

Original article

Future Production Prediction for Ghani Oil Field by using Prosper Software with Decline Curve Analysis

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Abstract

Nodal Analysis, defined as a systems approach to the optimization of oil and gas wells, is used to evaluate a complete producing system thoroughly. Every component in a producing well or all wells in a producing system can be optimized to achieve the objective flow rate most economically. In our study, two wells from the Ghani oil field have been used as a case study. Three production tests and a flowing pressure survey were collected and analysed using PROSPER Software to estimate the well productivity index at different times, as well as to calculate and plot the pressure gradient and compare the results obtained by different methods with the actual one. Consequently, to find the best method that gives us the least value of error comparing with actual one used to construct IPR-VLP performance (Nodal Analysis). The measured vertical flow pressures, for most wells, matched very well with the Fancher-Brown multiphase vertical correlation pressure. This behaviour is obtained because the wells are producing under natural flow. The sensitivity analysis has been performed to predict the future reservoir performance at different reservoir pressures, water cut, and Gas Oil Ratio (GOR). In the selected wells, the total oil reserves, remaining reserves and remaining productive life were estimated using Decline Curve Analysis (DCA), furthermore and at time in future, we could predict the future oil flow rate, reservoir pressure and bottom hole flowing pressure by linking the Decline Curve Analysis with the Nodal Analysis, finally, the prediction results revealed that the wells can continue producing for only a few more years.

Keywords. Oil Reserve, Decline Curve Analysis, Recovery Factor.

Introduction

The exploration and exploitation of hydrocarbons involve huge investments and risk. It is, however, the aim of the industry to devise means of producing as much hydrocarbon as possible from any discovered field to ensure maximum returns from the investments. Increasing the reserves of the reservoirs already in production through an improved development strategy constitutes for the oil companies a real opportunity and an economic alternative to costly and risky exploration surveys. Thus, a good integrated reservoir management is vital to achieve this aim, which involves reservoir simulation studies [1].

The simulation study is done using a model of the reservoir. The static model creates a replica of the reservoir as it is in a static condition. It contains models of the reservoir structure, shape, saturation, permeability, porosity, thickness, fluid contacts, and faults [2]. The dynamic model incorporates the flow properties and behaviour obtainable in the reservoir [3]. This thus involves a model of the reservoir fluid and rock behaviour with pressure change, the mobility of the fluid, well model, water influx model (for a water drive reservoir), and every other activity that affects the flow of the fluid from the subsurface to the surface [4]. It is worthy to note that there are a lot of uncertainties involved in the simulation due to the heterogeneity of the reservoir [5]. Thus, any model designed for a reservoir simulation study must recognize this to represent the reservoir as much as possible.

Prosper Software is a well-performing design and optimization program that is part of the Integrated Production Modelling toolkit (IPM). It is designed to allow the building of reliable and consistent well models, providing unique matching features, which tune PVT, multiphase flow correlations, and IPR to match measured field data, allowing a consistent well model to be built prior to use in prediction (sensitivities or artificial lift design). Prosper Software enables detailed surface pipeline performance and design (flow regimes, pipeline stability, slug size, and frequency) [6].

The huge cost of exploration and exploitation of the petroleum resources makes it necessary for the attainment of a high level of certainty in the methods adopted for its detection, quantification, planning, and production. Mapping the reservoir and understanding its characteristics reduces the uncertainties and provides better identification of hydrocarbon reserves [7], the cost of production and the degree of exploitation success rate, and helps to make the right decision about the field development plan. The major tool to guide, manage, and understand the reservoir is dynamic reservoir modelling [8]. In our study, two wells, which are RRR-32 and RRR-42, from the Ghani oil field as a case study. A comprehensive study was conducted to model and optimize these wells by using PROSPER Software and Decline Curve Analysis.

Optimizing the vertical lift performance (VLP) correlation of the whole Ghani oil field. In the selected wells, to perform nodal analysis to estimate optimum well flow rate and optimum well bottom hole flowing pressure, applying sensitivity Analysis for different parameters such as, reservoir pressure (P_r), water cut (WC) and Gas Oil Ratio (GOR), to estimate total oil reserves, remaining reserves and remaining productive life using

Decline Curve Analysis (DCA), finally, using the built model with decline curve analysis to predict the flow rate, reservoir pressure, and bottom hole flowing pressure at any future time.

Case study

Production nodal analysis by using PROSPER software

In our study, two wells, which are RRR-32 and RRR-42 from the Ghani oil field, have been analyzed as a case study. Three production tests were used to estimate well productivity index at different time in 2010 and 2013; flowing pressure survey were collected and analyzed by using Prosper Software in order and to compare the results obtained by different methods with the actual one to find the best method that gives us the less value of error comparing with actual one used for construct IPR-VLP (Nodal Analysis) performance and make prediction for future performance by using Sensitivity Analysis for different reservoir pressure, water cut and Gas Oil Ratio (GOR).

Work procedure

The procedure followed in this work is listed in the following steps:

- a) Data for well (RRR-32) was collected. (Table 1) shows the pressure survey for this well. The quality check for each test should be done to determine if the test is valid or not.

Table 1. Well (RRR-32) Flowing Gradient Survey Test, 2010

Depth, (ft)	Pressure, (Psia)	Temperature, (°F)	Pressure Gradient	Pressure/Depth
0	618	97	***	***
500	704	134	0.172	1.408
1000	796	151	0.184	0.796
1500	896	152	0.200	0.597
2000	1005	155	0.218	0.503
2500	1120	161	0.230	0.448
3000	1241	166	0.242	0.414
3500	1369	171	0.256	0.391
4000	1503	176	0.268	0.376
4500	1642	180	0.278	0.365
5000	1784	183	0.284	0.357
5200	1841	184	0.285	0.354
5400	1900	185	0.295	0.352
5600	1960	186	0.300	0.350
5805	2018	186	0.283	0.348

- b) The Prosper Software was used to calculate pressure at different depths (pressure gradient) by using most of the correlations available, to investigate their application with acceptable accuracy in the interest of multiphase flow correlations.
- c) For each test, matching techniques were used to reduce the value of error between the correlation and the actual one, as follows:
 - Estimate U value: This task must be done first since the temperature will affect the PVT used in the matching.
 - Correlation Comparison: This will show if the test is valid and allow the user to select which correlation will be chosen to represent the pressure drops in the well.
 - Match VLP: Match the correlation to valid tests.
 - Check the VLP/IPR intersection and, if needed, modify the IPR so that model results match those of the test. This will ensure that the model can reasonably represent the tests and identify possible discrepancies in the inflow model. If the VLP/IPR intersection shows a different rate than the one shown on the test, then of course, the discrepancy lies with the inflow.
- d) For each test, after matching, find the best method that gives the lowest value of error comparing with actual one.
- e) By using nodal analysis (IPR-VLP), trying to find the most suitable correlation that can be used as a general correlation for the flowing pressure gradient in the well (RRR-32).
- f) Finally, the application of sensitivity analysis for different reservoir pressures, water cut, and GOR to predict the future reservoir performance.

Tests analysis and calculations

Quality check for well test data

If the test point is completely outside established physical boundaries, it is suspected that the reported test data were inconsistent. The physical boundaries are defined by the [9] correlation that neglects slippage

effects between the phases and consequently underestimates the pressure loss [10]. Modified correlation that generally overestimates pressure drops in oil wells (Figure 1).

