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IMPACT OF TEMPORARY WELL SHUT-INS ON UNCONVENTIONAL RESERVOIR PERFORMANCE

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Authors:
Dr Tuba Firincioglu, Director Unconventional Reservoir Projects
Dr. Basar Basbug, Senior Consultant
Dr. Matt Freeman, Senior Reservoir Engineer
Vladimir Petunin, Senior Reservoir Engineer
Dr. Hulya Sarak, Reservoir Engineer

Abstract

This paper summarizes the expected reservoir response after temporary (3-6 month) shut-in periods, and the impact on oil production for different unconventional reservoir basins. The analyses discussed in this paper are based on NITEC's experience modeling unconventional reservoirs (UC) and our understanding of how these resources work. The results are based on new simulation forecasts from NITEC's extensive modeling experience with the major UC reservoirs. The results are generated using Ridgdeway Kite's 6X simulator. The figures are generated using NITEC's Lynx post processor. The findings represent example responses for typical wells within each basin. They may not apply to every well and every situation as they are merely examples and do not represent any specific asset or well.

The recent reduction in oil demand due to the COVID-19 pandemic will shape the oil industry in the upcoming months. Oil storage shortages in the United States have put an extra strain on the WTI pricing, which resulted in negative spot and front month futures prices during late April. Under these circumstances, oil companies responded by temporarily shutting-in production wells to prevent losing money on each barrel of oil they sell. The length of these temporary shut-ins is not known and will depend on how quickly the world recovers from the pandemic and the demand for oil returns.

When the market returns to more normal conditions and the shut-in wells are opened for production, the question will be, how will these wells perform after the temporary shut-in period? This issue needs to be addressed on two fronts: Reservoir and Operations. Once the reservoir response is understood, operational changes can be implemented to address the possible negative impact on production from the temporary shut-in period.

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Once a well is shut-in, the reservoir conditions near the well may change:

1. Pressure and fluid distribution around the wellbore, within the main SRV, and outside the main SRV
2. Connectivity distribution within the SRV
3. Local stresses within the SRV
4. Proppant distribution

These changes may have either a positive or negative impact on the production depending on the basin, its associated reservoir characteristics (matrix permeability, water saturation, presence of natural fractures), the characteristics of the hydraulically generated fractures (complexity-matrix access, tensile fracture extent, rate of fracture closure as a function of pressure, proppant placement) and the number of months of the shut-in.

This paper summarizes the expected reservoir response after temporary (3-6 month) shut-in periods, and the impact on oil production for different unconventional reservoir basins. The analyses discussed in this paper are based on NITEC's experience modeling unconventional reservoirs (UC) and our understanding of how these resources work. The results are based on new simulation forecasts from NITEC's extensive modeling experience with the major UC reservoirs. The results are generated using Ridgdeway Kite's 6X simulator. The figures are generated using NITEC's Lynx post processor. The findings represent example responses for typical wells within each basin. They may not apply to every well and every situation as they are merely examples and do not represent any specific asset or well.

Williston Basin

The Bakken and Three Forks wells will be positively affected by the shut-ins. Most wells will experience an increase in pressure due to the slow influx of fluids from higher pressure non-stimulated zones into the effective SRV. When the wells are re-opened using the same flowing pressure constraints as used before the shut-in period, the total liquid rate will increase due to the higher reservoir pressure in the effective SRV, providing higher oil rates. Higher water cut values may be observed for a short period of time followed by a brief period of lower water cut during the equilibration of the fracture and matrix conditions. Within weeks though, the water cut will stabilize at its pre-shut-in levels. Some of the Three Forks wells, if connected to the Middle and Lower Three Forks, may experience a drop in the stabilized water cut when compared to the pre-shut-in water cut values. This is due to the water slumping down through the fractures to the lower formations and away from the wellbore.

After the short initial higher water cut period these wells may sustain a higher oil production for a longer period. Eventually, both Bakken and Three Forks wells will return to their natural pre-shut-in production declines. Figures 1 and 2 are examples of the expected well behaviors for the Bakken and Three Forks, respectively. Please note that the examples provided below are for higher water cut areas of the Williston, as shut-ins will be more impactful in these areas.

