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Well Spacing Effects on Well Productivity in Coalbed Methane Reservoirs

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Abstract

Indonesia has large coalbed methane (CBM) reserves (453 TCF) and has the potential to supply domestic natural gas. One of the problems in producing gas from CBM is the amount of time that the dewatering process takes. The dewatering process involves draining water to reduce the pressure so that the methane gas can come out (as in Field X, Kalimantan). To accelerate the dewatering process, a well spacing method is used to determine the number of wells that will affect the cumulative gas production. A greater number of wells will increase CBM gas production but will also increase the cost and duration of production, so an economic analysis is needed to provide limits and determine the optimum yield. This paper will be conducted with a numerical simulator to discern the effects of well spacing on well productivity in CBM reservoirs. The result shows that models with 160 acres of well spacing have a recovery factor of 16,07%, 320 acres have a recovery factor of 11,5%, and 640 acres have a recovery factor of 5,82%. The result suggests that narrow spacing of wells causes greater cumulative gas production, but it plateaus (stabilizes) more quickly.

Keywords: *coalbed methane, gas production, natural gas, unconventional resources, well spacing effects*

1. Introduction

One of the energy sources in Indonesia that has great potential is natural gas. The more difficult discovery of conventional natural gas reserves, the Government is making efforts to accelerate the development of Non-Conventional Oil and Gas. As the discovery of conventional natural gas reserves becomes more difficult, the government is making efforts to accelerate the development of nonconventional oil and gas. One such type that shows great promise is coalbed methane (CBM) with potential reserves of 453 Tcf. With its considerable potential, CBM is expected to boost the development of the national natural gas industry [1].

In 'Government Regulation of the Republic of Indonesia: Number 79 of 2014 on National Energy Policy', it is stated that the primary energy mix target for the role of natural gas in 2025 is less than 20% [2].

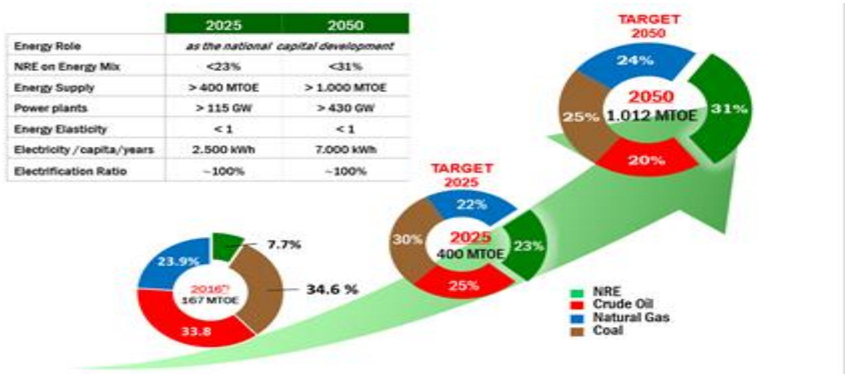

Figure 1. Primary Energy Mix [2]

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Figure 1 shows that to meet the target, the main objective in the National Energy Policy (NEP) is to secure sufficient energy availability for national needs, with a strategy to increase the exploration of resources, seeking inferred and/or proven reserves of energy, both from fossil types and new and renewable energy. One of the new energy types is coalbed methane.

To carry out more detailed and strategic steps in implementing the NEP, the government issued 'Presidential Regulation Number 22 of 2017 On National Energy General Plan' (RUEN). In the RUEN, oil and gas production targets are declared and policy measures to increase oil and gas production laid out [2].

