No.28- (9) 2020 Journal of Petroleum Research & Studies (JPRS)

Oil initially in place calculation by geologic and dynamic methods in Nahr Umar formation of Nasiriya oil field

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Abstract:

Original oil in place is most critical stages of reservoir management, where the economic advantage of the reservoir is evaluated by estimation of the petrophysical properties and oil reserves. This work was carried out in five wells of Nasiriya oilfield, which is one of the Iraqi oil fields in the southern region. The aim of this study is to calculate oil in place from available data in Nahr Umar formation, having a complex lithology by two methods (static and simulation). It was found that the static model used for computing the petrophysical distribution oil in place was equal to (114 SM^3 MM or 716 MM STB) and 117 MM SM^3 or 734 MM STB for the dynamic one.

Keywords: Shaly sand, 3D Petrophysical modeling, oil in place calculation

((إحتساب الإحتياطي النفطي بالطرق الجيولوجية والمكمنية لتكوين نهر عمر لحقل الناصرية النفطي))

الخلاصة:

تقييم الطبقات المكمنية هي من المراحل الأكثرأهمية في الادارة المكمنية، حيت يتم توضيح الفائدة الإقتصادية للمكمن عن طريق توزيع الخواص البتروفيزيائية وتقدير كمية النفط الموجود في المكمن.اجريت الدراسة على خمس ابار في حقل الناصرية النفطي جنوب العراق. حيث تم توزيع الخواص البتروفيزيائية على حجم المكمن بالطرق الجيوستاتيكية بإستخدام برنامج البترل ومن ثم احتساب الاحتياطي النفطي بالطريقة الجيولوجية. بعد ذلك تم ادخال بيانات المائع المكمني (PVT) واحتساب الضغط الشعري لإحتساب كمية النفط الموجود بالطريقة المكمنية.

وبعد بناء الموديل الجيولوجي ، تم حساب الاحتياطي النفطي والذي قدر ب 114 مليون متر مكعب ويساوي 716 قدم مكعب. ثم بعد ذلك، تم حساب الاحتياطي بعد بناء الموديل المكمني وقدر بحوالي 117 مليون متر وكعب وهو مايساوي 734 قدم مكعب.

Introduction:

Estimating the original oil in place is most important key for reservoir engineers to make a decision whether the discovered area is profitable or not [1]. In reservoir engineer's perception, the most used methods in the oil in place calculation are volumetric (geological or static) method and reservoir simulation method. The volumetric depends on the data of reservoir rock and reservoir fluid properties. However, the reservoir simulation needs a lot of information that starts with geological information and production history additional to reservoir rock and fluid properties [1]. The geological or volumetric is a simple method and doesn't require a lot of information; but it has limitations the reservoir heterogeneity. The heterogeneity can be solved by geostatistics. Geostatistics is "study of phenomena that vary in space and/or time"[2], also may be defined as a statistic algorithm tries to demonstrate the property in space depending on the assumption that the property has a degree of continuity. Reservoir engineers use it for estimating the reservoir properties in the area at which no data are available in the reservoir. Reservoir simulation uses to find the precise value of oil in place under different conditions, and also to help reservoir engineers to have a proper understanding of reservoir behavior and making the prediction which helps engineers for making investment decisions.

Case Study:

Nasiriya Oil Field is located in southeastern Iraq which is about 38 Km northwest of Nasiriya city as shown in Figure (1). Nahr Umar formation is one of the promising reservoirs, having a complex lithology which consists of Shaly sand in the upper section and limestone at lower section [3]. There are five wells penetrated Nahr Umar Formation (NS-1 to NS-5) . The objective that must be achieved for Nahr Umar Formation in Nasiriya Oil Field were constructing a 3D geologic model that will demonstrate the distribution of the different reservoir properties within the Nahr Umar Formation as well as oil-water contact determination to estimate OOIP by volumetric method. Then, making a fluid model

and saturation function model as well rock physics model to estimate OOIP by the simulation model.

Fig. (1) Location map of the studied wells along with oil field location map of the studied Wells along with oilfields

Methodology:

By PETREL 2015 software, the study includes building a geological model that consists of petrophysical modeling (ø, Sw, Vcl, k), static OOIP by the geological model (volumetric method) by implementing the necessary validation for water saturation distribution, oil in place calculation by static and dynamic methods as shown in Figure (2)

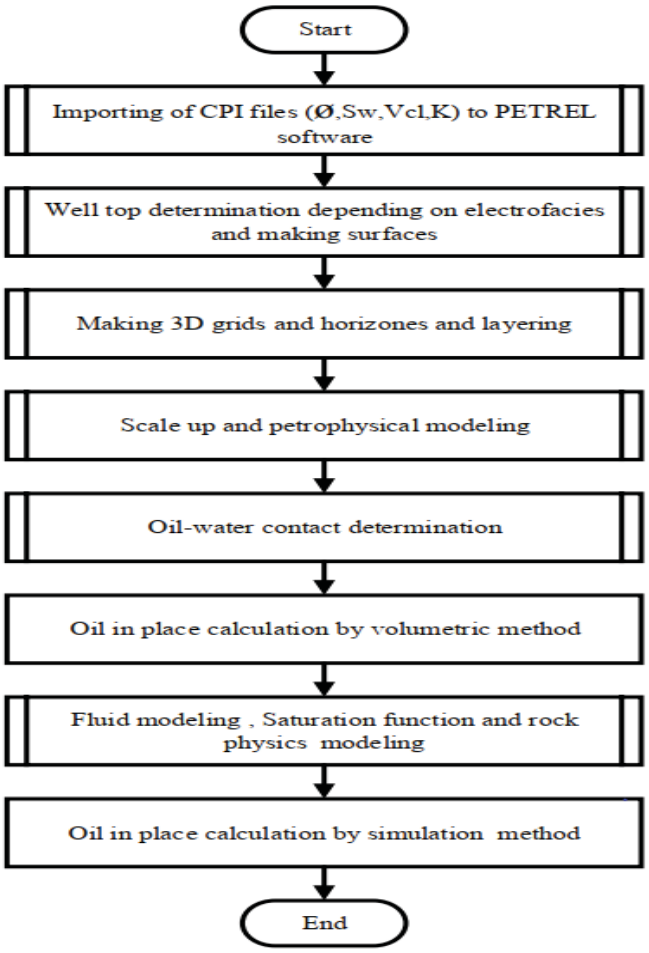

Fig. (2) Workflow chart of the methodology

Results and Discussion:

Static Model (Geological Model):

The most important phase of a reservoir study is probably the definition of a static model of the reservoir rock. Generally, the production capacity of a reservoir depends on its geometrical/ structural and petrophysical characteristics. A static reservoir study typically involves five main stages [4]:

Determination of Formation Tops Unit:

The formation tops determination is the first task for the reservoir engineer to build the static model. It can be done by determination of similar rock properties where the wells are correlated together. The main purpose is to determine the horizons of formation units and its sequence for accurate calculation of oil in place[4].

