Appendix I: EFD Regional Center
I.4 Water Based Drilling Fluid Systems in the Utica and Marcellus Shales (Task 5.4.3)

Assessment of the Environmental, Performance, and Economic Impact of Drilling Fluids Systems used in the Marcellus Shale and Utica Shale Plays in Ohio, Pennsylvania, and West Virginia

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Abstract

The objective is to determine the factors that influence how drilling fluid systems are selected based on environmental impact, cost, regulations and performance. Using this information, more environmentally acceptable fluids may be considered by operators and provide service providers with information on product development.

The determination of drilling fluid systems varies significantly based on the target formation, operating company, and regulatory jurisdiction. As drilling technology constantly evolves, companies could use environmentally friendly practices to improve environmental performance of oil and gas exploration. The Marcellus and Utica Shale are two of the largest and most active shale plays in the country with the heaviest activity being in the states of Ohio, Pennsylvania, and West Virginia. This study focuses on what influences the implementation of environmentally friendly drilling fluid systems both positively and negatively. This study was a collaboration of efforts involving an environmental-conscience drilling focus group, academia, and a drilling fluids service company.

The findings of this study will be used to better understand the incentives and disincentives operators face when choosing a drilling fluid system. These realizations can be the justification for promoting better operational practices as well as potential regulatory changes to promote friendly drilling fluids systems that benefits the environment, the operator, and the state.
Purpose

The objective is to determine the factors that influence how drilling fluid systems are selected based on environmental impact, cost, local government regulations, and performance. Using this information, the viability and benefits of regulations pertaining to EFD fluid in the applicable states will be assessed and potentially proposed by proponents in the drilling fluids industry.
Background

The determination of drilling fluid systems varies significantly based on the target formation, operating company, and regulatory jurisdiction. As drilling technology constantly evolves, so too should the use of environmentally friendly practices to reduce any negative impact of oil and gas exploration. The Marcellus Shale and Utica Shale are two of the largest and most active shale plays in the country with the heaviest activity being in the states of Ohio, Pennsylvania, and West Virginia. The study will focus on what influences the implementation of environmentally friendly drilling fluid systems both positively and negatively. This study is a part of Environmentally Friendly Drilling Program’s (EFD) Research Partnership to Secure Energy for America (RPSEA) Technology Integration Program (TIP). A Phase 1 report on this study was completed with the assistance of West Virginia University, Newpark Drilling Fluids and Ohio State University. Phase 1 was designed to conduct a literature search, document best practices and review regulations on fluids and drilling waste for the region.
Methodology

This phase of the study consisted of two parts: the preliminary collection of data and background information, and a survey of operators in the applicable areas that could provide insight into the processes used in the selection of the drilling fluid.

Part 1 of this phase of the study required that well data from the three states be collected and analyzed so that there could be a determination of the companies that most frequently operated under the conditions being studied. This well data was also used in the determination of the proper questions to be asked of aforementioned operators to determine what drilling fluids were most commonly used by each company and the factors that were accounted for in that determination.

The survey consisted of thirty-eight total questions when including the opportunity for comments that could explain the reasoning used for each response. The first question was a request for the contact information of the respondent, so that they could be provided the results of the study and they could be contacted if there was some problem with the processing of their submission. The second question probed about the type of mud used in the top hole section of the company’s drilling of the Marcellus Shale and/or the Utica Shale in whichever of the three states the company had wells. The options provided in the survey included air, freshwater, saltwater, oil, synthetic, diesel, mineral oils, and other with a request for elaboration on other. The third and fourth questions were identical with the exception that they referenced the intermediate and bottom hole sections, respectively. The respondents were then asked if their selection of fluid was influenced (encouraged or discouraged) by regulations, and if so, which regulation and the origin of that regulation (State, API, Federal, etc.). The next question asked if environmental stewardship was a factor in the selection process and if that stewardship was a company policy with an explanation of said policy. Environmental stewardship was defined as an internally compelling reason to go above and beyond set regulations to further protect the environment. As stated this can often be a company policy or less likely, a personal policy of the engineer.

The survey then requested a ranking of the importance of eight implicit factors on the determination of the best drilling fluid. These factors were the reduction of trucking and transportation, the removal and transportation of drilling waste for disposal, the impact on groundwater and water systems in the area, the impact on emissions, the reduction in impact and risk if a spill were to occur, the reduction of cost, the ease of mixing and handling and the health concerns of the onsite personnel. With the anticipation of cost being influential, the survey also
included a question asking whether the immediate costs (AFE cost) or the life cycle costs had a greater impact.

