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History Matching by Numerical Simulation for Undersaturated Oil Reservoir

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Abstract

A history-matching example is presented for undersaturted reservoir with a small aquifer that has been producing oil from two wells for two years. The methodology consists of building a simulation model and running a sensitivity analysis based on simulating a number of scenarios and uncertain aspects are tested and then compared with a base model. The sensitivity analysis was performed for each well, and pressure evaluation was included. The structures of this simulation include: using the early production data to identify original initially oil in place and porosity as the initial input parameters. The model parameters were adjusted to obtain the accurate water rate then the optimum development strategy of the remaining field life was predicted. A description of the model is provided along with sensitivity simulations and the results. Conclusion drawn from this history matching example include: (1) the worst scenario is to leave the field as it is, (2) the success shown by the scenario of drilling a new production well with adding polymer to the existing injection.

Keywords: History Matching, Undersaturated Reservoir, Numerical Simulation, Sensitivity Analysis

INTRODUCTION

Making the correct investment decision in the expensive and risky oil and gas industry, depends on the skill to predict correctly the future performance of petroleum reservoirs which has become one of the most key tasks of the reservoir engineer.

History matching using numerical reservoir simulation is used by the reservoir engineer to predict this performance and it largely depends on the assumptions made by him/her. This method involves alternating the of the reservoir properties in the model such that simulator reproduce the available observed data.

The model provided with all the necessary information, except the porosity whose was value was missing to be uniform for the entire reservoir. The material balance equation was used to calculate the porosity because the reservoir was above the bubble point pressure. This value is to be integrated before running the Eclipse model.

Problem Statement:

This study is to indicate which is the best strategy, and why does it work well by history matching the available data by numerically simulating them.

Study Objectives:

This study was conducted on a virgin oil field in order to achieve the following objectives:

- To identify original initially oil in place and porosity as the initial input parameters Using the early production data.
- To obtain the correct water rate by adjusting the model parameters.
- To predict the optimum development strategy of the remaining field life.
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1- IDENTIFYING THE INITIAL INPUT PARAMOURS

A. Reservoir STOOIP

As it was mentioned earlier, porosity is the single material balance equation unknown parameter. Rearranging the equation gives,

$$1-\left(\frac{N_p}{N}\right) = \frac{B_{oi}}{B_o}+\frac{B_{oi}}{B_o}\left(\frac{S_{wi}.c_w+c_{rock}}{1-S_{wi}}\right).\Delta \bar{p}$$

The above equation is used to calculate the oil in place relying on the fact that the reservoir remains above the bubble point pressure (3150 psia) during the initial stages of production and that there is negligible influx of water.

Assuming S_{wi} = 0.21 and in calculating B_o and B_{oi} , the gas-oil ratio initially is 0.29 Mscf/stb, STOOIP can be calculated as 7,638,076 Bbl's

B. Reservoir Porosity

Once STOOIP is calculated; the relationship:

$$STOOIP = V_b / B_{oi} \times Ø \times NTG \times S_{oil,}$$

can be used to calculate Ø that equals to 29%.

2- HISTORY MATCHING

After incorporating the required data, the model was run and for comparing of the calculated and historical values, the bottom-hole pressures was plotted against time in figure 2 and likewise oil production rate was also plotted against time in figure 3. An excellent match was shown specifically to oil production rate. The pressure profiles were offsetting from one another primarily as a result of the different start they had at the early time. The good match does not always mean that the model is accurate as it simply by estimating some parameters over others might lead to that.

Finally, water injection period followed by the primary production was included while running the model. For analyzing the model, the calculated values were compared to the historical ones in terms of water production rates as in figure 4 and bottom-hole pressures as in figure 5. The mismatch is quiet significant largely because the enormous uncertainty in the second layer permeability. Because other parameters are much more certain, it was focused to vary the second layer permeability for obtaining good match. The approach was to determine the uncertainty degree by varying the permeability with an increment darcy's unit to start notice the shifting of the curve up and to the left. It turned out that a permeability of 4100 md was the best match for these criteria. The simulation runs are shown in figures 6 and 7.

It could have achieved better match by changing other parameters such as permeability in other layers, the ratio kv/kh, and net-to-gross. Using a uniform kv/kh ratio generally has a big error because it may vary from one layer to another. Increasing this ratio will lead to sharper water front with later breakthrough time as a result of the gravity forces effect.

