Effect of different water injection rate on reservoir performance:A Case Study of Azadegan fractured oil reservoir

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Abstact

A naturally fractured reservoir may be divided vertically into several zones, i.e. gas cap, gas invaded, undersaturated oil, water invaded, and aquifer. Gravity drainage is the main oil producing mechanism in gas invaded zone. Depending on the wettability of the reservoir rock, the main recovery mechanism in water invaded zone will be gravity drainage or imbibition for oil wet or water wet rock, respectively.

When production from a reservoir starts after a while, the production will decrease because of reservoir depletion. To enhance the final recovery there are some scenarios, one of them is water injection. Water injection has been the most used recovery method in petroleum industries due to its advantages. The injected water displaces oil from porous media to producing wells and maintains the reservoir pressure above of saturation pressure, increasing the recovery process efficiently. One of important variable is injection rate that influence the water injection performance, therefore by simulating the reservoir with different injection rate we could obtain the proper one for reservoir development.

The goal of this work is to study the impact of water injection rate on the reservoir performance and simulate the water injection performance in reservoir scale. This work is a case study on Azadegan oil reservoir.

This work is done on investigation of water injection in sector A of Azadegan oil reservoir that it has a dual porosity manner. Water injection simulations were performed at different rates. Before any injections the plateau time is about 5000 days. After putting the injection wells and applies the rates it is observed that the plateau time is increased. Higher water injection rates results in higher oil production so water injection is suitable for this dual porosity case. Because water moves through fractures quickly and so capillary imbibition process can help push the oil to producing well.

Keywords: Azadegan oil reservoir, water injection, reservoir performance, fracture reservoir

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Master student-۱

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1- Introduction

The south-west of Iran is one of the areas that has the highest number of carbonate fractured reservoir. A naturally fracture reservoir consists of two distinct regions, a matrix region containing finer pores and having a high storage capacity, but a low permeability, is interconnected with the fracture network region, which has a low storage capacity, but higher permeability.

Most reservoir rocks are to some extent fractured, but the fractures have in many cases insignificant effect on fluid flow performance and may be ignored. In naturally fractured reservoirs, defined as reservoirs where the fractures have a significant impact on performance and oil recovery, fracture properties should be evaluated because they control the efficiency of oil production. Fractures are usually caused by brittle failure induced by geological features such as folding, faulting, weathering and release of lithostatic (overburden) pressure [1].

When production from a reservoir starts after a while, the oil production will decrease because the reservoir pressure decreased. Water injection has been the most used recovery method in petroleum industries due to its advantages: operational simplicity, low cost and favorable characteristics of displacemen.

1-1- Fracture reservoir zones and recovery mechanisms

A fractured reservoir may be divided vertically into several distinct zones sometime in its depletion period. These zones are mainly: gas cap, gas-invaded, gassing, under saturated oil, water invaded, and water zone .

The gassing zone consists of the portion of the reservoir where the pressure of the matrix is below the prevailing bubble-point pressure. In the lower portion of this zone, where $Sg < Sgc$, a solution gas drive mechanism takes place in the known sense of it, except for the volume of gas transfer due to diffusion. When free gas reaches its critical saturation in the upper portion of gassing zone, gas moves upward due to its lower density than oil. Therefore, the recovery due to the solution-gas drive mechanism is mainly a function of the rate of pressure drop and the resulting effect determines the final fluid saturation in the blocks.

In the under saturated portion of the reservoir two processes take place: a- expansion of the liquids and b- diffusion of gas through oil from matrix to the fracture. The diffusion process causes the oil in the matrix to lose some of its gas and therefore, oil from the fracture replaces the equivalent volume of lost gas. Gas and water-invaded zones are those portions of the reservoir in which oil saturated blocks are surrounded by gas or water within the fractures .

In a gas invaded zone, oil is draining out of these blocks essentially due to gravity drainage.

In a water invaded zone, for the case of water wettability in addition to gravity segregation, capillary imbibition also influences the recovery performance. In a strongly oil-wet reservoir, oil can be displaced from the matrix by water only by gravity forces, with capillary forces trying to retain the oil. In such case the water/oil gravity drainage process, as it is taking place below the fracture oil/water contact, is entirely analogous to the gas/oil gravity drainage process.

