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Application of R-Squared (R^2) in The Analysis of Estimated Water Encroachment into a Reservoir

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ABSTRACT

The purpose of this paper is to apply R-squared in the analysis of estimated water encroachment into the reservoir. The data used for this work were gotten from records and these data were used to estimate water encroachment using Van Everdingen-Hurst (VEH) and Carter-Tracy models. The R-squared was obtained by plotting the value of estimated water encroachment against time. The results show that all the R-squared gotten in this work are more than 90% as indicated in all the graphs plotted. These results indicated that the variables involved in the computation of water encroachment are all considered, and the results also show that VEH is more reliable since it has higher R-squared. This method of analysis is faster and easy when compared with other methods like Durbin Watson and t-test.

Keywords: Aquifer, boost, petroleum, reservoir oil, water encroachment, model.

1.0. Introduction

Water aquifers which surround oil reservoirs help to boost the reservoir pressure through water encroachment. When there is a pressure decline in the oil reservoir, the water aquifer responds to make up pressure decline by water encroachment into the reservoir (Amer et al.,2015). In the petroleum industry, different Models are used to calculate water encroachment (Klins et al.,1988; Oloro et al.,2011; Van Everdingen et al.,2015). In this paper, Van Everdingnen-Hurst and the Carter-Tracy Unsteady – state models were used (Carter and Tracy, 1960).

The Van Everdingnen-Hurst (VEH) mode (Van Everdingen et al.,2015) is the most complex of all these models. Its main benefit is it's realistic. Originally, its major disadvantage was it is difficult in the usage. Charts had to be repeatedly consulted to perform a calculation (Anthony, 2015**)**. To handle this problem, Fetkovich and Carter-Tracy models were used without tables and charts (Carter andTracy, 1960**;** Fetkovich, 1971). However, these models were only overviews of the VEH model. Since the VEH tables and charts were digitized, the prerequisite for the previous one has diminished.

R-squared (R^2) measures the percentage of dependent adjustable described by suggested explanatory variables that fall on the regression line. For an instant, 80% means that 80% of the variation of water encroachment values around the mean is explained by other values. In other words, 80% of the values fit the model (Abraham, 1983; Jean, 2011; Ross, 2019; John, 1974). The literature review revealed that different methods or Models (Durbin Watson t-test) (Montgomery et al., 2001) have been used to analyze the effectiveness of water encroachment model but they are unreliable, cumbersome and time-consuming. Hence in this study, estimation of water invasion into the reservoir will be carried out using Van Everdingen-Hurst unsteady-state and Cater-Tracy Unsteady-state models and the results will be analyzed using R- squared (Lee, 2006).

2.0. Materials and method

In this study, data were gotten from (Oloro et al., 2009) and these data were used to calculate water encroachment using Van Everdingen-Hurst and Carter-Tracy models (Van Everdingen and Hurst, 2015; Carter and Tracy, 1960**)**. The results were plotted on the graph sheet to determine R^2. The R squared was analyzed to determine which of the model is more effective for determining water encroachment into the reservoir.

The information in Table 1 was obtained from Oloro and Rai (2009) and was used with Equations 1 to 5 to compute the water encroachment using Van Everdingen-Hurst Model. In using the Carter-Tracy Model, Equation 6 and 7 was included to the equations.

Table 1: Pressure history of reservoir and aquifer properties

Time (days)	Pressure (Pisa)	Properties of the Aquifer	
0	3450	$R_{r(ft)}$	6642.5
18	3350	$\mu(C_p)$	0.17
26	3262	h(ft)	222
34	3154	Ɵ	165
42	3032	k(md)	2160
50	2904	ϕ	0.21
58	2780		
66	2698		

The following steps are followed using the Van Everdingen-Hurst Model:

Step1: Find water encroachment constant β using Equation 1.

$$\beta = 1.19\emptyset c_t h r_r^2 \left(\frac{\theta}{360}\right) \tag{1}$$

Step 2: For each period, compute ΔP using Equation 2.

$$\Delta P_N = \frac{1}{2}(P_{N-2} - P_N) \tag{2}$$

Step 3: Compute dimensionless time's t_D using Equation 3.