Due to the variation of top formation depth in the final geological report (FGR), and final well report, the top of Nahr Umar is distinguished by the electro faces of the formation, the data used are:- depth of the invasion, Gamma-ray corresponding log, density log, sonic log, neutron log. Figures (3) and (4) show the correlation of wells and units and Table (1) presents the number and depth of Nahr Umar formation units.

Table (1) Zoning tops of Nahr Umar formation

Well tops	wells				
	NS-1	NS-1	NS-1	NS-1	NS-1
	TVD(M)	TVD(M)	TVD(M)	TVD(M)	TVD(M)
Top of Nu-1	2396.06	2390.67	2404.87	2392.6	2388.33
Top of Nu-2	2406.69	2401.29	2410.17	2397	2394.96
Top of Nu-3	2413.93	2406.22	2422.8	2404.4	2401.74
Top of Nu-4	2427.63	2412.84	2436.19	2415.33	2409.79
Top of Nu-5	2431.36	2418.26	2449.18	2419.73	2413.92
Bottom of Nu-5	2483.59	2496.75	2491.47	2492.32	2494.74

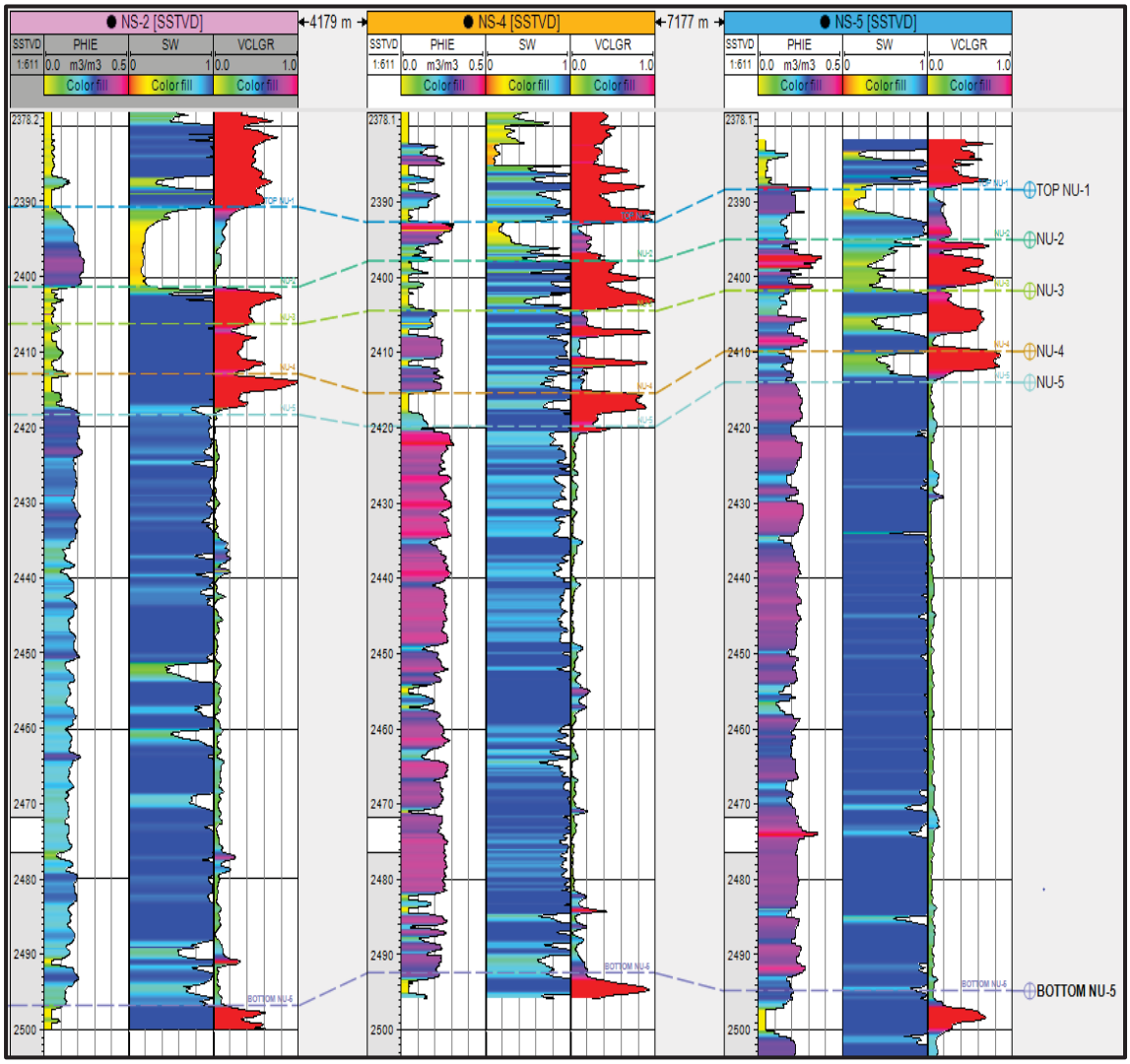

Fig. (3) Correlation between NS-2 and NS-4, NS-5

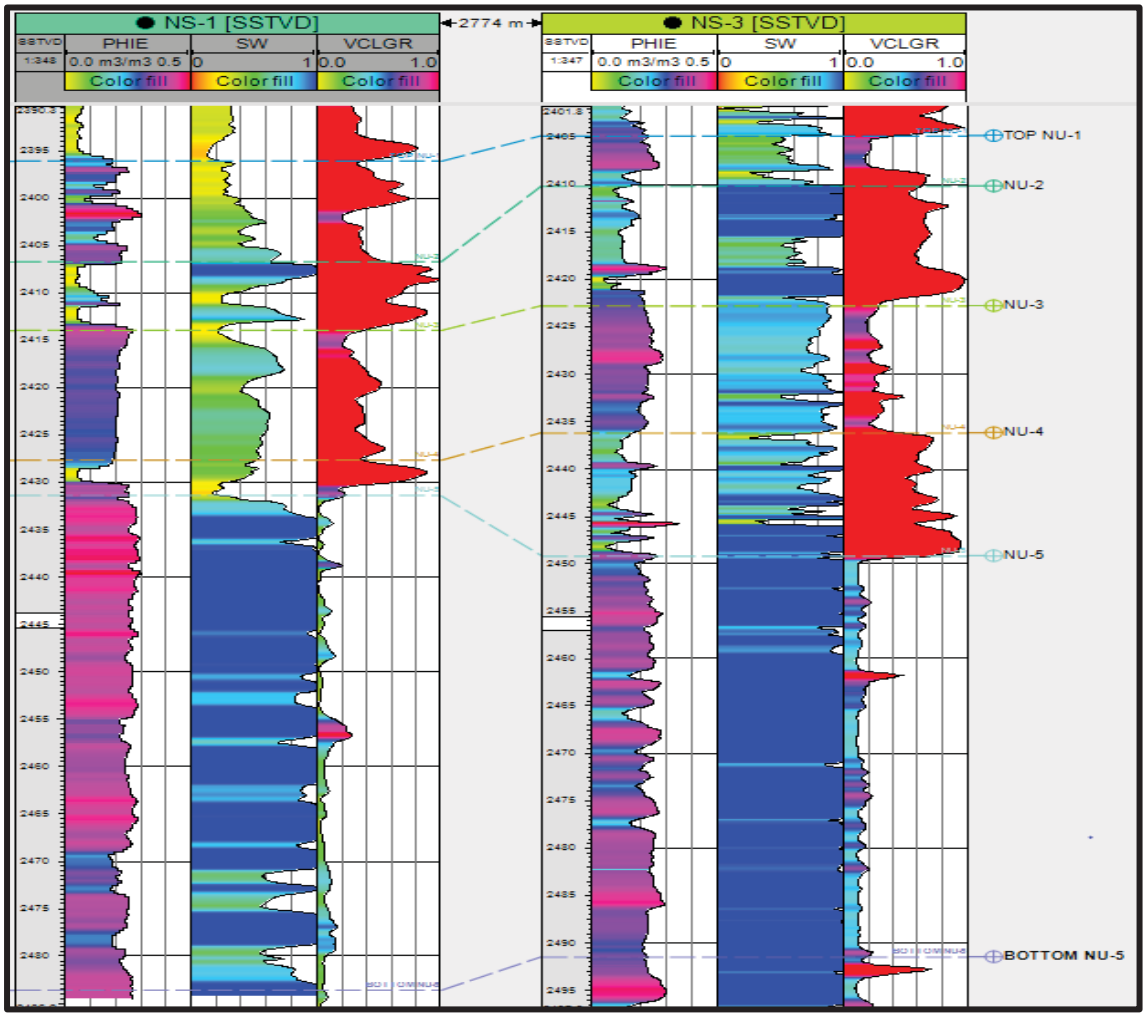

Fig. (4) Well correlation between NS-1, NS-3

Structural Modeling:

Reconstructing the geometrical and structural properties of the reservoir by defining a map with structural tops. The structural modeling can be achieved by merging the data of geological survey within the results of formation units at the previous step. These contour maps show that the Nahr Umar Formation is composed of two anticlines. Figure (5) shows the structural contour maps of Nahr Umar formation.

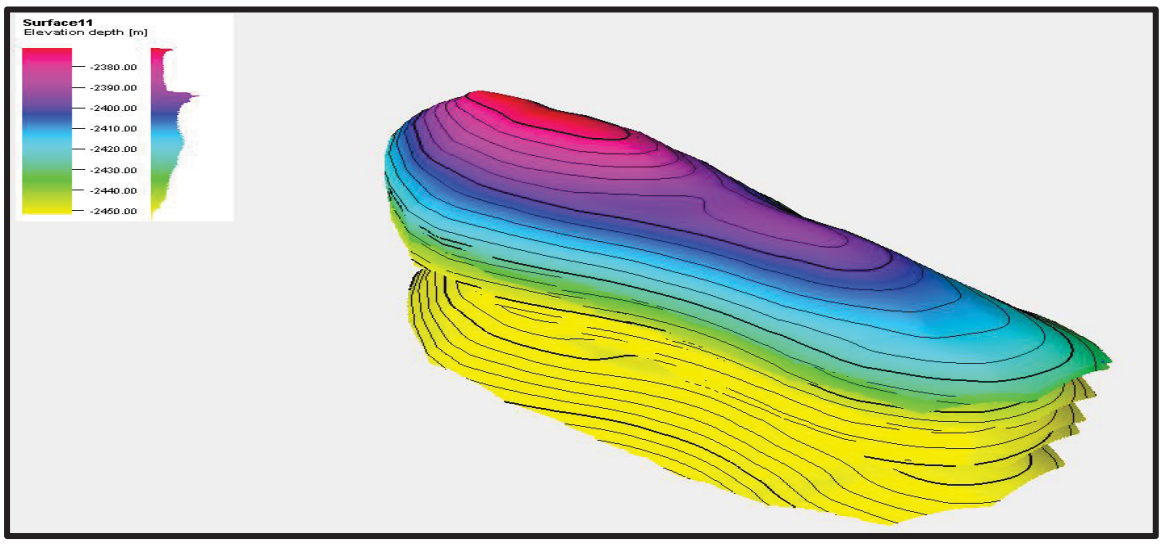

Fig. (5) Structural maps

Modeling of Petrophysical Properties:

Defining the quantity description of well logs data to estimate the main characteristics of reservoir rocks which are porosity, permeability, water saturation and volume of clay. The petrophysical characteristics results are merged to build the geological model. [2] Sequential Gaussian simulation is a new algorithm of geo-statistics that recommended to use with continuous property for reservoir modeling because of its simplicity, flexibility and it is reasonably efficient [5]. The geological model is represented as a reference to estimate the amount of oil in the reservoir; it forms a basis for the initialization of the dynamic model. In the following paragraphs the next stages are described in more details. The geological model is subdivided to a high number of grids. The properties of the grid estimate the amount of oil present. The quantitative study of a porous and permeable space in reservoir rock forms a part of petrophysics, a discipline which plays a fundamental role in reservoir studies. Petrophysical model is divided into three sub-models.

Porosity Model:

The values of Porosity were the output of well-log results (CPI) of Nahr Umar Formation; "sequential Gaussian simulation." method is used to distribute the porosity values to build a porosity model. Porosity has a low value where high clay volume is presented in the same grid. The porosity model is developed for each unit of Nahr Umar

Formation as displayed in Figure (6) and the porosity values for each unit tabulated in Table (2).