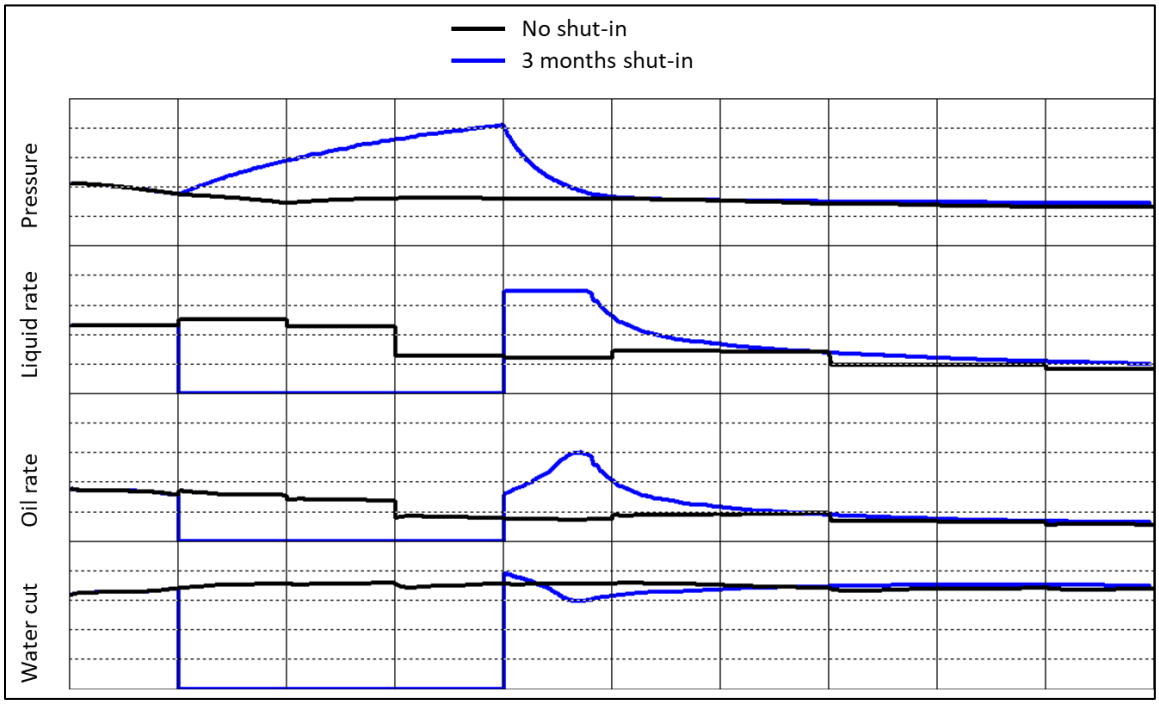

Figure 1. Bakken Well Example 1

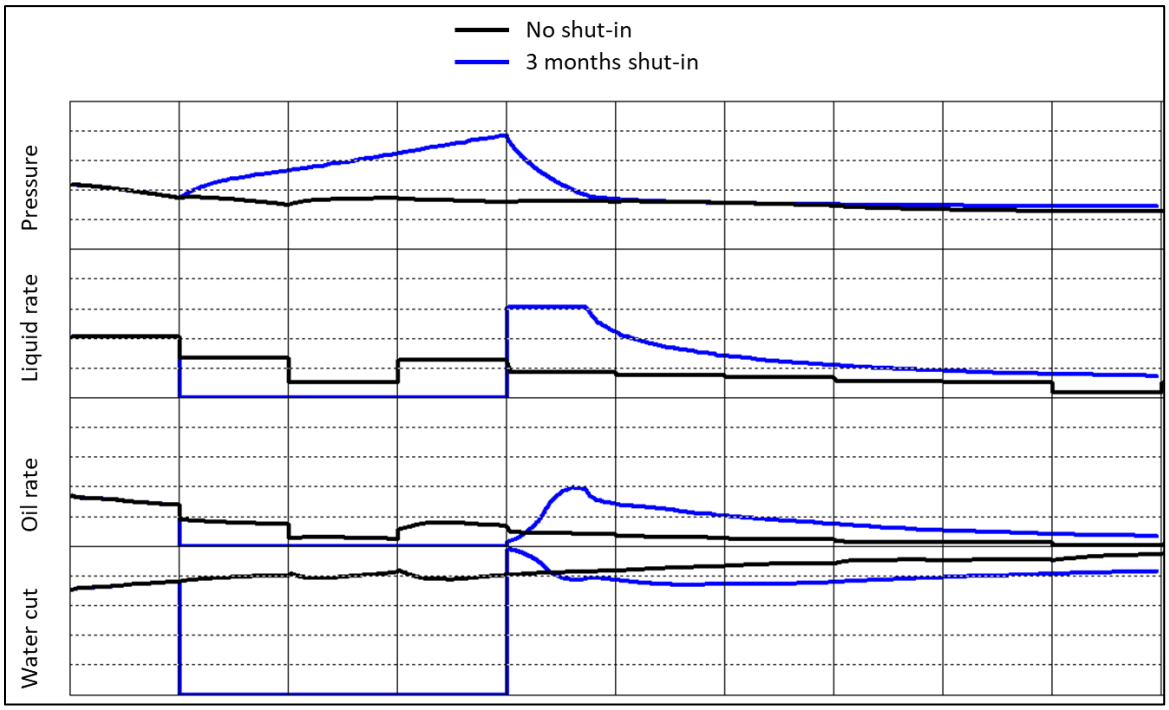

Figure 2. Three Forks Well Example 2

Delaware Basin

The impact of shut-ins on well performance in for the Delaware wells will depend on the vertical communication and the staggering of the wells. If the well is standalone or located stratigraphically in an upper layer, the oil production will be positively impacted by the shut-in. The pressure build-up related to the shut-in period will help to increase the total liquid rate. After the brief water cut increase period, the well will return back to the same oil rate as before the shut-in period. If the vertical communication is not limited, the water around the well will slump to lower layers resulting in lower sustained water cut values and higher oil rates as compared to the case with no shut-in.

In a staggered configuration, the well that is located in the lower portion of the reservoir will behave differently. The liquid production will also increase due to the pressure buildup , but for these wells in the lower portion of the reservoir, the water cut will increase due to gravity segregation. The well may or may not see a reduction in oil production depending on the vertical communication and proximity of the well above it. It is less likely for the lower well to experience an oil bump due to the pressure increase. Figures 3 and 4 show the performance of two wells that are located at the top and the bottom of a staggered chevron pattern, respectively. Figure 5 shows a cross sectional view of the water movement towards the bottom well.

