A SYMBIOTIC RELATIONSHIP BETWEEN GOLF COURSES AND HYDRO FRACTURING:

ACHIEVED THROUGH VISUAL, PHYSICAL, AND CHEMICAL MITIGATION TECHNIQUES

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ABSTRACT

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The golf course and fracing industries have experienced much success but now have encountered certain issues within their respective markets. These issues, such as negative public perception and poor environmental practices, have created somewhat of an impasse for the two if they wish to be successful in the future. This investigation examined how these two seeming incompatible land use types can come together in order to solve each other's problems.

The integration of fracing sites and golf courses provides a potential partnership between the two industries where they both complement each other in the exact areas in which they are lacking. Fracing can provide golf courses with the revenue necessary to pull them out of their financial hole while golf courses can provide fracing with the necessary land required to expand their operations but also provide the drainage infrastructure needed to safeguard the fracing process better. With minor structural interventions, the hydro-fracing process can put in place safety measures to prevent possible environmental disasters. These sites can potentially utilize bio-mediated soils in order to provide better clean up services and also aid in the sequestration and removal of potential contaminants. This infrastructure utilized for fracing can easily be retrofitted after the drilling process is complete and become an integral part of the golf course. These areas can be integrated with the course in the form of hazards, waste bunkers, or similar golf course elements.

The two industries, when combined, can create a symbiotic relationship with each other as they both fulfill the current needs of one another. This will help to propel them into the future by improving both their financial performance as well as their public perception. The successful integration of the two will then lead to a future where both can operate harmoniously within the framework of our human environment.

This project looked at how these two industries can be integrated through the exploration of a purposed fracing site on Eagle's Mere Country Club. This site was integrated into the framework of the course and various mitigation techniques were implemented for the site through the design of new golf course infrastructure. These fracing mitigation techniques will address visual problems, soil & water contamination, and a lack of safety structures. The key to these techniques is that they will mitigate the fracing site for its potential problems while also serving as integral components of the golf course.

After this exercise it was found that much of the problems associated with fracing in regard to soil and water cleansing must be done off site. The water cleansing process requires techniques which can only be performed at treatment centers and are not available on site. However, the introduction of bio-mediated soil can help in cleansing some potential contaminants in the soil and then aid in the removal of any contaminated soil left over, specifically in the event of any accidents. Visual mitigation can be accomplished through the strategic placement of various vegetative screening areas – also functioning in conjunction with the golf course. Further visual mitigation can be accomplished by properly planning the fracing site so as to limit its visual impact on the environment. Finally, various safety structures in the form of various swales can be constructed around a fracing site to serve as a potential containment area for any hazardous materials. These areas can later be retrofitted to be incorporated into the golf course and serve as a key component in the design of a golf course.

The techniques developed in this study are rudimentary in nature; however they provide the pivotal first step towards making the fracing and the golf course industries safer, more profitable, and accepted by a broader range of the general public.

CHAPTER 1: INTRODUCTION

HYDRO-FRACTURING STATUS

The current energy portfolio of the United States is becoming more and more polarized due to the increase of hydro-fracing well sites harvesting natural gas. Natural gas comes from various shale formations found at subterranean depths of 4000-8000 feet.[1] These areas can be tapped via drilling structures which extract the gas from underground deposits. Advancements in technology have offered allowances for increasing the amount of drilling due to increased profitability of each individual well. Natural gas has thus become a more prolific form of energy utilized in the U.S. and is projected to increase its market share tremendously over the next 30 years – an expected 32% increase by 2035 (Figure 1).[2] The president has even pledged his allegiance to this energy source and claims it can "*provide a century's worth of energy*".[3]

The Marcellus Shale play is the largest in the United States, covering approximately 95,000 square miles, and offers more obtainable natural gas than any other shale play (see Figure 2). It is estimated that there is 260-490 trillion cubic feet of natural gas within the Marcellus Shale. This amount of energy, if produced, would make the United States a larger energy producer than Saudi Arabia and Russia.[4] Subsequently, utilizing all the energy found in Marcellus Shale could create 600,000 jobs[4] and would set the U.S. economy apart from the rest of the world – sparking periods of growth similar to that of crude oil booms in the past.[5]

The fracing process has invigorated highly contested debate amongst the general public and energy companies due to potential environmental concerns it presents. In order to better recognize and address these concerns, the fracing process must first be understood in depth.

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[1] Zweig, Steve. "Hydraulic Fracturing (Hydro-fracing): The Risks and Rewards of the Controversial Drilling Technique." Heating Oil LLC, 30 Nov. 2009. Web. Apr. 2012. <http://www.heatingoil.com/wp-content/uploads/2009/11/hydraulic-3.pdf>.
[2] Arthur Et. All, J. Daniel. "Water Resources and Use for Hydraulic Fracturing in the Marcellus Shale Region." ALL Consulting, LLC. Web. 15 Mar. 2012.
[3] The Breakthrough Institute. "US Government Role in Shale Gas Fracking History: An Overview and Response to Our Critics." *The Breakthrough Institute: US Government Role in Shale Gas Fracking History: An Overview and Response to Our Critics*. 12 Mar. 2012. Web. 20 May 2012. <http://thebreakthrough.org/blog/2012/03/shale_gas_fracking_history_and.shtml
[4] The Editorial Board. "Our View: Oil and Gas Boom Offers Opportunities, Risks." USA Today. Gannett, 22 Nov. 2012. Web. <http://www.usatoday.com/story/opinion/2012/11/22/fracking-natural-gas-energy-independence/1721765/>.
[5] Smil, Vaclav. "Placing the American Gas Boom in Perspective." The American. The American Enterprise Institute, 3 May 2012. Web. <http://www.american.com/archive/2012/may/placing-the-american-gas-boom-in-perspective>.

Figure 1: Estimated U.S. Shale Gas Production

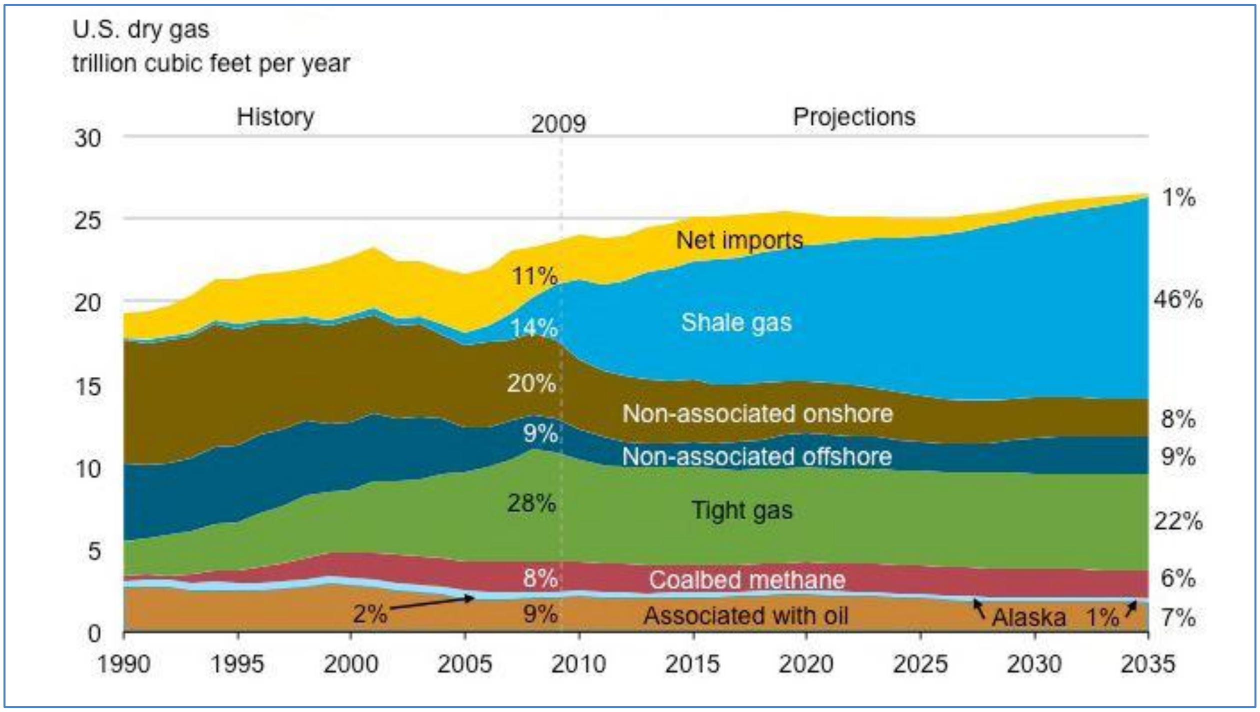
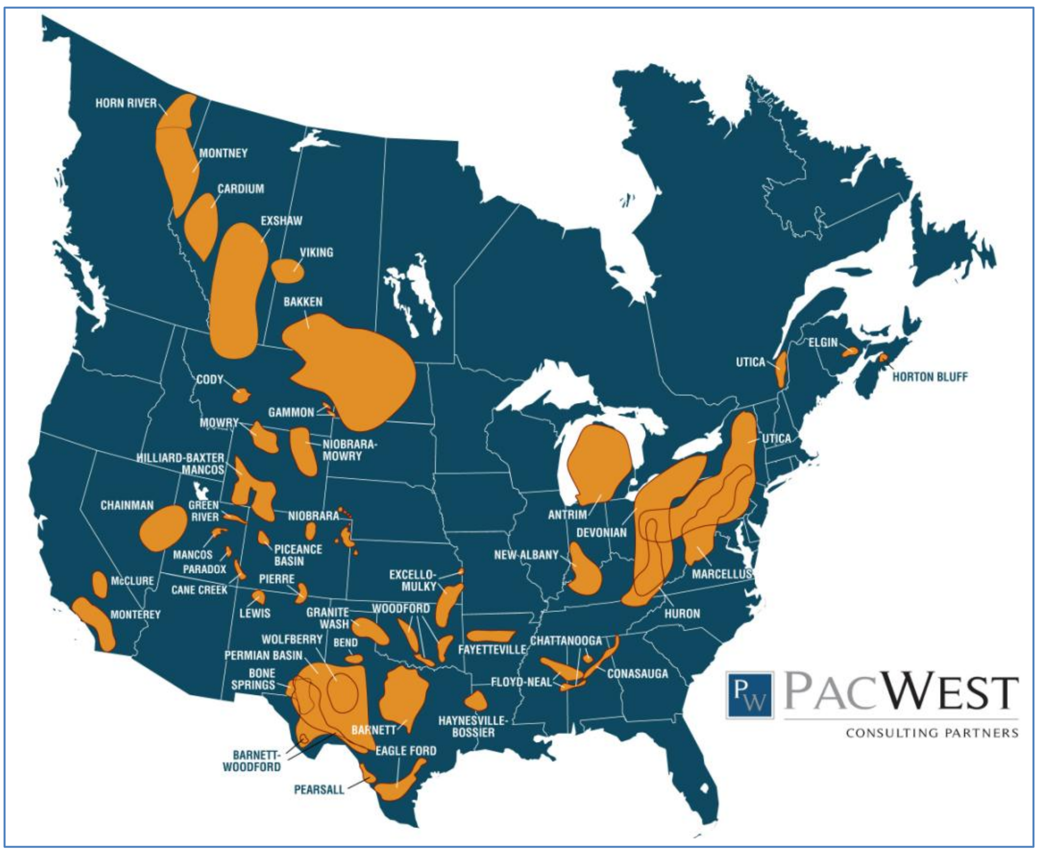


Figure 2: North American Shale Gas Plays



HYDRO-FRACING HISTORY

The drilling technique known as fracing has existed since the 1940s. Hydro-fracturing is the utilization of a high pressure water, chemical and sand mixture injected underground through well bores which causes fractures to occur in subsurface shale formations. However, it wasn't until horizontal drilling had become feasible, that this energy could be efficiently extracted.[2] The horizontal drilling technique was so successful because it created a way to extract energy from various shale plays, which up until then, were unobtainable due to their depth (4,000-8,000 ft.). Drilling at this depth required too much energy to vertically drill then could be brought up to the surface.[6] When vertical drilling was able to spread horizontally it had achieved a profitable method to extract energy - due to the increased drilling radius of horizontal exploration. This achievement was significant as shale could now provide a highly obtainable resource, due to its high porosity and low density, making it very harvestable via drilling.

In 2002 the hydro fracturing process and horizontal drilling techniques were combined resulting in one of the most profitable and efficient energy extraction techniques in history. These fractures expose natural gas which can be extracted and utilized as a form of energy.

There lies within this practice high contention amongst its critics and supporters due to the potential environmental hazards regarding the details of the drilling process.

HYDRO-FRACING PROCESS

The process of fracing has evolved over time and has become extremely efficient. Through various research tactics, an overall scientific methodology for finding, extracting, storing, and shipping this energy source has been established.

The drill site is selected through the work of geologists using seismic monitoring devices which detect the Marcellus Rock formation from 1 – 1.5 miles beneath the surface. Once Marcellus Shale is identified, a well pad is constructed above the site to engage in exploratory drilling. This site is obtained by an energy company through the purchase of the mineral rights associated with a certain plot of land. These

[6] Secretary of Energy Advisory Board. "Subcommittee Shale Gas Production Second Ninety Day Report." U.S. Department of Energy, 18 Nov. 2011. Web. 15 Mar. 2012. <http://www.shalegas.energy.gov/resources/111811_final_report.pdf>.

rights are obtained through a land lease agreement in which a dollars-per-acre amount is negotiated along with a royalty-based payment system for any gas sold from the site.[7]

A typical well pad is constructed on approximately 4-6 acres and can hold 1-9 wells depending on the spatial needs of equipment for a particular pad. The well pad is cleared of all vegetation and receives layers of sand and rock which is compacted in order to bear the load for the various equipment and storage tanks needed on site. There are also multiple pits dug on site fitted with plastic lining which will serve as containment structures for fracing flowback water until it can be transported or treated on site. A drill fixated on the well pad penetrates the ground until it is approximately 500 feet above the Marcellus Shale play (typically 4000-8000 feet deep). At this depth, referred to as the “kick point”, the drill is “turned” horizontal and spreads outward for up to 3 miles. A perforating gun is then displaced into the horizontal section of the drill hole and, using an electric charge, is detonated creating small fissures, which extend dendritically out from the horizontal portion of the well.[8]

Once the fissures are created, fracturing fluid is then pumped down into the horizontal well at very high pressure – approximately 15,000 psi. The fracturing fluid is composed of water, sand, and chemical additives – typically with 98% water, 1.5% sand, and 0.5% chemicals. A single well requires approximately 3-5 million gallons of water to be successfully fraced. This water is used primarily for the fracturing fluid but some is also used in mud-like slurry which cools the drill bit as it bores through the ground. Note Table 1, which details various chemicals used in the fracturing fluid and their corresponding impacts. These chemicals are the focal point of much of the debate regarding the safety of the fracing process. Certain experts claim these chemicals pose a sever threat to water resources and the overall health of the surrounding ecosystem.

After the fissures have been expanded via the fracturing fluid, the fluid is removed and placed into containment ponds or holding tanks until it can be transported to treatment facilities. The natural gas is now able to travel freely through the fissures, held open by sand, and through the perforations created

[7] McClure, Susan, and Roberta Winters. "Marcellus Shale Natural Gas Study Guide I-V." The League of Women Voters of Pennsylvania, 2010. Web.

[8] Packer, Kevin, and Brian DeRuschi. "Technology Taking America Out of Energy Crisis: The Rise of Fracking." University of Pittsburgh Swanson School of Engineering, 7 Feb. 2012

Table 1: Hydro-Fracturing Fluid Chemical Elements *(* = known carcinogen)*						
Element	*Common Name*	*Use*	*Vegetation Impact*	*Soil Impact*	*Wildlife Impact*	*Human Impact*
H_2O	Water	Create pressure and is base for chemical mixture	Too much water can cause certain plant species to drown	N/A	N/A	N/A
SiO_2	Sand	Keep fissures open to allow natural gas to flow out	N/A	N/A	N/A	N/A
HCL	Hydrochloric Acid	Break apart fissures in rock formation	Skin, Eye Irritant	Can alter soil pH	Can be toxic to wildlife	Can be toxic to humans
$[NH_4]^+[HSO_4]^-$	Ammonium Bisulfate	Eliminate oxygen content in frac fluid	Fertilizer	Can alter spil chemical composition	N/A	Corrosive to skin
$CH_2(CH_2CHO)_2$	Glutaraldehyde	Biocide to prevent bacterial growth and contamination	Can cause death of biological organisms and stop biological processes	Can kill microorganisms in soil	Can alter ecological processes	Skin, eye, nose, throat, lung irritant
NaCl	Sodum Chloride	Lower the viscosity of fluid	Can kill vegetation and make areas unable to grow future vegetation	Can alter soil pH	N/A	N/A
$C_{12}H_{23}$	Diesel	Lubricant	Can kill vegetation in large quantities	Can alter soil chemical composition	N/A	Fumes from burning can be an irritant
CH_3OH	Methanol	Fuel additive; bi-product of certain chemical reactions	Causes temperature increase	N/A	Air Pollutant	Respiratory irritant; lethal if ingested in large quantities
C_3H_8O	Isopropanol	Used as a product stabilizer	Can irritate or kill plant life	Can slightly disrupt soil pH	N/A	Eye irritant
NaOH	Sodium Hydroxide	Adjust composition pH	Can irritate or kill plant life easily	Greatly increases soil pH	Can alter ecological processes	Skin burns or blindness
$C_2H_6O_2$	Ethylene Glycol	Product stabilizer	Can kill plants in large quantities	Can alter microorganism life in soil	Can cause severe illness or death	Eye, respiratory, central nervous system disruption
C_6H_6	Benzene*	Diesel bi-product	N/A	N/A	Can cause severe cardiovascular/respiratory failure	Central nervous system & cardiovascular failure
C_7H_8	Toluene*	Diesel bi-product	N/A	N/A	Can cause respiratory failure and death	Can cause respiratory failure and death
$C_6H_4C_2H_6$	Xylene*	Diesel bi-product	N/A	N/A	Eye & respiratory irritant	Eye & respiratory irritant; can cause death or blindness; known carcinogen
C_8H_{10}	Ethylbenzene*	Diesel bi-product	N/A	N/A	Pulmonary adema, paralysis	Cardiovascular disruptor
$C_{10}H_8$	Naphthalene	Carrier fluid for active ingredients	Can adversely affect plant growing efficacy	N/A	Eye, nose, throat irritant	Eye, nose, throat irritant
C_7H_7Cl	Benzyl Chloride*	N/A	N/A	N/A	N/A	Known carcinogen
Cu	Copper	Bi-product	N/A	N/A	N/A	Skin irritant in high quantities
Pb	Lead	Bi-product	Toxin	N/A	Toxin	Toxin
C_3H_5NO	Acrylamide	Used as a friction reducer	N/A	N/A	Neuro & reproductive toxin & carcingogen	Central nervous system disruptor
CH_3COOH	Acetic Acid	Prevents metal oxide precipitation	N/A	N/A	Minor eye irritant	Minor eye irritant
$(AlO)_2SiO$	Aluminum Silicate	N/A	None	None	None	None
C_2H_6O	Ethanol	Product Stabilizer	N/A	N/A	N/A	N/A
$Al_6Si_2O_{13}$	Mullite	Keep fissures in rock open	N/A	N/A	N/A	N/A

earlier by the small explosions. A well cap is then placed on the drill hole and the natural gas can be pumped to the surface or saved for later use. This natural gas can be liquefied for ease of transport to potential users. For an extensive overview of the fracing process direct your attention to the "Horizontal Hydraulic Fracing" report in the appendix.[1]

Figure 3: Natural Gas Well Capped for Storage

After this process approximately 11% of the sand, water, and chemicals return to the surface and must be contained and treated. The remaining 89% remains underground and can potentially invade nearby subsurface water and soil systems (although this is considered very unlikely due to the extreme depth of drilling).[9] This potentially harmful water (frac fluid) located above and below ground, has the potential to compromise the health of wildlife populations, ecosystems, and drinking water supplies.

After drilling, the area essentially serves as a storage facility for all the natural gas underground and can be extracted from the well cap at a moment's notice (see Figure 3 for an image of a capped well drill

[9] Poole, David T. "Hydraulic Fracturing of Unconventional Gas Shales: Potential Pollutants, Treatments and Remediation." The Ohio State University, 18 May 2012. Web. <http://senr.osu.edu/images/Poole_final_MENR_project.pdf>.

hole). The area remains as is until no more natural gas is obtainable from the underground holding area. At this point, it is the duty of the energy company accountable for drilling to restore the site to its original condition within a 9-month period. This restoration is monitored by local governments and the associated governing entity.[10] Many times the oversight of this process is either done in a very cursory manner or not done at all. This has left fracing well pads, which have already been used, in a decrepit state and a nuisance to the aesthetics as well as local ecological systems of the area.

This novel energy harvesting technique is so new that it exists without much regulation and is able to keep many of the effects of its process hidden from public scrutiny. This process is currently exempted from The Clean Water Act, The Clean Air Act, and the Safe Drinking Water Act via the Energy Policy Act of 2005. This policy was initiated and promoted by the Bush administration.[11] This legislation further compounds the difficulty of regulating this industry and increases the negative public opinion. This negative opinion stems from the practice being viewed as being done "behind closed doors". As more and more research on the environmental degradation caused by fracing is revealed, there is increasing pressure from the public and various organizations to restrict and regulate how this process occurs.

HYDRO-FRACING PROBLEMS

The problems most identified with regarding fracing revolve around water, soil, visual resources, and an overall lack of safety infrastructure. These problems must be addressed and mitigated for if fracing expects to grow at the projected rate and have such a monumental and lucrative effect on the economy. By addressing these issues the public can potentially become accepting of the practice and it can gain more support from previous detractors.

First and foremost, the issues regarding water and fracing are the most contested. Each individual well used for fracing requires approximately 3-5 million gallons of water in order to be successfully fraced. This water is obtained by purchasing the rights to nearby water systems or through the direct purchase from a water distributor. With nearly 509,000 well pads and counting, and each well pad containing 1-9

[10] Zweig, Steve. "Hydraulic Fracturing (Hydrofracking): The Risks and Rewards of the Controversial Drilling Technique." Heating Oil LLC, 30 Nov. 2009. Web. Apr. 2012. <http://www.heatingoil.com/wp-content/uploads/2009/11/hydraulic-3.pdf>.

[11] Griffith, Benjamin E. "Fracking for Shale Gas: Energy Security & Sustainable Water Resources." *World Jurist Association 24th Biennial Congress on the Law of the World National Legal Cultures in a Globalized World*. N.p., 27 Oct. 2011. Web. <http://www.griffithlaw.net/document.pdf>.

wells, there is an immense amount of water necessary in order to properly undergo the drilling process. Clearly the amount of water used in this process is a staggeringly total, and if the projections of fracing grow at the expected rate, the expected use of water will increase proportionally. This expected water need is somewhat troubling in regard to environmental impacts but so is the chemical substances added to the water.

In order for the fracing process to work properly a mixture of various chemicals and compounds must be incorporated into the mixture (note Table 1). These chemicals all play a role in the fracing process and help to do things such as provide drill lubricant, prevent bacterial growth, aid in the fracturing of shale, etc. The troubling aspect to these chemicals comes in their potential contamination of both groundwater and surface water resources which can occur before, during, or after the drilling process takes place.

Potential soil contamination is another cause for concern regarding fracing and its impact on surrounding areas. All of the chemicals utilized in the water resources can similarly affect various soil resources and impact their role in the environment.

There are also the difficult visual problems presented by a fracing site. These areas are large and extend up to 100 feet in the air. These areas must be properly screened both at the site and at various locations which will have direct views oriented towards the site. The negative visual stigma associated with fracing and its supporting infrastructure creates a sizeable public perception problem which must be solved.

Finally, fracing lacks various safety structures which would help to safeguard the process better from contaminating surrounding areas. Currently, the open brine pits and chemical mixing areas can easily spill and spread throughout the landscape. This creates a major potential health hazard for surrounding areas and makes it much more difficult to manage and contain any potential contaminants.

The various problems regarding fracing involving water & soil contamination, visual resource degradation, and a lack of safety structures must be addressed in order to improve the fracing industry. In doing so, fracing can become better integrated within the framework of our ecosystems as the industry progresses into the future.

GOLF COURSE INDUSTRY STATUS AND PROBLEMS

The golf course industry is currently in disarray. Statistically speaking, 47% of golf courses worldwide have seen a decline in revenue along with a 39% decrease in rounds played per year.[12] These figures are indicators of the lack of financial revenue available for the public to pursue an interest in the game of golf. Without a growing customer base, an increasing number of golf courses will soon either be forced to change their design and management techniques in order to sustain themselves, or they will go bankrupt and close, turning into grey fields

Golf courses must view sustainable management and environmental stewardship as a competitive advantage to be gained against their opposition in the industry. The leading courses in the world are the ones incorporating environmental stewardship into their actual business models and generating large revenues because of it. As the golf industry continues to evolve, it will become more competitive amongst the surviving courses and subsequently breed new innovations in the field and spur on a new era in golf course design and management.[13] This new era will revolve around the original principles of golf course design:

- ✓ Hole variety
- ✓ Player experience
- ✓ Environmental strengths and weaknesses

These new innovations must come in the form of multi-use operations occurring on golf courses while experimenting in new industries and ways to create a sustainable revenue stream. Golf courses need to find a new revenue source which can relieve of them of their financially decrepit state and be re-invested into the course for re-designs and sustainable retrofitting. One potentially beneficial resource the golf course industry can utilize is the hydraulic fracturing drilling industry.

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[12] Sartori, Andrea. "Golf and the Economic Downturn." KPMG Consulting, 2010. Web. <http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/Golf-and-the-economic-downturn.pdf>.

[13] Dodson, Ronald G. *Sustainable Golf Courses: A Guide to Environmental Stewardship*. Hoboken, NJ: J. Wiley & Sons, 2005. Print.

IMAGE CREDITS

Figure 1

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Figure 2

PacWest Consulting Partners. "North America Shale Plays." Web. 21 May 2012. <http://pacwestcp.com/wp-content/uploads/2012/01/PacWest-NA-Shale-Plays-Template-Map-FINAL.jpg>.

Figure 3

Photo by Matthew Franko of Chesapeake Energy Well # HJMM WYO 1H - Cappucci 2H

Table 1

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CHAPTER 2: RESEARCH METHODOLOGY

RESEARCH QUESTION

If a golf course is designed as part of a visual improvement and ecological restoration structure for a fracing well pad, can it meet the requirements for successful mitigation practices while maintaining the integrity and viability of the golf course? If so, what would be the impacts on the way the game of golf is played and how would it need to potentially change? This information would be incredibly relevant in the industry as it will:

- ✓ Explore various repurposing of golf course infrastructure
- ✓ Study the best ways to mitigate for fracing waste products and offset the negative aesthetic qualities of well pads

If these two purposes can be researched and designed they can potentially lift the depressed golf industry and mitigate the harmful effects of fracing to a point where it can become publically safe and acceptable. This research can also potentially be applicable to other industries and provide fracing with measures that can make its process safer regardless of where it is performed.

GOLF COURSE AND FRACING INTEGRATION

The fracing industry can provide golf courses with an incredibly valuable revenue generator which serves as a mild inconvenience for a small period of time. This revenue can come from initial up front leasing profits and subsequent royalties associated with the selling and distribution of the natural gas harvested on site. This combination may seem odd but the two industries form somewhat of a unique combination in which each industry fills a void of the other.

Golf courses specialize in aesthetically pleasing environments and creating visually stimulating scenes. The harsh visual scenarios presented by fracing, provide golf courses a useful opportunity to integrate various screening and visual buffers for the fracing site into the golf design. These areas, when planned properly, can be identified ahead of time and serve as visual mitigation for fracing but also as an intricate part of the course design and strategy. This will limit the negative visual stigma associated with fracing and help to make fracing in the landscape appear less intrusive

Visual mitigation is effective but the process still requires infrastructure which can help to capture and cleanse an area from potential fracing water and soil hazards. Golf courses are designed essentially as giant storm water collection facilities. They are very effective at controlling where water on the course is directed to and is subsequently collected. They must be good at this practice as a majority of the time they are required by law to contain all stormwater on site and it is impermissible to have the water leave the area.[1] One of the major concerns with fracing is the potential for surface spills of various harmful chemicals, toxins, heavy metals, and radioactive materials. If this process were to occur on properly designed golf courses then any potential spill can successfully be contained on site and greatly diminish potential damage it could cause. This would effectively limit the impact potential fracing water contamination to the constraints of the course itself and help to prevent any outside ecosystem contamination.

The golf course can also lend its stormwater infrastructure to potential fracing sites as a means to add accident prevention and protection measure. Currently, there are no accident prevention structures surrounding fracing sites. This can lead to the potential for chemical spillage and absorption into nearby ecosystems, aquifers, and other valuable natural resources. If proper analysis and planning is done, then various swales, depressions, and other catchment areas can serve as safeguards against fracing accidents. This infrastructure can later be slightly remodeled to become part of a golf course in the form of hazards, waste bunkers, etc.

Golf courses integrated with fracing, if designed properly, have the potential to:

- ✓ Serve the overall community by helping to visually screen the fracing process
- ✓ Serve the environment by protecting valuable ecosystem processes and wildlife
- ✓ Serve the public by providing recreation and protecting valuable water resources
- ✓ Serve the energy companies by providing an economically beneficial way to mitigate for and contain the potentially harmful outputs caused by fracing
- ✓ Serve the golf course by providing a needed source of revenue
- ✓ Serve as a way to restore well pads after use

Through this development, a symbiotic relationship is created as certain golf course infrastructure can serve as a safeguard for the fracing process while also obtaining revenue from the very process it is

[1] "A Tale of Two Courses - Golf Course Industry." *Golf Course Industry - News, Resources for Golf Course Superintendents, Turf Care, Managers*. Golf Course Industry, 27 July 2010. Web. 11 Feb. 2012. <http://www.golfcourseindustry.com/gci-0710-tale-two-courses-cover-feature.aspx>.

protecting. This added revenue can help a golf course pay for rising maintenance fees and defray the loss of revenue due to a lack of greens fees and memberships. In certain instances the added revenue can provide a great opportunity to invest back into the golf course in a way that will attract new customers. This reinvestment can come in the form of course re-designs which cater more to increasing the experience for the player and improving the overall course design.

Another great redistribution of the added revenue from fracing can be in the form of sustainable retrofitting which can defray the accelerating costs of golf course maintenance. By reducing these costs they can also reduce their impact on the environment, which would make the industry more widely accepted among the general public.[2] Through sustainable retrofits, courses can become more self sufficient and able to exist on their own merits. Golf courses' ability to function on their own is an attribute they have lacked for some time and is a major reason for the decline in golf course success recently.[3]

This project will explore this integration by first addressing the status of both industries and what problems are associated with their current status. As these problems are identified, potential solutions can be hypothesized which relate to fracing and golf individually and collectively. Once these solutions are hypothesized a site will be selected in order to hypothetically implement the potential solutions. The chosen site will go through a critical analysis analyzing fracing and golf elements separately and collectively. All of the data collected in this phase will be synthesized to develop strength and weakness areas. By utilizing these areas the potential solutions can be implemented through the design of new golf course infrastructure which will aim to solve both the fracing and golf associated problems. (See Figure 1 for a research methodology diagram)

The integration of hydro-fracing and golf course retrofit design, in the long run, can make fracing safer, save the golf course industry by increasing revenue, and inspire an increase in sustainable golf course renovation. This can yield a long-term return on the short-term investment of fracing.

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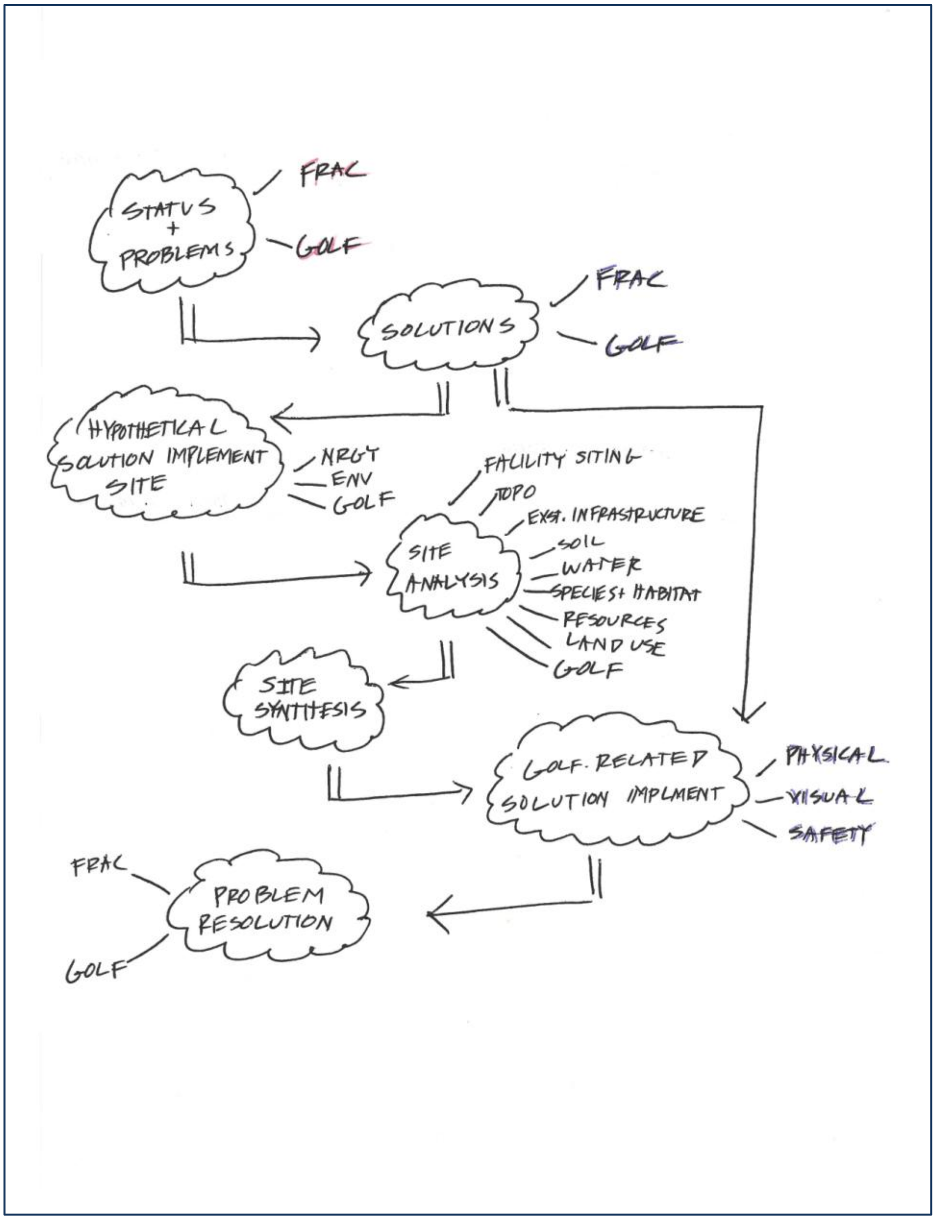
[2] Audubon, Internation. "Golf's Green Bottom Line: Uncovering the Hidden Business Value of Environmental Stewardship on Golf Courses." United States Golf Association, Sept. 2007. Web. <http://auduboninternational.org/PDFs/GolfsGreenBottomLine2009.pdf>.

[3]

Figure 1: Research Methodology Diagram



LIMITATIONS

This study will be limited in that finding a fracing site which resides on or adjacent to a golf course would require some luck and extremely fortuitous timing. Due to these circumstances, certain limitations and assumptions will be made.

In this study it is understood that Eagle's Mere Country Club in Sullivan County, Pennsylvania is exploring potential natural gas drilling on or in the vicinity of its existing golf course. The researcher will develop a hypothetical drilling site and utilize this for the duration of the study. This will be done as the time to process and wait for drilling site selection does not fall within the timeframe for the research process.

The study will also limit its evaluation of chemicals used in the fracing process to those which present the most potential danger to ecosystems. Many types of chemicals are used in this process in varying quantities and it is impossible to predict exactly which will be used. Also, the chemical information is protected by trademark laws and companies do not have to give full disclosure of the chemicals they use as it is considered proprietary information. Finally, due to the nature of their complexity they would require a chemist to provide a full and detailed examination of the chemicals used as this is beyond the scope of a landscape architect expertise as well as a master's project.

