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PREDICTION OF ”RATE OF PENETRATION” (ROP) ON DRILLING FORMATION ”X” PROGNOSIS WELL ”YN2” BASED ON THE REPRESENTATIVE MODELLING FROM DRILLING FORMATION ”X” ACTUAL WELL ”YN1” FIELD ”IP”

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Abstrak

Prediction value of the rate of penetration (ROP) in the drilling of the formation “X” well prognosis "YN2" in the field “IP” and the actual well "YN1" as a review of the selection of a representative Model-ROP at a depth of 2620 mbpl - 3000 mbpl in the "IP" field ". This study selected a representative Model-ROP from drilling the "X" formation of the actual well "YN1" in the "IP" field then predicting the rate of penetration (ROP) value in the drilling of the "X" formation of the "YN2" prognosis well in the "IP" field. ROPs used in this study include the Bingham Model (1966), Teale (2008) and Mottahari (2010). Prediction of the rate of penetration (ROP) value in the drilling of the "X" formation well "YN2" prognosis is done in stages including predicting the rate of penetration (ROP) value in the drilling of the "X" formation of the actual well "YN1" by collecting data including data on "YN1" actual well drilling includes bit records, drilling reports, well programs, and well profiles and then predicts the rate of penetration (ROP) value in the drilling of the "X" well formation "YN2" using drilling prognosis. Determine the drilling parameters needed to predict the value of the rate of penetration (ROP) has a difference in each model. In the Bingham model the parameters required include MD, WOB, RPM, T, and d-exp values. In the Teale model the required drilling parameters contain the actual MD, WOB, RPM, T, DB, and ROP values, MSE, μ and AB. In the Mottahari Model, the drilling parameters needed for MD, WOB, RPM, T, DB, actual ROP, σ, Wf (use function), G (model coefficients representing drillability), a = 0.50 and y = 1,50 is obtained from assumptions. In the Bingham Model has a coordination coefficient value (R^2) = 0.9985, the Teale Model has a coordination coefficient value (R^2) = 1 and the Mottahari Model has a co-coefficient value (R^2) = 1. The ROP model that represents the drilling of the "X" formation Actual wells "YN1" can all be used or all Model-ROPs represent to predict the value of the penetration rate (ROP) in drilling the "X" formation prognosis of the well "YN2". Calculate the estimated penetration rate (ROP) in the drilling of the "X" formation prognosis of the well "YN2" using the Bingham, Teale and Mottahari models through the prognosis of the drilling "YN2".

Keywords**:** *Rate of Penetration, ROP Model, Representative, Drilling Parameters.*

INTRODUCTION

Prediction of the rate of penetration (ROP) value in the drilling of the "X" formation well "YN2" prognosis lies in the "IP" field and the actual "YN1" field as a

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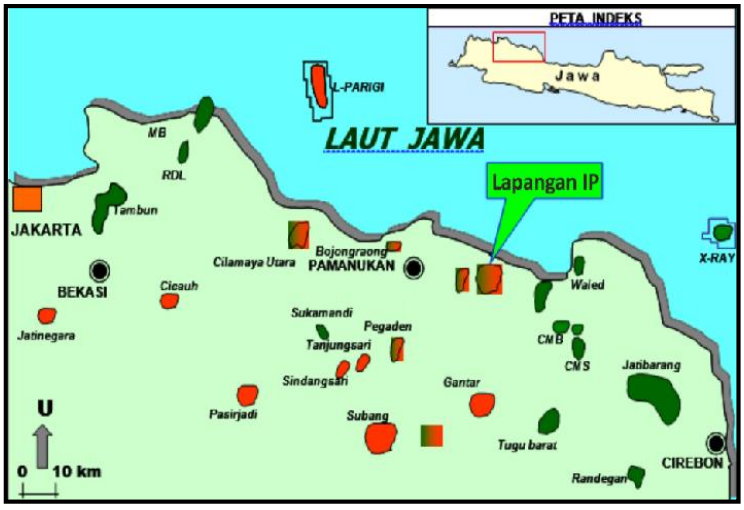
review of the selection of a representative Model-ROP at a depth of 2620 mbpl - 3000 mbpl in the "IP" field ". The "YN2" prognosis drilling well plan aims to develop gas from the TAF-5 sandstone reservoir as the main layer target and TAF-3.2 as an additional layer target. The type of well drilling is directional. In drilling operation the rate of penetration (ROP) value is affected by variables that cannot be changed and can be changed. The variable that cannot be changed is the characteristics of the rock being penetrated while the variable that can be changed includes drilling mud, hydraulics, drilling bits, and mechanical factors (WOB and RPM). In calculating the prediction of the rate of penetration (ROP) these variables are summarized in the ROP model equation. This study selected a representative Model-ROP from drilling the "X" formation of the actual well "YN1" in the "IP" field then predicting the rate of penetration (ROP) value in the drilling of the "X" formation well in the "YN2" prognosis well in the "IP" field. The study in this thesis uses several ROP models including Bingham (1966), Teale (2008) and Mottahari (2010). Prediction of the rate of penetration (ROP) value in the drilling of the "X" formation well "YN2" prognosis is done in stages including predicting the rate of penetration (ROP) value in the drilling of the "X" formation of the actual well "YN1" by collecting data including data on "YN1" actual well drilling includes bit records, drilling reports, well programs, and well profiles and then predicts the

rate of penetration (ROP) value in the drilling of the "X" well formation "YN2" using drilling prognosis.

GENERAL REVIEW OF THE FIELD

The "IP" field **(figure 1)** is located in the North West Java Basin, Java Island, Indonesia. Geographically, this field is located E = 828,562.45m N = 9,302,510,762 m.



Picture 1. Map Location on Field "IP"
(PT. Pertamina EP Asset 3, 2017)

