Petroleum Reserves Estimation Methods

Introduction

The process of estimating oil and gas reserves for a producing field continues throughout the life of the field. There is always uncertainty in making such estimates. The level of uncertainty is affected by the following factors:

1. Reservoir type,
2. Source of reservoir energy,
3. Quantity and quality of the geological, engineering, and geophysical data,
4. Assumptions adopted when making the estimate,
5. Available technology, and
6. Experience and knowledge of the evaluator.

The magnitude of uncertainty, however, decreases with time until the economic limit is reached and the ultimate recovery is realized, see Figure 1.

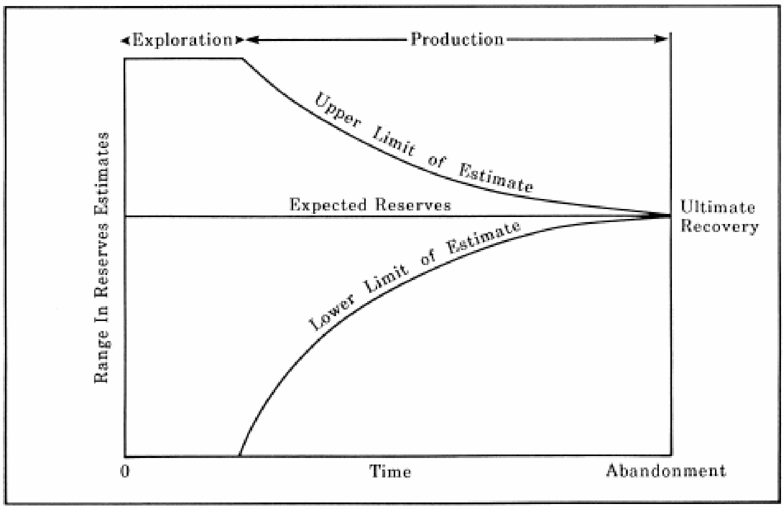

Figure 1: Magnitude of uncertainty in reserves estimates

The oil and gas reserves estimation methods can be grouped into the following categories:

1. Analogy,
2. Volumetric,
3. Decline analysis,
4. Material balance calculations for oil reservoirs,
5. Material balance calculations for gas reservoirs,
6. Reservoir simulation.

In the early stages of development, reserves estimates are restricted to the analogy and volumetric calculations. The analogy method is applied by comparing factors for the *analogous* and *current* fields or wells. A *close-to-abandonment* analogous field is taken as an approximate to the current field. This method is most useful when running the economics on the current field; which is supposed to be an *exploratory* field.

The volumetric method, on the other hand, entails determining the areal extent of the reservoir, the rock pore volume, and the fluid content within the pore volume. This provides an estimate of the amount of hydrocarbons-in-place. The ultimate recovery, then, can be estimated by using an appropriate recovery factor. Each of the factors used in the calculation above have inherent uncertainties that, when combined, cause significant uncertainties in the reserves estimate.

As production and pressure data from a field become available, decline analysis and material balance calculations, become the predominant methods of calculating reserves. These methods greatly reduce the uncertainty in reserves estimates; however, during early depletion, caution should be exercised in using them. Decline curve relationships are empirical, and rely on uniform, lengthy production periods. It is more suited to oil wells, which are usually produced against fixed bottom-hole pressures. In gas wells, however, wellhead back-pressures usually fluctuate, causing varying production trends and therefore, not as reliable.

The most common decline curve relationship is the *constant percentage decline* (*exponential*). With more and more low productivity wells coming on stream, there is currently a swing toward decline rates proportional to production rates (*hyperbolic and harmonic*). Although some wells exhibit these trends, hyperbolic or harmonic decline extrapolations should only be used for these specific cases. Over-exuberance in the use of hyperbolic or harmonic relationships can result in excessive reserves estimates.

Material balance calculation is an excellent tool for estimating gas reserves. If a reservoir comprises a closed system and contains single-phase gas, the pressure in the reservoir will decline proportionately to the amount of gas produced. Unfortunately, sometimes bottom water drive in gas reservoirs contributes to the depletion mechanism, altering the performance of the non-ideal gas law in the reservoir. Under these conditions, optimistic reserves estimates can result.