PROJECT FESABILITY VIA REGIONAL SUITABILITY ANALYSIS

The process for determining appropriate locations for a hydraulic fracturing well site is a complicated convergence of variables which all must be accounted for in order to run a successful and safe well. The emphasis in this process must come from a safety standpoint in order to protect all of those to be impacted by the drilling – including plants and animals. This safety is addressed by understanding the impact fracing can have on an area, and the areas surrounding it. Through this understanding an attempt can be made to minimize the overall footprint of the well pad on the landscape.[4] By limiting their impact, fracing sites can be less obtrusive in the landscape and give ecosystems a chance to rebound from the initial jolt caused by a drilling project.

This exercise was done as an attempt to justify the potential fracing on or adjacent to Eagle's Mere Country Club. Unfortunately, the time scale for the overall legal and financial process of fracing site selection does not fall within the time frame of this research project. By doing this suitability assessment of Sullivan County where Eagle's Mere is located, the researcher can move on confidently with the project and know that the anticipated work to be done is based in a logical sequence of potential events.

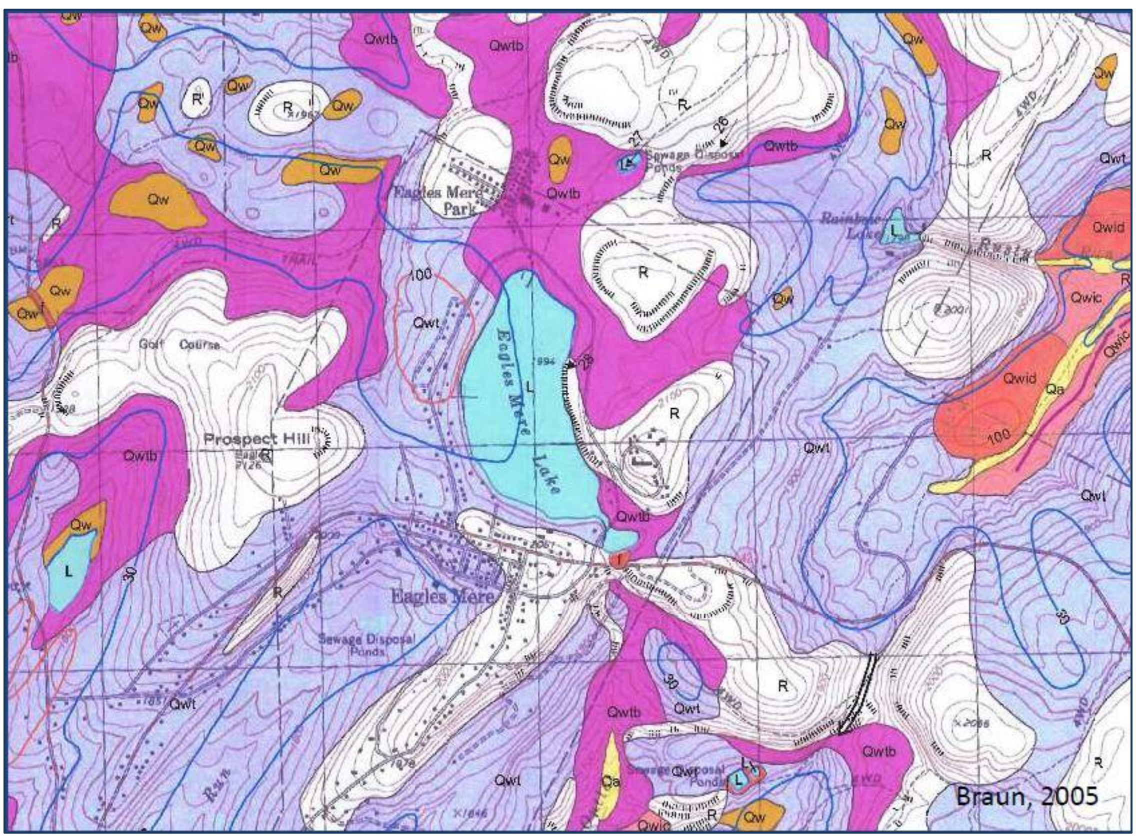
[4] Secretary of Energy Advisory Board. "Subcommittee Shale Gas Production Second Ninety Day Report." U.S. Department of Energy, 18 Nov. 2011. Web. 15 Mar. 2012. <http://www.shalegas.energy.gov/resources/111811_final_report.pdf>.

REGIONAL PERSPECTIVE

It is important to develop a regional scale when it comes to planning for hydraulic fracturing sites. This will help to better extrapolate the impact a well can have on an area, as well as, present scenarios or concerns which might go overlooked at the local level. The regional scale approach helps to guarantee that all of the people, plants, and animals to be impacted are accounted for in the planning process.

Perhaps the most important considerations to make when regionally planning a fracing site is in regard to the various watersheds in the area as they serve as drainage basins for any potential hazardous waste (see Figure 2 for a watershed map of Eagle's Mere Borough). The watersheds of the region will absorb any and all elements involved in fracing, whether it is water, diesel fuel, chemicals, etc. These water sheds must be identified so the overarching hydrology can be mapped out and understood by the engineers. Eagle's Mere and the surrounding areas in Sullivan County offer a multitude of resources which must be inventoried and analyzed through GIS in order to properly incorporate and utilize them in a suitability analysis.

Figure 2: Eagle's Mere Lake Watershed Map



GIS UTILIZATION

The first class of information that needs to be gathered to begin the regional analysis is resources utilized for fracing. This includes but is not limited to: water supplies, sand and rock manufacturing areas, roadways, and water treatment facilities. This data is important because drillers are required to develop their own infrastructure to construct a site and the less construction and travel they must go through during the entire drilling process will result in less overhead spending, greater profit, and decrease the chances of environmental mishaps.

The next set of data to collect deals with soil and the varying permeability within different soil types. It is crucial to know what types of soils will be on potential sites so the proper needs for drilling can be established. This will help to understand how the ground will percolate when exposed to liquids (perk test). It would be ideal to have perk test data so as to choose areas with the proper drainage for the drilling procedures performed on site. This information will determine how any potential disasters would react to certain sites as well as how structurally appropriate certain areas will be for placing massive infrastructure on them associated with fracing.

Another data set which must be obtained, which is linked to soil types, is the topography of the area. Through topographic analysis, various view sheds can be determined, drainage locations can be chosen and the overall lay of the land can be established. Also, to address the regional scale, any hydrologic connections (drainage) to surrounding areas can be established in order to plan for potential safeguards to protect surrounding hydrologic systems. The topography will also help to map out the potential facility location to minimize the construction needs (cut and fill) as well as to establish the drainage plan and locate structures for the particular area. This can save a company a lot of overhead in the construction process and also help to better prevent leakage to nearby areas causing environmental concerns.

The next important piece of data to be studied is the land use plan for the area in question. The land use plan is critical as it establishes what the adjacent areas are involved in and can better direct the synthesis process towards proper, analogous uses compatible with hydraulic fracturing. A second benefit for understanding a site’s land use plan is gaining a better understanding of where people are located within the context of a site.

It is also important to consider various environmental variables and data when performing fracing overlay synthesis. The first environmental factor to consider is the boundaries of various protected lands as dictated by local, regional, and federal governments. It is not only necessary to establish these lands but to also identify proper linkages and buffers for them so as to not disrupt their place in the landscape during or after the drilling of well pads. Protecting these areas will save an energy company capital from potential mitigation costs and fines as well as protect the surrounding area throughout the process.

For the same reasons, it is important to identify data layers which represent the natural resources of the area. These can range from aquifers, wetlands, to fossil fuels, carbon sequestration areas, etc. By identifying and protecting these areas the drillers can move towards an “energy positive” approach in which their impacts for energy drilling do not limit or take away from the other energy-creating processes occurring nearby.

Finally, it is important to identify what endangered species of plants and animals are residing within the area. The fracing process can be intrusive and many endangered species habitats must be protected when such a drastic change in the landscape occurs. By protecting the most vulnerable species, there is a good chance that many other species will be protected in the process as well.

All of this data is vitally important in the analysis and synthesis phases of the drilling site selection process. It is for this reason that this process is being proposed as a means to properly identify fracing sites with information which may not be currently utilized to it full potential. This data provides a positive step forward for the driller in regard to finding an acceptable location in the landscape to drill. To recap, the information utilized in the process is:

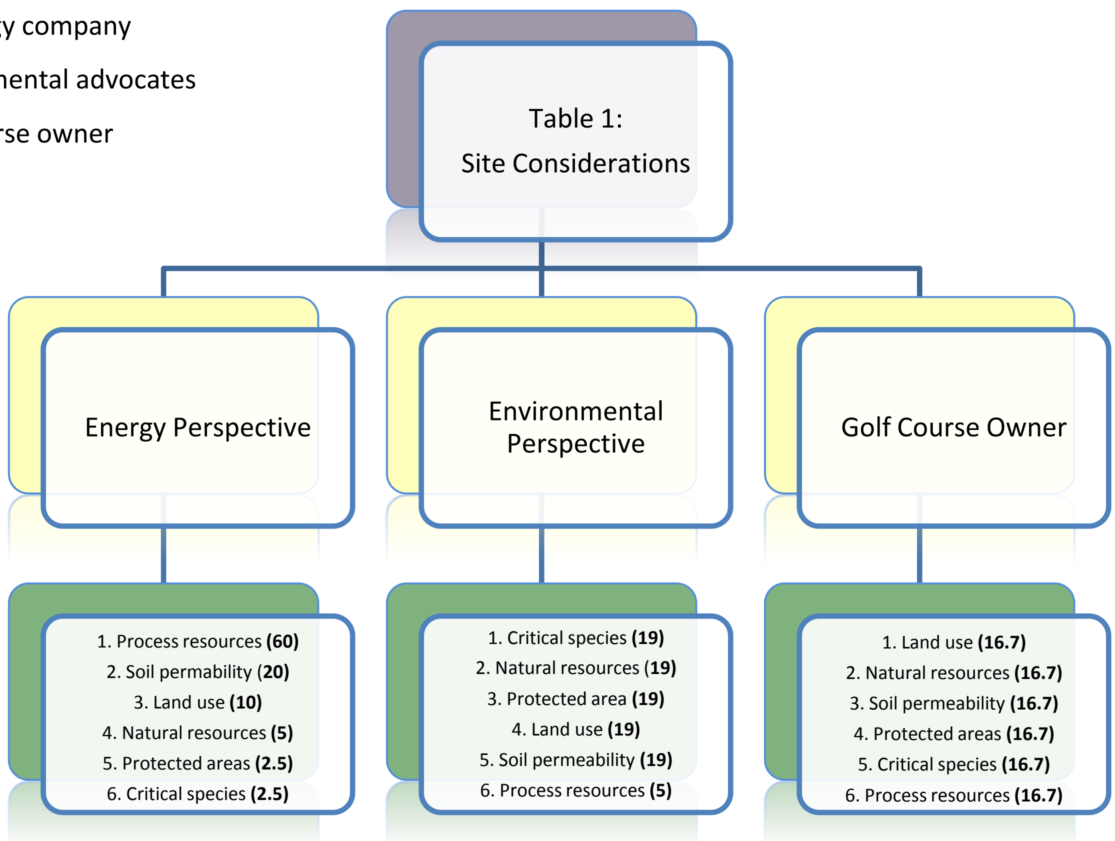
- ✓ Resources for fracing
- ✓ Soils
- ✓ Topography - hydrology
- ✓ Land use
- ✓ Protected areas
- ✓ Natural resources
- ✓ Endangered species

SELECTION CRITERIA OF DATA

Once the necessary data is obtained it can be given different weighting (numerical scale of 0-100) based on its importance associated with a particular stakeholder. The information can then be incorporated into GIS digital data and a priority list can be compiled for the different viewpoints represented by all parties involved (see Table 1). It is important to account for stake holder values within the data sets and make sure to incorporate these value estimations in the various scenarios presented in order to more accurately identify all stake holder opinions. It is up to the researcher to investigate and make assumptions regarding the hierarchy of the data in reference to each perspective utilized in the suitability process.

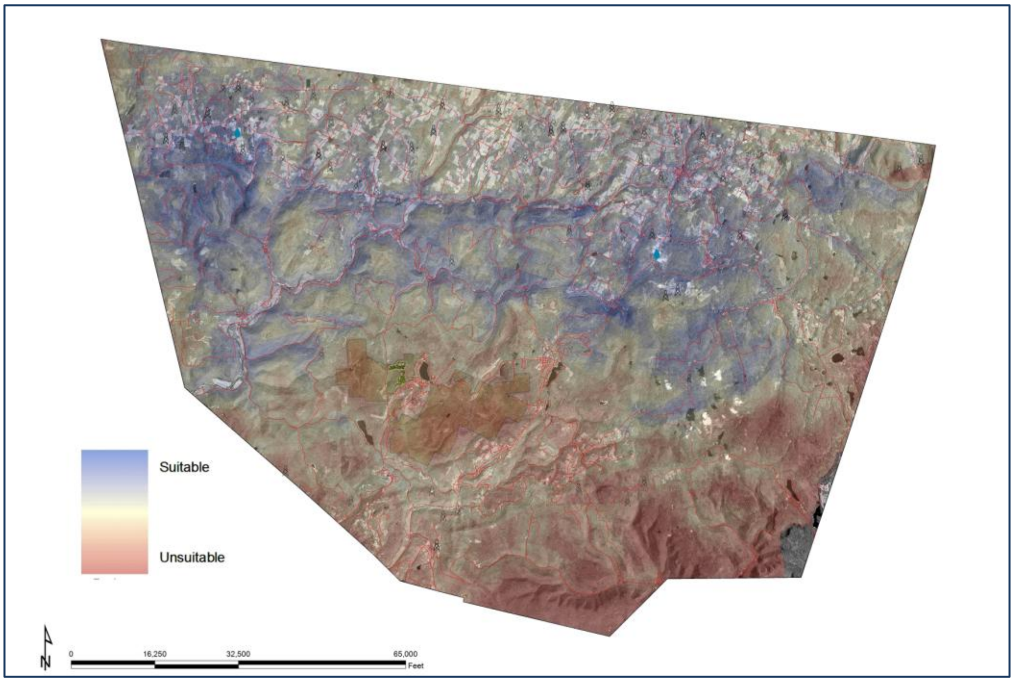
In this scenario for Sullivan County, various numerical values were ascribed to three distinct viewpoints based on their involvement in fracing. The three perspectives were that of:

1. An energy company
2. Environmental advocates
3. Golf course owner



It was assumed the energy company would be most concerned with the fracing process so they received the highest weighting for data regarding resources for fracing (60). Next, soil permeability and land use were ranked with corresponding values of (20) and (10) as this information would help to serve as a means to determine if a site could handle particular infrastructure. Finally environmental factors were ranked low and received values of (5) or less as these factors would not influence the decisions of an energy company. (Note Figure 3 for the energy company suitability map)

Figure 3: Energy Company Drilling Suitability Map



The environmental advocates received essentially the opposite weighting values of the energy company. It is believed their highest priority would be the environment so they had their highest weighted data represented as the environmental factors, such as: critical species, natural resources, and protected areas – all receiving values of (19). The environmental perspective also received values of (19) for land use and soil permeability as these factors will directly impact the viability of various habitat regimes and function with the environmental factors concurrently. Finally the fracing resources received a value of (5) as they were of the lowest importance to the environmental perspective group. (Note Figure 4 for the environmental advocate suitability map)

The final group to be represented in this assumptive analysis is the golf course owner. This perspective was valuable as it was assumed they would value the environment and the energy perspective equally – seeing as how they gain something from each. They want to successfully frac as a means to generate revenue but they also must protect their environmental resources as they are critical to the function and aesthetics of their golf course. Seeing as how both of these influences are important, all values in the golf course owner group received equal values of (16.7). This created an egalitarian approach to the golf course suitability analysis and formed somewhat of a compromise between the energy and environmental perspectives. (Note Figure 5 for the golf course suitability map)

Figure 4: Environmental Drilling Suitability Map

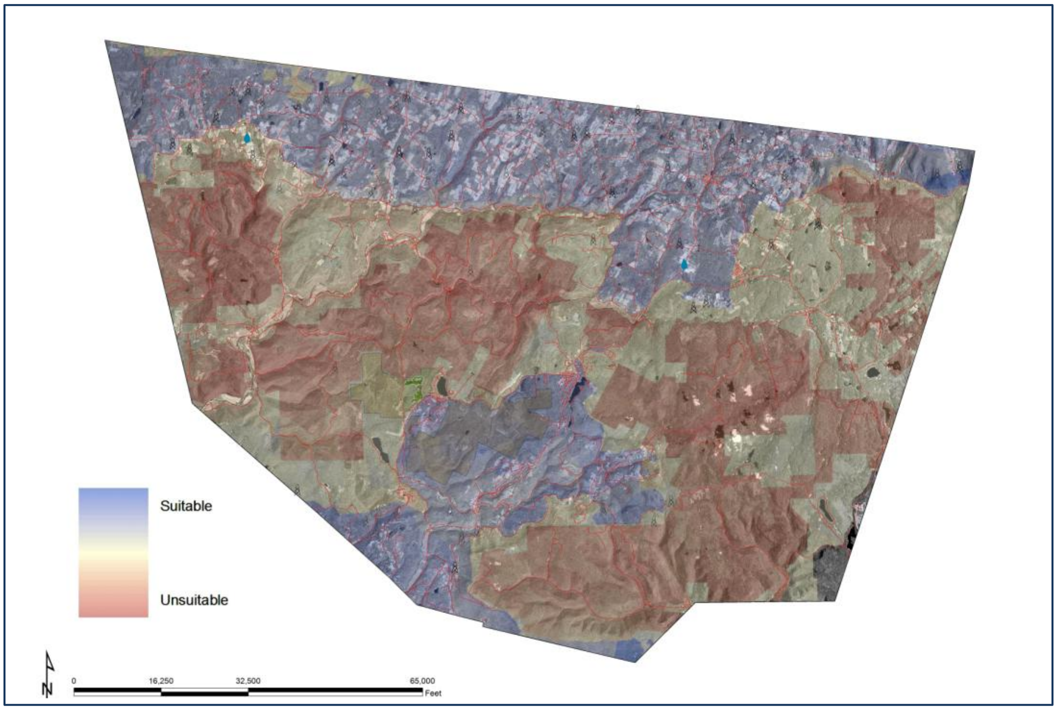
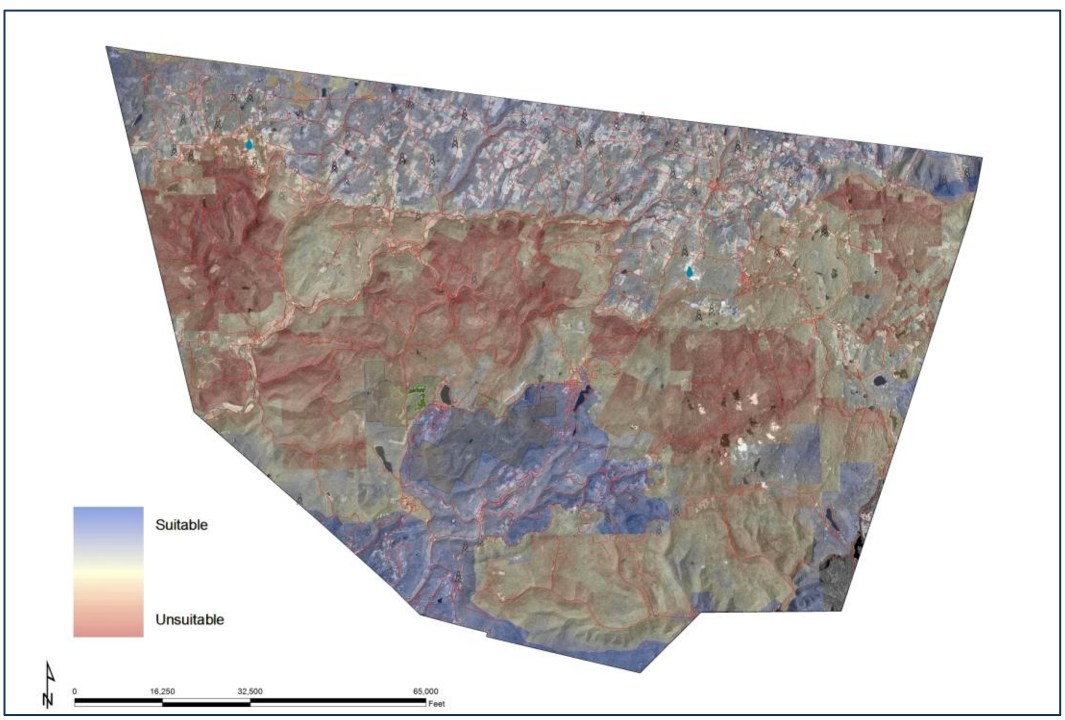


Figure 5: Golf Course Drilling Suitability Map



SUMMARY

This analysis served as a way to evaluate Sullivan County, as a whole, for potential fracing while identifying various stakeholder groups involved with the drilling process. In order to properly perform a more detailed analysis of Eagle's Mere Country Club for potential fracking the researcher had to properly evaluate the county as a whole as a means to justify the entirety of the research being done. Through the analysis of the county based on energy company, environmentalist, and golf course owner viewpoints, the researcher was able to determine that Eagle's Mere Country Club falls within a "moderate" suitability level for fracing and could potentially accommodate the needs of fracing while maintaining the integrity of the environmental factors present at the site.

Overall, the methodology outlined for this project will serve as a comprehensive way to analysis various components of fracing and golf course data from multiple scales. The process also outlines how this data will be utilized to inform the design decisions to be made and will yield a final result which is entrenched in conclusive data and reflects the nature of the site properly. This will result in a successful design and provide a potential blueprint on which Eagle's Mere could successfully integrate a fracing site within the framework of their golf course.

IMAGE CREDITS

Figure 1

Franko Matthew. Adapted graphic from overall research methodology

Figure 2

Lowrey, Todd A., Christopher D. Finton, and James R. Eby. "Hydrogeologic Report: Eagles Mere Lake and Vicinity Sullivan County, PA." Eagles Mere Lake & Watershed Committee, 25 Jan. 2011. Web. <http://protecteaglesmere.org/wp-content/uploads/Final-Eagles-Mere-Presentation-4_16_11-Read-Only.pdf>.

Figure 3

Franko Matthew. Adapted graphic from hydraulic fracturing site consideration analysis/synthesis.

Figure 4

Franko Matthew. Adapted graphic from hydraulic fracturing site consideration analysis/synthesis.

Figure 5

Franko Matthew. Adapted graphic from hydraulic fracturing site consideration analysis/synthesis.

Table 1

Franko Matthew. Adapted graphic from hydraulic fracturing site consideration analysis/synthesis

CHAPTER 3: CRITICAL ANALYSIS

INTRODUCTION

Fracing occurs wherever an energy company obtains a lease for mineral rights from a location where natural gas is located. There is no zoning regulation or other restrictions on where this occurs and in what quantity. Some areas have attempted to include this practice within land use planning (such as Pennsylvania cities) but those requests have either been blocked or denied by the state and federal government.[1] The time has come for fracing to find its proper place within the landscape and be appropriately integrated within the overall framework of our societies. In order to integrate fracing within the landscape, its impact must be fully understood. This impact comes from the visual intrusion of its nature, its potential impact on localized water and soil quality, and within the overall safety framework it lacks for surrounding areas.

After this understanding is achieved various factors can be evaluated in order to fixate a hypothetical fracing site on Eagle's Mere Country Club which will provide a suitable starting point to implement the mitigation techniques through golf course infrastructure. This golf course infrastructure will be designed in response to an existing analysis of Eagle's Mere Country Club which will be combined with the site analysis of Eagle's Mere which incorporates fracing into the analysis. This combination will culminate in the production of an overall synthesis analysis which presents an overall strength and weakness analysis of the site. This final map will dictate a major portion of the new course design which encapsulates the mitigation techniques to be utilized for fracing.

FRACING VISUAL PROBLEMS

The visual effects of hydraulic fracturing can be seen as extremely obtrusive and can greatly alter the visual impact of a landscape. The average fracing well pad is an approximate 4-6 acres with effects that spread far beyond this boundary. Fracing well pads create disturbances in both the vertical and horizontal realm of space. Both of these frames of reference must be addressed in the restoration phase of a fracing project in order to minimize their disturbance. This will improve the public perception of fracing and help to make the practice more widely accepted by the community.

[1] Navarro, Miery A. "Court Rejects a Ban on Local Fracking Limits." *Green Blog*. The New York Times, 26 July 2012. Web. <http://green.blogs.nytimes.com/2012/07/26/court-rejects-a-ban-on-local-fracking-limits/>.

FRACING VERTICAL VISUAL IMPACT

The vertical realm of the fracturing process is small in footprint but very substantial in regard to its visual impact. This visual impact is created by the drilling rig itself – often reaching 80-100 feet in height (see Figure 1). This equipment is used as the primary means for gaining access to the bedrock and subsequent natural gas located far below the surface. The vertical nature of fracing visual impacts can span across the landscape for miles and greatly alter the views associated with the area. The average drill rig can be seen from up to 5 miles away and therefore creates a major nuisance within the landscape. This nuisance cannot be addressed simply from a localized scale but should be incorporated within a larger impact area. This area takes into account locations which are far from the drill site but still affected by fracing's visual impact.

Figure 1: Hydro-Fracing Well Pad

FRACING HORIZONTAL VISUAL IMPACT

The horizontal impact of fracing comes from the substantial infrastructure associated with the process and subsequent transportation of the resources obtained through drilling. Every fracing well pad requires substantial roads to provide access to the site for large equipment such as drills, storage tanks, maintenance trucks, etc. The fracturing process requires a substantial amount of equipment which is extremely large and heavy which means the roads created for them are often far from "temporary" and can be considered comparable to the average unpaved road. This means that these roads cannot simply be erased from the landscape and leave their footprint long after the drilling process is over.

Figure 2: Natural Gas Pipeline

There is also the visual impact of the miles of pipelines (see Figure 2) which are constructed in order to transport the natural gas from the drilling sites to various storage, treatment, or distribution facilities. These pipelines can often have a greater impact on the land than the drilling sites themselves as they can span across miles of the landscape. These structures have a much greater edge effect to surrounding areas than an individual well pad. These disruptions can be extremely noticeable to humans from an aesthetic means and to wildlife from a habitat & migration means. Visual mitigation for these structures will prove to be more difficult than mitigation for drilling structures. The vast distances these structures span require a much more concerted effort from a planning perspective as well as more time-intensive mitigation. Due to the lengthy linear nature of these structures planning must include:

- ✓ Transportation networks
- ✓ Waterways

- ✓ Natural & protected areas
- ✓ Urban areas
- ✓ The movement of species
- ✓ Visual perspectives of roads, trails, railway

The large list of elements incorporated into pipeline planning requires that the process must be done from a regional scale in order to incorporate all the necessary information regarding the length of the pipe. These elements can scar the landscape and disrupt so many visual resources that there must be a means to conceal them from the general public in order to continue the fracturing process without destroying valuable visual resources. These visual resources often have strong indirect economic benefits and if they are overshadowed by the potential benefits of fracing they may be disregarded and lost forever.

WATER AND SOIL IMPACTS

In order to effectively frac a well, the energy company must utilize various chemicals and compounds in order to ensure the process works correctly. Certain chemicals, such as benzene, toluene, and xylene are incorporated into this process as they are bi-products of the diesel fuel used. These compounds are known human carcinogens and pose a serious threat to humans and wildlife if they are exposed to water resources or surrounding soil media.[2]

Along with these noxious compounds are other chemicals such as Hydrochloric Acid, Glutaraldehyde, Sodium Chloride, and Benzyl Chloride. These compounds are used to create fissures within the rock and also prevent any bacterial growth within the fluid system. These products can serve as a major threat to the well-being of humans and wildlife and if introduced to soil or water pose major health risks.[3]

Another subset of bi-products found in frac fluid are heavy metals and naturally occurring radioactive elements. Metals such as lead and copper become incorporated into the frac fluid after drilling occurs and can potentially contaminate various water sources or affect soil conditions. The presence of these

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[2] Environmental Protection Agency. "Benzyl Chloride (CASRN 100-44-7) | IRIS | US EPA."EPA. N.p., n.d. Web. 30 June 2012. <http://www.epa.gov/iris/subst/0393.htm>.

[3] "Workplace Safety & Health Topics - Chemicals." *Centers for Disease Control and Prevention*. N.p., 29 Sept. 2010. Web. 30 June 2012. <http://www.cdc.gov/niosh/topics/chemical.html>.

elements within an ecosystem can severely alter its health and cause catastrophic consequences for humans and wildlife. There are also naturally occurring radioactive elements found in frac fluid after drilling – most notably uranium. The uranium is released from shale during the fracturing process and can cause severe impacts to the health of any living organism. Uranium produces radon gas which can cause severe health problems for living organisms and also spread very easily as an air-borne hazard.[4]

These are just a handful of the elements used in fracing (refer to chemical table in the Appendix for full list of chemicals) which can cause severe water and soil contamination issues around drill sites. These elements pose an immediate threat to the quality of water and soil within a fracing area and must be properly planned for in order to ensure a lack of contamination potential. Due to the ease of movement of water and soil, if they become incorporated into water or soil systems they can easily be dispersed to other areas and quickly spread into a large area resulting in large-scale contamination.

Figure 3: Aerial Image of Fracing Sites

IMPACTS OF WELL PAD: POST-DRILLING SITE CONDITIONS

Fracing impacts include added roads & pipelines as a means to bring equipment to the site and carry the waste products as well as the harvested energy to its final destination. Another impact comes from the physical well pad itself – typically in the form of an approximate 6 acre square "postage stamp" on the landscape (see Figure 3 for an aerial image of a fracing site). The immediate impact to vegetation, soil,

[4] United States House of Representatives Committee on Energy and Commerce Minority Staff. "Chemicals Used in Hydraulic Fracturing." N.p., Apr. 2011. Web.

and wildlife extend from the well pad and entrance roads 300-500 feet from the boundaries of the physical site itself.[1]

The increased human activity at the drill site is another form of an ecosystem impact, which must be mitigated and planned for. The introduction of humans into the environment in a somewhat "human-less" area creates a disturbance which affects species populations and resource availability. The presence of humans cause a ripple effect throughout nearby ecological systems which alters their overall function.[1] There is a larger scale at which drilling impacts the landscape as well. The disruption of patches in the landscape can, through drilling infrastructure, negatively affect ecosystem connectivity and create negative, high-contrast edge affects. These disturbance patterns can lead to discontinuity in ecosystems and create:

- ✓ Isolated patches of species
- ✓ Homogeneity in overall system biodiversity
- ✓ Eventual local extinction of species.[5]

The affects of the well pad can also impact wind, humidity, hydrology, and soil erosion patterns – all of which can lead to changes in the microclimate of the area.[3] Changing the microclimate can induce species migration and affect the way species move in and out of the landscape. This fluctuation in species presence can provide opportunities for non-native species to colonize an area and become invasive. The impact of invasive species on the landscape can cripple biodiversity and lead to ecosystem homogeneity.[6]

Hydraulic fracturing well sites can create landscape fragmentation, a major ecological issue that compounds the air and water pollution already produced by their presence. By fragmenting the landscape they can set off chain reactions that can reach far beyond the perceived impact of the well pad itself.

LACK OF FRACING SAFETY INFRASTRUCTURE

[5] Dramstad, Wenche E., James D. Olson, and Richard T. T. Forman. *Landscape Ecology Principles in Landscape Architecture and Land-use Planning*. [Cambridge? Mass.]: Harvard University Graduate School of Design, 1996. Print.

[6] Voller, Joan. "Biodiversity and Interior Habitats: The Need to Minimize Edge Effects." British Columbia: Ministry of Forests Research Program, June 1998. Web. <http://www.for.gov.bc.ca/hfd/pubs/docs/en/en21.pdf>.

Despite the aforementioned environmental issues that plague fracing sites, there are essentially no safety measures in place in the form of physical infrastructure which can help to prevent accidents or contain potential contamination. Typically, fracing sites are located at higher elevations in order to prevent erosion problems. Subsequently, chemical and fluid holding areas are placed at the highest location of a well pad (see Figure 4) as these areas house all of the potentially harmful contaminants which could affects surrounding ecosystems. Despite the severity of their nature, these elements are often stored in open air with no safe guard mechanisms surrounding them to provide a means of containment if any is to breach the realm of its holding location. This is a major concern for fracing sites, from an environmental protection standpoint, and is an issue which can be provisioned for somewhat easily. Without any safety infrastructure in place things such as well explosions, severe weather events, human error, containment structure breech, etc. can directly expose these harmful components to the adjacent areas and subsequent surrounding systems.

Figure 4: Elevated Fracing Site

HYPOTHETICAL FRACING SITE

The next step in evaluating a fracing site's impact on the landscape will be to analyze the site and determine the most suitable location for potential fracing. In the case of Eagle's Mere, this process must be done hypothetically because the time frame for actual site selection does not fall within the time frame of the mater's project. There are three critical pieces of information which is utilized for determining fracing site selection as theorized by the researcher:

1. Topography
2. Existing infrastructure
3. Proximity to resources and development [7]

This determination was built on the work done by Upadhyay and Min out of Cornell University. They theorized various techniques to apply to fracing sites to help avoid negative visual perceptions which the research is applying as a means to limit potential visual and physical hazards to critical areas in the Eagle's Mere vicinity.

The first factor to use in locating a potential drill site is topography. This utilizes the topographic map of the area to find a site which is located towards a higher elevation. It is important to note the highest point is not selected as that would create a situation which would be difficult to mitigate for from a visual perspective. A point that is relatively higher than the surrounding area, but not the highest, would be ideal as this would not emphasize the size of the drill as a focal point but would help to prevent erosion due to its higher elevation.

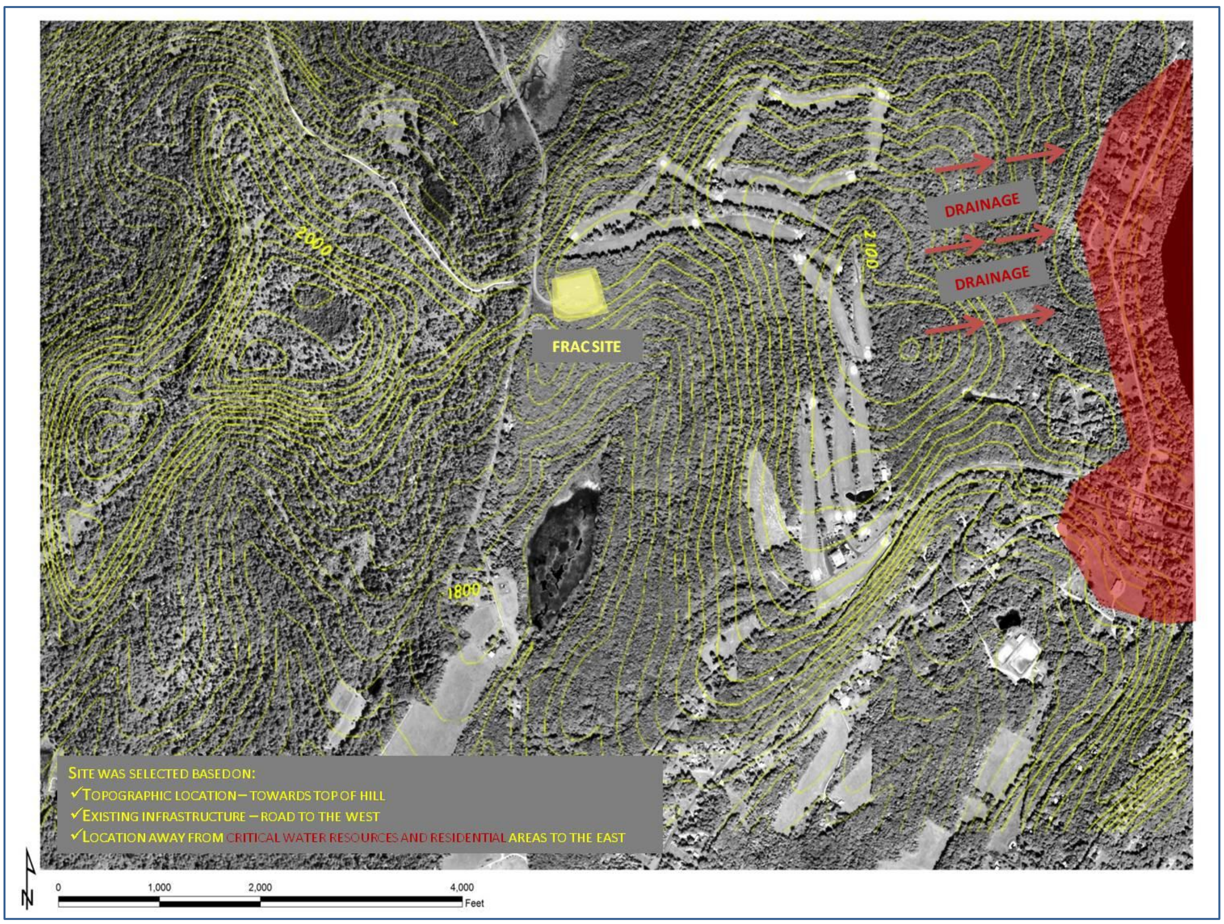
It is also critical to look for areas with existing infrastructure nearby so as to limit the amount of infrastructure which must be built in order to accommodate the well pad. This infrastructure can include electrical sources, water sources, roadways, and vegetative screening areas.

