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Water Flooding Design for Defa Oil Field

"Case Study"

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Abstract

Currently, water-flooding is responsible for a big portion of world oil production. The vertical sweep efficiency and the areal coverage each of these requires careful sampling to get represented reservoir rock and fluid properties measures of reservoir heterogeneity, Economically, a pilot is a desirable tool for studying oil recovery performance on reservoir sample and then scaled up to yield the performance to be expected from field performance.

Defa field was produced since 1968 with good oil flow rate reaching 200,000 BOPD but during the life of the field, the production decreased to 50,000 BOPD in 2001. So, this study was conducted to increase oil production by add some energy to the reservoir to increase average reservoir pressure and try to maintain it to initial pressure and to increase displacement and sweep efficiency.

The water flooding design was implemented in sector model in the Defa field using five spots pattern. The study was performed by using Excel and Water Drive software to achieve a good water flooding design. When comparing the results obtained from two calculation methods, the minimum error was equal 0.03 percent and the maximum error was around 12 percent. So, the results were acceptable and the process was recommended to the Defa-field.

Keywords: Water flooding; Software; Fractional Flow, Break through.

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تصميم نظام غمر المياه لحقل الدفا النفطي

"دراسة حالة"

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الملخص

حاليًا، تعد الفيضانات المائية مسئولة عن جزء كبير من إنتاج النفط العالمي. تتطلب كفاءة المسح الرأسي والتغطية المساحية أخذ عينات دقيقة للحصول على قياسات ممثلة لصخور المكمن وخصائص السوائل لعدم تجانس المكمن، ومن الناحية الاقتصادية، يعد البرنامج التجريبي أداة مرغوبة لدراسة أداء استخلاص النفط في عينة المكمن ومن ثم توسيع نطاقه للحصول على الأداء المتوقع من الأداء الميداني.

تم إنتاج حقل الدفا منذ عام 1968 بمعدل تدفق جيد للنفط يصل إلى 200,000 برميل يومياً ولكن خلال عمر الحقل انخفض الإنتاج إلى 50,000 برميل يومياً في عام 2001. لذلك أجريت هذه الدراسة لزيادة إنتاج النفط عن طريق إضافة بعض الطاقة إلى المكمن لزيادة إنتاجه. متوسط ضغط الخزان ومحاولة الحفاظ عليه عند الضغط الأولي ولزيادة كفاءة الإزاحة والكنس.

تم تنفيذ تصميم الغمر المائي في نموذج قطاعي في حقل ديفا باستخدام نمط النقاط الخمس. تم إجراء الدراسة باستخدام برنامج Excel و Water Drive للوصول إلى تصميم جيد لغمر المياه. عند مقارنة النتائج التي تم الحصول عليها من طريقتين للحساب، كان الحد الأدنى للخطأ يساوي 0.03 بالمائة وكان الحد الأقصى للخطأ حوالي 12 بالمائة. لذلك، كانت النتائج مقبولة وتمت التوصية بهذه العملية إلى حقل الدفا.

الكلمات المفتاحية: فيضانات المياه؛ البرمجيات؛ التدفق الجزئي، كفاءة المسح الراسي

1. Introduction

By nature crude oil is a limited resource. Nevertheless, the amount of crude oil available has to meet the worldwide demands. In petroleum reservoir engineering, the reservoir goes through multiple stages to maintain oil production at maximum levels. The first stage the reservoir produces oil by natural source of energy as drive (pressure or artificial lift). the second stage of hydrocarbon production, which an external fluid is injected into the reservoir through injection wells located in rock that has fluid communication with production wells. The secondary recovery stage reaches its limit when the injected fluid is produced in considerable amounts from the production wells and the production is no longer economical. the successive use of primary recovery and secondary recovery in an oil reservoir produces about 15% to 40% of the original oil in place.water flooding is a secondary-recovery method by which water is injected into a reservoir to obtain additional oil recovery through movement of reservoir oil to a producing well, after the reservoir has approached its economically productive limit by primary-recovery methods.

