DETERMINING OF FORMATION WATER SATURATION TO ESTIMATE REMINING HYDROCARBON SATURATION IN THE X LAYER Y FIELD

by Ratnayu Sitaresmi

DETERMINING OF FORMATION WATER SATURATION TO ESTIMATE REMINING HYDROCARBON SATURATION IN THE X LAYER Y FIELD

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Abstract

Efforts are made to find the remaining hydrocarbons in the reservoir, requiring several methods to calculate the parameters of reservoir rock characteristics. For this reason, logging and core data are required. The purpose of this research is to estimate the Remaining Hydrocarbon Saturation that can be obtained from log data and core data. With several methods used, can determine petrophysical parameters such as rock resistivity, shale volume, effective porosity, formation water resistivity, mudfiltrate resistivity and rock resistivity in the flushed zone (Rxo) and rock resistivity in the Uninvaded Zone which will then be used to calculate the Water Saturation value Formation (Sw) and Mudfiltrat Saturation. (Sxo) In this study four exploratory wells were analyzed. Shale volume is calculated using data from Gamma Ray Log while effective Porosity is corrected for shale volume. Rw value obtained from the Pickett Plot Method is 0.5 µm. The average water saturation by Simandoux Method were 33.6%, 43.4%, 67.0% and 39.7% respectively in GW-1, GW-2, GW-3 and GW-4 wells. While the average water saturation value by the Indonesian Method were 43.9%, 48.8%, 72.3% and 44% respectively in GW-1, GW-2, GW-3 and GW-4 wells. From comparison with Sw Core, the Simandoux Method looks more appropriate. Average mudfiltrate (Sxo) saturation by Simandoux Method were 65.5%, 68.2%, 77.0% and 64.6% respectively in GW-1, GW-2, GW-3 and GW wells -4. Remaining Hydrocarbon Saturation (Shr) was obtained by 34.5%, 31.8, 23%, 35.4% of the results of parameters measured in the flushed zone namely Rxo, Rmf and Sxo data. For the price of Moving Hydrocarbons Saturation or production (Shm) is 31.9%, 24.8%, 10%, 24.9% in wells GW-1, GW-2, GW-3 and GW-4.

Keywords : Water Saturation. Remining Hydrocarbon Saturation, , Simandoux Method, Sw Core, Moveble Hydrocarbon Saturation

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I. INTRODUCTION

The X layer is one of the layers that have been proven to produce petroleum in Y Field. In this X layer there are a total of 26 production wells that are still active. The Y field was in production from 1979 until the last production data obtained was in 2018. The purpose of this evaluation was to interpret 4 exploration wells namely GW-1, GW-2, GW-3, and GW-4 to calculate shale volumes, porosity, and water saturation and determine the water saturation calculation method suitable for use in the X Layer Y Field. The background of this evaluation is to find out the value of water saturation in the X layer, which can be used as a reference for further field development. Also, determining the appropriate method for calculating water saturation can be used as a reference in subsequent calculations in the Y field. The method used in this evaluation is to use Sw Simandoux and Sw Indonesia calculations which can be calculated manually using Microsoft Excel software. Log analysis conducted at this well is in the form of qualitative analysis and quantitative analysis.

II. LITERATURE REVIEW

Logging is the result of the recording log data that form a graph at a depth or time that shows the parameters that are measured continuously in a well. `Well logging is the work of recording or recording data on the condition of the subsurface for each predetermined depth from the surface to the well. There are two types of well logging, namely data recording is done at the time of well drilling and data recording is done after completion of the well.

Analysis of drilling well log data can be done qualitatively and quantitatively. Qualitatively, the practical way is to analyze the characteristics of log data charts, for the first step in identifying and zoning hydrocarbon reservoirs. While the quantitative analysis, namely by calculation using certain equations, to identify the advanced stages of the level of porosity, reservoir rock permeability, and water saturation [8].

Well log records provide the data needed for quantitative evaluation of hydrocarbons in place and provide information on the physical properties of rocks, namely the properties possessed by rock formations, which consist of resistivity, porosity, and water saturation.

