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Uncertainty Assessment for Field Development Study Using Monte Carlo Simulation on Salap Field Multilayer Gas Reservoir

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ABSTRACT

Uncertainty assessment for Field Development Study is often only carried out in a Deterministic Method by only creating scenario sensitivity based on theoretical assumptions without add subsurface risk factors. In the uncertainty assessment model, when a model is made with a variable that only has one value for each sensitivity is called the Deterministic Method. Meanwhile, when a model is made with a variable that has value in the form of a probability distribution, the method is called the Probabilistic Method. In the Probabilistic Method, the probability distribution is influenced by the risk factors, while in the Deterministic Method, these factors have no effect because the input value is only based on theoretical assumption. Uncertainty assessment for the Salap Field Development Study was carried out using the Probabilistic Method Monte Carlo Simulation. The results of the study provide the number of proven reservoirs, volume in place, volume of resources, number of development wells, plateau production period and field life that already accommodates subsurface risk factors and uncertainty in geological-reservoir data. The paper also compares the assessment result between the Probabilistic Method with the Deterministic Method to see how risk factors influenece the study results.

Keywords: assessment, development, exploration, prospect, study, uncertainty

I. INTRODUCTION

Salap Field is one of the onshore exploration prospects in the East Java Basin which has not been drilled before. Referring to the results of the seismic interpretation of the Salap Field and the reservoir characteristics of the AGT Field which produce from the samillar basin and formation, the formation target is multilayer gas reservoir with varying reservoir characteristics on each layer. The variation on reservoir characteristics in the analog field has become the basis for conducting an uncertainty assessment in the Salap Field Development Study.

Uncertainty assessment can be interpreted as a risk analysis by conducting an assessment of all uncertain variables to provide a range of success or failure as well as the implications that arise. The range and implications are needed in the decision-making process so that decision-makers have an analytical basis in making choices and can prepare alternative plans that accommodate risk and uncertainty factors.

In the uncertainty assessment model, when a model is made with a variable that only has one value for each sensitivity is called the Deterministic Method. Meanwhile, when a model is made with a variable that has value in the form of a probability distribution, the method is called the Probabilistic MethodIn the oil and gas industry, uncertainty assessment is often only carried out in a deterministic manner by making scenario sensitivity using theoretical assumptions without accommodating subsurface risk factors.

Field Development Studies should be carried out in a probabilistic manner, because the Deterministic Method can sometimes give overly optimistic estimation. Overly optimistic estimation often lead to inappropriate decision-making on planning for field development.

Monte Carlo simulation is one of the probabilistic methods that can be used to estimate the quantitative value of a model by utilizing the random number that is entered in the input of the calculation model. In Monte Carlo Simulation, a model is built with all input variables in the form of probability distribution data that correlated with random values from random numbers. The Monte Carlo simulation will perform a calculation simulation repeatedly with each input variable that changes according to a random value that appears. Iterations can be done up to thousands of times depending on the model complexity. The simulation will provide calculation results with many output values and forming a qualitative pattern that has a tendency to any value so that it can be interpreted quantitatively using the selected probability.

The topic of uncertainty assessment has been widely raised in journals that discuss field development study in the scope of development and exploration. Most of the researcher that discusses uncertainty assessment only mentions the advantages of the Probabilistic Method when compared to the Deterministic Method, without comparing the assessment results of the two methods using the same data.

Uncertainty assessment in this study is not only carried out probabilistically using Monte Carlo Simulation, but using the same data it is also carried out in a deterministically to provide an overview of the effect of subsurface risk factors on the uncertainty assessment results.

The purpose of this research is to conducting a field development study which is based on uncertainty assessment using the Probabilistic Monte Carlo Simulation Method that accommodates subsurface risk factors and geological-reservoir data uncertainty. The assessment results will be used as input in the Petroleum Expert Suites or PETEX Reservoir Simulation software. (GAP – MBAL – Prosper). By using the same input data, uncertainty assessment is also conducted using the Deterministic Method to compare the results with the study.

The purpose of this study is to provide study results in the form of PETEX Reservoir Simulation predictions which includes estimation of:

1. Number of proven reservoirs;
2. Volume of Gas in Place;
3. Volume of Gas Resources;
4. Number of Development Wells;
5. Plateau Production Period;
6. Field life.

II. METHODS

The methodology that used are:

1. Collecting Salap Field data and analog field data;
2. Determine the uncertainty variable in the study (Bulk Volume, Net to Gross, Porosity, Water Saturation, Net Pay and Permeability);
3. Performing centralized dat scale analysis for each uncertainty variables;
4. Estimates pressure and temperature of Reservoir C, D, E, and F on Salap Field;
5. Createing PVT correlation for Reservoir C, D, E and F;
6. Conducting Monte Carlo Simulation Modeling for Probabilistic Gas In Place Calculation;
7. Ploting Probability Density Function (PDF) and Cumulative Distribution Function (CDF) of Gas In Place from Monte Carlo Simulation;
8. Determinating the Scenario input variables P90, P50 and P10 as a Probabilistic Case uncertainty assessment to be used as input in the PETEX Reservoir Simulation;
9. Running PETEX Reservoir Simulation for Probabilistic Case P90, P50 and P10 Scenarios;
10. Making a summary of the results of the Probabilistic Case reservoir simulation as a result of the Salap Field development study based on the uncertainty assessment using Monte Carlo Simulation on a multilayer gas reservoir.
11. Determinating Low, Mid and High Scenario input variables as Uncertainty Assessment Deterministic Case to be used as input in the PETEX Reservoir Simulation;
12. Running PETEX Reservoir Simulation for Deterministic Case Low, Mid and High Scenarios
13. Sumarizing the results of the Deterministic Case reservoir simulation to be compared with the results of the study.

