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Laura H. Burney

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HYDRAULIC FRACTURING : STIMULATING YOUR WELL OR TRESPASSING?

Laura H. Burney* Professor of Law

St- Mary's University School of Law

San Antonio, Texas

St- Mary's University School of Law

University of Tulsa

Tulsa, Oklahoma
Norman J. Hyne** Professor of Petroleum Geology

St- Mary's University School of Law

University of Tulsa

Tulsa, Oklahoma

§ 19.01 Introduction

Hydraulic fracturing is a common method used to increase production from gas and oil ***wells***. During a frac job, a fluid is pumped down the ***well*** under pressure to ***fracture*** the reservoir. Sand is pumped into the ***fractures*** to hold the ***fractures*** open. The gas and oil then drains more rapidly out of the reservoir, through the ***fractures*** and into the ***well***. The extent of the ***fractures*** out from the wellbore can be determined only by theoretical calculations. These technical realities affect the application of several legal doctrines, including the rule of capture, common law ***trespass***, and implied covenants in the oil and gas lease. When these controversies reach the courts, a traditional policy conflict is also at play: whether to protect property rights or to encourage oil and gas production. This paper begins with a description of the technical aspects of ***hydraulic fracturing*** and then analyzes legal issues and policy considerations raised by this procedure.

§ 19.02 The Technical Aspects of Formation ***Fracturing***

[1] Introduction to the Problem

Hydraulic fracturing is a common method used to (1) increase the production rate and (2) increase the ultimate production from gas and oil ***wells***.[1] During a frac job, a frac fluid is pumped under pressure down the ***well*** to ***fracture*** the subsurface reservoir- Only theoretical methods are commonly used to predict the length of the induced ***fractures***. Direct and indirect measurement methods are uncommon, expensive, and inconclusive. The ***fractures*** and frac fluids can ***trespass*** adjacent leases.

[2] The Flow of Oil and Gas Through Reservoir Rocks

Wells are drilled into reservoir rocks to produce gas and oil. A reservoir rock is a rock that can both hold gas and oil (porosity) and transmit the gas and oil through the rock into a ***well*** (permeability). These reservoir rocks are given formal names such as the Bartlesville Sandstone or the Arbuckle Limestone. Most reservoir rocks are sedimentary rocks composed

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of sediments, formerly loose materials such as sand grains, mud particles, or seashells. Sandstones and carbonates (limestones and dolomites) are the most common sedimentary rocks that are reservoir rocks.

[a] Porosity

Porosity (Φ) is a measure of the pore spaces in a rock. Pores are the holes or voids between the solid particles in a sedimentary rock. It is measured as a percent volume of the rock. Because fluids (water, gas, and oil) occur in pore spaces, porosity is a measure of that rock's storage capacity for fluid. Pores range in size from extremely small (pinpoint pores) to large enough for a person to stand up in (cavernous pores) Most pores, however, are about one millimeter in size. Two types of pores are primary and secondary. Primary pores are formed as the sediments are originally deposited on the surface of the earth. Secondary pores are formed after the sediments have been buried in the surface. Primary pores are either intergranular (between sediment grains) or intragranular (within sediment grains). Most sedimentary rocks, especially sandstones, are deposited with significant intergranular porosity. The original intergranular porosity is usually quickly lost in fine-grained sediments such as shale and mudstone and in carbonate sands when they are buried in the subsurface due to compaction and cementation. Cementation is the natural precipitation of minerals in the pores of the rock. Primary intragranular porosity is usually found in carbonate sands but it is also often lost in the subsurface due to compaction and cementation. Common types of secondary pores are solution, intercrystalline, and ***fracture***. Solution pores are caused by the dissolution of mineral grains and can occur in any rock but are most common in limestone reservoirs. They are often described as moldic, vuggular, or cavernous. Secondary intercrystalline pores are located between mineral crystals in the rock. This is the most common in dolomites [$CaMg_2(CO_3)$] that are formed by the natural alteration of limestones [$CaCO_3$]. When limestone is converted into dolomite, there is a 13% decrease in mineral volume forming pores between the dolomite crystals. ***Fracture*** pores are formed by natural ***fractures*** in the rock. They occur in brittle rocks and often add only one to five percent porosity to the rock. Absolute porosity is the total volume percent of pores in the rock whereas effective porosity measures only the interconnected pores and is usually one to two percent lower than absolute porosity. Both cores and wireline ***well*** logs are used to accurately measure the porosity of a reservoir rock in a ***well***. Some typical porosities for an oil reservoir are shown below:

Porosity	
0 to 5%	negligible
5 to 10%	poor
10 to 15%	fair
15 to 20%	good
20 to 25%	very good

Natural gas compresses with pressure. Because of compression, natural gas reservoirs require smaller porosities than oil reservoirs.

[b] Permeability

Permeability (k) is a measure of the ease in which fluid can flow through a rock. The interconnections between pores allow fluids to flow through the rock. Permeability is measured in units of darcies or millidarcies. A darcy is the permeability in a rock that allows a fluid of 1 centipoise (cP) viscosity to flow at a velocity of 1 cm/s through a pressure drop of 1 atm/cm. A millidarcy is 1/1000th of a darcy. The greater the permeability of the rock, the easier it is for the fluids to flow through the rock. Some permeabilities for an oil reservoir are shown below:

Permeability (millidarcies)	
1 to 10	fair
10 to 100	good
100 to 1,000	very good

These values are for an oil reservoir. Because natural gas is more fluid than oil, less permeabilities are necessary for gas reservoirs.

The amount of fluid flowing through a rock is given by the equation:

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Q=-krhoA($_2$-p_1)/eta1

Q is the fluid discharge per unit time (cm3s-1), k is the permeability in darcies, rho is the fluid density (g cm-3), A is the cross section area of the flow (cm2), p_2-p_1 is the pressure drop (g cm-2), eta is the dynamic fluid viscosity (mPa s) and 1 is the length of the fluid flow (cm). Because the ***well*** creates a low pressure, fluids will flow through rocks that have permeability and into the ***well***. The two most important factors affecting the permeability of a rock are porosity and the size of the pore connections. If the porosity of one reservoir rock such as the Bartlesville Sandstone is plotted against permeability, there usually is a good linear relationship. Increasing porosity is matched by increasing permeability. This relationship is good only for one reservoir rock and other reservoir rocks, such as the Wilcox Sands or Arbuckle Limestone, cannot be mixed together. The size of the pores and the connections between the pores called pore throats also significantly affects permeability. Surface tension (capillary pressure) opposes the flow of fluids through the pores and pore throats whereas buoyancy and pressure can try to force the fluid through the pore throat (Figure 1, Appendix). The smaller the pores and pore throats, the greater the surface tension and the more difficult it is for the fluids to flow through the rock. Fine-grained sedimentary rocks, such as shales, mudstones, siltstones, and chalks, tend to have shmall pores and pore throats and very low or no permeabilities (Figure 2, Appendix). The size and the size distribution of pore throats can be measured in the laboratory by a method called the capillary pressure test.

Natural ***fractures*** can greatly enhance the permeability of the reservoir rock2 as shown in the equation:

$K_{f=}$ e2/12×eg/μ

K_f is ***fracture*** permeability, e is ***fracture*** width, g is acceleration of gravity, and μ is fluid viscosity- ***Hydraulic fracturing*** is a ***well*** ***stimulation*** method that induces ***fractures*** in the reservoir rock adjacent to the wellbore. If the ***fractures*** are natural, there are often two sets of ***fractures*** perpendicular to the bedding planes in the rock. The ***fractures*** are oriented either at (1) 90° or (2) 60° and 120° from each other.

The Austin Chalk of Texas and Louisiana is a very active oil and gas play. The chalk is a very fine-grained limestone with the permeability of the rock (matrix permeability) usually less than 1 millidarcy. Where it is productive, however, the chalk is naturally ***fractured***, giving it ***fracture*** permeability. The dominant ***fractures*** in the Texas portion of the Austin Chalk are oriented NE - SW.

Because of ***fracture*** orientation, sediment grain orientation, and other factors, permeability is highly directional and usually varies in both the horizontal and vertical direction. A complete permeability analysis would include vertical permeability $(K)_v$ and two horizontal permeabilities: maximum horizontal permeability (K_{max}) and minimum horizontal permeability (K_{min}).

Absolute permeability is the permeability of the rock if only one fluid (water, gas, or oil) is present. In all reservoirs, however, the gas or oil always shares the pores with water. Saturation is the relative percentage of oil and water or gas and water that shares the pores. It is expressed as a percent and always adds up to 100%. For example, an oil reservoir can be saturated with 80% oil and 20% water. Sandstones are water wet in that the water coats the sand grains and the oil occurs in the center of the pores. The water decreases the size of the pore throats and reduces the permeability of the rock for oil (Figure 3, Appendix). Effective permeability is the permeability of a fluid such as oil when another fluid such as water also occupies the pores. The higher the water saturation, the lower the effective permeability of the oil. Relative permeability is the ratio of effective permeability of a fluid such as oil at a certain saturation to absolute permeability of that fluid at 100% saturation (Figure 4, Appendix).