The survey then requested a ranking of more explicit, performance based factors, such as cooling and lubricating the bit, the formation of a filter cake, the minimization of reservoir damage, the allowance of formation evaluation, the ability to maintain wellbore stability, the prevention of corrosion and excessive wear, the facilitation of cementing and completing, the lubrication of the drill string, the rate of penetration, the cuttings carrying capacity, and the running of downhole motors and tools. Ranking of all 8 factors was not mandatory. Respondents were able to leave out factors they felt were inapplicable. The rankings were weighted so that the average importance of each factor would be established.

The respondents were then asked for the destination of the liquid waste and then the solid waste produced during the drilling process and why those locations were chosen. This question was specified to be the general destination of the waste and not the specific address of the disposal site. A follow up question was then asked if any waste was reused and/or recycled. If applicable, the respondents were then asked in what way the solids were reused and what reconditioning process needed to be applied to the drilling fluid so that it could be reused. The next question asked about the possible logistical concerns associated with the reuse of drilling fluid, such as transportation. The survey then asked what the respondent viewed as the more influential regulations: those concerned with drilling or those concerned with the disposal of the solids and drilling fluids. The final three questions inquired about the opinion of the individual responding to the survey with regards to company decisions. First, they were asked what changes or types of changes they would like to see in the regulations. Second, it was asked if their responses to the above described survey would vary in a more favorable market, such as the $100 per barrel market from a few years prior, and in what way the responses would have varied. The final question in the survey asked if, independent of the price of oil, the responses to this survey would have been different five to ten years earlier. This question implicitly asked how advances in technology and increased knowledge over time would have affected the responses to this survey.

The twenty-four regionally active operating companies of varying size in the Marcellus and Utica Shale region were then contacted about potentially participating in the study through the use of the survey. The responses of those companies that chose to participate were then recorded and analyzed to determine the greatest influences upon drilling fluid selection. Additional questions were asked to try to gain insight into how advances in technology, market conditions, and regulations affected these decisions.
Company A had the following responses. Company A is only active in Pennsylvania and has wells targeted at both the Marcellus and Utica Shale. Company A uses air in the top hole section and the intermediate section for both Marcellus and Utica. For the bottom hole section however, 98% of Marcellus wells were drilled with salt water based mud, while 2 out of 3 Utica wells were drilled with salt water based mud. The third was drilled with diesel mud. Company A claimed that regulations did not influence their drilling fluid selection. Company A also does not have a policy in place for environmental stewardship, so that did not influence the fluid selection. Company A ranked the factors in this order with descending importance: 1) Reduction of cost 2) Ease of mixing and handling 3) Removal and transportation of drilling waste for disposal 4) Reduction in trucking and transportation 5) Impact on emissions 6) Reduction in impact and risk if spill occurs 7) Impact on groundwater and water systems 8) Personnel health concerns. Company A’s decision is driven by its two most important factors. Company A found immediate cost to be most important. Company A ranked the following performance factors in descending order of importance: 1) Maintain wellbore stability 2) Cuttings carrying capacity 3) Rate of penetration 4) Running of downhole motors/tools 5) Facilitate cementing and completion 6) Cool and lubricate bit 7) Filter cake formation 8) Prevent corrosion and excessive wear 9) Allow for formation evaluation 10) Minimize reservoir damage 11) Drill string lubrication. Company A attempts to reuse the liquid waste, but if that is not possible, then it is solidified and taken to an approved site. Company A also takes the solid waste to a landfill because it is required. Company A’s only reconditioning process takes place with the mud pits. If the mud needs to be treated, then it is treated during the drilling/circulating process. Company A makes their decision based upon efficiency and cost nearly independent of regulations. The respondent for Company A would like to see an option for using the solid waste in some way, such as onsite roads. Company A’s responses would not change based upon the price of oil. Company A states that the only difference between now and 5-10 years ago in their selection is that they continue to improve upon the efficiency of their muds.

