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# INVESTIGATING THE IMPACT ON PRIVATE WATER SUPPLY OF HYDRAULIC FRACTURING COMMUNICATION WITH AN ABANDONED CONVENTIONAL GAS WELL IN NEW FREEPORT, PA

Kiley Miller

# INVESTIGATING THE IMPACT ON PRIVATE WATER SUPPLY OF HYDRAULIC FRACTURING COMMUNICATION WITH AN ABANDONED CONVENTIONAL GAS WELL IN NEW FREEPORT, PA

A Thesis

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By

Kiley Miller

August 2023

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Approved July 6, 2023

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# ABSTRACT

## INVESTIGATING THE IMPACT ON PRIVATE WATER SUPPLY OF HYDRAULIC FRACTURING COMMUNICATION WITH AN ABANDONED CONVENTIONAL GAS WELL IN NEW FREEPORT, PA

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August 2023

Thesis supervised by Dr. John F. Stolz

In June of 2022 a “frac out” occurred in New Freeport, PA when an unconventional gas well under development by hydraulic fracturing, communicated with an abandoned gas well to the surface. An initial “zone of impact” encompassed much of the town’s main thoroughfare. Water samples were obtained from 17 private water wells, 5 springs and 1 pond (31 total samples) and analyzed for cations, anions, and light hydrocarbons. Methane was found in 18 of the samples, both located within and outside of the “zone of impact”. Mass ratio analyses indicated contamination from both unconventional and conventional wells. Interferometric Synthetic Aperture Radar (InSAR) remote sensing revealed surface uplifts coinciding with the frac out. Return visits and resampling indicated that while methane levels had subsided slightly, other

contamination remained, thus a need for continued investigation to deem the water safe for drinking.

# DEDICATION

I would like to dedicate this work to my two children Maverick and Everbe. Their smiling faces and love remind me that my education, work, and future career is for a greater purpose. Most of all, I would like to dedicate this to the one who led me here. Thank you, God, for the passion and gifting to do all that I am doing and will do. Without the strength given to me through faith, none of this work would have been possible.

# ACKNOWLEDGEMENT

I would like to thank Duquesne University, the Center for Environmental Research Education, and the Stolz lab group for supporting this research and providing guidance and knowledge throughout my time here. I especially would like to thank the Heinz Endowments, Colcom Foundation, and Park Foundation for funding this work.

A special thanks to my thesis committee members, Dr. David Kahler, Dr. Daniel Bain, and Dr. Philip Reeder, as well as my research advisor, Dr. John Stolz, for their time and their guidance. Dr. Stolz, working in your research lab has been a rewarding experience, and I am grateful to have been a part of such an important mission to protect people's water sources and overall health. Through my work at Duquesne, I have grown confidence to speak for change from listening to the cries of those who are impacted by the fossil fuel industries.

Last but not least, I would like to acknowledge my friends and family for believing in me, motivating me, and encouraging me throughout my academic career. Thank you to my previous professors, you know who you are, from Washington and Jefferson College for believing in me then, so I can be here now.

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# LIST OF ABBREVIATIONS

Begin list of abbreviations here (the list of abbreviations is optional).

| | |
|---|---|
| Bcf | Billion cubic feet |
| Bdl | Below detection limit |
| BHL | Bottom hole |
| CG | Conventional gas |
| CO | Conventional oil |
| GC | Gas Chromatography |
| IC | Ion Chromatography |
| ICP-MS | Inductively Coupled Plasma — Mass Spectrometry |
| KOP | Kick off point |
| LP | Landing point |
| MCL | Maximum contaminant level |
| MDL | Minimum detection level |
| Mmcf | Million cubic feet |
| N/A | Not available |
| ND | Non detect |
| PADEP | Pennsylvania Department of Environmental Protection |
| SPUD | Drill date for a new well |
| Tcf | Trillion cubic feet |
| TH | Top hole |
| TVD | Total vertical depth |
| UG | Unconventional gas |
| UO | Unconventional oil |
| US EPA | U.S. Environmental Protection Agency |
| USGS | U.S. Geological Survey |

# CHAPTER 1: INTRODUCTION

## 1.1 Unconventional Gas Extraction From Marcellus Shale

### *1.1.1 Background*

The Stolz lab has been conducting field and lab analysis on private drinking water since 2012. This research arose when Dr. Stolz was contacted by someone concerned that their private water well had been impacted by unconventional drilling nearby. The research mission has expanded over the years hence, to investigate potential threats to water resources, both public and private. When possible, the aim is to provide baseline water quality data for homeowners before extractive activities, like unconventional oil and gas drilling, occurs. These results can serve as a comparison to measurements obtained following incidents. Research produced from this lab addresses an overarching question: does the development of unconventional oil and gas reserves pose a threat to surface and groundwater water quality?

### *1.1.2 History and Needs for Fuel*

Throughout the mid-1850s, much of the East Coast was in search of a cheap fuel source. Kerosene was the present source, however it involved immense work to make liquid kerosene from coal. Energy producers soon discovered a breakthrough to producing kerosene and the answer was petroleum. By using the existing kerosene-distilling infrastructure, liquid petroleum can be converted to kerosene (PIOGA, 2019). However, the energy producers needed to find petroleum. Seneca Oil Company joined the hunt for petroleum, hiring Edwin Drake to embark on the mission. In 1859, Colonel

Edwin Drake drilled the first oil well in Pennsylvania. The Townsend of Titusville, PA distinguished Drake as Colonel for his successful quest for oil. Today, Drake's first well serves as a National Historic Landmark and home to the Drake Well Museum and Park. This was only the beginning of the oil industry. This was a breakthrough, one that would strongly support and undermine the outcome of the economy. Wells in northwestern Pennsylvania produced several hundred thousand barrels, reaching three million barrels by 1862 (Belyadi et al., 2019). The swelling production of oil eventually led to a drop in price, driving many producers to lose business. However, the necessity of oil production was revamped when John D. Rockefeller founded Standard Oil in the 1870s along with the introduction of the automobile later on. Few industries today have the same impact on the state as oil and gas drilling. Pennsylvania's Gross Domestic Product from utilities was $282.60 billion in 2019, including services like natural gas and electricity generation (PIOGA, 2019). The growing need of oil and gas products today continues to bring profitability to oil and gas companies, landowners, and the economy.

Table 1.1: Brief Timeline of the Oil and Gas Industry (Stolz et al., 2022).

| Date | Event |
|---|---|
| Horizontal Directional Drilling Milestones | |
| 1930's | Use of a "Whipstock" to deflect well bore – allows for multiple wells from same pad |
| 1960's | Development of the "mud motor" |
| 1970's | Martin Cherrington – father of Horizontal Directional Drilling, HDD for pipelines |
| 1990's | Computer driven "smart" drills |
| Fracking Milestones | |
| 1865 | E.A.L. Roberts receives a patent for his "Exploding Torpedo" – first documented use of explosives; initially was gunpowder and later nitroglycerine |
| 1947 | Limestone formation at 2,500' in Hugoton KS |
| 1949 | Duncan OK and Holliday TX fracking of first commercial oil wells patented by Stanolind and licensed to Haliburton |
| 1980's | George Mitchell uses hydraulic fracturing in the Barnett (TX) shale |
| Modern HDD and Fracking | |
| 1980's | Elf Aquitaine – oil fields in southwest France |
| 1990's | Texas and North Dakota |
| 2005 | Energy Policy Act – exempts fracking and subsurface gas storage from Safe Drinking Water Act |

### *1.1.3 Shale Formations*

Oil and gas products in Pennsylvania are typically extracted from the Marcellus Shale formation that was deposited over 350 million years ago. Situated in the Appalachian basin, the shale forms the bottom part of a thick sequence of Devonian age sedimentary rocks (George, 2016).This formation extends from southern New York

across Pennsylvania, and into western Maryland, eastern Ohio, and West Virginia, providing rich benefits for oil and gas extraction. The Marcellus Shale has become one of the world's largest natural gas fields with an estimated 500 trillion cubic feet of natural gas (George, 2016). Over time, organic matter was deposited with the Marcellus shale under immense pressure and heat, forming hydrocarbons like natural gas. These products come from the remains of dead organisms that lived millions of years ago. Layers of sand, silt, and rock covered the dead organisms and formed the layers favorable for oil and gas extraction.

Another shale formation is growing attention from oil and gas companies. The Utica Shale is situated a few thousand feet below the Marcellus Shale formation. The Utica Shale is a black, organic rich shale of Middle Ordovician age that extends from Ohio, Pennsylvania, West Virginia, New York, Quebec, and other parts of eastern North America (King, 2012). This formation is receiving much attention as it contains large amounts of natural gas. According to the United States Geological survey, the Utica Shale is estimated to contain about 38 trillion cubic feet of natural gas.

### *1.1.4 Unconventional vs. conventional*

There are two general types of oil and gas reservoirs: unconventional and conventional reservoirs. Conventional reservoirs have oil and gas resources that are easy to produce, but difficult to locate. Typically, conventional wells are drilled into a sandstone formation that can range from 1,500 feet to 21,000 feet deep. Oil and gas can pass through these formations without hydraulic fracturing, yet most wells are still stimulated through fracturing for production efficiency. Unconventional reservoirs are

easy to locate as they are confined to a defined layer such as a shale, but difficult to produce. According to Pennsylvania law, an unconventional gas well is a well drilled into a shale formation below the base of the Elk Sandstone or its geologic equivalent where natural gas cannot be produced horizontally or vertically without being stimulated by hydraulic fracturing (PIOGA, 2019). Unconventional reservoirs require hydraulic fracturing in order to extract the products as the permeability for these reservoirs are less than 0.1 md (Belyadi et al., 2019). Unconventional drilling has become a target market and favored over conventional drilling. While unconventional drilling elicits greater complexity and risk, unconventional reservoirs are known for having a long lifetime of transient flow. However, many wells are needed to make this business and technique profitable.

### *1.1.5 Well Construction Process*

Once the proper permitting is acquired, construction of the well pad begins. Oil and gas activities involve deconstructing the environment to construct the oil and gas field. Land is cleared to make staging areas and storage yards, clear cutting trees and other vegetation. These areas are used to park equipment, store fuel tanks, sand bags, silt fencing, equipment parts, stakes, and to stockpile pipes (Figure 1.1). Stone gravel and large wood timber matting cover the staging areas to provide reinforcement.

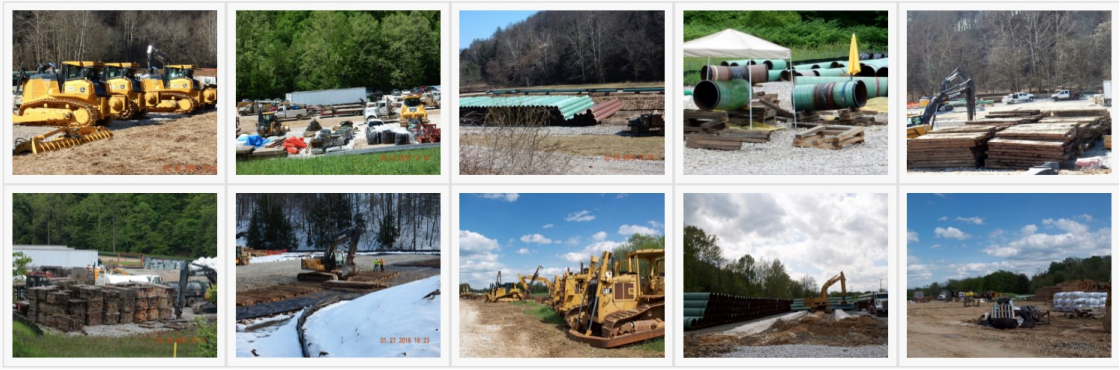


**Figure 1.1: Construction of staging areas and storage yards. Photos captured by Bill Hughes and Sierra Shamer (FracTracker Alliance, 2016).**

The pipeline right-of-way is constructed by clearing out trees and other vegetation (Figure 1.1). To place the pipeline, a trench is dug, and sandbags are placed within the trench to restrict water flow and support the pipe. This construction activity changes the hydrology of the land where the pipeline is placed. Once the pipeline is laid, the trench is filled in and evaluated. The pipeline companies apply for permits to withdraw millions of gallons of water from streams and rivers along the path of the pipeline (Figure 1.2). At high pressure, this water is sent through the pipeline to verify there are no leaks and to confirm that the pipeline is operational. Once the pipeline is confirmed safe to transport gas, the water is removed, and the line is filled with air and nitrogen to ensure remaining moisture is removed (Figure 1.3). The right-of-way is seeded and fertilized, and markers are placed where the pipeline is laid. At this stage, the pipeline is ready for gas extraction.

**Figure 1.2: Clear cutting the right-of-way. Images courtesy of FracTracker Alliance. Photos captured by Bill Hughes and Sierra Shamer (FracTracker Alliance, 2016).**

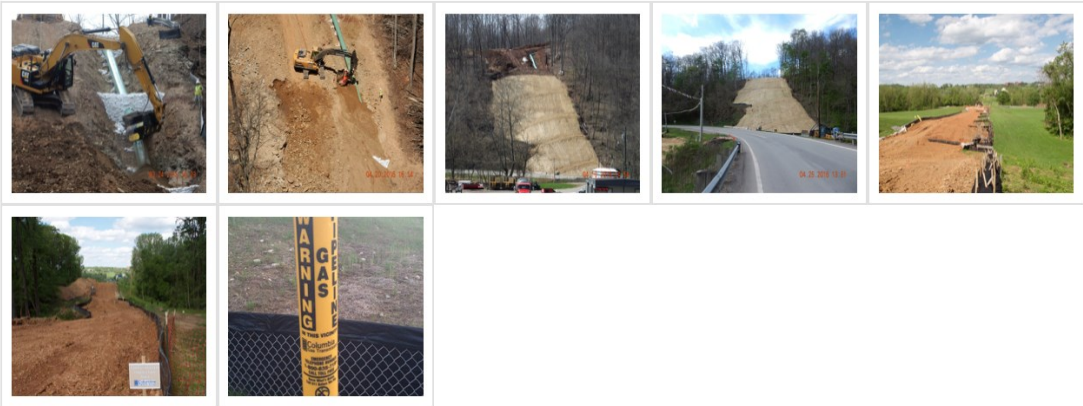



**Figure 1.3: Verifying pipeline operation and restoring the environment. Images courtesy of FracTracker Alliance. Photos captured by Bill Hughes and Sierra Shamer (FracTracker Alliance, 2016).**

Following the construction of the well pad, drilling of the well begins (Stolz et al., 2022). This is the noisiest step as drilling occurs. Drillers use mud to prevent the hole from collapsing as the hole is drilled. This mud is pumped down the drill pipe and out of the bit. The mud cools and lubricates the bit. The walls of the drill hole are coated by the mud, preventing any liquid leaking into the permeable formations. Hydrostatic pressure from the mud column eliminates potential for formation fluids from flowing into the wall. Once the hole is drilled, a solid steel casing is inserted into the hole. The casing gets filled with mud and the technician will apply a liquid cement slurry to the bottom of the hole to stabilize the steel casing. The cement slurry is cement powder and water. The cement is pumped down the casing followed by mud to force the cement up the sides of

the casing to the surface. Pumping stops when the slurry reaches the surface and the cement sets into place. This concludes the first surface casing cement stage, while the drilling process continues as the intermediate casing is cemented. The drilling phase generally lasts four to six weeks (George, 2016). Once the cement is in place, perforation occurs. An electrical signal is sent using a special carrier that is lowered into the hole and sets off a series of small explosive charges to perforate through the cement casing. As pinholes form, this opens a pathway for the reservoir of product to enter the well hole. This could conclude the process if a vertical well is being drilled, penetrating 100 ft of rock. However, if this is a horizontal well, the process extends to a greater length. When the well is complete, fracking typically begins, followed by production of the well. Horizontal unconventional wells apply a new technical advancement by drilling vertically down to the reservoir, then turning the drill bit to go sideways to access many hundreds of feet of rock. This advancement obtains more products compared to vertically drilled wells (Stolz et al., 2022). Horizontal drilling became a widely used and important method as the US had great reliance on imported oil (Belyadi et al., 2019).

### *1.1.6 Imbalance of conventional and unconventional wells*

Pennsylvania was and is a hotspot for oil and natural gas production. Specifically, there are over 17,000 unconventional wells to date (PA DEP - *Oil and Gas Inventory - Report Extracts*, 2023). Conventional wells are less popular today as drilling technology has advanced. An estimated 350,000 conventional oil and gas wells have been drilled in Pennsylvania, most of which are abandoned today (PIOGA, 2019). These wells are inactive, deemed abandoned or orphaned. An abandoned well is one where the operator is

no longer producing hydrocarbons. Whereas an orphaned well is abandoned and the operator is unknown or no longer economically viable (FrackTracker Alliance, 2022). In Western Pennsylvania alone, there are 8,840 abandoned and unplugged wells documented by the PA DEP (*'Orphaned' Wells Are a Problem in Pa., and There Are Many - WHYY*, 2021). In the industry's early years, regulatory programs neither mapped locations of drilled wells nor provided incentives to decommission wells (Raimi et al., 2021). Therefore, the reported abandoned wells are likely an underestimate of the true number of abandoned wells in the state.

Well plugging is a costly process, estimated from $10,000 to $1,000,000 per well, which is why many wells remain unplugged (Kang et al., 2019). Therefore, abandoned wells are a growing issue in Pennsylvania as many are not recorded and plugged. There are at least 200,000 improperly abandoned wells in Pennsylvania (Wells & Hester, 2018). The current method of well abandonment involves a series of cement plugs deep inside wells, restricting the flow of hydrocarbons. Portland cement is commonly used for this process, yet chemical degradation occurs readily in the presence of carbon dioxide and other substances (Raimi et al., 2021). Over time the well casing will wear down. Regardless, data has shown that both unplugged and plugged abandoned wells contribute to methane into the atmosphere (Wells & Hester, 2018).

This technique is not a full proof solution, therefore advanced techniques need to be sought out through review of current management practices (Kang et al., 2019). Poorly maintained or abandoned conventional oil and gas wells can connect aquifers and create conduits for methane or fracking fluids to migrate to the surface. Methane gas can enter domestic well water regardless of if hydraulic fracturing occurs. Just by drilling a gas

well, methane can be introduced to groundwater. To prevent methane and other contaminants from entering water supplies, the well casing must be properly cemented and sealed into the formation so there is no route for the reservoir gas to reach aquifers. The problem lies in the poorly designed and constructed wells (Belyadi et al., 2019). When only the casing across the reservoir is cemented, this provides a way for gas to escape through a leak or pass the poor cement seal. Moreover, a casing may be gas tight for a time, yet corrosion will eventually occur, degrading the barrier from gas escaping to aquifers (George, 2016).

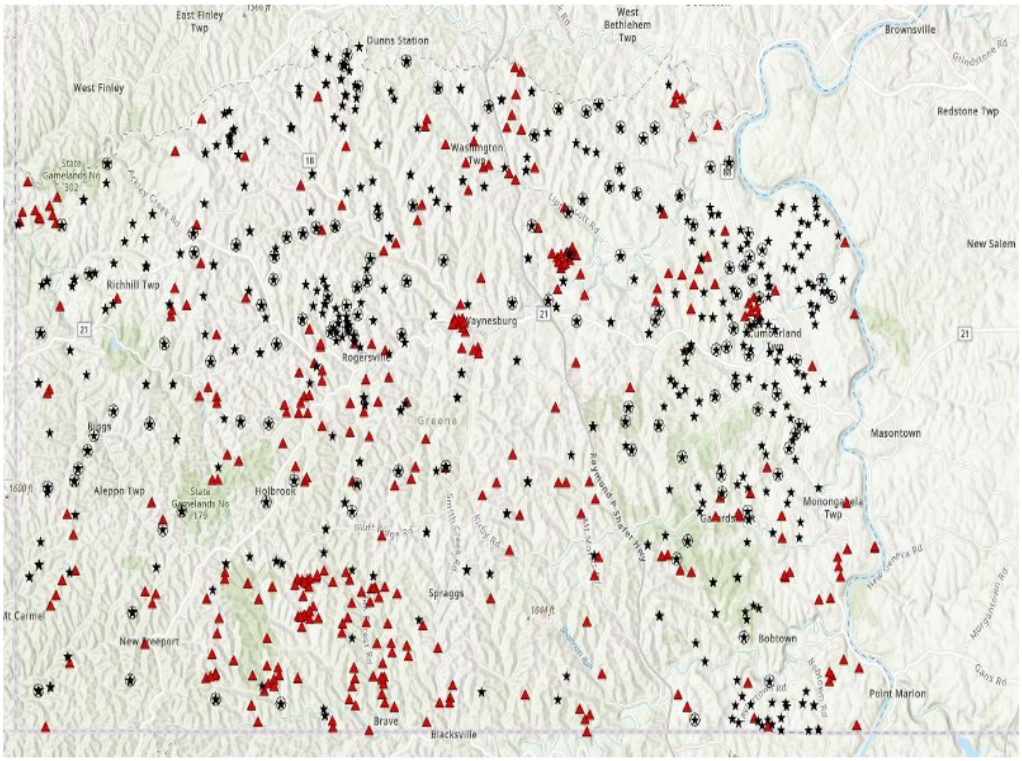



**Figure 1.4: Unconventional wells in relation to abandoned oil and gas wells in Greene County. Triangle corresponds to abandoned gas wells, star corresponds to active unconventional wells, and circle corresponds to unconventional well under violations. Data publicly accessible from PADEP.**

### *1.1.7 Hydraulic fracturing and related factors*

One groundbreaking innovation in acquiring oil and gas products was first credited to E.A.L. Roberts, known as hydraulic fracturing. Roberts received a patent in 1865 to use explosives with his “exploding torpedo” (Stolz et al., 2022). The process was

patented by the Stanolind company and licensed to Halliburton. Gun powder was initially used to fracture formations, but was later replaced with nitroglycerine. The first field testing on a gas field was done in 1947 in a limestone formation at 2,500' in Hugoton KS. The first commercial fracturing began in 1949. In the last twenty years, hydraulic fracturing has swept across the world. For unconventional wells, hydraulic fracturing is employed to stimulate the natural gas to flow to the well. To obtain this product, a field technician uses high pressure drilling to stimulate the flow of natural gas or oil (Figure 1.5). Large quantities of fluids like water, sand, and chemicals are added down the wellbore to enlarge fractures within the rock formation. Once stimulated, the fluid will return to the surface through the wellbore, known as "flowback" or "produced water". Produced water is defined as any type of water that flows to the surface from oil and gas wells (Wollin et al., 2020). When there are multiple wells present on a well pad, zipper fracking is recommended. Zipper fracking involves fracking a stage on one well while perforating and setting the plug on a different well. This can be performed on multiple wells at one time. This process is advantageous for producers as it saves time and money by continuously fracking and perforating. Modern hydraulic fracturing is often monitored by microseismic measurements and computer modeling (Stolz et al., 2022). In addition, an array of surface tiltmeters are used to measure fracture orientation. Downhole tiltmeters are used to provide resolution of the fracture height and length.

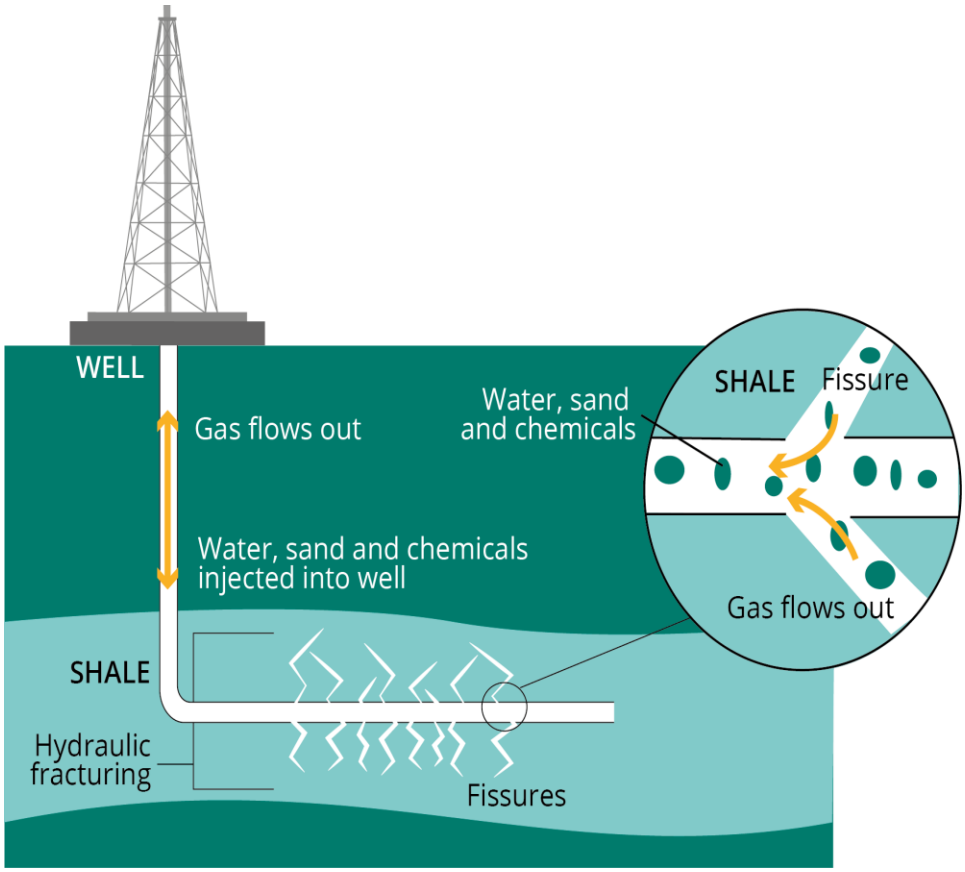



**Figure 1.5: Hydraulic fracturing process. Figure courtesy of European Environmental Agency.**

Advances in directional drilling technologies brought economic growth. At the end of 2000, crude oil was fifty dollars a barrel, and by June of 2008 it rose to 165 dollars a barrel (Stolz et al., 2022). These advances led to unforeseen incidents may occur. Produced water contains a complex mixture of potentially harmful organic and inorganic chemicals that originate from the naturally occurring geology, constituents of the frac fluid, and the transformation products from biotic and abiotic processes(Wollin et al., 2020).

A large majority of constituents in produced water are grouped in the following categories (Wollin et al., 2020):

1. Inorganic salts including those from chloride, bromide, sulfate, sodium, magnesium, and calcium
2. Metals including barium, manganese, iron, and strontium
3. Radioactive materials including radium-226 and radium-228
4. Oil, grease and dissolved organics, including benzene, toluene, ethylbenzene, and xylenes (BTEX)
5. Hydraulic fracturing chemicals, including tracers and their transformation products
6. Produced water treatment chemicals

Well drilling and hydraulic fracturing activities employ many chemicals that are largely trade secret. During the completion process of drilling a well, a well casing can fail. A failed casing may illicit the chemicals used during well construction to be released into the ground, making its way into groundwater and homeowner's wells. The EPA reported the most likely reason for drinking water contamination is casing damage and cementing of drilling holes that leads to spills (Wollin et al., 2020). Similarly, contamination events can occur by the high pressures used during hydraulic fracturing. Fluids flow and discharge to shallow aquifers due to high pressure of injected fracturing fluids in gas wells, which can cause groundwater contamination (Osborn et al., 2011). If zipper fracturing is employed for multiple wells at a time, it is likely that this is increasing the potential for more groundwater contamination. Samples collected from a fracking incident in Bradford County, PA resulting in contamination of a shallow aquifer were compared against oil and gas production waste waters. The samples from both sources were similar in composition. The PA DEP cited this gas company for violations

of the PA Oil and Gas Act and Clean Streams Law for permitting contamination of the aquifers (Llewellyn et al., 2015).

### *1.1.8 Frac outs*

New threats to water sources are surfacing where oil and gas activity is occurring near abandoned wells, such as a "frac out". A frac out is when a well that is being hydraulically fracked communicates with a nearby well or abandoned well, transporting its contaminants through the network and escaping to the surface. It is known that poorly maintained or abandoned convention oil and gas wells can create conduits for methane or brine to reach the surface (Shaheen et al., 2022). These aquifers are usually separated by aquitards. However, given the increase in hydraulic fracturing, the ground is being disrupted. Modeling studies are suggesting that these abandoned wells are acting as the facilitator for deep brines to reach water resources during fracturing in events where "out-of-zone" stimulation enables connectivity between unconventional and conventional drilling (Shaheen et al., 2022).

Many news articles have been released regarding the recent hydraulic fracturing incident, labeling the incident as a "frac out". While this event is not the first water quality disruption by the industry, this is the first to be reported in the PA DEP Oil and Gas Compliance database. Given the proposed research, the "frac out" incident in New Freeport could be the first reported case that is linked to communication between an abandoned well and hydraulically fracked well. A frac out can occur when a newly drilled well is being hydraulically fracked. Hydraulic fracturing stimulates cracks in the formations where oil and gas products are located. While this occurs, the fractures can elicit unintended communication with abandoned wells, sending the fracking fluids and

other materials into the well (Figure 1.6) (Wells & Hester, 2018). This can lead to potential contamination events (Osborn et al., 2011). The term “frac out” is a rather foreign term. This term has not been used in PA DEP Oil and Gas Compliance until the event in New Freeport, Pa. This draws the question of whether these incidents are common, or perhaps improperly documented. It is easy to remember the Deepwater Horizon blowout in the Gulf of Mexico, yet “small” scale incidents are largely unspoken about. While this activity supplies society’s fuel needs, much of the impact is hidden by loose management and regulation. Anya Litvak from the Pittsburgh Post-Gazette, wrote in July of 2022 that there were 45 incidents reported to the PA DEP in the past six years, suggesting that frac outs may occur more frequently (Litvak, 2022).

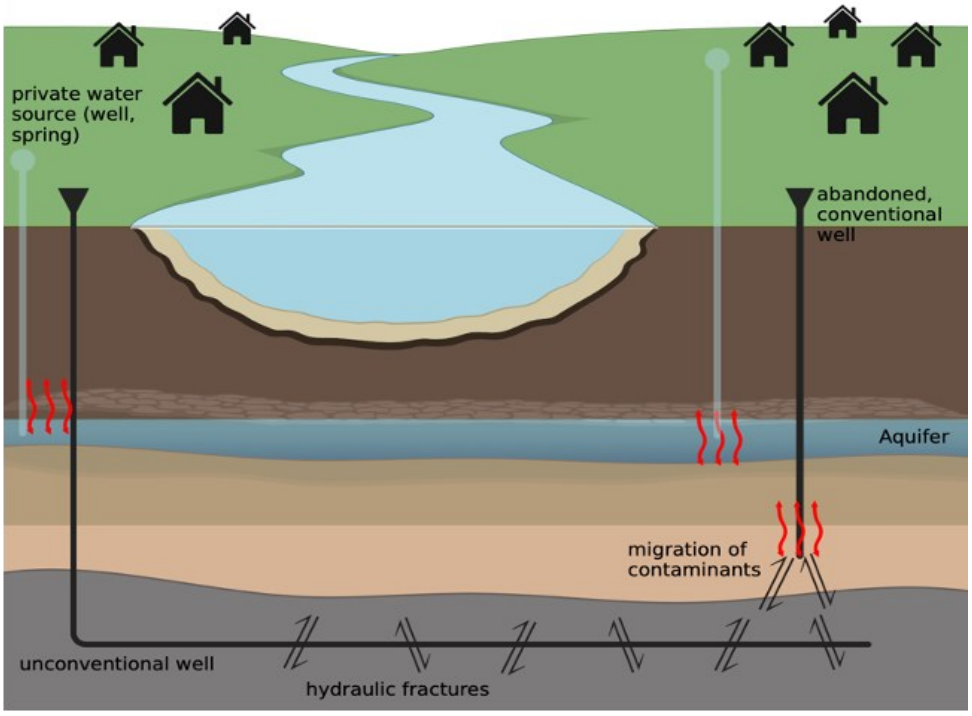



**Figure 1.6: Frac out incident. Visualization of direct communication between an unconventional well and an abandoned gas well, resulting in contamination of groundwater. Diagram created using BioRender.**

## 1.2 Regulations

### *1.2.1 Regulations for well approval*

Prior to preparing the well pad and extracting natural gas, oil and gas companies must secure mineral rights for the desired area and be approved to conduct the oil and gas activity. Lease agreements including royalties are often negotiated and agreed upon between the landowner and the oil and gas company. Once the mineral rights are obtained, seismic surveys are conducted to gain understanding of the stratigraphy. "Thumper trucks" are typically used to determine the stratigraphy by employing instruments that produce vibrations to make soundwaves. The soundwaves will interact with the underground rock layers and be reflected to produce models that are created by sensors that pick up the reflected soundwaves. The models will indicate the geologic formations, depths, and fault locations that will provide the surveyor with an idea of best drilling locations.

In Pennsylvania, a permit is first required to drill or alter a well (Clovis, 2009). To obtain a permit, an application must be filed to the PA DEP. The permit application must be accompanied by a plat prepared by an engineer or surveyor who has experience in the oil and gas field. This plat must show the political subdivision and county where the proposed well will be drilled and operated. In addition, the plat must also include a list of municipalities adjacent to the well site, the name of all surface landowners; and water purveyors whose water supplies are within 1,000 feet of proposed well location; the name of the owner of record or operator of all known underlying workable coal seams; the acreage in the tract to be drilled; the proposed location of the well determined by survey, courses, and distances of the location from two or more permanent identifiable points or

landmarks on the tract boundary corners; the proposed angle and direction of the well if the well is to deviate substantially from a vertical course; the number or other identification to be given the well; and any other information needed by the PA DEP (Office of Attorney General, 2020). The operator must identify the surface and bottom hole locations of any of the following having well bore paths within 1,000 feet measured horizontally from the vertical well bore and 1,000 feet measured from the surface above the entire length of a horizontal well bore. The following must be identified:

1. Active wells
2. Inactive wells
3. Orphan wells
4. Abandoned wells
5. Plugged and abandoned wells

The identification of the wells that are listed are to be found using the following:

1. Conducting a review of the DEP's well databases and other available well databases
2. Conducting a review of historical sources, such as farm property maps
3. Submitting a questionnaire by certified mail on forms provided by the DEP to landowners whose property is within the 1,000 feet described above to inquire the precise location of wells on their property.

Oil and gas companies must submit proof of notification with the well permit application. These notices must be sent to surface owners, those whom the tax notices for the surface property are sent. In addition, the surface landowners or water purveyors

should be advised of the advantage of taking their own pre-drilling or prealteration surveys. The PA DEP is to issue a permit within 45 days of the permit application submission unless the PA DEP denies the permit application. Permit applications can be denied for the following reasons:

1. The well site for which the permit is requested is in violation of any provision of 58 Pa 3201
2. The permit application is incomplete
3. Unresolved objections to the well location by the coal mine owner or operator remain.
4. The requirements of 58 Pa 3225 (relating to bonding) have not been met
5. PA DEP finds that the permit applicant, or any parent or subsidiary corporation of the permit applicant is in continuing violation of 58 Pa. 3201, unless the violation is being corrected to be satisfactory for the PA DEP
6. The permit applicant failed to pay the fee or file a report under Section 2303(c) (relating to administration), unless an appeal is pending.

*1.2.2 Regulations for drilling activity*

The general provision for well construction and operation is found under regulation 78a.73 under the Pennsylvania oil and gas regulations. During stimulation perforations, active, inactive, abandoned, and plugged and abandoned wells identified from above that likely penetrate within 1,500 feet measured vertically from the

stimulation must be visually monitored during stimulation activities. An operator that alters an orphan well, or an abandoned well or plugged and abandoned well by hydraulic fracturing must plug the altered well, or the operator may adopt the altered well and put it into production. In the event of an emergency, operators must follow the regulations described under 78a.55 of the emergency response for unconventional wells. An unconventional operator should report all well control incidents and losses of well control and well control emergencies within two hours of confirmation. As form of the precautionary principal, oil and gas operators are required to prepare and implement site-specific Preparedness, Prevention, and Contingency (PPC) plans (PA DEP, 2018) Specifically, unconventional well operators must develop a Pressure Barrier Policy (PBP) component within the PPC plan (Figure 1.7). These plans aim to prevent future drilling incidents that could result in the impact of private water supplies.

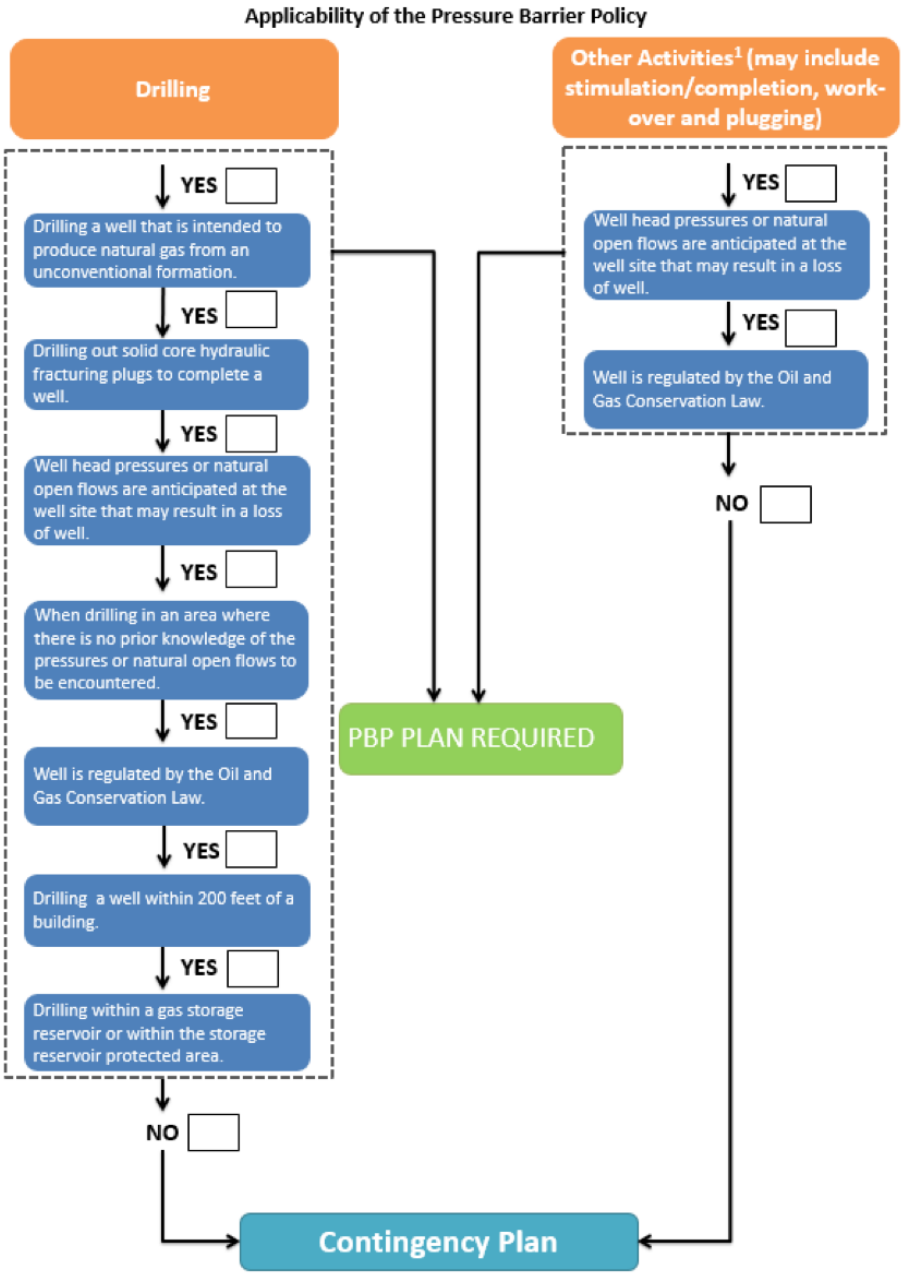



**Figure 1.7: PPC Plan (PA DEP, 2018).**

### *1.2.3 Regulations on protection of water supplies*

Unconventional oil and gas activity often occurs where there is no public water system (Office of Attorney General, 2020). Given this is the case, policies were designed to protect people while these activities occur. Regulations on the protection of water

supplies can be found under section 3218 of 58 Pa.C.S under 78a51 “Protection of water supplies”. Pennsylvania code states that any well operator who affects a public or private water supply by pollution or diminution within 2,5000 feet of the unconventional well bore (1,000 feet of a conventional well) must restore or replace the affected supply with an alternative water source until the pre-existing water quality and quantity is restored. The 2,500 feet distance is referred to as the rule of presumption. Any affected water outside of the 2,500 feet for unconventional drilling is not protected under this regulation. Regardless of this zone, it is advised that anyone who is affected by water contamination as a result of oil and gas operations contact the PA DEP to request an investigation. To protect the success of drilling companies, well operators can preserve its defense under this law by conducting predrilling or prealteration surveys. This provides the company the ability to document the quality of a water supply to support or refute a future claim that the drilling or alteration of the well affected the water supply.

### 1.3 Private Drinking Water

> *The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania’s public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.* Pennsylvania Constitution, Article 1, Section 27: The Environmental Rights Amendment

Since 1859, oil and gas has brought economic booms along with environmental plunder. This development has resulted in degradation of water quality. More than 43 million people, 15 percent of the U.S. population, rely on domestic (private) wells as their source of drinking water (Bowen et al., 2019). The construction and water quality of these wells are normally regulated, but not in Pennsylvania. In Pennsylvania, more than

three million residents use private groundwater wells as their drinking water source (Clark et al., 2021).

Protection of private drinking water near oil and gas activities is especially important given the lack of policy. Unlike private drinking water, public drinking water must be compared to the EPA's primary and secondary standards. The primary standards set are required to pass, while the secondary standards are recommended, but not required. Primary standards are those that have known health concerns, while the chemicals listed under secondary are distinguished by issues with taste, smell, odor, and cosmetic. Some states implement secondary standards as primary standards. Since private water is not regulated in Pennsylvania, it is the responsibility of the homeowner to ensure their water is safe for drinking. Private drinking water can be compared to both EPA's standards and the World Health Organizations standards (WHO, 2022).

### *1.3.1 Oil and Gas — Water Complaints*

Increases in complaints of well water disturbances and reports of pipeline incidents are sending scientists, policymakers, and the public to question the oil and gas industry's standards. From 2004 until 2016, 9,404 oil and gas-related complaints were filed to the PA DEP in the PA counties investigated in the study (Clark et al., 2021). Anyone who witnesses an impact, an environmental complaint can be filed by phone in the region of impact's office or submitted through the online form (PA DEP - *Environmental Complaints*, 2023). Complaints are typically filed for ongoing concerns, which would be handled during business hours. Common complaints in oil and gas include abandoned wells, private water supplies impacted, and gas migrations. However,

an environmental emergency refers to an active situation that requires immediate attention. For example, a major oil and gas spill would be considered an environmental emergency. To report an environmental emergency, one should call 1-800-541-2050.

### *1.3.2 Water Quality Impacts*

Determining whether chemicals used during hydraulic fracturing have been found in drinking water is complicated by the fact that Frac Focus, the official registry now lists over 175,000 chemicals (Stolz et al., 2022). However, some chemicals have been identified in water samples. The most commonly detected organic contaminants in one study found bromochloromethane, 1,2,-dichloroethene, benzene, and trichloroethene (Clark et al., 2022). All 17 inorganic chemicals measured were detected in at least twenty percent of PA homes. The most frequently detected inorganic chemicals were chloride, strontium, lithium, barium, sulfate, potassium, and sodium (Clark et al., 2022). In another study, methane was detected in eighty-two percent of drinking water samples. Homeowners living less than one kilometer from gas wells had methane-contaminated drinking water (Jackson et al., 2013). Methane leakage from oil and gas activity is directly attributed to hydraulic fracturing (Yudhowijoyo et al., 2018). There are various mechanisms for methane and other contaminants transport into water sources, but a growing concern is linked to abandoned wells and hydraulic fracturing activity.

### *1.3.3 Methane in Water*

Methane is the primary component of natural gas. This gas is colorless, tasteless, and odorless. There are two different forms of methane: thermogenic and biogenic

(Darrah et al., 2014). Methane can be emitted into the air via extraction and transportation of natural gas and oil from the ground. Likewise, methane is also emitted from livestock and organic waste. Methane is naturally found in rocks, but methane can also be produced from microbes (Darrah et al., 2014). While methane can be produced during microbial methanogenesis, the presence of higher-chain hydrocarbons at low methane-to-ethane ratios indicates deeper thermogenic gas, produced by hydraulic fracturing (Osborn et al., 2011). Based on mass ratio analysis, it can be determined whether the sample of methane is of biogenic or thermogenic origin. Regardless, high concentrations of methane present concerns. While methane is not a known health hazard, the presence of high methane in homes is a concern for explosion risk. Methane concentrations between five to fifteen percent by volume in the air present risk for explosion. The methane contamination action level is 7 mg/l, meaning above this level, the PA DEP advises homeowners to seek methods to lower the methane concentrations (PA DEP - *Methane*, 2023). The DEP will follow up with homeowners to reduce methane in their water supply. However, there has been debate on the level of methane that is harmful. PennState University states that methane concentrations below 10 mg/L are generally safe for use (Swistock, 2022). Methane concentrations can be reduced by installing a vent on the wellhead and installing water treatment.

### 1.4 Remote Sensing Technology

While chemical analysis is an effective way to detect water quality impacts, remote sensing technology could detect areas of concern that are not visible. Visible impacts may include impacts to water quality, land, and homes. Prior to observing these

impacts, InSAR technology could detect areas that may need additional monitoring. Interferometric Synthetic Aperture Radar (InSAR) is used to detect relative ground motion with millimetric accuracy in groundcover (Wang et al., 2022). InSAR makes high-density measurements over large areas by using radar signals from Earth-orbiting satellites to measure changes in land surface (Figure 1.8). Often, this technology can be confused with measuring seismicity. Seismicity refers to the frequency, intensity, and distribution of 'shaking' associated with earthquakes in a given area (Jordan et al., 2019). However, InSAR detects ground motion. Ground motion refers to the gradual movement of the ground surface of the landscape. The landscape can move upward (uplifts), downwards (subsidence), or sideways (horizontal/lateral) (Jordan et al., 2019). These various movements can be detected by satellites.

This technology has been applied across many different areas of study. In the last two decades, InSAR has undergone fast development and is widely used in monitoring surface displacements caused by unconventional gas injection and extraction. InSAR technology has been used for retrieving the displacements of the Hutubi (China) underground gas storage (Wang et al., 2022). Results revealed a long history of slow subsidence. Another study conducted environmental baseline monitoring (Jordan et al., 2019). InSAR was used to detect and monitor ground motion at shale gas sites (Jordan et al., 2019). The specific site investigated in the UK traditionally had major challenges with radar coherence prior to the use of InSAR technology. The authors reported that ground motion baselines and monitoring of any shale gas operation is vital. Given its ability to detect ground motion and identify uplifts and subsidence, it concluded that this application should be used for other regions where baseline monitoring is possible. Oil

and gas production involves continuous extraction from deep underground to the earth surface. These activities lead to instability of the ground surface, resulting in land subsidence (Fatholahi et al., 2021). Therefore, assessment of underground surface deformation in and surrounding oil and gas activity is critical for the protection of water quality and human health. There is great need for this research given the seldom monitored surface displacements included by gas recovery and injection/extraction.

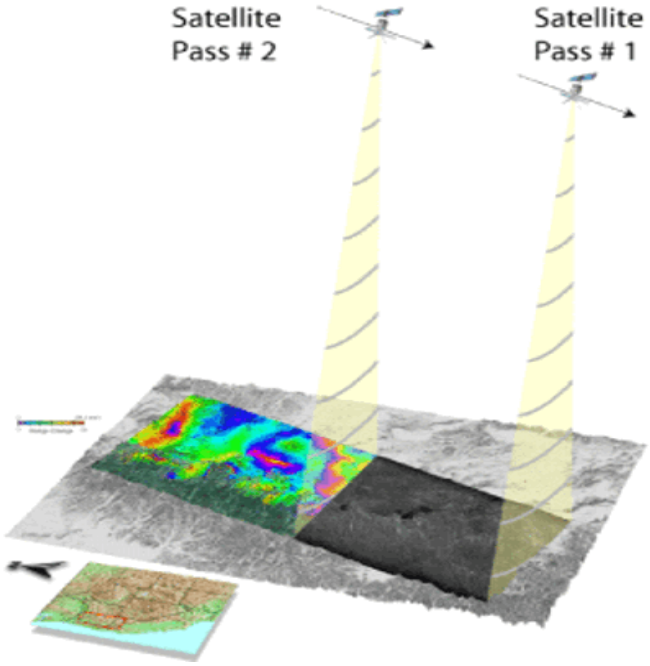



**Figure 1.8: InSAR technology. Two or more passes over a given area are required to create InSAR images used to measure changes in ground height (US Geological Survey, 2021) (public domain).**

## 1.5 Study Area

### *1.5.1 Demography*

New Freeport is in the far southwestern corner of Pennsylvania, consisting of a mainly rural region. It has a total area of 588 square miles and is approximately 32 miles long and 18 miles wide (Stone & Clapp, 1907). In the 1930 census, New Freeport was

home to 408 people (Stone, 1932). As of 2020, the population of New Freeport was 77. From the 2021 census, there was a reported 42 people with a racial composition of 100% white individuals. The population is continuing to decline in New Freeport. The average household income in New Freeport is $45,196 with a poverty rate of 18.37%. The median age in New Freeport is 53.8 years, 64.1 years for males, and 49.8 years for females (*New Freeport, Pennsylvania Population, 2023*).

### *1.5.2 Geology*

Greene County is a region of rolling hills and rural landscapes. The rocks exposed at the surface are estimated at 1,400 feet thick (Stone & Clapp, 1907). The surface rocks belong entirely to the Carboniferous system. The surface intersects four formations: the Greene, Washington, Monongahela, and the Conemaugh (Stone & Clapp, 1907). The Greene formation is the section of the highest rocks exposed in Pennsylvania down to the top of the Upper Washington limestone. This is around 700 feet in maximum thickness and is composed mostly of shale and shaly limestone. The Washington formation is a series of soft rocks that extend from Upper Washington limestone to the Waynesburg coal. The Upper Washington is 4 to 15 feet thick and broken into two or more beds by thin layers of shale. The Monongahela formation extends from the top of Waynesburg coal to the base of the Pittsburgh coal. This formation is 273 to 405 feet thick. The formation contains over 100 feet of limestone, heavy beds of sandstone, shales, and five coal seams (Stone & Clapp, 1907).

### *1.5.3 Water Sources and Usage*

New Freeport is located within the Fork Fish Creek watershed. There are 173 waterbodies within the Pennsylvania Fork Fish Creek watershed. Based on water quality assessments conducted by the EPA, twenty percent of the assessed waters are impaired (Figure 1.9) (EPA, 2023). The main impairment categories are sediment, degraded habitat, and nitrogen and phosphorus. There are eight public water systems serving Greene County (PA DEP - *Water_Source_Registration - Report Viewer*, 2023). Of these water systems, seven are sourced from surface water and one is ground water. However, New Freeport area specifically does not have public water systems, largely due to the small population of New Freeport (*New Freeport, Pennsylvania Population, 2023*). A public water system is defined as a system that serves at least 15 service connections or regularly serves an average of at least 25 people for at least 60 days of the year (PA DEP-*Noncommunity Water Systems*, 2023). While this could be possible if required, there are no potential water sources nearby that residents could hook up to if necessary. The nearby stream, Fork Fish creek, is an impaired watershed, therefore this would not be a safe option for residents to use for drinking water. The only option would be to use groundwater sources, yet if these sources become contaminated, this draws a major concern for residents to have access to safe drinking water.