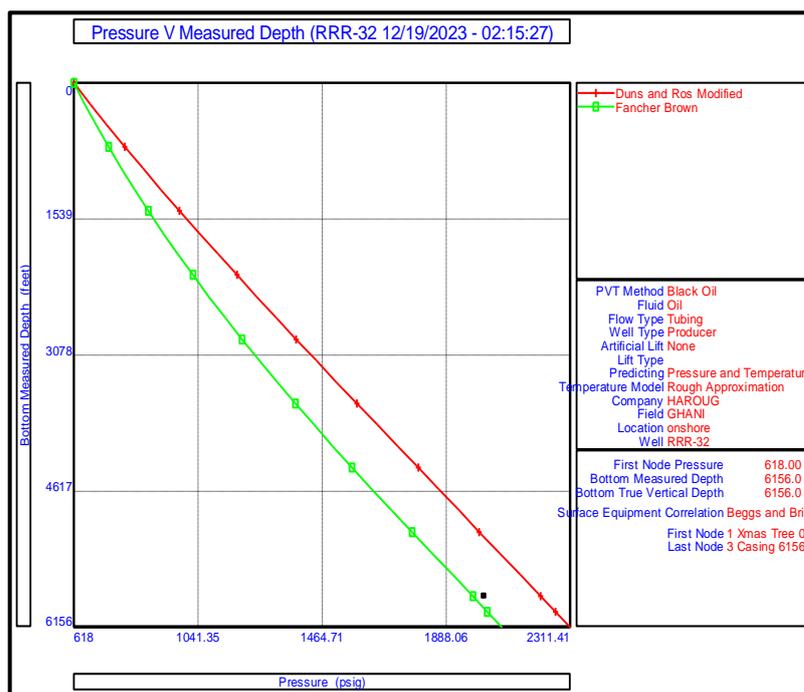


Figure 1. Flowing Gradient Survey, Test Validation (31/10/2010)

Error analysis using all multiphase flow correlations

The actual measurements of flowing pressure gradients, when compared with all existing correlations, in some cases give a good matching and other times do not give any match with the actual measured pressure data.

The following table shows the Error Analysis for this test by using all multiphase flow correlations.

Table 2. Flow Rate Error Analysis using All Multiphase Flow Correlations

Correlation	Before Matching %	After Matching %
Duns and Ros Modified	59.68	19.82
Hagedorn Brown	20.45	34.16
Fancher Brown	18.09	30.20
Petroleum Expert (PE-1)	26.80	31.70
Petroleum Expert (PE-2)	43.34	35.86
Petroleum Expert (PE-3)	33.64	39.02
Hydro-3P	12.5	36.28

From the multiphase pressure gradient curves, we found that some of the multiphase correlations don't have any solution in nodal analysis, as in the cases of [11], etc., and some of them increase the values of error after matching nodal analysis, like [12], the [9] may give not acceptable results compared with actual flowing pressure survey data, but after using the matching technique, we can get a good result compared with actual survey data, especially after matching nodal analysis to the reservoir pressure. Consequently, (Figure 2) shows that the [9] can be considered the best correlation for well (RRR-32).

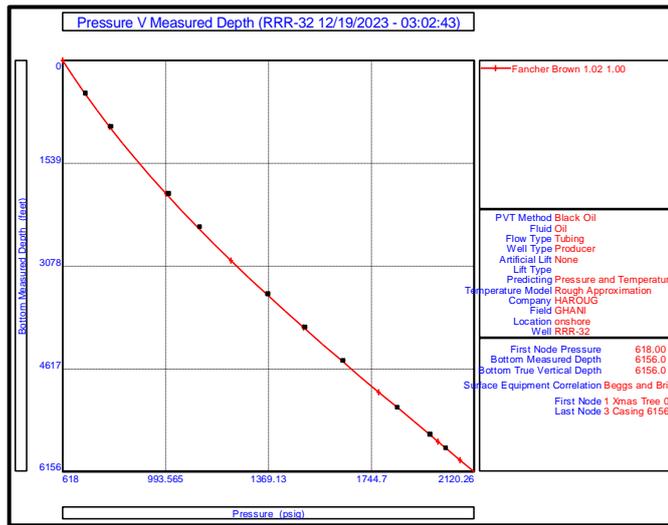


Figure 2. FGS using Fancher Brown Correlation After Matching, (31/10/2010)

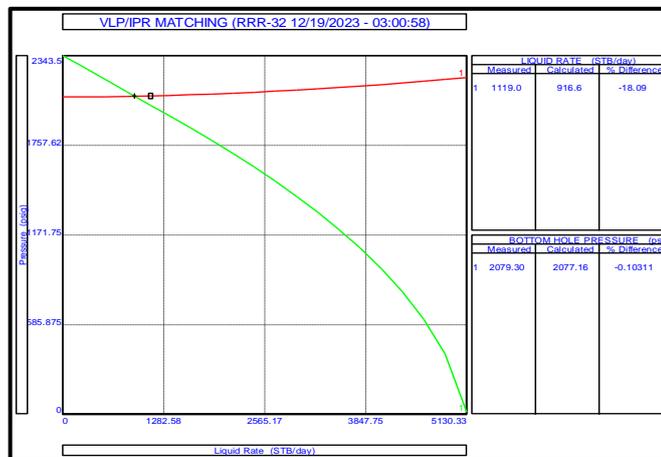


Figure 3. Nodal Analysis using Fancher Brown Correlation Before Matching, (31/10/2010)

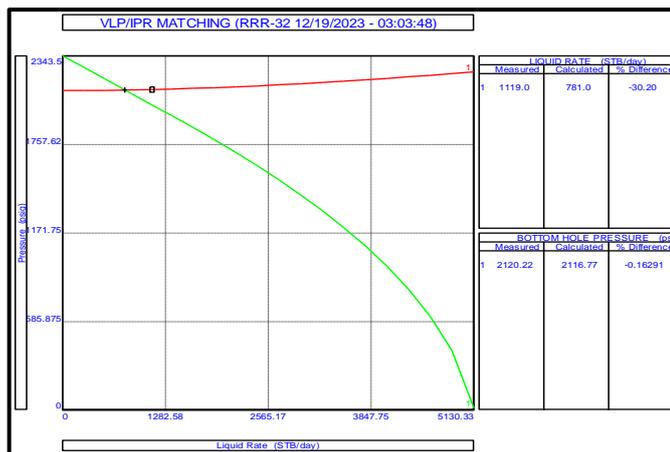


Figure 4. Nodal Analysis using Fancher Brown Correlation After Matching, (31/10/2010)

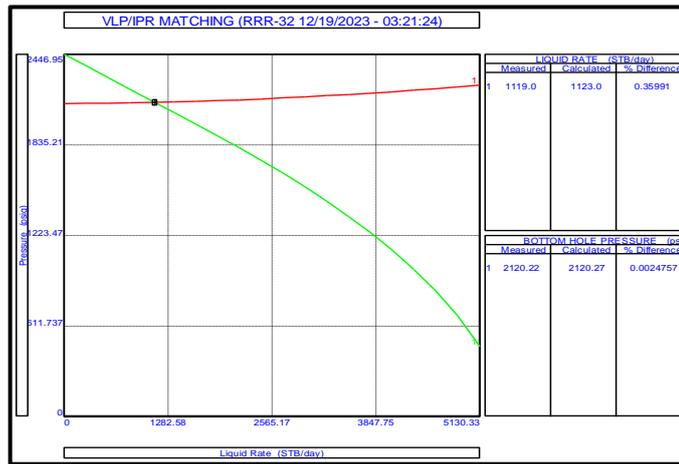


Figure 5. Nodal Analysis using Fancher Brown Correlation After Adjustment Reservoir Pressure

Sensitivity analysis

The reservoir pressure and the Gas Oil Ratio are the main factors affecting the calculations of multiphase flowing pressure correlations, especially in the case of solution gas drive, so in our study, we performed the sensitivity analysis to predict the future reservoir performance for different reservoir pressures, water cuts, and Gas Oil Ratio (GOR).

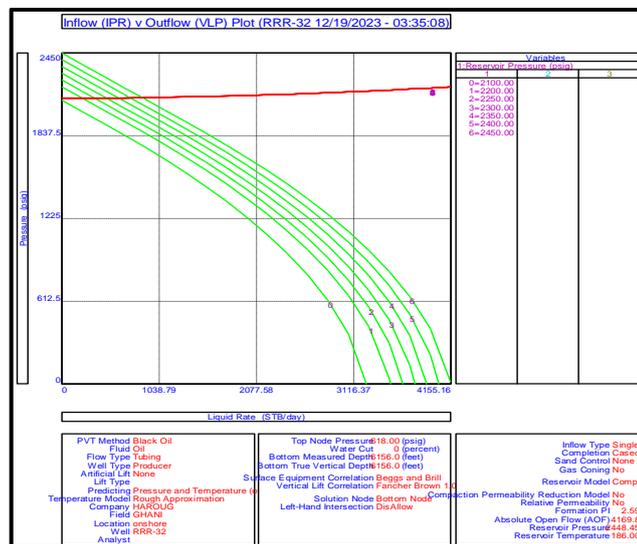


Figure 6. Sensitivity Analysis (for Reservoir Pressure) using Fancher Brown VLP Correlation

From (Figure 6) Figure 6), clearly indicated that reservoir pressure affecting on inflow curve (IPR curve), as well as the well (RRR-32), producing with a reservoir pressure drop from 2450 to 2200 psia, whereas the well will die when the reservoir pressure drops to 2100 psia. There is no intersection between inflow and outflow (IPR-VLP) curves.