Shale Volume (Vsh)

Shale volume can be calculated by several methods from several log curves. Some log curves that can be used to determine shale volume are Gamma Ray (GR) Logs, Spontaneous Potential (SP) Logs, Resistivity Logs, Neutron Logs, and Density Logs. Whereas in this study to calculate the amount of shale volume is the GR Log.

The determination of shale volume aims to correct parameters in gross formation. The shale volume of the GR Log can be calculated by the equation [1]

$$(V_{sh})GR = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad (1)$$

Formation Water Resistvity

Formation water resistivity is the resistance of the type of water that is in formation at the formation temperature. The resistivity symbol of formation water is Rw. Formation water resistivity can be calculated from log using Pickett Plot method. The Pickett Method, the plot can be used properly if the formation is clean, the lithology is consistent and the Rw is constant. This method is based on the Archie method [5]. Besides being used to estimate Sw, this method can also be used to estimate Rw, by making a cross plot between Rt and porosity on log paper. The outer most points on the cross plot lie in a line called Ro line. The point on this line has Sw = 100% or Sw = 1. At the intersection point between the line Sw = 1 with 100% porosity then

$$R_t = a \, x \, R_w \quad (2)$$

Porosity

Porosity is the total volume of rock pore space compared to the total rock volume . In the gross formation, porosity will be influenced by the large volume of shale contained in the formation. If the formation has a large volume of shale content, the porosity of the formation will be small. Some methods used to determine porosity are Sonic Log, Density Log, Neutron Log, and Neutron-Density Log [6]. To determine porosity using the density log using the equation

$$\emptyset D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \quad (3)$$

$$\emptyset N = Neutron\ Porosity\ Log \quad (4)$$

Then correction of porosity against the volume of shale in the well using the equation [2]

$$\emptyset N_{corr} = \emptyset N - (\emptyset N_{sh} \times V_{sh}) \quad (5)$$

$$\emptyset D_{corr} = \emptyset D - (\emptyset D_{sh} \times V_{sh}) \quad (6)$$

From this combination, effective porosity will be obtained. For fluids without gas content, porosity calculations can be used

$$\emptyset_{eff} = \frac{\emptyset N_{corr} + \emptyset D_{corr}}{2} \quad (7)$$

Whereas the porosity equation with neutrons and density whose fluids have an indication of gas is used the equation

$$\emptyset_{eff} = \sqrt{\frac{\emptyset N_{corr}{}^2 + \emptyset D_{corr}{}^2}{2}} \quad (8)$$

Water Saturation

Water saturation (Sw) is a fraction or percentage ratio of the volume of water fluid that occupies rock pores with total rock pore volume [11].

Simandoux Method [10]

$$S_w = \frac{a \times R_w}{2 \times \emptyset^m} \left[\sqrt{\left(\frac{V_{sh}}{R_{sh}}\right)^2 + \frac{4 \times \emptyset^m}{a \times R_w \times R_t}} - \frac{V_{sh}}{R_{sh}} \right] \quad (9)$$

Indonesia Mehod [10]

$$S_w^{n/2} = \frac{1/\sqrt{R_t}}{\left[\frac{V_{sh}^{(1-\frac{V_{sh}}{2})}}{\sqrt{R_{sh}}} + \frac{\phi^{m/2}}{\sqrt{a R_w}}\right]} \quad (10)$$

Average water saturation from a well or layer can use the equation below :

$$Sw_{avg} = \frac{\Sigma(\emptyset i \times hi \times Swi)}{\Sigma(\emptyset i \times hi)} \quad (11)$$

Saturation of Mud filtrate from Flushed Zone (Sxo) use the equation below:

$$S_{xo}^{n/2} = \frac{1/\sqrt{R_{xo}}}{\left[\frac{V_{sh}^{(1-\frac{V_{sh}}{2})}}{\sqrt{R_{sh}}} + \frac{\phi^{m/2}}{\sqrt{a R_{mf}}}\right]} \quad (12)$$

$$Shr = 1 - Sxo$$
$$Shm = Sxo - Sw$$

III. METHODOLOGY

Collecting data needed in this study such as LAS data and formation data. LAS data used in wells GW-1, GW-2, GW-3 and GW-4 are data from Microsoft Excel which can then be interpreted and converted into curves manually. Values of a, m, n are obtained from core data whose values are like values a, m, n for limestone. The fluid density is obtained at 1 gr/cc which is the density for freshwater. The temperature gradient is obtained at 4 °F/100 ft. Known surface temperature is 89 F. The table below is a summary of data that has been known:

Table 1. Known Log Parameters [3]

Parameter	Value	Unit
a	1	-
m	2	-
n	2	-
ρ fluid	1	gr/cc
T gradient	4	°F/100 ft
T surface	89	°F

The flowchart can be seen as follows:

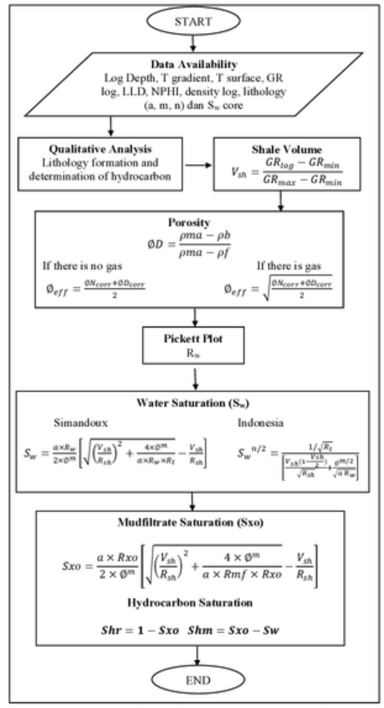

Figure 1. Flowchart S_w Calculation

IV. RESULTS AND DISCUSSION

Determining of Remaining Hydrocarbon Saturation in Y Field, petrophysical parameters such as shale volume, porosity, and formation water resistivity, mudfiltrate resistivity, Resistivity from Flushed Zone (Rxo) and Resistivity from Uninvaded Zone (Rt) are needed in four exploration wells, namely GW-1, GW-2, GW-3, and GW-4. This paper aims to determine water saturation and the proper method in the X-Layer Y Field. The first thing to do is the qualitative analysis to determine the permeable layer, fluid content and OWC (Oil Water Contact) limits. Qualitative interpretation is done by looking at the log curves (Quicklook).

After that, quantitative analysis is performed to determine the volume shale value, effective porosity and formation water resistivity used in determining the saturation of water, Saturation of Remaining Hydrocarbon and Saturation of Moveble Hydrocarbon.

After determining the permeable layer then determine the fluid content in the layer.

Low GR value in track 1 (GR Log) indicates the permeable zone and the higher GR indicates the impermeable zone [4].

High Resistivity in track 2 (ILd Log) indicates the hydrocarbon zone and the smaller Resistivity indicates the water zone [7].

Track 3 shows NPHI and RHOB curves. These log used to determine total porosity, and effective porosity. It can be used to indicate gas zone from cross over between NPHI and RHOB curves.

