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RESERVOIR MANAGEMENT BY IDENTIFYING SUBSURFACE UNCERTAINTIES AND IMPACT ON RECOVERY FACTOR AND PRODUCTION RATE

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Abstract

Understanding and management of subsurface uncertainties has become increasingly important for oil and gas companies to optimize reserve portfolios, make better field development decisions , improve day-to-day technical operations such as well planning and field development cost reduction.

The studied reservoir is located at carbonate sequences of Ilam formation, Iran; Average porosity and water saturation of the reservoir is about 25% and 43%. In this study, uncertainty analysis for three scenarios (natural depletion, Production with electrical submersible pump and Water Injection) were conducted to evaluate the complete range of uncertainties of Case study field simulation model. Sensitivity Analysis quantifies and apportions the uncertainty in a model's estimates based on the uncertainty in the model's parameters.

Key Words: Reservoir Management; Uncertainty; Recovery Factor; Production Rate.

1. Introduction

Petroleum reservoir management is a dynamic process that recognizes the uncertainties in reservoir performance resulting from our inability to fully characterize reservoirs and flow processes. It seeks to mitigate the effects of these uncertainties by optimizing reservoir performance through a systematic application of integrated, multidisciplinary technologies. It approaches reservoir operation and control as a system, rather than as a set of disconnected functions. As such, it is a strategy for applying multiple technologies in an optimal way to achieve synergy.

The reservoir management process must be tailored to individual fields depending on:

- ✓ Size
- ✓ Complexity
- ✓ Reservoir and fluid properties
- ✓ Depletion state
- ✓ Regulatory controls
- ✓ Economics

2. Methodology

With today's software, constructing a 3D geological model of the reservoir is relatively simple. Once a model is constructed, it should be easy and automatic to construct multiple versions. It was postulated that constructing multiple 3D models is the only way to assess the cumulative impact of data, interpretation, and modeling uncertainties on reservoir management decisions [6].

A typical 3D uncertainty analysis workflow is as follows:

(i) Evaluate the uncertainties – taking each step of the workflow along with all the parameters involved, one must quantify how much is unknown about each one of them.
(ii) Integrate the uncertainties – through the construction of a complete reservoir model;
(iii) Analyze the impact of constructing multiple models on the metrics used to make a decision.

(iv) Iterate to reduce the uncertainties until the risks are minimized sufficiently to allow decision making [1,3].

The main objective of this study is to uncertainty quantifying of the objective function. To meet this goal, the following procedure should be done.

1. Run Base Case
2. Define Objective Function
3. Identify Uncertainty Factor and Ranges
4. Sensitivity Analysis
5. Identify most influence Parameters
6. Uncertainty Analysis based on Experimental Design
7. Generate Result for each Scenario

Uncertainty analysis for three scenarios (natural depletion, Production with electrical submersible pump and Water Injection) were conducted to evaluate the complete range of uncertainties of Case study field simulation model. Sensitivity Analysis quantifies and apportions the uncertainty in a model's estimates based on the uncertainty in the model's parameters. Thus, sensitivity analysis can be used to determine the relative significance of reservoir parameters.

3. Run Base Case

Following parameters were considered as well and field operational constraints for three scenarios (Natural depletion, Production with electrical submersible pump and Water Injection):

- In all scenarios full field prediction is extended to 25 years.
- Target of field oil production rate is set to 10000 STB/day.
- Minimum wellhead pressures were taken 400 Pisa and 100 Pisa in terms of natural flow and utilizing artificial lift – multiphase pump - respectively.
- Maximum water cut (WCT) is set to 20%.
- Minimum well oil production rate is set to 60 STB/day.
- Maximum field gas oil ratio (GOR) is set to 1800 SCF/STB by attention to ability of surface facilities.
- Maximum well gas oil ratio is set to 600 SCF/STB in case of defining ESP in wells due to pump GOR constraint.