To focus the objectives of the study, the following are the scope and limitations that will be applied in the paper,

1. Hydrocarbon prospect of the Salap Field assumption will be referred with the analog field, which is dry gas without any impurities;
2. The marker depth data for each reservoir refers to the results of the seismic interpretation of the Salap Field;
3. The pressure and temperature data for each reservoir layer is calculated using the normal gradient at the marker depth from the seismic interpretation of the Salap Field;

4. Reservoir characteristics, fluid and formation transmissibility data is using analog field data;
5. Data uncertainty assessment is only applied on Geology- Reservoir data variables such as Bulk Volume (Vb), Net to gross (NTG), Porosity, Water Saturation (Sw), Net Pay (h) and Permeability (k);
6. Assumption of probability distribution for Volume Bulk (Vb) and Net to gross (NTG), is using Uniform distribution. Distribution type selection is based on analog field data distribution;
7. Assumption of probability distribution for Porosity and Water Saturation (Sw), is using Triangular distribution. Distribution type selection is based on analog field data distribution;
8. Assuming the probability distribution for Net Pay (h) and Permeability (k) is using the Discrete Binomial distribution. Distribution type selection is based on analog field data distribution;
9. The reservoir simulation software that used is Petroleum Expert Suites or PETEX (GAP-MBAL – Prosper).

Reservoir Model Description:

1. **Reservoir Model**: The reservoir model is assumed to be a Tank Model that created using the MBAL feature in GAP. There are 4 reservoir models for Zones C, D, E and F.
2. **Formation Productivity Model:** The formation productivity (Inflow Performance Relationship) model was created by using the Prosper model of the "Backpressure Method C and n". There are 40 formation productivity models that represent the IPR in Zones C, D, E and F for each well.
3. **Production Well Model**: The production well model is made with the assumption of a multilayer well completion equipped with Inflow Control Valve (ICV), Sliding Sleeve Door (SSD) and Stradle Packer so that the reservoir can be produced either commingly or selectively. There are 10 productions well models of, from SL-01 to SL-10.
4. **Assumption of Surface Facility**: Surface facility is assumed to be 1 junction manifold as Gas plant and a single 8" diameter header with 8 KM length and 1 Buyer Sales point with plant pressure 100 Psig. Upstream junction is 10 production wells in the Salap Field. While the dowstream is a header to the sales point.
5. **Prediction Simulation**: Prediction simulation starts on January 1st 2025 and ends on January 1st 2061 (End of PSC). Simulation time step is made per 1 year.
6. **Well/Zone Opening Schedule**: Opening and closing schedule works automatically using the open server feature in the GAP Simulation. The open server command string will control the number of wells and the number of zones that needed to achieve/maintain the total field production target. Even though the model wells are made of 10 wells, in the initial conditions only 1 well and 1 reservoir zone are open so that the number of open wells/zones will be controlled by the gas production target and the performance of each reservoir/well.

Field development timeline assumption:

1. **Phase #1 (2022-2023)**
   - Drilling 1 exploration well and 1 delineation well.
   - Preparation of POD Salap Field.
   - Preparation of Salap Field Sales Contract with buyers (2 MMSCFD for 5 years).
2. **Phase #2 (2023 – 2025)**
   - Salap Field POD approval.
   - Salap Field Sales Contract approval
   - Drilling 1 Development well.
3. **Phase #3 (2025 – 2030)**
   - Started gas sales to buyers with a sales target of 2 MMSCFD.
   - Development Drilling Campaign Salap Field based on POD approval.
   - Amendment of Salap Field Sales Contract (Ramp up sales from 2 MMSCFD to 20 MMSCFD for 5 years)

4. **Phase #4 (2030-2061)**

- Selling gas to buyer with sales target 20 MMSCFD.
- Continue produces field up to the end of PSC contract

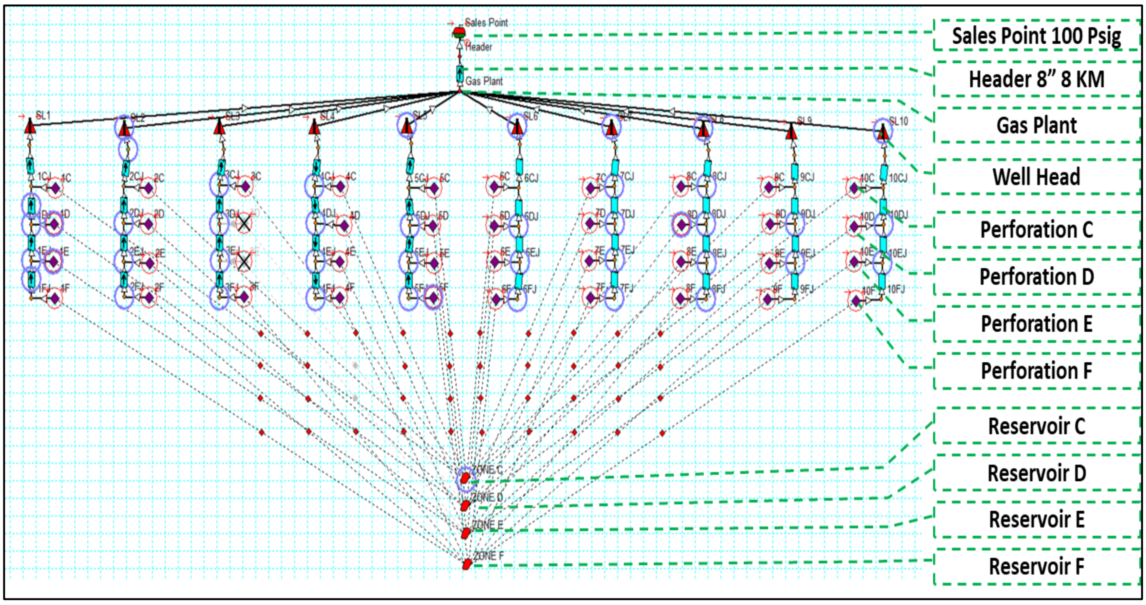

Figure 1. GAP – MBAL – PROSPER Model

III. RESULTS AND DISCUSSION

3.1. Uncertainty Assessment for Salap Field Development Study

There are 2 calculations that are simulated with the Monte Carlo Simulation, which are the calculation of Gas in Place and the calculation of transmissibility as input for the formation productivity model. In the calculation of Gas In Place the modeled input variables are Bulk Volume, Net to Gross, Porosity and Water Saturation on each reservoir Zone C, D, E and F. In the calculation of transmibility/formation productivity the modeled input variables are Net pay and Permeability on each reservoir Zone C, D, E and F.

