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Oil Field Development Scenario to Increase Oil Recovery Using Reservoir Simulation

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Abstract. Field “X” is an oil field located in the South Sumatra Basin. The field is located in an onshore area with reservoirs dominated by sandstone. Based on existing data, the average porosity of each layer is 18.9% and the average water saturation is 50.3%. The oil reserve calculate using volumetric method, from these calculation known the value original oil place (OOIP) is 23.454 MMSTB. Then, the calculation of recovery factor is done by using the JJ Arps. Methods. Based on this method, the RF value of each productive layer is known to be, A1 layer of 37.64733%, A2 RF layer at 38.01293% and A3 layer by 41.3509%. From these JJ. Arps, it can be estimated the productivity of reservoir from the initial oil reserve (OOIP condition). Field X first produced in 2016 and the field has a 30-year contract duration until 2047. In this field, the optimization of oil production is done by field development scenario of 5 step scenarios using the CMG Reservoir Simulation. The scenario consists of basecase by adding the infill wells, pressure maintenance, and waterflooding injection on the field X. From the simulation, it can be obtained the cumulative production, and recovery factor from each scenarios. On basic scenario or basecase condition or scenario 1 has an RF value of 6.039% and cumulative production is 1416500 MSTB, scenario 2 has an RF value of 12.29% and cumulative production is 2883000 MSTB, Scenario 3 has an RF value of 15.566% and cumulative production is 3650900 MSTB, scenario 4 has an RF value of 20.669% and cumulative production is 4847700 MSTB, and scenario 5 has an RF value of 21.435% and cumulative production is 5027400 MSTB. From the result of each scenarios, the scenario 5 is the best development scenario for the field “X”.

Keywords: Oil Field, Field Develompent, Scenario, Reservoir Simulation, and Recovery Factor

Abbreviations : STB (Stock Tank Barrel), BBL/d (Barrel/day), OOIP (Original Oil In Place), RF (Recovery Factor), CMG (Computer Modeling Group)

INTRODUCTION

The geology of the South Sumatra Basin is a result of tectonic activity that is closely related to the subduction of the Indo-Australian Plate, which moves north to northeast towards the relatively stationary Eurasian Plate.The plate subduction zone covers areas west of Sumatra Island and south of Java Island. Several small plates (micro-plates) that are between the interaction zones also move and produce convergence zones in various shapes and directions.The subduction of the Indo-Australian plate can affect rock conditions, morphology, tectonics and structures in South Sumatra. Plate tectonic collisions on the island of Sumatra produce forward arc, magmatic, and back arc lines (Bishop, 2000). The South Sumatra Basin is included in the Back Arc Basin which was formed due to the interaction between the Indo-Australian plate and the micro-Sundanese plate. This basin is divided into 4 (four) sub basins (Pulonggono, 1984), namely Jambi Sub Basin, North Palembang Sub Basin and South Palembang Sub Basin and Central Palembang Sub Basin. In this basin there are formations that were formed during the transgression phase and are grouped into the Telisa Group (Talang Akar Formation, Baturaja Formation, and Gumai Formation), the Palembang Group was deposited during the regression phase (Air Benakat Formation, Muara Enim Formation, and Kasai Formation), and Formation. Lemat and older lemat are deposited before the main transgression phase. The South Sumatra Basin is a productive basin producing oil and gas. This is evidenced by the large number of oil and gas seepage connected by the presence of the anticline. The seepage is located at the foot of the Gumai hill and the Barisan mountains. So that with the seepage event, it can be used as an early indication for exploration of the presence of hydrocarbons below the surface based on the petroleum system (Ariyanto, 2011).

Field "X" is an oil field located in the South Sumatra Basin. This field reservoir is located in the Talang Akar formation with 3 productive layers, namely layers A1, A2, and A3. This field is in an onshore area with a reservoir dominated by sandstones. At the beginning of its production, there were only 4 wells available in the field, namely X- 1, X-2, X-3, and X-4 wells. Based on the available data, it can be seen that the average porosity of each layer is 18.9% and the average water saturation is 50.3From the results of the calculation of reserves using the volumetric method, the original oil content (OOIP) was 23.48 MMSTB. The "X" field is an oil field that has just started producing, so it is necessary to carry out further field development using the reservoir simulation method.