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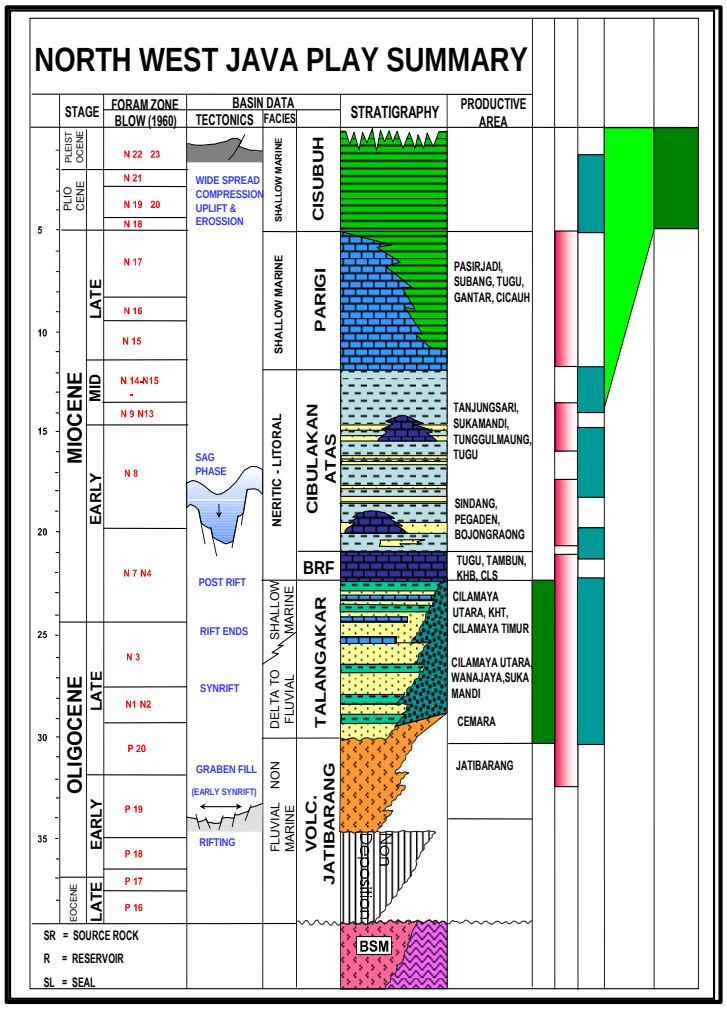
General stratigraphy of North West Java in a row from old to young is shown in **Figure 2.** are as follows: Jatibarang, Talangakar, Baturaja, Cibulakan, Parigi and Cisubuh. Based on seismic data, the "YN2" Well is expected to penetrate the peak of the Parigi Formation at 985 mbpl, the Upper Cibulakan Formation at 1030 mbpl, the Baturaja Formation (eq BRF) at 2285 mbpl, and the TalangAkar Formation (eq. TAF) at 2560 mbpl and the Jatibarang Formation at 2285 mbpl, and the TalangAkar Formation (eq. TAF) at 2560 mbpl and the Jatibarang Formation at 2285 mbpl, and the TalangAkar Formation (eq. TAF) at 2560 mbpl. 2958 mbpl. This paper study was conducted on the "X" formation, namely the Talangakar and Jatibarang formations. The Talangakar Formation has lithology beginning with alternating sandstone sediments with non-marin shale and ending with alternating between limestone, shale and sandstone in marin facies. The Jatibarang Formation has not very thick lithology found. This formation consists of tuff, breccia, agglomerates and base conglomerates. This formation was deposited on fluIial / non-marine-marine facies.



Picture 2. Statigrafi Well Drilling on Field “IP”
(PT.Pertamina EP Asset 3, 2017)

METHODOLOGY

The study in this paper uses several ROP models including the Bingham Model (1966), Teale (2008) and Mottahari (2010). The steps in this study are shown in the flowchart in **Figure 3.1.** Conduct a study of prediction of the rate of penetration (ROP) including data preparation, determining the parameters needed in each ROP model, and predicting the value of penetration (ROP) on various ROP models. In the Bingham model the parameters needed include MD, WOB, RPM, T, and d-exp values. In the Teale model drilling parameters needed include the values of MD, WOB, RPM, T, DB, and the actual ROP, MSE, μ and AB. In the Sunday Model drilling parameters needed include MD, WOB, RPM, T, DB, actual ROP, σ, Wf (wear function), G (the model coefficient which represents the drillability), a = 0.50 and y = 1.50 is obtained from the assumption.

STUDY LITERATURE

Rate of Penetration (ROP)

Rate of penetration (ROP) is the volume of rock removed per unit area (ft) per unit time (hour), or it can also be interpreted by the speed of bits destroying the rock to be penetrated and in general the rate of penetration (ROP) measures the speed or progress of the bit when drilling (Bourgoyne and Milheim, 1986).

Model-Model ROP

In calculating the rate of penetration (ROP) value at this writing, there are several models that can be used including the Bingham model (1966), Teale (2008), and Mottahari (2010). Calculation of rate of penetration (ROP) values based on the above ROP model adjusts to the drilling bits used in drilling operations.

1. Model Bingham (1966)

In 1966, Jorden and Shirley developed the Bingham model by introducing the d-exponent method used to increase the rate of penetration (ROP) detection rate of the over pressured zone. The basis of this equation is the Bingham model, this model is formulated in the following general **equation** (1).

$$ROP = 10^{d_{exp} * \log\left(\frac{12\,WOB}{10^6 d_b}\right) + \log 60\,N} \quad (1)$$

Where :

ROP = *rate of penetration,* ft/hr.
D-exp = *drillability exponent*, *dimensionless*.
WOB = *weigth on bit*, lbs.
N = *rotary per minute*s, rpm.
d_b = diameter bit, in.