There are several ways to qualitatively measure permeability in ***wells*** but only one quantitative method. Some wireline ***well*** logs will give an indication of permeable zones in a ***well***. The only quantitative method is to core the reservoir and use an instrument called a permeameter. A drillstem test can also be used to measure permeability. Drillstem test permeability, however, is an average of the zone tested and does not record permeability variations on a finer scale.

[c] Tight Sands and Dense Limestones

Not all sandstones and limestones are reservoir rocks. Some have no or very low permeabilities (<5 millidaricies) and are called tight sands and dense limestones. The term tight sands has been used to include all low permeability reservoirs such as siltstones, shales, and carbonates. Some tight sand reservoirs contain enormous reserves of oil or gas. These fields can produce if they have natural ***fractures*** that give the reservoir ***fracture*** permeability.3 An example of this is the Spraberry trend of Texas- It is located in the Midland basin, part of the Permian basin of west Texas. The trend has over 5,000 ***wells*** spread over 500 km2. The Spraberry reservoir is a siltstone with a porosity less than 10% and permeabilities ranging from 0.01 to 0.4 millidarcies. It contains an enormous amount of oil and has been called ″the world's largest reserve of unrecoverable oil.″ Low permeability reservoirs are candidates for ***well*** ***stimulation*** by ***hydraulic fracturing***.

[d] Skin or Formation Damage

As a ***well*** is being drilled, drilling mud is constantly being circulated and the ***well*** is always filled to the top with mud. Drilling mud is usually made with fresh water but is sometimes made with oil, either refined or synthetic, or salt water. The solid particles in the drilling mud are clays, usually a type called bentonite, and chemicals called additives. The weight of the drilling mud and the height of the drilling mud column in the ***well*** exerts a pressure on the drilling mud on the bottom of the ***well***. The weight of the drilling mud, measured in pounds per gallon (usually 9 to 10 pounds/gallon), can be adjusted by mud conditioning. Diluting the drilling mud with fresh water decreases the density. Adding more bentonite or special weighting materials to the drilling mud increases the density of the mud. The pressure of the fluid (water, gas, and oil) in the pores of the subsurface rocks is called fluid or reservoir pressure. It usually increases at a predictable 45 psi/100 ft of depth. Most ***wells*** are drilled with overbalance in which the pressure is higher on drilling mud than on the fluid in the pores of the rock. This prevents any formation fluids from flowing out of the rocks and into the ***well***. If formation fluids flowed into the ***well***, either the sides of the ***well*** could cave or sluffin, or a blowout could occur. Because of overbalance, some of the drilling mud is forced into any permeable rock through which the ***well*** is drilled. The solid clay particles in the drilling mud are plastered onto the sides of the wellbore, building up a filter or mud cake. The liquid, called mud filtrate, flows back into the rock. The area of the reservoir adjacent to the wellbore that is flushed with mud filtrate is called the invade zone. It goes back 0 to 100 inches from the wellbore, depending on the permeability of the rock. The mud filtrate can cause changes in the reservoir rocks such as swelling of clays that severely reduce the permeability of the reservoir adjacent to the wellbore. This is called formation or skin damage and can also occur in a ***well*** during ***well*** completion or workover. Petroleum engineers can measure the amount of skin damage by pressure tests on the ***well***. It is assigned a dimensionless number from +1 to +10, with the higher numbers the more damaged. Zero skin damage would be production from the reservoir with no effects. Skin damage in a ***well*** is commonly alleviated by ***hydraulic fracturing*** and can result in a negative skin damage number such as -3.5 or -4.5.

[3] ***Well*** ***Stimulation***

Well ***stimulation*** involves engineering methods used on the reservoir to increase the production rate from either an oil or gas ***well***. It can be used on both normal permeability reservoirs and ″tight sand″ reservoirs with low permeabilities. It is commonly used to remedy skin damage caused during drilling, completion, and workover of ***wells***. It is also used on disposal and injection ***wells*** to increase the injectives of the ***wells***. ***Well*** ***stimulation*** techniques are run by service companies, both international and local. Three types of ***well*** ***stimulation*** methods have been used.

[a] Explosive ***Fracturing***

Explosive ***fracturing*** is a ***well*** ***stimulation*** technique that dates back to the 1860s. The technique originally used nitroglycerin in a tin container called a torpedo. The torpedo was lowered down the ***well*** to reservoir level and then exploded. This produced a large cavity in the reservoir around the wellbore. The rubble was then cleaned out of the ***well*** by a sand pump or similar device. Giving the ***well*** a shot was a very common ***well*** ***stimulation*** technique at the turn of the century and was very successful. This method has declined since the 1940s with the introduction of acidizing and ***hydraulic fracturing*** and is very infrequently used today.

[b] Acidizing

Acidizing involves pumping an acid down the ***well*** to dissolve the reservoir rock adjacent to the wellbore. Acidizing was first attempted in 1894 but did not become popular until 1932 with the introduction of inhibiting agents. These are used in the acid to prevent corrosion of metal equipment in the ***well*** during the acid job. Two types of acid jobs are matrix and

fracture acidizing. In matrix acidizing, the acid is pumped back into the natural pores of the reservoir to dissolve the rock. In ***fracture*** acidizing, the acid is pumped under pressure into the natural ***fractures*** of the reservoir to enlarge the ***fractures***. The spent acid, dissolved rock, and sediments are then pumped back up the ***well*** during a backflush. In both techniques, channels are formed for the oil and gas to flow through the reservoir into the ***well***. The most common acid used is hydrochloric, but hydrofluoric, acetic, and formic acids are also used. Chemicals such as demulsifiers, surfactants, buffers, and sequesterants can also be added to the acid. Acid jobs are most effective on carbonate reservoirs but can also be used on sandstones, especially those that are naturally cemented by calcite.

[c] ***Hydraulic Fracturing***

During ***hydraulic fracturing***, a liquid is pumped under pressure down a ***well*** to ***fracture*** the reservoir rock. This creates channels for the oil and gas to flow through the reservoir into the ***well***. Two results of fracing are (1) increased production rate and (2) increased ultimate recovery. It is used both on producing oil and gas ***wells*** and on injection and disposal ***wells***. The first frac job was done by Pan American Petroleum (Amoco) on a ***well*** in the Hugoton gas field in Kansas. Haliburton was granted an exclusive license for ***hydraulic fracturing*** in 1949. This exclusive license was withdrawn in 1953 and now many service companies offer the service.

[i] Method

Frac jobs are done in three stages. First, a volume of the frac fluid called the pad is pumped under pressure down the ***well*** to initiate and propagate ***fractures*** in the reservoir rock. During the second stage, a slurry of the frac fluid and propping agents (proppants) is pumped down the ***well*** to extend the ***fractures*** and carry the propping agents deep into the ***fractures***. In the last stage called backflush, the frac fluid is pumped back up the ***well*** leaving the propping agents to hold open the ***fractures***. ***Hydraulic fracturing*** is not successful in relatively soft reservoir rocks that are found in some coastal and offshore areas. This is because the soft rocks close around the propping agents that become embedded in the rock and the induced ***fractures*** close tight.

[ii] Materials

The frac fluid must open and extend the ***fractures*** in the reservoir and transport the proppants back into the ***fractures***. The most common is a water-polymer solution.4 Polymers are formed by long, organic molecules and create a viscous solution when dissolved in water- Foam-based frac fluids using bubbles of nitrogen or carbon dioxide are also commonly used. Less commonly used are oil-based, alcohol-based, and emulsion-based frac fluids. Up to seven or eight additives are commonly used in the frac fluids. These include fluid-loss additives, biocides, breakers, buffers, surfactants, nonemulsifiers, clay stabilizers, foamers, friction reducers, temperature stabilizers, and diverting agents. The ideal frac fluid should have a relatively high viscosity when pumped down the ***well*** to transport the proppants back into the ***fractures***. It should have a relatively low viscosity at the end of the frac job so that it can be pumped out of the ***well*** (backflushed). To achieve this, crosslinked fluids are now commonly used. They are made of a water and crosslinked polymer solution. Several polymer strands are linked together with crossliners, commonly metals. This makes the solution relatively viscous. Breakers, enzymes, and oxidizers are used as crosslinked fluid additives to sever the links between the polymer strands in the subsurface reservoir and make the frac fluid less viscous. The most common propping agents are extremely ***well*** sorted, natural silica sands. The sands are described by the size of the sieve ranges such as 20/40, which correspond to sand diameters between 425 and 850 microns. Other propping agents are composed of sintered bauxite and ceramics. Sometimes spacing materials are used between the proppant particles to provide an optimum distribution of the proppants in the induced ***fractures***. These are urea, hydrocarbon resin, and sodium bisulfate.

