Sudan University of Science and Technology

College of Petroleum Engineering and Technology

Department of Petroleum Engineering

Decline Curve Analysis for Sudanese Oilfield

Case Study (South Al-Najma Oilfield)

تحليل منحنى الهبوط لحقل نفط سوداني

دراسة حالة (مربع 17)

This dissertation is submitted as a partial requirement of B.Tech. Degree (Honor) in Petroleum Engineering

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الاستـهلال

قال ربنا جل وعلا :

{ وَيَسْأَلُونَكَ عَنِ الرُّوحِ قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّنَ الْعِلْمِ إِلَّا قَلِيلًا }سورة الإسراء الأية رقم (85)

صدق الله العظيم

شكر وتقدير

أعرني لسانا ايها الشعر للشكر

وان تطق شكرا فلا كنت من شعر

نزجي أسمى آيات الشكر والتقدير لمنارات العلم والمعرفة ، الذين أعارونا الثمين من وقتهم حتى وصلنا إلى هنا ..

تجريـد

يعتبر النفط من أهم الصناعات التي تتحكم بالإقتصاد العالمي ،لذلك من المهم مراقبة إنتاج النفط وتوقع الإنتاج في المستقبل ،ومن هنا أتت الحوجة إلى تطوير الكثير من البحوث لدراسة معدلات إنخفاض الإنتاج.

تحليل منحيات الأنخفاض هو تمثيل بياني يستخدم لتحليل انخفاض معدلات انتاج النفط والغاز للحقول النفطية وكذلك التنبؤ بأدائية المكمن في المستقبل.

أن معدلات الانتاج تنخفض كدالة في الزمن وذلك بالنسبة لأنخفاض ضغط المكمن ويكون السبب في ذلك عادة هو التغيرفي حجوم الموائع المنتجة من المكمن ذاته.

عبر تمثيل هذه البيانات بيانيا يمكن رسم منحنيات الانخفاض التاريخي لادائية المكمن وبأفتراض أن معدل الأنخفاض المستقبلي سيسلك نفس اتجاه المنحني الناتج من الرسم ، فأنه يمكن التنبؤ باداء المكمن مستقبليا وايضا حساب كمية الاستخلاص النهائي المتوقع.

في هذا البحث فأن مربع 17 لحقل South Al-Najma النفطي والذي يقع في غرب السودان وتقدر انتاجيته الكلية ب 3,860 برميل في اليوم قد تم اخذه كمثال تطبيقي لتحليل منحنيات الأنخفاض في الأنتاج .

قامت الدراسة بأجراء تحليل لمنحنيات الأنخفاض وذلك باستخدام وسائل مختلفة لدراسة هذا الأنخفاض ، من أهمها برنامج Oilfield Manager (OFM-Software) بالأضافة الي برنامج Microsoft Excel Sheet (MS-Excel Sheet) ، وقد اجريت المقارنة بين النتائج المتحصل عليها بواسطة كل من الطريقتين.

تبين أن النتائج متقاربة جدا لجهة التنبؤ بمستقبل الأنتاج وكمية الاستخلاص النهائي المتوقع خلال العشر سنوات المقبلة.

Abstract

Oil and gas is the key word for industrial revolutionary occur worldwide, as in past and present the necessity of close monitoring for the oil and gas supply production.

Decline curve analysis (DCA) is a graphical representation used for analyzing declining production rates and predicting the future production performance of oil and gas wells. The production rates declines as a function of time; reservoir pressure drawdown, the change of the produced fluids volumes, are usually the cause. Fitting a line through the performance history and assuming this same trend will continue in future forms the basis of Decline curve analysis concept.

In this research block (17) of South Al-Najma oil field which located in western Sudan, it's with a total current productivity of (3,860 bbl./day), the data collected from the area has been used as an applicable for decline curve analysis study

The study conducts a decline curve analysis procedure, which have a variety of supporting tools, the most common type of these tools are oilfield manager (OFM-Software) and Micro-Soft Excel sheet (MS-Excel). A comparison study between Micro-soft Excel sheet and OFM-Software results has been done.

A Comparison study the result show identical feature from the two procedures.

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Chapter One

Introduction

1.1. Introduction

Oil is a black gore that runs through the veins of the modern global energy system. In some senses, oil can be seen as the black soul of our industrialized mechanized society and the trademark of lifestyle, its combustion brings energy in immense amounts and can drive a wide array of machines, tools and processes, oil can also be broken down and used as a feedstock in a wide range of chemical processes, providing variety of products advances from medicines to plastics.

The aim of this thesis is to investigate fundamental properties and behavior of crude oil production and examine some model approaches for creating realistic outlooks for the future.

The decline curve analysis is the most effective and important way for controlling and monitoring the oil production with predicting the parameters that can make huge effect to the oil production.

The basis of decline-curve analysis is to match past production performance histories or trends (i.e., actual production rate/time data) with a "model." Assuming that future production continues to follow the past trend, we can use these models to estimate original oil and gas in place and to predict ultimate oil and gas reserves at some future reservoir abandonment pressure or economic production rate, or we can determine the remaining productive life of a well or the entire field, in addition we can estimate the individual well flowing characteristics, such as formation permeability and skin factor, with decline-type-curve analysis techniques , Decline-curve methods, however, are applicable to individual well or the entire field.

From about 1975 to 2005, various methods have been developed for estimating reserves and fields performance.

These methods range from the basic material balance equation to decline- curve and type-curve analysis techniques.

1. There are two kinds of decline-curve analysis techniques, namely:
   Classical curve fit of historical production data.

2. Type-curve matching technique.
   Some graphical solutions use the both methods

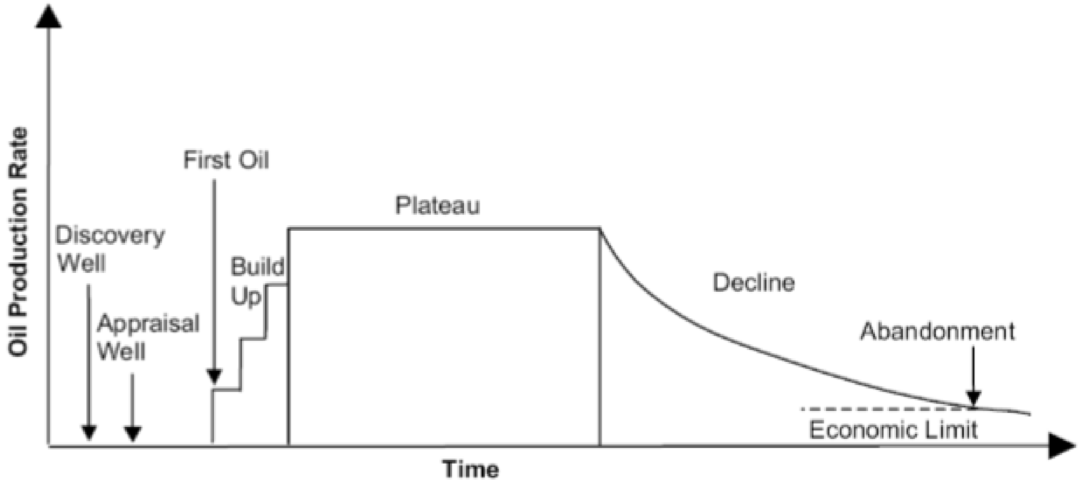


Figure 1 A theoretical production curve, describing the various stages of maturity. Source: Robelius (2007)

1.2. Field background

In this approach targeting a Sudanese oilfield at Block 17 (South AL-Najma) whose owned by an operating company, the field consist of Early Production Facility (EPF), 43 km Pipeline and (14 wells).

South AL-Najma field distance from Khartoum State about 900 Km (Western Sudan – Kourdofan), it has been put into operation since December 2012 and up to date, producing 3,860 BBLS of oil from (14) wells, plus two wells one in Sharif field and the other in Abou-Jabra field, now four out of these(14) wells were shut down.

Early production facility (EPF) and pipeline commissioned on Dec.2012.

The EPF is designed to process incoming of 22.5 KBPD with 35% WC, and outcome of 15 KBPD with maximum 0.5% WC.

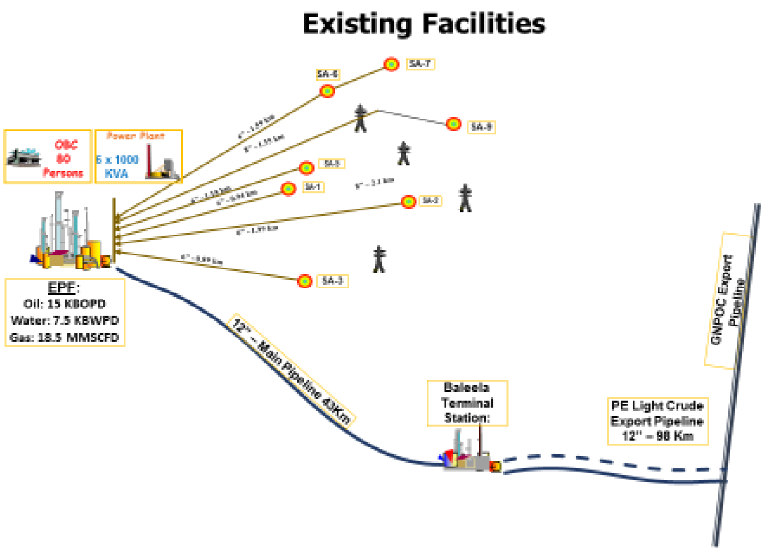


Figure 2 field map

1.3. Problem statement

Currently decreasing in oil production has been observed at South AL-Najma oilfield due to reservoir pressure drop, it has been observed that the drop in production, being faster than expected, so it's necessary to conduct a decline curve analysis procedure to extrapolate the future production profile for this oilfield.