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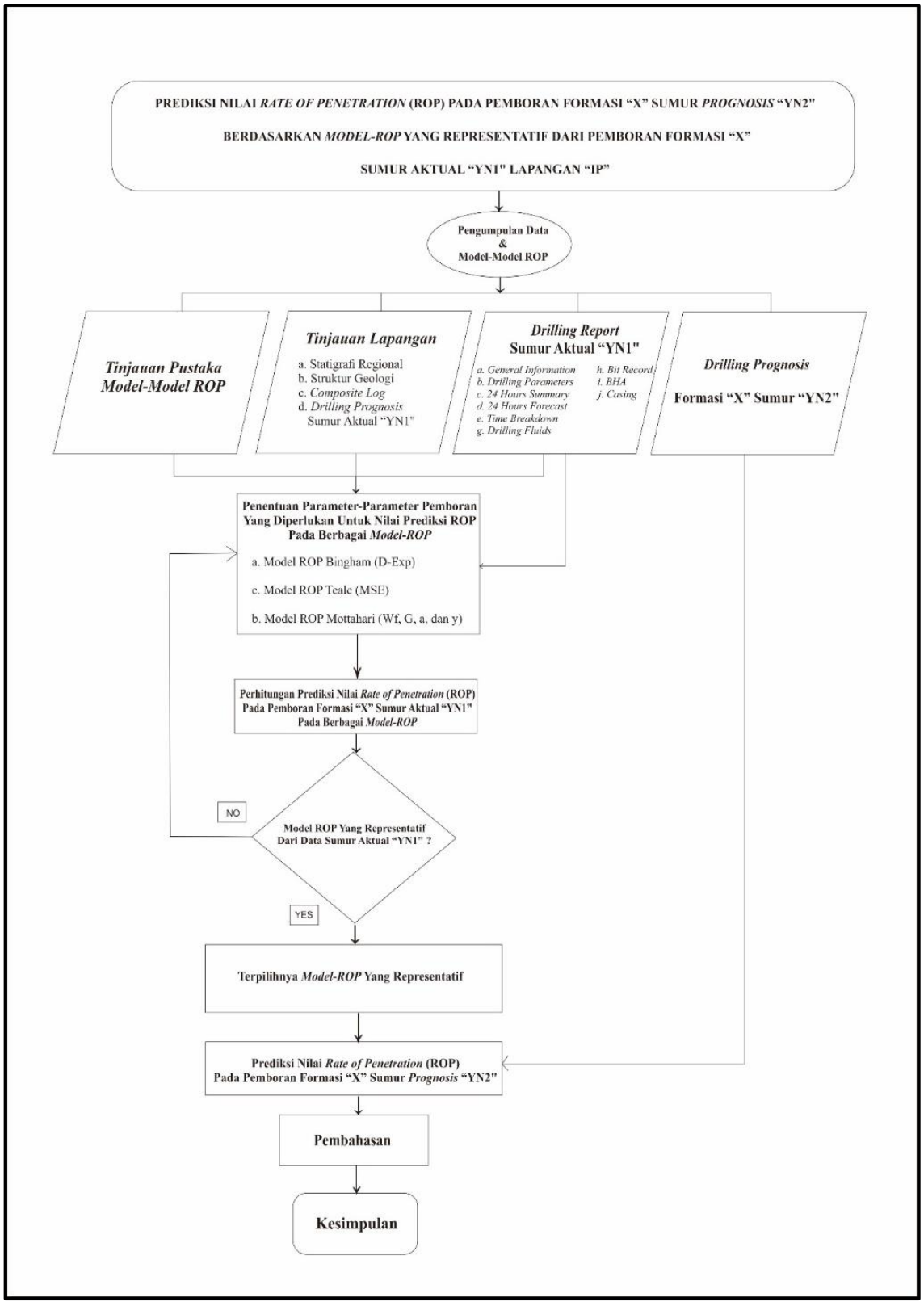

Figure 3.1. *Flowchart*

D-exponent is one method used to calculate the rate of penetration (ROP) value. D-Exponent normalizes the rate of penetration (ROP) for variations in drilling parameters. Jordan and Shirley modify the Bingham model where 'd-exp' replaces 'b' in the Bingham equation. The d-exponent value is calculated by the following **equation (2)** :

$$\log\left(\frac{ROP}{60\ N}\right) = d_{exp} * \log\left(\frac{12\ WOB}{10^6 d_b}\right) \quad (2)$$

D-exponent assumes that the value of d-exp at the well is the correlation of the closest well. First we determine the d-exp value of the actual well, then the value of the d-exp is used at the nearest well to predict the rate of penetration (ROP) value. The work process of the d-exponent is illustrated as shown in **Figure 4.1.**

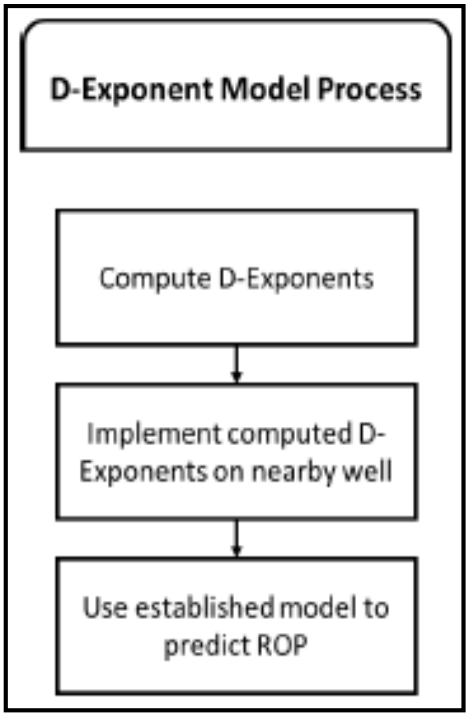

Figure 4.1. Workflow Prediction of ROP Value On the Bingham Model.
(Malik Alsenwar, 2017)

2. Model Teale (2008)

The Teale model calculates the amount of energy needed to drill the given rock volume (MSE). The MSE value from the nearest well can be used to calculate the predicted rate of penetration (ROP) value. Following the Teale modeling workflow with MSE values is shown in **Figure 4.2.**

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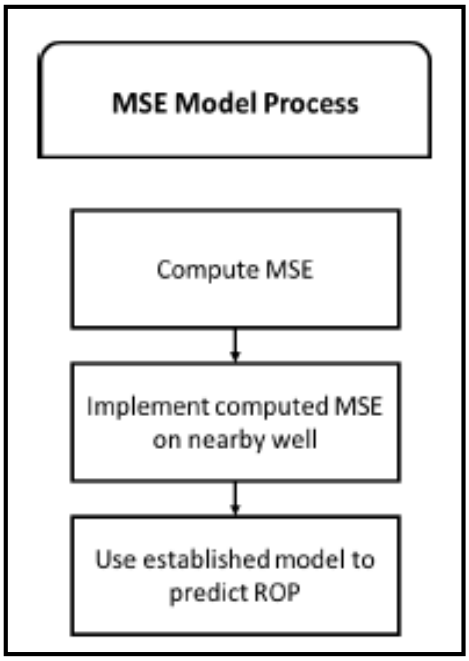

Figure. 4.2. Workflow Prediction of ROP Value On the Teale Model.
(Malik Alsenwar, 2017)

The MSE value in the drilling well is calculated first :

$$MSE = \frac{WOB}{A_B} + \frac{13.33 * \mu * RPM * WOB}{D_B * ROP} \quad (3)$$

Pessier and Fear introduced the specification of "sliding friction (μ)" determined by **equation (5)**. In field applications generally the value (μ) is assumed to be 0.25 for tricone bits and 0.5 for PDC bits while the bit area (AB) is determined by **equation (6)**.

$$\mu = 36\frac{T}{D_B * WOB} \quad (5)$$

A_B = 3,14 * D_B^2 / 4 **(6)**

After obtaining the MSE value from the previous well, continue calculating the predicted rate of penetration (ROP) according to the Teale Model **equation (7)**.

$$ROP = \left[\frac{1000\, MSE\, {d_b}^2 - 4\, WOB/\pi}{480 * T * N}\right]^{-1} \quad (7)$$

Where :
MSE = *mechanical specific energy*, psi.
ROP = *rate of penetration*, ft/jam.

d_b = *diameter bit*, in.
T = *torque*, ft/lbs.
WOB = *weigth on bit*, lbs.
N = *rotary per minutes*, rpm.
μ = *sliding friction*, *dimensionless*.
A_B = *bit area*, in^2.