This study was conducted on Defa oil field in order to achieve the following objectives. Determine reservoir heterogeneity for Defa field by using Dykestra parson method. Perform a water flooding design for the field in order to increase oil recovery. Predict oil and water flow rate for the field after water flooding. Compare the obtained results by using results from water drive software.

2. Water Flooding Methods

The perfect method for predicting water flood performance would of course include all pertinent fluid flow, well pattern, and heterogeneity effects.

The fluid flow effects include the influence of different water-oil relative permeability characteristics as they differ from reservoir to reservoir as a result of wettability, pore size distribution, and connate saturations.. The possible presence of an initial gas saturation formed by solution gas drive depletion or gas injection prior to water flooding would also be accounted for in the perfect prediction method. [1]

2.1 Simplified Dykstra and Parsons Method

Dykstra and Parsons proposed a correlation for predicting water flood oil recovery that uses the mobility ratio, permeability variation, and producing water–oil ratio as correlating parameters. Figure 1 shows the proposed graphical charts for the four selected WORs. [2]

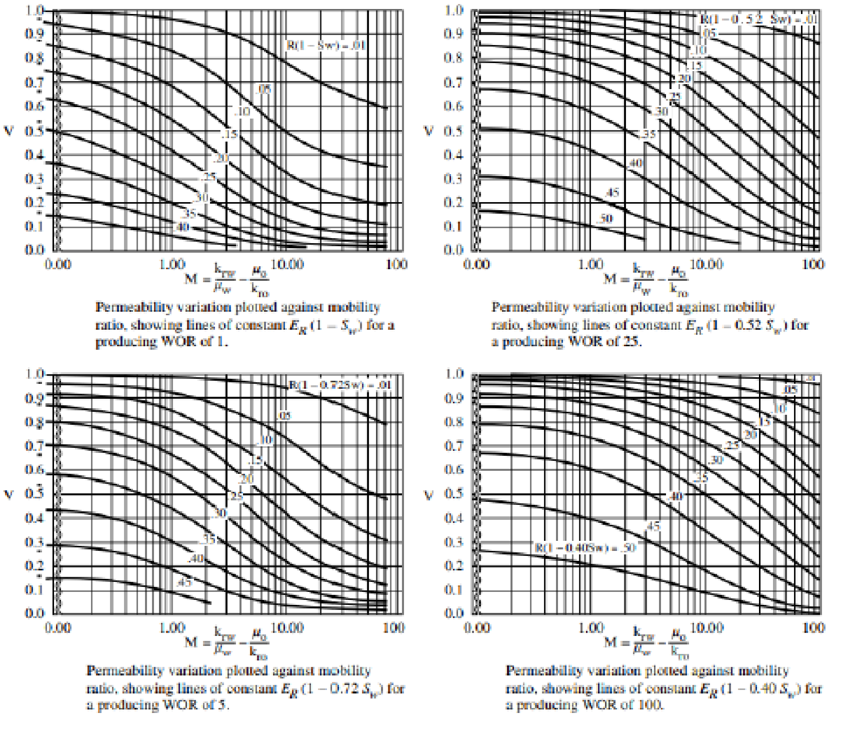

Figure1. Simplified Dykstra and Parsons curves. [3]

2.2 Stiles Method

This method basically involves accounting for the different flood-front positions in liquid filled, linear layers having different permeability, each layer insulated from the others, Stiles assumes that the volume of water injected into each layer depends only upon the K_h of that layer. This is equivalent to assuming a mobility ratio of unity. [4]

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3 Theory and Calculation

From the Figure 2 the initial water saturation of this area equal 30 percent, the oil relative at initial water saturation equal 0.58 and the end point of water equal 0.548.