3.1 Scenario One - Natural Depletion

The well pattern is containing 4 horizontal wells.

3.2 Scenario two – Production with electrical submersible pump (120 HP)

Second scenario is containing natural depletion with an alternative well head pressure of 600 psi – in base case WHP is considered as 400 psi – and production with artificial lift. By using multiphase pump on surface for increasing the WHP up to 400 psi, the constraint of WHP could be decreased to 100 and as an alternative 50 psi in this scenario of artificial lift.

3.3 Scenario three – Water Injection + ESP (60 HP)

Water injection scenario – with considering electrical submersible pump in production wells - was studied. For this purpose four wells producer and four wells injector are defined on reservoir flank. Comparison of oil recovery factors, field oil production rate for these three scenarios are shown in Figure 1 and respectively.

4. Define Objective Function

An objective function can be the result of an attempt to express a business goal in mathematical terms for use in decision analysis, operations research or optimization studies. Objective function was defined to implement sensitivity analysis of case study field:

Objective Function = Cumulative Oil Production /Originally Oil In-Place (Recovery Factor)

The objective function indicates how much each variable contributes to the value to be optimized in the problem.

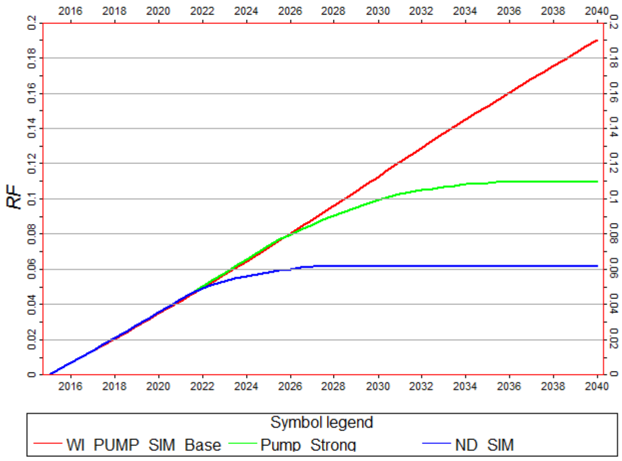

Figure 1 Comparison of oil recovery factor for three scenarios

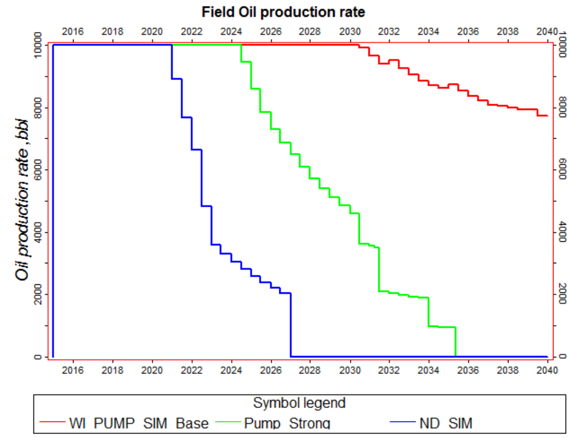

Figure 2 Comparison of field oil production rate for three scenarios

5. Identify uncertain factors and ranges

The purpose of this section is to prepare the input data to use in sensitivity analysis of case study field model. Due to the use of a static model with Geostatistical derived properties, there is the possibility of including Geostatistical parameters as uncertain parameters. Table 1 contains a summary of the input distributions type and their ranges for Model. Low and high values of factors were obtained by the following, in order of priority: statistical analysis of data, analogy, and personal judgment [1].

