Determination of Location and Production Rate of Infill Well Using Decline Curve Analysis Sectorization Method in Lakat Formation, Central Sumatra Field

by Dedy Kristanto

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Determination of Location and Production Rate of Infill Well Using Decline Curve Analysis Sectorization Method in Lakat Formation, Central Sumatra Field

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Abstract*—The Lakat Formation of Central Sumatra field is a mature field that has been produced since 1970, and in 2018 the recovery factor has reach of 25.9%. In order to increase the recovery factor, hence the infill well scenario will be executed. Determination of the location of infill wells was carried out using the Decline Curve Analysis (DCA) Sectorization Method, due to in this field there is no SCAL and PVT data. The DCA sectorization method uses statistical analysis based on HCPV and permeability value. Determination of the infill wells coordinate is based on an overlay map of the three HCPV sectors, are current, permeability, and cumulative production. This method divided the formation into good, medium, and poor classes. The infill well scenario is done in good and medium classes. The initial production rate of each infill well is determined by drawing a trendline on a combination of peak production, pressure, transmissibility, productivity index and time. The results of the analysis in the Lakat formation obtained in the good sector the exponential curve with decline rate of 7.3% has remaining reserve about 56 Mbbl. Whereas the medium sector by harmonic curve with decline rate 9.4% has remaining reserve about 71 Mbbl. The development of Lakat formation with 8 infill wells, including 6 locations in the good sector with an average initial production rate of 68 bbl/day, and 2 locations in the medium sector with an average initial production rate of 59 bbl/day. Based on the development scenario results in the Lakat layer of the Central Sumatra Field has obtained of oil production of 6479 MSTB and recovery factor of 36.1%.

***Keywords*—HCPV Current; Decline Curve Analysis; Sectorization; Production Rate**

I. INTRODUCTION

The Central Sumatra field is one of the mature fields that has been in production since 1970 and is located in the Central Sumatra basin. The Lakat Formation is the main reservoir in this field which consists of five layers. The Lakat formation has Original Oil in Place (OOIP) of 17.9 MMSTB with a Cumulative Production (Np) until December 2018 of 4.6 MMSTB, and a Recovery Factor of 25.9%. Until the end of December 2018, the number of wells in the Lakat layer has 21 wells, consisting of 8 production wells, 9 plug and abandon wells, 3 shut-in wells, and 1 injection/disposal well.

The development of the Lakat formation with infill well is expected to increase the oil production. The infill well scenario requires an accurate infill coordinate determination plan. In this case, determination of the infill coordinate in this formation using the Decline Curve Analysis sectorization method. Decline Curve Analysis sectorization is one method of determining residual oil reserves, this method is a substitute for reservoir simulation if the field data is incomplete (Ahmed, T. 2010; Arps, J.J. 1945; Agarwal, R.G. et.al. 1998; Meriandriani, et.al. 2015; Jongkittinarukom, K.D. 2020; McKinney, P.D., and Ahmed, T. 2005; Rahman, A, and Warto, U. 2019). This method is used in remaining reserve evaluation without Special Core Analysis (SCAL) and Pressure-Volume-Temperature (PVT) data usage. The determination of the sector is based on the reservoir properties model. By using statistical method, the distribution of Hydrocarbon Pore Volume (HCPV) current and permeability properties can be grouped into several sectors. Graphic analysis between log Qo Vs cumulative production (Np) can be seen if the status of the field/sector is mature or virgin (Gravetter, F. 2015; Rukmana, D. et.al. 2018). Determination of infill well coordinate is based on the HCPV current-permeability-cumulative production (Np) overlay map. One method to determine the initial production rate of infill well is by drawing a trendline on a combination of oil production peak, pressure, transmissibility (Kh), Productivity Index (PI), and time graphs (Brown, K.E. 1984; Agarwal, R.G. et.al. 1998).

The usage of the Decline Curve Analysis sectorization method is expected to be able to analyze the infill well coordinate more accurately and compose optimum production rate. Hence, determination of the location of the infill well and the optimum production rate will increase the oil recovery factor of this field.

II. RESEARCH METHODOLOGY

The Sectoral Decline Curve Analysis method begins by preparing the data, such as oil flow rate (Qo), liquid flow rate (Ql), cumulative oil production (Np), porosity, permeability, and saturation property models. The sectorization of the model uses statistical methods to determine of the infill wells coordinate and the production rate of each well, as well as the production forecasts.

