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RESEARCH ARTICLE

1D Geomechanical Model For Wellbore Stability in Z Field, Y Well Sanga Sanga Working Area, Kutai Basin

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Abstract

This research is about 1D geomechanical model for wellbore stability in Z Field, Y Well Sanga Sanga Working Area, Kutai Basin where wells have been drilled. The Purpose of this Research is to analyze the stability of the well starting from knowing the stress regime that occurs, predicting the occurrence of wellbore failure, and determining safe mud weight window for next drilling. The method use in this Research is a numerical modelling method using log data and drilling data that has been obtained and then managed using Techlog Software. The result of this Research show the magnitude of mechanical properties of the rock that have been obtained, then in general the stress regime that occurs in the Z Field formation is the normal regime even though the strike slip and reverse regime are inserted at a certain depth, then based on the prediction results of failure in this well is wide breakout, which in general occurs in lithology with sandstone, finaly safe mud weight window can be estimated properly, so that it can be used for further well drilling.

Keywords: Wellbore Stability, Drilling Mud Weight, Failure, Stress, Pore Pressure, Rock Strength, Rock Elastic

1. Introduction

There are several things that need to be analyzed in the development of oil and gas fields, especially the stability of the wellbore. Wellbore stability analysis has an impact on the drilling process to the production of a well because if there is damage to the well during drilling, it will reduce drilling efficiency and increase drilling costs (Darvishpour et al., 2019). In order to know the parameters or factors that influence the stability of the wellbore, a geomechanics reservoir Research is needed. Geomechanics is a science that focuses on the calculation of pressure/stress and its application to problems of fault and fluid flow in formations (Zoback, 2007). Models or tools that can be used to perform geomechanical analysis are Numerical Model and Mechanical Earth Models (MEM) (Zain-Ul-Abedin and Henk, 2020).

This research area is located on the onshore field in the Sanga Sanga working area, Kutai Kartanegara, East Kalimantan. Sanga Sanga working area is located in the Lower Kutai Basin. The Kutai Basin is the largest tertiary basin in Indonesia which has an area of 160,000 km2 with a thickness of sediment deposits of approximately 15,000 meters (Syarifuddin and Busono, 1998; BPPKA, 1997). Figure 1 shows the boundaries of this basin. To the north it is bounded by the Sangkulirang Fault and the Mangkalihat High which separate the Kutai Basin from the Tarakan Basin, to the east by the Mahakam Delta which opens to the Makassar Strait, to the southeast there is the Paternoster shelf which is separated by the Adang Fault, and to the west it is bounded by the Kuching High. The tectonic setting of the Kutai Basin is formed from the interaction between three plates, namely the Pacific, Australian, and Eurasian, where the direction of the structure in this basin is southwest-northeast (SW - NE) formed from the Samarinda Anticlinorium which is in the east - southeast area of the Kutai Basin (Supriatna et al., 1995).

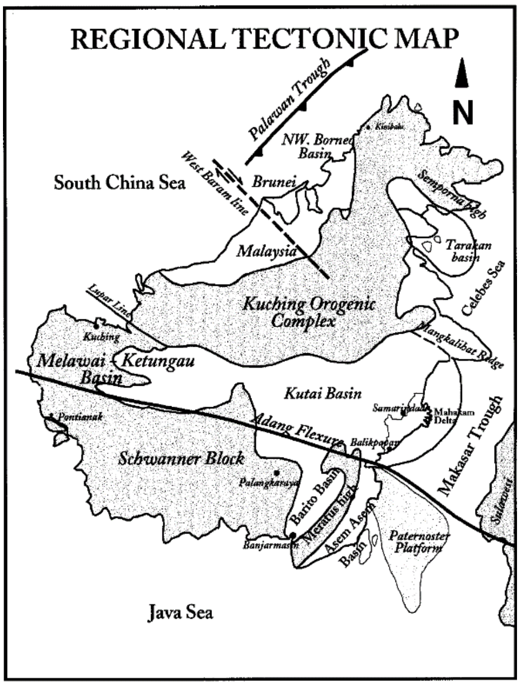


Fig 1. Regional Tectonic Map Kalimantan (Syarifuddin and Busono, 1998)