Reservoir simulation is a mathematical process to predict reservoir behavior. Reservoir modeling is carried out based on the results of geological modeling (static) combined with reservoir data (dynamic).

The purpose of reservoir simulation is to predict future reservoir performance and seek field development strategies in order to obtain an increase in oil recovery from the reservoir. Using a computer device allows a more detailed study to be carried out by dividing the reservoir into a number of grids and applying numerical equations for the flow in the porous media in each grid..Digital computer programs that are used to perform the calculations required in modeling studies are known as computer models. Software / software used in this simulation is CMG (Computer Modeling Group) software. During the simulation, data such as reservoir, production and geology are needed. If the data entered into the simulator is inaccurate, the resulting model has a low level of validity so that field development cannot be carried out. Reservoir simulation work in general starts with data preparation, model creation, initialization, running models, history matching, running field development scenarios, and finally evaluation and recommendations.

MATERIALS AND METHODS

Data Process

In carrying out the “X” field development scenario, steps or schemes need to be carried out starting from data preparation until the final goal is to calculate the recovery factor from the field development scenario. The schematic is shown in the flowchart below (Figure 1).

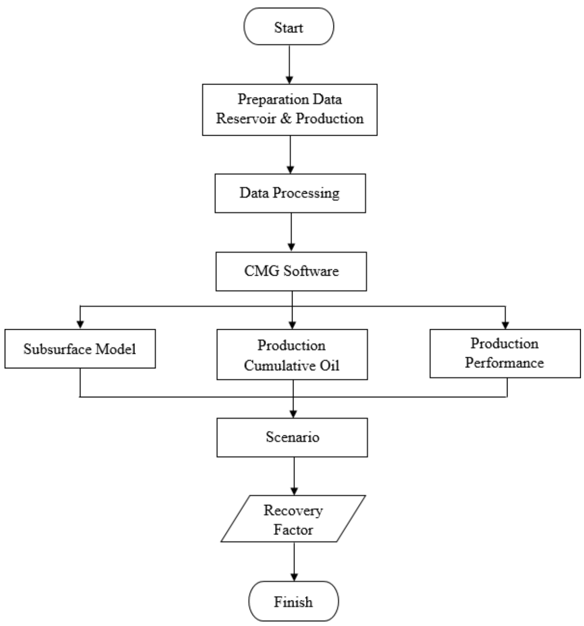

Figure 1. Flowchart

The first step is to prepare production and reservoir data. Production data includes the production rate of oil, water, water cut, and Gas Oil Ratio (GOR). Reservoir data includes data on reservoir rock characteristics and reservoir fluid characteristics. After that, data processing is carried out to calculate the initial backup and recovery factor using the JJ method. Arps. The next step is to immediately carry out a reservoir simulation. Reservoir simulation was performed using CMG (Computer Modeling Group) software. From the CMG software, we can determine the subsurface model, production cumulative oil, and production performance. After that, the field development scenario is carried out, in this case the “X” field development scenario consists of 6 scenarios. This field development scenario consists of adding infill wells, performing waterflooding on wells, and performing pressure maintenance.

This field development scenario can be carried out at layers A1, A2, and A3 for the "X" field until 2047. From these six scenarios, it can be determined the value of the recovery factor (RF) and production cumulative. If the rate of oil production in the scenario until 2047 is below the economic limit, the wells in that layer must be suspended. In addition, if the recovery factor is small, the development scenario for the "X" field on the layer must be replaced or added so that the Recovery Factor value is large and of course the oil production rate is above the economic limit.

Reservoir Simulation

In the field development scenario "X" a reservoir simulation using CMG Software is used. CMG (Computer Modeling Group) Software is used for single-phase, two-phase, or multi-phase reservoirs and can be used to create 3- dimensional models of reservoirs. Reservoir modeling is based on the map of the top structure, isoporosity, isopermeability and isonetpay obtained from the results of geophysical and geological studies. After knowing the 3D model of the field reservoir "X", it is initialized. Initialization is an activity carried out to determine the amount of oil reserves in the model created in software with the actual amount of reserves in the field (initial reservoir conditions). This can be seen by making a comparison between the results of the calculation of OOIP reserves (Original Oil In Place) from the simulator and the results of volumetric calculation of OOIP reserves. After initialization there is also the term History Matching or alignment. This history matching is done by modifying dynamic indicators without changing the results of the initialization process so that the production rate alignment between the model or simulator and the actual production data in the field. In addition, reservoir simulation can also be carried out in the field development with several scenarios that can be carried out in the "X" field. In this field development scenario it can be done by adding production wells or adding injection wells with the main objective of increasing field production. In the reservoir simulation for the field development scenario, the results will be the value of the field production flow rate "X" after running. The results of this runnning will determine or predict the amount of oil production in the "X" field for the next severalyears