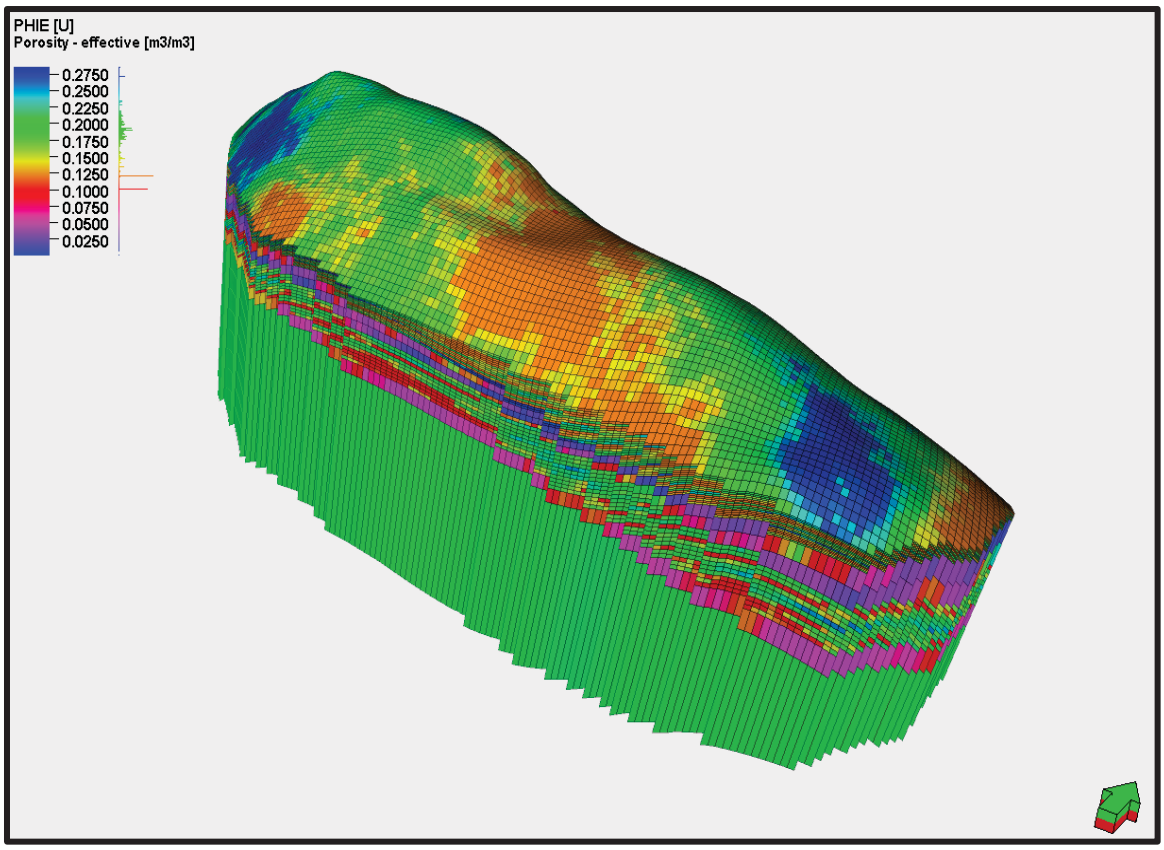

Fig. (6) 3D view of representing porosity model

Table (2) Porosity values of formation unit

Formation units	Porosity (%)			
	Minimum value	Maximum value	Mean value	Notes
NU-1	5	28	18	Pay zone
NU-2	0	23	7	High laminated clay
NU-3	1	25	14	
NU-4	4	14	9	
NU-5	13	22	18	Water zone

Water Saturation Model:

Water saturation model is made from the results of (CPI) of Nahr Umar Formation. The method which is used to build the saturation model is "sequential Gaussian simulation." This model is developed for each unit of the reservoir as shown in Figure (7). The Table (3) illustrates water saturation values for each unit:

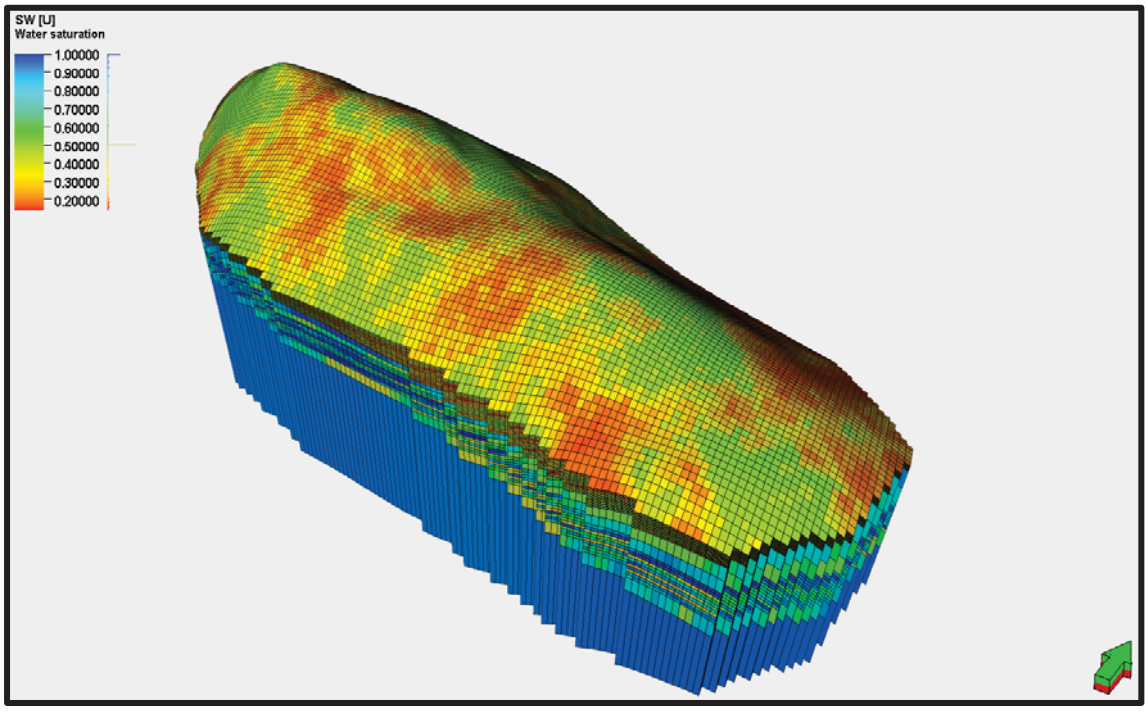

Fig. (7) 3D view of water saturation model

Table (3) Water saturation values of formation unit

Formation units	Water saturation (%)			
	Minimum value	Maximum value	Mean value	Notes
NU-1	18	52	40	Pay zone
NU-2	43	1	76	High laminated clay
NU-3	28	1	81	
NU-4	36	96	85	
NU-5	35	1	94	Water zone

The volume of clay model:

The modeling of clay is made from clay volume by gamma-ray that is presented in (CPI) of Nahr Umar Formation. The method that is used to build the clay volume model is "sequential Gaussian simulation." Figure (8) shows the developed Clay volume model for each unit, where volume of clay values for each unit was given in Table 4.

