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OIL RESERVES ANALYSIS IN BATANG FIELD WITH MATERIAL BALANCE METHOD FOR PRESSURE MAINTENANCE

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ABSTRACT

Material Balance method is a concept of material equilibrium with measurement of response from reservoir (pressure) due to production, injection, and influx activities so that it can calculate the appropriate Original Oil in Place. By creating a material balance model, it can be done the development plan of Batang Field with the aim of obtaining cumulative optimum oil production. Batang Field is still feasible to be developed using pressure maintenance scenarios seen from OOIP of 144.3 MMSTB, Recovery Factor of 14.9% and Current Pressure of 70-80 psi. Pressure Maintenance is a water injection with the aim of replacing the fluid that has been produced so that it is expected to keep the reservoir pressure from falling. Ideally this method requires Voidage Replacement Ratio (VRR) = 1 as the target injection. Economic calculation using Cost Recovery from this scenario shows a positive NVP ($ 2,865,000 USD). Therefore, development projects using Pressure Maintenance can be applied in the field. With this paper, it is hoped that it can increase reserves and lifespan of the Batang oil field.

***Keywords**: Material Balance; Reserve, Cost Recovery; Pressure Maintenace*

INTRODUCTION

Batang Field is a faulted anticline structure, with a major fault directed NW-SE in the form of an ascending fault located in the western part. The structure framework in this area is divided into several fault blocks and the main block is located in the middle-west. In general, there are three main fault directions (see **Fig. 1**), with productive formations in Duri and Bekasap Formations (see **Fig. 2**).

Batang Field has Original Oil in Place (OOIP) of 144.3 MMSTB with Recovery Factor around 14.9% in December 2020. This field still has the potential to be developed that can be calculated using the Material Balance method.Batang Field is an oil field with characteristics of heavy oil with a viscosity of up to 250 cp and an oil gravity of 22 API which has produced from 2 productive formations since 1976. The initial reservoir pressure varies according to the depth of the reservoir, from 160-250 psi with an average temperature of 800F. The Batang field reservoir is sandstone of good quality with average porosity and permeability of 31.75% & 7889 mD for the Duri formation and 27.6% & 4667 mD for the Bekasap formation, respectively.

The two formations that will be analyzed in this thesis have complete production data from January 1976 to December 2020. The cumulative production of the two layers is 21.56 MMSTB with a recovery factor of 14.94%. The final pressure on the Duri formation is 71 psi, and for the former formation it is 81.8 psi. With a small recovery factory and low pressure, the Batang field is a suitable candidate for pressure maintenance.

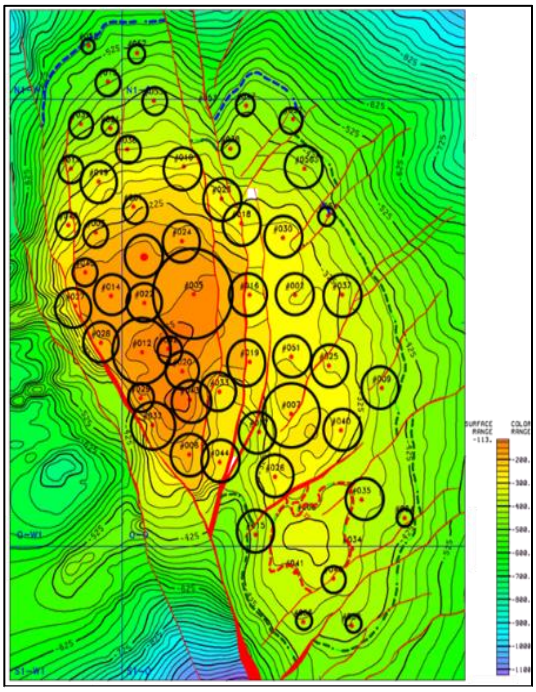


Figure 1 – Depth structure and drainage radius map of Batang Field

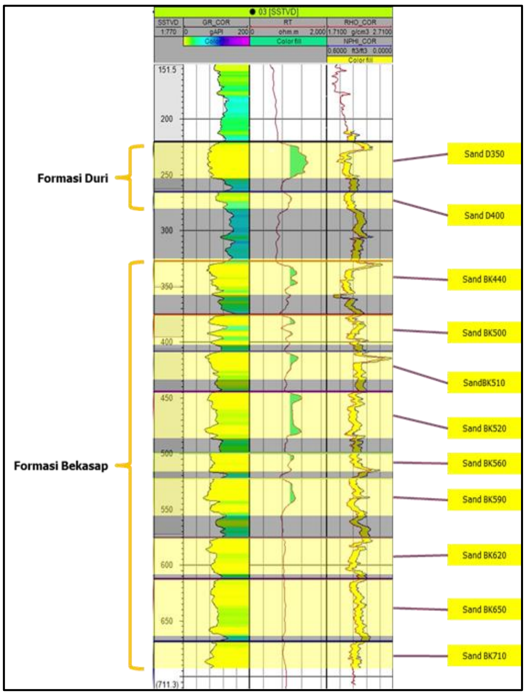


Figure 2 - Example of Log Type in Batang Field

METHODS

A. MATERIAL BALANCE METHOD

Material Balance Equations

Material balance equation is a volumetric material equilibrium equation that states that if the reservoir volume is constant, then the number of changes in fluid production, oil, water and gas volume is equal to zero.

$$N=\frac{N_p\left[B_t+(R_p-R_s)B_g\right]-(W_e-W_pB_w)}{(B_t-B_{ti})+mB_{ti}\left[\frac{B_g}{B_{gi}}-1\right]+B_{ti}(1+m)\left[\frac{S_{wi}C_w+C_f}{1-S_{wc}}\right]\Delta p}$$

In the general equation of material balance, there are variables which are a function of pressure, thus allowing the equation to be used in predicting reservoir behavior. These variables are: water and rock compressibility, formation volume factor, gas solubility, and water influx. This is because the more fluid that is produced, the greater the reservoir pressure drop. By entering these variables in accordance with the pressure drop into the equation, a material balance model will be obtained which is sufficient to represent the state of the reservoir below the surface. In applying the material balance equation, the assumptions used are as follows:

- Constant temperature value
- Equilibrium in pressure throughout the reservoir
- Reservoir volume constant

Havlena Odeh Straight-Line Method

This method is based on using the common equation of material balance as the basis for determining the amount in place by plotting linearly.

The general equation for material balance is then simplified based on the elements working in the reservoir by Havlena Odeh so that it can be a straight line equation.

$$F = N\left(E_o + m\,E_g + E_{f,w}\right) + W_e$$

Notes:

N : Original oil in-place, STB
N_p : Oil production cumulative, STB
G_p : Gas production cumulative, SCF
W_p : Water production cumulative, STB
R_p : G_p/N_p
W_e : Water influx
m : Gas cap volume
B_t : Formation volume factor total, bbl/STB
R_s : Disolved gas, SCF/STB
C_f, C_w : Formation compressibility, water compressibility, psi^{-1}
S_{wc} : Water connate saturation, fraction
F : Total hydrocarbon fluid withdrawal, bbl
E_o : Net oil expansion, bbl/SCF
E_g : Net gas expansion, bbl/SCF
E_{fw} : Net formation & water expansion, bbl/SCF

Interpretation using the straight-line method by applying these equations is very useful because it can be used simply to calculate Original Oil Inplace (OOIP). The OOIP results from these calculations can then be used to validate volumetric OOIP calculations through geological models.