The random number value is created by utilizing the RAND function feature in Microsoft Excel. The RAND function placed in a cell in the excel sheet will generate a random number between 0 to 1 for each iteration.

In the oil and gas exploration stage, subsurface risk factors are estimated by evaluating the parameters of the petroleum system of prospect's target. These parameters include:

1. Presence of source rock
2. Migration/time of migration (Migration/Timing)
3. Reservoir Rock Properties
4. Presence of Seal Rock
5. Presence of hydrocarbon traps in the structure (Containment)

Each parameter has a percentage probability of success or failure with a scale of 0% to 100% according to the completeness of the data and supporting concepts. Furthermore, the probability percentage of each parameter is multiplied to obtain the Probability of Geology (Pg), Geological Chance Factor (GCF) and Risk factor values.

The probability distribution of Volume Bulk and Net to Gross data for each reservoir is made using a uniform distribution type. The lower and upper limits of the distribution use the minimum and maximum values from the analysis of the centered scale data.

The random number generated by the random number becomes one of the inputs in the uniform distribution formula, so that the Volume Bulk and Net to Gross values are the results of the probability distribution that are correlated with the random numbers that appear.

Table 1. Uncertainty Assessment Model of Bulk Volume Variable

Zone	Bulk Volume (10^6 Acre.ft)				
	Random	Value	Min	Mean	Max
C	0 - 1	Uniform Dist	278,084	537,700	794,464
D	0 - 1	Uniform Dist	344,206	570,952	701,850
E	0 - 1	Uniform Dist	291,206	413,930	511,404
F	0 - 1	Uniform Dist	531,788	781,278	1,020,490

Table 2. Uncertainty Assessment Model of Net Pay Variable

Zone	Net To Gross (Frac)				
	Random	Value	Min	Mean	Max
C	0 - 1	Uniform Dist	0.06	0.12	0.18
D	0 - 1	Uniform Dist	0.06	0.09	0.11
E	0 - 1	Uniform Dist	0.03	0.23	0.43
F	0 - 1	Uniform Dist	0.06	0.10	0.15

The probability distribution of Porosity and Water Saturation data for each reservoir is made using a triangular distribution. The lower, middle and upper values of the distribution use the minimum, mean and maximum values from the analysis of the centered scale data.

The random number generated by the random number becomes one of the inputs in the triangular distribution formula, so that the Porosity and Water Saturation values are the results of the probability distribution that are correlated with random numbers that appear.

Table 3. Uncertainty Assessment Model of Porosity Variable

Zone	Porosity (Frac)				
	Random	Value	Min	Mean	Max
C	0 - 1	Triangular Dist	0.23	0.25	0.27
D	0 - 1	Triangular Dist	0.22	0.24	0.26
E	0 - 1	Triangular Dist	0.24	0.27	0.29
F	0 - 1	Triangular Dist	0.25	0.28	0.30

Table 4. Uncertainty Assessment Model of Water Saturation Variable

Zone	Water Saturation (Frac)				
	Random	Value	Min	Mean	Max
C	0-1	Triangular Dist.	0.50	0.48	0.46
D	0-1	Triangular Dist.	0.53	0.49	0.45
E	0-1	Triangular Dist.	0.53	0.48	0.43
F	0-1	Triangular Dist.	0.51	0.44	0.36

The probability distribution of the Net pays and Permeability data for each reservoir is made using a discrete distribution type. The lower, middle and upper values of the distribution use the minimum, mean and maximum values from the analysis of the centered scale data.

In the distribution of the permeability data, 1 permeability value of 0.1 mD is added as a value that represents the non-flowing and dry condition of the reservoir to accommodate subsurface risk factors that may occur.

The random value generated by the random number becomes one of the inputs in the discrete distribution formula so that the Net Pay and Permeability values are the results of the probability distribution that are correlated with random numbers that appear.

Table 5. Uncertainty Assessment Model of Net Pay Variable

Zone	Net Pay (ft)				
	Random	Value	Min	Mean	Max
C	0 - 1	Discrete Dist.	10.0	17.5	25.0
D	0 - 1	Discrete Dist.	6.0	10.5	15.0
E	0 - 1	Discrete Dist.	5.0	22.5	40.0
F	0 - 1	Discrete Dist.	8.0	15.0	22.0

Table 6. Uncertainty Assessment Model of Permeability Variable

Zone	Permeability (mD)					
	Random	Value	No Flow	Min	Mean	Max
C	0 - 1	Discrete Dist.	0.10	65	98	130
D	0 - 1	Discrete Dist.	0.10	53	124	195
E	0 - 1	Discrete Dist.	0.10	5	78	150
F	0 - 1	Discrete Dist.	0.10	13	72	130

3.2. Monte Carlo Simulation Result

In the Monte Carlo simulation model, subsurface risk factors are included in the permeability calculation model that has been discussed previously. In this study, the percentage of the permeability value that appears 0.1 mD/ Reservoir does not flow/dry is assumed to be 50% which used the Risk Factor that given by Geologist.

The number of iterations of the Monte Carlo simulation is determined by calculating the standard deviation value of the tested variables, determining the maximum error percentage value and the error value of the model and calculating the number of iterations required for the simulation with the standard deviation target to the calculated error value.

The results of the calculation of the iteration number show that to get a model with an error percentage below 3%, a minimum iteration that must be run is 10,000 iterations.

After all the data has been prepared, the Monte Carlo Simulation process is simulating for 10,000 iterations. The results of running create an output in the form of 10,000 Gas In Place values, each iteration number has an input variable with non-uniform categories in each reservoir C, D, E and F which depend on the random number that appears. This allows permutations between the minimum, mean and maximum variables in each simulation.