Figure 3: Delaware Well Example 1

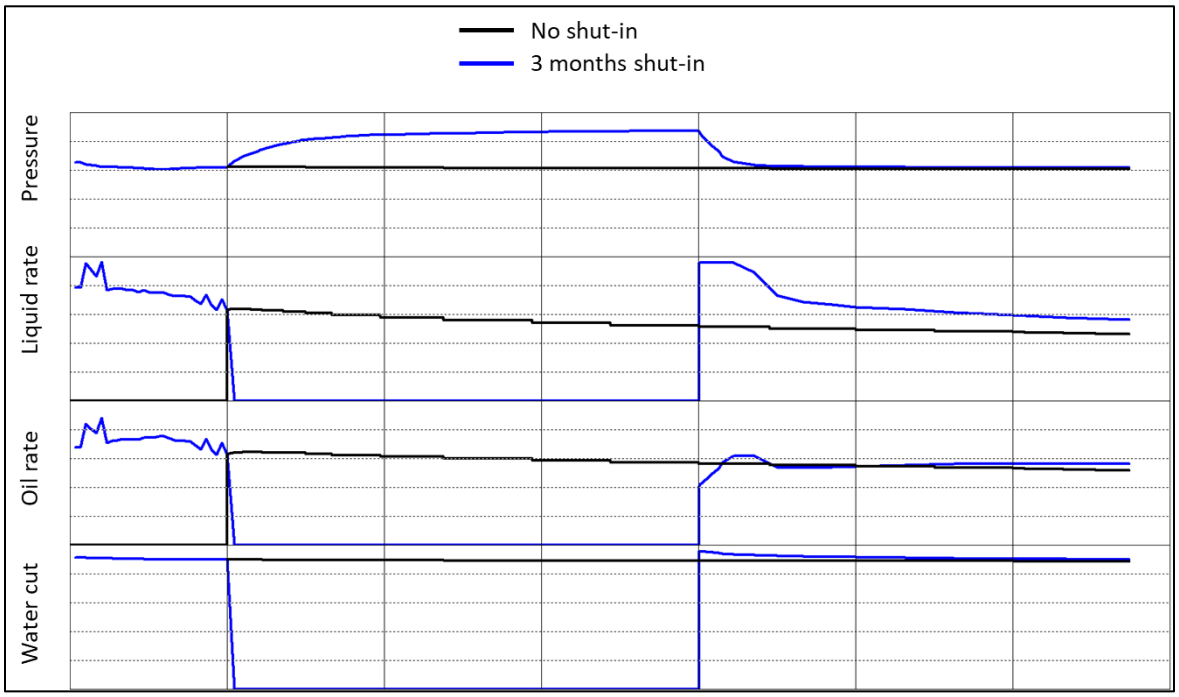

Figure 4: Delaware Well Example 2

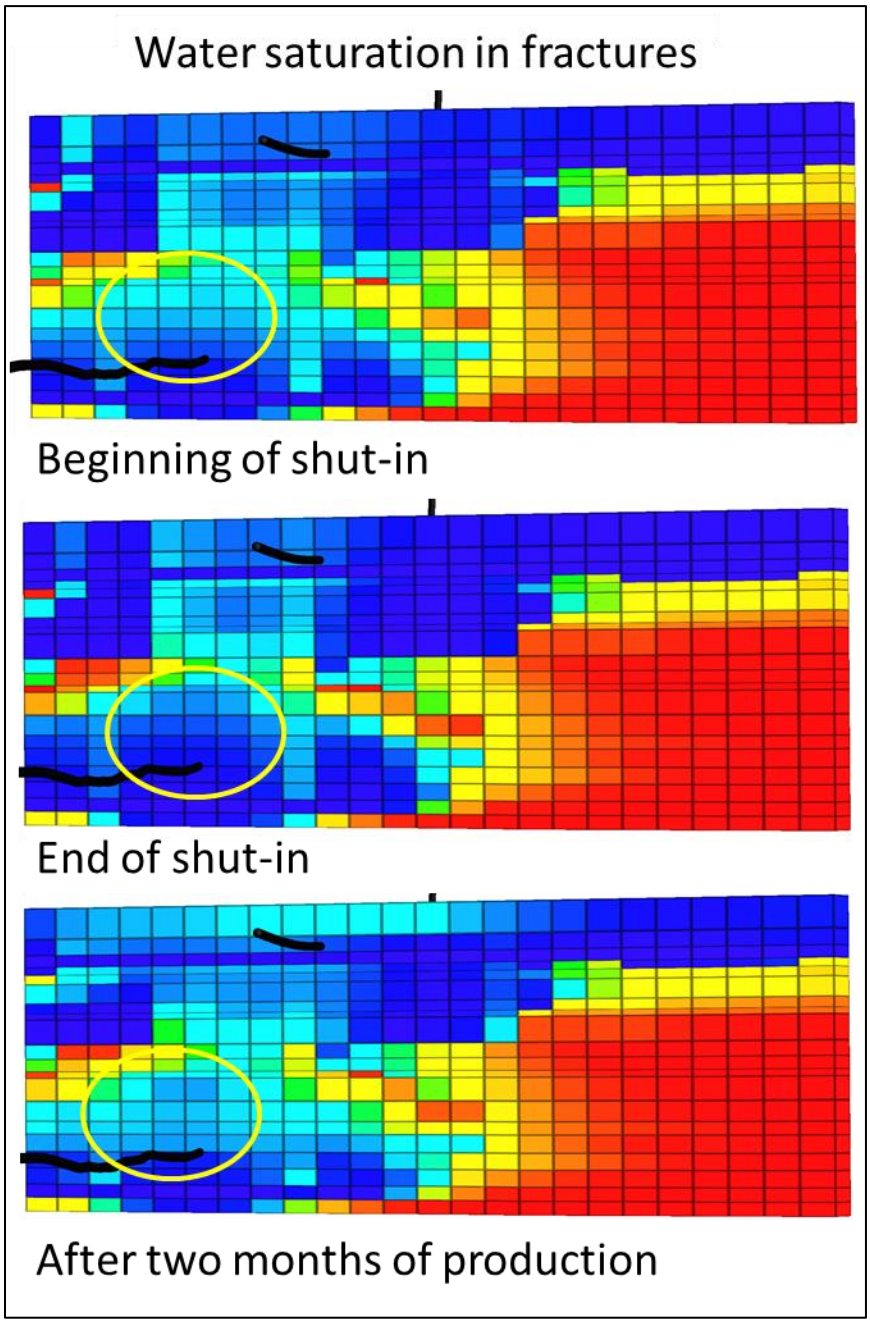

Figure 5: Water saturation change during shut-in –Delaware Example

Midland Basin

The Midland wells will generally not experience a negative impact from the shut-ins. These wells will come back with similar or slightly higher initial oil rates due to the pressure build up related to the shut-in period. Figure 6 is an example Midland well with a 3-month shut-in period.

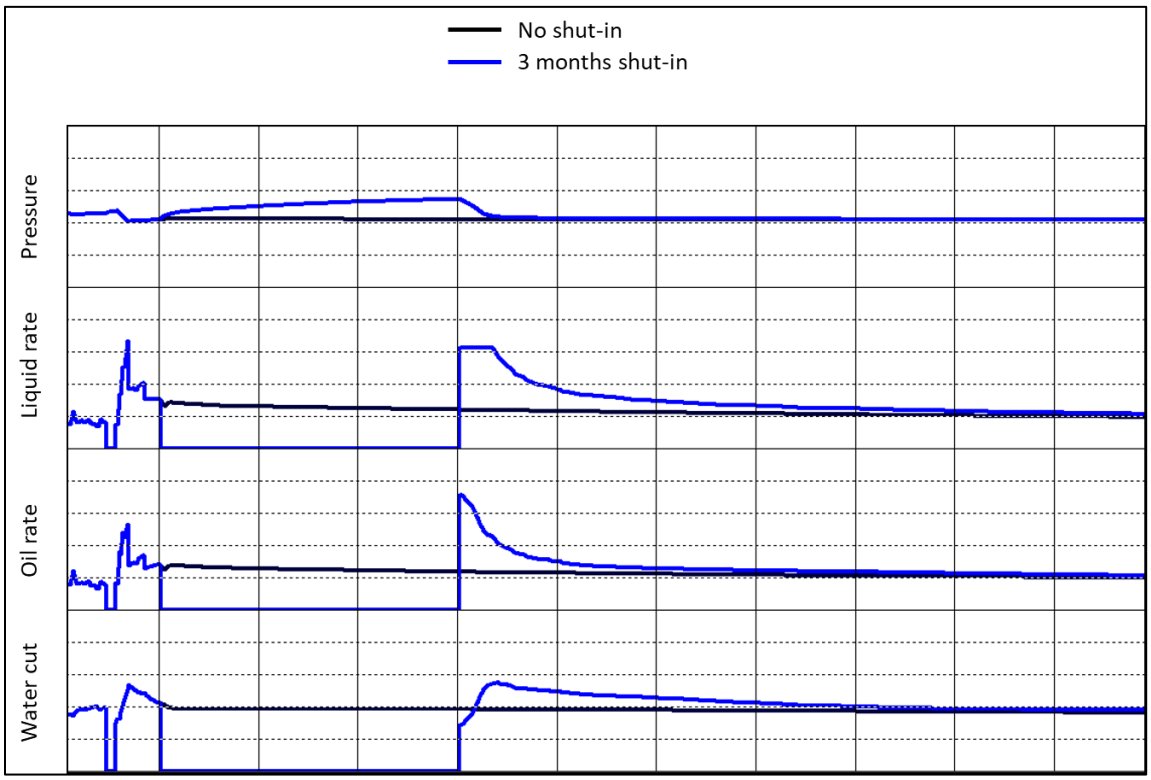

Figure 6: Midland Well Example 1

Eagle Ford Formation

Among the basins and formations discussed in this paper, the Eagle Ford stands alone as being the only true resource play. We do not expect to see significant changes in well performance after shut-ins unless very tight spacing is present in a DSU. Then the well shut-ins may impact the well interference, especially if the wells are located at structurally different elevations. Figure 7 shows an example Eagle Ford well response for a 6-month shut-in period. The pressure increase provides a very slight kick in production but the well maintains its original decline.