Table 1 Summary of Input Data for Model

Parameter	Distribution	Low	Base	High
Top Structure Depth	Seed	-10 s.d[1] (m)	0	+10 s.d (m)
Oil Water Contact (OWC)	Triangular	-3475 (m)	-3435	-3391 (m)
Vertical to Horizontal Ratio (K_z/K_x)	Uniform	0.1	0.2	1
Residual Oil Saturation (R.T 1)	Uniform	0.25	0.35	0.4
Residual Oil Saturation (R.T 2)	Uniform	0.25	0.38	0.45
Aquifer Porosity ($\varphi_{Aquifer}$)	Uniform	0.04	0.001	0.18
Aquifer Thickness ($h_{Aquifer}$)	Uniform	20 (m)	0.1	100 (m)
Aquifer Permeability ($K_{Aquifer}$)	Uniform	1(md)	0.001	30 (md)
Porosity Trend	Porosity Decreasing Ratio from Top into Bottom: List (1,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0.1)			
Permeability	This parameter is depends on Porosity			
Irreducible water saturation	This parameter is depends on Porosity			

6. Sensitivity Analysis

Design sensitivity analysis plays a critical role in inverse and identification studies, as well as numerical optimization, and reliability analyses. A crucial question that may be asked during exploratory reservoir analyses and data gathering is: "What is the relative significance of different reservoir parameters?" A parameter is significant if the knowledge of its exact value results in an appreciable reduction in the uncertainty of model estimates.

Updating of prior models of uncertainty generally requires complicated, expensive, laborious and time-consuming analyses. Sensitivity analysis is frequently performed to gain a better understanding of the influence of variables or parameters on the distributions of uncertainty. However, most sensitivity analysis approaches are not reusable because they are built for particular problem settings and specific applications.

Equal spacing sampling method was used to conduct sensitivity analysis of field model. Two samples were considered for each parameter. Finally, 2000 runs were performed to obtain relative significance of different reservoir parameters. Tornado chart was used to identify the factors that caused the greatest impact.

7. Identify Most Influence Parameters

Implementation of Sensitivity analysis on model using uncertain parameter described before would yield the tornado chart of Figure 3.

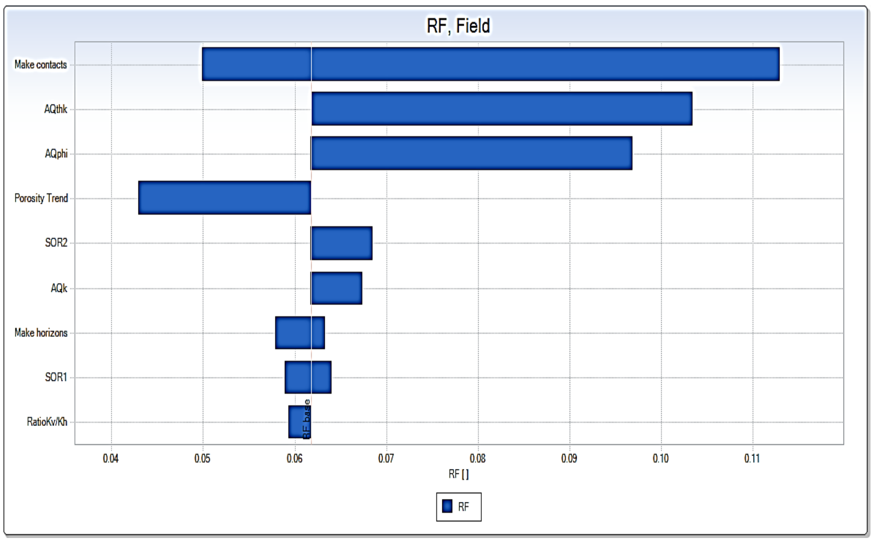

Figure 3 Tornado Chart resulting from implementation of sensitivity analysis on case study field model at year 2040

All major subsurface uncertainties identified and listed in Table 2. The list was developed from experience gained during simulation model building, analogy with a similar nearby reservoir, and expert field knowledge. There are 5 factors.

