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Original Research Article

Using Volumetric and Decline Curve Analysis as Techniques for Estimating Reserve

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Abstract: Management's decisions are dictated by the anticipated results from an investment. In the case of oil and gas, the Petroleum Engineer compares the estimated costs in terms of dollars for some investment opportunity as against the cash flow resulting from production of barrels of oil or cubic feet of gas. This analysis may be used in formulating policies for exploring and developing oil and gas properties. The present work therefore aimed at comparing two of the various methods of estimating reserve. These methods are: Volumetric and Decline Curve Analysis. The volumetric method of estimation was based on a detailed geological analysis. The Area Vs. Depth graph was plotted using planimetry readings, and this was used to estimate the reservoir bulk volume. Arithmetic averages of petrophysical data from five wells were used. The Net-To-Gross ratio of the average sand thickness was estimated from log responses; and thus, the reserve was estimated with this method. The decline curve analysis was based on observed production history. The reservoir used in this work shows an exponential decline trend with a constant. Thus, the-reserve was estimated with this method.

Keywords: Volumetric, Reservoir, Reserve, Decline Curve, Net-To-Gross Ratio, Exponential Decline.

1.0 INTRODUCTION

Reserves estimation is one of the most essential tasks in the petroleum industry. It is the process by which the economically recoverable hydrocarbons in a field, area, or region are evaluated quantitatively. A major goal in this initiative is preparation of training modules that represent industry's "recommended practices." Long before the issue caught the public's attention, however, reserves estimation was a challenge for the industry. The challenge stems from many factors, tangible and intangible, that enter the estimation process, and judgment is an integral part of the process. Uncertainty, along with risk, is an endemic problem that must be addressed. Consequently, the industry's record of properly predicting reserves has been mixed. Despite appeals from some quarters, there is currently no standardized reserves-estimation procedure (Rejas & Avinash, 2020).

Oil production forecasting is an important means of understanding and effectively developing reservoirs. Reservoir numerical simulation is the most mature and effective method for production forecasting, but its accuracy mostly depends on high-quality history matching and accurate geological models (Liu *et al.,* 2020).

The estimation of the initial oil in place is a crucial topic in the period of exploration, appraisal, and development of the reservoir (Al-Husseini & Hamd-allah, 2022). Oil reserves estimation is one of the most important tasks in petroleum engineering, because it is based on estimates of reserves that can be created by the companies or the increasing of the development plan for the field, and the consequent adoption of large financial investments. Therefore, it is important both to governments and major oil companies (Salih, 2016, and Dake, 2004). It helps the companies also, in ascertaining properly the time of abandonment of the project. This is dependent also on the price of crude oil in the international market. Reserve estimation involves the interpretation of geologic and/or mathematics, and qualitative calculations of the petrophysical data, PVT (Pressure, Volume, Temperature) and production histories of the reservoir to estimate the reserve. Therefore, knowledge of the size of a reservoir in terms of recoverable hydrocarbon is a prerequisite for evaluating the minimum rate of returns needed on any capital spent in the oil exploitation venture. The analysis presented in this paper compares two methods of estimating reserve. These methods are Volumetric and Decline Curve. The procedure can be used to estimate both oil and gas reserve but this work will be restricted to oil reserve estimation only. Finally, practical application of this ·approach is demonstrated. The volumetric method of estimating reserve can be very simple, requiring only well-logs and some estimated parameter. These are reservoir area, net pay thickness, porosity, initial water saturation and oil/gas formation volume factor. Reservoir area is estimated or, in a developed field, based on the spacing and contour mapping by using Auto-CAD. Net pay thickness is determined from well logs or core analysis. Porosity is calculated from well log or core analysis. Initial water saturation is calculated from well logs. Initial oil formation volume factor is determined from laboratory measurements of fluid samples or from correlation (San, 2019). The method is based completely on geological information; and the accuracy of the existing data impose a serious limitation on the result. Based on volumetric, the quantity of oil in place is calculated after drilling an exploration well in the reservoir, to obtain such important parameters as thickness of the formation, porosity, φ, saturation of fluids, areal coverage and formation volume factors.

Decline curve analysis or production decline analysis method of reserve estimation involves the analysis of production behavior as fluids are withdrawn. Decline curve analysis is a technique that can be applied to a single well, and total reservoir. It is 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 are selected to represent the real well behavior, the way of dealing with the production data, and the human errors that might happen during the life of the field (Rahuma & Omar, 2013).

