THE UNIVERSITY of TULSA

McDougall School of Petroleum Engineering

Reservoir Engineering 2 Midterm project

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- ***<u>Letter of Transmittal</u>***

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The purpose of part one of the midterm project was to interrogate the differences between the calculations in Excel and Eclipse when considering a 1D waterflood project with one injector and one producer. The purpose of part two of the project was to construct a 2D waterflood project in both Eclipse and CMG when using liquid rate and bottom hole pressure constraints, and to make a comparison of the results between the two constraints for each program.

Enclosed in this report are all requested results, graphs, and discussion from the two parts of the project.

Regards,

Abuzar Patel.

Part 1

Description: A 1-D water flood project is under consideration for a reservoir that is 300 ft wide, 20 ft thick, and 1000 ft long. The reservoir is horizontal and has porosity of 0.2 and an initial water saturation of 0.2 which is consider immobile. Residual oil saturation is 0.2. One producer is located on the one end of the reservoir and one injector is located on the other end. The injection rate is 300 bbl/day. Viscosity of water and oil are 1 and 2 cp. The relative permeability are given as: $krw = 0.8 * S4$; $kro = (1 - S)^2$

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The water flood duration is when water cut reaches 0.98.

You are asked to do following:

1. Calculate waterflood duration in days.

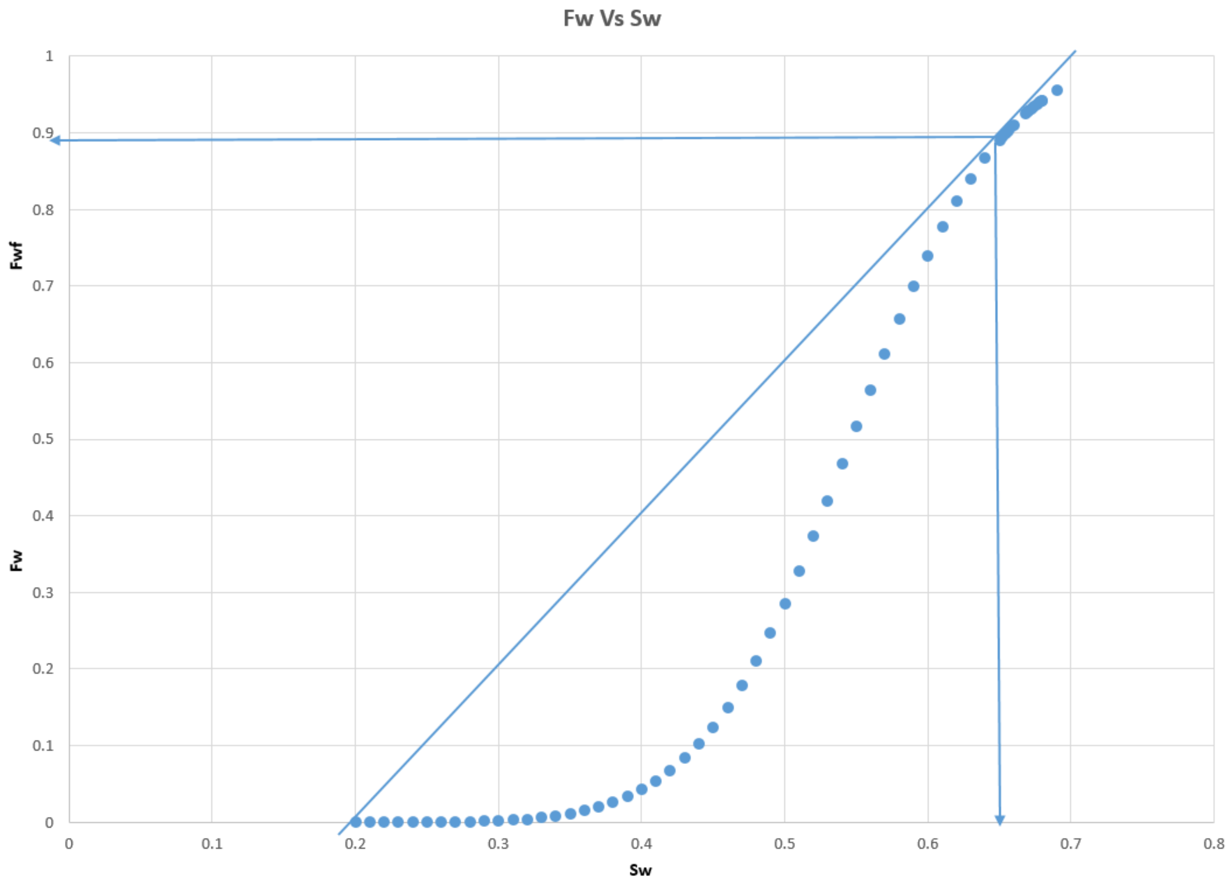
2. Calculate water breakthrough time in days.

3. Calculate cumulative oil production and plot cumulative oil production vs time, compare your excel and Eclipse results.