Oil displaced into the fractures will not be re-absorbed spontaneously by an overlying matrix block if the block is water-wet. In this case the ultimate oil recovery of a stack of blocks is equal to the movable oil, since in this case there is no capillary hold-up of oil. In a (strongly) water-wet reservoir the displacement of oil from the matrix will often be dominated by capillary force, and hence be called water/oil imbibition, The rate at which oil is produced

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from matrix block by this process depends on a number of parameters: matrix permeability, fluid viscosities, relative permeability's, capillary pressure and the dimensions of a matrix block.

Two different imbibition regimes can be considered. The co-current and counter current flow. Initially the flow regime is co-current i.e. oil and water flow have the same direction then, as soon as block is surrounded by water, the flow changes to counter current flow process, i.e. water and oil flow have two opposite direction [2].
In this study, simulation study results of the Azadegan oil reservoir in the south – west of Iran is presented. Water injection simulations were performed at different rates and water injection performance was studing. We used Eclipse 100 reservoir simulator.

2- State of Problem

The reservoir under this study started production from 1927/01/01. After a while, the production had to be decreased because of high gas rate production and this limitation in surface facilities is the main reason to do the following study.

To optimize our reservoir production, Water Injection scenarios is suggested.

This reservoir has the capability to be modeled in both single porosity and dual porosity as it is not completely proven to be one or the other, but my work is to do it in dual porosity .

3- Reservoir description

The Azadegan oil field is an oil field in Iran. The field is located 80 kilometres (50 mi) west of Ahvaz close to the Iraqi border (figure 1). The field has an approximate area of 900 square kilometres
The oil field was discovered in 1999. Iranian authorities claims that Azadegan field has oil-in-place reserves of about 33.2 billion barrels (5.28×10^9 m^3) and recoverable resources estimated at about 5.2 billion barrels (830×10^6 m^3). It is one of the NIOC Recent Discoveries and the biggest oil field found in Iran, in the last 30 years.

Figure1. Position of azadegan oil field in Iranian oil filed map

The reservoir is split into four sectors by means three big seal faults (figure 2), so our focus is mainly on three sectors in which oil producers are located. The forth sector which does not

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have any producer will not be developed in this work. All producers have simple completions like casing and perforation and they are all fully completed in reservoir thickness.

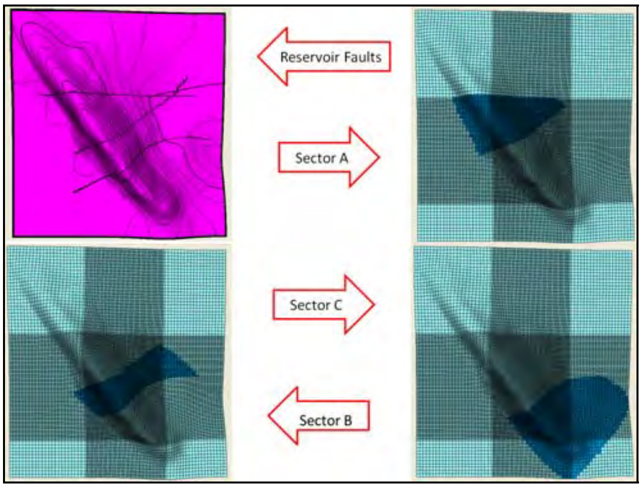

Figure 2. Reservoir sectors

3-1- Sector model description

A part of Azadegan reservoir was selected as sector model. In this study we select sector A.

3-2- Fluid and Rock properties

Flash and differential PVT tests were performed on samples from Sector A. The experimental data was used for analysis by PVT software; the simulated PVT data are given in below Table.

Table 1.Fluid properties

R_s (SCf/STB)	P_{bub} (psia)	B_{ob} (bbl/STB)	μo (cp)
2.725	18.24	1.017	0.88
14.14	32.03	1.045	0.823
24.85	45.82	1.07	0.772
36.28	60.64	1.096	0.721
46.68	74.09	1.119	0.678
56.35	86.5	1.14	0.641
66.93	99.94	1.164	0.603
75.12	110.3	1.181	0.577
85.88	123.7	1.205	0.545
111.4	155.1	1.259	0.482
	165	1.249	0.55
	175	1.239	0.6

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SCAL tests data including relative permeabilities i.e. krog, krow, krg, krog and capillary pressure i.e. Pc-ow, Pc-owi, Pc-og were normalized for sector model and are given Tables 2and 3.