Table 2 Original Uncertainty Factors and their Ranges

Factor	Low	High
Oil Water Contact (OWC)	-3475(m)	-3391(m)
Residual Oil Saturation R.T 2 (SOR)	0.25	0.45
Aquifer Porosity ($\varphi_{Aquifer}$)	0.04	0.18
Aquifer Thickness ($h_{Aquifer}$)	20(m)	100(m)
Porosity Trend	Porosity Decreasing Ratio from Top into Bottom: List (1,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0.1)	

8. Uncertainty Analysis based on Experimental Design

These approaches rely on simulation results to identify factors that have the largest impact on objective function. A fractional factorial sampler (full factorial) was chosen for its usefulness in screening a relatively large number of factors with an adequate number of simulations. With the use of experimental design it is possible to study the impact on parameters on a response without doing a mono-parameters sensitivity study which can be very time-consuming and does not explore the whole uncertainty domain. It investigates the effect of the various variables simultaneously in a series of experimental runs. A specific combination of properties (input variables) at different levels that make up multiple realizations of the 3-D geologic model. The results were analyzed to obtain the relationship between the input variables (properties) and the output responses.

9. Generate results for each scenario

The main objective is to quantify the uncertainties associated with reservoir performance simulation. In the following sections, three scenarios will be discussed.

9.1 Scenario One - Natural Depletion

The Base Case model was intended to provide the most likely scenario based on the current facies interpretation, core data and well production data. The range between the smallest and largest oil recovery factor values quantify the uncertainty associated with the reservoir simulation performance prediction (Figure 4).

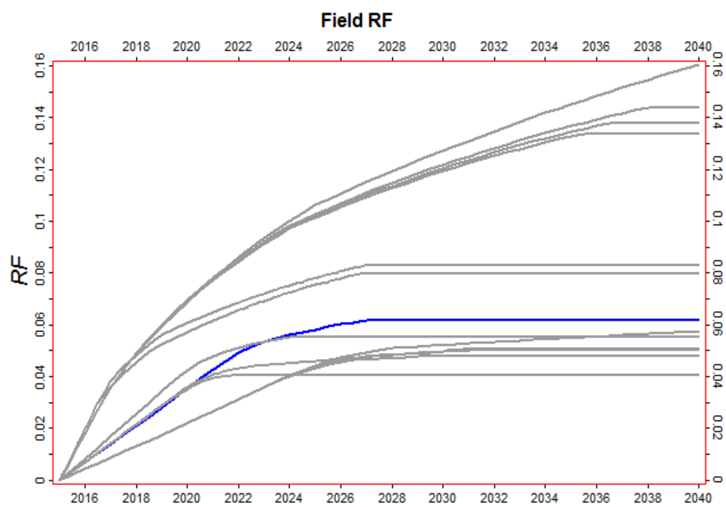

Figure 4 Oil recovery factor uncertainty quantification for natural depletion scenario

Figure 5 shows the optimistic and pessimistic conditions of oil production rate for natural depletion scenario.

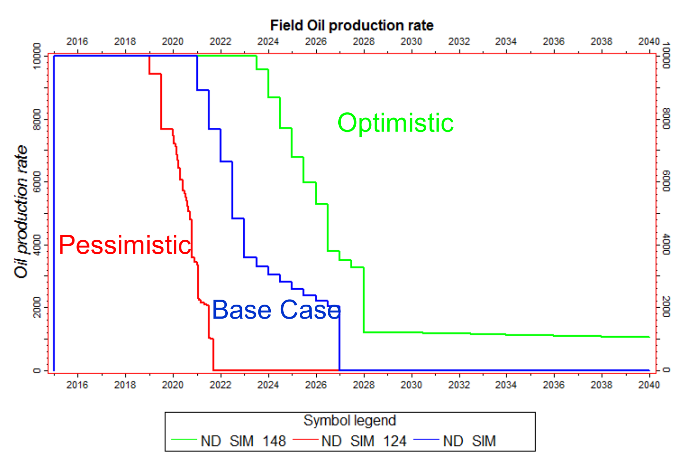

Figure 5 Comparison of oil production rates of base case (Blue), optimistic (Green) and pessimistic (Red) condition for natural depletion scenario

9.2 Scenario two – Production with electrical submersible pump (120 HP)

Another case for improving reservoir recovery is defining electrical submersible pumps (ESP) in the wells; this pump has been designed for production wells of case study field by attention to specific factor in this field. Uncertainty analysis was conducted and the results are shown in Figure 6.