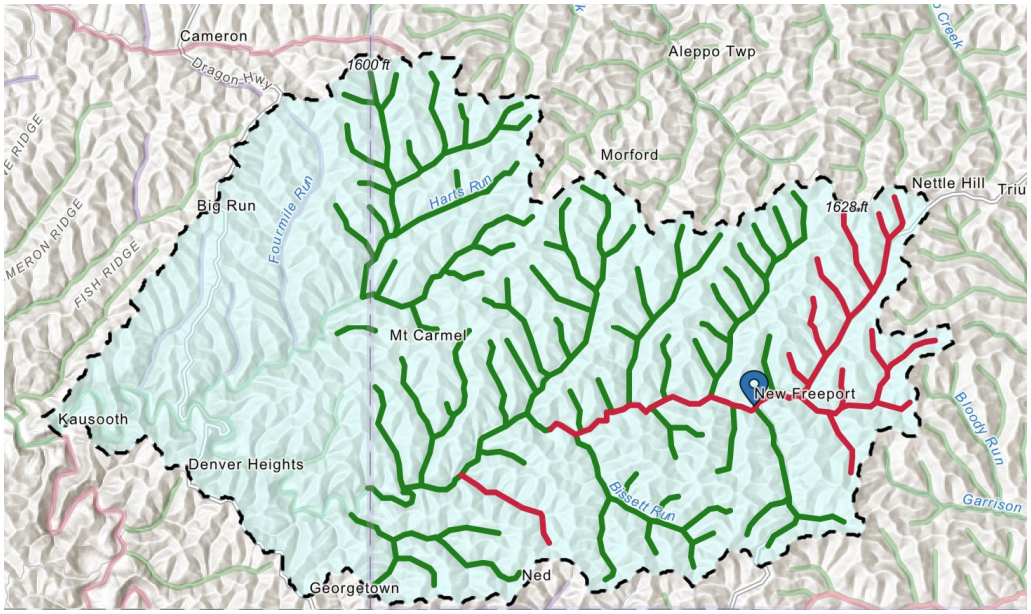



**Figure 1.9. Pennsylvania Fork Fish Creek watershed in Greene County, PA. Green indicates a healthy stream, while red indicates an impaired stream. Data and map provided by "How's My Waterway" (EPA, 2023).**

### *1.5.4 Weather*

In the warm season from May to September, New Freeport has an average daily high temperature about 73°F (*Freeport Climate, Weather By Month, Average Temperature (Pennsylvania, United States) - Weather Spark*, 2023). July is the hottest month of the year with an average high of 82°F. The cold season is from December to March and has an average daily high temperature below 45°F. January is the coldest month of the year with an average low of 23°F. June is the month with the most wet days, with an average of 12.1 days with at least 0.04 inches of precipitation. New Freeport has an average 3.5 inches of rainfall in June.

### *1.5.5 Land Cover Changes*

Given the hilly nature of the land, the county is better adapted to raising livestock and hay compared to crops (Stone, 1932). Greene county was originally covered by a vast

forest. Pine, spruce, and hemlocks dominated this area. However, large parts of the forest were cut for land availability for pasture, leaving roughly 15 percent of the original hardwood forest. In recent years, coal companies have realized the advantage of growing wood in and around mined areas. This led to motivation for large reforestation. Yet, with the introduction of unconventional drilling into Greene County, much of this activity would be reversed.

### *1.5.6 Soils*

The soils in this area fall into three broad groups: upland residual soils, terrace and old alluvial soils, and first-bottom or recent alluvial soils. About 89 percent of the county is covered by upland residual soils (Stone, 1932).

### *1.5.7 Drilling History*

> "Because in the not far distant future, Greene County is likely to become a much greater producer of minerals than at present, and to prepare the people for that event, this report was undertaken." – Ralph W. Stone (1932)

Greene county has produced oil continuously since 1886, yielding large amounts of natural gas since 1890 (PA DEP - *Oil and Gas Inventory - Report Extracts*, 2023). Currently, there are 1605 active, unconventional wells drilled in Greene County and 1803 active conventional wells drilled (based on viewing data on Feb 3rd, 2023). In addition, there are 398 reported abandoned conventional wells (PA DEP - *Oil and Gas Inventory - Report Extracts*, 2023). Currently these active unconventional wells are situated within these same areas of the abandoned conventional wells.

# CHAPTER 2: MATERIALS AND METHODS

## 2.1 Specific Aims and Research Questions

### *2.1.1 Background*

Many studies related to oil and gas extraction have been produced from the Stolz Water Lab at Duquesne University. Recent graduates have focused on topics like the impacts of oil and gas wastes on landfill leachate, underground gas storage regulation and impact on water quality, and oil and gas production. Overall, these studies have a focus on the impact of water quality by the oil and gas industry. Specifically in this study, New Freeport is the area of concern in the context of water quality. The purpose of this study is to investigate the water quality impact and its connection to the reported frac out in New Freeport PA in June of 2022. Pre-drill data does exist for the New Freeport area, so when available, the post frac out data will be compared to the pre-drill data.

On June 19th, a report of an incident was released in New Freeport, PA that advised the town of New Freeport not to drink their private water supply. Unfortunately, there is no certainty when the event actually occurred because the company at fault did not report the incident as soon as it happened. The residents of New Freeport were alerted via Facebook about the incident.

> "To all residents whom live on Main Street from the Firehall West to Herods run. EQT has contacted the TWP and informed us there was a FRAC OUT at the bottom of Fox Hill. All drilling in the direction of the FRAC OUT has stopped for now. EQT will be contacting you all to test your water to make sure it wasn't affected or contaminated. I DO NOT know when this will happen but suspect it will be in the next few days. If you smell gas or have discolored water DO NOT DRINK OR USE! PLEASE CONTACT EQT. Casey Durdines 412-354-7366 Or call one of the supervisor and we will relay the message TO EQT. THANK YOU Freeport TWP Board of Supervisors" – New Freeport Township

Fluids began percolating up the side of an abandoned well on a landowner's property. The landowner reported this to the drilling company that was drilling at the time. EQT investigated the impact and deemed it to be caused by the drilling on the Lumber well pad (13H). On June 20th, the Pennsylvania Department of Environmental Protection (PA DEP) became aware of the incident and conducted an on-site investigation. EQT reported that they were in the 100th stage of the fracking process when there was a loss in pressure. This event led an abandoned well (Reed #1) over 3,000 feet from the well bore to communicate with the well being fracked. Based on this investigation, the drilling company EQT faced several violations for the incident and the DEP forced all hydraulic fracturing operations to cease on June 21st. Beginning on June 20th, water testing was conducted by a private company on homeowner's water supply within 2,500 feet. The Stolz lab learned about this incident from The Center for Coalfield Justice. We received contacts from homeowners who were concerned about their water. On June 27th, we began conducting water quality analysis in New Freeport, PA.

### *2.1.2 Research Questions*

1. Based on homeowner surveys, were there observable signs of water quality impact?
2. Are brine and methane present in the water samples?
3. Were there any irregular land surface movements that occurred at the time of the "frac out" and/or near the "frac out" incident?

### *2.1.3 Hypotheses*

Hypotheses:

H-1 The frac out caused changes in water quality of the domestic water wells.

H- 2 Mass ratio analyses of water chemistry of domestic water well samples indicate source contamination.

H- 3 The frac out caused fugitive methane migration.

H-4 The frac out caused changes in surface elevation as detected by InSAR

### *2.1.4 Specific Aims*

To validate these four hypotheses, the following specific aims were conducted:

1. Explore the oil and gas reports produced by the PA DEP to better understand the level of oil and gas activity in New Freeport. How abundant is this activity in the landscape and where are these wells specifically located will be determined. From here, the environmental impacts will be investigated by exploring the oil and gas violations in New Freeport. A map will be created of the unconventional wells drilled in Greene County in relation to conventional wells (active or abandoned). This map will also include wells that have oil and gas violations.
2. An evaluation of water quality in New Freeport will be conducted using homeowner surveys to determine if homeowners noticed impacts and the changes in water quality that were observed. Information will be gathered from this survey that cannot be determined through chemical analysis, like well history and the time period where changes were noticeable.

3. An investigation of water quality based on chemical analysis. Collect samples from private water, testing for cations, anions, and volatile organic compounds. The purpose of this aim is to evaluate the level of impact by the frac out on these private water supplies.

4. Evaluate how remote sensing analysis can be used as a tool for mapping areas of potential contamination and frac out potential. Using InSAR, analyze the ground surface for any ground surface movement at the time of the frac out compared to the ground surface activity before the frac out. Irregular surface movement can be a clear indicator of the frac out incident, indicating that these incidents can be visualized using remote sensing. This could provide an effective solution to prevention and management of these incident for the oil and gas industry.

## 2.2 Materials and Methods

### *2.2.1 Field Analysis – Homeowner Survey*

Consent for conducting investigation is given to the homeowner to read and sign, agreeing with the information provided. This form covers the scope of the project, the source of funding, and information confidentiality (Appendix A). A survey is provided to each homeowner, collecting basic information about the well and inquiring about general water quality concerns. These six survey questions have been reviewed and approved by Duquesne University's Internal Review Board (IRB) under Protocol 2019-01-14 (Appendix B):

1. Do you have well water and where is your well located?

2. What kind of well is it (ex. artesian, rotary, cable tool)?
3. Do you know how deep the well is and have you noticed a change in your well depth?
4. Have you noticed any change in water quality (taste, smell, color) and if so, when?
5. Have you noticed any change in water flow or quantity?
6. Have you ever had the water tested and would you be willing to share those results?

*2.2.2 Field Analysis – YSI-Pro Plus Multimeter*

A YSI-Pro Plus Multimeter (YSI Incorporated, Yellow Springs, OH) is used for on-site preliminary water quality analysis. This instrument measures temperature (°C), dissolved oxygen (DO% and DO mg/L), pH, pressure (mmHg), specific conductivity (µS\cm), conductivity (µS), and total dissolved solids (TDS). Two measurements are collected for each well/sample site. Before the well lines are purged, the measurements are collected by fully submerging the probes in the sample. Once the device stabilizes, the measurements are recorded on a YSI data sheet (Appendix C). After the well lines are purged for 10 to 20 minutes, unless the homeowner chooses otherwise, the measurements are collected again. This second test assumes that the water that is being tested is coming directly from the well and not from residue in the pipes.

*2.2.3 Sample Collection*

Water samples are collected from homeowner's private water supply (Figure 2.1). Samples are collected pre-filtration systems when applicable. Given that the

homeowner's water lines are purged during YSI testing, the samples can be collected following those measurements. A total of 4 sample bottles are used for each sample source. Each sample is collected in a 1-L French square glass bottle that was autoclaved, and prerinsed with DI then sample water (VWR International, Bridgeport, NJ). To test for volatile organic compounds (VOCs), two pre-cleaned 40 mL amber glass vials with a screw cap and PTFE faced 0.125' silicone septa bottles are used. This analysis specifically requires the sample to be airtight, leaving no headspace to prevent methane escape from the water sample (Restek, Bellefonte, PA). Samples for cation analysis are collected in 60 mL glass bottles (VWR International, Bridgeport, NJ). These bottles are pre-acidified with 5-10 drops of nitric acid (10M $HNO_3$). All samples are collected and stored on ice in dark conditions and transported back to the lab and stored at 4°C until analysis.

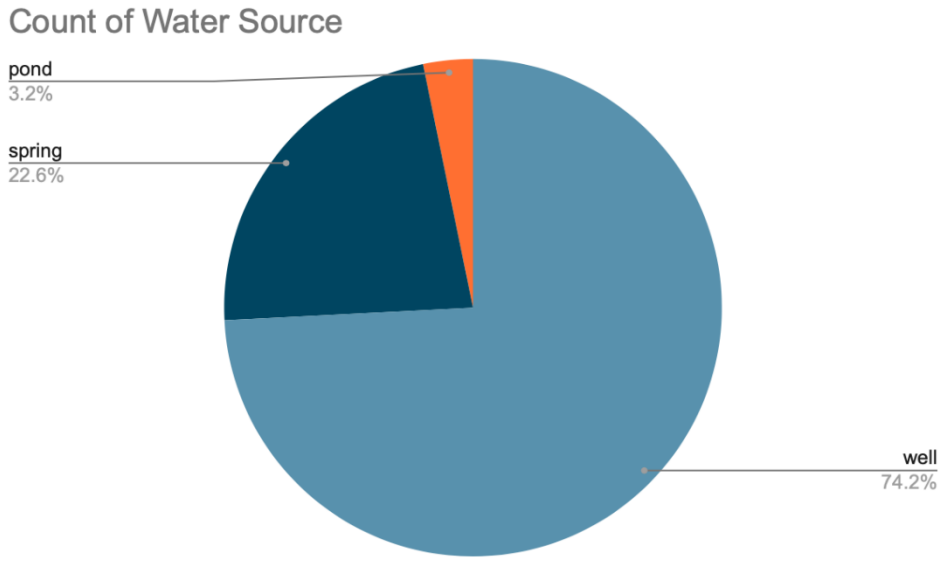



**Figure 2.1. Water sample sources. Water samples were collected from pond, spring, and well sources in New Freeport, PA.**

### *2.2.4 Data Mapping*

A hand-held GPS unit (GPSMAP 62s Garmin, Kansas City, KS, USA) is used to record the coordinates of the homeowner's well or spring location. Coordinates are collected for any surface water that was sampled, and in this case were ponds. Drilled unconventional and conventional oil and gas well were found on the Pennsylvania Department of Environmental Protection's Oil and Gas database, which is publicly accessible. All sample locations were mapped using the ArcGIS Pro (ESRI, Redlands, CA, USA). In addition, coordinates of unconventional and conventional wells acquired from the PADEP database were mapped using ArcGIS Pro.

### *2.2.5 Laboratory Analysis*

Samples are brought back to the lab at Duquesne University for analysis of anions, and volatile organic carbons (VOCs). Anion testing (IC) is performed in accordance with EPA Method 300.0. Light hydrocarbons are analyzed using Gas Chromatography and Flame Ionization Detection. Cation analysis (ICP-MS) is performed in the Bain Lab at the University of Pittsburgh. Once analysis is complete, water samples are compared to the National Primary and Secondary Drinking Water Standards (US EPA, 2015). Any results that are above the set drinking water standards warrant concerns

#### *2.2.5.1 Ion Chromatography (IC) – Anion Analysis*

Analysis of the anion's bromide ($Br^-$), fluoride ($F^-$), chloride ($Cl^-$), nitrate ($NO_3^-$), nitrite ($NO_2^-$), phosphate ($PO_4^{3-}$), and sulfate ($SO_4^{2-}$) are performed using Ion Chromatography, as described in Cantlay et al., 2020a (Table 2.1). Prior to analysis, the

water sample is filtered through a 0.2 μm PES filter (VWR, Bridgeport, NJ, USA) and a Dionex OnGuard II M filter (Dionex, Sunyvale, CA, USA) and Dioxen polyvials (Dionex, Sunyvale, CA, USA) to remove any suspended solids. 5 mL of the filtered sample is inserted into the 5 mL Dioxen polyvials and capped. A Dionex ICS-1100 Ion Chromatography System equipped with a UV/VIS detector and conductivity cell was used for sample analysis. Anions were separated using a Dionex IonPac AS22 Carbonate Eluent Anion-Exchange Column (2 X 250, 6 μm particle diameter) and a Dionex IonPac AG22 Guard Column (2 X 50mm) along with a Dionex ASRS-300 anion self-generating suppressor.

**Table 2.1. Minimum detection limits (MDLs) for target anions analyzed using IC are presented below.**

| ***Anion*** | ***Minimum Detection Limit (ppm)*** |
|---|---|
| *Fluoride* | 0.035 |
| *Chloride* | 0.01 |
| *Nitrite* | 0.02 |
| *Bromide* | 0.05 |
| *Nitrate* | 0.045 |
| *Phosphate* | 0.05 |
| *Sulfate* | 0.05 |

#### *2.2.5.2 Inductively Coupled Plasma Mass Spectrometry (ICP-MS) – Cation Analysis*

As described in Cantlay et al., 2020b, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is used for cation analysis. Water samples are prepared for analysis by filtering 1 mL of sample through a 0.2 μm PES filter (VWR, Bridgeport, NJ,

USA), followed by a dilution with 2% nitric acid. All cations measured using this analysis are described in Table 2.2. For quality control purposes, beryllium, germanium, and titanium are added as internal standards. In collaboration with the University of Pittsburgh, a Perkin-Elmer NexION 300x (Waltham, MA, USA) is used along with a Perkin Elmer S10 Autosampler and NexION 300x ICP-MS software for analysis of 32 metals in the water samples (EPA method 200.8, Revision 5.4).

**Table 2.2. Minimum detection limits (MDLs) for target cations analyzing using ICP-MS.**

| *Cation* | *Minimum Detection Limit (ppb)* |
|---|---|
| *Lithium (Li)* | 0.1 |
| *Boron (B)* | 2.5 |
| *Sodium (Na)* | 0.5 |
| *Magnesium (Mg)* | 3.5 |
| *Aluminum (Al)* | 2.5 |
| *Silicon (Si)* | 30 |
| *Phosphorus (P)* | 2 |
| *Potassium (K)* | 2 |
| *Calcium (Ca)* | 2.5 |
| *Titanium (Ti)* | 0.2 |
| *Vanadium (V)* | 2 |
| *Chromium (Cr)* | 0.1 |
| *Manganese (Mn)* | 1 |
| *Iron (Fe)* | 1.5 |
| *Cobalt (Co)* | 0.1 |
| *Nickel (Ni)* | 0.1 |
| *Copper (Cu)* | 2 |
| *Zinc (Zn)* | 1 |
| *Arsenic (As)* | 0.2 |
| *Selenium (Se)* | 0.5 |
| *Rubidium (Rb)* | 0.002 |
| *Strontium (Sr)* | 0.1 |
| *Molybdenum (Mo)* | 0.1 |
| *Silver (Ag)* | 8 |
| *Cadmium (Cd)* | 0.02 |
| *Tin (Sn)* | 0.2 |
| *Antimony (Sb)* | 0.2 |
| *Barium (Ba)* | 0.5 |
| *Tungsten (W)* | 0.004 |
| *Mercury (Hg)* | 0.07 |
| *Uranium (U)* | 0.03 |
| *Lead (Pb)* | 0.03 |

#### *2.2.5.3 Gas Chromatography (GC) – VOC Analysis*

Water samples are analyzed using a Shimadzu Nexis GC-2030AF (Columbia, MD, USA) with an HS-20 Headspace Autosampler and LabSolutions software. Standards are used to validate the calibration curve. The standards are not prepped in the laboratory.

Instead, the methane, ethane, ethene, and n-propane standards are purchased from LGC Standards (Manchester, NH, USA). The detection limits were 10 ppb for methane, ethane, ethene, and propane. The standards are run before analyzing the samples to confirm retention time and validate the calibration curve. The calibration curves are made for two ranges. The low calibration range is from 10 to 500 ppb and high calibration range is from 500 to 5,000 ppb. Samples above 5,000 ppb are diluted accordingly. The EPA requires certified labs to analyze VOC samples within 14 days of collection. However, the EPA recommends that the samples are analyzed as soon as possible due to phase separation (EPA, 2004). All samples are analyzed within 12-24 hours in this study. Methods for this analysis are based and modified from RSK-175 (RSKSOP175, 2004). The four VOCs measured in this analysis are: methane, ethane, ethene, and propane (Table 2.3).

**Table 2.3. Minimum detection limits (MDLs) for VOCs analyzed with GC.**

| *VOC* | *Minimum Detection Limit (ppb)* |
|---|---|
| *Methane* | 5 |
| *Ethane* | 5 |
| *Ethene* | 5 |
| *Propane* | 5 |

*2.2.6 Data Management and Analysis*

Handwritten YSI data sheets are manually entered into a Microsoft Excel spreadsheet and uploaded to the Google Drive, which is only accessible to Duquesne University researchers of this study. The two sets of YSI data that is collected for each sample is averaged and entered in a master Microsoft Excel spreadsheet. Each sample is assigned an identification number for organization (MS followed by a number), avoiding the use of names and home addresses for confidentiality. This spreadsheet holds all

sample data along with important sample information like GPS coordinates of sample locations and sample time. Each water quality parameter is reviewed and compared to the National Primary and Secondary Drinking Water Regulations that are set by the EPA (Table 2.4) (US EPA, 2015). Primary drinking water standards are legally enforceable standards that apply to public water systems (US EPA, 2015). Secondary drinking water standards are non-enforceable guidelines that regulate contaminants that may cause cosmetic effects and other impacts. However, states can choose to adopt these as enforceable standards. Since private water sources in Pennsylvania are not regulated, homeowners are responsible to monitor their own water sources to ensure the water is within healthy limits. Any result that is above the set primary or secondary standard limit is reported in red in both the master Microsoft Excel spreadsheet and the homeowner's report. Copies of the signed consent forms are made and stored in a binder in order by identification number. The original consent form is sent with the homeowner's water quality report. All homeowner letters are saved and stored in the Google Drive.

**Table 2.4. EPA Primary and Secondary Drinking Water Standards and MCLs (Appendix H) (US EPA, 2015)**

| **Primary Drinking Water Standards** | **MCL (mg/L)** |
|---|---|
| Antimony (Sb) | 0.006 |
| Arsenic (As) | 0.010 |
| Barium (Ba) | 2 |
| Cadmium (Cd) | 0.005 |
| Chromium (Cr) | 0.1 |
| Copper (Cu) | 1.3 |
| Fluoride (F) | 4.0 |
| Lead (Pb) | 0.015 |
| Nitrate (NO3) | 10 |
| Nitrite (NO2) | 1 |
| Selenium (Se) | 0.05 |
| Uranium (U) | 0.03 |
| **Secondary Drinking Water Standards** | **MCL** |
| Aluminum (Al) | 0.05 to 0.2 |
| Chloride (Cl) | 250 |
| Copper (Cu) | 1.0 |
| Fluoride (F) | 2.0 |
| Iron (Fe) | 0.3 |
| Manganese (Mn) | 0.05 |
| pH | 6.5 to 8.5 |
| Silver (Ag) | 0.10 |
| Sulfate | 250 |
| Total Dissolved Solids (TDS) | 500 |
| Zinc | 5 |

### *2.2.7 Reporting Data*

Once all chemical analyses are complete and entered into the master Microsoft Excel spreadsheet, the letters are written to the homeowners, including the results of their water quality analysis. Within the report, the EPA's Primary and Secondary Drinking Water Standards are included for the homeowner to compare their results. If applicable, methane reduction recommendations are included in the report. Homeowners are mailed a letter that includes any analytes exceeding the EPA MCLs, a detailed report of water

quality results, a copy of the EPA's standards for reference, and the original signed consent form.

### *2.2.8 Mass Ratio Analysis*

OriginLab 2021 software (OriginLab, Northampton, Massachusetts) is used for statistical analysis of cation and anion mass ratios comparing $BrSO_4$ vs Mg/Li, Ca/Mg vs. Ca/Sr, Mg/Na vs. $SO_4$/Cl, and $SO_4$/Cl vs. Mg/Li (Cantlay et al.,2020a; Cantlay et al., 2020b; Cantlay et al., 2020c). These ratios can be used to determine and compare different source(s) of impact on ground and surface water across unconventional gas (UG), conventional gas (CG), conventional oil (CO), and abandoned mine drainage (MD) brines. Surface and groundwater quality is known to change periodically and episodically (Cantlay et al., 2020a). Water quality changes can be reflected by using mass ratios to visualize the movement through the ratio plot. Moreover, these ratios could be critical for mapping contamination over time for contamination events like frac outs.

### *2.2.9 Geospatial Analysis*

#### *2.2.9.1 Using ArcGIS Pro*

Geospatial data is interpreted using ArcGIS Pro. Unconventional wells, conventional wells, and violations were mapped to better understand the level of abundance of oil and gas activity in this area. In addition, water sample sites are mapped in relation to the location of the well pad to gauge how widespread the impacted sources were showing on the map. Using a GPS system, the GPS coordinates of the sample site are taken directly at each water source like a water well or spring, if possible.

#### *2.2.9.2 Using InSAR Technology*

InSAR technology is used to conduct remote sensing analysis. The Small Baseline Subset (SBAS) approach is used in this study. SBAS is a multitemporal Interferometric Synthetic Aperture Radar (InSAR) algorithm that is used to resolve ground deformation. While precise ground-based techniques are available like in-situ geodetic data, these techniques are restricted to measure variations in the locations of limited set of criteria (Fatholahi et al., 2021). This method is also globally accepted for long-term measurement of ground surface movements over large areas at low costs. Interferometric synthetic aperture radar (InSAR) has accurately confirmed the assessment of ground surface movements at mm level using phase information of SAR images. InSAR measures differences in phases of a wave, that is captured between the two SAR images that are collected over the same area at different times.

Synthetic aperture involves using one antenna on the satellite and it collects signal over the earth. The antenna will move slightly to gain better range of signal over the area. Radar itself measures the time it takes for the signal to get to earth and back. The spatial resolution (synthetic aperture) involves a deconvolution integral so instead of getting a radar, it gets little chunks. This is where all physical tendencies are corrected for like the speed of light, movement of satellite, weather, and time it naturally takes for signal to move through each layers of the atmosphere. The interferometric part goes a step beyond this and takes two satellite images over two time periods. Here, one signal is sent by the satellite and waits for it to come back, then the satellite comes back and sends another signal, returning with an image over the same area. It is important to keep in mind that water is a natural inconvenience to this analysis. This system runs on the same

wavelengths as a microwave. Like a microwave, energy will be absorbed by the water. If you are measuring a frame near water, the satellite imaging could affect the frame. Therefore, you would discard the affected frame given this microwave effect.

Coherence is a measurement of radar response between the two SAR images received. Coherence can be both spatial and temporal and is highly dependent on the properties of ground cover. For example, coherence values are low in areas where it is heavily forested due to the canopy cover. New Freeport is situated largely in a rural area, therefore coherence is expected to be low regardless due to large canopy cover.

# CHAPTER 3: NEW FREEPORT RESULTS

## 3.1 Greene County Operators and Violations

Based on the occurrence of this frac out, it was important to research the general background of oil and gas industry in Greene County. An oil and gas company who applies for permitting and obtains rights to extract oil and gas are known as operators. Based on PA DEP compliance data, there are a total of 1605 operators (25 different operation companies) associated with unconventional wells in Greene County (Table 3.1). Count refers to the total number owned by a particular operator. For instance, the most appeared unconventional operator in Greene County is EQT Production Co with 612 counts, meaning EQT has 612 different sites under operation for oil and gas (Figure 3.1). The most appeared conventional operator in Greene County is Diversified Production LLC with 461 counts (Figure 3.2).

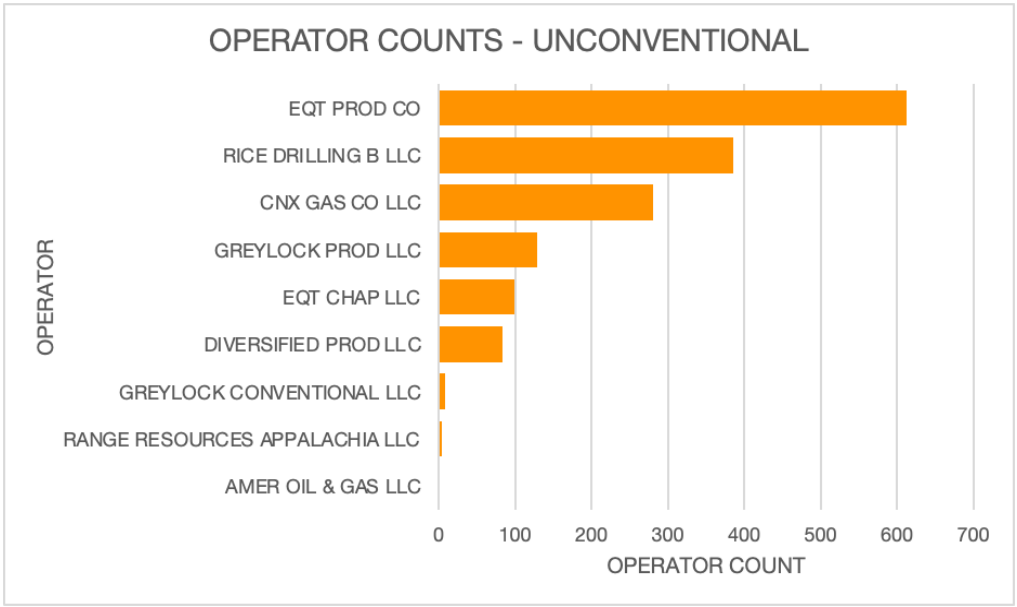



**Figure 3.1. Unconventional operator counts. Frequency of unconventional operators in Greene County, PA.**

**Table 3.1. Unconventional operators and total operators in for each company.**

| OPERATOR | Count of OPERATOR |
|---|---|
| EQT PROD CO | 612 |
| RICE DRILLING B LLC | 386 |
| CNX GAS CO LLC | 281 |
| GREYLOCK PROD LLC | 129 |
| EQT CHAP LLC | 99 |
| DIVERSIFIED PROD LLC | 84 |
| GREYLOCK CONVENTIONAL LLC | 9 |
| RANGE RESOURCES APPALACHIA LLC | 4 |
| AMER OIL & GAS LLC | 1 |
| Grand Total | 1605 |

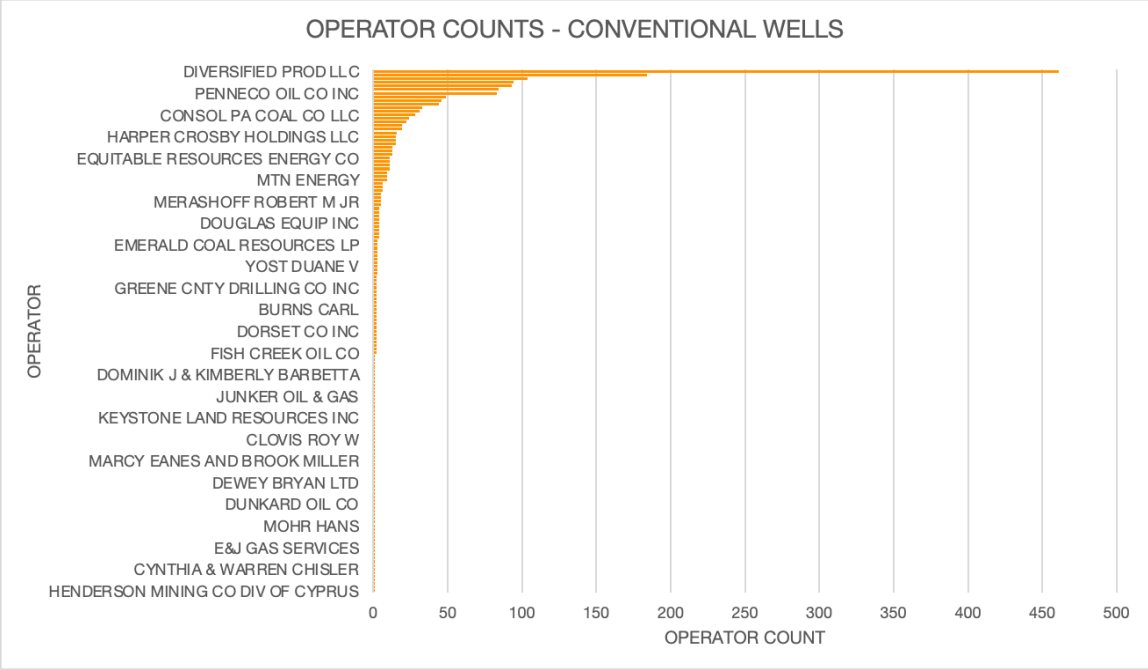



**Figure 3.2. Conventional operator counts. Frequency of conventional operator in Greene County, PA.**

The PA DEP sets specific regulations on the management of oil and gas activity. There are at least 207 defined regulations for oil and gas. When regulations are broken by oil and gas operators, the PADEP does follow up investigations. Violations are often

notified through environmental complaints, which can be filed on the PA DEP website (PA DEP - *Environmental Complaints, 2023*). Violations are grouped in two different categories: environmental and administrative. In Pennsylvania, there were a total of 2,704 administrative violations and 9363 environmental violations (PA DEP, 2020). In Greene County, 420 oil and gas violations are noted in the PA DEP oil and gas compliance database (PA DEP – *Oil and Gas Compliance*, 2023). The top three violation codes found in Greene County in descending order are 78a57(a), SWMA 301, and 78a54. All three codes are related to management of oil and gas wastes (Table 3.2).

**Table 3.2. Top 3 Violation Codes in Greene County, Pennsylvania(*Oil and Gas Compliance - Report Extracts*, 2023).**

| Violation Code | Violation Description |
|---|---|
| 78a57(a) | CONTROL, STORAGE AND DISPOSAL OF PRODUCTION FLUIDS - Operator failed to collect brine and other fluids produced during operation of the well in a tank, series of tanks, or other device approved by the Department for subsequent disposal or reuse. |
| SWMA 301 | MANAGEMENT OF RESIDUAL WASTE - Person operated a residual waste processing or disposal facility without obtaining a permit for such facility from DEP. Person stored, transported, processed, or disposed of residual waste inconsistent with or unauthorized by the rules and regulations of DEP. |
| 78a54 | GENERAL REQUIREMENTS - Operator failed to control and dispose of fluids, residual waste and drill cuttings, including tophole water, brines, drilling fluids, drilling muds, stimulation fluids, well servicing fluids, oil, and production fluids in a manner that prevents pollution of the waters of the Commonwealth and in accordance with 25 Pa. Code §§ 78a.55 – 78a.58 and 78a.60 – 78a.63. |

Based on the top three violations, it is evident that control and safety of waste is an issue. The use of horizontal drilling paired with hydraulic fracturing often results in large volumes of flowback, as shown in the figure below. This is a key attribute that distinguishes wastes in hydraulic fracturing compared to wastes generated in other exploration and production activities (US EPA, 2016). The produced water is stored in pits and tanks until treatment, disposal, or recycling. Some states permit reinjection of produced water underground for disposal, however given the geography of Pennsylvania,

reinjection is not advised. Instead, the water is treated for non-potable reuse or sent to landfills. Safe management of oil and gas waste is critical. The waste produced from fracking contains the injected chemicals as well as naturally occurring materials like metals, radionuclides, metals, and hydrocarbons, all which can be harmful for human exposure and the environment (Table 3.3). Radon exposure is a large concern. An estimated 21,000 lung cancer deaths each year in the U.S. is attributed to radon-related cases (US EPA, 2016). Radon gas inhalation is the 2nd leading cause of lung cancer (Simms et al., 2021). Those handling and transporting this waste are the ones with the greatest exposure. While oil and gas waste are not treated as hazardous waste, employees and those exposed need to be taught and equipped for protection from this waste.

**Table 3.3 Oil and gas waste produced by fractured wells collected during calendar year 2022. (FrackTracker Alliance, 2022).**

| Waste Type | Barrels | Tons |
|---|---|---|
| Brine Co-Product (in Barrels) | 12,674 | |
| Drill Cuttings (in Tons) RWC 810 | | 844,401 |
| Drilling Fluid Waste (in Barrels) RWC 803 | 404,180 | |
| Drilling Fluid Waste (in Tons) RWC 803 | | 2,975 |
| Filter Socks (in Tons) RWC 812 | | 125 |
| Other Oil & Gas Wastes (in Barrels) RWC 899 | 3,097,891 | |
| Other Oil & Gas Wastes (in Tons) RWC 899 | | 8,593 |
| Produced Fluid (in Barrels) RWC 802 | 59,493,479 | |
| Produced Fluid (in Tons) RWC 802 | | 137,449 |
| Servicing Fluid (in Barrels) RWC 808 | 44,714 | |
| Servicing Fluid (in Tons) RWC 808 | | 2,090 |
| Soil Contaminated by Oil & Gas Related Spills (in Tons) RWC 811 | | 28,193 |
| Spent Lubricant Waste (in Barrels) RWC 809 | 242 | |
| Synthetic Liner Materials (in Tons) RWC 806 | | 17,034 |
| Unused Fracturing Fluid Waste (in Barrels) RWC 805 | 21,760 | |
| Unused Fracturing Fluid Waste (in Tons) RWC 805 | | 928 |
| Waste comment only | | |
| Waste Water Treatment Sludge (in Tons) RWC 804 | | 13,543 |
| Sum | 63,074,941 | 1,055,331 |

The frac out in New Freeport was listed under the oil and gas compliance database for a violation (PA DEP - *Oil and Gas Compliance - Report Extracts*, 2023). The spud date of this well pad was June 7th 2021. Recall that the frac out occurred around June 19th 2022. Specifically, Lumber well 13H well received an inspection by the PA DEP on June 23rd 2022, citing them with a violation of 78A73(C). This violation code is violation of the general provision for well construction and operation. The operator failed to cease stimulating the well when visual monitoring indicated a well communication incident had taken place. These changes are noticeable by a change in pressure or volume

changes, indicative of abnormal fracture propagation. The operator continued hydraulic fracturing operations after a confirmed communication incident. Hydraulic fracturing operations at the Lumber well site continued until June 21st, 2022. The Lumber well pad operated by EQT is at fault for the frac out (Figure 3.3).

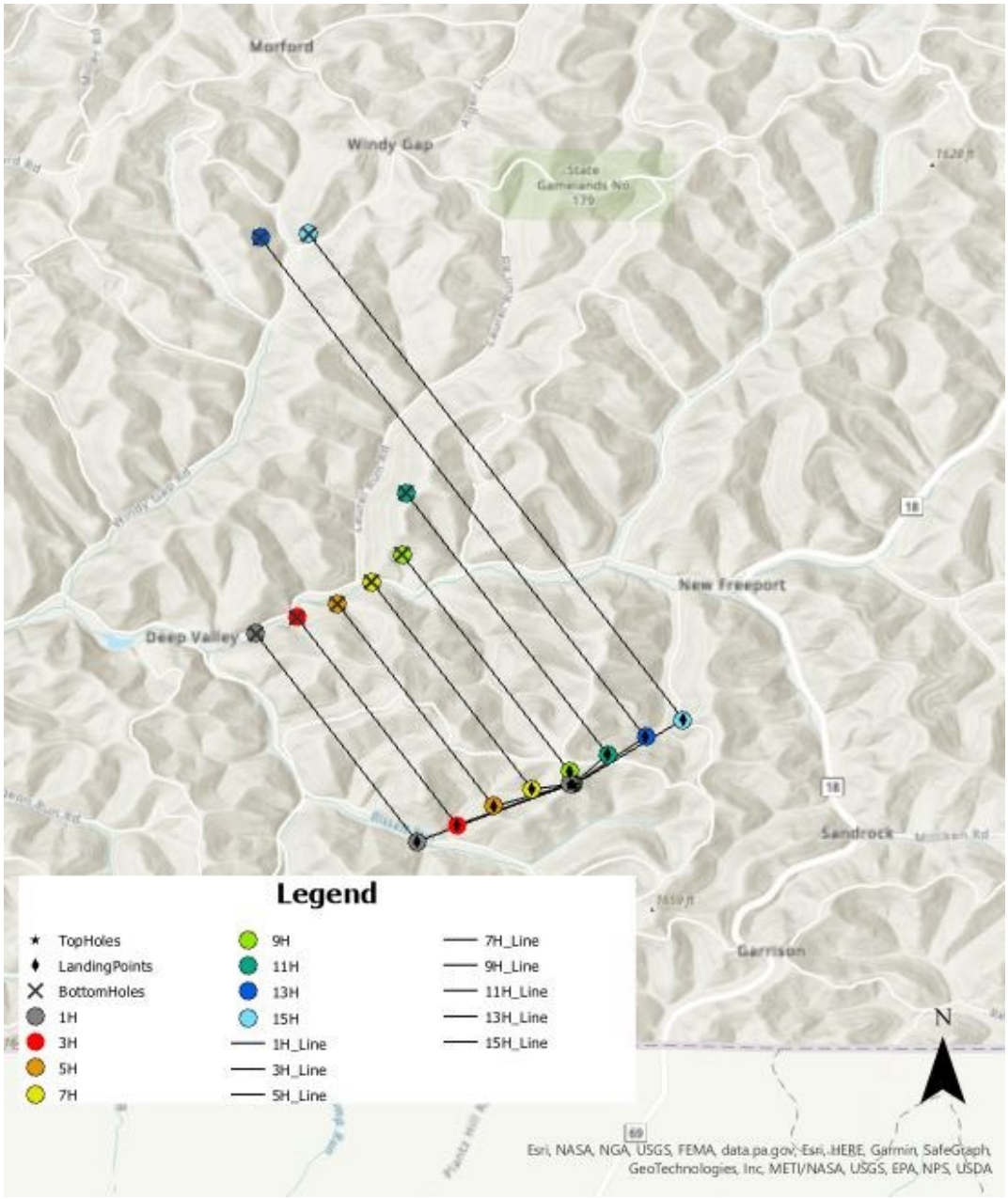



**Figure 3.3. Individual wells associated with Lumber Well Pad. A total of eight wells are included in the permit. Map produced using ArcGIS Pro.**

## 3.2 Well Water Quality

### *3.2.1 Historical Water Quality*

Predrill data was provided to us for three of the sample sites where samples were collected (Appendix G). These samples were collected and analyzed by Moody and Associates, Inc. This company was appointed to do the pre-drill analysis, who also support mining companies in technical matters. At the time that these samples were collected, the homeowner indicted no abnormal quality such as odor, cloudiness, taste or color. Given we had limited access to pre-drill reports, only one of the samples out of the 5 pre-drill reports had large differences in methane concentrations when comparing pre and post drilling activity. For two sites, the pre-drill methane concentrations were less than the post-frac out measurements. MS1977 contained 3,050 ppb of methane, compared to 1,490 ppb in the pre-drill data.

Post frac out water tests results of all of New Freeport samples can be found in Appendix F. Samples (31 total) were collected from June 2022 to February 2023 (Figure 3.4). Of the 31 samples, 5 samples were samples collected from previously sampled sites. Samples collected were given a standard identification, MS followed by a number.

Results were compared with the EPA's Primary and Secondary Drinking Water Standards. Analytes that exceeded the MCLs were noted within the homeowner's letter and within the analysis. Of the 31 samples, 8 analytes exceeded the EPA's standards. Primary standards that were exceeded are cadmium and lead. The secondary standards that were exceeded are aluminum, iron, manganese, pH, and TDS. Iron (16 samples) and manganese (13 samples) were the top two most commonly exceeding MCLs in the New Freeport analysis.

Methane is not listed under these standards, but three samples were above the PA DEP action limit for methane. Based on survey answers, changes in water quality were observed following the frac out.

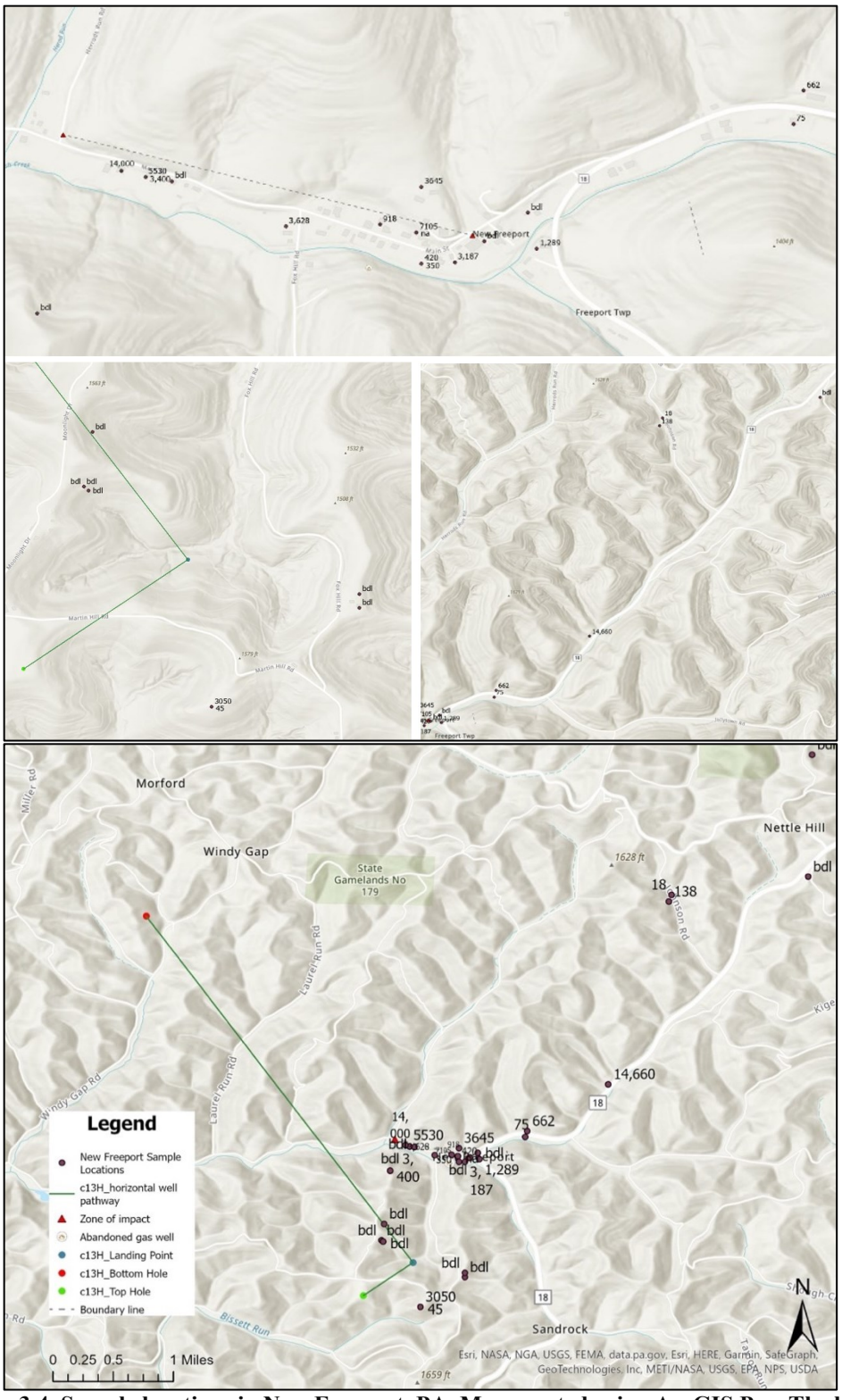



**Figure 3.4. Sample locations in New Freeport, PA. Map created using ArcGIS Pro. The bottom map includes a zoomed out view of the total area of investigation. Each sample location is labeled with its methane result. The top three maps are the zoomed in sections of the map where samples were collected.**

**Table 3.4. Analytes above the limits set by EPA and the PA DEP (for methane) in water samples collected in New Freeport.**

| Analyte | MCL | Range | Mean |
|---|---|---|---|
| **Cd** | 0.005 mg/L | <0.0001 – 0.0207 | 0.0020 mg/L |
| **Pb** | 0.015 mg/L | 0 – 0.1942 | 0.0094 mg/L |
| **Al** | 0.05 to 0.2 mg/L | 0 – 0.144 | 0.047 mg/L |
| **Fe** | 0.3 mg/L | 0 – 5.91 | 0.62 mg/L |
| **Mn** | 0.05 mg/L | 0 – 3.318 | 0.28 mg/L |
| **pH** | 6.5 – 8.5 | 7.1 – 9.4 | 7.9 |
| **TDS** | 500 mg/L | 123 – 529 | 319 mg/L |
| **$CH_4$** | 7,000 ppb | 0 – 14,660 | 3451 ppb |

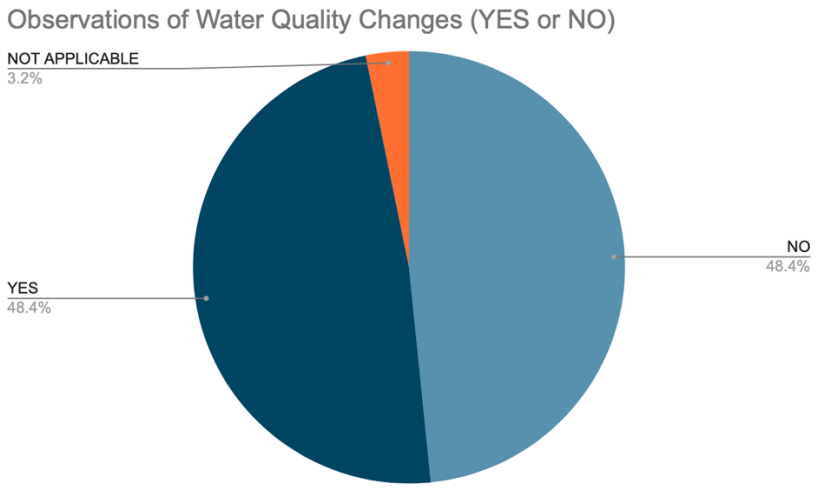
*3.2.2 Field Analysis and Homeowner Survey*

Field analysis included 22 households and 31 samples were collected across these households. Of the 31 samples, five samples were resampling of previous sites. A total of 31 surveys were collected. Survey results indicated that 54.2% of survey respondents did not know the well construction type: rotary, cable tool, or artesian. Given that many respondents did not know the history of the well construction, few respondents knew the estimated depth of their well (45.8%). The average known well depth was 239.7 feet, with the shallowest well at 35 feet and the deepest well at 2000 feet. Water quality issues of individuals private water supply were reported for most homes sampled in New Freeport in Spring 2022 to Spring 2023. Aside from one pond sample, half of the survey participants reported observing water quality changes (Figure 3.5a). The most frequent negative observation of water quality changes was odor (46.7%) (Figure 3.5b). Of the 31 surveys, nine surveys indicated complaints of bad odor in water. Aside from the normal sulfur smell, homeowners reported a “petroleum” and “diesel” like odor.

> “The water smelled bad three weeks ago and has slow flow” – homeowner

When asked if the water source has been tested, 25 water sources were indicated to have been tested previously. Many homeowners agreed to share these water quality results, with five providing their data.

**(a)**




**(b)**

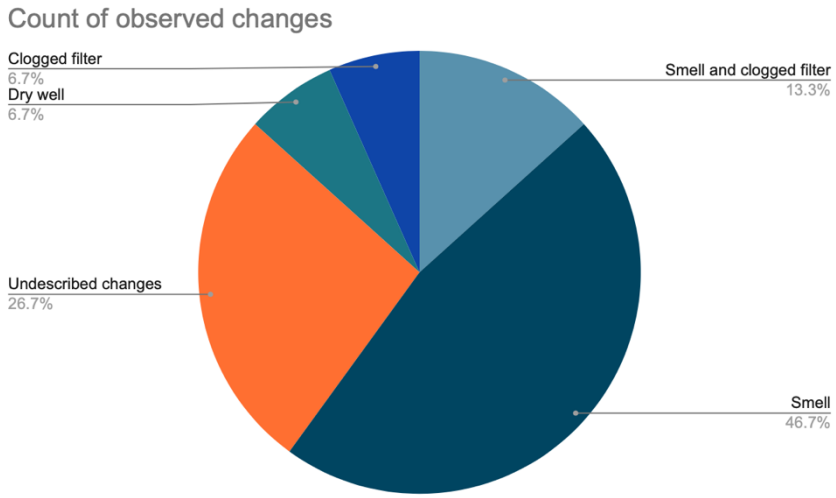



**Figure 3.5. Survey responses from New Freeport homeowners from 2022 to 2023. (a) whether or not homeowner's noticed water quality changes. Samples were not applicable when collecting surface water. (b) if changes were observed, what types of water quality changes were present.**

Using a YSI to collect on site basic water quality parameters, 31 samples were measured for temperature, DO (%), DO (mg/L), pH, specific conductivity, conductivity, and TDS. Out of these samples, pH and TDS were reported above the EPA standard limit. The maximum limit for pH is above or below a pH range of 6.5-8.5. Out of 31 samples, six samples were above this limit with the highest pH reading of 9.4. The maximum limit for TDS is 500 mg/L. Four samples were above this limit with the highest of 529 mg/L.