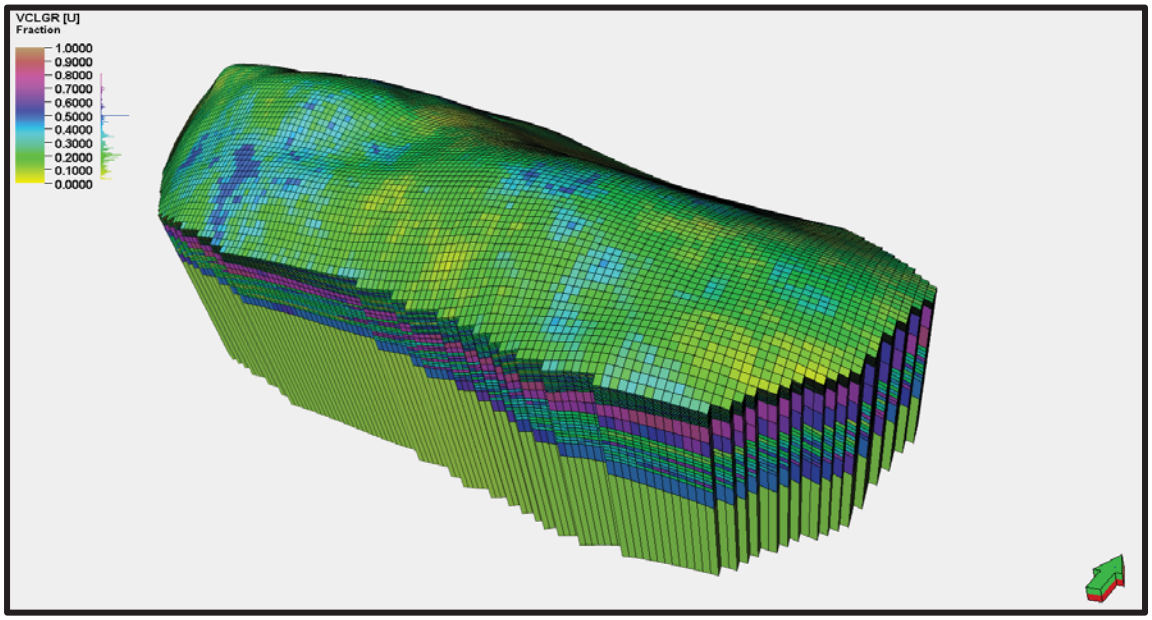

Fig. (8) 3D view of clay volume model

Table (4) Clay volume values of formation unit

Formation units	The volume of clay (%)			
	Minimum value	Maximum value	Mean value	Notes
NU-1	2	68	22.8	Pay zone
NU-2	3	100	63	High laminated clay
NU-3	5	93	30	
NU-4	2	100	62	
NU-5	0.03	69	8	Water zone

Permeability Model:

The permeability values are distributing over the permeability model according to "Sequential Gaussian simulation" method. Permeability was estimated by margining neural network technique and hydraulic flow units method [6, 7]. Figure (9) shows the permeability distribution and Table (5) illustrates the permeability of each unit in Nahr Umar formation.

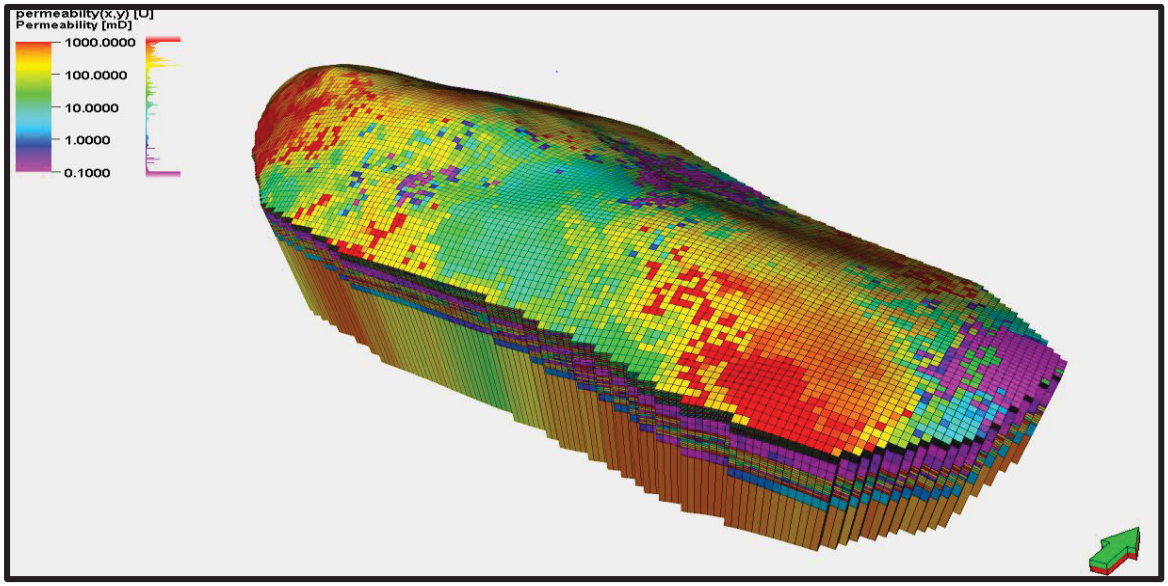

Fig. (9) 3D view of permeability model

Table (5) Permeability values of formation units

Formation units	permeability (MD)			
	Minimum value	Maximum value	Mean value	Notes
NU-1	0.1	1797	412	Pay zone
NU-2	0	6	0.8	High laminated clay
NU-3	0	1189	232	
NU-4	0.1	2.3	0.91	
NU-5	1	703	266	Water zone

Oil Water Contact:

Water contact is the lowest level of producible oil, oil and water are produced above this reservoir height until the relative permeability to water becomes extremely low and only oil will flow[8]. After studying well logs for Nahr Umar formation it has been noticed that the (O.W.C) level at (2440 m). Figure (10) shows the oil-water contact for Nahr Umar formation.

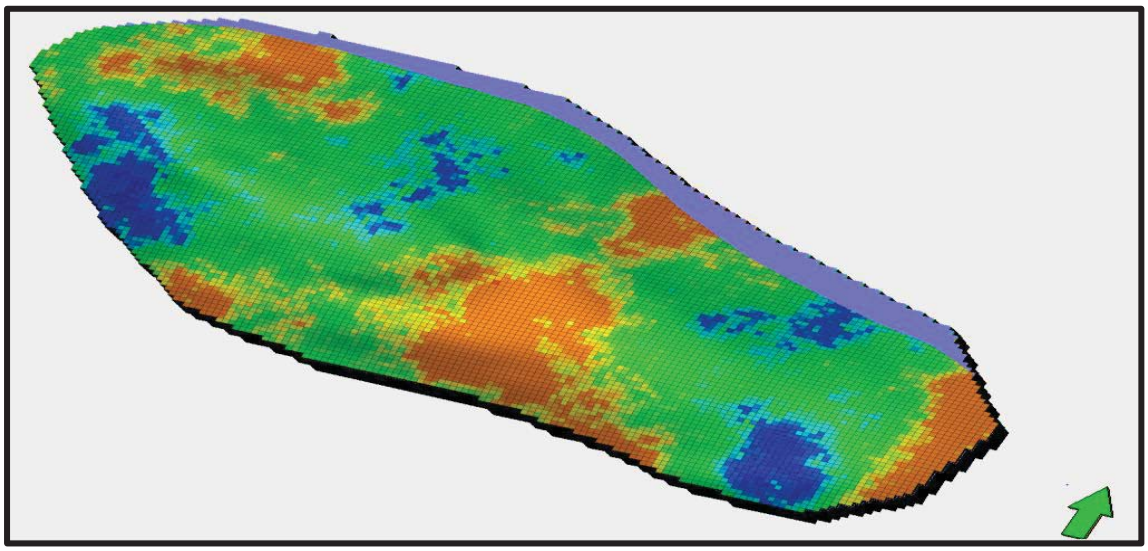

Fig. (10) Oil-water contact

Calculation of Hydrocarbons in Place by Static Model

Estimation of oil originally in Place (OOIP) represents the last stage of the static model. The geological provides all necessary information needed to use volumetric equation[9]. Original oil in place (OOIP) in an oil reservoir is given by:

$$N = \frac{7758 * ø * \mathrm{A} * \mathrm{H} * S_O}{Bo}$$

Where:

N = OOIP (STB)

ø = reservoir porosity (fraction)

A = reservoir area (acres)

H = net thickness of oil zone

S_O= initial reservoir oil saturation (fraction) ،

Bo = initial oil formation volume factor (RB/STB)

After building porosity, water saturation models and determining the oil-water contact (OWC), Petrel software has been used to calculate the initial oil in place (OIIP) for Nahr Umar formation in Nasiriya field. It's determined as (114) million cubic meter, (721) million barrel.