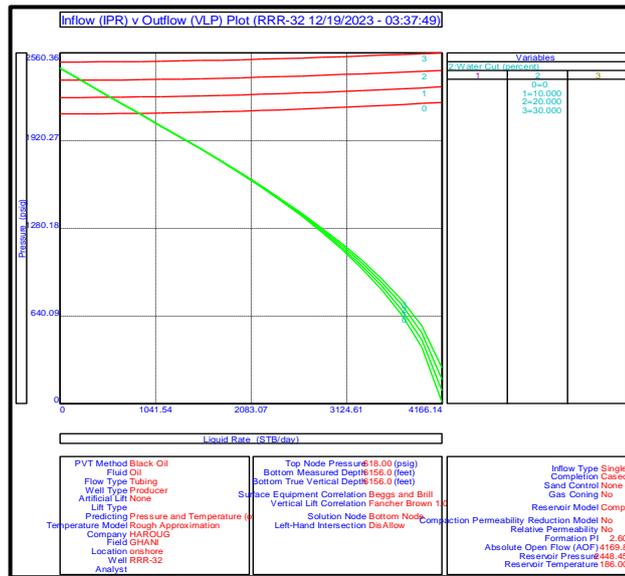


Figure 7. Sensitivity Analysis (for Water Cut) using Fancher Brown VLP Correlation

Figure 7 (Figure 7) clearly indicates that water cut affecting on outflow curve (VLP curve), as well as the well (RRR-32), producing with water cut increasing from 0 to 20%, whereas the well will die if water cut increases to 30%, there is no intersection between the inflow and outflow (IPR-VLP) curves.

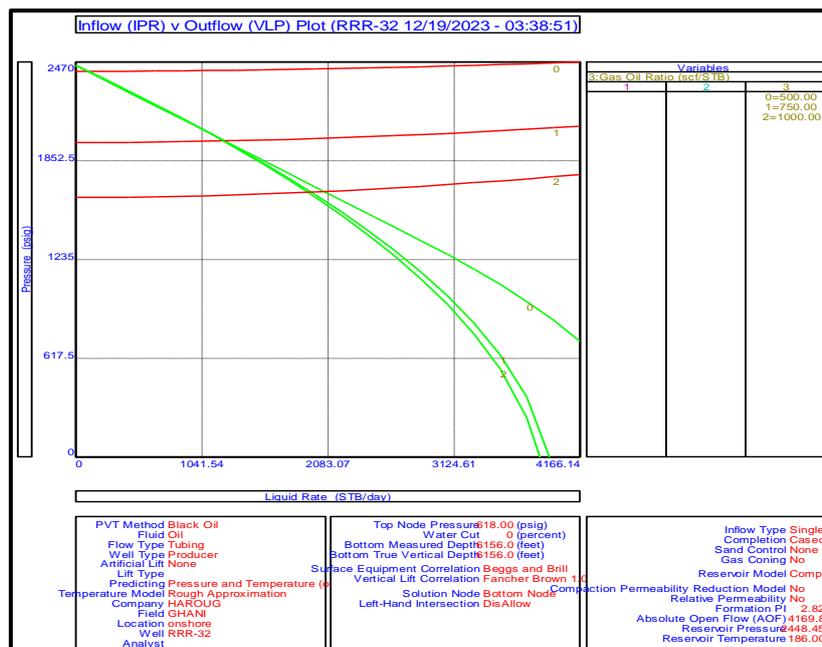


Figure 8. Sensitivity Analysis (for GOR) using Fancher Brown VLP Correlation

From (Figure 8), clearly indicate that Gas Oil Ratio affecting on outflow curve (VLP curve), as well as well (RRR-32), producing with Gas Oil Ratio increasing from 500 to 1000 SCF/STB, whereas the well will cease production if Gas Oil Ratio decrease to 450 SCF/STB, there is no intersection between inflow and outflow (IPR-VLP) curves.

➔ Well (RRR-42) Flowing Gradient Survey Test, 2010

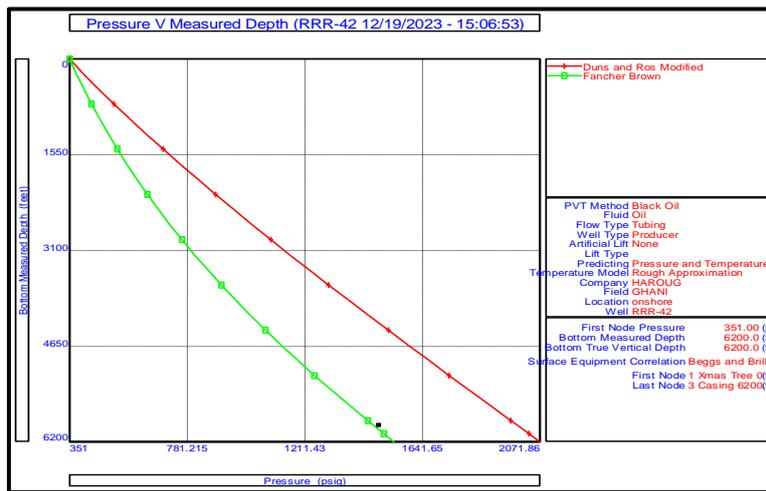


Figure 9. Flowing Gradient Survey, Test Validation (05/11/2010)

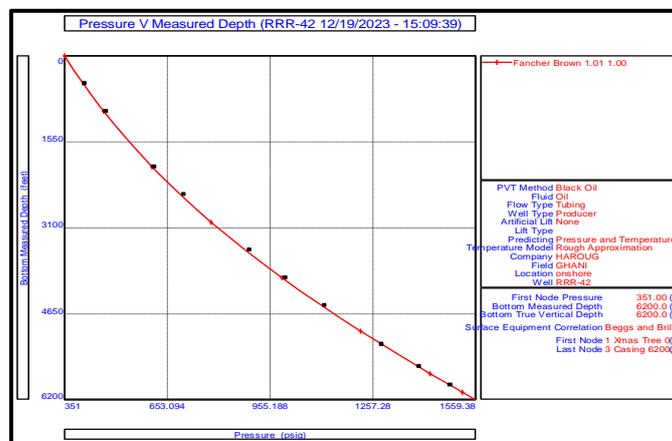


Figure 10. FGS using Fancher Brown Correlation After Matching, (05/11/2010)

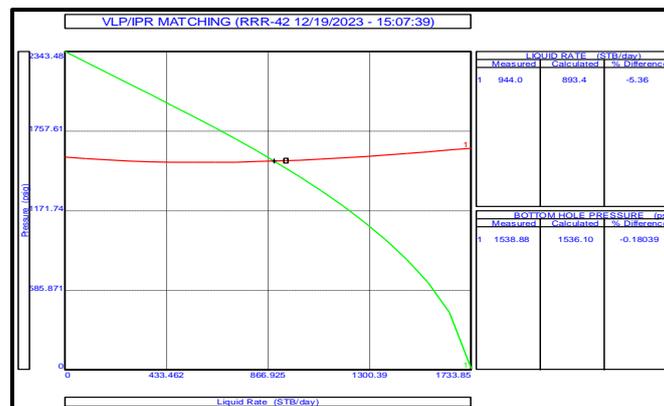


Figure 11. Nodal Analysis using Fancher Brown Correlation Before Matching, (05/11/2010)

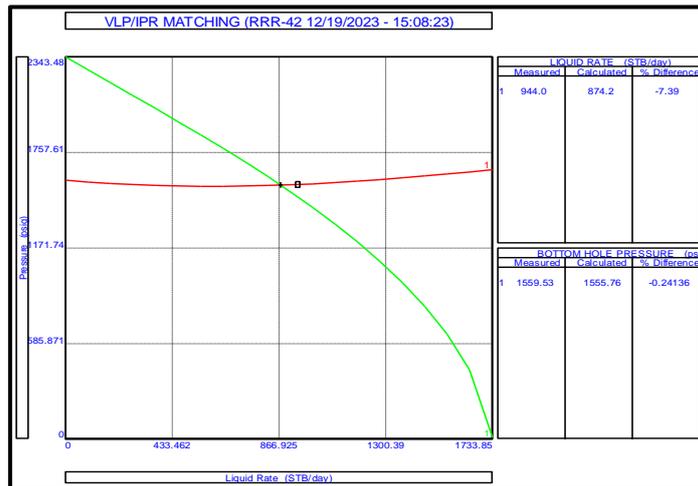


Figure 12. Nodal Analysis using Fancher Brown Correlation After Matching, (05/11/2010)