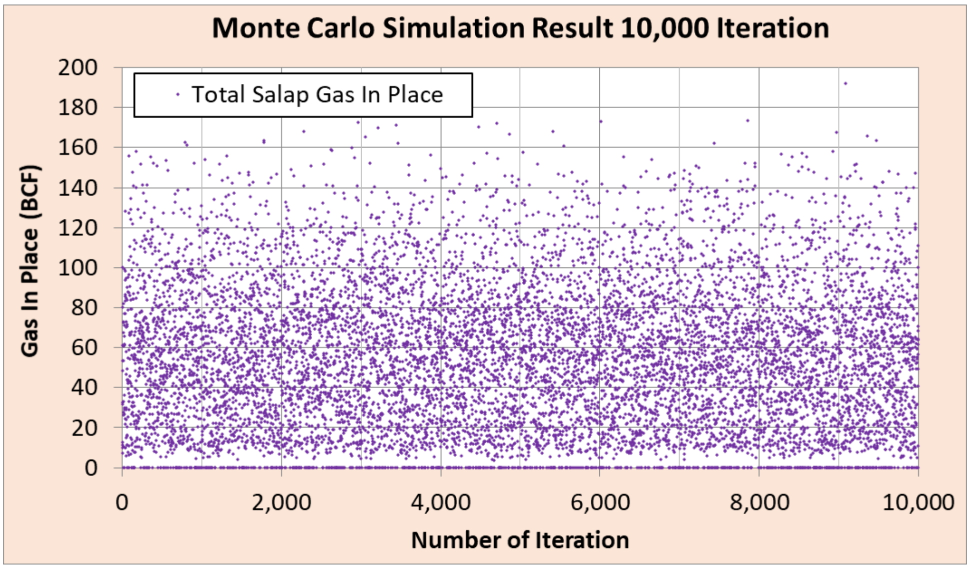

Figure 2. Monte Carlo Simulation Result on Gas In Place Calculation

From 10,000 iterations on Gas in Place calaculation, an analysis is required to categorizes Gas in Place into P90, P50 and P10 Scenario based on the percentile value of the data on the CDF plot. The value of Gas in Place will be used to determine the iteration number where the variable in the iteration number will be used as the input data in the Probabilistic Case simulation, both for the value of Gas In Place and Transmibility/Formation Productivity.

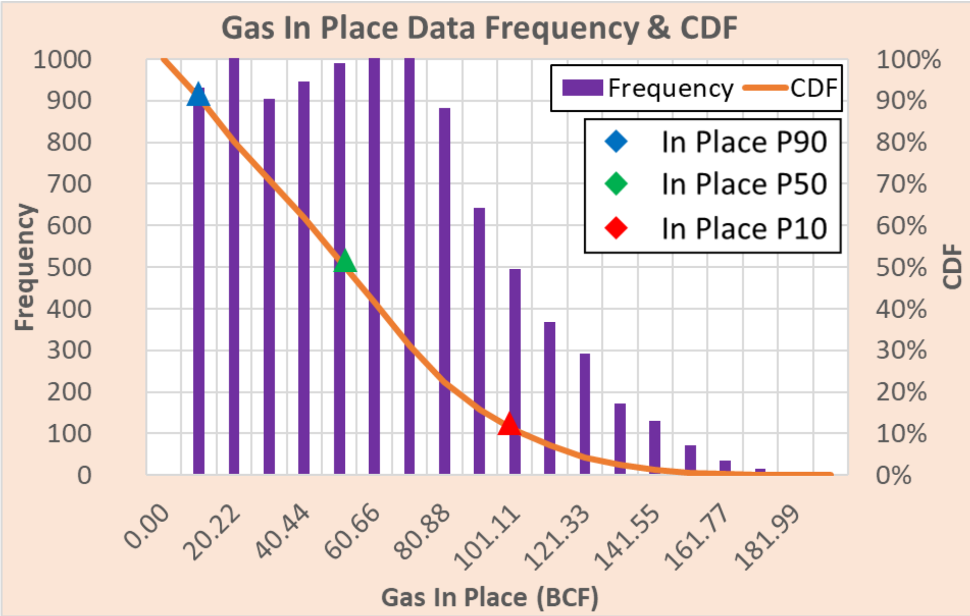

Figure 3. Gas In Place Data Frequency and Cumulative Distribution Function Plot

Table 7. Iteration Selection as Input to to Simulation Probabilistic Case

Scenario	In Place	Iteration
P90	10.95	Iteration 1536
P50	51.43	Iteration 2185
P10	100.69	Iteration 4500

3.3. Reservoir Simulation Using Probabilistic Uncertainty Assessment Data Input (Salap Field Development Study)

The Probabilistic Case Simulation is divided into 3 scenarios, which are P90, P50 and P10 scenarios. All variables are input based on the data on the iteration number that has been categorized previously. In contrast to the Deterministic Case, the input variables in the Probabilistic Case have varied categories, thus allowing permutations between the minimum, mean and maximum variables.

Table 8. Gas In Place Data Input to Simulation Probabilistic Case

Gas In Place - Probabilistik			
Volumetric Record	P90 - 1536	P50 - 2185	P10 - 4500
OGIP C (BCF)	Dry	Dry	22.85
OGIP D (BCF)	10.95	15.26	13.67
OGIP E (BCF)	Dry	Dry	45.37
OGIP F (BCF)	Dry	36.17	18.79
OGIP Total (BCF)	10.95	51.43	100.69

In the Probabilistic Case Scenario P90, all variables inputted in the simulation use the variables in Iteration Number 1536, both the bulk volume, net to gross, porosity and water saturation variables for the calculation of gas in place as well as the net pay and permeability variables for the calculation of transmibility/formation productivity on Zone D. Since the proven reservoir is only Zone D

In the Probabilistic Case Scenario P50, all variables inputted in the simulation use the variables in Iteration Number 2185, both the bulk volume, net to gross, porosity and water saturation variables for the calculation of gas in place as well as the net pay and permeability variables for the calculation of transmibility/formation productivity on Zone D & F. Since the proven reservoir is only Zone D & F.

