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Prediction of Field Scale SAGD Performance based on Vertical Well Log Data

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Summary

This study investigates the performance estimation of Steam-Assisted Gravity Drainage (SAGD) using simulation results derived from vertical well log data in the McMurray Formation. Multiple reservoir models were developed to simulate SAGD performance, incorporating both homogeneous and heterogeneous modeling approaches. The homogeneous models utilized arithmetic and bottom-weighted averages, while the heterogeneous models employed layer cake and facies fraction-preserved approaches. The facies fraction-preserved model maintained anisotropic reservoir properties, honoring the observed facies fraction from vertical well logs. Simulation results from these models were compared to a reference model, where a horizontal well was positioned near the selected vertical well. Results identified the layer cake model as the most accurate for predicting SAGD performance based on log data.
Contour maps were subsequently created to estimate SAGD performance across different reservoir areas. Three mapping strategies were explored: (1) using the generally best-performing modeling approach across all performance parameters, (2) utilizing the dominant modeling approach for each parameter across the dataset, and (3) selecting the best modeling approach for each parameter and individual well. Among these, contour maps based on the parameter-specific and well-specific best modeling approach provided the closest performance estimates to the reference model. However, due to practical limitations in pre-determining optimal models for new areas, the layer cake modeling approach was recommended as a reliable alternative for generating contour maps. These maps can effectively estimate SAGD performance within specific drainage areas, providing valuable guidance for reservoir management and development planning.

Theory / Method / Workflow

This research estimates SAGD performance in the McMurray Formation using contour maps derived from simulation results based on vertical well log data. The well logs include key reservoir properties such as facies, porosity, permeability, and oil saturation as functions of depth.
The development of contour maps follows two main steps:

1. **Determining the optimal modeling method for SAGD simulation:**
   SAGD performance was simulated using reservoir properties extracted from vertical well logs. Input datasets were created using arithmetic average, bottom-weighted average, layer cake, and facies fraction-preserved approaches. Bottom-weighted average properties assigned 90% weight to the bottom seven meters of the reservoir and 10% to the remaining depth (Shin et al., 2019). The facies fraction-preserved model is a heterogeneous model that maintains the observed facies proportions obtained from well log data.
   SAGD simulations assumed horizontal wells with 800-meter lateral lengths and 5-meter well spacing. The reservoir pressure was set at 2,700 kPa, with injection and production pressures

of 3,600 kPa and 2,700 kPa, respectively. Additional operating conditions followed prior optimization studies in the McMurray Formation (Nguyen-Le et al., 2024).
Net present value (NPV) was calculated as a function of revenue, operating expenses, and capital expenses, with assumptions including a capital cost of 6 million USD per well pair (Nguyen-Le et al., 2024), a bitumen price of 48 USD/bbl, and a steam generation cost of 12 USD/bbl (Jaimes and Clarke, 2020; Sidahmed et al., 2019). Simulation results were validated against a reference model, which was based on a representative vertical well located near a horizontal SAGD well pair. The modeling method that best replicated the reference model's performance was identified most suitable for the McMurray Formation.

2. **Generating contour maps based on simulation results:**
   Three mapping strategies were applied:
   - Mapping using the generally best-performing modeling approach across all performance parameters.
   - Mapping based on the dominant modeling approach for each performance parameter across the dataset.
   - Mapping using the best modeling approach for individual performance parameters and wells.

Data from the selected modeling approaches were integrated, and SAGD performance results were spatially plotted and interpolated to generate contour maps. These maps enable performance estimation for SAGD well pairs across the reservoir using area-averaging techniques.

Results, Observations, Conclusions

Eight vertical-horizontal well pairs from a pilot area in the McMurray Formation were analyzed (Figure 1). Vertical well log data was processed to generate input for SAGD performance simulations using various modeling approaches. Horizontal wells served as reference models to validate the accuracy of the simulations.