South AL-Najma Decline in production rates as follows:

Table 1 Field average production yearly

Year	**Production average (bbl./day)**
2013	5350
2014	8000
2015	7800
2016	4800
2017	3860

1.4. Research objectives

The main objective of this study is to forecasting the behavior of the wells or the entire reservoir in future at South Al-Najma oilfield based on production declining for the historical data collected.

The specific objectives studied as the following:

1. To predict the oil production for the next (10) years.
2. To Estimate Expected Ultimate Recovery (EUR) based on the decline curve analysis.
3. Compare the results that will be achieved from Microsoft Excel computation and Oil field manager software (OFM).

1.5. Project Lay Out

- **Chapter One:**
  Include introduction, project background, problem statement and objectives.
- **Chapter Two:**
  Here find enclose, literature review and theoretical background.
- **Chapter Three:**
  Represent project methodology.
- **Chapter Four:**
  Contain results and discussion.
- **Chapter Five:**
  Consist of conclusion and recommendations.

Chapter Two

Literature Review and Theoretical Background

This chapter presents the literature study on decline curve analysis with various theories which used to analyze the decline curves of an abandoned well or entire oilfield.

2.1. Literature Review:

H.M Roeser in 1925 showed that by using (Trial and error method), we could obtain same equally & reliable results of the method of least squares. He illustrated his method (Trail & Error) with examples of both the exponential & hyperbolic types of decline-curves.

R.H Johnson & A.L Bollens in 1927 They introduced a novel statistical method called (Loss ratio method).

A curve to be investigated with this method usually shows, after proper smoothing out, either a constant loss-ratio or constancy in the differences of successive loss-ratio.

H.C Miller in 1942 Introduced the pressure drop cumulative relationship on a log-log paper, showed how changes in reservoir performance can be detected by abrupt (declining sharply) changes in the slope of such a curve.

J.J ARPS, MEMBER A.I.M.E., (May 1944), declares that During a period of severe production declining, production-decline curves will significantly losing their importance to estimate the reserves, because the production rates of all wells were constant or almost constant.

To solve this problem following engineering methods were developed to understand reservoir performance:

1. Electric-logs
2. Core analysis Data
3. Bottom-hole pressure behavior
4. Physical characteristics of reservoir fluids.

Production rate is the most available and logic characteristic which we can rely on to find out a solution for both problems shown above and the method will be either one of the following:

1. Plotting this Variable (Production rate vs. time)
2. Plotting (Production rate vs. cumulative production).

Arps (1945) proposed that the "curvature" in the production-rate-versus-time curve can be expressed mathematically by a member of the hyperbolic family of equations. Arps recognized the following three types of rate-decline behavior:

1. Exponential decline
2. Harmonic decline
3. Hyperbolic decline

Ramsay, (1968) has expressed that rate-time decline curve extrapolation is one of the oldest and most often used tools of the petroleum engineer. The various methods used always have been regarded as strictly empirical and generally not scientific. Results obtained for a well or leases are subject to a wide range of alternate interpretations, mostly as a function of the experience and objectives of the evaluator. Recent efforts in the area of decline curve analysis have been directed toward a purely computerized statistical approach, its basic objective being to arrive at a unique "unbiased" interpretation.

Mikael hook, kjell Aleklett, 2008, The field subclasses to giant oil, smaller oil field, natural gas liquid, condensate

Giant field decline 13% annually, other fields decline faster especially condensate about 40% annually forecasting for this field is important because Norway is a major oil exporter and the decline will affect all who are dependent on it is export methodology depended on all oil most be analyzed separately.

Conclusion normally will have dramatically reduced export volume of oil by 2030.

A.J. Clark, (2011) proposed a new empirical model for production forecasting in extremely low permeability oil and gas reservoirs based on logistic growth models. The new model incorporates known physical volumetric quantities of oil and gas into the forecast to constrain the reserve estimate to a reasonable quantity.

The new model is easy to use, and it is very capable of trending existing production data and providing reasonable forecasts of future production. The logistic growth model does not extrapolate to non-physical values.

Khulud M. Rahuman, H. Mohamed, N. Hissein, and S. Giuma (April 2013) Decline curve analysis is a technique can be applied to a single well, and total reservoir.

Decline analysis routinely used by engineers to estimate initial hydrocarbon in place, hydrocarbon reserves at some abandonment conditions, and forecasting future production rate. The remaining reserve depends on the production points that selected to represent the real well behavior.

Comparison between the hand calculation and decline curve analysis (DCA) program give result nearly similar to each other by the end of the forecasting period.

2.2. Theoretical Background

Decline curve analysis is a technique can be applied to a single well, or entire reservoir. Routinely used by engineers to estimate initial hydrocarbon in place, hydrocarbon reserves at some abandonment conditions, and forecasting future production rate.

The remaining reserve depends on the production points that selected to represent the real behavior of the well, the way of dealing with the production data, and the human errors that might happen during the life of the field.

Decline curve analysis is the most currently method used for reserve estimation when historic production data are available and sufficient.

Decline curves were commonly used to represent or extrapolate the production data are members of a hyperbolic family, the method of extrapolating a “trend” for the purpose of estimating future performance must satisfy the condition that the factors that caused changes in past performance, for example, decline in the flow rate, will operate in the same way in the future. These decline curves are characterized by three factors:

1. Initial production rate or the rate at some particular time.
2. Curvature of the decline.
3. Rate of decline.

2.2.1. Decline Types

Based on what has been covered so far, the engineer performing a decline curve analysis (DCA) required being aware of the following:

1. The most representative period in history that will also represent future.
2. The decline trend during that period.
3. The start point (rate) of forecast.
4. The constraints under which the forecast needs to be made.

However one more factor, also extremely important at this stage is to determine type of decline. Since the signature of shape may not be apparent on a log production rate (q) vs. time (most used plot), literature provides many ways was to look at the same data, combine this information with other knowledge about the fields before making the conclusions.

Depending on the value of the decline exponent (b), the decline exponent has three different types (Arps -1945):

2.2.1.1 Exponential Decline

In the exponential decline, the well's production data plots as a straight line on a semi log paper. The equation of the straight line on the semi log paper is given by (b=0):

$$q = q_i e^{-Dit} \quad \text{.................................} \quad \text{Eq. (2.1)}$$

Where: q = Well's production rate at time t, (STB/day)

q_i = Well's initial production rate, (STB/day)

D_i = Initial nominal exponential decline rate, t=0, (day^{-1})

b = Decline exponent

t = time (day)

Table 2 Exponential Equations (b=0)

Description	Equation
Production rate	$q = q_i e^{-Dit}$
Cumulative Oil Production	$N_P = \frac{q_i - q}{D}$
Nominal Decline Rate	$D = -ln(1 - D_e)$ $D_e = \frac{q_i - q}{q_i}$
Effective Decline Rate	$D_e = 1 - e^{-D}$
Life	$t = \frac{ln(q_i/q)}{D}$

2.2.1.2 Hyperbolic Decline

Alternatively, if the well's production data plotted on a semi-log paper concaves upward, and then it is modeled with a hyperbolic decline. The equation of the hyperbolic decline is given by (0<b<1):

$$q = q_i(1 + bD_i t)^{-\frac{1}{b}} \quad \text{……………………..Eq. (2.2)}$$

Where: q = Well's production rate at time t, (STB/day)

q_i = Well's initial production rate, (STB/day)

D_i = Initial nominal exponential decline rate, t=0, (day^{-1})

b = Decline exponent

t = time (day)

Table 3 Hyperbolic Equations (0<b<1)

Description	Equation
Production rate	$q = q_i(1 + bD_it)^{-\frac{1}{b}}$
Cumulative Oil Production	$N_P = \frac{{q_i}^b}{D_i(1-b)}({q_i}^{1-b} - q^{1-b})$
Nominal Decline Rate	$D_i = \frac{1}{b}[(1 - D_{ei})^{-b} - 1]$ $D_{ei} = \frac{q_i - q}{q_i}$
Effective Decline Rate	$D_e = 1 - e^{-D}$
Life	$t = \frac{(q_i/q)^b - 1}{bD_i}$