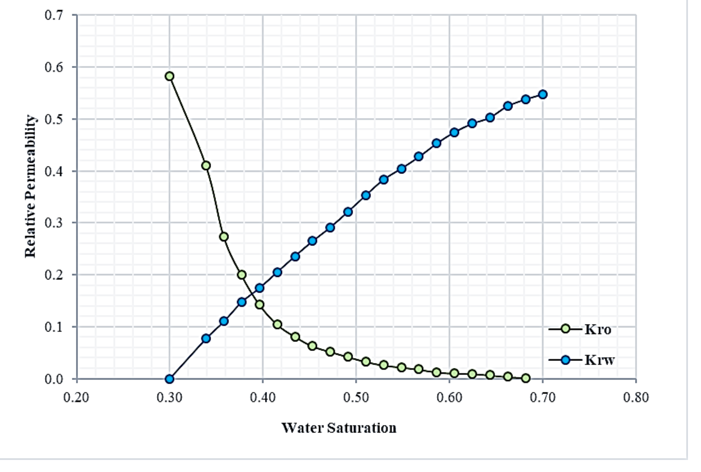

Figure2. Oil and Water relative permeability curve

- **Oil Initial in Place**

The oil initial in place at start of water flooding was calculated using volumetric equation

$$Ns = \frac{7758AL\emptyset So}{Bo}$$

Where:

A: Area this equal 40 Acer from selected sector using scales around 20.1 acres for each 0.85cm^2.

L: Distance from production and injection this equal 500 ft using the pattern area 20.

So: oil saturation at start of flooding equal 55.5 %. Bo= oil formation volume factor equal 1.27 Rb/STB.

Ns: oil initial at start of the process is equal to 4.7 MMSTB.

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- **Distance between Wells;**

The distance between Injection and Production Wells was equal two-time radius of the well. The pattern area is equal to 20 acres divided by 4. Thus, the drainage area for each well is equal to 5 acre, then the radius and the length will equal 250 ft and 500ft respectively.[5]

- **Reservoir Heterogeneity;**

The reservoir heterogeneity was calculated using Dykstra Parson Coefficient as known Permeability variation. The main data required was routine core analysis "Permeability and thickness". The procedures to calculate Variations were the following;

- Divide permeability samples so that all samples represent layers of equal thickness.
- Arrange the permeability data in the order of decreasing value.

- **Water Injection Rate;**

Water injection rate was estimated from injectivity test. Based on the company records, the best injection flow rate for Defa field was equal 1MBWPD, with this flow rate can save and reduce damage problem.

4. Water Drive Software.

Water drive software is a collection of classical Water drive calculations and routines intended for petroleum reservoir engineers toanalyze the water-oil displacement processes for both homogeneous single layer and heterogeneous multi-layered systems, and permit the calculation of waterflood performance with time for oil recovery, producing water cut and water injection.

The software used in this study was developed by ALWAHA Company. The software is used to perform a quick water flooding design using the existing and popular water flooding method.

5. Results and Discussion

Based on the relative permeability curve (figure 3), the fractional flow curve and the derivative curve were performed as shown in figure 4.

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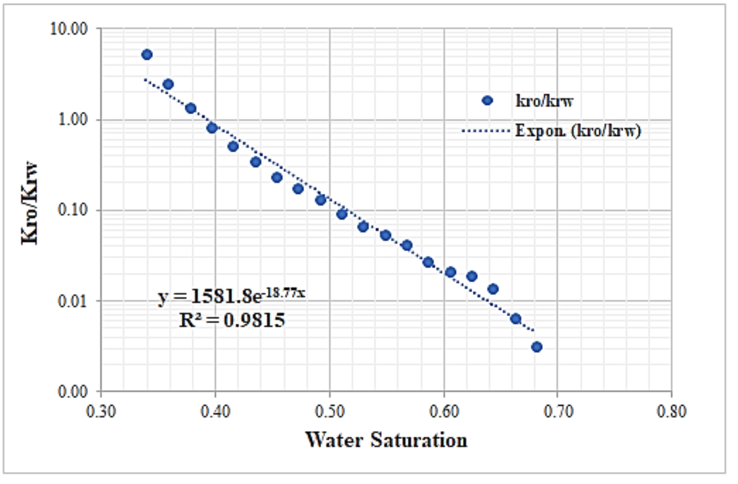

Figure 3. Relative permeability curve.

