Integrating production geoscience and engineering: Can smart wells mitigate uncertain reservoir behaviour?*

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Geologic heterogeneity is a key control on fluid flow during hydrocarbon production. Typically, heterogeneity has an adverse effect on recovery, reducing the efficiency with which injected fluids such as water or gas can sweep hydrocarbons from the reservoir. To understand, model and predict fluid flow, it is essential to understand and model geologic heterogeneity. Yet this is challenging, because heterogeneity is complex and subsurface data is limited. Poor understanding of heterogeneity leads to increased uncertainty in predictions of hydrocarbon recovery, and increases the risk associated with hydrocarbon extraction. Worldwide, oil companies produce (on average) three barrels of water for every barrel of oil; a key cause of this excessive water production is geologic heterogeneity.

One approach to reducing uncertainty is to develop improved understanding and models of geologic heterogeneity and its impact on flow. However, this cannot eliminate uncertainty, because the large volumes of reservoir rock between wells are typically heterogeneous at lengthscales below the resolution of seismic data. Reservoir behaviour is always uncertain to a greater or lesser degree. An alternative approach to handling this uncertainty is the development of proactive reservoir management techniques, facilitated by improved technology. So-called 'smart' (also termed 'advanced' or 'intelligent') wells are equipped with downhole sensors to monitor well and reservoir conditions, and with valves (inflow control valves or ICVs) to control the inflow of fluids from the reservoir to the well. This combination of monitoring and control technology has the potential to mitigate uncertain reservoir behavior, because it allows the operator to manage production from single and multiple wells.

Despite their promise, only a small number of smart wells have been installed worldwide. One reason is that formulating control strategies to operate smart wells is challenging, because it requires the integration of geology (to understand what heterogeneities are present and how they may impact on flow), geophysics (to develop and apply suitable monitoring technologies) and engineering (to develop and operate inflow control valves). Control strategies can be either 'reactive' or 'proactive'. Reactive strategies change the settings of ICVs in response to adverse changes in flow, such as the arrival of unwanted fluids, measured within the well or the adjacent reservoir. Proactive strategies change the settings of ICVs in response to changes in flow measured or predicted in the

reservoir at some distance away from the well. The advantage of proactive strategies is that problems, such as the approach of unwanted fluids, can be mitigated before they impact production from the well.

This presentation describes ongoing research to use smart wells to mitigate uncertain reservoir behavior, including the development of new downhole reservoir monitoring technology. This technology allows flow to be imaged several tens to hundreds of meters away from a production well, which contrasts with most other downhole monitoring methods which sample only the region immediately adjacent to the well. Simulation results suggest that proactive control of inflow to the well in response to these monitoring data, using simple feedback control algorithms, can significantly enhance recovery even when the reservoir does not behave as predicted.