2.2.1.3 Harmonic Decline

A special case of the hyperbolic decline is known as "harmonic decline", where b is taken to be equal to 1. The following table summarizes the equations used in harmonic decline (b=1):

$$q = \frac{q_i}{1+D_it} \quad \text{Eq.(2.3)}$$

Where: q = Well's production rate at time t, (STB/day)

q_i = Well's initial production rate, (STB/day)

D_i = Initial nominal exponential decline rate, t=0, (day^{-1})

b = Decline exponent

t = time (day)

Table 4 Harmonic Decline Equations (b=1)

Description	**Equation**
Production rate	$q = \frac{q_i}{1 + D_i t}$
Cumulative Oil Production	$N_P = \frac{q_i}{D_i}\ln(\frac{q_i}{q})$
Nominal Decline Rate	$D_i = \frac{D_{ei}}{1 - D_{ei}}$
Effective Decline Rate	$D_{ei} = \frac{q_i - q}{q_i}$
Life	$t = \frac{(q_i/q) - 1}{D_i}$

The three decline curves have a different shape on Cartesian and semi-log graphs of oil & gas production rate vs. time and oil & gas production rate vs. cumulative gas production. Consequently, these curve shapes can help identify the type of decline for a well and, if the trend is linear, extrapolate the trend graphically or mathematically to some future point

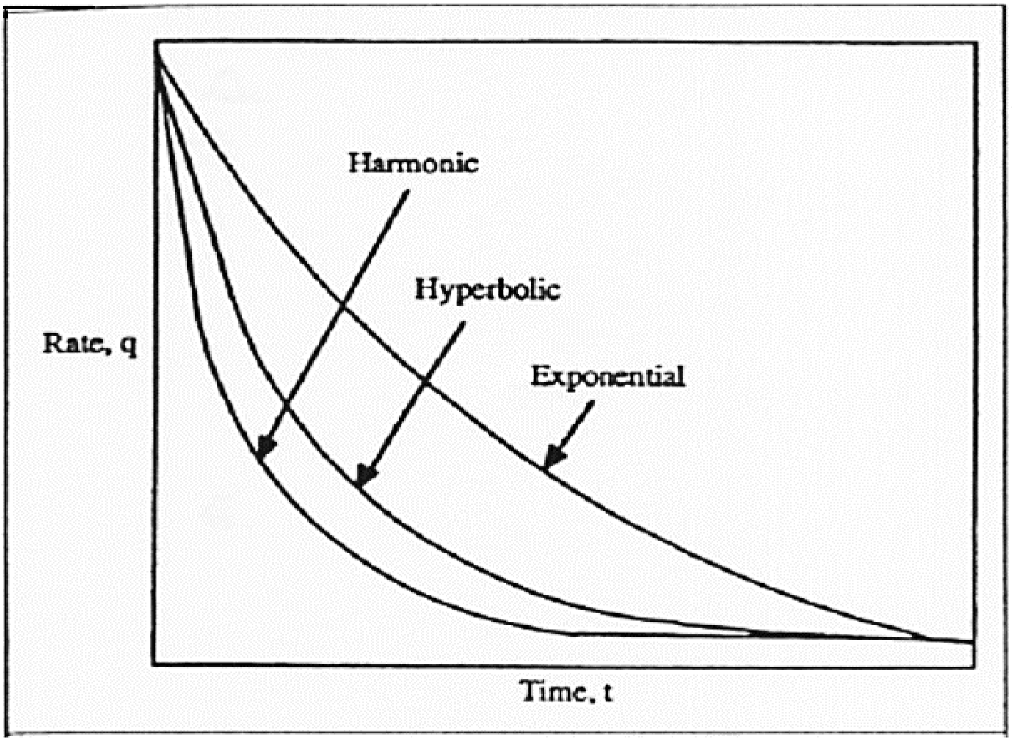


Figure 3 Decline Curve Shapes for a Semi log plot of Rate VS. Time [john lee 1996]

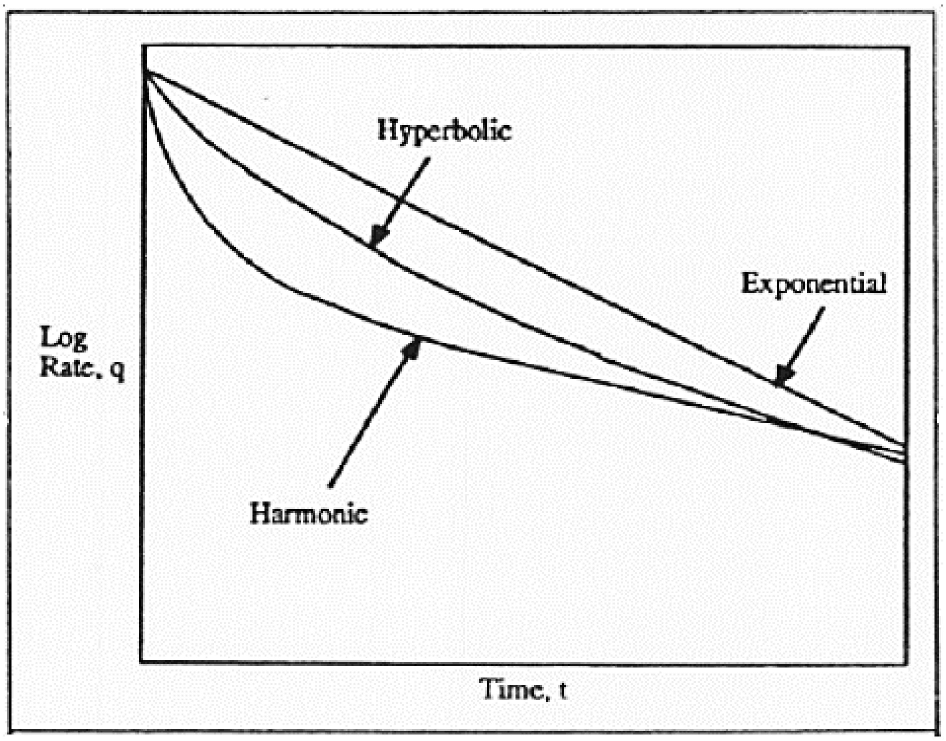


Figure 4 Decline Curve Shapes for a Semi log plot of Rate VS. Time [john lee 1996]

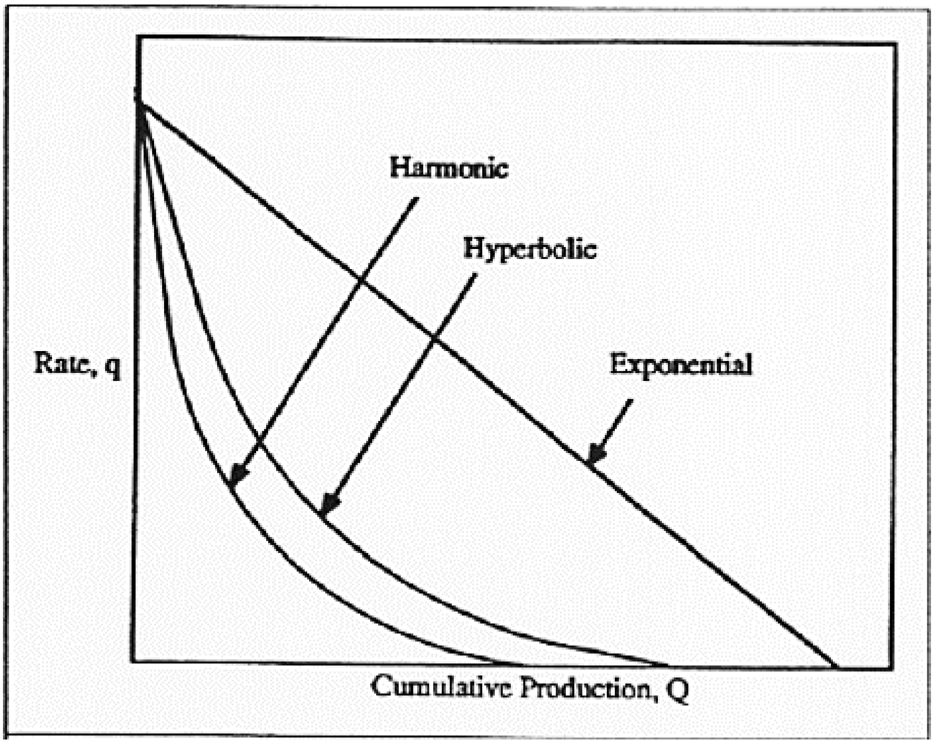


Figure 5 Decline Curve Shapes for a Cartesian plot of Rate VS. Cumulative [john lee 1996]