RESULTS AND DISCUSSION

Model Reservoir dan Original Oil In Place (OOIP)

In CMG, it can model shapes and maps both isoporosity, isopermeability, and isonetpay maps. Isoporosity map is a map or model that depicts the distribution of a uniformity of porosity on the map. An isopermeability map is a map or model that describes the distribution of a permeability uniformity on the map. And isonetpay is a map or model that describes the distribution of a uniform productive zone.

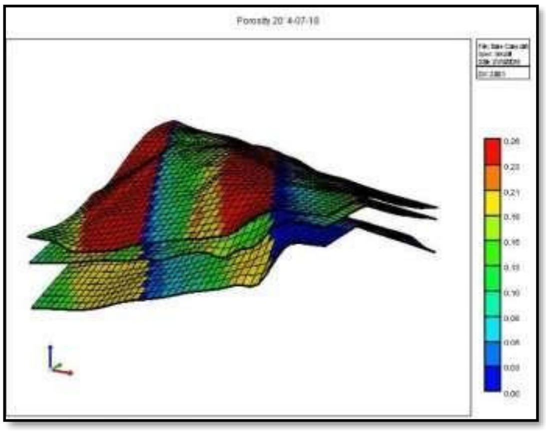

Figure 2. Isoporosity Map

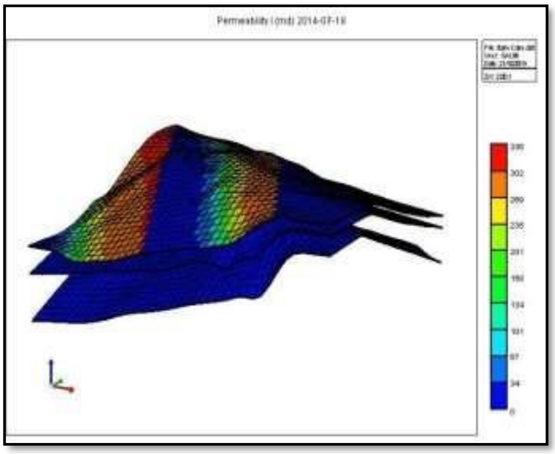

Figure 3. Isopermeability Map

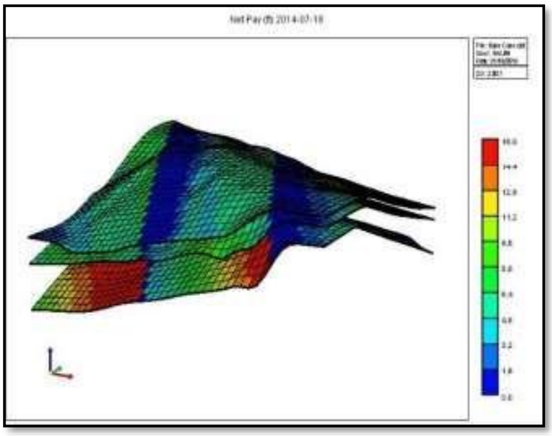

Figure 4. Isonetpay Map

In addition, the volumetric reserve value or Original Oil In Place (OOIP) is obtained from layers A1, A2, and A3. Field development "X" is carried out based on volumetric view calculations because it is still in the early stages of development and there is no production data.

Table 1. The Result of OOIP of Each Layer

Layer	OOIP (STB)	OOIP (MMSTB)
A1	5234454.013	5.254
A2	11604038.98	11.604
A3	6622675.852	6.622

Based on the table above, it can be seen that each layer has a different and quite large OOIP value. The largest OOIP value is at layer A1, which is 11,604 MMSTB. So that the total OOIP value of the field "X" is 23.48 MMSTB.