The stratigraphy in the Kutai Basin consists of several lithologies, namely sandstone, claystone, coal and carbonate. The Kutai Basin consists of several formations, from bottom to top, it is : Pamaluan Formation, this formation has a thickness of 1500 m which is mostly in a deep marine depositional environment. This formation consists of sandstone with interclations of claystone, shale, lime stone, and siltstone. Bebuluh Formation, this formation has a thickness of 900 m which is intersected with the Pamaluan formation and is dominated by limestone formed in the early Miocene with interlamination of sandy limestone and clay shale. Pulau Balang Formation, This formation covers the Pamaluan Formation and the Bebuluh Formation which were deposited in a deltaic environment to shallow marine. The lithology in this Formation consists of sandstone, graywacke, limestone, claystone, dacite tuff, and coal interlamination with a thickness of 3 to 4 meters. Balikpapan Formation, this formation has a thickness of 1000 to 1500 meters overlies Pulau Balang Formation which is mostly deposited in a deltaic environment. The lithology in this Formation consists of quartz sandstone, claystone, shale, and coal with a thickness of 5 to 10 meters. Kampung Baru Formation, this formation has a thickness of 900 meters which was deposited in a delta environment. The lithology of this formation consists of quartz sandstone with interlaminations of clay, shale, silt and coal with a thickness of 3 meters. Alluvial, deposition that occurs unconformably over the Kampung Baru Formation which is in a river, swamp, beach and delta environment that has continued to the present day. This deposition consists of gravel, sand, and silt.

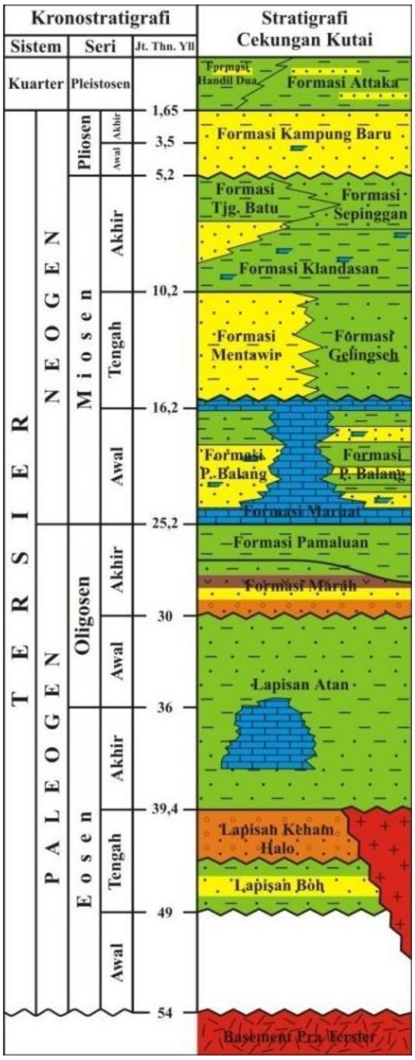


Fig 2. Kutai Basin Stratigraphy
(Satyana et al., 1999)

2. Material and Methods

2.1 1 Dimension Geomechanical Model

Initially the formation of a field is in a balanced condition before the well is drilled. Although during drilling, the drilling fluid can replace the rock that has been drilled, the presence of the wellbore can cause a redistribution of stress around the wellbore. If the stress exceeds the strength of the rock, it can make the well unstable, causing problems in the well (Kang et al., 2009). There are several problems if the well becomes unstable, namely: hole collapse, stuck pipes, hole enlargement, fracture, lost circulation, and others, so that these problems increase drilling costs and decrease drilling efficiency (Albukhari et al., 2018). To prevent these things from happening, it is necessary to evaluate the stability of the wellbore by creating a geomechanical model to reduce the risk in drilling wells and to provide recommendations for safe mud weight in drilling (Plumb et al., 2000).

1 dimensional geomechanical model is usually called the 1D Mechanical Earth Model (MEM). 1D MEM is a numerical representation of in-situ stress conditions and mechanical properties along the well. 1D MEM can provide information about the condition of the well so that it can provide solutions to any well problems if unwanted things occur. In addition, this 1D model can help optimize field development such as the optimal location for injection and production wells, determine the optimal trajectory for wellbore stability, design well development, and predict a safe range of drilling mud weight values (Plumb et al., 2000). Illustration of the Geomechanical Model can be seen in Figure 3.

Creating 1D Geomechanical Model, several data are needed, such as core data, drilling reports, and well log data such as calipers, gamma rays, density, sonic, neutron porosity, and resistivity to represent well conditions (Zain-Ul-Abedin and Hank, 2020). The results of the data processing can be in the form of values of pore pressure, in-situ stress, elastic properties of rock, rock strength (Plumb et al., 2000).