The parameters db, T, WOB, and N can be obtained from the drilling report and mud log.

3. Model Mottahari

The Mottahari model for increasing PDC was slightly developed to promote what Hareland introduced. This model is incorporated in the wear function of the bit (Wf) and the effect of rock strength (σ) on the model to determine the value of the penetration rate (ROP). The Mottahari Model assumes perfect bit cleaning. The ROP model according to Mottahari is as follows :

$$ROP = W_f \cdot \left(\frac{G.RPM^{\gamma}.WOB^{\alpha}}{D_B.\sigma} \right) \quad (8)$$

Where :
ROP = *rate of penetration,* ft/jam.
Wf = *wear function, nondimensional.*
G = *the model coefficient which represents the drillability*, *dimensioless.*
RPM = *rotary per minutes*, rpm.
WOB = *weigth on bit*, lbs.
D_B = *diameter of bit*, in.
σ = *confined rock strength*, psi. = (*grad compressive strength* x mTVDSS)
a = WOB *exponent*.
y = RPM *exponent*.

RPM, WOB, DB, and σ parameters were obtained from drilling reports, prognosis data and composite logs. While W_f is obtained from **equation (9)**, G is obtained from **equation (11)** and values a and y from the model coefficients assuming values a = 0.50 and y = 1.50.

$$W_f = 1 - \left(\frac{\Delta BG}{8} \right)^{\omega} \quad (9)$$

$$\Delta BG = C_a \sum_{i=1}^{n} RPM^{C_1} \left(\frac{WOB}{1000}\right)^{C_2} \left(\frac{\sigma}{1000}\right) x_i \quad (10)$$

$$G = ROP * DB * \sigma / W_f * WOB^a * RPM^y \quad (11)$$

STUDY CASE

Calculation of Rate of Penetration (ROP) Value Prediction in The "X" Well Activity Form "YN1" Field "IP" Field in Various Model-ROP

In calculating the prediction of the rate of penetration (ROP) value in the "X" formation of the actual well "YN1" for various Model-ROPs, the first step is to collect drilling parameters from the drilling report and the actual well record bit "YN1", the second determines the parameters drilling parameters needed for prediction of the rate of penetration (ROP) values on various ROP Models, the third calculates the predicted value of rate of penetration (ROP) for three Model-ROPs which include the Bingham Model (1965), Teale Model (2008) and Mottahari (2010).

a. Collection of Drilling Parameters "YN1" Actual Well Drilling Report and Bit Record

Drilling parameters are collected from the actual drilling report data and the actual well record bit "YN1" including the measured depth (MD mtr), drilling rate (rate of penetration, ROP mtr / hour), weight of the bit (weigth on bit, WOB klbs), rotational speed on bits (rotary per minutes, RPM), torque (torque, kft / lb), and bit diameter (db, in), in this study the measured drilling depth was carried out at 2620 mtr - 3000 mtr as shown in **Table V-1.**

Determination of Drilling Parameters Required for Rate of Penetration Prediction (ROP) in Various Model-ROP

Determination of drilling parameters needed to predict the rate of penetration (ROP) value in the drilling of the "X" formation of the actual well "YN1" on various models has different drilling parameters, the ROP models to be analyzed include the ROP Bingham model, Teale and Mottahari.

a. Drilling Parameters Required for Prediction The Value of Penetration (ROP) in the Bingham ROP Model (1966)

The Bingham Model, the drilling parameters needed to predict the rate of penetration (ROP) include MD, WOB, RPM, T, and d-exp **equation (2)**. The results of determining the d-exp parameter are shown in **Table V-2.**

b. Drilling Parameters Needed to Determine the Rate of Penetration (ROP) Value According to the ROP Teale (2008) Model

The Teale model drilling parameters needed to determine the value of rate of penetration (ROP) include MD, WOB, RPM, T, Db, and actual ROP, MSE **equation (3)**, μ **equation (5)**, and A_B **equation (6)**. The results of determining the MSE, μ, and A_B parameters are presented in **Table V-3.**

c. Drilling Parameters Required for Prediction Rate of Penetration (ROP) Value in the Mottahari ROP Model

The Mottahari model drilling parameters needed for prediction of the rate of penetration (ROP) include MD, WOB, RPM, T, DB, actual ROP, σ, W_f (wear function) **equation (9)**, G (the coefficient models representing the drillability) **equation (11)**, a = 0.50 and y = 1.50 obtained from the assumptions. The results of determining the parameters W_f, G, a and y are presented in **Table V-4.**

Rate of Penetration (ROP) Prediction Calculations in Drilling Formation "X" Actual Well "YN1" on Various Model-ROP

Based on **Table V-2, Table V-3,** and **Table V-4,** the prediction of the rate of penetration (ROP) prediction in the drilling of the "X" formation of the actual "YN1" for various ROP models is presented in **Table V-5.**

Selecting Representative ROP Models From "X" Well Formation Formation "YN1" Actual and Predicting Rate of Penetration (ROP) Value in Drilling "X" Formation "YN2" Prognosis Well

In the selection of a representative ROP model from the actual "X" well formation "YN1" drilling and predicting the rate of penetration (ROP) value in the "X" well formation prognosis "YN2" is done with the first stage of selecting a representative ROP model with steps including: comparing the actual rate of penetration (ROP) value vs. the predicted rate of penetration (ROP) value in various ROP models, then choosing a representative ROP model from the drilling of the "X" formation of the actual well "YN1", the second stage predicts the rate of penetration (ROP) in drilling the "X" formation of the "YN2" prognosis well based on a representative ROP model of the actual "YN1" well.

Selection of Reprsentative ROP Models From Formation "X" Well Actual "YN1"

The selection of a representative ROP model is carried out by the first stage comparing the actual rate of penetration (ROP) value vs. the rate of penetration (ROP) value in various ROP models, secondly based on the first stage a plot of the comparison chart of the actual rate of penetration (ROP) vs value rate of penetration (ROP) of the actual well "YN1" in various ROP models in one part of the picture, the

third plot is made a graph of the actual rate of penetration (ROP) value vs the actual well rate of penetration (ROP) in various ROP models and then get the coefficient correlation (R^2) in each ROP model. The highest (R^2) value and approaching 1 is the representative ROP model.

a. Comparison of Rate of Penetration (ROP) Actual VS Prediction Rate of Penetration (ROP) in Various Model-ROP

To get a representative ROP model, a comparison of the actual rate of penetration (ROP) vs prediction of the rate of penetration (ROP) in various models is based on **Table V-1** and **Table V-5** as shown in **Table VI-1.**

Based on Table **VI-1.** A plot graph is made between the actual value of penetration (ROP) of the "YN1" well vs the predicted rate of penetration (ROP) value for the various Model-ROP presented in **Figure 6.1.**

Based on **Figure 6.1.** The actual plot of the value of penetration (ROP) VS graph of the predicted rate of penetration (ROP) plot is made in the Bingham model presented in **Figure 6.2.** shows the value of the correlation coefficient (R^2) on the Bingham model of 0.9985.