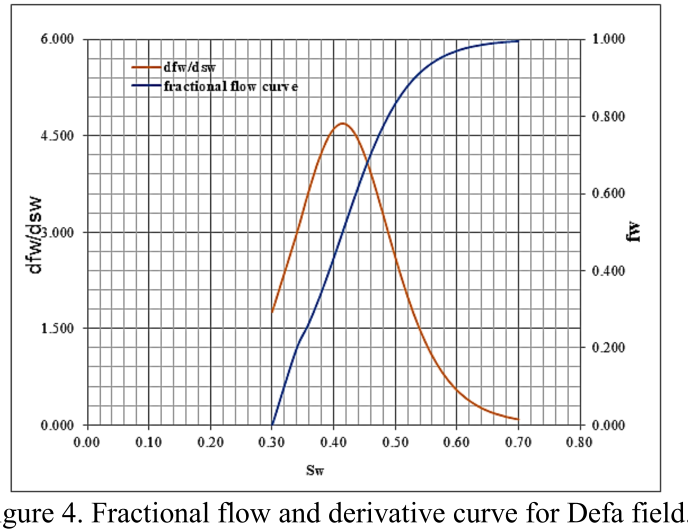

Figure 4. Fractional flow and derivative curve for Defa field.

After construct fractional flow curve and derivative curve the water flooding calculation will started by break through time calculations.

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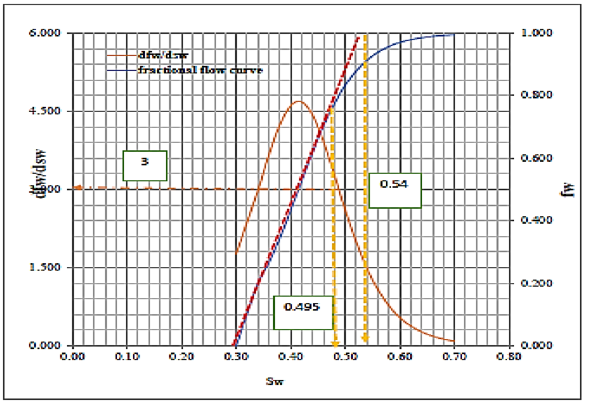

Fig. 5. : Fractional flow curve at Breakthrough.

Tablr 1. Results at Breakthrough

Steps	Parameter	Result	Unit
1	Sw@BT	49.5	%
2	Avg. Sw@Bt	54	%
3	Fw	76	%
4	dfw/dsw	3	--
5	Ed=	34	%
6	Edmax=	57	%
7	Time@BT	4.8	Year
8	Np	1.29	MMSTB
9	WOR	3.2	BBl/BBL
10	WORs	4	BBL/STB
11	WI"PVi"	24	%
12	Wi Volume	2.4	MMBblWater

Sw=water saturation & BT=breakthrough

5.2 Water Flooding After Break Through

The performance of water flooding after breakthrough calculation is important to identify the recovery and behavior of water flooding process for any formation. The performance is started by estimate water saturation after breakthrough at selected water cut (fw= 95%) as shown in Figure 6.

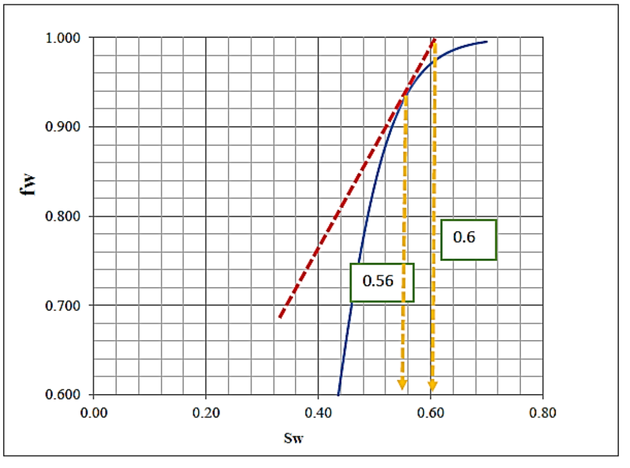

Figure 6. Fractional flow curve at Breakthrough

The last calculation results after breakthrough was introduced in table (2)

Table 2.Results after Breakthrough

Steps	Parameter	Result	Unit
1	Sw	56	%
2	Avg. Sw	60	%
3	Fw	94	%
4	Ed=	42.8	%
5	Edmax=	57	%
6	Time	7	Years
7	Np	1.7	MMSTB
8	WOR	15	BBl/BBL
9	WORs	19	BBL/STB
10	Sw	56	%

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5.3 Dykstra and Parsons Method.