4. Calculate oil production rate and plot oil production rate vs time, compare your excel and Eclipse results.

Results

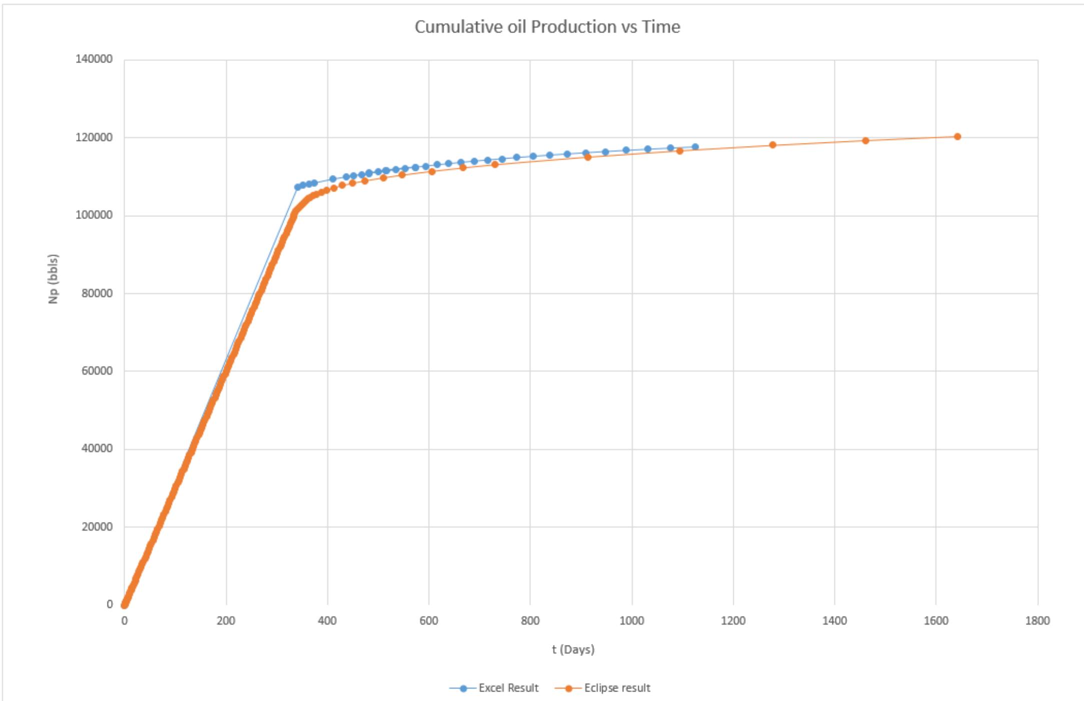
To begin with we firstly used the waterflood inputs to design a Buckley-Leverett type solution in Excel. The first step in Buckley-Leverett type was to construct the fractional flow of water vs. saturation plot for this reservoir.



As we can see from the above graph that our Fwf is almost to be 0.9 in actual 0.899 and Sw to be 0.65. Using the values found from the frictional flow curve and necessary excel calculations we found the following :

1) Breakthrough Time **- 352 days**
2) Cumulative oil production – 117650 bbls
3) Waterflood Duration Days – 1125 Days

Next we used Eclipse using the same parameters for the same reservoir and calculated cumulative oil production vs time and oil production rate vs time for both excel and eclipse. Our whole point here was to get similar result for excel and eclipse.



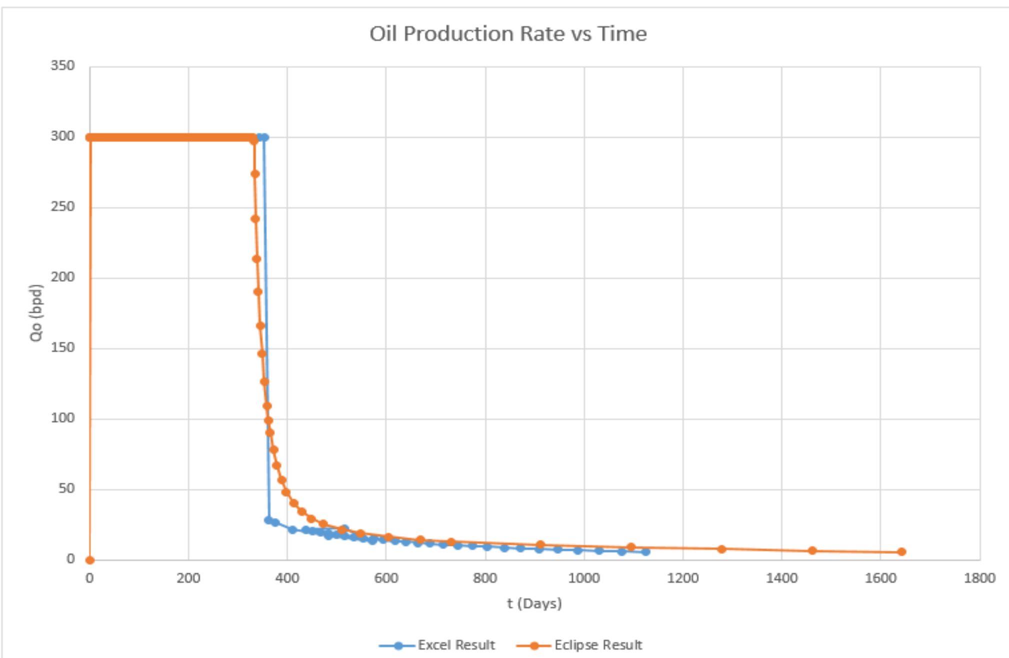
The Cumulative oil production graph clearly show similar result between excel and eclipse. Eclipse show a slight higher cumulative oil production standing at 120385 bbls however excel shows 117,649 bbls. This difference is due to the length. Eclipse data runs for a period of 1642 days on the other hand excel time is 1125 days. The difference of 517 days causes the difference in the cumulative oil production