Oil in Place by Dynamic Model:

Fluid Model:

The required data to build fluid model is provided from PVT report of Nahr Umar formation in Nasiriya field, which is consisted of mean characteristic of the reservoir. The main fluid properties are illustrated in Figures (11 to 13).

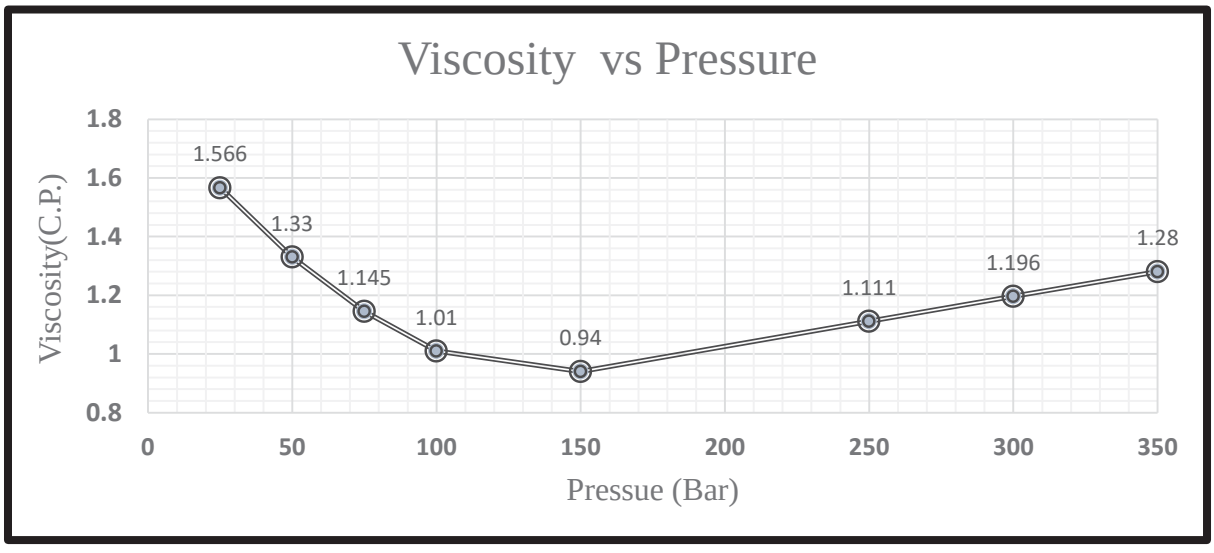

Fig. (11) Viscosity vs. Pressure

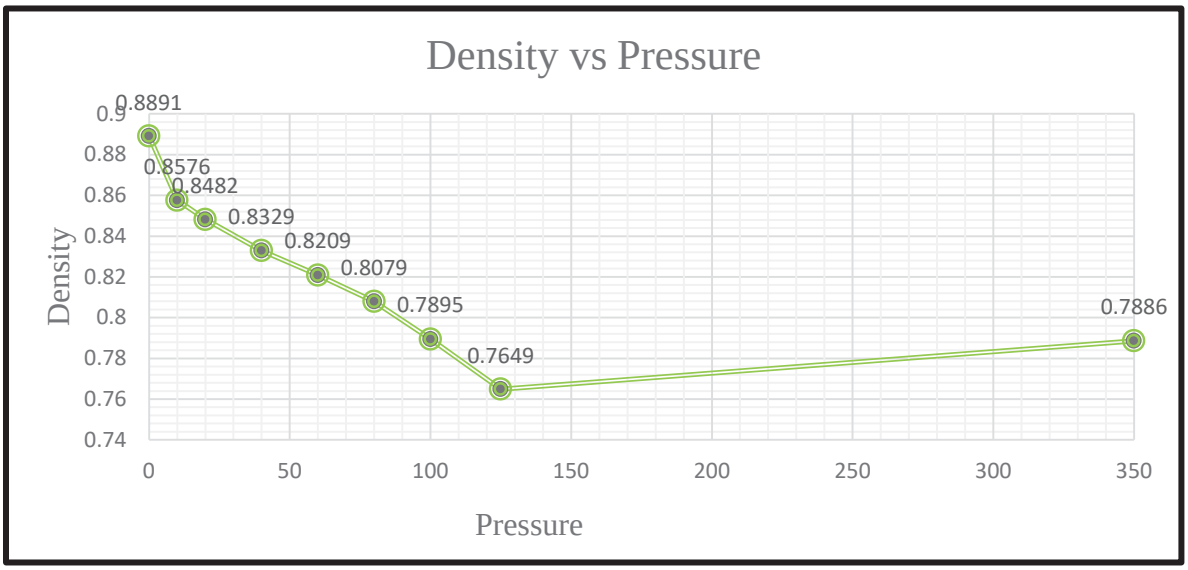

Fig. (12) Density vs. Pressure

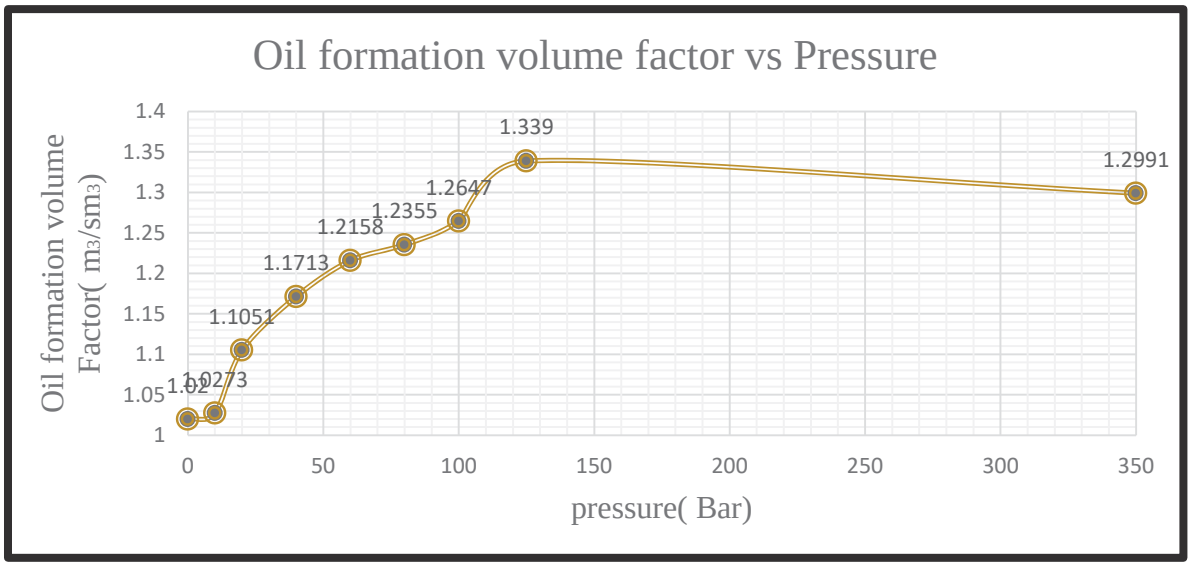

Fig. (13) Oil formation volume factor vs. Pressure

Water Saturation Function:

Alternative methods are used to estimate the relative permeability of the two-fluid which is presented (oil-water) due to the special core analysis report SCAL was not provided. The capillary pressure values are very important because it determines the thickness of the transition zone, which have a considerable impact on oil initially in place.