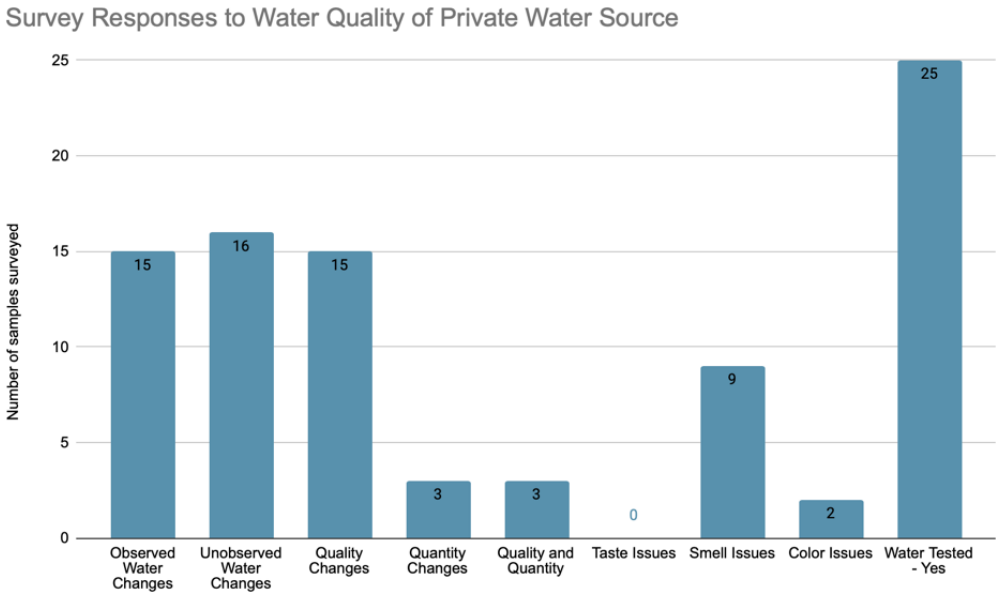



**Figure 3.6. Overall survey responses by New Freeport homeowners from 2022 to 2023 (n=31).**

### *3.2.3 Chemical Analysis*

#### *Ion Chromatography Analysis*

Ion chromatography analysis was conducted for fluoride, chloride, nitrate, bromide, nitrite, phosphate, and sulfate. No parameters measured above the EPA standard limits. Fluoride was found in 17 water samples, ranging from 0.03 to 0.39 mg/L. Chloride was detected in all of the samples, ranging from 0.3 to 101.38 mg/L. Nitrite was detected

in only one sample, and detected at 0.14 mg/L. Nitrate was found in 21 of the samples. Phosphate was present in 18 samples, ranging from 0.02 to 0.38 mg/L. Sulfate was also found in all of the samples, ranging from 0.1 to 26.56 mg/L. Bromide was found in seven of the samples, ranging from 0.02 to 0.09 mg/L.

*ICP-MS Analysis*

Cation analysis was carried out for 32 metals. Cadmium and lead were the only analytes that exceeded the primary set standards by the EPA. Only one sample exceeded the limit, which was reported at 0.0207 mg/L of cadmium. Likewise, only one sample was over the limit for lead at 0.1942 mg/L. Barium was found in all of the samples, but below the primary set standard. The highest sample with barium was reported at 1.32 mg/L, which is close to the action limit of 2 mg/L. Aluminum, manganese, and iron were above the secondary standard limits. Aluminum was detected in all but two samples. Seven samples had exceeded the set limit for aluminum, with the highest measurement of 0.621 mg/L. Manganese was found in all but three samples. This analyte was above the limits in 13 samples, with the highest reported at 3.318 mg/L. Iron was detected in all but two samples. Iron exceeded the standard limits in 16 samples, with the highest reported at 5.91 mg/L.

*Gas Chromatography Analysis*

Gas chromatography was carried out for methane, ethane, ethene, and propane for each sample. Methane and ethane were both found in samples from New Freeport. Methane levels ranged from 18 to 14,660 ppb, some samples below detectable levels. The home with the highest levels of methane at 14,660 ppb, MS 2063, also exceeded the secondary drinking water standards for pH and TDS. The contamination action level

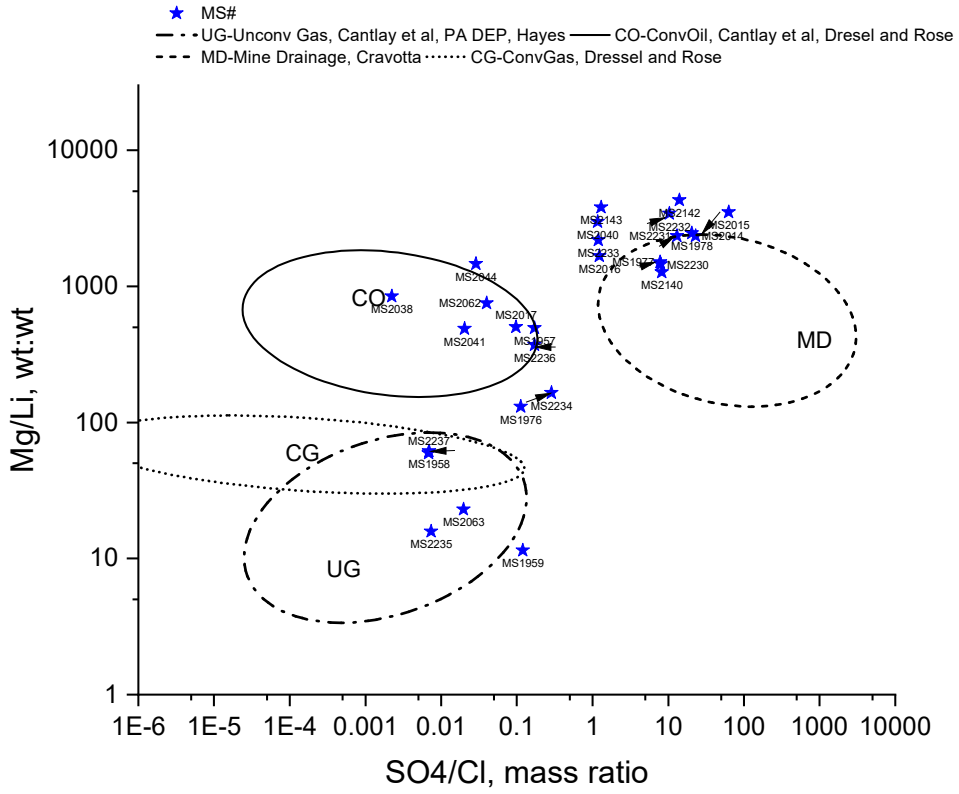
recommended by the PA DEP for methane in homes is 7 ppm (7000 ppb). In comparison, Penn State University recommends homeowners to routinely monitor their wells at concentrations between 10 to 28 mg/L (Swistock, 2022). Based on Penn State's opinion, homeowners with methane concentrations below 10 mg/L are generally considered safe. It is evident that there are inconsistencies with the level of methane that is harmful.

Three water samples measured above the PA DEP action level of 7 ppm. While methane is not a known toxicant, water concentrations of methane around 28 ppm pose a potential explosion risk (PA DEP - *Methane*, 2023). High methane levels can impair health as methane in the air displaces oxygen and can cause symptoms of oxygen deprivation. Determining the cause of methane increase is important given these risks. Based on the methane-to-ethane ratios, these samples had low methane-to-ethane ratios indicating a deeper thermogenic gas. In a similar study, methane concentrations were thermogenic and increased in proximity to gas wells (Osborn et al., 2011). Any homeowner with methane above 7 ppm is recommended to reduce methane levels. This can be reduced by installing a vent on your wellhead. It is also recommended to install a water treatment system. For preventative measures, a gas leak detector can be installed in home. In addition, water testing can be conducted to ensure the water quality is within drinking water standards. Ethane levels ranged from 0 to 400 ppb, with some samples below the detection limit. Ethane was detected in seven samples. Ethene or propane were not detected in any of the samples.

### 3.3 Mass Ratio Analysis

After calculating the analyte ratios of interest from the water quality results, the 31 samples were plotted on the four OriginLab graphs. Analyte ratios were plotted for $SO_4$/Cl to Mg/Li, Mg/Na to $SO_4$/Cl, Ca/Mg to Ca/Sr, and Br/$SO_4$ to Mg/Li. The figures below show the analyte ratios plotted in relation to potential sources of water impacts. All of the samples plotted fell within each of the potential sources (mine drainage, unconventional gas, conventional gas, and conventional oil). Each star denotes a sample and the sample is labeled by its methane concentration or MS number (Appendix I).

**(a)**



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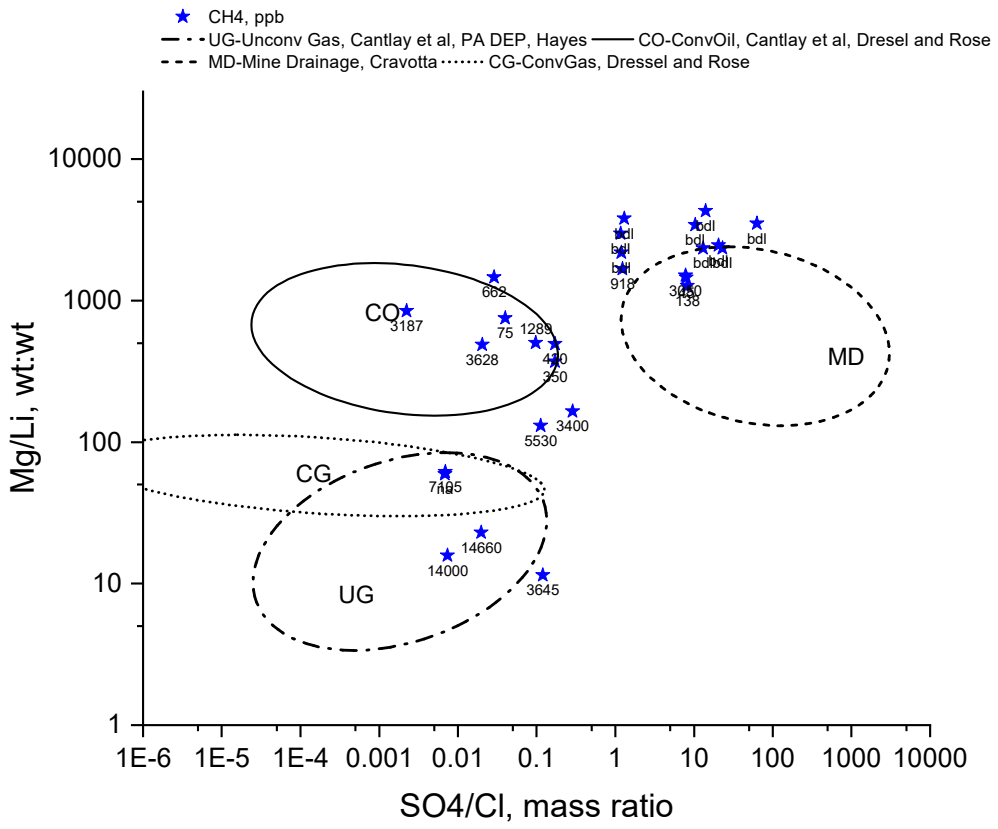


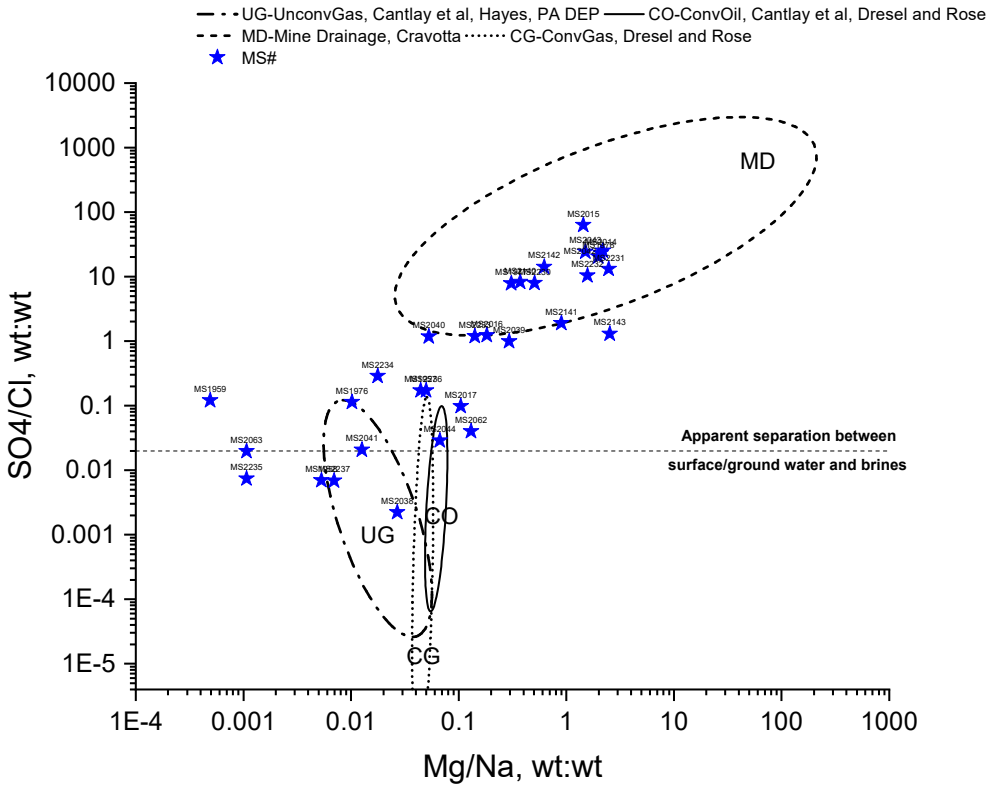

**Figure 3.7. $SO_4$/Cl to Mg/Li ratio. (a) Plot is labeled based on MS number. (b) Plot is labeled based on methane concentrations in each sample. Figure created by Dr. Tetiana Cantlay and used with permission.**

Based on the analyte ratios of $SO_4$/Cl to Mg/Li, the samples collected lay in mine drainage, conventional oil, conventional oil, and unconventional gas ratio space. Five of the sample sites were resampled. These sites were compared for changes in analyte concentrations across 2022 and 2023. Lithium and magnesium increased from the previous sample collection at four of the sample sites. Chloride increased at three of the resampled sites. Of the resampled sites, one resampled pair plotted in conventional gas, MS1958 and MS2237. Sample From June 2022 to February 2023, results shifted closer towards conventional gas (Figure 3.7). Another resampled pair (MS1976 and MS2234) plotted in the center of the plot. Comparing July 2022 sample to February 2023 sample,

results shifted closer towards mine drainage. This sample source nearly doubled its sulfate concentration compared to the original sample, from 3.9 to 7.55 mg/L. One sample (MS1957) plotted near conventional oil. When this source was resampled (MS2236), there was a shift closer to conventional oil ratio space. Chloride increased from 70.7 to 81.74 mg/L, while sulfate slightly increased from 12.1 to 14.01 mg/L.

A cluster of samples are found near and within mine drainage. One of the samples near the mine drainage boundary exceeded its MCL for cadmium (MS2016). This sample also had a high sulfate and high chloride level, which is why this sample plotted right outside of the mine drainage boundary. Sulfate is a major contaminant in mine drainage, which is present in all the samples with mine drainage (Cantlay et al., 2020b). Two samples, MS2063 and MS2235, plotted in unconventional gas brines had low magnesium, lithium, and sulfate levels, but high chloride levels. These two samples were the same two samples with the highest reported methane found in New Freeport. This key finding are consistent with the high methane results found in the two samples being of unconventional gas origin.

**(a)**


UG-UnconvGas, Cantlay et al, Hayes, PA DEP
CO-ConvOil, Cantlay et al, Dresel and Rose
MD-Mine Drainage, Cravotta
CG-ConvGas, Dresel and Rose
MS#
MD
UG
CO
CG
Apparent separation between
surface/ground water and brines
SO4/Cl, wt:wt
Mg/Na, wt:wt
10000
1000
100
10
1
0.1
0.01
0.001
1E-4
1E-5
1E-4
0.001
0.01
0.1
1
10
100
1000
MS2015
MS2142
MS2231
MS2141
MS2143
MS2040
MS2234
MS1959
MS1976
MS2017
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MS2041
MS2235
MS2237
MS2038

**(b)**

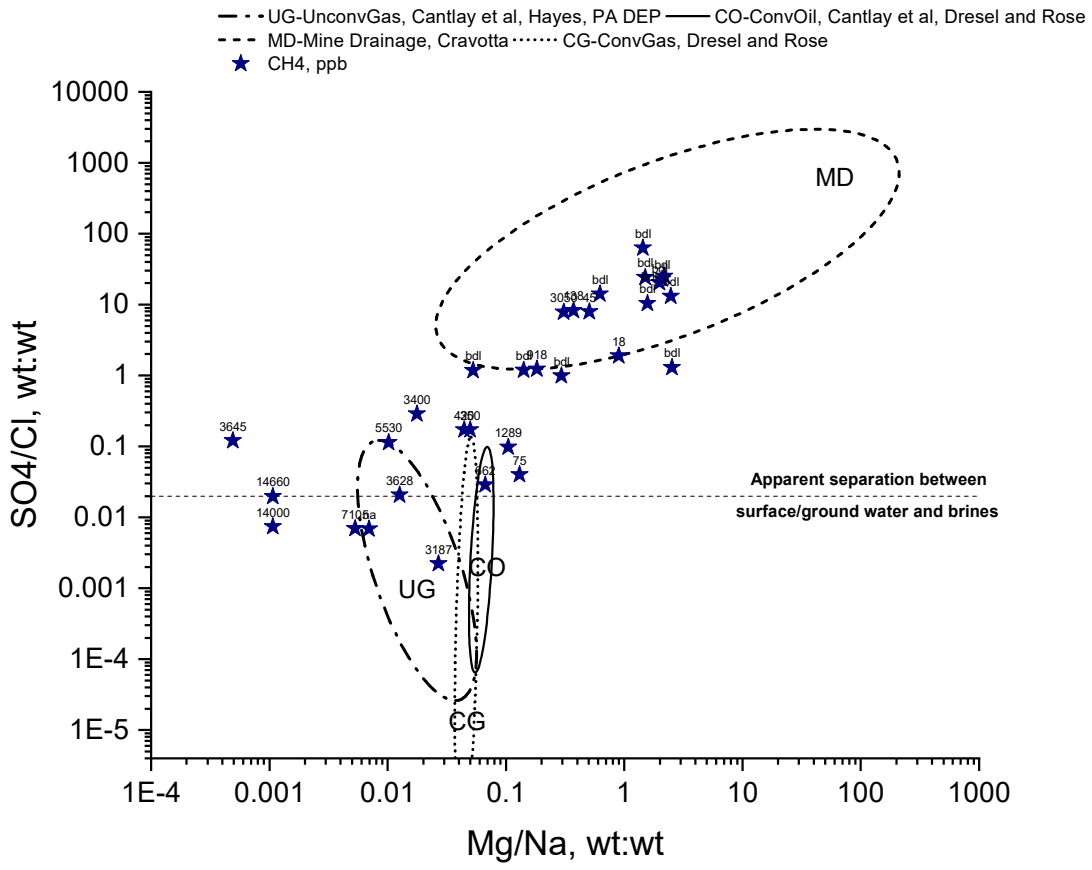
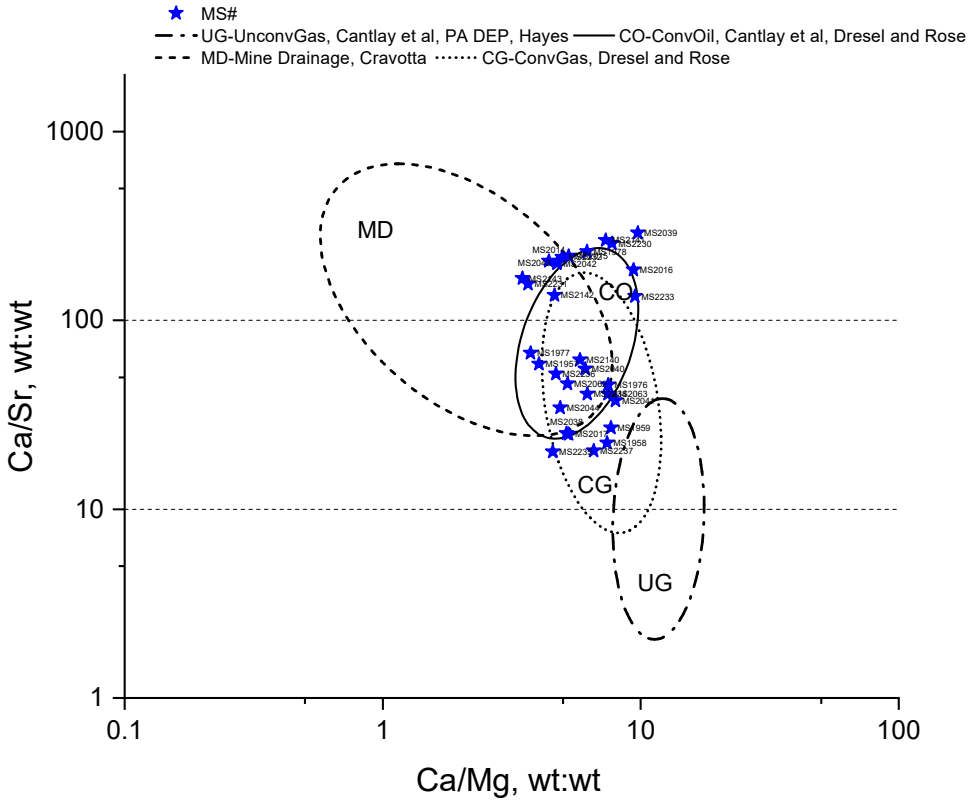



**Figure 3.8. Mg/Na to $SO_4$/Cl ratio. (a) Samples are labeled by MS number. (b) Samples are labeled by methane concentration. Figure made by Dr. Tetiana Cantlay and used with permission.**

The $SO_4$/Cl to Mg/Na mass ratio provides the ability to compare conventional and unconventional flowback and produced water samples to mine drainage and surface and groundwater samples (Cantlay et al., 2020b). Based on the Mg/Na to $SO_4$/Cl ratios, many of the samples lay within mine drainage ratio space (Figure 3.8). These samples had a much higher $SO_4$/Cl mass ratio compared to the samples impacted by unconventional and conventional sources. Only one sample plotted in the conventional oil ratio space, MS2044. Four samples plotted in unconventional gas, MS2237, MS2038, MS2041, MS1976. These samples all had high chloride to low sulfate ratio and high sodium to low

magnesium. Potential impacts to water quality from mine drainage sources were also seen within Mg/Na to $SO_4$/Cl.

**(a)**



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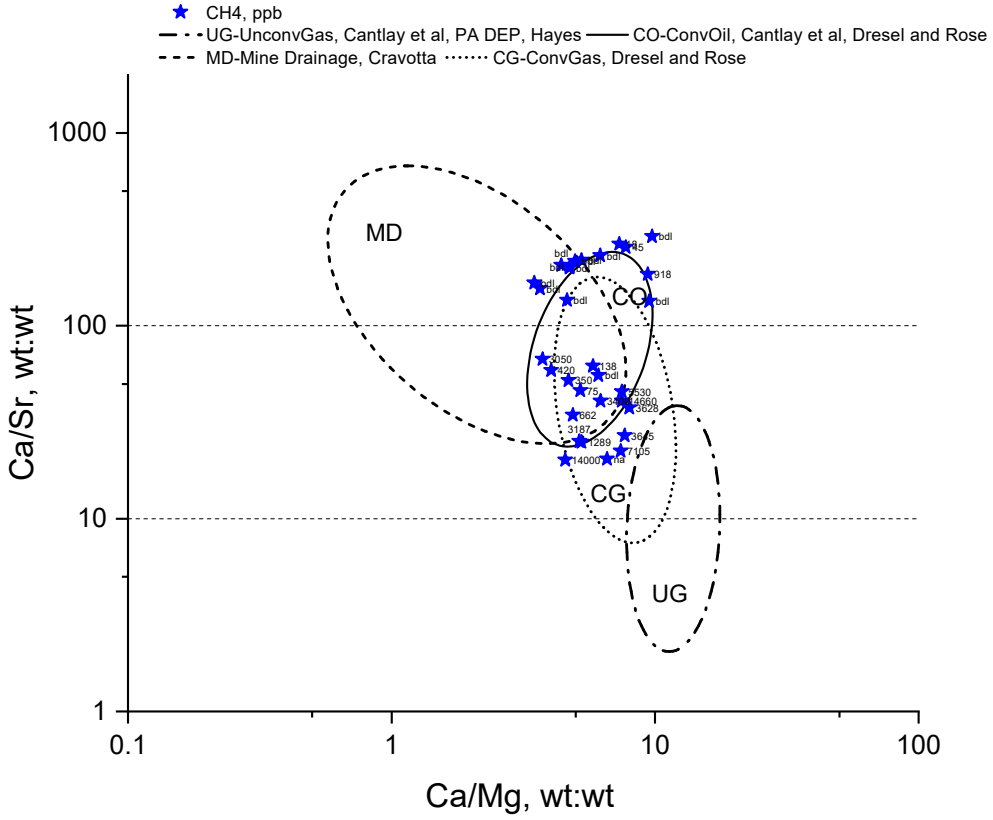
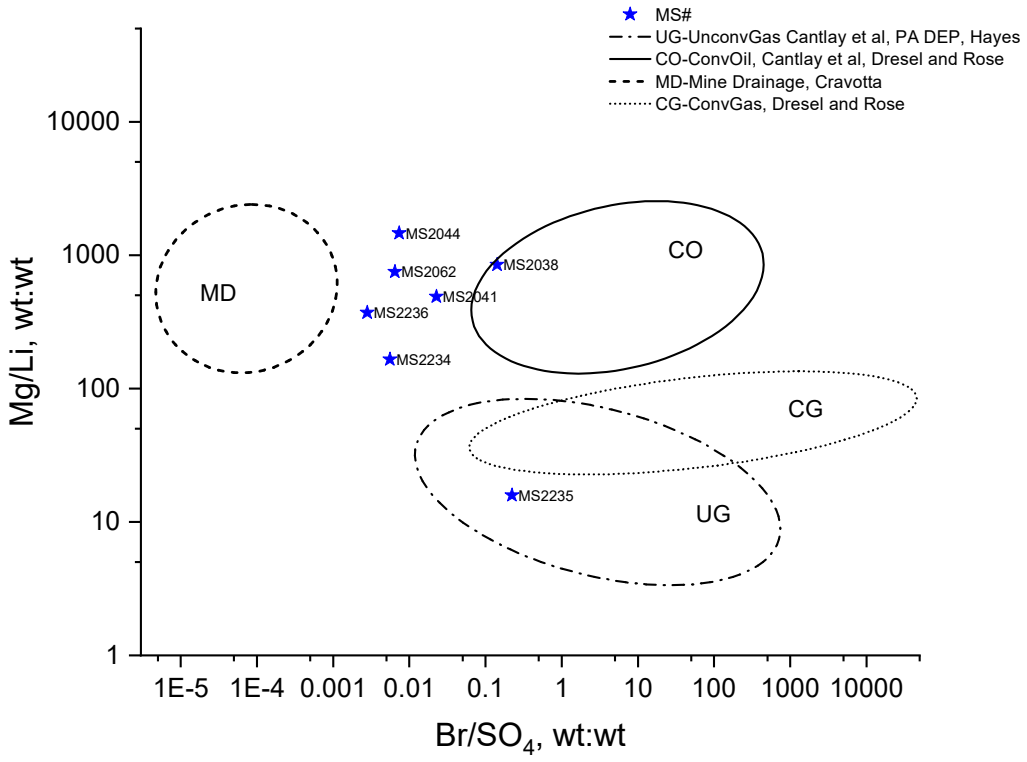



**Figure 3.9. Ca/Mg to Ca/Sr ratio. (a) Samples are labeled by MS number. (b) Samples are labeled by methane concentration. Figure made by Dr. Tetiana Cantlay and used with permission.**

Based on the Ca/Mg to Ca/Sr ratios, the samples lay within mine drainage, conventional oil, and conventional gas ratio space. This plot shows that most of the samples are grouped inside of the conventional oil (Figure 3.9). However, the different sources of impact overlap each other, indicating that these samples have several impact sources.

**(a)**


MS#
UG-UnconvGas Cantlay et al, PA DEP, Hayes
CO-ConvOil, Cantlay et al, Dresel and Rose
MD-Mine Drainage, Cravotta
CG-ConvGas, Dresel and Rose
MD
CO
CG
UG
MS2044
MS2062
MS2038
MS2041
MS2236
MS2234
MS2235
Mg/Li, wt:wt
10000
1000
100
10
1
1E-5
1E-4
0.001
0.01
0.1
1
10
100
1000
10000
Br/SO4, wt:wt

**(b)**

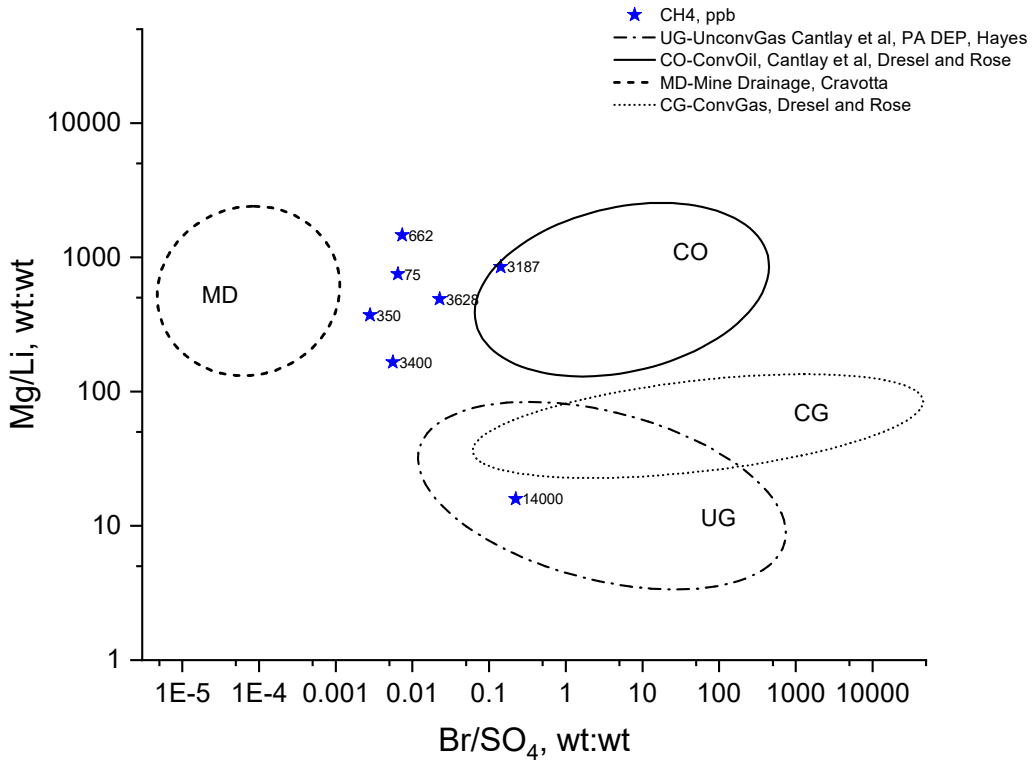



**Figure 3.10. Br/$SO_4$ to Mg/Li ratio. (a) Samples are labeled by MS number. (b) Samples are labeled by methane concentration. Figure made by Dr. Tetiana Cantlay and used with permission.**

Five samples clustered in the center of the plot between mine drainage and conventional oil ratio space. One sample (MS2038) plotted inside of the conventional oil ratio space (Figure 3.10). Another sample (MS2235) plotted inside of unconventional gas. This sample had the second highest methane level reported (14,000 ppb), but had the lowest magnesium level compared to the rest of the samples in this plot. The sample with the highest methane (MS2063 —14,660 ppb) did not have bromide present. Not all the samples had bromide, which is why not all the samples appear in this plot. Those that do have bromide concentrate in mine drainage, unconventional gas, and in the center of the plot between conventional oil and mine drainage. Of the 31 samples, seven samples had detectable levels of bromide ranging from 0.02 to 0.09 mg/L (MS2038, MS2041,

MS2044, MS2062, MS2234, MS2235, MS2236). The samples that have the highest bromide were MS2234 (0.04 mg/L), MS2235 (0.09 mg/L), and MS2236 (0.04 mg/L). Lithium levels ranged from 0.004 to 0.017 mg/L. Sulfate levels ranged from 0.1 to 14.01 mg/L. Magnesium levels ranged from 0.19 to 12.5 mg/L.

### 3.4 Remote Sensing Analysis

Remote sensing analysis was conducted throughout Pennsylvania, but the two areas of focus were the area surrounding the frac out and the area east of the frac out, shown by the boxed areas (Figure 3.11). These areas were selected to evaluate the potential for contamination traveling east. There were clear uplifts in the land found in both boxed areas. High concentrations of methane were found in both boxed in areas where pronounced uplifts in land were found. The top two wells with the highest methane levels were 14,000 ppb at 35 feet depth (west box) and 14,660 ppb at 62 feet depth (eastern box). Overall, land surface movement was detected at the time of the frac out. In the west box, near the end of May and early June, a dramatic change was detected in land surface by satellite (Figure 3.12). Similarly, in the east box, a gradual change in land surface was detected near the end of May and early June (Figure 3.13). Both areas were detecting land surface movements in the form of uplifts. Based on the current analysis, it cannot be confirmed with full certainty that the frac out caused to land surface movement. However, it is likely that the frac out and the land surface movement were related. Historical land surface movement data confirmed this was not a common trend.

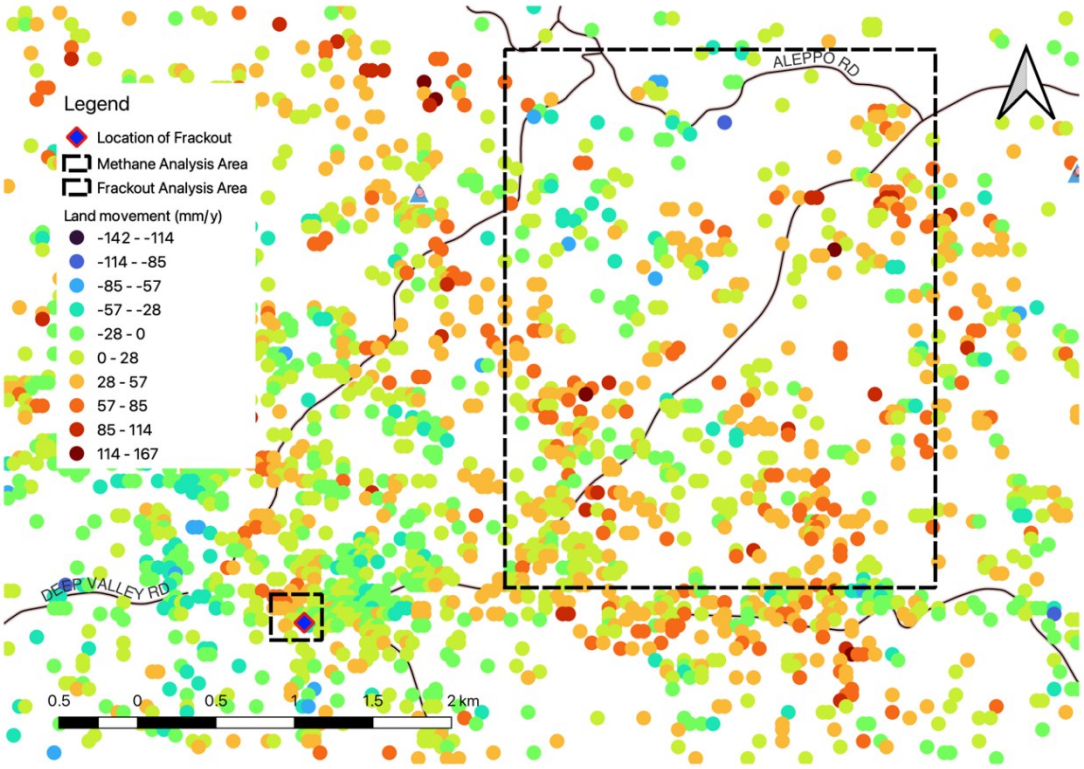



**Figure 3.11 Land movement in millimeters per year. Much of the land surface movement is seen outside of the frac out location and more in the east location box. Figure made using QGIS (2023).**

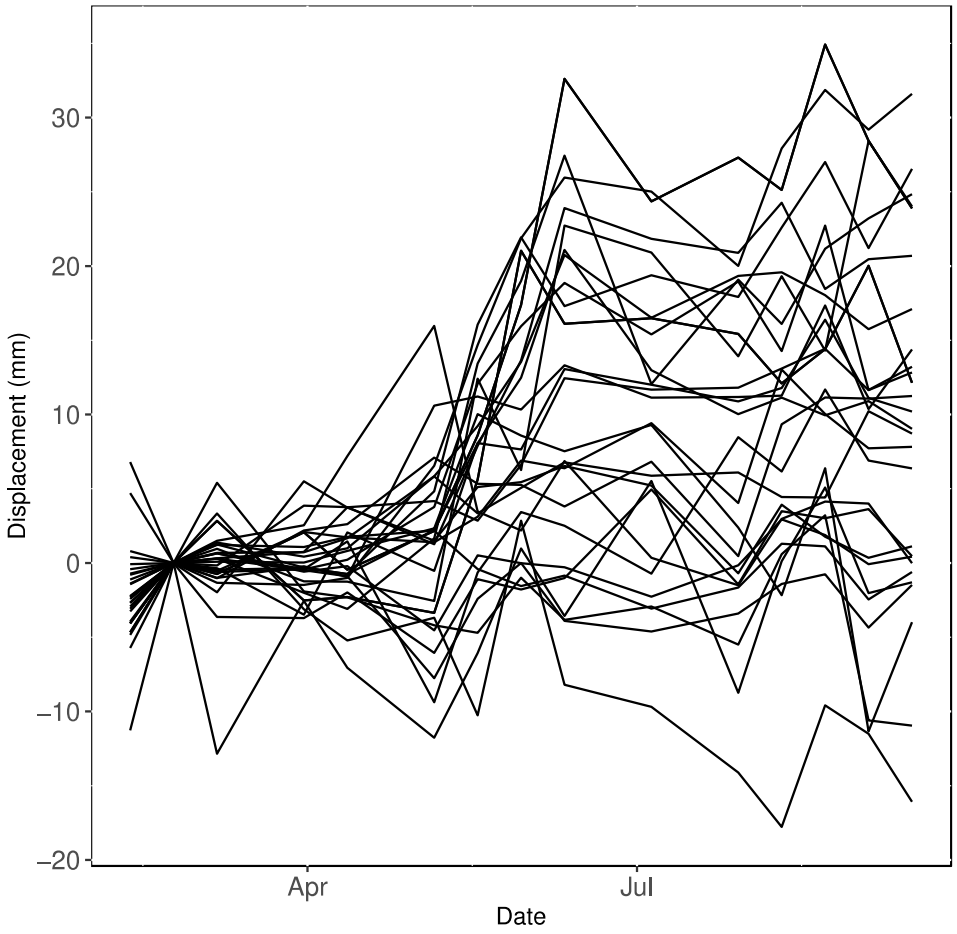



**Figure 3.12. Displacement of land surface in millimeters for 2022 in the west box. Near the end of May, and early June, a dramatic change was detected in the land surface by satellite, particularly uplifts in the land. Figure made using RStudio (2020).**

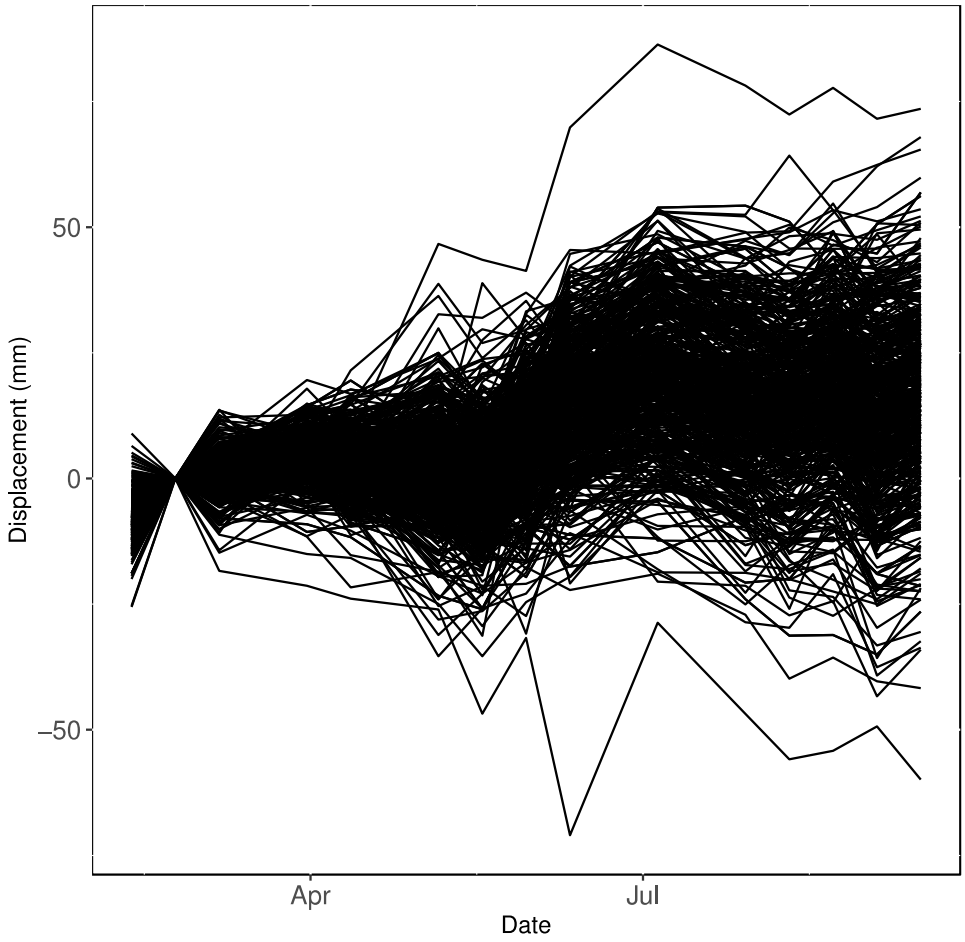



**Figure 3.13. Displacement of land surface in millimeters for 2022 in the east box. Near the end of May, and early June, a gradual change was detected in the land surface by satellite, particularly uplifts in the land. Figure made using RStudio (2020).**

# CHAPTER 4: DISCUSSION

## 4.1 Water Quality Analysis

### *4.1.1 Homeowner Surveys*

Based on the gathered evidence, the frac out event coincided with changes in the water quality of New Freeport. The unconventional well that was over 3,000 feet from a conventional well elicited unintended communication that not only sent contaminants into the abandoned well, but also transported contaminants to private water supplies in New Freeport. Half of the homeowners within this study indicated changes in their water quality following the frac out incident. Most of the reports were quality changes, not quantity changes.

> "My son took a shower, got hives, and felt sick. We almost took him to the hospital, but he got better."—Homeowner

### *4.1.2 Field and Chemical Analysis*

Where changes indicated by homeowners were observed, the chemical analysis indicated at least an exceedance in a primary or secondary standard and/or fugitive methane. Almost all homeowners indicated that they have pre-drill water quality analysis to compare their current results to. While only five reports were made available for comparison, no reports of high methane were found in the pre-drill data. Laboratory method measurements of methane reported below 1,500 ppb for pre-drill. The post frac out samples with high methane cannot be compared to pre-drill data since this data was not available for these sample sites.

While the USGE activities started in Greene County in 2006, a significant number of homeowners reported noticeable changes in quality and/or quantity to their private water supply since the recent frac out event. Of the 31 samples collected post frac out, eight analytes exceeded the EPA primary and secondary water quality standards. These set of standards are commonly compared to chemical data. However, the World Health Organization provides more background on the health concerns by these constituents (Table 4.1).

Cadmium and lead exceeded the primary standards in one sample, separately. Cadmium can be introduced by several influences both natural and anthropogenic. Natural influences of cadmium could be from the corrosion of galvanized pipes or the erosion of natural deposits. Anthropogenic influences of cadmium could include discharge from metal refineries or runoff from paints and waste batteries. Coal or combustion of coal could also contribute to cadmium in the environment. The potential health effects for long term exposure to cadmium are liver damage. Lead is a common contaminant and potential toxicant. Lead could be introduced from the corrosion of household plumbing systems or erosion of natural deposits. While the maximum contaminant level is 0.015, the goal is zero as there is no known safe blood level of lead. The impacts of lead can be seen at an early age. Infants and children contaminated by lead will show delays in physical or mental development. Adults may develop kidney problems and have high blood pressure.

**Table 4.1. WHO standards compared to EPA standards.**

| Chemical | WHO guideline | EPA guideline | Remarks | Common Sources |
|---|---|---|---|---|
| Arsenic | 0.01 | 0.01 | Skin damage or problems with circulatory systems | Erosion of natural deposits |
| Barium | 1.3 | 2 | Increase in blood pressure | Discharge of drilling wastes, metal refineries, natural deposits |
| Cadmium | 0.003 | 0.005 | Kidney damage | Corrosion of galvanized pipes, erosion of natural deposits |
| Chromium | 0.05 | 0.1 | Allergic dermatitis | Discharge from steel and pulp mills |
| Fluoride | 1.5 | 4.0 (primary) 2.0 (secondary) | Bone disease | Water additive, erosion of natural deposits |
| Lead | - | 0.015 | Delays in physical and mental development of infants and children | Corrosion of household plumbing, natural deposits |
| Manganese | 0.08 | 0.05 | | |
| Nitrate | 50 | 10 | Serious illness, death in infants | Runoff from fertilizers, leaching septic tanks |
| Nitrite | 3 | 1 | Serious illness, death in infants | Runoff from fertilizers, leaching septic tanks |
| Selenium | 0.04 | 0.05 | Hair or fingernail loss, numbness in fingers or toes | |

The secondary standards that exceeded the set standards were aluminum, iron, manganese, pH, and TDS. Iron (16 samples) and manganese (13 samples) were the top two most commonly exceeding MCLs in the New Freeport analysis. Methane is not listed under these standards, but three samples were above the PA DEP action limit for methane. The contamination action level recommended by the PA DEP for methane in homes is 7 ppm (7000 ppb). In comparison, Penn State University recommends homeowners to routinely monitor their wells at concentrations between 10 to 28 mg/L (Swistock, 2022). Based on Penn State's opinion, homeowners with methane concentrations below 10 mg/L are generally considered safe. It is evident that there are inconsistencies with the level of methane that is considered safe. Determining the cause of methane increase is important given these risks. Based on the methane-to-ethane ratios, these samples had low methane-to-ethane ratios indicating a deeper thermogenic gas. In addition, the ethane that was found in the samples are likely to be thermogenic. Ethane is not generally coproduced during microbial methanogenesis, which is an indicator of deeper thermogenic gas (Osborn et al., 2011).

## 4.2 Rule of Presumption

### *4.2.1 Current Policy*

The results of this current study brought attention to ineffective policy. A large issue lies in the rule of presumption. The rule of presumption states that any water supply that is negatively affected within 2,500 feet of an unconventional well bore (1,000 feet of a conventional well) must be restore or replaced by the well operator who causes the pollution (Section 3218(c), Title 58; PA DEP). This rule was developed for non-Frac Out conditions, so any affected water outside of the 2,500 feet for unconventional drilling is

not protected under this regulation. Regardless of this zone, it is advised that anyone who is affected by water contamination as a result of oil and gas operations contact the PA DEP to request an investigation. Well operators can challenge the presumption under this law by conducting predrilling or prealteration surveys and comparing these data with post-drilling samples. This provides the company the ability to document the quality of a water supply to support or refute a future claim that the drilling or alteration of the well affected the water supply.

> To protect the integrity of drilling companies, well operators can preserve its defense under section 3218 of 58 Pa.C.S under 78a51 by conducting predrilling or prealteration surveys.

This regulation does not protect against these cases where frac outs and other events occur outside the zone of presumption. The wells that were impacted in this study were distant from 13H well head. Much of the impact was seen over 2,500 feet from the unconventional well head. Similar incidents have occurred such as the case in Beaver Run Reservoir. A well was being fracked and a drop in pressure was known, yet the issues were not reported until public complaints were made. CNX was cited for two violations: 78.73(a) and OGA3219. Violation 78.73(a) is the same violation that EQT was cited for in the New Freeport frac out. Violation OGA3219 is the failure to use casing of sufficient strength and other safety devices to prevent blowouts, explosions, and fires.

*4.2.2 Advances to the Rule of Presumption*

In a 2020 comment and response published by the PA DEP, a comment was made to improve the zone of presumption regulation.

> "While wanting to support the Department's efforts, we find a number of areas of the proposed policy to be inadequate to protect the health and quality of life of families living in the shale fields. We have seen water supplies impacted far beyond the presumptive zone. We believe those families, or the Commonwealth if its waters are compromised, should be compensated if it can be determined where the impact came from, regardless of the distance or the time involved." – Anonymous

In response to this comment, the Department agreed to conduct a water supply investigation when a request is made in the case of a water supply that falls outside of the area of rebuttable presumption (Walentosky, 2020). Following this investigation, if the Department determines that a water supply was adversely impacted by oil and gas operations, then the same expectations in the technical guidance document for the permanent restoration or replacement of the water supply should be applied. However, the Environmental Quality Board reports that they do not have the authority to expand the scope of this statutory requirement and can only offer recommendations to this comment.

> "Section 3218(c) of the 2012 Oil and Gas Act establishes the presumption of liability. The presumption encompasses situations in which the water supply is within 2,500 feet of the unconventional well bore, and the pollution takes place within twelve months of the later of several listed activities. The Environmental Quality Board does not have regulatory authority to expand the scope of the statutory presumption." – Environmental Quality Board, PA DEP (2020)

While some recommendations have been proposed, limited action has been taken to prevent widespread impacts by frac outs. One of the samples had 14,660 ppb of methane and was 6,369 feet from the abandoned well and 12,400 feet from the top hole of the 13H

well (Table 4.2). To create better policies, impact zones should be based on observations in Frac Out cases. Based on the contamination spreading over 6,000 feet, the 2,500 feet zone of presumption is not enough. Instead of creating a zone of presumption around the well head for the activity that causes the frac out, a zone defined by a distance around the abandoned well allowing communication with shallow aquifers should be specified. In New Freeport, all of the water sources investigated within 2,500 feet of the 13H well were below detection limit for methane or less than 3,050 ppb, which is below a level of concern. However, all wells within 2,500 feet of the abandoned well that communicated with the 13H well reported methane as highest as 14,000 ppb. The wells with high concentrations of methane were of shallow well depth. The top two wells with the highest methane levels were 14,000 ppb at 35 feet depth and 14,660 ppb at 62 feet depth. As the contamination caused communication with the abandoned well, it is likely that this also spread contaminants to the streams. Although not investigated, Fork Fish Creek may have been impacted by the frac out. Fork Fish Creek runs right along Main Street, therefore any contaminants could have spread downstream as the 13H well communicated with the shallow aquifer.

**Table 4.2. Methane concentrations and well information.**

| MS Number | Methane (ppb) | Well Depth (ft) | Distance from 13H well (ft) | Distance from abandoned well (ft) |
|---|---|---|---|---|
| MS1957 | 420 | 159.4 | 6,679 | 320 |
| MS1958 | 7105 | - | 6,870 | 401 |
| MS1959 | 3,645 | 160 | 7,202 | 712 |
| MS1976 | 5,530 | 69.16 | 6,701 | 1,523 |
| MS1977 | 3,050 | 125 | 1,987 | 6,378 |
| MS1978 | bdl | - | 2,488 | 4,092 |
| MS2016 | 918 | 60 | 6,827 | 348 |
| MS2017 | 1,289 | 60 | 7,129 | 1,024 |
| MS2041 | 3,628 | 40 | 6,586 | 597 |
| MS2044 | 622 | 45 | 9,069 | 2,965 |
| MS2063 | 14,660 | 62 | 12,400 | 6,369 |
| MS2235 | 14,000 | 35 | 6,715 | 1,673 |

## 4.3 Methane Measurements

The PA-DEP did follow up with homeowners who reported concerns with their water. The department conducted water quality analyses like the 2020 comment response document addressed. However, the PA-DEP did not report levels of methane for concern (i.e., above 7 ppm). Further, their methane concentrations for the same wells Duquesne tested were lower. Our lab samples were processed either the same day or within 24 hours of collection. The PA-DEP 9243 method, allows for a holding time for the light hydrocarbon of up to 7 days (PA DEP, 2012). This was the protocol the PA-DEP

followed for the New Freeport samples (i.e., 7 day hold time) and could be the explanation for the lower values. The EPA Standard Operating Procedure under this same method states that samples must be analyzed within 14 days of collection (EPA, 2004). The Government of British Columbia, Canada, however, recommends conducting analysis as soon as possible, given separation phase risk (Government of British Columbia, 2017). It seems prudent to analyze samples for light hydrocarbons as soon after sampling as possible.