Material Balance with MBAL Method

The Material Balance model in this study was created using IPM-MBAL Software from Petroleum Expert (Petex). MBAL is a software developed by Petroleum Experts Limited since the early 1990s. MBAL software has become one of the industry standards for accurate Material Balance modeling. As the name implies, this software uses the concepts of classical Material Balance in the literature which is integrated into one software including the straight-line Havlena-Odeh method.

MBAL Preparation and Input

Material Balance model in this paper is made using IPM-Mbal Software from Petroleum Expert (Petex). In the initial step of making the Material Balance model, it is necessary to determine the simulation mode to be used, namely Black Oil. This Black Oil simulation mode is used for reservoir types that do not experience changes in fluid composition with a decrease in pressure due to production. The Black Oil simulation only considers changes in the physical properties of the fluid as a parameter used in calculating the material balance. This mode is suitable for reservoirs with fluid types: heavy oil, medium oil, and dry gas.

The required reservoir and production data inputs can be seen in **Fig. 3**-**Fig. 5**. The data that needs to be prepared in the MBAL software is almost the same as the data used in manual calculations of Material Balance, including:

- Initial Condition, including: initial reservoir pressure, temperature, water saturation and porosity
- PVT data, reservoir fluid data containing: gas solubility (Rs), formation volume factor (Bo) and specific gravity (SG)
- Production data is production vs time data in the form of: oil rate, gas rate, water rate, injection rate and reservoir pressure.