This is a plot of Oil production rate vs time. Once again we can see similar trends from excel and eclipse.
Here we have a straight horizontal line at 300 bpd which is our injection rate. Once the break through time is reached we see a big fall in our oil production rate. For excel breakthrough time was found to be 352 days but for eclipse it was almost 330 days. A difference of 20 days can be considered as a small difference and hence graphs are similar.

<u>Part 2</u>

Description:

The problem requires you to run a 2-D water flooding case in a 2-phase oil and water reservoir using Eclipse and CMG. The reservoir can be considered as a 100*100*3-grid system. The size of each grid block is 30ft*30ft with a constant thickness of 30 ft in in all three layers. There are



one injector (I1) and four producers (P1 to P4) deployed a five-spot pattern in the reservoir.

The depth of the top layer is 7000 ft. Porosity is 0.17 for all grid blocks. Permeability are 150 md, 100 md and 50 md for both x and y direction in the upper, middle and lower layer. Assume permeability in z direction is very small. The initial pressure of the reservoir is 4000 psi. Suppose your wells are operated by BHP, 7000 psi for injector and 3300 psi for producers.

Initial water saturation is 0.2, irreducible water saturation is 0.2 for all grid blocks. Corey correlation of relative permeability is applied with the following properties:

$krw = 0.8 * S4; kro = (1 - S)^{2}$

Wells Locations:

WELLS	LOCATIONS
I1	(50,51)
P1	(17,13)
P2	(90,13
P3	(80,65)
P4	(20,77)

1) Build your data file using the given properties. You can assume reasonable numbers if some properties you think are necessary but not given. Your data file must be error free.

2) Plot Cumulative oil production vs time, oil and water production rate vs time for producers

3) Determine water breakthrough time in days, and cumulative oil production in bbls for each producer.

4) Suppose you want to control the injector and producers by flow rate instead of BHP. Set injection rate to 4400 stb/day and well production liquid rate target to 1100 stb/day. Water flood time duration is 20 years. Determine water breakthrough time by layer, and cumulative oil production in bbls for each producer. Plot Cumulative oil production vs time, oil and water production rate vs time for producers.

Bonus questions:

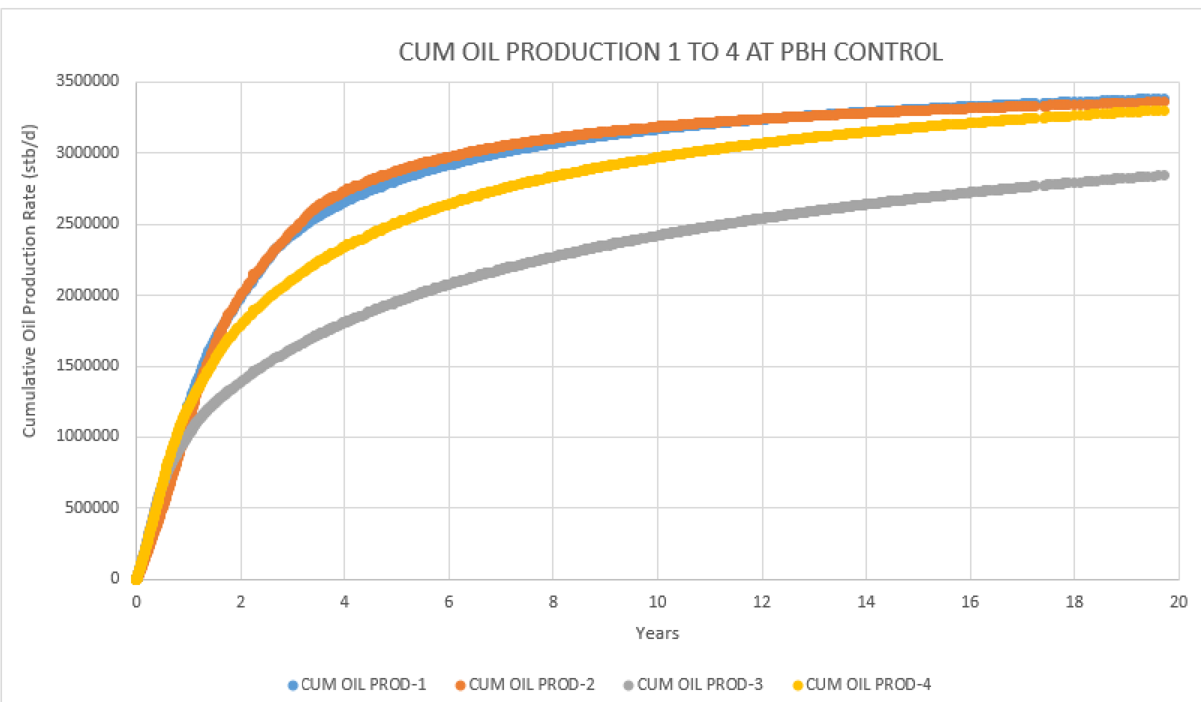
Use CMG to repeat 1 -4.