The overall oil recovery is determined from Figure 1 as shown before. Then, Plot WOR versus EV on a Cartesian scaleand determine the vertical sweep efficiency at breakthrough (EV@BT) by extrapolating the WOR versus EV curve to WOR = 0 as shown in Figure 7. Table 3 shows the main data and results for Dykstra and Parsons Method.

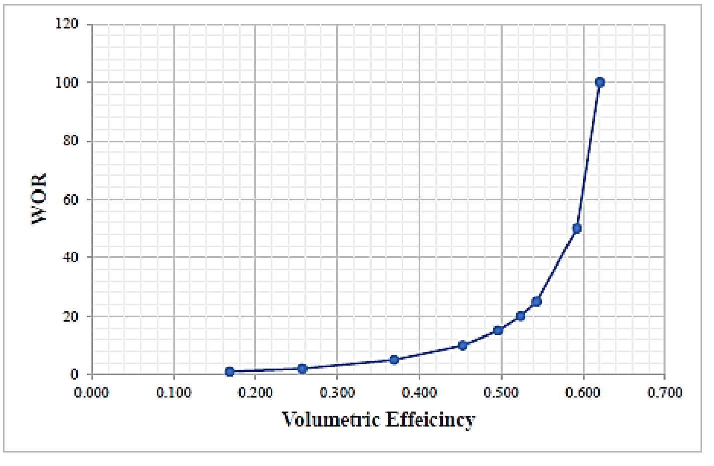

Figure 7. The volumetric Sweep efficiency result

Table 3. The main data for the Dykstra method calculations

Parameter	Value	Unit
Pore Volume	6827040	BBL
OIIP	4.7	MMSTB
Mobility Ratio	0.708	--
ED @ Bt	34	%
Areal Sweep	0.736	--
Variations	0.887	--
Fill Up	0	BBL
EV @ BT	0.19	--
Wi Bt	406	MBBL
NP @ BT	0.319	MMSTB

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The cumulative water produced at any given value of WOR is obtained by finding the area under the curve of WOR versus NP, as shown in Figure 8.

