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Production Forecast Using Decline Type Curve (Case Study for Reservoir X, Field Y)

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ABSTRACT

Decline curve analysis (DCA) is the most common method applied practice in the evaluation of reservoir parameters and to forecast future production of oil and gas, also to estimate ultimate recovery and reserves. Predicting the production rates from a given well is the most considerable interest in the oil and gas industry. The objective of this work presents the use of decline curve analysis to obtain the type of decline, remaining oil reserve and oil productivity in reservoir X field Y. Production data is the only available information which used in DCA, by plotting rate of production versus time for a given well, an extrapolation can be made to provide an estimate of the future rates of production for that well. Result shows the types of decline for these wells are exponential decline curves and the total EUR for reservoir X from well A, well B and well C started producing until July 2016 was 24,835,856.82 with RF 29%. While the total amount of oil reserves that can be taking is 82,316.82 STB for 17 months from January 2015 to July 2016.

Keywords: Decline curve analysis, remaining oil reserve, cumulative production and production lifetime.

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1. Introduction

Field Y is a type of oil field which located in Timor Sea, formerly called Joint Petroleum Development Area (JPDA) where the area is about 200 km from southern Timor-Leste and 500 km northwest of Darwin, Australia. This field began production in 2011 with an original oil in place (OOIP) 86.9 MMSTB. Reservoir X has been produced several years with three wells, and the rate of production also started decrease till a temporary shut in, in December 2015 which with cumulative oil production was 26.23 MMSTB.

Evaluating production performance of conventional and unconventional reservoir are very important, because it helps to understand the risk involved in the development of these reservoir, also to understand production mechanisms, fluid properties, reservoir characterization and behave. Then, search for the proper method that can be used to predict the future performance of these reservoirs more accurately and reduce risk as a basis for oil and gas development planning (Kocoglu et al., 2020). According to Dan et al., (2018), decline curve analysis is one of the method used to estimate the amount of oil reserves based on production data after a certain time interval. The decrease in production rate is influenced by various factors, including the driving mechanism, pressure, physical properties of rock and reservoir fluids.

Decline curve analysis is one of the fundamental tools used in forecasting production rate and estimate oil recovery (Bhattacharya and Nikolaou, 2013). One of the most important tasks of a reservoir engineer is able to predict lifetime of production well. These production forecasts are used for estimating remaining reserves, optimizing production operations, business planning, safe, economic, and sustainable exploitation of oil and gas (Onyemaechi et al., 2020).

Due to this, it is necessary to estimate the remaining oil reserves that can still be produced up to the economic limit using the decline curve method, which aims to predict the production rate, cumulative oil production and production life time at "X" Reservoir, Y field. Therefore, the purpose of this research is to evaluate the remaining oil reserves that can be extracting up to the economic limit as a basis for development planning in Y field. This work presents the use of decline curve analysis to obtain the type of decline, remaining oil reserve and oil productivity in reservoir X field Y.

2. Literature Review

There are a lot of studied had been done to investigate on the production decline analysis in the oil and gas field (Kegang and Jun., 2012). Many studied had been conducted and has significant contributions globally for the oil and gas exploration and development (Arps, 1945; Arps, 1956; Fetkovich et al., 1980; Fetkovich et al., 1987; Fetkovich et al., 1996).

One of the most empirical result presented by Arps had been applied for many decades and proved applicable tool in production forecast. Production decline is related to the reservoir pressure, different reservoir fluid and reservoir drive mechanism (Kegang and Jun., 2012). DCA is the most important fundamentals in petroleum engineering to forecast reserve, forecasting future production rates, forecasting life of a well, EOR and even to determine the OOIP. Other researcher had been conducted research and

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published focus on oil and gas production decline, such as: Ehlig-Economides and Ramey, 1981; Chen and Poston, 1989; Duong, 1989; Doublet et al, 1994; Rodriguez and Cinco-Ley, 1993; Callard and Schenewerk, 1995; Agarwal et al, 1998; Hagoort, 2003; Yang, 2009; Keshinro et al., 2018; Han et al, 2019; Kianinejad et al, 2019; Kaur et al, 2020).

Conditions that can influence and change decline rate are separator pressure, tubing size, choke position, workovers, compression and operating hours. During these conditions do not change the trending decline can be analyzed and extrapolated to forecast future well performance.

Developed by J.J. Arps in 1940 it is one of the first method used for decline curve analysis. The Arps decline regarded as the condition shown relationship between rate production and time in oil production well (Dou et al., 2009), as indicated by the following equation:

$$q(t) = q_i (1 + nD_i t)^{-1/n} \quad (1)$$

Where:

$q(t)$ = oil production rate at production time
q_i = initial oil production rate
n = decline exponent
D_i = initial decline rate

The three types of curves Arps used to best fit data to predict flow rate vs time are exponential, hyperbolic and harmonic. If the value of n = 0, then it is called exponential decline, if the value of 0 < n <1 is called hyperbolic decline and for the value n = 1 is called harmonic decline.