[iii] Equipment

An aerial view of ***hydraulic fracturing*** equipment layout is shown in Figure 5, Appendix. The frac fluid is mixed and stored in frac tanks. The frac fluid is mixed with proppants in the desired proportions in a blender. Pump trucks are connected to a manifold to pressurize the frac fluid and pump it down the ***well***. The pumps range from 700 to 1,600 in horsepower. When surface pressures exceed 10,000 psi or pumping times are greater than 4 hours, equipment called intensifiers are used to increase the pumping pressure. All the equipment is mounted on wheels and can be driven or towed out to the wellsite. The frac job is monitored and regulated from the frac van. Sometimes a wellhead isolation tool is used on the surface of the ***well*** during a frac job. It protects the wellhead from excessive pressures and abrasive sands during the frac job. The gallons of frac liquid and pounds of proppants pumped downhole are used to describe a frac job. A typical frac job would be 43,000 gallons of frac fluid and 68,000 pounds of sand. A massive frac job is a large volume frac job with over 1,000,000 gallons of frac fluid and 3,000,000 pounds of sand.

[iv] ***Fracture*** Geometry and Dimensions

At shallow depths above 2,000 feet, the induced ***fractures*** are horizontal. Below 2,000 feet the ***fractures*** are vertical. There are two ***fractures*** at 180° (Figure 6, Appendix). They are oriented perpendicular to the minimum stress direction of the reservoir rock, which is usually known.5

The volume of the ***fractures*** (height x length x width) is directly proportional to the volume of the frac fluid pumped- Some of the frac fluid will flow into the pores of the reservoir rock and be lost. This is called leakoff. A fluid-loss additive is used in the frac fluid to minimize leakoff. However, about 50% of the frac fluid is lost to leakoff. Because the expanding width of the ***fracture*** compresses the rock, the ***fracture*** width is dependent on the elastic modules (compressibility) of the rock. It is also dependent on the pump rate and the fluid properties. ***Fracture*** width usually can be approximated by equations.6 ***Fracture*** height and length are much harder to estimate. Figure 7 (Appendix) shows the relationship between the volume of frac fluid injected and the height and length of the induced ***fractures***.7 This shows that the length of the ***fracture*** is inversely related to the height of the ***fracture***- Lower ***fracture*** heights correspond to longer ***fractures*** with the same volume of frac fluid pumped. The only case in which the height of the induced ***fracture*** is known with any certainty is when the reservoir rock is overlain and underlain by rocks that have 3 to 4 times the elastic modules of the reservoir rock. These rocks will limit the upward and downward growth of ***fractures***. Shales have been shown to do this in some small frac jobs. In most frac jobs, the height and therefore the length of the ***fractures*** can only be estimated. There are some equations that can be used to approximate the ***fracture*** height and width.8 Generally, the induced ***fractures*** will range from a few feet to three thousand feet long. The desired length of the ***fractures*** is inversely related to the permeability of the reservoir rock (Figure 8, Appendix). Lower permeability reservoirs require longer induced ***fractures***. In a tight gas sand reservoir, the desired ***fracture*** length is several thousand feet long. Gas and oil ***wells*** are located on drilling and spacing units (DSU). This is the surface acreage on which only one ***well*** can be located. A typical DSU for a producing oil ***well*** is 40 or 80 acres and for a gas ***well*** is 640 acres. The distance of a ***well*** in the center of a DSU to the DSU edge is shown in the table:

DSU (acres)	Distance from center to DSU edge (feet)
40	660
80	933
640	2,640

For tight gas sand, the desired length of the induced ***fracture*** can exceed the distance to the DSU boundary and ***trespass*** onto another lease.

There is an economically optimum length for the induced ***fractures*** (Figure 9, Appendix). Longer ***fractures*** result in greater production rates and ultimate production.9 Longer ***fractures*** also are more expensive because they require higher volumes of frac fluid, proppants, and higher pump horsepowers-

[v] ***Fracture*** Length Measurement

Fracture height is inversely proportional to ***fracture*** length. In a ***well*** that has been fraced, ***fracture*** height can be measured indirectly by (1) a temperature log, (2) a gamma ray log using radioactively tagged proppants that were injected during the frac job, and (3) a noise log.10 ***Fracture*** height can be measured directly by (1) impression packers, (2) sonic borehole televiewers, (3) downhole television cameras, and (4) microresistivity borehole image logs-11 None of these methods is commonly run in a ***well***. On the surface, the length of the induced ***fractures*** could be measured by three methods, all of which are very expensive and very uncommon.12 The first method uses a network of 3-D geophones on the surface to record the sounds of rock ***fracturing***- Triangulation of the sound could show the extent of ***fractures***. The second method would use rings of electrodes on the surface around the ***well***. Because the frac fluid contains electrolytes, the extent of frac fluid invasion could be traced. The third method uses tiltmeters that detect very small changes in the orientation of the ground surface. The tiltmeters would be positioned around the ***well***. The results of a tiltmeter survey over a frac job13 are shown in Figure 10, Appendix. The ground surface directly above the induced ***fractures*** is depressed whereas the ground surface on either side is uplifted. The surface variations are extremely small and are measured in thousandths of an inch. Tiltmeters are less sensitive to deeper frac jobs and are sensitive to environmental conditions such as rain.

Only two methods can be used to determine if an induced ***fracture*** has crossed a lease line. The first would be if frac fluids were produced in an adjacent ***well***. This would be very improbable as the frac fluids are backflushed at the end of the frac job and reside in the subsurface for only a relatively short time. It would also be impossible to determine the origin of the frac fluid, either transported through the induced ***fracture*** or by leakoff through the reservoir. The second method would be to run a tiltmeter survey on the adjacent lease. This could be done only during the frac job.

[vi] Economics of *Hydraulic Fracturing*

The petroleum industry spends about 1 1/2 billion dollars each year on ***hydraulic fracturing*** worldwide. About 50% of the gas ***wells*** and 30% of the oil ***wells*** drilled in the United States are fraced. ***Wells*** can be fraced before they are brought on production and several times during the life of a ***well***. An individual frac job's cost depends on three factors. First is the volume of the materials (frac fluid and proppants) used. Second is the pump horsepower utilized. In general, the deeper the ***well***, the greater the horsepower needed. It also increases with the volume of frac fluid pumped. Third is the location of the frac job. In some areas, such as Oklahoma or western Canada, the equipment is readily available and the location cost is relatively low. In other areas, such as some third world countries or offshore, the equipment costs are higher. An individual frac job generally costs between 5 and 15% of the total cost of the ***well*** and can range from $20,000 to $2 1/2 million. Some frac jobs on light sands can cost up to 80% of the total ***well*** cost.

Hydraulic fracturing is done primarily to (1) increase the production rate and (2) increase the ultimate recovery. Several equations are available to predict the effects of ***fracture*** length and conductivity on ***well*** productivity.14 Production increases are in the range of 1 1/2 to 30 times the initial rate and are generally best in gas ***wells***, especially in tight sands-***Hydraulic fracturing*** is the most frequent remedy used in ***wells*** with skin or formation damage. ***Hydraulic fracturing*** is the universal ***well*** completion technique in tight gas sands. The federal government financially encourages it with special tax credits for non-conventional fuels under Section 29. ***Hydraulic fracturing*** also increases the ultimate production from the ***well*** by both extending the drainage radius of the ***wells*** and the life of the ***well***. In general, ***hydraulic fracturing*** will increase the ultimate production of a ***well*** by 5 to 15%. The increased production rates and ultimate recoveries made possible by ***hydraulic fracturing*** are economic necessities for many ***wells***.

§ 19.03 The Legal Issues and Policy Considerations Raised by *Hydraulic Fracturing*

The practical realities of ***hydraulic fracturing*** raise questions regarding the application of two fundamental principles of oil and gas law: (1) The rule of capture, and (2) the doctrine of implied covenants. Regarding the first principle, the question is whether fracing constitutes a permissible process under the rule of capture or an impermissible ***trespass***, justifying an injunction or an award of damages.15 Answering this question requires examining the general common law definition of ***trespass*** and the parameters of the rule of capture in oil and gas jurisprudence-15.1 In order to determine whether fracing constitutes an actionable ***trespass***, this paper will also review the courts' treatment of analogous subsurface processes, particularly secondary-recovery operations. This review reveals that some courts have been willing to depart from the technical definition of ***trespass*** in order to promote recognized public policy goals. Because ***hydraulic fracturing*** can result in a ″technical″ ***trespass***, the question then becomes whether that procedure raises public policy concerns which would justify shielding an operator from liability on the basis of ***trespass***.

The answer to the ***trespass*** question will necessarily impact the analysis of the implications of fracing for the second doctrine, implied covenants. Implied covenant liability is determined on the basis of the reasonable and prudent operator standard. If fracing constitutes an actionable ***trespass***, a court would be less likely to determine that a reasonable and prudent operator would use the procedure. But even if ***trespass*** liability is unlikely, other considerations, primarily cost, could justify an operator's decision to refrain from fracing. However, if fracing has been used successfully by other operators in the area, a court could determine that an operator that has failed to frac has not fulfilled its implied covenant

[redacted]

obligations. As always, determining whether an operator has violated implied covenant duties will involve a fact-intensive inquiry.