### 4.4 InSAR Technology

Based on remote sensing analysis, it is apparent that the ground surface movements did not only occur in New Freeport, but also in other areas throughout Pennsylvania. It is unclear the exact influences that caused these clear peaks of uplifted areas. Therefore, more analysis in each of these uplifted areas are necessary to address the cause of impacts and whether this was natural. For New Freeport specifically, the areas of uplift are less noticeable compared to other uplifted areas. However, based on historic surface movement, the uplifted areas do not appear to be of natural origin.

Originally, the town of New Freeport reported that the zone of impact was the zone from the firehouse to the west to Herod's Run Rd. Based on the water quality analysis, the water samples outside of the designated zone of impact had reported water quality impacts, including high methane. Based on this reported disturbance, it is clear that re-evaluation of the zone of presumption is necessary to protect water sources from frac out events.

# CHAPTER 5: SUMMARY AND FUTURE DIRECTION

## 5.1 Importance of Study

The mission of the Stolz Water Quality Project is to investigate past, current, and emerging threats to water resources. This is achieved, in part, by providing free water testing and providing homeowners with support by synthesizing water quality reports and recommendations. In all, the goal is to educate the public and emphasizes the importance of water quality protection.

The purpose of this study was to evaluate the frac out incident that occurred in June of 2022 in New Freeport, PA. Limited information was found at the time that these reports were made. After receiving news on this incident, on June 27$^{th}$, we stepped in to monitor the situation, conducting water quality analysis. The main goal of collecting such data was to ensure people had safe drinking water.

## 5.2 Review of Aims

### *5.2.1 Research Questions*

1. Based on homeowner surveys, were there observable signs of water quality impact?
2. Were brine and methane present in the water samples?
3. Were there any irregular land surface movements that occurred at the time of the "frac out" and/or near the "frac out" incident?

Based on the homeowner surveys, it was apparent that changes in water quality had been observed. Eight of the samples showed evidence for brine while 18 of the

samples had methane present. These results suggest that there had been communication with both unconventional and conventional plays. Thermogenic methane was found in 18 of the samples, both located within and outside of the "zone of impact", including three samples above the PADEP action limit. Preliminary InSAR data support the hypothesis that irregular land surface movements had occurred concurrent with the frac out incident.

## 5.3 Water Quality Changes

It is evident that unconventional drilling is continuing to increase in New Freeport. This can be visually seen through the map of Greene County depicting oil and gas violations, abandoned wells, and active unconventional wells. As this activity increases, so should monitoring. Based on the survey responses, there is evidence to suggest that the frac out caused noticeable changes in many homeowners' domestic water wells. Their water has still not returned to its pre-frac out conditions. Our chemical data compared to pre-drill data largely differs with respect to methane levels. While we were only able to compare to three sample locations, this still draws concern for further assessment on the wells in the area. For frac out analysis to be deemed sufficient for deciding whether the water is safe and not impacted by a frac out incident, more specific analysis needs to be performed by the industry and the DEP. Applying mass ratio analysis and measuring all water quality parameters that are standardly measured is highly recommended.

### *5.3.1 Addressing Concerns*

While many homeowners received notice of high methane and other contaminants, homeowners are left wondering what to do next. These next steps need to be addressed,

whether through the company at fault, the PADEP, and/or the town. Homeowners deserve to be provided with next steps following this incident. Through community meetings and collaboration with other environmental agencies, homeowners could be better informed on how to move forward. It is necessary for homeowners with concerns of methane in their water to seek ways of methane mitigation. In a similar study, methane concentrations were thermogenic and increased in proximity to gas wells (Osborn et al., 2011). Any homeowner with methane above 7 ppm is recommended to reduce methane levels.

### *5.3.2 Recommendations for Methane Reduction*

The PA DEP recommends that wells with high levels of methane should install well water vents by a qualified water well driller or plumber (Figure 5.1). The vent should extend above any possible flood level, potential ignition sources, and areas of exposure. This vent should have watertight connections to prevent surface water from entering. This vent will reduce methane levels in your wellhead. It is also recommended to install a water treatment system. For preventative measures, a gas leak detector can be installed in home. In addition, water testing can be conducted to ensure the water quality is within drinking water standards. As stated previously, based on different opinions, there is not a definitive agreement to level of methane that warrants mitigation. Some reports say that methane below 10,000 ppb is safe, while the PA DEP recommends monitoring at 7,000 ppb. This inconsistency should be addressed for homeowners and the scientific community to know best management in the case of an incident like a frac out.

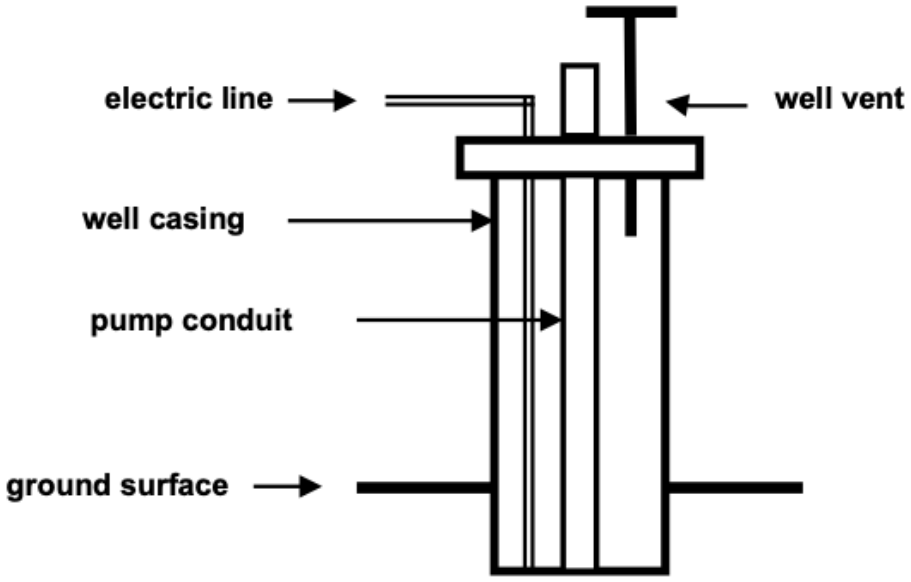



**Figure 5.1. Proper well venting design (PA DEP, 2013).**

## 5.4 Prevention and Evaluation of Frac Outs

### *5.4.1 Chemical Analysis*

While many of the homeowners do have pre-drill data, the DEP analyte list is not sufficient and sensitive to potential frac out incidents. To address the impacts of frac out incidents, this analyte list needs to include the full analyte list, including analytes that would suggest a frac out occurred. Mass ratio analysis was employed to identify types of contamination that is present in surface and groundwater. This analysis can be an effective tool to protect private and public water sources and track impacts (Cantlay et al., 2020a). This tool should be used in future studies and by the DEP to evaluate the spread of a frac out. Mass ratio analysis showed that there are multiple impacts to the water that was sampled. The presence of chemistries of both unconventional and conventional contaminants was found in the samples and suggests communication between the abandoned conventional well and the fracked unconventional well. Chemistries

characteristic of acidic mine drainage were also found in the water samples, as the frac out may have remobilized mine wastes.

*5.4.2 Remote Sensing Analysis*

InSAR appears to be a powerful tool that can be applied in many different areas. For oil and gas specifically, InSAR technology could serve as an important monitoring device for management. While this technology has been used for other research in oil and gas, this study has drawn new insight for monitoring. At sites where uplift was clearly present, contamination was likely to also be found. This finding provided insight for investigating future areas impacted by frac out. If this technology can accurately pinpoint small-scale impacts like oil and gas frac outs, then oil and gas operators could use this technology to monitor these areas. Given the data found, InSAR potentially has the resolution necessary to document these disturbances. In the future, operators could implement this tool to look for areas of ground surface movements. If there are irregular surface movements, operators could employ water quality testing in the areas where major changes are visible on the map and validate InSAR technology to see if the water is impacted by the ground surface movement. In addition, the oil and gas compliance data could be analyzed to see if there are any complaints and frac outs reported around the time the ground surface movements occur.

This could provide an effective solution to prevention and management of these incidents for the oil and gas industry. Given the detection of ground surface movement near well pads, it is promising that InSAR technology could be used as a tool for oil and gas management. Having a tool to better monitor unintended contamination events will help to detect potential areas of concern. The assessment of ground surface displacement

is critical for monitoring production and surrounding infrastructure to properly manage. Without using this technology, frac outs and other incidents are likely to go unnoticed until it is too late. With lack of state regulations on private well water, homeowners outside of the zone of presumption are not protected against any events that may impair the quality and quantity of their private water supply.

### *5.4.3 Advocating Protection by Policy*

Given documented impacts, state-level regulations should not only encourage, but require periodic testing of private well water (Bowen et al., 2019). This will not only monitor the integrity of the well, but most importantly ensure the protection of human health and present the risks associated with drinking their private water supply.

Given that most residents in this rural area depend on private water sources, this is a tremendous concern for the longevity of their water. The residents that reported changes in their water quality after the frac out had occurred may become more cautious about future impacts. In addition, this contamination event may have stimulated a greater care for learning and protecting our water sources before there are no safe sources left. Policies are what support and enforce the protection from environmental incidents. To prevent frac out incidents, current policies need to be revised, as described in the table below (Table 5.1). In addition, future policies need to be developed to properly track and manage these incidents.

**Table 5.1. Policy recommendations.**

| Policy Recommendations | How to implement | Based on this study |
|---|---|---|
| **Zone of Presumption** | This should be based on a distance from the well that was communicated, not the well that caused the incident. | Impacts were seen greater than 6,000 feet from the abandoned well. Additional assessment needs to be done to determine how widespread the impacts are. |
| | (In the event of a frac out with no well communication report): The PADEP should map all unconventional and conventional wells in the particular county. Based on location, drilling direction, and well depth, the PADEP should wisely choose a number of wells to ensure no presence of fluid migration in the area. | |
| **Tracking the migration of contaminants caused by frac out** | The frac out needs to be tracked from starting point (well being hydraulically fracked) to end point (where release occurs) to determine spread of contamination. Wells within 3,000 feet automatically need to be investigated for methane and other contaminates. | All shallow wells had high methane reported. Shallow wells need to be highly monitored in event of a frac out incident. Samples from a variety of well depths (both deep and shallow wells). |
| **Proper reporting of frac outs** | Within the PADEP compliance database for oil and gas, these frac outs need to be labeled “frac out”. The specific cause and effect need to be addressed by the investigator in a concise and scientific manner. | These frac out incidents need to be concisely measured and reported so future decisions can be made to determine the proper distance for the zone of presumption. |

We recommend additional assessments be done to provide data that will support the determined rule of presumption distance. The distance that is set should be one that will provide the farthest distance that a frac out could impact, ensuring those within this distance equal rights to alternative water sources if water is impacted as described under the rule of presumption policy. Revisions to the rule of presumption is necessary to protect the rights of those who face impacts to their wells by frac out incidents. Desired updates to this policy would help the PADEP by increasing efficiency, decreasing areas of investigation, limiting concerns, expanding the knowledge of impact, and decreasing widespread complaints.

### 5.5 Advocate for Environmental Protection

Many homeowners expressed devastation towards the changes in the environment that they have experienced. There is a clear care by many for the protection of natural resources. Just by hearing personal stories from homeowners, it is evident how much they care about the environment in which they are living in.

> "We used to go to the forest and gather different berries, mushrooms, ginseng but with all the trees that were cut down and completely demolishing the forest, we don't have that anymore."—Homeowner

Awareness of our impact will draw people in for change. Without these homeowners voicing their water quality concerns, these impacts would have been invisible to the public eye. None of this work would have been possible without being aware of the impacts surrounding us. To contribute this knowledge to the public, all credit is given to those who indicated water quality concerns.

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# APPENDICES

# APPENDIX A: CONSENT FOR PARTICIPATION

DUQUESNE UNIVERSITY
BAYER SCHOOL OF NATURAL AND ENVIRONMENTAL SCIENCES
CENTER FOR ENVIRONMENTAL RESEARCH & EDUCATION

331 FISHER HALL
600 FORBES AVENUE
PITTSBURGH, PA 15282
TEL 412.396.4367
FAX 412.396.4092
www.duq.edu/environmental-science

**CONSENT TO PARTICIPATE IN A RESEARCH STUDY**

| | |
|---|---|
| **TITLE:** | Well Water Survey of Six Counties in Western Pennsylvania |
| **INVESTIGATOR:** | John F. Stolz, Professor<br>Center for Environmental Research and Education<br>Duquesne University, Pittsburgh PA 15282<br>Phone: 412 396 4367 Fax: 412 396 4092 stolz@duq.edu |
| **SOURCE OF SUPPORT:** | Heinz Endowments, Colcom Foundation |
| **PURPOSE:** | In response to the recent incidents in water well quality changes in the area, we are undertaking a survey to determine if there is a pattern to these disturbances and how it relates to the local hydrology. Our goal is to use GIS to map the location of water wells within the local watershed in an effort to locate the source and mechanism of contamination. |
| **YOUR PARTICIPATON**: | You will be asked 6 questions regarding your water quality and quantity. You will also be asked if you have had previous water testing done and whether you'd be willing to share those results. We may also request a sample of your well water for testing either at the time of the survey or at a later date. |
| **RISKS AND BENEFITS:** | There are no known risks beyond those of everyday life. |
| **COMPENSATION:** | There is no compensation for participating in the survey. |
| **CONFIDENTIALITY:** | All information provided and collected will be confidential. Participants will not be identified in any report or summary of the surveys released. |
| **RIGHT TO WITHDRAW:** | You may withdraw from the study at any time and we will withdraw your data as well. |

**SUMMARY OF RESULTS:** You will be provided a summary of your well water test results that we conduct and an explanation of these results.

**VOLUNTARY CONSENT:** I have read the above statements and understand what is being requested of me. I also understand that my participation is voluntary and that I am free to withdraw my consent at any time, for any reason. On these terms, I certify that I am willing to participate in this research project.

I understand that should I have any further questions about my participation in this study, I may call Dr. Joseph Kush, Chair of the Duquesne University Institutional Review Board (412-396-1151).

Please feel free to contact me (Dr. Stolz) if you have any questions (412 396 4367; stolz@duq.edu)

SIGNATURES: Both the researcher and subject should sign, and each should hold a copy with original signatures.

_____ _____

Participant's Signature Date

_____ _____

Researcher's Signature Date

# APPENDIX B: IRB APPROVAL

**Attachments:**
- 2019-01-14 Consent Form Revised Stamped.pdf

Institutional Review Board
DUQUESNE UNIVERSITY

*Duquesne University IRB* *Protocol Exemption Notification*

To: John Stolz
From: David Delmonico, IRB Chair
Subject: Protocol #2019/01/14
Date: 01/08/2020

The protocol **2019/01/14. Survey of Well Water Quality in Western PA** has been verified by the Institutional Review Board as **Exempt** according to 45CFR46.101(b)(2): (2) Tests, Surveys, Interviews on 01/22/2019.

If applicable, the consent form and/or recruitment flier have been stamped and are attached to this email or are accessible via Mentor. Please use these stamped versions to distribute or display.

Exempt status means there is no specific expiration date, and you are not required to file annual reviews or termination reports. However, any unanticipated problems, adverse effects on subjects, or protocol deviations must be immediately reported to the IRB Chair before proceeding with the study.

Further, any changes to your study requires the filing of an amendment and is subject to the approval of the IRB Chair. You must wait for approval before implementing any changes to the original protocol. Changes to your protocol may affect the exempt status of your research.

Please contact me if you have any questions regarding this study.

Best wishes in your research,

David Delmonico, Ph.D.
Institutional Review Board, Chair
irb@duq.edu

# APPENDIX C: YSI DATASHEET AND SURVEY QUESTIONS

| YSI DATA SHEET | | | | | |
|---|---|---|---|---|---|
| **Homeowner Information** | | | | **Well Information** | |
| Address: | | | | GPS Latitude: | |
| City, State, Zip: | | | | GPS Longitude: | |
| Mailing Address: | | | | Elevation (ft): | |
| County: | | | | MS Number: | |
| Township: | | | | | |
| **Sample Information** | | | | | |
| Date: | | Sample Source: | | | |
| Time: | | Sample Location: | | | |
| Pre/Post Drill: | | Sampled By: | | | |
| **Test #1** | | **Test #2** | | **Average** | |
| Temp (°C) | | Temp (°C) | | #DIV/0! | |
| DO (%) | | DO (%) | | #DIV/0! | |
| DO (mg/L) | | DO (mg/L) | | #DIV/0! | |
| pH | | pH | | #DIV/0! | |
| Pressure (mmHg) | | Pressure (mmHg) | | #DIV/0! | |
| Spf. Cond.(µS/cm) | | Spf. Cond.(µS/cm) | | #DIV/0! | |
| Cond. (µS) | | Cond. (µS) | | #DIV/0! | |
| TDS | | TDS | | #DIV/0! | |
| **Survey Questions:** | | | | | |
| 1. Do you have well water and where is your well located? | | | | | |
| 2. What type of well is it? (e.g. artesian, rotary, cable tool)? | | | | | |
| 3. Do you know how deep the well is? Have you noticed any change in your well depth? | | | | | |
| 4. Have you noticed any change in water quality, if so when? | | | | | |
| 5. Have you noticed any change in the water flow of quantity? | | | | | |
| 6. Have you had the water tested? Would you be willing to share those results? | | | | | |
| **Notes:** | | | | | |

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name: EQT PROD CO | Legal Name: EQT PRODUCTION COMPANY | DEP Client ID#: 146983 | Phone: 724-271-7380 | FAX: 724-749-5581 |
| Mailing Address (Street or PO Box): 400 WOODCLIFF DRIVE | Address 2: | | | |
| City: CANONSBURG | State: PA | Zip +4: 15317 | | |
| Email Address: espine@eqt.com | 24/7 Emergency Contact Name / Number: EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name: LUMBER | | | |
| Well #: 1H | Serial #: | Project # (from DEP): | |
| County: GREENE | Municipality: SPRINGHILL TWP | 911 Address of Well site (or nearest intersection): MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?: Y | Is this a Coal well?: Y | Bond Agreement ID: 9399 - BLANKET ($850,000) | Well Deepest Point (TVD): 7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number: 1 | Wellbore Name: WELLBORE SURFACE HOLE LOCATION | Type of Wellbore: GAS | Wellbore Configuration: Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name: LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?: Y | ESCGP Number: ESG073019009-00 | Will this well be built on a well pad?: Y | Well Pad: 156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS - | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?* | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the 'Coordination of a Well Location with Public Resources' form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

## PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name<br>EQT PROD CO | Legal Name<br>EQT PRODUCTION COMPANY | DEP Client ID#<br>146983 | Phone<br>724-271-7380 | FAX<br>724-749-5581 |
| Mailing Address (Street or PO Box)<br>400 WOODCLIFF DRIVE | Address 2 | | | |
| City<br>CANONSBURG | State<br>PA | Zip +4<br>15317 | | |
| Email Address<br>espine@eqt.com | 24/7 Emergency Contact Name / Number<br>EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name<br>LUMBER | | | |
| Well #<br>1H | Serial #<br> | Project # (from DEP)<br> | |
| County<br>GREENE | Municipality<br>SPRINGHILL TWP | 911 Address of Well site (or nearest intersection)<br>MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?<br>Y | Is this a Coal well?<br>Y | Bond Agreement ID<br>9399 - BLANKET ($850,000) | Well Deepest Point (TVD)<br>7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number<br>1 | Wellbore Name<br>WELLBORE SURFACE HOLE LOCATION | Type of Wellbore<br>GAS | Wellbore Configuration<br>Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name<br>LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?<br>Y | ESCGP Number<br>ESG073019009-00 | Will this well be built on a well pad?<br>Y | Well Pad<br>156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS - | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?* | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the 'Coordination of a Well Location with Public Resources' form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.5400 -80 26 19.9500 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2475 |
| Offset West (in feet) | 6245 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.5400 -80 26 19.9500 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 45 20.9200 -80 27 53.3500 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 16862 |
| Bottom Hole Lat/Long | 39 45 20.9200 -80 27 53.3500 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 16862 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
| Well Pad Corner 4 Lat/Long | 39 44 34.2528 -80 26 22.3296 | |
| Well Site GPS Location Lat/Long | 39 44 35.6244 -80 26 19.3272 | |
| Well Site Access Road GPS Lat/Long | 39 44 41.7984 -80 26 15.8424 | |
| Metadata Method<br>GPS - UNSPECIFIED | Accuracy (in ft.)<br>±2 | Datum<br>North American Datum of 1983 |

| SUBMISSION INFORMATION | |
|---|---|
| Pursuant to the Pennsylvania Electronic Transactions Act - Act 69, you are about to engage in an electronic transaction with the Commonwealth of Pennsylvania. You are submitting official information. Any false statement is subject to substantial civil and criminal penalties, including 18 P.S. section 4904 (relating to unsworn falsification to authorities). | |
| I hereby certify that, for all interested parties identified in this application for which written consent or an "Affidavit of Non-Delivery of Certified Mail" has not been uploaded, copies of the well plat have been sent via certified mail and I have received a return receipt verifying delivery. | |
| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 04:52:23 PM |

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# WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 1H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N56° 03' 45"W 8620' | 7,832' | 16,862' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 16,862' |

| Surface Owner/Water Purveyor w/Water Supply within 1000'/3000' | Latitude Longitude of Water Supply |
|---|---|
| 1. RALPH SIX ET UX | 39°44'46.53" -80°26'40.51" |
| 2. WILSON RESOURCES LLC | 39°44'56.17" -80°26'37.62" |
| 3. TROY SHIELDS ET AL | 39°44'43.28" -80°26'20.63" |
| 4. PURE BRED HOLDINGS, LLC | 39°44'49.09" -80°26'08.39" |
| 5. EDWARD MARK MOSES ET US | 39°44'54.00" -80°25'56.15" |
| 6. THOMAS J JUNKER ET UX | 39°44'30.57" -80°25'54.60" |
| 7. CHARLES JACKSON ET UX | 39°44'33.63" -80°25'45.61" |
| 8. DAVID R HUNTLEY | 39°44'33.94" -80°25'41.67" |
| 9. DAVID R HUNTLEY | 39°44'35.76" -80°25'44.20" |
| 10. THOMAS A CHESS III ET UX | 39°44'24.94" -80°25'47.11" |
| 11. COBIN J DIXON ET UX | 39°44'15.36" -80°25'56.07" |
| 12. COBIN J DIXON ET UX | 39°44'14.89" -80°26'02.08" |
| 13. TROY SHIELDS ET AL | 39°44'13.62" -80°26'15.04" |
| 14. TROY SHIELDS ET AL | 39°44'21.41" -80°26'13.30" |
| 15. TROY SHIELDS ET AL | 39°44'13.00" -80°26'25.25" |
| 16. TROY SHIELDS ET AL | 39°44'10.35" -80°26'28.64" |
| 17. TROY SHIELDS ET AL | 39°44'13.44" -80°26'33.56" |
| 18. TROY SHIELDS ET AL | 39°44'10.31" -80°26'37.60" |
| 19. GREGORY B NULL ET AL | 39°44'19.97" -80°26'47.30" |

| Municipality: where the well will be drilled, adjacent to the well, or within 3000 feet | Coal related parties |
|---|---|
| ALEPPO TOWNSHIP | Contura Coal Resources, LLC-Owner, All Seams |
| FREEPORT TOWNSHIP | Monongalia County Coal Company-Operator, Monongalia County Mine |
| GILMORE TOWNSHIP | |
| JACKSON TOWNSHIP | |
| SPRINGHILL TOWNSHIP | |
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## WELL LOCATION PLAT

Page 2 Notifications

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| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
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|---|---|---|---|
| Troy Shields ET AL | N56° 03' 45"W 8620' | 7,832' | 16,862' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 16,862' |

| | | |
|---|---|---|
| 20. KSH LLC | 39°44'35.81" | -80°26'53.08" |
| 21. THOMAS A BUSSOLETTI ET AL | 39°44'59.35" | -80°26'04.33" |
| 22. WENDY SAUL | 39°45'02.67" | -80°26'11.44" |
| 23. TROY SHIELDS ET AL | 39°44'11.77" | -80°26'06.42" |
| 24. TROY SHIELDS ET AL | 39°44'08.10" | -80°26'14.95" |
| 25. THOMAS A BUSSOLETTI ET AL | 39°44'59.94 | -80°26'11.68 |
| 26. GEORGE D SIX | 39°44'36.81" | -80°25'41.14" |
| 27. MARLIN B GEHO | 39°44'11.79" | -80°25'55.25" |
| 28. PURE BRED HOLDINGS, LLC | 39°44'54.95" | -80°26'09.88" |
| 29. THOMAS A BUSSOLETTI ET AL | 39°44'56.00" | -80°26'10.29" |
| 30. THOMAS A BUSSOLETTI ET AL | 39°44'59.22" | -80°26'11.27" |
| 31. THOMAS A BUSSOLETTI ET AL | 39°44'59.96" | -80°26'11.36" |
| 32. TROY STONEKING ET UX | 39°44'18.24" | -80°25'45.55" |
| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
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# WELL LOCATION PLAT

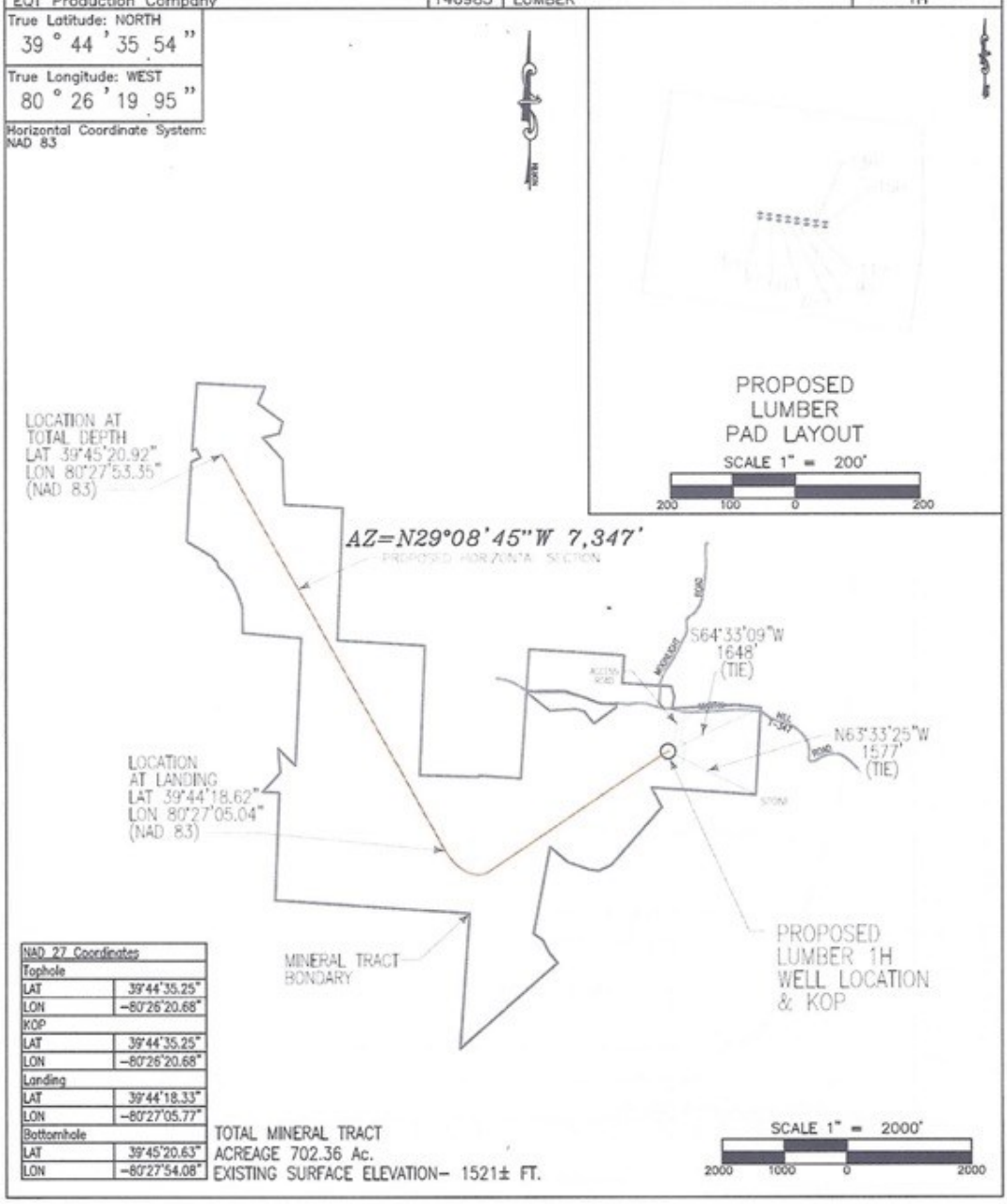
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 1H |

True Latitude: NORTH
39 ° 44 ' 35 . 54 "

True Longitude: WEST
80 ° 26 ' 19 . 95 "

Horizontal Coordinate System:
NAD 83




| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.25" |
| LON | -80°26'20.68" |
| KOP | |
| LAT | 39°44'35.25" |
| LON | -80°26'20.68" |
| Landing | |
| LAT | 39°44'18.33" |
| LON | -80°27'05.77" |
| Bottomhole | |
| LAT | 39°45'20.63" |
| LON | -80°27'54.08" |

TOTAL MINERAL TRACT
ACREAGE 702.36 Ac.
EXISTING SURFACE ELEVATION- 1521± FT.

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# WELL LOCATION PLAT

PAGE 4 Well Plan

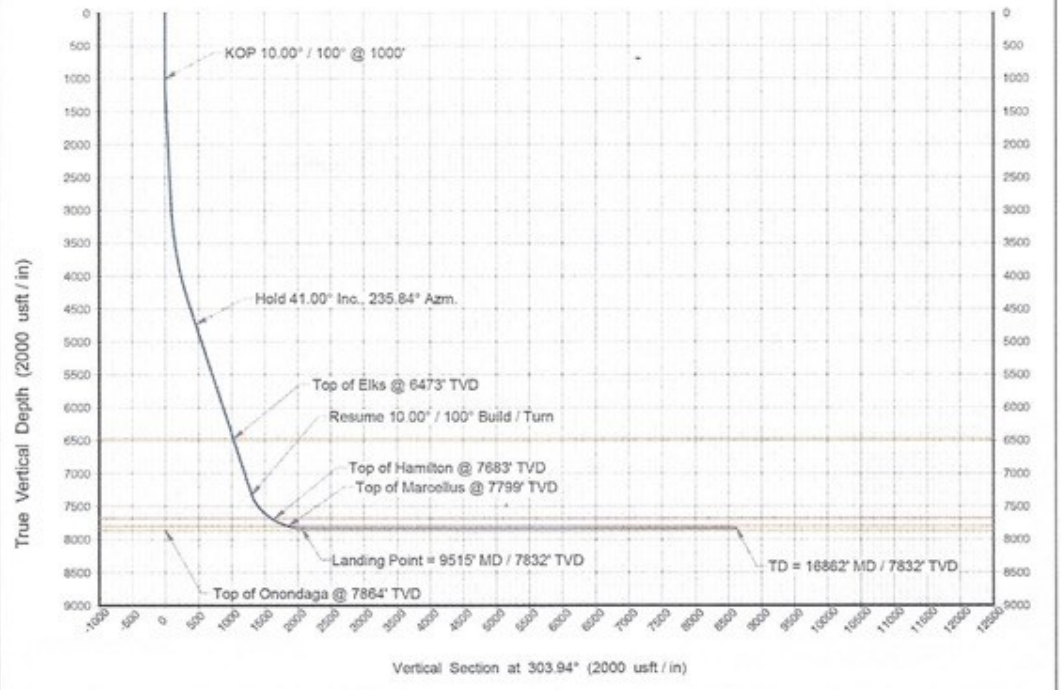
| DEP Use Only | Permit # |
|---|---|

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 1H |

| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : 1,000' | TMD : 1,000' | | 39° 44' 35.54" | 80° 26' 19.95" |
| Landing Point : | TVD : 7,832' | TMD : 9,515' | | 39° 44' 18.62" | 80° 27' 05.04" |
| Projected Bottom Hole: | TVD : 7,832' | TMD : 16,862' | | 39° 45' 20.92" | 80° 27' 53.35" |

G / M — Azimuths to Grid North
Magnetic North: -8.95
Magnetic Field
Strength: 51,766.14
Dip Angle: 66.63
Date: 07/10/2020
Model: IGRF2015

NAD 83



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name<br>EQT PROD CO | Legal Name<br>EQT PRODUCTION COMPANY | DEP Client ID#<br>146983 | Phone<br>724-271-7380 | FAX<br>724-749-5581 |
| Mailing Address (Street or PO Box)<br>400 WOODCLIFF DRIVE | Address 2 | | | |
| City<br>CANONSBURG | State<br>PA | Zip +4<br>15317 | | |
| Email Address<br>espine@eqt.com | 24/7 Emergency Contact Name / Number<br>EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name<br>LUMBER | | | |
| Well #<br>3H | Serial #<br> | Project # (from DEP)<br> | |
| County<br>GREENE | Municipality<br>SPRINGHILL TWP | 911 Address of Well site (or nearest intersection)<br>MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?<br>Y | Is this a Coal well?<br>Y | Bond Agreement ID<br>9399 - BLANKET ($850,000) | Well Deepest Point (TVD)<br>7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number<br>1 | Wellbore Name<br>WELLBORE SURFACE HOLE LOCATION | Type of Wellbore<br>GAS | Wellbore Configuration<br>Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name<br>LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?<br>Y | ESCGP Number<br>ESG073019009-00 | Will this well be built on a well pad?<br>Y | Well Pad<br>156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?* | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the 'Coordination of a Well Location with Public Resources' form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

pennsylvania

**PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL**

| | |
|---|---|
| Have any coal rights been severed from the surface estate? | Y |
| If the coal rights been severed from the surface estate, have the owners of the workable and unworkable coal seams been notified? | Y |
| Is this a "non-conservation" gas well? | Y |
| If the well will penetrate a workable coal seam, and the well is a 'non-conservation' gas well, does the location comply with the distance requirements of Section 7 of the Coal and Gas Resource Coordination Act (at least 1,000 feet from all existing wells) and, if part of a well cluster, at least 2,000 feet from any other existing cluster, as measured from the center of the well bore of the nearest well? | N |
| Will the well be part of a Well Cluster which is an area within a well pad intended to host multiple horizontal wells and which comprises an area no greater than 5,000 square feet? | Y |
| Will this well be part of a Well Cluster that already has an approved OG-57 waiver? | N |
| Will this well be drilled into solid coal or into an open underground void? | SOLID CORE |
| Will the well be drilled through an operating coal mine, or within 1,000 feet of the boundary? | Y |
| Provide the names of Mine(s) and Operator(s): | MONONGALIA COUNTY MINE - MONONGALIA COUNTY COAL COMPANY |
| Does it meet the Gas Well Pillar Study? | Y |
| Has the surface landowner been notified and provided a copy of the Landowner Notification of Right to Participate in Alternative Dispute Resolution to Coal Bed Methane Wells (form 5500-FM-OG0053)? | N |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.5300 -80 26 19.7600 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2475 |
| Offset West (in feet) | 6230 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.5300 -80 26 19.7600 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 45 25.8700 -80 27 41.0600 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 16379 |
| Bottom Hole Lat/Long | 39 45 25.8700 -80 27 41.0600 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 16379 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
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| Metadata Method<br>GPS - UNSPECIFIED | Accuracy (in ft.)<br>±2 | Datum<br>North American Datum of 1983 |

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| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 05:01:26 PM |

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL AND GAS MANAGEMENT

# WELL LOCATION PLAT

PAGE 1 Surface Location

| | |
|---|---|
| Auth ID #: | |
| Permit #: | |
| Project #: | |

Denotes location of top of well on topo map.

Well is located on topo map 2475 feet south of latitude 39 ° 45 ' 00 "

Well is located on topo map 6230 feet west of longitude 80 ° 25 ' 00 "

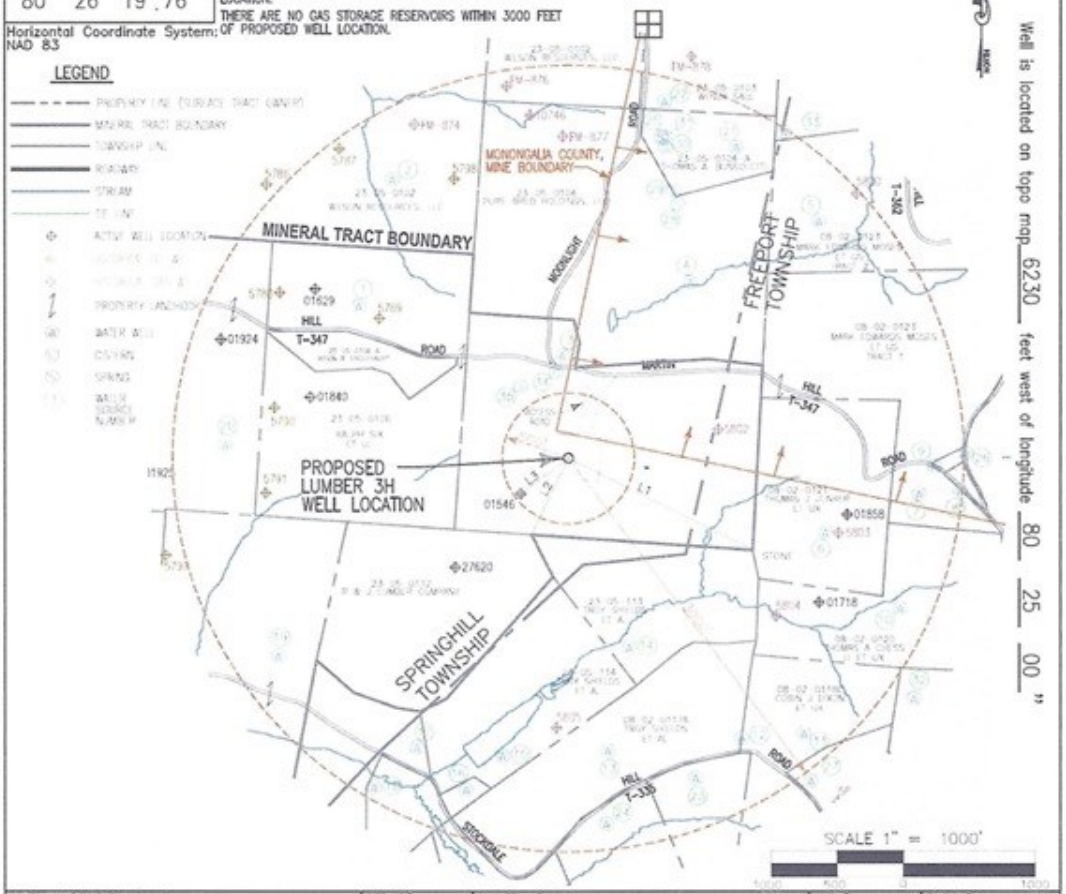
True Latitude: NORTH
39 ° 44 ' 35.53 "

True Longitude: WEST
80 ° 26 ' 19.76 "

Horizontal Coordinate System: NAD 83

NOTES:
THE PURPOSE OF THIS PLAT IS FOR THE LOCATION OF A PROPOSED GAS WELL AND DOES NOT REPRESENT A CLOSED BOUNDARY SURVEY. PROPERTY LINES AND OWNERS WERE OBTAINED FROM VARIOUS FIELD EVIDENCE, TAX RECORDS, AND AERIAL MAPPING.
NO STRUCTURES EXIST WITHIN 500 FEET OF PROPOSED WELL LOCATION.
THERE ARE NO GAS STORAGE RESERVOIRS WITHIN 3000 FEET OF PROPOSED WELL LOCATION.

LEGEND




| | | | | | |
|---|---|---|---|---|---|
| Applicant / Well Operator Name: EQT Production Company | DEP ID#: 146983 | Well (Farm) Name: LUMBER | | Well #: 3H | Serial #: |
| Address: 400 WOODCLIFF DRIVE, CANONSBURG, PA 15317 | | County: GREENE | Municipality: SPRINGHILL TOWNSHIP | | Well Type: GAS |
| 911 address of well site: 454 MARTIN HILL ROAD, NEW FREEPORT, PA 15352 | | USGS 7 1/2' Quadrangle Map Name: HUNDRED | Map Section: 2 | | Surface Elevation: 1521± ft. |
| Surveyor or Engineer: THOMAS C. SMIT, PLS | Phone #: (412) 278-2100 | Dwg #: | Date: 09/09/2020 | Scale: 1"=1000' | Unit Acreage: 877.17 |
| Lat & Long Metadata Method: GPS | Accuracy: 3± ft. | Datum: NAD 83 | Elevation Metadata Method: GPS | Accuracy: 5± ft. | Datum: NAVD 88 | Survey Date: 01/28/2020 |

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Page 2 Notifications

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|---|---|---|---|
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| | | |
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| 19. GREGORY B NULL ET AL | 39°44'19.97" | -80°26'47.30" |

| | |
|---|---|
| ALEPPO TOWNSHIP | Contura Coal Resources, LLC-Owner, All Seams |
| FREEPORT TOWNSHIP | Monongalia County Coal Company-Operator, Monongalia County Mine |
| GILMORE TOWNSHIP | |
| JACKSON TOWNSHIP | |
| SPRINGHILL TOWNSHIP | |
| | |
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| | |

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Page 2 Notifications

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| | | |
|---|---|---|
| 20. KSH LLC | 39°44'35.81" | -80°26'53.08" |
| 21. THOMAS A BUSSOLETTI ET AL | 39°44'59.35" | -80°26'04.33" |
| 22. WENDY SAUL | 39°45'02.67" | -80°26'11.44" |
| 23. TROY SHIELDS ET AL | 39°44'11.77" | -80°26'06.42" |
| 24. TROY SHIELDS ET AL | 39°44'08.10" | -80°26'14.95" |
| 25. THOMAS A BUSSOLETTI ET AL | 39°44'59.94 | -80°26'11.68 |
| 26. GEORGE D SIX | 39°44'36.81" | -80°25'41.14" |
| 27. MARLIN B GEHO | 39°44'11.79" | -80°25'55.25" |
| 28. PURE BRED HOLDINGS, LLC | 39°44'54.95" | -80°26'09.88" |
| 29. THOMAS A BUSSOLETTI ET AL | 39°44'56.00" | -80°26'10.29" |
| 30. THOMAS A BUSSOLETTI ET AL | 39°44'59.22" | -80°26'11.27" |
| 31. THOMAS A BUSSOLETTI ET AL | 39°44'59.96" | -80°26'11.36" |
| 32. TROY STONEKING ET UX | 39°44'18.24" | -80°25'45.55" |
| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
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8000-PM-OOGM0002 Rev. 6/2014

# WELL LOCATION PLAT

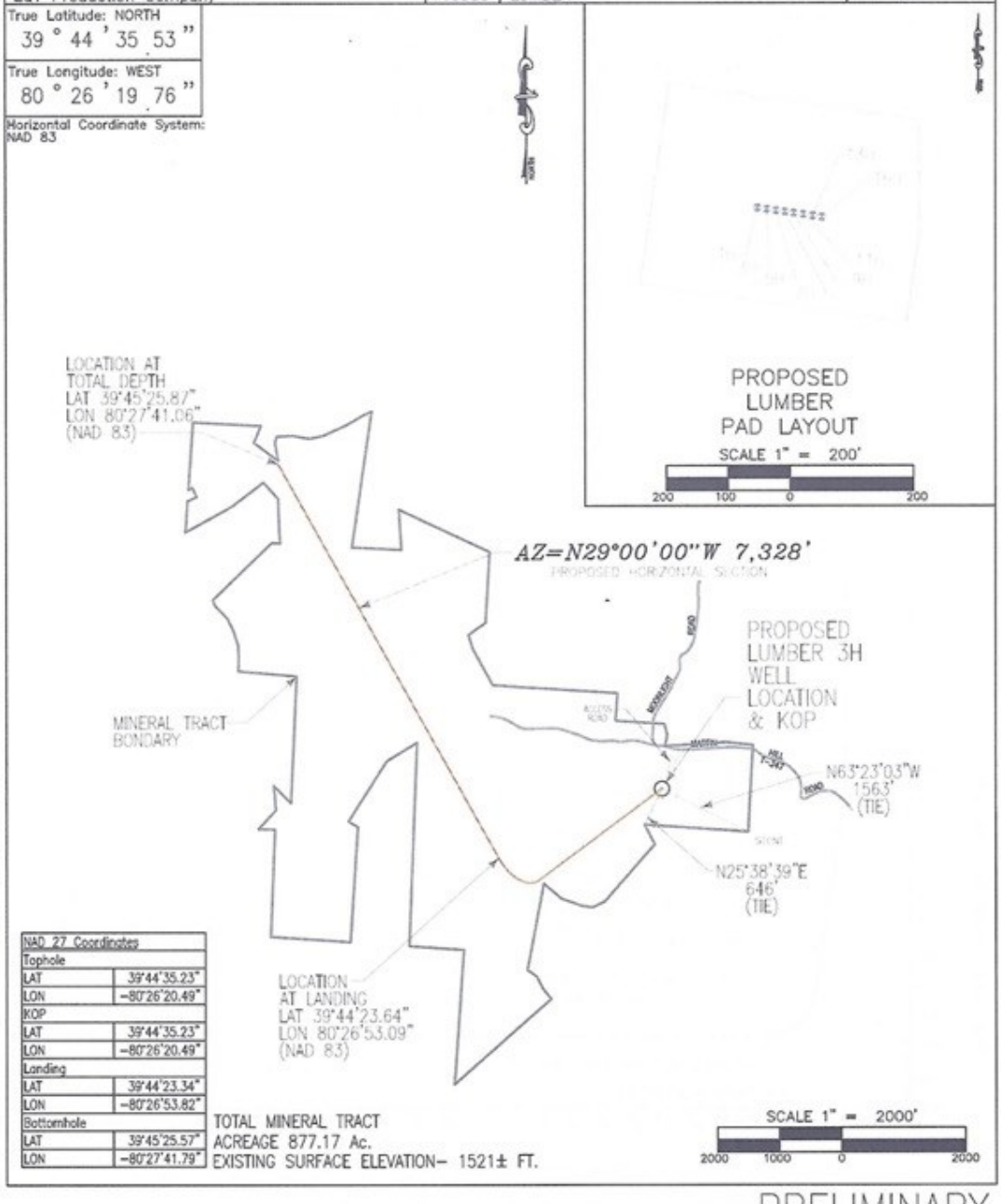
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 3H |

True Latitude: NORTH
39 ° 44 ' 35 . 53 "

True Longitude: WEST
80 ° 26 ' 19 . 76 "

Horizontal Coordinate System:
NAD 83




| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.23" |
| LON | -80°26'20.49" |
| KOP | |
| LAT | 39°44'35.23" |
| LON | -80°26'20.49" |
| Landing | |
| LAT | 39°44'23.34" |
| LON | -80°26'53.82" |
| Bottomhole | |
| LAT | 39°45'25.57" |
| LON | -80°27'41.79" |

TOTAL MINERAL TRACT
ACREAGE 877.17 Ac.
EXISTING SURFACE ELEVATION- 1521± FT.

PRELIMINARY

8000-PM-OOGM0002 Rev. 6/2014

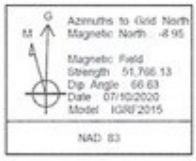
# WELL LOCATION PLAT

PAGE 4 Well Plan

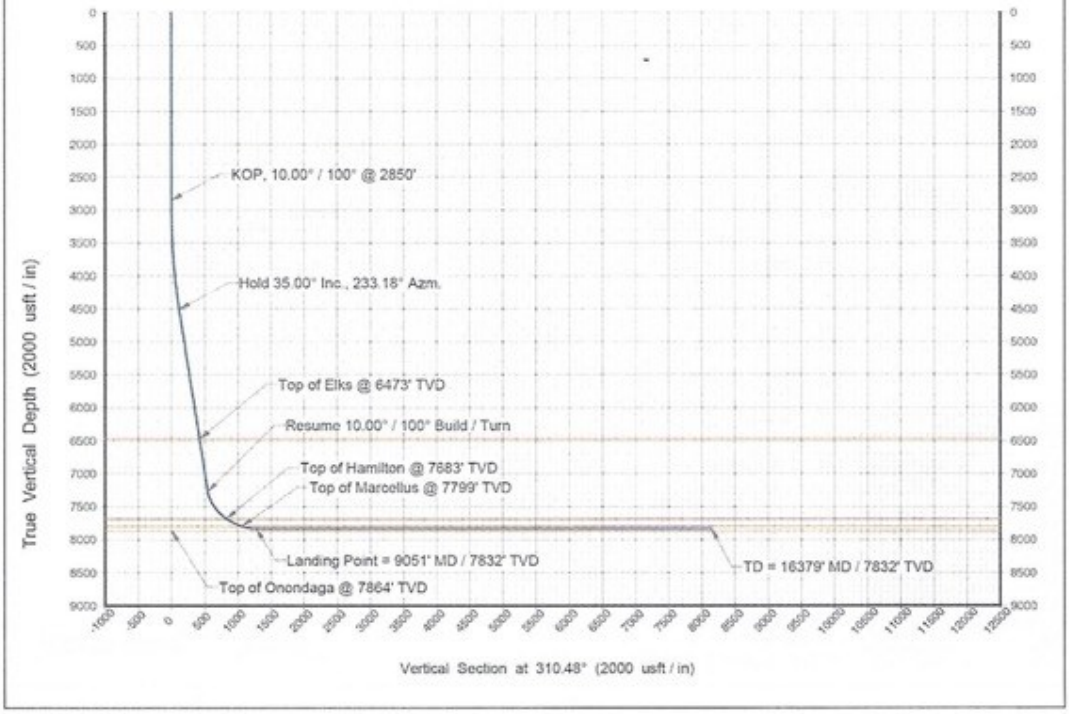
| DEP Use Only | Permit # |
|---|---|
| | |

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 3H |

| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : 2,850' | TMD : | 2,850' | 39° 44' 35.53" | 80° 26' 19.76" |
| Landing Point : | TVD : 7,832' | TMD : | 9,051' | 39° 44' 23.64" | 80° 26' 53.09" |
| Projected Bottom Hole: | TVD : 7,832' | TMD : | 16,379' | 39° 45' 25.87" | 80° 27' 41.06" |




NAD 83



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name: EQT PROD CO | Legal Name: EQT PRODUCTION COMPANY | DEP Client ID#: 146983 | Phone: 724-271-7380 | FAX: 724-749-5581 |
| Mailing Address (Street or PO Box): 400 WOODCLIFF DRIVE | Address 2: | | | |
| City: CANONSBURG | State: PA | Zip +4: 15317 | | |
| Email Address: espine@eqt.com | 24/7 Emergency Contact Name / Number: EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name: LUMBER | | | |
| Well #: 5H | Serial #: | Project # (from DEP): | |
| County: GREENE | Municipality: SPRINGHILL TWP | 911 Address of Well site (or nearest intersection): MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well? Y | Is this a Coal well? Y | Bond Agreement ID: 9399 - BLANKET ($850,000) | Well Deepest Point (TVD): 7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number: 1 | Wellbore Name: WELLBORE SURFACE HOLE LOCATION | Type of Wellbore: GAS | Wellbore Configuration: Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name: LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit? Y | ESCGP Number: ESG073019009-00 | Will this well be built on a well pad? Y | Well Pad: 156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?* | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the "Coordination of a Well Location with Public Resources" form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| | |
|---|---|
| Have any coal rights been severed from the surface estate? | Y |
| If the coal rights been severed from the surface estate, have the owners of the workable and unworkable coal seams been notified? | Y |
| Is this a "non-conservation" gas well? | Y |
| If the well will penetrate a workable coal seam, and the well is a 'non-conservation' gas well, does the location comply with the distance requirements of Section 7 of the Coal and Gas Resource Coordination Act (at least 1,000 feet from all existing wells) and, if part of a well cluster, at least 2,000 feet from any other existing cluster, as measured from the center of the well bore of the nearest well? | N |
| Will the well be part of a Well Cluster which is an area within a well pad intended to host multiple horizontal wells and which comprises an area no greater than 5,000 square feet? | Y |
| Will this well be part of a Well Cluster that already has an approved OG-57 waiver? | N |
| Will this well be drilled into solid coal or into an open underground void? | SOLID CORE |
| Will the well be drilled through an operating coal mine, or within 1,000 feet of the boundary? | Y |
| Provide the names of Mine(s) and Operator(s): | MONONGALIA COUNTY MINE - MONONGALIA COUNTY COAL COMPANY |
| Does it meet the Gas Well Pillar Study? | Y |
| Has the surface landowner been notified and provided a copy of the Landowner Notification of Right to Participate in Alternative Dispute Resolution to Coal Bed Methane Wells (form 5500-FM-OG0053)? | N |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.5100 -80 26 19.5700 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2480 |
| Offset West (in feet) | 6215 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.5100 -80 26 19.5700 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 45 30.0600 -80 27 28.9300 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 15723 |
| Bottom Hole Lat/Long | 39 45 30.0600 - -80 27 28.9300 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 15723 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
| Well Pad Corner 4 Lat/Long | 39 44 34.2528 -80 26 22.3296 | |
| Well Site GPS Location Lat/Long | 39 44 35.6244 -80 26 19.3272 | |
| Well Site Access Road GPS Lat/Long | 39 44 41.7984 -80 26 15.8424 | |
| Metadata Method<br>GPS - UNSPECIFIED | Accuracy (in ft.)<br>±2 | Datum<br>North American Datum of 1983 |

| SUBMISSION INFORMATION | |
|---|---|
| Pursuant to the Pennsylvania Electronic Transactions Act - Act 69, you are about to engage in an electronic transaction with the Commonwealth of Pennsylvania. You are submitting official information. Any false statement is subject to substantial civil and criminal penalties, including 18 P.S. section 4904 (relating to unsworn falsification to authorities). | |
| I hereby certify that, for all interested parties identified in this application for which written consent or an "Affidavit of Non-Delivery of Certified Mail" has not been uploaded, copies of the well plat have been sent via certified mail and I have received a return receipt verifying delivery. | |
| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 05:13:40 PM |

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL AND GAS MANAGEMENT

# WELL LOCATION PLAT

PAGE 1 Surface Location

| | |
|---|---|
| Auth ID #: | |
| Permit #: | |
| Project #: | |

Denotes location of top of well on topo map.

