COMPUTER MODELLING GROUP LTD.

STARS

# CRC uses Simulation to Improve Economics in Bakersfield Thermal Project

CMOST AI

## Benefits

- Quantify recovery from field development options to screen thermal processes and determine optimal well pattern
- Well spacing optimization improved project economics
- Identified CSS as the best recovery process for short-term development
- Determined crestal steamflooding to be superior for long-term development, rather than pattern steamflooding

### Why Implement?

Reservoir with >100 years of production, with limited success

### Why Simulate?

Understand reservoir characteristics and identify optimum process to maximize recovery

### Results

Estimated **$10M to $15M USD** saved during years 1 to 5. **185x** cost/benefit ratio for simulation project

In 2006, California Resources Corporation (CRC) acquired the 35Z section of the Midway-Sunset reservoir, located 20 miles (32 km) southwest of Bakersfield, California. The reservoir contains heavy (13-16° API), viscous (450-1125 cp) oil in dipping sand packages.

Historically, primary production yielded a low recovery factor, and thermal processes had mixed success. In addition, the majority of CRC's 35Z wells have not been producing since the 1980's. Given the history of mixed success in the reservoir, and the variety of recovery processes applied, CRC undertook a project to understand the reservoir characteristics and response to recovery techniques prior to any significant development investment. The early characterization and modelling carried out on the 35Z section helped turn this development into a full-field thermal operation.

## Workflow

A multidisciplinary team of petrophysicists, geologists, and engineers created a geological model specifically for simulation and a built-for-purpose reservoir model. A three-component simulation fluid model was constructed, taking particular care to collect and match several viscosity measurements versus temperature. Analytical heat loss models for the underburden and overburden were applied to maintain heat loss accuracy without sacrificing runtime. This 3D compositional model used STARS™, a thermal and advanced processes simulator, to undertake the history match and forecast optimization.

Production fluid rates and well pressure data from newly drilled wells were used to calibrate the simulation model during the history matching process. CMG's automated history matching workflow was carried out using CMOST™ AI. Communication and input between the petrophysicists, geologists and engineers was key to achieving a history match.


*Midway Sunset reservoir location, approximately 20 miles southwest of Bakersfield, California, USA.*

The calibrated full field model was used to assess the feasibility of several reservoir development plans through simulation forecasts and optimization. CRC's goals were to evaluate the potential for thermal recovery versus cold production, and to estimate the performance of steamflooding versus Cyclic Steam Stimulation (CSS) for long-term field development. In addition, CRC also considered well spacing and operational parameters.

With CMOST AI, CRC used a sensitivity study to manage uncertainty in the geology and the model calibration, which was a result of the unavailable SCAL data in the relative permeability match. The model also contained a numerical aquifer, whose properties (size, compressibility) were not well known. Varying these properties within the forecast models assessed the sensitivity of the field development decisions, and determined which development plan should be used for each field case.

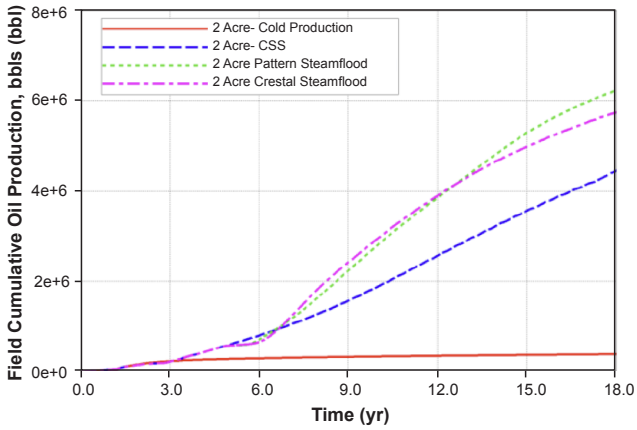
## Results

Full-field development plans were evaluated, designed, and implemented through pilot data gathering and simulation. Thermal recovery, including CSS and steamflooding, proved to be superior to cold production, resulting in significant oil recovery improvement.

Simulation identified the optimal short-term development plan is a CSS process with longer cycle times, whereas the optimal long-term development plan is crestal steamflooding. However, if geological continuity hinders crestal steamflood effectiveness, the forecasts show converting to a 5-spot pattern will also optimize oil recovery.

CRC realized significant economical improvements by switching the well spacing from 1-acre to 2-acre spacing for the life of the field. Taking into account the cost savings from drilling and servicing fewer wells, and the SOR improvement, CRC estimates a $10-$15 MM in savings over the first 5-years of project. Considering the relatively low cost of simulation compared to the project economics, this decision saved CRC $185 for each $1 spent on simulation.

The resulting project is well underway and currently consists of 40 cyclic steam wells at a 2-acre spacing. After completing several injection and production cycles, CRC confirms the well performance is similar to the simulation forecasts. Eventually, the field will switch to crestal steamflooding, as proposed by the simulation study results.




*Forecasted cumulative oil production, based on process; the results show Crestal Steamflood, using 2-acre spacing will provide optimal economics.*

*This case study is based upon SPE 185647-MS "Midway-Sunset 35Z Case Study: A Journey from Geo-cellular Grids to Field Operations"†. To read the full technical paper, please visit www.onepetro.org*

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