Table 2. SCAL tests data for gas oil system

S_g	K_{rg}	K_{rog}	P_{cog}
0	0	0.72	0
0.02	0	0.622	0.034
0.05	0.015	0.498	0.061
0.07	0.026	0.427	0.073
0.1	0.042	0.338	0.09
0.12	0.056	0.288	0.095
0.15	0.078	0.226	0.102
s0.17	0.093	0.191	0.107
0.2	0.116	0.147	0.115
0.22	0.134	0.122	0.12
0.25	0.161	0.091	0.128
0.27	0.178	0.073	0.133
0.3	0.204	0.051	0.141
0.32	0.223	0.039	0.146
0.35	0.251	0.023	0.154
0.37	0.272	0.015	0.159
0.4	0.303	0.007	0.167
0.42	0.325	0.003	0.173
0.45	0.359	0.003	0.183
0.47	0.383	0	0.193
0.5	0.42	0	0.207
0.52	0.446	0	0.217
0.55	0.486	0	0.232
0.57	0.514	0	0.242
0.6	0.557	0	0.256
0.62	0.59	0	0.276
0.65	0.64	0	0.305
0.67	0.673	0	0.329
0.7	0.723	0	0.364
0.72	0.756	0	0.409
0.75	0.806	0	0.476
0.77	0.84	0	0.571
0.8	0.89	0	0.713
0.82	0.924	0	1.312

Table 3. SCAL tests data for oil water system

S_w	K_{rw}	K_{row}	P_{cow}
0.18	0	0.72	0.61
0.2	0.011	0.598	0.34
0.23	0.027	0.451	0.232
0.25	0.038	0.373	0.16
0.28	0.051	0.28	0.13
0.3	0.059	0.231	0.11
0.33	0.074	0.175	0.092
0.35	0.084	0.146	0.08
0.38	0.1	0.112	0.068
0.4	0.111	0.094	0.06
0.43	0.127	0.072	0.048
0.45	0.137	0.06	0.04
0.48	0.154	0.045	0.036
0.5	0.165	0.035	0.034
0.53	0.183	0.023	0.031
0.55	0.195	0.015	0.029
0.58	0.223	0.007	0.027
0.6	0.242	0.003	0.025
0.63	0.277	0.002	0.023
0.65	0.3	0.001	0.021
0.68	0.341	0	0.019
0.7	0.369	0	0.017
0.73	0.406	0	0.015
0.75	0.43	0	0.014
0.78	0.436	0	0.012
0.8	0.44	0	0.01
0.83	0.446	0	0.008
0.85	0.45	0	0.007
0.88	0.456	0	0.005
0.9	0.46	0	0.003
0.93	0.466	0	0.002
0.95	0.47	0	0.002
0.98	0.476	0	7E-04
1	0.48	0	0

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3-3- Injection wells

The injection wells are drilled in below positions

Well-01 (x,y)=(22,81)

Well-02 (x,y)=(50,31)

Well-02 (x,y)=(65,57)

and perforated in block 14.

Oil production rate in sector A is 40 (sm^3/day)

Table 4.Injection wells geometry (x, y z)

Well Name	Well Type	Surface X	Surface Y	TD (MD)
A_WINJ_01	Injection water	543200	3764430	1500
A_WINJ_02	Injection water	544791	3766915	1500
A_WINJ_03	Injection water	545549	3766103	1500

Table 5.wells properties

Well Name	Complition	TOP (MD)	BOT (MD)
A_WINJ_01	Casing	0	1500
A_WINJ_01	Perforation	893.34	985.72
A_WINJ_02	Casing	0	1500
A_WINJ_02	Perforation	914.78	971.73
A_WINJ_03	Casing	0	1500
A_WINJ_03	Perforation	916.62	970.21

3-4- Production wells

Figure 9 shows the list of wells present in the field. All producers have simple completions like casing and perforation and they are all fully completed in reservoir thickness.

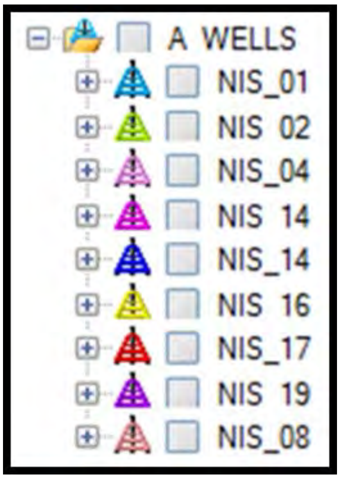

Figure 3. list of production wells present in the field

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3-5- Data analysis

In this project, we applied a dual continuum approach in black oil simulator (ECLIPS 100) First of all we run the base case and see the results. Then add 3 well to number of wells in data file WELLDIMS.