2.1. Exponential

An exponential decline for oil production well can be obtained using the following equation:

$$q(t) = q_i e^{-Dt} \quad (2)$$

For oil cumulative production the following equation can be applied:

$$N_p = \frac{(qi - q)}{D} \quad (3)$$

Where:

N_p = cumulative production

2.2. Hyperbolic

Hyperbolic decline in the oil production, the following equation can be use:

$$q(t) = q_i (1 + nD_i t)^{-1/n} \quad (4)$$

For oil cumulative production:

$$N_p = q_i^n/D_i (1/1\text{-}n) (q_i^{1-n} - q^{1-n}) \quad (5)$$

2.3. Harmonic

Harmonic decline in the oil production, the following equation can be use:

$$q(t) = q_i /(1 + D_i t) \quad (6)$$

For oil cumulative production:

$$Np = q_i /D_i \ln q /q_i \quad (7)$$

Table 1. Arp's Models (1945)

Decline exponent value	Decline Type	Arp's Models
N=0	*Exponential*	$q_t = q_i e^{-Dit}$
0<n<1	*Hyperbolic*	$q_t = q_i(1 + nD_i t)^{\frac{-1}{b}}$
N=1	*Harmonic*	$q_t = q_i(1 + nD_i t)^{-1}$

2.4. Estimated Ultimate Recovery

EUR is an estimate of the total amount of oil that could ever be recovered from the volume initially in place. The EUR is typically broken down into three main categories: cumulative production, discovered reserves, both commercial and sub-commercial, and undiscovered resource (Yu, 2013). Cumulative production is an estimate of all of the oil produced up to a given date. Discovered, commercial, reserves, are typically broken down into proved, probable, and possible reserves. Production data is one of the key parameters used in oil and gas industry to determine the life span of producing hydrocarbon, in order to predict the profitability of oil reserve. Oil reserve is estimated volumes of oil, condensate, natural gas, natural gas liquids and other commercially related substances can be taken from the amount accumulated in the reservoir (B.C. and Hawkins, 1991).

2.5. Recovery Factor

The ratio of reserves to oil initially in place for a given field is often referred to as the recovery factor. Recovery factor is the ratio of the amount of oil or gas that can be extracted to the amount of oil or gas in place by using primary, secondary or tertiary recovery technology. Recovery factors vary widely across countries, geologies and technologies, and may change over time based on operating history and in response to changes in technology and economics (Dake, 1978).

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Table 2. Summary of production decline equations (Fetkovich et al.,1996)

Decline Type	Hyperbolic	Exponential	Hamonic
Rate Time	$q(t) = q_i/ (1+bD_it)^{1/b}$	$q(t)=q_i/e^{D_it}$	$q(t)=q_i/(1+D_it)$
Time to q(t)	$t = \{[q_i/q(t)]^b-1\}/bD_i$	$t = In[q_i-q(t)]/D_i$	$t = \{[q_i/q(t)]-\}/D_i$
Cumulative –Time	$Q_P =[q_i/(1-b)D_i][1-(1+bD_it)^{(b-1/b)}]$	$Q_P =(q_i/D_i)(1-e^{-D_it})$	$Q_p=(q_i/D_i)[In(1+D_it)]$
Rate-Cumulative	$Q_p =[q_ib/(1-b)D_i]\ [q_i^{(1-b)}q(t)^{(1-b)}]$	$Q_p=[q_i- q(t)]/Q_{Di}$	$Q_p=(q_i/D_i)In[q_i/q(t)]$
From Rate-Cum. D_i at q(t)=0	$D_i= [1/(1-b)]/2(Q_{puo})$	$D_i=q_i/Q_{pou}$	D_i *is not definable; (*Q_{puo} *is infinite).*
D_i(oil)	$D_i = [(2n+1)/2](qi/N_{puo})$ $N_{puo}=N$ *x (RF) Where RF =f* (k_g/k_o)	$n = 0.5;D_i= (q_i/N_{puo})$	*Not derivable*
D_i(gas)	$D_i=2n(q_i/G)$ $G= G_i$ *x (RF) Where RF =* $[1- (P_{wf}/PR)]$	$n= 0.5;D_i=(q_i/G)$	*Not derivable*
b(oil) Where pwf = 0	$b = (2n-1)/(2n+1)$*Where n is between 0.5 and 1*		
b(gas) Where Pwf = 0	$b = (2n-1)/(2n$ *Where n is betwee 0.5 and 1*		

3. Research Methods

In this research using quantitative data, which is the emphasis of research on collecting and analyzing numerical data; it concentrates on measuring the scale, range and frequency of phenomena. In this study obtained data from report which addressed by Z company (FDP, 2009). The data source used in writing this research is secondary data, in which refer to production profile for tree different well such as well A, well B and well C. These wells located in reservoir X field Y. After known the time and its production profile, then applied decline curve analysis method to obtain the type of decline, remaining oil reserve and oil productivity in reservoir X field Y. In this research using excel as a tool for analyze and constructing the graph. Production data in this research refer to fluid rate (oil, water, and gas), time and production history, fluid components, tracers and subsurface pressure.

Table 4. Data of reservoir X field Y for case study (FDP, 2009)

Parameter	Value	Unit
OOIP	86,900,000.00	STB
Production rate	7717	STB
Cumulative production	24,753,540.00	STB
Field economic limit rate	3,000	STB/D

Pressure data refer to formation testing, BHP, THP, and continuous downhole monitoring (Wheaton, 2016). Production profile data for well A, well B and well C in reservoir X filed Y which used in this research discussed briefly in table 3 (appendix) and table 4.

4. Results and Discussions

4.1. Selecting Production Trend for Decline Curve Analysis

Result shows there were three wells such as well A was drilled on 16 November 2010 with 3,510 MDRT. Well B was drilled 10 days later with measure depth 3,549 and well C was drilled on 09 January 2011 with the same MDRT of well A. These well were chosen to be analyzed because they met the decline criteria which during this period there were no changed in production patterns in the wells started from the beginning production in October 2011, nevertheless with time flowed by the rate production started to decrease till December 2015, then these wells were shut in.