When calculating reserves using any of the above methods, two calculation procedures may be used: *deterministic* and/or *probabilistic*. The deterministic method is by far the most common. The procedure is to select a single value for each parameter to input into an appropriate equation, to obtain a single answer. The probabilistic method, on the other hand, is more rigorous and less commonly used. This method utilizes a distribution curve for each parameter and, through the use of *Monte Carlo Simulation*; a distribution curve for the answer can be developed. Assuming good data, a lot of qualifying information can be derived from the resulting statistical calculations, such as the minimum and maximum values, the mean (average value), the median (middle value), the mode (most likely value), the standard deviation and the percentiles, see Figures 2 and 3.

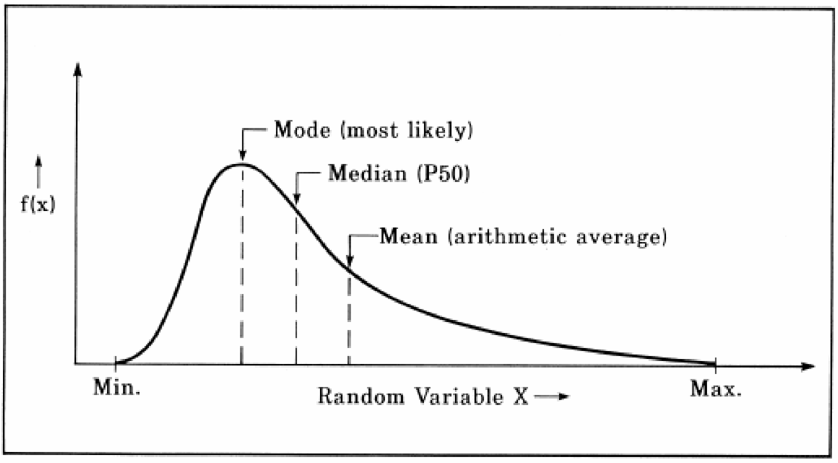

Figure 1: Measures of central tendency

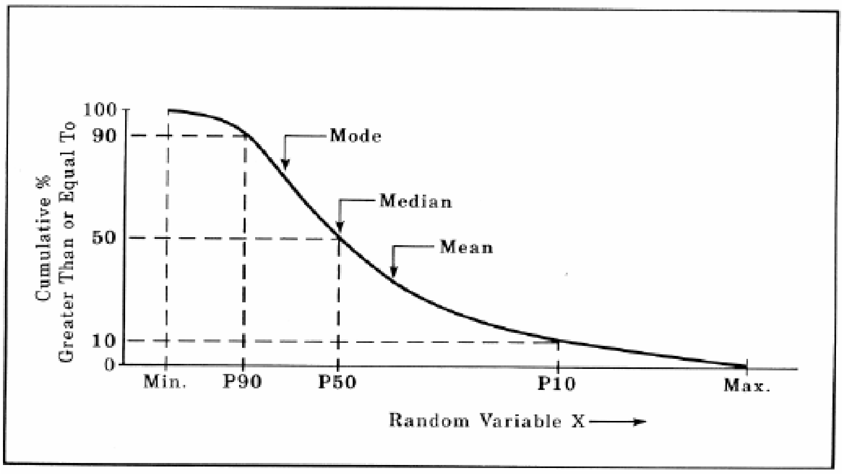

Figure 3: Percentiles

The probabilistic methods have several inherent problems. They are affected by all input parameters, including the most likely and maximum values for the parameters. In such methods, one can not back calculate the input parameters associated with reserves. Only the end result is known but not the exact value of any input parameter. On the other hand, deterministic methods calculate reserve values that are more tangible and explainable. In these methods, all input parameters are exactly known; however, they may sometimes ignore the variability and uncertainty in the input data compared to the probabilistic methods which allow the incorporation of more variance in the data.

A comparison of the deterministic and probabilistic methods, however, can provide quality assurance for estimating hydrocarbon reserves; i.e. reserves are calculated both deterministically and probabilistically and the two values are compared. If the two values agree, then confidence on the calculated reserves is increased. If the two values are away different, the assumptions need to be reexamined.