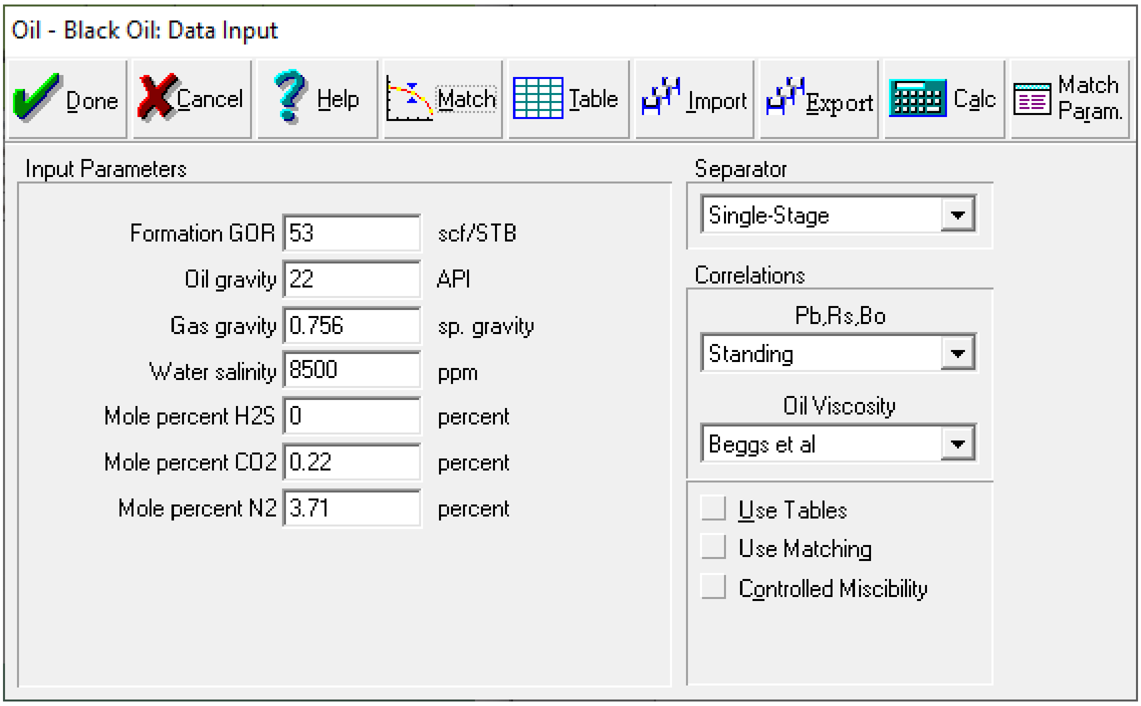


Figure 3 - Fluid Data Input in Mbal software

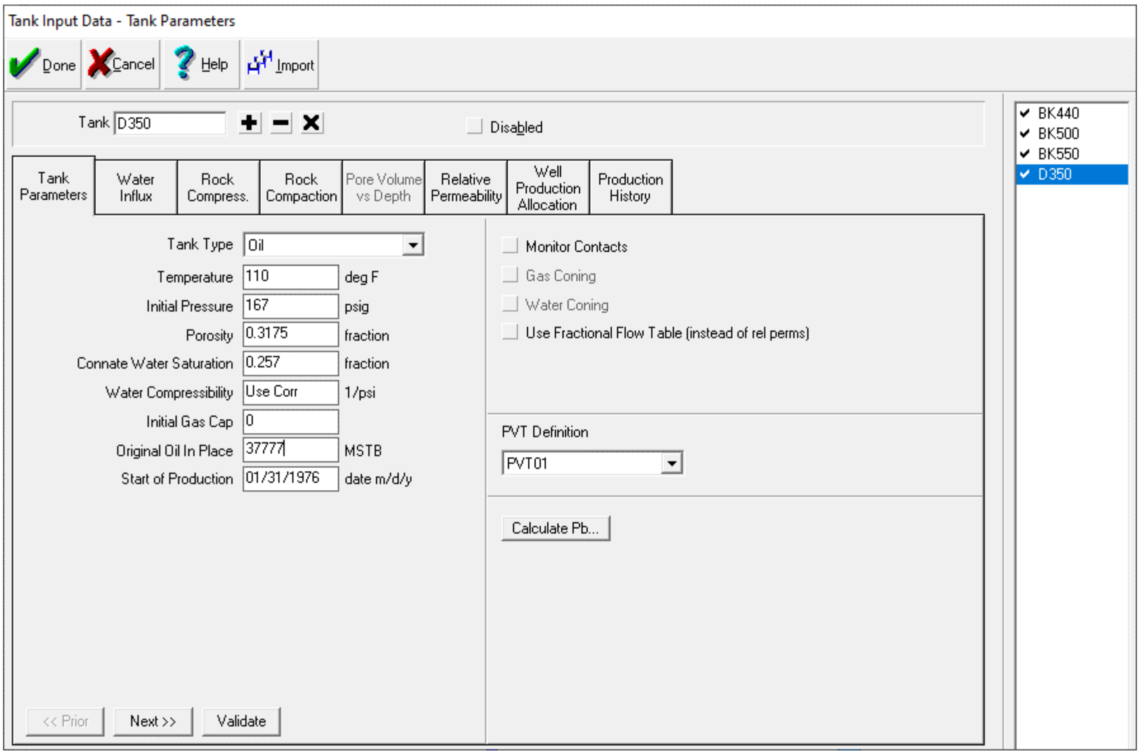
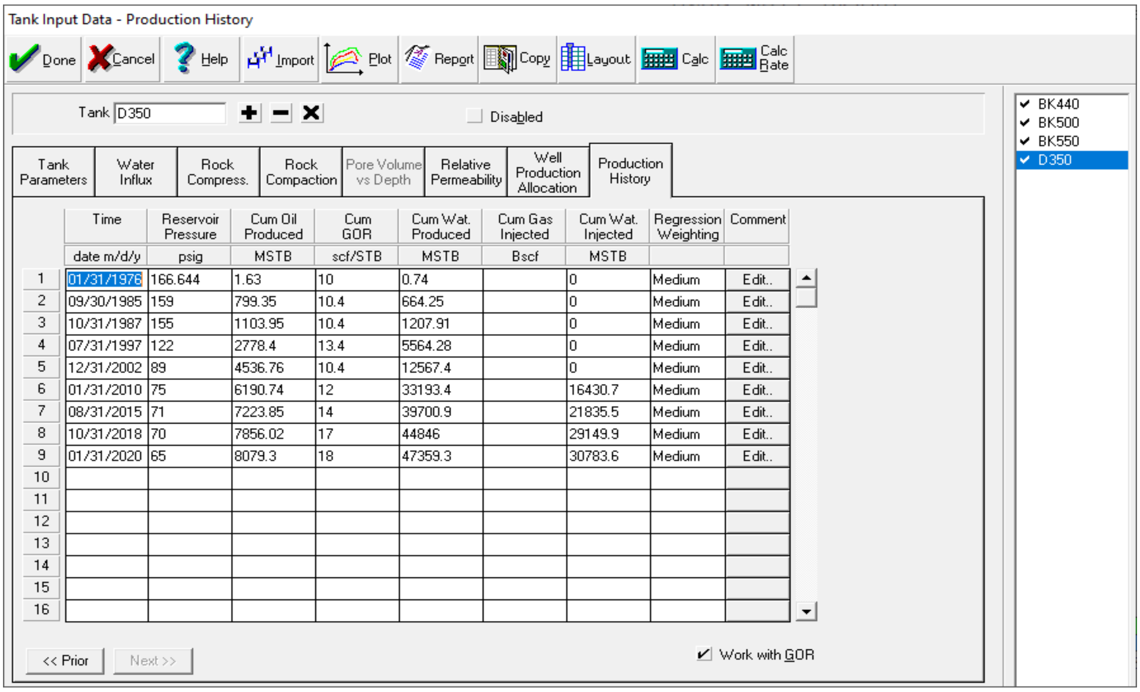


Figure 4 - Initial Condition Data Input in Mbal software



	Time	Reservoir Pressure	Cum Oil Produced	Cum GOR	Cum Wat. Produced	Cum Gas Injected	Cum Wat. Injected	Regression Weighting	Comment
	date m/d/y	psig	MSTB	scf/STB	MSTB	Bscf	MSTB		
1	01/31/1976	166.644	1.63	10	0.74		0	Medium	Edit..
2	09/30/1985	159	799.35	10.4	664.25		0	Medium	Edit..
3	10/31/1987	155	1103.95	10.4	1207.91		0	Medium	Edit..
4	07/31/1997	122	2778.4	13.4	5564.28		0	Medium	Edit..
5	12/31/2002	89	4536.76	10.4	12567.4		0	Medium	Edit..
6	01/31/2010	75	6190.74	12	33193.4		16430.7	Medium	Edit..
7	08/31/2015	71	7223.85	14	39700.9		21835.5	Medium	Edit..
8	10/31/2018	70	7856.02	17	44846		29149.9	Medium	Edit..
9	01/31/2020	65	8079.3	18	47359.3		30783.6	Medium	Edit..
10									
11									
12									
13									
14									
15									
16									

Figure 5 - Production Data Input in Mbal software

Then the calculation of in-place using straight line method (Havlena-Odeh) which can be seen in **Fig. 6**. In-place calculation result from material balance model for Duri Formation is 50.14 MMSTB and Bekasap Formation is 90.70 MMSTB

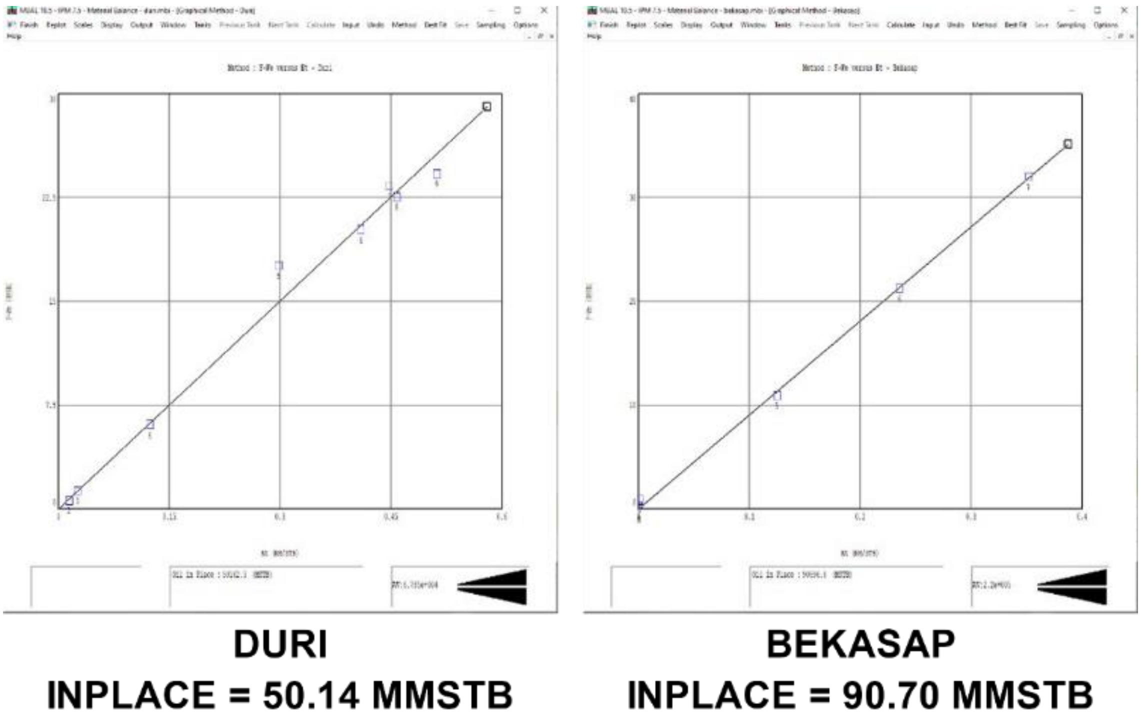


Figure 6 - Material Balance Inplace Calculation

B. FORECASTING

Basecase

The next stage is to forecast from the material balance model. Forecast basecase is basically a forecast with the assumption that the field is only produced, without any other developments such as drilling new wells or conversion of injection wells. The limit used is a minimum reservoir pressure of 40 psi as an assumption of abandon pressure. The forecast results using material balance method for Duri Formation of 1.17 MMSTB and Bekasap Formation of 2.92 MMSTB **(**see **Fig. 7)**.

