# **Wellbore Pressure** and **Fluid Communication** Associated with **Hydraulic Fracturing**

## BRIEFING PAPER

## BACKGROUND

Wellbore pressure and fluid communication is the ability to detect pressure variations (increases or decreases) and fluid flows between wellbores during hydraulic fracturing. The ability to detect pressure pulses and fluid flow between oil and gas wells in conventional oil and gas producing formations is well known. Pressure pulses have been used by petroleum engineers and geologists for decades as an important tool to characterize and estimate various properties of producing formations and to determine remaining reserves. Fluid flow between wells is fundamental to enhanced oil recovery techniques in conventional formations, primarily water-flooding, which has been practiced essentially since the beginning of the oil industry and CO2 flooding, which has been practiced since the mid-1970's.

In hydraulic fracturing operations of nonconventional (shales and tight sands) formations, relatively large volumes of fluids are pumped into a producing formation at pressures greater than the formation's fracture pressure to create a fracture network. Since shale formations have extremely low permeabilities, the primary fracture network that is created during hydraulic fracturing operations is designed to extend radially up to several hundred feet (150-300 feet is typical, American Oil and Gas Reporter, July 2010, article by Kevin Fisher) out from the wellbore.

As a result, operators need to properly plan well completion operations to control pressure/fluid movement within the target geologic formation so that these changes do not adversely interact with nearby or offset wells. A critical aspect of this planning is to evaluate the area around the well to be fractured to identify offset wells that penetrate (or come close to penetrating) the target formation. The design and construction (including plugging) of each offset well meeting specific criteria should be reviewed to determine its ability to maintain pressure integrity should the new fracture network intersect with any existing fracture network or the wellbore.

Factors that should be considered in evaluating the integrity offset wells include well design and construction, casing depths, cement properties and placement, production and maintenance history and nay other relevant factors. With proper planning potential risks posed by pressure communication between wells can be safely and effectively managed.

# SCENARIOS

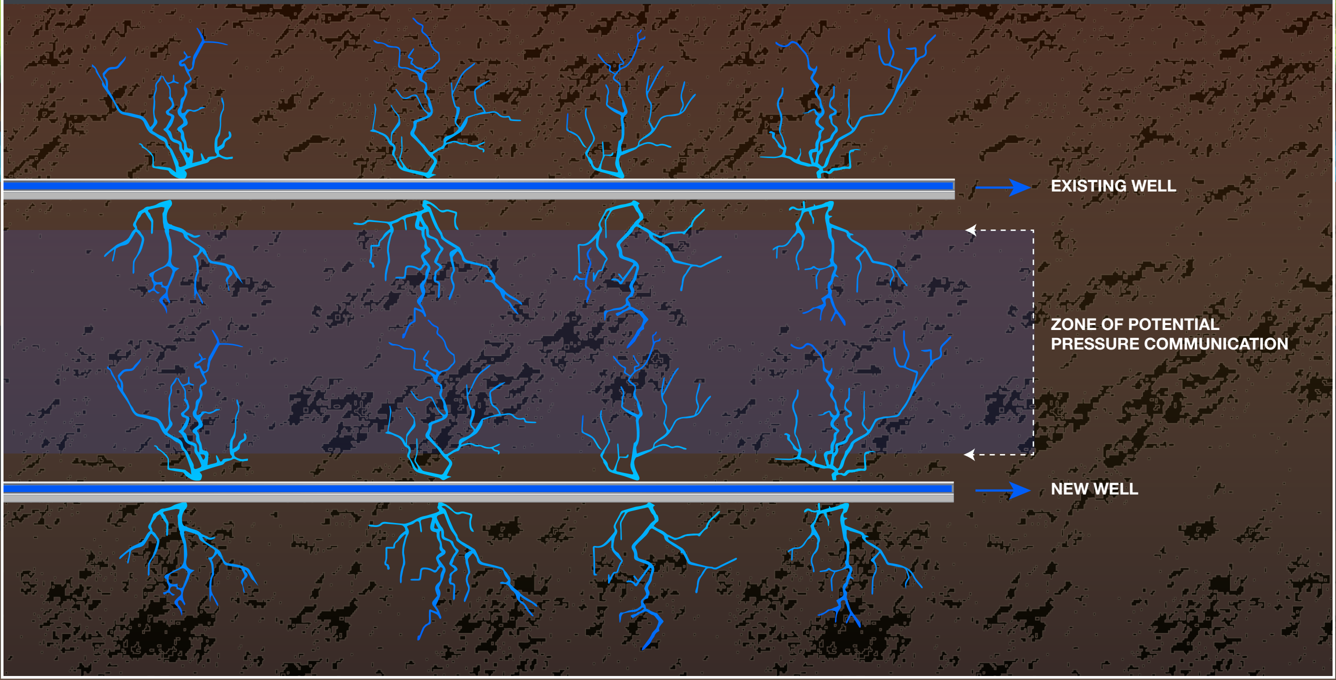
There are several general scenarios that could lead to wellbore communication. Understanding those scenarios is an important aspect of selecting the most effective monitoring and mitigation strategies to avoid an undesired outcome. The risks associated with pressure communication are associated with the exposure of the wellbore tubulars (production tubing or casing strings) or other equipment to excessive pressure or the introduction of fracturing fluids into a wellbore and associated production equipment or into other geologic formations.