In the Probabilistic Case Scenario P10, all the variables inputted in the simulation use the variables in Iteration Number 4500, both the bulk Volume, Net to Gross, Porosity and Water saturation variables for the calculation of Gas in Place as well as the Net pay and permeability variables for the calculation of transmibility/formation productivity on Zone C, D E and F respectively.

Table 9. Transmibility Data Input to Simulation Probabilistic Case

Transmibility - Probabilistik			
Trans Record	P90 - 1536	P50 - 2185	P10 - 4500
Net Pay C	-	-	18
Net Pay D	15	6	15
Net Pay E	-	-	40
Net Pay F	-	15	22
k C, md	0.10	0.10	65
k D, md	124	124	124
k E, md	0.10	0.10	5
k F, md	0.10	130	13

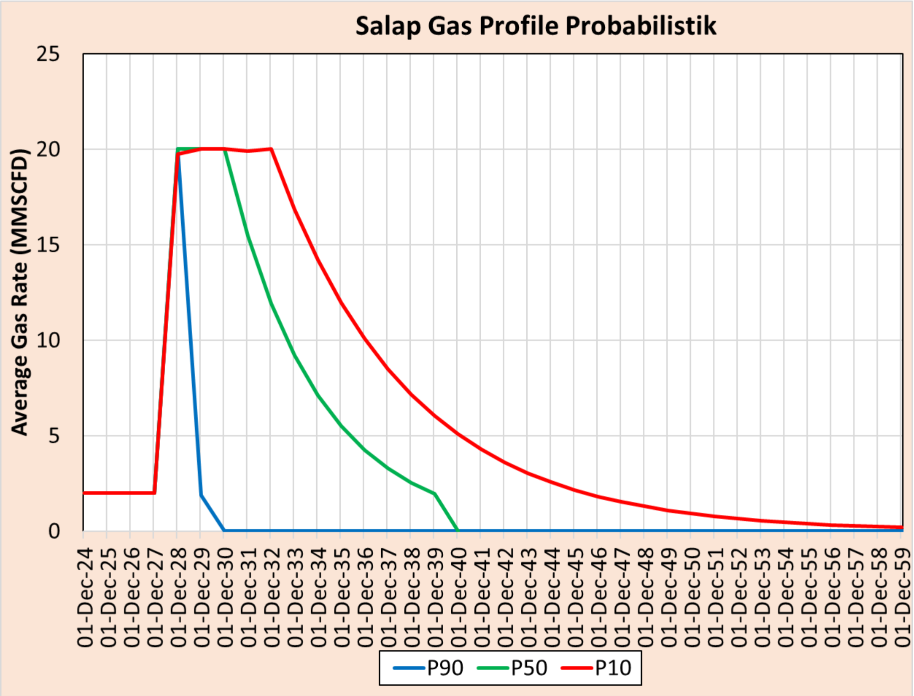

Figure 4. Probabilistic Case Production Profile Forecast

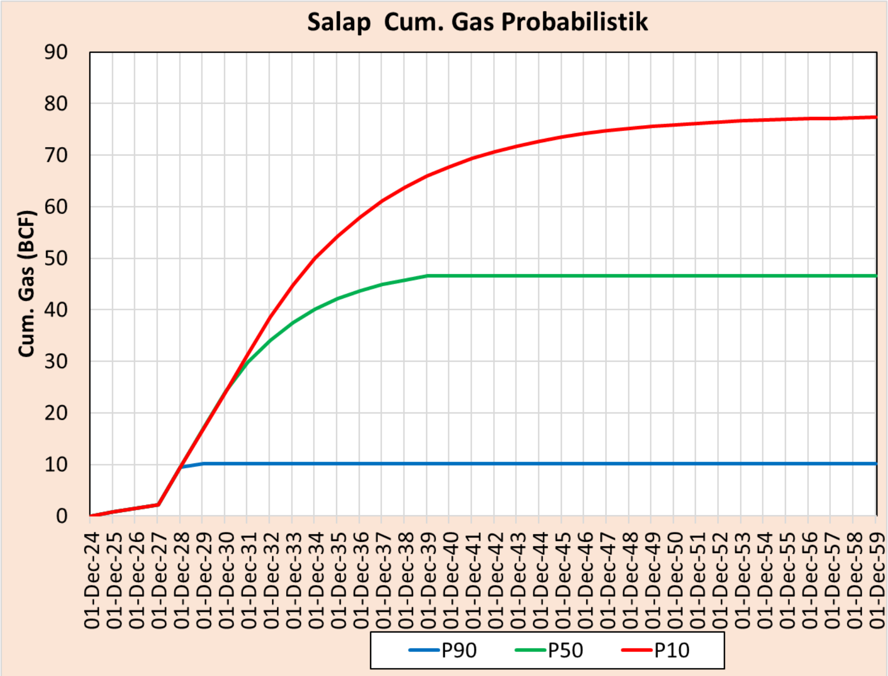

Figure 5. Probabilistic Case Cummulative Profile Forecast

The Probabilistic Case Scenario P90 simulation result shows that the field can produce 20 MMSCFD for 1 year with the required number of development wells as many as 10 producing wells from Reservoir D. Total resources at the end of the simulation are 10.2 BCF (RF 93%) with Field Life producing above 1 MMSCFD (technical limit) for 6 years. Remaining resources in this scenario are included in the marginal category at the end of the simulation.

The Probabilistic Case Scenario P50 simulation shows that the field can produce 20 MMSCFD for 3 years with the required number of development wells as many as 10 producing wells from Reservoir D and F. Total resources at the end of the simulation are 45.6 BCF (RF 80%) with Field Life producing above 1 MMSCFD (technical limit) for 16 years. Remaining resources in this scenario are included in the marginal category at the end of the simulation.

The Probabilistic Case Scenario P10 Simulation shows that the field can produce 20 MMSCFD for 5 years with the required number of development wells as many as 10 producing wells from Reservoir C, D, E and F. Total resources at the end of the simulation are 77.3 BCF (RF 77%) with Field Life production above 1 MMSCFD (technical limit) for 26 years. Remaining resources in this scenario are included in the marginal category at the end of the simulation.

