University of Regina

Performance Optimization of Hybrid Steam-Solvent (Huff-n-Puff) Processes in a Post-CHOPS Reservoir

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Problem Statement

Cold Heavy Oil Production with Sand (CHOPS) usually leaves the reservoir with about 85-90% of its OOIP. Implementation of the hybrid steam-solvent processes can improve mobility and increase oil recovery.

Objectives

The goal of this project is to evaluate the performance of the hybrid steam-solvent processes, determine which co-injected solvent mixture will optimize production and examine its effects on the huff-n-puff method.

Methodology

- Data collection form IHS AccuMap & AccuLog, and literature.
- Development a 3D reservoir geological model with CMG Builder.
- Material balance (MB) calculation to determine average reservoir pressure.
- Perform history matching with MBE and sand production history by CMG CMOST-AI.
- Evaluate performance of the best scenario of the hybrid steam-solvent processes.
- Examine the effect of variable time setting from sensitivity analysis.
- Perform economic analysis for the hybrid steam-solvent process.

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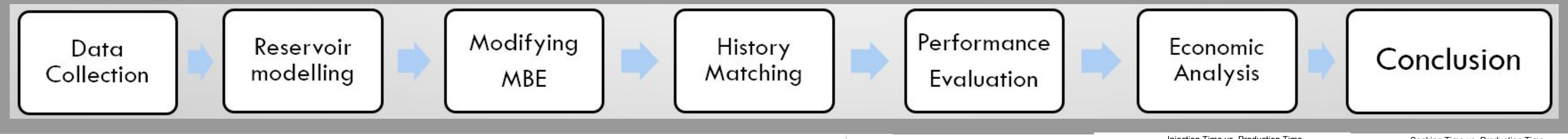
References

Songolzadeh, M., Soleimani, M., Takht Ravanchi, M., & Songolzadeh, R. (2014). Carbon dioxide separation from flue gases: A technological review emphasizing reduction in greenhouse gas emissions. *The Scientific World Journal*, *2014*, 1-34. doi:10.1155/2014/828131

Yang, S., Fan, Z., & Yang, D. (2020). A modified Pressure-gradient-based (PGB) sand Failure criterion for dynamically and preferentially characterizing WORMHOLE growth and propagation During Chops processes. *Journal of Petroleum Science and Engineering*, *192*, 107250. doi:10.1016/j.petrol.2020.107250