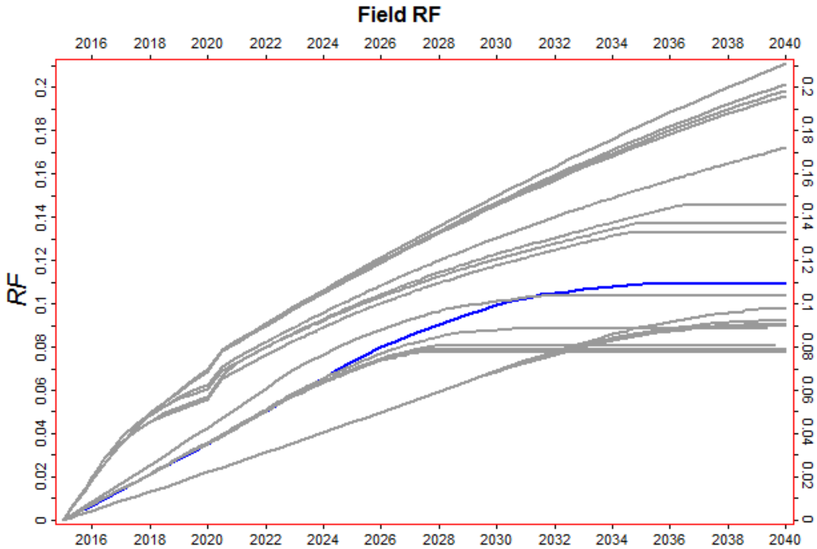

Figure 6 Cumulative oil Production uncertainty quantification for electrical submersible pumps scenario

Figure 7 shows the optimistic and pessimistic condition of oil production rate for Production with electrical submersible pump scenario.

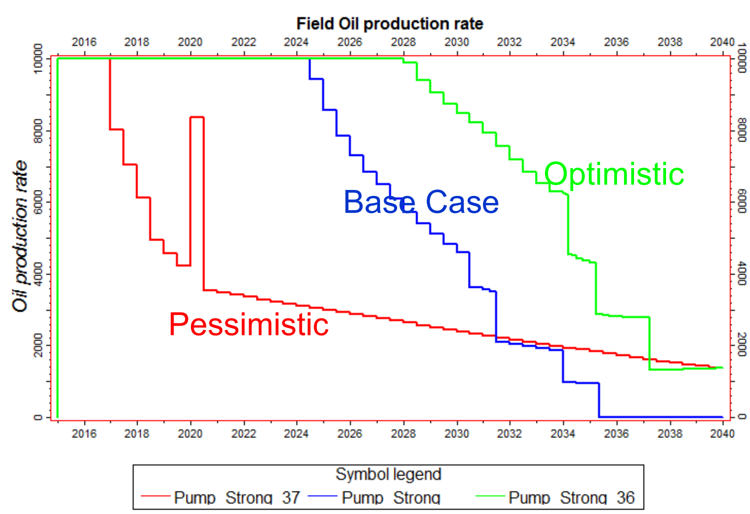

Figure 7 Comparison of oil production rate of base case (Blue), optimistic (Green) and pessimistic (Red) condition for Production with electrical submersible pump scenario

9.3 Scenario three – Water Injection + ESP (60HP)

One of the top concerns for case study field reservoir is absence of any information about water oil contact level and aquifer activity. It is worthy of note that defining injection wells in reservoir flank for water injection scenario is strongly influenced by the water-oil contact depth.