Company B had the following responses. Company B is active in Pennsylvania, Ohio, and West Virginia and has wells targeted at both the Marcellus and Utica Shale. Company B uses air in the top hole section. However, they use synthetic mud for the intermediate and the bottom hole sections. This is consistent for both Utica and Marcellus wells, but Utica wells typically use saltwater muds. Company B claimed that regulations did not influence their drilling fluid selection. Company B does have a policy in place for environmental stewardship, and it was described as, “Internal objectives and the Marcellus Shale Coalition certification drove the synthetic fluid selection. Air is used because of its reduced environmental impact, particularly through the shallow fresh water aquifers, coal seams and mines.” Company B ranked the factors in this order with descending importance: 1) Reduction of cost 2) Impact on groundwater and water systems.
3) Reduction in impact and risk if spill occurs 4) Reduction in trucking and transportation 5) Removal and transportation of drilling waste for disposal 6) Personnel health concerns 7) Impact on emissions 8) Ease of mixing and handling. Company B found lifecycle cost to be most important. Company B ranked the following performance factors in descending order of importance: 1) Rate of penetration 2) Maintain wellbore stability 3) Facilitate cementing and completion 4) Allow for formation evaluation 5) Cuttings carrying capacity 6) Cool and lubricate bit 7) Running of downhole motors/tools 8) Drill string lubrication 9) Minimize reservoir damage 10) Prevent corrosion and excessive wear 11) Filter cake formation. Company B commented that ranking these factors was difficult because their synthetic mud provides all of the benefits. Company B always reuses synthetic mud when possible, but if it is not possible, then the liquid is solidified and taken to a landfill. Company B also takes the solid waste to a landfill. Internal standards and regulations are the reason for this method of disposal. Company B has looked into the recycling of solid waste for use, but has yet to find a method that is economically feasible. Company B attempts to remove the solids on site to reduce logistical concerns. The logistical problems are described as such, “For fluids that become unusable because of the excessive incorporation of drilled solids (LGS – low gravity solids), the only regulatory acceptable method to reduce the LGS is through dilution, unless the mud company has a waste generator permit (which is extremely hard to obtain). If the LGS cannot be controlled at the rig site, the transportation of the fluid to the liquid mud plant for dilution costs a significant amount of money and generates excess volume.” Company B believes that both drilling and disposal regulations are relatively equally influential. The respondent for Company B would like to see an option for recycling solid cuttings. Company B’s responses would not change based upon the price of oil, but they would be able to recover more synthetic drilling mud and therefore place less in landfill if the price of oil was higher. Company B’s respondent stated that the regulations have been more restrictive and costly, but that there has been little change to “responsible” operators.

Company C had the following responses. Company C is active in Pennsylvania and West Virginia and has wells targeted at both the Marcellus and Utica Shale, but only provided information on their top hole Utica wells in Pennsylvania. Company C uses air in the top hole and intermediate sections for both formations in both states. Company C specified that if a gas storage interval was drilled, then they converted to salt water or salt water mud to drill the gas storage interval. Company C uses air until the kickoff point, at which time they switch to synthetic oil based muds in West Virginia and southwestern Pennsylvania, but diesel based muds are used instead of synthetic in northeast Pennsylvania. Company C claimed that regulations did influence their drilling fluid selection because diesel based muds are not permitted in West Virginia, so synthetic was also used in the southwest Pennsylvania for consistency. Company C’s only policy in respect to environmental stewardship is to evaluate the environmental impact of the systems used. Company C ranked the factors in this order with descending importance: 1) Reduction in impact
and risk if spill occurs 2) Removal and transportation of drilling waste for disposal 3) Reduction in trucking and transportation 4) Reduction of cost 5) Ease of mixing and handling 6) Impact on emissions 7) Personnel health concerns 8) Impact on groundwater and water systems. Company C found immediate cost to be most important. Company C ranked the following performance factors in descending order of importance: 1) Cool and lubricate bit 2) Rate of penetration 3) Maintain wellbore stability 4) Minimize reservoir damage 5) Running of downhole motors/tools 6) Cuttings carrying capacity 7) Filter cake formation 8) Drill string lubrication 9) Prevent corrosion and excessive wear 10) Facilitate cementing and completion 11) Allow for formation evaluation. Company C always reuses liquid waste when possible, but if it is not possible, then the liquid is hauled to a disposal well and the oil based mud waste is solidified and taken to a landfill. Company C also takes the solid waste to a landfill. This method of disposal was selected because it had the least environmental impact. Company C uses a dual centrifuge system to remove fine solids, but many solids cannot be removed and so the mud must be diluted to maintain the desired properties. Company C believes that drilling regulations were more influential because disposal regulations are the same for diesel and synthetic muds. The respondent for Company C would like to see consideration for diesel based systems where currently prohibited if the environmental responsibility of the operator is verified. Company C’s responses would not change based upon the price of oil. Company C’s respondent believes there would be no changes from 5-10 years ago and now.