**Fracture network intersection:** As the well density in a nonconventional formation (shale) increases, the potential for intersection of the fracture networks between wells also increases. The majority of these wells are vertical down to some point above the producing formation and then horizontal through the producing formation. Ideally, when a shale formation is completely developed for oil/gas production, the fracture networks of adjoining wells should fully penetrate the productive formation or may overlap slightly. If these fracture networks intersect, pressure/fluid from a well being fractured may be detected in an offset well through the producing formations and the production casing/tubing. The main source of risk is associated with the movement of pressure/fracturing fluid into that offset well. **See Figure 1**.

**Fracture network and offset wellbore intersection:** Many areas undergoing shale development have had prior exploration or development activity. As a result, the potential for existing wells (known or unknown), either producing, idle, or plugged, to pose a risk of pressure communication is present. The majority of these older wells are vertical to their total depth. Regardless of their operational status, any existing wells within a specified distance of the new well that comes close to or penetrates the formation that is being considered for hydraulic fracturing or nearby formations should be reviewed so that there is a reasonable degree of confidence that formation's isolation is maintained within the existing wellbores. In these situations, the point of detection of communication would most likely be a casing annulus, i.e. the surface casing by production (or intermediate) casing annulus. The main source of risk is associated with both pressure effects on the exposed casing string and with the potential for fracturing fluid to migrate into other formations via the conduit offered by the existing wellbores. **See Figure 2**.

**FIGURE 1.** Potential Pressure Communication Thru Fracture Network Intersection

(Plan View– Showing Horizontal Wellbore/Fracture Section)



## Isolation Verification, Mitigation, and Monitoring

With reasonable isolation verification, mitigation, and monitoring measures, the risk of a potential adverse outcome associated with communication between wellbores during hydraulic fracturing operations can be safely managed.

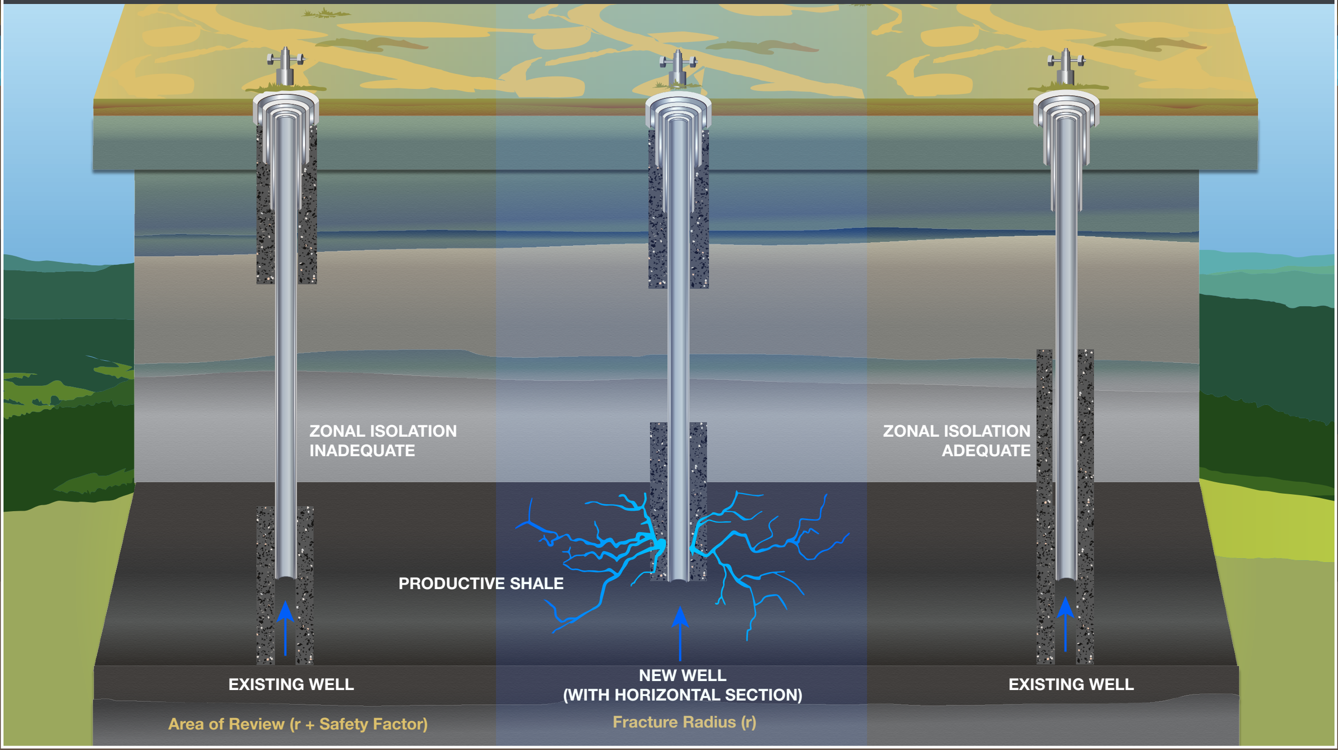
The first step in this process is establishing the criteria to identify offset wells for evaluation. The identification process should include existing and plugged oil and gas wells, injection wells, and water wells. The criteria used for this process should be based on regional geologic conditions, operator experience and available public information. One approach for establishing the size of the evaluation zone or area of review (AOR) is to use the estimated fracture radius (r) for the planned hydraulic fracturing job, including an appropriate safety factor. The AOR is the lateral and vertical distance around the new wellbore and the target formation that will be used to identify all existing or plugged wells for further evaluation. The magnitude of the safety factor should be based on modeling results, local experience, and prior job results.