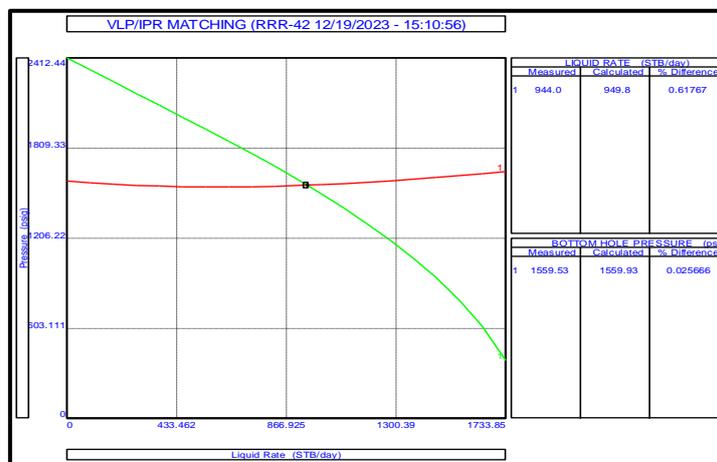


Figure 13. Nodal Analysis using Fancher Brown Correlation After Adjustment Reservoir Pressure

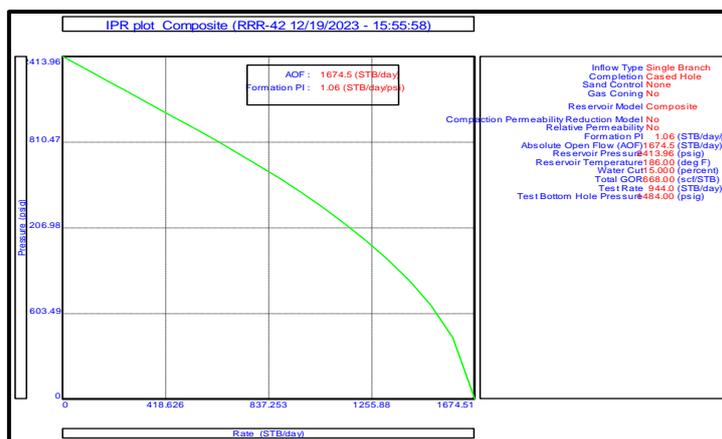


Figure 14. Inflow Performance Curve After Adjustment Reservoir Pressure, (05/11/2010)

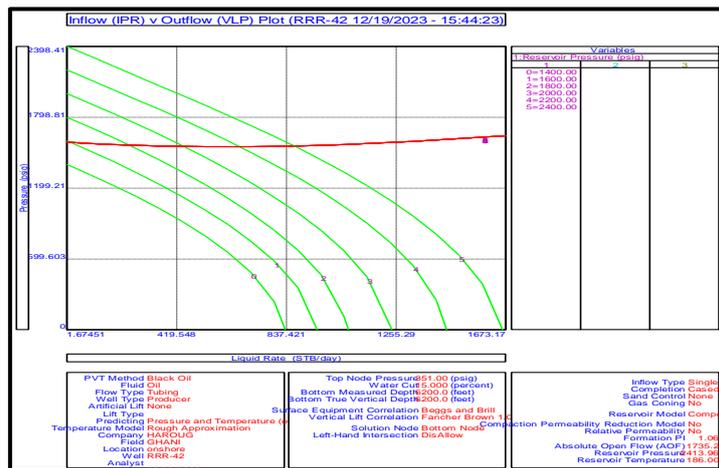


Figure 15. Sensitivity Analysis (for Reservoir Pressure) using Fancher Brown VLP Correlation

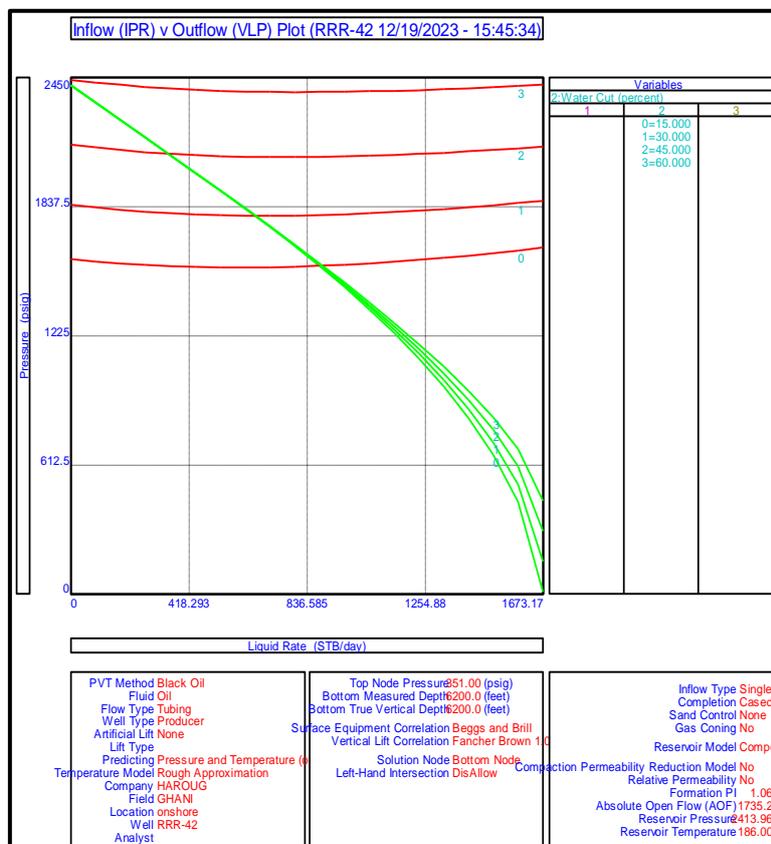


Figure 16. Sensitivity Analysis (for Water Cut) using Fancher Brown VLP Correlation