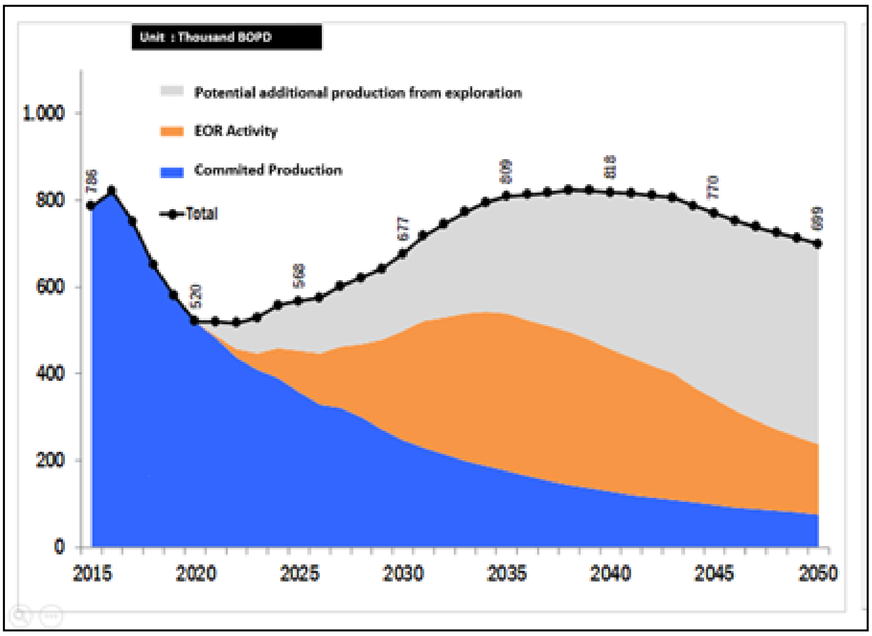

Figure 2. Petroleum Production Targets According to RUEN [2]

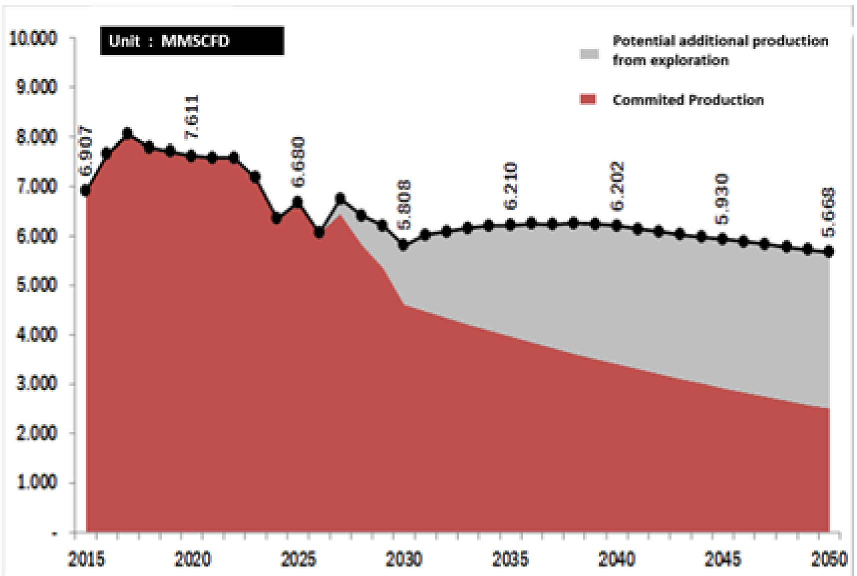

Figure 3. Petroleum Production Targets According to RUEN [2]

Figure 2 predicts an increase in Indonesia's natural gas production up to 2050 supported by significant new exploration activities. This is expected to increase the ratio of reserve recovery to 100% by 2025. Steps have been put in place to achieve policies to

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increase oil and gas production, one of which is conducting basic oil and gas exploration research into how to increase reserves, including research into nonconventional oil and gas, pretertiary petroleum systems, volcanic petroleum systems, and biogenic gas. The nonconventional oil and gas research referred to includes the development of shale gas, CBM, and gas hydrate reservoirs. Research into development of CBM carried out to date has supported policies in achieving increased natural gas production [2].