The production decline analysis is a traditional method of identifying wells production pattern and predicting its performance and life based on real production data. The study of the application of the production decline curves which uses one of the empirical models either the exponential, hyperbolic or the harmonic decline curves which occur often in the later life of production units has been done. Decline curve analysis applies oil production versus time plots to extrapolate an estimation of the future production rates for wells (Ibrahim, 2021). Many factors influenced production rates, and consequently decline curves. These are proration, changes in production methods, workover, well treatments; pipeline disruptions, and weather and market conditions. Production decline refers to the annual reduction in the rate of crude oil production from single field or from a group of fields, particularly, after a peak in production (Hook *et al.,* 2013). These oil production declines could be caused by factors such as the aging of the fields, war & conflicts, sand production, poor reservoir characterization, high water cuts, floods and poor technologies (Riak, 2024).

2.0 METHODOLOGY

In this study, a field example is used and an oil reservoir is considered. The oil reservoir employed is located in the Niger Delta area of Nigeria, an oil-bearing reservoir, which was tested for production in March 1985 and placed on product1on in 1986.

2.1 Volumetric Estimation of A2 Reservoir

Volumetric method for estimating stock tank oil initially in place (STOIIP) is based upon log response, core analysis and/or geological parameter to determine the bulk volume, porosity, fluid saturation and fluid analysis (PVT data) to determine the oil formation volume factor.

2.2 Steps in Volumetric Estimation

The steps used in volumetric estimation are based on the available data. The following are required for any volumetric estimation to be done; Geological data, Petrophysical data and PVT data.

A. Geological Data

The structural map is the basic Geological data required. It is a map showing the level and depths of the reservoir increase in a field. This structural map is planimetered to get the area of each contour line. This is done either with a digital or mechanical planimeter. Planimetering is done normally up to the GOC and OWC. Before planimctering, the planimeter is set up to a scale factor of the structural map. The general scale in most Niger Delta structural maps including the one used in this work is $I: 25000cm$.For a mechanical planimeter therefore, the following conversions are made.

$$scale\ 1: 25000\ cm$$

$$1: 250\ m$$

This means that 1cm on paper is equivalent to 250m in the reservoir

$$= 250m\ x\ 3.281ft\ x\ 1m^{-1}$$

$$= 820.25ft$$

$$1\ unit\ from\ planimetering = 1sqft$$

$$Or\ 1sqcm\ on\ map = (820.25)^2 ft^2$$

$$1ft^2 = \frac{1}{(820.25)^2}cm^2$$

Converting this to acres;

$$1\ acre = 43560ft^2$$

$$1ft^2 = \frac{1}{43560}acre$$

Therefore,

$$\frac{1}{(820.25)^2}cm^2 = \frac{1}{43560}acre$$

$$1cm^2 = \frac{(820.25)^2}{43560}acre$$

Therefore, I planimeter unit

$$= \frac{820.25^2 ft^2}{43560\, ft^2/acre} = 15.445 acres$$

The cumulative bulk volume of the reservoir can be estimated from the structural map by the help of a Depth Vs. Area graph of the structural map (see Figure l). At this stage, only the top sand curve is plotted. Then to obtain the base sand curve, the average thickness of the reservoir is added to each of the depth and corresponding areas earlier plotted. The contact levels are marked out and the bulk volume is calculated from the graph up to the oil water contact.

B. Petrophysical Data

Petrophysical Data required for volumetric estimation include Porosity,φ, Connate water saturation (S_{wc}), Oil saturation (S_o), Shale factor (F), also known as net gross factor, sand thickness, sand top ($ft - ss$), sand base ($ft - ss$), GOC, and WOC. Because of reservoir heterogeneity, weighted average of these data is usually used during evaluations. Petrophysical data are obtained from self-potential (Spontaneous potential) logs and gamma-ray logs run on the wells drilled into the reservoir A2; from which petrophysical properties of interest are determined.

C. PVT Data

The initial oil formation volume factor is the main PVT parameter required for volumetric calculation. It enables the calculation of STOIIP (stock tank oil initially in place) and other PVT parameters. A2 reservoir was producing through petrophysical parameters as obtained from the logging of five wells, depicted in Table 1.

2.3 Reservoir Volume

The volume of the oil-bearing rock in A2 reservoir under consideration is a very important parameter in the estimation of STOIIP. The Depth Vs. Area graph is the method used in this work and for all cases where the geometry of the reservoir is represented by contour map, structure map or some form of thickness map. The area enclosed by each contour depth obtained were deployed against corresponding measured depth (see Figure I). From the structural map or log response, the Gas-oil contact and Oil-water-contact were inferred. Each is represented within the reservoir zone by a straight horizontal line. The space enclosed by the GOC and OWC gives the gross oil-bearing volume of the reservoir. The planimetry constant used was 15.45 acres as was got from the scaled structural map. The planimetry readings for A2 reservoir are shown in Table 2.