Company D had the following responses. Company D has both Marcellus and Utica wells in Pennsylvania, but only Utica wells in Ohio. Company D uses air in the top hole and intermediate sections for both formations in both states. Company D uses synthetic muds in the bottom hole section of all wells. Company D claimed that regulations did not influence their drilling fluid selection. Company D is not influenced by environmental stewardship and has no policy pertaining to it. Company D ranked the factors in this order with descending importance: 1) Removal and transportation of drilling waste for disposal 2) Ease of mixing and handling 3) Reduction of cost 4) Personnel health concerns 5) Reduction in trucking and transportation 6) Impact on emissions 7) Reduction of impact and risk if spill occurs 8) Impact on groundwater/water systems. Company D found immediate cost to be most important. Company D ranked the following performance factors in descending order of importance: 1) Rate of Penetration 2) Maintain wellbore stability 3) Cuttings carrying capacity 4) Running of downhole motors/tools 5) Cool and lubricate the bit 6) Drill string lubrications 7) Facilitate cementing and completion 8) Prevent corrosion and excessive wear 9) Minimize reservoir damage 10) Filter cake formation 11) Allow for formation evaluation. Company D uses injection wells or frac impoundments for the liquid waste so that the water can be reused for completions. The solid waste and residual base oil are combined with a mix-off material and loaded into a tri-axle to be trucked to a landfill. Company D uses a closed loop system with 3 shale shakers, drying shakers, and centrifuges. Company D’s logistical concerns with
The reuse of drilling fluid are transportation from one pad to another and monitoring the solids content of the mud from well to well. Company D believes that drilling regulations were more influential. The respondent for Company D would like to see continued use of diesel systems in Ohio and Pennsylvania. Company D’s responses would not change based upon the price of oil. Company D’s respondent believes there would be no change in responses since the introduction of synthetic oil based muds to the market in 2009.

Company E had the following responses. Company E has both Marcellus and Utica wells in Pennsylvania, Ohio, and West Virginia. Company E uses freshwater in the top hole section for both formations in all states because their studies showed that using air risked increasing turbidity levels within fresh water aquifer zones. For the intermediate section, Company E uses “a combination of dusting / misting depending on depth. Dusting includes use of rock oil up to 6 gallons per hour and is most efficient in terms of ROP. Misting is the most efficient if wellbore integrity problems are expected and includes use of 5% KCl at 15-40 gallons per minute and 3-4 gallons per hour of soap for hole cleaning.” Company E uses synthetic mud for the bottom hole section. Company E claimed that regulations did not influence their drilling fluid selection because their company policy was more restrictive. Their company policy prohibits diesel based muds in favor of synthetic muds which they recognize as the most environmentally friendly fluids available that make economic sense. Company E ranked the factors in this order with descending importance: 1) Personnel health concerns 2) Impact on groundwater/water systems 3) Reduction in impact and risk if spill occurs 4) Impact on emissions 5) Removal and transportation of drilling waste for disposal 6) Reduction in trucking/transportation 7) Reduction of cost 8) Ease of mixing and handling. Company E found lifecycle cost to be most important. Company E ranked the following performance factors in descending order of importance: 1) Maintain wellbore stability 2) Filter cake formation 3) Cool and lubricate the bit 4) Cuttings carrying capacity 5) Rate of Penetration 6) Facilitate cementing and completion 7) Prevent corrosion and excessive wear 8) Minimize reservoir damage 9) Drill string lubrication 10) Allow for formation evaluation 11) Running of downhole motors/tools. Company E explained that they do not take many logs in the Appalachian Basin, so formation evaluation was ranked low, and that the casing and cementing is more responsible for reservoir damage than drilling. Company E transports its solid and liquid waste to an approved landfill. Company E does not reuse or recycle its waste because its field trials have shown it to be lack economic sense for them to do so. Company E attempted to use composite inert encapsulation of solid waste material for road base or pad site fill. Company E uses synthetic based mud polymers to coagulate solids particles in order to mechanically remove them from the fluid. Excessive centrifuging is needed to remove solids content. Colloidal solids less than 5 microns were noted to be of concern. Company E’s logistical concerns with reuse of drilling fluid are the transportation of high weight mud and that it could limit volume and increase the number of trucks needed. Company E believes that disposal regulations have the highest cost.
impact and are more stringent and thus are more influential. The respondent for Company E would like to see a different classification and disposal requirements for the use of inert synthetic based muds or low toxicity mineral oils with low (if any) aromatic content. Company E’s responses would not change based upon the price of oil. Company E’s respondent believes there would be no change in responses 5-10 years ago.