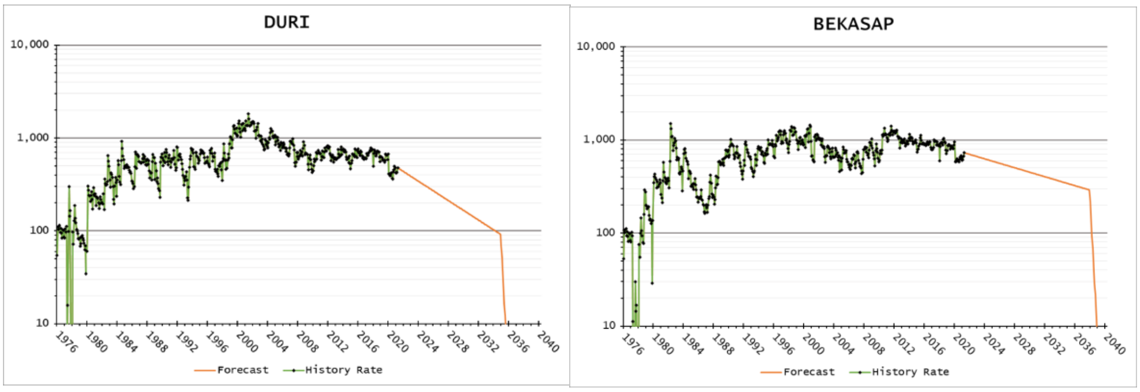


Figure 7 - Forecast Results from Material Balance method

The results were compared with decline curve analysis method. decline index (D_i) is obtained by selecting decline trend of production when the number of wells is constant (see **Fig. 8**).

From the analysis of the downward trend for the same number of wells, it was found that the Decline Index (Di) was 8.8% for the Duri formation and 5.95% for the Bekasap formation. On the basis of the Di, then a production withdrawal was carried out with a production rate in December 2020 of 479 BOPD and 643 BOPD for the Duri and Bekasap formations, respectively. The Decline Curve method produces forecasts for the Duri Formation of 1.44 MMSTB and the Bekasap Formation of 3.14 MMSTB. This shows that the forecast results using the material balance method are not too far from the forecast results using the decline curve method. (See **Table 1**)

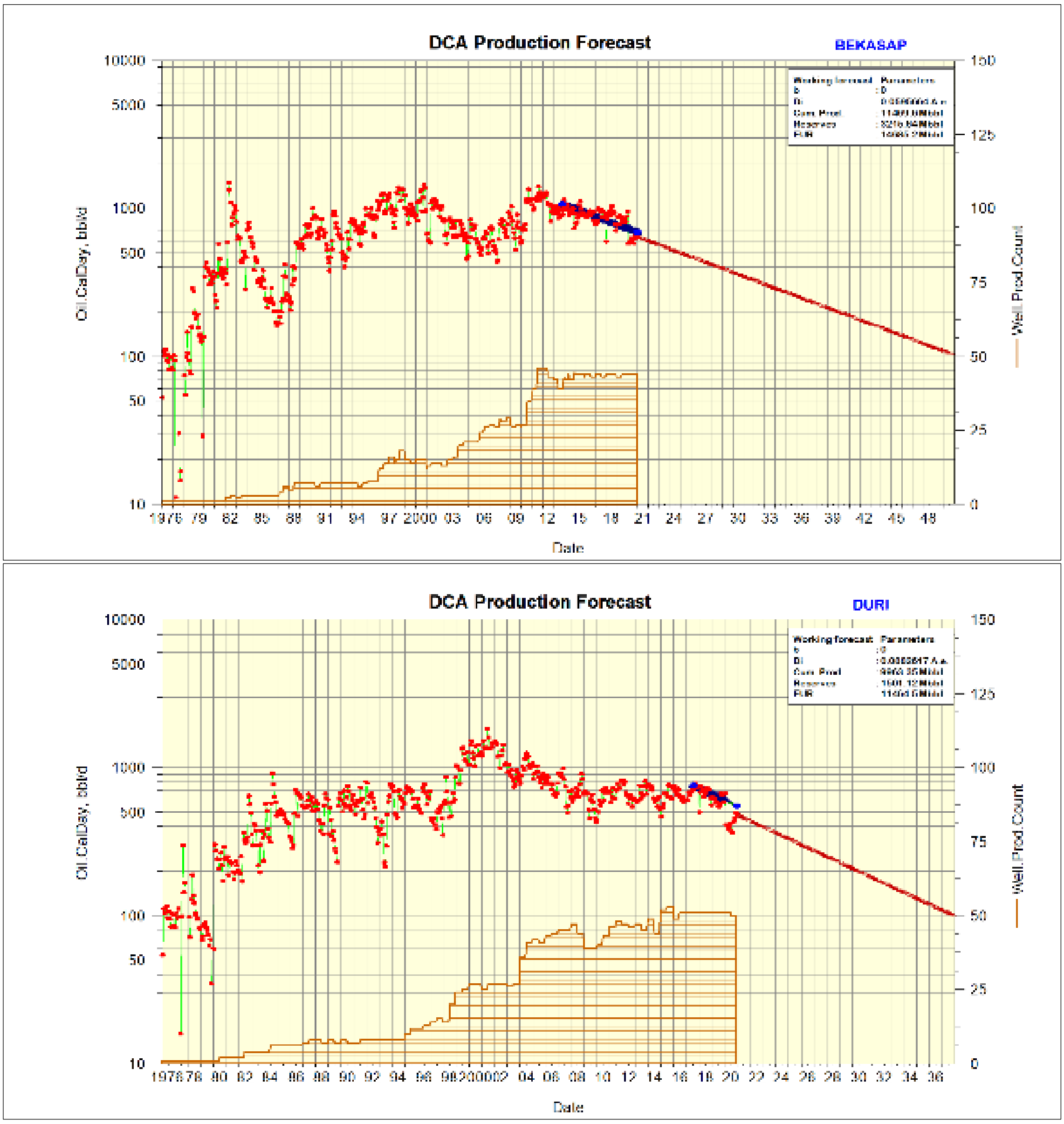


Figure 8- Reserve Analysis Using Decline Curve Analysis

TABLE 1

Material Balance Vs Decline Curve Analysis Comparison

Formasi	Kumulatif Produksi MMSTB	EUR Basecase			Cadangan Basecase	
		Mbal MMSTB	DCA MMSTB	Selisih	Mbal MMSTB	DCA MMSTB
Duri	10.02	11.19	11.46	-2.5	1.17	1.44
Bekasap	11.55	14.47	14.69	-1.5	2.92	3.14

Pressure Maintenance Scenario

The principle of pressure maintenance is to do an injection in the reservoir using water. This injection is generally carried out on dead wells or wells with low oil production. This is done so that the space left by the produced fluid can be replaced directly by injection water, thereby maintaining a stable pressure in the reservoir and extending the life of the field. Pressure maintenance is chosen as a development plan because of several factors, namely:

- Reservoir pressure in the Batang Field is low,
- Distance of each well that is already close does not allow for drilling infill wells
- Remaining reserves are still quite large.