The fifth record in WCONINJE is Surface flow rate target or upper limit (BHP max=5000 psia). Each time we change it and observe the results in office.

4- Result & discussion

The results of simulation can be observed from Figures 4- 19.

Figures 4-8 show reservoir performance without water injection. Fracture oil and gas saturation at the end of production can be seen in Figure 4 and figure 5 Respectively. It shows that there is a huge gas cap at the end when there is not water injection.

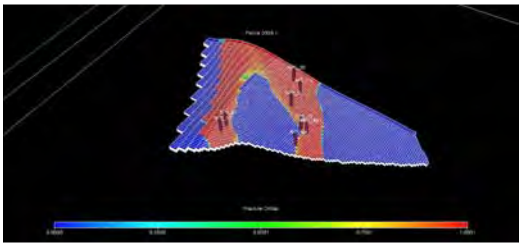

Figure 4. Fracture oil saturation at the end (without injection well)

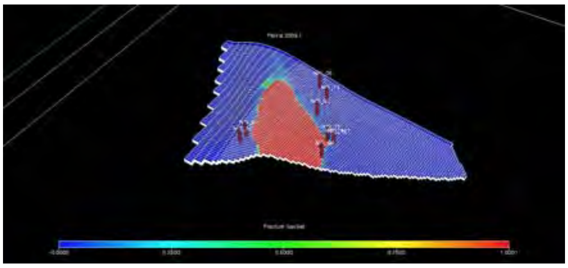

Figure 5. Fracture gas saturation at the end (without injection well)

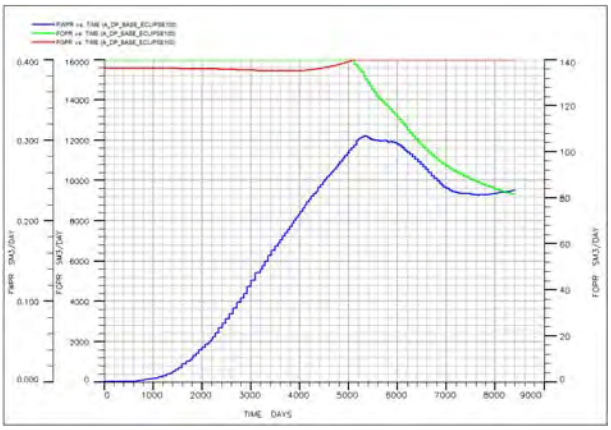

Figure 6. Water, gas and oil production rates without injection

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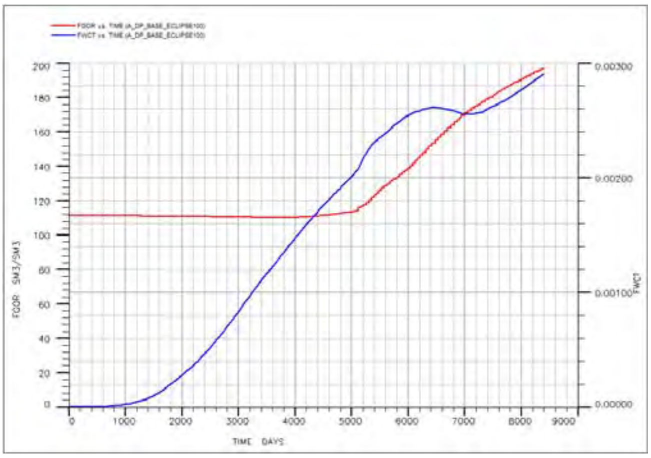

Figure 7. FWC and FGOR without injection

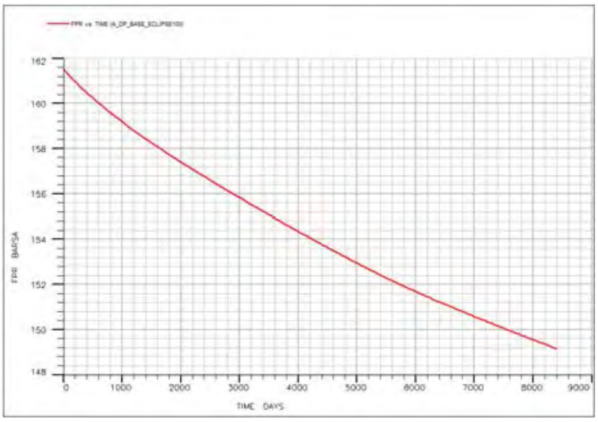

Figure 8. Field pressure (FPR) without injection

Results of simulation after water injection can be seen in figure 9-19
Figures 9-13 show reservoir performance when we have 50 SM^3/Day injection rate.