Company F had the following responses. Company F has both Marcellus and Utica wells in Pennsylvania, Ohio, and West Virginia. Company F uses air in the top hole and intermediate sections for both formations in all states, but brine is occasionally used in Utica to stabilize the Salina salt formation and set the intermediate casing. Company F uses mineral oil muds in the bottom hole section of wells in all states. Company F claimed that state regulations pertaining to the use of diesel based muds did influence their drilling fluid selection. Company F’s selection process is not influenced by environmental stewardship and has no policy pertaining to it, but must still be approved by the environmental and regulatory departments of Company F to assure regulatory compliance. Company F ranked the factors in this order with descending importance: 1) Reduction of cost 2) Reduction in trucking/transportation 3) Ease of mixing and handling 4) Removal and transportation of drilling waste for disposal 5) Reduction in impact and risk if spill occurs 6) Impact on groundwater/water 7) Impact on emissions 8) Personnel health concerns. Company F commented that the chief concern was cost, that most of the other items are out of the operators' hands, and that a service company may rank these differently. Company F found immediate cost to be most important with this explanation for why: “In today's market we are concerned with up front capital expenditure (CAPEX). Keeping our spending to a minimum and maximizing cash flow is the most important. If we were busy drilling many wells and the market was good, we would begin to focus on life cycle costs and becoming more efficient.” Company F ranked the following performance factors in descending order of importance: 1) Cuttings carrying capacity 2) Rate of penetration 3) Maintain wellbore stability 4) Facilitate cementing and completion 5) Running of downhole motors/tools 6) Cool and lubricate the bit 7) Prevent corrosion and excessive wear 8) Drill string lubrication 9) Minimize reservoir damage 10) Filter cake formation 11) Allow for formation evaluation. Company F takes its liquid waste to the service company's plant to be stripped of solids and conditioned for reuse. The solid waste is disposed of in a certified landfill. Company F stated the most difficult part of reconditioning is the removal of low gravity solids. Company F believes that drilling regulations were more influential. The respondent for Company F would like to see uniformity from state to state in the region. Company F’s responses would not change based upon the price of oil. Company F’s respondent believes that the greatest change over the past 5-10 years is that the operators have improved and learned how to drill in the Marcellus and Utica regions.

Company G had the following responses. Company G only has Marcellus wells in Pennsylvania. Company G uses air in the top hole and intermediate sections. Company G uses
synthetic muds in the bottom hole section of wells. Company G claimed that neither regulations nor environmental stewardship influenced their decision and they have no company policy in place regarding either. Company G ranked the factors in this order with descending importance: 1) Reduction of cost 2) Ease of mixing and handling 3) Removal and transportation of drilling waste for disposal 4) Reduction in trucking/transportation 5) Impact on groundwater/water systems 6) Personnel health concerns 7) Reduction in impact and risk if spill occurs 8) Impact on emissions. Company G found immediate cost to be most important. Company G ranked the following performance factors in descending order of importance: 1) Maintain wellbore stability 2) Cool and lubricate the bit 3) Rate of penetration 4) Minimize reservoir damage 5) Running of downhole motors/tools 6) Filter cake formation 7) Prevent corrosion and excessive wear 8) Cuttings carrying capacity 9) Facilitate cementing and completion 10) Drill string lubrication 11) Allow for formation evaluation. Company G takes its liquid synthetic mud back to the mud provider, while the produced fluid is treated and disposed of through a disposal well. The solid waste is disposed of in a certified landfill, but some companies are reusing solid waste as aggregate and fill material on pads. Company G reuses the synthetic muds after they have been centrifuged and treated on the rig to remove solids. Their logistical concern with the reuse of the drilling fluid is that all recycled and delivered mud must be trucked. Company G avoids contamination concerns by placing liners in all tanks to prevent contamination. Company G believes that disposal regulations were more influential in their drilling fluid selection. The respondent for Company G believes that diesel fluids and synthetic fluids should be regulated equally. Company G’s responses would not change based upon the price of oil. Company G’s respondent believes that the greatest change in responses between now and 5-10 years ago would be due to the heightened regulations on disposal.

Company H had the following responses. Company H has both Marcellus and Utica wells in Pennsylvania and Ohio, but only Marcellus wells in West Virginia. Company H uses air in the top hole and intermediate sections of all wells, unless there is not an air package available for the Marcellus wells, in which case some use water based muds. Company H uses synthetic muds in the bottom hole section of all wells except for the Utica wells in Ohio, in which they use diesel based mud. Company H claimed that state regulations regarding diesel based muds influenced the fluid selection. Company H also has a policy that addresses environmental stewardship in the fluid selection. Company H ranked the factors in this order with descending importance: 1) Impact on groundwater/water systems 2) Personnel health concerns 3) Reduction of cost 4) Removal and transportation of drilling waste for disposal 5) Ease of missing and handling 6) Reduction in impact and risk if spill occurs 7) Reduction in trucking/transportation 8) Impact on emissions. Company H found lifecycle cost to be most important. Company H ranked the following performance factors in descending order of importance: 1) Maintain wellbore stability 2) Minimize reservoir damage 3) Facilitate cementing and completion 4) Rate of penetration 5) Running of downhole motors/tools 6) Prevent corrosion and excessive wear 7) Filter cake formation 8) Cuttings carrying
capacity 9) Cool and lubricate the bit 10) Drill string lubrication 11) Allow for formation evaluation. Company H sends its used liquid mud to the landfill where it is solidified. The solid waste is disposed of in a certified landfill because company policy is opposed to earthen pits. Company H reuses some liquid waste. They also use a specific service company’s cleaned recycled produced water as a mist while air drilling in Ohio below the surface casing string. The logistical concern with the reuse of drilling fluid is that fluids brought from other pads must be tested for the surfactant and amount of solids in the fluid. Company H believes that drilling regulations were more influential. The respondent for Company H believes that diesel fluids should be allowed in every state in the area and that it should be permissible to land farm cuttings. Company H’s responses would not change based upon the price of oil. Company H’s respondent believes that the greatest change in responses between now and 5-10 years ago would be the use of an “oil” based system.