Voidage Replacement Ratio (VRR)

VRR is a comparison between the volume of water injected with the cumulative fluid that has come out. VRR = 1 is used as a target injection because the fluid that has been produced has been replaced with injected water so that the pressure can be kept from falling.

$$\text{VRR}=\frac{\text{Injected Volume}}{\text{Produced Volume}}=\frac{\text{Injected Volume}}{\text{Oil Cum.+Water Cum.}}$$

Injection Well Allocation

By calculating the target of VRR = 1, then the length of time required during the period of filling-up reservoir allocation of injection wells, as well as the injection rate of each well can be determined.

$$q_{inj_{Duri}}=\frac{\text{Injected Volume}}{\text{Years} \times 365}\text{Bbl/d}$$

$$q_{inj_{Duri}}=\frac{66{,}325\ \text{MBbl}\times 1000}{5\times 365}=36{,}342\ \text{Bbl/d}$$

$$\text{Well Allocation}=\frac{36{,}342\ \text{Bbl/d}}{2{,}000\ \text{Bbl/d}}\approx \mathbf{18\ Well}$$

$$q_{inj_{Bekasap}}=\frac{\text{Injected Volume}}{\text{Years} \times 365}\text{Bbl/d}$$

$$q_{inj_{Bekasap}}=\frac{55{,}049\ \text{MBbl}\times 1000}{5\times 365}=30{,}164\ \text{Bbl/d}$$

$$\text{Well Alocation}=\frac{30{,}164\ \text{Bbl/d}}{2{,}000\ \text{Bbl/d}}\approx \mathbf{15\ Well}$$

Batang Field Forecast results with injection scenario for pressure maintenance showed an increase in oil recovery in Duri Formation by 404.7 MSTB and Bekasap Formation by 1025.8 MSTB (see **Fig. 9 & Table 2**).

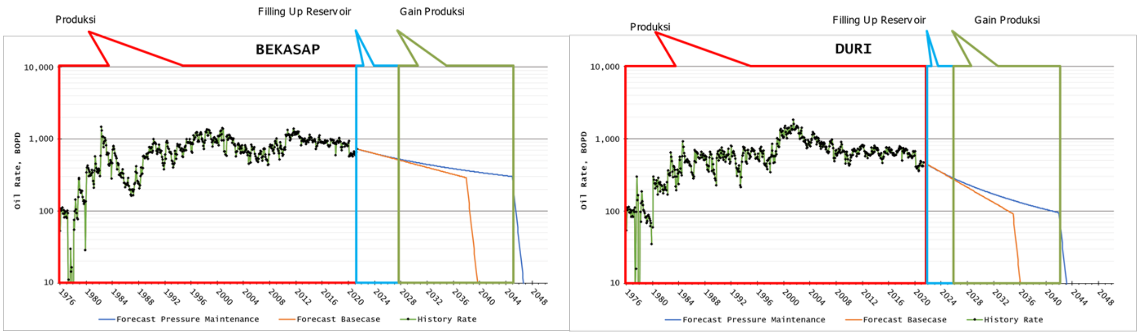


Figure 9 - Forecast Pressure Maintenance

TABLE 2
Tabulation of Forecast using Pressure Maintenance

	Duri						Bekasap						Total Gain	
	Basecase		Injeksi		Gain		Basecase		Injeksi		Gain			
	Rate BOPD	Kumulatif MSTB	Rate BOPD	Kumulatif MSTB	Rate BOPD	Kumulatif MSTB	Rate BOPD	Kumulatif MSTB	Rate BOPD	Kumulatif MSTB	Rate BOPD	Kumulatif MSTB	Rate BOPD	Kumulatif MSTB
2021	422	154	422	154	0	0	616	225	616	225	0	0	0	0
2022	451	318	451	318	0	0	702	481	702	481	0	0	0	0
2023	408	467	408	467	0	0	679	729	679	729	0	0	0	0
2024	362	600	362	600	0	0	642	963	642	963	0	0	0	0
2025	322	717	322	717	0	0	609	1,186	609	1,186	0	0	0	0
2026	284	821	292	824	8	3	575	1,396	577	1,396	2	1	10	4
2027	252	913	266	921	14	8	544	1,594	554	1,598	9	4	24	12
2028	223	994	243	1,010	20	15	515	1,782	529	1,792	15	9	34	25
2029	199	1,067	224	1,091	25	24	488	1,960	509	1,977	20	17	45	41
2030	176	1,131	206	1,166	30	35	461	2,129	487	2,155	26	26	56	62
2031	156	1,188	190	1,236	35	48	436	2,288	468	2,326	32	38	67	86
2032	138	1,238	177	1,300	39	62	413	2,438	451	2,491	38	52	77	114
2033	123	1,283	165	1,361	42	78	392	2,581	436	2,650	44	68	87	146
2034	108	1,322	154	1,417	45	94	369	2,716	420	2,803	50	87	96	181
2035	95	1,357	144	1,469	49	112	350	2,844	406	2,951	56	107	105	219
2036	31	1,368	135	1,518	104	150	331	2,964	393	3,094	62	130	166	280
2037	4	1,370	127	1,565	123	195	314	3,079	381	3,233	68	154	191	349
2038	1	1,370	120	1,609	119	238	292	3,186	369	3,368	76	182	196	421
2039	0	1,370	113	1,650	113	280	99	3,222	358	3,499	259	277	372	556
2040	0	1,370	107	1,689	107	319	14	3,227	348	3,625	334	398	441	717
2041	0	1,370	102	1,726	102	356	2	3,228	339	3,749	337	521	439	878
2042	0	1,370	95	1,761	95	391	0	3,228	329	3,869	329	641	424	1,032
2043	0	1,370	32	1,773	32	403	0	3,228	320	3,986	320	758	353	1,161
2044	0	1,370	5	1,775	5	404	0	3,228	312	4,100	312	872	317	1,276
2045	0	1,370	1	1,775	1	405	0	3,228	301	4,210	301	982	302	1,387
2046	0	1,370	0	1,775	0	405	0	3,228	103	4,247	103	1,020	103	1,424
2047	0	1,370	0	1,775	0	405	0	3,228	15	4,253	15	1,025	15	1,430
2048	0	1,370	0	1,775	0	405	0	3,228	2	4,254	2	1,026	2	1,430
2049	0	1,370	0	1,775	0	405	0	3,228	0	4,254	0	1,026	0	1,430
2050	0	1,370	0	1,775	0	405	0	3,228	0	4,254	0	1,026	0	1,430

C. RESERVES

Based on the classification of reserves according to PSME 2011, Oil and or gas reserves are grouped into three main sections, namely:

- **Proved reserves** are those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods, and government regulations.
- **Probable reserves** are those unproved reserves which analysis of geological and engineering data suggests are more likely than not to be recoverable, In this context, when probabilistic methods are used, there should be at least a 50% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable reserves.
- **Possible reserves** are those unproved reserves which analysis of geological and engineering data suggests are less likely to be recoverable than probable reserves. In this context, when probabilistic methods are used, there should be at least a 10% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable plus possible reserves.