Table 10. Probabilistic Case Summary

CASE PROBABILISTIK							
No.	Case	In Place (BCF)	Resources (BCF)	RF	Dev.Well	Plateu (Years)	Field LIfe (Years)
1	P90	10.95	10.20	93%	10	1	6
2	P50	51.43	46.50	90%	10	3	16
3	P10	100.69	77.30	77%	10	5	26

3.4. Reservoir Simulation Using Deterministic Uncertainty Assessment Data Input

The Deterministic Case Simulation is divided into 3 scenarios, which are Low, Mid and High scenarios. All variables are inputted with data that have uniform categories, so that there are no permutations between the minimum, mean and maximum variables in the Deterministic Case simulation.

Table 11. Deterministic Uncertainty Assessment of in Place Calculation

Zone	Bulk Volume (10^6 Acre.ft)			Net To Gross (Frac)			Porosity (Frac)			Water Saturation (Frac)			Bgi
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	(RCF/SCF
C	278,084	537,700	794,464	0.06	0.12	0.18	0.23	0.25	0.27	0.50	0.48	0.46	0.0235
D	344,206	570,952	701,850	0.06	0.09	0.11	0.22	0.24	0.26	0.53	0.49	0.45	0.0174
E	291,206	413,930	511,404	0.03	0.23	0.43	0.24	0.27	0.29	0.53	0.48	0.43	0.0158
F	531,788	781,278	1,020,490	0.06	0.10	0.15	0.25	0.28	0.30	0.51	0.44	0.36	0.0122

Table 12. Deterministic Uncertainty Assessment of Transmibility Calculation

Zone	Net Pay (ft)			Permeability (mD)		
	Min	Mean	Max	Min	Mean	Max
C	10.0	17.5	25.0	65	98	130
D	6.0	10.5	15.0	53	124	195
E	5.0	22.5	40.0	5	78	150
F	8.0	15.0	22.0	13	72	130

Table 13. Gas In Place Data Input to Simulation Deterministic Case

Volumetric	Low	Mid	High
OGIP C (BCF)	3.29	15.26	38.63
OGIP D (BCF)	5.34	15.23	28.71
OGIP E (BCF)	2.45	35.67	99.41
OGIP F (BCF)	12.79	44.93	106.55
OGIP Total (BCF)	23.88	111.09	273.31

In the Deterministic Case Low Scenario, all variables entered in the simulation use the minimum value of the centralized data scale analysis, both the bulk Volume, Net to Gross, Porosity and Water saturation variables for the calculation of Gas in Place as well as the Net pay and Permeability variables for the calculation of transmibility/formation productivity on each reservoir Zone C, D, E and F.

In the Deterministic Case Mid Scenario, all variables inputted in the simulation use the mean value of the centralized data scale analysis, both the bulk Volume, Net to Gross, Porosity and Water saturation variables for the calculation of Gas in Place as well as the Net pay and Permeability variables for the calculation of transmibility/formation productivity on each reservoir Zone C, D, E and F.

In the Deterministic Case High Scenario, all the variables inputted in the simulation use the maximum value of the centralized data scale analysis, both the bulk Volume, Net to Gross, Porosity and Water saturation variables for the calculation of Gas in Place as well as the Net pay and Permeability variables for the calculation of transmibility/formation productivity on each reservoir Zone C, D, E and F.

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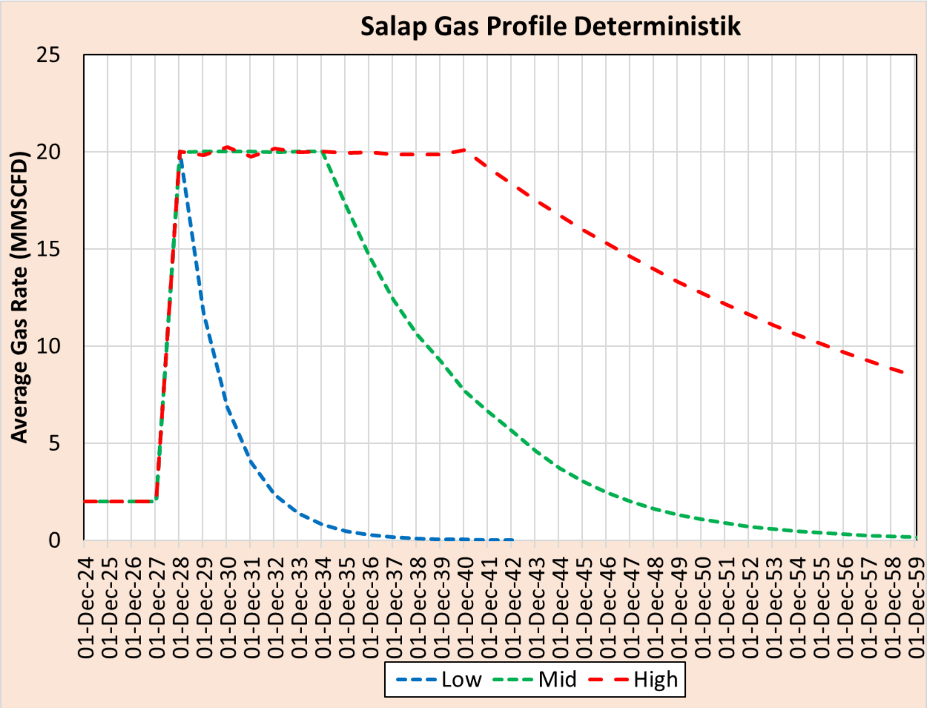