Design Process



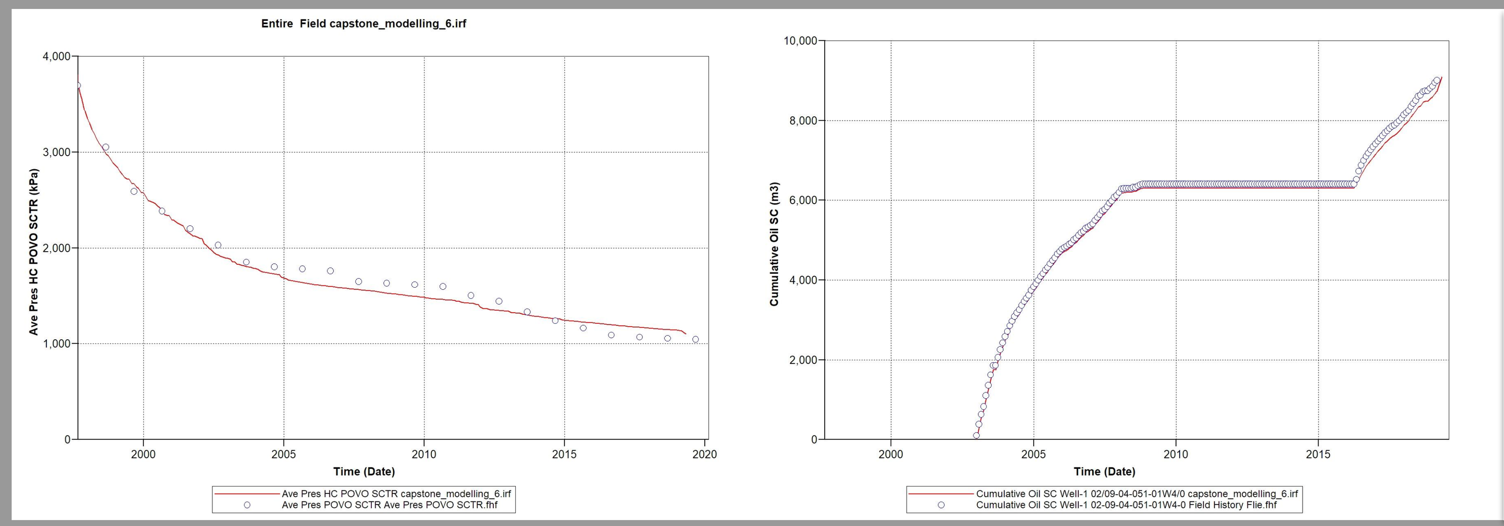


Figure 4: Reservoir Pressure History Match(left) and Oil Production History Match (right)

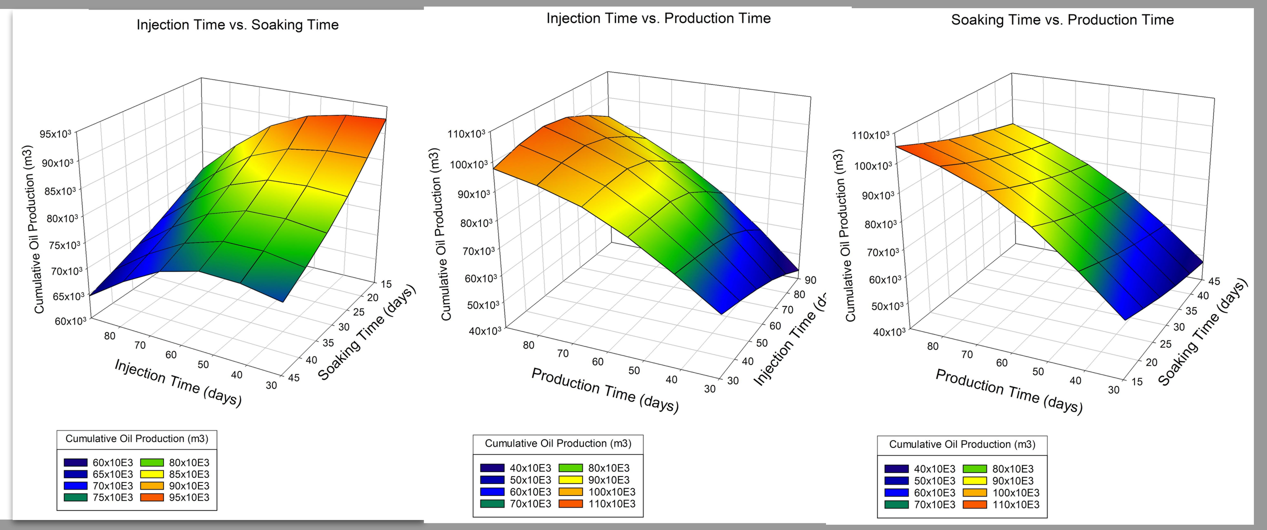


Figure 7: 3D plots with prinjection time, soaking time, and production time vs. cumulative oil production

Table 1: Thirteen scenarios for 10-year performance prediction in a Post CHOPS reservoir

Scenario No.	Compositions of the injected fluids
#1	100.0 mol% CO_2
#2	100.0 mol% flue gas
#3	5.0 mol% C_3H_8 + 5.0 mol% n-C_4H_{10} + 90.0 mol% CO_2
#4	5.0 mol% C_3H_8 + 5.0 mol% n-C_4H_{10} + 90.0 mol% flue gas
#5	100.0 mol% steam
#6	90.0 mol% CO_2 + 10.0 mol% steam
#7	90.0 mol% flue gas +10.0 mol% steam
#8	4.5 mol% C_3H_8 + 4.5 mol% n-C_4H_{10} + 81.0 mol% CO_2 + 10.0 mol% steam
#9	4.5 mol% C_3H_8 + 4.5 mol% n-C_4H_{10} + 81.0 mol% flue gas + 10.0 mol% steam
#10	10.0 mol% CO_2 + 90.0 mol% steam
#11	10.0 mol% flue gas + 90.0 mol% steam
#12	0.5 mol% C_3H_8 + 0.5 mol% n-C_4H_{10} + 9.0 mol% CO_2 + 90.0 mol% steam
#13	0.5 mol% C_3H_8 + 0.5 mol% n-C_4H_{10} + 9.0 mol% flue gas + 90.0 mol% steam