[1] Is Fracing a Permissible Process under the Rule of Capture or an Impermissible *Trespass*?

[a] Defining ″*Trespass*″

The classic common law definition of ***trespass*** is an unauthorized and direct breach of the boundaries of another's land.16 Under this definition, no intent to ***trespass*** is required, and the act resulting in the ***trespass*** must be volitional, direct, and immediate-17 Similarly, the modern view is that a ***trespass*** is committed when a person ″enters or remains upon land in the possession of another without a privilege to do so created by the possessor's consent or otherwise.″18 The trespasser will be liable ″if his intrusion has been intentional, negligent, or the result of an abnormally dangerous activity in which he is engaged-″19

In a variety of situations, landowners have asserted that oil and gas operations fall within these definitions of ***trespass***. The most obvious example is an operator that drills a ***well*** without the landowner's permission.20 In those situations, a court must determine whether the trespasser acted in good faith or bad faith in order to determine damages-21 If the act occurred in good faith, the trespasser is allowed to recover its drilling costs.22 A bad faith ***trespass***, however, subjects the driller to liability for all of the production obtained without deductions-23

Less obvious ***trespass*** examples occur below the surface as the result of activities such as secondary-recovery operations,24 salt water injection,25 or underground gas storage,26 when substances migrate across property lines- For example, in a ***well***-known early case involving underground gas storage, *Hammonds v. Central Kentucky Natural Gas Co*.,27 the appellant, Della Hammonds, sought to hold a gas company liable in ***trespass*** for having stored its gas in an exhausted reservoir beneath her property. While the court recognized that the injected gas may have physically invaded the appellant's property, it held the company was not liable in ***trespass*** because it had lost title to the gas. In reaching that conclusion, the court relied upon a fundamental principle of oil and gas law, the rule of capture.28

[b] ***Trespass*** and the Rule of Capture

[i] Defining the Rule of Capture

American courts developed the rule of capture in a time of relative ignorance about oil and gas production, through analogy to the law of wild animals. Based on this analogy, courts determined that an owner of land ″acquires title to the oil or gas which he produces from ***wells*** drilled thereon.″29 The rule shields the owner from liability for draining the oil from her neighbor's tract; the neighbor's remedy is to ″go and do likewise-″30 Ignoring potential doctrinal differences, courts have generally followed this rule whether the jurisdiction follows the ownership-in-place or non-ownership theory for defining the property interest in oil and gas.31 Moreover, despite scientific strides that revealed the inappropriateness of the wild-animal analogy, the rule of capture has endured as a basic principle of oil and gas law-32 Since the turn of the century, however, courts and legislatures have redefined the rule in order to promote the goals of conservation, protection of correlative rights, and more recently, protection of the environment.33 For example, courts and legislatures eventually rejected the *Hammonds* view that gas reinjected into a reservoir for storage becomes subject to the rule of capture, choosing instead to emphasize the public policy goal of promoting gas storage-34

[ii] The ″*Negative Rule of Capture*″

As originally formulated, the rule of capture shields a land-owner from liability for drainage occurring when she drills a ***well*** which is bottomed beneath the vertical boundaries of her own land. As mentioned above, several common oil and gas operations, such as secondary-recovery projects and gas storage, raise questions about ***trespass*** liability when substances are injected into a landowner's ***well***. Professors Williams and Meyers would extend the rule of capture to provide protection from ***trespass*** liability in these instances:

Just as under the rule of capture a landowner may capture such oil or gas as will migrate from adjoining premises to a ***well*** bottomed on his own land, so also may he inject into a formation substances which may migrate through the structure to the land of others, even if this results in the displacement under such land of more valuable with less valuable substances.35

[redacted]

The Texas Supreme Court relied upon this ″negative rule of capture″ in *Railroad Commission of Texas v- Manziel*, 36 a case involving a secondary-recovery project. In *Manziel*, the Whelans and the Manziels were operators in a field with rules providing for eighty-acre production units. The ***wells*** were to be located on that unit 660 feet from lease lines. The Whelans had unitized all of their leased properties but had no unitization agreement with the Manziels. The Whelans planned a water-flooding program designed to recover an estimated 930,000 barrels of oil. To implement this plan, they had received an order from the Railroad Commission, the state's regulatory agency, permitting injection of water into a ***well*** located only 206 feet from lease lines, rather than the 660 feet set forth in the field rules. The purpose of the water-injection program was to recover oil left in place after initial, or primary, recovery by sweeping water towards one ***well***. Because the injected water ″spreads out radially from the injection ***well*** bore,″ water inevitably crosses lease lines.37 The Manziels claimed this physical intrusion of water constituted a ***trespass***, justifying their request to set aside the Railroad Commission's order-

In ruling against the Manziels, the Texas Supreme Court relied upon the ″negative rule of capture,″ quoting the same treatise set forth above.38 However, the court also relied extensively on public policy considerations and framed the issue narrowly as ″whether a ***trespass*** is committed when secondary recovery waters from an authorized secondary recovery project cross lease lines-″39 Therefore, it is questionable whether *Manziel* represents a broad endorsement of the negative rule of capture, which would insulate the injector from liability in a private ***trespass*** cause of action. Instead, as discussed below, *Manziel* may represent a narrower principle: a neighboring landowner is not entitled to an injunction when an operator plans to conduct a secondary-recovery project pursuant to a valid commission order.40

Whether *Manziel* is interpreted narrowly or broadly, it stands as virtually the only case to have relied upon the ″negative rule of capture-″ Even Williams and Meyers have recognized that their proposed rule never developed in case law, with the exception of *Manziel*.41 Therefore, in determining whether fracing beyond lease or unit lines constitutes an actionable ***trespass***, courts likely will turn to a traditional definition of the rule of capture, rather than the extended version proposed by Williams and Meyers. Moreover, even if the negative rule of capture had been widely adopted, fracing may not fit within the parameters of that rule. Williams' and Meyers' rule contemplates the injection of substances which ″may migrate″ across lease lines. As the technical portion of this paper reveals, fracing involves the injection of fluids designed physically to penetrate the formation to create cracks propped open by sand. In light of these technical differences between secondary-recovery projects and fracing, courts have analogized fracing to slant-hole drilling. These ***wells***, as described below, do not constitute a valid exercise of the rule of capture.

[iii] The ″No Slant-Hole Drilling″ Caveat

The general rule of capture applies to procedures taking place on land in which the operator has a property right. Even the proposed ″negative rule of capture″ is limited to substances ″which may migrate″ from the injector's land to the land of others. These rules, however, do not sanction a slant-hole ***well***, a ***well*** which begins on one tract but then deviates and bottoms on an adjacent tract. Because this procedure involves a direct, physical intrusion, courts have uniformly ruled that it constitutes an actionable ***trespass***.42 For example, in *Hastings Oil Co- v. Texas Co*.,43 the Texas Company sought a temporary injunction alleging Hastings had drilled a ***well*** on its property which deviated and bottomed under lands held by the Texas Company. In upholding the trial court's temporary injunction, the Texas Supreme Court opined that:

in instances of ***trespass*** to mining property greater latitude is allowed courts of equity than in restraining ordinary ***trespasses*** to realty, ″since the injury goes to the immediate destruction of the minerals which constitute the chief value of this species of property.″ ***Trespasses*** of this character are irreparable because they subtract from the very substance of the estate, hence equity is quick to restrain them.44

While Texas is an ownership-in-place jurisdiction, courts in non-ownership jurisdictions have also viewed slant-hole ***wells*** as deviating from the boundaries of the rule of capture, resulting in an actionable ***trespass***-45

[c] The Secondary-Recovery Analogy

In light of the courts' universal view of slant-hole drilling as a subsurface ***trespass***, plaintiffs will urge courts to analogize to those cases when alleging that a neighbor's frac job has resulted in a ***trespass***. The fracing defendants, however, will point to cases involving secondary-recovery operations as providing the more appropriate analogy. Several courts have addressed the ***trespass*** question in the context of secondary-recovery projects. Specifically, as in *Manziel*, courts have been asked to enjoin water-flooding projects on the basis that the injected water will sweep across lease or unit lines, resulting in an impermissible ***trespass***.