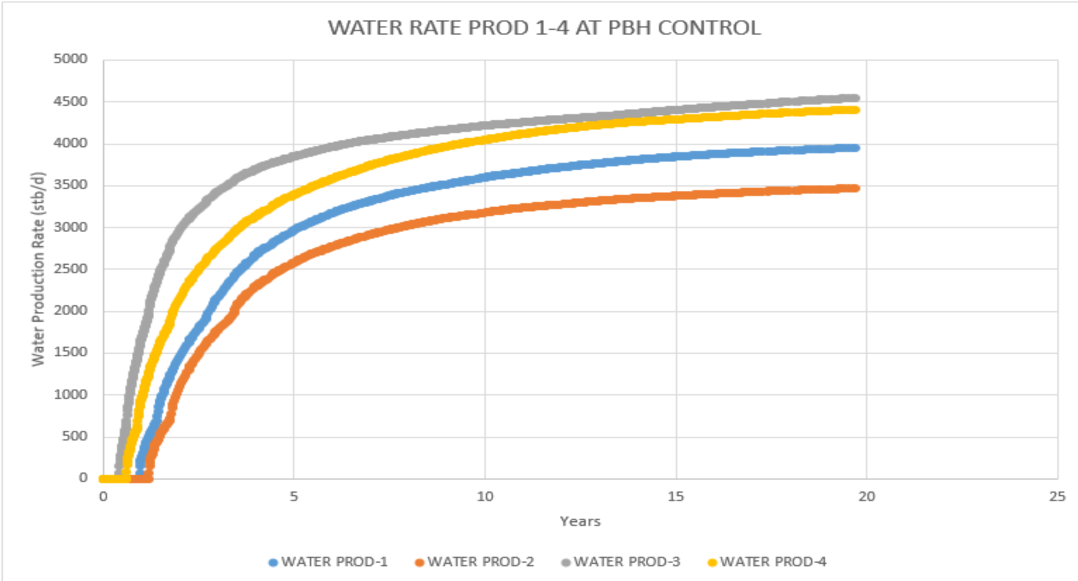
Results:

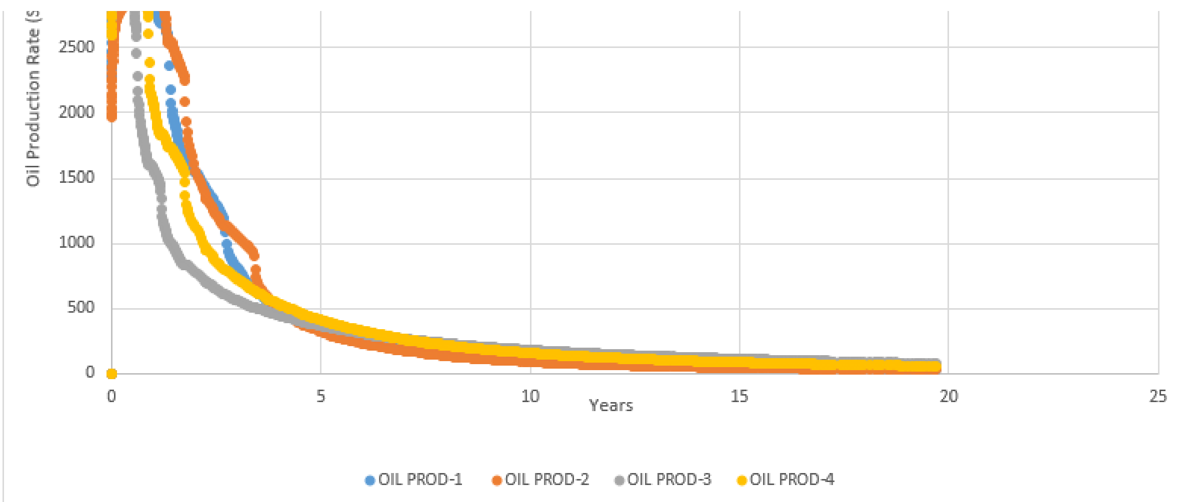
Firstly we created eclipse file for the given inputs and made sure it was free of errors. We ran the eclipse file for the first case which was at constant bottom hole pressure for four producers and one injector. Injector rate was set at a 7000 psi where as producers were at 3300 psi. With the given inputs we created results for cumulative oil production, oil production rate and water rate vs time for all four producers. The graphs are given below:

CONSTANT PBH CONTROL

The above graph tells us about relationship between the break through time and cumulative oil production. Producer 2 has the longest breakthrough time and therefore has the highest cumulative oil production rate. Producer one show similar results as producer 2. Producer three has the fastest breakthrough time and therefore the least cumulative oil production rate. Producer four lies just before producer three.