One issue that can complicate things in the Eagle Ford is the presence of bentonite. If a well is shut-in right after hydraulic fracturing was completed, then the injected water will remain in the formation providing more contact time with the reservoir rock. This additional water contact time may result in swelling of the bentonite facies causing a productivity reduction around the well.

Figure 7: Eagle Ford Well Example

Scoop and Stack – Osage Formation

In circumstances where a well drilled in the Osage Series can be treated as standalone, a lengthy shut-in will result in the gradual recharging of the fracture network with fluids. This recharging is very slow. Even after a 6-month shut-in period, the fracture network pressure and the well bottom-hole pressure will not have recharged back to the initial reservoir pressure. When production resumes, the liquid rate will be similar to the liquid rate observed at the same bottom-hole pressure during the initial drawdown. The initial post-shut-in water cut will see a spike lasting approximately up to one month before declining back to the baseline water cut. However, this increased water cut is not so severe that the net oil rate drops below the pre-shut-in level. Essentially, the oil rate remains stable before and after the shut-in, but water rate increases significantly for a short period of time.

The Osage and Meramec Series are known to be fractured. In circumstances where the wells are drilled and completed in a wine rack configuration and where the wells can be expected to be in communication through the fracture network, the shut-in period will tend to amplify and exaggerate the existing inter-well interactions. The water cut in the shallower wells where the inter-well communication is significant will drop when the wells are re-opened due to oil-water gravity segregation which allows the water to drain away from these shallower wells and into the deeper wells in the wine rack pattern. Consequently, the deeper wells in a wine rack pattern will experience a significant increase in their water cut values, due to the water slumping through the fracture network and into the SRVs of these wells, as depicted in Figure 9.