Based on **Figure 6.1.** The actual plot rate of penetration (ROP) graph is made VS prediction of the rate of penetration (ROP) value in the Teale model presented in **Figure 6.3.** shows the correlation coefficient (R^2) on the Teale model of 1.

Based on **Figure 6.1.** The actual plot rate of penetration (ROP) graph is made VS prediction of the rate of penetration (ROP) value on the Mottahari model is presented in **Figure 6.4.** shows the correlation coefficient (R2) on the Mottahari model of 1.

Based on **Figure 6.2**, **Figure 6.3**, and **Figure 6.4.** a comparison table of correlation coefficient (R^2) was made in the various ROP models as shown in **Table VI-2.**

Table VI-2. Comparison of R^2 Value in Various ROP Models

MODEL ROP / Koefisien Korelasi	Model ROP Bingham	Model ROP Teale	Model ROP Mottahari
R^2	0,9985	1	1

b. Selection of Representative ROP Model From Drilling of Formation "X" Actual Well "YN1"

The representative ROP model is the ROP model which has the greatest correlation coefficient (R^2) approaching number 1. Based on **Table VI-2.** then the representative ROP model of drilling the "X" formation of the actual well "YN1" is the Bingham, Teale and Mottahari models.

Rated of Penetration (ROP) Value Prediction in The Drilling Formation "X" Well Prognosis "YN2"

The prediction of the rate of penetration (ROP) value in the drilling of the "X" well formation "YN2" in the "X" formation is done by the first step collecting the prognosis data for the drilling of the "X" well formation "YN2" from the drilling prognosis parameters, the second calculates the predicted value rate of penetration (ROP) in the drilling of the "X" formation well "YN2" prognosis with a representative model that is the Bingham, Teale and Mottahari models.

a. Collection of Prognosis Drilling Parameters in Drilling of "X" Formation "YN2" Well

The drilling prognosis parameters in the "X" well formation "YN2" include MD (measured depth,) Db (bit diameter,) T (torque), WOB (weigth on bit,) and RPM (rotary per minutes) as shown in **Table VI-3** and more in Appendix D, formations to be penetrated include the Talangakar (TAF) and Jatibarang (JTB) formations, 7 inch casing, L-80 grade, 8.5 inch PDC drilling bit, and using BHA DD RSS, a fresh water mud type program with Sg 1.52, Vis 60, PV 26, Yp 37, GS 10/18, FL <5, and K + 30k, planning on the cementing program with a 1.50 Sg tail and lead 1, 65 Sg

b. Prognosis Drilling Parameters Required to Determine Rate of Penetration (ROP) Prediction in Drilling of "X" Formation Prognosis Well "YN2" Bingham Model

In the Bingham model the drilling parameters needed to determine the predicted rate of penetration (ROP) include MD (measured depth), DB (bit diameter), WOB (weigth on bit), RPM (rotary per minute), and predictive value of d-exp **equation(2)** on the "X" formation well "YN2" prognosis as shown in **Table VI-4.**

c. Prognosis Drilling Parameters Required to Determine the Rate of Penetration (ROP) Prediction in Drilling of the "X" Formation Prognosis Well "YN2" Teale Model

In the Teale model drilling parameters needed to determine the predicted rate of penetration (ROP) include MD (measured depth), DB (bit diameter), T (torque), WOB (weight on bit,) and RPM (rotary per minutes), prediction of MSE (mechanical specific energy) **equation (3)**, μ (bit specific coefficient of sliding friction) **equation(5)** and A_B (bit area) **equation(6)** on the formation of "X" well prognosis "YN2" as shown in **Table VI-5.**

d. Prognosis Drilling Parameters Required to Determine the Rate of Penetration (ROP) Prediction in Drilling of the "X" Formation Prognosis Well "YN2" Mottahari Model

In the Mottahari model the drilling prognosis parameters needed for prediction of the rate of penetration (ROP) include MD, TVD, WOB, RPM, T, DB, actual ROP, σ, W_f (wear function) **equation(9)**, G (the model coefficient which represents the drillability) **equation(11)**, a = 0.50 and y = 1.50 is obtained from the assumption on the "X" formation of the "YN2" prognosis well as shown in **Table VI-6.**

e. Prediction of Rate of Penetration (ROP) Value in Drilling of "X" Formation of "YN2" Prognosis in Bingham, Teale and Mottahari Models

Based on the required parameters shown in Table VI-3, Table VI-4, Table VI-5 and Table VI-6. the results obtained from the prediction of the rate of penetration (ROP) value in the drilling of the "X" formation well "YN2" prognosis in the Bingham, Teale, and Mottahari models are presented in **Table VI-7.**

CONCLUSION

From the study results of the prediction of the rate of penetration (ROP) values in the drilling of the "X" formation well "YN2" prognosis based on a representative ROP model of the drilling of the actual "X" well formation "YN1" field "IP".

1. Based on the calculation of the predicted rate of penetration (ROP) value from the drilling of the "X" formation of the actual well "YN1" in the Bingham model, the d-exponent value per depth (ft) and R2 = 0.9988, in the Teale model, the MSE value (mechanical specific energy) per depth (ft) and R2 = 1 and in the Mottahari model obtained values of BG, Wf, G, a, y (per depth, ft) and R^2 = 1. ROP models Bingham, Teale and Mottahari are ROP models that representative of drilling the "X" formation of the actual well "YN1" because it has a large value and close to 1 so that it is used in the calculation of the prediction of the rate of penetration (ROP) in the drilling of the "X" formation well "YN2" prognosis

2. Calculation of prediction of the rate of penetration (ROP) value in the drilling of the "X" formation well "YN2" prognosis in each representative ROP model has a value that is close to each other, this proves the more accurate the predicted results of the values that have been obtained.

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18. _____*Drilling Report* "YN1" Lapangan "IP", 2017, PT. Pertamina EP Asset 3.
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20. _____*Drlling Prognosis* "YN2" Lapangan "IP", 2019, PT. Pertamina EP Asset 3.