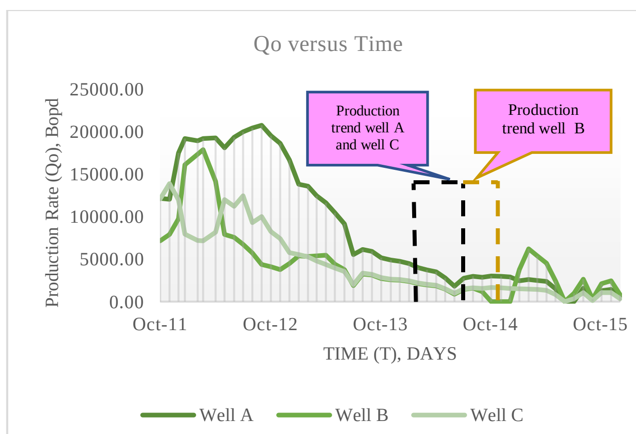

Figure 1. Production trend analysis on well A, well B and well C

Due to these, well A and well C were taken at the same months and year which was from august 2014 till January 2015, on the other hand well B was taken from January 2015 till may 2015 with different rate production

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each well, because they were dramatically depleted. The first trend with rate production 2982 BOPD which were gradually declining to 2436 and the second trend were steady fall from 3765 to 2452 BOPD, even well C also was dramatically decrease from 1627 to 1516 BOPD as shown in Figure 1.

4.2. Decline Type Curve

To determine the decline curve type more accurately in these three wells case, then there were used two methods, such as loss ratio and trial error x2-chisquare test.

a. Loss ratio method - well A, well B and well C

Determination of decline curve type in well A, well B and well C can be done by using the loss ratio method that is by dividing oil production rate in a certain period with the loss of production during that period. Result in table 5, table 6 and table 7 show the value of decline (b) in extrapolation of production data using the loss ratio method for well A = 1.085077951, well B = -0.187432768 and well C = 9.780645161. However, according to Arps (1945), the value of exponent decline does not meet the specified conditions (0 ≤ b ≥ 1). Therefore, this method cannot be applied in determining the right type of decline curve. The next extrapolation method is the trial error and x2-chisquare test method. The trial error is a method by determining the value of oil production rate (qo) for all values of decline (b = 0 to b = 1). This method is done by calculating the difference in squares between the actual oil production rate (qo actual) and the prediction of oil production rate (qo forecast), then divided with qo forecast, so that the smallest x2 value is obtained which shows the smallest deviation from the actual qo value.

Table 5. Results of calculating decline curve type using loss ratio method at well A

WELL A								
t	**Time**	**q**	**dq**	**dt**	**D=-(dq/dt)/q**	**a=-(qo/(dq/dt))**	**da=a2-a1**	**b=-(da/dt)**
	Month	**Bopd**	**Bopd**	**Month**				
0	Aug-14	2982						
1	Sep-14	2865	117	-1	0.04	24.4871795	24.487	24.487
2	Oct-14	3029	-164	-1	-0.05	-18.4695122	-42.957	-42.957
3	Nov-14	2965	64	-1	0.02	46.3281250	64.798	64.798
4	Dec-14	2885	80	-1	0.03	36.0625000	-10.266	-10.266
5	Jan-15	2436	449	-1	0.18	5.4253898	-30.637	-30.637
b=∑b/n					**0.22**			**5.425**
b		**1.085077951**						

Table 6. Result of calculating decline curve type using loss ratio method at well B

WELL A								
t	**Time**	**q**	**dq**	**dt**	**D=-(dq/dt)/q**	**a=-(qo/(dq/dt))**	**da=a2-a1**	**b=-(da/dt)**
	Month	**Bopd**	**Bopd**	**Month**				
0	Jan-15	3765.00						
1	Feb-15	6194.00	-2429.00	-1	-0.392	-2.550020585	-2.550	-2.550
2	Mar-15	5393.00	801.00	-1	0.149	6.732833958	9.283	9.283
3	Apr-15	4516.00	877.00	-1	0.194	5.149372862	-1.583	-1.583
4	May-15	2452.00	2941.00	-1	1.199	0.833730024	-5.899	-5.899
b=∑b/n						**1.14999961**		
b		**-0.187432768**						

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Table 7. Result of calculating decline curve type using loss ratio method at well C

WELL A								
t	**Time**	**q**	**dq**	**dt**	**D=-(dq/dt)/q**	**a=-(qo/(dq/dt))**	**da=a2-a1**	**b=-(da/dt)**
	Month	**Bopd**	**Bopd**	**Month**				
0	Aug-14	1,627.00						
1	Sep-14	1,561.00	66.00	-1	0.04	23.6515152	23.652	23.652
2	Oct-14	1,652.00	-91.00	-1	-0.06	-18.1538462	-41.805	-41.805
3	Nov-14	1,621.00	31.00	-1	0.02	52.2903226	70.444	70.444
4	Dec-14	1,547.00	74.00	-1	0.05	20.9054054	-31.385	-31.385
5	Jan-15	1,516.00	31.00	-1	0.02	48.9032258	27.998	27.998
b=∑b/n					**0.07**			**48.903**
b		**9.780645161**						