Field Background

Figure 1: Field Map (Retrieved from Accumap)

Table 2: Properties of Lloydminster CHOPS reservoir used in the simulation model

Reservoir Properties	Value
Well Location	C0/12-26-050-01W4/0
Depth to reservoir top (m)	550
Net pay (m)	4.69
Porosity	0.31
Oil saturation	0.75
Horizontal rock permeability kh (mD)	581.14
kv/kh	0.1
Effective rock compressibility (1/kPa)	0.0000485
Reference pressure (kPa)	3703
Initial reservoir temperature	22
Reference depth (m)	730

MBE Modification

The material balance equation is used to calculate the average reservoir pressure over time. (See Figure 2)

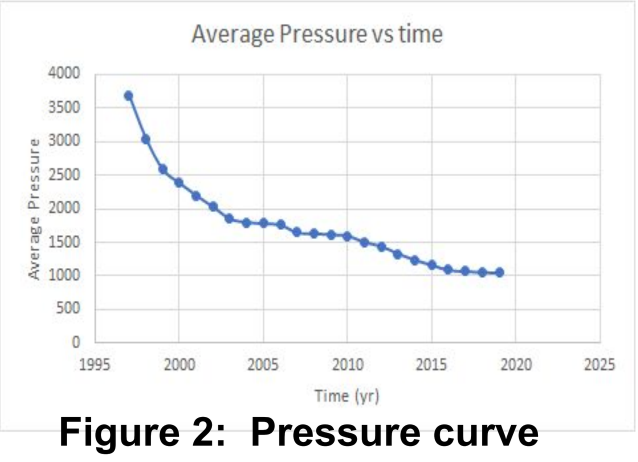


Figure 2: Pressure curve calculated from MBE

Reservoir Modelling

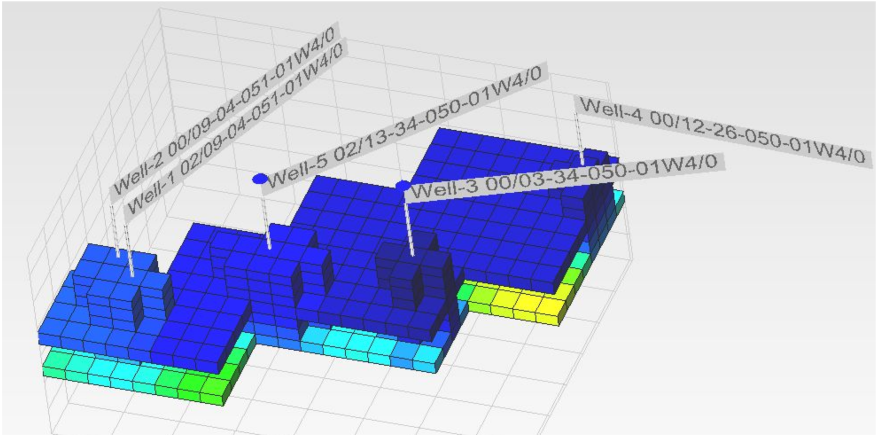


Figure 3: Reservoir model from Heavy Oil Post-CHOPS reservoir in the West Lloydminster Field and 3D model map

History Matching

- The reservoir pressure matches at an global error of 3% with production rate as as input constraints.
- The simulated sand production of well UWI 02-13-34-050-01W4-0 only has 5% error.
- Oil production profile were perfectly matched from 1997 to 2019 profiles for 5 wells.

Performance Evaluation

With 351 data retrieved from CMG STARS therma recovery simulator, the most optimal case is the 100 mol% of flue gas injection with injection period in 60 days; soaking period in 45 days and production period in 90 days

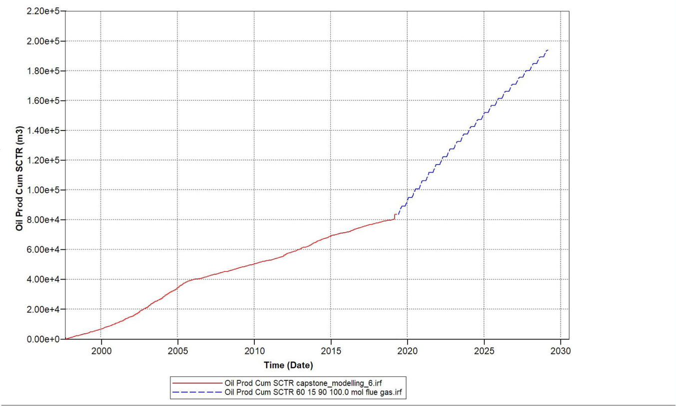


Figure 5: 10-year CSS performance prediction in a Post CHOPS reservoir with 100%mol flue gas injection method