The systematic description of the work steps during the research can be described as follows:

a. Data collection include:
   - Oil flow rate (Qo, bopd).
   - Fluid flow rate (Ql, bfpd).
   - Cumulative oil production (Np).
   - Model properties of permeability and HCPV (Hydrocarbon Pore Volume) current.

b. Determine of the HCPV current value using the equation:

$$HCPV=7758*Vb*\emptyset*(1-Swc) \quad (1)$$

c. Statistical calculations on the distribution model HCPV current property and the distribution model permeability property. Using the formula:
   - Determine the range of data

   $$R = \text{Highest Data - Lowest data} \quad (2)$$

   - Class Interval with Sturges rules as follow:

   $$(K) = 1 + 3.3 \log n \quad (3)$$

   with n = the number of grids available.

   - Determine the Interval range (p)

   $$p = R/K \quad (4)$$

   - Create a tabulation based on the existing data.
   - Determine the value of the frequency using Tally rules.
   - Then create three categories (Good, Medium, Poor) from the HCPV Current and permeability data, using a comparison between the range of the data and the number of class intervals. The division is done by finding the upper quartile (75%) and lower quartile (25%).

d. Combine the results of the three sectors of HCPV current and permeability, so that will get nine new sectors. from the new sector it was rebuilt so as to get three new sectors final a combination of HCPV current and permeability.

e. Perform a decline curve analysis based on each sector that has been made. Decline Curve types are divided into three types, namely Harmonic, Hyperbolic and Exponential Declines (Arps, J.J. 1945; Agarwal, R.G. et.al. 1998; Rukmana, D. et.al. 2018).
   - Exponential Equation Decline

   $$q = q_i \, e^{-D_i t} \quad (5)$$

   - Hyperbolic Equation Decline

   $$q = q_i \, (1 + bD_i t)^{-\frac{1}{b}} \quad (6)$$

   - Harmonic Equation Decline

   $$q = \frac{q_i}{1+D_i t} \quad (7)$$

f. Determination of the location of the infill wells in each sector based on the Overlay Map of the Three Sector Combination HCPV current-permeability-cumulative production (Np). In addition, it also considers the cumulative production bubble map and the cumulative water cut (%) contour map of each sector.

g. Determine of the initial oil rate (Qoi) prediction by drawing the trendline on the graph between; semi-log Qpeak vs time; pressure vs time; Qpeak vs transmissibility semi-log; semi-log Qpeak vs pressure; Qpeak vs Productivity Index (PI) semi-log; Productivity Index (PI) vs transmissibility. Experiments from these graphs, selected the trendline draw with the largest R^2 value.

h. Conducted production forecasting.

i. Determination of the Estimate Ultimate Recovery (EUR), Remaining Reserve (RR), and Recovery Factor (RF) which obtained from the development scenario results.

III. RESULTS AND DISCUSSION

A. Determining Sectorization Using Statistical Methods

The model properties are obtained from the export data of the Petrel software which has a total grid of 2095500 with I x J x K; 75 x 55 x 508 on the Central Sumatra Field and for the Lakat layer it consists of 56 layers. Then do the summation of the HCPV Current and the average of the permeability properties. From this data using the statistical method of Gravetter F.J. (2015) it could be determined each class interval where for the frequency value using the Tally rule where by entering each data into its respective class interval according to the existing data value. Then create three categories (Good, Medium, Poor) from the HCPV current and permeability data, using a comparison between the data range and the number of class intervals. The division is done by finding the upper quartile (75%) and lower quartile (25%). Data distribution of statistical method is shown in Table 1, while the sectoral distribution is shown in Table 2, respectively.

Furthermore, combine three sectors of HCPV current with three sectors of permeability so that nine new sectors are obtained, of which nine sectors are simplified into three sectors taking into account the cumulative production (Np) of each well. Overlay map of three sectors combination between HCPV current, permeability and cumulative oil production (Np). The combination results obtained that the good sector has good Np also (HCPV > 17349.04 and Permeability > 99.14), the medium sector has medium Np (HCPV = 6476.27 - 17349.04 and Permeability = 21.01 - 99.14), and the Poor sector has bad Np (HCPV < 6476.27 and Permeability < 21.01). The combination results of HCPV-permeability for 9 sector is shown in Fig. 1, while for 3 sector is shown in Fig. 2.