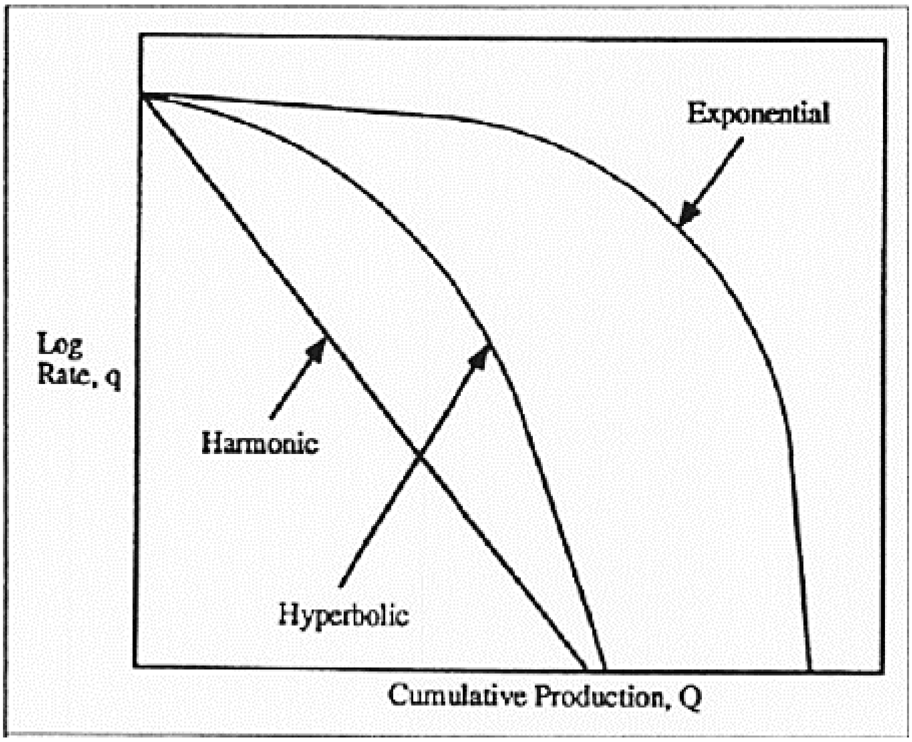


Figure 6 Decline Curve Shapes for a Cartesian plot of Rate VS. Cumulative [John lee 1996]

2.2.2. Fetkovich Decline Type Curve

The Fetkovich decline type curves are based on analytical solutions to the flow equations for production at constant bottom hole pressure (BHP) from a well centered in a circular reservoir or drainage area with no-flow boundaries. Although these type curves were developed for a homogeneous-acting reservoir, they can be used for analyzing long-term gas-production data from hydraulically fractured wells during the pseudo radial flow period and once the outer reservoir boundaries affect the pressure response. Fig. (7) is an example of the Fetkovich decline type curves for both rate/time and cumulative production/time analyses.

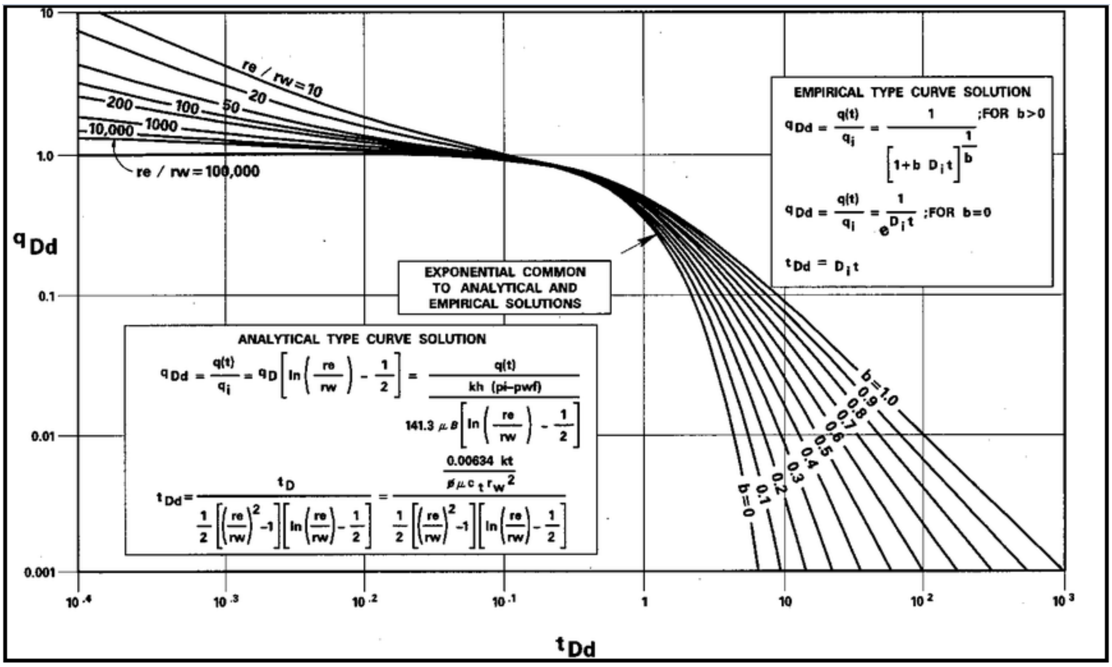


Figure 7 Fetkovich Decline Type Curve

Chapter Three
The Methodology

3.1. Methodology Brief

Selecting an appropriate methodology is most the important process for accurate forecasting the future production, as a planning to take the right decision should be based on the recoverable percentage of the original hydrocarbon in place, as well as the residual amount of this oil when the economic limit is reached before the need for any secondary recovery mechanism is involved, for the case of a naturally producing reservoir-well relationship.

Decline curve analysis (DCA) is a method used for the prediction of future hydrocarbon production by analyzing past production.

Forecasting crude oil production can be done in many different ways, but in order to provide realistic outlooks, one must be mindful of the physical laws that affect extraction of hydrocarbons from a reservoir.

Decline curve analysis is a long established tool for developing future outlooks for oil production from an individual well or an entire oilfield.

Extrapolation of production history has long been considered the most accurate and defendable method of estimating the remaining recoverable reserve from a well and, the entire reservoir.

Using decline curve analysis gives a better tool for describing future oil production on a field-by-field level. Reliable and reasonable forecasts are essential for planning and necessary in order to understand likely future world oil production.

3.2. Decline curve analysis tools

In this research two methods of decline curve analysis techniques have been used, which include the following:

1. Microsoft Excel Sheet
2. Oil Field Manager (OFM Software)

3.2.1. Microsoft Excel Sheet

Using Microsoft Excel as per the following steps bellow: Calculating the decline rate (D) from the equation given by Arps (1945)

$$D = \frac{1 * \mathrm{dq}}{\mathrm{q} * \mathrm{dt}} \dots\dots\dots\dots\dots\dots\dots\dots\dots Eq(3.1)$$

1. Using daily production data to plot, oil flow rate versus time on a Semi-log graph paper.
2. Depending on the curve shape which result from above plotting, decline curve type will be identified as one of the following:
   i. Exponential decline
   ii. Harmonic Decline
   iii. Hyperbolic Decline
3. Determining the Expected Ultimate Recovery (EUR) using:

   EUR = historical oil cumulative + forecasting oil cumulative

   Forecasting oil cumulative $= \frac{q_i}{D_i} - \frac{q}{D_i}$ .... Eq.(3.2)

Where: q = Production rate at the end of forecasting period, (bbl./day)

q_i = Initial Prod.Rate at the beginning of forecasting, (bbl./day)

D_i = Initial nominal exponential decline rate, t=0, (day^{-1})

3.2.2. Oil Field Manager (OFM) Software

For oilfield manager (OFM software), well and reservoir analysis software, offers advanced production surveillance views and powerful production forecasting tools to manage and improve oil and gas fields performance throughout the entire life cycle of the field .

OFM software allows view, relate, and analyze reservoir and production data with comprehensive workflow tools, such as interactive base maps with production trends, bubble plots, diagnostic plots, decline curve analysis, and type curve analysis. Recent architectural changes and usability improvements further enable organization to be more productive.

The OFM application provides a privilege access to the data quickly, wherever it may be located spreadsheets, databases, or other repositories. It also acts as a single point of analysis for reservoir and production engineers to collaborate and manage more wells in less time.

The multiple visualization canvases (charts, reports, and maps) and fast filtering data fed to enable improvement for field performance by promptly identifying the well or wells that offer an opportunity to increase production.