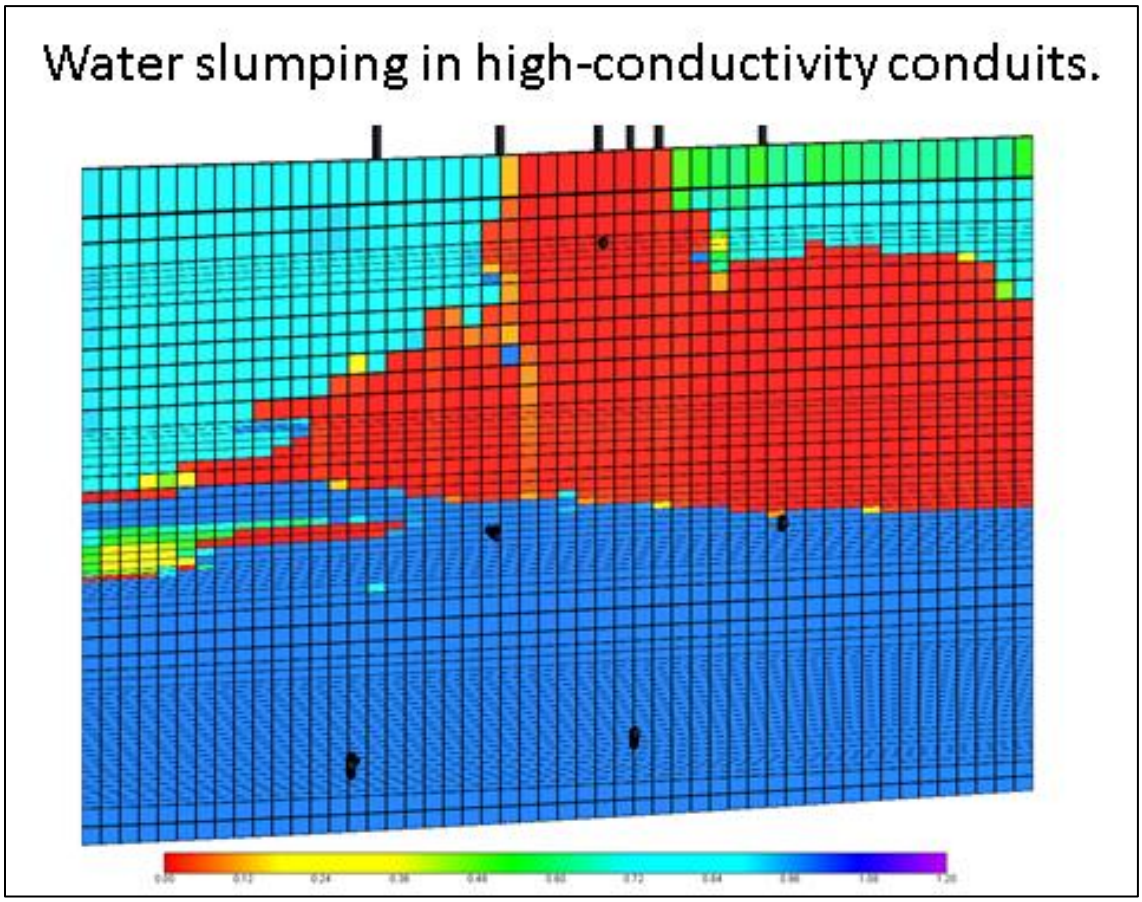

Figure 9: Water segregation in high conductivity fractures

Stress and Property changes around the well during shut-in

In unconventional reservoirs the reservoir properties change as a function of stress. No property remains static under the changing reservoir conditions related to production or shut-ins. During shut-in, when the pressure distribution changes, stresses and the fracture properties will change. Figure 10 shows the net stress in a DSU with three wells. Warmer colors show higher net stress, which is the difference between the pore pressure and breaking stress. At the beginning of the shut-in, due to the recent production, the net stress is high around the wells. At the end of the shut-in, the stress equilibrates. Once the production starts, net stress increases around the wells, becoming similar to pre shut-in net stress levels.

Figure 11 shows the connectivity change around a few sample wells during the shut-in period. Hot colors represent higher connectivity. As the pressure increases in the SRV during the shut-in period, the connectivity of the SRV increases due to the inflation of the fractures. After the wells

are opened the pressure levels return to their pre-shut-in levels, and consequently the connectivity levels also return to their pre-shut-in levels. This is one of the primary reasons why wells initially perform better after the shut-in. Figures 10 & 11 are an example from one basin of the changes in net stress and connectivity from one basin. The same changes (physics) applies to all the unconventional reservoir basins but will differ in magnitude for each basin.