Relative Permeability Estimation:

Because of relative permeability data is not available. Corey model is used to estimate the relative permeability's of two fluids which are presented by oil and water critical water saturation should be determined clearly because that value of water saturation at which the fluid begins in movement [10]. Relative permeability curves are shown in Figure (14).

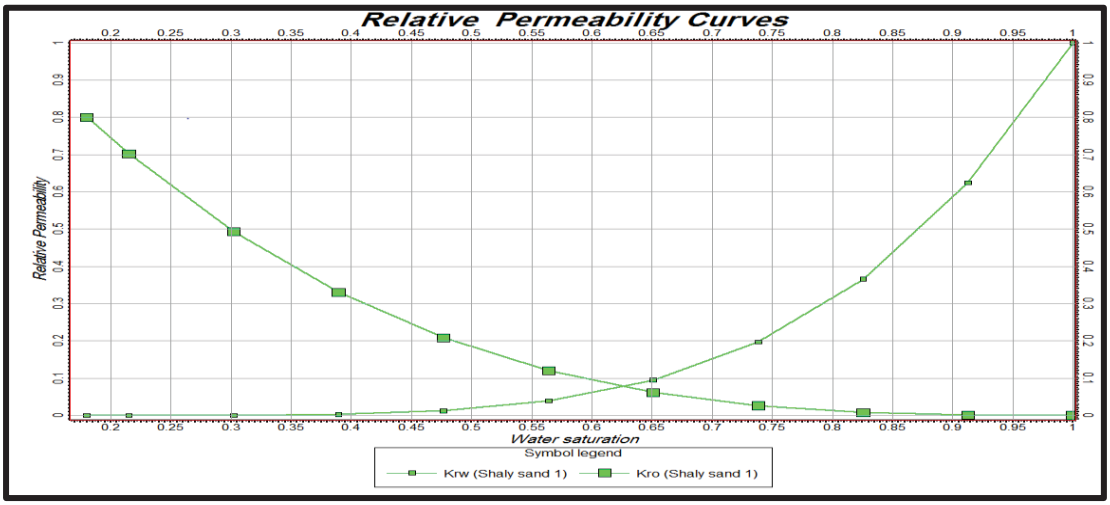

Fig. (14) Relative permeability curves

Capillary Pressure:

Capillary pressure is a very important value because it determines the transition zone thickness of reservoir. Thus, it effects on oil in place amount which is calculated by simulation model. The simulation model distributes the water saturation in reservoir bore volume which is depending on the permeability. The permeability is most parameter which affects capillary pressure. The capillary pressure increased as decreasing in permeability. Hawkins-Luffel and Harris's approach are used to estimate capillary pressure [11] [112]. The result of capillary pressure is shown in Figure (15).

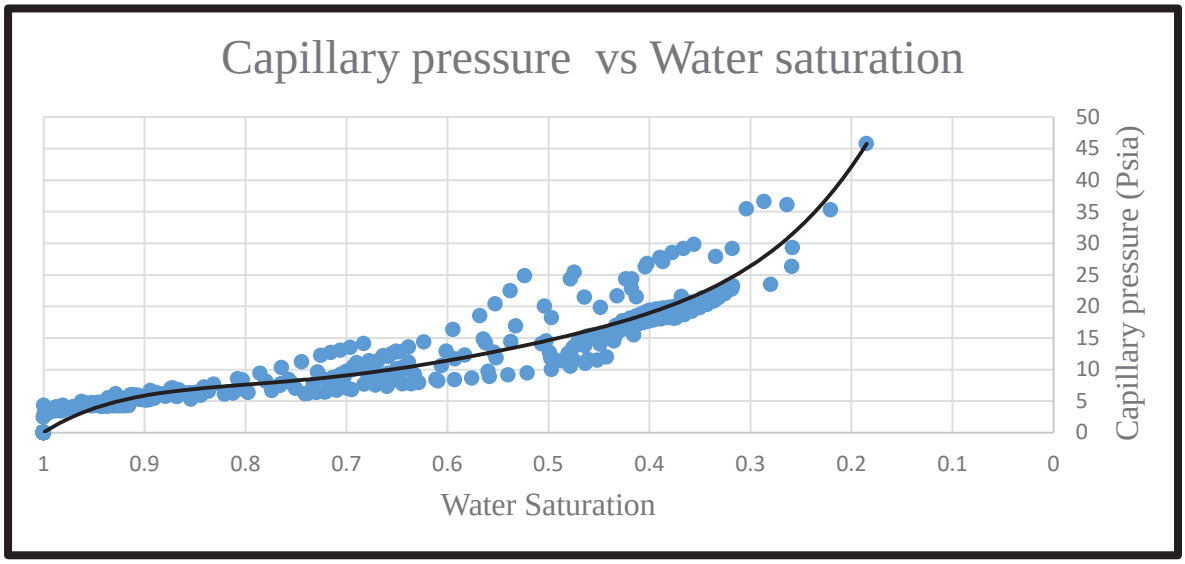

Fig. (15) Capillary pressure curve

OOIP by Simulation Model:

After the completing of pressure and saturation-dependent properties (PVT and SCAL). Oil in place can be calculated by pressure-saturation distribution process in dynamic model. This process depends on implicit pressure explicit saturation (IMPES) method. The value of original oil in place can be considered valid if the vertical saturation distribution in simulation model equal to the saturation that was estimated by logs. Figure (16) shows the matching in water saturation by static and dynamic model [13]. Figure (17) illustrates the OOIP by Dynamic model which is equal to 117 MM sm^3 and 734 MM STB, respectively. The oil in place that calculated by dynamic or simulation model differs from the value of oil in place, which is calculated by the static model because of the SCAL report is not provided. So. Hawkins-Luffel and Harris's approach are used to predict the transition zone. The value of OOIP by the dynamic model is helpful to improve OOIP that estimated by the static model because of the two values do not differ extremely.