Production Optimization

In the "X" field development scenario, 5 field development scenarios will be carried out so that the production obtained remains optimum. Scenario 1 is basecase (4 wells available in the “X” field), namely X-1, X-2, X-3 wells and X-4 wells. Scenario 2 with the addition of 5 infill wells to basecase, then scenario 3 is done by adding 2 pressure maintenance wells to scenario 2. For scenario 4, scenario 3 is added with 2 injection water flooding wells. The last scenario is scenario 5, which is scenario 4 plus 1 infill well, 1 pressure maintenance well, and 1 waterflood well. scenario 5, the addition of waterflood wells comes from the transition of production wells X-4. Because in 2030 the X- 4 well can no longer produce.

Basecase or Scenario-1

Basecase from the "X" Field is to produce four (4) existing wells, namely wells X-1, X-2, X-3, and X-4 with an average oil rate of 143,5969 BBL/day, Recovery factor of 6.039% which produced for 22 years. The amount of OOIP for Field "X" is 23454 MSTB.

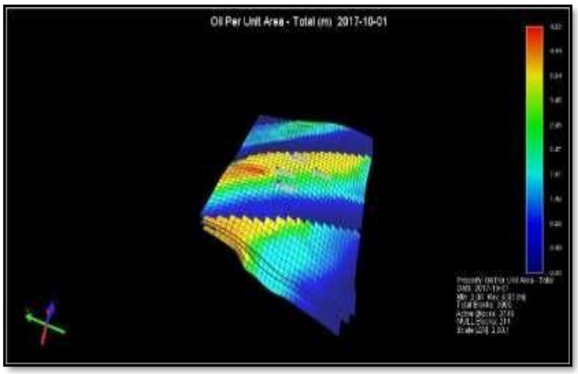

Figure 5. Field Development Simulation of Skenario-1

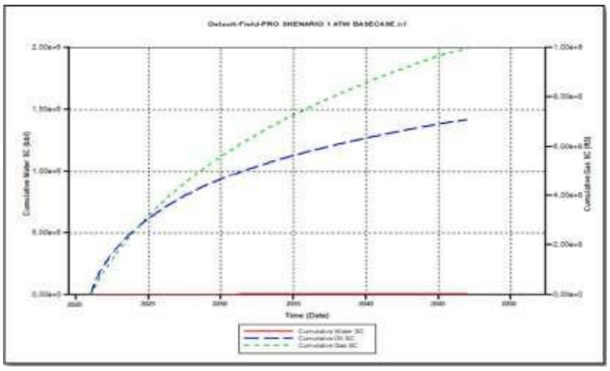

Figure 6. Production Cummulative of Scenario-1

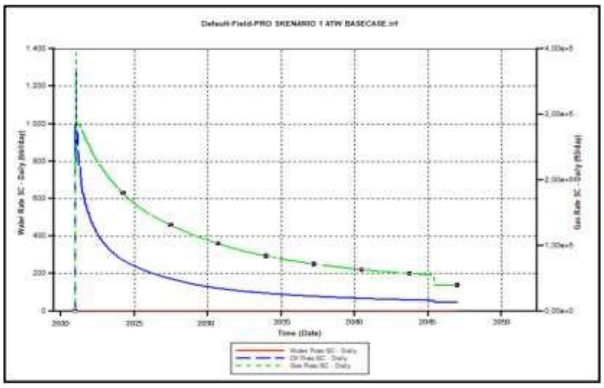

Figure 7. Production Performance of Skenario-1

Scenario-2

Scenario-2 of the "X" Field is to add five new wells or 5 infill wells, namely Infill-1, Infill-2, Infill-3, Infill-4, and Infill-5. In scenario 2, the average oil rate increases to 292.3119 BBL /day with a Recovery Factor of 12.3% produced until 2047.