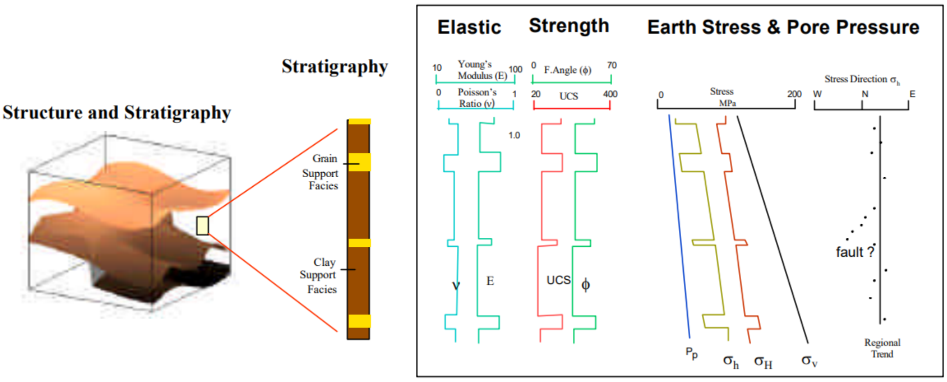


Fig. 3. Schematic mechanical earth model (Plumb et al., 2000)

2.2 Pore Pressure & Fracture Pressure

Pore pressure is an important parameter for determining effective stress in 1D MEM (Zain-Ul-Abedin and Hank, 2020). Pressure can be divided into three types, it is underpressure, normal pressure, and overpressure. Normal pressure is a condition where the formation pressure is equal to the hydrostatic pressure. Generally, the normal pressure value is 0.433 psi/ft for fresh water. Underpressure is a condition where the formation pressure is below hydrostatic pressure. While overpressure is a condition where the formation pressure is above the hydrostatic pressure (Swarbrick et al., 1998). To obtain pore pressure values can be done with various correlations, one of which is the Eaton method. Eaton's method can utilize data obtained from sonic logs and resistivity logs. The following is the equation of the Eaton method (Eaton, 1975).

Log Sonik

$$P = S - \left((S - Pn) \times \left(\frac{\Delta tn}{\Delta t} \right)^3 \right) \qquad (1)$$

Log Resistivitas

$$P = S - \left((S - Pn) \times \left(\frac{Ri}{Rn} \right)^{1.2} \right) \qquad (2)$$

In determining the overpressure zone using the Eaton method, it does not only use log data results, but requires another parameter called the Normal Compaction Trend (NCT). NCT Is a normal line which becomes a benchmark in the event of overpressure. The image illustrating the NCT line on the sonic log can be seen in Figure 4.

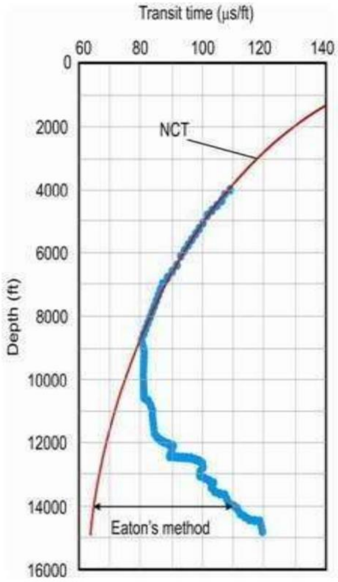


Fig 4. Normal Compaction Trand on Sonic Log (Eaton, 1975)

Determining fracture pressure can be obtained using several equations, one of which is the Matthews & Kelly method. The fracture pressure value can be calibrated using the results obtained from the LOT test to ensure that the calculated data is correct. The following is the equation used to calculate fracture pressure (Paul et al., 2009).

$$FRP = \left(\frac{\mu}{1-\mu} \right) (S - P) + P \qquad (3)$$

2.3 Elastic Property

Elastic Property is needed for 1D Geomechanical modeling, where the parameters consist of young's modulus, shear's modulus, bulk's modulus, and Poisson's ratio. Elastic property is a measurement of the strength of a solid material to return to its original shape and size after being subjected to a force, then the force is removed, however, if the stress limit is exceeded, it will leave permanent damage to the solid material (Zoback, 2007).

Elastic Property is divided into two categories namely static and dynamic. In measuring the dynamic elastic property can be done using certain logging data. While the measurement of static elastic property can be done using core data analysis that comes from tests in the laboratory. Although the dynamic data does not yet represent the actual static data, these values can be transferred using empirical correlations that depend on lithology data whose application can be validated with calibration data, if core data is available (Abeden Hank.2020). The correlation between dynamic modulus and static modulus is (Albukhari et al., 2018): dynamic young's modulus has a greater value than static young's modulus, the ratio between dynamic and static modulus approaches usually becomes one when confining pressure increases, the dynamic Poisson ratio is generally has a smaller value than the static Poisson ratio.