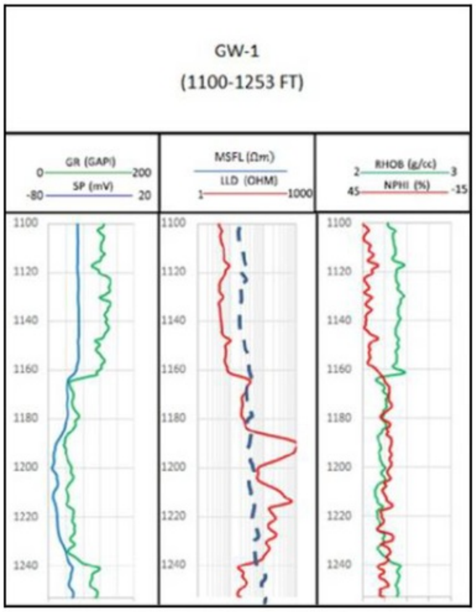

Figure 2. Triple Combo GW-1 Well

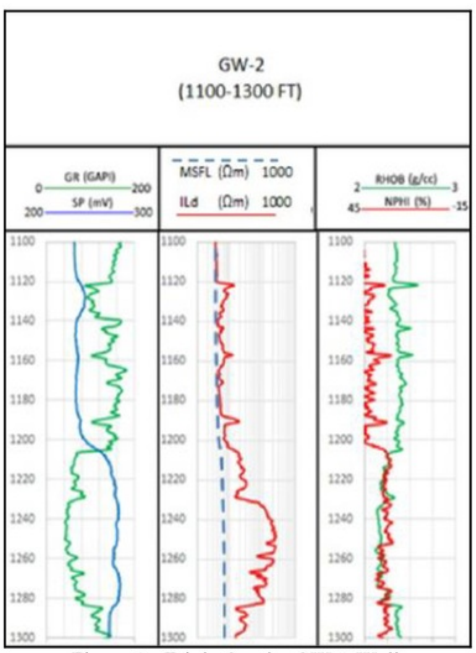

Figure 3. Triple Combo GW-2 Well

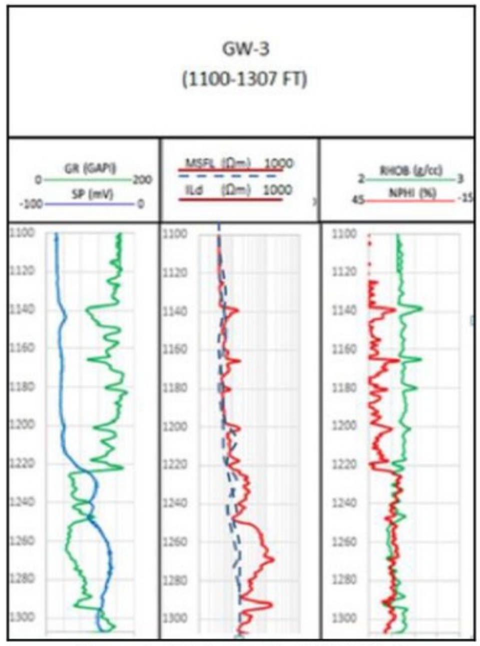

Figure 4. Triple Combo GW-3 Well

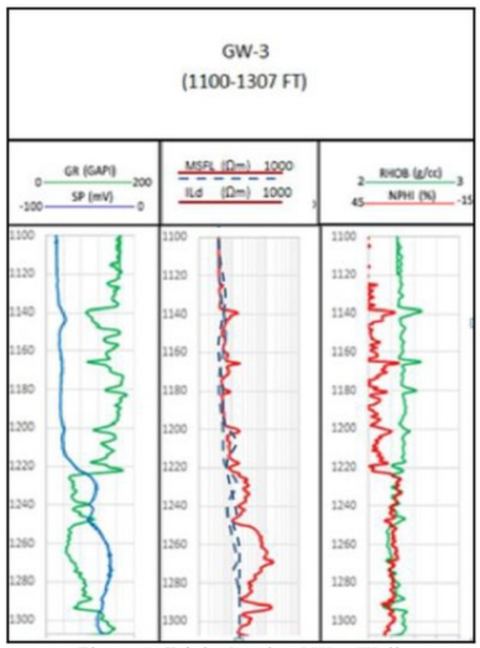

Figure 5. Triple Combo GW-4 Well

Figure 2 shows the log of GW-1 well. There is a hydrocarbon zone at 1163-1238ft which is characterized by low GR (50°API), higher resistivity compared to other zones and there are NPHI and RHOB crossover curves.

Figure 3 shows the log of GW-2 well. There is a hydrocarbon zone at 1207-1283ft, which is characterized by low GR (40°API), higher resistivity compared to other zones and there are NPHI and RHOB crossover curves.

Figure 4 shows the log of GW-3 well. There is a hydrocarbon zone at 1225-1293ft, which is characterized by low GR (40°API), higher resistivity value compared to other zones and there are NPHI and RHOB crossover curves.

Figure 5 shows the log of GW-4 well. There is a hydrocarbon zone at 1268-1309ft, which is characterized by low GR 50°API), higher resistivity compared to other zones and there are NPHI and RHOB crossover curves [1].

The lithology in X Layer is dominated by limestone which can be determined by crossplot between the neutron log and density log shown in Figure 6 [9].