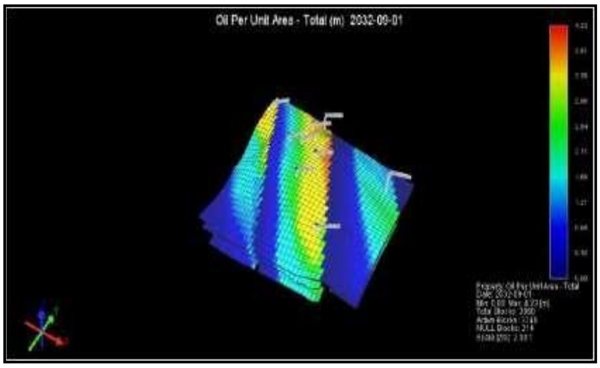

Figure 8. Field Development Simulation of Skenario-2

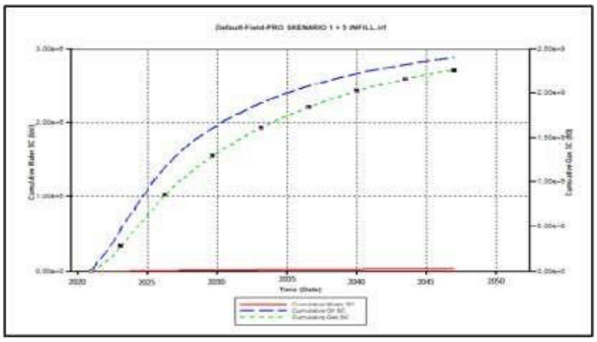

Figure 9. Production Cummulative of Scenario-2

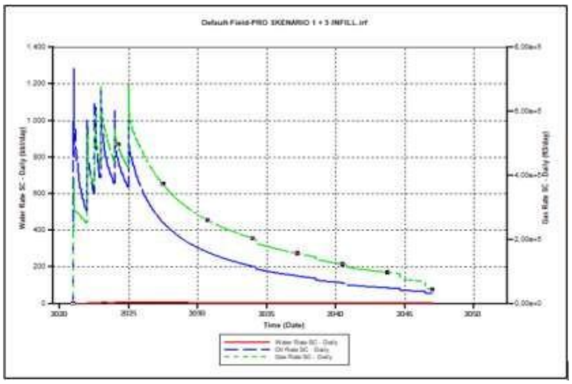

Figure 10. Production Performance of Skenario-2

Scenario-3

Scenario-3 from Field "X" is to add two pressure maintenance wells, namely PM-1 and PM-2. This scenario is a continuation of scenario 2 which is added with 2 pressure maintenance wells. In scenario 3, the average oil rate increases to 445.605 BBL /day with a Recovery Factor of 15.566% produced until 2047.

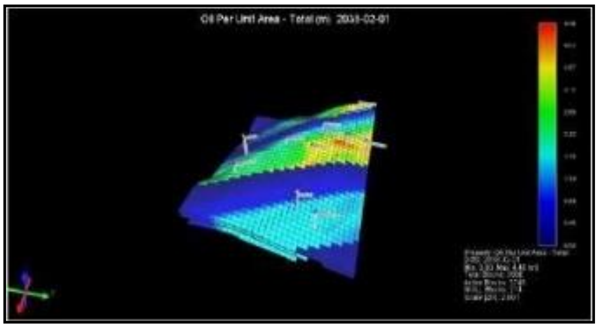

Figure 11. Field Development Simulation of Skenario-3

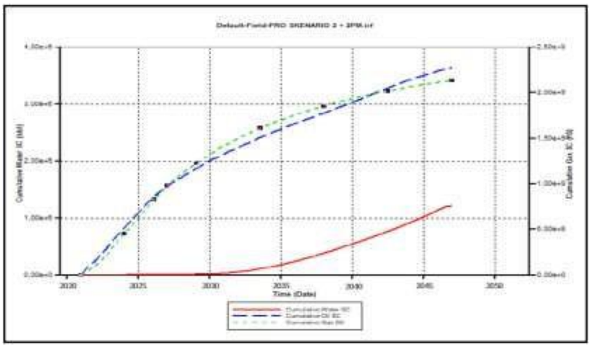

Figure 12. Production Cummulative of Scenario-3

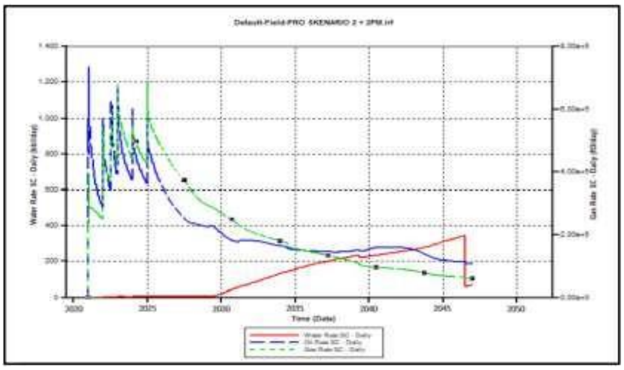

Figure 13. Production Performance of Skenario-3

Scenario-4

Scenario-4 from the "X" Field is to add two injection wells, namely water flooding consisting of WF-1 and WF-2 wells. This scenario is a continuation of scenario 3 which is added with 2 water flooding wells. In scenario 4, the average oil rate increases to 526,1006 BBL / d with a RecoveryFactor of 20.669% produced until 2047.