2.4 Gross Volume Computation

A2 reservoir shows a uniform sand development trend so that the Area Vs. Depth graph approach is considered sufficiently accurate for estimation of gross volume. From the cumulative bulk volume area- depth graph (Figure l), the gross oil-bearing volume of the reservoir is that bounded by the GOC and OWC. The entire volume of A2 reservoir is underlain by bottom water, so the curve for the base reservoir is replaced by a straight line at the OWC depth.
Area of trapezium ABCD (i.e., area enclosed by GOC and OWC)

$$= 1/2\ (sum\ of\ parallel\ sides) x (perpendicular\ height)$$

$$\text{ABCD} = 1/2\ (8450 + 5150) x (10348 - 102262)$$

$$= 584800 \text{ acreft}$$

This gives a gross oil-bearing volume of 584800 $acreft.$ From the interpretation of the structural map, the gross thickness is $(10348 - 10262)\ ft\ - ss,$ which gives 86ft as the gross thickness. From the summary of the log response, the average net oil sand is 63 ft. Therefore, Net/gross ratio,

$$\text{F} = 63/86 = 0.73$$

2.5 Volumetric Calculation

After the above analysis, the complete data as determined are as follows:

$$V_b = 584800\ acreft$$
$$F = 0.73$$
$$\emptyset = 15\%$$
$$S_{wc} = 23\%$$
$$B_{oi} = 1.308\ \mathrm{rb}/stb$$

Therefore,

$$STOIIP = \frac{7758xV_bx\emptyset xF(1 - S_{wc})}{B_{oi}}$$
$$= \frac{7758x584800x0.15x0.73x(1 - 0.23)}{1.308}$$
$$= 292.452x10^{-1}stb$$
$$= 292MMstb$$

Decline curve analysis method of reserve estimation is a graphical representation of production curve that decreases with time. The curves are known as "decline curves". There is generally decline in the production rate and the trend of the decline is interpreted in a graph and used to estimate the initial hydrocarbon in place.

2.6 Estimation of A2 Reservoir Using Decline Curve Analysis

For the field example used in this work, the data required for decline curve analysis are obtained from the past production history of the reservoir and are deployed as Log of production rate vs time (see Figure 2). The plot shows that production rate was fairly constant between 1986 and 1990 but declines afterwards. This indicates that A2 reservoir has a constant or exponential decline from 1990 to 1996. The maximum amount of produceable oil from the reservoir was calculated to be 193.10 MMSTB. Considering up to 1996 when the estimation was done, a cumulative production of 16.570 MMSTB has been obtained from A2 reservoir. Therefore, the estimate of STOIIP of the reservoir is got by adding cumulative production up to 1996 to maximum oil produceable (N_{pmax}) from the reservoir.

Therefore, $STOIIP = 16.570x10^6 + 193.10x\ 10^6$

$$= 209.67MMSTB$$

Table 1: Electrical Log Data

Well	Top sand (ft-ss)	Bottom sand (ft-ss)	Net oil sand Top sand (ft)	Porosity (%)	Water saturation (%)
2T	10123	10408	73	13.0	28.0
3T	10110	10364	66	18.0	22.0
4T	10190	10466	62	16.0	24.0
5T	10191	10443	61	15.0	21.0
6T	10178	10450	51	14.0	20.0
	AVERAGE		63	15.2	23.0

Table 2: Planimetry Readings

Depth (ft-ss)	1st reading	2nd reading	Average reading	Area (acre) Average x 15.45
10150	142.40	142.40	142.40	2200
10200	227.0	226.00	226.50	3500
10250	310.70	310.70	310.70	4800
10300	333.30	333.30	333.30	5150
10350	411.50	411.50	411.50	6350
10400	547.00	546.80	546.90	8450

Table 3: Petrophysical Data of A2 Reservoir

Porosity	15 %
Connate water saturation S_{wc}	23 %
Net to gross ratio (F)	0.73 %
Gas- oil-contact (GOC)	10262 ($ft - ss$)
Oil-water-contact (OWC)	10348 ($ft - ss$)
Average sand thickness	63 (ft)
Area of oil leg (A)	85000 ($acres$)

Permeability (K)	$585\ md$
Water plus rock compressibility	$0.7\ x\ 10^{-6}\ psi^{-1}$
Aquifer configuration	40
Water viscosity	$0.53\ cp$