In resolving these cases, courts in some jurisdictions have either avoided or modified ***trespass*** liability for operators conducting secondary-recovery projects, but largely on public policy grounds. Recall that while the *Manziel* court quoted the ″negative rule of capture,″ the court's opinion also emphasized public policy considerations before refusing to enjoin the water-flood operation. For example, the court pointed to a state statute which made it ″the policy of this state to encourage the secondary recovery of oil.″46 In addressing the Manziel's ***trespass*** argument the court concluded:

It cannot be disputed that such operations should be encouraged, for as the pressure behind the primary production dissipates, the greater is the public necessity for applying secondary recovery forces- It is obvious that secondary recovery programs could not and would not be conducted if any adjoining operator could stop the project on the ground of subsurface ***trespass***.47

The Supreme Court of Nebraska reached a similar conclusion in *Baumgartner v. Gulf Oil Corp*.48 In that case, the plaintiff, who had refused to join a secondary-recovery project that had been authorized by the state's conservation commission, brought an action for ***trespass*** and conversion- The plaintiff claimed that the defendant's water-flooding project had swept oil from under land leased to him into ***wells*** on the defendant's unit. As in *Manziel*, the court pointed to state statutes which made it the public policy of the state to encourage secondary-recovery operations. The court continued to stress the importance of secondary recovery by noting, ″[t]o appreciate the importance of the legislative policy, one needs only to understand the importance of secondary oil recovery in Nebraska.... 'As in previous years, the recovery of secondary oil formed a prominent part of Nebraska's producing picture.″49 After quoting extensively from *Manziel*, the supreme court reversed the trial court's order in favor of the plaintiff.50

Not all jurisdictions, however, have shielded operators conducting secondary-recovery operations from ***trespass*** liability- In *Jameson v. Ethyl Corp*.,51 the Arkansas Supreme Court denied an injunction upon the condition that the landowner received compensation for the minerals extracted, in excess of natural depletion, from her land through the secondary-recovery project.52 In *Jameson*, Ethyl held leases to remove brine or salt water from approximately 15,000 acres located in the Kerlin Brine Field- Jameson owned a tract in that field, but she and Ethyl had been unable to agree on leasing terms. Eventually, Ethyl began a recycling process to obtain ″an efficient and maximum recovery of brine from the Field.″53

As in *Manziel* and *Baumgartner*, the Supreme Court of Arkansas turned to public policy considerations, as expressed in a state statute.54 However, the *Jameson* court viewed its statute as requiring courts to protect correlative rights as ***well*** as to promote secondary recovery:

Inherent in such laws is the realization that transient minerals such as oil, gas and brine will be wasted if a single landowner is able to thwart secondary recovery processes, while conversely acknowledging a need to protect each landowner's rights to some equitable portion of pools of such minerals-55

Ultimately, the court decided it could both protect property rights and encourage secondary recovery by granting conditional relief to the landowner. In reaching this conclusion, the court expressly considered whether secondary-recovery processes should be protected under the rule of capture:

A determination that a ***trespass*** or nuisance occurs through secondary recovery processes within a recovery area would tend to promote waste of such natural resources and extend unwarranted bargaining power to minority landowners. On the other hand, a determination that the rule of capture should be expanded to cover the present situation could unnecessarily extend the license of mineral extraction companies to appropriate minerals which might be induced to be moved from other properties through such processes and, in any event, further extend the bargaining power of such entities to reduce royalty payments to landowners who are financially unable to ″go and do likewise″....56

A recent federal district court relied on this quote from *Jameson* in resolving another controversy over brine recovered by secondary-recovery methods- In *Deltic Timber Corp. v. Great Lakes Chemical Corp*.,57 the court restated Arkansas law as follows: ″As noted in *Jameson*, the law of capture does not envision the use of injection ***wells*** as employed through secondary recovery processes. Rather, the rule is applied to brine which is merely drained through 'natural depletion.″58 Significantly, in providing this summary the court noted that Arkansas had not followed *Manziel*'s application of the ″negative rule of capture-″59

In summary, in deciding whether secondary-recovery projects are permissible processes under the rule of capture, courts have sought guidance from state statutes which express a public policy of encouraging secondary-recovery operations. According to the *Jameson* court, however, the Arkansas statute did justify expanding the rule of capture to include secondary-recovery projects. In *Manziel* and *Baumgartner*, on the other hand, the courts cited state statutes as support for deciding in favor of operators conducting secondary-recovery projects. However, as noted in the discussion of *Manziel*, that determination may not represent a broad extension of the rule of capture to protect operators from a private cause of action for ***trespass*** liability. Instead, courts may be more influenced by another factor: whether the secondary-recovery operation was conducted pursuant to a valid order of the state's regulatory commission.

[d] The Effect of Commission Orders on the ***Trespass*** Question

As noted in the discussion of *Manziel* above, the Texas court may have been more influenced by the commission's approval of the secondary-recovery operation, than by Williams' and Meyers' proposed ″negative rule of capture.″ Recall that the court framed the issue narrowly as ″whether a ***trespass*** is committed when secondary recovery waters from an authorized secondary recovery project cross lease lines.″60 The court also proclaimed that ″we are not confronted with the tort aspects of such practices-″61 In removing the injunction the lower court had imposed, the supreme court held:

We conclude that if, in the valid exercise of its authority to prevent waste, protect correlative rights, or in the exercise of other powers within its jurisdiction, the Commission authorizes secondary recovery projects, a ***trespass*** does not occur when the injected, secondary recovery forces move across lease lines, and the operations are not subject to an injunction on that basis. The technical rules of ***trespass*** have no place in the consideration of the validity of the orders of the Commission.62

Similarly, in *Baumgartner*, the court admitted, ″[w]e cannot ignore the fact that the operation of [the unit] was specifically authorized and approved by commission-..and that the project was at all times conducted in conformity with the order of the commission.″63 Moreover, while the *Baumgartner* court quoted *Manziel*'s reliance on the ″negative rule of capture,″ its holding was narrowly tailored:

[W]e hold where a secondary recovery project has been authorized by the commission the operator is not liable for willful ***trespass*** to owners who refused to join the project when the injected recovery substance moves across lease lines.64

Baumgartner and *Manziel*, however, do not represent the approach used by most courts- In fact, commentators have concluded that ″the prevailing weight of judicial opinion is that tort liability exists in private lawsuits for damages caused by a unit's operations.″65 For example, in *Greyhound Leasing & Financial Corp. v. Joiner City Unit*,66 an operator conducted a commission-approved secondary-recovery operation by injecting salt water which crossed unit lines- The court refused to insulate the operator from damages in a private nuisance action.67 In reaching that conclusion the court stated, ″[w]e do not consider that [*Manziel*], although cited by the defendant, can be authority for a contrary position in the face of Oklahoma decisions.″68

The *Jameson* court, as described above, similarly refused to insulate an operator from damages liability- In that case, however, the secondary-recovery project had been conducted *without* commission approval; but that fact did not motivate the Arkansas court to reject the *Manziel* approach. Instead, the *Jameson* court relied on the policy goals expressed in the state's unitization statute, even though it questioned whether the statute applied to Ethyl's project. In reviewing that statute, as described above, the court concluded that its goals did not justify expanding the rule of capture to include protection for operators conducting secondary-recovery projects.

In light of the foregoing cases, one can conclude that in many jurisdictions the ″technical rules of ***trespass***″ will be strictly enforced even when the procedure has been approved by the state's regulatory commission. Some courts, however, as evidenced by *Manziel, Baumgartner*, and *Jameson*, could be influenced by two factors: (1) whether the process was conducted pursuant to a valid commission order, and (2) the public policy position on the procedure as expressed in state statutes. Unfortunately for the fracing defendant, however, neither of these factors will prove useful in defending a ***trespass*** cause of action since there is very little regulation directly addressing that procedure.

[e] Regulations Addressing Fracing

Unlike secondary-recovery procedures, ***fracturing*** has not been directly regulated or encouraged in state statutes. However, fracing is mentioned in several states' conservation statutes. In both Virginia and West Virginia fracing is included in the definition of ***well*** ″***stimulation***.″69 Furthermore, these two states, due to their coalbed methane production, have regulations requiring the operator to obtain a permit prior to fracing, which gives the coal owners a right of notification and the opportunity to object to sand fracing operations-70 Georgia requires an operator to notify the Director of its Environmental Protection Division prior to ***fracturing*** treatments, and further stipulates that these treatments may not cause injury to the formation.71 Additionally, Georgia's statute defining the board's jurisdiction distinguishes ***fracturing*** from secondary-recovery methods-72 Moreover, Kentucky and Pennsylvania exclude ***fracturing*** from their respective statutes defining waste,73 and South Dakota excludes ***fracturing*** from its statute requiring applications for ***well*** injection and modifications-74 New Mexico requires approval of production restoration projects and ***well*** workover projects. This procedure requires an application for any procedure that increases production, including ***fracturing***, which is not routine maintenance that a ″reasonable and prudent operator″ would perform to maintain ***well*** production.75 Finally, Indiana and Vermont give jurisdiction to their commissions to regulate the ***stimulation*** of ***wells*** without specifically defining any methods-76 However, fracing is not included as a recognized form of enhanced recovery in compulsory unitization acts.77 For example, in Texas the legislature did not include ***fracturing*** in its definition of secondary-recovery- This omission led Professor Weaver to conclude that the Railroad Commission cannot authorize fracing procedures as ″it is doubtful that [fracing] fits into the category of cooperative agreements that the Railroad Commission can approve under § 101.011 of the Voluntary Unitization Act.″78