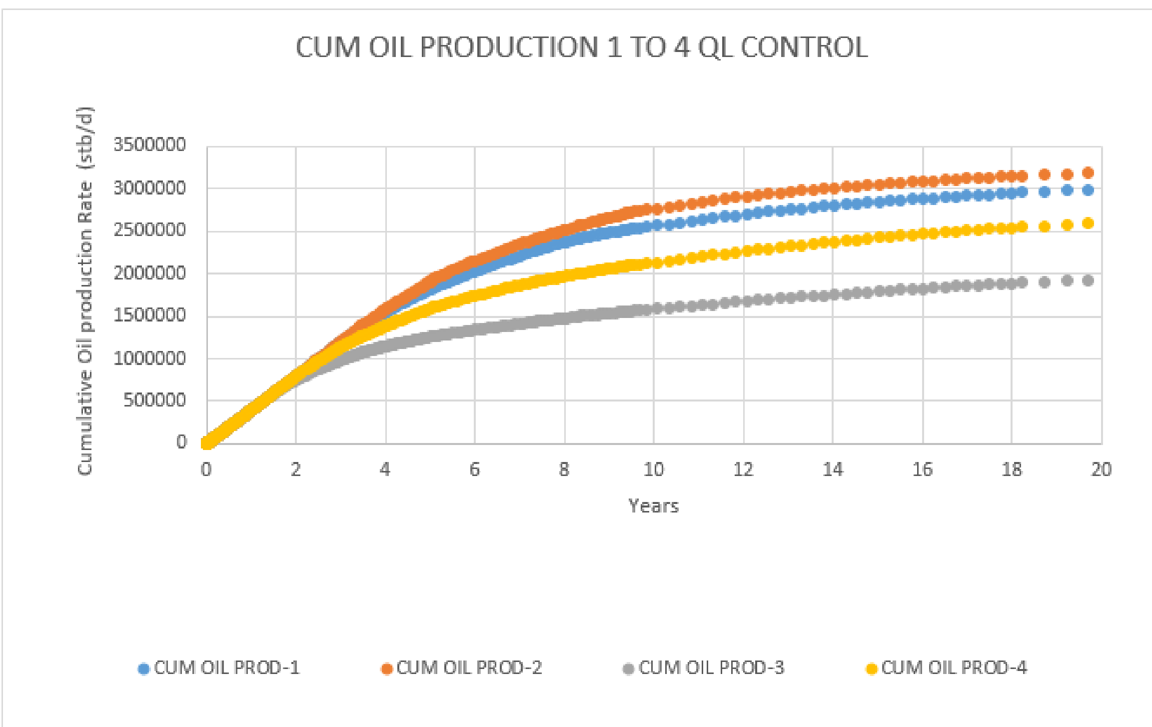


The above graph is of oil production rate vs time. Initially for a short period of time the oil production rate increases and then we observe three dips before achieving a steady decline. This as a result of the eclipse constant bottomhole pressure constrain and due to the different breakthrough time for each layer in the formation which in turn is due to the different permeability of the layers.

Three different breakthrough time is also observed in the above graph. Each producer increases sharply from zero, this is at the initial breakthrough time and then slight jump again for the second and the third breakthrough time. Note three different layers hence three different breakthrough times.

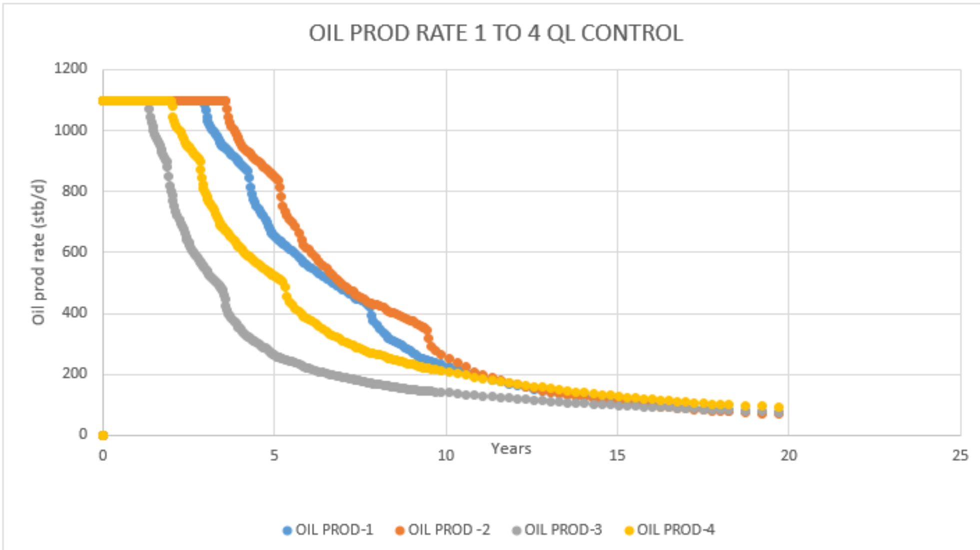
In conclusion we found the initial breakthrough time for producers one to four to be 338 days, 427 days, 145 days and 216 days respectively. Also we found the cumulative oil production for producers one to four to be 3384590 bbl, 3361349 bbl, 2847924 bbl and 3304058 bbl respectively. Total oil production was found to be 12897922bbls.