Finally, it is also important to identify any residential or critical water bodies within the area as they would be of utmost importance to safeguard from the fracing from a visual and physical perspective. By utilizing topographic maps, the potential hydrologic flow lines for water sources can be determined and any associated water bodies or developed areas linked to them can be accounted for. This will help to establish a fracing site out of the localized watersheds of critical water resources or development areas.

[7] Upadhyay, Sarita Rose, and Min Bu. "Visual Impacts of Natural Gas Drilling in the Marcellus Shale Region." Cornell University, Dept. of City and Regional Planning:, 2010. Web. <http://www.cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Visual%20Impact_Final%20Report.pdf>.

In the case of Eagle's Mere, these factors were utilized in evaluating the site and certain factors dictated the selection of the potential fracing well pad (seen in Figure 5). In this scenario the location was selected as it was towards the top of the primary elevations in play, it was situated adjacent to an existing road which will decrease overhead infrastructure cost, and was located on the opposite side of a watershed associated with Eagle's Mere Lake and an adjacent residential community. Once the potential fracing site has been determined, a comprehensive analysis can be done which evaluates the site from a golf course standpoint, overall site standpoint, and visual standpoint. These analyses will culminate in an overall strength and weakness map which will guide the design of the golf course while utilizing the needs for fracing.

Figure 5: Fracing Well Pad Site Selection Analysis



COURSE ANALYSIS (EAGLES MERE COUNTRY CLUB)

Eagle's Mere Country Club located in north central Pennsylvania presents a country club lifestyle destination which provides all the typical facets of a country club:

- ✓ tennis courts
- ✓ golf
- ✓ clubhouse
- ✓ locker room
- ✓ pool

The course is just minutes away from Eagle's Mere Lake which serves as a tourist destination for people from the northeast region of the United States – notably New York and New Jersey. The course has existed since 1911 and was designed by William S. Flynn.[8] The course provides a modest par 70 challenge playing 6150 yards from the "back tees" with a course rating of 69.4 and slope of 119. The course rating is the expected score a "scratch" golfer would attain for 18 holes of play – a course rating of 70 would correspond to an "average" level of difficulty for Eagle's Mere. The slope represents the discrepancy between the expected score for a "bogey golfer" and "scratch golfer" for 18 holes. These values ranges from 55-155 (Eagle's Mere is 119).[9] Based on these numbers Eagle's Mere plays as a somewhat easy layout and would be better served by additions which would increase its difficulty level in order to attract a wider range of player abilities.

Figure 6: Eagle's Mere Signature Hole - "A View to New York"

[8] Eagle's Mere Country Club Scorecard.
[9] United States Golf Association. "National Course Rating Database." *National Course Rating Database*. N.p., 2012. Web. <http://ncrdb.usga.org/NCRDB/>.

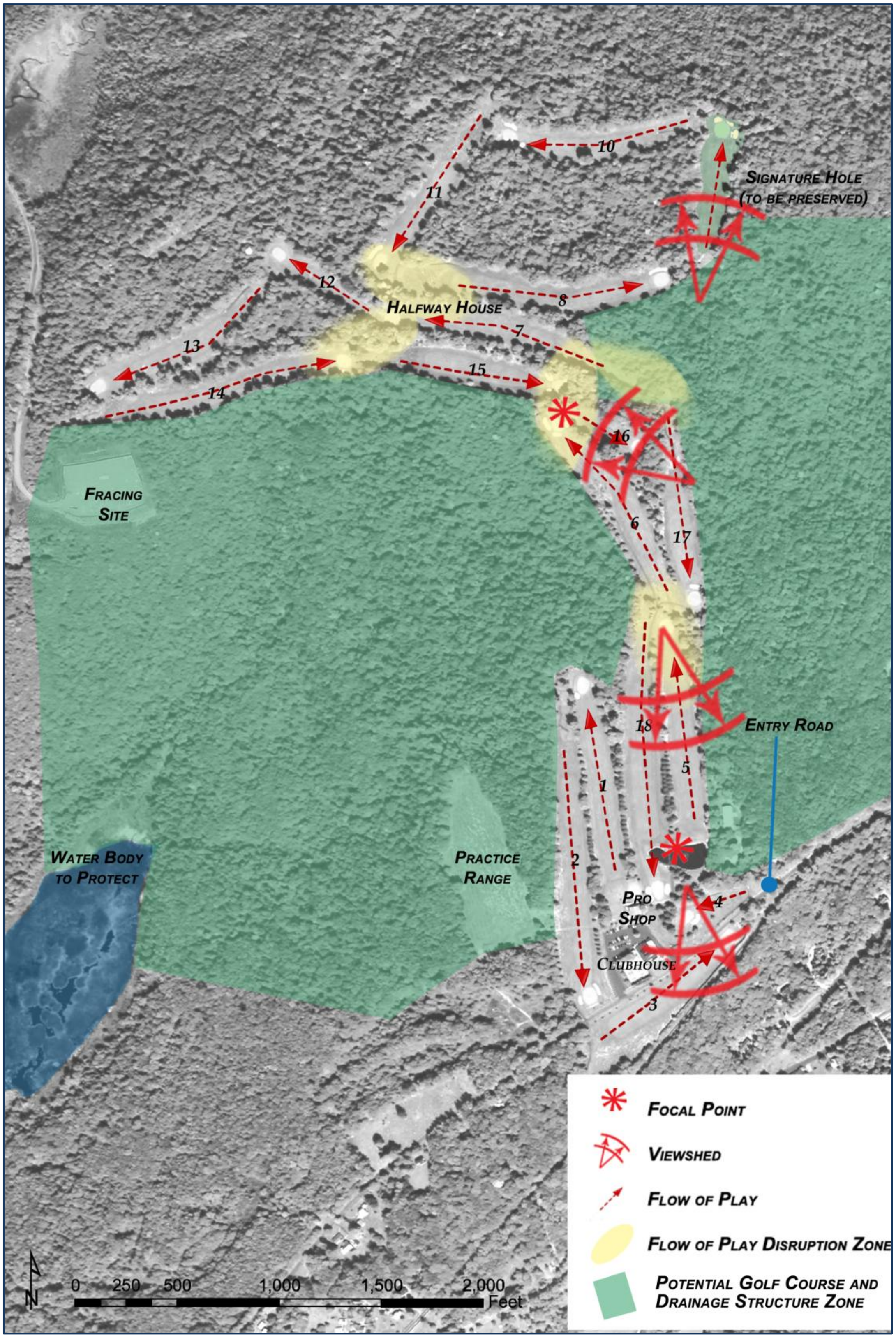
The course is most noted for its strong elevation changes and corresponding views (see Figure 6). The course is spread out over the top of a large hill and provides a great vantage point to gaze at the endless mountains of Pennsylvania. The topographic challenges facing a course situated on top of a hill have given rise to some issues with how the course is laid out.

There are two main course layout types – loop and core. In the loop layout, the holes are laid out in a circular fashion and the 9th green and 10th tees are not setup to bring players back to the clubhouse (see Figure 7). The core layout is a more compact course footprint, which brings players back to the clubhouse at the end and beginning of a nine hole stretch (see Figure 8). In the case of Eagle's Mere Country Club a combination of the two layout styles is used. There is a cluster of early holes (1-5) all of which play around the clubhouse, but the rest of the holes follow more of a loop format – with the first nine ending and second nine beginning away from the club house (see Figure 9 for a golf analysis of Eagle's Mere).[10] There can be different reasons this layout type may have been chosen. This layout however is not conducive to the country cub style of golf and does not provide the opportunity for players to only play nine holes without being stranded on the course. The loop method also often creates odd scenarios in which holes cross paths or the logical flow from one hole to another may be difficult to understand. This creates an unpleasant experience for the golfer and can lead to frustration leading further to poor play and an overall unenjoyable experience for the golfer.

Figure 7: Loop Course Layout **Figure 8: Core Course Layout**

[10] Graves, Robert Muir., and Geoffrey S. Cornish. *Golf Course Design*. New York: J. Wiley, 1998. Print.

Figure 9: Eagle's Mere Golf Analysis



It also hurts the clubhouse to not have players be able to access refreshments or other necessities between nines – this often results in the construction of a “halfway house” which provides such amenities.

Eagle’s Mere pays to run a halfway house on hole number 7. If the course fit into more of a core layout, players could return to the clubhouse after the first nine, eliminating the need for a halfway house and increasing the facility’s revenue from clubhouse purchases.

The enjoyment of players, one of the cornerstones of golf course design, also hinges on the style of play presented to the player. There are three basic styles of play used in golf course design: (1) strategic (2) penal (3) heroic.

The strategic design places certain hazards/obstacles at places to avoid and provides “safety” areas for a player to bail out to. This style of golf course design is considered more traditional and seen in older golf courses.[16]

The penal design type places multiple hazards/obstacles in a player’s way where the player’s only goal is to avoid them. This is opposed to the strategic design in which a player is encouraged to “plan” a path around the hazards/obstacles and is given multiple paths in which to avoid them.

The final design strategy employed is the heroic method. This method places large hazards/obstacles in the way of a player creating a major decision in regard to how to attack them. If the player challenges them, they are often rewarded greatly from succeeding or punished severely for failing. The player will also be presented with a “low-challenge” option but can often be punished slightly for choosing this route.[13]

At Eagle’s Mere; the style of play is mostly strategic for a majority of the holes. This is in keeping with the “country club” style of play in which holes are somewhat simply designed and do no present a large amount of variety or rigor. Most of the holes are straight ahead or maintain a slight dog-leg either left or right. Of the 14 non-par 3 holes, six dog-leg and the remaining eight are straight forward. The six doglegs provide three to the left and three to the right – creating good balance and not favoring one type of shot over the other. However, the course provides no opportunities for heroic moments or shots for the players. Even the final par 5 - 18th has its water hazard some 50 yards before the green. If this water was nestled closer to the green players would be left with an incredibly dramatic finish to their round. The water hazard does provide one of the best focal points on the course (see Figure 10) and provides the player with a lasting image after their round.

Figure 10: Water Focal Point at Number 18 at Eagle's Mere

The course provides some useful focal points by providing vistas at highpoints (see Figure 11), showy water features, and tremendous view sheds both at the beginning and end of holes. These features are not only aesthetically pleasing to the players but can serve as way-finding devices to help players navigate the course.

The most noteworthy aspect to the course is the drastic elevation changes a player will experience throughout the round. These create scenic vistas, blind shots, and give many holes specific character through elevation alone. The course also establishes individual hole character through amenity features such as rock outcroppings and fern meadows surrounding trees. This is a great way to boost the aesthetic appeal of a course with less physical dynamics or appeal.[11]

Figure 11: Elevated View at Eagle's Mere- Hole Number 6

Eagle's Mere Country Club is a golf course which can provide modest challenge to its players while creating memorable experiences with incredible views. The overall flow of the course could be re-worked to fit the core layout model and provide a more enjoyable experience for the user while providing more efficient services from the golf course.

The course could also benefit from the variety some heroic holes would provide the players with. As of now, the course plays mostly to the strategic nature (which is a testament to its age and more conventional, old-style design) but could greatly benefit from more opportunities for the golfer. The inclusion of a new nine holes could be the perfect way to remedy all of these problems. A new nine holes would create the opportunity to re-route the course and create a more playable course in terms of

[11] Hurdzan, Michael J. *Golf Course Architecture: Evolution Sin Design, Construction, and Restoration Technology*. Hoboken, New Jersey: John Wiley & Sons, 2006. Print.

the natural flow of play. This would also provide multiple varieties of 18 hole courses that could be played which would provide a new look for the members while maintaining the integrity and history of the original design. The new nine holes would be best suited as a heroic style of play, a contrasting element that can be integrated in the more mundane, strategic layout that currently exists.

SITE ANALYSIS (EAGLE'S MERE COUNTRY CLUB)

The physical analysis of the site works together with the course analysis by identifying opportunity and weakness areas related to both golf and fracing. The key to this analysis id identifying areas that, not only can be renovated or protected, but are actually able to accommodate everything required for golf and fracing to succeed. These physical characteristics include but are not limited to:

- ✓ soil type
- ✓ slopes
- ✓ wetland areas
- ✓ property shape
- ✓ irrigation water source
- ✓ electricity source
- ✓ tree cover
- ✓ existing transportation infrastructure
- ✓ critical vegetated areas
- ✓ wildlife habitat
- ✓ depth to water table
- ✓ wind patter

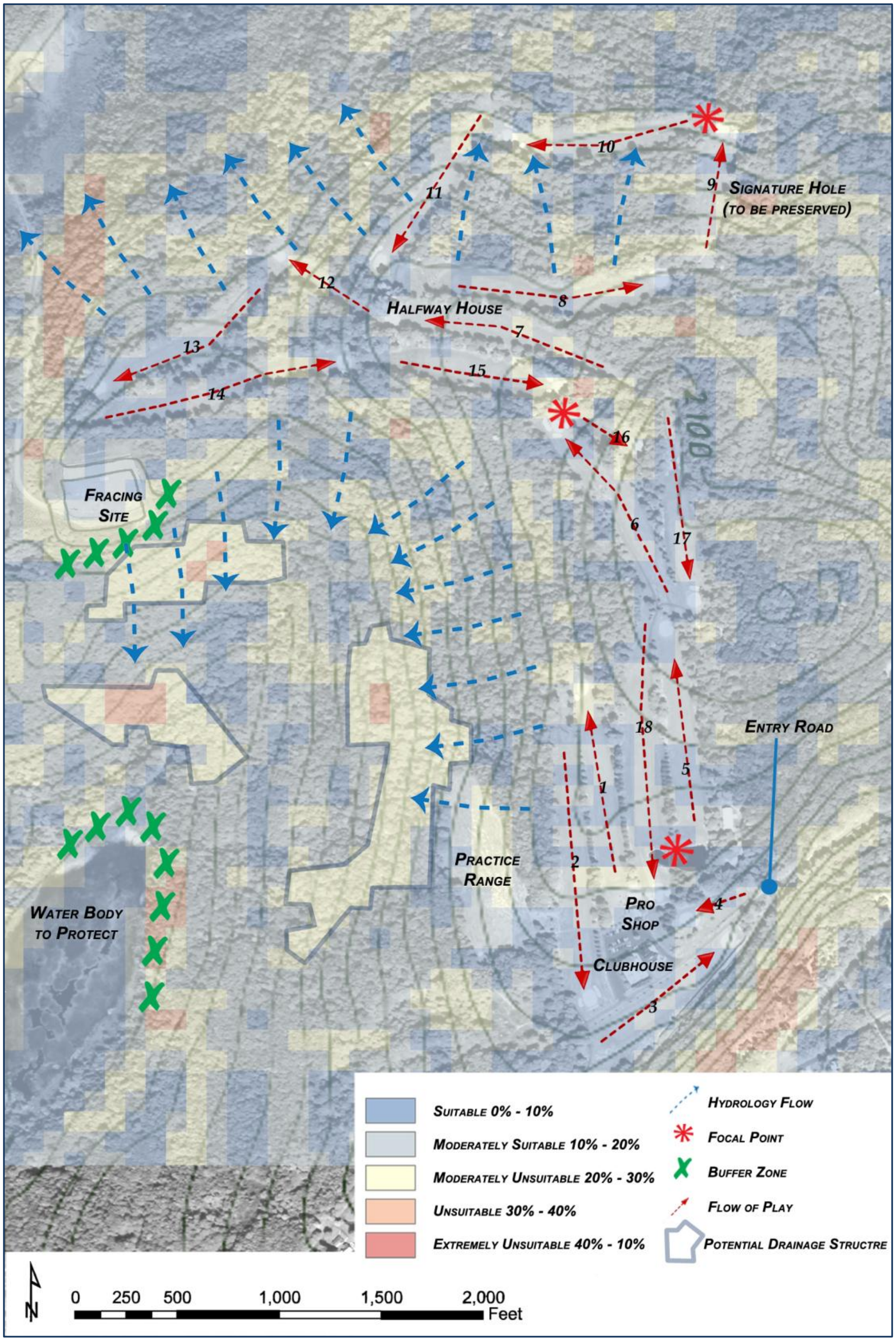
The soil types that must be identified are those that are well-drained (suitable for golf course development) and poorly drained soils (not suitable for development). [13] By identifying these areas a designer can establish zones which would be prone to flooding and water pooling – these areas would cause destruction to the golf course, once established, and raise management costs. Also, many plant species require well drained soils (including many golf course grasses) and poorly drained soil will drown much of the vegetation planted there. Data regarding the soil at Eagle's Mere was unobtainable, but due to the high vegetative quality in the area and the existing success of the golf course, it can be assumed the site has soils which would be beneficial for golf courses and provide the proper drainage necessary for a successful golf course development.

Slopes are another critical factor to consider in the site analysis phase. The slopes of the site work directly with the soil types indicating a specific angle of repose to establish areas of critical erosion potential so they can be avoided and maintained with vegetation to stabilize their slopes. The topography and accompanying slopes will also identify critical areas that are too steep for proper golf course play and management – a minimum of 2% to a maximum of 40% with the most suitable slopes falling between 2% - 10%.[14] The slope analysis will also reveal low areas which will often coincide with wetland areas. At Eagle's Mere the slopes are fairly steep due to the nature of the course being situated on the top of a mountain. This creates a distinct character to the holes and limits the remaining amount of properly sloped areas that are useable. The slopes at Eagle's Mere vary greatly ranging from 0-40% (see Figure 12 for the overall site analysis). This would indicate that the site has many areas that would not be suitable for golf course infrastructure, but that could serve as aesthetic areas or some sort of drainage or containment function.

Wetland areas should be avoided in order to prevent future flooding, to thwart any seepage of chemicals into water systems, and to avoid infringement on critical wildlife habitat.[15] Associated with wetlands is the various known depth to the water table on site as this will inform what areas are appropriate for construction infrastructure and major earth-moving practices. Depth to water table is critical as it establishes areas not to build on as well as protect from aquifer contamination. Eagles Mere has two nearby wetland areas to the Southwest and East. These areas should be buffered and protected from potential golf course and fracing run off. These areas can be protected by golf course infrastructure designed in conjunction with the newly proposed golf course.

Water and electricity sources must also be identified so clubhouse function can be established and course irrigation can be assured. This will also help to limit the infrastructure needed during course construction. In regard to Eagle's Mere, this data was unable to be obtained, but due to the existing infrastructure on site, it can be assumed that ample water and electric sources exist along with data of their corresponding location.

Figure 12: Eagles Mere Site Analysis



Existing tree cover and transportation infrastructure will be valuable information to obtain in the site analysis phase so as to inform how much land clearing will be necessary in the future – a major construction cost contributor.[13] Eagle's Mere has a vast collection of trees (note the aerial backdrop in Figure 12). Newly proposed holes will require a large amount of tree removal. Ideally, some of these trees can be relocated to be incorporated into the visual mitigation practices for fracing and function as strategic components of the course design.

The location of vegetated areas will be a valuable information source as they will dictate critical wildlife habitat. It is paramount to establish, protect, and buffer these areas during the site design process. These areas are intrinsic to native flora and fauna and their survival will be a key factor to the future ecological success of the site and subsequently to the course itself (note Figure 12 for areas to buffer).[15]

In the case of a golf course and hydraulic fracing partnership, new considerations arise in terms of physical factors to be identified in the site analysis phase. The well pad must be clearly identified and analyzed for vegetation growth feasibility and impact on the overall landscape. This designation must carefully take into consideration hydrology, slopes, soils, and other factors dealing with the transport of materials of the fracing site to nearby habitats or water bodies.

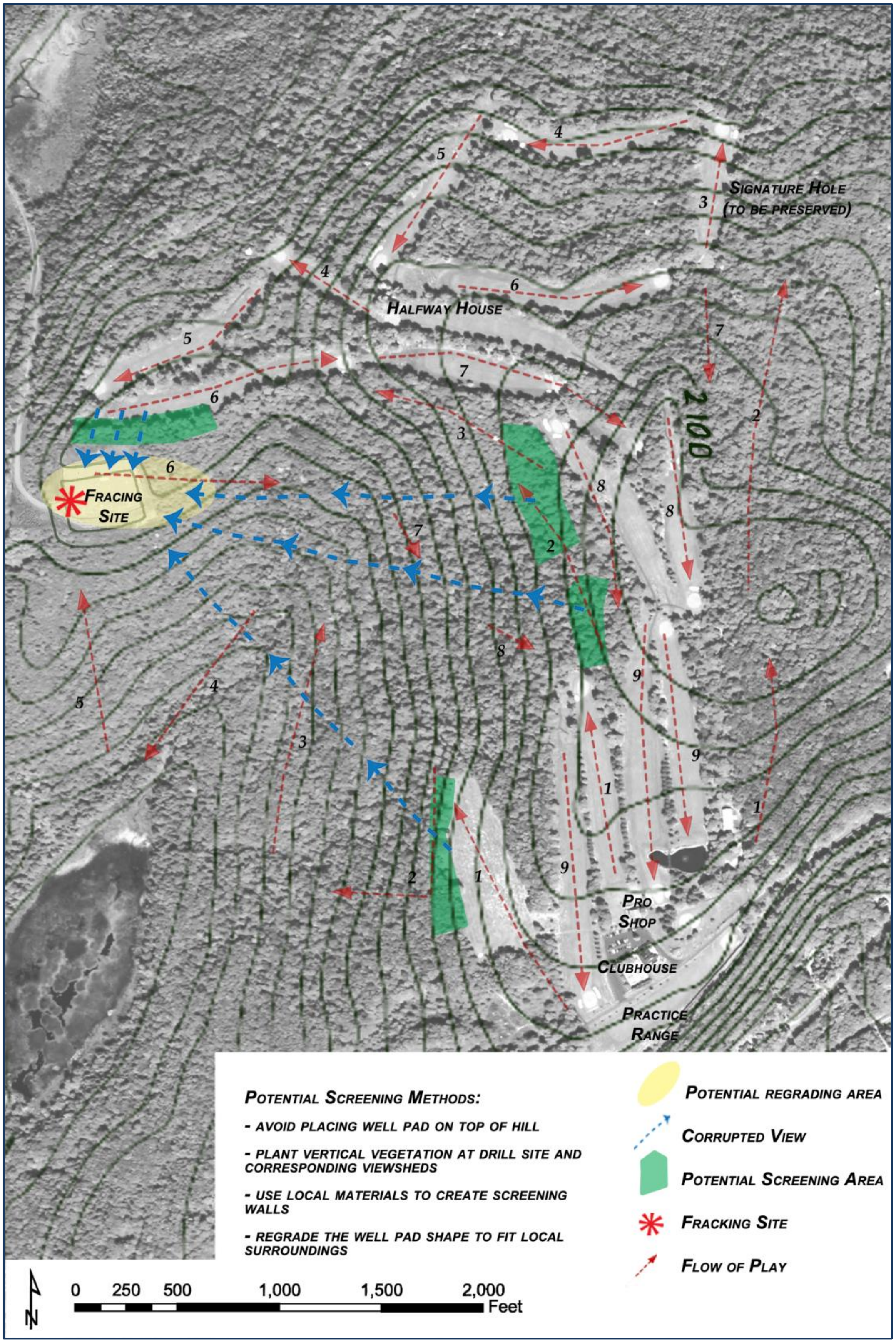
Due to the hazardous nature of the fracing process, anything from the site must either be contained and/or filtered via a buffer from the other program elements located nearby. This is a critical process in the establishment of wildlife on site, as it will facilitate population regeneration and bring nature back into the site after drilling has occurred.

VISUAL ANALYSIS (EAGLE'S MERE COUNTRY CLUB)

It is also important to address the visual sight lines from various locations on the course which could dictate views directed at the fracing site. These views can be unappealing to the player and must be mitigated for in order to preserve the aesthetic quality of the golf course. Figure 13 shows where these sight lines occur at Eagle's Mere and identifies areas which must be buffered from the visual impact of drilling.

It is the golf course architect's responsibility to create an aesthetically pleasing integration of fracing and golf that can also serve as potential wildlife habitat and integration area. The architect's design will also have a lasting impact on the future management of the course. The architect must find a balance between design and maintenance feasibility in order to maintain the viability of the golf course over

Figure 13: Eagles Mere View Analysis



time.[12] A proper design will provide a unique golfing experience while providing a course that a superintendent can easily maintain while avoiding any major management issues (such as flooding, mowing difficulties and vegetation mortality).

This analysis is critical as it will play a pivotal role in the design of the new golf course while simultaneously provided the much needed fracing visual screening. These areas identified as “potential screening areas” will be carried through the design process and incorporated into the strategic location of various vegetation. The visual impact of fracing and its integration with golf will be the most notable to the public and dictate their first impression of the area. By critically blocking any negative views, the design can properly introduce users of the site to pleasant views leading to an overall enjoyable golf experience without the intrusion of fracing infrastructure.

SITE SYNTHESIS: STRENGTH AND WEAKNESSES

The valuable work done in the critical analysis phase which included (1) golf (2) fracing (3) overall site characteristics and (4) visual impacts can all provide input which can be utilized in an overall site synthesis map which will identify strength and weakness areas for potential fracing and golf course integration. A synthesis map combines all of this information (see Figure 14) and will help to dictate the design process. This ensures that all the work done in the site analysis phase properly transitions and reveals itself in the course design and fracing integration phase. Much of the information presented in the synthesis map will be utilized in the golf course design process and play an intricate role in all phases of design. It will inform areas to take advantage of for golf course purposes, areas to utilize for fracing mitigation, and areas to avoid in terms of any form of golf or fracing infrastructure. This will lead to the proper integration of fracing and golf course design while maintaining the functionality of both uses during their respective time frames of operation.

[12] Dodson, Ronald G. *Managing Wildlife Habitat on Golf Courses*. Chelsea, MI: Ann Arbor, 2000. Print.

Figure 14: Eagles Mere Site Synthesis Map

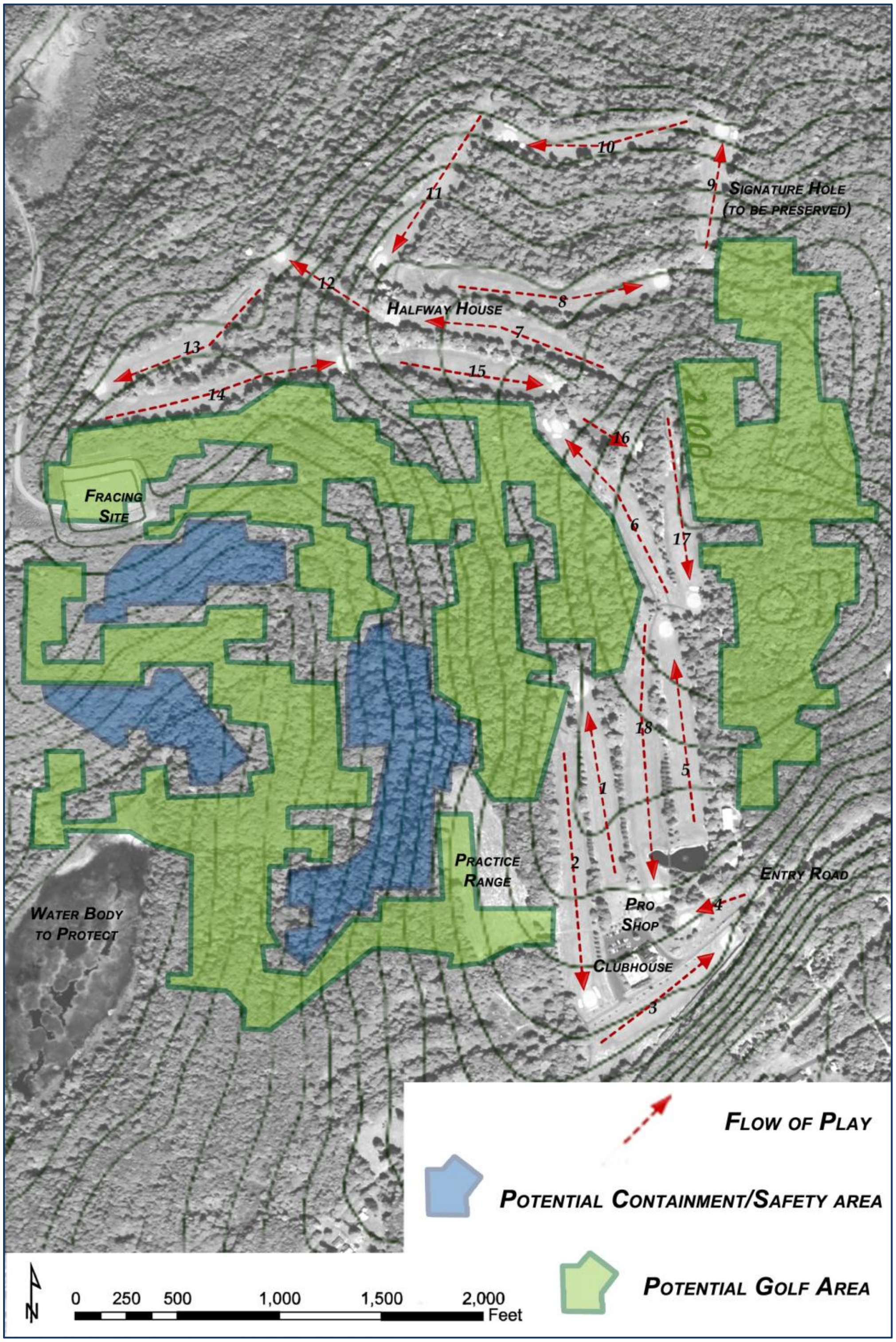


IMAGE CREDITS

Figure 1

http://inspirationgreen.com/hydraulic-fracking-basics.html

Figure 2

Photo by Matthew Franko of natural gas pipeline in Sullivan County Pennsylvania

Figure 3

"Industrial Scars".http://jhenryfair.com/aerial/portfolio/gas_drilling.html

Figure 4

"Hydraulic Fracturing in the Lehigh Valley". http://sites.lafayette.edu/egrs251-fa11-fracking/what-is-hydraulic-fracturing/

Figure 5

Fracing site selection analysis diagram composed by Matthew Franko

Figure 6

Photo by Matthew Franko of 6th hole at Eagle's Mere Country Club. "A View to New York"

Figure 7

Graves, Robert Muir., and Geoffrey S. Cornish. *Golf Course Design*. New York: J. Wiley, 1998. Print.

Figure 8

Graves, Robert Muir., and Geoffrey S. Cornish. *Golf Course Design*. New York: J. Wiley, 1998. Print.

Figure 9

Golf Analysis Diagram composed by Matthew Franko

Figure 10

Photo by Matthew Franko of water focal point at number 18 at Eagle's Mere Country Club

Figure 11

Photo by Matthew Franko of an elevated view point at Eagle's Mere Country Club hole number 6

Figure 12

Eagle's Mere Country Club site analysis provided by Matthew Franko

Figure 13

Eagle's Mere Country Club view analysis provided by Matthew Franko

Figure 14

Eagle's Mere Country Club site synthesis map provided by Matthew Franko

CHAPTER 4: SOLUTIONS

VISUAL MITIGATION

Sarah Kuehn has proposed the use of vegetative screening barriers located at strategic locations within the landscape which block views directed at drilling sites. The use of existing and proposed vegetation is an effective way to block or obscure the visual impacts of fracing sites. Seeing as how drill rigs average 80-100 feet in height, it is reasonable to assume that the entire rig would be difficult to block. However, enough of the rig can be blocked so as to remove it from the "obvious" view of the average person. This can be achieved through various vegetative screening measures located adjacent to human activities which will facilitate in blocking view sheds overlooking a fracing site.

Attributing Kuehn's theory to Pennsylvania fracing sites could offer substantial screening vegetation due to the state's vast amount of pines. The state is inhabited by large, long-lived pines which can come close to reaching the heights needed to block the fracturing drills entirely. Most notably the Eastern White Pine, *Pinus rigida*[1], and the Scots Pine, *Pinus sylvestris,*[2] which reach average heights of 90 feet and 70 feet respectively. These trees can be utilized to contribute to the visual blocking of the vertical nuisances created by fracing.[3] The location of these trees, or similar ones, can be chosen and preserved with these vegetative buffers incorporated into the site design process. These trees can be utilized at Eagle's Mere either as:

- ✓ Existing trees to be preserved
- ✓ Existing trees to be relocated
- ✓ Proposed trees to be planted

It is important to understand that the drilling rig is an integral part of the fracing process and cannot simply be removed from the site. However, its visual impact can be considered when selecting the location for the rig. In doing so, the exposure of this massive structure to the public can be limited. This vertical element can be hidden by incorporating aspect analysis through GIS services when selecting sites and utilizing the data to locate visual problem areas before drilling begins. Once these areas are identified they can be planned for and incorporated into the overall drilling site plan. Note Figure 1, in

[1] Cook. "Common Trees of Pennsylvania - Eastern White Pine." *Common Trees of Pennsylvania - Eastern White Pine*. N.p., n.d. Web. 19 July 2012. <http://www.cookforest.com/articles/trees/eastern-whitepine.cfm>.
[2] Cook. "Common Trees of Pennsylvania - Scots Pine." *Common Trees of Pennsylvania - Scots Pine*. N.p., n.d. Web. 19 July 2012. <http://www.cookforest.com/articles/trees/scotspine.cfm>.
[3] Kuehn, Sarah. "Landscape Practices on Gas Well Sites in North Texas: Perceptions of Selected Industry Representatives and Regulators." University of Texas at Arlington, Dec. 2011. Web.

Chapter 3 for a detailed view shed analysis of Eagle's Mere which identifies potential visual problem areas associated with the fracing site. These areas were identified before the design process took place and lead to the placement of various vegetation at the associated negative areas. This vegetation served as a buffer to various fracing site lines but also as an integral piece of the design strategy associated with the respective holes.

The location of residential, commercial, recreational, and transportation networks can also be evaluated when selecting a drill site, so it can be oriented away from these areas, reducing its visual exposure to the public. This will lead to less of an overall impact to the public and decrease public perception of the rig. At Eagle's Mere, the location of a residential neighborhood to the east of the site was taken into account when selecting the drilling site (see Figure 5 in Chapter 3). This limited the impact the site had on nearby residents as it kept the drill from their immediate line of sight.

PHYSCIAL MITIGATION

There are many ways in which the physical impacts of a fracing site can be mitigated for. A vitally important aspect to incorporate into fracing physical mitigation has to do with drainage and soil. An integral part of the drainage design will come through the creation of various containment structures which will facilitate in collecting runoff and preventing the spread of harmful chemicals throughout the site. Within these containment areas, bio-mediated soils can be implemented to further advance the cleansing and containment strategies in place. By controlling drainage and amending soil, the impacts of a fracing site on water and soil resources can be effectively contained and either cleansed or removed. Also, various parts of the drainage and containment infrastructure can be utilized simultaneously as safety structures which limit the spread of any hazardous material in the event of an accident or equipment malfunction.

DRAINAGE AND SOIL

The soil removed for the creation of fracing infrastructure should be stockpiled and placed in an area which will not be at risk of coming into contact with natural or man-made drainage patterns (to avoid contamination). This soil should also be properly labeled so as to avoid confusion with other soils stored on site. It is also important to make sure the top soil is not mixed with any sub-soil as the top soil will be best for re-using on the site post-drilling.