Based on that, then basecase forecast results for the Duri Formation of 1.44 MMSTB and the Bekasap Formation of 3.14 MMSTB can be classified as proved reserves of the Batang field. This is because without developing and adding production facilities, oil can be extracted to its economic limit.

Development using pressure maintenance can increase the value of reserves as probable reserves by maintaining pressure and extending the production life of the Batang field. Additional reserves may be in the Duri Formation of 404.7 MSTB and the Bekasap Formation of 1025.8 MSTB (see **Fig. 10**)

D. COMMERCIAL

The economic analysis in this paper uses Cost Recovery calculations with an investment period of 30 years until 2050. Cost Recovery is a mechanism for returning investment funds and operating costs by the government to contractors in the form of profit sharing after oil and gas fields have started producing (see **Fig. 11**)

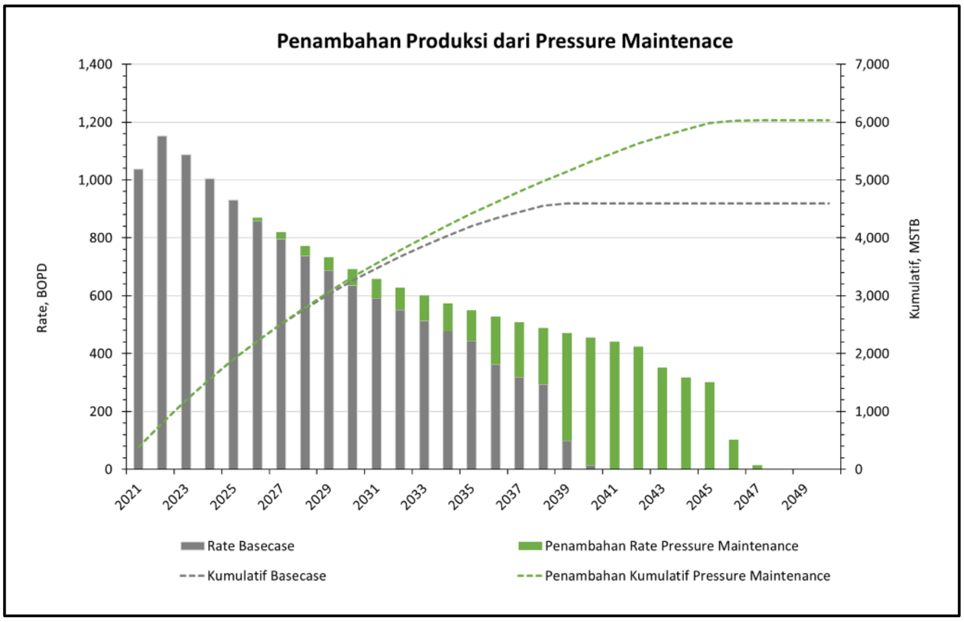


Figure 10 - Production Comparison from Pressure Maintenance Scenario

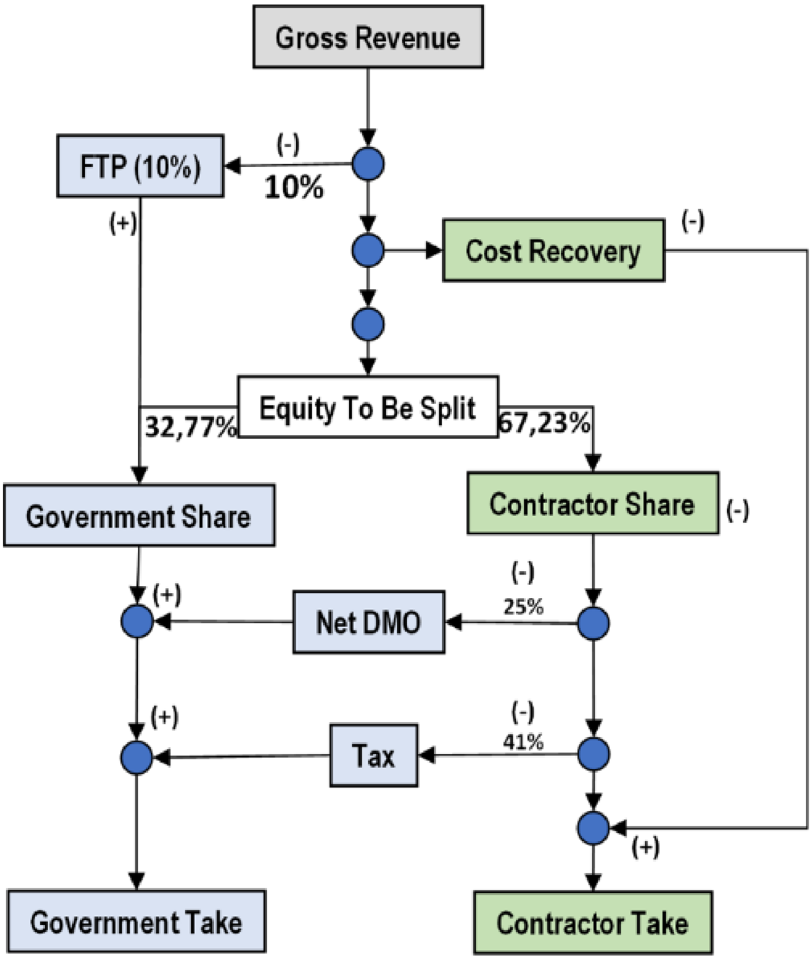


Figure 11 - Cost Recovery Scheme

Investment

The total development cost in the form of Capex (Capital Expenditure) is $6,605,000 USD consisting of $4,460,000 USD tangible and $2,145,000 USD intangible. These investments are in the form of well conversion costs, completion, flowline, injection pumps and construction of a water treatment plant. From this investment, the cost of well conversion and completion is intangible capex because it is a type of service, while the cost for flowline, injection pump and water treatment plant construction is tangible because it is a type of goods. The cost details can be seen at (**Table 3**). For Opex (Operational Expenditure) lifting and maintenance costs are $12.5 USD/Barrel.