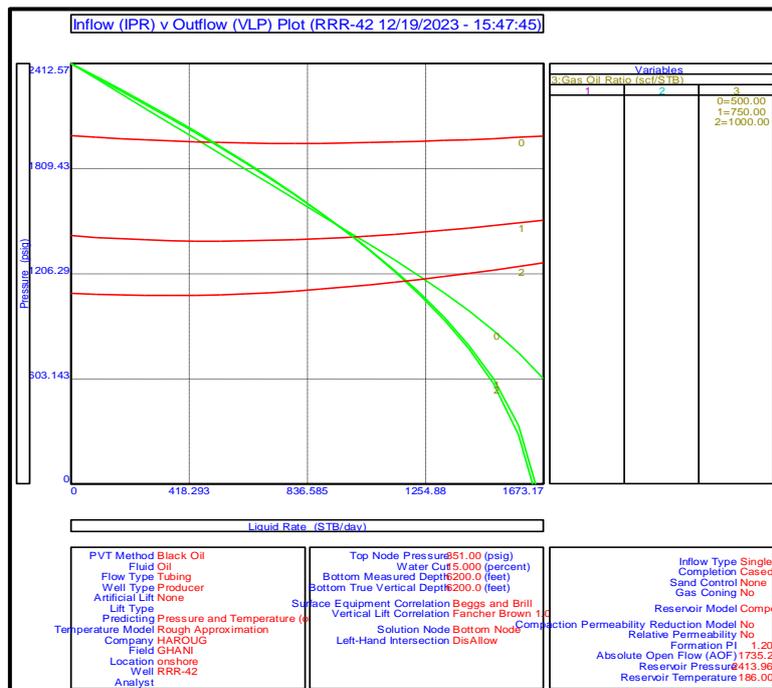


Figure 17. Sensitivity Analysis (for GOR) using Fancher Brown VLP Correlation

→ Well (RRR-42) Flowing Gradient Survey Test, 2013

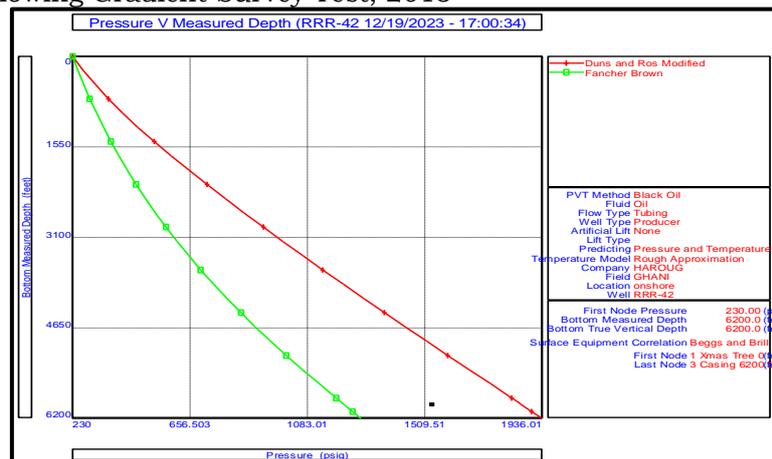


Figure 18. Flowing Gradient Survey, Test Validation (17/03/2013)

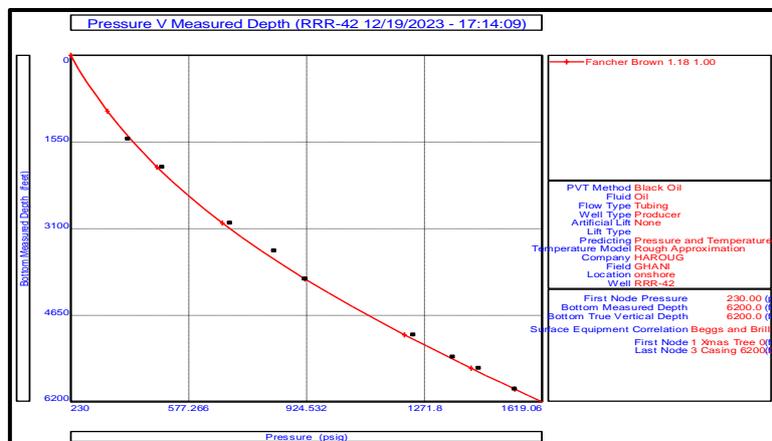


Figure 19. FGS using Fancher Brown Correlation After Matching, (17/03/2013)

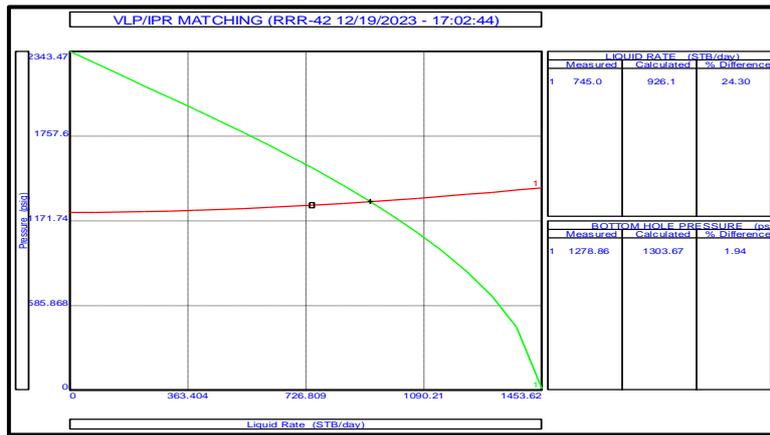


Figure 20. Nodal Analysis using Fancher Brown Correlation Before Matching, (17/03/2013)

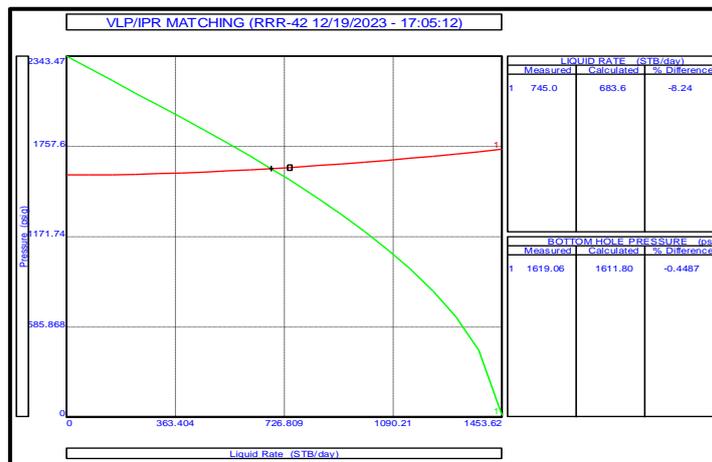


Figure 21. Nodal Analysis using Fancher Brown Correlation After Matching, (17/03/2013)

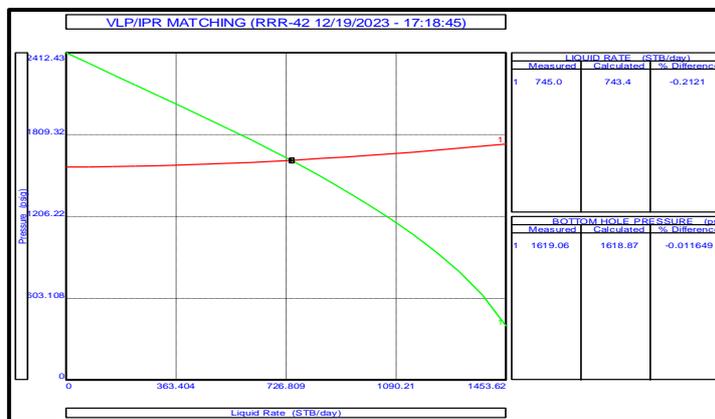


Figure 22. Nodal Analysis using Fancher Brown Correlation After Adjustment Reservoir Pressure

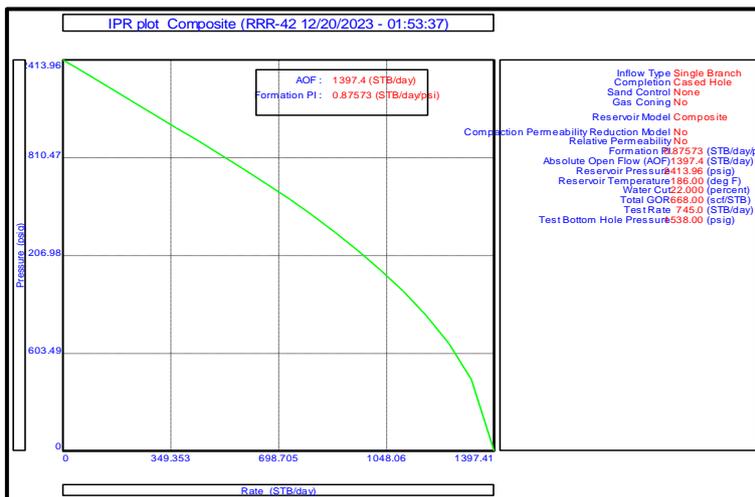


Figure 23. Inflow Performance Curve After Adjustment Reservoir Pressure, (17/03/2013)

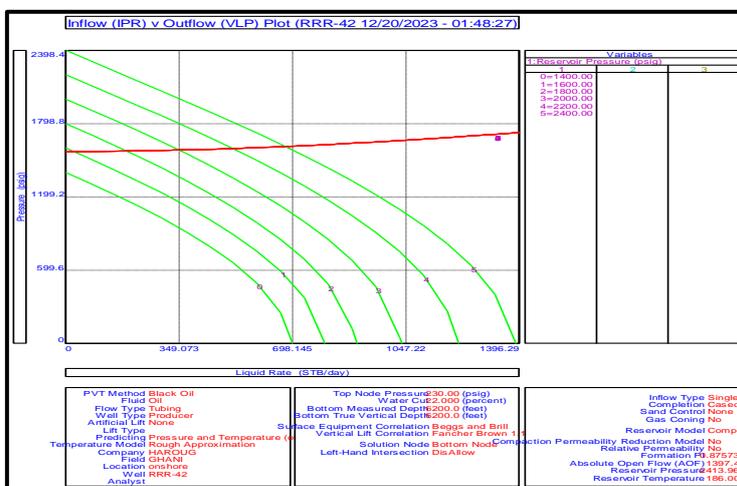


Figure 24. Sensitivity Analysis (for Reservoir Pressure) using Fancher Brown VLP Correlation