[f] Case Law and Fracing

[i] Cases Addressing Fracing and Commission Orders

The lack of direct regulation regarding fracing obviously explains the paucity of cases discussing the effect of a commission's order directly authorizing the procedure. However, at least three cases have considered fracing as a factor when considering the validity of other commission orders. In *Columbia Gas Transmission Corp. v. Smail*,79 a federal district court granted a preliminary injunction which limited an operator's ability to sand frac its ***well***- The plaintiff, Columbia Gas Transmission Corporation, operated a natural gas storage reservoir in the Clinton formation. The defendant, Smail, obtained a permit from the state conservation agency to drill and complete a ***well*** into the Clinton formation on a tract which was within, or near, the boundaries of the storage reservoir. Columbia sought to permanently enjoin Smail from drilling and completing this ***well*** on the grounds that it would produce Columbia's stored gas. At trial, evidence was also presented regarding the effects of fracing the Smail ***well***. After weighing Smail's right to drill a ***well*** on its property, and the potential injury Columbia might sustain if the ***well*** were improperly fraced, the court granted a preliminary injunction preventing Smail from fracing the ***well*** without giving Columbia notice and an opportunity to object to the proposed fracing treatment.80

In *Zinke & Trumbo, Ltd. v. State Corporation Commission*,81 the Kansas Supreme Court recognized that sand fracing treatments could result in production from another's lease- In that case, Zinke & Trumbo, Ltd. (Zinke) and Sho-Bar were operators with ***wells*** in the same field. Sho-Bar sand fraced a ***well*** located 330 feet from Zinke's lease line, resulting in a flow rate increase of over five times the ***well***'s natural flow. According to evidence produced at trial, a ***fracture*** of at least 400 feet was created. Since the fraced ***well*** was located only 330 feet from the lease line, the court concluded that the ***fracture*** ″obviously penetrated Zinke's lease.″82 In this field, the commission had based proration orders on a standard 50/50 formula, allocating 50% of the total pool allowable to the adjusted open flow of each ***well*** and 50% based upon the acreage attributed to each ***well***.83 Zinke challenged this formula on the ground that using the adjusted open flow of the fraced Sho-Bar ***well*** ignored the artificially enhanced open flow caused by fracing into the heart of the reservoir located

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under Zinke's leases-84 Additionally, Zinke claimed the increased flow from the fraced ***well*** came from Zinke's leases, meaning the proration formula gave Sho-Bar an unjust record for its ″***trespass***.″85 The Kansas Supreme Court agreed with Zinke and held that the commission's duty to protect correlative rights required it to use evidence of ***fracture*** treatments as a factor in making a proration order-86

As in *Zinke*, the Supreme Court of Wyoming agreed with a lower court's conclusion that ***fracturing*** had resulted in an improper ***trespass***. In *ANR Production Co. v. Kerr-McGee Corp*.,87 the state's commission had ordered ANR to shut in a ***well*** after concluding that ANR's ***fracture*** treatment of a ***well*** it had drilled in the Second Bench formation ″had caused substantial communication″ into another formation, the First Bench-88 In an earlier case, the Wyoming Supreme Court upheld the commission's decision.89 Subsequently, the operator of the unit producing from the First Bench sued ANR for conversion and ***trespass***-90 In that case, the district court concluded that ANR had ***trespassed*** into the First Bench.91 On appeal, ANR apparently did not challenge the ***trespass*** conclusion- Instead, it disputed the amount of damages.92

Zinke, Smail, and *Kerr-McGee* demonstrate that state courts and administrative agencies are concerned with the impact of fracing on correlative rights.92.1 However, while these courts effectively treated fracing as a subsurface ***trespass***, these cases did not directly address that question. In fact, as described in the next section, with the exception of one state, Texas, state appellate courts have not analyzed the ***trespass*** issue raised by fracing.

[ii] Case Law Addressing Whether Fracing Constitutes a *Trespass*

Despite the frequent use of fracing throughout the past several decades, courts have rarely been asked to determine whether that procedure constitutes an actionable ***trespass***. One of the few cases which has addressed this question is *Gregg v. Delhi-Taylor Oil Corp*.93 In that case, the plaintiff, Delhi-Taylor Oil Corporation, sought to enjoin Gregg's sand fracing operation- Gregg had an oil and gas lease on a tract which was only 75 feet wide and Delhi had a lease on lands surrounding Gregg's lease. Gregg had drilled a ***well*** which was 37.5 feet from Delhi's lease on the east and 80 feet from Delhi's lease on the south. When Gregg planned to sand frac this ***well***, Delhi sought to ″enjoin a subsurface ***trespass*** by Gregg.″94 In defending against Delhi's suit, Gregg argued that the state's regulatory agency, the Railroad Commission, had primary jurisdiction over the matter. The trial court agreed and dismissed the case.

While the *Gregg* case reached the Supreme Court of Texas on this jurisdictional issue, the court also addressed the ***trespass*** question.95 In so doing, the court relied on a traditional definition of ***trespass***: ″[E]ntry upon another's land need not be in person, but may be made by causing or permitting a thing to cross the boundary of the premises-″96 In analyzing whether fracing fit that definition the court stated:

The invasion alleged is direct and the action taken is intentional. Gregg's ***well*** would be, for practical purposes, extended to and partially completed in Delhi-Taylor's land. The pleadings allege a physical entrance into Delhi-Taylor's leasehold. While the drilling bit of Gregg's ***well*** is not alleged to have extended into Delhi-Taylor's land, the same result is reached if in fact the cracks or veins extend into its land and gas is produced therefrom by Gregg.97

In light of this ″physical entrance,″ the court analogized to slant-hole drilling and determined, in dicta, that fracing involved a ***trespass***, and not a valid exercise of the rule of capture-

Although *Gregg* was decided a year before *Manziel*, the supreme court in *Gregg* also considered an issue which was determinative in the later case: whether the commission had approved the procedure. On that issue, the *Gregg* court noted the commission ″had made no rules″ regarding fracing.98 Therefore, the court viewed it ″as an open question″ whether the commission could in fact authorize such a procedure- A year later, in *Manziel*, the supreme court did address this question. After stating that the commission-approved secondary-recovery procedures did not constitute a ***trespass***, the court limited the implications of that statement for fracing operations: ″The latter statement is not authority for the proposition that the type of deliberate action involved in sand fracing [sic] would not be a ***trespass***, or as authorizing the Commission to license such action.″99 In reaching that conclusion, the *Manziel* court cited *Gregg* with approval.

In light of the *Gregg* decision,100 one might have concluded that in Texas, ***fracturing*** across lease lines subjects an operator to liability in ***trespass***- However, in a case decided thirty years after *Gregg* the Texas courts issued opinions which

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have left the law unclear. In *Geo Viking, Inc. v. Tex-Lee Operating Co*.,101 Geo Viking, an oil field service company, had been hired by Tex-Lee to sand frac one of Tex-Lee's ***well*** in Lee County, Texas. In order to meet Tex-Lee's expressed requirements, Geo Viking designed a frac treatment having a propped length of 1,000 feet.102 During the execution of the treatment, Geo Viking experienced mechanical problems with a critical piece of equipment,103 resulting in a premature termination of the frac job- The ***well*** never produced in paying quantities and was later plugged.104

The failed frac job prompted Tex-Lee to sue Geo Viking for damages under the Texas Deceptive Trade Practices Act. Geo Viking countered Tex-Lee's claim by arguing that if the frac job had been performed as planned, it would have extended beyond the boundaries of the unit. Therefore, Geo Viking requested the trial court to instruct the jury not to consider the value of any oil and gas reserves obtained from outside the unit.105 The trial court refused this request-

On appeal, Geo Viking argued that the trial court had erred by refusing its request, arguing that Tex-Lee had no right to recover oil produced by fracing beyond unit lines. In upholding the trial court's refusal to give the requested instruction, the appellate court allocated only one paragraph to the ***trespass*** issue and decided it was ″without merit.″106 As an explanation for its ruling, the court provided only a curt recitation of the rule of capture:

This rule permits the owner of a tract to drill as many ***wells*** on his land as the Railroad Commission will allow and provides that he is not liable to adjacent land owners whose lands are drained as a result of his operations- The remedy of an injured land owner under such circumstances is generally said to be self-help.107

A concurring justice only briefly acknowledged the ***trespass*** issue: ″If Geo Viking is responsible for depriving Tex-Lee of production, it cannot defend on the basis that Tex-Lee might have secured some of that production by [having ***trespassed***] on someone else's land. That is a matter between Tex-Lee and the other landowner.″108

Only the dissenting opinion scrutinized the rule of capture as applied to ***hydraulic fracturing***- In his dissent, Judge Grant noted that the rule of capture applies only if the producing ***well*** does not commit a ***trespass***. In support of this principle, Judge Grant cited *Gregg*, and reiterated its statement ″that fracing under another person's lands had all the necessary elements to be a ***trespass***....″109 For that reason, Judge Grant concluded that Tex-Lee's damage recovery should have been limited as Geo Viking requested.