TABLE 3
Cost Details in Pressure Maintenance Scenario

Investasi	Barang	Biaya, USD	Jumlah	Unit	Total, USD
Capex Intangible	Konversi Sumur	$ 50,000	33	Sumur	$ 1,650,000
Capex Intangible	Komplesi	$ 15,000	33	Sumur	$ 495,000
Capex Tangible	Fowline	$ 20,000	33	Sumur	$ 660,000
Capex Tangible	Pompa Injeksi @10,000 Bwpd	$ 100,000	8	Buah	$ 800,000
Capex Tangible	Water Treatment Plant	$ 1,500,000	2	Unit	$ 3,000,000
Total Capex					$ 6,605,000
Opex	Lifting Cost & Maintenace	$ 12.5	/Bopd		

For tangible capex, it is necessary to calculate depreciation to determine the decline in the value of the investment in these goods. In this thesis, the calculation of depreciation uses the decline balance method for 5 years with a rate of depreciation of 25% (see **Table 4**).

Net Present Value (NPV)

Net Present Value (NPV) is the difference between the value of incoming financial flows and the value of outflows over a period. Economic analysis using NPV is the most common way used by companies to evaluate the viability of a business, project, or investment. A positive NPV indicates that the projected income from an investment or project is greater than the costs incurred. Based on the economic analysis, it was found to be positive at $2,865,000 USD (see **Table 5 & Table 6**)

Internal Rate of Return (IRR) & Pay Out Time (POT)

Pay Out Time (POT) is the time required for the return of investment, or in other words the length of time required to achieve cumulative revenue equal to the investment. POT of this development for 11.7 Years. While the Internal Rate of

Return (IRR) is an indicator of the efficiency level of an investment. If the calculation of the internal rate of return shows a larger number, the better the investment made. The IRR of this development is 11%. (see **Table 5 & Table 6**)

TABLE 4
Depreciation Using Decline Balance

Tahun	Depresiasi 2021	Depresiasi 2022	Depresiasi 2023	Total Depresiasi
2021	$ 557,500	$ -	$ -	$ 557,500
2022	$ 418,125	$ 557,500	$ -	$ 975,625
2023	$ 313,594	$ 418,125	$ -	$ 731,719
2024	$ 235,195	$ 313,594	$ -	$ 548,789
2025	$ 705,586	$ 235,195	$ -	$ 940,781
2026	$ -	$ 705,586	$ -	$ 705,586
2027	$ -	$ -	$ -	$ -
Total	**$ 2,230,000**	**$ 2,230,000**	**$ -**	**$ 4,460,000**

TABLE 5
Economic Parameters

PARAMETER	UNIT	UNIT
Oil Production	MBbl	1,430
Oil Price	US$/BBL	65
Production Time	Year	29
Gross Revenue	MUS$	92,982
FTP	MUS$	4,649
· Contr. FTP	MUS$	3,125
· Gov. FTP	MUS$	1,524
Invesment	MUS$	6,605
· Sunk cost	MUS$	
· Tangible	MUS$	4,460
· Intangible	MUS$	2,145
Operating Expenditure	MUS$	17,953
Operating Cost	MUS$	17,953
Abandonment	MUS$	-
· **Cost Recovery**	MUS$	24,558
(% to Gross Revenue)	%	26
· **Unrecovered Cost**	MUS$	-
(% to Gross Revenue)	%	-
Equity to be Split	MUS$	63,775
· Contr. Equity	MUS$	42,874
· Gov. Equity	MUS$	20,901
Contractor:		
· Net Cash Flow	MUS$	27,370
(% to Gross Rev.)	%	29
· IRR	%	11
· NPV	MUS$	2,865
· POT	year	11.7
Government:		
· FTP + Equity	MUS$	22,425
· Tax	MUS$	18,630
· Net DMO	MUS$	-
· Net Cash Flow	MUS$	41,054
(% to Gross Rev.)	%	44
· Gov. NPV @ 10%	MUS$	6,021