Without any accurate data about contact, these wells might be penetrating completely in water zone. The range between the smallest and largest oil recovery factor values quantify the uncertainty associated with the reservoir simulation performance prediction (Figure 8).

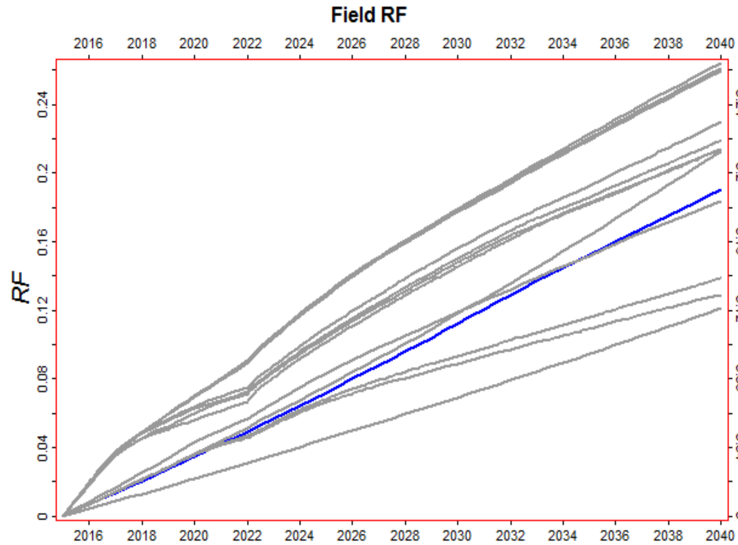

Figure 8 Cumulative oil production uncertainty quantification for water injection with electrical submersible pump scenario

Figure 9 The optimistic and pessimistic condition of oil production rate for production with electrical submersible pump scenario.

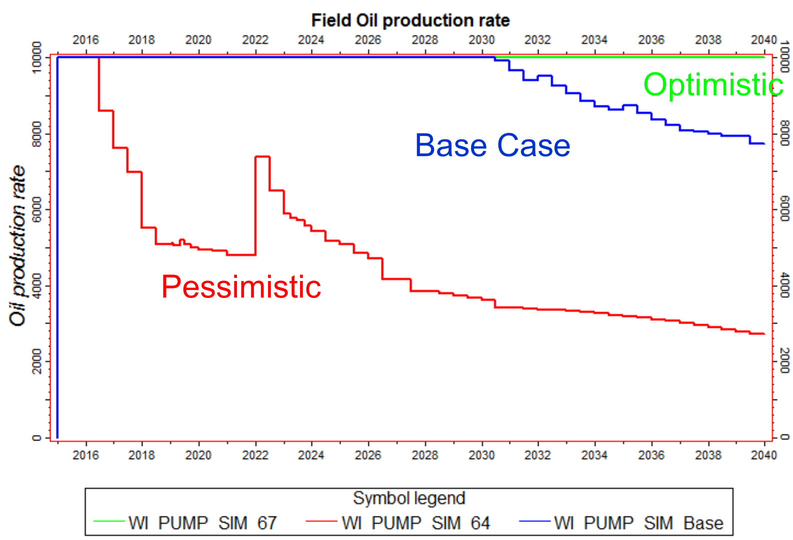

Figure 9 Comparison of oil production rate of base case (Blue), optimistic (Green) and pessimistic (Red) condition for water injection with electrical submersible pump scenario

10. Conclusion

Oil Water Contact (OWC), Aquifer Porosity ($\varphi_{Aquifer}$), Aquifer Thickness ($h_{Aquifer}$), residual oil saturation and Porosity Trend have the largest impact on defined objective function for case study model. In comparison with oil production rate of three production scenarios (Natural Depletion, Electrical submersible pump (120 HP) and Water Injection + ESP (60HP)), water injection with ESP pump in base case, optimistic and pessimistic condition had better rate and if there are reliable data of aquifer condition, it will good to develop this scenario.

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