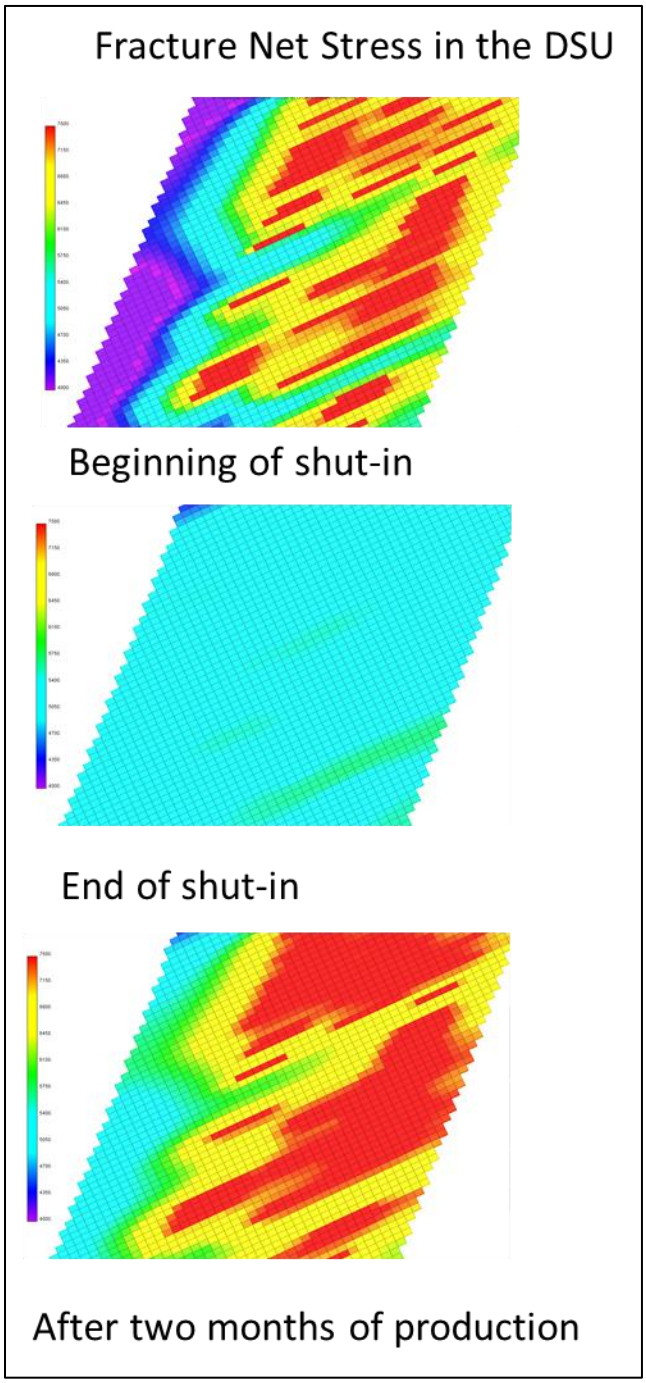

Figure 10: Net Stress change during shut-in

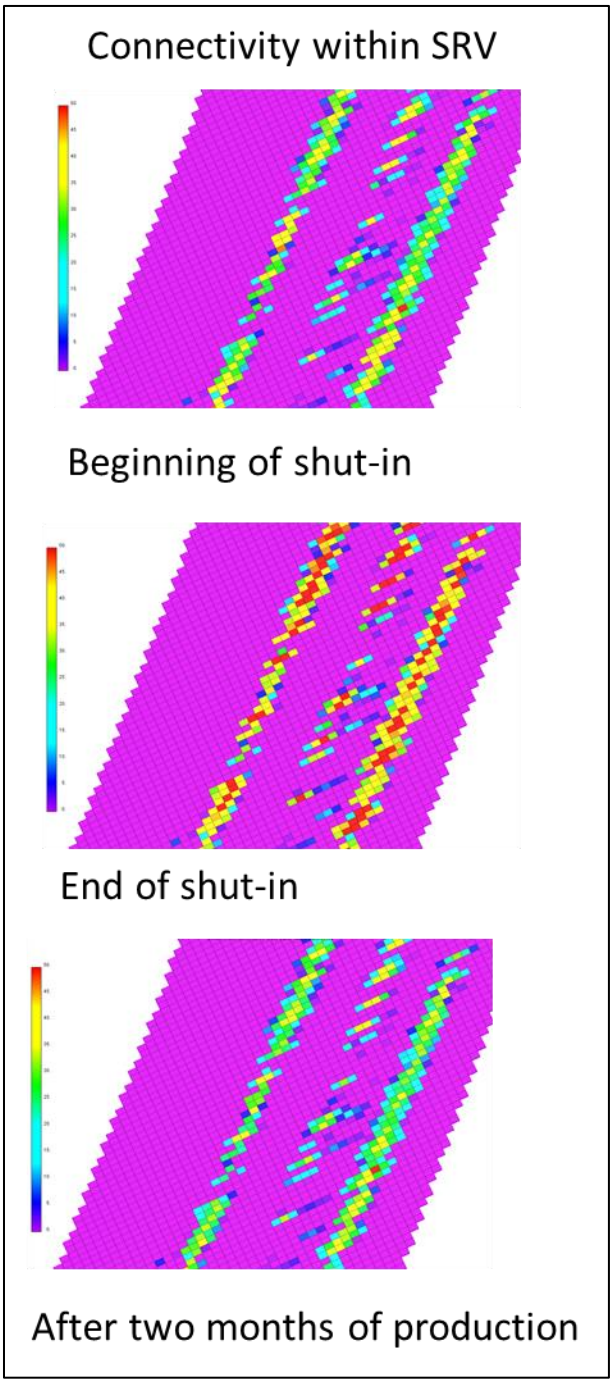

Figure 11: Connectivity change within SRV during shut-in