$$t_D = \frac{0.00633Kt}{\mu C_t r_r^2} \tag{3}$$

Step 4: Compute dimensionless cumulative water encroachment (Q_{PD}) using the values of t_D calculated in step 3. Because we are assuming an infinite-acting aquifer, we can use Equation 3 since the value of t_D is greater than 0.001 and also lesser than 200 we can use Equation 4.

$$Q_{PD} = \frac{1.2839 t_D^{1/2} + 1.19328 t_D + 0.26987 t_D^{3/2} + 4)}{1 + 0.616599 t_D^{3/2} + 0.0413008 t_D} \tag{4}$$

Step 5: Compute W_e using Equation 5.

$$W_e(t_{DN}) = \beta \sum_{t=1}^{n} \Delta P_i Q_{PD}(t_N - t_{i-1})_D \tag{5}$$

The following steps are followed using the Carter-Tracy model:

Step 1: Find water encroachment constant β using Equation 1

Step 2: For every time period, compute ΔP using Equation 6.

$$\Delta P_n = Paqi - P_n \tag{6}$$

Step 3: Compute dimensionless time's t_D using Equation 3.

Step 4: Compute dimensionless pressures at every of dimensionless time computed in step3. The dimensionless pressures are calculated with Equation 7.

$$P_D(t_D) = \frac{716.441 + 46.7984 t_D^{1/2} + 270.038 t_D + 71.0098 t_D^{3/2}}{1296.86 t_D^{1/2} + 1204.73 t_D^{3/2} + 538.072 t^2 + 142.41 t_D^{5/2}} \tag{7}$$

Where β=water encroachment constant, c_t = total aquifer compressibility, c_f = aquifer rock compressibility, c_w = aquifer water compressibility, h = net formation thickness, e_w = water influx rate from aquifer, P_{aq} = aquifer pressure, P_D = Dimensionless pressure, P_r = Pressure at aquifer/reservoir interface, ΔP = Difference between initial aquifer pressure and pressure at original reservoir/aquifer boundary, r_r = radius to aquifer/reservoir interface ra = radius of the aquifer , Φ = Porosity of the aquifer ,We = Cumulative water influx, K = permeability, n = refers to the current time step.

3.0. Results and discussion

From Figure 1, it can be observed that water encroachment into the reservoir computed by Carter-Tracy Model is more than that of Van Everdingen-Hurst (VEH). The R-squared obtained were above 90%. This is an indication that all the variables that are involved in water encroachment computation were highly considered. R squared of VEH is higher than that of Carter-Tracy, hence Van Everdingen-Hurst Model is more reliable (Krause et al., 2005).

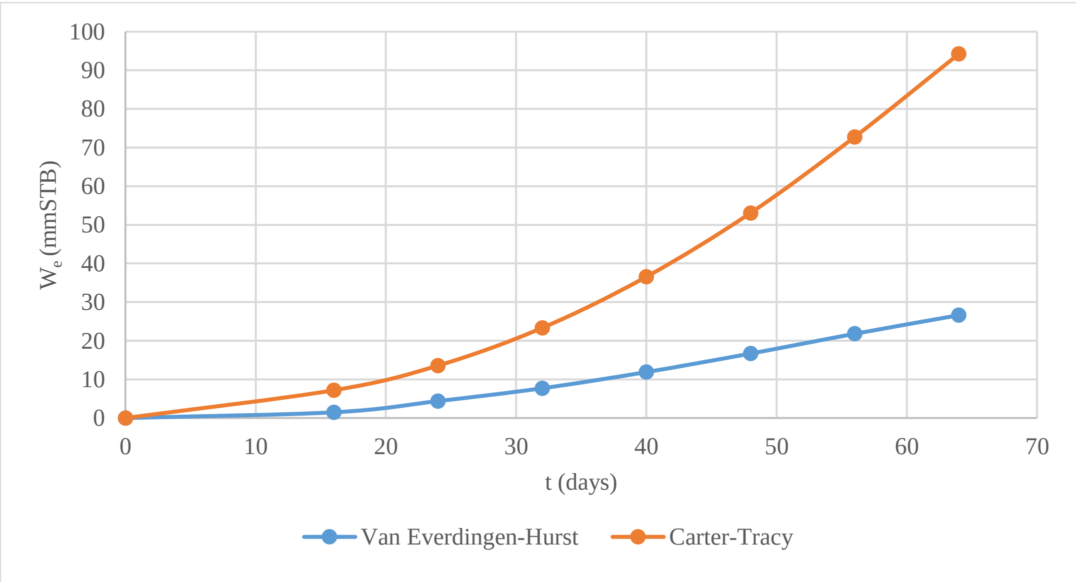

Figure 1: Results for Van Everdingen-Hurst and Carter-Tracy models

The relationship between W_e and time including the corresponding R^2 value is shown in Fig. 2 for Van Everdingen-Hurst model. It can be seen that water encroachment increases with time and it is dependent on the reservoir pressure. If the reservoir pressure is low, more water will encroach into the reservoir to counterbalance the decline in pressure.