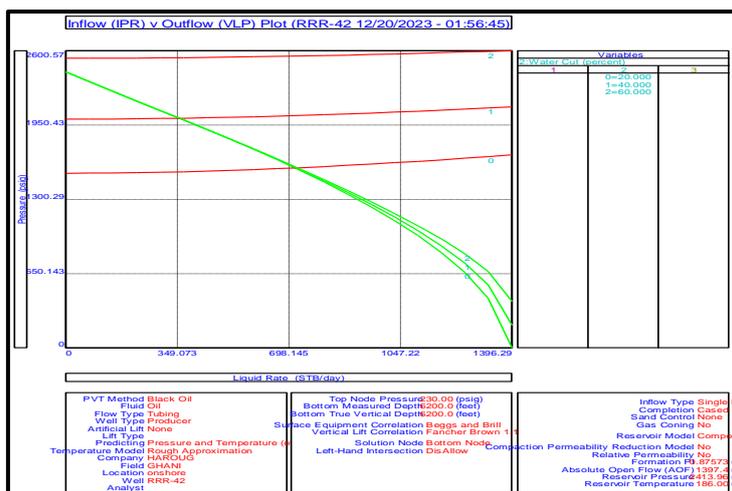


Figure 25 Sensitivity Analysis (for Water Cut) using Fancher Brown VLP Correlation

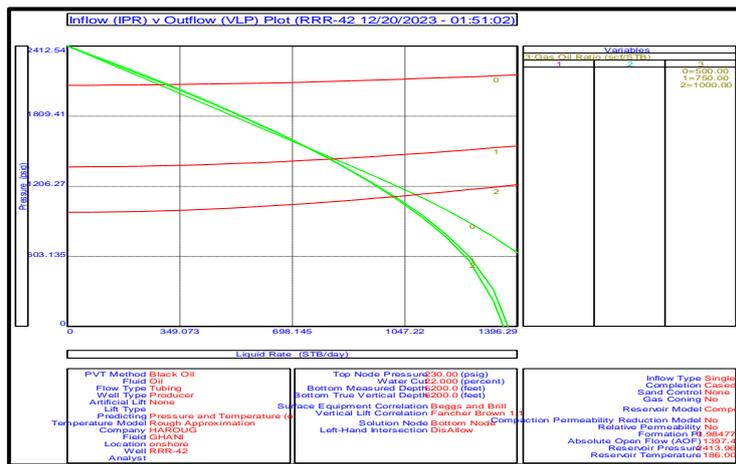


Figure 26. Sensitivity Analysis (for GOR) using Fancher Brown VLP Correlation

Production decline curve analysis

Production Decline Analysis is a useful tool for predicting future production rates, estimating remaining oil reserves, and estimating remaining productive life. The basic assumption in the Production Decline Analysis is that the parameters controlling the trend of the decline curve in the past will continue to govern its trend in the future in a uniform manner. Forecasts are made by extrapolating trends to an endpoint. The endpoint requirement is easily met, since known or estimated operating costs usually make it possible to determine accurately the economic-limit rate and thus the endpoint of the curve. Decline Curve Analysis can only be used to estimate the proven reserves, which can be recovered from the current development scheme.

- Well (RRR-32) Analysis and Calculations

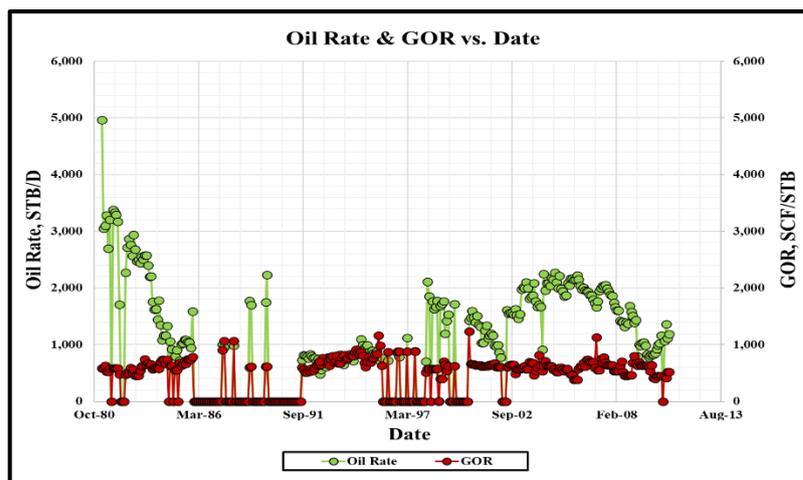


Figure 27. Oil Rate and Gas Oil Ratio during Production Period, (RRR-32)

Production forecasting via decline curve analysis

From the production history shown in (Figure 27), we analysed the last production decline period starting from (01/07/2007) to (01/10/2008), which is likely to give the most realistic results in prediction calculations.

Table 3. Range of the Decline Curve Analysis (Last Period)

Range Analysis	Start Date	End Date	No. of points
Last Period	01/07/2007	01/10/2008	16

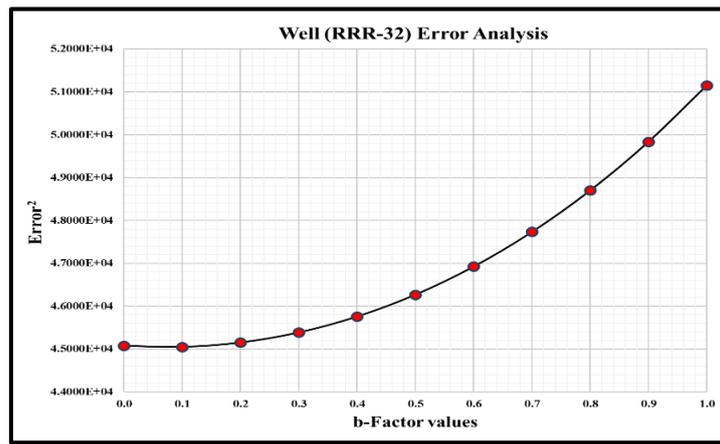


Figure 28. Error Analysis for Well (RRR-32)

From the error analysis of the last production decline period, from (Figure 28), we found that the type of decline is a hyperbolic decline, with an initial value of oil rate of 2107 STB/D, and a decline rate of $0.39751 \text{ year}^{-1}$ results are summarized in the table below:

Table 4. Results of Decline Analysis (Last Period)

Decline Type	Hyperbolic
Reservoir Factor (b)	0.1
Decline Rate (a_i)	$0.39751 \text{ Year}^{-1}$
Initial Flow Rate (q_i)	2107 STB/D
q_{cal} at End of Decline Period	1295 STB/D

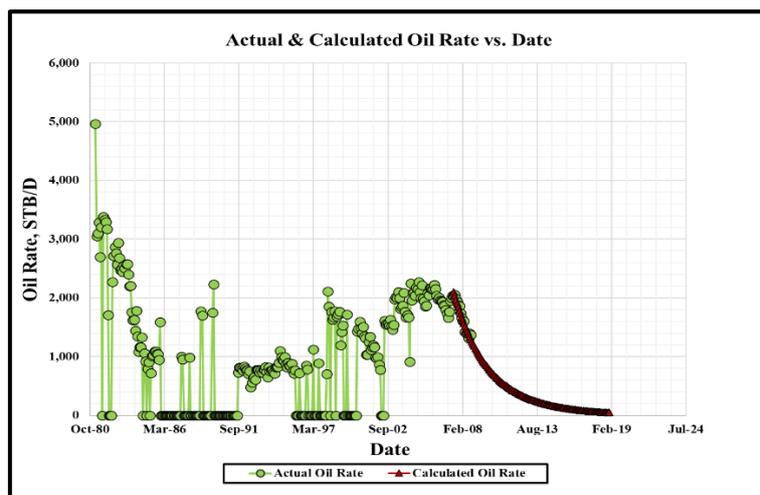


Figure 29. Actual and Calculated Oil Rate with Forecast, (RRR-32)