TABLE 6
Economic Calculation Tabulation using Pressure Maintenance

Year	Recoverable Oil (MBbl)	Oil Price, US$	Gross Rev, M US$	FTP	Rev after FTP	Capital Cost			Opex	Total Capital Depreciation	Cost to be Recover	Cost Recovery	Unrecovered	FTP Oil Pertamina	FTP Oil Governmen	DMO	DMO Fee	Taxable Income	Tax	Net Pertamina	Pertamina Cashflow	GOI Take	POT Year
						Tangible	Intangibl	Total															
2021	-	-	-	-	-	2,230	1,073	3,303	-	557.5	1,630.0	-	1,630.0	-	-	-	-	-	-	-	(3,302.5)	-	-
2022	-	-	-	-	-	2,230	1,073	3,303	-	975.6	3,678.1	-	3,678.1	-	-	-	-	-	-	-	(3,302.5)	-	-
2023	-	-	-	-	-	-	-	-	-	731.7	4,409.8	-	4,409.8	-	-	-	-	-	-	-	-	-	-
2024	-	-	-	-	-	-	-	-	-	548.8	4,958.6	-	4,958.6	-	-	-	-	-	-	-	-	-	-
2025	-	-	-	-	-	-	-	-	-	940.8	5,899.4	-	5,899.4	-	-	-	-	-	-	-	-	-	-
2026	3.56	65	232	12	220	-	-	-	44.7	705.6	6,649.7	220.0	6,429.7	7.8	3.8	38.9	38.9	7.8	3.2	4.6	179.9	6.9	-
2027	8.61	65	560	28	532	-	-	-	108.1	-	6,537.8	531.8	6,006.0	18.8	9.2	94.1	94.1	18.8	7.6	11.2	434.9	16.8	-
2028	12.54	65	815	41	774	-	-	-	157.4	-	6,163.4	774.3	5,389.1	27.4	13.4	137.0	137.0	27.4	11.1	16.3	633.3	24.5	-
2029	16.59	65	1,078	54	1,024	-	-	-	208.2	-	5,597.2	1,024.3	4,573.0	36.2	17.7	181.2	181.2	36.2	14.7	21.6	837.7	32.3	-
2030	20.52	65	1,334	67	1,267	-	-	-	257.5	-	4,830.5	1,267.2	3,563.3	44.8	21.9	224.2	224.2	44.8	18.2	26.7	1,036.3	40.0	-
2031	24.38	65	1,585	79	1,506	-	-	-	306.0	-	3,869.4	1,505.7	2,363.6	53.3	26.0	266.4	266.4	53.3	21.6	31.7	1,231.4	47.5	-
2032	28.09	65	1,826	91	1,734	-	-	-	352.5	-	2,716.1	1,734.3	981.8	61.4	29.9	306.8	306.8	61.4	24.9	36.5	1,418.4	54.8	-
2033	31.68	65	2,059	103	1,956	-	-	-	397.5	-	1,379.3	1,379.3	-	69.2	33.7	346.1	346.1	456.9	185.1	271.9	1,253.6	407.8	11.66
2034	34.89	65	2,268	113	2,155	-	-	-	437.9	-	437.9	437.9	-	76.2	37.2	381.2	381.2	1,230.3	498.3	732.0	732.0	1,098.0	-
2035	38.37	65	2,494	125	2,369	-	-	-	481.5	-	481.5	481.5	-	83.8	40.9	419.1	419.1	1,352.8	547.9	804.9	804.9	1,207.4	-
2036	60.46	65	3,930	196	3,733	-	-	-	758.8	-	758.8	758.8	-	132.1	64.4	660.5	660.5	2,131.9	863.4	1,268.5	1,268.5	1,902.7	-
2037	69.56	65	4,522	226	4,295	-	-	-	873.0	-	873.0	873.0	-	152.0	74.1	759.9	759.9	2,452.8	993.4	1,459.4	1,459.4	2,189.1	-
2038	71.37	65	4,639	232	4,407	-	-	-	895.7	-	895.7	895.7	-	155.9	76.0	779.7	779.7	2,516.6	1,019.2	1,497.4	1,497.4	2,246.0	-
2039	135.81	65	8,828	441	8,386	-	-	-	1,704.4	-	1,704.4	1,704.4	-	296.7	144.7	1,483.6	1,483.6	4,788.7	1,939.4	2,849.3	2,849.3	4,274.0	-
2040	160.89	65	10,458	523	9,935	-	-	-	2,019.2	-	2,019.2	2,019.2	-	351.5	171.4	1,757.7	1,757.7	5,673.2	2,297.6	3,375.6	3,375.6	5,063.3	-
2041	160.20	65	10,413	521	9,892	-	-	-	2,010.5	-	2,010.5	2,010.5	-	350.0	170.6	1,750.1	1,750.1	5,648.6	2,287.7	3,360.9	3,360.9	5,041.4	-
2042	154.76	65	10,059	503	9,556	-	-	-	1,942.2	-	1,942.2	1,942.2	-	338.1	164.8	1,690.6	1,690.6	5,456.8	2,210.0	3,246.8	3,246.8	4,870.2	-
2043	128.66	65	8,363	418	7,945	-	-	-	1,614.7	-	1,614.7	1,614.7	-	281.1	137.0	1,405.6	1,405.6	4,536.8	1,837.4	2,699.4	2,699.4	4,049.1	-
2044	115.54	65	7,510	376	7,135	-	-	-	1,450.1	-	1,450.1	1,450.1	-	252.4	123.1	1,262.2	1,262.2	4,074.1	1,650.0	2,424.1	2,424.1	3,636.2	-
2045	110.18	65	7,162	358	6,804	-	-	-	1,382.8	-	1,382.8	1,382.8	-	240.7	117.4	1,203.7	1,203.7	3,885.1	1,573.5	2,311.6	2,311.6	3,467.4	-
2046	37.58	65	2,443	122	2,321	-	-	-	471.7	-	471.7	471.7	-	82.1	40.0	410.6	410.6	1,325.2	536.7	788.5	788.5	1,182.8	-
2047	5.35	65	347	17	330	-	-	-	67.1	-	67.1	67.1	-	11.7	5.7	58.4	58.4	188.5	76.3	112.2	112.2	168.2	-
2048	0.76	65	49	2	47	-	-	-	9.5	-	9.5	9.5	-	1.7	0.8	8.3	8.3	26.8	10.9	16.0	16.0	23.9	-
2049	0.11	65	7	0	7	-	-	-	1.4	-	1.4	1.4	-	0.2	0.1	1.2	1.2	3.8	1.6	2.3	2.3	3.4	-
2050	0.02	65	1	0	1	-	-	-	0.2	-	0.2	0.2	-	0.0	0.0	0.2	0.2	0.5	0.2	0.3	0.3	0.5	-
2051	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**1,430**		**92,982**	**4,649**	**88,333**	**4,460**	**2,145**	**6,605**	**17,953**	**4,460**	**74,440**	**24,558**	**-**	**3,125**	**1,524**	**15,627**	**15,627**	**45,999**	**18,630**	**27,370**	**27,370**	**41,054**	**11.66**

RESULTS AND DICUSSION

Based on these indicators, development projects using pressure maintenance are economically feasible to apply in the field because they have a positive NPV value. However, the IRR and POT indicators show a long return on capital (± 12 years), this is because the production gain is not obtained immediately at the time the project is executed because there is a reservoir filling-up period of 5 years.

CONCLUSION

From the content of the paper the author made several conclusions, there are:

1. Batang Field still has a additional reserve of 1,430.5 MSTB that can be produced using pressure maintenance scenario.
2. Water injection for Pressure maintenance is the most suitable scenario for Batang Field because the reservoir pressure is low, the distance of each well that has been tight, and the remaining reserves are still quite large.
3. To fulfill the injection target with VRR=1, a filling-up period of 5 years is required from injection at 33 wells with a rate of 2,000 BWPD for each well.
4. Total development cost in the form of Capex (Capital Expenditure) of $ 6,605,000 USD consisting of $ 4,460,000 USD tangible and $ 2,145,000 USD intangible, resulting in NPV = $ 2,865,000 USD, IRR = 11%, and POT=11.7 years.
5. This development project is still profitable because it has a positive NPV value. On the other hand, the IRR and POT indicators show a long return on capital (± 12 years), because of there is a period of filling-up reservoir for 5 years.

REFERENCES

Abu Ela Ela, M., "Reservoir Characteriation from Material Balance Results Analysis", SPE 108648, Society of Petroleum Engineers, 2007.

Ahmed, Tarek, "Reservoir Engineering Handbook", 2nd Ed., Gulf Publishing Company, Boston, London, Auckland, Johannesbourg, Melbourne, New Delhi, 2001.

Ahmed, Tarekh and McKiney., "Advance Reservoir Engineering", Gulf Profesional Publishing, Oxford, 2004.

Amyx, J.W., Bass, D.W.Jr., Whiting, R.L, "Petroleum Reservoir Engineering Physical Properties", Mc Graw Hill Books Company, New York, Toronto, London, 1960.

Dake, L.P., "Fundamentals of Reservoir Engineering", Elsevier Science B.V., Amsterdam, Netherlands, 1978.

Havlena, D. and odeh, A. S, "The Material balance as an equation of a straight line", jour. Pet. Tech, 1963.

Havlena, D. and odeh, A. S, "The Material balance as an equation of a straight line – Part II, Field Case", Jour. Pet. Tech, 1964.

Rukmana, Dadang., "Teknik Reservoir Teori dan Aplikasi", Pohon Cahaya, Yogyakarta, 2012

Kanu, Austin and Obi, Mike, "Advancement in Material balance Analysis", Nigeria, 2014.

Walsh, M.P., Ansah, J., and Raghavan, R.: 'The New Generalized Material Balance as an Equation of a Straight-Line: Part 1—Applications to Undersaturated and Volumetric Reservoirs", Midland, TX, 1994.

PRMS Guidelines for Application of the Petroleum Resources Management System, 2011.

PTK Financial Budget and Reporting Manual of Production Sharing Contract dan Chart of Account, PTK-063/SKKMA0000/2017/S0, SKK Migas, 2017.

Tracy, G.W., "Simplified Form of the Material Balance Equation", SPE-438-G, Society of Petroleum Engineers, Tulsa, Okla, 1955.

Woods, Rex W. and Muskat Morris, "An Analysis of Material Balance Calculations, SPE-945124-G, Society of Petroleum Engineers, 1945.