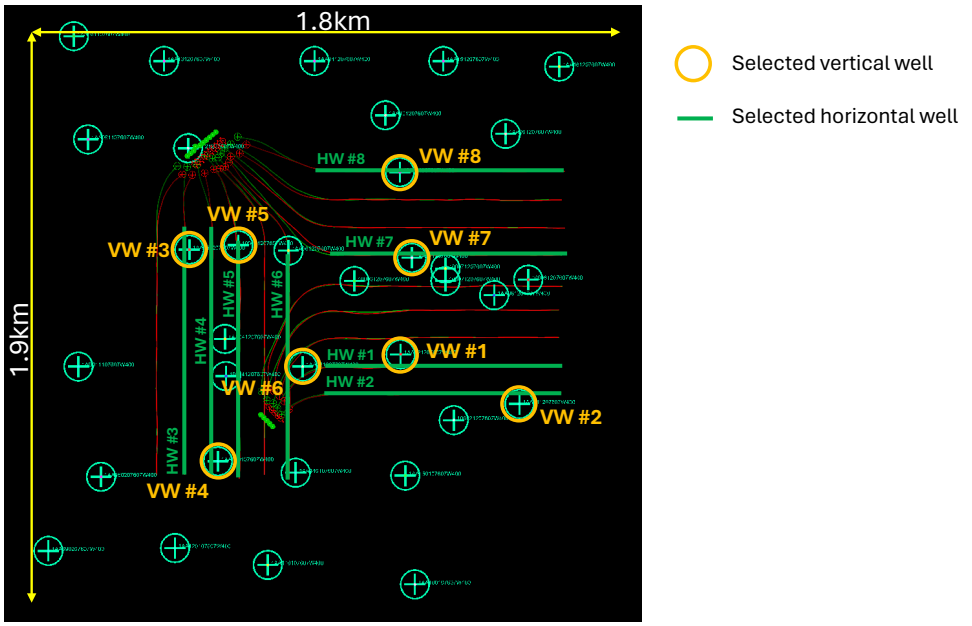

Figure 1. Selected vertical-horizontal wells for the modeling and simulation of SAGD performance.

The layer cake modeling approach showed as the most accurate for predicting SAGD performance, with results closely aligning with reference models (Figure 2). However, the optimal modeling approach varied by performance parameter and well model. For instance, at SOR = 4, the layer cake model dominated for cumulative steam-oil ratio (CSOR), calendar-day oil rate (CDOR), and NPV. In contrast, the homogeneous arithmetic average model was most effective for cumulative oil production.

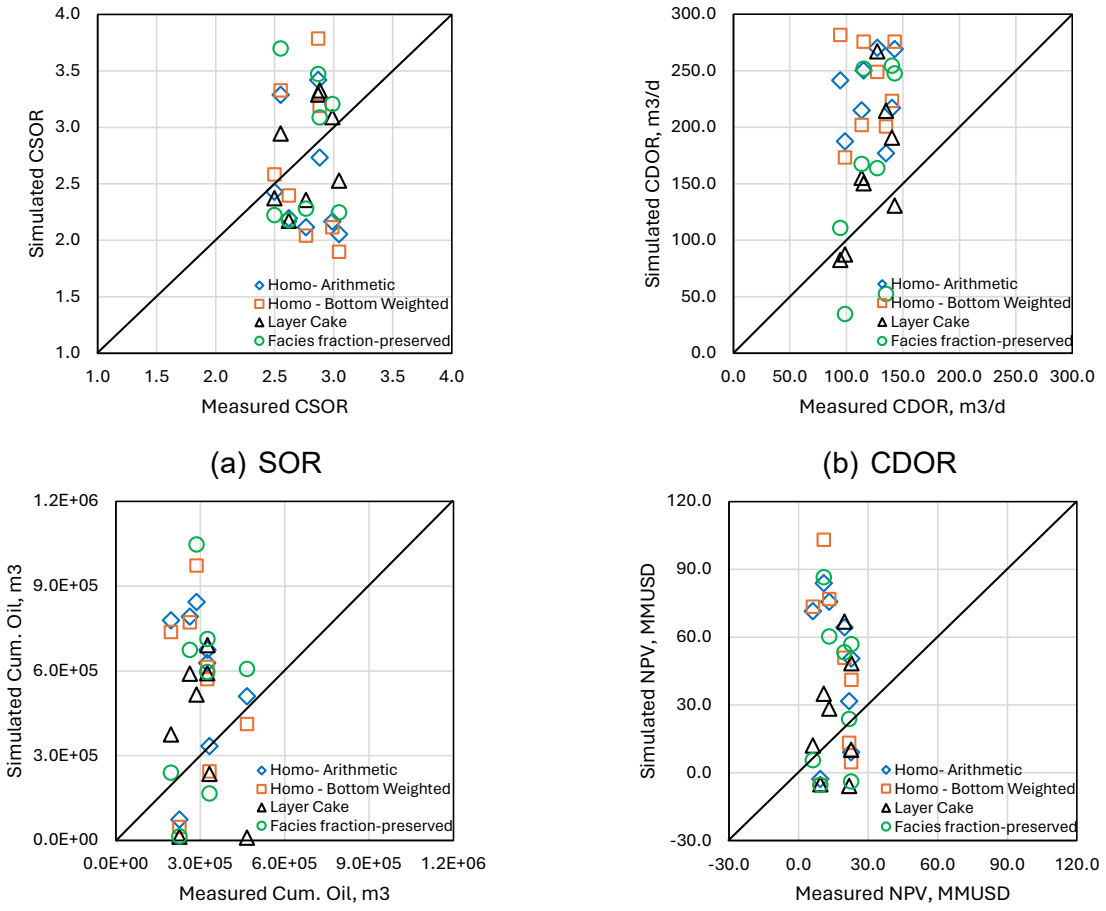

Figure 2. SAGD simulation results at SOR = 4 from different modeling approaches compared to that of reference models.