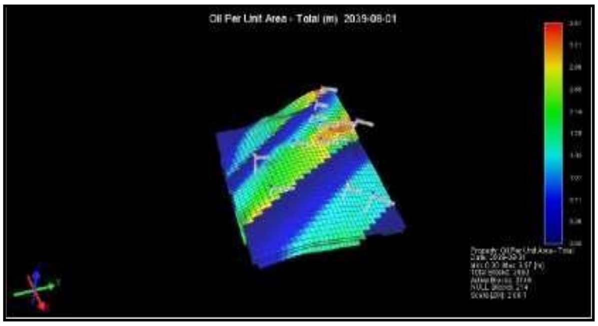

Figure 14. Field Development Simulation of Skenario-4

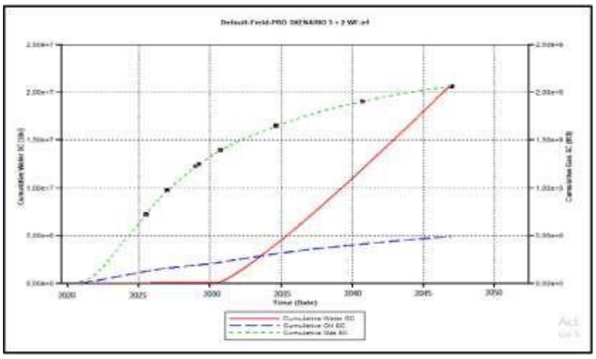

Figure 15. Production Cummulative of Scenario-4

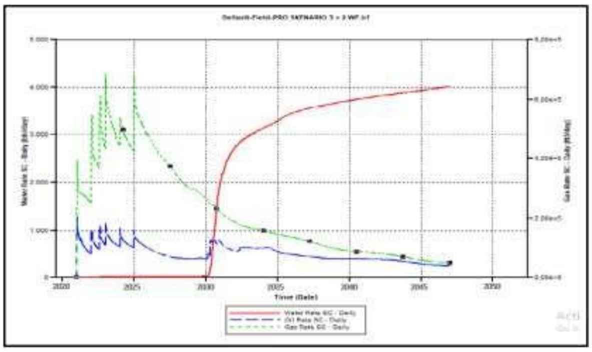

Figure 16. Production Performance of Skenario-4

Scenario-5

Scenario-5 from Field “X” is to add one infill well, one water flooding injection well, and one pressure maintenance injection well consisting of infill wells-6, WF-3 and PM-3. Water flooding injection wells are carried out at well X-4 because in 2030 well X-4 cannot produce or crosses the economic limit so well X-4 dies. Because of this, the X-4 well was used as a water flooding injection well. This scenario is a continuation of scenario 4 which is added with 1 water flooding well, 1 pressure maintenance well, and 1 infill well. In scenario 5, the average oil rate increases to 535.109 BBL/d with a Recovery Factor of 21.435% produced until 2047.