1.1. Characteristic of CBM

The characteristics of a CBM reservoir have several fundamental differences compared to conventional gas reservoir. In CBM, coal functions as source rock as well as reservoir rock. Coal is an anisotropic and heterogeneous porous medium characterized by two different porosity systems (dual porosity). CBM gas is stored in coal through a process called adsorption. The gas attaches to the coal micropore (matrix). Fractures also known as cleats, in coal (cleats) can also contain free gas or gas that is saturated by water (Figure 4) [3]. Differences between CBM reservoirs and conventional gas reservoirs are presented in Table 1 [4]. CBM is methane gas trapped in coal and exploited below the surface (200-700 meters). Methane gas in CBM stored (adsorbed) in micropores that have a large storage capacity. That large capacity is a function of pressure (the higher the pressure, the greater the potential for large storage capacity). Production of methane gas at the coal bed is done by reducing the reservoir pressure in the coal seam.

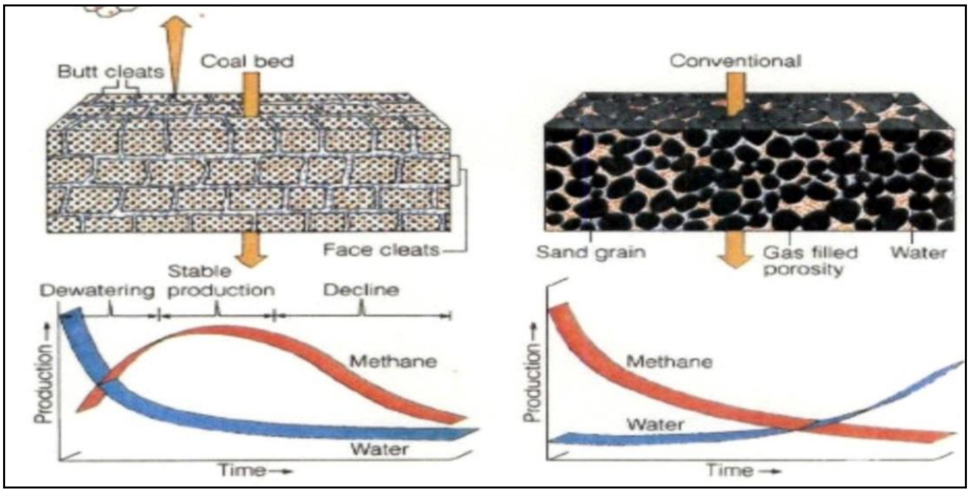

Figure 4. Conventional Gas Production Profile with CBM Gas [3]

Table 1. Comparison of the characteristics of Conventional Gas Reservoir with CBM

Conventional Gas Reservoir	CBM Reservoir
Gas flow to the wellbore using the Darcy equation	Gas flow to the wellbore using equation: a. Diffusion with Fick's law through micropore b. Darcy's equation through fracturing
Gas stored in pores.	Gas is stored through adsorption on the surface of the micropore
Water production will increase over time.	Water production will decrease over time
Gas composition can be known through logging.	Gas composition can be known through coring results

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1.2. Production of CBM

Research conducted by Zulkarnain (2005) discusses the factors that influence the production of methane gas in CBM, namely the effects of well spacing, anisotropic permeability and cleat compression and matrix shrinkage effects. The well spacing effect is the effect of decreasing pressure on the well due to the connection between the wells. In conventional gas reservoirs such conditions are undesirable because they will accelerate the loss of pressure. In contrast to conventional gas reservoirs, the CBM reservoir well spacing effect is beneficial because it can accelerate the pressure reduction and dewatering process so that the gas will come out faster. The unequal permeability is one of the factors that influence CBM methane gas production. This anisotropic permeability caused by the CBM reservoir has the characteristics of dual porosity reservoir, cleat and matrix (Zulkarnain (2005) **Erreur ! Source du renvoi introuvable.**; Wicks et al. (1986) **Erreur ! Source du renvoi introuvable.**; Young et al. (1991)**Erreur ! Source du renvoi introuvable.**).

Various studies related to factors affecting the production of methane gas in CBM have been conducted. Young et al. (1991) conducted a simulation study of the beneficial effects of well spacing in CBM production in the Northern San Juan Basin. The study proved that the presence of well spacing has a beneficial effect on methane production, and the well spacing and fracture length influence CBM production. The study concluded that an optimal well distance can be determined for producing methane given the variability in reservoir properties from the reservoir in the San Juan Basin. Interference between wells due to well spacing is useful for exploiting gas in CBM reservoirs [7].