b. Trial error and x2-chisquare test method - well A, well B and well C

Based on results of table 8, the smallest ∑ X2 is the fit value 115,799 and the value is obtained from data sum of august 2014 to January 2015, with values b = 0 and Di = 0.0404 per month. Results of table 9 show the smallest ∑ X2 is 5331.456 and the value is obtained from data sum of January to December 2015, with values of b = 0 and Di = 0.1072 per month. Calculation results of table 10 show the smallest ∑ X2 (the fit value) is 6.78 and the value is obtained from data sum of August 2014 to January 2015, with values b = 0 and Di = 0.0141 per month, where the declination curve in the well A, well B and well C are exponential decline. According to Ahmed (2010), the type of exponential decline curve is using equation (1) will mold a straight line curve if the production rate is plotted against time on semi-log paper. Therefore, from the results of calculations using the trial error and x2-chisquare test method, the exponential decline curve can be used to forecast the production of these three wells.

4.3. Forecast of Oil Production Rate and Cumulative Oil Production at Well A, Well B and Well C

The results of qo forecast, Np forecast, EUR till qlimit calculation shown in table 11, table 12 and table 13. Based on production history, well A started producing oil from the October 2011 to December 2015. Then proceed with a decline curve analysis to predict the remaining oil reserves, that can be still produced up to the limit of the production flow rate (qlimit) 1000 BOPD.

The decline analysis data was taken from august 2014 to January 2015, where the cumulative amount of production of well A in January 2015 was 12,450,150.00 STB, well B was 5,977,290.00 STB and well C was 6,326,100 STB. The results of the analysis are obtained, EUR in well A from the beginning of the production well until November 2016 was 12,485,655.98 STB, for well B EUR 12 months was 6,003,083 STB and EUR in well C from the beginning of the production until around 29 months if calculated from January 2015 to June 2017 amounted to 6,362,696 STB. While ERR in well A that can be produced from January 2015 to November 2016 was 35,544.554 STB as shown in table 11, ERR well B that can be produced from September 2015 to around 12 months if calculated from January 2015 to January 2016 was 25,418.543 STB as shown in table 11 and ERR well C that can be produced from January 2015 to June 2017 was 36,085,029 STB as shown table 13.

Figure 2. Graph of oil production rate and cumulative production at well A

The time limit of production that needed to take the remaining reserves of well A is around 22 months if

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calculated from January to November 2016, remaining reserves of well B is around 12 months if calculated from September to August 2016 and well C the time limit that needed to take remaining reserves is around 29 months if calculated from January to June 2015. These can be stated that these wells are still feasible to be produced because still contains sufficient oil reserves. While RF in well A, well B and well C are 14%, 7% and 7%. Figure 2, Figure 3 and figure 4.4 show a graph of oil and cumulative production rates at well A, well B and well C from the beginning of well's production to the flow rate limit production.

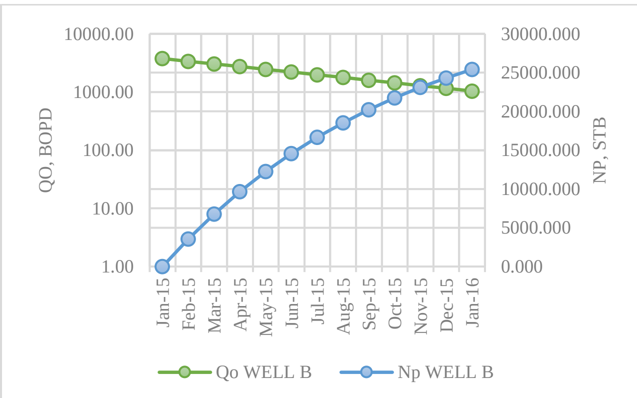

Figure 3. Graph of oil production rate and cumulative production at well B

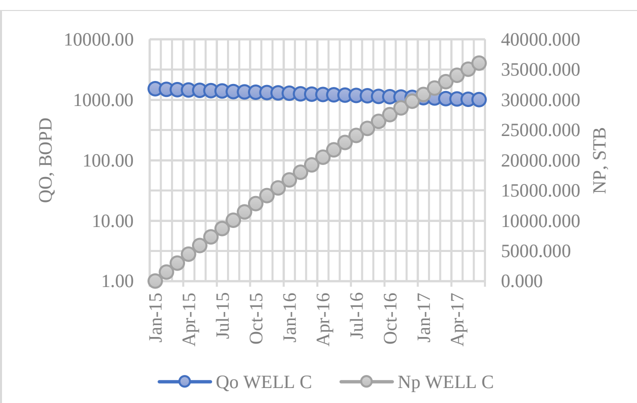

Figure 4. Graph of oil production rate and cumulative production at well C

4.4. Analysis of Total Well A, Well B and Well C Reservoir X Field Y

Result table 14 show EUR of reservoir X from the beginning of production until July 2016 with amount 24,835,856.82 STB. While the ERR in reservoir X that can be produced from January 2015 to July 2016 is 82,316.82 STB. The time needed to extract the remaining oil reserves is approximately 17 months calculated from January 2015 until July 2016. Total RF in reservoir X was 29 %. Due to this, these wells are still potential to be developed based on the prevailing prevision of company with economic limit rate 3000 BOPD. Figure 5. Shows the results of total analysis in well A, well B and well C based on field economic limit.