Figure 1: Fracing Brine Pit

The strict drainage requirements of fracing sites necessitate that the site be re-graded (post-drilling) to reverse all of the steps taken to prep the site for drilling. The pre-drilling grading consists of constructed retention ponds (lined with special tarps), drainage ditches, canals, berms, silt fences, retention walls and other structures used to move all of the water on site into the proper areas and maintain the structural integrity of the drainage system.[3] There are also special "brine pits" which must be filled with sub-soil and then covered with top soil as part of the restoration process. This is another reason why it is so important to save topsoil and sub-soil which can be used to refill brine pits (see Figure 1 for an image of a brine pit). All of the pits constructed on site should be located in areas of lower risk for aquifer (or other groundwater) source contamination. These areas must be re-filled with the aforementioned topsoil and sub-soil saved before drilling.[4] The well pad will also severely compact the soil and hinder proper drainage, soil aeration, water infiltration, etc. This compacted land must be restored in order to:

- ✓ De-compress the soil
- ✓ Re-establish the topsoil and sub-soil to the original depth
- ✓ Re-establish all the contours to match the contours of pre-drilling conditions.[5]

By addressing these issues a fracing site can be properly integrated back into the natural form of the land and function properly. In the case of Eagle's Mere, the fracing site was re-grading to naturally fit the lay of the land but also as an integral piece of the golf course. The site drainage work that had to be done post-fracing served a purposed in the design intent of the golf course as it functioned as a new tee box for the course. The potential for this was identified in the course routing phase which will be discussed in Chapter 5.

CONTAINMENT AND SAFETY STRUCTURES

During the planning process it is important to note the existing contours (which will be altered by the well pad) and how they function within the greater context of the surrounding site. This must be done so they can be fully restored and re-established after all drilling activities are finished and the site is restored to its natural condition. These contours can be manipulated to form various drainage areas for the site and can help to solve the containment problems associated with fracing site. By creating various structures such as trenches, littoral zones, and containment areas, any fracing hazards can be controlled and potentially mitigated for on site. Currently, there are no true drainage structure requirements for fracing sites and any potential cleansing opportunities are not utilized. These containment areas can be utilized as cleansing zones which will serve to help clean water and soil and decrease the effort needed to restore and cleanse various resources from the site. At Eagle's Mere, these containment areas were located directly around the fracing site and later utilized as part of the golf course design process. They were created into a tee box along with a surrounding waste bunker. The key component to these containment structures is the integration of bio-mediated soils within them to serve as a cleansing and containment enhancement making them more useful and effective for mitigation (See Figure 2 and Figure 3 for before and after diagrammatic sections of the containment areas.

[4] Poole, David T. "Hydraulic Fracturing of Unconventional Gas Shales: Potential Pollutants, Treatments and Remediation." The Ohio State University, 18 May 2012. Web. <http://senr.osu.edu/images/Poole_final_MENR_project.pdf>.

Figure 2: Fracing Containment Trenches Before

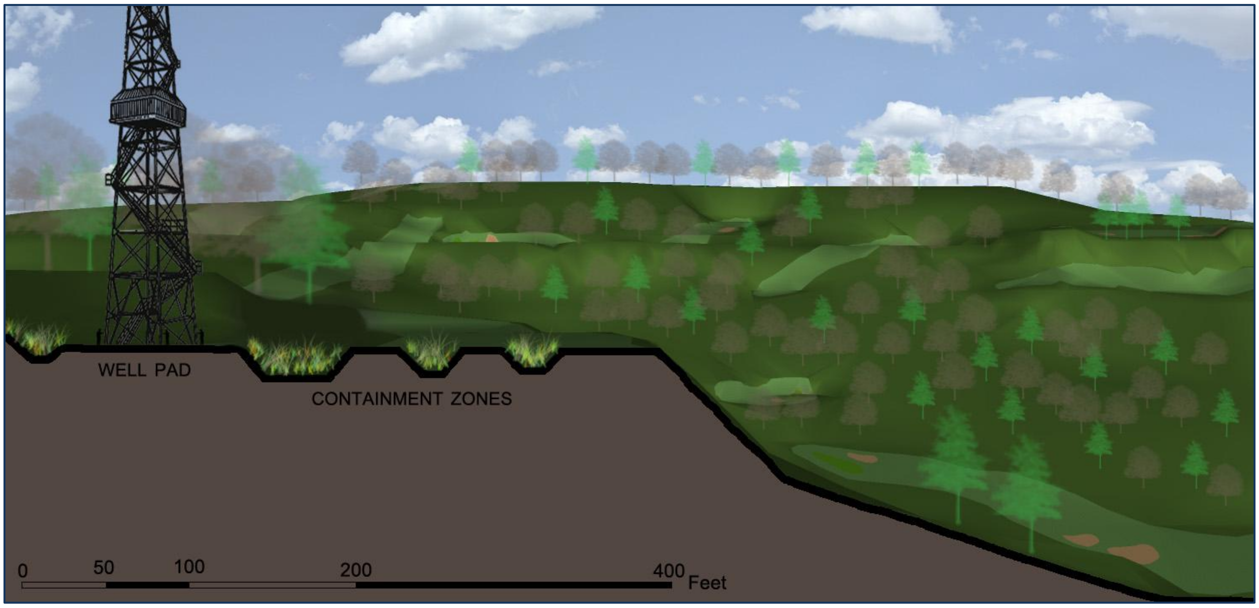
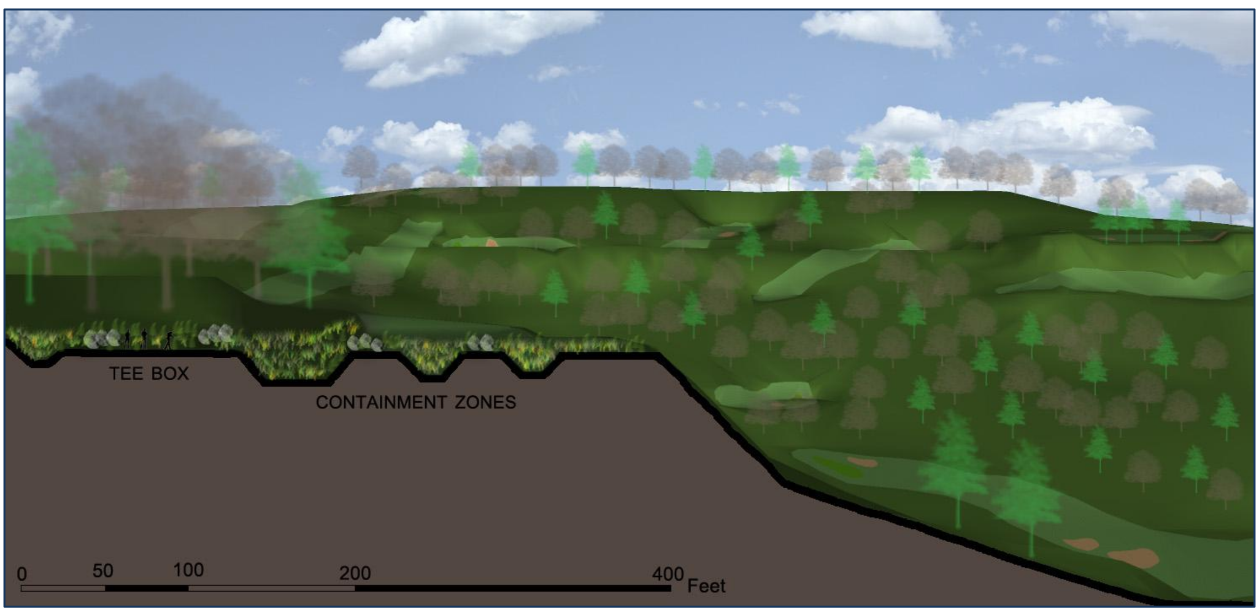


Figure 3: Fracing Containment Structures After



These areas designed for drainage, containment, and treatment can also serve a valuable safety structure during the fracing process. Currently, safety structures are non-existent around fracing sites. Refer back to Figure 1 and note how there are no safety structures associated with the fracing brine pit. All of the hazards chemicals and post-fracing waste is stored in these pits which are open to the air and susceptible to all sorts of potential disasters. In the event of a flood, wind storm, human error, etc.

anything spilled from the frac site will flow directly into the surrounding areas and not be safeguarded for in any way. Through the implementation of a simple trench system, these potential accidents could be prevented and reduce the chances of any potential environmental disasters. In the case of Eagle's Mere, these safety structures also function as potential cleansing areas as they can be outfitted with bio-mediated soil and vegetation. After they have served their purpose for fracing, they can be utilized as various forms of golf course infrastructure and be integral in the design process. At Eagle's Mere the safety structures directly surrounding the fracing site were retrofitted to serve as a waste bunker surrounding a tee box which was also created from previous the fracing site. This development was present through all phases of the course design and utilized as an important aspect to the planning and design of the course.

BIOMEDIATED SOIL

New advancements in geotechnical and geochemical engineering have provided very exciting technology available for site cleansing and restoring. This new wave of technology is centered on the introduction of biologic organisms which change the chemical and physical properties of the media they are introduced into.[5] This method of chemical and physical site remediation and restoration is referred to as "bio-mediated" processes. These micro-organisms are introduced into the media and through their own metabolic processes either take in harmful pollutants and contain them or they change the molecular structure of the surrounding environment.[6] This can be an incredibly useful practice for restoring a fracing site after it has been drilled on and potentially contaminated. The bio-mediated organisms can be introduced into the soil and successfully clean out various harmful chemicals and absorb other heavy metals, toxins, and radioactive materials. After this, different bio-mediated organisms can be introduced that will change the physical structure of the media making it easier to remove or serve as a way to contain the harmful agents found in the soil until proper cleansing procedures can take place. This structural alteration would turn it from a porous and lose consistency

[5] DeJong, J.T. "Biogeochemical Processes and Geotechnical Applications: Progress, Opportunities, and Challenges." University of California, Davis: Department of Civil and Environmental Engineering, n.d. Web. <http://www.sil.ucdavis.edu/Geotechnique-Bio-Soils.pdf>.

[6] Heckman, John R. "Restoration of Degraded Land: A Comparison of Structural and Functional Measurements of Recovery." Virginia Polytechnic Institute and State University, Apr. 1997. Web. <http://scholar.lib.vt.edu/theses/available/etd-1416152839711171/unrestricted/etd.pdf>.

into a dense and un-porous structure - resulting in better chemical sequestration within the soil and subsequently easier to clean up and remove pollutants. [7]

At Eagle's Mere, these organisms could be used in any area which serves as a containment zone for the golf course or fracing site. This includes but is not limited to trenches, littoral zones, containment areas, bunkers, waste bunkers, water hazards, etc. These ideas are grand in nature and would serve well from the input of chemical, geological, and environmental engineers. By integrating this technique with fracing the industry could forge on into a new era of more environmentally-sound practices.

SOLUTIONS SUMMARY

Clearly, there is a lot that can be done in terms of fracing site mitigation and restoration. Visual mitigation can be achieved through proper planning and utilization of vegetative screening. This vegetation can be incorporated effectively into golf course design for both aesthetics and strategic purposes.

The introduction of various soil containment techniques can also help to preserve the quality and effectiveness of the soil on site. This allows for it to be utilized post fracing for restoration and golf course design.

Drainage and containment areas can also be implemented adjacent to and in the proximity of fracing sites in an attempt to control the flow of water and debris from the site and contain it for proper cleaning. This cleansing and removal can be enhanced through the use of bio-mediated soil which will lead to better overall fracing mitigation. These drainage and containment structures can be easily incorporated into golf course design as various infrastructure related to the flow of play. This integration can easily be achieved due to their similar design and function. These drainage and containment areas also can serve as safety structures which safeguard the area from potential runoff contamination associated with fracing accidents and disasters.

[7] D, Jason T., Brina M. Mortsensen, Brian C. Martinez, and Douglas C. Nelson. "Bio-Mediated Soil Improvments." Ecological Engineering, Feb. 2010. Web. 07 Jan. 2013. <http://www.sciencedirect.com/science/article/pii/S0925857409000238>.

All of these techniques can serve as a means to achieve the purpose of solving the visual, water, soil, and safety problems associated with fracing while simultaneously providing intriguing components to golf course design.

IMAGE CREDITS

Figure 1

"Industrial Scars". http://jhenryfair.com/aerial/portfolio/gas_drilling.html

Figure 2

Fracing Image Section created by Matthew Franko

Figure 3

Fracing Image Section created by Matthew Franko

CHAPTER 5: MITIGATION IMPLEMENTATION THROUGH GOLF COURSE DESIGN

GOLF COURSE DESIGN INTEGRATED WITH FRACING

The process of golf course design is one which requires a routing pan, sizing plan, shaping plan, cut and fill analysis, and eventual master plan. All of the techniques used through the design process are very capable of incorporating fracing infrastructure into its methodology.

From the golf standpoint an evaluation of the potential area must take place, along with an evaluation of any existing golf infrastructure and how it can be improved. This analysis will inform the routing, sizing, and eventual master planning of a newly designed golf course. Note Figure 9 in Chapter 3 to see the golf analysis done for Eagle's Mere.

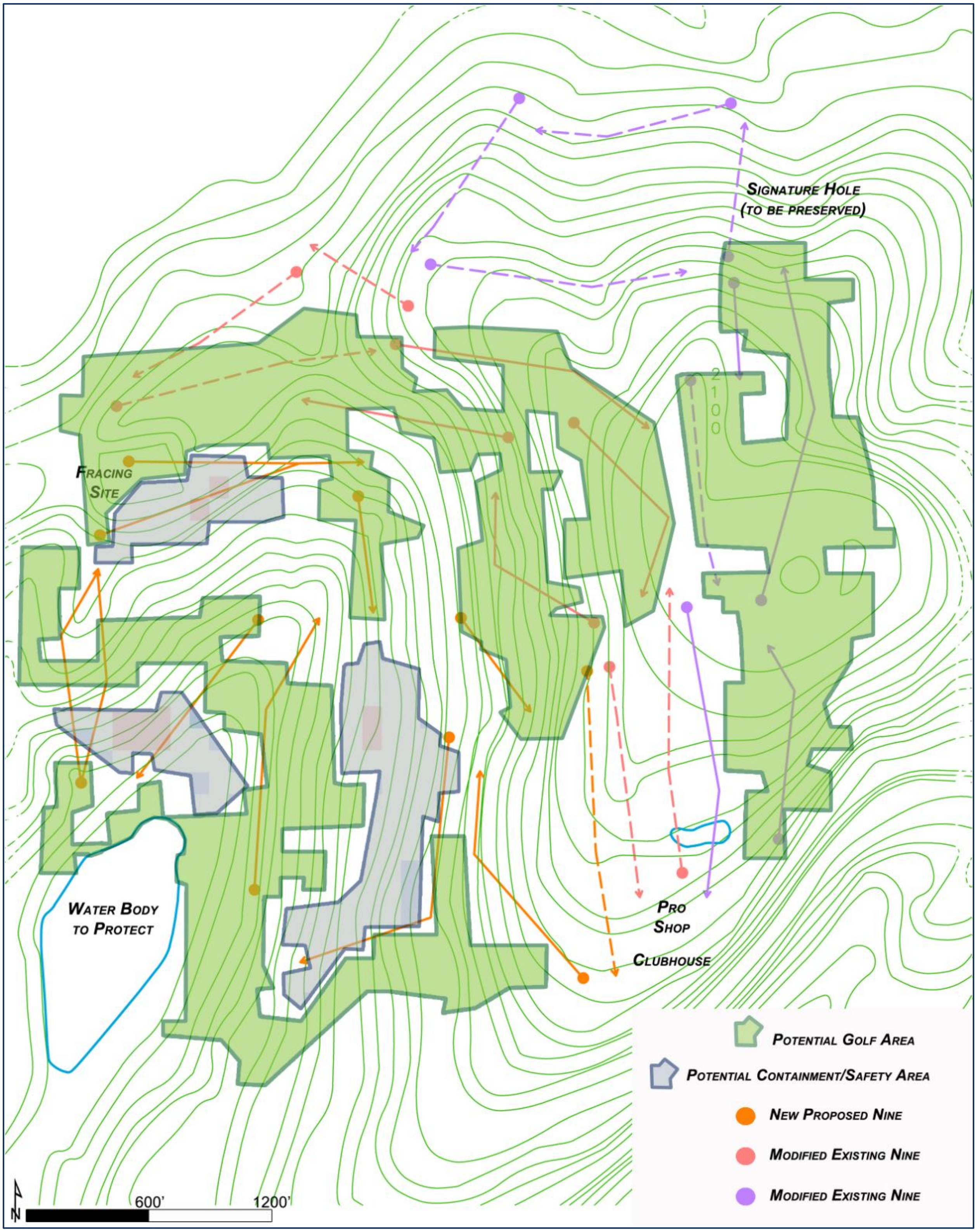
The fracing side of things requires simultaneous evaluation of site feasibility as well as identification of the potential problems the drilling will have on the current and future functionality of the golf course. This will help implement potential drilling while play still occurs. It will also help to identify where implementation of additional safety features can be integrated as well as areas in need of visual mitigation. This infrastructure can be converted to integrated pieces of the golf course after the drilling is completed.

Through these processes you will see the development of a fracing site (post-drilling) be utilized in the design and development of a golf course which incorporates the fracing infrastructure as an integral part of the course design methodology. In order for the fracing and golf course integration to be successful the golf course must be designed in the proper manner and follow all the attributable steps to creating a successful golf course development.

GOLF COURSE ROUTING PLAN

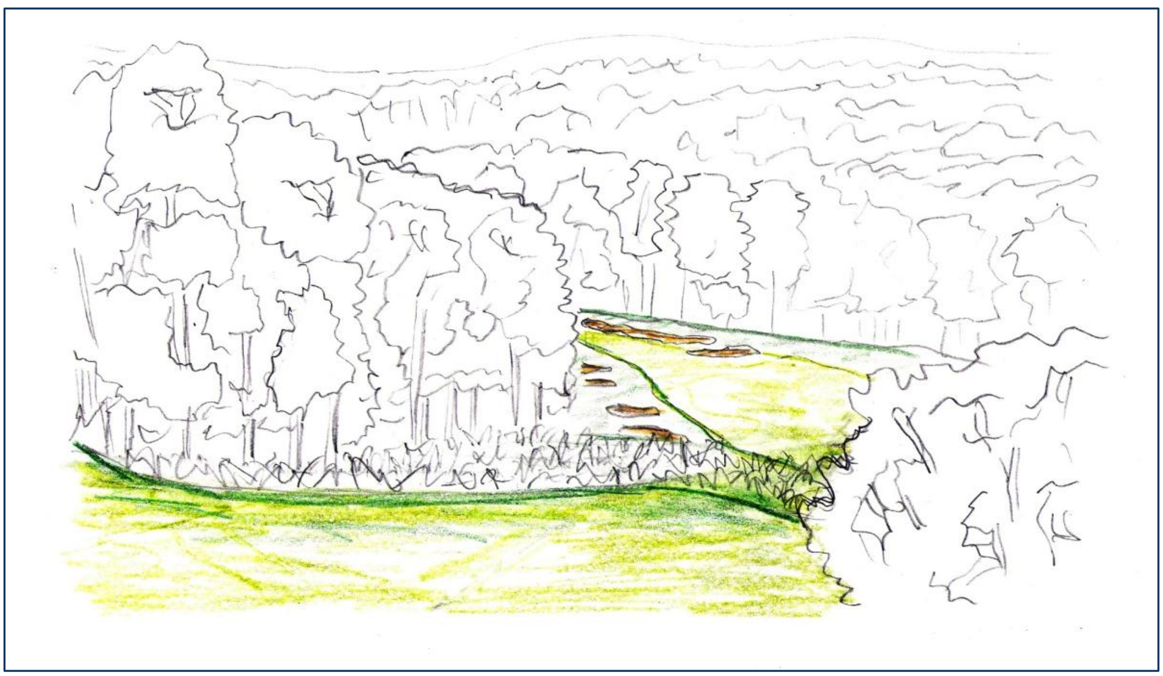
The course design process must always begin with a topographic analysis resulting in the routing plan for potential holes. The routing process is comprised of identifying all the potential locations for holes and how they will interact with each other. In this process the architect can dictate a certain flow of play and achieve many of the strategic sequence of events which are to occur for the player. It is in this stage

Figure 1: Course Routing Plan



that the proper loops of play can be assured in an attempt to have players always start and finish at the clubhouse. It is typical to utilize the topographic map in this process in an attempt to find the flatter areas for tees and greens in order to minimize the amount of earthwork which must be done later in the construction phase of the project (note Figure 1). For the Eagle's Mere design, the opportunity areas from the site synthesis analysis were combined with the topography in the routing phase. This allowed the pivotal information gathered in the critical analysis study to be incorporated into the earliest stages of golf course design. This will help to design the holes around the fracing site and properly incorporate it into the golf course. The routing phase will also be crucial in the cut and fill process and help to dictate how many uphill, downhill, side hill, level, straight and dog-leg shots are presented to the player. While developing the routing, it is important to achieve a balance of all of these shot types so as to provide the player with multiple scenarios so as to avoid a monotony of hole types.

Figure 2: Hole Concept Sketch



This is also a great opportunity for the architect to begin sketches in order to experiment with what the course will look like and what type of character it will have – example sketches in Figures 2 and 3. The conceptualizing of holes in this phase will ultimately lead to the course's overall character and aesthetic qualities.

Fracing can be integrated into this process by incorporating its existing infrastructure into the strategic location of golf-specific areas. The fracing site itself can be identified by flat terrain which would be useful as some form of tee or green. The fracing site can also dictate the prescribed location of various stormwater and safety structures. By identifying these areas in the routing phase, they can remain constant throughout the design process and be effectively utilized in the final golf course plan.

Figure 3: Hole Concept Sketch

In the case of Eagle's Mere Country Club, the new routing is intended to eliminate awkward hole crossing and provide more variety and heroic shot making opportunities for the player. Three new nine hole layouts have been proposed which can be played in any combination so the player can add variety to their round by incorporating drastic elevation changes and many subsequent heroic opportunities. This added variety is crucial in terms of adding enjoyment for players and helping to maintain the golf course's appeal in the long-term.[1] The routing has also incorporated the fracing site as a potential tee box and specifically designed holes to utilize various littoral collection areas as either aesthetic accents or backdrops. By successfully routing the course while integrating fracing into the process, Eagle's Mere is effectively utilizing the various techniques needed to mitigate for the problems associated with fracing, while maintaining the integrity and playability of the golf course.

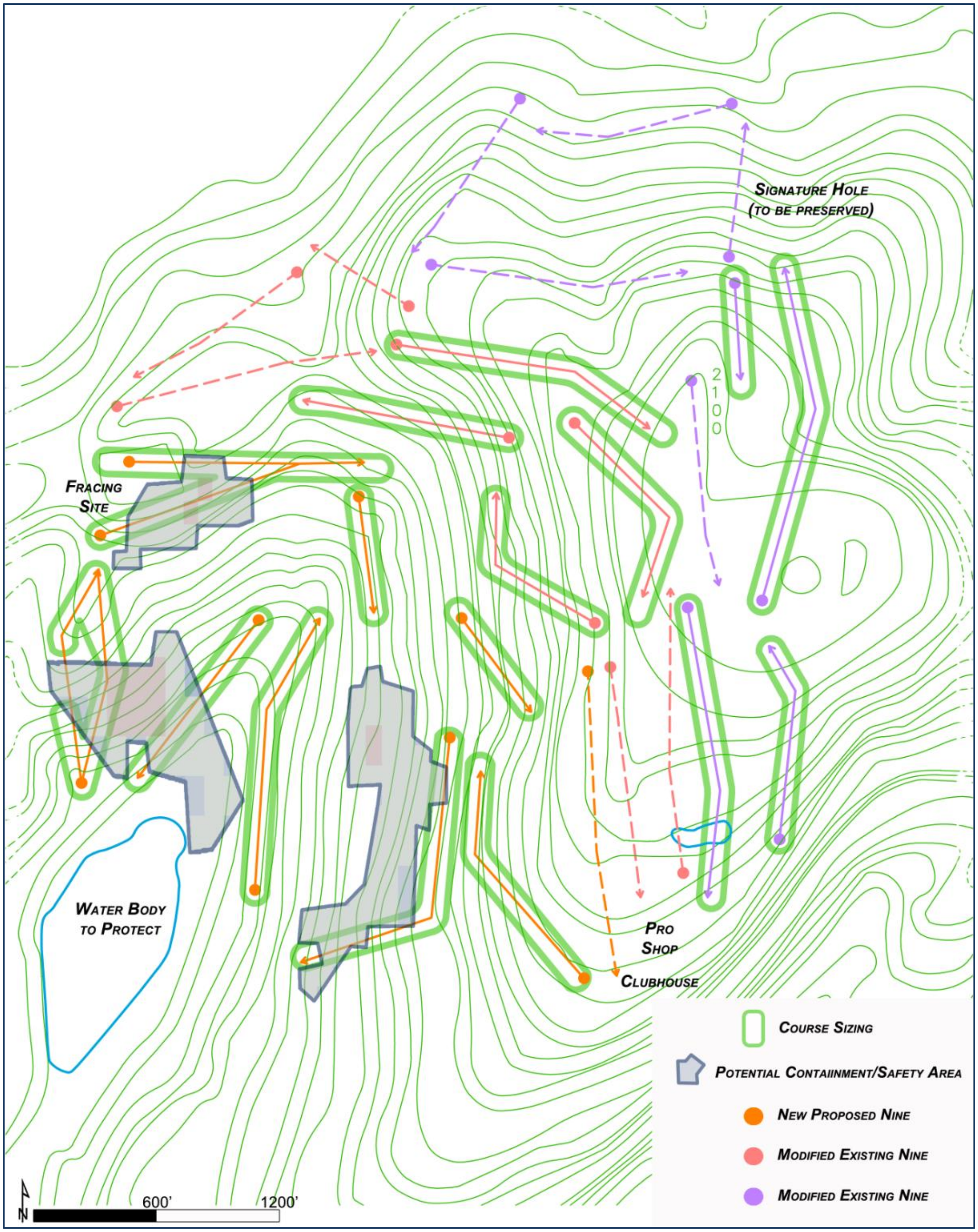
GOLF COURSE SIZING PLAN

The routing process can often demand the most time for the overall project as it will lay the groundwork for the entire course. However, once routing is established, it is important to incorporate course sizing into the concept to make sure it will effectively fit the space it is intended to. This process takes the linear characteristics established in the routing phase and begins to give some dimensions to each hole. There is no true hole design during this process, but it is essentially setting aside the land necessary for certain features needed for each individual hole. This guarantees that the dimensions necessary can be supported by the topography and will establish proper proximity for adjacent holes. This is a crucial step in the course design process as it serves as a safeguard for setting aside the required land needed to create each hole separately.

This is also a great time to establish potential conflicts between holes and gives a better vision to what the overall course is intended to be. In Figure 4 the sizing plan for the new Eagle's Mere Country Club is depicted to provide a comprehensive example of the appropriate sizing phase after routing is completed. This stage shows how the new holes will fit into the existing landscape and demonstrates how the holes fit next to each other in order to achieve a proper layout. This step in the design process is also incorporating the fracing-related sites into it consideration by considering the size and shape of the fracing site in conjunction with the hole surrounding it. This is also helping to ensure that the necessary sizing and placement of fracing mitigation infrastructure is achieved and balanced in conjunction with the golf course.

[1] Doak, Tom. *The Anatomy of a Golf Course*. Short Hills, NJ: Burford, 1992. Print.

Figure 4: Course Sizing Plan



GOLF COURSE SHAPING PLAN

The course shaping process is where the first detailed design can begin to be implemented and the actual course can begin to take shape. In this stage the subtle nuances of each hole can begin to reveal themselves and the overall course strategy developed in the routing phase can begin to take shape. Each hole will now be given a specific shape which corresponds to how the hole must react to the introduction of hazards, rough, the creation of various sight angles, and existing or proposed fracing infrastructure. Here the various aspects to each hole can be identified and experimented with such as bunker shape, rough proximity, green shape, etc.

This phase is crucial to maintaining a variety between where hazards are placed as well as how each hole is played. Through the addition of various hazards a certain style of play can be dictated to the user, either:

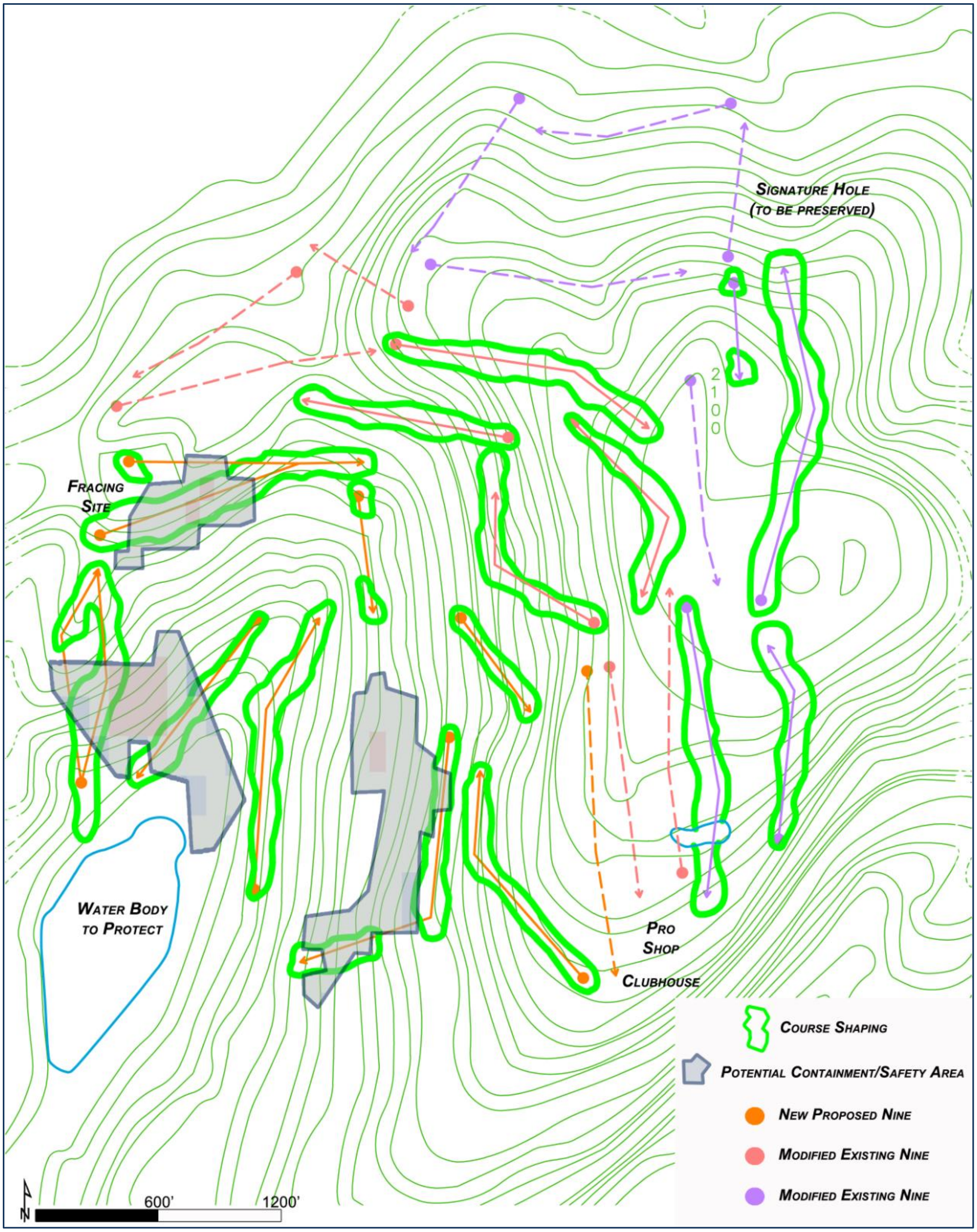
- ✓ Heroic
- ✓ Strategic
- ✓ Penal.

It is important to maintain a balance of these types of holes which is achievable through the placement of certain hazards or landing zones. By placing trees, bunkers, or landing zones in the proper places, a player can be enticed into a heroic shot or forced to make a more conservative play. Creating a balance between these types of situations is critical as it will provide variety to the player.[2]

At Eagle's Mere, the orange layout (the entire new 9 holes) serves as the primary heroic component while the existing course presents the necessary penal and strategic scenarios to create balance. Many of the fracing mitigation areas have been integrated in the new heroic layout as they provide the needed hazards to encourage a heroic opportunity. The Eagle's Mere course shaping map can be noted in Figure 5. As the hazards, safe zones, and fracing mitigation areas are implemented, more information can be gained topographically and should be noted as it will be crucial in the next phase – cut and fill.

[2] Shackelford, Geoff. *Grounds for Golf: The History and Fundamentals of Golf Course Design*. New York: T. Dunne, 2003. Print

Figure 5: Course Shaping Plan



GOLF COURSE CUT AND FILL PLAN

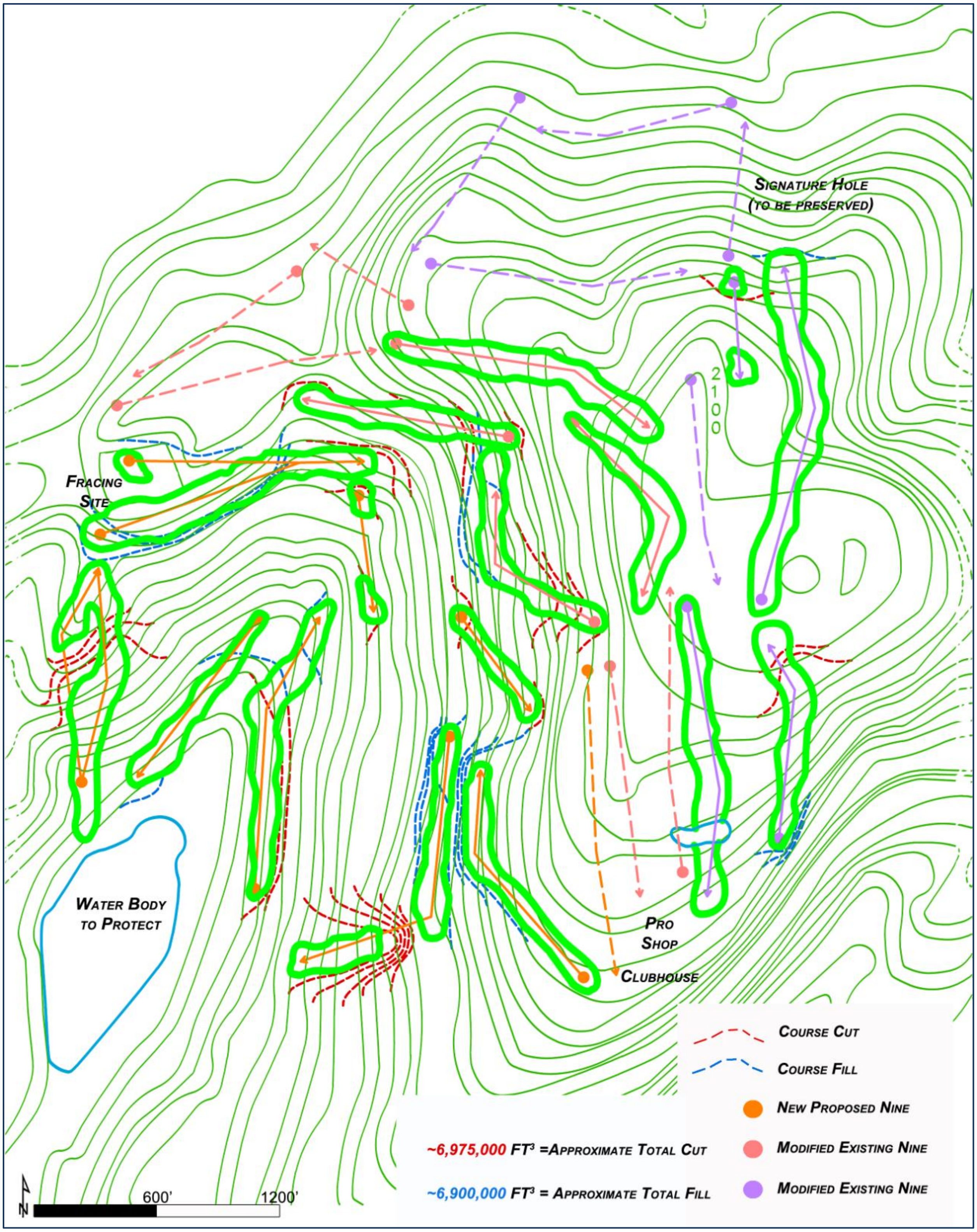
The cut and fill stage is the ultimate feasibility evaluation in regard to the overall golf course plan as it will dictate the overall financial cost associated with the amount of earth moving done to achieve the design. This process is a system of analyzing the existing topography and then calculating how much land must be removed or added in order to achieve the layout desired. Typically, the cut and fill occurs mostly on the tees and greens as these are the most desirable level locations for the golf course. They must be level as anything greater than approximately a 3% slope will be unusable by the players for potential shots.[2]

There will also be a fair amount of cut and fill done to the fairway sections of a course as these areas provide the opportunity to create side slopes on the fairways as well as level landing zones for the players to utilize. It is important to provide a balance of these areas as they can play into the strategic layout of a hole. For example, a player may be provided with a flat area to reach for an approach shot but is far from the green; whereas an un-level area can be provided which will be closer to the green but offer a more challenging shot.