Chaianansutcharit et al. (2001) investigated the effects of well disturbances on coal methane performance. They conduct simulation studies to study the effects. They proved that the disturbance of a well has a positive impact on the coal methane reservoir. Good disturbances can increase methane recovery. They stated that the disturbance of a well could accelerate gas production and that a two-well system could achieve total recovery earlier than a one-well system [8].

Nugrahanti (2017) discussed the factors that influence the production of CBM gas, namely, the combination of the reservoir and geological parameters, such as double porosity, anisotropic permeability, relative permeability, desorption time, and water saturation. To produce methane gas, the fractures in the coal must be drained to move the gas into the well. When water flows out of the reservoir, its pressure decreases, permeability relative to water decreases, and the water flow rate decreases. After the saturation pressure is reached, the coal will start releasing gas. This gas diffuses from the matrix and desorbs into the cleat. [9] Wahid et al. (2018) discuss methods of increasing methane gas production using nitrogen and carbon dioxide injection. Based on these various studies, researchers will discuss the effects of well spacing on CBM gas production, especially the CBM field in Kalimantan for optimizing the development of CBM in Indonesia [10].

2. Methodology

Reservoir simulation software was used to predicting gas production in the CBM reservoir. The reservoir model used is rectangular with homogeneous reservoir characteristics. It is modelled on the dual-porosity mode, which takes into account variations in the cleats and matrix characteristics of the coal bed. The reservoir model was made based on the data obtained in the field (Table 2). To find out the effects of well spacing, several variations of well spacing were selected, specifically 160 acres (figure 5), 320 acres (figure 6) and 640 acres (figure 7). The addition of wells is assumed to be 6 wells in 1 year, the number of wells in each well spacing is in figure 8. Each well spacing is carried out running with a variable gas constraint rate of 200 mscf/day, 225 mscf/day and 250 mscf/day, based on the results of running basecase at the beginning of the

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simulation. Simulation carried out for 25 years. Simulation results were grouped and compared to analyse the effects of well spacing.

Table 2. Reservoir Parameters for Simulation

Reservoir Parameter		
Area	10.321	acre
Depth	750	meters
Coal Thickness	90,22	Feet
Coal Density	1,35	gr/cc
Water Saturation	0,3	
Matrix Porosity	0,0005	
Fracture Porosity	0,12	
Matrix Permeability	0,23	mD
Fracture Permeability	2,3	mD
Initial Reservoir Pressure	750	Psi
Langmuir Volume	554,44	SCF/Ton
Langmuir Pressure	353	Psi
Gas Content	345,02	SCF/Ton
Initial Gas Composition	1	Fraction
Equilibrium pressure at initial gas content	750	Psi