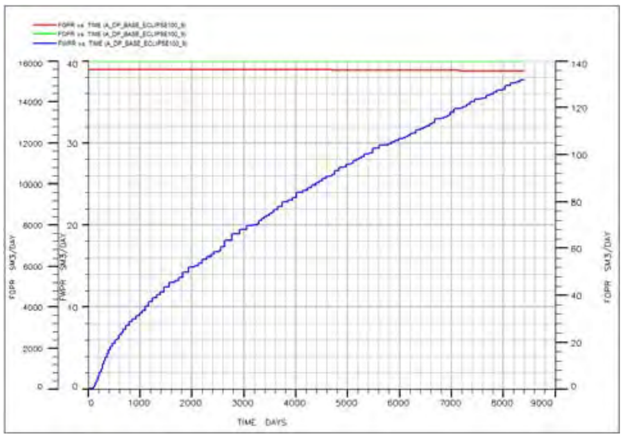

Figure 9. Water, gas and oil production rates

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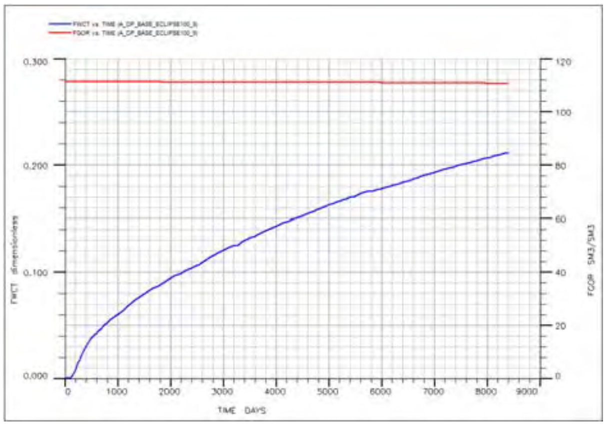

Figure 10. Field water cut (FWC) and field gas oil ratio (FGOR)

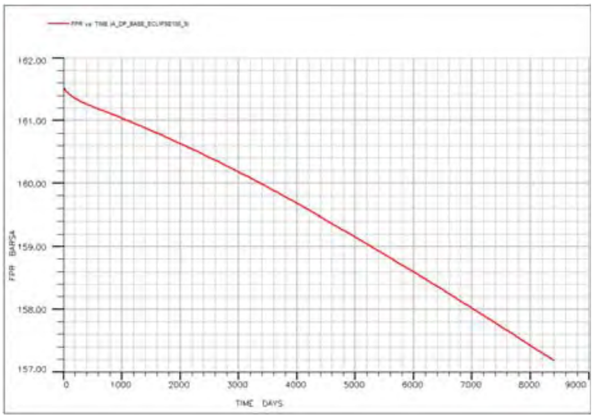

Figure 11. Field reservoir pressure (FPR)