Geo Viking appealed to the Texas Supreme Court. Initially, that court issued an opinion which agreed with Judge Grant's dissent.110 With that opinion, the Texas Supreme Court answered the question posed by this paper, holding that fracing beyond lease or unit lines ″constitutes a subsurface ***trespass***-″111 However, six months later the court withdrew that opinion. Instead, it declined Geo Viking's application for writ of error with the noncommittal statement that ″we should not be understood as approving or disapproving the opinions of the court of appeals analyzing the rule of capture or ***trespass*** as they apply to ***hydraulic fracturing***.″112

What motivated the Texas Supreme Court to adopt this course of action? Professor Burney has offered this explanation:

By belatedly denying the application for writ of error, the Texas Supreme Court deprived Texas jurisprudence of the guidance provided by its first opinion- This side-step suggests that the court recognized that a finding of ***trespass*** would discourage ***hydraulic fracturing*** and hinder development. The court, rather than overtly address policy, masked its role by simply allowing the lower court's ambiguous opinion to stand.113

Similarly, Professor Jacqueline Weaver has suggested, by comparing *Geo Viking* to *Manziel*, that the court wanted to encourage the use of ***fracturing***.

Return to the excerpt of the court's opinion in *Manziel*, substituting ″***hydraulic fracturing***″ for ″secondary recovery.″ To paraphrase the resulting excerpt, it is obvious that ***fracturing*** operations could be encouraged and that they will not occur if adjoining operators can stop them on the ground of subsurface ***trespass***. The proper measurement of damages at issue in the *Geo Viking* case implicates much larger public policy matters affecting the ultimate recovery of oil and gas in Texas.114

According to both of these writers, the Texas court's actions can be explained as an effort to promote fracing as desirable public policy-115 In other jurisdictions, defendants in fracing cases could also urge courts to exempt them from ***trespass*** liability on public policy grounds.116 In asserting policy, these defendants would again ask courts to analogize to the *Manziel / Baumgartner* secondary-recovery cases- But in considering that analogy, courts should question whether ***hydraulic fracturing*** should be treated the same as secondary-recovery operations from a public policy point of view.

[g] Fracing and Public Policy

In analyzing the ***trespass*** question, the *Manziel* and *Baumgartner* courts viewed secondary-recovery operations as promoting valuable public policy goals, which state legislatures had expressly endorsed in statutes. However, as demonstrated above, state legislatures have not similarly embraced ***fracturing*** processes. Without such legislative endorsement, can one argue that ***fracturing*** implicates the same policy considerations as secondary-recovery?

According to the *Gregg* and *Manziel* decisions, the answer should be no. In *Gregg*, the court expressed the following views of fracing. First, as noted above, from a technical standpoint, the court analogized fracing to slant-hole drilling, and described the process as ″direct″ and ″intentional,″ resulting in a ″physical entrance″ into the adjoining property.117 Regarding the public policy implications, the court stated:

While the process may increase production from an individual ***well***, there is nothing in any of these cases to show that the process is necessary from the public's standpoint to increase the total recovery from the common source- In any event, no such rules have been promulgated.118

A year later, in *Manziel*, the Texas Supreme Court extolled the virtues of secondary-recovery as essential for the ultimate recovery of hydrocarbons. On the contrary, the court characterized fracing as ″the type of deliberate action″ which could constitute a ***trespass***.119

To summarize, the earlier Texas cases apparently viewed fracing as increasing only the *rate* of recovery for individual ***wells***, and as having no significant value in ensuring the *ultimate* recovery of hydrocarbons in the state- As the technical discussion of this paper demonstrates, however, that conclusion may be too general. In fact, in many formations fracing may be the only technique which will result in any significant production.120 In addition to this fact, in support of the view that fracing should be encouraged to increase the ultimate recovery of oil and gas, one could cite federal legislation, specifically the Natural Gas Policy Act of 1978121 and the ″*tight gas and tax credit*″-122 These statutes provided incentives for the production of oil or gas from high-cost formations. Although these statutes did not specifically mention fracing, that process is typically used in the low permeability formations mentioned in these acts. Indeed, it may have been the policies suggested by these acts, which were passed after the *Gregg* and *Manziel* decisions, as ***well*** as the practical value of fracing in particular formations in Texas,123 which motivated the Texas Supreme Court to withdraw its opinion labeling fracing a subsurface ***trespass***-

[h] Summary of the ***Trespass*** Question

Under both common law and modern definitions, a ***trespass*** occurs if a ″thing″ physically crosses property boundaries.124 As the technical discussion of this paper demonstrates, this definition is satisfied when fracing extends beyond lease or unit lines since fracing inevitably involves a direct, physical intrusion of the pad and propping fluids into the adjoining neighbor's property-125 These technical realities likely would prevent a court from applying the ″negative rule of capture,″ which, by definition, applies only to substances which ″may migrate″ across property lines. In light of the direct intrusion caused by fracing, courts may follow the lead of the *Gregg* court and analogize fracing to slanthole drilling, a process which constitutes an actionable ***trespass*** rather than a permissible process under the rule of capture. Unable to rely on the rule of capture, the defendant in a fracing case may then urge a court to shield it from ***trespass*** liability on public policy grounds, citing the *Manziel* and *Baumgartner* secondary-recovery cases as examples. Those cases, however, may require commission-approval for the process in order to avoid ***trespass*** liability. Moreover, many courts have rejected the *Manziel / Baumgartner* approach in addressing the ***trespass*** question in secondary-recovery cases. Regardless, without express legislative endorsement of fracing as promoting valuable public policy goals, courts could refuse to exempt the process from ″the technical rules of ***trespass***.″

[i] Practical Problems Resulting from a ***Trespass*** Answer

If courts conclude that fracing can result in a ***trespass***, they will face other practical problems. To illustrate the practical effects of a ***trespass*** answer, some of these problems are discussed briefly below:

[i] The Battle of the Experts

Both the fracing operator and the complaining neighbor will be forced to present expert testimony to aid a court or jury in determining whether fracing has indeed extended beyond lease or unit lines. As noted by the appellate court in *Geo Viking*, such expert testimony involves ″probabilities rather than certainties.″126 To complicate the problem, large tract owners might use this proof problem to their advantage to create doubt about whether a ***trespass*** has occurred- Small tract owners desiring to frac their ***wells***, on the other hand, will have difficulty avoiding an injunction based on ***trespass***. Such was the case in *Gregg*, where the fracing defendant's lease was only 75 feet wide. However, in most cases pooling could alleviate this problem for the small tract owner.127 In addition to requiring expert testimony to prove a ***trespass*** has taken place, courts will also require expert testimony to prove damages.128

[ii] The Good Faith/Bad Faith Determination

If a plaintiff successfully establishes that a ***trespass*** has occurred, he will then want to establish that the ***trespass*** occurred in bad faith, to increase his damage recovery.129 That question will create another proof problem for the defendant- Possible questions will include whether the fracing defendant should have known that its ***fracturing*** treatment would extend beyond lease lines.

[iii] Who are the Parties?

By definition, ***trespass*** is a tort committed against the person in possession.130 Therefore, the plaintiffs in an action for ***trespass*** caused by fracing would include the mineral estate owner or her lessee-131 Those without a possessory interest, such as royalty owners, should be precluded from initiating the cause of action, at least in ownership-in-place jurisdictions.132 These non-possessory interest owners, would, of course, expect their share of any recovery-133 The potential defendants would obviously include the fracing operator. However, one author has noted that in slant-hole cases courts have expanded the list to include the shareholders of corporate operators.134

[iv] The Statute of Limitations

The typical limitations period for the tort of ***trespass*** is two years from when the cause of action accrues.135 However, plaintiffs needing to avoid the limitations bar will assert the discovery rule or claims of fraudulent concealment, creating more procedural problems for courts and parties in a fracing ***trespass*** case-

The foregoing list of practical problems is not intended to be exhaustive. Rather, it demonstrates that other issues, in addition to policy considerations, may influence courts as they consider whether fracing constitutes a ***trespass***. Indeed, it may have been these practical problems, as much as public policy concerns, which motivated the Texas Supreme Court to retreat from its original decision. These proof problems could also discourage plaintiffs from filing ***trespass*** lawsuits, explaining the dearth of case law on the issue. Rather than file suit, landowners may decide to accept the invitation inherent in the rule of capture and ″go and do likewise.″

§ 19.04 The Implications of Fracing for the Doctrine of Implied Covenants

[1] In General

As discussed in the previous section, when an operator fracs a ***well*** on his property, neighboring landowners may consider bringing a ***trespass*** cause of action against that operator, seeking an injunction or damages. Those same facts, however, may convince the neighboring landowners to bring suit against their own lessees for failing to frac a ***well*** on their properties.136 In that instance, the landowners will base their causes of action on the doctrine of implied covenants-

Historically, courts have invoked the doctrine of implied covenants to impose additional duties on a lessee under an oil and gas lease.137 In delineating these implied duties, most courts have adopted the reasonable and prudent operator standard- Under that standard, a lessee must act as a reasonably prudent operator under the circumstances, having due regard for the interests of both the lessor and the lessee.138 Significantly, that standard does not require the lessee to act as a fiduciary, subordinating its interests to those of the lessor.