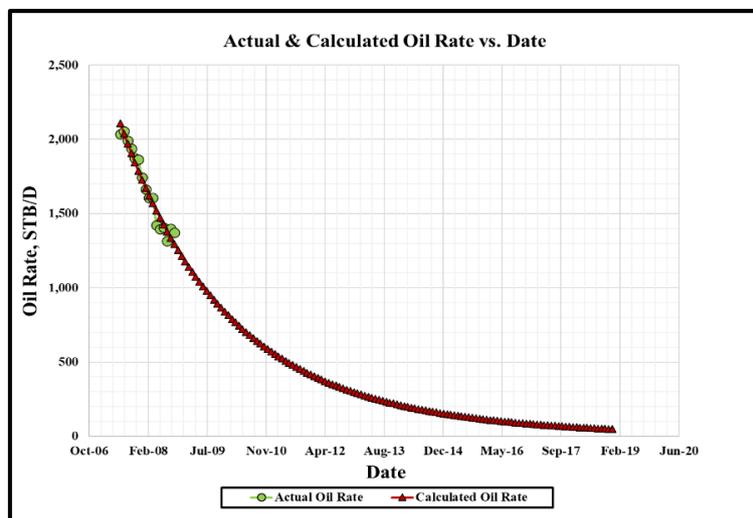


Figure 30. Actual and Calculated Oil Rate during Decline Period with Forecast, (RRR-32)

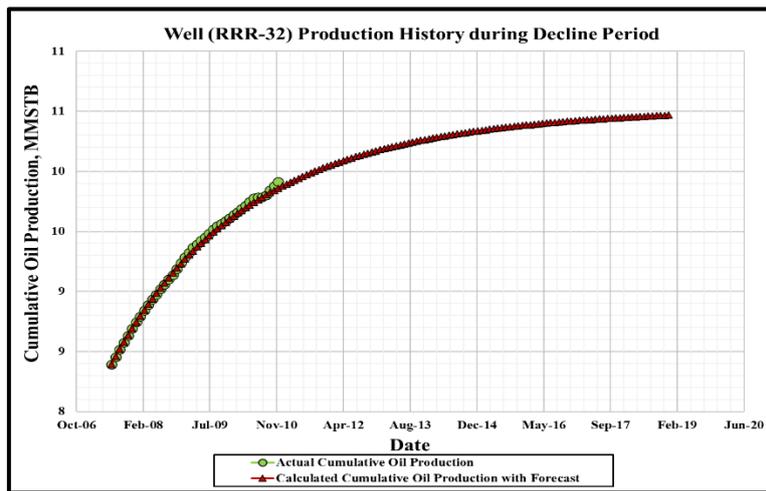


Figure 31. Actual and Calculated Cumulative Oil Production with Forecast, (RRR-32)

Table 5. Summary of Results for Production Decline Curve Analysis, (RRR-32)

Range Analysis	Start Date	End Date
Decline Period	01/07/2007	01/10/2008
No. of Points	16	
Decline Type	Hyperbolic	
Reservoir Factor (b)	0.1	
Decline Rate (a_i)	0.39751 Year ⁻¹	
Initial Flow Rate (q_i)	2107 STB/D	
Assumed Economic Rate (q_e)	50 STB/D	
q_{cal} at End of Decline Period	1295 STB/D	
Cum N _p at End of Decline Period	9.138 MMSTB	
Remaining Reserves	1.330 MMSTB	
Total Reserves	10.468 MMSTB	
Abandonment Time (t_a)	11.427 Year	
Total Well Life	37.778 Year	

Well (RRR-42) Analysis and Calculations

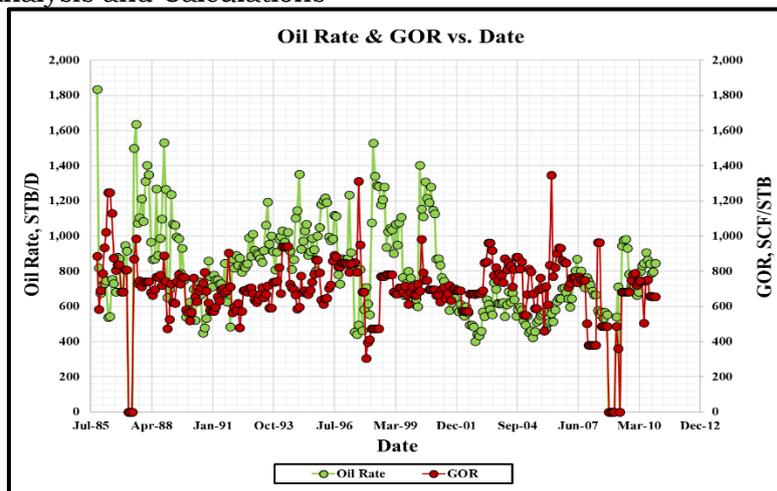


Figure 32. Oil Rate and Gas Oil Ratio during Production Period, (RRR-42)

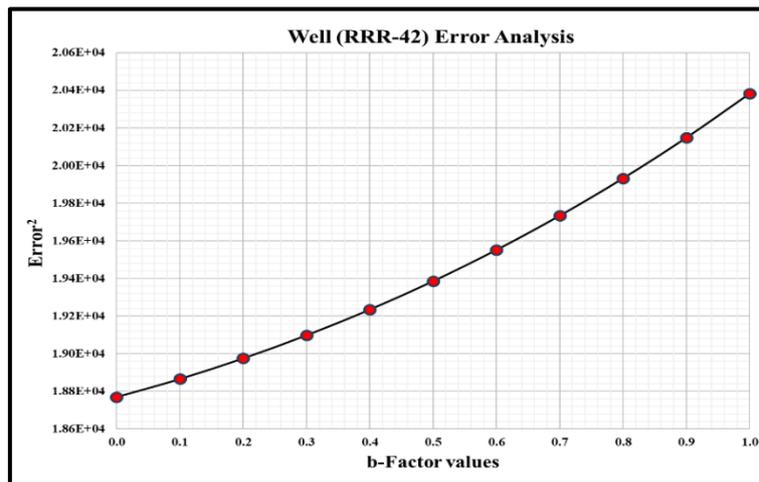


Figure 33. Error Analysis for Well (RRR-42)

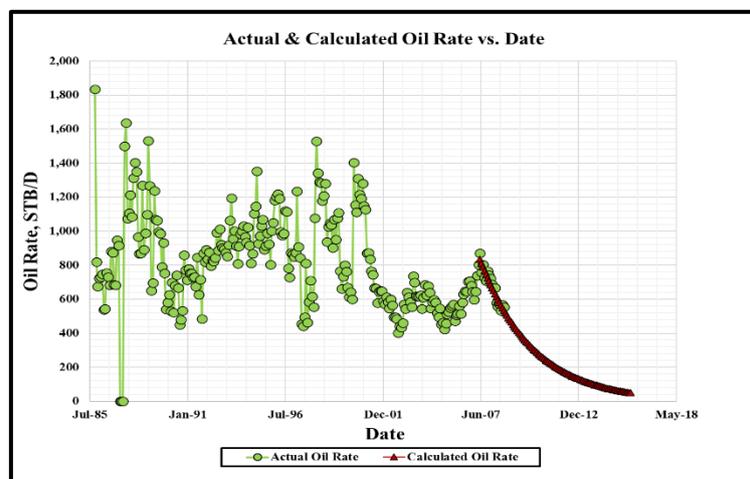


Figure 34. Actual and Calculated Oil Rate with Forecast, (RRR-42)

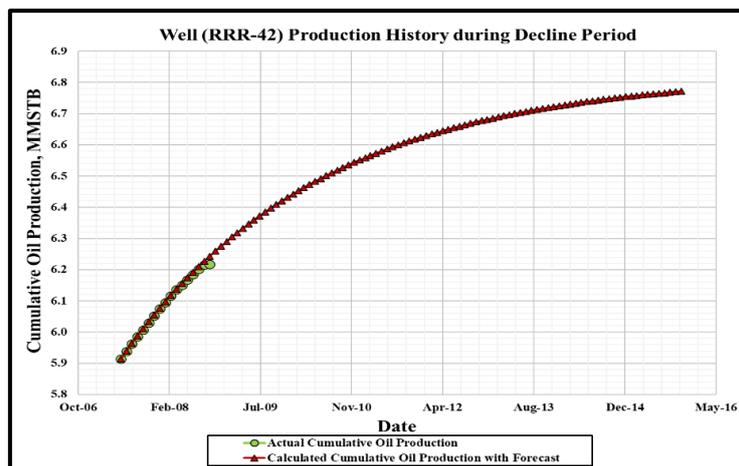


Figure 35. Actual and Calculated Cumulative Oil Production with Forecast, (RRR-42)