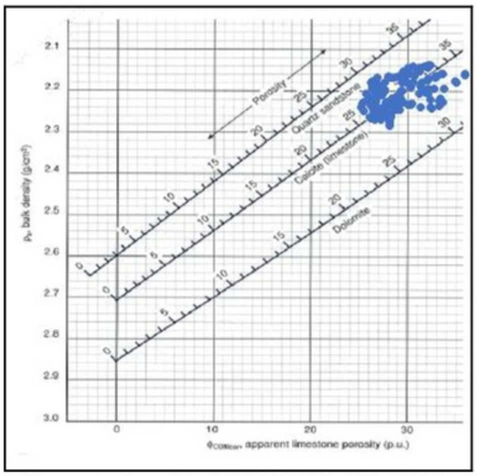

Figure 6. Cross Plot NPHI/RHOB GW-1 Well

From the result of logging can be seen that the fluid contained oil and water at the bottom. This is indicated by the overlay between NPHI Log and RHOB Log, the quantitative log interpretation is determining shale volume, effective porosity and water saturation in flushed zone and uninvaded zone in the four wells. The existence of a thin shale in the formation makes it necessary to do a calculation to get the volume shale that affects the calculation of the Simandoux Method and the Indonesian Method. The first thing to do in calculating shale volume is to determine the value of GR clean and GR shale. The results obtained from GW-1 wells are GR clean of 34ºAPI and GR shale of 145ºAPI, in GW-2 wells GR net is 40ºAPI and GR shale is 182ºAPI, in GW-3 wells GR clean is 45ºAPI and GR shale is 185ºAPI and in GW-4 wells obtained a GR clean of 51ºAPI and GR shale of 184ºAPI. Calculation of shale volume using the log GR curve because the GR log is considered capable of distinguishing radioactive (shale) elements and non-radioactive elements (formation rocks). By using the GR log, the average shale volume in GW-1 is 17,2%, GW-2 is 13,2%, GW-3 is 16,7% and GW-4 is 11,5%. The next thing to do is to determine the effective porosity. In determining effective porosity is used the combination of porosity logs, namely Neutron-Density Log. It is expected that the accuracy obtained will be higher than calculating porosity using only one log curve. In GW-1 wells, the effective porosity value of 23,6% is obtained, for GW-2 wells the effective porosity value is 26,8%, for GW-3 wells the effective porosity value is 21,9% and for GW-4 wells the effective porosity value is 22,5%. This shows that the porosity at the Y Field X Layer has a very good value. After determining the porosity analysis, then find the resistivity of formation water of the formation temperature. This formation temperature is used to correlate formation water resistivity obtained from the Pickett Plot Method as shown in Figure 7.

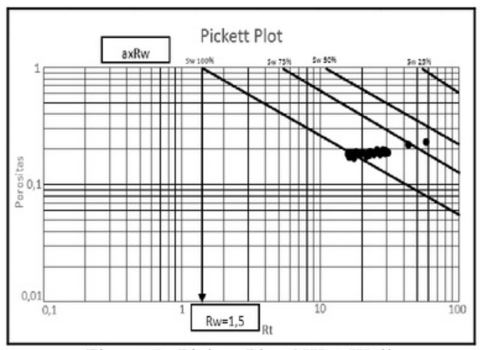

Figure 7. Pickett Plot GW-1 Well

The water resistivity obtained for the GW-1 well was 1.52 Ωm @137.02ºF. From water resistivity is 1.5Ωm@138.83ºF obtained a salinity 2100 ppm. Before determining the Sw, data such as tortuosity (a), cementation factor (m) and saturation exponent (n) are needed. This data is usually obtained from SCAL (Special Core Analysis). Values a, m and n obtained from SCAL the value are 1, 2 and 2.

Then start calculating the Sw with the Simandoux Method and the Indonesian Method at each depth analyzed and then averaged. From the results of water saturation average, the Sw calculation using the Simandoux Method in GW-01 wells is 33,6%, GW-02 is 43,4%, GW-3 is 67,0% and GW-4 is 39,7%. The results of water saturation using the Indonesian Method on GW-1 wells are 43,9%, GW-2 is 48,8%, GW-3 is 72,3% and GW-4 is 44,0%. and Indonesian Method. Comparison of Sw

Core with Sw Simandoux and Indonesia shown in Figure 8.