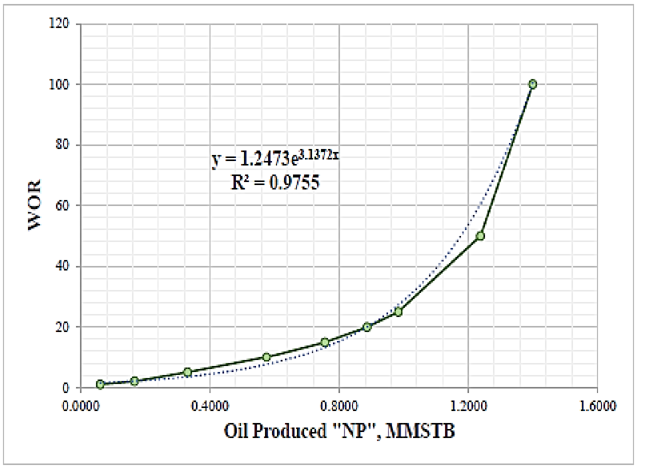

Figure 8. Cumulative water production

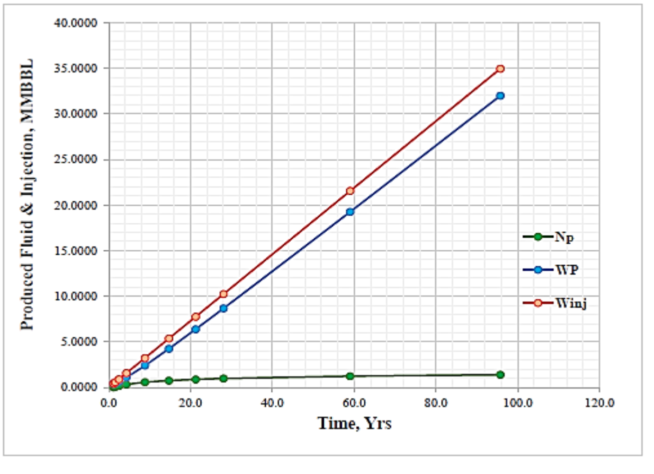

Figure 9. The Produced and Injection Fluid with Time

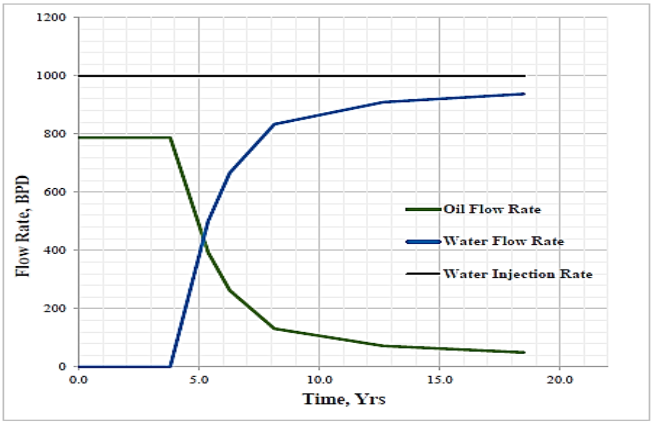

Figure 10. The fluid rate during life of flooding process

5.4 Software Results

Water drive solutions software was used in this study to verify the results obtained from hand calculations "Excel Program".Numerical simulation of the water performance can be over-simplified to meet the demand of computing and the history matching is a subjective process. That is, various results may be obtained on the basis of the same data .[8]The following figure shows the Dykstra plot.

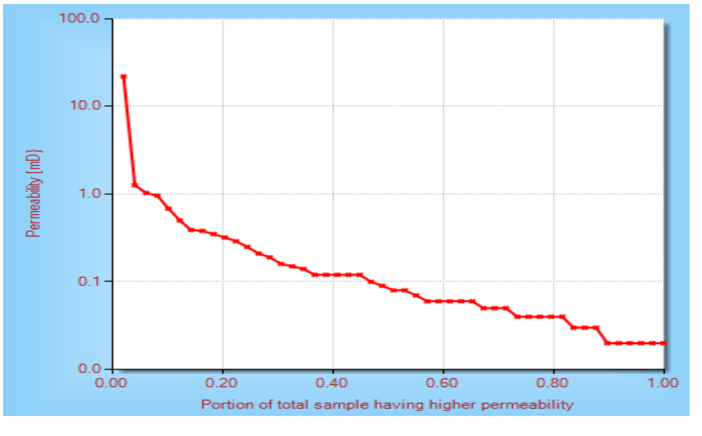

Figure 11. Dykstra coefficient plot

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The permeability variation is equal to 0.865from software. The Vertical sweep efficiency EVi is equal to 0.195 and the breakthrough will happen after 950 days.

The first calculation was the recover factor from water flooding design as shown in Figure 12.

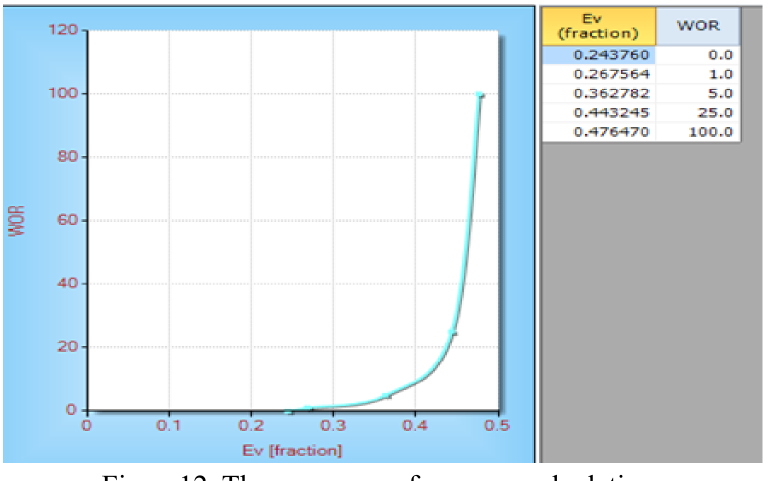

Figure12. The recover performance calculations

The oil recover factor after water flooding design is equal to 0.205.The predicted results will be introduced in the Figure 13.