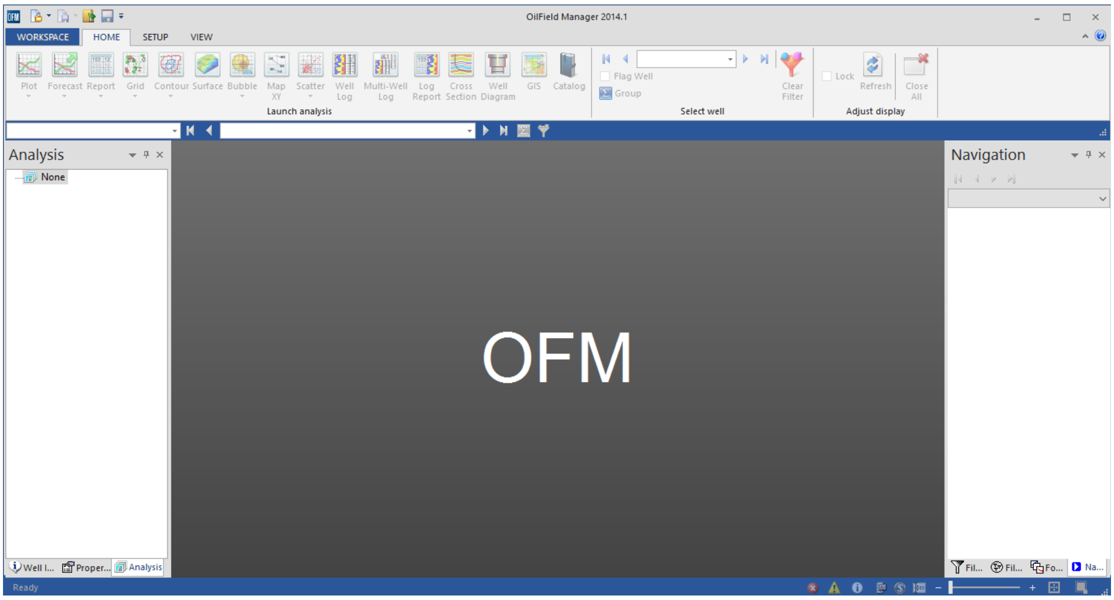


Figure 8 OFM Software Interface

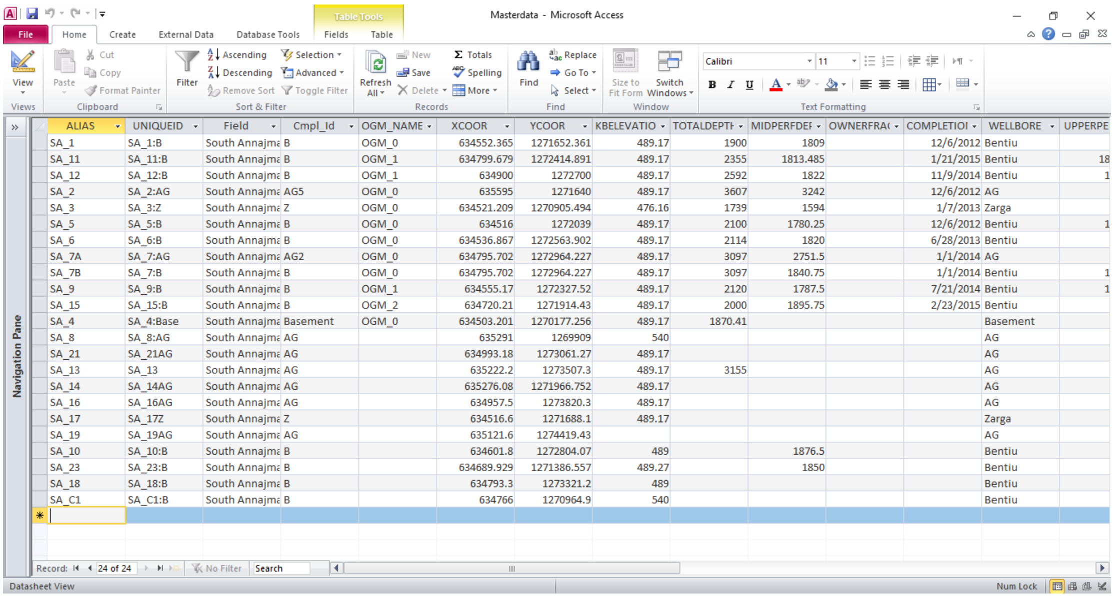
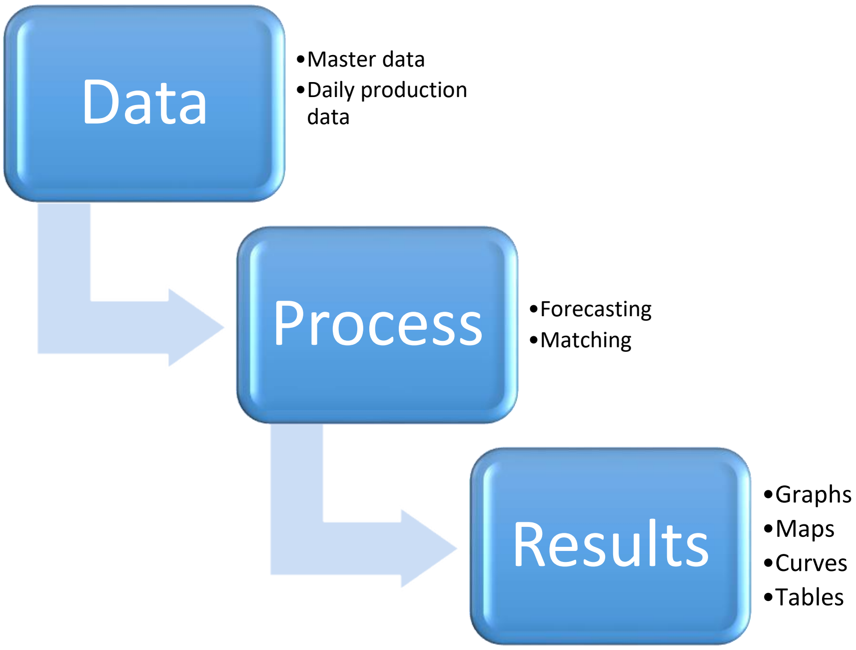


Figure 9 OFM Master Data Bas

Figure (10) OFM-Software flow chart for Data Analysis & Resulting:



3.2.3. OFM-Software Rules

OFM-Software Forecasting module consists of four major categories (techniques);

- Empirical (using Arps equations)
- Fetkovich
- Locke & Sawyer
- Analytical Transient solutions

-

CHAPTER FOUR

Results and Discussion

4.1. Data collection

Data shown below is obtained from a field master data & daily production data:

Table 5 SA-1daily production data

Well	Date	THP	CHP	FLP	FLT	Choke size	Pi	Ti	Fluid	Oil
SA_1	22-Dec-12	200	100	500	53.9	12.8	1709	80	1589	1589
SA_1	23-Dec-12	200	100	500	53.8	12.8	1727	81	1589	1589
SA_1	24-Dec-12	200	100	500	53.8	12.8	1861	81	1521	1521
SA_1	25-Dec-12	230	120	490	46	10	1876	81	1343	1343
SA_1	26-Dec-12	230	120	490	46	10	1760	81	1265	1265
SA_1	27-Dec-12	250	140	495	47	10	1828	81	1265	1265
SA_1	28-Dec-12	220	100	495	50	11.5	1832	81	1406	1406
SA_1	29-Dec-12	250	120	495	49	10	1827	80.5	1462	1462
SA_1	30-Dec-12	250	120	495	48	10	1821	80	1456	1456
SA_1	31-Dec-12	250	120	495	47	10	1819	80	1413	1413
SA_1	01-Jan-13	250	120	495	47	10	1814	80	1341	1341
SA_1	02-Jan-13	245	120	495	49	10	1811	80	1331	1331
SA_1	03-Jan-13	245	120	495	49	10	1810	80	1325	1325
SA_1	04-Jan-13	245	120	495	49	10	1810	80	1343	1343
SA_1	05-Jan-13	245	120	495	49	10	1810	80	1307	1307
SA_1	06-Jan-13	245	100	490	49	10	1810	80	1315	1315
SA_1	07-Jan-13	245	100	495	48	10	1810	80	1272	1272
SA_1	08-Jan-13	250	105	500	49	10	1810	80	1322	1322
SA_1	09-Jan-13	250	105	500	49	10	1810	80	1364	1364
SA_1	10-Jan-13	240	95	490	48	10	1810	80	1352	1352
SA_1	11-Jan-13	245	100	495	48	10	1810	80	1341	1341
SA_1	12-Jan-13	240	100	500	48	10	1810	80	1359	1359

Table 6 Master data for entire field

Wells	Completion Type	OGM name	Elevation	Total depth	Formation	Upper perforation	Lower perforation
SA_1	B	OGM_0	489.17	1900	Bentiu	1746	1758
SA_11	B	OGM_1	489.17	2355	Bentiu	1806.63	1820.34
SA_12	B	OGM_1	489.17	2592	Bentiu	1820.7	1823.3
SA_2	AG5	OGM_0	489.17	3607	AG	3240	3243
SA_3	Z	OGM_0	476.16	1739	Zarga	1588	1600
SA_5	B	OGM_0	489.17	2100	Bentiu	1755.5	1785
SA_6	B	OGM_0	489.17	2114	Bentiu	1815	1825
SA_7A	AG2	OGM_0	489.17	3097	AG	2748	2755
SA_7B	B	OGM_0	489.17	3097	Bentiu	1837.5	1844
SA_9	B	OGM_1	489.17	2120	Bentiu	1782.5	1792.5
SA_15	B	OGM_2	489.17	2000	Bentiu	1859	1932.5
SA_4	Basement	OGM_0	489.17	1870	Basement	NA	NA
SA_8	AG	OGM_0	540	3071	AG	NA	NA
SA_21	AG	OGM_0	489.17	3017	AG	1879	1915
SA_13	AG	OGM_0	489.17	3155	AG	NA	NA
SA_14	AG	OGM_0	489.17	1741	AG	1573	1650

4.2. Results and Discussion

In this study two methods of decline curve analysis techniques have been used, which include the following:

4.2.1. Microsoft Excel Sheet Results

1. Graphs shown hereinafter are results of plotting the field collected data using MS-Excel sheet.
2. Tables shown here results from calculations of decline rate using formulas.
3. For best of analyzing& understanding the Production severe declining, South Al-Najma wells (1 and 5) and in addition to entire field daily production and accumulative Production data has been chosen as an applicable example to run the calculations in this approach.