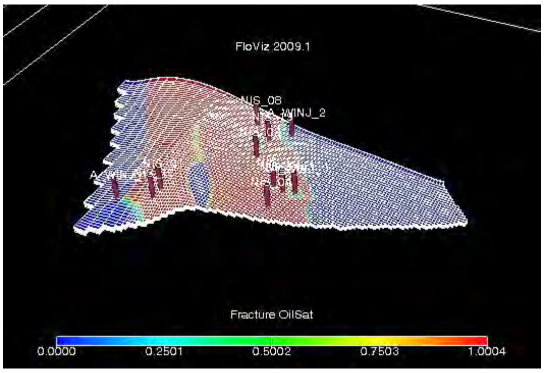

Figure 12. Fracture oil saturation at the end

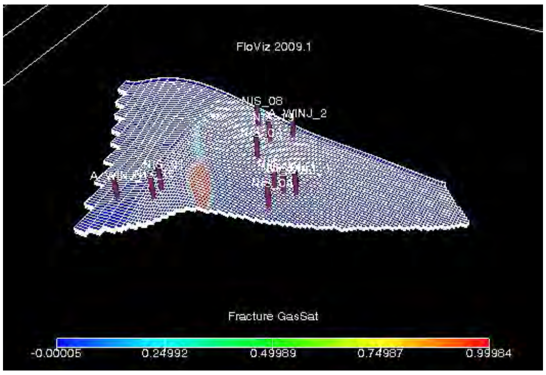

Figure 13. Fracture gas saturation at the end

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Comparison of figures 4,5 with figures 12,13 demonstrate that when we have water injection, Gas cap decreased.

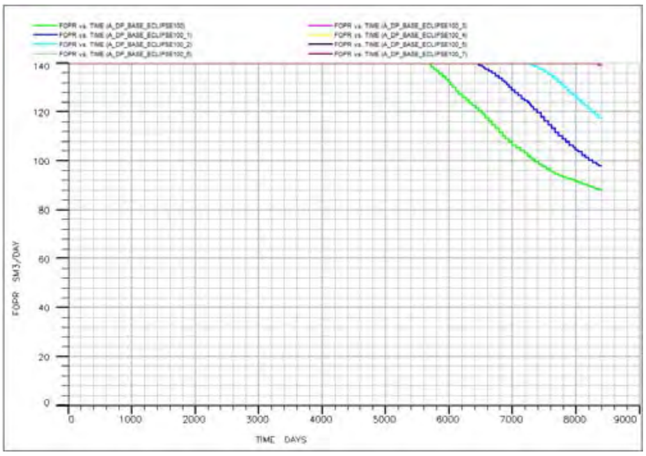

Figure 14. Field Oil Production Rate (FOPR) for Qinj=5, 10, 15, 20, 25 SM^3/Day

Comparison of various scenarios can be seen In figure 14. It shows that Plateau time increases by increasing the injection rate.It demonstrate that capillary imbibition will be developed and help push the oil to producing well.

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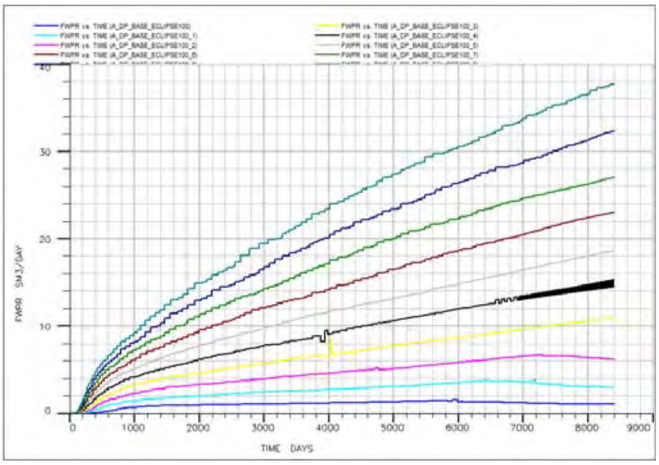

Figure 15. Field water production rate (FWPR) comparison for Qinj=5, 10, 15, 20, 25, 30, 35, 40, 45, 50 SM^3/Day.

As we can see from the figure of water production curves (figure 15), water production in more than 15 SM^3/Day water injection rate,water injection rises up rapidly.

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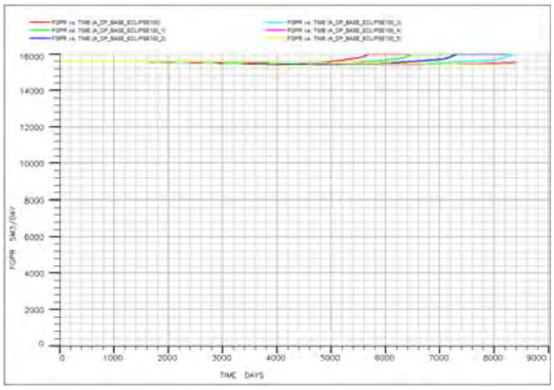

Figure 16. Field Gas Production Rate (FGPR) for Qinj=5, 10, 15, 20, 25, 30 SM^3/Day