True Latitude: NORTH
39 ° 44 ' 35.51 "

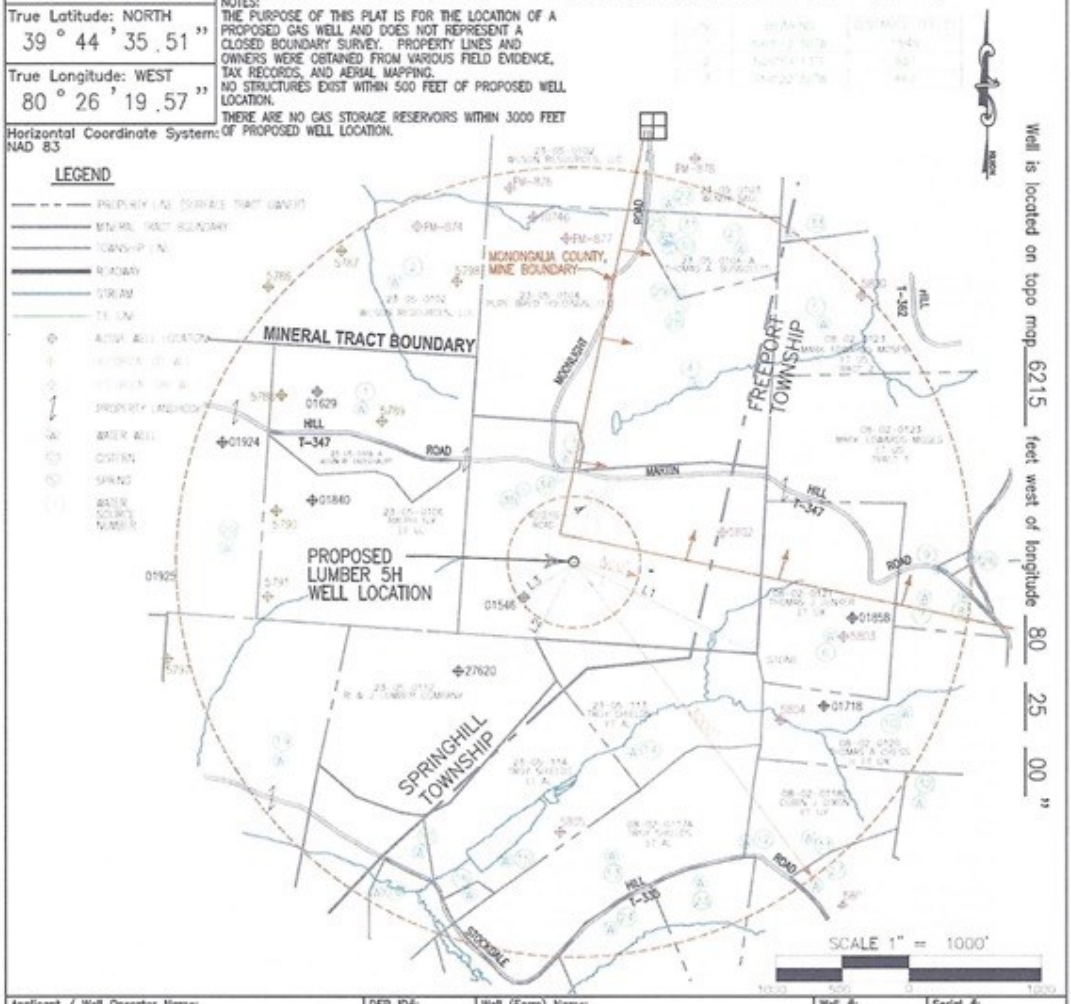
True Longitude: WEST
80 ° 26 ' 19.57 "

Horizontal Coordinate System: NAD 83

Well is located on topo map 2480 feet south of latitude 39 ° 45 ' 00 "

Well is located on topo map 6215 feet west of longitude 80 ° 25 ' 00 "

NOTES:
THE PURPOSE OF THIS PLAT IS FOR THE LOCATION OF A PROPOSED GAS WELL AND DOES NOT REPRESENT A CLOSED BOUNDARY SURVEY. PROPERTY LINES AND OWNERS WERE OBTAINED FROM VARIOUS FIELD EVIDENCE, TAX RECORDS, AND AERIAL MAPPING.
NO STRUCTURES EXIST WITHIN 500 FEET OF PROPOSED WELL LOCATION.
THERE ARE NO GAS STORAGE RESERVOIRS WITHIN 3000 FEET OF PROPOSED WELL LOCATION.




| | | | | | | |
|---|---|---|---|---|---|---|
| Applicant / Well Operator Name: EQT Production Company | DEP ID#: 146983 | Well (Farm) Name: LUMBER | | Well #: 5H | Serial #: | |
| Address: 400 WOODCLIFF DRIVE, CANONSBURG, PA 15317 | | County: GREENE | Municipality: SPRINGHILL TOWNSHIP | | Well Type: GAS | |
| 911 address of well site: 454 MARTIN HILL ROAD, NEW FREEPORT, PA 15352 | | USGS 7 1/2' Quadrangle Map Name: HUNDRED | Map Section: 2 | | Surface Elevation: 1521± ft. | |
| Surveyor or Engineer: THOMAS C. SMIT, PLS | Phone #: (412) 278-2100 | Dwg #: | Date: 09/09/2020 | Scale: 1"=1000' | Unit Acreage: 786.00 | |
| Lat & Long Metadata Method: GPS | Accuracy: 3± ft. | Datum: NAD 83 | Elevation Metadata Method: GPS | Accuracy: 5± ft. | Datum: NAVD 88 | Survey Date: 01/28/2020 |

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## WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 5H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N42° 42' 44"W 7734' | 7,832' | 15,723' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 15,723' |

| | | |
|---|---|---|
| 1. RALPH SIX ET UX | 39°44'46.53" | -80°26'40.51" |
| 2. WILSON RESOURCES LLC | 39°44'56.17" | -80°26'37.62" |
| 3. TROY SHIELDS ET AL | 39°44'43.28" | -80°26'20.63" |
| 4. PURE BRED HOLDINGS, LLC | 39°44'49.09" | -80°26'08.39" |
| 5. EDWARD MARK MOSES ET US | 39°44'54.00" | -80°25'56.15" |
| 6. THOMAS J JUNKER ET UX | 39°44'30.57" | -80°25'54.60" |
| 7. CHARLES JACKSON ET UX | 39°44'33.63" | -80°25'45.61" |
| 8. DAVID R HUNTLEY | 39°44'33.94" | -80°25'41.67" |
| 9. DAVID R HUNTLEY | 39°44'35.76" | -80°25'44.20" |
| 10. THOMAS A CHESS III ET UX | 39°44'24.94" | -80°25'47.11" |
| 11. COBIN J DIXON ET UX | 39°44'15.36" | -80°25'56.07" |
| 12. COBIN J DIXON ET UX | 39°44'14.89" | -80°26'02.08" |
| 13. TROY SHIELDS ET AL | 39°44'13.62" | -80°26'15.04" |
| 14. TROY SHIELDS ET AL | 39°44'21.41" | -80°26'13.30" |
| 15. TROY SHIELDS ET AL | 39°44'13.00" | -80°26'25.25" |
| 16. TROY SHIELDS ET AL | 39°44'10.35" | -80°26'28.64" |
| 17. TROY SHIELDS ET AL | 39°44'13.44" | -80°26'33.56" |
| 18. TROY SHIELDS ET AL | 39°44'10.31" | -80°26'37.60" |
| 19. GREGORY B NULL ET AL | 39°44'19.97" | -80°26'47.30" |

| | |
|---|---|
| ALEPPO TOWNSHIP | Contura Coal Resources, LLC-Owner, All Seams |
| FREEPORT TOWNSHIP | Monongalia County Coal Company-Operator, Monongalia County Mine |
| GILMORE TOWNSHIP | |
| JACKSON TOWNSHIP | |
| SPRINGHILL TOWNSHIP | |
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## WELL LOCATION PLAT

Page 2 Notifications

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| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 5H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N42° 42' 44"W 7734' | 7,832' | 15,723' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: 1 | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | | 15,723' |

| | | |
|---|---|---|
| 20. KSH LLC | 39°44'35.81" | -80°26'53.08" |
| 21. THOMAS A BUSSOLETTI ET AL | 39°44'59.35" | -80°26'04.33" |
| 22. WENDY SAUL | 39°45'02.67" | -80°26'11.44" |
| 23. TROY SHIELDS ET AL | 39°44'11.77" | -80°26'06.42" |
| 24. TROY SHIELDS ET AL | 39°44'08.10" | -80°26'14.95" |
| 25. THOMAS A BUSSOLETTI ET AL | 39°44'59.94 | -80°26'11.68 |
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| 27. MARLIN B GEHO | 39°44'11.79" | -80°25'55.25" |
| 28. PURE BRED HOLDINGS, LLC | 39°44'54.95" | -80°26'09.88" |
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| 30. THOMAS A BUSSOLETTI ET AL | 39°44'59.22" | -80°26'11.27" |
| 31. THOMAS A BUSSOLETTI ET AL | 39°44'59.96" | -80°26'11.36" |
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| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
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# WELL LOCATION PLAT

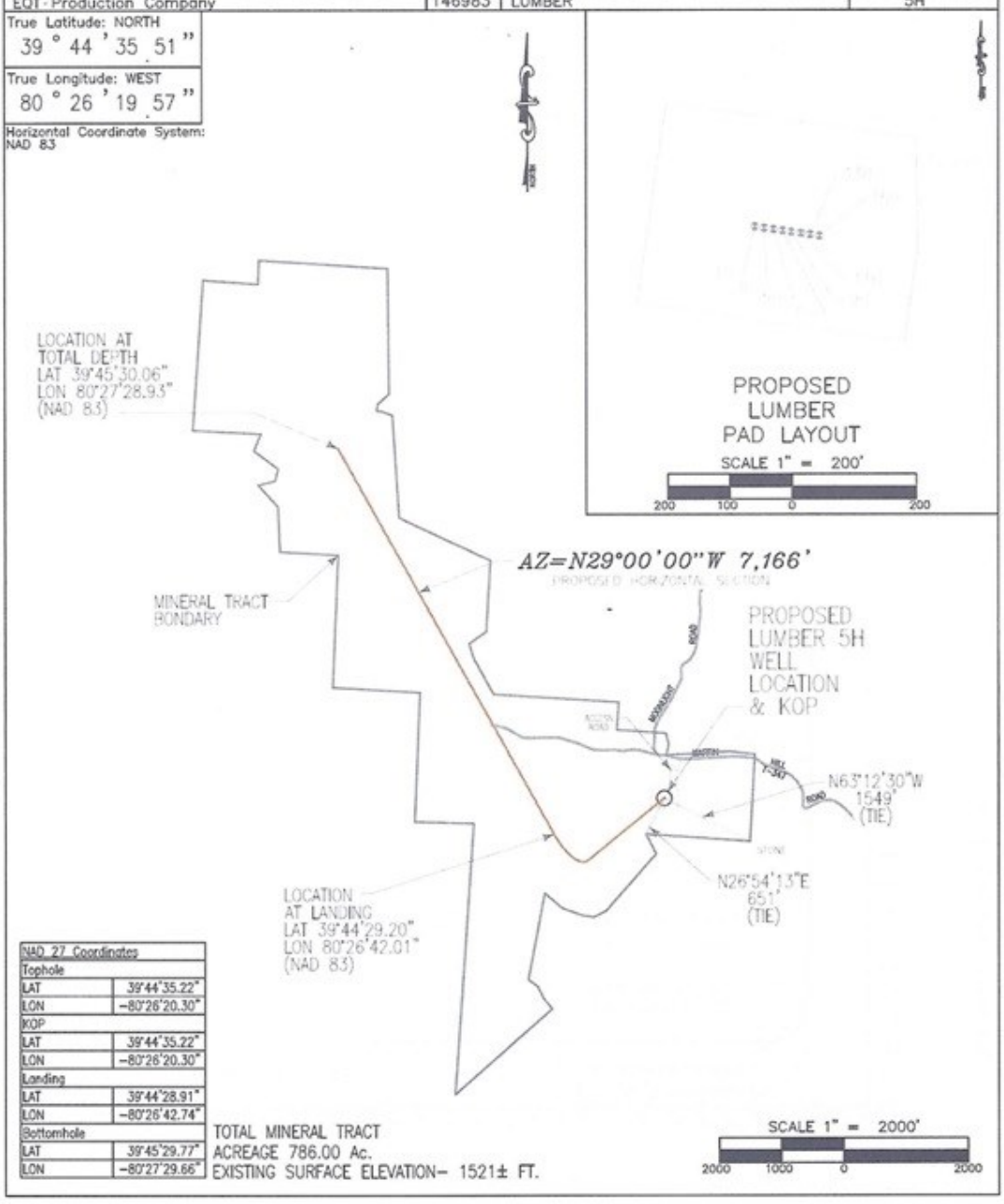
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT - Production Company | 146983 | LUMBER | 5H |

True Latitude: NORTH
39 ° 44 ' 35 . 51 "

True Longitude: WEST
80 ° 26 ' 19 . 57 "

Horizontal Coordinate System:
NAD 83




| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.22" |
| LON | -80°26'20.30" |
| KOP | |
| LAT | 39°44'35.22" |
| LON | -80°26'20.30" |
| Landing | |
| LAT | 39°44'28.91" |
| LON | -80°26'42.74" |
| Bottomhole | |
| LAT | 39°45'29.77" |
| LON | -80°27'29.66" |

TOTAL MINERAL TRACT
ACREAGE 786.00 Ac.
EXISTING SURFACE ELEVATION- 1521± FT.

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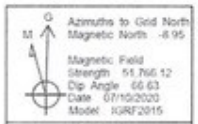
# WELL LOCATION PLAT

PAGE 4 Well Plan

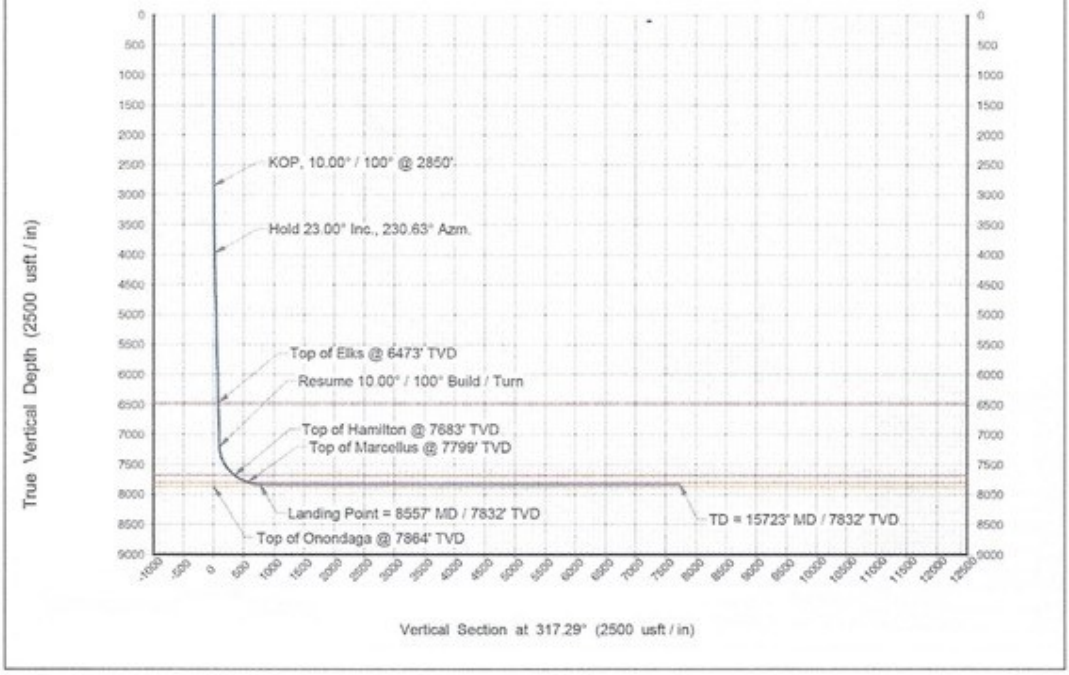
| DEP Use Only | Permit # |
|---|---|
| | - |

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 5H |

| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : 2,850' | TMD : | 2,850' | 39° 44' 35.51" | 80° 26' 19.57" |
| Landing Point : | TVD : 7,832' | TMD : | 8,557' | 39° 44' 29.20" | 80° 26' 42.01" |
| Projected Bottom Hole: | TVD : 7,832' | TMD : | 15,723' | 39° 45' 30.06" | 80° 27' 28.93" |




NAD 83



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name: EQT PROD CO | Legal Name: EQT PRODUCTION COMPANY | D&P Client ID#: 146983 | Phone: 724-271-7380 | FAX: 724-749-5581 |
| Mailing Address (Street or PO Box): 400 WOODCLIFF DRIVE | Address 2: | | | |
| City: CANONSBURG | State: PA | Zip +4: 15317 | | |
| Email Address: espine@eqt.com | 24/7 Emergency Contact Name / Number: EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name: LUMBER | | | |
| Well #: 7H | Serial #: | Project # (from DEP): | |
| County: GREENE | Municipality: SPRINGHILL TWP | 911 Address of Well site (or nearest intersection): MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?: Y | Is this a Coal well?: Y | Bond Agreement ID: 9399 - BLANKET ($850,000) | Well Deepest Point (TVD): 7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number: 1 | Wellbore Name: WELLBORE SURFACE HOLE LOCATION | Type of Wellbore: GAS | Wellbore Configuration: Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name: LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?: Y | ESCGP Number: ESG073019009-00 | Will this well be built on a well pad?: Y | Well Pad: 156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or peoposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?" | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the "Coordination of a Well Location with Public Resources" form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

pennsylvania

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| | |
|---|---|
| Have any coal rights been severed from the surface estate? | Y |
| If the coal rights been severed from the surface estate, have the owners of the workable and unworkable coal seams been notified? | Y |
| Is this a "non-conservation" gas well? | Y |
| If the well will penetrate a workable coal seam, and the well is a 'non-conservation' gas well, does the location comply with the distance requirements of Section 7 of the Coal and Gas Resource Coordination Act (at least 1,000 feet from all existing wells) and, if part of a well cluster, at least 2,000 feet from any other existing cluster, as measured from the center of the well bore of the nearest well? | N |
| Will the well be part of a Well Cluster which is an area within a well pad intended to host multiple horizontal wells and which comprises an area no greater than 5,000 square feet? | Y |
| Will this well be part of a Well Cluster that already has an approved OG-57 waiver? | N |
| Will this well be drilled into solid coal or into an open underground void? | SOLID CORE |
| Will the well be drilled through an operating coal mine, or within 1,000 feet of the boundary? | Y |
| Provide the names of Mine(s) and Operator(s): | MONONGALIA COUNTY MINE - MONONGALIA COUNTY COAL COMPANY |
| Does it meet the Gas Well Pillar Study? | Y |
| Has the surface landowner been notified and provided a copy of the Landowner Notification of Right to Participate in Alternative Dispute Resolution to Coal Bed Methane Wells (form 5500-FM-OG0053)? | N |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.4900 -80 26 19.3800 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2480 |
| Offset West (in feet) | 6200 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.4900 -80 26 19.3800 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 45 36.6300 -80 27 18.6200 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 15599 |
| Bottom Hole Lat/Long | 39 45 36.6300 -80 27 18.6200 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 15599 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
| Well Pad Corner 4 Lat/Long | 39 44 34.2528 -80 26 22.3296 | |
| Well Site GPS Location Lat/Long | 39 44 35.6244 -80 26 19.3272 | |
| Well Site Access Road GPS Lat/Long | 39 44 41.7984 -80 26 15.8424 | |
| Metadata Method<br>GPS - UNSPECIFIED | Accuracy (in ft.)<br>±2 | Datum<br>North American Datum of 1983 |

| SUBMISSION INFORMATION | |
|---|---|
| Pursuant to the Pennsylvania Electronic Transactions Act - Act 69, you are about to engage in an electronic transaction with the Commonwealth of Pennsylvania. You are submitting official information. Any false statement is subject to substantial civil and criminal penalties, including 18 P.S. section 4904 (relating to unsworn falsification to authorities). | |
| I hereby certify that, for all interested parties identified in this application for which written consent or an "Affidavit of Non-Delivery of Certified Mail" has not been uploaded, copies of the well plat have been sent via certified mail and I have received a return receipt verifying delivery. | |
| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 05:18:21 PM |

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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL AND GAS MANAGEMENT

# WELL LOCATION PLAT

PAGE 1 Surface Location

| | |
|---|---|
| Auth ID #: | |
| Permit #: | |
| Project #: | |

Denotes location of top of well on topo map.

True Latitude: NORTH
39 ° 44 ' 35.49 "

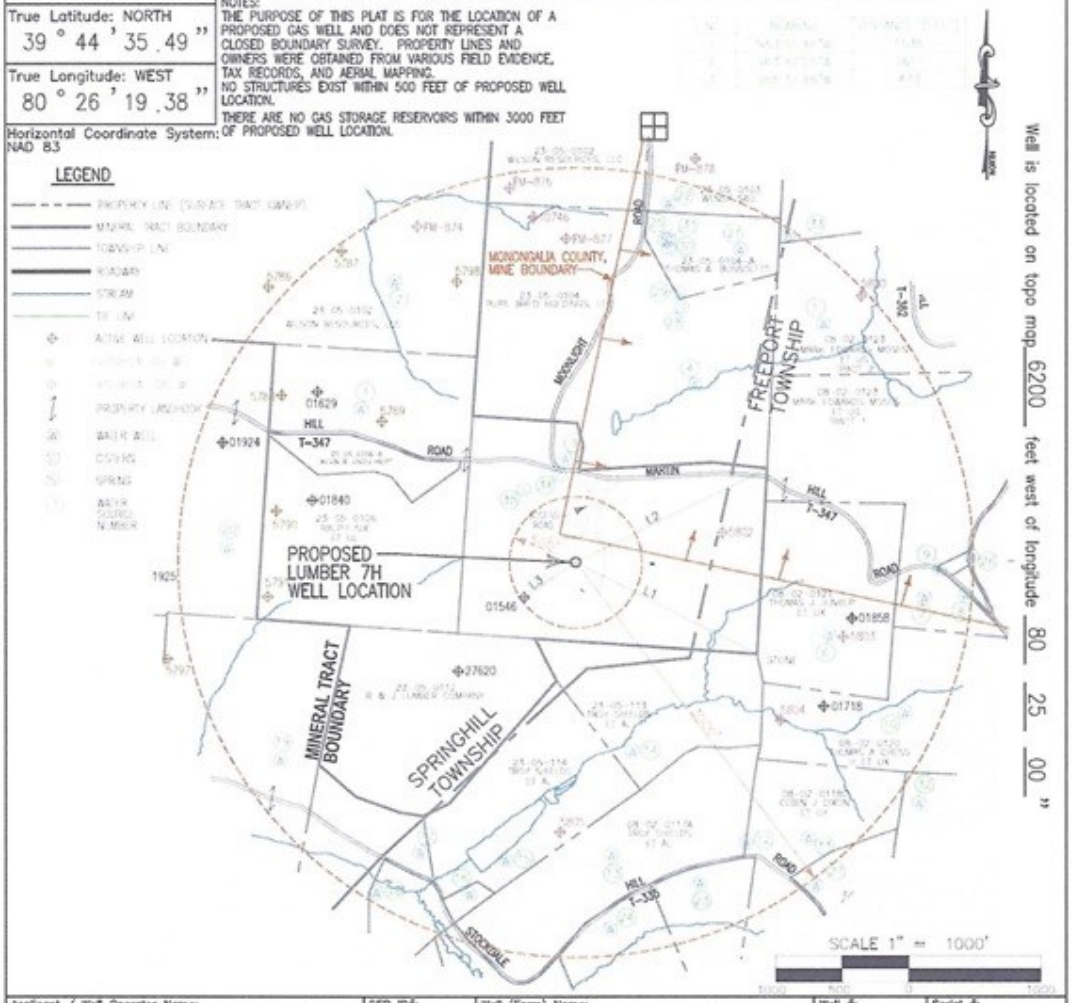
True Longitude: WEST
80 ° 26 ' 19.38 "

Horizontal Coordinate System: NAD 83

Well is located on topo map 2480 feet south of latitude 39 ° 45 ' 00 "

NOTES:
THE PURPOSE OF THIS PLAT IS FOR THE LOCATION OF A PROPOSED GAS WELL AND DOES NOT REPRESENT A CLOSED BOUNDARY SURVEY. PROPERTY LINES AND OWNERS WERE OBTAINED FROM VARIOUS FIELD EVIDENCE, TAX RECORDS, AND AERIAL MAPPING.
NO STRUCTURES EXIST WITHIN 500 FEET OF PROPOSED WELL LOCATION.
THERE ARE NO GAS STORAGE RESERVOIRS WITHIN 3000 FEET OF PROPOSED WELL LOCATION.

Well is located on topo map 6200 feet west of longitude 80 ° 25 ' 00 "




| | | | | | |
|---|---|---|---|---|---|
| Applicant / Well Operator Name: EQT Production Company | DEP ID#: 146983 | Well (Farm) Name: LUMBER | | Well #: 7H | Serial #: |
| Address: 400 WOODCLIFF DRIVE, CANONSBURG, PA 15317 | | County: GREENE | Municipality: SPRINGHILL TOWNSHIP | | Well Type: GAS |
| 911 address of well site: 454 MARTIN HILL ROAD, NEW FREEPORT, PA 15352 | | USGS 7 1/2 Quadrangle Map Name: HUNDRED | Map Section: 2 | | Surface Elevation: 1521± ft. |
| Surveyor or Engineer: THOMAS C. SMIT, PLS | Phone #: (412) 278-2100 | Dwg #: | Date: 09/09/2020 | Scale: 1"=1000' | Unit Acreage: 777.20 |
| Lat & Long Metadata Method: GPS | Accuracy: 3± ft. | Datum: NAD 83 | Elevation Metadata Method: GPS | Accuracy: 5± ft. | Datum: NAVD 88 |
| | | | | | Survey Date: 01/28/2020 |

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## WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 7H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N35° 02' 49"W 7725' | 7,832' | 15,599' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 15,599' |

| | | |
|---|---|---|
| 1. RALPH SIX ET UX | 39°44'46.53" | -80°26'40.51" |
| 2. WILSON RESOURCES LLC | 39°44'56.17" | -80°26'37.62" |
| 3. TROY SHIELDS ET AL | 39°44'43.28" | -80°26'20.63" |
| 4. PURE BRED HOLDINGS, LLC | 39°44'49.09" | -80°26'08.39" |
| 5. EDWARD MARK MOSES ET US | 39°44'54.00" | -80°25'56.15" |
| 6. THOMAS J JUNKER ET UX | 39°44'30.57" | -80°25'54.60" |
| 7. CHARLES JACKSON ET UX | 39°44'33.63" | -80°25'45.61" |
| 8. DAVID R HUNTLEY | 39°44'33.94" | -80°25'41.67" |
| 9. DAVID R HUNTLEY | 39°44'35.76" | -80°25'44.20" |
| 10. THOMAS A CHESS III ET UX | 39°44'24.94" | -80°25'47.11" |
| 11. COBIN J DIXON ET UX | 39°44'15.36" | -80°25'56.07" |
| 12. COBIN J DIXON ET UX | 39°44'14.89" | -80°26'02.08" |
| 13. TROY SHIELDS ET AL | 39°44'13.62" | -80°26'15.04" |
| 14. TROY SHIELDS ET AL | 39°44'21.41" | -80°26'13.30" |
| 15. TROY SHIELDS ET AL | 39°44'13.00" | -80°26'25.25" |
| 16. TROY SHIELDS ET AL | 39°44'10.35" | -80°26'28.64" |
| 17. TROY SHIELDS ET AL | 39°44'13.44" | -80°26'33.56" |
| 18. TROY SHIELDS ET AL | 39°44'10.31" | -80°26'37.60" |
| 19. GREGORY B NULL ET AL | 39°44'19.97" | -80°26'47.30" |

| | |
|---|---|
| ALEPPO TOWNSHIP | Contura Coal Resources, LLC-Owner, All Seams |
| FREEPORT TOWNSHIP | Monongalia County Coal Company-Operator, Monongalia County Mine |
| GILMORE TOWNSHIP | |
| JACKSON TOWNSHIP | |
| SPRINGHILL TOWNSHIP | |
| | |
| | |
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| | |

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# WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 7H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N35° 02' 49"W 7725' | 7,832' | 15,599' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 15,599' |

| | | |
|---|---|---|
| 20. KSH LLC | 39°44'35.81" | -80°26'53.08" |
| 21. THOMAS A BUSSOLETTI ET AL | 39°44'59.35" | -80°26'04.33" |
| 22. WENDY SAUL | 39°45'02.67" | -80°26'11.44" |
| 23. TROY SHIELDS ET AL | 39°44'11.77" | -80°26'06.42" |
| 24. TROY SHIELDS ET AL | 39°44'08.10" | -80°26'14.95" |
| 25. THOMAS A BUSSOLETTI ET AL | 39°44'59.94 | -80°26'11.68 |
| 26. GEORGE D SIX | 39°44'36.81" | -80°25'41.14" |
| 27. MARLIN B GEHO | 39°44'11.79" | -80°25'55.25" |
| 28. PURE BRED HOLDINGS, LLC | 39°44'54.95" | -80°26'09.88" |
| 29. THOMAS A BUSSOLETTI ET AL | 39°44'56.00" | -80°26'10.29" |
| 30. THOMAS A BUSSOLETTI ET AL | 39°44'59.22" | -80°26'11.27" |
| 31. THOMAS A BUSSOLETTI ET AL | 39°44'59.96" | -80°26'11.36" |
| 32. TROY STONEKING ET UX | 39°44'18.24" | -80°25'45.55" |
| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
| | | |
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# WELL LOCATION PLAT

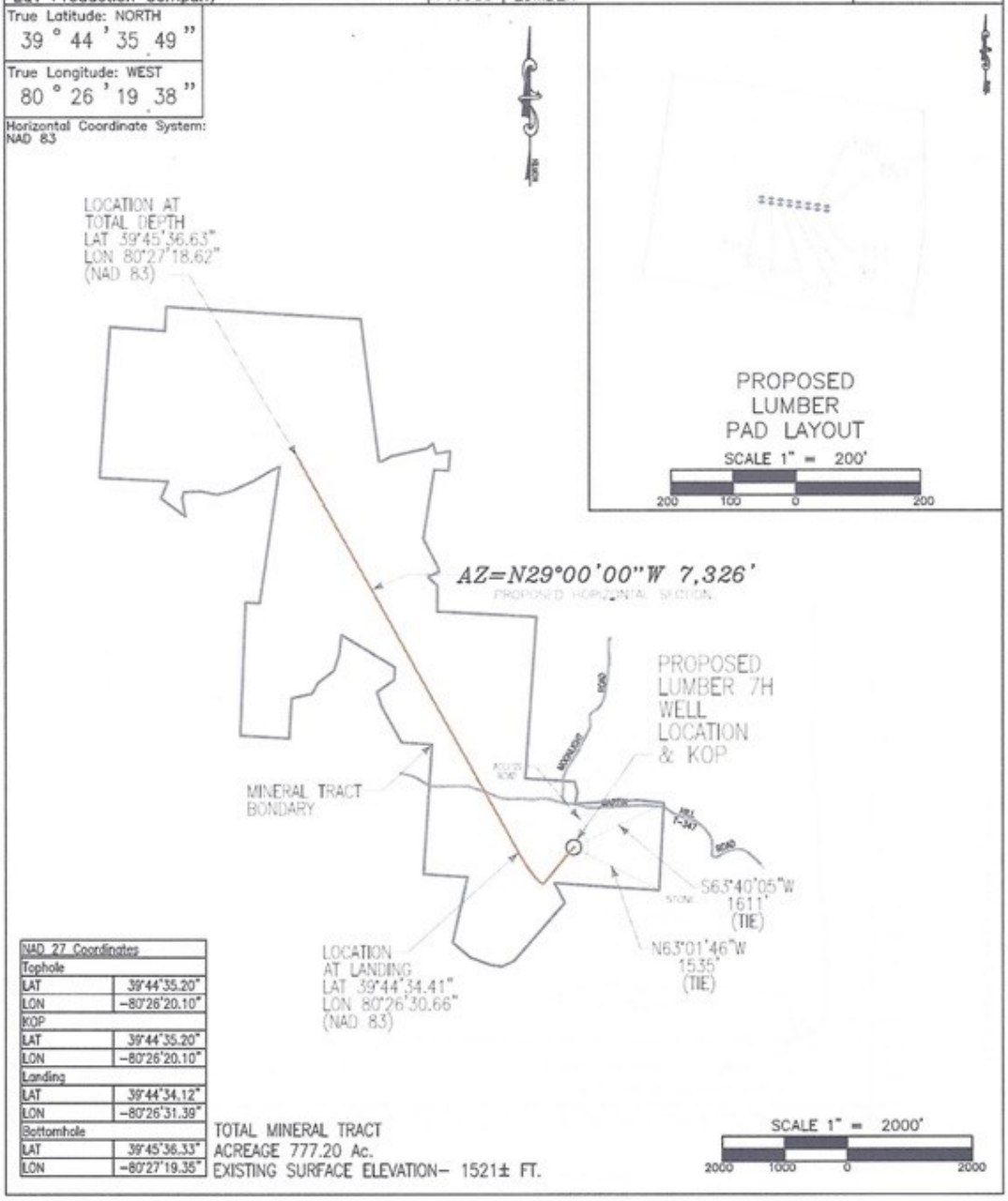
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 7H |

True Latitude: NORTH
39 ° 44 ' 35 . 49 "

True Longitude: WEST
80 ° 26 ' 19 . 38 "

Horizontal Coordinate System:
NAD 83




| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.20" |
| LON | -80°26'20.10" |
| KOP | |
| LAT | 39°44'35.20" |
| LON | -80°26'20.10" |
| Landing | |
| LAT | 39°44'34.12" |
| LON | -80°26'31.39" |
| Bottomhole | |
| LAT | 39°45'36.33" |
| LON | -80°27'19.35" |

TOTAL MINERAL TRACT
ACREAGE 777.20 Ac.
EXISTING SURFACE ELEVATION- 1521± FT.

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# WELL LOCATION PLAT

PAGE 4 Well Plan

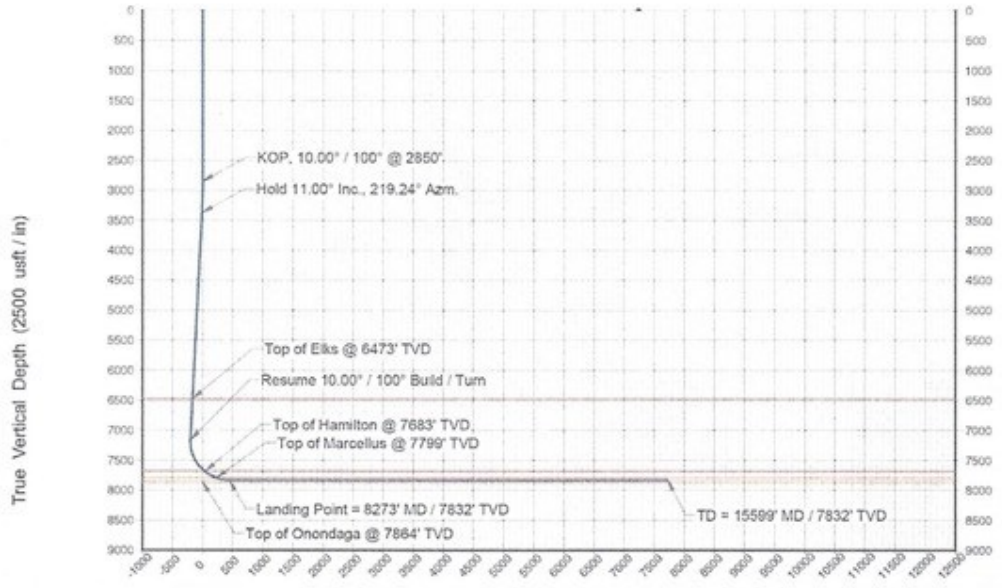
DEP Use Only | Permit #

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 7H |

| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : 2,850' | TMD : | 2,850' | 39° 44' 35.49" | 80° 26' 19.38" |
| Landing Point : | TVD : 7,832' | TMD : | 8,273' | 39° 44' 34.41" | 80° 26' 30.66" |
| Projected Bottom Hole: | TVD : 7,832' | TMD : | 15,599' | 39° 45' 36.63" | 80° 27' 18.62" |

G / M — Azimuths to Grid North
Magnetic North -8.95
Magnetic Field
Strength 51,766.11
Dip Angle 66.63
Date 07/10/2020
Model IGRF2015

NAD 83



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

**PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL**

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name: EQT PROD CO | Legal Name: EQT PRODUCTION COMPANY | DEP Client ID#: 146983 | Phone: 724-271-7380 | FAX: 724-749-5581 |
| Mailing Address (Street or PO Box): 400 WOODCLIFF DRIVE | Address 2: | | | |
| City: CANONSBURG | State: PA | Zip +4: 15317 | | |
| Email Address: espine@eqt.com | 24/7 Emergency Contact Name / Number: EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name: LUMBER | | | |
| Well #: 9H | Serial #: | Project # (from DEP): | |
| County: GREENE | Municipality: SPRINGHILL TWP | 911 Address of Well site (or nearest intersection): MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?: Y | Is this a Coal well?: Y | Bond Agreement ID: 9399 - BLANKET ($650,000) | Well Deepest Point (TVD): 7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number: 1 | Wellbore Name: WELLBORE SURFACE HOLE LOCATION | Type of Wellbore: GAS | Wellbore Configuration: Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name: LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?: Y | ESCGP Number: ESG073019009-00 | Will this well be built on a well pad?: Y | Well Pad: 156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?" | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the 'Coordination of a Well Location with Public Resources' form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| | |
|---|---|
| Have any coal rights been severed from the surface estate? | Y |
| If the coal rights been severed from the surface estate, have the owners of the workable and unworkable coal seams been notified? | Y |
| Is this a "non-conservation" gas well? | Y |
| If the well will penetrate a workable coal seam, and the well is a 'non-conservation' gas well, does the location comply with the distance requirements of Section 7 of the Coal and Gas Resource Coordination Act (at least 1,000 feet from all existing wells) and, if part of a well cluster, at least 2,000 feet from any other existing cluster, as measured from the center of the well bore of the nearest well? | N |
| Will the well be part of a Well Cluster which is an area within a well pad intended to host multiple horizontal wells and which comprises an area no greater than 5,000 square feet? | Y |
| Will this well be part of a Well Cluster that already has an approved OG-57 waiver? | N |
| Will this well be drilled into solid coal or into an open underground void? | SOLID CORE |
| Will the well be drilled through an operating coal mine, or within 1,000 feet of the boundary? | Y |
| Provide the names of Mine(s) and Operator(s): | MONONGALIA COUNTY MINE - MONONGALIA COUNTY COAL COMPANY |
| Does it meet the Gas Well Pillar Study? | Y |
| Has the surface landowner been notified and provided a copy of the Landowner Notification of Right to Participate in Alternative Dispute Resolution to Coal Bed Methane Wells (form 5500-FM-OG0053)? | N |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.4800 -80 26 19.1900 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2480 |
| Offset West (in feet) | 6185 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.4800 -80 26 19.1900 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 45 44.8200 -80 27 09.5700 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 15885 |
| Bottom Hole Lat/Long | 39 45 44.8200 -80 27 09.5700 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 15885 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
| Well Pad Corner 4 Lat/Long | 39 44 34.2528 -80 26 22.3296 | |
| Well Site GPS Location Lat/Long | 39 44 35.6244 -80 26 19.3272 | |
| Well Site Access Road GPS Lat/Long | 39 44 41.7984 -80 26 15.8424 | |
| Metadata Method<br>GPS - UNSPECIFIED | Accuracy (in ft.)<br>±2 | Datum<br>North American Datum of 1983 |

| SUBMISSION INFORMATION | |
|---|---|
| Pursuant to the Pennsylvania Electronic Transactions Act - Act 69, you are about to engage in an electronic transaction with the Commonwealth of Pennsylvania. You are submitting official information. Any false statement is subject to substantial civil and criminal penalties, including 18 P.S. section 4904 (relating to unsworn falsification to authorities). | |
| I hereby certify that, for all interested parties identified in this application for which written consent or an "Affidavit of Non-Delivery of Certified Mail" has not been uploaded, copies of the well plat have been sent via certified mail and I have received a return receipt verifying delivery. | |
| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 05:25:00 PM |

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DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL AND GAS MANAGEMENT

# WELL LOCATION PLAT

PAGE 1 Surface Location

| | |
|---|---|
| Auth ID #: | |
| Permit #: | |
| Project #: | |

Denotes location of top of well on topo map.

True Latitude: NORTH
39 ° 44 ' 35.48 "

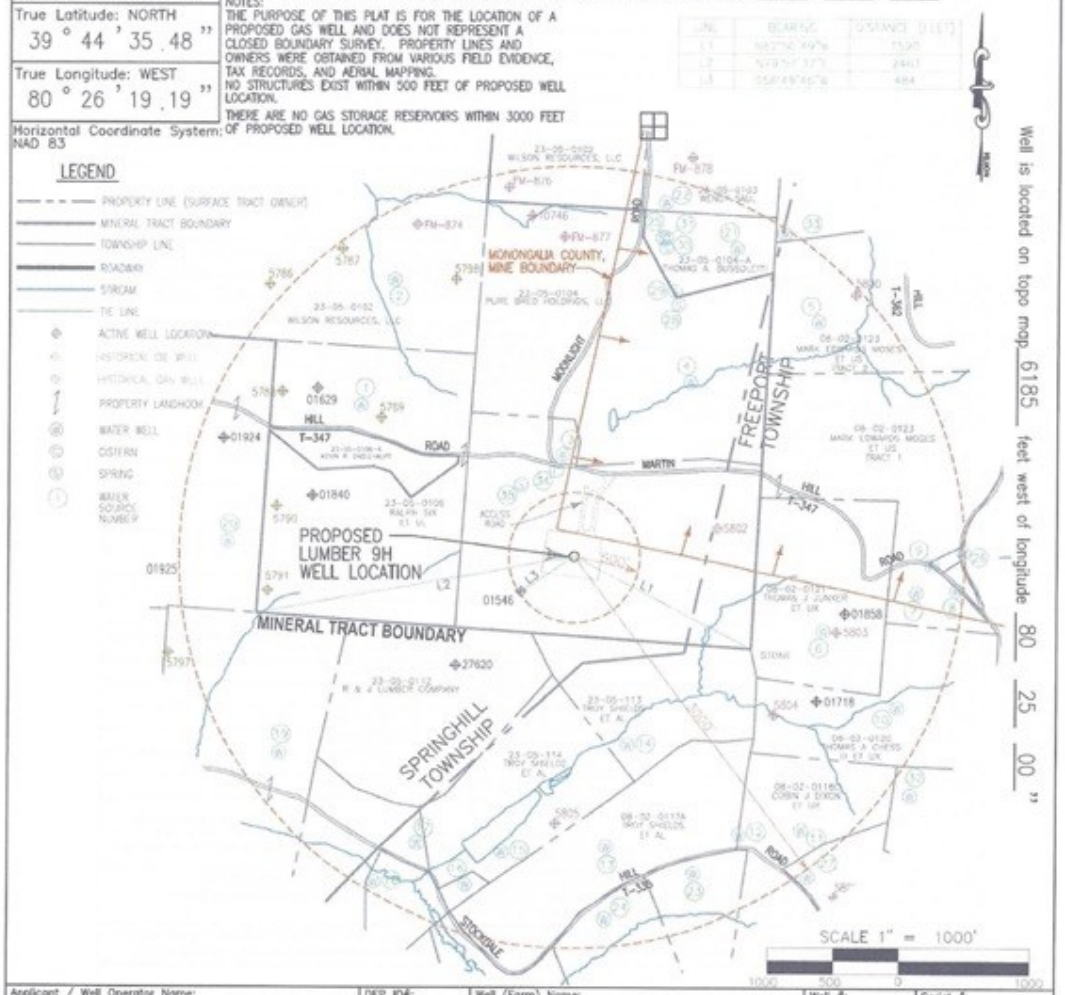
True Longitude: WEST
80 ° 26 ' 19.19 "

Horizontal Coordinate System: NAD 83

Well is located on topo map 2480 feet south of latitude 39 ° 45 ' 00 "

Well is located on topo map 6185 feet west of longitude 80 ° 25 ' 00 "

NOTES:
THE PURPOSE OF THIS PLAT IS FOR THE LOCATION OF A PROPOSED GAS WELL AND DOES NOT REPRESENT A CLOSED BOUNDARY SURVEY. PROPERTY LINES AND OWNERS WERE OBTAINED FROM VARIOUS FIELD EVIDENCE, TAX RECORDS, AND AERIAL MAPPING.
NO STRUCTURES EXIST WITHIN 500 FEET OF PROPOSED WELL LOCATION.
THERE ARE NO GAS STORAGE RESERVOIRS WITHIN 3000 FEET OF PROPOSED WELL LOCATION.




| | | | | | |
|---|---|---|---|---|---|
| Applicant / Well Operator Name: EQT Production Company | DEP ID#: 146983 | Well (Farm) Name: LUMBER | Well #: 9H | Serial #: | |
| Address: 400 WOODCLIFF DRIVE, CANONSBURG, PA 15317 | | County: GREENE | Municipality: SPRINGHILL TOWNSHIP | Well Type: GAS | |
| 911 address of well site: 454 MARTIN HILL ROAD, NEW FREEPORT, PA 15352 | | USGS 7 1/2' Quadrangle Map Name: HUNDRED | Map Section: 2 | Surface Elevation: 1521± ft. | |
| Surveyor or Engineer: THOMAS C. SMIT, PLS | Phone #: (412) 278-2100 | Dwg #: | Date: 09/09/2020 | Scale: 1"=1000' | Unit Acreage: 549.08 |
| Lat & Long Metadata Method: GPS | Accuracy: 3± ft. | Datum: NAD 83 | Elevation Metadata Method: GPS | Accuracy: 5± ft. | Datum: NAVD 88 | Survey Date: 01/28/2020 |

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# WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 9H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N27° 32' 09"W 8045' | 7,832' | 15,885' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: 1 | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | | 15,885' |

| | | |
|---|---|---|
| 1. RALPH SIX ET UX | 39°44'46.53" | -80°26'40.51" |
| 2. WILSON RESOURCES LLC | 39°44'56.17" | -80°26'37.62" |
| 3. TROY SHIELDS ET AL | 39°44'43.28" | -80°26'20.63" |
| 4. PURE BRED HOLDINGS, LLC | 39°44'49.09" | -80°26'08.39" |
| 5. EDWARD MARK MOSES ET US | 39°44'54.00" | -80°25'56.15" |
| 6. THOMAS J JUNKER ET UX | 39°44'30.57" | -80°25'54.60" |
| 7. CHARLES JACKSON ET UX | 39°44'33.63" | -80°25'45.61" |
| 8. DAVID R HUNTLEY | 39°44'33.94" | -80°25'41.67" |
| 9. DAVID R HUNTLEY | 39°44'35.76" | -80°25'44.20" |
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| 12. COBIN J DIXON ET UX | 39°44'14.89" | -80°26'02.08" |
| 13. TROY SHIELDS ET AL | 39°44'13.62" | -80°26'15.04" |
| 14. TROY SHIELDS ET AL | 39°44'21.41" | -80°26'13.30" |
| 15. TROY SHIELDS ET AL | 39°44'13.00" | -80°26'25.25" |
| 16. TROY SHIELDS ET AL | 39°44'10.35" | -80°26'28.64" |
| 17. TROY SHIELDS ET AL | 39°44'13.44" | -80°26'33.56" |
| 18. TROY SHIELDS ET AL | 39°44'10.31" | -80°26'37.60" |
| 19. GREGORY B NULL ET AL | 39°44'19.97" | -80°26'47.30" |

| | |
|---|---|
| ALEPPO TOWNSHIP | Contura Coal Resources, LLC-Owner, All Seams |
| FREEPORT TOWNSHIP | Monongalia County Coal Company-Operator, Monongalia County Mine |
| GILMORE TOWNSHIP | |
| JACKSON TOWNSHIP | |
| SPRINGHILL TOWNSHIP | |
| | |
| | |
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| | |

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# WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 9H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N27° 32' 09"W 8045' | 7,832' | 15,885' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: 1 | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | | 15,885' |

| | | |
|---|---|---|
| 20. KSH LLC | 39°44'35.81" | -80°26'53.08" |
| 21. THOMAS A BUSSOLETTI ET AL | 39°44'59.35" | -80°26'04.33" |
| 22. WENDY SAUL | 39°45'02.67" | -80°26'11.44" |
| 23. TROY SHIELDS ET AL | 39°44'11.77" | -80°26'06.42" |
| 24. TROY SHIELDS ET AL | 39°44'08.10" | -80°26'14.95" |
| 25. THOMAS A BUSSOLETTI ET AL | 39°44'59.94 | -80°26'11.68 |
| 26. GEORGE D SIX | 39°44'36.81" | -80°25'41.14" |
| 27. MARLIN B GEHO | 39°44'11.79" | -80°25'55.25" |
| 28. PURE BRED HOLDINGS, LLC | 39°44'54.95" | -80°26'09.88" |
| 29. THOMAS A BUSSOLETTI ET AL | 39°44'56.00" | -80°26'10.29" |
| 30. THOMAS A BUSSOLETTI ET AL | 39°44'59.22" | -80°26'11.27" |
| 31. THOMAS A BUSSOLETTI ET AL | 39°44'59.96" | -80°26'11.36" |
| 32. TROY STONEKING ET UX | 39°44'18.24" | -80°25'45.55" |
| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
| | | |
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# WELL LOCATION PLAT

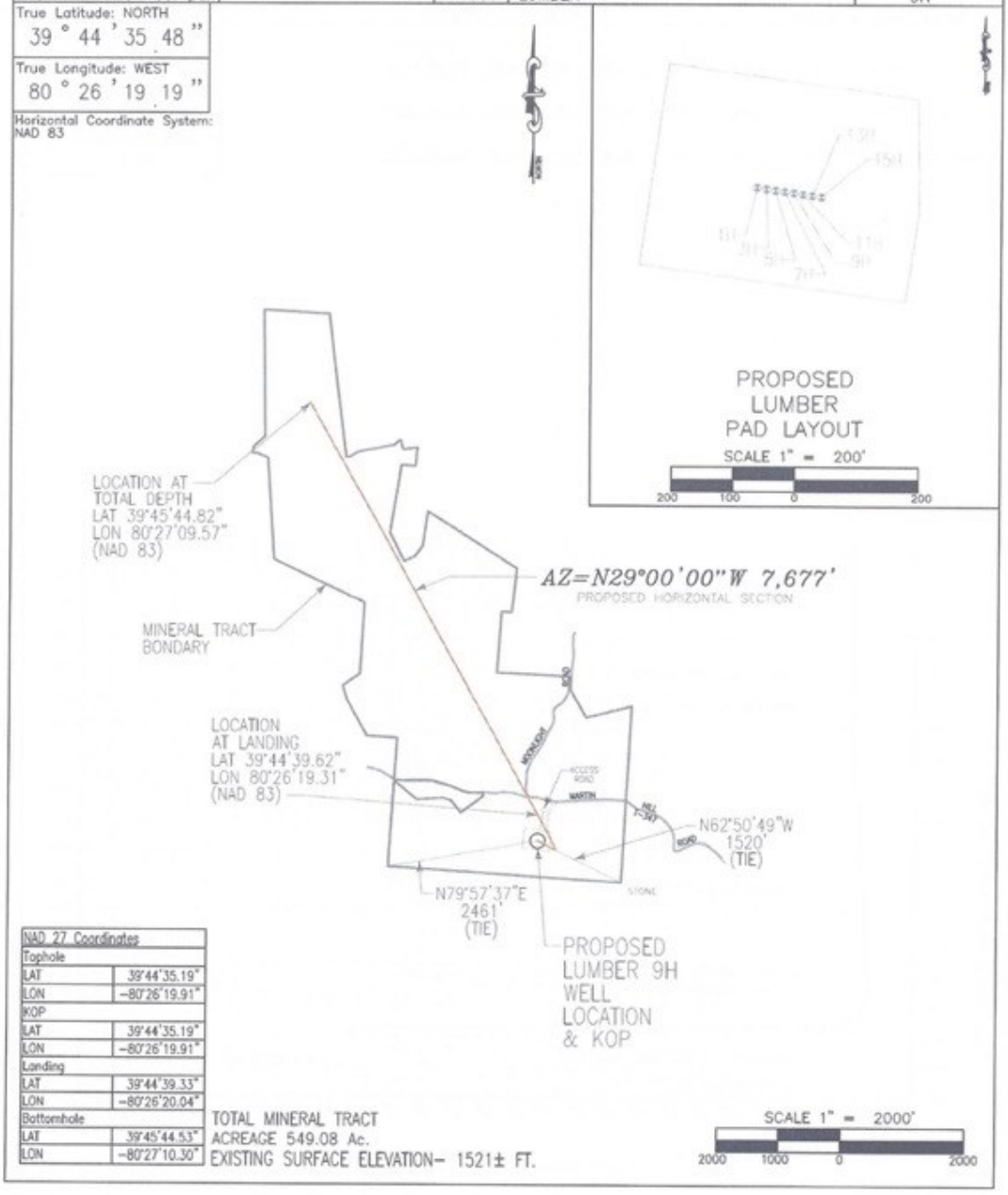
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 9H |

True Latitude: NORTH
39 ° 44 ' 35 . 48 "

True Longitude: WEST
80 ° 26 ' 19 . 19 "

Horizontal Coordinate System:
NAD 83




| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.19" |
| LON | -80°26'19.91" |
| KOP | |
| LAT | 39°44'35.19" |
| LON | -80°26'19.91" |
| Landing | |
| LAT | 39°44'39.33" |
| LON | -80°26'20.04" |
| Bottomhole | |
| LAT | 39°45'44.53" |
| LON | -80°27'10.30" |

TOTAL MINERAL TRACT
ACREAGE 549.08 Ac.
EXISTING SURFACE ELEVATION- 1521± FT.

