Introduction to Monte Carlo Simulation

Oil and Gas Reserve Estimation

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Introduction to Modeling

Numerical Models

- All numerical models have input values
- Input values can be a discrete number such as 1, 5, 621 or continuous such as 1.234532 or 99.23421
- The input value may be absolutely certain or stochastic (follows a random pattern)
- Stochastic input values the norm in models, absolute certainty is a luxuary

Stochastic Models

- The input values will follow any one of the numerous statistical distributions, for example the Normal Distribution or the Uniform Distribution
- For example, population height follows the normal distribution
- Selection of distribution depends on scientific observation of historical data and professional judgment

Limitation of Stochastic Models

- Stochastic models by their very nature cannot be calculated definitively, unlike say the floor area of your office (length x breadth = total area)
- Stochastic models do provide the average answer (assuming that all input values represent the average input value) but tell you nothing of the range or probability of possible answers.
- This can be critical when determining the likely profitability of a venture, safety of a drug or building

Monte Carlo Method

The Monte Carlo Method

- A method of random sampling the Stochastic input values to provide a picture of the output distribution values and probabilities
- The quality of the random number generator is critical, Lumenaut used the Mersenne twister algorithm

The Monte Carlo Method - Details

- One iteration random samples each stochastic input, setting up a new set of input values
- The model then takes these inputs and calculates the outputs
- These outputs are recorded
- The process is repeated x time until sufficient repeat samples are collected to provide a probability breakdown for a range of output values

An Oil and Gas Example

An Oil and Gas Example

- Calculation of potential oil reserves
- Limited information available of extent of reserve, rock type, pressure, gas content, water content, and percentage recoverable hydrocarbons
- Use Monte Carlo Method to bracket uncertainty

Oil Reserve Equation

Hydrocarbon in Place = GRV x N/G x Porosity x Sh / FVF

- Gross Rock volume - amount of rock in the trap above the hydrocarbon water contact
- N/G - net/gross ratio - percentage of the GRV formed by the reservoir rock (range is 0 to 1)
- Porosity - percentage of the net reservoir rock occupied by pores (typically 5-35%)
- Sh - hydrocarbon saturation - some of the pore space is filled with water - this must be discounted
- FVF - formation volume factor - oil shrinks and gas expands when brought to the surface. The FVF converts volumes at reservoir conditions (high pressure and high temperature) to storage and sale conditions

Recoverable Hydrocarbons

Recoverable Hydrocarbons = Hydrocarbons in Place x Percentage Recoverable Hydrocarbons

- Recoverable hydrocarbons - amount of hydrocarbon likely to be recovered during production. This is typically 10-50% in an oil field and 50-80% in a gas field.

The Lumenaut Excel Monte Carlo Model

Variables	Values
GRV (cubic kilometers)	**0.10**
N/G	**50%**
Porosity (%)	**15%**
Water Saturation (%)	**25%**
FWF	**1.3**
Total Oil Reserves (million cubic meters)	4.327
Total Oil Reserves (Million Stock Tank Barrels)	27.22
Recoverable Hydrocarbons	**45%**
Total Recoverable Oil (cubic kilometers)	1.95
Total Recoverable Oil (Million Barrels)	**12.25**

See accompanying Excel Model *Oil Reserve Estimation.xls*

Explanation

- Cells in Green Represent Input Values
- Cells in Orange Represent Output Value, in this case the Total Recoverable Oil in Million Barrels

Inputs Settings

Cell Name:	GRV (cubic kilometers)
Cell:	Model!$B$6
Distribution:	Normal
Mean:	0.1
SD:	0.01
Min:	0.06
Max:	0.14

Cell Name:	N/G
Cell:	Model!$B$7
Distribution:	Normal
Mean:	0.5
SD:	0.05
Min:	0.23
Max:	0.7

Cell Name:	Porosity
Cell:	Model!$B$8
Distribution:	Normal
Mean:	0.15
SD:	0.01
Min:	0.11
Max:	0.19