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Table 1. Data Distribution of Statistical Method

Value		Number of Data	Range Value	Number of Block	Interval Range	Median
Min (Bbl)	**Max (Bbl)**					
203	**35800**	**1506**	**35597**	**11**	**3236**	**12338**
No of Block	**Interval Block**		**Mid Interval**	**Freq**	**Freq (%)**	**Freq. Cum (%)**
	Lower	**Upper**				
1	203	3439	1821	217	14.41	14.41
2	3439	6675	5057	169	11.22	25.63
3	6675	9911	8293	204	13.55	39.18
4	9911	13147	11529	216	14.34	53.52
5	13147	16384	14765	256	17.00	70.52
6	16384	19620	18002	231	15.34	85.86
7	19620	22856	21238	121	8.03	93.89
8	22856	26092	24474	36	2.39	96.28
9	26092	29328	27710	29	1.93	98.21
10	29328	32564	30946	16	1.06	99.27
11	32564	35801	34182	11	0.73	100.00
				1506		

Table 2. Sectoral Distribution Using Statistical Method

Value		Number of Data	Range Value	Number of Block	Interval Range	Median
Min (Bbl)	**Max (Bbl)**					
203	**35800**	**1506**	**35597**	**11**	**3236**	**12338**
No of Block	**Interval Block**		**Mid Interval**	**Freq**	**Freq (%)**	**Freq. Cum (%)**
	Lower	**Upper**				
Poor	203	6476	3339	708	47.01	47.01
Medium	6476	1734	1191	540	35.86	82.87
Good	17349	35801	26574	258	17.13	100.00
				1506		

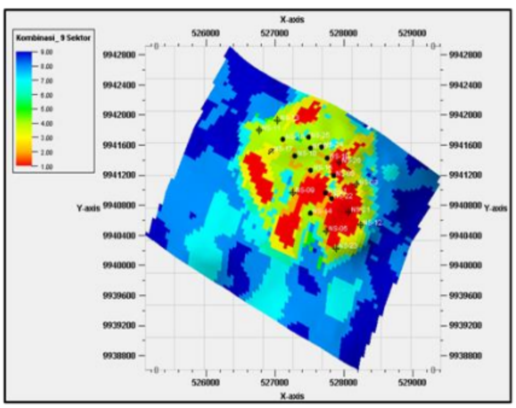

Fig. 1. Combination 9 Sector HCPV-Permeability

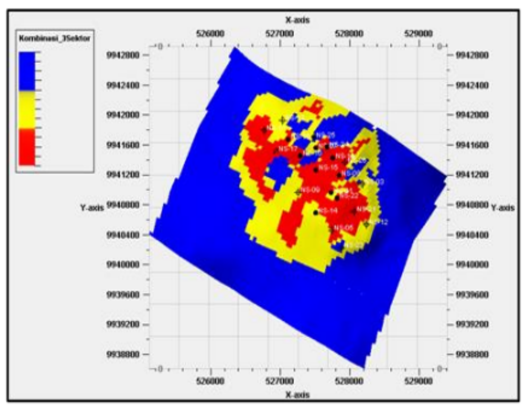

Fig. 2. Combination 3 Sector HCPV-Permeability

B. Decline Curve Analysis and Evaluation

From the overlay map of the combination of three sectors, it can be seen that the wells are included in the good sector, namely NS-21, NS-22, NS-01, NS-15, NS-08, NS-19, NS-24, NS-10, NS -17, NS-11, medium sector namely NS-05, NS-13, NS-14, NS-12, NS-07, NS-16, NS-09, NS-26, bad sector namely NS-23, NS -25, NS-03. Based on Arps. J.J. (1945) and Agarwal, R.G. et.al. (1998), then analyzed the decline curve per sector that has been determined. The results of the decline curve analysis are obtained in both sectors, namely the exponential type with decline rate (Di) is 7.3%. For the medium sector, the type of decline obtained is harmonic with decline rate (Di) is 9.4%. While, in the poor sector, no decline curve analysis was carried out because in that sector the status of the well on 01/12/2011 was plug and abandon and also the last shut-in and oil rate was only 1 bbl/day. The results of Decline Curve Analysis of good sector and medium sector are shown in Fig. 3 and Fig. 4, while the results summary is shown in Table 3, respectively.