2.4 Rock Strength

Rock strength is a very important parameter if the geometric stresses from laboratory tests are obtained specifically (Fjaer et al., 2008). Several correlations involving rock strength can be used to identify geomechanical characters when core data is not available. Rock strength parameters : Unconfined compressive strength (UCS), Friction angle, Tensile Strength, and Cohesion (Ayoub et al. 2019).

UCS is an important parameter in limiting the maximum horizontal stress and obtaining an envelope that is suitable for the formation. The UCS obtained is usually correlated with various petrophysical and geomechanical parameters such as compressional velocity, porosity, shale volume, and Young's modulus, where this type of correlation can improve UCS predictions from well log derived data without a laboratory core test (Albukhari et al. 2018). The following is the UCS equation based on Horsrud 2001:

$$UCS = 0.77 + \left(\frac{304.8}{\Delta tc}\right)^{2.92} \qquad (4)$$

Correlating friction angle (FANG) with petrophysical parameters is quite limited because even weak formations have high friction angle values, therefore the right approach to obtain friction angle values is when you have completed the UCS test (Albukhari et al. 2018). using petrophysical data, the friction angle can be calculated using the Plumb correlation as follows:

$$FANG = 26.5 - 37.4(1 - \phi - Vclay) + 62.1(1 - \phi - Vclay)2 \qquad (5)$$

In addition to using the equation above to measure the value of the friction angle, you can use the empirical correlation that is in the SLB Techlog software (Figure 5). This method uses gamma ray data to obtain a friction angle value with a linear correlation and uses a cutoff as shown below (Albukhari et al. 2018).

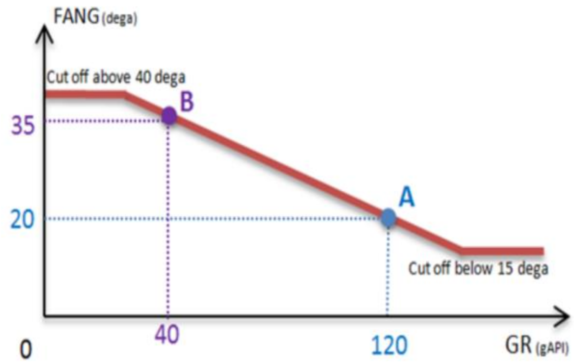


Fig 5. Determining Friction Angle from Data GR

In order to evaluate the tensile failure of the well wall related to the stress concentration, it is necessary to know the tensile strength criteria. Correlation analysis shows that the best tensile strength for reservoir rock is 1/10 of UCS (Ayoub et al. 2019). To calculate the value of tensile strength in this Research using the Griffith equation (1921) as follows.

$$TSTR = K \times UCS \qquad (6)$$

2.5 In-Situ Stress

Horizontal stress and vertical stress are in-situ stresses that can be used to represent the three principal stresses in rock formations, where the horizontal stress represents two values, namely horizontal maximum and horizontal minimum. Estimating the horizontal stress is the key to accurately modeling the stress regime (Ayoub et al. 2019). Determination of horizontal stress in this Research uses a poro-elastic approach using the following equation (Abeden Hank, 2020).

$$S_{hmin} = \frac{v}{1-v}Sv - \frac{v}{1-v} \propto P_p + \propto P_p + \frac{E}{1-v^2}\varepsilon_h + \frac{vE}{1-v^2}\varepsilon_h \qquad (7)$$

$$S_{Hmax} = \frac{v}{1-v}Sv - \frac{v}{1-v} \propto P_p + \propto P_p + \frac{E}{1-v^2}\varepsilon_H + \frac{vE}{1-v^2}\varepsilon_H \qquad (8)$$

To find the vertical pressure value, it can be obtained by calculating the overburden pressure based on density (Abeden Hank.2020). Overburden pressure can be defined as the vertical pressure generated by the weight of all material, both fluid and granules, which are in the formation layer above it. So from this, the overburden gradient value is generally 1 psi/ft (Albukhari et al. 2018). Overburden pressure can be calculated using the following equation (Abeden Hank. 2020).

$$Sv = g\int_0^{TVD} \rho_{b(z)} \qquad (9)$$

The vertical pressure in this case is calculated using the extrapolation method available in the techlog software. The following is an equation using the extrapolation method.

$$\rho_{extrapolated} = \rho_{mudline} + A_0 \times (TVD - AirGap - Water\ Depth)^{\alpha} \qquad (10)$$