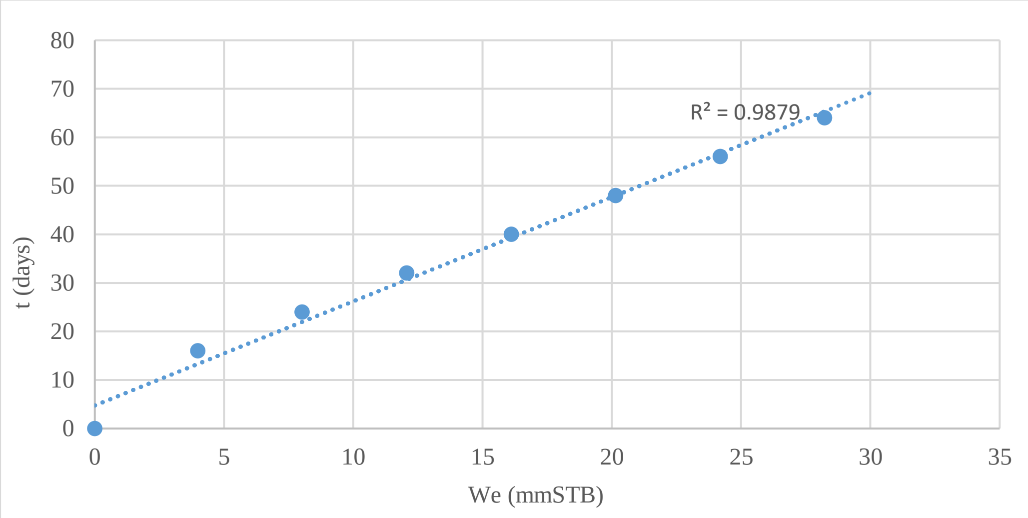

Figure 2: R^2 for Van Everdingen-Hurst model

The high value of R^2 obtained implies a high degree of acceptance and reliability while the low value of R^2 means that all the variables that are involved in water encroachment computation were not highly considered. From literature, it has been confirmed that Van Everdingen is more reliable (Joao and Osvair, 2007).

Comparing the R^2 values of Figure 2, Figure 3, Figure 4 and Figure 5 of the two Models, Van Everdingen-Hurst unsteady state Model compared better. This implies that VEH is more reliable for estimation of water encroachment (Khulud, et al., 2013).

Figure 4 and Figure 5 demonstrate the effect of pressure on water encroachment using Van Everdingen-Hurst and Carter-Tracy Models. It shows that as the production of oil is increasing the pressure will decline. This, therefore, necessitates the encroachment of more water from the aquifer into the reservoir to offset the imbalance. R^2 for both Models shows that VEH is more effective according to Joao and Osvair**.**