Table 6. Summary of Results for Production Decline Curve Analysis, (RRR-42)

Range Analysis	Start Date	End Date
Decline Period	01/06/2007	01/10/2008
No. of Points	17	
Decline Type	Exponential	
Reservoir Factor (b)	0	
Decline Rate (a_i)	0.33421 Year ⁻¹	
Initial Flow Rate (q_i)	835 STB/D	
Assumed Economic Rate (q_e)	50 STB/D	

q _{cal} at End of Decline Period	534 STB/D
Cum Np at End of Decline Period	6.217 MMSTB
Remaining Reserves	0.555 MMSTB
Total Reserves	6.772 MMSTB
Abandonment Time (t _a)	8.424 Year
Total Well Life	30.019 Year

Production prediction using sensitivity analysis (PROSPER software) with decline curve analysis

Finally, Production Decline Curve Analysis was performed to predict the future oil rate for wells (RRR-32) and (RRR-42) at any future time, and then combined with the Nodal Analysis to estimate reservoir pressure, bottom hole flowing pressure, and the possibility of well production under current and future conditions.

- Well (RRR-32) Production Prediction

Table 7. Possibility of Future Production using Sensitivity Analysis with DCA, (RRR-32)

Date	DCA	Sensitivity Analysis (PROSPER)	
	Oil Rate, (STB/D)	Reservoir Pressure, (psig)	Bottom Hole Flowing Pressure, (psig)
01/10/2010	624	2356	2115.5
01/10/2012	316	2235	2113.8
01/10/2014	167	2178	2113.3
01/10/2016	92	2149	2113.2
01/10/2018	50	2133	2113.2

From the results shown in the table above, it is clear to us that the well (RRR-32) continues to produce for a short period, and therefore, the pressure drop value will decrease to 20 psia when the well is abandoned.

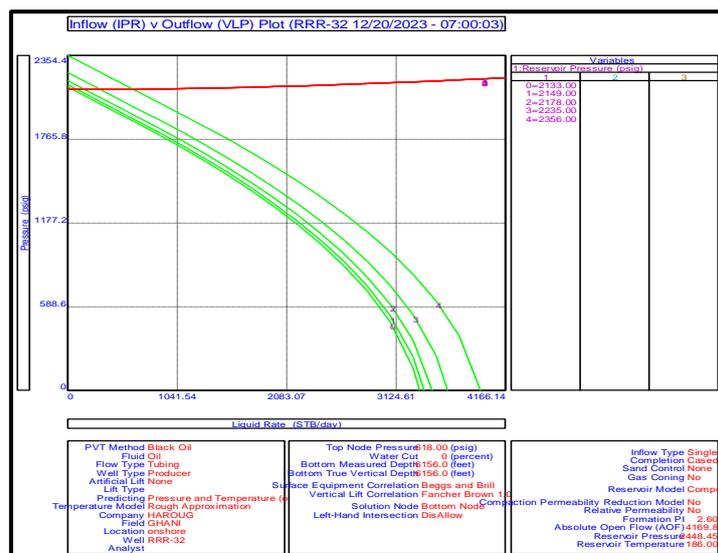


Figure 36. Production Prediction using Sensitivity Analysis, (RRR-32)

- Well (RRR-42) Production Prediction

Table 8. Possibility of Future Production using Sensitivity Analysis with DCA, (RRR-42)

Date	DCA	Sensitivity Analysis (PROSPER)	
	Oil Rate, (STB/D)	Reservoir Pressure, (psig)	Bottom Hole Flowing Pressure, (psig)
01/10/2009	382	2170	1592
01/10/2010	274	2003	1582
01/10/2012	140	1789	1573
01/10/2015	50	1645	1570

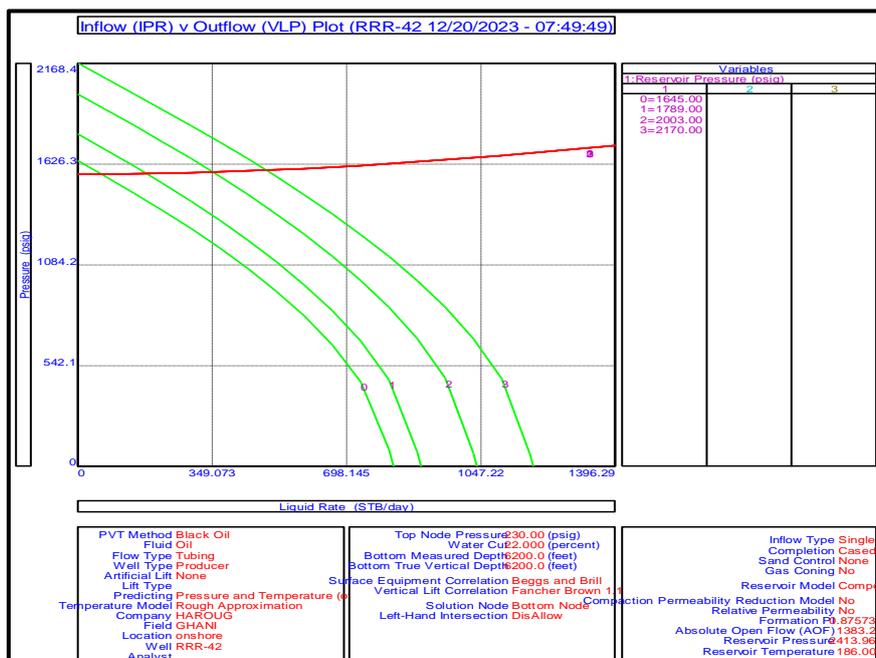


Figure 37. Production Prediction using Sensitivity Analysis (RRR-42)

Conclusion

Based on the research conducted in this study, several key conclusions were reached regarding the optimization and prediction of well performance. The investigation determined that the Lasater correlation provided the most accurate PVT matches for bubble point pressure, solution Gas-Oil Ratio (GOR), and oil formation volume factor, while Beggs et al. proved superior for calculating oil viscosity. It was observed that while parameters such as reservoir pressure, flow rate, bottom hole flowing pressure, water cut, and surface free GOR significantly influenced the accuracy of these correlation matches, other factors like PVT properties, well configuration, and depth had no notable effect.

The study highlights those matching techniques within the Prosper software are essential for aligning multiphase correlations with real-world data points. This process effectively minimizes error margins for specific models—such as the Fancher and Brown correlation—which is vital for nodal analysis and optimization, though it can conversely increase error values for others, like the Hydro-3P correlation. Furthermore, the vertical multiphase flow gradient curves for wells RRR-32 and RRR-42 were found to follow distinct correlations unique to each well's specific behavior. Notably, the Fancher and Brown correlation demonstrated the capability to predict future multiphase flowing pressure gradients for any well in the reservoir, provided the future flow rate is known.

In cases of solution gas drive, reservoir pressure and GOR were identified as the primary factors impacting the calculation of multiphase flowing pressure correlations. By integrating Production Decline Analysis (DCA) with Nodal Analysis, the study successfully forecasted well potential, future reservoir pressure, and bottom hole flowing pressure. Ultimately, the prediction results for wells RRR-32 and RRR-42 suggest that these wells are nearing the end of their production cycle and will only remain viable for a few more years. Based on these Decline Curve Analysis estimates, the study concluded by determining the total oil reserves, remaining reserves, and the remaining productive life for both wells.

Recommendations

Building upon the outcomes of this study, several recommendations for future research have been identified to enhance field management and predictive accuracy. It is suggested that similar graphical multiphase flow pressure gradient correlations be constructed for any field where existing industry-standard correlations fail to provide an adequate match with observed flowing pressure data. Furthermore, expanding the scope of this study to encompass all wells within the Ghani oil field is highly recommended. By doing so, a complete network model can be established, providing the comprehensive data necessary for informed decision-making regarding the future development and optimization of the field.

Conflict of interest. Nil

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