Wormhole Generation

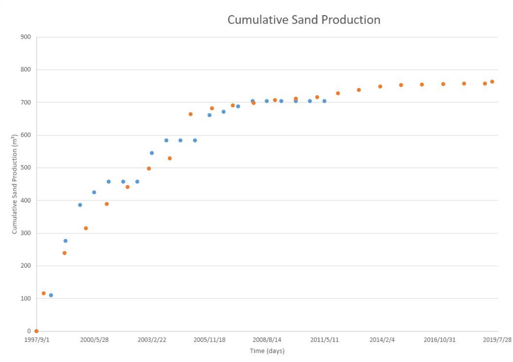


Figure 6:Sand Production History Match

Sensitivity Analysis

With the results from Figure 7 & 8, it can be concluded that the optimal case will be:

- A moderate injection time (60 days).
- A shorter injection time (15 days).
- A longer injection time (90 days).

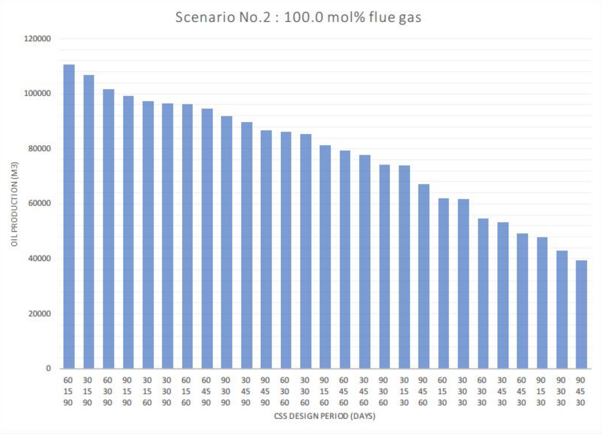


Figure 8: Cumulative oil production vs. different time setting for 100 mol% flue gas

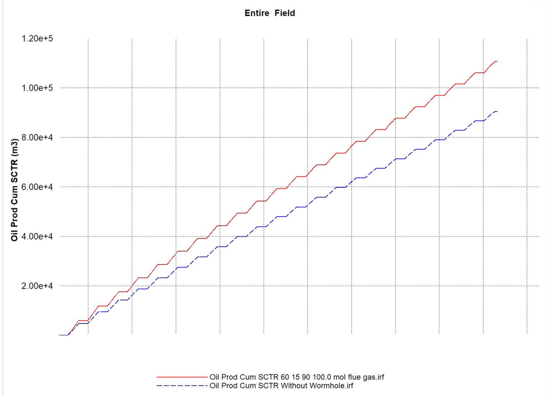


Figure 9:Wormhole Effect Comparison

Economic Analysis

- Using the 13 scenarios stated in Table 1, a Net Present Value (NPV) plot is generated for each scenario. The aim is to determine which scenario will achieve the highest NPV during a 10 year performance evaluation in a Post-CHOPS reservoir.
- The results show that Scenario #2 (100 mol% flue gas) gives the highest NPV value.

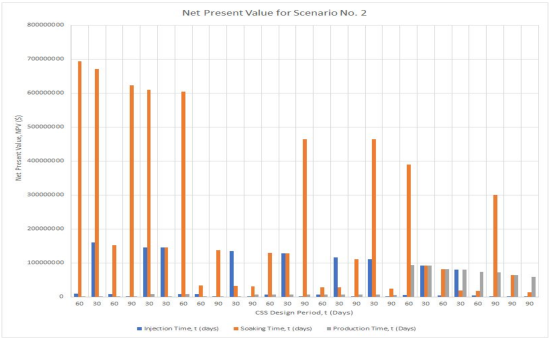


Figure 10: Net Present Value Calculation Results for scenario #2

Conclusions

- The optimal case for the steam-solvent injection in a post-CHOPS reservoir is 100 mol% flue gas and steam which produces an additional 1.1E6 cubic meters of oil during a ten year period.
- The wormhole network included in the geological model increases oil recovery under various hybrid steam-solvent processes.