# Unconventional Multi-Well History Match and Optimization: A Bakken Case Study

CMOST-AI

## Benefits

- Novel way to history match multi-well child-parent interactions.
- Successful optimization of well spacing considering the impact of well-to-well interactions.

### Why Implement?

Appropriate placement of infill wells in unconventional resources is essential for large-scale development of these assets.

### Why Simulate?

Investigate scenarios at a multi-pad field scale level.

### Results

Realize a significant improvement in Net Present Value (NPV) over the base case development scenario.

Due to computational capacity and a lack of an established workflow, full field development scenarios for unconventional reservoirs using simulation modelling are rarely done. During a history match study, matching all of the well production data using consistent property modifications across the field is challenging. To predict how child wells will interact with parent wells without extensive data or time-consuming geomechanical calculations can be difficult. This study utilizes CMG's reservoir simulation technology to streamline these processes to perform a multi-pad history match and well density optimization.

## Workflow

An undersaturated black oil reservoir within the Bakken and Three Forks formations was investigated. The area consisted of six parent wells and four child wells which were completed using three different hydraulic fracture treatment designs: slick water, crosslinked gel, and a slick water-crosslink hybrid. An IMEX™ simulation model was constructed to represent the area and the fractures were modelled using CMG's planar fractures with assigned half lengths, heights, and conductivities. An areal view of the wells in the simulation model is presented in *Figure 1*.

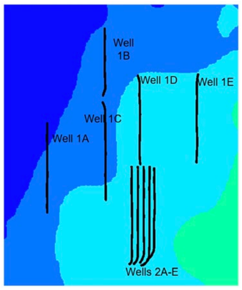


*Figure 1: Areal View of the Development Area*

To correctly predict the performance of future wells, a history match was performed using consistent modifications across the formation. The history matching challenge is that each well's historical performance is different. The difference in production is primarily the result of various fracture treatment designs. During the prediction period, these different treatment designs were evaluated to determine which gave the best performance. To address these two concerns, each fracture treatment design was assigned a unique planar fracture template with consistent fracture properties. With this approach, all stages were completed with the same design so that they had the same hydraulic fracture properties. This reduced the number of history matching variables by not having to match fracture properties on a per well or per frac basis.

The complete history match procedure was completed using a combination of CMOST™ and manual matching. To simplify the matching process and strengthen the predictability, the history match was completed in a series of steps:

1. History match a single well to obtain the matrix properties of the Bakken and the fracture properties of the slick water fracture type.
2. While preserving the matched properties from Step 1, complete a history match on a second well to obtain the properties of the Three Forks and crosslinked gel fractures.
3. Apply the final matched values to the remainder of the wells in a single field scale model and slightly adjust the height of the fractures.
4. History match the child wells to model the parent-child interactions. Obtain the slick water-X-link Hybrid fracture properties.

No local area modifiers were needed which yielded greater predictability for drilling new wells.

The final portion of the history match correctly modelled child and parent well behaviour. Three physical inputs were used as the critical parameters:

1. **Uneven half-lengths on the child well.** Both the "left" side and "right" side were history matching parameters.
2. **Overlapping fractures between the child and parent well.** The amount of overlap was varied to model the influence on the parent well.
3. **Accounting for frac-fluid from the child well.**

*Figure 2* shows the modelling of the child-parent interactions. The image on the left is an areal view. It identifies the uneven half-lengths of the child well as well as the connection and overlap with the parent fractures. The image in the bottom right shows the same phenomena with the wells going into the page (gun barrel view). The plot in the upper right is the water production of the parent well. The red box indicates the time when the child well is drilled leading to a spike in water production.

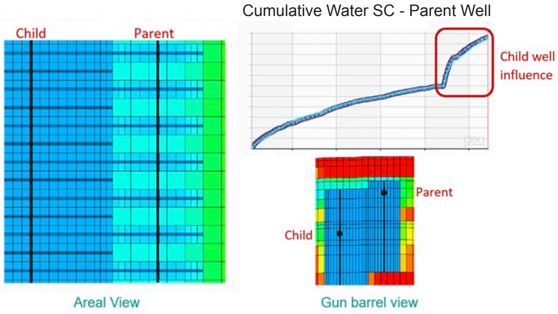

*Figure 2: Overlapping fractures and parent well water production*

## Results

A full field well density optimization was successfully performed in an area which contained previously drilled and depleted wells. Aside from using geomechanics, predicting how a newly drilled child well's fractures will grow and interact with a parent well is challenging. Leveraging the results of the history match, an analytical correlation was developed to describe the relationship between pressure depletion, distance and child well fracture half-length.

Although the ultimate objective of the study was to determine the appropriate well placement, other parameters influenced the results and could be optimized in parallel. Using CMOST, a net present value (NPV) optimization was performed on cluster spacing, proppant tonnage, well spacing and operating drawdown. The results determined that the well drilled adjacent to a parent well should be spaced at a larger distance when compared to successive infill wells. This is due to the parent well's influence. It was also discovered that at close distances to the parent, the nearest child well was highly sensitive to the NPV calculation. Once at a safe distance, the impact was diminished.

After the initial optimization, the drawdown was investigated. When a more aggressive drawdown was used, it promoted closer well spacing. This is because more oil was produced at early times and became less discounted by the NPV formula. Since the reservoir was undersaturated, a more aggressive operating strategy was possible.

Prior to performing a simulation study, an original well placement strategy was developed assuming no well interactions and similar performance of child and parent wells. *Figure 3* compares the optimal NPV case determined by CMOST to the original development strategy. From the figure a noticeable reduction in the proposed number of wells to be drilled is observed. This directly translates into lower capital costs and lower recovery. Despite a reduction in oil recovery, the optimal well spacing scenario yielded a 75% increase in NPV over the base case. Drilling a larger number of wells would result in greater recovery but not enough to counteract the adverse effects of well to well fracture driven interactions. This case study shows how CMG's simulation-based workflow can be used to solve large scale problems in a timely manner, which is vital in the continued development of unconventional assets.

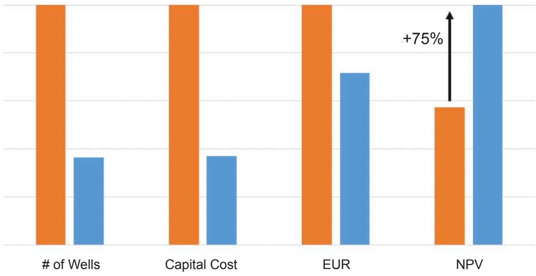

*Figure 3: Comparison between base design (orange) and optimal (blue)*

***This case study is based upon the webinar*** *"Unconventional Multi-Well History Match and Optimization: A Bakken Case Study" which can be found here: https://www.cmgl.ca/events/unconventional-multi-well-history-match-and-optimization-bakken-case-study*

*Thank you to Continental Resources for providing permission to publish this case study and present the webinar.*

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