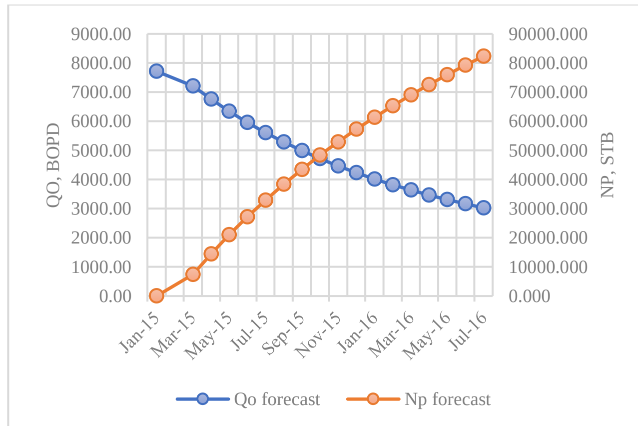

Figure 5. Graph of total Qo and Np forecast versus time at reservoir X field Y

5. Conclusions and Future Research

5.1. Conclusions

Following conclusions can be drawn, a). The selection of well trends to be analyze taken from different months such as well A, well C start from August 2014 to January 2015, and well B was taken from January 2015 to May 2015, because they matched the parameter of sorting trends where the selection was based on graph of decreasing production rate. Therefore, the method of determining decline curve type used trial error and x2-chisquare test methods. It obtains values b and D_i for each well such as: well A (b = 0; D_i = 0.0404), well B (b = 0; D_i = 0.1072) and well C (b = 0; D_i = 0.0141). Due to this, the types of decline for these wells are exponential decline curves. b). Based on field economic limit 3000 BOPD, obtain the total EUR for reservoir X from well A, well B and well C started producing until July 2016 was 24,835,856.82 with RF 29%. While the total amount of oil reserves that can be taking is 82,316.82 STB for 17 months from January 2015 to July 2016.

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5.2. Future Research

For well A, well B and well C in reservoir X field Y still have production life for around 17 months. However, to get more accurate results, it can be confirmed by using an adequate program and/or application (simulation study), and if the results obtained are not too different, then it is recommended to continue the production activities by considering economic analysis.

Abbreviation

BHP = bottom hole pressure
BOPD = barrel oil per day
BOPM = barrel oil per month
BWPD = barrel water per day
EOR = enhanced oil recovery
EUR = estimated ultimate recovery
ERR = estimated remaining reserve
MDRT = measured depth rotary table
MMSTB = million stock tank barrels
OOIP = original oil in place
OGIP = original gas in place
RF = recovery factor
SCF = standard cubic feet
STB = stock tank barrel
T = time/day
THP = tubing head pressure

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Appendix

Table 3. Oil production profile data at Field Y

Time (Months)	WELL A		WELL B		WELL C	
	Qo (stb/d)	NP Oil (stb/m)	Qo (stb/d)	NP Oil (stb/m)	Qo (stb/d)	NP Oil (stb/m)
Oct-11	12160	364800	7145	214350	12065	361950
Nov-11	12017	725310	7897	451260	13880	778350
Dec-11	17499	1250280	9751	743790	11955	1137000
Jan-12	19169	1825350	16104	1226910	7945	1375350
Feb-12	18901	2392380	17322	1746570	7169	1590420
Mar-12	19193	2968170	17869	2282640	7164	1805340
Apr-12	19246	3545550	14151	2707170	8172	2050500
May-12	18069	4087620	7895	2944020	12000	2410500
Jun-12	19311	4666950	7565	3170970	11217	2747010
Jul-12	19976	5266230	6715	3372420	12457	3120720
Aug-12	20414	5878650	5721	3544050	9302	3399780
Sep-12	20736	6500730	4356	3674730	9993	3699570
Oct-12	19512	7086090	4119	3798300	8229	3946440
Nov-12	18618	7644630	3771	3911430	7423	4169130
Dec-12	16652	8144190	4496	4046310	5753	4341720
Jan-13	13818	8558730	5366	4207290	5549	4508190
Feb-13	13557	8965440	5318	4366830	5275	4666440

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Mar-13	12432	9338400	5397	4528740	4771	4809570
Apr-13	11624	9687120	5455	4692390	4356	4940250
May-13	10445	10000470	4419	4824960	3957	5058960
Jun-13	9138	10274610	3760	4937760	3552	5165520
Jul-13	5528	10440450	1900	4994760	1997	5225430
Aug-13	6133	10624440	3222	5091420	3355	5326080
Sep-13	5897	10801350	3120	5185020	3217	5422590
Oct-13	5150	10955850	2725	5266770	2813	5506980
Nov-13	4877	11102160	2563	5343660	2643	5586270
Dec-13	4741	11244390	2508	5418900	2589	5663940
Jan-14	4484	11378910	2372	5490060	2447	5737350
Feb-14	3993	11498700	2113	5553450	2179	5802720
Mar-14	3708	11609940	1962	5612310	2024	5863440
Apr-14	3514	11715360	1863	5668200	1922	5921100
May-14	2785	11798910	1472	5712360	1518	5966640
Jun-14	1814	11853330	873	5738550	967	5995650
Jul-14	2732	11935290	1445	5781900	1491	6040380
Aug-14	2982	12024750	1578	5829240	1627	6089190
Sep-14	2865	12110700	1170	5864340	1561	6136020
Oct-14	3029	12201570	0	5864340	1652	6185580
Nov-14	2965	12290520	0	5864340	1621	6234210
Dec-14	2885	12377070	0	5864340	1547	6280620
Jan-15	2436	12450150	3765	5977290	1516	6326100
Feb-15	2591	12527880	6194	6163110	1464	6370020
Mar-15	2471	12602010	5393	6324900	1424	6412740
Apr-15	2363	12672900	4516	6460380	1335	6452790
May-15	1497	12717810	2452	6533940	821	6477420
Jun-15	0	12717810	0	6533940	0	6477420
Jul-15	0	12717810	991	6563670	328	6487260
Aug-15	1591	12765540	2643	6642960	1048	6518700
Sep-15	188	12771180	303	6652050	130	6522600
Oct-15	1300	12810180	2102	6715110	1073	6554790
Nov-15	1423	12852870	2449	6788580	1049	6586260
Dec-15	467	12866880	836	6813660	337	6596370

