence of shale that extends across ~25,000 acres at depths less than 3,000 feet in the Sanford sub-basin, Lee and Chatham counties. Despite controversies of supporting and denying the hydraulic fracturing in North Carolina, this study only focuses on quantifying the impact of shale gas production on the existing water resources of the region. The amount of water that is used in fracking could be significant depending on the location. Our preliminary analysis using USGS's monitoring data on surface water resources and a general assessment of the potential water use by the fracking activities, we concluded that the surface water resources of North Caroline will not be affected at all as far as water quantity is concerned. However, there exist many other potential risks including environmental concerns. Whether extracting the shale gas of North Carolina is a good decision or not depends on the complete evaluation of the shale reservoirs and how well environmental impacts can be addressed.

The environmental impact study has to evaluate all of the risks involved in the stimulation of the shale gas reservoirs using hydraulic fracturing and horizontal drilling. The contamination of any of the surface or underwater resources in the Durham-Sanford and the Wadesboro subbasins could have terrible consequences due to the natural richness of the area and also because it is the fastest growing area in the state of North Carolina.

It is impossible to perform the extraction of this shale gas without taking any risks, but it is possible to minimize them. The balances between the economical possible benefit and the environmental risks to take have the answer to the problem.

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