Table 4: Summary of Results

Method	Results
Volumetric	$292\ MMSTB$
Decline curve analysis	$210\ MMSTB$

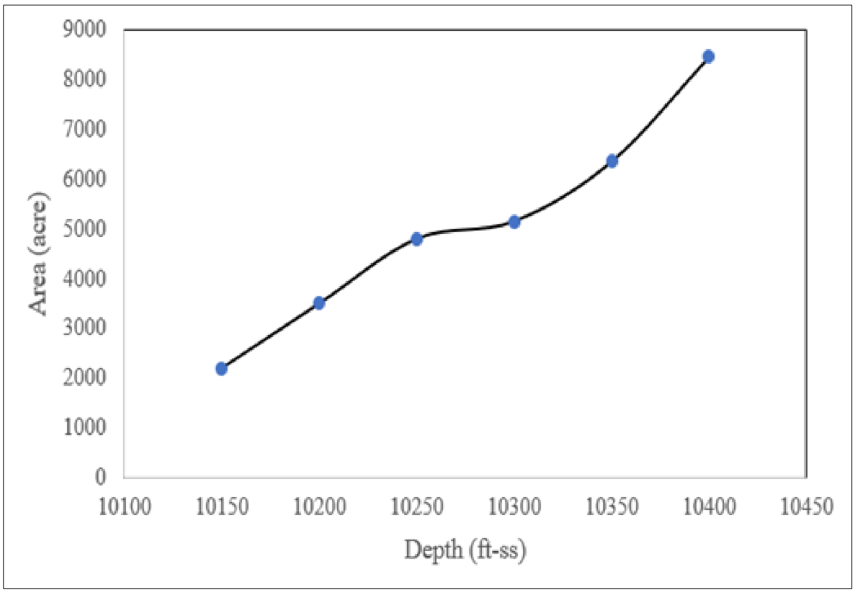

Fig. 1: Plot of Depth vs. Area for gross volume

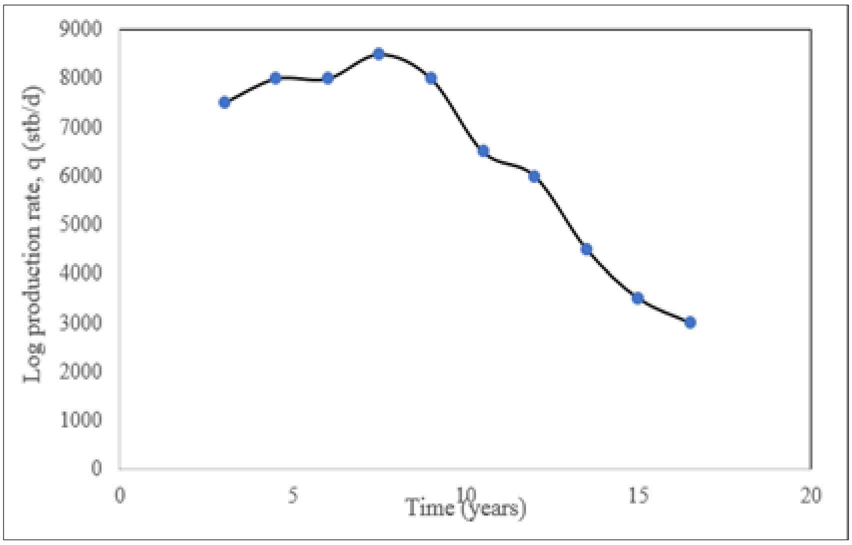

Fig. 2: Plot of Production rate vs. Time

3.0 DISCUSSION

This study has examined the use of volumetric and decline curve techniques of reserve estimation for evaluating the stock tank oil initially in place (STOIIP) of A2 reservoir. The result from the decline curve analysis is lower than that of volumetric by 82MMSTB. The results obtained from the different methods differ because of the different assumptions made, level of accuracy and the method of approach of each. The volumetric result is an over-estimation and it is referred to as a rough estimation of the work. This is because the parameters used are based on the initial geologic data of the reservoir. Decline curve analysis result obtained may be very close to the accurate value since it is based on the actual production history of the reservoir. Theoretically, the decline curve result has a higher level of accuracy, but however, its results are subjective and depends on the judgment of the estimator.

4.0 CONCLUSION

The STOIIP obtained from the Volumetric method was $292MMstb$.The production history of A2 reservoir indicated a fairly constant rate between 1986 and 1990 after which the rate started declining. The semi-log plot of rate vs. time (see Figure 2) indicates that A2 reservoir has exponential decline. Decline curve analysis method estimated the reserve as $210MMstb$. Therefore, the evaluation and estimation of reserve using any method will depend on the time of estimation. The quantity of data available, the expertise and ingenuity of the estimator.

5.0 RECOMMENDATIONS

After a quantitative analysis of A2 reservoir, the following recommendations are made:

1. Volumetric method should be used in the quantitative evaluation of newly discovered reservoirs.
2. As production from the reservoir progresses, the volumetric value should be updated using the material balance method.
3. The operating companies are required to pay more attention to the accuracy of reserve estimation and are advised to re-evaluate reservoir at frequent intervals of years to update the result with the production performance of the reservoir. This will ensure the companies' profitability, effective reservoir management and sound/effective decision making.

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