3- OPTIMUM DEVELOPMENT STRATEGY PREDICTION FOR REMAINDER OF FIELD LIFE

According to the available budget for drilling two more wells or injecting polymer at the same cost, it is aimed in this part of the study to predict the development strategy after trying different scenarios and choosing the best of them to be adopted in the remaining field life. The sweep efficiency and reaching the maximum economic limit were used as criteria of comparison in seven scenarios, it turned up that drilling one more production well in addition to adding polymer to the existing injection well is the best strategy (refer to figure 8 and table 1).

This strategy has two advantages; firstly, it will be able to reach the reservoirs segments that cannot be reached using one production well and, the better mobility and sweep efficiency that will be achieved by the higher viscosity of the polymer.

To leave the situation “as it is” was the worst-case scenario since it gave the lowest flow efficiency, as well as the lowest cumulative oil production, and high water cut. In this scenario, the flow twisted paths was established since the very beginning of injection, because of that, injecting more water will leave behind some of the same un-swept oil.

Table 1: Summary of the Different Scenarios Results.

No.	Technique	FOE	Life Span
1	Keep The Situation As It Is	55.4	MAY/2022
2	Drill One Production And Add Polymer To The Current Injection	68.2	SEP/2022
3	Drill One Injection Well And Add Polymer	50.3	MAR/2021
4	Drill Two Wells (One Production And One Injection)	53.7	FEB/2012
5	Drill One Injection Well	44.3	SEP/2019
6	Drill One Sidetrack And Add Polymer To The Current Injection	40.5	JUN/2021
7	Drill Two Production Wells	62.4	SEP/2022
8	Drill One Sidetrack And One Injection	40.9	JUN/2021

CONCLUSION:

After preparing, building, and running the base model, number of scenarios were tried and it has been concluded from this history-matching example that the worst scenario is to leave the field as it is because of the lowest flow efficiency it gave. Furthermore, the scenario of drilling a new production well with adding polymer to the existing injection showed a great success, so it was recommended as the best development strategy for the field.

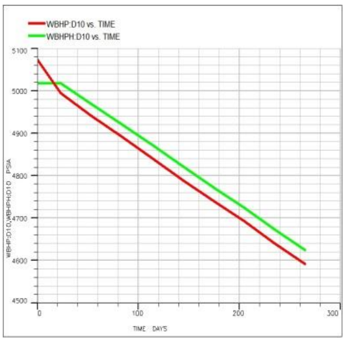


Figure 1: Historical and Calculated Bottom-Hole Pressures.

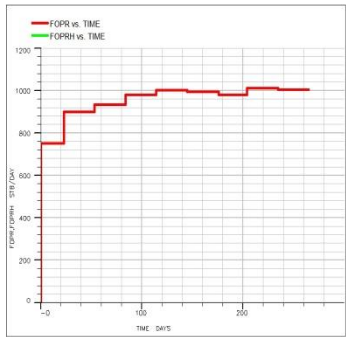


Figure 2: Historical and Calculated Oil Production Rates.

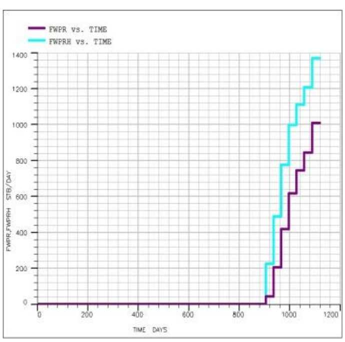


Figure 3: Historical and Calculated Water Production Rates.