Contour maps were generated using the three mapping strategies. Among these, maps created using the parameter-specific and well-specific best modeling approaches yielded the closest performance estimates to the reference model (Figure 3). However, applying this approach to new areas is challenging due to the lack of pre-determined optimal models. The layer cake approach provided robust results, making it a practical choice for estimating SAGD performance and developing performance contour maps for unexplored regions. These findings demonstrate the utility of contour maps in predicting SAGD performance for specific drainage areas, aiding decision-making in reservoir development.

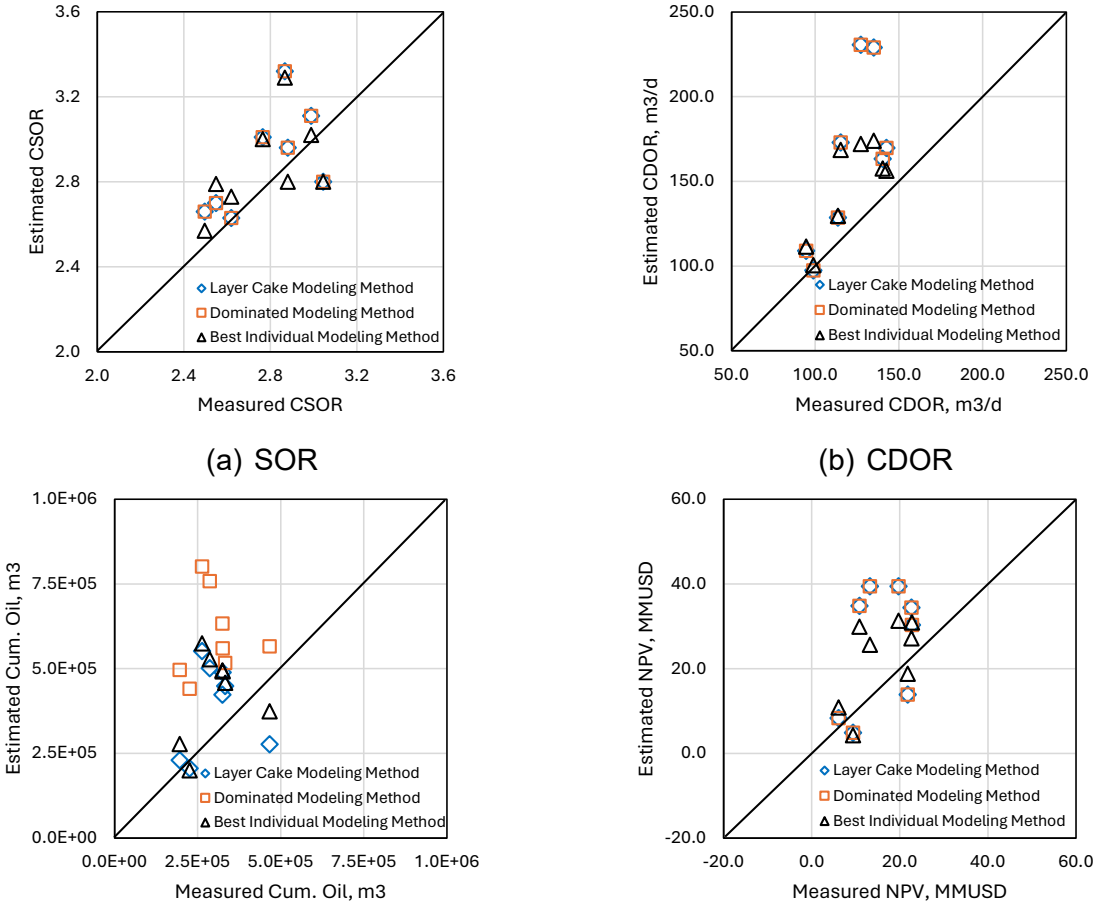

Figure 3. Estimated average SAGD performance at SOR = 4 from different contour mapping methods compared to that of reference models.

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