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FIGURES :

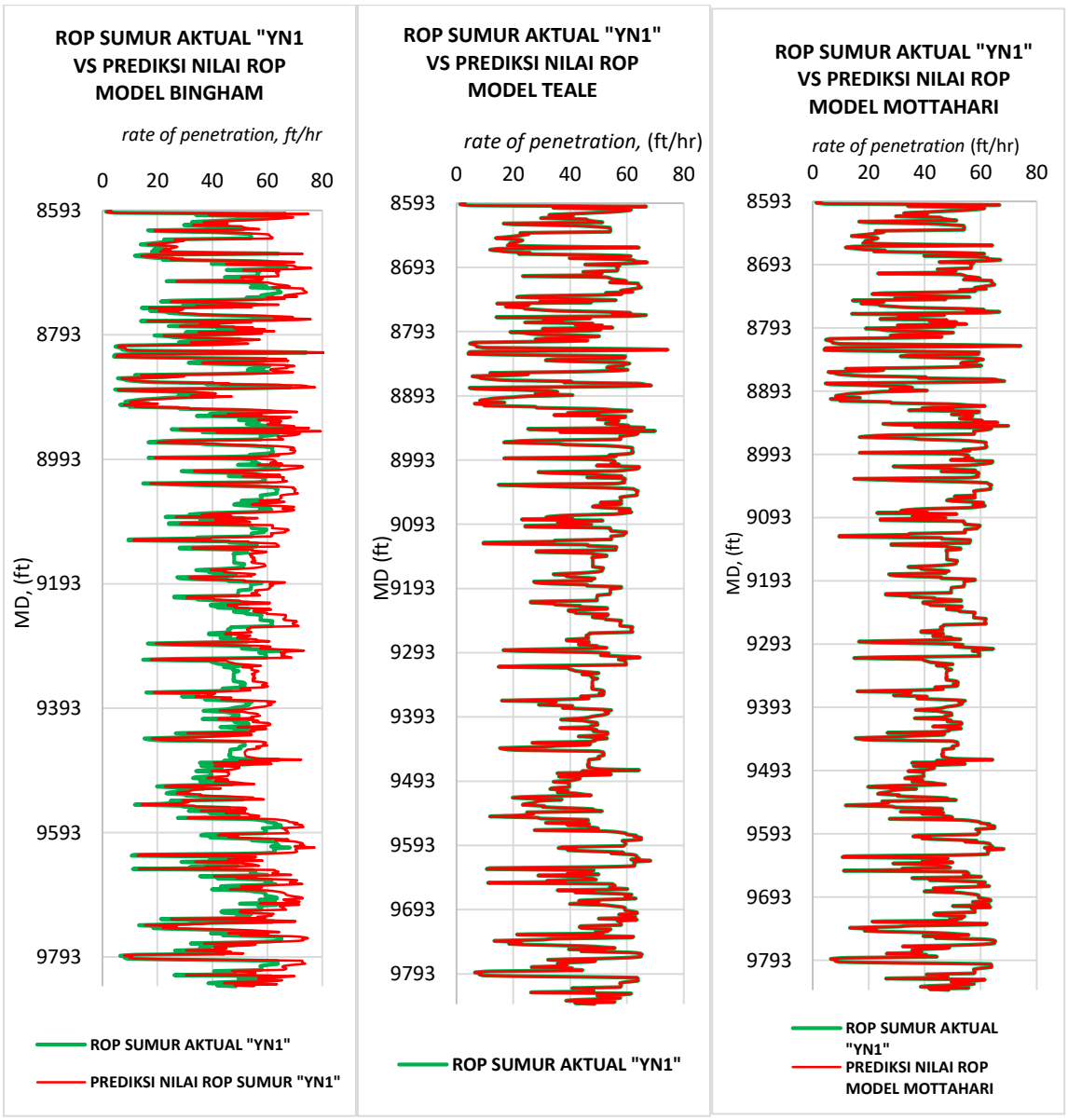

Figure 6.1. The Actual Value of Penetration (ROP) of the "YN1" Well VS The Predicted Rate of Penetration (ROP) Value for The Various Model-ROP

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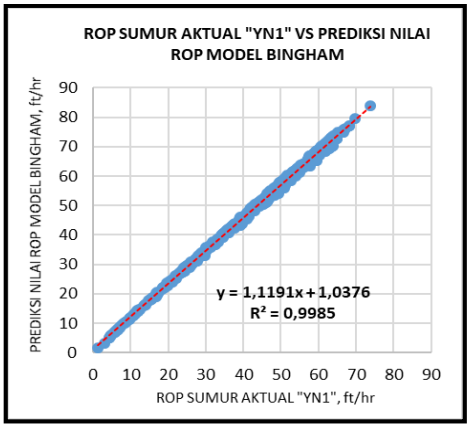

Figure 6.2. Actual Rate of Penetration (ROP) Value VS Prediction Value Rate of Penetration (ROP) on the Bingham Model

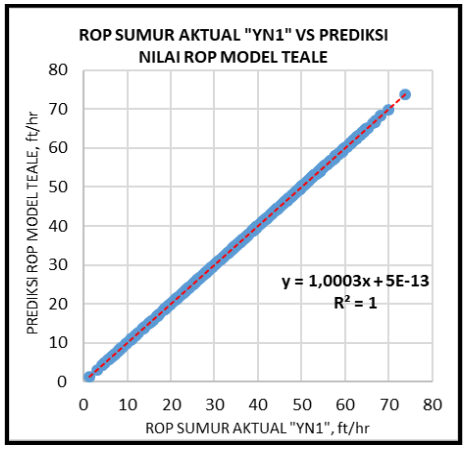

Figure 6.3. Actual Rate of Penetration (ROP) Value VS Prediction Value Rate of Penetration (ROP) on Teale Models

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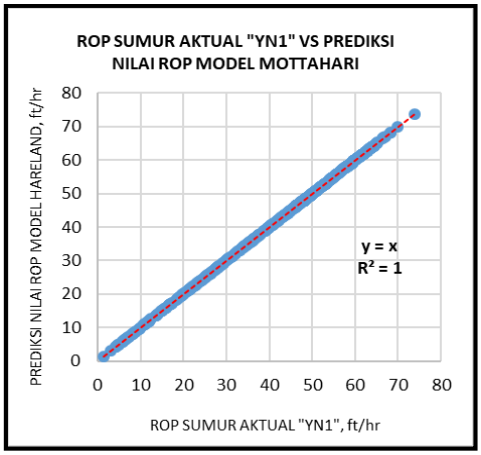

Figure 6.4. Actual Rate of Penetration (ROP) Value VS Prediction Value Rate of Penetration (ROP) in the Mottahari Model

TABLE :

Table V-1.