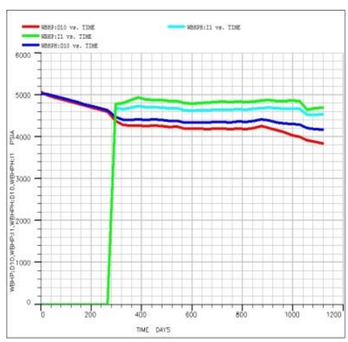


Figure 4: Historical and Calculated Bottom-Hole Pressure

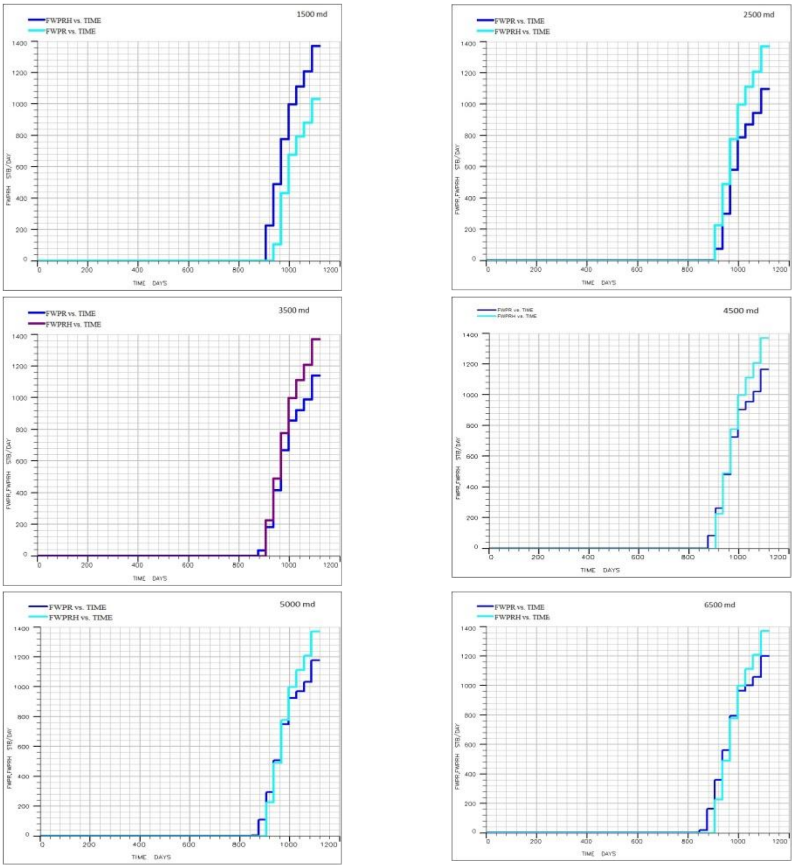
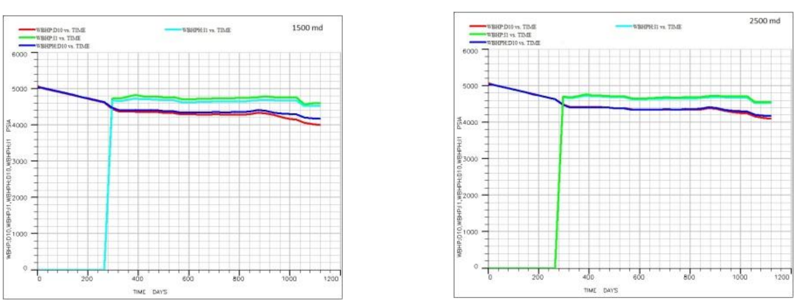


Figure 5: History Matching Of Water Production Rates



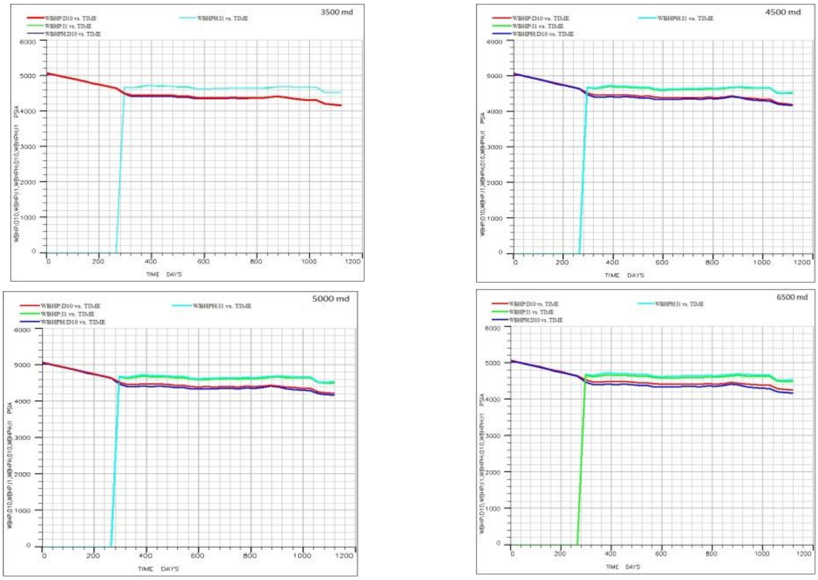


Figure 6: History Matching of Bottom Hole Pressure.

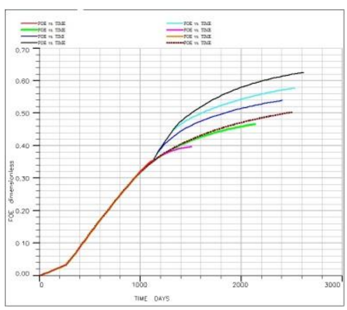


Figure 7: Scenarios Sweep Efficiency.

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