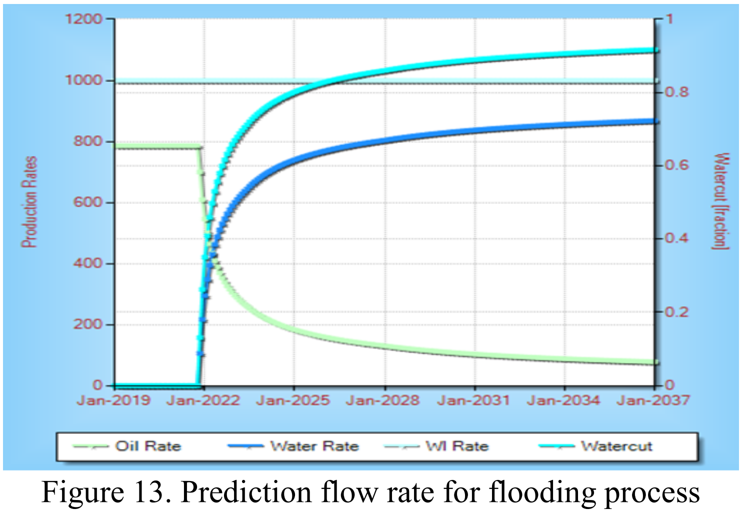

Figure 13. Prediction flow rate for flooding process

The following steps were used to perform a simple water flooding design using Dykstra method. The oil flow rate before breakthrough equal 787 and water rate equal zero, at break through the oil flow rate reduce and water flow rate increase with time. The final economic oil rate will equal 47 BOPD after 20 years from water flooding either wise at this point the water flow rate around 900 BWPD, water cut will reach 93%.

5.5 Comparisons of the Results

The water flooding design for Defa field was performed using the most popular method "Dykstra Method" and was calculated by two different software "Excel and Water Drive". In this section the data obtained by two methods was compared to reduce uncertainty from calculation results. The following table introduces the results from both calculation software's and the error for this result if we using Water drive software as reference point.

TABLE 4 . The comparisons between Results "Excel and Water drive Software

Parameter	Value		Diff	Rel. Error
	Excel	W.D Software		%
Permeability Variations	0.889	0.865	0.2	2.7
Oil Recovery	0.19	0.205	0.03	7
Oil Flow rate before B.T	787	787.2	0.20	0.03
Oil Produced Before B.T	1.11	1.14	0.02	2.6
Water Injection before B.T	1.37	1.40	0.02	1.61
Break Through time	950	935	13.00	1.7
Oil Flow rate at B.T	743.7	746.1	2.4	0.32
Water Flow rate at B.T	52.06	49.2	2.86	5.81
Oil Produced at B.T	1.14	1.15	0.01	0.87
Water Injection at B.T	1.45	1.46	0.01	0.88

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Water Cut at Break through	0.054	0.061	0.01	11.48
Final Oil rate	45.5	45.70	0.20	0.44
Final water rate	908.4	908.2	0.2	0.02
Final oil Produced	1.9	1.85	0.17	8.42
Final Water Produced	5	4.88	0.6	12
Final Water Injection	7.5	7.45	0.05	0.67
Final Water Cut	0.94	0.93	0.01	1.07

6. Conclusions

- ✓ In this study the water flooding design was implemented in sector model in the Defa field using five spots pattern .
- ✓ The study performed by using two software “Excel and Water Drive” to achieve a good water flooding design .
- ✓ The results were very close with average error around 4% .Therefore, we recommend apply this method for the Defa-field .
- ✓ The oil recovery was equal 20% from the OIIP after 20 years from water flooding process. The water flooding was stopped after water cut reach 94% because the oil flow rate will decrease to 45 BOPD and the water flow rate reach 900 BWPD.

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