Figure 6. Deterministic Case Production Profile Forecast

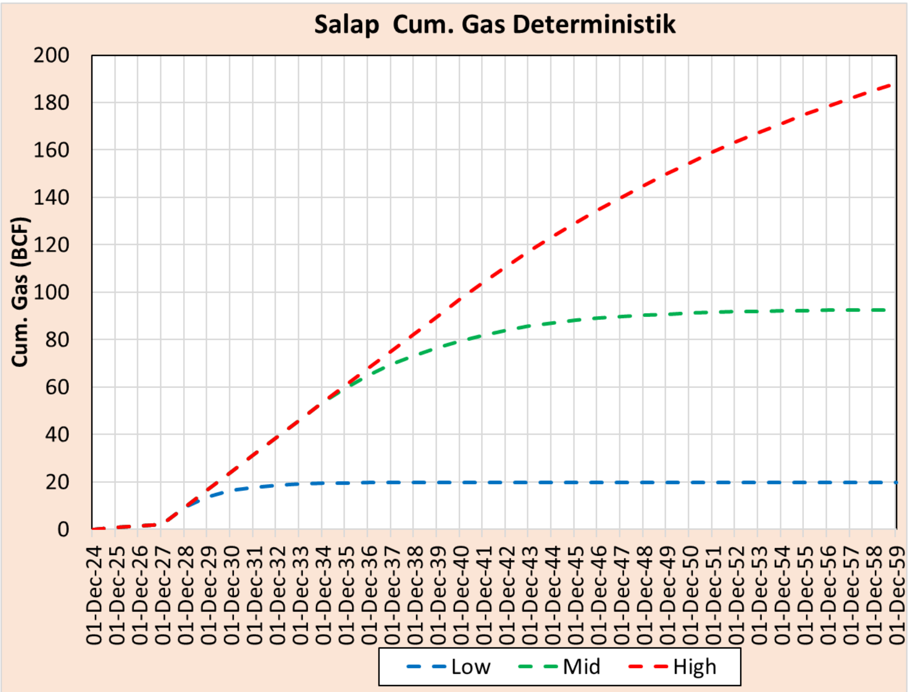

Figure 7. Deterministic Case Cumulative Profile Forecast

The Deterministic Case Low Scenario Simulation result shows that the field can produce 20 MMSCFD for 1 year with the required number of development wells as many as 10 producing wells from Reservoir C, D, E, and F. Total resources at the end of the simulation is 19.8 BCF (RF 83 %) with Field Life producing above 1 MMSCFD (technical limit) for 10 years. Remaining resources in this scenario are in the marginal category at the end of the simulation.

The Deterministic Case Mid Scenario Simulation result shows that the field can produce 20 MMSCFD for 7 years with the required number of development wells as many as 3 producing wells from Reservoir C, D, E, and F. Total resources at the end of the simulation is 92.6 BCF (RF 83 %) with Field Life producing above 1 MMSCFD (technical limit) for 27 years. Remaining resources in this scenario are in the marginal category at the end of the simulation contract.

The Deterministic Case High Scenario Simulation result shows that the field can produce 20 MMSCFD for 13 years with the required number of development wells as many as 2 producing wells from Reservoir C, D, E, and F. Total resources at the end of the simulation are 188 BCF (RF 69 %) with Field Life producing above 1 MMSCFD (technical limit) for 36 years. The RF value shows that Remaining Resources is still high at the end of the simulation.

Table 14. Deterministic Case Summary

CASE DETERMINISTIK							
No.	Case	In Place (BCF)	Resources (BCF)	RF	Dev.Well	Plateu (Years)	Field Life (Years)
1	Low	23.88	19.80	83%	10	1	10
2	Mid	111.09	92.61	83%	3	7	27
3	High	273.31	188.04	69%	2	13	36

3.5. Probabilistic Vs Deterministic Uncertainty Assessment Result Comparison

1. **Discovery Status Comparison**
   In the Discovery Status comparison, Case Deterministic assumes that all Reservoir C, D, E, and F at the Salap Field Are Proven in both Low, Mid and High Scenarios. In the other hand, in the Probabilistic Case result shows that not all reservoirs are Proven. In Scenario P90 only Zone D that Proven. In Scenario P50 only Zone D and F that Proven and for P10 all Zone C, D, E and F Are Proven.

2. **Comparison of Total Gas in Place**
   In the estimated of Total Gas in Place Total Reservoir C, D, E and F, Case Deterministic shows the estimated Total Gas in Place range are 23 – 273 BCF. In the other hand, in the Probabilistic Case, the estimated range for Total Gas in Place are 10 – 100 BCF.

3. **Comparison of Total Gas Resources**
   In the estimated of Total Gas Resources Reservoir C, D, E and F, Case Deterministic shows the estimated range of Gas Resources are 20 – 188 BCF (RF 69 - 83 %), in the other hand the Probbilistic Case shows the estimated range of Gas Resources are 10 - 70 BCF (RF 77 - 93%).

4. **Comparison of Development Wells**
   In the required development wells to achieve the sales target of 20 MMSCFD, Case Deterministic, shows that the field requires 10 development wells in the Low Scenario, 3 development wells in the Mid Scenario and 2 development wells in the High Scenario. In the other hand the Probabilistic Case shows that the field requires 10 development wells in all Scenarios P90, P50 and P10.

5. **Comparison of Plateau Production Period**
   In the 20 MMSCFD plateau production period comparison, Case Deterministic shows that the plateau production lasts for 1 year for the Low Scenario, 7 years for the Mid Scenario and 13 years for the High Scenario. In the other hand, in the Probabilistic Case, the plateau production lasts for 1 year for the P90 scenario, 3 years for the P50 scenario and 5 years for the P10 scenario.

6. **Comparison of Field Life**
   In comparison of field life on produces above 1 MMSCFD (technical limit), the Deterministic Case shows that the field life lasts for 10 years for the Low Scenario, 27 years for the Mid Scenario and 36 years for the High Scenario. In the other hand, the Probabilistic Case shows that the field life lasts for 6 years for the P90 scenario, 16 years for the P50 scenario and 26 years for the P10 scenario.