Measured depth (mtr)	Measured Depth (ft)	WOB (klbs)	RPM (rpm)	Torque (ft/lb)	Db (in)	ROP Sumur Aktual "YN1" (ft/jam)
2620,00	8593,60	11,36	72,00	5523,13	8,50	3,02
2620,50	8595,24	10,00	201,00	2351,49	8,50	1,34
2621,00	8596,88	13,37	201,00	2179,95	8,50	5,67
2621,50	8598,52	10,37	201,00	2784,31	8,50	66,72
2622,00	8600,16	9,55	201,00	2900,61	8,50	34,44
2622,50	8601,80	11,12	201,00	2640,30	8,50	49,00
2623,00	8603,44	11,64	201,00	2595,43	8,50	61,17
2623,50	8605,08	8,21	201,00	2465,76	8,50	59,63
2624,00	8606,72	6,29	201,00	2795,90	8,50	54,91
2624,50	8608,36	6,37	201,00	3031,25	8,50	47,63
2625,00	8610,00	3,20	201,00	3380,98	8,50	39,62
2625,50	8611,64	6,93	201,00	4447,51	8,50	32,60

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Table V-2.

Measured depth (mtr)	Measured Depth (ft)	WOB (klbs)	RPM (rpm)	Torque (kft/lb)	Db (in)	ROP Sumur Aktual "YN1" (ft/jam)	*d-exp*
2620,00	8593,60	11,36	72,00	5523,13	8,50	3,02	1,76
2620,50	8595,24	10,00	201,00	2351,49	8,50	1,34	2,14
2621,00	8596,88	13,37	201,00	2179,95	8,50	5,67	1,93
2621,50	8598,52	10,37	201,00	2784,31	8,50	66,72	1,23
2622,00	8600,16	9,55	201,00	2900,61	8,50	34,44	1,36
2622,50	8601,80	11,12	201,00	2640,30	8,50	49,00	1,33
2623,00	8603,44	11,64	201,00	2595,43	8,50	61,17	1,29
2623,50	8605,08	8,21	201,00	2465,76	8,50	59,63	1,19
2624,00	8606,72	6,29	201,00	2795,90	8,50	54,91	1,14
2624,50	8608,36	6,37	201,00	3031,25	8,50	47,63	1,17
2625,00	8610,00	3,20	201,00	3380,98	8,50	39,62	1,06
2625,50	8611,64	6,93	201,00	4447,51	8,50	32,60	1,28

Table V-3.

Measured depth (mtr)	Measured Depth (ft)	WOB (klbs)	RPM (rpm)	Torque (ft/lb)	D_B (in)	ROP Sumur Aktual "YN1" (ft/jam)	*μ (dimensionless)*	A_B (in^2)	MSE (psi)
2620,00	8593,60	11,36	72,00	5523,13	8,50	3,02	2,06	56,72	875,49
2620,50	8595,24	10,00	201,00	2351,49	8,50	1,34	1,00	56,72	2334,59
2621,00	8596,88	13,37	201,00	2179,95	8,50	5,67	0,69	56,72	513,12
2621,50	8598,52	10,37	201,00	2784,31	8,50	66,72	1,14	56,72	55,90
2622,00	8600,16	9,55	201,00	2900,61	8,50	34,44	1,29	56,72	112,61
2622,50	8601,80	11,12	201,00	2640,30	8,50	49,00	1,01	56,72	72,13
2623,00	8603,44	11,64	201,00	2595,43	8,50	61,17	0,94	56,72	56,85
2623,50	8605,08	8,21	201,00	2465,76	8,50	59,63	1,27	56,72	55,35
2624,00	8606,72	6,29	201,00	2795,90	8,50	54,91	1,88	56,72	68,09
2624,50	8608,36	6,37	201,00	3031,25	8,50	47,63	2,02	56,72	85,08
2625,00	8610,00	3,20	201,00	3380,98	8,50	39,62	4,47	56,72	113,97
2625,50	8611,64	6,93	201,00	4447,51	8,50	32,60	2,72	56,72	182,24

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Table V-4.

Measured Depth (ft)	TVD (ft)	WOB (klbs)	RPM (rpm)	Torque (ft/lb)	Db (in)	ROP Sumur Aktual "YN1" (ft/jam)	σ (psi)	W_f	G	a	y
8593,60	8367,15	11,36	72,00	5523,13	8,50	3,02	0,65	0,74	2,90	0,50	1,50
8595,24	8368,15	10,00	201,00	2351,49	8,50	1,34	0,65	0,71	0,31	0,50	1,50
8596,88	8369,65	13,37	201,00	2179,95	8,50	5,67	0,65	0,70	1,14	0,50	1,50
8598,52	8370,65	10,37	201,00	2784,31	8,50	66,72	0,65	0,71	15,03	0,50	1,50
8600,16	8372,15	9,55	201,00	2900,61	8,50	34,44	0,65	0,71	8,06	0,50	1,50
8601,80	8373,15	11,12	201,00	2640,30	8,50	49,00	0,65	0,70	10,71	0,50	1,50
8603,44	8374,65	11,64	201,00	2595,43	8,50	61,17	0,65	0,70	13,10	0,50	1,50
8605,08	8375,65	8,21	201,00	2465,76	8,50	59,63	0,65	0,72	14,93	0,50	1,50
8606,72	8377,15	6,29	201,00	2795,90	8,50	54,91	0,65	0,72	15,51	0,50	1,50
8608,36	8378,15	6,37	201,00	3031,25	8,50	47,63	0,65	0,72	13,38	0,50	1,50
8610,00	8379,65	3,20	201,00	3380,98	8,50	39,62	0,65	0,75	15,23	0,50	1,50
8611,64	8380,65	6,93	201,00	4447,51	8,50	32,60	0,65	0,72	8,82	0,50	1,50

Table V-5.

Measured Depth (ft)	Prediksi Nilai ROP Model Bingham (ft/jam)	Prediksi Nilai ROP Model Teale (ft/jam)	Prediksi Nilai ROP Model Mottahari (ft/jam)
8593,60	3,02	3,02	3,02
8595,24	1,65	1,35	1,34
8596,88	6,82	5,68	5,67
8598,52	75,02	66,73	66,72
8600,16	39,21	34,45	34,44
8601,80	55,60	49,02	49,00
8603,44	69,15	61,19	61,17
8605,08	66,80	59,65	59,63
8606,72	61,22	54,92	54,91
8608,36	53,27	47,64	47,63
8610,00	43,83	39,63	39,62
8611,64	36,83	32,61	32,60
8613,28	45,44	40,88	40,87
8614,92	43,34	39,11	39,10
8616,56	32,97	29,69	29,68

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Table VI-1.