Using available records, the operator should then identify all wells within the AOR and start the review process. The next step of this process is to eliminate all wells that do not penetrate or come near the target formation (using an appropriate safety factor) and therefore pose no risk of pressure communication. The remaining wells, those that do penetrate or come near the target formation, will require further evaluation; e.g. rock properties and fracture propagation and the design, construction and plugging status, if applicable, of those wells. At a screening level, this evaluation should result in the remaining wells being categorized as follows:

- Zonal isolation and construction adequate, monitor only,
- Zonal isolation and/or construction questionable, further diagnostic work required,
- Zonal isolation and/or construction inadequate, remedial action or mitigation plan required.

**FIGURE 2.** Potential Pressure Communication Thru Fracture Network/Wellbore Intersection

(Vertical View Showing Fracture Network and Casing/Cement)



# SUMMARY

Communication between wellbores during hydraulic fracturing operations has been a relatively rare occurrence. One source (King, SPE 152596, 2012) suggests that in a highly developed area like the Barnett Shale, fracture communication between wells occurs about 10% of the time and that fracture to wellbore communication may occur once every ten thousand hydraulic fracturing events. Regardless, where shale development occurs in mature producing areas or as shale development matures in newer development areas, the potential for pressure communication between wellbores is a risk that responsible operators will consider and can safely manage. When properly managed, the risks posed by potential communication can be safely and effectively mitigated.

This briefing paper describes general processes and procedures that responsible operators are following. It is important to recognize however, that case specific conditions can be highly variable and therefore any solutions can be highly individualized to meet those case specific conditions. There are no “one size fits all” solutions for sound risk management. Each case should be considered on its own merits.

The AOR used for identifying existing wells that could be affected by hydraulic fracturing operations should be established using reasonable criteria such as predicted fracture length and orientation with reasonable safety factors. The risk assessment of wells within the AOR should be based on reasonable event scenarios. Monitoring and remedial action decisions should be based on careful consideration of the specific conditions of each case and the near-term and long-term implications of those actions.

A determination that zonal isolation is adequate can be based on several factors including calculated cement volumes that fill the casing annulus to some reasonable height above the top of the target formation, proper cement pumping operations (cement volumes, displacement volumes, pumping pressures, and cement rheology) were within the planned parameters, no indications of cement channeling or lost returns, casing and tubing strength is adequate for the anticipated pressures, and an adequate number/placement of casing centralizers.

A determination that zonal isolation is questionable would be based on the design parameters described above not being met or from data that is questionable or unavailable. In these cases, additional diagnostic work should be performed on these wells conform their status and identify any necessary mitigation actions that should be taken.

There are several approaches operators can consider including pressure and pump testing and various electronic diagnostic tools to assess the quality and placement of cement and placement and the condition of the casing and tubing. Most diagnostic tools, while capable of providing valuable information, require a significant degree of skill and experience to interpret, thus overdependence on these tools is cautioned. After diagnostic analysis is complete, the questionable wells will be re-categorized as either adequate or inadequate. In some cases there may be challenges with access to wells operated by others or that are in an orphan or other unknown status. In those cases it may be appropriate for the operator to enlist the help of the state regulatory agency in resolving those challenges. A determination that zonal isolation is inadequate will lead to remedial action in most cases.

For wells that are not adequately plugged, additional cementing is the most likely remedial action, although case specific conditions may dictate other mitigation actions. For wells that are still active (production or injection), the proposed remedial action is a more complicated decision and should be based on the case specific situation and issues. Very importantly, perforating the production casing in a producing well to achieve improved zonal isolation should not be the default approach. Perforating the casing in a producing well can create additional wellbore integrity issues that should be very carefully considered before this approach is used. In some situations the best long term mitigation approach may be to simply monitor pressures and establish pressure thresholds that can be used to manage the hydraulic fracturing operation should the threshold criteria be exceeded.