4.2.1.1 South Al-Najma 01 (SA-01)

Figure 11 SA-01 Flow Rate vs. time (History) on Semi-log

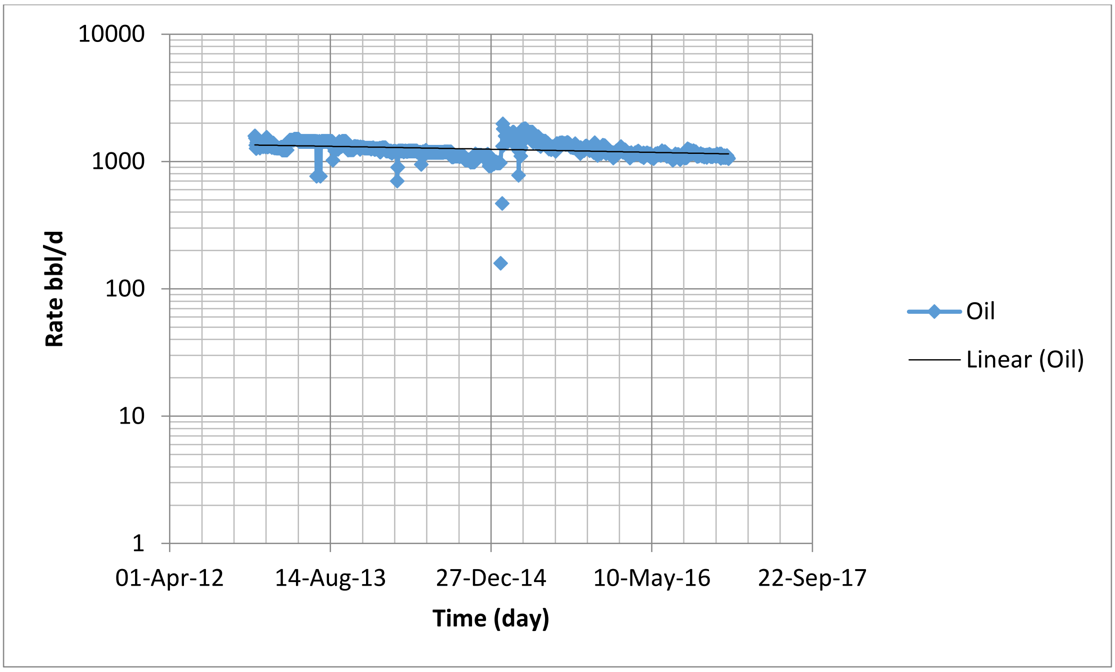


Table 7 SA-1 Parameters (Excel sheet)

Decline Exponent (b)	Prod. Rate(qi) (bbl/d)	Decline Rate (D) (1/day)	Forecast. Starting(Ti)
0	1055	0.002756	1/4/2017

For table (8), production rates at date from (01/31/2017) until (12/31/2027) has been calculated using Eq. (2.1)

Table 8 SA-01 Flow Rate vs. time (Forecasting)

Date	Production rate (bbl/d)
01/04/2017	1055
01/31/2017	1052.419
08/31/2021	904.2044
10/31/2025	787.5798
12/31/2027	733.0379

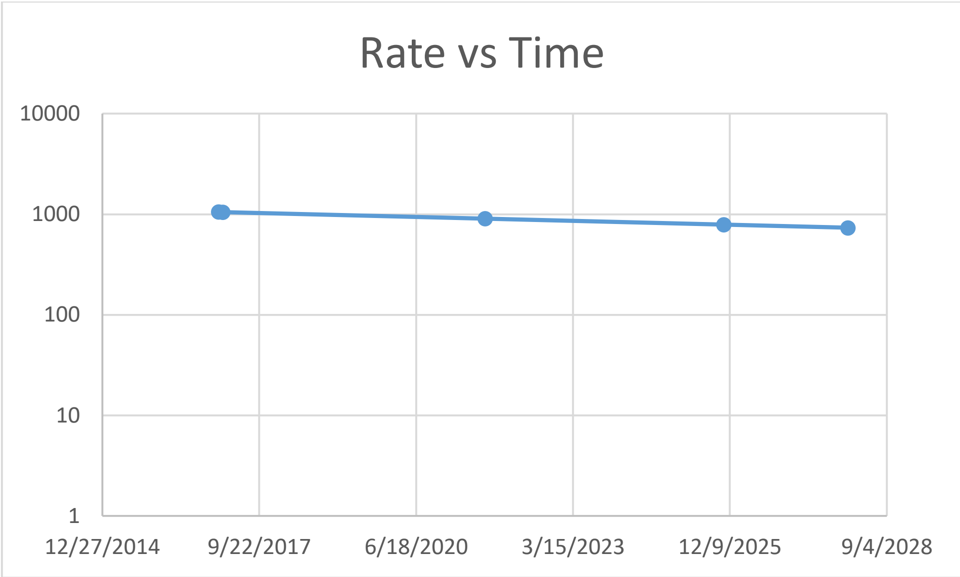


Figure 12 SA-01 Flow Rate vs. time (Forecasting on Semi-log)

3.2.1.2 South Al-Najma 05 (SA-05)

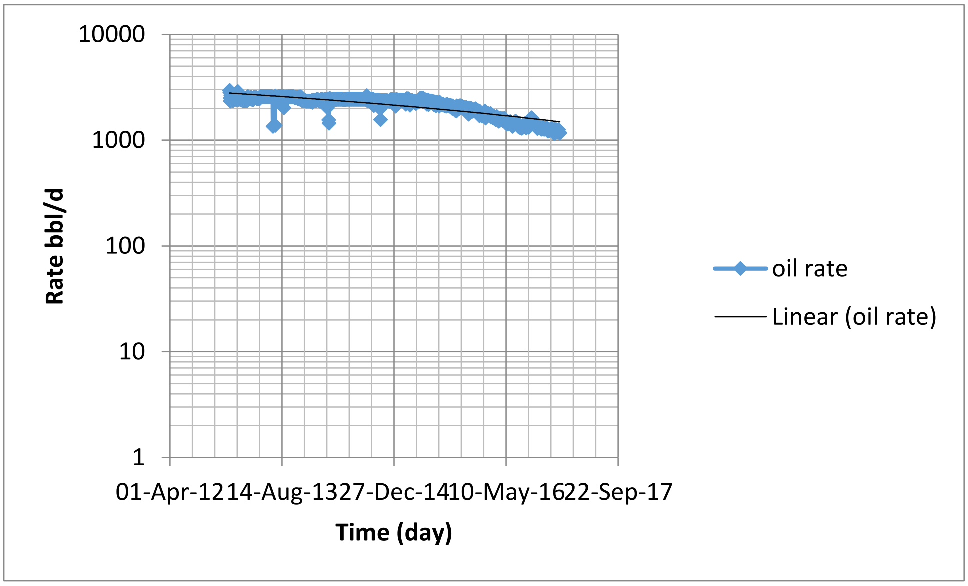


Figure 13 - 4.6, SA-05 Flow Rate vs. Time (History on Semi-log)

Table 9 SA-5 Parameters (Excel sheet)

Decline Exponent (b)	Prod. Rate(qi) (bbl/d)	Decline Rate (D) (1/day)	Forecast. Starting(Ti)
0	1166	0.013618	1/4/2017

For table (10), production rates at date from (01/31/2017) until (12/31/2027) has been calculated using Eq. (2.1)

Table 10 SA-05 Flow Rate vs. Time (forecasting)

Date	Rate
1/4/2017	1166
1/31/2017	1151.989
8/31/2021	551.3
10/31/2025	275.5427
12/31/2027	193.3664