Company I had the following responses. Company I has Marcellus wells in Pennsylvania and Utica wells in Ohio. Company I uses air in the top hole sections of all wells and in the intermediate sections of Ohio wells. Freshwater is used in the Pennsylvania wells. Company I uses synthetic muds in the bottom hole section of all wells, unless the lateral in a Marcellus well is short, in which case a salt water polymer is used. Company I claimed that regulations did not influence the fluid selection. Company I does have a policy that addresses environmental stewardship in the fluid selection, but did not specify. Company I only ranked the Impact on groundwater/water systems first in importance and did not rank any of the other factors. Company I found lifecycle cost to be most important. Company I ranked the ability to maintain wellbore stability most important, but did not rank any of the other performance factors, stating that none of them should be sacrificed and that a fluid should be used that meets all of the needs. Company I sends its synthetic back to the mud company, while the water is processed and taken to a recycling facility or injection well. The solid waste is disposed of in a certified landfill. Company I reuses some liquid waste. Company I reconditions the fluid through dewatering, processing, and diluting.

Companies J and K submitted incomplete responses. Company J only stated that a drilling fluid not listed in the question was used in their Marcellus wells in Ohio and that the impact on groundwater/water was the most important factor in fluid selection. Company K responded with the fact that they have Marcellus and Utica wells in West Virginia and Utica wells in Ohio. Air is used in the top hole and intermediate sections of all of these wells. However in the bottom hole section, diesel fluids are used in Ohio, salt water fluids are used in the West Virginia Marcellus wells and synthetic fluids are used in the West Virginia Utica wells.

Did a regulation influence your drilling fluid selection? (Was your fluid of choice encouraged or discouraged by regulation?)
Figure 1: Pie chart of responses to the influence of regulations upon the selection of drilling fluids

Did environmental stewardship greatly influence your drilling fluid selection?

Answered: 9  Skipped: 5

66.6% No
33.3% Yes

Figure 2: Pie chart of the responses to influence of environmental stewardship on the selection process

55.56% No
44.44% Yes
**Figure 3:** Bar graph representation of importance of performance factor when choosing a drilling fluid.

**Figure 4:** Pie chart regarding the existence of a company policy regarding environmental stewardship.
**Figure 5:** Bar chart of the average ranking of implicit factors upon the selection of a drilling fluid.

**Figure 6:** Pie chart of whether immediate or life cycle costs are more important.
Which of the following was reused/recycled?

Answered: 8  Skipped: 6

Liquid Waste: 87.5%
Neither: 12.5%

**Figure 7:** Pie chart regarding whether the drilling waste was reused or recycled
Results and Discussion

The data shows that most companies tend to use similar types of fluids in each particular section of the well, regardless of the state, which can be seen in the common use of air in the top hole section with fresh water based muds being the only other response recorded. In the intermediate section air was again the most commonly used drilling fluid with synthetic based being the next most common. These fluids accounted for all but one response which cited freshwater. In some instances, a salt or brine fluid base may be introduced during drilling if unexpected geology is encountered, but is not typically part of the drilling fluid system design.

The bottom hole section had the most variety in responses. The most common answer was synthetic based mud for all states in both Marcellus and Utica wells. Other responses included diesel, mineral oils, salt water, and other. It was noted that the company that indicated mineral oils used this regardless of target formation or state. Some companies kept their drilling fluid selections the same across state lines if they were targeting the same formation and if regulators permitted. The one clear difference is the preference of operators to use diesel based muds, in states which permit it, over synthetic because diesel based muds perform similarly to synthetic based muds at a significantly reduced cost. The use of diesel based muds in the bottom hole section is neither explicitly allowed nor disallowed in written rules in any of the three states studied. Instead, it is generally a case by case decision on the part of the regulators taking into account the location of the well, the reputation of the company, and the current economic market. Multiple respondents stated that regulators in West Virginia do not permit the use of diesel based muds under any circumstances. Due to this, operators tend to use synthetic based mud as the most common alternative. Interestingly, the respondent from Company H stated that regulators in Pennsylvania did not permit the use of diesel based muds by Company H while other companies were permitted. Several respondents noted that regulators in both Pennsylvania and Ohio began permitting the use of diesel based muds more freely in 2015. It was believed by several of the respondents that this shift in permitting occurred in response to the concurrent period of low oil and gas prices in order to help operators cut costs.