After using the constant bottomhole pressure constrain on eclipse we switched it to constant flowrate. In this case our injector rate was set at 4400 stb/d and producers were set at 1100 stb/d. After running the Eclipse we produced the following plots for cumulative oil production, oil rate and water rate vs time.

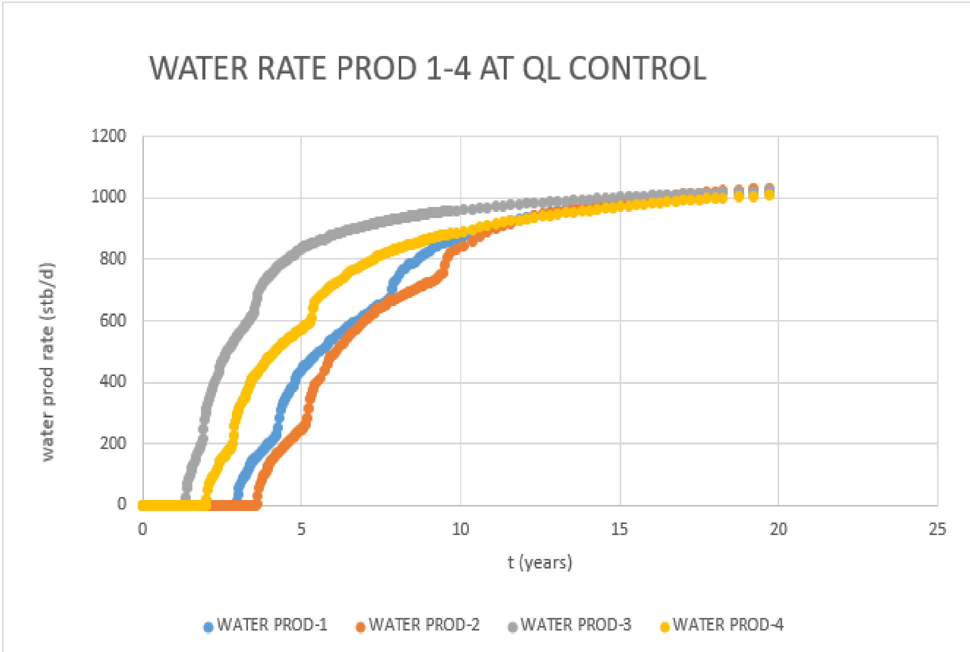


The graph above of cumulative oil production for liquid control rate shows similar relationship, between the breakthrough time and cumulative oil production, to constant bottom hole pressure graph. The relationship still holds true for both the cases.

The oil production rate graph for liquid control is different than constant bottomhole pressure



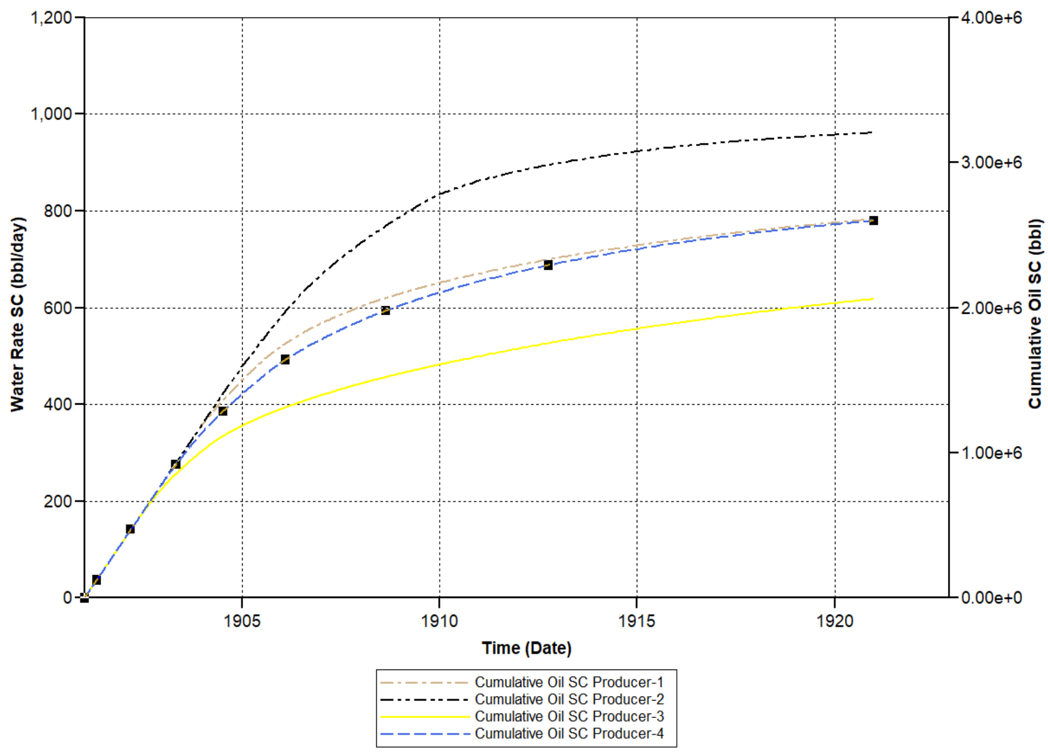
case. As we can see from the graph the oil production rate is constant and much lower in this case before initial break through time for each producers. After breakthrough just like the water production (see graph below) the graph displays three different breakthroughs for each producer.