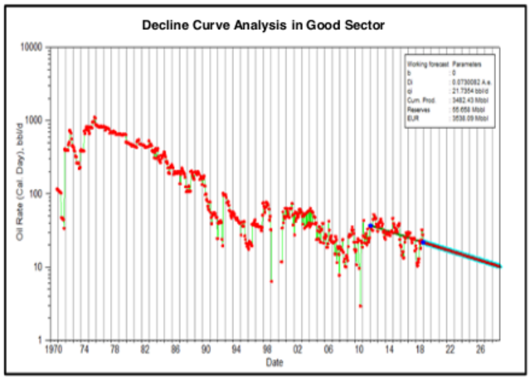

Fig. 3. Decline Curve Analysis of Good Sector

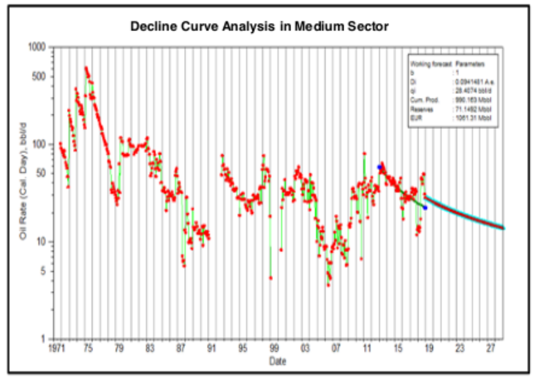

Fig. 4. Decline Curve Analysis of Medium Sector

Table 3. Results Summary of Decline Curve Analysis

Sector	b	Decline Rate (Di)	qi (bbl/day)	Np@ Des 2018	Estimate Ultimate Recovery (Mbbl)	Remaining Reserve (Mbbl)
Good	0	0.073	21.73	3482	3538	55.6
Medium	1	0.094	28.40	990	1061	71.1

C. Determination of Infill Well Location

Determination of the location of the Lakat Field Layer infill wells in Central Sumatra, in both good and medium sectors, is determined based on the HCPV current distribution map and permeability distribution map of the field or can be seen directly on the overlay map of the three-sector combination of HCPV current-permeability-cumulative production (Np). It was also considering the cumulative production bubble map and cumulative water cut contour map (%).

After further analysis and consideration on the Lakat Layer Central Sumatra Field, hence chosen 8 locations of Infill well coordinates as recommendations, including 6 coordinates in the good sector and 2 coordinates in the medium sector. Fig. 5, shows the result of infill well location based on three sector combinations of HCPV current-permeability-cumulative production. Fig. 6, shows the result of infill well location based on cumulative production bubble map and cumulative water cut. Furthermore, in Table 4 shows the recommendation of infill well coordinate.

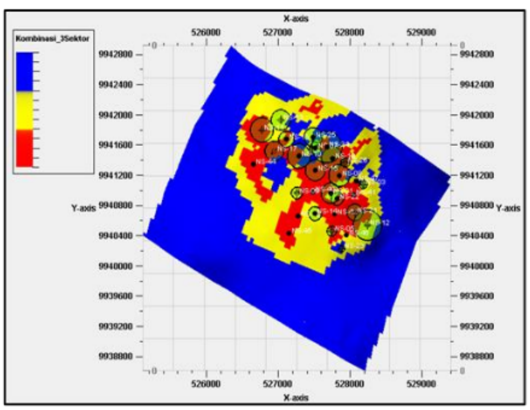

Fig. 5. Location of Infill Well Based on Three Sector Combination of HCPV Current-Permeability-Cumulative Production (Np)

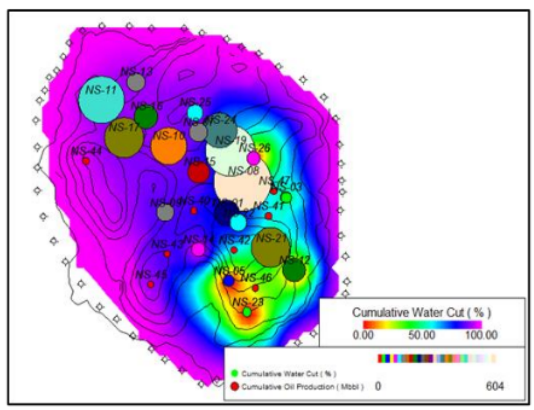

Fig. 6. Location of Infill Well Based on Cumulative Production Bubble Map and Cumulative Water Cut Contour Map