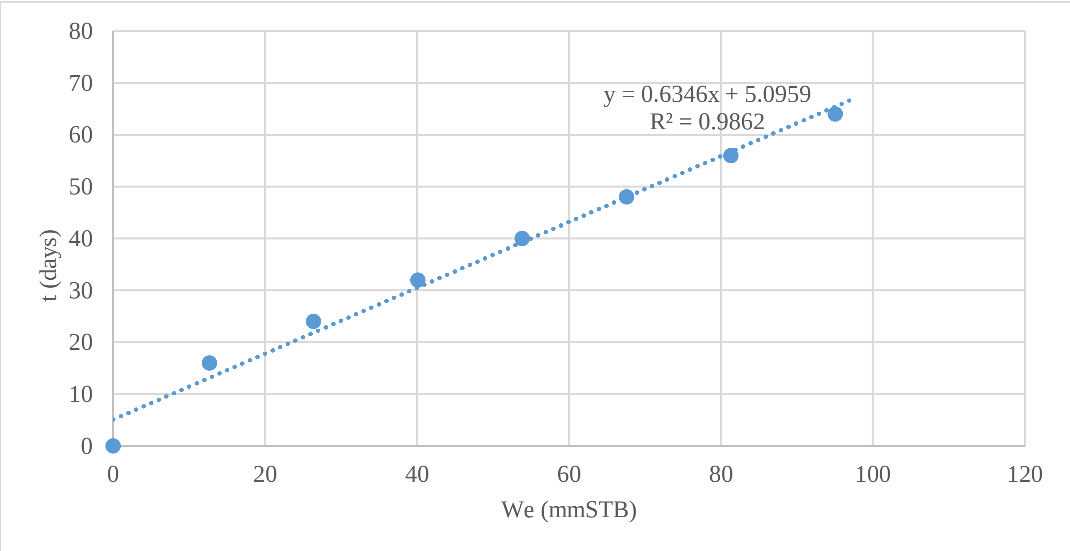

Figure 3: R^2 for estimated Carter-Tracy model

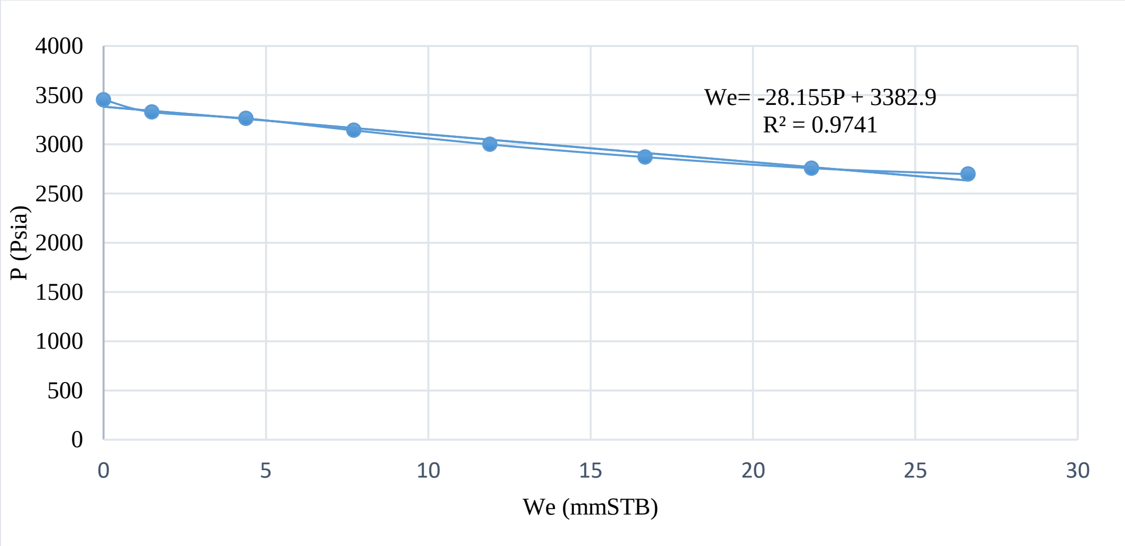

Figure 4: Effect of Pressure on Oil Recovery using Van Everdingen-Hurst Model

Figure 6 shows the behavior of pressure with time. It can be observed that pressure decreases with time, and this is an indication that oil recovery is inversely proportional to the time and corroborates the earlier report by Khulud et al., 2013. Production of oil from a reservoir is divided into 3 methods: primary, secondary and tertiary recovery. Numerous factors regulate the production flows in most oil fields. Basic understanding of these is necessary for better understanding of decline and depletion behavior. Actually, oil recovery involves fluid flows through the porous material that makes up the oil field. Fluid movements in a reservoir hinge on several factors which include a decline in pressure that is explained more comprehensively by Satter et al. (2008).

Primary recovery occurs naturally by energy such as reservoir pressure, to drive oil to the surface. Oil is simply allowed to flow on its own pressure except fluids are injected into the reservoir. However, the pressure gradient reduces as oil is produced **(**Daniel, et al., 2010).