Regulations regarding drilling fluid selection were significant in that three out of nine respondents stated that regulations directly influenced their choice of drilling fluids. All of those who said regulations directly affected their choice of drilling fluids pointed to state regulations. Company C stated that regulations preventing diesel based fluids in West Virginia influenced their decision to use synthetic based muds in Southwestern Pennsylvania. Company C would have preferred the use of diesel based mud in West Virginia as well as Pennsylvania. However, even though Company C uses diesel mud effectively in the Northeastern Pennsylvania, they feel it is better to use a synthetic base in Southwestern Pennsylvania to keep it regionally consistent with nearby West Virginia operations. It should be noted that Company C is not active in Ohio.
Four out of nine of the respondents stated that environmental stewardship as a company policy was heavily factored into the decision. This meant that these four companies felt enough of a responsibility to the environment to solidify their stances in the form of company policies. The respondent from Company E stated that they “strive to use the most environmentally friendly fluids available that make economic sense for [their] projects” and has “taken a hard stance against the use of diesel based mud systems and has not permitted their use in any of [their] global operations.”

When it came to selecting a drilling fluid based on the offered factors, the most important factor amongst many operators was the ability to reduce cost. This comes as no surprise since economic decisions are the driving force in any business and the oil and gas industry is no exception. What came as a surprise was the fact that nearly every company noted that their drilling fluid selection process was not at all directly impacted by the low commodity prices. It was specifically stated that regardless of the price environment, the most efficient and cost effective system should be used. Reduction of cost was followed by the removal and transportation of drilling waste for disposal, and the impact on the groundwater and water systems in the area, which both had similar rankings on the survey. The average ranking of the next four factors (Reduction in trucking and transportation, reduction of impact and risk if spill occurs, ease of mixing and handling, and personnel health concerns) was similar enough to consider them of equal importance to most operators in the area. The lowest ranked factor listed in the survey was the impact on emissions. Though cost was generally the most important factor in the decision making process, there was a divide as to why this was the case. Five respondents thought the immediate cost (AFE cost) was a greater factor, while the other four thought of the life cycle cost as being more important. One of the respondents stated that their reasoning for accounting for the immediate cost was that the life cycle cost analysis was typically used more often when the industry is in a stronger market and the companies are able to spend more time to try and improve their efficiency over the life of the project. In the low market price conditions of today, companies are trying to keep their upfront capital expenditures at a minimum and their cash flows at a maximum.

The next question in the survey accounted for the more explicit performance factors that determined the fluid selection. These factors ended up in four tiers of importance based upon the average rankings from the survey. The two most important factors accounted for in the selection process are the ability to maintain wellbore stability and the rate of penetration. The second tier of importance included the cooling and lubricating capabilities on the bit, the cuttings carrying capacity, the running of downhole motors and tools, and to facilitate cementing and completion. The third tier focused upon the formation of the mud filter cake, the minimization of the reservoir damage, and the prevention of corrosion and excessive wear. The final and least important pair of factors are the lubrication of the drill string and the allowance of formation evaluation. Although
these were consistent patterns amongst the responses, one respondent did state that all of these factors were important and should not be undervalued. It should be noted that though these responses can be considered to be fairly accurate generalizations, there are always particular instances when the value of these factors can be totally different based on objectives.

When asked about the disposal of the solid wastes, there was a unanimous agreement that solid cuttings in the area are simply taken to an approved landfill because reuse of solids is not permitted. As for the disposal of the liquid waste, any fluid that can be reused or recycled is either returned to the fluid company or used again by the operating company. Once the liquid’s usefulness has been exhausted, it is either placed in an injection well, or it is solidified and taken to an approved landfill. There was a disagreement as to whether the disposal regulations or the drilling regulations were more influential, although there were slightly more responses leaning towards drilling operations being slightly more important. One of the most telling patterns in the responses of the operators was that, although the industry is currently facing low market conditions, almost all believed that their responses to the questions on the survey would not have changed in better market conditions. This indicates that the desire to have regulations that make both economic and environmental sense is constant regardless of other conditions.
Conclusions

The study sample attempted to represent a larger scope of operations and drilling fluid selection processes in the Marcellus Shale and Utica Shale. Respondents from several companies with varying budgets and activity levels in the region partook in this study. All respondents from said companies were reputable sources with positions in engineering, many of whom had positions with decision making authority.