3. Result and Discussion

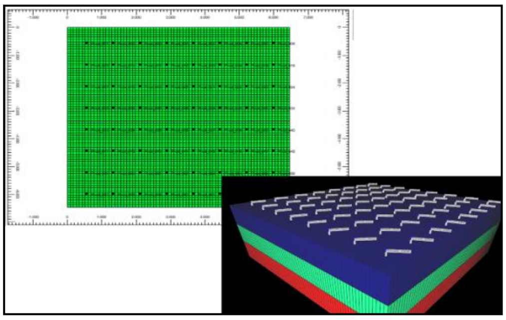

Figure 5. Well spacing 160 acres c

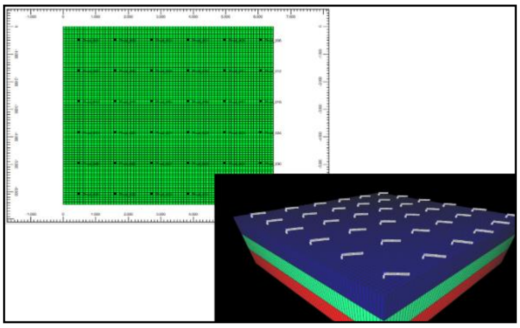

Figure 6. Well spacing 320 acres

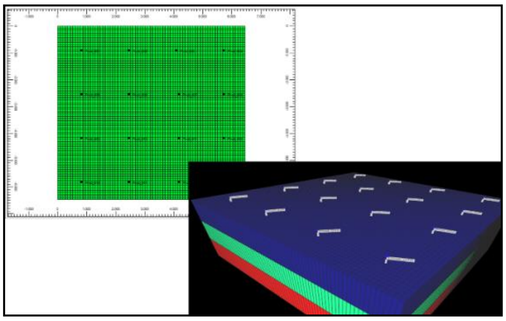

Figure 7. Well spacing 640 acres

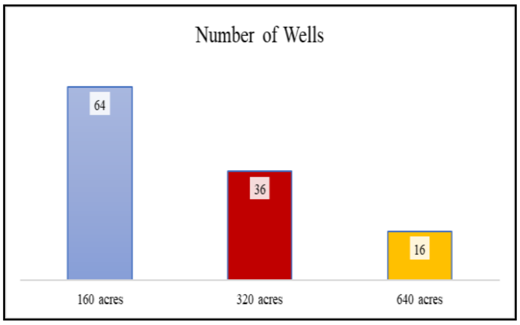

Figure 8. Number of wells

The simulation results show a gas rate produced by 160-acre well spacing in figure 9, it shows that gas rate of 200 mscf/day have maximum gas produce 4.672 mmscf/year and the condition of the plateau during 6 year, 225 mscf/day produce 5.225 mmscf/year during 4 years and 250 mscf/day produce 5.647 mmscf/years during 2 year. It means that need long time (14 years) until the gas plateau.

Gas rate produced by 320-acre well spacing in figure 10, it shows that gas rate of 200 mscf/day have maximum gas produce 2.628 mmscf/year and the condition of the plateau

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during 7 year, 225 mscf/day produce 2.956 mmscf/year during 12 years and 250 mscf/day produce 3.285 mmscf/years during more than 15 years. It means that need 7 years until the gas plateau.

Gas rate produced by 640-acre well spacing in figure 11, it shows that gas rate of 200 mscf/day have maximum gas produce 1.168 mmscf/year, 225 mscf/day produce 1.314 mmscf/year, 250 mscf/day produce 1.460 mmscf/years and all gas rate the condition of the plateau more than 15 years. It means that need 4 years until the gas plateau. Figure 12 shows cumulative gas produced with 160 acres, 320 acres and 640 acres well spacing. The result suggests that narrow spacing of wells causes greater cumulative gas production, but it plateaus (stabilizes) more quickly.

For all scenarios, these results can occur because the gas content in the coal seam adsorbed in the matrix exits faster along with a pressure drop. This can be indicated by the number of wells 160-acre well spacing is greater than 320-acre well spacing and 640-acre well spacing, making the pressure drop faster. The pressure drawdown caused by the interference between wells enhanced the desorption of methane to the cleat system, therefore creating a beneficial impact on gas production unlike the case in conventional gas reservoir. A greater number of production wells can more quickly decrease the reservoir pressure in the drainage area, producing more cumulative gas. This shows that the well spacing effect will increase the rate of gas production and increase the cumulative gas production.