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Table 8. Calculation results of decline curve type using trial error and x2-chisquare test method at well A

WELL A									
	Time	**t**	**0**	**1**	**2**	**3**	**4**	**5**	**Cumulative**
		Months	**Aug-14**	**Sep-14**	**Oct-14**	**Nov-14**	**Dec-14**	**Jan-15**	
b	**Di**	**qo Actual, bopd**	2982.00	2865	3029	2965	2885	2436	**X^2**
0	0.0404	**qo, bopd**	2982.000	2863.793	2750.271	2641.249	2536.550	2436.000	
		X^2	0.000	0.001	28.248	39.684	47.867	0.000	115.799
0.1	0.0409	**qo, bopd**	2982.000	2862.852	2748.920	2639.955	2535.723	2436.000	
		X^2	0.000	0.002	28.537	40.021	48.110	0.000	116.670
0.2	0.0413	**qo, bopd**	2982.000	2861.904	2747.566	2638.665	2534.904	2436.000	
		X^2	0.000	0.003	28.827	40.359	48.352	0.000	117.542
0.3	0.0417	**qo, bopd**	2982.000	2860.949	2746.209	2637.380	2534.091	2436.000	
		X^2	0.000	0.006	29.120	40.698	48.592	0.000	118.416
0.4	0.0421	**qo, bopd**	2982.000	2859.986	2744.849	2636.098	2533.285	2436.000	
		X^2	0.000	0.009	29.416	41.036	48.831	0.000	119.292
0.5	0.0426	**qo, bopd**	2982.000	2859.017	2743.487	2634.822	2532.487	2436.000	
		X^2	0.000	0.013	29.713	41.376	49.069	0.000	120.170
0.6	0.0430	**qo, bopd**	2982.000	2858.040	2742.123	2633.550	2531.695	2436.000	
		X^2	0.000	0.017	30.013	41.715	49.305	0.000	121.050
0.7	0.0435	**qo, bopd**	2982.000	2857.055	2740.757	2632.283	2530.910	2436.000	
		X^2	0.000	0.022	30.314	42.055	49.539	0.000	121.931
0.8	0.0439	**qo, bopd**	2982.000	2856.064	2739.388	2631.020	2530.132	2436.000	
		X^2	0.000	0.028	30.618	42.395	49.773	0.000	122.814
0.9	0.0444	**qo, bopd**	2982.000	2855.065	2738.018	2629.763	2529.361	2436.000	
		X^2	0.000	0.035	30.924	42.735	50.004	0.000	123.698
1	0.0448	**qo, bopd**	2982.000	2854.059	2736.646	2628.511	2528.596	2436.000	
		X^2	0.000	0.042	31.232	43.076	50.235	0.000	124.585

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Table 9. Calculation results of trial error and x2-chisquare test method at well B

WELL B								
	Time	**t**	**0**	**1**	**2**	**3**	**4**	**Cumulative**
		Months	**Jan-15**	**Feb-15**	**Mar-15**	**Apr-15**	**May-15**	
b	**Di**	**qo Actual, bopd**	3765.00	6194	5393	4516	2452	**X^2**
0	0.1072	**qo, bopd**	3765.000	3382.236	3038.384	2729.491	2452.000	
		X^2	0.000	2337.513	1824.724	1169.308	0.000	5331.546
0.1	0.1095	**qo, bopd**	3765.000	3376.368	3031.408	2724.822	2452.000	
		X^2	0.000	2351.359	1839.777	1177.441	0.000	5368.577
0.2	0.1119	**qo, bopd**	3765.000	3370.428	3024.451	2720.230	2452.000	
		X^2	0.000	2365.445	1854.890	1185.485	0.000	5405.820
0.3	0.1144	**qo, bopd**	3765.000	3364.417	3017.517	2715.712	2452.000	
		X^2	0.000	2379.771	1870.055	1193.439	0.000	5443.264
0.4	0.1170	**qo, bopd**	3765.000	3358.336	3010.607	2711.271	2452.000	
		X^2	0.000	2394.337	1885.266	1201.300	0.000	5480.902
0.5	0.1196	**qo, bopd**	3765.000	3352.188	3003.727	2706.904	2452.000	
		X^2	0.000	2409.142	1900.515	1209.066	0.000	5518.723
0.6	0.1223	**qo, bopd**	3765.000	3345.973	2996.877	2702.613	2452.000	
		X^2	0.000	2424.185	1915.796	1216.738	0.000	5556.719
0.7	0.1250	**qo, bopd**	3765.000	3339.693	2990.062	2698.397	2452.000	
		X^2	0.000	2439.465	1931.101	1224.312	0.000	5594.878
0.8	0.1279	**qo, bopd**	3765.000	3333.351	2983.284	2694.256	2452.000	
		X^2	0.000	2454.981	1946.422	1231.788	0.000	5633.192
0.9	0.1308	**qo, bopd**	3765.000	3326.948	2976.546	2690.188	2452.000	
		X^2	0.000	2470.730	1961.754	1239.165	0.000	5671.649
1	0.1339	**qo, bopd**	3765.000	3320.486	2969.850	2686.195	2452.000	
		X^2	0.000	2486.710	1977.087	1246.442	0.000	5710.240