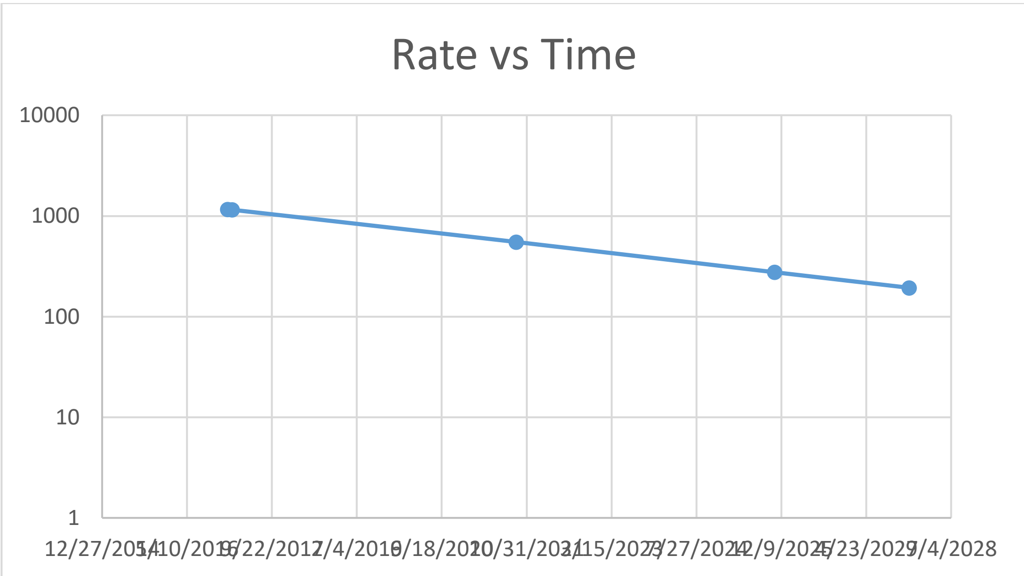


Figure 14 SA-05 Flow rate vs. Time (forecasting on Semi-log)

4.2.1.3 South Al-Najma Field (SA-Entire Field)

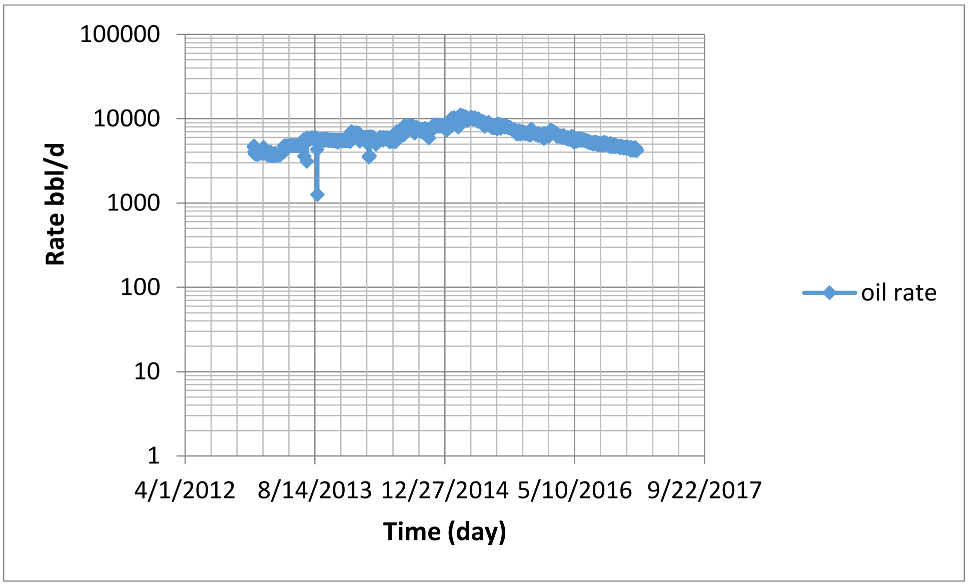


Figure 15 SA-Entire Field Flow Rate vs. Time (history on Semi-log)

Table 11 SA- Field Parameters (Excel sheet)

Decline Exponent (b)	Prod. Rate(qi) (bbl/d)	Decline Rate (D) (1/day)	Forecast. Starting(Ti)
0	4159.42	0.00384	1/4/2017

For table (12), production rates at date from (01/31/2017) until (12/31/2027) has been calculated using Eq. (2.1)

Table 12 SA-Entire Field Flow Rate vs. Time (forecasting)

Date	Rate
1/4/2017	4159.42
1/31/2017	4145.26765
8/31/2021	3356.10133
10/31/2025	2769.46386
12/31/2027	2506.29019

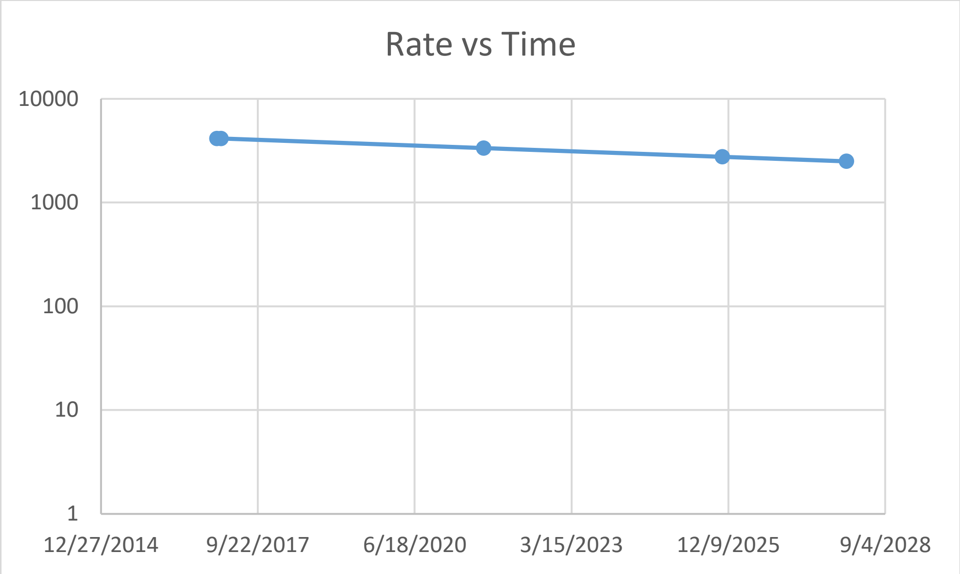


Figure 16 SA-Entire Field Flow Rate vs. Time (forecasting on semi-log)

4.2.2. OFM Software Results

1. Graphs shown hereinafter are results of plotting the field collected data using OFM-Software.
2. Tables shown here outcomes from OFM-Software output results.
3. South Al-Najma (1&5) along with entire field daily production and accumulative Production data has been used as an example.

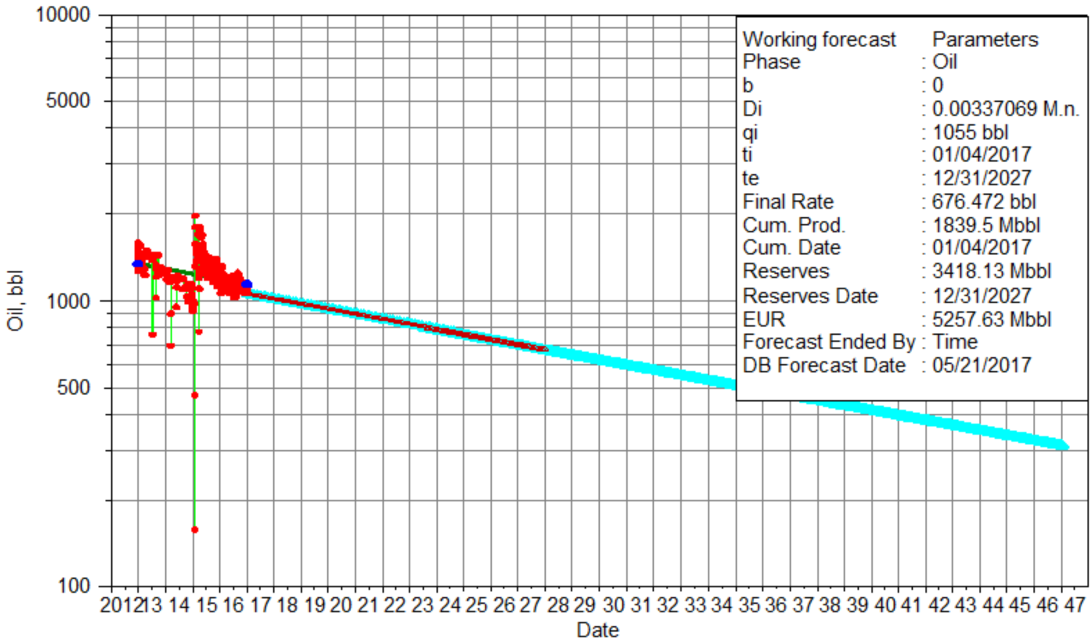


Figure 17 SA-1 Flow Rate vs. Time (Semi-log)

b	Di (M.n.)	qi (bbl/d)	ti	Te	qe (bbl/d)	Res. (Mbbl)
0.00	0.003370	1055	1/4/2017	12/31/2027	676.472	3418.13

Table 13 AS-1 Parameters (OFM)