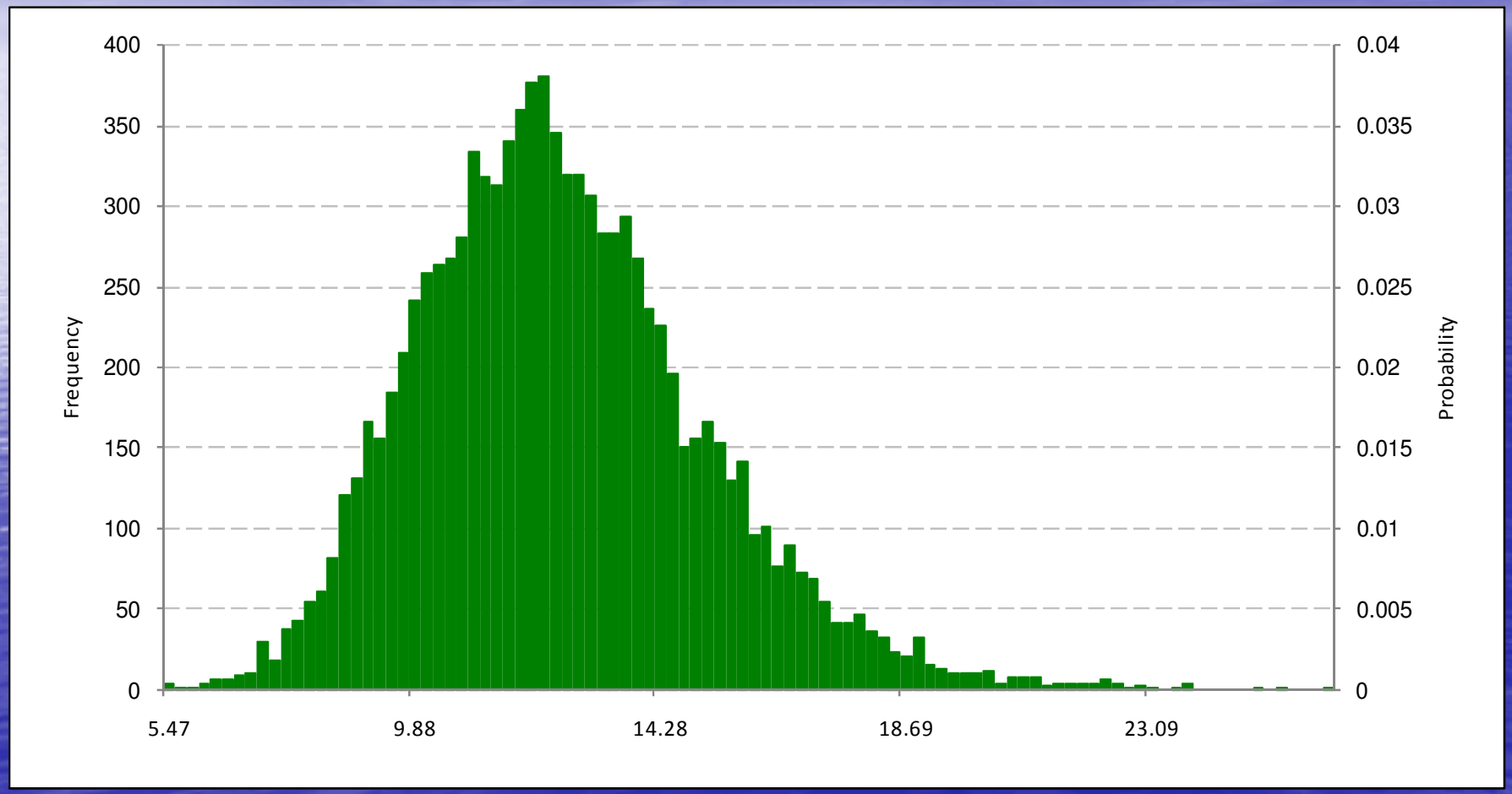
Cell Name:	Water Saturation
Cell:	Model!$B$9
Distribution:	Triangular
Min Point	0.184
Mid Point	0.25
Max Point	0.3
Min:	0.184

Input Settings

Cell Name:	FWF	Cell Name:	Recoverable Hydrocarbons
Cell:	Model!$B$10	Cell:	Model!$B$15
Distribution:	Normal	Distribution:	Uniform
Mean:	1.3	Mean:	0.45
SD:	0.1	Min:	0.48
Min:	1.0	Max:	Recoverable Hydrocarbons
Max:	1.7		

Simulation Results

- Model Run for 10,000 iterations



Total Recoverable Oil (Million Barrels)

What Does this Mean?

- The distribution of expected possible oil reserves follows a log normal distribution

Simulation Results

Total Recoverable Oil (Million Barrels)

Mean	12.38
Median	12.15
Mode	N/A
Stand. Deviation	2.54
Variance	6.45
Mean Std. Error	0.03
Range	20.98
Range Min	5.26
Range Max	26.24
Skewness	0.59
Kurtosis	0.74

What Does this Mean?

- The average expected oil reserve is 12.4 million barrels
- The minimum expected oil reserve is 5.26 million barrels and the maximum expected oil reserve is 26.24 million barrels

Simulation Results

Total Recoverable Oil (Million Barrels)

Percentile	Min to Max
0%	5.26
10%	9.32
20%	10.23
30%	10.94
40%	11.58
50%	12.15
60%	12.77
70%	13.49
80%	14.34
90%	15.70
100%	26.24

What Does this Mean?

- 10 percent chance that reserves will be between 5.26 and 9.319 million barrels
- 50 percent chance that reserves will be between 5.26 and 12.149 million barrels
- 50 percent chance that reserves will be between 12.15 and 26.24 million barrels
- 20 percent chance that reserves will be between 11.58 and 12.769 million barrels
- 10 percent chance that reserves will be between 15.7 and 26.24 million barrels

How can we use the Results?

- Can be used to determine whether risks of extraction outweigh the rewards of extraction
- This can be done economically if add cost of extraction/transportation and expected price of oil to the model then can calculate range of revenues and profits together with probabilities
- Comparisons can be made with other oil extraction options company may have to determine most likely productive field.