The cut and fill process is one which can help to further advance the strategy and balance created in the routing and sizing processes. This cut and fill stage is crucial as it must reinforce the ideas set forth in the routing and sizing steps and not conflict with them – rendering them useless. For example, if an easy hole is created after a very challenging hole in order to create a “breather” for a player, then it would not be wise to create a drastic elevation and slope change on this hole as it will make it play harder and therefore not achieve the original goal.

The overall feasibility of the potential course layout is not geared towards how much cut and fill is needed but more about how balanced it is. By achieving a balance of cut and fill the topsoil needed for the creation of the course can be found on site. When all the “cut” dug out can be used for “fill” then the final product will not require the purchase of needed soil or the selling of leftover soil. It is important to note that if complete balance is not achievable then it would be more advantageous to have extra cut

Figure 6: Course Cut and Fill Analysis



as this will provide a surplus as opposed to a deficit of soil. This excess can potentially be sold for financial gain.[1]

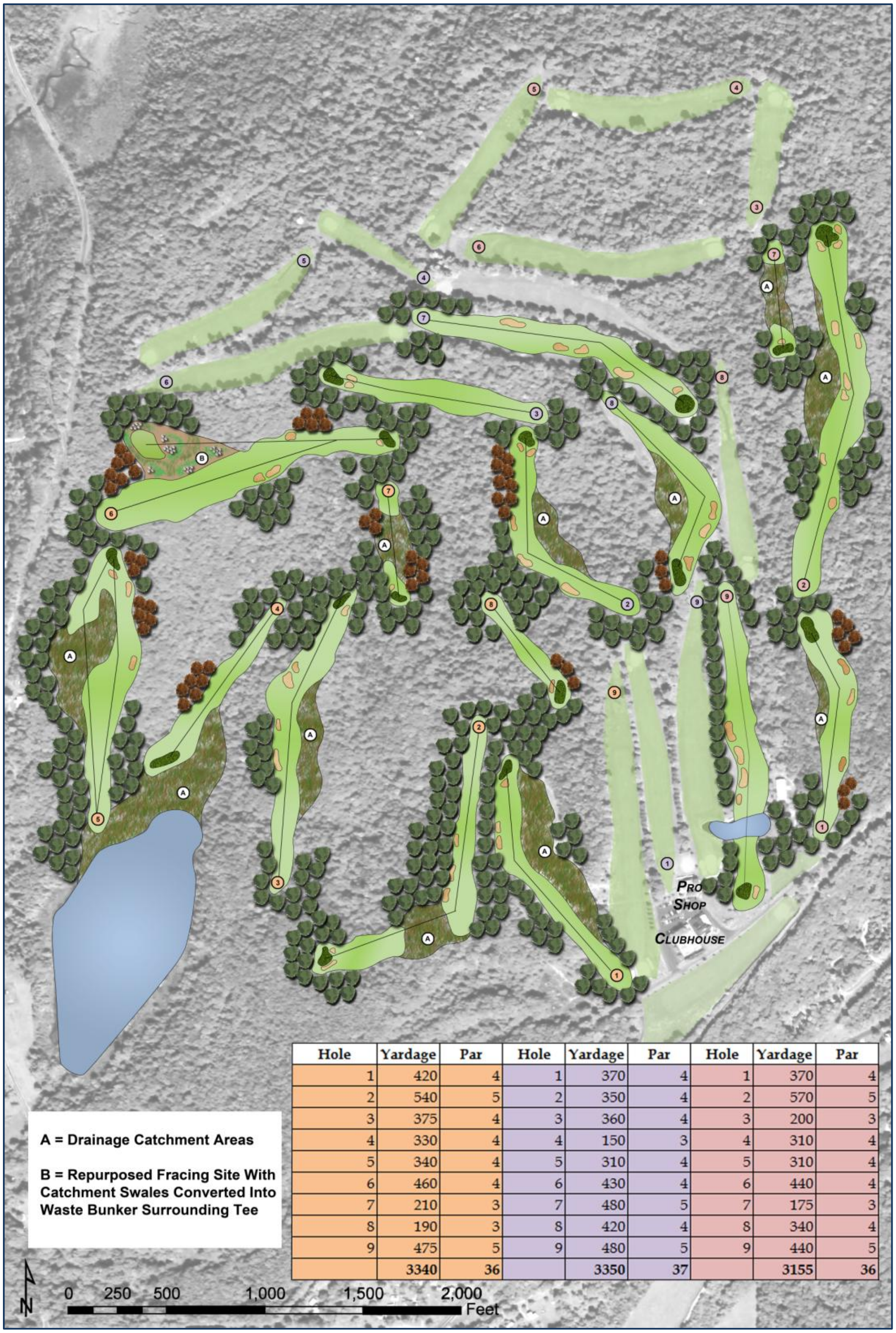
A cut and fill analysis for Eagle's Mere was done which included the fracing site (post-drilling) into the process (see Figure 6). This analysis shows how the existing site was utilized as a tee box and provided a useful area in which a lot of potential cut was avoided. This analysis also displays how much cut and fill was estimated to be needed in order to achieve the desired design. These estimations were very similar in totals and helped to dictate subtle changes in the design in order to get the numbers as close as possible. In doing this it helped to establish the appropriateness of the fracing and golf course integration from an earthmoving standpoint.

GOLF COURSE MASTER PLAN

In the master plan phase all of the larger conflicts can be worked out such as hole length, flow of play, etc. and more details can be addressed and worked through. This is where the course design can begin to reveal itself and will show its true nature. The intent of this plan is to provide people with a grand vision for the course and will include any special features which the course will bring to the table – such as fracing mitigation infrastructure. This plan demonstrates the culmination of all the previous design steps and serves as a means to demonstrate the overall goal of the final plan.

An example of a master plan for the fracing and golf integration at Eagle's Mere can be seen in Figure 7 which is the culmination of Figures 1-6. This plan depicts the overall site and shows an illustrative example of how the entire course is laid out and integrated with the fracing mitigation areas. The course has been outfitted with various techniques used for potential physical, chemical, and visual mitigation zones which address the fracing site and incorporate it into the course design. These techniques, which were established in the critical analysis phase and carried throughout the golf course design phase, can be seen their true form via the final master plan.

Figure 7: Course Master Plan



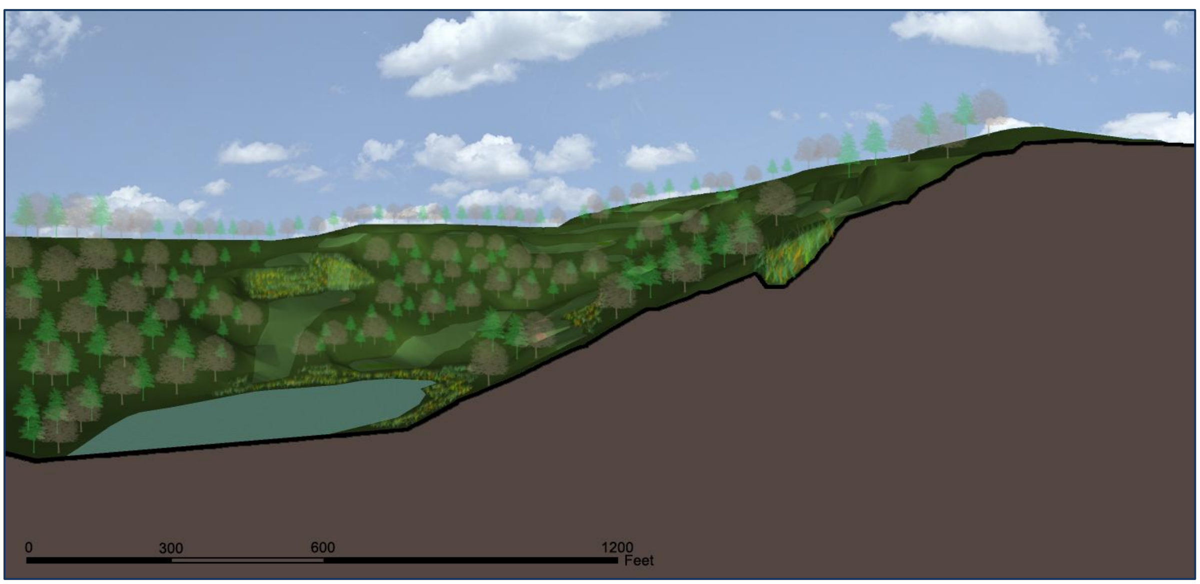
Hole	Yardage	Par	Hole	Yardage	Par	Hole	Yardage	Par
1	420	4	1	370	4	1	370	4
2	540	5	2	350	4	2	570	5
3	375	4	3	360	4	3	200	3
4	330	4	4	150	3	4	310	4
5	340	4	5	310	4	5	310	4
6	460	4	6	430	4	6	440	4
7	210	3	7	480	5	7	175	3
8	190	3	8	420	4	8	340	4
9	475	5	9	480	5	9	440	5
	3340	36		3350	37		3155	36

SITE DETAILS: DRAINAGE AND CONTAINMENT

First, the issue of physical and chemical mitigation must take place within and around the golf course as its known inhabits previously drilled the land. Physical mitigation can come in the form of various structures integrated into the stormwater and management plan through the use of trenches and littoral zones used for stormwater collection and potential cleansing. The use of strategically placed littoral zones is a great way to incorporate safeguards for groundwater intrusion areas as well as water filtration areas. If you note Figure 7 (the Master Plan), all the areas labeled "A" are man-made littoral zones which serve as:

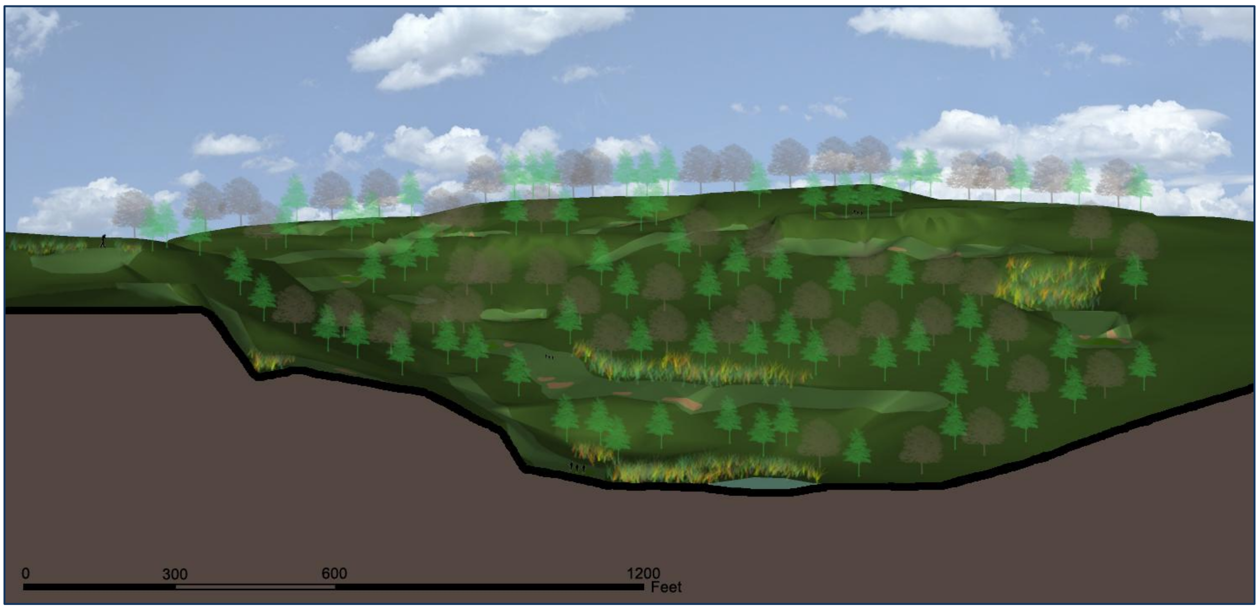
(1) Overflow structures for certain wet areas (preventing golf course damage during flooding)
(2) Water filtration zones as they are located in the direct path of runoff
(3) Catchment zones where any potentially polluted water can be held until it is either cleansed or harvested

Figure 8: Strategic Littoral Zones - Shown in Areas with Bright Colored Grasses



The littoral zones which serve as catchment and safety structures can be seen in Figure 8 and Figure 9 depicted in section-elevation form. These areas can also be outfitted with the bio-mediated soil mentioned in Chapter 4. The use of this cleansing and hazard removal technique increases the efficacy of these drainage and containment structures – making them more effective in the landscape. It is also important to treat these created littoral zones as “no-spray zones” in which pesticides and fertilizers are not incorporated into their management plan. These areas can receive high levels of runoff and must be preserved in an attempt to not overload them from potential Phosphorous and Nitrogen contamination.[3]

Figure 9: Strategic Littoral Zones - Shown in Areas with Bright Colored Grasses



These areas can be interspersed throughout the course and serve as a valuable fracing protection structure along with water quality improvement mechanisms. After the physical containment and treatment methods have been addressed, the potential visual problems associated with the drilling structures can be implemented.

SITE DETAILS: VISUAL MITIGATION

It is critical to understand and plan for the impact drilling structures can have on the flow of play and potential visual hazards within the area. Although fracturing often takes place in rural areas, by creating

[3] Dodson, Ronald G. *Sustainable Golf Courses: A Guide to Environmental Stewardship*. Hoboken, NJ: J. Wiley & Sons, 2005. Print.

Figure 10: Fracing Visual Impact - Section-Elevation (Before)

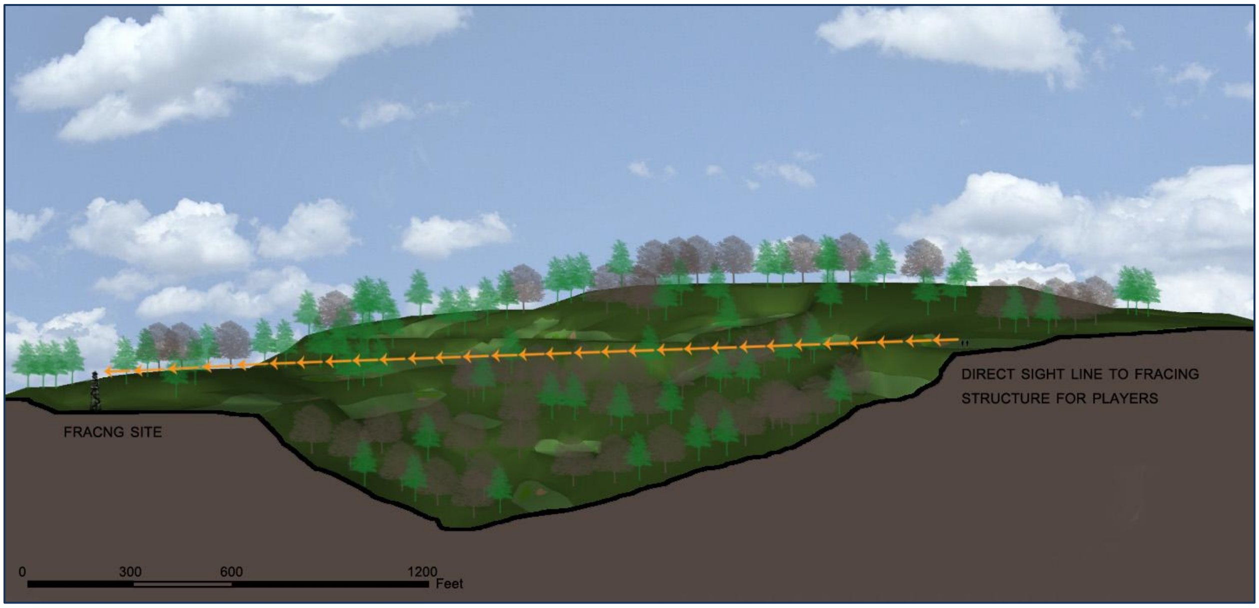
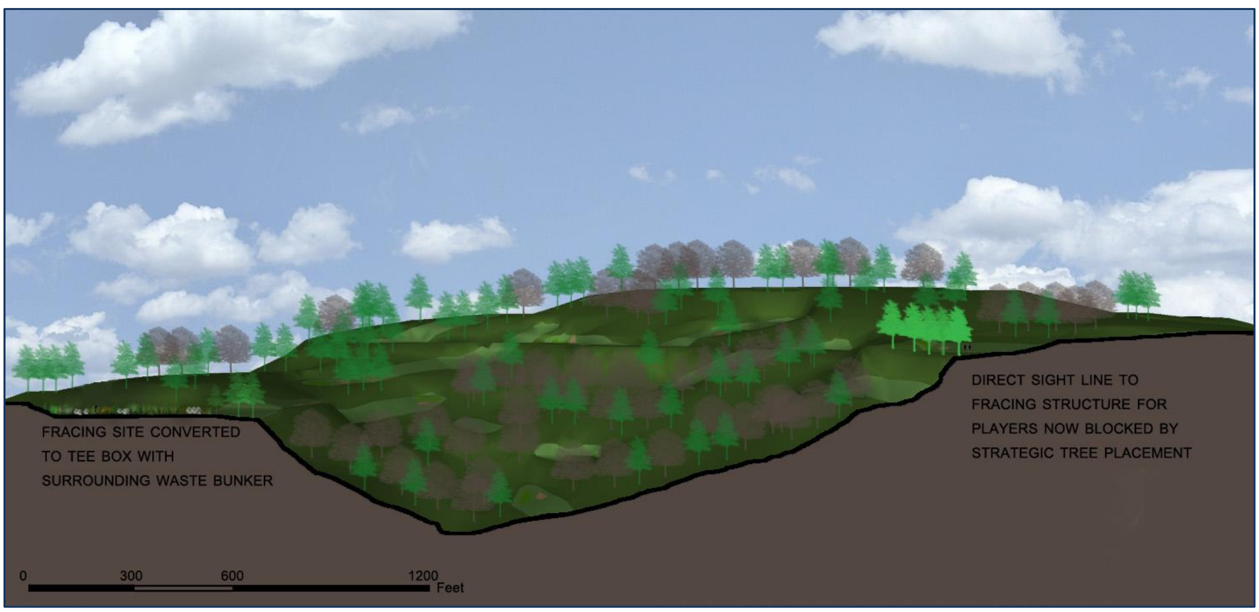


Figure 11: Fracing Visual Impact - Section-Elevation (After)

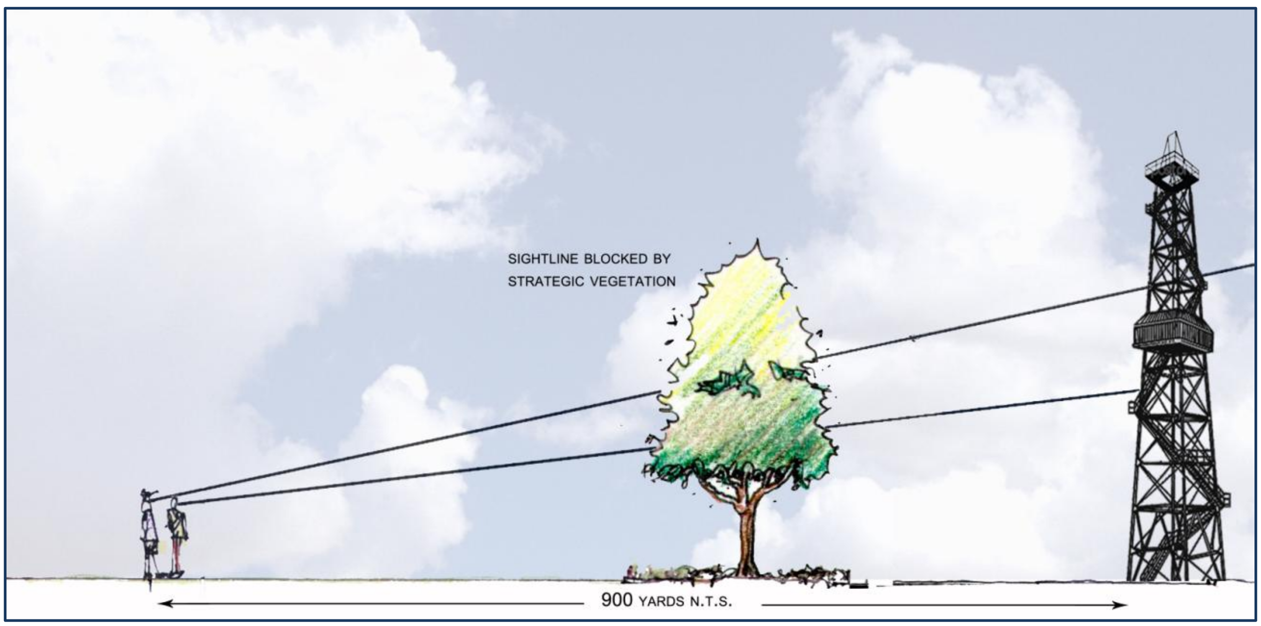


an atmosphere which humans can find acceptable; it will help to boost the public perception of the fracturing process in more populated areas.[4] They can also provide potential aesthetic enhancements to

[4] Kuehn, Sarah. "Landscape Practices on Gas Well Sites in North Texas: Perceptions of Selected Industry Representatives and Regulators." University of Texas at Arlington, Dec. 2011. http://dspace.uta.edu/bitstream/handle/10106/9543/Kuehn_uta_2502M_11493.pdf?sequence=1Web.

an area based on the site line mitigation utilized to buffer the fracing site. Examples of how these visual mitigation structures works can be seen in Figures 10-11, depicting section-elevations of potential sight line problems and how they can be solved via the addition of strategically placed vegetative cover. This technique has been utilized at Eagle's Mere to serve as a visual mitigation for fracing as well an intricate part to the strategic design of the course and the development of its aesthetic. The site line mitigation needs were present in the planning stages of the course and facilitated in dictating the design and implementation of various hole components and accent areas. For a diagrammatic section of this visual mitigation occurring away from the drilling site, refer to Figure 12.

Figure 12: Diagrammatic Sight Line Blocking Section



SITE DETAILS: SAFETY STRUCTURES

The golf course is in need of various depressions in which to outfit water hazards, bunkers, and other penalizing infrastructure associated with golf course design. At Eagle's Mere the potential safety structures (trenches and swales) created around the fracing site can be retrofitted and utilized as hazard areas associated with the newly designed golf course. These structures, although serving as part of the golf course, can also still effectively prevent any potential fracing hazards left behind from spreading throughout the landscape. Note Figure 2 and Figure 3 in Chapter 4 for before and after diagrammatic section-elevations of the fracing site at Eagle's Mere and how the containment and safety structures function. These images demonstrate the protective nature of the trenches during fracing, as well as how they are integrated with the golf course, post-fracing. The trenches and swales can be molded and shaped in order to fit the lay of the land surrounding the fracing site so as to appear to fit in properly with the design intent at Eagle's Mere. Since much re-grading is done to prep a site for fracing this is a very easy safety measure to retrofit after drilling has finished as all the necessary equipment required will be on site.

CONCLUSION

All of this bio-technology combined with the other physical and visual mitigation techniques can provide the basis necessary to create a safer hydraulic fracturing process and successful marriage between the fracing process and golf course infrastructure. A final before and after view of a fracing site at Eagle's Mere converted into a part of a golf hole can be seen in Figure 13 and Figure 14. The drainage, containment, and treatment techniques along with the visual appeal and sequestration safety structures provided by a golf course can clearly be integrated into the drilling process. This integration is beneficial as it provides necessary mitigation for fracing while still providing useful golf course infrastructure.

Figure 13: Fracing Site Aerial Perspective (Before)

Figure 14: Fracing Site Aerial Perspective (After)

IMAGE CREDITS

Figure 1

Course routing plan created by Matthew Franko

Figure 2

Hole concept sketch created by Matthew Franko

Figure 3

Hole concept sketch created by Matthew Franko

Figure 4

Course sizing diagram created by Matthew Franko

Figure 5

Course shaping diagram created by Matthew Franko

Figure 6

Course cut and fill diagram created by Matthew Franko

Figure 7

Fracing littoral safety zones section-elevation created by Matthew Franko

Figure 8

Fracing littoral safety zones section-elevation created by Matthew Franko

Figure 9

Fracing visual section created by Matthew Franko

Figure 10

Fracing visual section created by Matthew Franko

Figure 11

Created by Matthew Franko

Figure 12

Visual screening diagram created by Matthew Franko

Figure 13

Fracing site aerial perspective created by Matthew Franko

Figure 14

Fracing site aerial perspective created by Matthew Franko

CHAPTER 6: CONCLUSIONS

FRACING INDUSTRY PROBLEMS AND NEEDS

The natural gas industry has advanced both technologically and politically as its representation in the energy market has grown 28% since 2002. The innovations of horizontal drilling techniques are, by far, the largest contributor to the immense growth in the industry. The growth of this industry is still young in comparison to older methods of fossil fuel extraction and still has much to be seen from technological and legislative perspectives. Much of the future of this industry will be determined based on the growth of safety measures and the industry's ability to hold itself accountable for its processes. The industry will also need to find solutions for many of the environmental problems created by its practices. The industry is currently seeking to find technologies or ideas which can fill the gaps present in the industry and successfully mitigate their impact on the landscape.

GOLF COURSE INDUSTRY PROBLEMS AND NEEDS

Golf courses are in desperate need of funds as the industry's average yearly revenue continues to decrease. To be sustainable, this revenue must come from improved course playability through better design techniques[1]. The industry must find a way to fill the voids in their revenue stream for the short-term, in order to invest in much needed course re-designs which will provide long-term financial gains.

Golf courses offer certain attributes which are very unique and cannot be found in many other areas due to their large size and drainage infrastructure. The drainage systems on golf courses are immense systems which control a majority of water present on the course. Golf courses are very effective in their stormwater management practices and their usefulness in these areas must be utilized if they are to expand their future and become successful once more. Golf courses could utilize their infrastructure within other industries for an increase in revenue in order to fill the debt left by recent market trends and a dip in their overall profitability.

GOLF COURSE AND FRACING INTEGRATION

[1] GSCAA. "Golf Course Environmental Profile: Property Profile and Environmental Stewardship of Golf Courses Volume I." Environmental Institute for Golf, 2007. Web. <http://www.eifg.org/programs/GCRPfullreport.pdf>

The search for a new revenue source for golf courses could come in the form of constructing temporary fracing sites within the property. The fracing industry, although booming, is dealing with a major public perception issue and is seen by many as a source for potential environmental degradation.[2] The major issues of concern regarding fracing are:

- ✓ Visual stigma
- ✓ Groundwater and soil pollution
- ✓ Surface water pollution
- ✓ Negative visual impacts
- ✓ Lack of safety measures surrounding well pads

All of these problems can be solved by utilizing golf course infrastructure. The golf course industry presents the necessary resources for the fracing industry to improve its practices and advance itself. Fracing sites can receive the needed visual mitigation through the implementation of vegetation associated with golf course design and aesthetic. Fracing sties can also achieve proper methods to sequester, clean, and remove any potential hazards through the utilization of existing or proposed golf course infrastructure in the form of:

- ✓ Absorption trenches
- ✓ Diversion ditches
- ✓ Retention areas
- ✓ Water and soil cleansing areas via man-made littoral zones

Highly needed safety structure can also be implemented during the drilling process to protect the site as drilling occurs. After drilling has taken place, these areas can be retrofitted quite easily to be reintegrated with the golf course and serve as important pieces associated with course design and play. In order to advancing the effectiveness of the drainage, containment or safety structures, bio-mediated soil can be introduced as a means to effectively neutralize harmful waste within the soil and also provide potential containment and removal of this waste in an effective manner.

The fracing industry would “pay back” the golf course for these services with an added revenue stream and help the course re-establish its financial roots. These financial gains could be reinvested in the

[2] Wiseman, Hannah. "Trade Secrets, Disclosure, and Dissent in a Fracturing Energy Revolution." Columbia Law Review: Sidebar 111 (2011): 1-13. Print.

course through sustainable measures that would decrease the course's lifetime maintenance costs and increase player enjoyment – leading to a sustainable and profitable future.

The two industries could greatly benefit from their integration. Golf courses can solve the visual, water, soil, and safety problems associated with fracing and fracing sites can provide a revenue source for golf courses to lift them from their depressed state.

RELEVANCE TO LANDSCAPE ARCHITECTURE

Landscape architects could find themselves in the middle of this combination of industries as they possess the skill set required to undertake the task of integrating golf course design with hydraulic fracturing methodologies. This profession is uniquely trained in, not only developing land in a particular way, but also in choosing the proper location for development. Chapter 2, Research Methodology, demonstrates the site selection process and how well suited a landscape architect would be at selecting and evaluating potential fracing sites. The analysis ability of a landscape architect is uniquely valuable to the fracing industry and could greatly improve upon its current practices. Landscape architects also can serve the fracing and golf course design industries by lending an aesthetic eye to their overall processes and integration. The profession implements the particular skill of problem solving, like an engineer, while establishing an aesthetic appeal much akin to that which an artist could create. The fracing industry could be uniquely impacted by the landscape architecture profession and could also introduce them more into the golf course design industry.

Landscape architects can also utilize their talents across multiple disciplines as a way to introduce the initial first steps in mitigation process within more land use types. Also, due to the many disciplines landscape architects work with, their advancement of fracing mitigation techniques can make it more noticeable to other professionals whom they work this. This has the potential to generate more advancements over a broad spectrum of disciplines resulting in a broader range of useful fracing mitigation techniques.

NEW TECHNOLOGY ON THE HORIZON

There are many ways in which the fracing industry has implemented new technologies in order to decrease its draw on natural resources and make themselves more sustainable for the future.

There is new technology which can incorporate DNA markers into the fracing fluid used and subsequently trace each well's fluid individually – creating a sort of "bar code" for every fracing fluid solution created.[3] This data can be used in conjunction with a baseline for the area's water quality and monitor it throughout the fracing process and even afterwards in order to assure the quality of the water isn't affected. If the water becomes contaminated it can be determined very quickly and the proper protective and reactive measures can take place.

Another major breakthrough in the fracing industry was introduced by Gasfrac Energy Services (based out of Canada) in which propane gel is used in place of the current fracturing fluid mixture. This technology has been quoted as a "game changer" for the industry as it essentially eliminates the use of water (90% reduction) in the process as well as creates no hazardous waste bi-products. The technology behind this innovation is linked to the chemical interaction of gelled propane and the gases released by the fracturing in the shale. In this process the gelled propane provides the necessary lubricant for equipment, and mimics all the other effects that "typical" fracing fluid achieves. Then, once the fractures occur and the natural gas is released, the propane mixes with the gas resulting in a reaction which eliminates the gel-like properties of the propane. The resultant bi-product of this process is a gaseous form of propane which is no different than that drilled and extracted with hazardous fracturing fluid. [4]

These technologic advancements can reduce a tremendous amount of environmental concerns in regard to fracing and eliminate the high water demands associated with this drilling technique. By utilizing this technology with the integration of the mitigation techniques discussed in this research, the fracing industry can severely limit its impact on the landscape and become a less intrusive form of fossil fuel extraction.

It is important to note these advances as the technology behind this industry is moving extremely fast and the research regarding its mitigation techniques must progress in a similar fashion. This study

[3] Revkin, Andrew C. "Traceable Gas-Drilling Fluids." The NY Times, 8 Jan. 2013. Web. 8 Jan. 2013. <http://dotearth.blogs.nytimes.com/2013/01/08/ideas-to-watch-in-2013-traceable-frackin-fluids/?smid=tw-nytimesscience>.

[4] Milmo, Sean. "Fracking with Propane Gel." *Fracking With Propane Gel*. RSC Chemical Solutions, 15 Nov. 2011. Web. 01 Aug. 2012. <http://www.rsc.org/chemistryworld/News/2011/November/15111102.asp>.

regarding Eagle's mere occurred over the course of 12 months. If the future research regarding fracing mitigation can be conducted throughout many disciplines and continuously over time, then more advances can be made which can be applicable to more and more land use types. This is will create many more opportunities to develop mitigation techniques which can advance along with technology.

SUMMARY

The marriage of fracing and golf courses is one that may be difficult to satiate at first, but when their wants and needs are analyzed, their truly integral nature can be expressed. Both the fracing and golf industries have shown needs in various public perception and safety realms. They are currently seeking to find technologies or ideas which can fill the gaps present in their respective industries. Golf courses can fill the spatial and safety needs of fracing and fracing can fulfill the financial needs of golf courses. The two industries create a symbiotic relationship with one another which fulfills their individual needs but also makes them both more financially viable and acceptable by the general public – both major factors influencing their future growth and success.

CHAPTER 7: LITERATURE REVIEW

GOLF COURSE SUSTAINABILITY

White, Charles B. *Turf Managers Handbook for Golf Course Construction, Renovation and Grow-in*. Chelsea, MI: Ann Arbor, 2000. Print.

This book is a resource for understanding how turf on a golf course is implemented and managed along with an appropriate cost estimation guide for installation and upkeep. This book will serve as a means to evaluating turfgrass growth potential in fracing wastewater sites. The text will help to understand what conditions are needed to achieve successful turf growth and maintenance and how the introduction of a used fracing site will impact it.

Dodson, Ronald G. *Sustainable Golf Courses: A Guide to Environmental Stewardship*. Hoboken, NJ: J. Wiley & Sons, 2005. Print.

This book is the leader in sustainable golf course design and management. It will play a crucial role in creating a sustainable design with future management in mind. This resource which will be at the heart of creating a golf course which can exist in harmony/in contrast to the adverse potential effects of fracing.

Dodson, Ronald G. *Managing Wildlife Habitat on Golf Courses*. Chelsea, MI: Ann Arbor, 2000. Print.

This book will serve as a supplemental resource to the previous resource mentioned. It elaborates on the principles of various habitats and explains how to successfully maintain quality animal habitat on golf courses. Sustainable golf course design and habitat creation play major roles in getting various tax credits and other financial benefits to offset the coast of construction and maintenance. Designing a golf course which creates/enhances animal habitat will also make the integration of fracing and golf courses more palatable for the general public.

Dramstad, Wenche E., James D. Olson, and Richard T. T. Forman. *Landscape Ecology Principles in Landscape Architecture and Land-use Planning*. [Cambridge, Mass.]: Harvard University Graduate School of Design, 1996. Print.

This resource will play a critical role in outlining the structure of the site in order to have to maintain the proper spatial relationship with surrounding ecosystems. The text outlines a regional perspective in regards to ecosystem and how they interact. This will be critical during the analysis phase of the project as it will help to drive proper site selection regarding interaction with surrounding areas. This resource will also be critical after the feasibility assessment has been conducted in order to drive the location of various aspects to both fracing and golf.

Mirimichi, Golf Club. "Facility Case Study: Mirimichi Golf Course." Mirimichi Golf Club, 2009. Print.

This article serves as a real-life account of the sustainable golf course practices outlined in various resources and demonstrates how multiple ideas can function together in a successfully run business. The course is an Audubon International Sanctuary Gold Certified course (the first in the U.S.) and provides various methods for sustainable golf course design and management. Most noteably, the text outlines various methods of preventing chemical and fuel contamination on site and dictates proper storage techniques for the aforementioned substances. This will be a valuable resource regarding fracing site containment in order to properly restore the fracing site and protect the surrounding area during and after drilling.