SCALE 1" = 2000'
2000 1000 0 2000

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# WELL LOCATION PLAT

PAGE 4 Well Plan

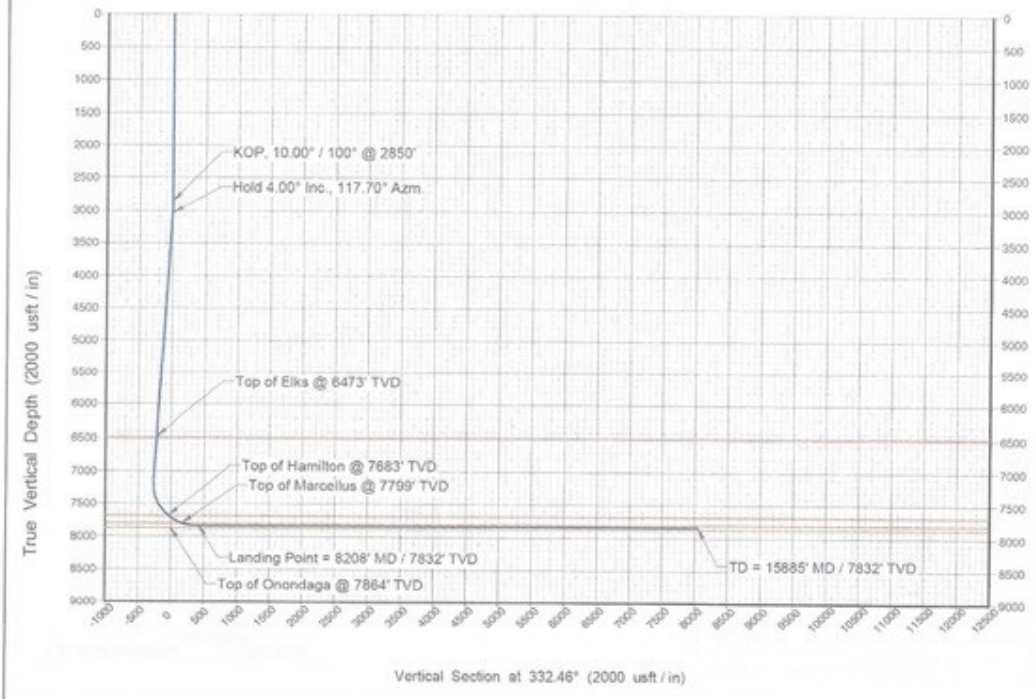
| DEP Use Only | Permit # |
|---|---|

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 9H |

| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : 2,850' | TMD : 2,850' | | 39° 44' 35.48" | 80° 26' 19.19" |
| Landing Point : | TVD : 7,832' | TMD : 8,208' | | 39° 44' 39.62" | 80° 26' 19.31" |
| Projected Bottom Hole: | TVD : 7,832' | TMD : 15,885' | | 39° 45' 44.82" | 80° 27' 09.57" |

G M — Azimuths to Grid North
Magnetic North : -8.95
Magnetic Field
Strength : 51,766.10
Dip Angle : 66.63
Date : 07/10/2020
Model : IGRF2015

NAD 83



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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name: EQT PROD CO | Legal Name: EQT PRODUCTION COMPANY | DEP Client ID#: 146983 | Phone: 724-271-7380 | FAX: 724-749-5581 |
| Mailing Address (Street or PO Box): 400 WOODCLIFF DRIVE | Address 2: | | | |
| City: CANONSBURG | State: PA | Zip +4: 15317 | | |
| Email Address: espine@eqt.com | 24/7 Emergency Contact Name / Number: EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name: LUMBER | | | |
| Well #: 11H | Serial #: | Project # (from DEP): | |
| County: GREENE | Municipality: SPRINGHILL TWP | 911 Address of Well site (or nearest intersection): MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?: Y | Is this a Coal well?: Y | Bond Agreement ID: 9399 - BLANKET ($850,000) | Well Deepest Point (TVD): 7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number: 1 | Wellbore Name: WELLBORE SURFACE HOLE LOCATION | Type of Wellbore: GAS | Wellbore Configuration: Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name: LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?: Y | ESCGP Number: ESG073019009-00 | Will this well be built on a well pad?: Y | Well Pad: 156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?" | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the 'Coordination of a Well Location with Public Resources' form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

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OFFICE OF OIL & GAS MANAGEMENT

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PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| | |
|---|---|
| Have any coal rights been severed from the surface estate? | Y |
| If the coal rights been severed from the surface estate, have the owners of the workable and unworkable coal seams been notified? | Y |
| Is this a "non-conservation" gas well? | Y |
| If the well will penetrate a workable coal seam, and the well is a 'non-conservation' gas well, does the location comply with the distance requirements of Section 7 of the Coal and Gas Resource Coordination Act (at least 1,000 feet from all existing wells) and, if part of a well cluster, at least 2,000 feet from any other existing cluster, as measured from the center of the well bore of the nearest well? | N |
| Will the well be part of a Well Cluster which is an area within a well pad intended to host multiple horizontal wells and which comprises an area no greater than 5,000 square feet? | Y |
| Will this well be part of a Well Cluster that already has an approved OG-57 waiver? | N |
| Will this well be drilled into solid coal or into an open underground void? | SOLID CORE |
| Will the well be drilled through an operating coal mine, or within 1,000 feet of the boundary? | Y |
| Provide the names of Mine(s) and Operator(s): | MONONGALIA COUNTY MINE - MONONGALIA COUNTY COAL COMPANY |
| Does it meet the Gas Well Pillar Study? | Y |
| Has the surface landowner been notified and provided a copy of the Landowner Notification of Right to Participate in Alternative Dispute Resolution to Coal Bed Methane Wells (form 5500-FM-OG0053)? | N |

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.4600 -80 26 19.0000 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2480 |
| Offset West (in feet) | 6170 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.4600 -80 26 19.0000 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 46 03.2400 -80 27 08.4000 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 17591 |
| Bottom Hole Lat/Long | 39 46 03.2400 -80 27 08.4000 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 17591 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
| Well Pad Corner 4 Lat/Long | 39 44 34.2528 -80 26 22.3296 | |
| Well Site GPS Location Lat/Long | 39 44 35.6244 -80 26 19.3272 | |
| Well Site Access Road GPS Lat/Long | 39 44 41.7984 -80 26 15.8424 | |
| Metadata Method<br>GPS - UNSPECIFIED | Accuracy (in ft.)<br>±2 | Datum<br>North American Datum of 1983 |

| SUBMISSION INFORMATION | |
|---|---|
| Pursuant to the Pennsylvania Electronic Transactions Act - Act 69, you are about to engage in an electronic transaction with the Commonwealth of Pennsylvania. You are submitting official information. Any false statement is subject to substantial civil and criminal penalties, including 18 P.S. section 4904 (relating to unsworn falsification to authorities). | |
| I hereby certify that, for all interested parties identified in this application for which written consent or an "Affidavit of Non-Delivery of Certified Mail" has not been uploaded, copies of the well plat have been sent via certified mail and I have received a return receipt verifying delivery. | |
| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 05:31:03 PM |

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL AND GAS MANAGEMENT

# WELL LOCATION PLAT

PAGE 1 Surface Location

| Auth ID #: | |
|---|---|
| Permit #: | |
| Project #: | |

Denotes location of top of well on topo map.

True Latitude: NORTH
39 ° 44 ' 35.46 "

True Longitude: WEST
80 ° 26 ' 19.00 "

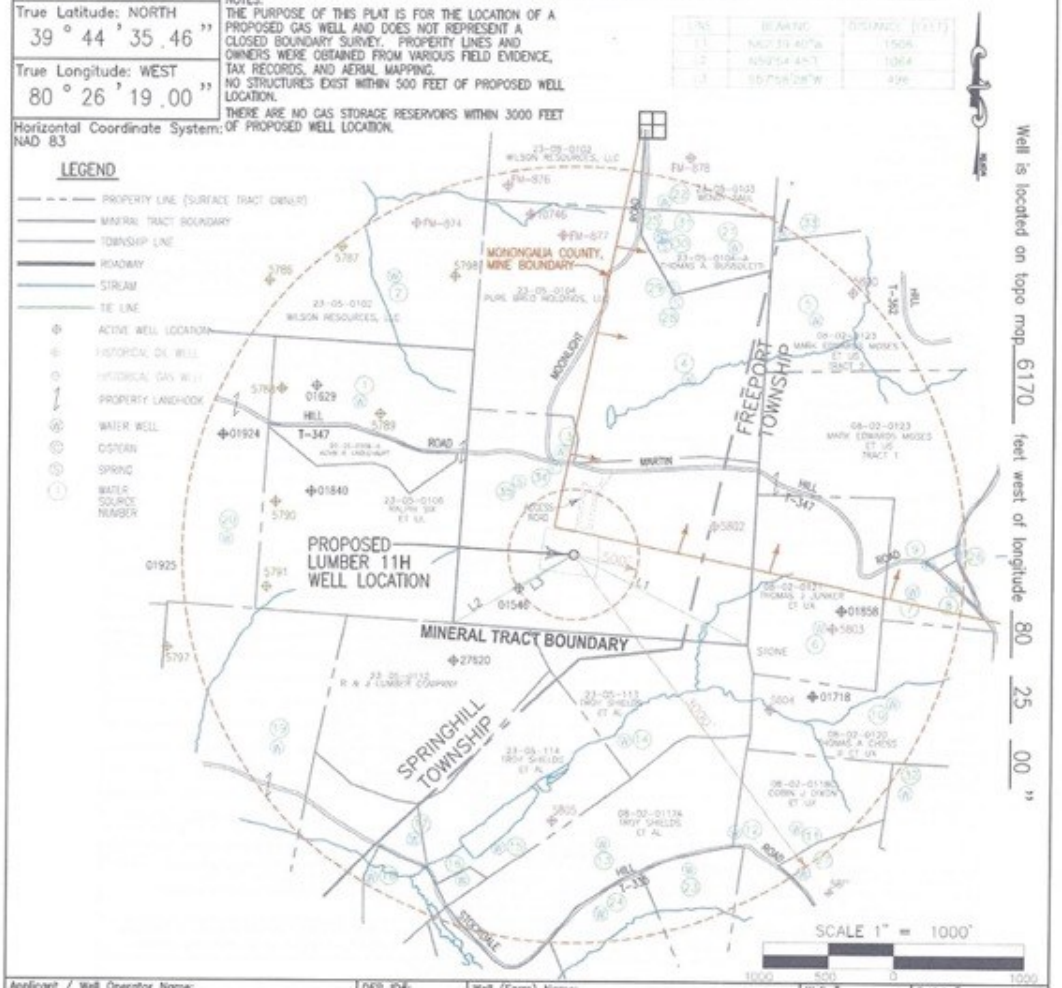
Horizontal Coordinate System: NAD 83

Well is located on topo map 2480 feet south of latitude 39 ° 45 ' 00 "

Well is located on topo map 6170 feet west of longitude 80 ° 25 ' 00 "

NOTES:
THE PURPOSE OF THIS PLAT IS FOR THE LOCATION OF A PROPOSED GAS WELL AND DOES NOT REPRESENT A CLOSED BOUNDARY SURVEY. PROPERTY LINES AND OWNERS WERE OBTAINED FROM VARIOUS FIELD EVIDENCE, TAX RECORDS, AND AERIAL MAPPING.
NO STRUCTURES EXIST WITHIN 500 FEET OF PROPOSED WELL LOCATION.
THERE ARE NO GAS STORAGE RESERVOIRS WITHIN 3000 FEET OF PROPOSED WELL LOCATION.

| LINE | BEARING | DISTANCE (FEET) |
|---|---|---|
| L1 | N62°39'40"W | 1504 |
| L2 | N59°54'45"E | 1064 |
| L3 | S57°59'28"W | 496 |




| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: | Serial #: |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 11H | |

| Address: | County: | Municipality: | Well Type: |
|---|---|---|---|
| 400 WOODCLIFF DRIVE, CANONSBURG, PA 15317 | GREENE | SPRINGHILL TOWNSHIP | GAS |
| 911 address of well site: | USGS 7 1/2 Quadrangle Map Name: | Map Section: | Surface Elevation: |
| 454 MARTIN HILL ROAD, NEW FREEPORT, PA 15352 | HUNDRED | 2 | 1521± ft. |

| Surveyor or Engineer: | Phone #: | Dwg #: | Date: | Scale: | Unit Acreage: |
|---|---|---|---|---|---|
| THOMAS C. SMIT, PLS | (412) 278-2100 | | 09/09/2020 | 1"=1000' | 710.19 |

| Lat & Long Metadata Method: | Accuracy: | Datum: | Elevation Metadata Method: | Accuracy: | Datum: | Survey Date: |
|---|---|---|---|---|---|---|
| GPS | 3± ft. | NAD 83 | GPS | 5± ft. | NAVD 88 | 01/28/2020 |

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# WELL LOCATION PLAT

Page 2 Notifications

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| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
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| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N21° 43' 50"W 9684' | 7,832' | 17,591' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 17,591' |

| | | |
|---|---|---|
| 1. RALPH SIX ET UX | 39°44'46.53" | -80°26'40.51" |
| 2. WILSON RESOURCES LLC | 39°44'56.17" | -80°26'37.62" |
| 3. TROY SHIELDS ET AL | 39°44'43.28" | -80°26'20.63" |
| 4. PURE BRED HOLDINGS, LLC | 39°44'49.09" | -80°26'08.39" |
| 5. EDWARD MARK MOSES ET US | 39°44'54.00" | -80°25'56.15" |
| 6. THOMAS J JUNKER ET UX | 39°44'30.57" | -80°25'54.60" |
| 7. CHARLES JACKSON ET UX | 39°44'33.63" | -80°25'45.61" |
| 8. DAVID R HUNTLEY | 39°44'33.94" | -80°25'41.67" |
| 9. DAVID R HUNTLEY | 39°44'35.76" | -80°25'44.20" |
| 10. THOMAS A CHESS III ET UX | 39°44'24.94" | -80°25'47.11" |
| 11. COBIN J DIXON ET UX | 39°44'15.36" | -80°25'56.07" |
| 12. COBIN J DIXON ET UX | 39°44'14.89" | -80°26'02.08" |
| 13. TROY SHIELDS ET AL | 39°44'13.62" | -80°26'15.04" |
| 14. TROY SHIELDS ET AL | 39°44'21.41" | -80°26'13.30" |
| 15. TROY SHIELDS ET AL | 39°44'13.00" | -80°26'25.25" |
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| 17. TROY SHIELDS ET AL | 39°44'13.44" | -80°26'33.56" |
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| 19. GREGORY B NULL ET AL | 39°44'19.97" | -80°26'47.30" |

| | |
|---|---|
| ALEPPO TOWNSHIP | Contura Coal Resources, LLC-Owner, All Seams |
| FREEPORT TOWNSHIP | Monongalia County Coal Company-Operator, Monongalia County Mine |
| GILMORE TOWNSHIP | |
| JACKSON TOWNSHIP | |
| SPRINGHILL TOWNSHIP | |
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# WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name<br>EQT Production Company | DEP ID#<br>146983 | Well (Farm) Name<br>LUMBER | Well #<br>11H | Serial #<br> |
|---|---|---|---|---|
| Surface Landowner / Lessor:<br>Troy Shields ET AL | | Angle & Course of Deviation (Drilling):<br>N21° 43' 50"W 9684' | Anticipated True Vertical Depth Feet (TVD):<br>7,832' | Anticipated Total Measured Depth Feet (TMD):<br>17,591' |
| Target Formation(s):<br>Marcellus | | Deepest Formation to be penetrated:<br>Marcellus | Number of laterals: 1 | Total footage to be drilled all laterals:<br>17,591' |

| | | |
|---|---|---|
| 20. KSH LLC | 39°44'35.81" | -80°26'53.08" |
| 21. THOMAS A BUSSOLETTI ET AL | 39°44'59.35" | -80°26'04.33" |
| 22. WENDY SAUL | 39°45'02.67" | -80°26'11.44" |
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| 25. THOMAS A BUSSOLETTI ET AL | 39°44'59.94 | -80°26'11.68 |
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| 27. MARLIN B CEHO | 39°44'11.79" | -80°25'55.25" |
| 28. PURE BRED HOLDINGS, LLC | 39°44'54.95" | -80°26'09.88" |
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| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
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# WELL LOCATION PLAT

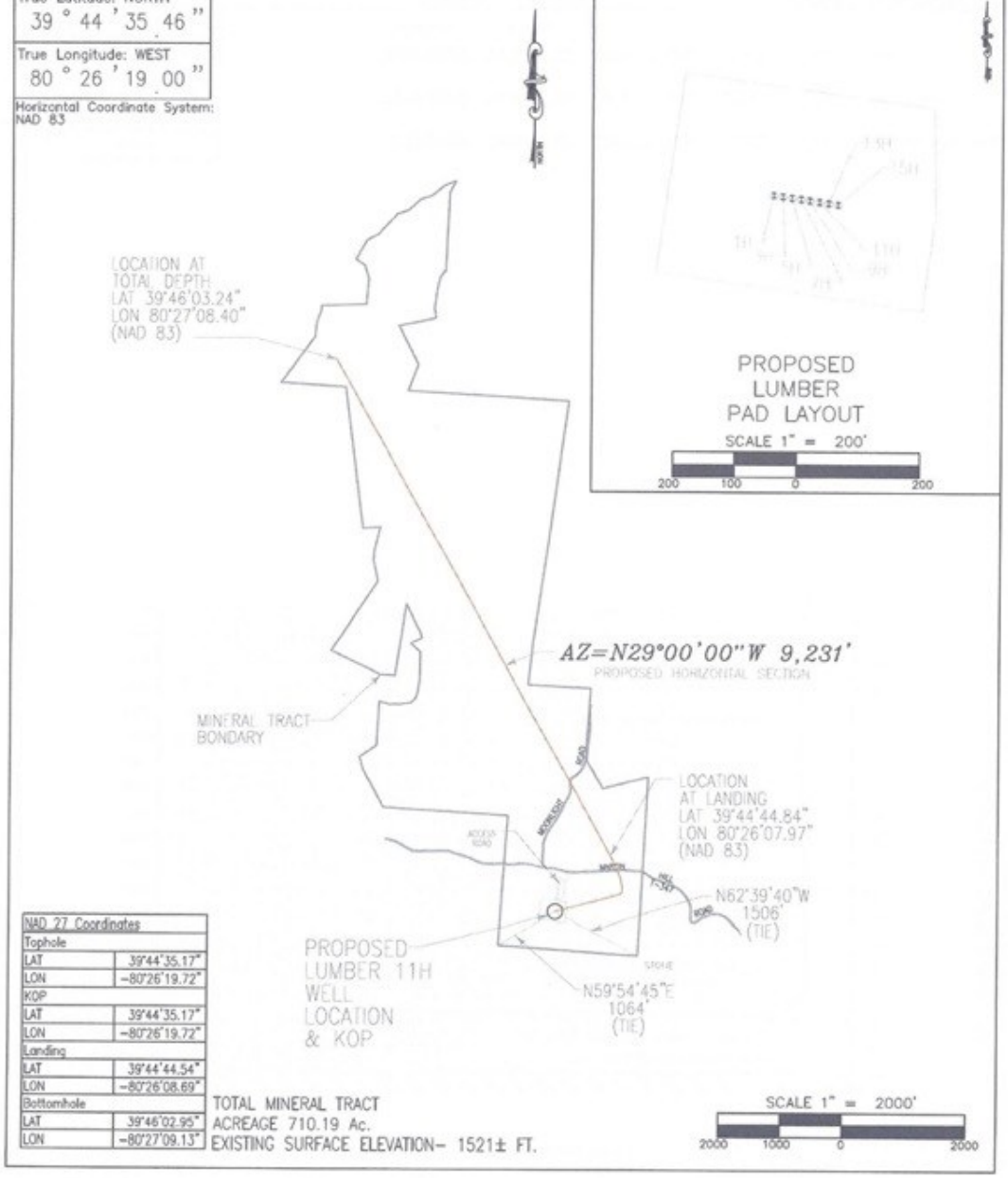
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 11H |

True Latitude: NORTH
39 ° 44 ' 35 . 46 "

True Longitude: WEST
80 ° 26 ' 19 . 00 "

Horizontal Coordinate System:
NAD 83




PROPOSED LUMBER PAD LAYOUT
SCALE 1" = 200'
200 100 0 200

| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.17" |
| LON | -80°26'19.72" |
| KOP | |
| LAT | 39°44'35.17" |
| LON | -80°26'19.72" |
| Landing | |
| LAT | 39°44'44.54" |
| LON | -80°26'08.69" |
| Bottomhole | |
| LAT | 39°46'02.95" |
| LON | -80°27'09.13" |

TOTAL MINERAL TRACT ACREAGE 710.19 Ac.
EXISTING SURFACE ELEVATION- 1521± FT.

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# WELL LOCATION PLAT

PAGE 4 Well Plan

| DEP Use Only | Permit # |
|---|---|
| | |

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 11H |

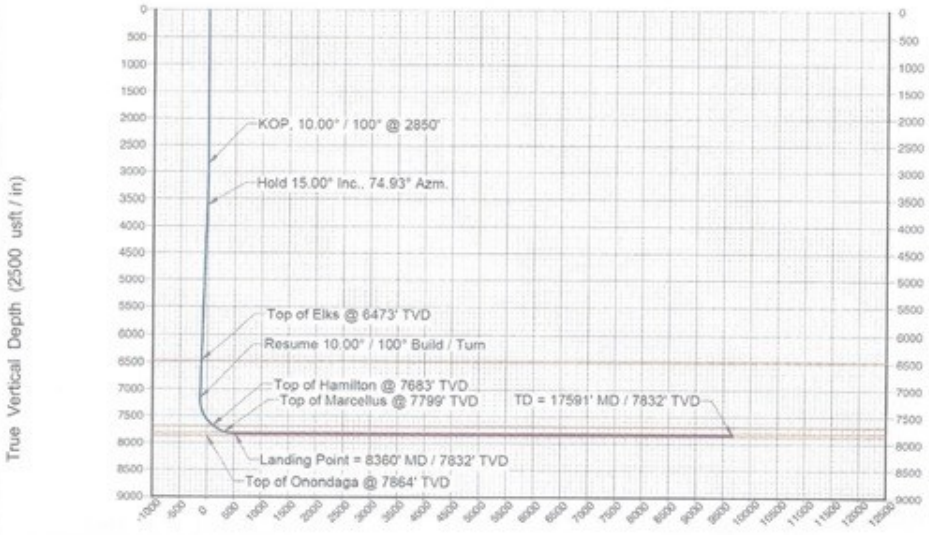
| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : | 2,850' | TMD : 2,850' | 39° 44' 35.46" | 80° 26' 19.00" |
| Landing Point : | TVD : | 7,832' | TMD : 8,360' | 39° 44' 44.84" | 80° 26' 07.97" |
| Projected Bottom Hole: | TVD : | 7,832' | TMD : 17,591' | 39° 46' 03.24" | 80° 27' 08.40" |

G M

Azimuths to Grid North
Magnetic North : -8.95

Magnetic Field
Strength : 51,768.10
Dip Angle : 66.63
Date : 07/10/2020
Model : IGRF2015

NAD 83



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# WELL LOCATION PLAT

Page 2 Notifications

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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name: EQT PROD CO | Legal Name: EQT PRODUCTION COMPANY | DEP Client ID#: 146983 | Phone: 724-271-7380 | FAX: 724-749-5581 |
| Mailing Address (Street or PO Box): 400 WOODCLIFF DRIVE | Address 2: | | | |
| City: CANONSBURG | State: PA | Zip +4: 15317 | | |
| Email Address: espine@eqt.com | 24/7 Emergency Contact Name / Number: EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name: LUMBER | | | |
| Well #: 13H | Serial #: | Project # (from DEP): | |
| County: GREENE | Municipality: SPRINGHILL TWP | 911 Address of Well site (or nearest intersection): MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?: Y | Is this a Coal well?: Y | Bond Agreement ID: 9399 - BLANKET ($850,000) | Well Deepest Point (TVD): 7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number: 1 | Wellbore Name: WELLBORE SURFACE HOLE LOCATION | Type of Wellbore: GAS | Wellbore Configuration: Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name: LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?: Y | ESCGP Number: ESG073019009-00 | Will this well be built on a well pad?: Y | Well Pad: 156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?* | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the 'Coordination of a Well Location with Public Resources' form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| | |
|---|---|
| Have any coal rights been severed from the surface estate? | Y |
| If the coal rights been severed from the surface estate, have the owners of the workable and unworkable coal seams been notified? | Y |
| Is this a "non-conservation" gas well? | Y |
| If the well will penetrate a workable coal seam, and the well is a 'non-conservation' gas well, does the location comply with the distance requirements of Section 7 of the Coal and Gas Resource Coordination Act (at least 1,000 feet from all existing wells) and, if part of a well cluster, at least 2,000 feet from any other existing cluster, as measured from the center of the well bore of the nearest well? | N |
| Will the well be part of a Well Cluster which is an area within a well pad intended to host multiple horizontal wells and which comprises an area no greater than 5,000 square feet? | Y |
| Will this well be part of a Well Cluster that already has an approved OG-57 waiver? | N |
| Will this well be drilled into solid coal or into an open underground void? | SOLID CORE |
| Will the well be drilled through an operating coal mine, or within 1,000 feet of the boundary? | Y |
| Provide the names of Mine(s) and Operator(s): | MONONGALIA COUNTY MINE - MONONGALIA COUNTY COAL COMPANY |
| Does it meet the Gas Well Pillar Study? | Y |
| Has the surface landowner been notified and provided a copy of the Landowner Notification of Right to Participate in Alternative Dispute Resolution to Coal Bed Methane Wells (form 5500-FM-OG0053)? | N |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.4500 -80 26 18.8000 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2485 |
| Offset West (in feet) | 6155 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.4500 -80 26 18.8000 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 47 19.7300 -80 27 52.0200 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 26354 |
| Bottom Hole Lat/Long | 39 47 19.7300 -80 27 52.0200 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 26354 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
| Well Pad Corner 4 Lat/Long | 39 44 34.2528 -80 26 22.3296 | |
| Well Site GPS Location Lat/Long | 39 44 35.6244 -80 26 19.3272 | |
| Well Site Access Road GPS Lat/Long | 39 44 41.7984 -80 26 15.8424 | |
| Metadata Method: GPS - UNSPECIFIED | Accuracy (in ft.): ±2 | Datum: North American Datum of 1983 |

| SUBMISSION INFORMATION | |
|---|---|
| Pursuant to the Pennsylvania Electronic Transactions Act - Act 69, you are about to engage in an electronic transaction with the Commonwealth of Pennsylvania. You are submitting official information. Any false statement is subject to substantial civil and criminal penalties, including 18 P.S. section 4904 (relating to unsworn falsification to authorities). | |
| I hereby certify that, for all interested parties identified in this application for which written consent or an "Affidavit of Non-Delivery of Certified Mail" has not been uploaded, copies of the well plat have been sent via certified mail and I have received a return receipt verifying delivery. | |
| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 05:36:40 PM |

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL AND GAS MANAGEMENT

# WELL LOCATION PLAT

PAGE 1 Surface Location

Auth ID #:
Permit #:
Project #:

Denotes location of top of well on topo map.

True Latitude: NORTH
39 ° 44 ' 35.45 "

True Longitude: WEST
80 ° 26 ' 18.80 "

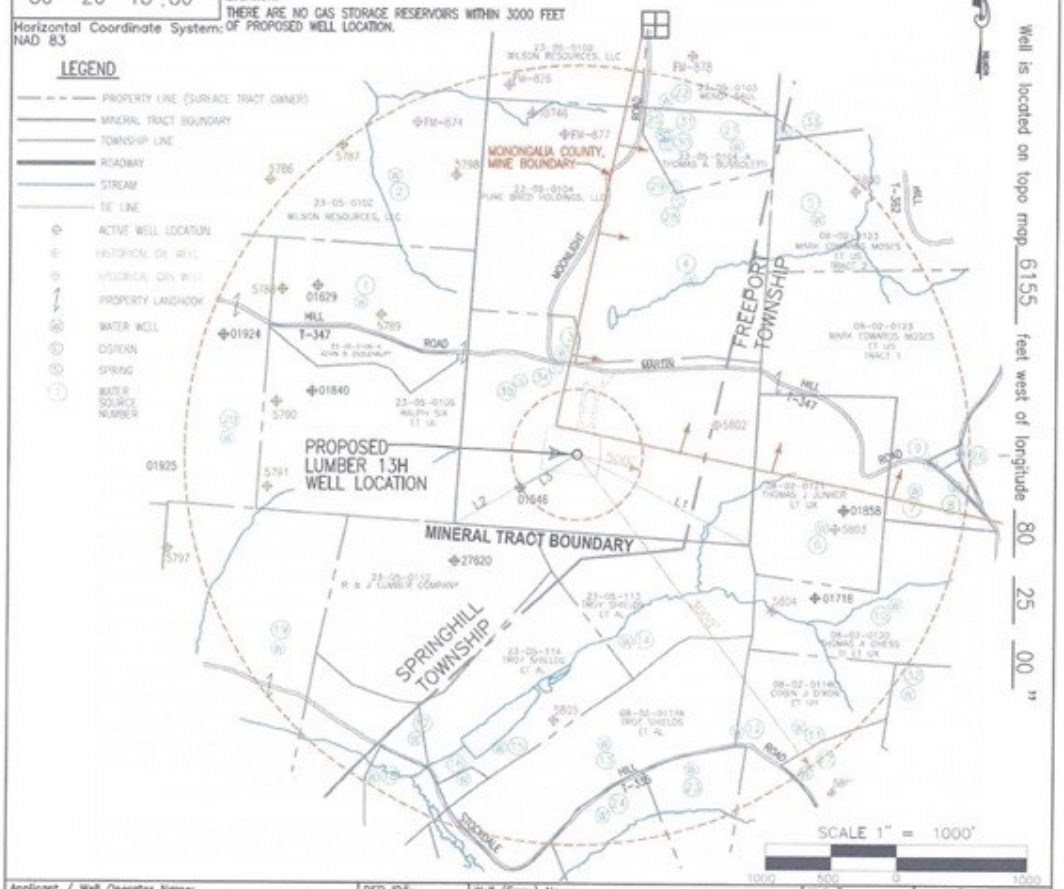
Horizontal Coordinate System: NAD 83

Well is located on topo map 2485 feet south of latitude 39 ° 45 ' 00 "

Well is located on topo map 6155 feet west of longitude 80 ° 25 ' 00 "

NOTES:
THE PURPOSE OF THIS PLAT IS FOR THE LOCATION OF A PROPOSED GAS WELL AND DOES NOT REPRESENT A CLOSED BOUNDARY SURVEY. PROPERTY LINES AND OWNERS WERE OBTAINED FROM VARIOUS FIELD EVIDENCE, TAX RECORDS, AND AERIAL MAPPING.
NO STRUCTURES EXIST WITHIN 500 FEET OF PROPOSED WELL LOCATION.
THERE ARE NO GAS STORAGE RESERVOIRS WITHIN 3000 FEET OF PROPOSED WELL LOCATION.

| LINE | BEARING | DISTANCE (FEET) |
|---|---|---|
| L1 | N42°39'19"W | 1492' |
| L2 | N60°24'25"E | 1976' |
| L3 | S59°54'04"W | 501' |




| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: | Serial #: |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 13H | |

| Address: | County: | Municipality: | Well Type: |
|---|---|---|---|
| 400 WOODCLIFF DRIVE, CANONSBURG, PA 15317 | GREENE | SPRINGHILL TOWNSHIP | GAS |

| 911 address of well site: | USGS 7 1/2 Quadrangle Map Name: | Map Section: | Surface Elevation: |
|---|---|---|---|
| 454 MARTIN HILL ROAD, NEW FREEPORT, PA 15352 | HUNDRED | 2 | 1521± ft. |

| Surveyor or Engineer: | Phone #: | Dwg #: | Date: | Scale: | Unit Acreage: |
|---|---|---|---|---|---|
| THOMAS C. SMIT, PLS | (412) 278-2100 | | 09/09/2020 | 1"=1000' | 1420.06 |

| Lat & Long Metadata Method: | Accuracy: | Datum: | Elevation Metadata Method: | Accuracy: | Datum: | Survey Date: |
|---|---|---|---|---|---|---|
| GPS | 3± ft. | NAD 83 | GPS | 5± ft. | NAVD 88 | 01/28/2020 |

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# WELL LOCATION PLAT

Page 2 Notifications

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| Troy Shields ET AL | N21° 53' 43"W 18,148' | 7,832' | 26,354' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 26,354' |

| | | |
|---|---|---|
| 1. RALPH SIX ET UX | 39°44'46.53" | -80°26'40.51" |
| 2. WILSON RESOURCES LLC | 39°44'56.17" | -80°26'37.62" |
| 3. TROY SHIELDS ET AL | 39°44'43.28" | -80°26'20.63" |
| 4. PURE BRED HOLDINGS, LLC | 39°44'49.09" | -80°26'08.39" |
| 5. EDWARD MARK MOSES ET US | 39°44'54.00" | -80°25'56.15" |
| 6. THOMAS J JUNKER ET UX | 39°44'30.57" | -80°25'54.60" |
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| JACKSON TOWNSHIP | |
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|---|---|---|---|
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| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 26,354' |

| | | |
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| 31. THOMAS A BUSSOLETTI ET AL | 39°44'59.96" | -80°26'11.36" |
| 32. TROY STONEKING ET UX | 39°44'18.24" | -80°25'45.55" |
| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
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8000-PM-OOGM0002 Rev. 6/2014

# WELL LOCATION PLAT

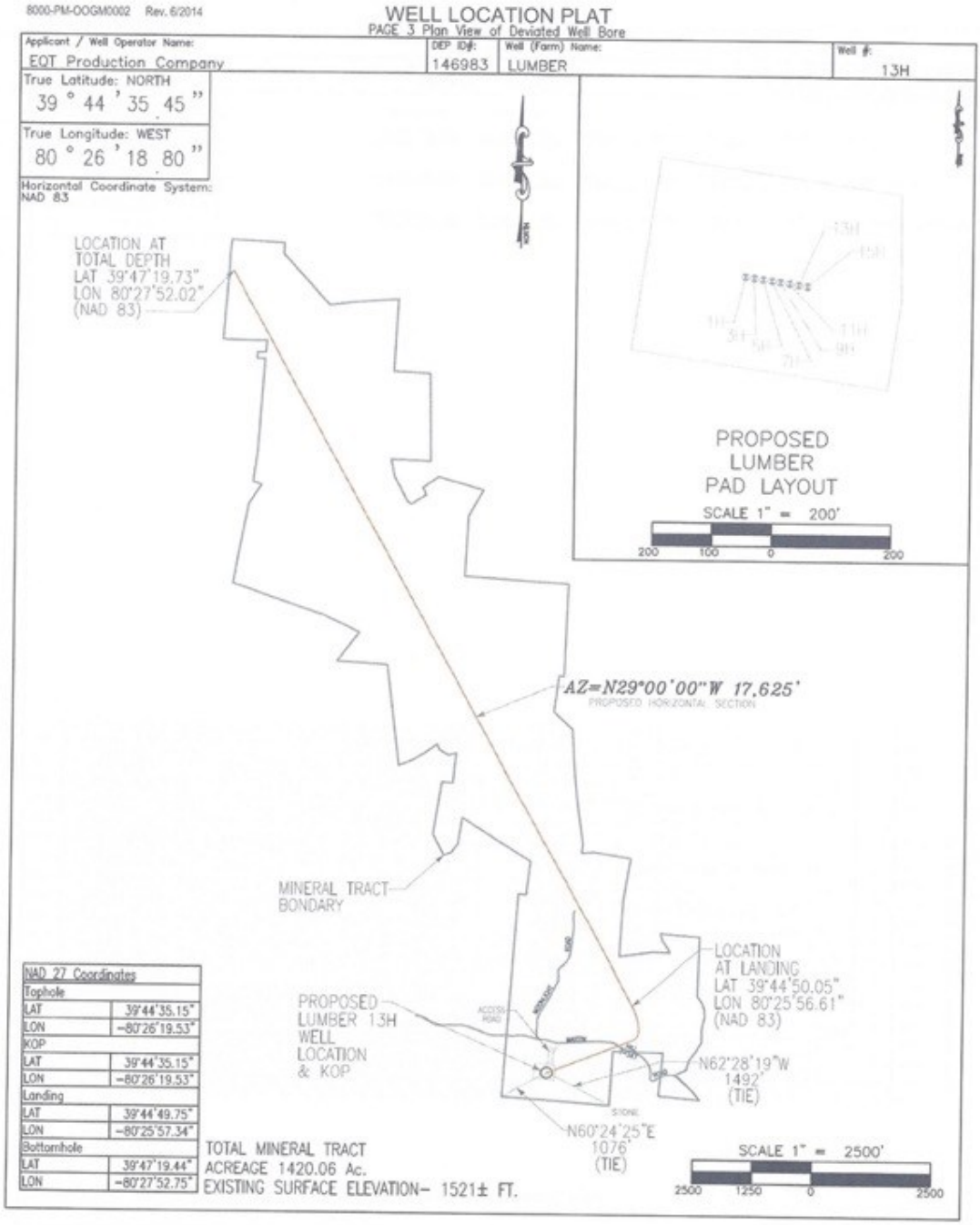
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 13H |

True Latitude: NORTH
39 ° 44 ' 35 45 "

True Longitude: WEST
80 ° 26 ' 18 80 "

Horizontal Coordinate System:
NAD 83




| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.15" |
| LON | -80°26'19.53" |
| KOP | |
| LAT | 39°44'35.15" |
| LON | -80°26'19.53" |
| Landing | |
| LAT | 39°44'49.75" |
| LON | -80°25'57.34" |
| Bottomhole | |
| LAT | 39°47'19.44" |
| LON | -80°27'52.75" |

TOTAL MINERAL TRACT
ACREAGE 1420.06 Ac.
EXISTING SURFACE ELEVATION- 1521± FT.

8000-PM-OOGM0002 Rev. 6/2014

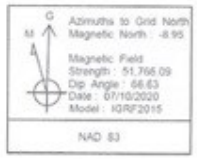
# WELL LOCATION PLAT

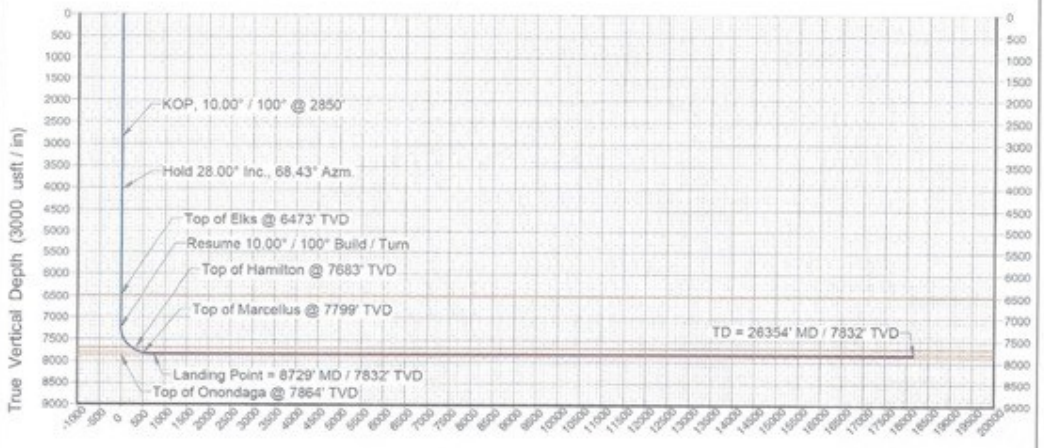
PAGE 4 Well Plan

| DEP Use Only | Permit # |
|---|---|
| | |

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 13H |

| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : 2,850' | TMD : | 2,850' | 39° 44' 35.45" | 80° 26' 18.80" |
| Landing Point : | TVD : 7,832' | TMD : | 8,729' | 39° 44' 50.05" | 80° 25' 56.61" |
| Projected Bottom Hole: | TVD : 7,832' | TMD : | 26,354' | 39° 47' 19.73" | 80° 27' 52.02" |



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| APPLICANT INFORMATION | | | | |
|---|---|---|---|---|
| Applicant (Operator) Name: EQT PROD CO | Legal Name: EQT PRODUCTION COMPANY | DEP Client ID#: 146983 | Phone: 724-271-7380 | FAX: 724-749-5581 |
| Mailing Address (Street or PO Box): 400 WOODCLIFF DRIVE | Address 2 | | | |
| City: CANONSBURG | State: PA | Zip +4: 15317 | | |
| Email Address: espine@eqt.com | 24/7 Emergency Contact Name / Number: EQT EMERGENCY CONTACT 833-990-1534 | | | |

| WELL INFORMATION | | | |
|---|---|---|---|
| (Well) Farm Name: LUMBER | | | |
| Well #: 15H | Serial #: | Project # (from DEP): | |
| County: GREENE | Municipality: SPRINGHILL TWP | 911 Address of Well site (or nearest intersection): MARTIN HILL ROAD ALEPPO PA 15310 | |
| Is this an Unconventional well?: Y | Is this a Coal well?: Y | Bond Agreement ID: 9399 - BLANKET ($850,000) | Well Deepest Point (TVD): 7832 |

| WELLBORE INFORMATION | | | |
|---|---|---|---|
| Wellbore Number: 1 | Wellbore Name: WELLBORE SURFACE HOLE LOCATION | Type of Wellbore: GAS | Wellbore Configuration: Horizontal Well |

| WELL PAD INFORMATION | | | |
|---|---|---|---|
| Well Pad Name: LUMBER WELL PAD | | | |
| Will the proposed well location be covered under an existing or previous Erosion and Sediment Control General Permit?: Y | ESCGP Number: ESG073019009-00 | Will this well be built on a well pad?: Y | Well Pad: 156276-LUMBER WELL PAD |

| COORDINATION QUESTIONS | |
|---|---|
| Will the well be subject to the Oil and Gas Conservation Law? | N |
| Will the proposed limit of disturbance of the well site be within 100 feet measured horizontally from any watercourse or any high quality or exceptional value body of water or any wetland one acre or greater in size? | N |
| Will the well penetrate or be within 3,000 feet of an active gas storage reservoir boundary? | N |
| Is the proposed well location within the permitted perimeter of an active, abandoned or proposed landfill? | N |
| Will the vertical well bore of the unconventional well be drilled within 500 feet from any existing building or an existing water supply?* | N |
| Will the vertical well bore of the unconventional well be drilled within 1,000 feet from any existing water well, surface water intake, reservoir or other water supply extraction point used by the water purveyor? | N |
| Is this permit application for a well that will be drilled on a well site for which construction was completed prior to April 16, 2012? | N |
| Will the well be located where it may impact a public resource as outlined in the 'Coordination of a Well Location with Public Resources' form 5500 PM-OG0076? | N |
| Will any portion of the well site be located within a Special Protection watershed? | N |
| Is this well part of a development which requires an Earth Disturbance Permit for Oil and Gas Activities disturbing more than 5 acres? | Y |
| Will the well or well site be located within a defined 100 year floodplain or where the floodplain is undefined, within 100 feet of the top of the bank of a perennial stream or within 50 feet of the top of the bank of an intermittent stream? | N |
| Is the well to be located within a 1-mile radius of a well drilled to or through the same formation where hydrogen sulfide (H2S) has been found while drilling? | N |
| Did you have a PNDI hit for the PA Department of Conservation and Natural Resources Bureaus of Forestry and Topographic and Geologic Survey? | N |
| Did you have a PNDI hit for the PA Fish and Boat Commission? | N |
| Did you have a PNDI hit for the PA Game Commission? | N |
| Did you have a PNDI hit for the U.S. Fish and Wildlife Service? | N |

| COAL MODULE | |
|---|---|
| Will the well penetrate a workable coal seam? | Y |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| | |
|---|---|
| Have any coal rights been severed from the surface estate? | Y |
| If the coal rights been severed from the surface estate, have the owners of the workable and unworkable coal seams been notified? | Y |
| Is this a "non-conservation" gas well? | Y |
| If the well will penetrate a workable coal seam, and the well is a 'non-conservation' gas well, does the location comply with the distance requirements of Section 7 of the Coal and Gas Resource Coordination Act (at least 1,000 feet from all existing wells) and, if part of a well cluster, at least 2,000 feet from any other existing cluster, as measured from the center of the well bore of the nearest well? | N |
| Will the well be part of a Well Cluster which is an area within a well pad intended to host multiple horizontal wells and which comprises an area no greater than 5,000 square feet? | Y |
| Will this well be part of a Well Cluster that already has an approved OG-57 waiver? | N |
| Will this well be drilled into solid coal or into an open underground void? | SOLID CORE |
| Will the well be drilled through an operating coal mine, or within 1,000 feet of the boundary? | Y |
| Provide the names of Mine(s) and Operator(s): | MONONGALIA COUNTY MINE - MONONGALIA COUNTY COAL COMPANY |
| Does it meet the Gas Well Pillar Study? | Y |
| Has the surface landowner been notified and provided a copy of the Landowner Notification of Right to Participate in Alternative Dispute Resolution to Coal Bed Methane Wells (form 5500-FM-OG0053)? | N |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL & GAS MANAGEMENT

PERMIT APPLICATION TO DRILL AND OPERATE AN UNCONVENTIONAL WELL

| WELLBORE SURFACE-HOLE LOCATION | |
|---|---|
| Surface elevation (in ft.) | 1521 |
| Latitude/Longitude | 39 44 35.4300 -80 26 18.6100 |
| Metadata Method | GPS CARRIER PHASE KINEMATIC RELATIVE POSITION |
| Accuracy (in ft.) | 3 |
| Datum | North American Datum of 1983 |
| Reference Elevation | 1521 |
| USGS Map Name | HUNDRED |
| USGS Map Section # | 2 |
| Offset South (in feet) | 2485 |
| Offset West (in feet) | 6140 |

| WELLBORE LOCATION INFORMATION | |
|---|---|
| **WELLBORE SURFACE HOLE LOCATION** | |
| Type of Wellbore | GAS |
| Wellbore Configuration | Horizontal Well |
| Target Formation | MARCELLUS FORMATION(MARCF) |
| Producing Formation | MARCELLUS FORMATION(MARCF) |
| Oldest Formation Penetrated | MARCELLUS FORMATION(MARCF) |
| Wellbore Origin Point Lat/Long | 39 44 35.4300 -80 26 18.6100 |
| Wellbore Origin Point True Vertical Depth (TVD) | 0 |
| Wellbore Origin Point Total Measured Distance (TMD) | 0 |
| Wellbore Deepest Point Lat/Long | 39 47 20.8000 -80 27 37.4700 |
| Wellbore Deepest Point True Vertical Depth (TVD) | 7832 |
| Wellbore Deepest Point Total Measured Distance (TMD) | 26431 |
| Bottom Hole Lat/Long | 39 47 20.8000 -80 27 37.4700 |
| Bottom Hole True Vertical Depth (TVD) | 7832 |
| Bottom Hole Total Measured Distance (TMD) | 26431 |

| WELL PAD LOCATION INFORMATION | | |
|---|---|---|
| Well Pad Corner 1 Lat/Long | 39 44 37.4820 -80 26 21.8544 | |
| Well Pad Corner 2 Lat/Long | 39 44 37.0284 -80 26 16.6740 | |
| Well Pad Corner 3 Lat/Long | 39 44 33.7668 -80 26 16.8000 | |
| Well Pad Corner 4 Lat/Long | 39 44 34.2528 -80 26 22.3296 | |
| Well Site GPS Location Lat/Long | 39 44 35.6244 -80 26 19.3272 | |
| Well Site Access Road GPS Lat/Long | 39 44 41.7984 -80 26 15.8424 | |
| Metadata Method<br>GPS - UNSPECIFIED | Accuracy (in ft.)<br>±2 | Datum<br>North American Datum of 1983 |

| SUBMISSION INFORMATION | |
|---|---|
| Pursuant to the Pennsylvania Electronic Transactions Act - Act 69, you are about to engage in an electronic transaction with the Commonwealth of Pennsylvania. You are submitting official information. Any false statement is subject to substantial civil and criminal penalties, including 18 P.S. section 4904 (relating to unsworn falsification to authorities). | |
| I hereby certify that, for all interested parties identified in this application for which written consent or an "Affidavit of Non-Delivery of Certified Mail" has not been uploaded, copies of the well plat have been sent via certified mail and I have received a return receipt verifying delivery. | |
| Submitted By | OLIVIA PISHIONERI |
| Document Generated | 09/08/2020 05:42:18 PM |

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF OIL AND GAS MANAGEMENT

# WELL LOCATION PLAT

PAGE 1 Surface Location

| | |
|---|---|
| Auth ID #: | |
| Permit #: | |
| Project #: | |

Denotes location of top of well on topo map.