Table 4. Recommendations of Location Coordinate of Infill Wells of Lakat Layer

Sector	Proposed Well	X	Y	Z	Permeability (mD)	Net Thickness (ft)	Water Cut (%)
Good	NS-40	527478.98	9940981	1320	189	21	85
Good	NS-41	528047.41	9940941	1312	153	20	70
Good	NS-42	527784.83	9940688	1320	171	25	72
Good	NS-43	527274.97	9940659	1340	141	20	80
Good	NS-44	526655.07	9941347	1378	254	22	90
Good	NS-45	527150.01	9940434	1380	247	27	80
Medium	NS-46	527947.45	9940409	1335	187	18	40
Medium	NS-47	528087.75	9941125	1317	142	19	68

D. Determination of Initial Oil Rate (Qoi)

Determination of the initial oil rate (Qoi) is needed in order to find out what the initial oil rate is for a well that has just been opened at a certain time. Determination of Qoi could be done by various methods depending on the available data, one of which is by drawing a trendline on the intermediate chart; semi-log Qpeak vs time; pressure vs time; Qpeak vs transmissibility semi-log; semi-log Qpeak Vs pressure; Qpeak vs PI semi-log; PI vs transmissibility (Rukmana, D. et.al. 2018).

Experiments from these graphs, selected the trendline draw with the largest R^2 value, which indicates that the greater the R^2 value, the better the interpretation of the trendline draw. In the Lakat layer of Central Sumatra field for the good sector and the medium sector, it is found that the best trendline is from the pressure vs time and Productivity Index (PI) vs transmissibility charts with a value of $R^2 = 1$, as shown in Fig. 7 and Fig. 8. From the results of the pressure vs time graph, the pressure value against time is obtained when the infill well is carried out for each well, then from the results of the PI vs Kh graph, the PI value against Kh will be obtained. After getting the PI value, we could then find the Qmax value for each infill well using the Darcy minimum data equation (Brown, K.E. 1984; Agarwal, R.G. et.al. 1998). After getting the Qmax value, then looking for the Qoptimum value for each infill well, for determining Qoptimum it can be divided into three categories, Optimist (80% of Qmax), Moderate (60% of Qmax) and Pessimistic (40% of Qmax). In this research, the Qoptimum used is from the pessimistic category (40% of Qmax), where the results of initial production rate shown in Table 5.

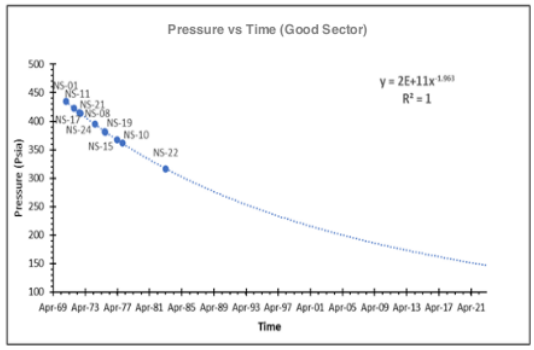

Fig. 7. Graph of Pressure vs Time of Lakat Layer

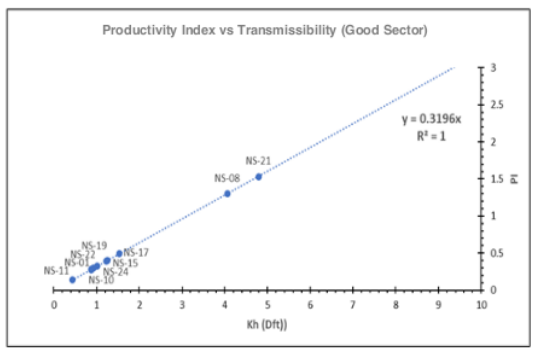

Fig. 8. Graph of Productivity Index vs Transmissibility (Kh) of Lakat Layer

Table 5. Initial Production Rate Results of Infill Wells in Lakat Layer

Sector	Proposed Well	Date	Initial Pressure (Psi)	Transmissibility (Dft)	Productivity Index (Bbl/d/Psi)	Max. Production Rate (Bbl)	Initial Production Rate (Bbl)
Good	NS-40	01/08/2021	151	3.97	1.27	191	76
Good	NS-41	01/11/2021	150	3.06	0.98	147	59
Good	NS-42	01/02/2022	149	4.28	1.37	206	82
Good	NS-43	01/05/2022	149	2.82	0.90	136	54
Good	NS-44	01/08/2022	148	5.59	1.79	269	108
Good	NS-45	01/11/2022	148	6.67	2.13	321	128
Medium	NS-46	01/02/2023	147	3.37	1.08	162	65
Medium	NS-47	01/05/2023	147	2.70	0.86	130	52