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Table 10. Calculation results of trial error and x2-chisquare test method at well C

WELL C									
	Time	**t**	**0**	**1**	**2**	**3**	**4**	**5**	**Cumulative**
		Months	**Aug-14**	**Sep-14**	**Oct-14**	**Nov-14**	**Dec-14**	**Jan-15**	
b	**Di**	**qo Actual, bopd**	1627.00	1561	1652	1621	1547	1516	**X^2**
0	0.0141	**qo, bopd**	1627.000	1604.168	1581.657	1559.461	1537.577	1516.000	
		X^2	0.000	1.162	3.128	2.428	0.058	0.000	6.78
0.1	0.0142	**qo, bopd**	1627.000	1604.104	1581.562	1559.368	1537.516	1516.000	
		X^2	0.000	1.158	3.137	2.436	0.059	0.000	6.79
0.2	0.0142	**qo, bopd**	1627.000	1604.040	1581.467	1559.274	1537.455	1516.000	
		X^2	0.000	1.155	3.146	2.443	0.059	0.000	6.80
0.3	0.0143	**qo, bopd**	1627.000	1603.975	1581.372	1559.181	1537.394	1516.000	
		X^2	0.000	1.151	3.154	2.451	0.060	0.000	6.82
0.4	0.0143	**qo, bopd**	1627.000	1603.910	1581.277	1559.088	1537.333	1516.000	
		X^2	0.000	1.148	3.163	2.459	0.061	0.000	6.83
0.5	0.0144	**qo, bopd**	1627.000	1603.845	1581.182	1558.995	1537.272	1516.000	
		X^2	0.000	1.145	3.172	2.466	0.062	0.000	6.84
0.6	0.0144	**qo, bopd**	1627.000	1603.780	1581.087	1558.902	1537.212	1516.000	
		X^2	0.000	1.141	3.181	2.474	0.062	0.000	6.86
0.7	0.0145	**qo, bopd**	1627.000	1603.715	1580.991	1558.809	1537.151	1516.000	
		X^2	0.000	1.138	3.189	2.481	0.063	0.000	6.87
0.8	0.0145	**qo, bopd**	1627.000	1603.650	1580.896	1558.717	1537.091	1516.000	
		X^2	0.000	1.134	3.198	2.489	0.064	0.000	6.88
0.9	0.0146	**qo, bopd**	1627.000	1603.584	1580.800	1558.624	1537.031	1516.000	
		X^2	0.000	1.131	3.207	2.496	0.065	0.000	6.90
1	**0.0146**	**qo, bopd**	1627.000	1603.518	1580.705	1558.532	1536.972	1516.000	
		X^2	0.000	1.127	3.216	2.504	0.065	0.000	6.91

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Table 11. Forecast of oil production rate and cumulative oil production at well A

WELL A					
Time	Months	q	2436	Np (Jan-15)	12,450,150.00
		b=	0	EUR	
		Di=	0.0404		
		qo (forecast)	Np(forecast)	STB	MMSTB
		BOPD	STB		
0	Jan-15	2436.00	0.000	12,450,150.00	12.45
1	Feb-15	2339.55	2387.449	12,452,537.45	12.45
2	Mar-15	2246.91	4680.367	12,454,830.37	12.45
3	Apr-15	2157.95	6882.498	12,457,032.50	12.46
4	May-15	2072.50	8997.435	12,459,147.44	12.46
5	Jun-15	1990.44	11028.633	12,461,178.63	12.46
6	Jul-15	1911.63	12979.405	12,463,129.40	12.46
7	Aug-15	1835.94	14852.937	12,465,002.94	12.47
8	Sep-15	1763.25	16652.287	12,466,802.29	12.47
9	Oct-15	1693.43	18380.391	12,468,530.39	12.47
10	Nov-15	1626.38	20040.072	12,470,190.07	12.47
11	Dec-15	1561.98	21634.038	12,471,784.04	12.47
12	Jan-16	1500.14	23164.892	12,473,314.89	12.47
13	Feb-16	1440.74	24635.131	12,474,785.13	12.47
14	Mar-16	1383.69	26047.157	12,476,197.16	12.48
15	Apr-16	1328.91	27403.274	12,477,553.27	12.48
16	May-16	1276.29	28705.696	12,478,855.70	12.48
17	Jun-16	1225.76	29956.548	12,480,106.55	12.48
18	Jul-16	1177.22	31157.873	12,481,307.87	12.48
19	Aug-16	1130.61	32311.633	12,482,461.63	12.48
20	Sep-16	1085.84	33419.709	12,483,569.71	12.48
21	Oct-16	1042.85	34483.911	12,484,633.91	12.48
22	Nov-16	1001.56	35505.976	12,485,655.98	12.49
23	Dec-16	961.90	36487.573	12,486,637.57	12.49

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Table 12. Forecast of oil production rate and cumulative oil production at well B