True Latitude: NORTH
39 ° 44 ' 35.43 "

True Longitude: WEST
80 ° 26 ' 18.61 "

Horizontal Coordinate System: NAD 83

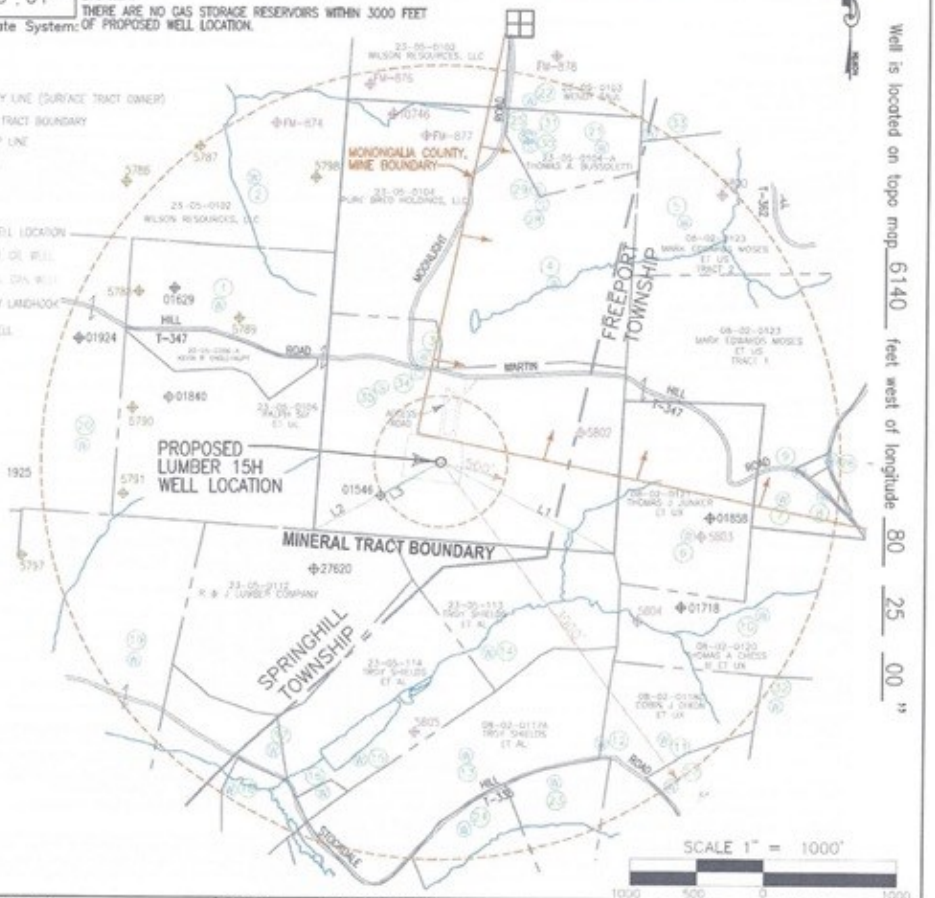
Well is located on topo map 2485 feet south of latitude 39 ° 45 ' 00 "

Well is located on topo map 6140 feet west of longitude 80 ° 25 ' 00 "

NOTES:
THE PURPOSE OF THIS PLAT IS FOR THE LOCATION OF A PROPOSED GAS WELL AND DOES NOT REPRESENT A CLOSED BOUNDARY SURVEY. PROPERTY LINES AND OWNERS WERE OBTAINED FROM VARIOUS FIELD EVIDENCE, TAX RECORDS, AND AERIAL MAPPING.
NO STRUCTURES EXIST WITHIN 500 FEET OF PROPOSED WELL LOCATION.
THERE ARE NO GAS STORAGE RESERVOIRS WITHIN 3000 FEET OF PROPOSED WELL LOCATION.

LEGEND

- PROPERTY LINE (SURFACE TRACT OWNER)
- MINERAL TRACT BOUNDARY
- TOWNSHIP LINE
- ROADWAY
- STREAM
- TIE LINE
- ACTIVE WELL LOCATION
- HISTORICAL OIL WELL
- HYDROFRACK GAS WELL
- PROPERTY LANDMARK
- WATER WELL
- CISTERN
- SPRING
- WATER SOURCE NUMBER




| | | | | | | |
|---|---|---|---|---|---|---|
| Applicant / Well Operator Name: EQT Production Company | DEP ID#: 146983 | Well (Farm) Name: LUMBER | | Well #: 15H | | Serial #: |
| Address: 400 WOODCLIFF DRIVE, CANONSBURG, PA 15317 | | County: GREENE | | Municipality: SPRINGHILL TOWNSHIP | | Well Type: GAS |
| 911 address of well site: 454 MARTIN HILL ROAD, NEW FREEPORT, PA 15352 | | USGS 7 1/2' Quadrangle Map Name: HUNDRED | | Map Section: 2 | | Surface Elevation: 1521± ft. |
| Surveyor or Engineer: THOMAS C. SMIT, PLS | Phone #: (412) 278-2100 | Dwg #: | Date: 09/09/2020 | Scale: 1"=1000' | Unit Acreage: 1247.56 | |
| Lat & Long Metadata Method: GPS | Accuracy: 3± ft. | Datum: NAD 83 | Elevation Metadata Method: GPS | Accuracy: 5± ft. | Datum: NAVD 88 | Survey Date: 01/28/2020 |

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# WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 15H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N18° 27' 02"W 178.31' | 7,832' | 26,431' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 26,431' |

| | | |
|---|---|---|
| 1. RALPH SIX ET UX | 39°44'46.53" | -80°26'40.51" |
| 2. WILSON RESOURCES LLC | 39°44'56.17" | -80°26'37.62" |
| 3. TROY SHIELDS ET AL | 39°44'43.28" | -80°26'20.63" |
| 4. PURE BRED HOLDINGS, LLC | 39°44'49.09" | -80°26'08.39" |
| 5. EDWARD MARK MOSES ET US | 39°44'54.00" | -80°25'56.15" |
| 6. THOMAS J JUNKER ET UX | 39°44'30.57" | -80°25'54.60" |
| 7. CHARLES JACKSON ET UX | 39°44'33.63" | -80°25'45.61" |
| 8. DAVID R HUNTLEY | 39°44'33.94" | -80°25'41.67" |
| 9. DAVID R HUNTLEY | 39°44'35.76" | -80°25'44.20" |
| 10. THOMAS A CHESS III ET UX | 39°44'24.94" | -80°25'47.11" |
| 11. COBIN J DIXON ET UX | 39°44'15.36" | -80°25'56.07" |
| 12. COBIN J DIXON ET UX | 39°44'14.89" | -80°26'02.08" |
| 13. TROY SHIELDS ET AL | 39°44'13.62" | -80°26'15.04" |
| 14. TROY SHIELDS ET AL | 39°44'21.41" | -80°26'13.30" |
| 15. TROY SHIELDS ET AL | 39°44'13.00" | -80°26'25.25" |
| 16. TROY SHIELDS ET AL | 39°44'10.35" | -80°26'28.64" |
| 17. TROY SHIELDS ET AL | 39°44'13.44" | -80°26'33.56" |
| 18. TROY SHIELDS ET AL | 39°44'10.31" | -80°26'37.60" |
| 19. GREGORY B NULL ET AL | 39°44'19.97" | -80°26'47.30" |

| | |
|---|---|
| ALEPPO TOWNSHIP | Contura Coal Resources, LLC-Owner, All Seams |
| FREEPORT TOWNSHIP | Monongalia County Coal Company-Operator, Monongalia County Mine |
| GILMORE TOWNSHIP | |
| JACKSON TOWNSHIP | |
| SPRINGHILL TOWNSHIP | |
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## WELL LOCATION PLAT

Page 2 Notifications

DEP Statewide toll-free phone number for reporting cases of water contamination which may be associated with development of oil and gas resources is 1-866-255-5158.

| Applicant / Well Operator Name | DEP ID# | Well (Farm) Name | Well # | Serial # |
|---|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 15H | |

| Surface Landowner / Lessor: | Angle & Course of Deviation (Drilling): | Anticipated True Vertical Depth Feet (TVD): | Anticipated Total Measured Depth Feet (TMD): |
|---|---|---|---|
| Troy Shields ET AL | N18° 27' 02"W 17831' | 7,832' | 26,431' |

| Target Formation(s): | Deepest Formation to be penetrated: | Number of laterals: | Total footage to be drilled all laterals: |
|---|---|---|---|
| Marcellus | Marcellus | 1 | 26,431' |

| | | |
|---|---|---|
| 20. KSH LLC | 39°44'35.81" | -80°26'53.08" |
| 21. THOMAS A BUSSOLETTI ET AL | 39°44'59.35" | -80°26'04.33" |
| 22. WENDY SAUL | 39°45'02.67" | -80°26'11.44" |
| 23. TROY SHIELDS ET AL | 39°44'11.77" | -80°26'06.42" |
| 24. TROY SHIELDS ET AL | 39°44'08.10" | -80°26'14.95" |
| 25. THOMAS A BUSSOLETTI ET AL | 39°44'59.94 | -80°26'11.68 |
| 26. GEORGE D SIX | 39°44'36.81" | -80°25'41.14" |
| 27. MARLIN B GEHO | 39°44'11.79" | -80°25'55.25" |
| 28. PURE BRED HOLDINGS, LLC | 39°44'54.95" | -80°26'09.88" |
| 29. THOMAS A BUSSOLETTI ET AL | 39°44'56.00" | -80°26'10.29" |
| 30. THOMAS A BUSSOLETTI ET AL | 39°44'59.22" | -80°26'11.27" |
| 31. THOMAS A BUSSOLETTI ET AL | 39°44'59.96" | -80°26'11.36" |
| 32. TROY STONEKING ET UX | 39°44'18.24" | -80°25'45.55" |
| 33. ALBERT L KING | 39°45'00.62" | -80°25'59.79" |
| 34. TROY SHIELDS | 39°44'42.03" | -80°26'21.19" |
| 35. TROY SHIELDS | 39°44'40.88" | -80°26'24.62" |
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# WELL LOCATION PLAT

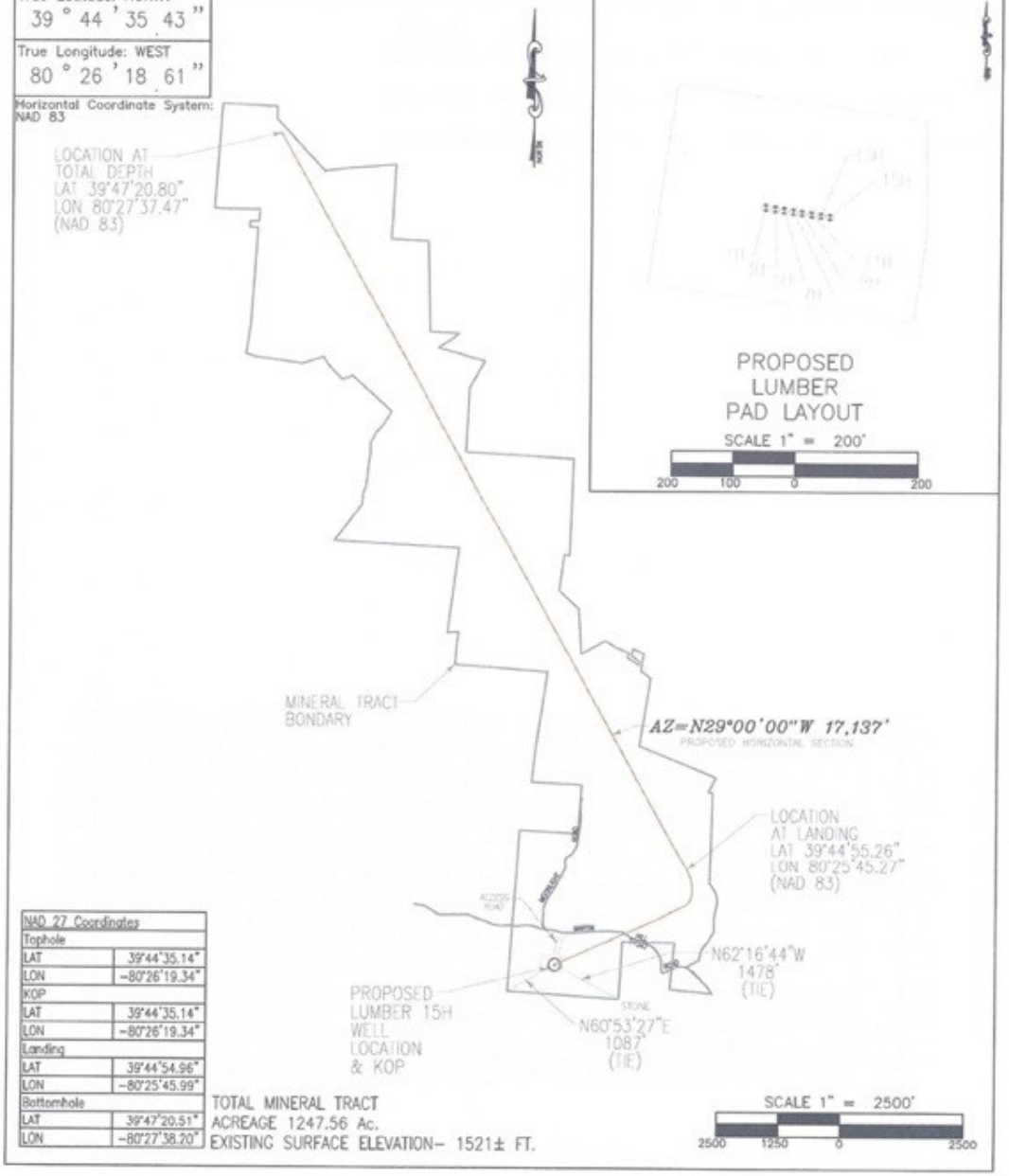
PAGE 3 Plan View of Deviated Well Bore

| Applicant / Well Operator Name: | API Well #: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT Production Company | 146983 | LUMBER | 15H |

True Latitude: NORTH
39 ° 44 ' 35 . 43 "

True Longitude: WEST
80 ° 26 ' 18 . 61 "

Horizontal Coordinate System:
NAD 83







| NAD 27 Coordinates | |
|---|---|
| Tophole | |
| LAT | 39°44'35.14" |
| LON | -80°26'19.34" |
| KOP | |
| LAT | 39°44'35.14" |
| LON | -80°26'19.34" |
| Landing | |
| LAT | 39°44'54.96" |
| LON | -80°25'45.99" |
| Bottomhole | |
| LAT | 39°47'20.51" |
| LON | -80°27'38.20" |

TOTAL MINERAL TRACT ACREAGE 1247.56 Ac.
EXISTING SURFACE ELEVATION– 1521± FT.

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# WELL LOCATION PLAT

PAGE 4 Well Plan

| DEP Use Only | Permit # |
|---|---|
| | |

| Applicant / Well Operator Name: | DEP ID#: | Well (Farm) Name: | Well #: |
|---|---|---|---|
| EQT PRODUCTION COMPANY | 146983 | LUMBER | 15H |

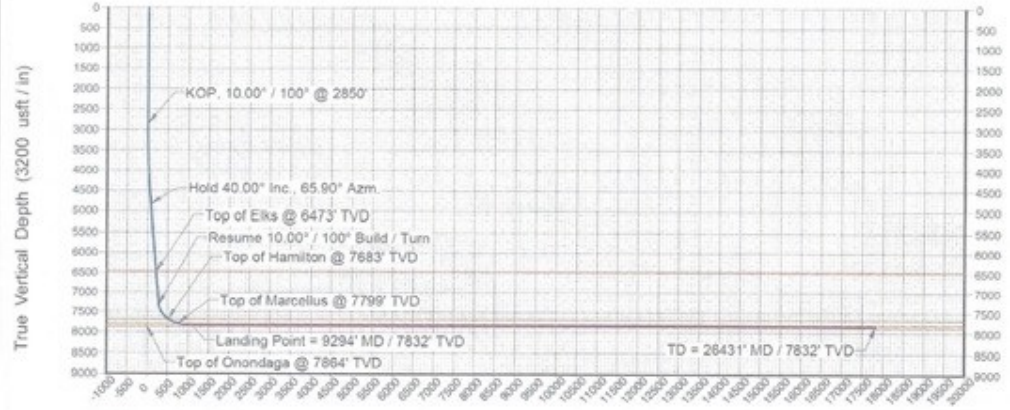
| | | | | Latitude | Longitude |
|---|---|---|---|---|---|
| KOP : | TVD : 2,850' | TMD : 2,850' | | 39° 44' 35.43" | 80° 26' 18.61" |
| Landing Point : | TVD : 7,832' | TMD : 9294' | | 39° 44' 55.26" | 80° 25' 45.27" |
| Projected Bottom Hole: | TVD : 7,832' | TMD : 26,431' | | 39° 47' 20.80" | 80° 27' 37.47" |

G / M

Azimuths to Grid North
Magnetic North : -8.95

Magnetic Field
Strength : 51,766.08
Dip Angle : 66.63
Date : 07/10/2020
Model : IGRF2015

NAD 83



APPENDIX E: GIS SOURCES BY LAYER

| Data Layer | Source |
|---|---|
| Basemap | ESRI World Topographic Map |
| Unconventional Wells | Obtained from the PADEP Well Inventory dataset https://www.depgreenport.state.pa.us/ReportExtracts/OG/OilGasWellInventoryReport |
| Abandoned Wells | PASDA, https://www.pasda.psu.edu/uci/SearchResults.aspx?Keyword=abandoned+wells |
| Unconventional Well Violations | Obtained from the PADEP Oil and Gas Compliance dataset https://www.depgreenport.state.pa.us/ReportExtracts/OG/OilComplianceReport |
| Well Pad | Lumber well pad information obtained from the PADEP |

# APPENDIX F: WATER QUALITY RESULTS

*Field Analysis*

| Sample Number | Sample Date | Sample Source | Temp | DO % | DO (mg/L) | pH |
|---|---|---|---|---|---|---|
| **MS1957** | 6/27/22 | well | 16.8 | 7.3 | 0.71 | 7.45 |
| **MS1958** | 6/27/22 | well | 21.1 | 9.75 | 0.86 | 8.56 |
| **MS1959** | 6/27/22 | well | 17.35 | 17.55 | 1.64 | 9.24 |
| **MS1976** | 7/19/22 | well | 16.3 | 12.2 | 1.195 | 8.38 |
| **MS1977** | 7/19/22 | well | 20.8 | 6.95 | 0.61 | 7.16 |
| **MS1978** | 7/19/22 | spring fed cystern | 19.6 | 14 | 1.28 | 8.795 |
| **MS2014** | 8/9/22 | spring | 17.2 | 69.2 | 6.63 | 7.06 |
| **MS2015** | 8/9/22 | spring | 22.7 | 75.6 | 6.5 | 7.7 |
| **MS2016** | 8/9/22 | well | 16.65 | 33.05 | 3.285 | 7.46 |
| **MS2017** | 8/9/22 | well | 20.15 | 47.55 | 4.33 | 7.34 |
| **MS2038** | 8/23/22 | well | 16.25 | 38 | 3.6 | 7.84 |
| **MS2039** | 8/23/22 | well | 20.5 | 39.5 | 3.5 | 6.77 |
| **MS2040** | 8/23/22 | well | 21 | 9.15 | 0.8 | 7.475 |
| **MS2041** | 8/23/22 | well | 18.3 | 48.5 | 4.505 | 8.15 |
| **MS2042** | 8/23/22 | well | 22.75 | 53.9 | 4.55 | 6.675 |
| **MS2043** | 8/23/22 | well | 23.25 | 47.5 | 4.05 | 6.795 |
| **MS2044** | 8/23/22 | well | 18.65 | 13.3 | 1.235 | 7.62 |
| **MS2062** | 9/7/22 | well | 24.35 | 21 | 1.765 | 7.38 |

| Sample Number | Sample Date | Sample Source | Pressure (mmHg) | SpC | Conductivity | TDS |
|---|---|---|---|---|---|---|
| **MS1957** | 6/27/22 | well | 736.2 | 737.5 | 623.5 | 478.85 |
| **MS1958** | 6/27/22 | well | 735 | 709.5 | 656.5 | 461 |
| **MS1959** | 6/27/22 | well | 733.8 | 788.5 | 674.5 | 512.5 |
| **MS1976** | 7/19/22 | well | 732.6 | 621.5 | 518 | 403.75 |
| **MS1977** | 7/19/22 | well | 720.5 | 301.35 | 277.5 | 195.9 |
| **MS1978** | 7/19/22 | spring fed cystern | 720.9 | 203.1 | 182.8 | 132.35 |
| **MS2014** | 8/9/22 | spring | 724.9 | 236.5 | 201.6 | 153.4 |
| **MS2015** | 8/9/22 | spring | 722.4 | 221.2 | 214.5 | 144.1 |
| **MS2016** | 8/9/22 | well | 733 | 490.95 | 403.35 | 319.15 |
| **MS2017** | 8/9/22 | well | 369.415 | 590.5 | 537 | 193.085 |
| **MS2038** | 8/23/22 | well | 733.15 | 690 | 575 | 448.5 |
| **MS2039** | 8/23/22 | well | 733 | 406.4 | 372.5 | 264.3 |
| **MS2040** | 8/23/22 | well | 732.5 | 595 | 549 | 386.95 |
| **MS2041** | 8/23/22 | well | 732.38 | 646 | 562.5 | 419.5 |
| **MS2042** | 8/23/22 | well | 720.7 | 303.05 | 290.2 | 194 |
| **MS2043** | 8/23/22 | well | 720.7 | 318.6 | 308.3 | 208.6 |
| **MS2044** | 8/23/22 | well | 730 | 786 | 694 | 510.5 |
| **MS2062** | 9/7/22 | well | 734.45 | 805 | 787 | 523.5 |

| Sample Number | Sample Date | Sample Source | Temp | DO % | DO (mg/L) | pH |
|---|---|---|---|---|---|---|
| **MS2063** | 9/7/22 | well | 17.5 | 30.05 | 2.55 | 9.075 |
| **MS2140** | 11/10/2022 | well | 13.4 | 55.65 | 5.49 | 8.02 |
| **MS2141** | 11/10/2022 | pond | 9.9 | 86.5 | 9.53 | 7.87 |
| **MS2142** | 11/10/2022 | spring | 19.2 | 90.2 | 9.28 | 8.37 |
| **MS2143** | 11/10/2022 | well | 22.25 | 73.05 | 6.27 | 7.64 |
| **MS2230** | 2/16/2023 | well | 10.5 | 52.7 | 5.54 | 8.71 |
| **MS2231** | 2/16/2023 | spring fed cystern | 9.95 | 75 | 8.27 | 8.23 |
| **MS2232** | 2/16/2023 | spring | 14.8 | 69.1 | 6.98 | 8.72 |
| **MS2233** | 2/16/2023 | well | 13.85 | 41.9 | 4.21 | 7.65 |
| **MS2234** | 2/16/2023 | well | 21.05 | 22.35 | 1.79 | 8.15 |
| **MS2235** | 2/16/2023 | well | 12 | 19.1 | 1.92 | 9.38 |
| **MS2236** | 2/16/2023 | well | 33.05 | 14.45 | 1 | 7.68 |
| **MS2237** | 2/16/2023 | well | 15.1 | 61.8 | 6.19 | 8.81 |

| Sample Number | Sample Date | Sample Source | Pressure (mmHg) | SpC | Conductivity | TDS |
|---|---|---|---|---|---|---|
| **MS2063** | 9/7/22 | well | 733.5 | 815.5 | 699 | 529 |
| **MS2140** | 11/10/2022 | well | 734.65 | 413.75 | 324.05 | 269.1 |
| **MS2141** | 11/10/2022 | pond | 734.4 | 239.8 | 175.3 | 156.7 |
| **MS2142** | 11/10/2022 | spring | 727 | 345.6 | 291.2 | 224.8 |
| **MS2143** | 11/10/2022 | well | 725.9 | 570.5 | 541.5 | 370.7 |
| **MS2230** | 2/16/2023 | well | 721.5 | 188.65 | 136.6 | 122.7 |
| **MS2231** | 2/16/2023 | spring fed cystern | 722.05 | 240.05 | 171.4 | 156.1 |
| **MS2232** | 2/16/2023 | spring | 736.6 | 193.6 | 156.4 | 125.6 |
| **MS2233** | 2/16/2023 | well | 733.7 | 323.55 | 254.7 | 210.25 |
| **MS2234** | 2/16/2023 | well | 733.55 | 602 | 555.5 | 391.4 |
| **MS2235** | 2/16/2023 | well | 733.4 | 696.5 | 525.75 | 452.95 |
| **MS2236** | 2/16/2023 | well | 732.3 | 758.5 | 862.5 | 496.8 |
| **MS2237** | 2/16/2023 | well | 736.8 | 681 | 552 | 442 |

*Light Hydrocarbon Analysis*

| Sample Number | Lab Analysis Date | Methane, ppb | Ethene, ppb | Ethane, ppb | Propane, ppb |
|---|---|---|---|---|---|
| **MS1957** | 6/27/22 | 420 | bdl | 5 | bdl |
| **MS1958** | 6/27/22 | 7105 | bdl | 165 | bdl |
| **MS1959** | 6/27/22 | 3645 | bdl | 70 | bdl |
| **MS1976** | 7/19/22 | 5530 | bdl | 190 | bdl |
| **MS1977** | 7/19/22 | 3050 | bdl | 7 | bdl* |
| **MS1978** | 7/19/22 | bdl | bdl | bdl | bdl |
| **MS2014** | 8/10/22 | bdl | bdl | bdl | bdl |
| **MS2015** | 8/10/22 | bdl | bdl | bdl | bdl |
| **MS2016** | 8/10/22 | 918 | bdl | 9 | bdl |
| **MS2017** | 8/10/22 | 1,289 | bdl | 4 | bdl |
| **MS2038** | 8/24/22 | 3,187 | bdl | 51 | bdl |
| **MS2039** | 8/24/22 | bdl | bdl | bdl | bdl |
| **MS2040** | 8/24/22 | bdl | bdl | bdl | bdl |
| **MS2041** | 8/24/22 | 3,628 | bdl | 65 | bdl |
| **MS2042** | 8/24/22 | bdl | bdl | bdl | bdl |
| **MS2043** | 8/24/22 | bdl | bdl | bdl | bdl |
| **MS2044** | 8/24/22 | 662 | bdl | 25 | bdl |
| **MS2062** | 9/8/22 | 75 | bdl | bdl | bdl |

| Sample Number | Lab Analysis Date | Methane, ppb | Ethene, ppb | Ethane, ppb | Propane, ppb |
|---|---|---|---|---|---|
| **MS2063** | 9/8/22 | 14,660 | bdl | 147 | bdl |
| **MS2140** | 11/11/2022 | 138 | bdl | bdl | bdl |
| **MS2141** | 11/11/2022 | 18 | bdl | bdl | bdl |
| **MS2142** | 11/11/2022 | bdl | bdl | bdl | bdl |
| **MS2143** | 11/11/2022 | bdl | bdl | bdl | bdl |
| **MS2230** | 2/17/2023 | 45 | bdl | bdl | bdl |
| **MS2231** | 2/17/2023 | bdl | bdl | bdl | bdl |
| **MS2232** | 2/17/2023 | bdl | bdl | bdl | bdl |
| **MS2233** | 2/17/2023 | bdl | bdl | bdl | bdl |
| **MS2234** | 2/17/2023 | 3,400 | bdl | bdl | bdl |
| **MS2235** | 2/17/2023 | 14,000 | bdl | 400 | bdl |
| **MS2236** | 2/17/2023 | 350 | bdl | 25 | bdl |
| **MS2237** | na | na | na | na | na |

*Cation Analysis*

| Sample # | Lab Analysis Date | Li | B | Na | Mg | Al | Si | P |
|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | | | | 0.05-0.2 | | |
| **MS1957** | 6/27/22 | 0.012 | 0.105 | 132.1 | 5.88 | 0.002 | 5.06 | 0.014 |
| **MS1958** | 6/27/22 | 0.014 | 0.098 | 159.8 | 0.85 | 0.001 | 4.77 | bdl |
| **MS1959** | 6/27/22 | 0.008 | 0.140 | 192.9 | 0.10 | 0.015 | 3.75 | 0.093 |
| **MS1976** | 7/19/22 | 0.010 | 0.111 | 131.8 | 1.35 | 0.003 | 3.85 | bdl |
| **MS1977** | 7/19/22 | 0.005 | 0.054 | 23.9 | 7.34 | 0.003 | 4.89 | bdl |
| **MS1978** | 7/19/22 | 0.002 | 0.011 | 2.2 | 4.36 | 0.050 | 2.63 | 0.048 |
| **MS2014** | 8/9/22 | 0.002 | 0.011 | 2.60 | 5.45 | 0.002 | 3.81 | bdl |
| **MS2015** | 8/9/22 | 0.001 | 0.010 | 3.56 | 5.11 | 0.015 | 4.30 | bdl |
| **MS2016** | 8/9/22 | 0.004 | 1.490 | 33.26 | 6.10 | 0.621 | 5.64 | 0.27 |
| **MS2017** | 8/9/22 | 0.015 | 0.098 | 70.35 | 7.35 | bdl | 4.85 | bdl |
| **MS2038** | 8/23/22 | 0.004 | 0.063 | 131.09 | 3.52 | bdl | 5.84 | bdl |
| **MS2039** | 8/23/22 | bdl | 0.038 | 17.82 | 5.25 | 0.008 | 4.17 | 0.073 |
| **MS2040** | 8/23/22 | 0.002 | 0.066 | 96.13 | 5.09 | 0.006 | 4.64 | bdl |
| **MS2041** | 8/23/22 | 0.004 | 0.080 | 135.47 | 1.72 | 0.006 | 4.65 | 0.031 |
| **MS2042** | 8/23/22 | bdl | bdl | 4.02 | 8.82 | 0.056 | 5.50 | bdl |
| **MS2043** | 8/23/22 | bdl | bdl | 5.65 | 8.51 | 0.015 | 5.19 | bdl |
| **MS2044** | 8/23/22 | 0.005 | 0.046 | 117.66 | 7.87 | 0.002 | 6.57 | bdl |
| **MS2062** | 9/7/22 | 0.017 | 0.078 | 95.36 | 12.47 | 0.065 | 7.56 | bdl |

| Sample # | Lab Analysis Date | K | Ca | Ti | V | Cr | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | | | | 0.1 (total) | 0.050 | 0.30 |
| **MS1957** | 6/27/22 | 1.05 | 23.73 | 0.002 | 0.001 | 0.001 | 0.87 | 0.54 |
| **MS1958** | 6/27/22 | 1.01 | 6.28 | 0.002 | <0.001 | bdl | 0.01 | 0.08 |
| **MS1959** | 6/27/22 | 0.48 | 0.73 | 0.002 | bdl | 0.001 | <0.01 | bdl |
| **MS1976** | 7/19/22 | 0.80 | 10.09 | 0.001 | 0.000 | 0.001 | 0.04 | 0.16 |
| **MS1977** | 7/19/22 | 1.14 | 27.50 | 0.001 | bdl | bdl | 0.08 | 0.43 |
| **MS1978** | 7/19/22 | 1.54 | 26.98 | 0.001 | bdl | 0.001 | 0.03 | 0.21 |
| **MS2014** | 8/9/22 | 1.47 | 24.03 | bdl | bdl | <0.001 | <0.01 | 0.15 |
| **MS2015** | 8/9/22 | 1.40 | 26.85 | bdl | bdl | <0.001 | <0.01 | 0.15 |
| **MS2016** | 8/9/22 | 6.86 | 57.15 | 0.003 | <0.001 | 0.002 | 0.31 | 1.84 |
| **MS2017** | 8/9/22 | 2.45 | 38.64 | bdl | bdl | <0.001 | 0.06 | 0.29 |
| **MS2038** | 8/23/22 | 1.74 | 18.17 | bdl | bdl | bdl | 0.169 | 0.32 |
| **MS2039** | 8/23/22 | 9.17 | 51.09 | bdl | bdl | bdl | 0.004 | 0.42 |
| **MS2040** | 8/23/22 | 1.66 | 31.02 | bdl | bdl | bdl | 0.096 | 0.44 |
| **MS2041** | 8/23/22 | 1.52 | 13.74 | bdl | bdl | bdl | 0.104 | 0.59 |
| **MS2042** | 8/23/22 | 1.52 | 41.84 | bdl | bdl | <0.001 | 0.000 | 0.52 |
| **MS2043** | 8/23/22 | 1.47 | 40.44 | bdl | bdl | <0.001 | 0.009 | 0.48 |
| **MS2044** | 8/23/22 | 1.77 | 38.34 | bdl | bdl | <0.001 | 0.103 | 0.67 |
| **MS2062** | 9/7/22 | 2.14 | 65.02 | 0.002 | 0.0006 | 0.001 | 0.30 | 1.50 |

| Sample # | Lab Analysis Date | Co | Ni | Cu | Zn | As | Se | Rb |
|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | | <1.3 | 5.000 | 0.010 | 0.050 | |
| **MS1957** | 6/27/22 | <0.001 | 0.002 | 0.003 | 0.025 | 0.001 | 0.001 | 0.001 |
| **MS1958** | 6/27/22 | <0.001 | 0.001 | 0.004 | 0.019 | 0.001 | 0.001 | 0.001 |
| **MS1959** | 6/27/22 | <0.001 | <0.001 | 0.004 | 0.016 | <0.001 | 0.001 | <0.001 |
| **MS1976** | 7/19/22 | <0.001 | bdl | 0.006 | 0.019 | 0.005 | 0.001 | 0.001 |
| **MS1977** | 7/19/22 | <0.001 | bdl | 0.072 | 0.023 | 0.001 | <0.001 | 0.001 |
| **MS1978** | 7/19/22 | <0.001 | <0.001 | 0.039 | 0.016 | bdl | <0.001 | 0.001 |
| **MS2014** | 8/9/22 | 0.0001 | <0.001 | 0.002 | 0.014 | bdl | bdl | <0.001 |
| **MS2015** | 8/9/22 | 0.0001 | 0.001 | 0.003 | 0.022 | bdl | bdl | <0.001 |
| **MS2016** | 8/9/22 | 0.0017 | 0.004 | 0.119 | 4.173 | 0.001 | bdl | 0.002 |
| **MS2017** | 8/9/22 | 0.0001 | 0.002 | 0.016 | 0.030 | bdl | bdl | 0.002 |
| **MS2038** | 8/23/22 | 0.0001 | bdl | bdl | 0.009 | bdl | bdl | 0.002 |
| **MS2039** | 8/23/22 | 0.0002 | bdl | 0.014 | 0.052 | bdl | 0.002 | 0.000 |
| **MS2040** | 8/23/22 | 0.0001 | bdl | 0.021 | 0.049 | bdl | 0.003 | 0.001 |
| **MS2041** | 8/23/22 | 0.0001 | bdl | 0.029 | 0.088 | bdl | bdl | 0.002 |
| **MS2042** | 8/23/22 | 0.0002 | bdl | 0.152 | 0.043 | bdl | 0.001 | 0.001 |
| **MS2043** | 8/23/22 | 0.0002 | bdl | 0.071 | 0.039 | bdl | bdl | 0.001 |
| **MS2044** | 8/23/22 | 0.0002 | bdl | 0.001 | 0.011 | bdl | bdl | 0.002 |
| **MS2062** | 9/7/22 | 0.0002 | 0.001 | 0.016 | 0.089 | 0.001 | 0.001 | 0.002 |

| Sample # | Lab Analysis Date | Sr | Mo | Ag | Cd | Sn | Sb | Cs |
|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | | 0.1000 | 0.0050 | | 0.0060 | |
| **MS1957** | 6/27/22 | 0.40 | 0.0006 | 0.0005 | bdl | 0.0001 | bdl | 0.00004 |
| **MS1958** | 6/27/22 | 0.28 | 0.0005 | 0.0026 | bdl | 0.0002 | bdl | 0.00004 |
| **MS1959** | 6/27/22 | 0.03 | 0.0013 | 0.0004 | bdl | 0.0001 | bdl | 0.00004 |
| **MS1976** | 7/19/22 | 0.22 | 0.0016 | 0.0004 | bdl | <0.0001 | bdl | 0.00002 |
| **MS1977** | 7/19/22 | 0.41 | 0.0303 | 0.0006 | <0.0001 | 0.0002 | <0.0001 | 0.00001 |
| **MS1978** | 7/19/22 | 0.12 | 0.0002 | 0.0009 | bdl | bdl | bdl | 0.00001 |
| **MS2014** | 8/9/22 | 0.12 | 0.0001 | bdl | bdl | bdl | 0.0001 | bdl |
| **MS2015** | 8/9/22 | 0.12 | 0.0079 | bdl | bdl | bdl | <0.0001 | bdl |
| **MS2016** | 8/9/22 | 0.31 | 0.0004 | bdl | 0.0207 | bdl | 0.0007 | 0.00002 |
| **MS2017** | 8/9/22 | 1.55 | 0.0003 | bdl | bdl | bdl | 0.0001 | 0.00002 |
| **MS2038** | 8/23/22 | 0.72 | 0.0002 | bdl | <0.0001 | bdl | bdl | 0.00002 |
| **MS2039** | 8/23/22 | 0.18 | 0.0006 | bdl | 0.0001 | 0.0057 | 0.0001 | 0.00000 |
| **MS2040** | 8/23/22 | 0.56 | 0.0023 | bdl | 0.0001 | bdl | bdl | 0.00004 |
| **MS2041** | 8/23/22 | 0.37 | 0.0008 | <0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.00002 |
| **MS2042** | 8/23/22 | 0.21 | 0.0005 | 0.0009 | <0.0001 | bdl | <0.0001 | bdl |
| **MS2043** | 8/23/22 | 0.20 | 0.0007 | 0.0003 | <0.0001 | bdl | 0.0002 | bdl |
| **MS2044** | 8/23/22 | 1.11 | 0.0003 | bdl | <0.0001 | bdl | bdl | 0.00002 |
| **MS2062** | 9/7/22 | 1.41 | 0.0009 | 0.0011 | 0.0002 | 0.0215 | 0.0001 | 0.00005 |

| Sample # | Lab Analysis Date | Ba | W | Hg | Pb | Bi | U |
|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | 2.00 | | 0.0020 | 0.015 | | 0.03000 |
| **MS1957** | 6/27/22 | 0.23 | 0.0099 | na | 0.0003 | bdl | bdl |
| **MS1958** | 6/27/22 | 0.24 | 0.0095 | na | 0.0001 | bdl | bdl |
| **MS1959** | 6/27/22 | 0.04 | 0.0100 | na | 0.0004 | bdl | bdl |
| **MS1976** | 7/19/22 | 0.15 | 0.0013 | na | 0.0004 | bdl | bdl |
| **MS1977** | 7/19/22 | 0.09 | 0.0008 | na | 0.0041 | bdl | 0.0003 |
| **MS1978** | 7/19/22 | 0.04 | 0.0005 | na | 0.0002 | bdl | 0.0001 |
| **MS2014** | 8/9/22 | 0.02 | bdl | na | bdl | bdl | 0.0002 |
| **MS2015** | 8/9/22 | 0.03 | bdl | na | bdl | bdl | 0.0002 |
| **MS2016** | 8/9/22 | 0.42 | bdl | na | 0.1942 | bdl | 0.0003 |
| **MS2017** | 8/9/22 | 0.63 | bdl | na | 0.0012 | bdl | <0.0001 |
| **MS2038** | 8/23/22 | 0.57 | 0.0035 | na | bdl | bdl | bdl |
| **MS2039** | 8/23/22 | 0.07 | 0.0038 | na | 0.0025 | bdl | 0.0001 |
| **MS2040** | 8/23/22 | 0.19 | 0.0015 | na | 0.0006 | bdl | 0.0001 |
| **MS2041** | 8/23/22 | 0.35 | 0.0015 | na | 0.0103 | bdl | bdl |
| **MS2042** | 8/23/22 | 0.04 | 0.0014 | na | 0.0061 | <0.0001 | 0.0002 |
| **MS2043** | 8/23/22 | 0.04 | 0.0008 | na | 0.0011 | bdl | 0.0002 |
| **MS2044** | 8/23/22 | 0.85 | 0.0005 | na | 0.0013 | bdl | bdl |
| **MS2062** | 9/7/22 | 1.32 | 0.012 | na | 0.0003 | 0.0003 | bdl |

| Sample # | Lab Analysis Date | Li | B | Na | Mg | Al | Si | P |
|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | | | | 0.05-0.2 | | |
| **MS2063** | 9/7/22 | 0.010 | 0.147 | 209.05 | 0.22 | 0.011 | 4.10 | 0.030 |
| **MS2140** | 11/10/2022 | 0.006 | 0.029 | 21.75 | 8.09 | 0.007 | 6.59 | 0.214 |
| **MS2141** | 11/10/2022 | <0.001 | 0.105 | 5.65 | 5.1 | 0.029 | 1.86 | 0.496 |
| **MS2142** | 11/10/2022 | 0.002 | 0.038 | 14.78 | 9.24 | 0.011 | 4.18 | bdl |
| **MS2143** | 11/10/2022 | 0.006 | 0.028 | 9.06 | 22.98 | 0.144 | 3.67 | bdl |
| **MS2230** | 2/16/2023 | 0.002 | 0.024 | 7.12 | 3.6 | 0.042 | 3.13 | 0.035 |
| **MS2231** | 2/16/2023 | 0.004 | 0.013 | 3.47 | 8.59 | 0.057 | 4.09 | bdl |
| **MS2232** | 2/16/2023 | 0.002 | 0.01 | 3.4 | 5.34 | 0.046 | 3.8 | 0.01 |
| **MS2233** | 2/16/2023 | 0.002 | 0.014 | 26.9 | 3.82 | 0.066 | 2.99 | 0.03 |
| **MS2234** | 2/16/2023 | 0.014 | 0.122 | 128.68 | 2.27 | 0.009 | 4.69 | 0.003 |
| **MS2235** | 2/16/2023 | 0.012 | 0.124 | 178.58 | 0.19 | 0.015 | 3.99 | 0.063 |
| **MS2236** | 2/16/2023 | 0.017 | 0.112 | 125.27 | 6.25 | 0.045 | 5.56 | 0.034 |
| **MS2237** | 2/16/2023 | 0.019 | 0.104 | 158.98 | 1.11 | 0.019 | 4.68 | 0.02 |

| Sample # | Lab Analysis Date | K | Ca | Ti | V | Cr | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | | | | 0.1 (total) | 0.050 | 0.30 |
| **MS2063** | 9/7/22 | 0.67 | 1.68 | 0.001 | 0.0006 | 0.001 | 0.01 | 0.04 |
| **MS2140** | 11/10/2022 | 0.98 | 47.11 | 0.003 | bdl | bdl | 0.99 | 5.91 |
| **MS2141** | 11/10/2022 | 9.34 | 37.34 | 0.001 | bdl | bdl | 3.318 | 0.97 |
| **MS2142** | 11/10/2022 | 0.65 | 42.8 | <0.001 | bdl | bdl | 0.038 | 0.33 |
| **MS2143** | 11/10/2022 | 2.4 | 79.91 | bdl | <0.0001 | bdl | 0.002 | 0.58 |
| **MS2230** | 2/16/2023 | 0.87 | 27.86 | 0.002 | 0.0002 | bdl | 0.003 | 0.16 |
| **MS2231** | 2/16/2023 | 1.18 | 31.48 | 0.002 | 0.0003 | bdl | 0.006 | 0.16 |
| **MS2232** | 2/16/2023 | 1.46 | 26.54 | 0.002 | 0.0002 | bdl | 0.002 | 0.13 |
| **MS2233** | 2/16/2023 | 1.32 | 36.3 | 0.001 | 0.0005 | bdl | 0.015 | 0.24 |
| **MS2234** | 2/16/2023 | 0.82 | 14.11 | 0.002 | 0.0005 | bdl | 0.088 | 0.23 |
| **MS2235** | 2/16/2023 | 0.41 | 0.87 | 0.002 | 0.0009 | bdl | 0.008 | bdl |
| **MS2236** | 2/16/2023 | 1.35 | 29.35 | 0.002 | 0.0014 | bdl | 1.073 | 0.46 |
| **MS2237** | 2/16/2023 | 1.04 | 7.28 | 0.002 | 0.0011 | bdl | 0.008 | 0.01 |

| Sample # | Lab Analysis Date | Co | Ni | Cu | Zn | As | Se | Rb | Sr |
|---|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | | <1.3 | 5.000 | 0.010 | 0.050 | | |
| **MS2063** | 9/7/22 | 0.0001 | bdl | 0.005 | 0.007 | 0.002 | 0.001 | 0.001 | 0.04 |
| **MS2140** | 11/10/2022 | bdl | 0.002 | 0.007 | bdl | 0.006 | <0.001 | 0.001 | 0.76 |
| **MS2141** | 11/10/2022 | 0.0005 | 0.001 | 0.01 | bdl | 0.001 | <0.001 | 0.002 | 0.14 |
| **MS2142** | 11/10/2022 | bdl | 0.002 | 0.005 | bdl | bdl | 0.001 | bdl | 0.32 |
| **MS2143** | 11/10/2022 | <0.0001 | 0.003 | 0.013 | bdl | <0.001 | 0.001 | 0.001 | 0.48 |
| **MS2230** | 2/16/2023 | 0.0001 | bdl | 0.037 | bdl | <0.001 | bdl | 0.003 | 0.11 |
| **MS2231** | 2/16/2023 | 0.0001 | bdl | 0.223 | bdl | <0.001 | bdl | <0.001 | 0.2 |
| **MS2232** | 2/16/2023 | 0.0001 | bdl | 0.003 | bdl | 0.001 | bdl | <0.001 | 0.12 |
| **MS2233** | 2/16/2023 | 0.0002 | bdl | 0.084 | 0.744 | 0.001 | bdl | 0.001 | 0.27 |
| **MS2234** | 2/16/2023 | <0.0001 | bdl | 0.005 | bdl | 0.001 | bdl | 0.001 | 0.35 |
| **MS2235** | 2/16/2023 | <0.0001 | bdl | 0.007 | bdl | 0.001 | bdl | 0.001 | 0.04 |
| **MS2236** | 2/16/2023 | 0.0001 | bdl | 0.007 | bdl | 0.002 | bdl | 0.002 | 0.56 |
| **MS2237** | 2/16/2023 | <0.0001 | bdl | 0.01 | bdl | 0.002 | bdl | 0.001 | 0.36 |

| Sample # | Lab Analysis Date | Mo | Ag | Cd | Sn | Sb | Cs | Ba |
|---|---|---|---|---|---|---|---|---|
| **MCL, ppm** | | | 0.1000 | 0.0050 | | 0.0060 | | 2.00 |
| **MS2063** | 9/7/22 | 0.0014 | 0.0002 | 0.0001 | 0.0018 | 0.0001 | 0.00002 | 0.02 |
| **MS2140** | 11/10/2022 | bdl | bdl | <0.0001 | 0.0012 | bdl | bdl | 0.69 |
| **MS2141** | 11/10/2022 | bdl | bdl | 0.0001 | 0.0067 | bdl | bdl | 0.17 |
| **MS2142** | 11/10/2022 | bdl | bdl | 0.0001 | 0.0062 | bdl | bdl | 0.05 |
| **MS2143** | 11/10/2022 | bdl | bdl | <0.0001 | 0.0047 | bdl | bdl | 0.23 |
| **MS2230** | 2/16/2023 | 0.0086 | 0.0007 | <0.0001 | 0.014 | 0.0004 | 0.00013 | 0.02 |
| **MS2231** | 2/16/2023 | 0.0004 | 0.0004 | <0.0001 | 0.055 | 0.0002 | 0.00002 | 0.08 |
| **MS2232** | 2/16/2023 | 0.0007 | 0.0003 | <0.0001 | 0.083 | 0.0002 | <0.0001 | 0.06 |
| **MS2233** | 2/16/2023 | 0.0005 | 0.0002 | 0.0002 | 0.079 | 0.0003 | 0.00001 | 0.31 |
| **MS2234** | 2/16/2023 | 0.0027 | 0.0001 | <0.0001 | 0.075 | 0.0001 | 0.00001 | 0.28 |
| **MS2235** | 2/16/2023 | 0.0011 | 0.0001 | bdl | 0.061 | <0.0001 | bdl | 0.07 |
| **MS2236** | 2/16/2023 | 0.0006 | 0.0001 | 0.0002 | 0.052 | <0.0001 | 0.00001 | 0.44 |
| **MS2237** | 2/16/2023 | 0.0004 | 0.0001 | 0.0001 | 0.039 | <0.0001 | <0.0001 | 0.42 |

| Sample # | Lab Analysis Date | W | Hg | Pb | Bi | U |
|---|---|---|---|---|---|---|
| **MCL, ppm** | | | 0.0020 | 0.015 | | 0.03000 |
| **MS2063** | 9/7/22 | 0.010 | na | bdl | 0.0002 | bdl |
| **MS2140** | 11/10/2022 | bdl | na | 0.0005 | bdl | bdl |
| **MS2141** | 11/10/2022 | bdl | na | bdl | bdl | bdl |
| **MS2142** | 11/10/2022 | bdl | na | bdl | bdl | 0.0003 |
| **MS2143** | 11/10/2022 | bdl | na | 0.0018 | bdl | 0.0021 |
| **MS2230** | 2/16/2023 | 0.0024 | na | 0.0004 | 0.0002 | 0.0002 |
| **MS2231** | 2/16/2023 | 0.0013 | na | 0.0003 | 0.00008 | 0.0004 |
| **MS2232** | 2/16/2023 | 0.0009 | na | 0.0009 | 0.00006 | 0.0004 |
| **MS2233** | 2/16/2023 | 0.0006 | na | 0.0029 | 0.00003 | 0.0003 |
| **MS2234** | 2/16/2023 | 0.0006 | na | 0.0019 | 0.00001 | 0.0002 |
| **MS2235** | 2/16/2023 | 0.0007 | na | 0.0006 | bdl | 0.0001 |
| **MS2236** | 2/16/2023 | 0.0003 | na | 0.0007 | bdl | 0.0001 |
| **MS2237** | 2/16/2023 | 0.0004 | na | 0.0009 | bdl | <0.0001 |