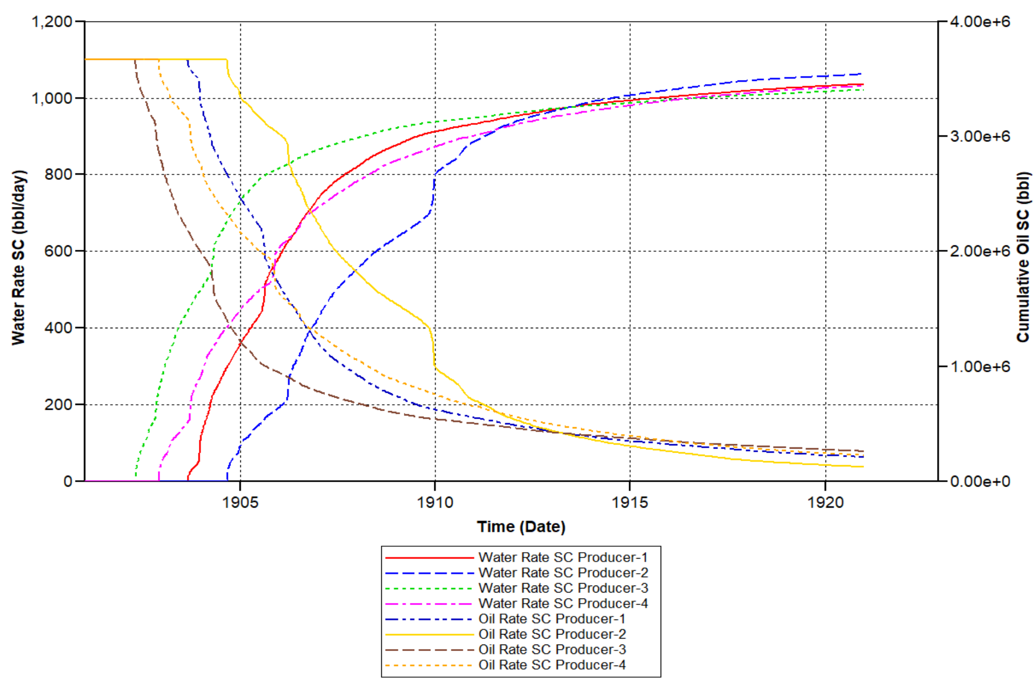


In conclusion we found the initial breakthrough time for producers one to four to be 1065 days, 1299 days, 470 days and 709 days respectively. Also we found the cumulative oil production for producers one to four to be 3002142 bbls, 3199311 bbls, 1943736 bbsl and 2611555 bbls respectively. Total oil production was found to be 10756744bbls. Once again in this case producer 3 has the earliest breakthrough time and the lowest cumulative oil production. With the constant liquid rate it is observed to have higher breakthrough times and lower cumulative oil production than constant bottom hole pressure case. This is because much more water was injected.