WELL B					
Time	**Months**	**q**	**3765**	**Np (Jan-15)**	**5,977,290.00**
		b=	**0**	**EUR**	
		Di=	**0.1072**		
		qo (forecast)	**Np (forecast)**	**STB**	**MMSTB**
		BOPD	**STB**		
0	Jan-15	3765.00	0.000	5,977,290.00	5.98
1	Feb-15	3382.27	3570.218	5,980,860.22	5.98
2	Mar-15	3038.45	6777.509	5,984,067.51	5.98
3	Apr-15	2729.58	9658.766	5,986,948.77	5.99
4	May-15	2452.11	12247.131	5,989,537.13	5.99
5	Jun-15	2202.84	14572.379	5,991,862.38	5.99
6	Jul-15	1978.91	16661.256	5,993,951.26	5.99
7	Aug-15	1777.75	18537.791	5,995,827.79	6.00
8	Sep-15	1597.03	20223.568	5,997,513.57	6.00
9	Oct-15	1434.69	21737.979	5,999,027.98	6.00
10	Nov-15	1288.85	23098.444	6,000,388.44	6.00
11	Dec-15	1157.83	24320.612	6,001,610.61	6.00
12	Jan-16	1040.13	25418.543	6,002,708.54	6.00
13	Feb-16	934.40	26404.864	6,003,694.86	6.00

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Table 13. Forecast of oil production rate and cumulative oil production at well C

WELL C					
Time	**Months**	**q**	**1516**	**Np (Jan-15)**	**6,326,100.00**
		b=	**0**	**EUR**	
		Di=	**0.0141**		
		qo (forecast)	**Np(forecast)**	**STB**	**MMSTB**
		BOPD	**STB**		
0	Jan-15	1516.00	0.000	6,326,100.00	6.33
1	Feb-15	1494.77	1505.362	6,327,605.36	6.33
2	Mar-15	1473.85	2989.648	6,329,089.65	6.33
3	Apr-15	1453.21	4453.152	6,330,553.15	6.33
4	May-15	1432.86	5896.165	6,331,996.17	6.33
5	Jun-15	1412.80	7318.975	6,333,418.97	6.33
6	Jul-15	1393.02	8721.864	6,334,821.86	6.33
7	Aug-15	1373.52	10105.111	6,336,205.11	6.34
8	Sep-15	1354.29	11468.991	6,337,568.99	6.34
9	Oct-15	1335.33	12813.775	6,338,913.77	6.34
10	Nov-15	1316.63	14139.731	6,340,239.73	6.34
11	Dec-15	1298.20	15447.122	6,341,547.12	6.34
12	Jan-16	1280.02	16736.208	6,342,836.21	6.34
13	Feb-16	1262.10	18007.246	6,344,107.25	6.34
14	Mar-16	1244.43	19260.487	6,345,360.49	6.35
15	Apr-16	1227.00	20496.182	6,346,596.18	6.35
16	May-16	1209.82	21714.576	6,347,814.58	6.35
17	Jun-16	1192.89	22915.911	6,349,015.91	6.35
18	Jul-16	1176.18	24100.427	6,350,200.43	6.35
19	Aug-16	1159.72	25268.357	6,351,368.36	6.35
20	Sep-16	1143.48	26419.936	6,352,519.94	6.35
21	Oct-16	1127.47	27555.391	6,353,655.39	6.35
22	Nov-16	1111.68	28674.948	6,354,774.95	6.35
23	Dec-16	1096.12	29778.831	6,355,878.83	6.36
24	Jan-17	1080.77	30867.258	6,356,967.26	6.36
25	Feb-17	1065.64	31940.446	6,358,040.45	6.36
26	Mar-17	1050.72	32998.608	6,359,098.61	6.36
27	Apr-17	1036.01	34041.955	6,360,141.95	6.36
28	May-17	1021.50	35070.694	6,361,170.69	6.36
29	Jun-17	1007.20	36085.029	6,362,185.03	6.36
30	Jul-17	993.10	37085.163	6,363,185.16	6.36

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Table 14. Total forecast of Qo and oil Np well A, well B, well C

WELL (A+B+C)				
Time	**Months**	**qo (forecast)**	**Np (forecast)**	**EUR**
		BOPD	**STB**	**STB**
0	Jan-15	7717.00	0.000	24,753,540.00
1	Mar-15	7216.59	7463.029	24,761,003.03
2	Apr-15	6759.21	14447.524	24,767,987.52
3	May-15	6340.74	20994.415	24,774,534.42
4	Jun-15	5957.48	27140.732	24,780,680.73
5	Jul-15	5606.09	32919.987	24,786,459.99
6	Aug-15	5283.57	38362.525	24,791,902.53
7	Sep-15	4987.21	43495.838	24,797,035.84
8	Oct-15	4714.57	48344.845	24,801,884.85
9	Nov-15	4463.45	52932.145	24,806,472.15
10	Dec-15	4231.86	57278.247	24,810,818.25
11	Jan-16	4018.01	61401.773	24,814,941.77
12	Feb-16	3820.29	65319.642	24,818,859.64
13	Mar-16	3637.24	69047.241	24,822,587.24
14	Apr-16	3467.54	72598.566	24,826,138.57
15	May-16	3310.00	75986.364	24,829,526.36
16	Jun-16	3163.54	79222.250	24,832,762.25
17	Jul-16	3027.21	82316.819	24,835,856.82
18	Aug-16	2900.11	85279.740	24,838,819.74