*Anion Analysis*

| Sample # | Lab Analysis Date | Fluoride | Chloride | Nitrite | Bromide |
|---|---|---|---|---|---|
| **MCL, ppm (mg/L)** | | **4 (2)** | **250.00** | **3.30** | |
| **MS1957** | 6/28/22 | 0.11 | 70.7 | bdl | bdl |
| **MS1958** | 6/28/22 | 0.13 | 58.5 | bdl | bdl |
| **MS1959** | 6/28/22 | 0.36 | 28.0 | bdl | bdl |
| **MS1976** | 7/20/22 | 0.15 | 34.3 | bdl | bdl |
| **MS1977** | 7/20/22 | 0.03 | 1.9 | bdl | bdl |
| **MS1978** | 7/20/22 | bdl | 0.3 | bdl | bdl |
| **MS2014** | 8/10/22 | bdl | 0.3 | bdl | bdl |
| **MS2015** | 8/10/22 | bdl | 0.3 | bdl | bdl |
| **MS2016** | 8/10/22 | 0.07 | 17.0 | 0.14 | bdl |
| **MS2017** | 8/10/22 | 0.07 | 46.8 | bdl | bdl* |
| **MS2038** | 8/24/22 | 0.09 | 66.8 | bdl | 0.02 |
| **MS2039** | 8/24/22 | bdl | 19.0 | bdl | bdl |
| **MS2040** | 8/24/22 | 0.06 | 18.1 | bdl | bdl |
| **MS2041** | 8/24/22 | 0.26 | 38.6 | bdl | 0.02 |
| **MS2042** | 8/24/22 | bdl | 0.5 | bdl | bdl |
| **MS2043** | 8/24/22 | bdl | 0.5 | bdl | bdl |

| Sample # | Lab Analysis Date | Nitrate | Phosphate | Sulfate | Bicarbonate | Carbonate |
|---|---|---|---|---|---|---|
| **MCL, ppm (mg/L)** | | **44.30** | | **250.00** | | |
| **MS1957** | 6/28/22 | bdl | bdl | 12.1 | 305.0 | bdl |
| **MS1958** | 6/28/22 | bdl | 0.08 | 0.4 | 287.9 | 14.4 |
| **MS1959** | 6/28/22 | bdl | 0.20 | 3.4 | 334.3 | 48.0 |
| **MS1976** | 7/20/22 | bdl | bdl | 3.9 | 283.0 | 21.6 |
| **MS1977** | 7/20/22 | bdl | bdl | 14.7 | 175.7 | bdl |
| **MS1978** | 7/20/22 | 5.1 | 0.33 | 6.9 | 97.6 | 9.6 |
| **MS2014** | 8/10/22 | 1.8 | 0.07 | 6.8 | 107.4 | bdl |
| **MS2015** | 8/10/22 | 2.3 | 0.12 | 17.6 | 107.4 | bdl |
| **MS2016** | 8/10/22 | 28.5 | 0.32 | 21.0 | 209.8 | bdl |
| **MS2017** | 8/10/22 | 1.0 | bdl | 4.6 | 292.8 | bdl |
| **MS2038** | 8/24/22 | 0.02 | 0.06 | 0.1 | 275.7 | bdl |
| **MS2039** | 8/24/22 | 6.95 | 0.38 | 18.8 | 183.0 | bdl |
| **MS2040** | 8/24/22 | 0.05 | 0.02 | 21.2 | 331.8 | bdl |
| **MS2041** | 8/24/22 | 0.02 | 0.20 | 0.8 | 336.7 | 7.2 |
| **MS2042** | 8/24/22 | 3.71 | 0.07 | 11.4 | 175.7 | bdl |
| **MS2043** | 8/24/22 | 3.92 | 0.07 | 11.6 | 161.0 | bdl |

| Sample # | Lab Analysis Date | Fluoride | Chloride | Nitrite | Bromide |
|---|---|---|---|---|---|
| **MCL, ppm (mg/L)** | | **4 (2)** | **250.00** | **3.30** | |
| **MS2044** | 8/24/22 | 0.03 | 95.9 | bdl | 0.02 |
| **MS2062** | 9/8/22 | bdl | 101.38 | bdl | 0.03 |
| **MS2063** | 9/8/22 | 0.29 | 75.88 | bdl | bdl* |
| **MS2140** | 11/10/2022 | 0.03 | 2.6 | bdl | bdl |
| **MS2141** | 11/10/2022 | bdl | 2.67 | bdl | bdl |
| **MS2142** | 11/10/2022 | bdl | 1.89 | bdl | bdl |
| **MS2143** | 11/10/2022 | bdl | 12.87 | bdl | bdl |
| **MS2230** | 2/16/2023 | 0.03 | 1.31 | bdl | bdl |
| **MS2231** | 2/16/2023 | bdl | 0.73 | bdl | bdl |
| **MS2232** | 2/16/2023 | bdl | 1.45 | bdl | bdl |
| **MS2233** | 2/16/2023 | 0.03 | 13.84 | bdl | bdl |
| **MS2234** | 2/16/2023 | 0.28 | 26.33 | bdl | 0.04 |
| **MS2235** | 2/16/2023 | 0.39 | 54.5 | bdl | 0.09 |
| **MS2236** | 2/16/2023 | bdl | 81.74 | bdl | 0.04 |
| **MS2237** | 2/16/2023 | 0.17 | 73.19 | bdl | bdl |

| Sample # | Lab Analysis Date | Nitrate | Phosphate | Sulfate | Bicarbonate | Carbonate |
|---|---|---|---|---|---|---|
| **MCL, ppm (mg/L)** | | **44.30** | | **250.00** | | |
| **MS2044** | 8/24/22 | 0.02 | bdl | 2.8 | 353.8 | bdl |
| **MS2062** | 9/8/22 | 0.02 | bdl | 4.06 | 327.0 | bdl |
| **MS2063** | 9/8/22 | 0.01 | 0.15 | 1.50 | 258.6 | 57.6 |
| **MS2140** | 11/10/2022 | bdl | bdl | 21.0 | 200.1 | bdl |
| **MS2141** | 11/10/2022 | bdl | bdl | 5.08 | 136.6 | bdl |
| **MS2142** | 11/10/2022 | 16.6 | bdl | 26.56 | 146.4 | bdl |
| **MS2143** | 11/10/2022 | 10.09 | bdl | 16.71 | 297.7 | bdl |
| **MS2230** | 2/16/2023 | 1.41 | bdl | 10.46 | 97.6 | bdl |
| **MS2231** | 2/16/2023 | bdl | 0.06 | 9.53 | 126.9 | bdl |
| **MS2232** | 2/16/2023 | 1.38 | bdl | 15.11 | 136.6 | bdl |
| **MS2233** | 2/16/2023 | 5.15 | 0.09 | 16.46 | 141.5 | bdl |
| **MS2234** | 2/16/2023 | bdl | 0.03 | 7.55 | 341.6 | bdl |
| **MS2235** | 2/16/2023 | bdl | 0.15 | 0.4 | 370.9 | 9.6 |
| **MS2236** | 2/16/2023 | 0.06 | bdl | 14.01 | 278.2 | bdl |
| **MS2237** | 2/16/2023 | 0.31 | 0.07 | 0.5 | 346.5 | bdl |

APPENDIX G: PRE-DRILL COMPARISONS TO CURRENT DATA

**Sample Site 1 Comparison**

*Field Analysis (no laboratory analysis provided)*

| Sample | pH | DO (%) | DO (mg/L) | Cond. (uS/cm) | TDS (mg/L) | Methane (ppb) |
|---|---|---|---|---|---|---|
| Predrill | 7.47 | 20.9 | 1.05 | 1210 | 773 | 5440 |
| Post Frac Out | | | | | | |
| MS1976 | 8.38 | 12.2 | 1.195 | 518 | 403.75 | 5530 |
| MS2234 | 8.15 | 22.35 | 1.79 | 555.5 | 391.4 | 3400 |

**Sample Site 2 Comparison**

*Field Analysis*

| **Sample** | **pH** | **Spc. Cond.** |
|---|---|---|
| Predrill (well 1) | 6.97 | 256 |
| Predrill (well 2) | 7.71 | 453 |
| Post Frac Out | | |
| MS1977 | 7.16 | 301.35 |
| MS2230 | 8.71 | 188.65 |

*Laboratory Analysis*

| **Sample** | **Methane (ppb)** | **Ethane (ppb)** | **Propane (ppb)** | **Bromide (ppb)** | **Chloride** | **Nitrate** | **TDS** | **Sulfate** |
|---|---|---|---|---|---|---|---|---|
| Predrill (well 1) | 1490 | 0.0157 | 0.0150 | <0.400 | 2.27 | <2.000 | 88.0 | 14.8 |
| Predrill (well 2) | <25.0 | <0.0100 | <0.0150 | <0.400 | <2.00 | <2.000 | 52.0 | 23.9 |
| Post Frac Out | | | | | | | | |
| MS1977 | 3050 | 7 | bdl | bdl | 1.9 | bdl | 195.9 | 14.7 |
| MS2230 | 45 | bdl | bdl | bdl | 1.31 | 1.41 | 122.7 | 10.46 |

| Sample | Aluminum | Arsenic | Barium | Calcium | Chromium | Iron | Lithium |
|---|---|---|---|---|---|---|---|
| Predrill (well 1) | <0.100 | <0.00800 | 0.0954 | 30.4 | <0.00500 | 0.605 | <0.0100 |
| Predrill (well 2) | 1.55 | 0.0180 | 0.154 | 67.9 | <0.00500 | 3.23 | <0.0100 |
| Post Frac Out | | | | | | | |
| MS1977 | 0.003 | <0.001 | 0.09 | 27.5 | bdl | 0.43 | 0.005 |
| MS2230 | 0.042 | <0.001 | 0.02 | 27.86 | bdl | 0.16 | 0.002 |

| Sample | Magnesium | Manganese | Sodium | Lead | Selenium | Zinc |
|---|---|---|---|---|---|---|
| Predrill (well 1) | 7.39 | 0.0648 | 16.1 | <0.00800 | <0.0200 | <0.0200 |
| Predrill (well 2) | 20.0 | 0.532 | 7.03 | <0.00800 | <0.0200 | <0.0200 |
| Post Frac Out | | | | | | |
| MS1977 | 7.34 | 0.08 | 23.88 | 0.0041 | <0.001 | 0.023 |
| MS2230 | 3.6 | 0.003 | 7.12 | 0.0004 | bdl | bdl |

**Sample Site 3 Comparison**

*Field Analysis*

| Sample | pH | Spc. Cond. |
|---|---|---|
| Predrill (spring 1) | 7.59 | 200 |
| Predrill (spring 2) | 7.38 | 294 |
| Post Frac Out | | |
| MS1978 | 8.80 | 203.1 |
| MS2231 | 8.23 | 240.05 |
| MS2232 | 8.72 | 193.6 |

*Laboratory Analysis*

| Sample | Methane (ppb) | Ethane (ppb) | Propane (ppb) | Bromide (ppb) | Chloride | Nitrate | TDS | Sulfate |
|---|---|---|---|---|---|---|---|---|
| Predrill (spring 1) | bdl | bdl | bdl | <0.400 | <2.00 | <2.000 | 26 | 8.77 |
| Predrill (spring 2) | bdl | bdl | bdl | <0.400 | 2.99 | <2.000 | 64 | 23 |
| Post Frac Out | | | | | | | | |
| MS1978 | bdl | bdl | bdl | bdl | 0.3 | 5.1 | 132.35 | 6.9 |
| MS2231 | bdl | bdl | bdl | bdl | 0.73 | bdl | 156.1 | 9.53 |
| MS2232 | bdl | bdl | bdl | bdl | 1.45 | 1.38 | 125.6 | 15.11 |

| Sample | Aluminum | Arsenic | Barium | Calcium | Chromium | Iron | Lithium |
|---|---|---|---|---|---|---|---|
| Predrill (spring 1) | <0.100 | <0.00800 | 0.0498 | 23.7 | <0.00500 | <0.200 | <0.0100 |
| Predrill (spring 2) | <0.100 | <0.00800 | 0.0665 | 40.8 | <0.00500 | <0.200 | <0.0100 |
| Post Frac Out | | | | | | | |
| MS1978 | 0.050 | bdl | 0.04 | 26.98 | 0.001 | 0.21 | 0.002 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MS2231 | 0.057 | <0.001 | 0.08 | 31.48 | bdl | 0.16 | 0.004 |
| MS2232 | 0.046 | <0.001 | 0.06 | 26.54 | bdl | 0.13 | 0.002 |

| **Sample** | **Magnesium** | **Manganese** | **Sodium** | **Lead** | **Selenium** | **Zinc** |
|---|---|---|---|---|---|---|
| Predrill (spring 1) | 5.75 | <0.0200 | 2.52 | <0.00800 | <0.0200 | <0.0200 |
| Predrill (spring 2) | 9.15 | <0.0200 | 5.42 | <0.00800 | <0.0200 | <0.0200 |
| Post Frac Out | | | | | | |
| MS1978 | 4.36 | 0.03 | 2.2 | 0.0002 | <0.001 | 0.016 |
| MS2231 | 8.59 | 0.006 | 3.47 | 0.0003 | bdl | bdl |
| MS2232 | 5.34 | 0.002 | 3.4 | 0.0009 | bdl | bdl |

# National Primary Drinking Water Regulations

EPA

| Contaminant | MCL or TT[1] (mg/L)[2] | Potential health effects from long-term[3] exposure above the MCL | Common sources of contaminant in drinking water | Public Health Goal (mg/L)[2] |
|---|---|---|---|---|
| Acrylamide | TT[4] | Nervous system or blood problems; increased risk of cancer | Added to water during sewage/ wastewater treatment | zero |
| Alachlor | 0.002 | Eye, liver, kidney, or spleen problems; anemia; increased risk of cancer | Runoff from herbicide used on row crops | zero |
| Alpha/photon emitters | 15 picocuries per Liter (pCi/L) | Increased risk of cancer | Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation | zero |
| Antimony | 0.006 | Increase in blood cholesterol; decrease in blood sugar | Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder | 0.006 |
| Arsenic | 0.010 | Skin damage or problems with circulatory systems, and may have increased risk of getting cancer | Erosion of natural deposits; runoff from orchards; runoff from glass & electronics production wastes | 0 |
| Asbestos (fibers >10 micrometers) | 7 million fibers per Liter (MFL) | Increased risk of developing benign intestinal polyps | Decay of asbestos cement in water mains; erosion of natural deposits | 7 MFL |
| Atrazine | 0.003 | Cardiovascular system or reproductive problems | Runoff from herbicide used on row crops | 0.003 |
| Barium | 2 | Increase in blood pressure | Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits | 2 |
| Benzene | 0.005 | Anemia; decrease in blood platelets; increased risk of cancer | Discharge from factories; leaching from gas storage tanks and landfills | zero |
| Benzo(a)pyrene (PAHs) | 0.0002 | Reproductive difficulties; increased risk of cancer | Leaching from linings of water storage tanks and distribution lines | zero |
| Beryllium | 0.004 | Intestinal lesions | Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries | 0.004 |
| Beta photon emitters | 4 millirems per year | Increased risk of cancer | Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation | zero |
| Bromate | 0.010 | Increased risk of cancer | Byproduct of drinking water disinfection | zero |
| Cadmium | 0.005 | Kidney damage | Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints | 0.005 |
| Carbofuran | 0.04 | Problems with blood, nervous system, or reproductive system | Leaching of soil fumigant used on rice and alfalfa | 0.04 |

LEGEND


DISINFECTANT


DISINFECTION BYPRODUCT


INORGANIC CHEMICAL


MICROORGANISM


ORGANIC CHEMICAL


RADIONUCLIDES

| Contaminant | MCL or TT[1] (mg/L)[2] | Potential health effects from long-term[3] exposure above the MCL | Common sources of contaminant in drinking water | Public Health Goal (mg/L)[2] |
|---|---|---|---|---|
| Carbon tetrachloride | 0.005 | Liver problems; increased risk of cancer | Discharge from chemical plants and other industrial activities | zero |
| Chloramines (as $Cl_2$) | MRDL=4.0[1] | Eye/nose irritation; stomach discomfort; anemia | Water additive used to control microbes | MRDLG=4[1] |
| Chlordane | 0.002 | Liver or nervous system problems; increased risk of cancer | Residue of banned termiticide | zero |
| Chlorine (as $Cl_2$) | MRDL=4.0[1] | Eye/nose irritation; stomach discomfort | Water additive used to control microbes | MRDLG=4[1] |
| Chlorine dioxide (as $ClO_2$) | MRDL=0.8[1] | Anemia; infants, young children, and fetuses of pregnant women: nervous system effects | Water additive used to control microbes | MRDLG=0.8[1] |
| Chlorite | 1.0 | Anemia; infants, young children, and fetuses of pregnant women: nervous system effects | Byproduct of drinking water disinfection | 0.8 |
| Chlorobenzene | 0.1 | Liver or kidney problems | Discharge from chemical and agricultural chemical factories | 0.1 |
| Chromium (total) | 0.1 | Allergic dermatitis | Discharge from steel and pulp mills; erosion of natural deposits | 0.1 |
| Copper | TT[5]; Action Level=1.3 | Short-term exposure: Gastrointestinal distress. Long-term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level | Corrosion of household plumbing systems; erosion of natural deposits | 1.3 |
| *Cryptosporidium* | TT[7] | Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps) | Human and animal fecal waste | zero |
| Cyanide (as free cyanide) | 0.2 | Nerve damage or thyroid problems | Discharge from steel/metal factories; discharge from plastic and fertilizer factories | 0.2 |
| 2,4-D | 0.07 | Kidney, liver, or adrenal gland problems | Runoff from herbicide used on row crops | 0.07 |
| Dalapon | 0.2 | Minor kidney changes | Runoff from herbicide used on rights of way | 0.2 |
| 1,2-Dibromo-3-chloropropane (DBCP) | 0.0002 | Reproductive difficulties; increased risk of cancer | Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards | zero |
| o-Dichlorobenzene | 0.6 | Liver, kidney, or circulatory system problems | Discharge from industrial chemical factories | 0.6 |
| p-Dichlorobenzene | 0.075 | Anemia; liver, kidney, or spleen damage; changes in blood | Discharge from industrial chemical factories | 0.075 |
| 1,2-Dichloroethane | 0.005 | Increased risk of cancer | Discharge from industrial chemical factories | zero |

LEGEND

DISINFECTANT | DISINFECTION BYPRODUCT | INORGANIC CHEMICAL | MICROORGANISM | ORGANIC CHEMICAL | RADIONUCLIDES

| Contaminant | MCL or TT[1] (mg/L)[2] | Potential health effects from long-term[3] exposure above the MCL | Common sources of contaminant in drinking water | Public Health Goal (mg/L)[2] |
|---|---|---|---|---|
| 1,1-Dichloroethylene | 0.007 | Liver problems | Discharge from industrial chemical factories | **0.007** |
| cis-1,2-Dichloroethylene | 0.07 | Liver problems | Discharge from industrial chemical factories | **0.07** |
| trans-1,2, Dichloroethylene | 0.1 | Liver problems | Discharge from industrial chemical factories | **0.1** |
| Dichloromethane | 0.005 | Liver problems; increased risk of cancer | Discharge from industrial chemical factories | **zero** |
| 1,2-Dichloropropane | 0.005 | Increased risk of cancer | Discharge from industrial chemical factories | **zero** |
| Di(2-ethylhexyl) adipate | 0.4 | Weight loss, liver problems, or possible reproductive difficulties | Discharge from chemical factories | **0.4** |
| Di(2-ethylhexyl) phthalate | 0.006 | Reproductive difficulties; liver problems; increased risk of cancer | Discharge from rubber and chemical factories | **zero** |
| Dinoseb | 0.007 | Reproductive difficulties | Runoff from herbicide used on soybeans and vegetables | **0.007** |
| Dioxin (2,3,7,8-TCDD) | 0.00000003 | Reproductive difficulties; increased risk of cancer | Emissions from waste incineration and other combustion; discharge from chemical factories | **zero** |
| Diquat | 0.02 | Cataracts | Runoff from herbicide use | **0.02** |
| Endothall | 0.1 | Stomach and intestinal problems | Runoff from herbicide use | **0.1** |
| Endrin | 0.002 | Liver problems | Residue of banned insecticide | **0.002** |
| Epichlorohydrin | TT[4] | Increased cancer risk; stomach problems | Discharge from industrial chemical factories; an impurity of some water treatment chemicals | **zero** |
| Ethylbenzene | 0.7 | Liver or kidney problems | Discharge from petroleum refineries | **0.7** |
| Ethylene dibromide | 0.00005 | Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer | Discharge from petroleum refineries | **zero** |
| Fecal coliform and *E. coli* | MCL[6] | Fecal coliforms and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes may cause short term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems. | Human and animal fecal waste | **zero[6]** |

**LEGEND** DISINFECTANT · DISINFECTION BYPRODUCT · INORGANIC CHEMICAL · MICROORGANISM · ORGANIC CHEMICAL · RADIONUCLIDES

| Contaminant | MCL or TT[1] (mg/L)[2] | Potential health effects from long-term[3] exposure above the MCL | Common sources of contaminant in drinking water | Public Health Goal (mg/L)[2] |
|---|---|---|---|---|
| Fluoride | 4.0 | Bone disease (pain and tenderness of the bones); children may get mottled teeth | Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories | **4.0** |
| *Giardia lamblia* | TT[7] | Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps) | Human and animal fecal waste | **zero** |
| Glyphosate | 0.7 | Kidney problems; reproductive difficulties | Runoff from herbicide use | **0.7** |
| Haloacetic acids (HAA5) | 0.060 | Increased risk of cancer | Byproduct of drinking water disinfection | **n/a[9]** |
| Heptachlor | 0.0004 | Liver damage; increased risk of cancer | Residue of banned termiticide | **zero** |
| Heptachlor epoxide | 0.0002 | Liver damage; increased risk of cancer | Breakdown of heptachlor | **zero** |
| Heterotrophic plate count (HPC) | TT[7] | HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is. | HPC measures a range of bacteria that are naturally present in the environment | **n/a** |
| Hexachlorobenzene | 0.001 | Liver or kidney problems; reproductive difficulties; increased risk of cancer | Discharge from metal refineries and agricultural chemical factories | **zero** |
| Hexachloro-cyclopentadiene | 0.05 | Kidney or stomach problems | Discharge from chemical factories | **0.05** |
| Lead | TT[5]; Action Level=0.015 | Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure | Corrosion of household plumbing systems; erosion of natural deposits | **zero** |
| *Legionella* | TT[7] | Legionnaire's Disease, a type of pneumonia | Found naturally in water; multiplies in heating systems | **zero** |
| Lindane | 0.0002 | Liver or kidney problems | Runoff/leaching from insecticide used on cattle, lumber, and gardens | **0.0002** |
| Mercury (inorganic) | 0.002 | Kidney damage | Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands | **0.002** |
| Methoxychlor | 0.04 | Reproductive difficulties | Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, and livestock | **0.04** |
| Nitrate (measured as Nitrogen) | 10 | Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome. | Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits | **10** |

**LEGEND** DISINFECTANT · DISINFECTION BYPRODUCT · INORGANIC CHEMICAL · MICROORGANISM · ORGANIC CHEMICAL · RADIONUCLIDES

| Contaminant | MCL or TT[1] (mg/L)[2] | Potential health effects from long-term[3] exposure above the MCL | Common sources of contaminant in drinking water | Public Health Goal (mg/L)[2] |
|---|---|---|---|---|
| Nitrite (measured as Nitrogen) | 1 | Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome. | Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits | 1 |
| Oxamyl (Vydate) | 0.2 | Slight nervous system effects | Runoff/leaching from insecticide used on apples, potatoes, and tomatoes | 0.2 |
| Pentachlorophenol | 0.001 | Liver or kidney problems; increased cancer risk | Discharge from wood-preserving factories | zero |
| Picloram | 0.5 | Liver problems | Herbicide runoff | 0.5 |
| Polychlorinated biphenyls (PCBs) | 0.0005 | Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer | Runoff from landfills; discharge of waste chemicals | zero |
| Radium 226 and Radium 228 (combined) | 5 pCi/L | Increased risk of cancer | Erosion of natural deposits | zero |
| Selenium | 0.05 | Hair or fingernail loss; numbness in fingers or toes; circulatory problems | Discharge from petroleum and metal refineries; erosion of natural deposits; discharge from mines | 0.05 |
| Simazine | 0.004 | Problems with blood | Herbicide runoff | 0.004 |
| Styrene | 0.1 | Liver, kidney, or circulatory system problems | Discharge from rubber and plastic factories; leaching from landfills | 0.1 |
| Tetrachloroethylene | 0.005 | Liver problems; increased risk of cancer | Discharge from factories and dry cleaners | zero |
| Thallium | 0.002 | Hair loss; changes in blood; kidney, intestine, or liver problems | Leaching from ore-processing sites; discharge from electronics, glass, and drug factories | 0.0005 |
| Toluene | 1 | Nervous system, kidney, or liver problems | Discharge from petroleum factories | 1 |
| Total Coliforms | 5.0 percent[8] | Coliforms are bacteria that indicate that other, potentially harmful bacteria may be present. See fecal coliforms and *E. coli* | Naturally present in the environment | zero |
| Total Trihalomethanes (TTHMs) | 0.080 | Liver, kidney, or central nervous system problems; increased risk of cancer | Byproduct of drinking water disinfection | n/a[9] |
| Toxaphene | 0.003 | Kidney, liver, or thyroid problems; increased risk of cancer | Runoff/leaching from insecticide used on cotton and cattle | zero |
| 2,4,5-TP (Silvex) | 0.05 | Liver problems | Residue of banned herbicide | 0.05 |
| 1,2,4-Trichlorobenzene | 0.07 | Changes in adrenal glands | Discharge from textile finishing factories | 0.07 |

LEGEND

| Contaminant | MCL or TT[1] (mg/L)[2] | Potential health effects from long-term[3] exposure above the MCL | Common sources of contaminant in drinking water | Public Health Goal (mg/L)[2] |
|---|---|---|---|---|
| 1,1,1-Trichloroethane | 0.2 | Liver, nervous system, or circulatory problems | Discharge from metal degreasing sites and other factories | 0.2 |
| 1,1,2-Trichloroethane | 0.005 | Liver, kidney, or immune system problems | Discharge from industrial chemical factories | 0.003 |
| Trichloroethylene | 0.005 | Liver problems; increased risk of cancer | Discharge from metal degreasing sites and other factories | zero |
| Turbidity | TT[7] | Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria. These organisms can cause short term symptoms such as nausea, cramps, diarrhea, and associated headaches. | Soil runoff | n/a |
| Uranium | 30µg/L | Increased risk of cancer, kidney toxicity | Erosion of natural deposits | zero |
| Vinyl chloride | 0.002 | Increased risk of cancer | Leaching from PVC pipes; discharge from plastic factories | zero |
| Viruses (enteric) | TT[7] | Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps) | Human and animal fecal waste | zero |
| Xylenes (total) | 10 | Nervous system damage | Discharge from petroleum factories; discharge from chemical factories | 10 |

LEGEND: DISINFECTANT; DISINFECTION BYPRODUCT; INORGANIC CHEMICAL; MICROORGANISM; ORGANIC CHEMICAL; RADIONUCLIDES

## NOTES

**1** Definitions
- **Maximum Contaminant Level Goal (MCLG):** The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- **Maximum Contaminant Level (MCL):** The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- **Maximum Residual Disinfectant Level Goal (MRDLG):** The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- **Maximum Residual Disinfectant Level (MRDL):** The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- **Treatment Technique (TT):** A required process intended to reduce the level of a contaminant in drinking water.

**2** Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

**3** Health effects are from long-term exposure unless specified as short-term exposure.

**4** Each water system must certify annually, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05 percent dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01 percent dosed at 20 mg/L (or equivalent).

**5** Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

**6** A routine sample that is fecal coliform-positive or E. coli-positive triggers repeat samples--if any repeat sample is total coliform-positive, the system has an acute MCL violation. A routine sample that is total coliform-positive and fecal coliform-negative or E. coli-negative triggers repeat samples--if any repeat sample is fecal coliform-positive or E. coli-positive, the system has an acute MCL violation. See also Total Coliforms.

**7** EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:
- ***Cryptosporidium*:** 99 percent removal for systems that filter. Unfiltered systems are required to include Cryptosporidium in their existing watershed control provisions.
- **Giardia lamblia:** 99.9 percent removal/inactivation
- **Viruses:** 99.9 percent removal/inactivation
- ***Legionella*:** No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, according to the treatment techniques in the surface water treatment rule, *Legionella* will also be controlled.
- **Turbidity:** For systems that use conventional or direct filtration, at no time can turbidity (cloudiness of water) go higher than 1 nephelometric turbidity unit (NTU), and samples for turbidity must be less than or equal to 0.3 NTU in at least 95 percent of the samples in any month. Systems that use filtration other than the conventional or direct filtration must follow state limits, which must include turbidity at no time exceeding 5 NTU.
- **HPC:** No more than 500 bacterial colonies per milliliter
- **Long Term 1 Enhanced Surface Water Treatment:** Surface water systems or ground water systems under the direct influence of surface water serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- **Long Term 2 Enhanced Surface Water Treatment:** This rule applies to all surface water systems or ground water systems under the direct influence of surface water. The rule targets additional *Cryptosporidium* treatment requirements for higher risk systems and includes provisions to reduce risks from uncovered finished water storages facilities and to ensure that the systems maintain microbial protection as they take steps to reduce the formation of disinfection byproducts. (Monitoring start dates are staggered by system size. The largest systems (serving at least 100,000 people) will begin monitoring in October 2006 and the smallest systems (serving fewer than 10,000 people) will not begin monitoring until October 2008. After completing monitoring and determining their treatment bin, systems generally have three years to comply with any additional treatment requirements.)
- **Filter Backwash Recycling:** The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

**8** No more than 5.0 percent samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or E. coli. If two consecutive TC-positive samples, and one is also positive for E. coli or fecal coliforms, system has an acute MCL violation.

**9** Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:
- **Haloacetic acids:** dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- **Trihalomethanes:** bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

## NATIONAL SECONDARY DRINKING WATER REGULATION

National Secondary Drinking Water Regulations are non-enforceable guidelines regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, some states may choose to adopt them as enforceable standards.

| Contaminant | Secondary Maximum Contaminant Level |
|---|---|
| Aluminum | 0.05 to 0.2 mg/L |
| Chloride | 250 mg/L |
| Color | 15 (color units) |
| Copper | 1.0 mg/L |
| Corrosivity | Noncorrosive |
| Fluoride | 2.0 mg/L |
| Foaming Agents | 0.5 mg/L |
| Iron | 0.3 mg/L |
| Manganese | 0.05 mg/L |
| Odor | 3 threshold odor number |
| pH | 6.5-8.5 |
| Silver | 0.10 mg/L |
| Sulfate | 250 mg/L |
| Total Dissolved Solids | 500 mg/L |
| Zinc | 5 mg/L |

### FOR MORE INFORMATION ON EPA'S SAFE DRINKING WATER:

visit: **epa.gov/safewater**

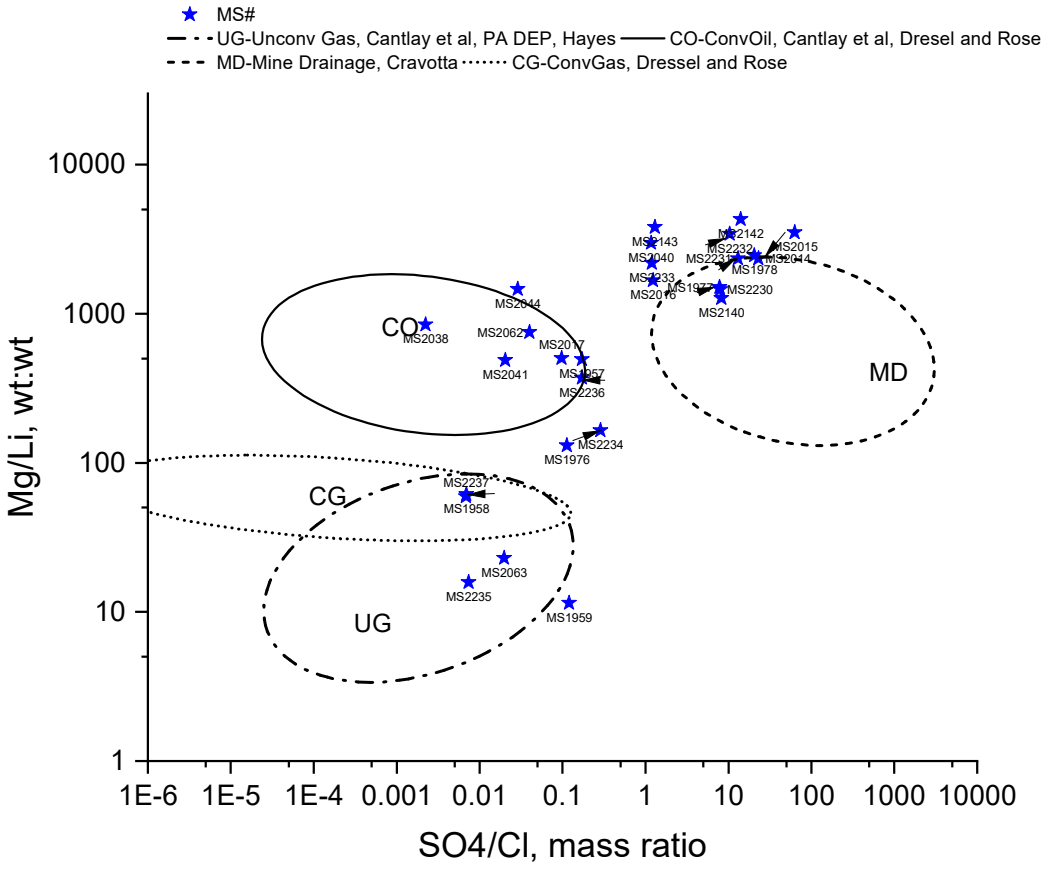
call: **(800) 426-4791**

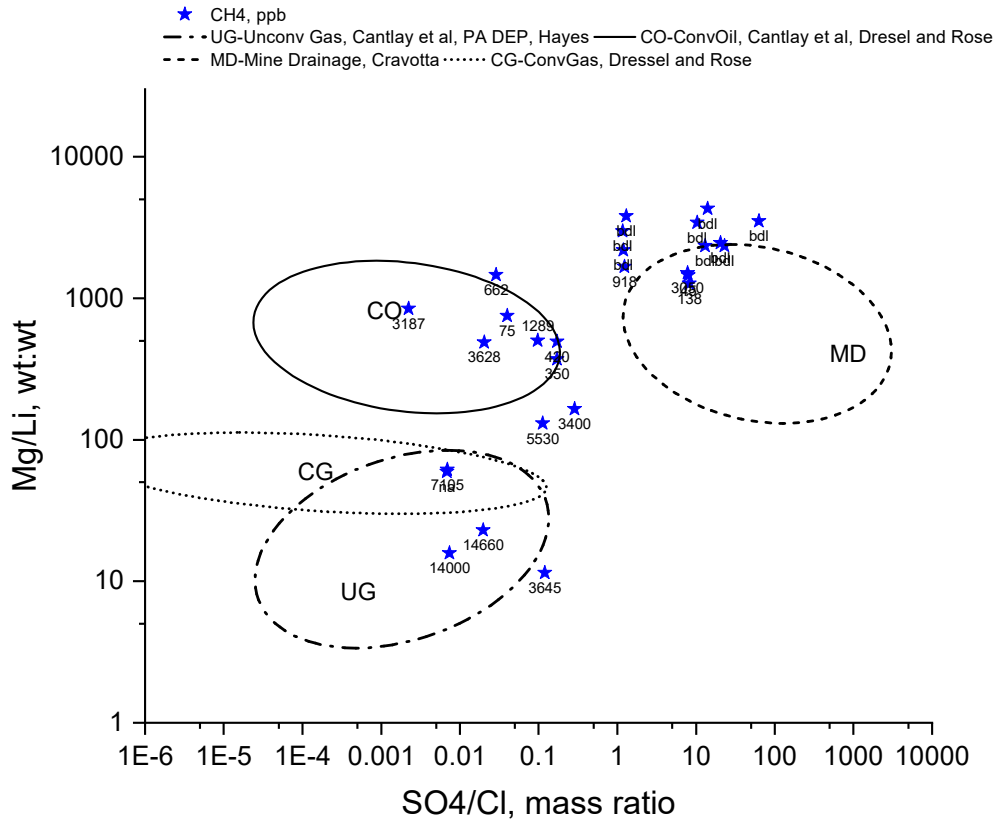
### ADDITIONAL INFORMATION:

To order additional posters or other ground water and drinking water publications, please contact the National Service Center for Environmental Publications at: **(800) 490-9198**, or email: **nscep@bps-lmit.com**.

OFFICE OF GROUND WATER AND DRINKING WATER

# APPENDIX I: MASS RATIO ANALYSIS

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CO-ConvOil, Cantlay et al, Dresel and Rose
MD-Mine Drainage, Cravotta
CG-ConvGas, Dressel and Rose
Mg/Li, wt:wt
SO4/Cl, mass ratio
CO
MD
CG
UG
662
3187
75
1289
3628
420
350
3400
5530
7185
14660
14000
3645
bdl
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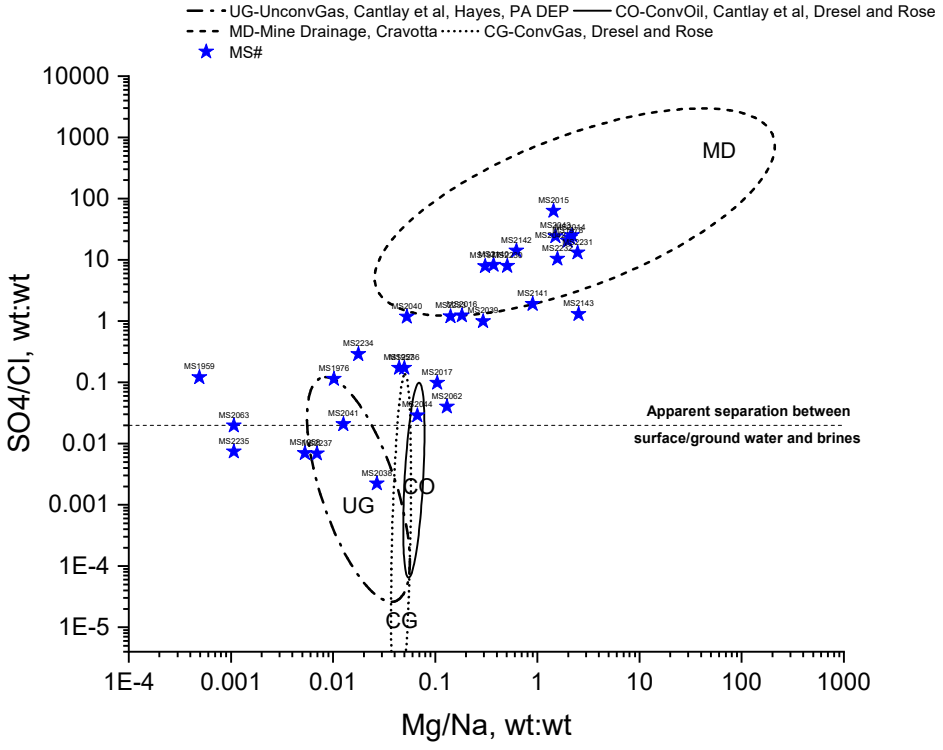
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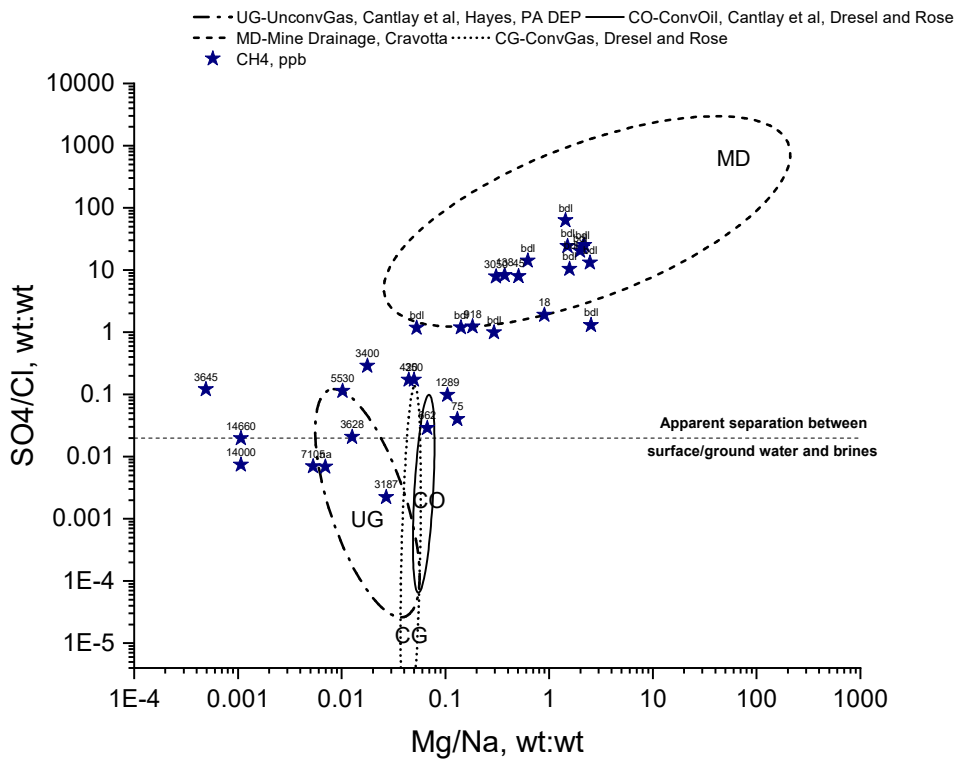
MD-Mine Drainage, Cravotta
CG-ConvGas, Dressel and Rose
MS#
SO4/Cl, wt:wt
Mg/Na, wt:wt
MD
UG
CO
CG
Apparent separation between
surface/ground water and brines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Apparent separation between
surface/ground water and brines
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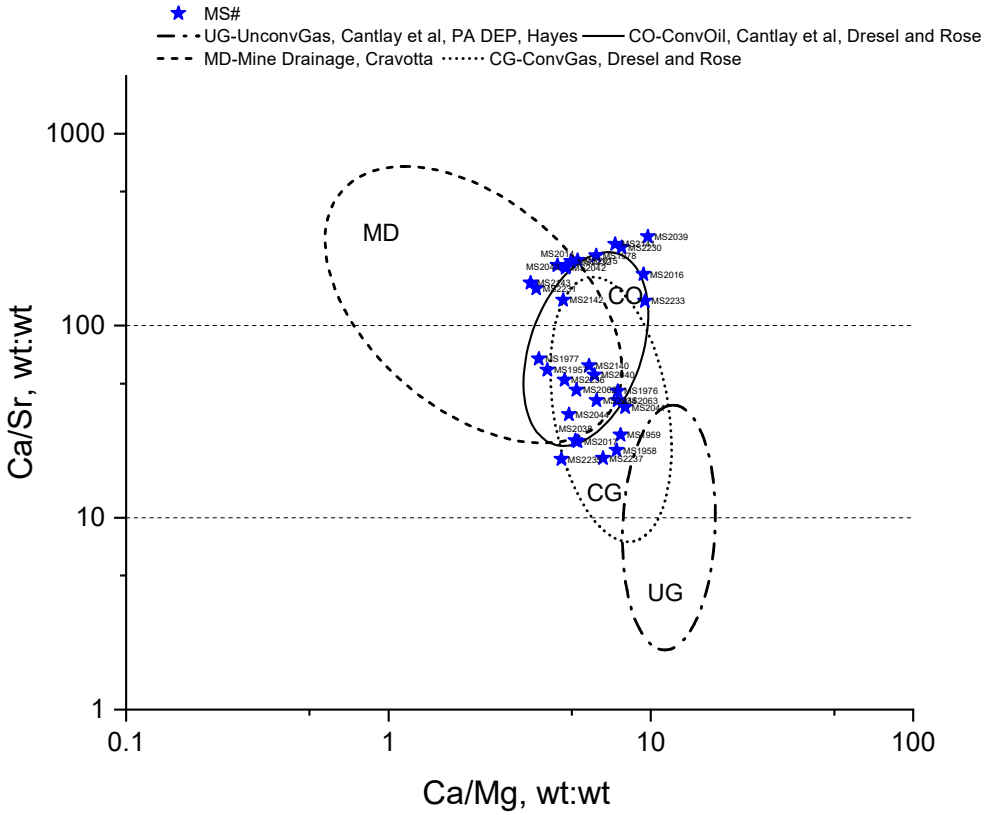
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MD-Mine Drainage, Cravotta
CG-ConvGas, Dresel and Rose
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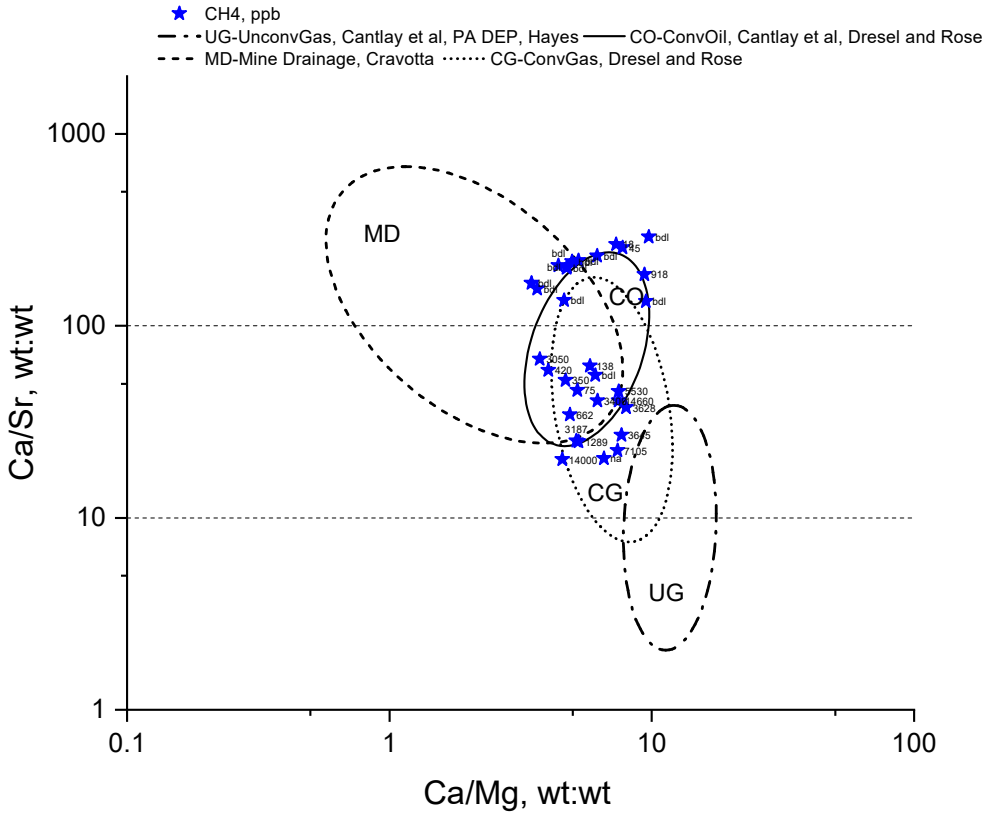
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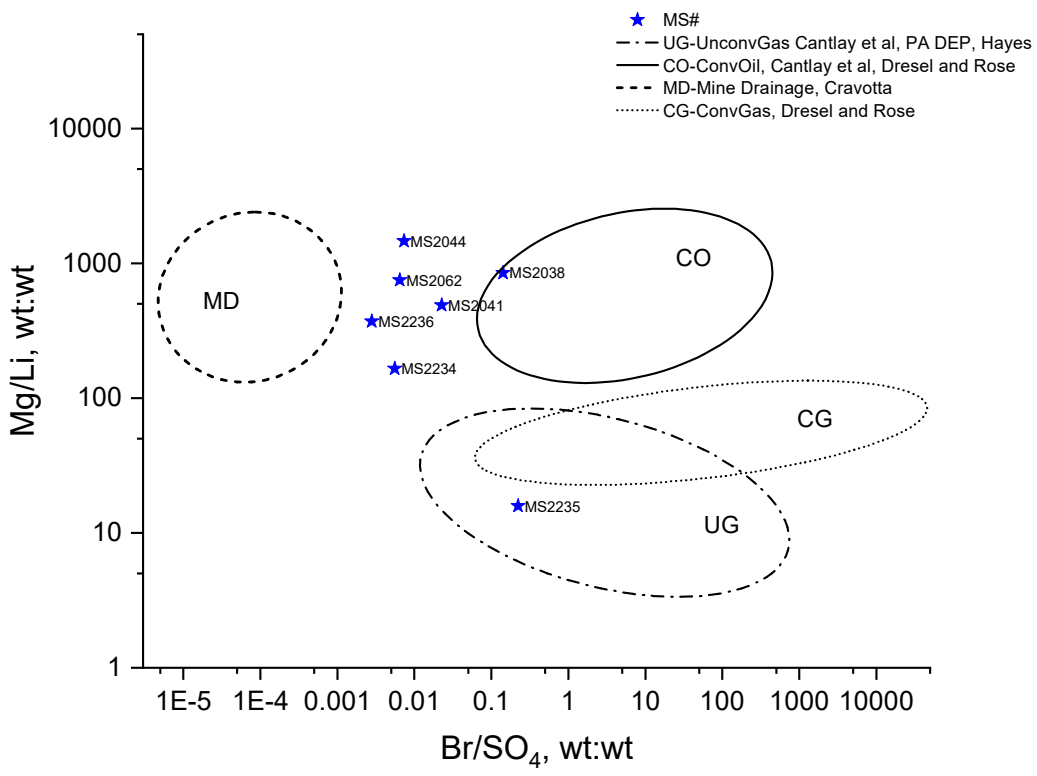
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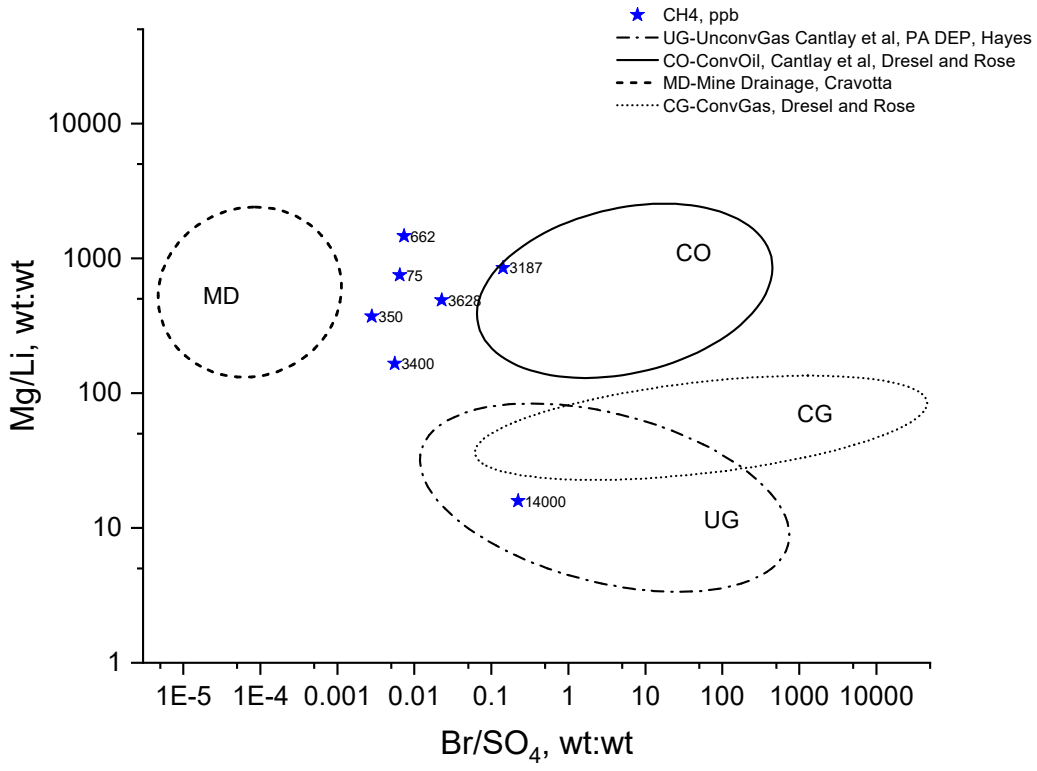
Br/SO4, wt:wt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10000
Br/SO4, wt:wt