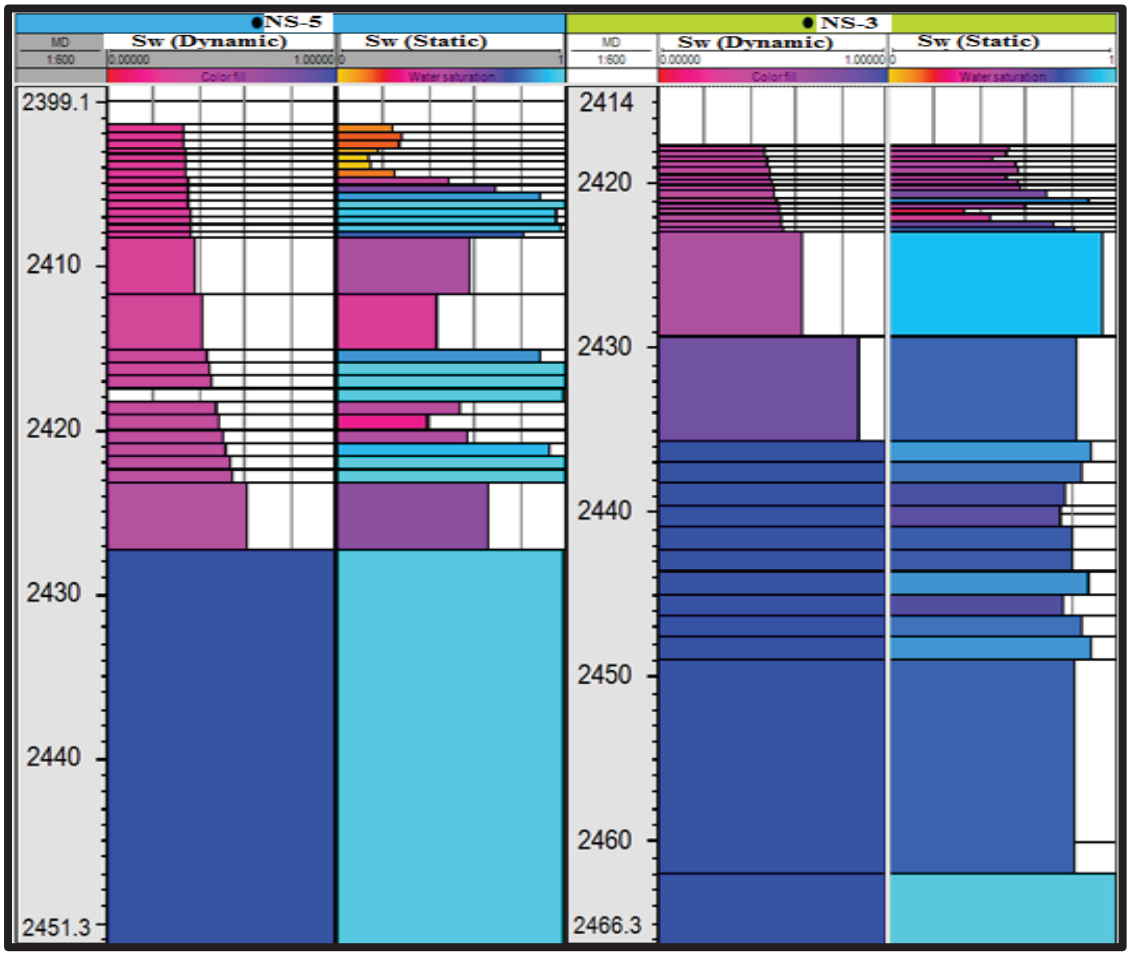

Fig. (16) Water saturation matching between Static and Dynamic

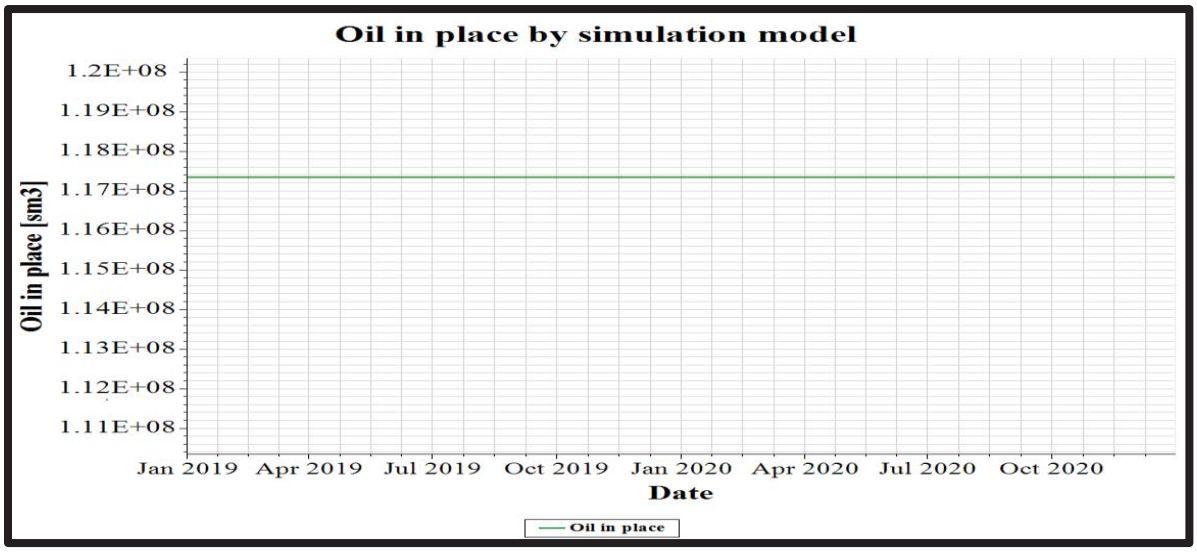

Fig. (17) OOIP by the simulation model

Conclusion:

Depending on the petrophysical properties distribution (effective porosity (Øe), permeability (k), the volume of clay (VCL), water saturation (Sw)), the pay zone is NU-1 with high of porosity and permeability and low water saturation. NU-2 has a high volume of clay and low porosity, NU-3 has medium to high water saturation, NU-4 low permeability and porosity. NU-5 has high water saturation and porosity and permeability.

The oil in place that is calculated by the static model equal to (114 MM SM^3 or 716 MM STB) and (117.3 MM SM^3 734 MM STB) in the dynamic model.

The calculated of OOIP in this study is more than the value that calculated by REPSOL Company which equal to 107 MM SM^3 or 668 MM STB). The difference between the value that calculated in this study and the value of REPSOL is described below:

a- The model which is used for water saturation calculation in REPSOL company is Archie model. Archie model is not suitable in shaly-sand formation but Indonesia model is preferred for this type of formations at which used in this study.

b- REPSOL's company study mentions that there is a bad condition to correlate the wells and predict the units of the reservoir. If the units are not determined correctly the distribution of petrophysical properties is in the study more specific tools are used to determine the lithology more accurate.

Nomenclature

CPI:	Computer Processed interpretation
FGR:	Final geological report
FWR:	Final well report
OIIP:	Oil Initially in Place
OWC:	Oil Water Contact
P:	Pressure
Pc:	Capillary pressure
PVT:	pressure-volume-temperature
RTKB	Rotary Table Kelly Bushing
SCAL:	Special core analysis
TVD:	Total vertical depth

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