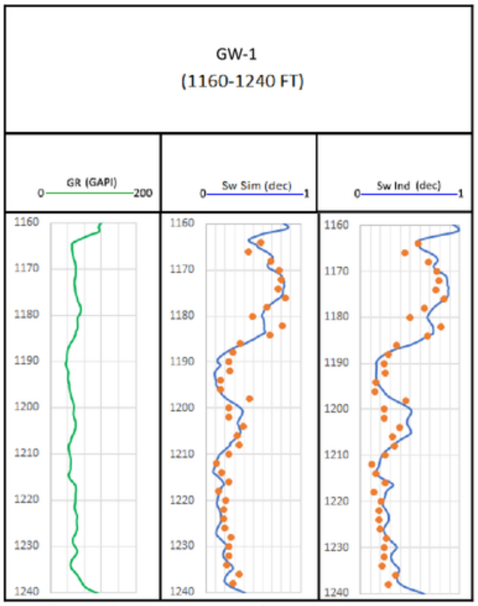

Figure 8. Comparison of Sw Core with Sw Simandoux and Indonesia

Comparative analysis can be done by charting the trendline in Microsoft Excel by entering both data, namely S_w Core and S_w from the method we want to compare as shown in figures 9 and 10.

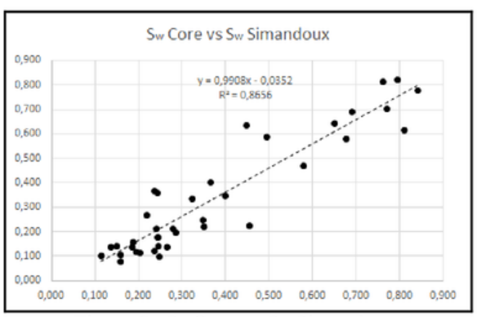

Figure 9. S_w Core vs S_w Simandoux

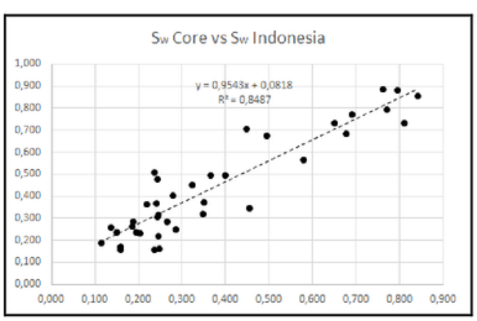

Figure10. S_w Core vs S_w Indonesia

After a comparison, the Simandoux S_w value is closer to the S_w Core value because the value is still close to the trendline with R^2 value of 0.865 which is closer to one while the Indonesian Sw value is farther than the trendline and R^2 value of 0.848 which is less than one.

V. CONCLUSION

From the research that has been done, the conclusions that can be drawn are as follows:

1. Formation in the X Layer Y Field in the form of limestone with temperatures ranging from 135-140ºF. The zones analyzed in GW-1, GW-2, GW-3 and GW-4 wells were 1163-1238 ft, 1207-1283 ft, 1225-1293 ft and 1268-1309 ft, respectively.
2. From the results of gamma ray log, the average Vshale obtained in wells GW-1, GW-2, GW-3 and GW-4 were 17,2%, 13,2%, 16,7% and 11,5%. The effective porosity value is obtained by using the Neutron-Density log method, namely in wells GW-1, GW-2, GW-3 and GW-04 respectively 23,6, 26,8%, 21,9% and 22,5%.
3. Water saturation (S_w) in the X layer by Simandoux Method on GW-1 wells on average by 33,6%, GW-2 on average by 43,4%, GW-3 on average by 67%, GW-4 on average amounted to 39,7%. Water saturation (S_w) in the X layer by the Indonesian Method in GW-1 wells is an average of 43,9%, GW-2 is 48,8%, GW-3 is 72,3%, and GW-4 is 0.440. From the results of water saturation, it can be seen that the best method of water saturation in the X layer is the Simandoux method because it has results that are closer to the S_w Core data..
4. Remaining Hydrocarbon Saturation (Shr) was obtained by 34.5%, 31.8, 23%, 35.4% of the results of parameters measured in the flushed zone namely Rxo, Rmf and Sxo data. Movable Hydrocarbon Saturation (Shm) was obtained by 31.9%, 24.8%, 10%, 24.9% in wells GW-1, GW-2, GW-3 and GW-4.

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