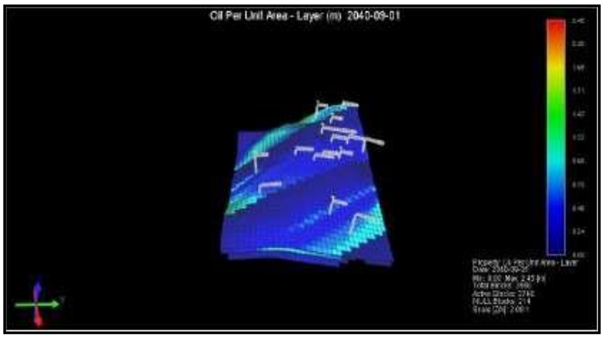

Figure 17. Field Development Simulation of Skenario-5

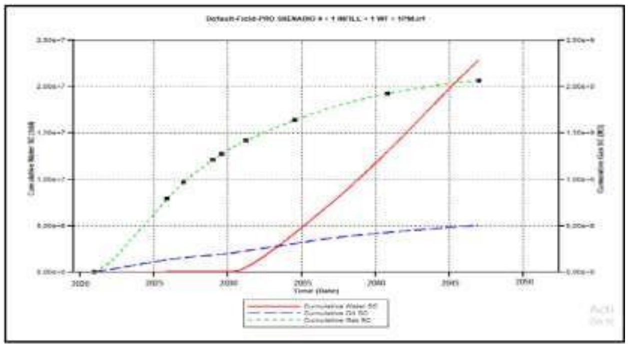

Figure 18. Production Cummulative of Scenario-5

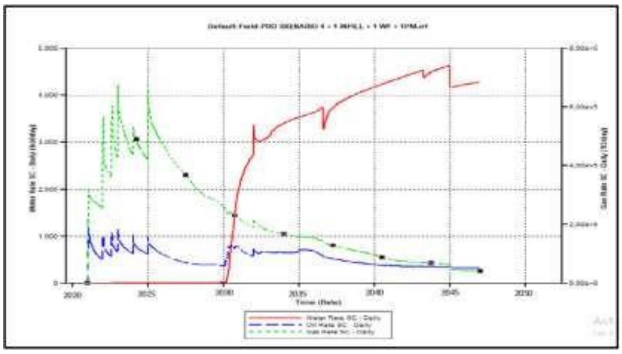

Figure 19. Production Performance of Skenario-5

Discussion

After the scenario from 1 to 5 is carried out, the next step is to calculate the RF value and production cumulative from each scenario. This step aims to determine the RF value and cumulative production in each scenario so that it can consider in which scenario "X" Field has a large RF value and cumulative production. In that scenario that will be developed in Field "X". The value of RF and cumulative production in each scenario can be shown in the table below.

Table 2. The Result of Recovery Factor (RF) and Cummulative Production values

Scen ario	Total Well	RF (%)	Cummulative Production (MMSTB)
1	4	6.039%	1416.5
2	9	12.29%	2883
3	11	15.566%	3650.9
4	13	20.669%	4847.7
5	15	21.435%	5027.4

From the table above, it can be seen that scenario 5 has the highest RF and cumulative production values compared to scenarios 1 to 4 with a total of 15 wells. and small cumulative production, namely amounting to 6,039% and 1416.5 MMSTB. Therefore it is necessary to develop the field by adding several production wells and injection wells from scenarios 2 to 5 to increase oil production in the "X" Field from 2020-2047. If the development scenario "X" is not carried out, it is predicted that Field "X" will not be able to produce again until 2030 because the field production value "X" is below the economic limit rate. In this case the economic limit rate is 5 STB / day.

In the field development "X", the total production and injection wells are 15 wells with the addition of wells up to scenario 5 being 11 wells from basecase / scenario-1. The oil well consists of 9 production wells (including 3 wells available in the "X" / basecase field and 6 infill wells) and 6 injection wells (including Waterflooding wells and Pressure Maintenance wells). In scenario 5 there is a change in the status of the well from a production well to an injection well because oil production is below 5 STB / day (small production). In addition, the RF value obtained in scenario-5 is 21,435% so that the increase in RF value from basecase / scenario-1 is 15.4%.

CONCLUSION

1. Field X consists of 3 productive layers which will be developed, each of which has oil reserves as follows:
   - Layer A1: 5,254 MMSTB
   - Layer A2: 11,604 MMSTB
   - Layer A3: 6,622 MMSTB
2. In field X, there are 4 wells that are already in production and based on the results of scenario 1 which is the basecase, the RF value is only around 6.039%. Scenario 1 only produces until 2030 so it is necessary to carry out further field development.
3. Based on the analysis of several scenarios with a production time of up to 2047, scenario 5 is the best scenario to develop Field X with a total of 15 wells. The cumulative oil production at Field X using scenario 5 is MMSTB with a recovery factor of 21.435%.
4. Based on the analysis results from field X, it can be seen that the more injection wells that are made, the oil production will also increase, this is due to the wider area of water sweeping, so that the remaining oil will also be swept away by the injection water.

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