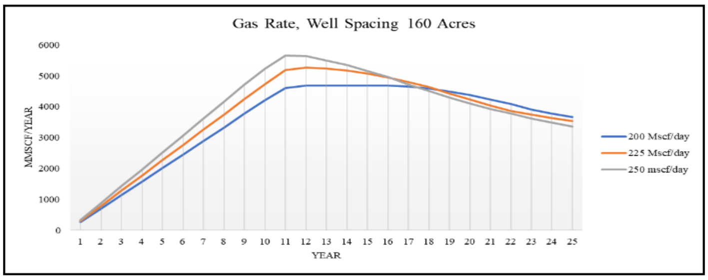

Figure 9. Gas rate, well spacing 160 acres

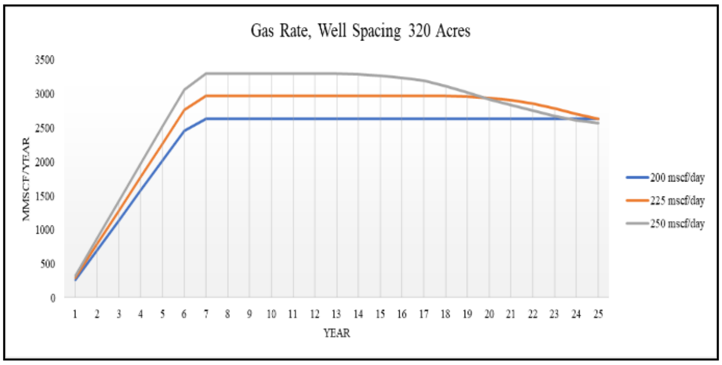

Figure 10. Gas rate, well spacing 320 acres

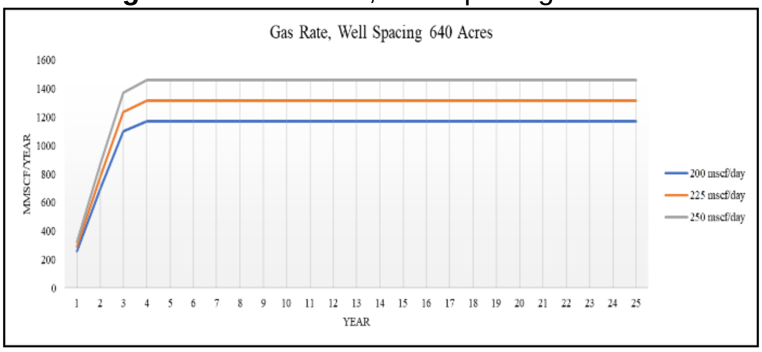

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Figure 11. Gas rate, well spacing 640 acres

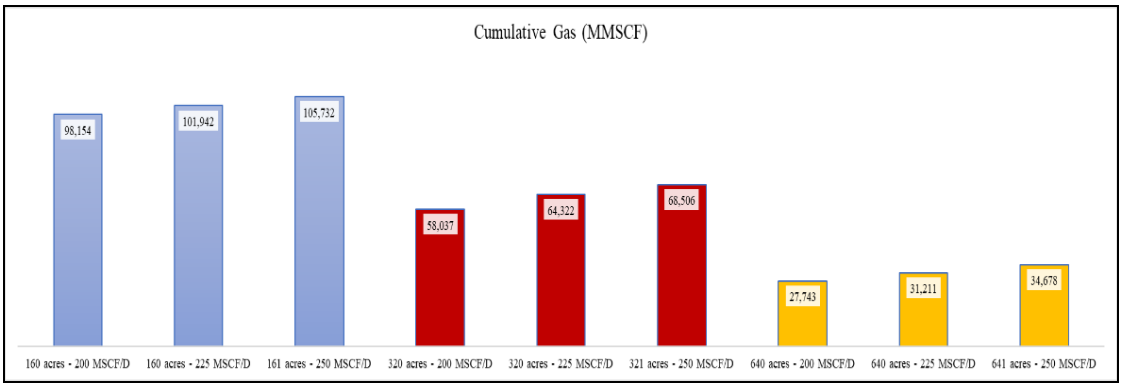

Figure 12. Cumulative Gas Production Profile

4. Conclusion

1. Well Productivity in Coalbed methane influenced by well spacing effects that make reservoir pressure decrease so the methane gas can come out faster. The result suggests that narrow spacing of wells causes greater cumulative gas production, but it plateaus (stabilizes) more quickly and more production wells are needed.
2. The result shows that models (gas rate of 250 mscf / day) with 160 acres of well spacing have a recovery factor (RF) of 16,07%, 320 acres have a RF of 11,5%, and 640 acres have a RF of 5,82%. From that result choose scenario, 160 acres well spacing with a gas rate of 250 mscf / day as the best scenario because it has the greatest recovery factor and cumulative gas which is 105,73 MMSCF with RF 16,07%.
3. For the next analysis, an economic study is needed to determine the right well spacing and gas rate.

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