While commentators have noted that the reasonably prudent operator standard provides the overarching principle for determining the extent of a lessee's implied duties,139 courts have addressed covenants according to specific actions typically demanded by lessors- To reflect that approach, commentators have categorized the implied covenant duties as follows: (1) the implied covenant to develop the lease, (2) the implied covenants of protection, including to protect against drainage, and (3) the implied covenants to manage and administer the lease, which includes a duty to use successful modern methods of production and development.140

[2] The Implied Covenants Implicated by Fracing

[a] Development

To satisfy the implied covenant to develop, a lessee must develop the lease as a reasonably prudent operator, even after production has been obtained. In general, lessors rely on this covenant when they believe their lessees should have drilled additional ***wells***. However, a lessee is not required to drill additional ***wells*** unless it will be profitable to the lessee after including costs of drilling, completing, equipping, and producing. Only a few states have adopted an exception to this profitability criterion by recognizing a separate duty for a lessee to further explore.141 As one court described the covenant to develop, ″it is the duty of the lessee to continue the development of the property and to put down as many ***wells*** as may be reasonably necessary to deplete the oil and gas reserves underlying the premises for the common advantage of both the lessor and the lessee-″142 Because fracing is conducted on existing ***wells***, the implied covenant to develop is arguably not implicated when a lessor claims a reasonably prudent operator would have fraced a ***well*** on his property. Technically, in that instance the lessor should rely on the implied covenant to diligently manage and administer the lease.

[b] Use of Modern Methods of Production

Instead of asserting breach of the implied covenant to develop, lessors who believe their lessees have breached their duties by failing to frac should assert breach of the implied covenant to manage and administer the lease, which includes a duty to use modern methods of production. Courts have historically been willing to impose such a duty. For example, in *Rhoads Drilling Co. v. Allredy*,143 the court found a lessee had failed to act as a reasonable prudent operator by failing to install a pump on an oil ***well***- Furthermore, in *Wadkins v.Wilson Oil Corp.*,144 a lessee who had failed to acidize a ***well*** was found to have breached implied covenant duties.145

Courts and commentators have also relied on this implied covenant to require lessees to engage in secondary-recovery operations-146 According to one treatise, such a duty arises ″where it may be shown that such operations would be profitable to the lessee, and proven methods of operation were available.″147 One of the first cases directly to address this duty was *Waseco Chemical & Supply Co- v. Bayou State Oil Corp*.148 In that case, lessees in the area were using the fireflood method of recovering oil in place. According to the trial court, that procedure was ″the only method of producing the Bellevue field and [was] for a number of years...the normal [and] efficient method.″149 After considering a number of factors,150 the appellate court upheld the lower court's cancellation of the lease-151

Under the *Waseco* analysis, a court could determine that a lessee has breached its implied duties by failing to frac if that procedure was ″the normal [and] efficient method″ of production in the area. As in *Waseco*, however, a number of factors must be considered, including the cost of the procedure, the risks involved, and geological data, before concluding that a lessee has an implied duty to frac a ***well***.

[redacted]

Additionally, the distinction between fracing and secondary recovery from a public policy point of view, as discussed in the ***trespass*** analysis above, could impact the application of implied covenant duties to use particular methods of production. As an explanation for implying duties to engage in secondary-recovery operations, one court stated, ″[I]n keeping with the policy of the State of Illinois of promoting the secondary recovery of oil ... [i]t is an implied right and duty of a reasonably prudent operator under an oil and gas lease to adopt a system providing for the secondary recovery of oil.″152 Until states embrace fracing techniques as they have secondary-recovery operations, courts may be more hesitant to impose a duty to frac a ***well*** under the implied covenant to use modern methods of production-

[c] Drainage

A lessee has a duty to prevent drainage of oil and gas to adjoining properties. While this covenant is typically breached by the lessee's failure to drill an offset ***well*** in response to drilling on other tracts, there may be situations where a reasonable and prudent operator would frac a ***well*** to counteract drainage. Specifically, if a neighboring operator has fraced a ***well***, other operators could expect increased drainage from their tracts. Fracing in this instance might be especially appropriate if regulations prohibit a lessee from drilling another ***well***. However, just as an operator is not required to drill an offset ***well*** unless it would be profitable, a lessee will not be required to engage in an unprofitable fracing operation.153

[3] Summary of Fracing and Implied Covenants

As in any case involving a claim that a lessee has breached its implied covenant obligations, a court considering whether a lessee has breached those duties by failing to frac will consider a number of factors, including the porosity and permeability of the formation, the likelihood that fracing would cause damage to the formation, whether other operators in the area are fracing, and the costs involved. Additionally, a court would consider the answer to the first question considered in this paper: whether fracing constitutes an actionable ***trespass***. If the answer is yes, a court could conclude that a reasonable and prudent operator would not risk the tort liability. Alternatively, an affirmative answer to the ***trespass*** question could suggest that a reasonably prudent operator would take other action to avoid the ***trespass*** lawsuit, such as pooling or seeking administrative exceptions to ***well***-spacing requirements. In light of these factors, and the proof and predictability problems inherent in fracing, one can only speculate whether failure to frac would constitute a breach of implied covenant duties in any given fact situation.

§ 19.05 Conclusion

The technical realities of formation ***fracturing*** could eventually challenge courts in applying two fundamental oil and gas law principles, the rule of capture and the doctrine of implied covenants. Regarding implied covenants, a landowner may successfully argue that a reasonably prudent operator would frac a ***well*** to offset drainage or to manage the lease properly, as long as it would be profitable for the lessee to do so. As in any implied covenant case, determining whether an operator has breached its implied covenant obligations by failing to frac will involve a fact-intensive inquiry. In particular, implied covenant liability could depend upon whether the jurisdiction views fracing across lease or unit lines as an actionable ***trespass***. In answering that question, courts should avoid the Texas court's approach in *Geo Viking*. In that case, the Texas Supreme Court created uncertainty about property rights by failing directly to address the role of policy or to answer the ***trespass*** question. Instead, courts should overtly weigh the unique practical and policy considerations raised by ***hydraulic fracturing*** and fashion appropriate remedies. However, in light of the direct and invasive nature of fracing, many courts will likely analogize that process to slant-hole drilling, as in *Gregg*. At that point, the defendant in a ***trespass*** case based on fracing will turn to public policy considerations to provide a shield from liability. But if fracing does indeed have policy implications which would justify denying an injunction or damages to neighboring landowners, state legislatures should endorse that procedure as they have other subsurface operations considered crucial to the efficient development of oil and gas. Even then, as demonstrated by the secondary-recovery cases, many courts could still determine that fracing constitutes a technical ***trespass***, subjecting an operator or landowner to liability when ***fractures*** cross lease or unit lines. And, as demonstrated by *Smail, Zinke*, and *Kerr-McGee*, this ***trespass*** conclusion will also influence state agencies as they strive to protect the correlative rights of landowners affected by ***hydraulic fracturing***.

Figure 1 Magnified view showing the flow of a fluid such as oil through a pore throat connecting two pores.

Figure 2 The relationship between porosity, permeability, and sediment grain size. Fine-grained sedimentary rocks such as shales have low permeabilities because of small pore throats.

Figure 3 The effect of saturation (two fluids) in decreasing the size of the pore throat and the effective permeability of oil or gas in the reservoir.

Figure 4 The effect of saturation on the relative permeabilities (k_r) of an oil (k_o) and a gas (k_g) reservoir. Note that lower oil and gas saturations are directly related to lower relative permeabilities.

Figure 5 Aerial view of a frac job. Modified from H.O. McLeod and G.D. Cooper, ″Field Implementation of ***Hydraulic Fracturing***,″ 12 *Society of Petroleum Engineers Monograph* (1989).

Figure 6 The wellbore with two induced ***fractures*** at 180° in the reservoir.

Figure 7 The relationship between induced ***fracture*** height and length. Note that for the same frac fluid volume, there is an inverse relationship between height and length. R.W. Veatch Jr., ″Overview of Current ***Hydraulic Fracturing*** Design and Treatment Technology-Part 1″, *Journal of Petroleum Technology* (1983).

Figure 8 Desired ***fracture*** length for various reservoirs. L.E. Elkins, ″Western Tight Sands Major Research Requirements,″ *Gas Research Inst./American Gas Assoc./U.S. DOE Intl. Gas Research Conference*, 1980.

Figure 9. Figures showing the increase in production revenue from longer ***fracture*** lengths (A), the increase in ***hydraulic fracturing*** costs with longer ***fractures*** (B), and the economically optimum ***fracture*** length (C). R.W. Veatch Jr., ″Economics of ***Fracturing***,″ 12 *Society of Petroleum Engineers Monograph* (1989).

Figure 10 A tiltmeter survey over an induced ***fracture*** in the sub-surface reservoir. L.L. Lacy and M.B. Smith, ″***Fracture*** Azimuth and Geometry Determination,″ 12 *Society of Petroleum Engineers Monograph* (1989).