The respondents largely cited the reduction of cost as the most important factor in their decision making process. The bottom line is always an important factor in any business. This is especially true in the unconventional gas plays where large amounts of capital are required to operate on a normal basis and risk is always present. Reduction of cost is a factor that the operating company largely has control over. They have the ability to increase efficiencies through competition, implementation of new technology, and experimenting. It is thought that the control they exercise over this factor is the reason it is viewed as the most important aspect in the drilling fluid selection process.

Several respondents noted that regulations directly affected their drilling fluid selection. It should be argued that nearly every company’s decision making process is directly affected by regulations, perhaps more than the reduction of cost. The difference between cost reduction and regulation is that the individual operator has effectively no control over regulations beyond lobbying. In a certain light, the regulations imposed on drilling fluid selection are not factors in any decision making process. A factor is defined as “something that helps produce or influence a result.” The imposed regulations are assumed to be absolute in the sense that they are either abided by, or not. There is no varying degree of adherence to imposed regulation. Assuming all operators follow these regulations absolutely, then imposed regulations do not become part of the decision making process; they instead become the objective that the decision making process must arrive at.

The regulations in discussion all pertain to environmental protection; they essentially remove the environmental aspect of the drilling fluid selection from the decision making process. Since adherence to the regulation is absolute, most operators surveyed did not have companywide environmental protection policies in place regarding drilling fluids. It would be fair to assume that adherence to the imposed regulation is their environmental policy in this regard. It breaks the entire process into its simplest form: adherence to environmental regulation is as far as the company needs to go in order to protect the environment. There is no real incentive to further protect the environment beyond what state regulators say is sufficient.

The states’ respective regulations are generally viewed as beneficial to the environment. Perception of regulators who enact these regulations is generally positive amongst the general
public. The perception is that those who enacted these regulations considered the health of workers, the safety of the public, and the protection of the environment to be the most important issues. The regulations restricting the use of diesel based fluids were originally imposed to eliminate the negative environmental impact perceived with diesel fluids. All three states had similar restrictions on diesel based fluid for this same reason. The notion that the environment is paramount in this decision could be easily challenged since regulations in both Pennsylvania and Ohio that restricted the use of diesel based fluids were recently relaxed. The softening of these regulations came in response to the struggles of operators in the concurrent low price market. Though very few if any operators would object to the relaxed restrictions on diesel based fluids, it suggests that regulations are most contingent on the market conditions rather than the environment. There is no evidence to suggest that diesel based systems become less environmentally impactful when the price of gas goes below a certain threshold. This suggests that just as the operators are most concerned with reduction of cost, some state regulators appear to be most concerned with protecting business and tax revenue at the cost of the environment in some cases.

To further complicate this matter, as summarized in the “Oil and Gas Regulations in Ohio, Pennsylvania, and West Virginia related to the Use and Disposal of Drilling Fluids and Drill Cuttings”, these regulations vary from state to state. As previously mentioned, restrictions on diesel based fluids were recently softened in Pennsylvania and Ohio but not West Virginia. Again, there is no evidence to suggest that diesel based fluid is less impactful once it crosses a state border line. This creates inconsistency for operators. This inconvenience was noted by an operator that actually chose less cost effective synthetic based fluid over the preferred diesel based fluid to keep their operations consistent in the Southwestern Pennsylvania and Northwestern West Virginia. It is frustrating and counterproductive for operators to have to drill wells targeting the same formation under different regulations depending on what side of a border they are on. Keeping up with all these regulations creates a major hindrance to effectively doing business, focusing on improving technology, increasing efficiency, and reducing environmental impact.

Although there are many inconsistencies among the regulations in the states of the region, one of the few things that are found to be similar is the requirement to dispose of the solid cuttings in a landfill approved by the state. This is a reasonable requirement assuming that the solid waste is of no use, but many operators claimed that the opportunity to land farm the cuttings and build lease roads and pads from these cuttings could reduce cost and help their business. With the knowledge that there is a potential alternative to the landfill, there exists probable cause to examine the potential harmful effects of land farming these cuttings in the region. If the process is then found to be free of environmental risk, then it would be in the best interest to allow the use of land farming because it would simultaneously reduce costs for the companies and reduce the volume of landfill space used for cutting disposal.
A solution to this problem would be sensible regulations that govern what is essentially the same task in each state. These regulations should be consistent across state lines and across varying market conditions. The regulations should benefit the operator, the state in which the operator is doing business, and most importantly, the environment across the region. This three-way intersection can be a difficult one to navigate and design, but implementation would be beneficial for all parties.

References

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