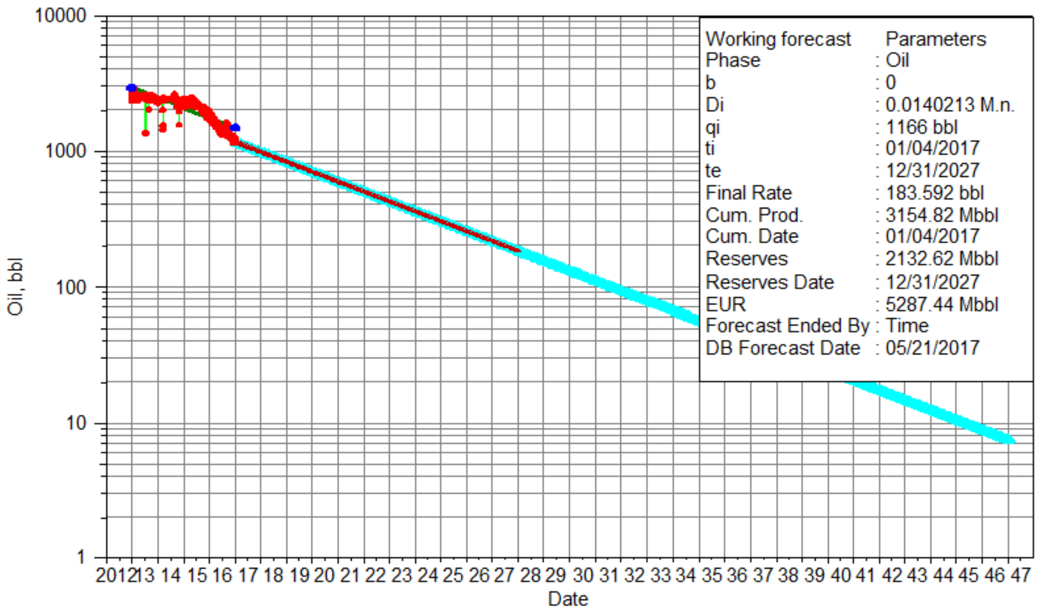


Figure 18 SA-5 Flow Rate vs. Time (Semi-log)

b	Di (M.n.)	qi (bbl/d)	ti	Te	qe (bbl/d)	Res. (Mbbl)
0.00	0.014021	1166	1/4/2017	12/31/2027	183.592	2132.62

Table 14 SA-5 parameters (OFM)

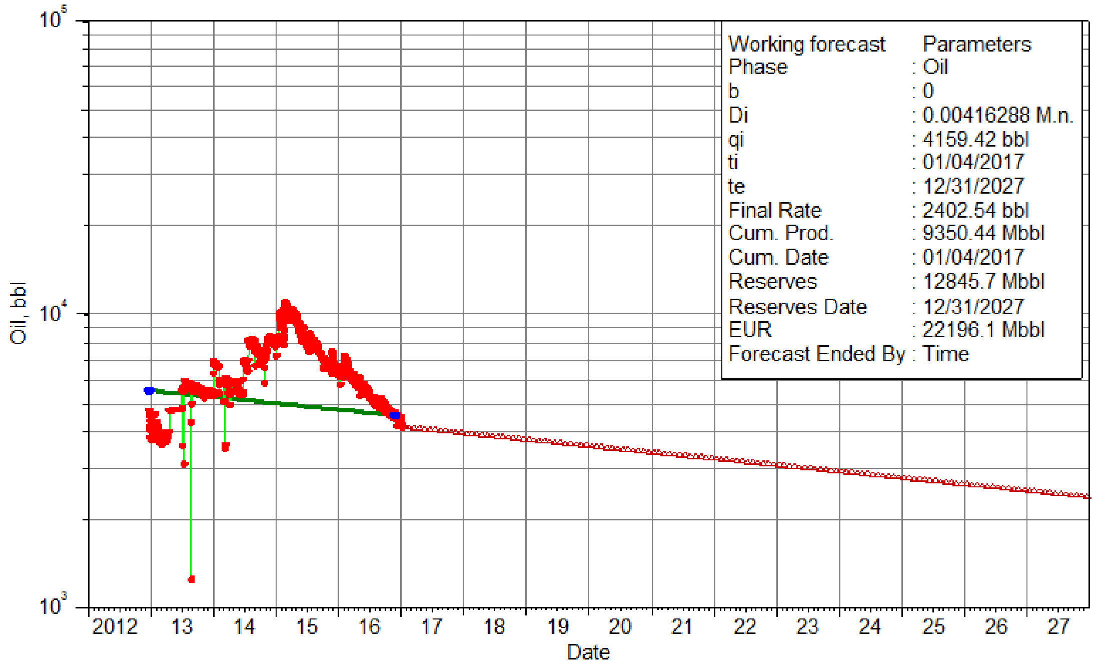


Figure 19 SA-Entire Field Flow Rate vs. Time (Semi-log)

Table 15 Entire Field parameters (OFM)

b	Di (M.n.)	qi (bbl/d)	(ti)	(te)	(qe) (bbl/d)	Res. (M.bbl)
0.00	0.004162	4159.42	1/4/2017	12/31/2027	2402.54	12845.7

4.2.3. Comparison between OFM-Software and MS Excel sheet results

After using data collected from the field and hence applied the decline curve analysis methods here enclose is the concise of comparison between both tools which been used in this research as it appears at the following schedules:

Table 16 entire field Comparison in results between OFM-software and Excel Sheet

Parameters	OFM	Excel Sheet
Di	0.004162	0.00384
qi(bbl/d)	4159.42	4159.42
Historical cumulative(Mbbl.)	9350.43	9350.43
Final rate at 2017 (bbl./d)	2402.54	2506.29
EUR (Mbbl.)	22196.1	22446.326

Table 17 SA-1 Comparison in results between OFM-software and Excel Sheet

Parameters	OFM	Excel Sheet
Di	0.00337	0.00276
qi(bbl/d)	1055	1055
Historical cumulative(Mbbl)	1839.5	1839.5
Final rate at 2017 (bbl/d)	676.472	733.0379
EUR (Mbbl.)	5257.63	5388.082

Table 18 Table SA-5 Comparison in results between OFM-software and Excel Sheet

Parameters	OFM	Excel Sheet
Di	0.01402	0.01362
qi(bbl/d)	1166	1166
Historical cumulative(M.bbl)	3154.82	3154.82
Final rate at 2017 (bbl/d)	183.592	193.366
EUR (M.bbl.)	5287.44	5327.18

Comparison shown above, indicate that results obtained from OFM-Software and Excel sheet were likely similar to each other, except for values (Final rate, EUR) which being calculated using Excel sheet were little bit higher than OFM–Software results, this due to the fact that the decline rate calculated by Excel sheet is slightly less than OFM.

Meaning to say that when using OFM-Software accurate result is obtained, because choosing the decline rate is more accurate and less error than using Excel sheet, also the best straight line on OFM-software using filtered data, but in Excel sheet just the real data without filtration is being used.

By the other hand using Excel sheet will give somehow good result can be used for the future forecasting for individual well or entire field.

Table 19 Wells Decline rate

Well Name	Di
SA-7 A	0.4278
SA-17	0.1609
SA11	0.1303
SA-23	0.1083
SA-C-1	0.0725
SA-7B	0.0696
SA-21	0.0066
SA-12	0.0641
SA-9	0.0594
SA-5	0.0140
SA-15	0.0506
SA-18	0.0058
SA-1	0.00337
SA-6	0.00335

Table (19) shows the decline rate for individual well, sorted in descending order for a purpose of comparison.

Out of this a conclusion can be made that wells with a high rate of decline will have a greater and faster expected declining in productivity than those with a low rate of decline, therefore, wells with a low rate of decline expected to maintain the total productivity of the entire field for a longer period of time.

Note that when the decline rate (D) is high means the production rate will decrease faster than expected, so the experience revealed that the decline in production affected by many factors like the artificial life applied and the production adjustment, such as choke size and pumps frequency.

Chapter Five

Conclusion and Recommendations

5.1. Conclusion

- The study uses the historical production data that collected from day one of the starting of production, until April 2017.
- Using OFM software and Microsoft excel for the decline curve analysis allow a verification result of prediction of production performance for field or individual well.
- The study uses the historical deterioration in production; the exponential decline method has been used to gain best results.
- The comparison between OFM and Micro-Soft Excel both are provide similar results.
- The forecasting results are achieved considering the next 10 years.
- The Expected Ultimate Recovery (EUR), calculated by the end of Year 2027 for entire field.
- The benefit from decline curve analysis is to figure out the future production, that's to optimize and develop the field before it reaches the abandonment point.

5.2. Recommendations

1. In case of using OFM software it's preferable to be applied for the naturally produced well, to achieve best and accurate results of decline curve analysis technique, the reservoir must be put into production of natural energy drive without any intervention by further recovery methods.
2. When there are some wells producing naturally the right discussion is to keep them run naturally instead of installing down hole pumps.
3. This study focus only on the future perdition of the field without considering the economic side, so its recommended that incase a new study made, economic can be taken into consideration.
4. Its recommended to conduct an EOR process in association with decline curve analysis to give more hands so such problem.

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