GSCAA. "Golf Course Environmental Profile: Property Profile and Environmental Stewardship of Golf Courses Volume I." Environmental Institute for Golf, 2007. Web. <http://www.eifg.org/programs/GCRPfullreport.pdf>

This article will serve as a valuable resource for getting a large-scale idea of golf course design and maintenance from a nation-wide perspective. This will be critical for better understanding the economic behind the golf market and how the entire industry handles various issues and concerns. This article articulates on the economic drivers behind golf and how they will shape the future of the industry. This will be valuable in evaluating the future success of golf courses and how the intervention of fracing can affect them economically.

GSCAA. "Golf Course Environmental Profile: Water Use and Conservation Practices on U.S. Golf Courses Volume II." Environmental Institute for Golf, 2007. Web. <http://www.eifg.org/programs/EIFG_GCEP_Vol_2.pdf>.

This article serves as an intricate resource in understanding a nation-wide standpoint on water usage and regulation for golf courses. This will be extremely beneficial in understanding the water regulations and procedures which must be implemented in order to design a site which can function with fracing wastewater. The interaction of fracing water laws and golf course water laws will serve as key factors in determining fracing feasibility on the proposed site as well as the future management of the fracing site and golf course.

Franko, Matthew. *Sustainable Golf Course Design: A Look into the Problems and Future Solutions of the Golf Course Design and Management Industry*. Winter Park, 2010. Print.

This resource was an endeavor explored by the author as an undergraduate thesis and will provide various collection and synthesis of information regarding the economic and environmental viability of sustainable golf course design. It will be a critical component to analyze how a golf course works with the influence of secondary resources.

Love, Bill. "An Environmental Approach to Golf Course Design." *American Society of Golf Course Architects* (2008). Print.

This resource will serve as an outlining guide for various site types found on which one wishes to construct/renovate a golf course. It provides an overview of various citing and synthesis practices and demonstrates the proper means of protecting/mitigating for various environmental resources found on golf courses.

GOLF COURSE DESIGN

Shackelford, Geoff. *Grounds for Golf: The History and Fundamentals of Golf Course Design*. New York: T. Dunne, 2003. Print.

This book will serve as a primary resource for analyzing the history of how golf courses were successfully designed in the past and what critical techniques/aspects must remain present in this proposed new golf course function. The text provides a rich history of golf course design culminating in a methodology to design a golf course in current times using techniques and styles discussed in the historical section of the book.

Doak, Tom. *The Anatomy of a Golf Course*. Short Hills, NJ: Burford, 1992. Print.
This book outlines again the history of the golf course but provides it in context with current design standard and techniques. This will serve again as a historical reference but also provide a more current implementation method of various techniques which will help a golf course succeed under various conditions/uses. Multiple scenarios are explored in this text with various corresponding methodologies used to design in keeping with the site-specific constraints presented.

Graves, Robert Muir., and Geoffrey S. Cornish. *Golf Course Design*. New York: J. Wiley, 1998. Print.
This book is considered to be a valuable resource in terms of organizing and understanding all the various aspects to golf course design and how to properly deploy techniques in order to create a successful golf course on all levels. For decades this text has been the primary resource for golf course architects as it provides a thorough overview of the details one must address when designing a golf course. The topics include site analysis, site synthesis, golf course design history, the technical process of golf course design and construction, the economic side to golf course design, restoration techniques used on golf courses, and the future of the golf course design industry.

Hurdzan, Michael J. *Golf Course Architecture: Evolutions in Design, Construction, and Restoration Technology 2nd Edition*. Hoboken, NJ: J. Wiley & Sons, 2006. Print.
This book is considered to be another industry-leading resource to golf course design and overall facility performance. This is will as a main guide for design principles, routing, and all other components of successful golf course design including the economic background to proper golf course design as well as providing industry standards which will facilitate the design process. These principles will be critical to complete the feasibility study, the site analysis & synthesis phase, as well as to help guide the design process and make sure the proper steps are being taken.

Harris, Charles W., Nicholas T. Dines, and Kyle D. Brown. *Time-saver Standards for Landscape Architecture: Design and Construction Data*. New York: McGraw-Hill, 1998. Print.
This book provides a brief section of golf course design information and diagrams which will be very useful in designing a golf course in the proper fashion. This resource will help to maintain a consistent design standard and make sure all of the proper methodologies are implemented.

Hurdzan, Dr. Michael J. *Building a Practical Golf Facility: A Step-by-Step Guide to Realizing a Dream*. Brookfield: American Society of Golf Course Architects. Print.
This brief book provides an incredibly valuable resource as it not only provide the general outline for golf course design but most importantly provides multiple case studies to how this process was implemented in various locations and how many difficulties were overcome through strategic design. This will be a valuable resource to me as it will demonstrate real life scenarios of how to implement all the golf course design techniques I have studied.

American Society of Golf Course Architects. "The Golf Course Remodeling Process." (2006). Print.
This brief resource provide a valuable check list of sorts which will play an integral role in the site analysis and synthesis phase focused on golf course design/renovation.

Hazelrigg, George. "Garbage In, Golf Out: Former Landfills near Boston Become 27 Holes of Golf." ***Landscape Architecture*** **(2005): 1-6. Print.**
This resource will be utilized to understand how a golf course can be designed to handle potentially harmful chemicals. The techniques overviewed in this text will be analogous to the intervention of fracing site son golf courses and how they can function properly during and after the drilling process has taken place.

GOLF COURSE ECONOMIC RESOURCES

Audubon, Internation. "Golf's Green Bottom Line: Uncovering the Hidden Business Value of Environmental Stewardship on Golf Courses." United States Golf Association, Sept. 2007. Web. <http://auduboninternational.org/PDFs/GolfsGreenBottomLine2009.pdf>.
This article will serve as a primary economic resource for understanding the economic benefits of any form of environmental services conducted on a golf course which will aid in the feasibility study. The text discusses the current economic status of the industry as well as how different golf course functions can generate revenue and contribute to the overall economic viability of the course. This will be very relevant to the topic of introducing fracing on golf courses as it can be a great revenue generator and help to stabilize a golf course financially.

Potter, Dan. "USGA Green Section Record: A Publication on Turfgrass Managment." (2010). Print.
This resource will play a pivotal role in justifying various design technique used in regard to the feasibility of constructing a golf course around an abandoned fracing site. This is a phenomenal resource for describing tricks used to save money in both the design and management of any golf course and can further the financial incentives of fracing on a golf course if money can be saved along with revenue generation from the drilling.

"A Tale of Two Courses - Golf Course Industry." ***Golf Course Industry - News, Resources for Golf Course Superintendents, Turf Care, Managers*****. Golf Course Industry, 27 July 2010. Web. 11 Feb. 2012. <http://www.golfcourseindustry.com/gci-0710-tale-two-courses-cover-feature.aspx>.**
This article will serve as a case study, but not as much from the design and maintenance realm; instead it will serve as an economic business model case study so as to better manage a golf course. This resource will provide insight regarding the managerial facet to golf course operation in order to better integrate the business end of the golf course with the physical characteristics of the golf course which generate revenue. By better understanding the business, maintenance, and design potion of golf course operation a designer can better enhance each element so they work together in a synergistic fashion.

Sartori, Andrea. "Golf and the Economic Downturn." KPMG Consulting, 2010. Web. <http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/Golf-and-the-economic-downturn.pdf>.

This again is a critical resource as to understanding what caused the problems which have lead golf courses to their currently depressed state. KPMG Consulting is a world-wide leader in consulting and will provide top of the line analysis of golf and the economic downturn. This resource will help to better understand how the golf course industry's history lead to their poor performance during the recession of 2008 so as to safeguard courses from this result in the future.

Hay, John J., Alan W. Hodges, and Charles R. Hall. "Estimating the Economic Impact of the U.S. Golf Course Industry: Challenges and Solution." HortScience, June 2008. Web. <http://hortsci.ashspublications.org/content/43/3/759.full.pdf+html>.

This is a key resource as it outlines the economic problems which caused the collapse of the golf course industry but also provides valuable information on how to fix the situation and what potential solutions could look like. It will be very valuable to have solutions not just put forth by designers but by economists as well – a combination of the two will be utilized in the feasibility portion of this project. The solutions proposed in this article can be juxtaposed with other various fracing-based solutions so as to evaluate the efficacy of the potential resolutions.

Hueber, David. "“Code Blue” for U.S. Golf Course Real Estate Development: “Code Green” for Sustainable Golf Course Redevelopmen." Journal of Sustainable Real Estat, May 2010. Web. <http://www.costar.com/josre/pdfs/JOSREMay2010SustainableGolfCourses.pdf>.

The key to this article is it utilizes both business and design strategy in breaking down the problem existing in the golf course industry as well as in providing potential solutions. This resource will help in evaluating the economic feasibility of fracing on golf courses and during the site diagram phases of the post-fracing visual mitigation.

Morris, Michael D. "THE GOLF COURSE BUDGET PROCES." Crystal Downs Country Clu. Web. <http://archive.lib.msu.edu/tic/mitgc/article/2001161.pdf>.

A very basic article, this resource simply outlines the process for creating a working budget for a golf course. Although this will not play a major role in a golf course design project it will be very important to understand the overall golf course design process and how to utilize it in order to create a business model for a particular site.

Swartz, John. "Golf Clubs Suffer in Recession as Membership Dwindles." USA Today, 3 Aug. 2010. Web. <http://usatoday30.usatoday.com/money/economy/2010-08-03-golf03_CV_N.htm>.

This resource serves as an overview of the currently golf industry trends in the United States since the recession in 2008. This article will be critical for shedding light on the current depressed state of the golfing industry and help to justify why golf courses need an added revenue source such as fracing.

FRACING RESOURCES

Wiseman, Hannah. "Trade Secrets, Disclosure, and Dissent in a Fracturing Energy Revolution." *Columbia Law Review: Sidebar* 111 (2011): 1-13. Print.

This resource is a great place to start when determining the elements used in fracing and the ramifications they have on the environment. This article addresses the secrecy issues related to fracing and its practices and how they may be required to reveal information on their processes. This would be critical to a potential fracing project as it will help understand the current and future trends of the fracing industry.

Mooney, Chris. "The Truth About Fracing." *Scientific American* (2011). Print.

This article provides a great analysis of how fracing works and explains it in terms which can be easily understood by the average person. This will be a great resource to help me get a base knowledge of the process in order to facilitate my exploration of more advanced articles and resources detailing fracing practices. It will also facilitate in explaining the fracing process to those without knowledge regarding the subject resulting in a better educated public and audience.

Lustgarten, Abraham. "EPA: Chemicals Found in Wyo. Drinking Water Might Be From Fracking." Pro Publica, 25 Aug. 2009. Web. 22 Feb. 2012. <http://www.citizenscampaign.org/PDFs/fracing-news/EPA_%20Chemicals%20Found%20in%20Wyo.%20Drinking%20Water%20Might%20Be%20From%20Fracing%20-%20ProPublica.pdf>.

This article was published in conjunction with the EPA in an attempt to classify the problems that fracing can cause to water systems, including human drinking water resources. This article will help to specify the potential problem fracing causes on water resources in order to better understand what needs to be done to help fix the problem. By identifying the issues fracing causes to water sources I will be able to use this information to move forward with potential solutions.

Rham, Dianne. "Regulating Hydraulic Fracturing in Shale Gas Plays: The Case of Texas." Elsevier, 2 Mar. 2011. Web. <http://pdn.sciencedirect.com/science?_ob=MiamiImageURL&_cid=271097&_user=2139813&_pii=S0301421511001893&_check=y&_origin=article&_zone=toolbar&_coverDate=31-May-2011&view=c&originContentFamily=serial&wchp=dGLzVlB-zSkzk&md5=5f592b43a4796ecd0b991694a76c75fa/1-s2.0-S0301421511001893-main.pdf>.

This article provides a great legal analysis of the way states are addressing the fracing industry. In addressing the legal issues they will inadvertently address the chemicals used and consequences they can cause in various environments. This article will be useful in helping me understand the current legal issues regarding fracing in order to evaluate its future.

Brown, Valerie J. "Putting the Heat on Gas." *National Center for Biotechnology Information*. U.S. National Library of Medicine, 2 Feb. 2007. Web. 22 Feb. 2012. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817691/pdf/ehp0115-a00076.pdf>.

This is a very brief article that addresses the potential harmful compounds used in fracing known as VOCs (volatile organic compounds). This resource will be critical in understanding the fracing process from both the physical and chemical aspects of the process. This will help evaluate the efficacy of potential golf course infrastructure integration with abandoned fracing sites.

Northrup, James L. "The Unique Environmental Impacts of Horizontally Hydrofracking Shale." Otsego 2000, 18 Aug. 2010. Web. <http://fracingfreeireland.org/wp-content/uploads/2011/08/10aug19_NorthrupEPAcommentsFracing2010.pdf>.

This article is another great resource which explains how fracing is done. It will be absolutely critical to become an expert at the fracing process and to understand how it works from all levels. I must achieve this understanding if I hope to successfully conduct a feasibility study and advance those findings further.

Manuel, John. "EPA Tackles Fracing." ***National Center for Biotechnology Information*****. U.S. National Library of Medicine, May 2010. Web. 22 Feb. 2012. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2866701/pdf/ehp-118-a199.pdf>.**

This article, although brief is a great resource for providing scientific assumptions as to what chemicals are used in the fracing process. Understanding what chemicals are used in this process will be at the heart of understanding the environmental problems fracing creates and, more impoirtantly, how they can be contained and mitigated for.

Poole, David T. "Hydraulic Fracturing of Unconventional Gas Shales: Potential Pollutants, Treatments and Remediation." The Ohio State University, 18 May 2012. Web. <http://senr.osu.edu/images/Poole_final_MENR_project.pdf>.

This is a comprehensive evaluation of the post-drilling consequences of the fracing process and what can be done to mitigate any impact the drilling has on the surrounding landscape. There is a detailed list of restoration and remediation techniques described in the text which can be implemented post-fracing on a golf course to visually mitigate the site and help to provide benefits for the surrounding ecosystem. These techniques will be utilized in the visual mitigation phase of fracing on a golf course and provide substantial benefits to advancing the integration of golf courses and fracing.

Lowrey, Todd A., Christopher D. Finton, and James R. Eby. "Hydrogeologic Report: Eagles Mere Lake and Vicinity Sullivan County, PA." Eagles Mere Lake & Watershed Committee, 25 Jan. 2011. Web. <http://protecteaglesmere.org/wp-content/uploads/Final-Eagles-Mere-Presentation-4_16_11-Read-Only.pdf>.

This report was conducted by hydrologists as there is currently an interest in fracing in Sullivan County, Pennsylvania. More specifically, the Eagles Mere Lake vicinity is of high interest, especially around the Eagles Mere Golf Course area. This report is crucial to help understand the hydrology of the site, the soils in the surrounding area, the topography existing within the area, and the areas of concern regarding drainage and flood plains. This document is a critical resource and evaluation to have when planning a fracing site. It will help to site the proper fracing location so as to lessen its impact on the area as well as help to provide proper mitigation after the drilling takes place.

Suchy, Daviel R., and K. David Newell. "Hydraulic Fracturing of Oil and Gas Wells in Kansas." ***KGS Pub. Inf. Circ. 32*****--. Kansas Geological Survey, Dec. 2011. Web. <http://www.kgs.ku.edu/Publications/PIC/pic32.html>.**

This article provides a brief overview of the fracing process and provides meaningful statistics regarding the process. It serves as an introductory piece of information which will provide a holistic overview of the fracing industry, its impacts on the landscape, and its impact on the economy.

Pennsylvania League of Women Voters. "Marcellus Shale Natural Gas: From the Ground to the Customer." N.p., 2009. Web. <http://www.bfenvironmental.com/pdfs/Marcellus_Shale_Study_Guide_Parts_1-5.pdf>.

This document provides an extremely comprehensive examination of the fracing process, specifically the fracing process regarding Marcellus Shale formations. Marcellus Shale is found in the northeastern United States and is the rock formation occurring in Sullivan County where Eagles Mere Country Club is located. This document provides specifics regarding the fracing process both physical and economic. It is critical to study the specific rock formation which will be drilled as it is able to provide more accurate data and incite regarding Pennsylvania's site-specific situations regarding the fracing debate.

Griffith, Benjamin E. "Fracking for Shale Gas: Energy Security & Sustainable Water Resources." ***World Jurist Association 24th Biennial Congress on the Law of the World National Legal Cultures in a Globalized World*****. N.p., 27 Oct. 2011. Web. <http://www.griffithlaw.net/document.pdf>.**

This resource is valuable as it provides a view of fracing from the perspective of a globalization of the world economy. This establishes its base in water resources and evaluates the efficacy of using water for fracing from a world-wide resource perspective. This article provides great data regarding water usage involving the fracing process and compares it to world-wide resources and evaluates it effectiveness as well as how to make it more sustainable. This is a critical analysis to utilize when evaluating the prospect of developing a fracing site as it allows for the understanding of the water needed to successfully drill a site as well as the impact the water extraction can have on surrounding areas. This facilitates in the overall feasibility evaluation and helps to provide direction for post-drilling mitigation.

Arthur, J. Daniel, Mike Uretsky, and Preston Wilson. "Water Resources and Use for Hydraulic Fracturing in the Marcellus Shale Region." ALL Consulting, LLC, n.d. Web. <http://fracfocus.org/sites/default/files/publications/water_resources_and_use_for_hydraulic_fracturing_in_the_marcellus_shale_region.pdf>.

This resource is a valuable analysis of the water resources necessary for hydraulic fracturing. More specifically, it evaluates the water resources available and necessary for fracing occurring in the northeastern United States in the Marcellus Shale region. This provides a valuable regional analysis of the overall watershed in the Marcellus Shale region and evaluates the impact fracing can have on the region and its water resources. The article also provides valuable data regarding fracing and data extrapolating fracing impact on the area in the foreseeable future.

Frac Focus. "What Chemicals Are Used." ***Frac Focus Chemical Disclosure Registry*****. N.p., 2013. Web.< http://fracfocus.org/chemical-use/what-chemicals-are-used>**

This resource will be utilized in an appendix and used to show what chemicals can be contained in hydro-fracing fluid as well as their associated OSHA registration number, purpose, and function.

Leff, Eugene. "Leff Letter of Concern." Scenic Hudson, 11 Jan. 2012.

This document is a letter sent by a representative of the New York State Department of Environmental Conservation regarding fracing in New York state. Currently, a moratorium has been placed on fracing in the state until more information can be obtained regarding the practice. This letter outlines various changes to current regulations established for fracing in an effort to make it safer and protect resources better. The information set forth in this document can be utilized in the fracing mitigation proposed for Eagles Mere Country Club before and after drilling would take place. These guidelines will help to develop a framework for potential fracing mitigation and greatly help to plan the entirety of the project.

Reins, Leonie. "The Shale Gas Extraction Process and Its Impacts on Water Resources." Review of European Community & International Environemntal Law, 2012. Web. <http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9388.2012.00733.x/pdf>.

The resource provides an overview of the fracing process's impact on water resources from a global scale. The natural gas harvest from fracing is a global commodity so it is important to understand fracing impact on water resources from a global scale. This article juxtaposes fracing regulation in the United States and Europe. It is important to establish an understanding of fracing regulation worldwide in order to understand all possible types of regulation imposed on the process. This article specifically identifies water resource laws and provides examples from multiple international areas. This is a valuable resource as ideas presented in regulation can be attributed to the mitigation techniques utilized before, during, and after drilling has taken place.

Currie, Katrina M., and Elizabeth B. Stelle. "Pennsylvania's Natural Gas Boom: Economic & Environmental Impacts." ***Policy Brief from the Commonwealth Foundation*** **22.05 (2010): 1-12.**

This article provides a more detailed look at the impacts fracing has on the Pennsylvania environment and economy. It evaluates the impacts the process can have on the environment and various resources but also provides data regarding the amount of money it would generate for the state's economy as well as how many estimated jobs it would create. This is a valuable resource for balancing the benefits versus the costs fracing would have on an area and play a role in determining whether or not fracing should take place in an area.

Rendell, Edward, and John Hanger. "Northeastern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report." Pennsylvania Department of Environmental Protection, Bureau of Air Quality, 12 Jan. 2011. Web. <http://www.dep.state.pa.us/dep/deputate/airwaste/aq/aqm/docs/Marcellus_NC_05-06-11.pdf>.

This report was a study conducted by the Pennsylvania Department of Environmental Protection, Bureau of Air Quality. The study monitored and evaluated the affects fracing had on air quality by measuring air pollutants expelled during the fracing process and comparing them to national standards. This is a valuable study as it addresses the air pollution component to the fracing process which often goes overlooked in analysis of drillings impact on the environment. This evaluation was critical in determining the feasibility of drilling on or near a golf course as well as evaluating the condition which would be present before, during, and after drilling. This data can be synthesized to make a determination of the overall impact fracing has on atmospheric conditions and how it would impact localized areas.

SEAB Subcommittee. "The SEAB Shale Gas Production Subcommittee Ninety-Day Report." Secretary of Energy Advisory Board, 11 Aug. 2011. Web.
<http://www.shalegas.energy.gov/resources/081111_90_day_report.pdf>.
This is an extremely detailed report on the environmental impacts of fracing done by the congressional Energy Advisory Board Subcommittee on Shale Gas production. The document outlines in immense detail the fracing process and how each component of the process impacts the environment. The report evaluates multiple aspects of fracing including multiple versus single drill well pads and the impact they can have on the environment, seismic activity, water resources, etc. This is a very valuable resource as it represents a federal evaluation of the fracing industry and will be utilized to dictate future regulation. The information found here can be utilized to evaluate mitigation measures and develop them so they better alleviate the impacts from the fracing process.

Steingraber, Sandra. "The Potential Health Impacts of Hydraulic Fracturing Wastewater and Drill Cuttings." New York State Senate Standing Committee on Environmental Conservation, 12 Dec. 2011.
This report was done by the New York State Senate Standing Committee on Environmental Conservation on the affects fracing flow back water can have on the surrounding environment. This is a valuable report as approximately 11% of the water-chemical-sand mixture used in the fracing process returns to the service and poses the greatest risk for environmental pollution and water resource contamination. By evaluating the risks associated with the flow back water, proper protection and mitigation features can be developed for utilization before, during, and after the drilling process. This report is an extremely comprehensive analysis of the impacts fracing flow back water can have and will greatly affect feasibility assessments as well as mitigation techniques.

Watson, Blake. "Fracking - Facts and Fears." University of Dayton, 29 Feb. 2012. Web.
<http://www.udayton.edu/directory/law/documents/watson/fracking_facts_fears_04092012.pdf>.
This report is an overview of the fracing process and evaluates the potential risks associated with hydraulic fracturing. The article most notably points out variation law suits pending regarding fracing which is valuable as these suits will most likely lead to new regulations and established legal precedents which can alter the way fracing is conducted and subsequently mitigated for. This report provides an immense wealth of facts which can be utilized to strength arguments, play a role in establishing feasibility assessments, and helping the public gain a better understanding of fracing impacts.

Packer, Kevin, and Brian DeRuschi. "Technology Taking America Out of Energy Crisis: The Rise of Fracking." The University of Pittsburgh: Swanson School of Engineering, 7 Feb. 2012. Web.
This article provides an interesting evaluation of the fracing process from a technological standpoint. It examines a laymen's view of the fracing process but focuses its details on the technology behind the drilling technique – most notably the horizontal aspect to the drilling process which made the entire

system profitable. The article also details the energy future of American and how the introduction of natural gas can revitalize the economy and create jobs. This a valuable resource to utilize in order to understand the fracking process and the impact it will have on our future. Understanding this aspect to the fracing industry will play a vital role in determining the feasibility of drilling in certain location by providing an economic forecast for the future.

Langley, Diane. "Technology Advances Push Greener Side of Fracing." *Drilling Contractor*. N.p., 2011. Web. <http://www.drillingcontractor.org/technology-advances-push-greener-side-of-fracing-9329>.

This article focuses specifically on the most sustainable techniques used in fracing as well as technology currently being developed to further advance the sustainable of the fracing process. This article is critical to gaining an understanding of the future of fracing technology to better understand the potential for this energy harvesting method and evaluating its sustainability for the future. Pointed out in this article are various ways to recycle fracing flow back water, ways to limit the amount of mechanical work needed to drill, etc. This provides a great overall summary of the most successful technological advances in the industry and gives a great inclination as to where the future of this drilling practice is headed.

Bu, Min. "Visual Impacts of Natural Gas Drilling in the Marcellus Shale Region." Cornell University, Department of City and Regional Planning, 2010. Web. <http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Visual%20Impact_Final%20Report.pdf>.

This is a tremendously valuable article as it points out specific visual obstructions created by the fracing process. These obstructions are all demonstrated with corresponding photographs and provide an excellent overview of the visual problems associated with the fracing process. It is critical to amass this type of data so it can be applied to the fracing site at Eagles mere Country Club and serve as a stand in for the potential visual mitigation problems which could affect that site.

Kuehn, Sarah. "Landscape Practices on Gas Well Sites in North Texas: Perceptions of Selected Industry Representatives and Regulators." The UIniversity of Texas at Arlington, Dec. 2011. Web. <http://dspace.uta.edu/bitstream/handle/10106/9543/Kuehn_uta_2502M_11493.pdf?sequence=1>.

This paper is an incredibly valuable resource as it outlines the various visual problems associated with Fracing but provides multiple solution scenarios to best mitigate against their visual obtrusiveness. The potential solution are based on certain legal criteria already established but expands upon them further and advances them so they are more affective and visually appealing. This resource will serve as a base model for visual mitigation techniques and be further advanced through site-specific analysis and through a creative means of applying them to a particular site.

DeJong, J.T. "Biogeochemical Processes and Geotechnical Applications: Progress, Opportunities, and Challenges." University of California, Davis: Department of Civil and Environmental Engineering, n.d. Web. <http://www.sil.ucdavis.edu/Geotechnique-Bio-Soils.pdf>.

This resource demonstrates the potential possibility of using biotic organisms (most notably bacteria) as a means to clean and changes the physical properties of various soils in order to achieve certain physical and chemical properties. This technique can be applied to fracing sites in order to clean out harmful chemicals and to change the structural properties of the soil in order to prevent pollutants to spread to nearby soil/water systems.

Heckman, John R. "Restoration of Degraded Land: A Comparison of Structural and Functional Measurements of Recovery." Virginia Polytechnic Institute and State University, Apr. 1997. Web. <http://scholar.lib.vt.edu/theses/available/etd-1416152839711171/unrestricted/etd.pdf>.
This article provides a basis for soil remediation for physical and chemical properties as well as means to measure the efficacy of such practices. This will provide techniques which can be applied to fracing sites in order to amend any damaged soils by the drilling process. This can also provide techniques for measuring the success of the soil remediation in order to improve the site and potential future fracing restoration projects.

D, Jason T., Brina M. Mortsensen, Brian C. Martinez, and Douglas C. Nelson. "Bio-Mediated Soil Improvments." Ecological Engineering, Feb. 2010. Web. 07 Jan. 2013. <http://www.sciencedirect.com/science/article/pii/S0925857409000238>.
This is a compelling article which highlights the potential structural advantages of bio-mediated soils in the fracing clean up and restoration process. This is evidence for the potential improvement in cleaning up fracing sites and also trapping harmful chemicals within the soil for easier removal and chemical sequestration. This article also presents the potential of using micro organisms to absorb and remove harmful chemicals, heavy metals, toxins, and radioactive materials from the soil. This geo-technology provides great potential for advancement in the chemical engineering field and could help to make fracing an overall safer process.

Revkin, Andrew C. "Traceable Gas-Drilling Fluids." The NY Times, 8 Jan. 2013. Web. 8 Jan. 2013. <http://dotearth.blogs.nytimes.com/2013/01/08/ideas-to-watch-in-2013-traceable-frackin-fluids/?smid=tw-nytimesscience>.
This is a great resource for presenting new technology for establishing a way to track fracing fluid in order to evaluate potential leaking problems from well sites and providing the ability to identify where any potential contamination has come from. This will be an incredibly valuable resource in advancing the future of the fracing industry and making it more acceptable to the general public.

APPENDIX

Hoizontal Hydraulic Fractuing

A Documentation of its History, Litigation & Process with an Overview of its Possible Mitigation & Future Potential

8/9/2012

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Fracing History

Natural gas was discovered in the United States in the 1900s and quickly became the supplier of a large portion of America's energy resources – providing approximately 60% of the country's energy. This energy source continued to evolve and by the 1930s many people were using natural gas to power the heating and cooling of their homes. This technology then further evolved into natural gas powered refrigerators and hot water heaters. Natural gas power was being incorporated into many different devices and was clearly becoming a valuable resource for the country as an integral component of daily activities. In the 1940s natural gas was able to be liquefied which made transportation of the energy source incredibly simple and brought the industry to the forefront of the country's energy market.[1] Coincidently, hydraulic fracturing began in 1940 as a means to further extract oil and gas from previously perceived fully taped wells in Kansas.[2] This was a simple measure of extraction in which water, chemicals, and sand were injected vertically into drilled wells in an attempt to create fissures in rock formations allowing for the extraction of oil and gas. This process was utilized for decades as it created a way to advance the extraction of hydrocarbons from drilling sites making them more efficient as they produced more energy. After the 1980s this process had begun to dry up and there was a lack of production from the vertical hydro-fracturing method of energy extraction. Up until 1991 drilling only occurred in a vertical fashion, which limited the radius of extraction from each well and significantly detracted from the obtainable resources per site. Mitchell Energy successfully drilled the first horizontal well in 1991 which significantly increased the radius of extraction achievable by a single well and created a much more efficient process of energy extraction (one well could now produce far more

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[1] Gas Technology Institute. "History of Natural Gas Industry." *Natural Gas History*. Energy Resource Department, 2012. Web. 20 May 2012. <http://www.mesaaz.gov/energy/nghistory.aspx>.

[2] The Breakthrough Institute. "US Government Role in Shale Gas Fracking History: An Overview and Response to Our Critics." *The Breakthrough Institute: US Government Role in Shale Gas Fracking History: An Overview and Response to Our Critics*. 12 Mar. 2012. Web. 20 May 2012. <http://thebreakthrough.org/blog/2012/03/shale_gas_fracking_history_and.shtml>.

hydrocarbons). In 2002 the hydraulic fracturing process and horizontal drilling techniques were combined in order to create one of the most profitable and efficient energy extraction techniques in history. This drilling techniques was so successful because it created a way to extract energy from various shale plays, which up until then, were unobtainable. Previously, shale plays such as Marcellus Shale were unobtainable because their depth (4,000-8,500 ft.) required too much energy to vertically drill than could be brought up to the surface. [3] When this vertical well was able to spread horizontally at the depth of Marcellus Shale it had achieved a profitable method to extract energy from a previously unprofitable area. This achievement was significant as Marcellus Shale now provided a highly obtainable resource as it has a high porosity and low density which makes its energy very harvestable via horizontal hydro-fracturing. The Marcellus Shale play in the United States covers approximately 95,000 square miles with more obtainable natural gas than any other shale play (see Figure 1).

It is estimated that there is 260-490 trillion cubic feet of natural gas within the Marcellus Shale - which is the equivalent energy needed to heat 15 million homes for an entire year.[4] Since the advancement of horizontal hydro-fracturing the amount of energy coming from natural gas in the U.S. increased from approximately 2% to 30%. This energy source has now grown to comprise 22% of the overall energy use in the United States with estimates to contribute up to 46% by 2035 (See Figures 2 & 3).[5] This resource has been embraced by America's leaders and has stood at the forefront of various energy policies. President Barack Obama has stated, "…recent innovations have given us the opportunity to tap large reserves – perhaps a century's worth".[3] The president clearly supports this practice and has included it in his "Blueprint for a Secure Energy Future" which was a major part of his 2012 Stat of the Union

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[3] Secretary of Energy Advisory Board. "Subcommittee Shale Gas Production Second Ninety Day Report." U.S. Department of Energy, 18 Nov. 2011. Web. 15 Mar. 2012. <http://www.shalegas.energy.gov/resources/111811_final_report.pdf>.

[4] Watson, Blake. "FRACKING – FACTS AND FEARS." University of Dayton; Dayton League of Women Voters, 9 Apr. 2012. Web. 1 May 2012. <http://www.udayton.edu/directory/law/documents/watson/fracking_facts_fears_04092012.pdf>.

[5] Arthur Et. All, J. Daniel. "Water Resources and Use for Hydraulic Fracturing in the Marcellus Shale Region." ALL Consulting, LLC. Web. 15 Mar. 2012.

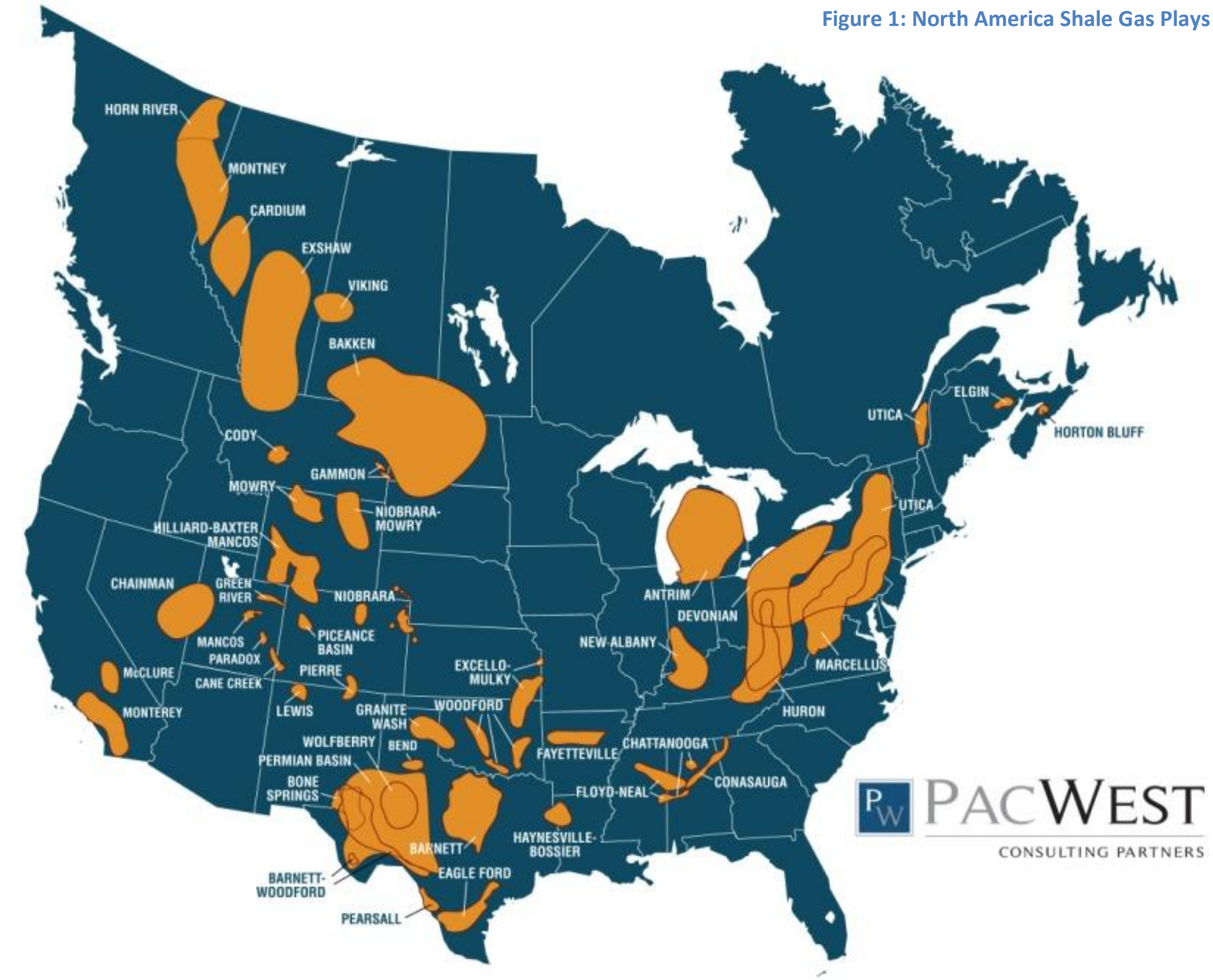

Figure 1: North America Shale Gas Plays

Address. The president believes the extraction of natural gas could create 600,000 jobs in the future which would be part of the approximate 200,000 jobs it has created thus far.[6] All signs indicate that the horizontal hydro-fracturing process will continue into the future and play a major role in the economic development of the United States.