Table 15. Uncertainty Assessment Result Comparison Between Probabilistic with Deterimistic

Parameter	CASE PROBABILISTIK			CASE DETERMINISTIK		
	P90	P50	P10	Low	Mid	High
Number of Proven Reservoir	1	2	4	4	4	4
In Place (BCF)	10.95	51.43	100.69	23.88	111.09	273.31
Resources (BCF)	10.20	46.50	77.30	19.80	92.61	188.04
RF (%)	93%	90%	77%	83%	83%	69%
Dev.Well	10	10	10	10	3	2
Plateu (Years)	1	3	5	1	7	13
Field Life (Years)	6	16	26	10	27	36

IV. CONCLUSION

1. Uncertainty assessment for Salap Field Developmen Study was conducted using Probability Method Monte Carlo Simulation that allows permutations of variable categories in each simulation. There is a subsurface reservoir dry risk factor which is also included in the simulation. With influence of risk factor, the Salap Field is estimated to have the potential Gas in Place 11 – 100 BCF, Gas Resources 10 – 77 BCF, the number of development wells required are 10 wells, plateau production period are 1-5 years and field life above technical limit are 6- 26 years.
2. Uncertainty assessment also conducted using Deterministic method as comparison. The uncertainty assessment Deterministic Case of the Salap Field is discrete and there are no permutations of variable categories in each simulation. No risk factors for subsurface reservoir dry were included in the simulation. Without these risk factors, the Salap Field is estimated to have the potential Gas in Place 23 – 273 BCF, Gas Resources 19 – 188 BCF, the number of development wells required are 2 - 10 wells, plateau production period are 1-13 years and field life above technical limit are 10-36 years.
3. The Deterministic Method sometimes gives overly optimistic study results than the Probabilistic Method in all aspects. This is because the assessment of uncertainty data is limited and there is no risk of subsurface reservoir dry that included in the study.
4. Field Development Studies should be carried out probabilistically, because the Deterministic Method can sometimes provide overly optimistic estimation.
5. Overly optimistic estimates often lead to inappropriate decision-making in field development planning and could be mislead the development strategy.
6. Beside due to the output of the Deterministic Method which tends to be overly optimistic, the Probabilistic Method is recommended because it can perform a broader assessment of data uncertainty and subsurface risk than the Deterministic Method. So that all aspects of uncertainty and risk factors can be accommodated in the simulation.

REFERENCES

Algdamsi, Hossein; Amtereg, Ahmed; Agnia, Ammar; Alusta, Jamal; Alkouh, Ahmed. (2019). ‘Evaluation of Probability Point Estimate Methods for Uncertainty Analysis of Hydrocarbon in Place as an Alternative Techniques to Monte Carlo Simulation’. Abu Dhabi International Petroleum Exhibition & Conference 2019.

Alijoyo, Antonius; Wijaya, Bobby; Jacob, Intan. (2019). ‘*Standar Simulasi Monte Carlo*'. Center for Risk Management & Sustainability.

Beggs, H. Dale. (1984). ‘Gas Production Operation’. Oil and Gas Consultants International Inc.

Chaudhry, Amanat U. (2004). ‘Oil Well Testing Handbook”. Gulf Publishing Elsevier.

Cebastiant, A.; Osbon, R.A. (2011). ‘Experimental Design for Resources Estimation: Comparison with Probabilistic Method’. SPE Reservoir Characterization and Simulation Conference 2011.

Fajar, Adnan. (2008). ‘*Aplikasi Simulasi Monte Carlo Dalam Estimasi Biaya Proyek*'. SMARTEK Journal November 2008 Edition.

Hariwibowo, Andrie. (2001). ‘Integrated Reservoir Management*: Sebuah Paradigma Baru Pengusahaan Hulu Eksplorasi – Produksi Minyak dan Gas Bumi di Indonesia*’. Simposium Nasional IATMI 2001.

Itotoi, Ibiada Harrison; Ojeke, Akpoebi; Nnamdi, Dike; Umurhohwo, Jonathan; Benjamin, Osaigbovo; AkaChidike, Kanu. (2010). ‘Managing Reservoir Uncertainty in Gas Field Development Using Experimental Design’. SPE International Conference and Exibition 2010.

Masoudi, Pedram; A. Zahedi; Ali, Moradzadeh; Farshid, Alirezaei et Mohammad, Zamanzadeh Seyed. (2011). 'Estimation of in place hydrocarbon volume in multilayered reservoirs using deterministic and probabilistic approaches'. Energy Exploration & Exploitation Journal 2011 Edition.

Mohammed, Auwalu Inuwa; Abdurahman, Hassan; Ibrahim, Sulaiman Dodo; Adamu, Bello Mohammed. (2018). 'Uncertainty Modelling in Multi-Layered Reserve Estimation Using Monte Carlo Simulation'. SPE Nigeria Annual International Conference and Exhibition 2018.

Murtha, James A. (2008). 'Decision Involving Uncertainty'. Palisade Corporation Manual 2008 Edition.

Otis, Robert M; Schneidermann, Nahum. (1997). 'A Process for Evaluating Exploration Prospects'. American Association of Petroleum Geologist Journal 1997 Edition.

Petroleum Expert Team. (2015). 'PETEX Integrated Production Modelling Software'. Product Information 2015 Edition.

Popova, Oksana. (2018). 'Analogy in the World of Geological Uncertainties, or How Reservoir Analogs May Refine Your Probabilistic Geomodel'. SPE Annual Caspian Technical Conference and Exhibition Kazakhstan 2018.

Rukmana, Dadang; Kristanto, Dedy; Aji, V. Dedi Cahyoko. (2012). '*Teknik Reservoir: Teori dan Aplikasi'*, Penerbit-Percetakan Pohon Cahaya 2012 Edition.

Siddiqui, Mohammed; Al-Yateem, Karam; Al-Thawadi, Abdulla. (2007). 'A New Tool to Evaluate the Feasibility of Petroleum Exploration Projects Using a Combination of Deterministic and Probabilistic Methods'. SPE Middle East Oil & Gas Show and Conference 2007.

Society of Petroleum Engineers Team. (2018). 'Petroleum Resources Management System: Revised 2018', Petroleum Resources Classification Guidance 2018 Edition.

Supriyadi, Ricky Agus. (2013). 'On the Use of Risk and Uncertainty Analysis in Conceptual Stage of Petroleum Project' (Master Thesis). Norway: University of Stavenger.