Measured Depth **(ft)**	**ROP Sumur Aktual "YN1" (ft/jam)**	**Prediksi Nilai ROP Model Bingham (ft/jam)**	**Prediksi Nilai ROP Model Teale (ft/jam)**	**Prediksi Nilai ROP Model Mottahari (ft/jam)**
8593,60	3,02	3,02	3,02	3,02
8595,24	1,34	1,65	1,35	1,34
8596,88	5,67	6,82	5,68	5,67
8598,52	66,72	75,02	66,73	66,72
8600,16	34,44	39,21	34,45	34,44
8601,80	49,00	55,60	49,02	49,00
8603,44	61,17	69,15	61,19	61,17
8605,08	59,63	66,80	59,65	59,63
8606,72	54,91	61,22	54,92	54,91
8608,36	47,63	53,27	47,64	47,63
8610,00	39,62	43,83	39,63	39,62

Table VI-3.

Measured Depth **(mtr)**	***Measured Depth*** **(ft)**	**TVD (ft)**	**D_B (in)**	**T (ft/lbs)**	**RPM (rpm)**	**WOB (klbs)**
2805,00	9200,40	8777,36	8,5	5744,97	212,10	7,19
2805,50	9202,04	8778,24	8,5	5831,80	212,10	4,66
2806,00	9203,68	8779,55	8,5	5301,65	212,10	6,08
2806,50	9205,32	8780,42	8,5	5794,54	212,10	9,39
2807,00	9206,96	8781,73	8,5	5621,41	212,10	9,90
2807,50	9208,60	8782,61	8,5	6401,68	212,10	2,06
2808,00	9210,24	8783,92	8,5	5781,06	212,10	11,07
2808,50	9211,88	8784,80	8,5	6114,86	212,10	16,50
2809,00	9213,52	8786,11	8,5	5802,51	212,10	15,40
2809,50	9215,16	8786,98	8,5	6193,16	212,10	14,36
2810,00	9216,80	8788,30	8,5	5135,23	212,10	15,40
2810,50	9218,44	8789,17	8,5	5901,36	212,10	15,47

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Table VI-4

Measured Depth (mtr)	Measured Depth (ft)	TVD (ft)	D_B (in)	T (ft/lbs)	RPM (rpm)	WOB (klbs)	D-exp
2805,00	9200,40	8777,36	8,5	5744,97	212,10	7,19	1,19
2805,50	9202,04	8778,24	8,5	5831,80	212,10	4,66	1,09
2806,00	9203,68	8779,55	8,5	5301,65	212,10	6,08	1,17
2806,50	9205,32	8780,42	8,5	5794,54	212,10	9,39	1,28
2807,00	9206,96	8781,73	8,5	5621,41	212,10	9,90	1,30
2807,50	9208,60	8782,61	8,5	6401,68	212,10	2,06	0,95
2808,00	9210,24	8783,92	8,5	5781,06	212,10	11,07	1,33
2808,50	9211,88	8784,80	8,5	6114,86	212,10	16,50	1,48
2809,00	9213,52	8786,11	8,5	5802,51	212,10	15,40	1,62
2809,50	9215,16	8786,98	8,5	6193,16	212,10	14,36	1,59
2810,00	9216,80	8788,30	8,5	5135,23	212,10	15,40	1,54
2810,50	9218,44	8789,17	8,5	5901,36	212,10	15,47	1,54

Table VI-5.

Measured Depth (mtr)	Measured Depth (ft)	Diameter Bit (in)	T (ft/lbs)	RPM (rpm)	WOB (klbs)	*μ (bit spesific coefficient of sliding friction)*	A_B (bit area) in^2	MSE (psi)
2805,00	9200,40	8,5	5744,97	212,10	7,19	3,38	56,72	150,22
2805,50	9202,04	8,5	5831,80	212,10	4,66	5,30	56,72	152,44
2806,00	9203,68	8,5	5301,65	212,10	6,08	3,69	56,72	150,61
2806,50	9205,32	8,5	5794,54	212,10	9,39	2,61	56,72	164,66
2807,00	9206,96	8,5	5621,41	212,10	9,90	2,40	56,72	160,49
2807,50	9208,60	8,5	6401,68	212,10	2,06	13,18	56,72	182,61
2808,00	9210,24	8,5	5781,06	212,10	11,07	2,21	56,72	165,07
2808,50	9211,88	8,5	6114,86	212,10	16,50	1,57	56,72	174,68
2809,00	9213,52	8,5	5802,51	212,10	15,40	1,60	56,72	312,57
2809,50	9215,16	8,5	6193,16	212,10	14,36	1,83	56,72	333,58
2810,00	9216,80	8,5	5135,23	212,10	15,40	1,41	56,72	208,54
2810,50	9218,44	8,5	5901,36	212,10	15,47	1,62	56,72	239,61

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Table VI-6.

Measured Depth (mtr)	Measured Depth (ft)	TVD (ft)	D_B (in)	T (ft/lbs)	RPM (rpm)	WOB (klbs)	Wf *(nondimensional)*	G *(dimensioless)*	a	y
2805,00	9200,40	8777,36	8,5	5744,97	212,10	7,19	0,62	16,19	0,50	1,50
2805,50	9202,04	8778,24	8,5	5831,80	212,10	4,66	0,64	19,47	0,50	1,50
2806,00	9203,68	8779,55	8,5	5301,65	212,10	6,08	0,62	16,00	0,50	1,50
2806,50	9205,32	8780,42	8,5	5794,54	212,10	9,39	0,60	13,33	0,50	1,50
2807,00	9206,96	8781,73	8,5	5621,41	212,10	9,90	0,60	12,98	0,50	1,50
2807,50	9208,60	8782,61	8,5	6401,68	212,10	2,06	0,67	25,46	0,50	1,50
2808,00	9210,24	8783,92	8,5	5781,06	212,10	11,07	0,60	12,40	0,50	1,50
2808,50	9211,88	8784,80	8,5	6114,86	212,10	16,50	0,57	10,52	0,50	1,50
2809,00	9213,52	8786,11	8,5	5802,51	212,10	15,40	0,58	5,73	0,50	1,50
2809,50	9215,16	8786,98	8,5	6193,16	212,10	14,36	0,58	5,90	0,50	1,50
2810,00	9216,80	8788,30	8,5	5135,23	212,10	15,40	0,58	7,61	0,50	1,50

Table VI-7.

Measured Depth (MD-ft)	Prediksi Nilai ROP Formasi "X" Sumur "YN2" Model Bingham (ft/jam)	Prediksi Nilai ROP Formasi "X" Sumur "YN2" Model Teale (ft/jam)	Prediksi Nilai ROP Formasi "X" Sumur "YN2" Model Mottahari (ft/jam)
9200,40	53,92	53,94	53,92
9202,04	53,92	53,94	53,92
9203,68	49,63	49,64	49,63
9205,32	49,63	49,64	49,63
9206,96	49,40	49,41	49,40
9208,60	49,40	49,41	49,40
9210,24	49,40	49,41	49,40
9211,88	49,40	49,41	49,40
9213,52	26,17	26,18	26,17