<u>Fracing History – Pennsylvania</u>

The state of Pennsylvania is not historically a drilling state as its major contribution to the nation's energy supply came in the form of coal. The state supplied a majority of the coal from the northeast portion of the country from the early to mid 1900s and continues to supply a large portion of the

[6] Obama, Barack. "The Blueprint for a Secure Energy Future." The White House, 1 Mar. 2012. Web. 20 May 2012. <http://www.whitehouse.gov/sites/default/files/email-files/the_blueprint_for_a_secure_energy_future_oneyear_progress_report.pdf>.

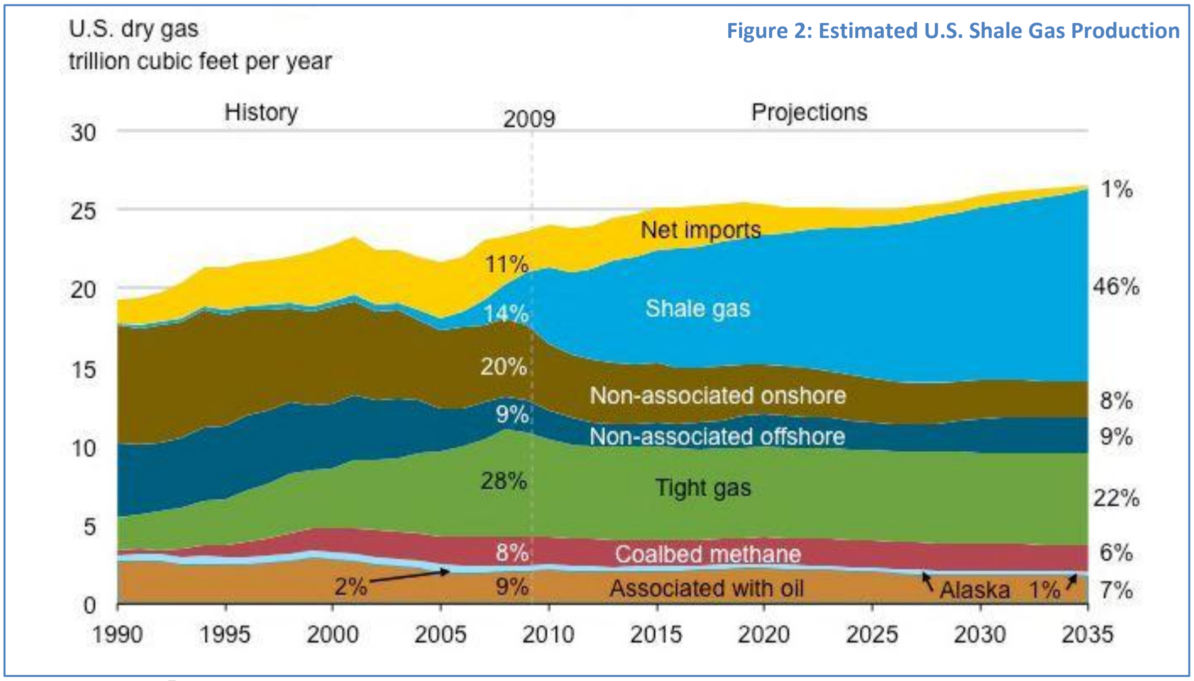

Figure 2: Estimated U.S. Shale Gas Production

nation's coal.[7] Since the discovery of natural gas in the state, coal has taken a back seat to the development of drilling for this innovative new energy source which is touted to burn with 70% less carbon emissions than coal. Despite coal still supporting nearly 45% of the nation's energy needs, natural gas is considered to be the next revolution in energy supplies for the country and is seen as a transition resource to shift from fossil fuels to renewable energies.[8] This has created a substantial increase in the research and development of natural gas in Pennsylvania and has led to the drilling of 1,526 wells from 2005-2010 and future growth is believed to continue at a similar rate up to 2035. This growth is expected due to the fact that Pennsylvania holds the largest known reserves of natural gas in the United States. This energy source has been a huge contributor to the Pennsylvania economy – in 2009 the development of natural gas contributed $389 million dollars in state tax revenue and created an estimated 44,000 jobs. This has lead to the advancement of the standard of living and raised the

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[7] Pennsylvania Department of Environmental Protection. "Pennsylvania Mining History." Web. 21 May 2012. <http://www.dep.state.pa.us/dep/deputate/minres/districts/homepage/california/underground/pa%20mining%20history/pennsylvania_mining_history.htm>.

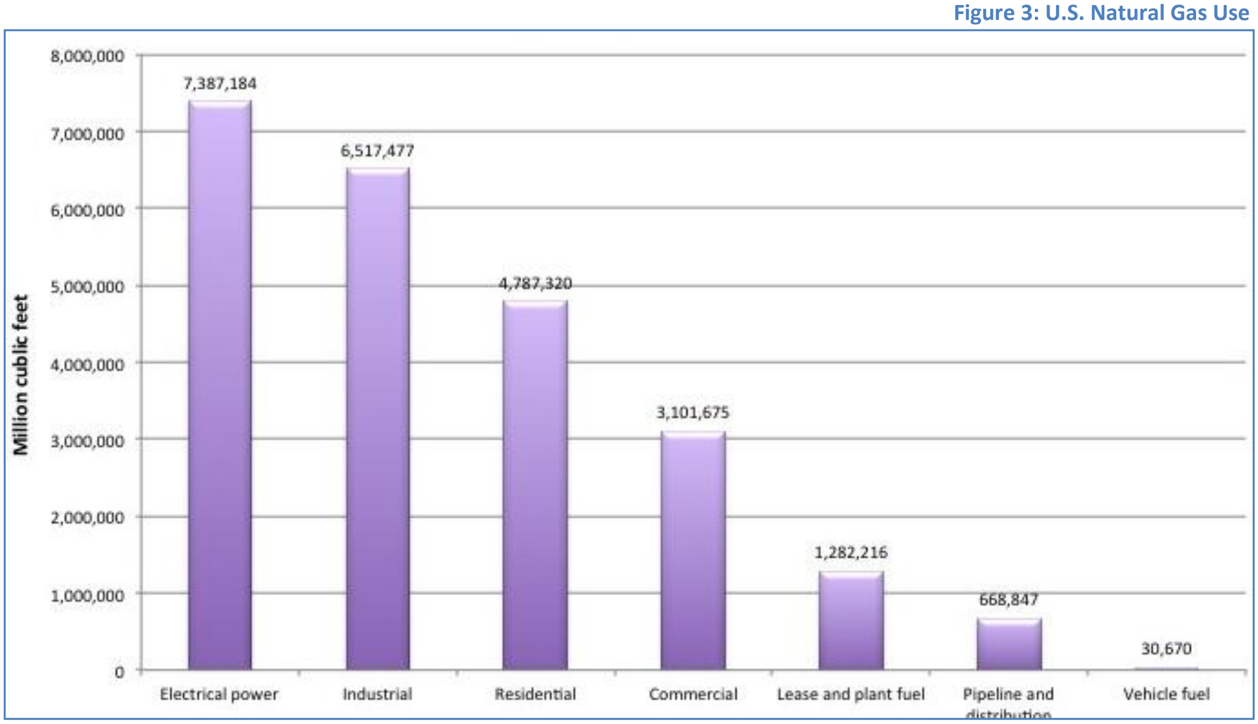
[8] Fulton, Mark, Nils Mellquist, Saya Kitasei, and Joel Bluestein. "Comparing Life-Cycle Greenhouse Gas Emissions From Natural Gas and Coal." World Watch Institute, 25 Aug. 2011. Web. <http://www.worldwatch.org/system/files/pdf/Natural_Gas_LCA_Update_082511.pdf>.

income rate per capita - leading to a more successful and competitive state economy. Due to the intensive nature of natural gas drilling, various organizations have been given the task of regulating this practice in an attempt to protect Pennsylvania's citizens and wildlife. The main contributors to this regulation come from the Pennsylvania Department of Environmental Protection, Pennsylvania Fish & Boat Commission, Pennsylvania Department of Transportation, Pennsylvania Department of Conservation & Natural Resources, and various multi-state watershed management organizations. All of these organizations play an active role in monitoring natural gas extraction and are key components in advancing its development throughout the state. To date, these organizations have been very successful in managing the natural gas extraction process as only 0.25% of wells drilled in the state have lead to negative impacts on drinking water. Due to the large amounts of water needed for hydro-fracing, these state agencies have set various standards and requirements of all companies using water resources and dictates how these resources must be treated. Current state regulations dictate that if anyone withdrawals over 10,000 gallons of water per day for a 30-day time frame they must obtain a permit and be evaluated by various regulatory agencies.[9] There are certain environmental concerns regarding horizontal hydro-fracturing that the state has addressed and carefully studies and monitors these concerns in order to limit the amount of environmental degradation occurring due to the process. The first, and primary concern, revolves around water. The PA Department of Environmental Protection regulates the water extracted to be used in the fracing process by requiring that energy companies obtain permits for the water's use and also evaluates all water wells within 100 ft. of a proposed drilling site. This evaluation is critical as it determines a baseline for the well's health and, once drilling has started, can be used in conjunction with water well evaluation post-drilling in order to determine if fracing has had any impact on the water quality. There is also a major concern with the amount of water

[9] Currie, Katrina M., and Elizabeth B. Stelle. "Pennsylvania's Natural Gas Boom: Economic & Environmental Impacts." Commonwealth Foundation Volume 22 Number 05, June 2010. http://www.commonwealthfoundation.org/doclib/20100607_marcellusshaledrilling.pdf

required for the drilling process as roughly 2-10 million gallons of water are needed for each individual well. The state currently allows this water to be sold and traded without much oversight; however, the Susquehanna and Delaware River Basins have created multi-state governing agencies that have the power to intervene in the water purchasing and water use process. These agencies are very effective regulators due to the fact that they are comprised of members from multiple states. Each member wants to do what is best for its state/region and, as a collective; this group ultimately makes decisions based on the best actions for all states involved in the form of compromises. The main focus of these organizations is on the chemicals used in fracing and how wastewater is handled after the drilling process. The chemicals used in the fracturing fluid only make up 0.5-1.5% of the overall composition, but

Figure 3: U.S. Natural Gas Use



due to the large quantities of water this can still yield a result of nearly 15,000 gallons of chemicals used per well. In 2008, legislation was passed which dictated that drilling companies must disclose the chemicals used in the hydro-fracturing process but did not require the release of the proportions of these chemicals as that is considered proprietary information. This determination caused much distress for regulators because when the fracing fluid is pumped into the ground a portion of it returns to the surface at salinity rates higher than sea water, while also carrying with it calcium, potassium, chloride, carbonates, various heavy metals, and radioactive materials naturally occurring in shale such as radium – which produces radon gas. A large portion of the chemicals that return to the surface are known human carcinogens and must be treated and disposed of in the proper manner. This treatment and disposal process is arguably the most debated topic in regard to hydro-fracturing. There are three options for treating this wastewater when it returns to the surface: (1) on-site recycling in which the water is treated & re-used on-site or transported to another site – this practice is extremely expensive and is yet to prove profitable for drilling companies (2) injection underground - a majority of which is done in Ohio and requires used fracing water to travel great distances on public roads (3) sent to wastewater treatment plants throughout the state; however, there are only 8 water treatment plants in Pennsylvania which can successfully treat the water from hydro-fracing. The decisions regarding where to store, how to treat, and how to transport this waste water will likely determine the future success of the horizontal hydro-fracturing process in the future.

The hydro-fracturing process has also been linked to the emission of varies sources of air pollution and poses potential hazards to the general public and wildlife. Emissions come from mainly 2 sources: the drilling process itself and the use of machinery in the fracturing process. Some of the emissions documented are Methane, Nitrogen Oxide, VOCs (volatile organic compounds), BTEX (Benzene, Toluene, Ethyl Benzene, & Xylenes), Carbon Monoxide, Ozone, Hydrogen Sulfide, and various others.[10] Despite the volatile nature of these compounds it has been determined that the quantities of their occurrence are negligible and do not pose any direct threat to humans.[11] The Pennsylvania Department of Environmental Protection conducted studies of horizontal hydro-fracturing wells in Sullivan and

[10] McClure, Susan, and Roberta Winters. "Marcellus Shale Natural Gas Study Guide I-V." The League of Women Voters of Pennsylvania, 2010. Web.

[11] Rendell, Edward, and John Hanger. "Northeastern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report." Pennsylvania Department of Environmental Protection, Bureau of Air Quality, 12 Jan. 2011. Web.

Susquehanna counties using a “Mobile Analytic Unit”, air canister samples, and infrared image samples. These collection methods all discovered the volatile compounds mentioned earlier; however, none of them were considered excessive when compared to the National Ambient Air Quality Standards. Another compound found at the sites tested was methyl mercaptan also known as “malodor”. This compound puts off a very off-putting smell but poses no serious health risks to humans. The concentrations of this compound were very low and also below National Ambient Air Quality Standards.

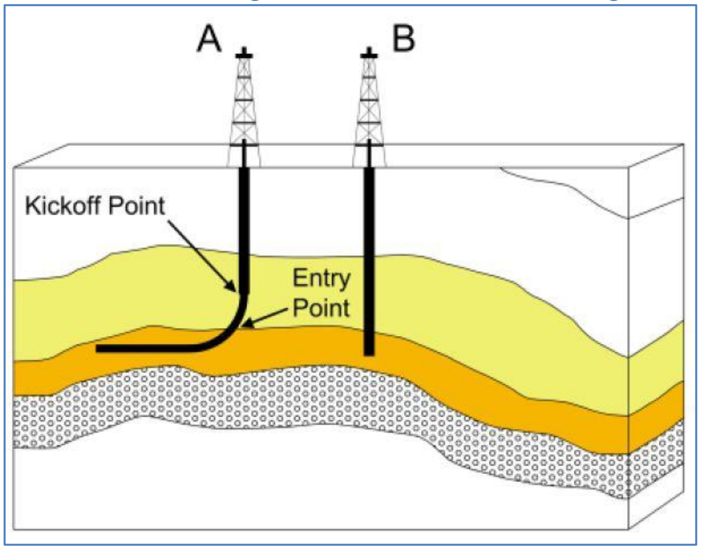
Litigation – National & Pennsylvania

The litigation in regard to horizontal hydro-fracturing is somewhat controversial in nature. From a national standpoint there is not much regulation or management from the federal government. In fact, the hydro-fracturing industry is exempt from the Clean Water Act and the Safe Drinking Water Act which are both major regulations set in place to protect humans and wildlife for general water needs. The Clean Water Act was passed in 1972 and regulates safety measures regarding surface waters via the National Pollutant Discharge Elimination System permitting. The Safe Drinking Water Act, passed in 1974, was implemented to protect public drinking water reserves and regulate any liquids to be injected underground. This act also allowed the EPA to create standards for all underground liquid injections. Both of these acts would help to manage the waste water issues produced from hydro-fracturing but the Bush administration exempted the hydro-fracturing industry from both of these acts via the Energy Policy Act of 2005. This act has helped speed the development of technology and occurrence of wells drilled in the United States; however, the lack of regulation has lead to high public scrutiny of the drilling technique and caused many misconceptions regarding the process. Many states have had to implement their own regulation measures in order to manage the hydro-fracturing industry in order to protect their environment and associated environmental capital. Pennsylvania has enacted many different preventative and management laws which are aimed at protecting the environment and valuable water resources associated with it. The Oil and Gas Act established the right of the state to regulate exploration and production of natural gas, manage standards for drilling and protective casing, monitor the financial responsibility of energy companies, and head the management of restoration projects to make sure all sites are restored properly. The Clean Streams Law was also passed in order to protect valuable Pennsylvania surface waters and develop policies and penalties for discharging any waste fluids into rivers or streams. The Solid Waste Management Act was established to regulate all solid forms of hydro-fracturing waste products and dictate the proper transport and disposal of the waste. The Water Resource Planning Act was also established in order to mandate that studies be done on water availability, water use, and future water needs in order to prevent the destruction of various watersheds and resources. These acts may seem like a great safety net for the process; however, the hydro-fracturing industry has found a loop hole which does not deem the waste products from drilling to be classified as "hazardous waste" which allows them to be exempt for certain regulation standards and keeps energy companies from having to disclose the proportions of chemicals used in fracture fluid. There was also a piece of legislation passed, The Pennsylvania Oil and Gas Act, which limits the amount of input municipalities can have and leaves a majority of regulation up to the state.[10] Although many municipalities don't have the resources to fully regulate the industry, they still deserve the right to be involved in the regulation process. State-wide management agencies will struggle to fully manage all fracturing wells in Pennsylvania, especially if the industry continues to grow at its current rate. The response to this limitation in the northeast has been the formation of the Susquehanna and Delaware River Basin management organizations. These organizations are multi-state groups based on the overarching watersheds of the Pennsylvania, New York, and Delaware.[9] These organizations provide regional perspective and operate at a scale which is very suitable for hydro-fracturing regulation.

Legislation has been proposed at the federal level by the STRONGER organization (State Review of Oil and Natural Gas Environmental Regulations) which is known as the FRAC Act (Fracturing Responsibility and Awareness of Chemicals). This act would repeal the hydro-fracturing industry exemption from the

Safe Drinking Water Act and The Clean Water Act while establishing provisions for regulations specific to hydro-fracturing via the following guidelines: (1) Improvement of air quality by reducing emissions of regulated pollutants and methane caused by hydro-fracturing and implement comprehensive studies to compile the overall carbon footprint of fracing (2) Protect water supply and quality by regulating methane contamination of water supplies, safeguard cement features designed to prevent leaks underground, and mandate how the liquid wastes from hydro-fracturing are to be stored and treated (3) Create background water quality measures by requiring mandatory water resource testing before any drilling occurs in order to provide base line data to accurately evaluate a well's impact on water resources (4) Mandate that all chemicals used in the hydro-fracturing be disclosed along with the specific proportions for each well drilled (5) Reduce the use of diesel fuel in all fracturing operations (6) Mandate short and long term studies on fracturing wells impact on communities, land uses, and wildlife ecologies and then provide management plans to mitigate for all disturbances caused by drilling.[12] This litigation is yet to be passed and is considered by many to be ahead of its time and too broad to dictate regulations on a nation-wide scale for drilling practices that change based on geologic composition.

Figure 4: Horizontal vs. Vertical Drilling Radius



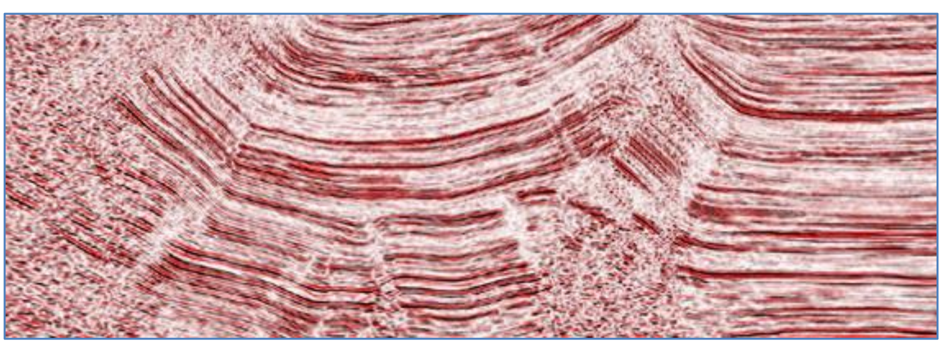
<u>Fracing Process</u>

The process of fracing has evolved over time and, through various methodologies, has generated an overall scientific methodology for finding, extracting, storing, and shipping this energy source. The natural gas located within the Marcellus Shale rock formation was often considered inefficient to drill

[12] DeGette. "H.R. 1084." U.S. Government 112th Congress, 15 Mar. 2011. Web. <http://www.gpo.gov/fdsys/pkg/BILLS-112hr1084ih/pdf/BILLS-112hr1084ih.pdf>.

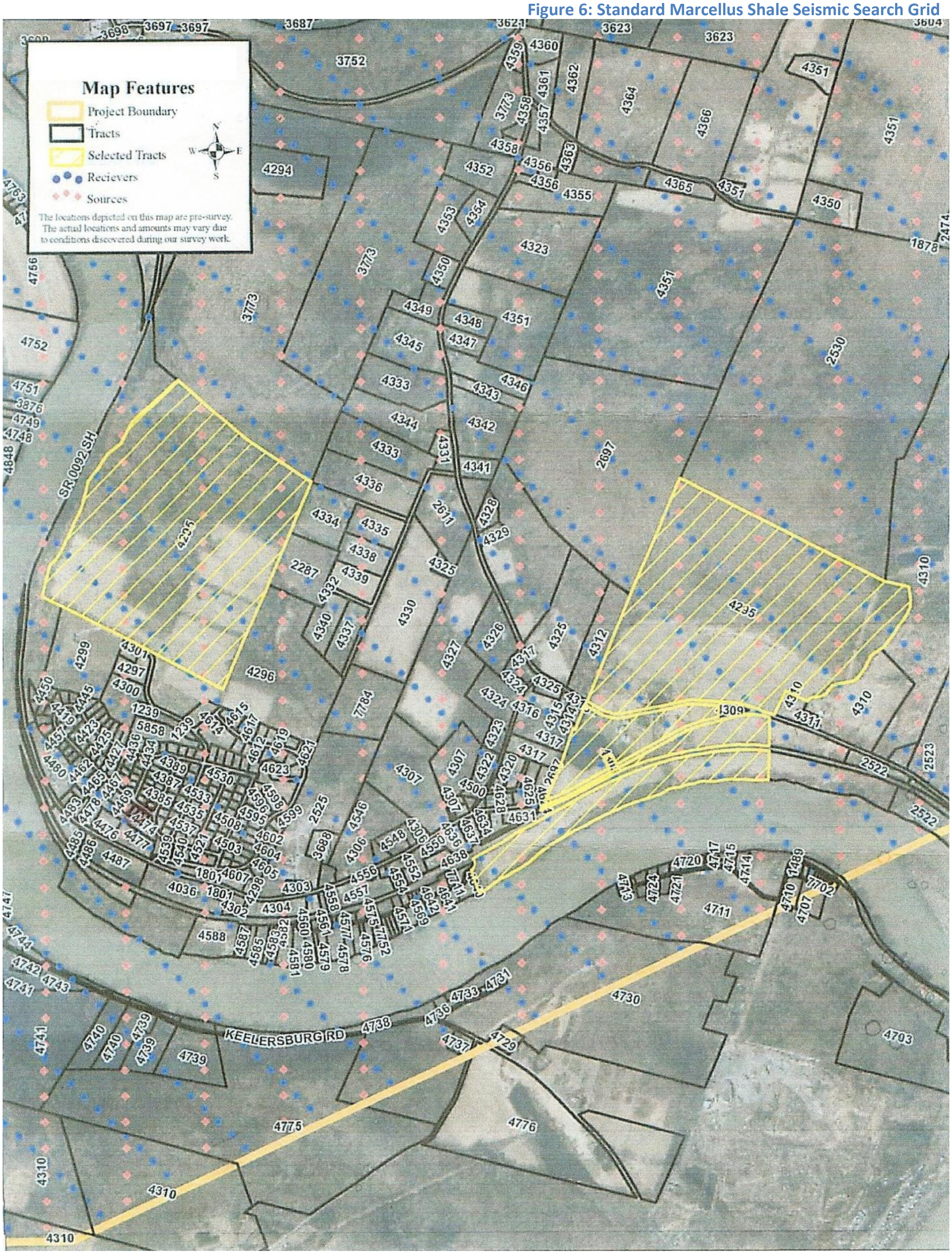
for because it required more energy to extract it than could be produced from the ground. The horizontal drilling technique revitalized the industry by expanding the drilling radius for every well and made Marcellus Shale a profitable rock formation for natural gas extraction - see Figure 4. The drill site is selected through the work of geologists using seismic monitoring devices which detect the Marcellus Rock formation one to one and a half miles beneath the surface. This is achieved by using historical records of underground rock formation - which are readily available in Pennsylvania due to the high use of coal and subsequent coal mining in the area. By using this information, geologists can approximate areas in which Marcellus Shale plays are expected to be located. Once these areas are located the mineral rights for the area(s) must be identified and acquired by the subsequent owner(s). Mineral rights are essentially the ownership of the materials beneath of surface of a particular plot of land and are quite often sold and traded separately from the above ground land owner rights. Quite often the mineral rights for a property will be owned by someone other than the person who owns the "above ground" property rights – this can lead to the permission of drilling on someone's property without their consent or expectation of any return of capital gained on the site. Geologists determine where the exact location of the Marcellus Shale formation is by setting up a grid of charges spaced out approximately 280-300 feet by 280-300 feet in a diagonal pattern for the length of the property.[13] This grid covers the area suspected to have Marcellus Shale underneath it or the area which has been obtained through the purchasing of mineral rights. Then charges are set underground at a depth of approximately 20 feet and

Figure 5: Standard Marcellus Shale Seismic Test Results



[13] Tucker, Corey – Contact Agent. Geokinetics. 570-945-5672.

Figure 6: Standard Marcellus Shale Seismic Search Grid



detonated. The seismic affects after the detonation produces signature readings for Marcellus Shale formations and geologists interpret the data which reveal the varying depth and thickness of any shale plays.[10] The geologists then use this information to decide exactly where to drill (see Figure 5 for a typical result from seismic testing) as well as when the drill must be redirected and begin to travel horizontally so as to stay within the shale play and collect more natural gas. A typical grid system on a property can be seen in Figure 6. This process is critical because there is a great variation in thickness and depth to the Marcellus Shale (seen in Figure 7) and in order to be efficient and achieve profitability, drillers must be able to strike Marcellus Shale and subsequent natural gas on a strong majority of the sites they drill. Before the energy company will fully invest in the mineral rights, testing, and future drilling of a site they will confer with local and state authorities regarding various infrastructure and environmental requirements and standards – these include details such as location & size of access roads as well as water quality standard testing. Once a site has been approved by the proper authorities and tested by geologists the energy company will fully invest in a lease with the owner of the mineral rights for the property. This transaction typically allows the energy company to drill on the owner's land in exchange for an amount of money per acre of leased land. This money is guaranteed to the leaser even if no natural gas is found or is deemed unobtainable. If however, natural gas is found, the leaser will receive royalty payments as a percentage of the profit from selling the drill's gas for a duration of time agreed upon by both parties (in Pennsylvania the minimum royalty percentage is 12.5%).[10]

The actually drilling process of a well is relatively simple and can be completed in approximately 50 days. A typical well pad is constructed on approximately 6 acres and can hold 6-10 wells depending on the spatial needs of equipment for a particular well pad. The well pad is cleared of all vegetation and receives layers of sand and rock compacted to maintain the load for the various equipment and storage tanks needed on site. There are also multiple pits dug on site with plastic lining which will serve as containment structures for fracing flowback water until the waste can be transported to a treatment

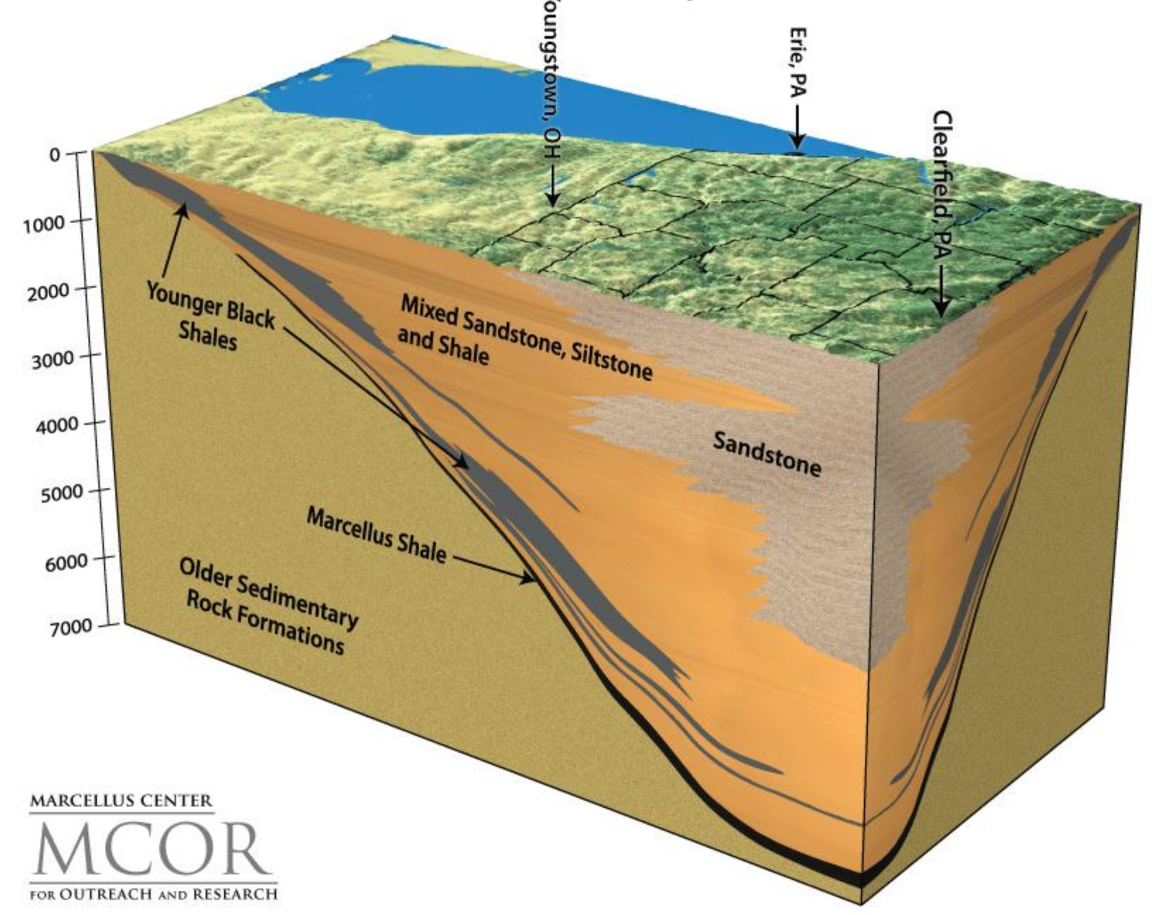


Figure 7: Marcellus Shale Formation Cross Section

facility or recycled on site. Once the site is prepped for drilling a specialized drill head used for the rock formations found on site will drill going beyond the ground water depth - greater than 300 feet in most areas. Once the desired depth is reached, steel tubing is placed down through the drilled hole and around the drill itself while providing spacing between the drill and the surrounding casing. Concrete is then pumped down the well and out the opening at the bottom forcing it back up vertically which provides a second protective layer surrounding the drill bit and creating a barrier between the overall drill hole and surrounding hydro-geologic features. At this stage there is a layer of concrete, a layer of steel, and another layer of concrete between the drill and the surrounding rock. The drill will then penetrate deeper into the ground until it is approximately 500 feet above the Marcellus Shale play (typically 6000-8000 feet deep). At this depth, referred to as the “kick point”, the vertical drilling

Figure 8: Natural Gas Well Caped for Storage

equipment is retracted from the well bore and special horizontal drilling equipment is lowered into the drill hole. This equipment begins drilling in a curved fashion until an approximate 90 degree angle is achieved and the drill bit can spread horizontally out through the shale formation. The horizontal drilling typically extends for 14,000 feet depending on the surrounding geology and location of other vertical and horizontal drilling locations. Next, a second layer of steel tubing is placed down the length of the drill bore which is then filled with concrete again – similar to the first layer of concrete casing at the shallower depth. Once this is complete there is a double layer of steel and concrete (approximately 6 inches thick) at the shallower depth near ground water resources and a single layer of steel and concrete (approximately 3 inches thick) at the final depth and horizontal reach of the well bore. The drill is then extracted as it is no longer required in the hydro-fracturing process. A perforating gun is then displaced into the horizontal section of the drill hole and, using an electric charge, fires through the drill hole creating small fissures which extend dendritically out from the horizontal portion of the drill hole.[14] At this point the fracturing fluid is then pumped down into the horizontal well section at very high pressure – approximately 15,000 psi. The fracturing fluid is composed of water, sand, and chemical additives – typically with 98% water, 1.5% sand, and 0.5% chemicals. A single well requires approximately 4-7 million gallons of water to be successfully fraced. This water is used primarily for the fracturing fluid but some is also used in mud-like slurry which cools the drill bit as it boroughs through the ground. Note Figure 9 which details various chemicals used in the fracturing fluid and their corresponding impacts.

After the fissures have been expanded via the fracturing fluid, the fluid is removed and placed into containment ponds or holding tanks until they can be transported to treatment facilities. The natural gas is now able to travel freely through the fissures held open by sand and through the perforations created earlier by the small explosions. A well cap is then placed on the drill hole and the natural gas can be pumped to the surface. The natural gas returns to the surface in a mixture of water and natural elements located underground. Notably, Uranium which produces Radon gas is often included in the natural gas mixture which returns to the surface. This mixture is treated and the natural gas is removed from the mixture and stored separately. This natural gas can then be liquefied for ease of transport to potential users. A well cap is then placed on the drill hole in order to preserve any natural gas from escaping. Now the area essentially serves as a storage facility for all the natural gas underground and can be extracted from the well caps at a moment's notice – see Figure 8 for an image of a capped well hole. The area remains as is until no more natural gas is obtainable from underground. At this point, it is the duty of the energy company responsible for drilling to restore the site to its original condition within a 9 month period. This restoration is monitored by local governments and the associated governing

[14] Packer, Kevin, and Brian DeRuschi. "Technology Taking America Out of Energy Crisis: The Rise of Fracking." University of Pittsburgh Swanson School of Engineering, 7 Feb. 2012

Figure 9: Hydro-Fracturing Fluid Chemical Elements *(* = known carcinogen)*						
Element	*Common Name*	*Use*	*Vegetation Impact*	*Soil Impact*	*Wildlife Impact*	*Human Impact*
H_2O	Water	Create pressure and is base for chemical mixture	Too much water can cause certain plant species to drown	N/A	N/A	N/A
SiO_2	Sand	Keep fissures open to allow natural gas to flow out	N/A	N/A	N/A	N/A
HCL	Hydrochloric Acid	Break apart fissures in rock formation	Skin, Eye Irritant	Can alter soil pH	Can be toxic to wildlife	Can be toxic to humans
$[NH_4]^+[HSO_4]^-$	Ammonium Bisulfate	Eliminate oxygen content in frac fluid	Fertilizer	Can alter spil chemical composition	N/A	Corrosive to skin
$CH_2(CH_2CHO)_2$	Glutaraldehyde	Biocide to prevent bacterial growth and contamination	Can cause death of biological organisms and stop biological processes	Can kill microorganisms in soil	Can alter ecological processes	Skin, eye, nose, throat, lung irritant
NaCl	Sodum Chloride	Lower the viscosity of fluid	Can kill vegetation and make areas unable to grow future vegetation	Can alter soil pH	N/A	N/A
$C_{12}H_{23}$	Diesel	Lubricant	Can kill vegetation in large quantities	Can alter soil chemical composition	N/A	Fumes from burning can be an irritant
CH_3OH	Methanol	Fuel additive; bi-product of certain chemical reactions	Causes temperature increase	N/A	Air Pollutant	Respiratory irritant; lethal if ingested in large quantities
C_3H_8O	Isopropanol	Used as a product stabilizer	Can irritate or kill plant life	Can slightly disrupt soil pH	N/A	Eye irritant
NaOH	Sodium Hydroxide	Adjust composition pH	Can irritate or kill plant life easily	Greatly increases soil pH	Can alter ecological processes	Skin burns or blindness
$C_2H_6O_2$	Ethylene Glycol	Product stabilizer	Can kill plants in large quantities	Can alter microorganism life in soil	Can cause severe illness or death	Eye, respiratory, central nervous system disruption
C_6H_6	Benzene*	Diesel bi-product	N/A	N/A	Can cause severe cardiovascular/respiratory failure	Central nervous system & cardiovascular failure
C_7H_8	Toluene*	Diesel bi-product	N/A	N/A	Can cause respiratory failure and death	Can cause respiratory failure and death
$C_6H_4C_2H_6$	Xylene*	Diesel bi-product	N/A	N/A	Eye & respiratory irritant	Eye & respiratory irritant; can cause death or blindness; known carcinogen
C_8H_{10}	Ethylbenzene*	Diesel bi-product	N/A	N/A	Pulmonary adema, paralysis	Cardiovascular disruptor
$C_{10}H_8$	Naphthalene	Carrier fluid for active ingredients	Can adversely affect plant growing efficacy	N/A	Eye, nose, throat irritant	Eye, nose, throat irritant
C_7H_7Cl	Benzyl Chloride*	N/A	N/A	N/A	N/A	Known carcinogen
Cu	Copper	Bi-product	N/A	N/A	N/A	Skin irritant in high quantities
Pb	Lead	Bi-product	Toxin	N/A	Toxin	Toxin
C_3H_5NO	Acrylamide	Used as a friction reducer	N/A	N/A	Neuro & reproductive toxin & carcinogen	Central nervous system disruptor
CH_3COOH	Acetic Acid	Prevents metal oxide precipitation	N/A	N/A	Minor eye irritant	Minor eye irritant
$(AlO)_2SiO$	Aluminum Silicate	N/A	None	None	None	None
C_2H_6O	Ethanol	Product Stabilizer	N/A	N/A	N/A	N/A
$Al_6Si_2O_{13}$	Mullite	Keep fissures in rock open	N/A	N/A	N/A	N/A

entity.[15] Many times the oversight of this process is either done in a very cursory manner or not done at all. This has left fracing well pads that have already been used in a decrepit state and a nuisance to the aesthetics of the area as well as local ecological systems.