E. Central Sumatra Field Development Scenario

The Central Sumatra Field of Lakat Layer carried out field development scenarios in the good and medium sectors. By doing a scenario, namely the addition of 6 infill wells in the good sector and 2 infill wells in the medium sector with the predicted initial production rate (Qoi) based on Table 5. In Fig. 9, shows the forecast of basecase production (8 production wells) + 8 infill wells in good and medium sectors.

The results of the development scenario in the good sector and the medium sector, where the EUR in the good sector + 6 infill wells is 4897 MSTB and the EUR in the medium sector + 2 infill wells is 1406 MSTB. The Cumulative Production (Np) of Lakat Layer Central Sumatra Field in December 2018 was 4650 MSTB and obtained an RF of 25.9%. For the results of the addition of the infill scenario, the RF was 36.1%. Hence, the increase in RF after developing the Infill scenario is 10.2%.

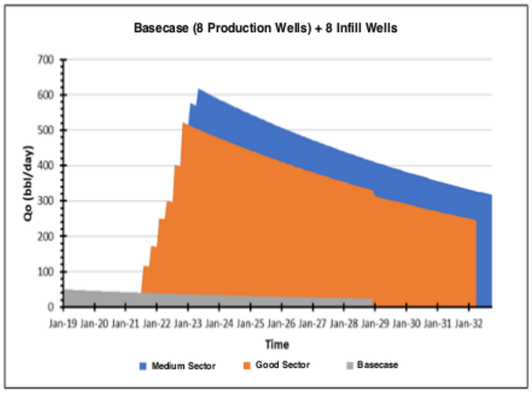

Fig. 9. Result of Production Forecast: Basecase (8 Production Wells) + 8 Infill Wells

Table 6. Production Forecast Results of Infill Wells in Lakat Layer

Sector	Oil in Place [MSTB]	Np@Des 2018 [MSTB]	EUR Scenario [MSTB]	ΔNp [MSTB]	Recovery Factor Basecase (%)	Recovery Factor (%)
Good	17927	3482	4897	1414	25.9	36.1
Medium		990	1406	415		
				1829		

IV. CONCLUSIONS

Based on the analysis and discussion, there are some results as a conclusion as follows:

1. Analysis of the HCPV current and permeability model properties is calculated using statistical methods so that it can create three categories, namely good sector (HCPV > 17349.04 bbl and permeability > 99.14 mD), medium sector (HCPV = 6476.27 - 17349.04 bbl and permeability = 21.01 - 99.14 mD), and poor sectors (HCPV < 6476.27 bbl and permeability < 21.01 mD).
2. The wells that are included in the good sector are NS-21, NS-22, NS-01, NS-15, NS-08, NS-19, NS-24, NS-10, NS-17, NS-11, medium sector is NS-05, NS-13, NS-14, NS-12, NS-07, NS-16, NS-09, NS-26, and poor sector are NS-23, NS-25, NS-03.
3. Decline curve analysis obtained in both types of decline sector that is exponential with decline rate (Di) is 7.3%, and for the medium sector the type of decline obtained is harmonic with Di is 9.4%.
4. Overlay map analysis of three sectors HCPV current-permeability-cumulative production by considering the cumulative production bubble map and cumulative water cut (%) contour map of each sector in the Lakat Layer of Central Sumatra Field, selecting 8 locations of Infill well coordinates as recommendations, including 6 coordinates on good sector and 2 coordinates on medium sector.
5. The best trendline from the graphs of pressure vs time and PI vs Kh with a value of R^2 = 1. The Qoi of the infill well of NS-40 is 76 bbl/day, NS-41 is 59 bbl/day, NS-42 is 82 bbl/day, NS -43 is 54 bbl/day, NS-44 is 108 bbl/day, NS-45 is 128 bbl/day, NS-46 is 64 bbl/day, and NS-47 is 52 bbl/day.
6. The cumulative production (Np) of the Lakat Layer of Central Sumatra Field in December 2018 was 4650 MSTB and obtained a RF of 25.9%. The additional of infill well scenario results have the RF 36.1%, hence increasing in RF by 10.2%.

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