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Modeling Water Production in Tight Gas Formations after Hydraulic Fracturing

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Abstract

Tight gas formations with low permeability require hydraulic well stimulation to achieve economical production rates. While in some cases the desired increase in gas production rates can be achieved, there have been cases where greatly increased water production occurred, severely affecting gas production.
In the present study, we investigate the reasons for the increase in water production using a real-world field case. The study aims to uncover the mechanisms leading to this problem and to understand the sensitivity to field parameters in order to provide a matrix for early project de-risking.

We have developed a simple box model based on petrophysical data that allows us to match the production history with a minimum of assumptions through numerical simulations. In addition, flow regimes on the field scale were characterized by analyzing the water flow field and the spatial distribution of the macroscopic capillary and gravity number, indicating where the flow is driven by viscous forces, gravity, and where by capillary forces; A variation of the capillary number by several orders of magnitude results in a zone near the hydraulic fracture in which water accumulates by capillary suction. The extent of the zone is so great that the water supply to the well will be maintained for a long time; rather years than weeks.

In a further step, the sensitivities were examined by a tornado analysis to understand the relevant parameter space. After determining the ranges, we simulated production scenarios with different combinations of parameter values through experimental design methods. On the resulting response surface, regions of critical parameter combinations are identified in order to determine in which cases water production is expected after stimulation and in which the well can be safely stimulated. The model provides further guidance for a minimum set of petrophysical data needed to assess the risk of water banking due to well stimulation.