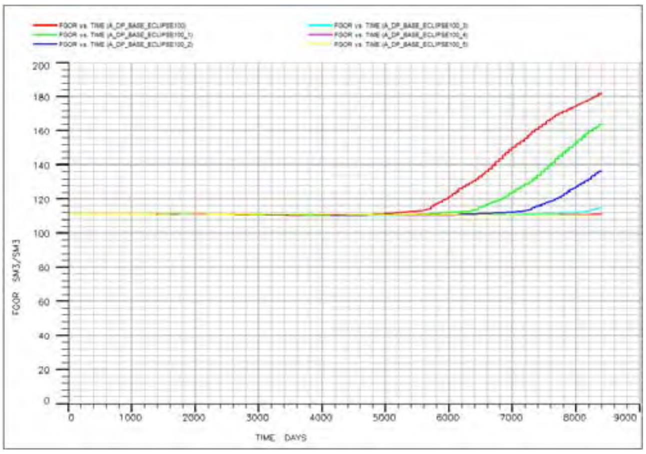

Figure 17. FGOR for Qinj=5, 10, 15, 20, 25, 30 SM^3/Day

Field gas production rate (FGPR) from figure 16 shows that gas produces has not significant change with various water injection rate but Field GOR is rapidly decreased in water injection rate more than 15 SM^3/Day (figure 17).

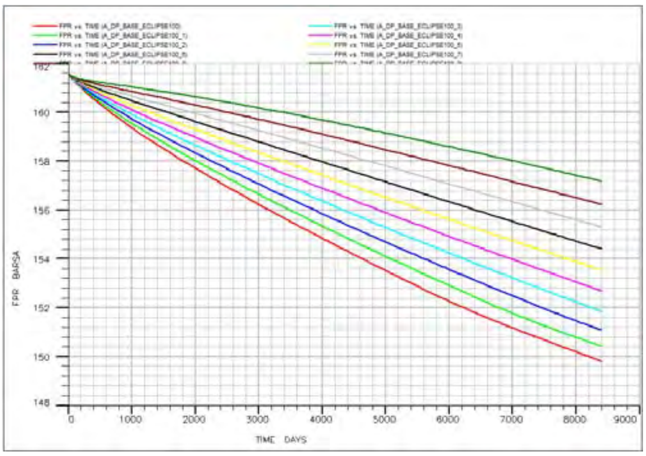

Figure 18. Compresion of field reservoir pressure (FPR) for Qinj=5, 10, 15, 20, 25, 30, 35, 40, 45, 50 SM^3/Day

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As figure 18 shows that water injection support the reservoir pressure. So pressure maintenance occur.

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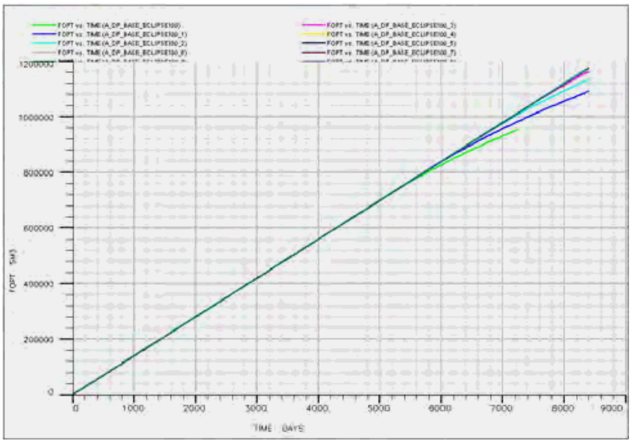

Figure 19. Field Oil Production Total (FOPT) for Qinj=5, 10, 15, 20, 25, 30, 35, 40, 45, 50 SM^3/Day

Figure 19 shows that oil production increases from 96000 m^3 to 120000 m^3 by increasing the water injection rate. As it can be seen in 50 SM^3/Day water injection rate is giving much better cumulative produced oil than other cases.

5- Conclusion

Above the various scenarios of water injection is discussed. Finally we conclude that:

1. Water production rate is very low till Qinj =15 SM^3/Day and doesn’t make significant problem. So it will be Higher if we inject more water.

2. After water injection, breakthrough will be sooner at fracture, but reservoir pressure will be maintained and capillary imbibitions process will be better so plateau time increase.

3. It is obvious when water rate increase, producing GOR will be decrease so oil production rate increase.

4. In a water invaded zone, for this case, in addition to gravity segregation, capillary imbibition also increase the recovery performance so increase the plateau time.

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