Fracing Visual Mitigation

The visual effects of hydraulic fracturing can be seen as extremely obtrusive and can greatly alter the visual impact of a landscape. The average fracing well pad is an approximate 6 acres with effects that spread far beyond this boundary. Fracing well pads create disturbances in both the vertical and horizontal realm of space. Both of these frames of reference must be addressed in the restoration phase of a fracing project in order to minimize the disturbance caused by the process. This will greatly increase the public perception of fracing and help to make the practice more widely accepted by the community. The vertical realm of the fracturing process is small in footprint but very substantial in regard to its visual impact. This visual impact is created by the drilling rig itself – often reaching 80 feet in height, see Figure 10. This equipment is used as the primary means for gaining access to the bedrock and subsequent natural gas located far below the surface. Obviously, this rig cannot simply be removed from the site as it is crucial to the drilling process; however, it is important to consider visual impact when fracturing well pads are chosen so as to limit the exposure of this massive structure to the public. This vertical element can be blocked by incorporating aspect analysis through GIS services when selecting sites. It can also survey the location of residential, commercial, recreational, and transportation networks when selecting a drill site so it can be oriented away from these areas and reduce its visual exposure to the public. The use of existing and proposed vegetation is also a great way to block or obscure the visual impacts of these sites. Seeing as how the rigs average 80 feet in height it is reasonable to assume that the entire rig would be difficult to block; however, enough of the rig can be blocked so as to remove it from the

[15] Zweig, Steve. "Hydraulic Fracturing (Hydrofracking): The Risks and Rewards of the Controversial Drilling Technique." Heating Oil LLC, 30 Nov. 2009. Web. Apr. 2012. <http://www.heatingoil.com/wp-content/uploads/2009/11/hydraulic-3.pdf>.


Figure 10: Fracing Drill on Well Pad

"obvious" view of the average person. For example, the state of Pennsylvania contains vast expanses of large, long-lived pines which can come close to reaching the heights needed to block the fracturing drills overall. Most notably the Eastern White Pine, *Pinus rigida*[16]*,* and the Scots Pine, *Pinus sylvestris,*[17] which reach average heights of 90 feet and 70 feet respectively. These trees can be utilized to contribute to the visual blocking of the vertical nuisances created by fracing.[18] The horizontal impact of fracturing comes from the substantial infrastructure associated with the fracturing process and subsequent transportation of the resources obtaining through fracturing. Every fracing well pad requires substantial roads to provide access to the site for large equipment such as drills, storage tanks, maintenance trucks,

[16] Cook. "Common Trees of Pennsylvania - Eastern White Pine." *Common Trees of Pennsylvania - Eastern White Pine*. N.p., n.d. Web. 19 July 2012. <http://www.cookforest.com/articles/trees/eastern-whitepine.cfm>.
[17] Cook. "Common Trees of Pennsylvania - Scots Pine." *Common Trees of Pennsylvania - Scots Pine*. N.p., n.d. Web. 19 July 2012. <http://www.cookforest.com/articles/trees/scotspine.cfm>.
[18] Kuehn, Sarah. "Landscape Practices on Gas Well Sites in North Texas: Perceptions of Selected Industry Representatives and Regulators." University of Texas at Arlington, Dec. 2011. Web.

etc. The fracturing process requires a substantial amount of equipment which is extremely large and heavy which means the roads created for them are often far from “temporary” and can be considered comparable to the average unpaved road. This means that these roads cannot simply be erased from the landscape and leave their footprint long after the drilling process is over. There is also the visual impact of the miles of pipelines (see Figures 11, 12) which are constructed in order to transport the natural gas from the drilling sites to various storage, treatment, or distribution facilities. These pipelines can often have a greater impact on the landscape than the drilling sites themselves as they can span across miles of the landscape and have a much greater edge effect to surrounding areas than an individual well pad. These disruptions can be extremely noticeable to humans from an aesthetic means and to wildlife from a habitat & migration means – see Figure 13. Visual mitigation for these structures will prove to be more difficult than mitigation for drilling structures. The vast distances these structures span require a much more concerted effort from a planning perspective as well more time-intensive structural mitigation through the use of physical objects. The planning of these pipelines is similar to the planning needed for well pad site selection but must take into account many more factors. Due to the lengthy linear nature of these structures planning must include: transportation networks, waterways, natural & protected areas, urban areas, visual perspectives of roads, trails, railways, and the movement of species. The large list of elements incorporated into pipeline planning begs that the process must be done from a regional scale in order to incorporate all the necessary information regarding the length of the pipe. These elements can scar the landscape and disrupt so many visual resources that there must be a means to conceal them from the general public in order to continue the fracturing process without destroying valuable resources. These visual resources often have strong indirect economic benefits and if they are overshadowed by the potential benefits of fracing they may be disregarded and lost forever. It is also very important to identify the visual economic values of an area before a pipeline is sent through it. Once this value is identified, a cost-benefit analysis can be conducted in order to make sure the economic value of the pipeline won't be less than the visual value of the natural area (in which case it can be determined that the pipeline would yield a net loss and should therefore not be constructed in a proposed area). This type of analysis would help to locate pipelines into areas of lesser aesthetic value and therefore have a diminished impact on the overall landscape as a whole.[19]

There are certain factors which will help to dictate proper visual mitigation techniques for both the vertical and horizontal landscapes. These factors include (1) land use of area of interest and surrounding areas, (2) environmental factors such as species present, species of concern, ecosystem & natural patches, geologic makeup, climate, (3) city, state & federal regulations, (4) surrounding mitigation banks, and (5) community values.

Figure 11: Natural Gas Pipeline

[19] NaturalGas. "The Transportation of Natural Gas." *NaturalGas.org*. N.p., 2011. Web. 19 July 2012. <http://www.naturalgas.org/naturalgas/transport.asp>.

(1): By analyzing land use patterns, visual mitigation can be better managed by maintaining concurrency amongst the development of the area in question. Different land uses will create different public/animal perceptions. These perceptions must align with the reclaimed well pad in order to transition smoothly through the restoration process.

(2): Analyzing environmental factors of the area will produce results that may not be directly noticeable but will lay the groundwork for the restoration's success in the future. Once the proper types of species can be documented then vegetation can be selected which will provided for the survival of the species in the area (done in moderation to avoid the area being decimated by local animal/insect populations). By creating suitable animal habitat in these areas the restoration process can be vastly accelerated as the species introduction will increase the succession process. If the proper species are accounted for, that can lead to the proper analysis of the ecosystem within the area and all attempts to mimic that ecosystem through restoration can be improved upon. The study of the geologic makeup of a restoration area is also important in regard to visual mitigation for its direct impact to site lines as well as dictating vegetation patterns. Finally the climate must be considered in the planning and restoration processes of well pad in order to aid in site drainage and plant selection. Restoration practitioners must take climatic factors into account in order to create a long-lasting restoration site which can hold up to the elements.

(3): It is also critical to identify regulations from all levels of government in order to generate a restoration plan which can concurrently appease local, state, and federal guidelines. This will help to guarantee the success of the restoration by utilizing assistance and oversight from all levels of authority as well as guaranteeing that no work will have to be redone.

(4): Another key factor in fracing visual mitigation planning is the identification of any surrounding mitigation banks. It would be wise to incorporate them into site restoration and visual mitigation as this would elevate the success of the overall mitigation system and provide a smoother transition into the existing area for aesthetic gains provided to all users.

(5): Finally community values must be addressed in order to successfully mitigate the negative visual affects of fracing. By doing so, all stakeholders can address their needs and the restoration practitioners can try to incorporate them into their designs. The project can only be successful if the people living with it can appreciate it and find its transition into the landscape suitable. By identifying and utilizing these (5) factors for both site selection and reclamation a well pad can be better hidden during the drilling process and better restored after.

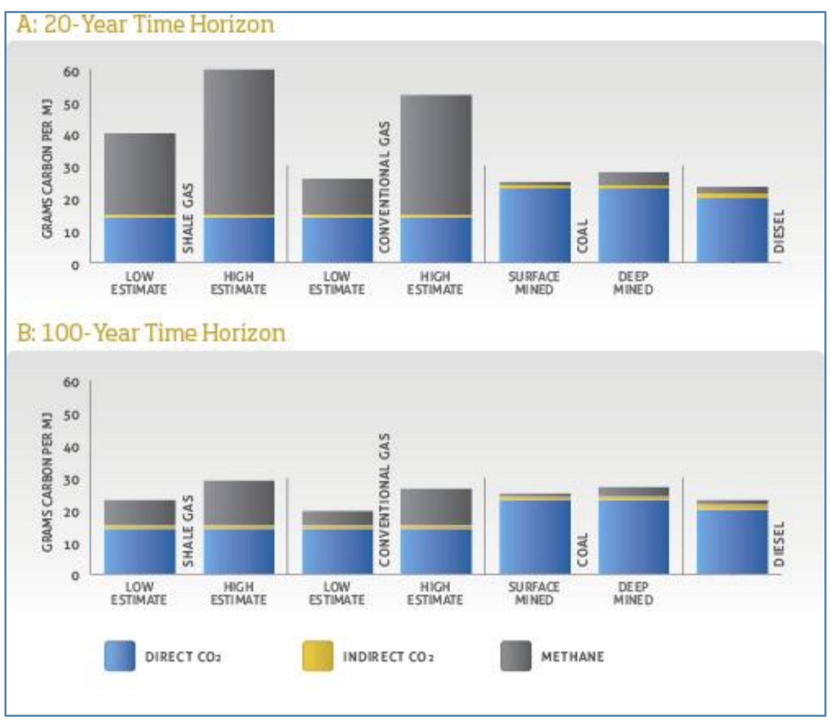
There are a handful of techniques that can be used in the visual mitigation process for fracing well pads. First vegetative screening should be utilized in a fashion that both screens the well pad but also fits into the landscape. This can be difficult as many well pads are rectangular with straight edges and a proper

Figure 12: Natural Gas Pipeline Over Mountain

designer must recreate natural curvature to blend the harsh well pad into a soft landscape for a positive visual aesthetic. A great way to transition from the hard edges of a well pad is through the use of masonry walls. Although not part of a "natural" landscape, these elements can provide a middle ground between developed and undeveloped land. The masonry wall will dictate somewhat of a rustic quality while providing a subtle reminder of "what was" in order to put the area into perspective for future users. Apart from masonry walls, general fencing can also be utilized in the landscape to protect fauna from any hazardous parts of the landscape. These fences can be artfully constructed with a weathered look and use espaliered plant material in order to create the illusion that these fences have been present for some time and blend into the landscape.

Finally, it is important to note that if the visual mitigation can be assembled concurrently with the drilling process then it will also help to block auditory pollution and help to limit the negative sound effects associated with the fracturing process. This secondary auditory mitigation will keep various fauna within the general area as opposed to encourage mass species migration. By keeping valuable species within the area they will be more likely to repopulate the site post-drilling and accelerate the overall restoration processes. The noise reduction will also be appreciated by any human populations which also inhabit the area. Although fracturing often takes place in rural areas, by creating an atmosphere which humans can find acceptable will

Figure 13: Estimated Emissions of Various Fossil Fuels



help to boost the public perception of the fracturing process.[18]

Visual mitigation is a crucial element to the fracing process. It can be assumed that the future of drilling by fracturing will rely on proper visual mitigation in order to encroach closer to human populations without drawing high scorn from nearby populations. This mitigation will also be crucial as more and more well pads are created and must be properly restored and managed if they wish to continue to grow and expand as a "clean" energy of the future.

Fracing Future & Outlook

Natural gas extracted through hydraulic fracturing has exploded into the energy industry and become a major player in the markets of fossil fuels. The current President of the United States, who has established a "moderately liberal" role in terms of environmental policy, has whole-heartedly supported natural gas and the hydraulic fracturing process as a means to further the country's energy independence.[6] As the industry has advanced, both technologically and politically, its portion of the market has grown 28%.[5] The innovation of horizontal drilling techniques are, by far, the largest contributor to this immense growth – most of which has occurred over the last 15 years.[10] The growth of this industry is still young in comparison to older methods of fossil fuel extraction. There is much to be seen in the future for hydro-fracing from technological and legislative perspectives.

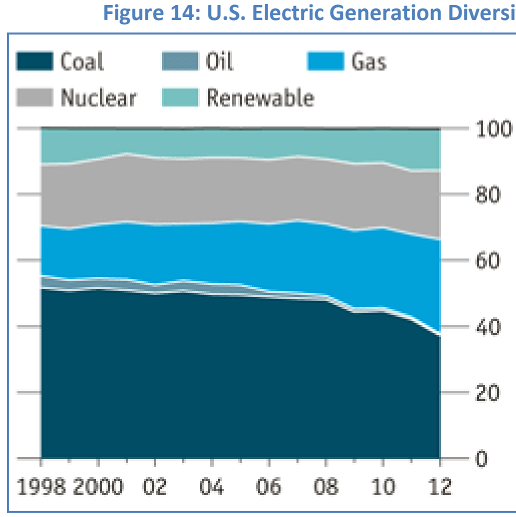
The technology behind hydraulic fracturing, which created the current "boom" of natural gas, has somewhat slowed since its inception due to the large amount of capital and labor going towards finding, procuring, and drilling sites. Recent environmental movements and concerns have pushed energy companies to invest more capital into the research and development of techniques to make fracing more environmentally sensitive and reduce its carbon footprint.   There are arguments that fracing has higher and lower emissions than its nearest competitor: coal. Unfortunately, there is not much data on the carbon footprint of fracing due to the relative young age of the process. The primary concern with fracing is the amount of methane released during the drilling process (note Figure 13). Methane is a bi-product of the fluid used in the drilling process and also is released naturally from the ground as the bedrock is fractured. It is important to note that methane causes 21 times more heat to be trapped by the Earth's atmosphere making; however, it only stays active for 12 years after emission (as opposed to 50-200 years for CO_2).[20] This makes methane less of a "worry" in terms of a source of climate change, but the intensity of the gas's heating characteristics does raise concern for increasing its release into the atmosphere at a rate which rises as rapidly as hydro-fracing. On the other hand, the longevity of CO_2 in the atmosphere is a cause for concern regarding the coal industry. Coal was a powerhouse, figuratively and literally, for the United States for over a century which has lead to large deposit of CO_2 in the atmosphere – actively playing a role in global climate change. With the intervention of natural gas drilling, CO_2 emissions have lowered in relation to the decrease in coal energy production and has lead to the overall diversification of America's "energy portfolio" (see Figure 14). Technological advances in the fracing industry still loom on the horizon as the possibilities are explored by researchers. Many of these advances will be in the equipment and products used in the fracturing process as opposes to various drilling techniques. For example a technique has been developed which lessens the need for proppant by 45%. This process works by created a synthetic fiber-based network within fracturing fluid which aids in transport of fluid and fracture preservation. This reduces the need for water and other chemicals required to generate the proper solution to form proppant required for successful drilling.[21] Another major breakthrough in the fracing industry was introduced by Gasfrac Energy Services (based out of Canada) in which propane gel is used in place of the current fracturing fluid mixture. This technology has been quoted as a "game changer" for the industry as it essentially eliminates the use of

[20] Koerner, Brenden. "Is Methane Really Worse for the Environment than Carbon Dioxide?"*Slate Magazine*. N.p., 27 Nov. 2007. Web. 01 Aug. 2012. <http://www.slate.com/articles/health_and_science/the_green_lantern/2007/11/the_other_greenhouse_gases.html>.

[21] Langley, Diane. "Technology Advances Push Greener Side of FracingÂ |Â Drilling Contractor." *Drilling Contractor*. N.p., 4 May 2011. Web. <http://www.drillingcontractor.org/technology-advances-push-greener-side-of-fracing-9329>.

water (90% reduction) in the process as well as creates no hazardous waste bi-products. The technology behind this innovation is linked to the chemical interaction of gelled propane and the gases released by the fracturing in the shale. In this process the gelled propane provides the necessary lubricant for equipment, and mimics all the other effects that “typical” fracing fluid achieves. Then, once the fractures occur and the natural gas is released, the propane mixes with the gas resulting in a reaction which eliminates the gel-like properties of the propane. The resultant bi-product of this process is a gaseous form of natural gas which is no different than that drilled and extracted with hazardous fracturing fluid. Essentially, a bi-product of natural gas is used to drill for more natural gas. This technology can reduce a tremendous amount of environmental concerns in regard to fracing and eliminate the high water demands associated with this drilling technique.[22] Another valuable technological advance in the fracing industry is in the technology related to water contamination prevention. Halliburton has developed a system called CleanSuite Technologies which provides micro-seismic monitoring, 3D fracture mapping (showing predictions and locations of shale fractures), UV light sterilization (eliminating the need for biocides), and has created a fracturing fluid using only ingredients found on the US Food & Drug Administration’s CFR 21 list (a list of foods for human consumption). Halliburton has also developed an advanced technology used for treating fracturing flowback waste on site for reuse on other wellbores. This process utilizes electro-coagulation and reduces the amount of times fracing flowback water must be stored or transported on public roads. It should be noted that after an entire well pad is drilled the fluid then must be transported as the well site shuts down. At this point the fluid can be significantly

Figure 14: U.S. Electric Generation Diversity



[22] Milmo, Sean. "Fracking with Propane Gel." *Fracking With Propane Gel*. RSC Chemical Solutions, 15 Nov. 2011. Web. 01 Aug. 2012. <http://www.rsc.org/chemistryworld/News/2011/November/15111102.asp>.

“cleaned” but still poses a potential threat to flora and fauna in large quantities. Baker Hughes has developed a technology which utilizes “ultra-high quality foam” which is projected to eliminate 95% of the water needs for a typical fracing well. This technique however has not disclosed the composition of the “high-quality foam”. The drawback to all of these revolutionary technologies is the higher associated costs that accompany them. Many of these processes increase the production costs associated with a well pad from 20%-40%. It has been estimated that these increases in overhead can easily be made up over time still does not sit well with customers and investors looking for immediate rewards.[21] The goal from a political perspective must be to make these technologies cheaper and draft legislation promoting the more efficient and safer manner of hydraulic fracturing.

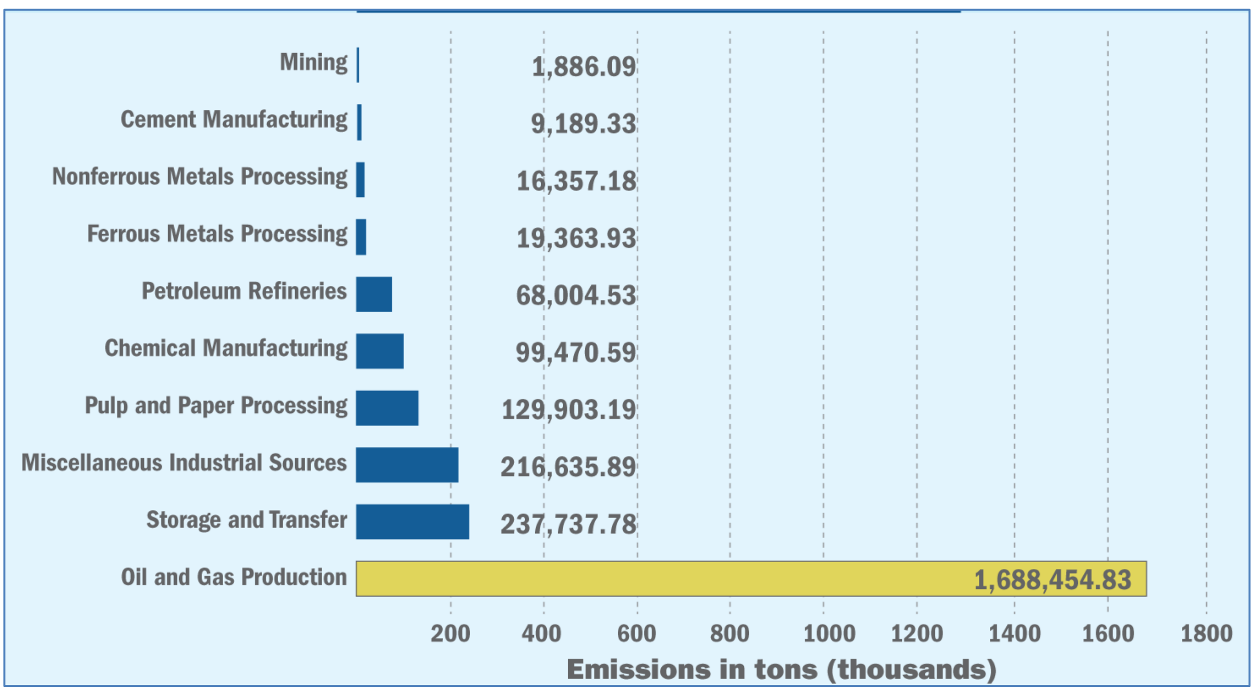
A major piece of legislation, put forth by the EPA has set the pieces in motion for regulation to constrain the harmful practices of hydro-fracing which in turn can boost insentive for a cleaner process. The EPA is required to evaluate New Source Performance Standards for various industries every eight years; however, no evaluation of natural gas production had occurred since 1985. This was startling considering the major role oil and gas production plays in terms of VOC emmions (see Figure 15). This fact was brought to the EPA by various environmental groups which subsequently evaluted the fracing process as a whole. This evaluation found many violations of the Ground Ozone Standard of 75 ppb which natural gas drilling sites were violating. The EPA then established rules in July of 2011 and by April of 2012 had passed regulations regarding air quaility and hydraulic fracing sites in an attempt mitigate the damage that had been done.

The rules apply to wells drilled since August 23rd, 2011 and have until 2015 to comply (some provisions must be met within 60 days due to the severity of the threat). (1) Emissions equipment must be installed on site which seperates mixed solids, liquids, and gases which as the return to the surface of a wellbore. (2) All the equipment used in the natural gas drilling, shipment, treatment, and storage process must reduce their overall emissions based on various extenuating factors – while monitoring and reporting these figures on a regular basis. (3) All states must monitor and report the natural gas drilling emissions rates in regard to the Ground Ozone Standardsand report the findings to the EPA.

The EPA has estimated that these new regulations will eliminate 95% of the VOCs from an approximated 12,800 fraced and re-fraced wells for 2015. Also, it is estimated that these procedures will result in a major reduction of methane gas emissions from fracing well site which would amount to the equivalent of 18 million tons of CO_2. There will be a negative cost associated to these new regulations which the energy companies must absorb; however; the EPA estimates that these new restrictions will result in a decrease of negative health benefits by $400 million dollars.[23] The argument can be made that these savings easily offsets the associated costs of complying with the new regulations.

These regulations, in my opinion, represent the tip of the ice berg for what is needed to truly make this process safe. It is logically to conclude that natural gas is will play a major role in the future energy

Figure 15: U.S. VOC Emissions by Industry

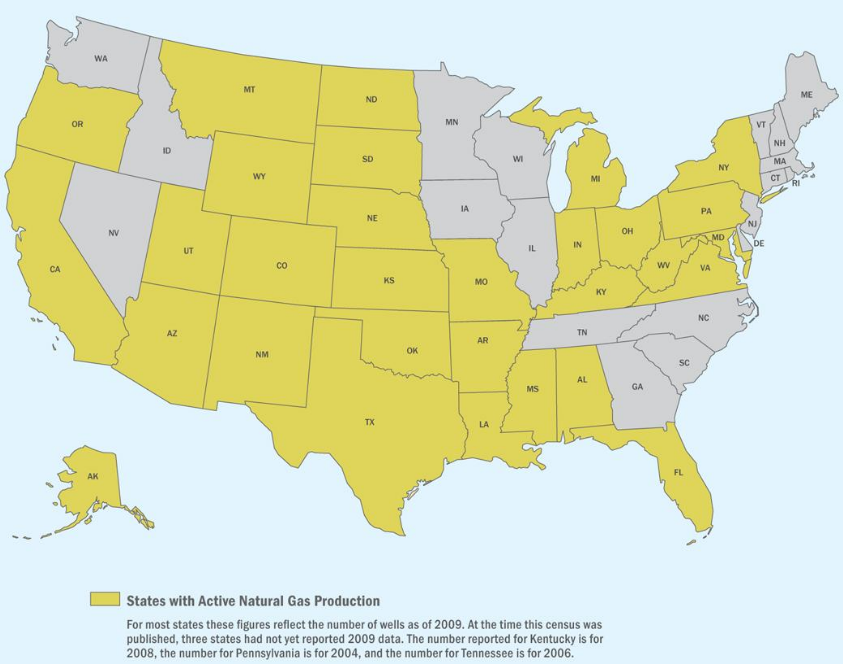


[23] Weinhold, Bob. "The Future of Fracking: New Rules Target Air Emissions for Cleaner Natural Gas Production." *Environmental Health Perspectives:*. N.p., 2 July 2012. Web. 29 July 2012. <http://ehp03.niehs.nih.gov/article/info%3Adoi/10.1289/ehp.120-a272>.

needs of the United States and to think it can simply be abandoned would be impractical. It is also safe to assume that the current standards in place for natural gas extraction are much too lax and must be retrofitted to accommodate the needs of the environment while accounting for the safety of all living things. The EPA has begun to set the standards for hydraulic fracturing in air emissions, but water standards and land planning standards must be addressed to encompass all the impacts fracing has on the environment.

Water use by the industry must be cut severely if this process hopes to have any chance on sustaining itself over the course of our future. This can be met through regulatory action limiting the amount of water allowed per well while also establishing impact estimates on local and regional water bodies so as not to disrupt them. Statewide agencies must also be appointed in order to monitor large-scale water systems which serve jurisdictions which cannot be met via state boundaries. These organizations can work together and provide a form of checks and balances between each other to help ensure the “self-

Figure 16: U.S. States with Active Natural Gas Production



States	No. of Wells
Texas	121,534
Oklahoma	52,287
West Virginia	42,645
New Mexico	39,497
Colorado	38,278
Pennsylvania	35,928
Wyoming	32,617
Ohio	28,181
Kansas	26,025
Louisiana	18,519
Kentucky	13,330
Michigan	10,462
Virginia	7,078
New York	6,995
Utah	6,860
Arkansas	6,859
Montana	6,760
Alabama	6,157
California	4,142
Mississippi	1,734
Alaska	1,046
Indiana	620
North Dakota	509
Nebraska	354
South Dakota	137
Oregon	23
Arizona	6
Maryland	4
Florida	4
Missouri	2

Source: U.S. Energy Information Administration[22] policing” of fracing regulators. Water rights must also be adopted which sets a standard for energy companies to replace all or a majority of the water back to the systems they were extracted from in a condition which is suitable for the associated ecosystem. By further limiting and regulating the water resources used in this process, a more clean and sustainable method of extraction can be fostered through a business mentality – all while maintaining ecological integrity in doing so.

Land planning is another area of regulation which must be addressed in regard to fracing. The EPA has delegated this power to state governments which is understandable when one considers how many states actively participate in fracing (see Figure 16). These states must be required by the EPA to incorporate horizontal hydro-fracing techniques into its comprehensive plans and associated land use zoning regulations. Due to the immense “arm length” a wellbore can have through associated horizontal drilling techniques, it is important to understand and legislate that understanding in the form of land use buffering and protection. Fracing must be able to be limited to certain boundaries and associated uses such as food production, schools, endangered species habitats, wildlife corridors, urban enterprise zones, central business districts, and critical wetlands must be protected from negative fracing consequences. Natural gas will be a major energy source for our future and can greatly help to reduce our dependence on foreign fuels so as long as we don’t sacrifice the health of our people and our environment to do so.

Image Appendix

Figure 1
PacWest Consulting Partners. "North America Shale Plays." Web. 21 May 2012. <http://pacwestcp.com/wp-content/uploads/2012/01/PacWest-NA-Shale-Plays-Template-Map-FINAL.jpg>.

Figure 2
Secretary of Energy Advisory Board. "Subcommittee Shale Gas Production Second Ninety Day Report." U.S. Department of Energy, 18 Nov. 2011. Web. 15 Mar. 2012. <http://www.shalegas.energy.gov/resources/111811_final_report.pdf>.

Figure 3
Medical Reports Chicago. ""Fracking - the Quest for Energy Independence"" Future of Fracking Holds Promise for U.S. Energy Outlook. Northwestern University, 25 May 2012. Web. 27 May 2012. <http://news.medill.northwestern.edu/chicago/news.aspx?id=198624>.

Figure 4
Helms, Lynn. "Horizontal Drilling." DMR Newsletter Volume 35 No. 1, n.d. Web. 14 June 2012. <https://www.dmr.nd.gov/ndgs/newsletter/NL0308/pdfs/Horizontal.pdf>.

Figure 5
"Geokinetics: Seismic Data Processing Services." *Geokinetics: Seismic Data Processing Services*. N.p., n.d. Web. 23 June 2012. <http://www.geokinetics.com/Services/Seismic-Processing-21.html>.

Figure 6
Marcellus Shale natural gas seismic search map - provided by Cory Tucker of Geokinetics Drilling Services. 570-945-5672

Figure 7
Finton, Chris, Todd Lowrey, and Meiser & Earl Inc. "Hydrogeologic Report: Eagles Mere Lake & Vicinity - Sullivan County, PA." Eagles Mere Community Hall, 16 Apr. 2011. Web. 4 Apr. 2012. <http://protecteaglesmere.org/wp-content/uploads/Final-Eagles-Mere-Presentation-4_16_11-Read-Only.pdf>.

Figure 8
Photo by Matthew Franko of Chesapeake Energy Well # HJMM WYO 1H - Cappucci 2H

Figure 9
Environmental Protection Agency. "Benzyl Chloride (CASRN 100-44-7) | IRIS | US EPA."*EPA*. N.p., n.d. Web. 30 June 2012. <http://www.epa.gov/iris/subst/0393.htm>.

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Figure 10
Photo by Matthew Franko of well pad in Sullivan County Pennsylvania

Figure 11
Photo by Matthew Franko of natural gas pipeline in Sullivan County Pennsylvania

Figure 12
Photo by Matthew Franko of natural gas pipeline in Wyoming County Pennsylvania

Figure 13
Howarth, Robert, Renee Santoro, and Anthony Ingraffea. "Methane and the Greenhouse-Gas Footprint of Natural Gas From Shale Formations." Cornell University, 13 Mar. 2011. Web. <http://www.springerlink.com/content/e384226wr4160653/fulltext.pdf?MUD=MP>.

Figure 14
London, A.W. "America's Falling Carbon Dioxide Emissions." *The Economist*. The Economist Newspaper, 25 May 2012. Web. 28 July 2012. <http://www.economist.com/blogs/schumpeter/2012/05/americas-falling-carbon-dioxide-emissions>.

Figure 15, 16
Weinhold, Bob. "The Future of Fracking: New Rules Target Air Emissions for Cleaner Natural Gas Production." *Environmental Health Perspectives:*. N.p., 2 July 2012. Web. 29 July 2012. < http://ehp03.niehs.nih.gov/article/slideshow.action?uri=info:doi/10.1289/ehp.120-a272&imageURI=info:doi/10.1289/ehp.120-a272.g003#>.

Chemical Name	CAS	Chemical Purpose	Product Function
Hydrochloric Acid	007647-01-0	Helps dissolve minerals and initiate cracks in the rock	Acid
Glutaraldehyde	000111-30-8	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	012125-02-9	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	061789-71-1	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Tetrakis Hydroxymethyl-Phosphonium Sulfate	055566-30-8	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Ammonium Persulfate	007727-54-0	Allows a delayed break down of the gel	Breaker
Sodium Chloride	007647-14-5	Product Stabilizer	Breaker
Magnesium Peroxide	014452-57-4	Allows a delayed break down the gel	Breaker
Magnesium Oxide	001309-48-4	Allows a delayed break down the gel	Breaker
Calcium Chloride	010043-52-4	Product Stabilizer	Breaker
Choline Chloride	000067-48-1	Prevents clays from swelling or shifting	Clay Stabilizer
Tetramethyl ammonium chloride	000075-57-0	Prevents clays from swelling or shifting	Clay Stabilizer
Sodium Chloride	007647-14-5	Prevents clays from swelling or shifting	Clay Stabilizer
Isopropanol	000067-63-0	Product stabilizer and / or winterizing agent	Corrosion Inhibitor
Methanol	000067-56-1	Product stabilizer and / or winterizing agent	Corrosion Inhibitor
Formic Acid	000064-18-6	Prevents the corrosion of the pipe	Corrosion Inhibitor
Acetaldehyde	000075-07-0	Prevents the corrosion of the pipe	Corrosion Inhibitor
Petroleum Distillate	064741-85-1	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Potassium Metaborate	013709-94-9	Maintains fluid viscosity as temperature increases	Crosslinker
Triethanolamine Zirconate	101033-44-7	Maintains fluid viscosity as temperature increases	Crosslinker
Sodium Tetraborate	001303-96-4	Maintains fluid viscosity as temperature increases	Crosslinker
Boric Acid	001333-73-9	Maintains fluid viscosity as temperature increases	Crosslinker
Zirconium Complex	113184-20-6	Maintains fluid viscosity as temperature increases	Crosslinker
Borate Salts	N/A	Maintains fluid viscosity as temperature increases	Crosslinker
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Crosslinker
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Crosslinker
Polyacrylamide	009003-05-8	“Slicks” the water to minimize friction	Friction Reducer
Petroleum Distillate	064741-85-1	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Friction Reducer
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Friction Reducer
Guar Gum	009000-30-0	Thickens the water in order to suspend the sand	Gelling Agent
Petroleum Distillate	064741-85-1	Carrier fluid for guar gum in liquid gels	Gelling Agent
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for guar gum in liquid gels	Gelling Agent
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Gelling Agent
Polysaccharide Blend	068130-15-4	Thickens the water in order to suspend the sand	Gelling Agent
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Gelling Agent
Citric Acid	000077-92-9	Prevents precipitation of metal oxides	Iron Control
Acetic Acid	000064-19-7	Prevents precipitation of metal oxides	Iron Control
Thioglycolic Acid	000068-11-1	Prevents precipitation of metal oxides	Iron Control

Sodium Erythorbate	006381-77-7	Prevents precipitation of metal oxides	Iron Control
Lauryl Sulfate	000151-21-3	Used to prevent the formation of emulsions in the fracture fluid	Non-Emulsifier
Isopropanol	000067-63-0	Product stabilizer and / or winterizing agent.	Non-Emulsifier
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Non-Emulsifier
Sodium Hydroxide	001310-73-2	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Potassium Hydroxide	001310-58-3	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Acetic Acid	000064-19-7	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Sodium Carbonate	000497-19-8	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Potassium Carbonate	000584-08-7	Adjusts the pH of fluid to maintains the effectiveness of other components, such as crosslinkers	pH Adjusting Agent
Copolymer of Acrylamide and Sodium Acrylate	025987-30-8	Prevents scale deposits in the pipe	Scale Inhibitor
Sodium Polycarboxylate	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Phosphonic Acid Salt	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Lauryl Sulfate	000151-21-3	Used to increase the viscosity of the fracture fluid	Surfactant
Ethanol	000064-17-5	Product stabilizer and / or winterizing agent.	Surfactant
Naphthalene	000091-20-3	Carrier fluid for the active surfactant ingredients	Surfactant
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Surfactant
Isopropyl Alcohol	000067-63-0	Product stabilizer and / or winterizing agent.	Surfactant
2-Butoxyethanol	000111-76-2	Product stabilizer	Surfactant