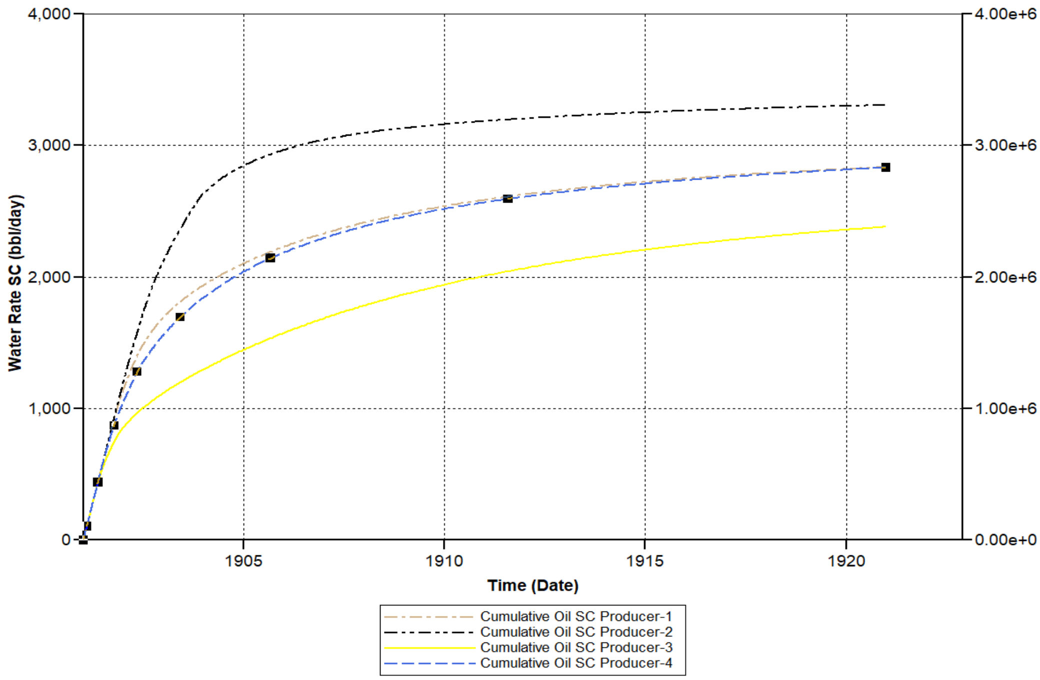
Bonus Part

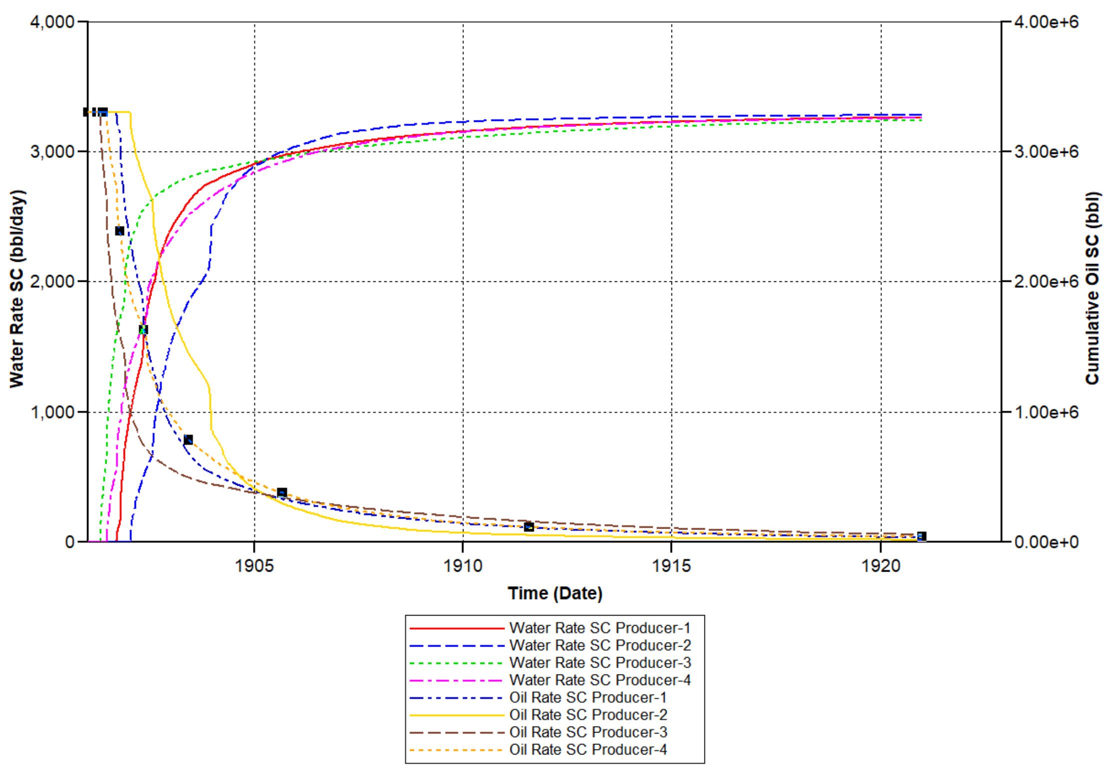
CMG: Liquid Rate Constrain





CMG: Constant bhp constrain





For the liquid rate constraint case, breakthrough times for producers one through four respectively are 973 days, 1339 days, 473 days and 697 days, with cumulative production respectively as be 2607010bbl, 3204950bbl ,2060640bbl , 2598730bbl. The total cumulative oil produced is 10471330

For the constant bottom hole pressure constraint case, breakthrough times for producers one through four respectively are 252 days, 374 days, 111 days and 171 days, with cumulative production respectively as be 2833530bbl, 3304390bbl ,2379910bbl and 2829600bbl. The total cumulative oil produced is 11347430bbls

The differences between bottom hole pressure and liquid rate constraints are similar between Eclipse and CMG, with the liquid rate constrained case having much lower oil production rates before breakthrough and much lower cumulative oil production totals. There are differences between the values of breakthrough time and cumulative oil between the two programs, but this is likely due to the CMG's consideration of gas breakout from the oil in the reservoir, and Eclipse two-phase flow model considering only oil and water.