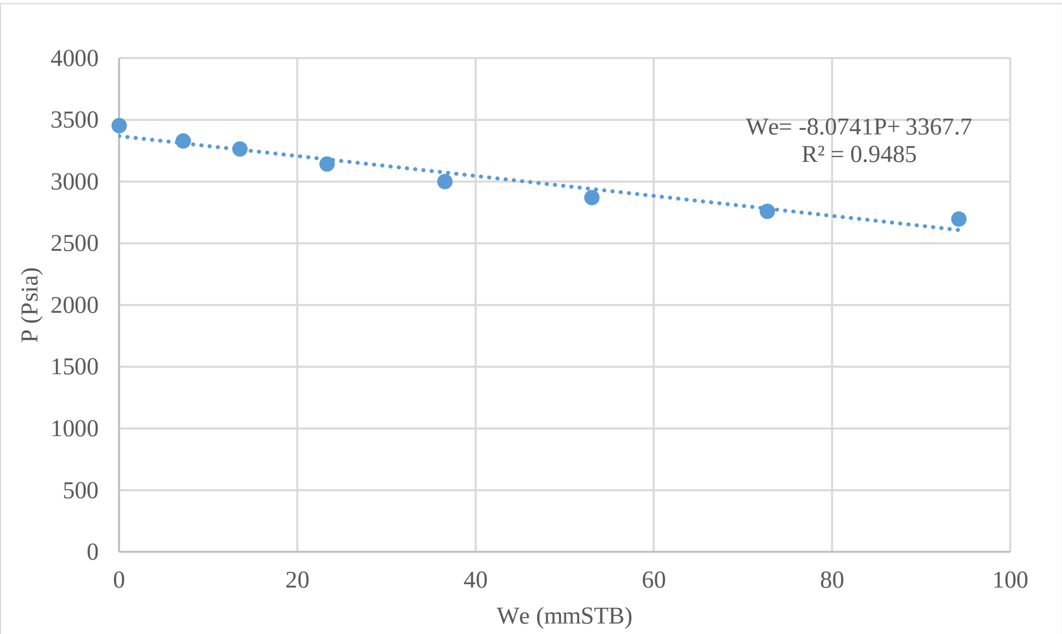

Figure 5: Effect of pressure on oil recovery using Carter-Tracy model

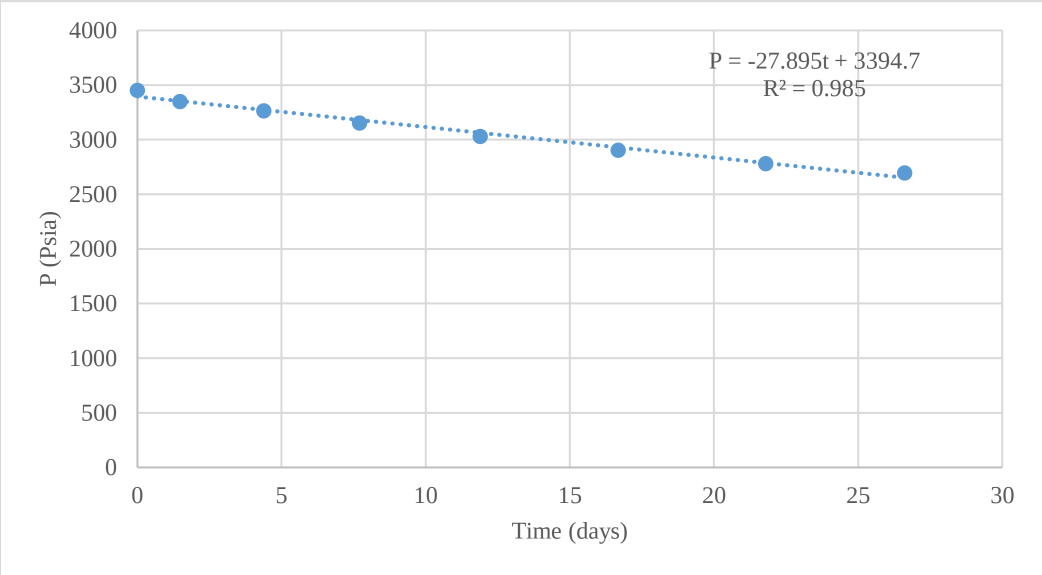

Figure 6: Behavior of pressure with time for VEH

4.0. Conclusions

Two models were used to estimate water encroachment and the R-squared was obtained by plotting the value of estimated water encroachment against time. The results of application of R-squared in the analysis of estimated water encroachment into the reservoir show that Van Everdingen-Hurst Model is more reliable.

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