2.6 Stress Regime

With the values of vertical stress, minimum horizontal stress, and maximum horizontal stress, the stress regime of the formation can be identified. Based on Anderson's classification (1951) Stress regime is divided into three conditions, namely (Zoback, 2007): Normal Stress Regime. In this condition, the vertical stress value is greater than the maximum and minimum horizontal stress values, while the maximum horizontal stress is greater than the minimum horizontal stress (Sv > SHmax > Shmin). In this regime the vertical stress value is very large so that normal faulting can occur. Strike-slip Stress Regime. In this condition, the largest value is the maximum horizontal stress, then the vertical stress in the middle, and the smallest is the minimum horizontal stress (SHmax > Sv > Shmin). In this regime the maximum value of the horizontal stress works very large and if the difference in value between SHmax and Shmin is very large then faulting can occur. Reverse Stress Regime. In this condition, the maximum horizontal stress is the largest, then followed by the minimum horizontal stress in the middle, and the smallest is the vertical stress (SHmax > Shmin > Sv). In this regime the maximum value of the horizontal stress works very large which is then followed by the minimum horizontal stress so that it can cause reverse faulting or commonly called thrust faulting.

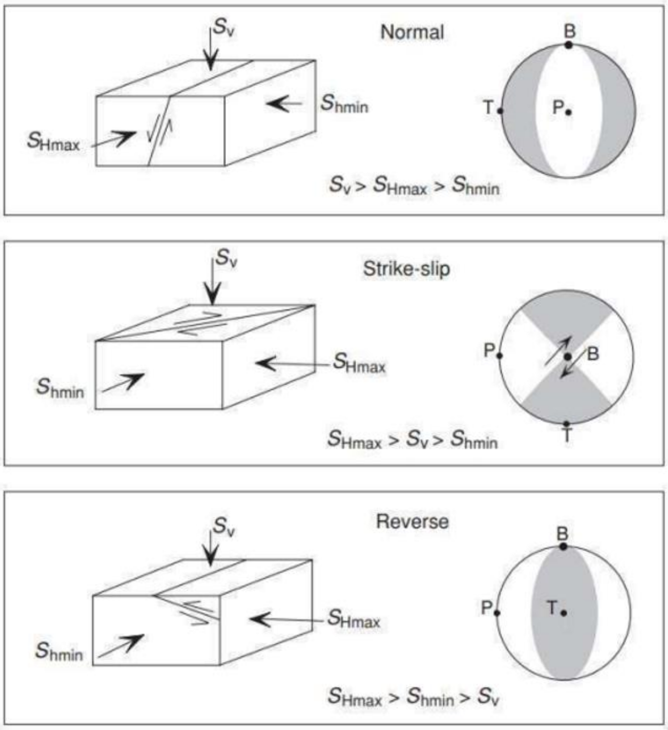


Fig. 6. Stress regime illustration based on Anderson's classification (Zoback, 2007)

2.7 Failure Criteria

Failures that occur in the integrity of the wellbore always cause increased costs, more difficult repair operations, and allow for contamination of the surrounding environment (Wu et al., 2020). Shear and tensile failure are the main causes of mechanical instability in boreholes (Darvishpour et al., 2019).

Shear Failure can occur if the shear stress exceeds the shear strength of the rock around the wellbore. Differences in failure criteria can provide different recommendations for drilling mud weights. If it is below a predetermined limit (minimum mud weight), the pressure of the drilling fluid will cause shear failure on the wall of the wellbore so that the occurrence of shear failure is the minimum value of the weight of the drilling mud (Darvishpour et al., 2019; Kang et al., 2009).

Tensile Failure occurs when the stress of the drilling mud exceeds the tensile strength of the formation. Tensile failure generally occurs when the effective principal stress exceeds the tensile strength of the rock formation (Kang et al., 2009; Pasic et al., 2007). Determination of tensile failure can be an indication in determining the weight of drilling mud. If it exceeds the specified upper limit (Maximum Mud Weight), the drilling mud will cause tensile failure on the wellbore. Therefore, tensile failure is a sign of the upper limit of the safe value of drilling mud weight (Darvishpour et al., 2019).

2.8 Safe Mud Weight Window

The predicted weight of drilling mud can be determined if the pore pressure, elastic property, rock strength, and principle stress orientation are known. Prediction of drilling mud weight with appropriate drilling fluid density is carried out to control wellbore stress induction in maintaining wellbore stability and minimizing drilling fluid invasion into the reservoir (Darvishpour et al., 2019). Figure 7 illustrates the pressure and weight of drilling mud that affect wellbore stability. The wellbore pressure must be higher than the pore pressure that causes collapse and must be lower than the minimum horizontal stress strength, so that from this the well is stable and does not cause failure in accordance with the failure criteria. If the mud weight value is below the minimum mud weight value, a breakout mud weight can occur, causing shear failure, whereas if it exceeds the maximum mud weight value, it can cause a breakdown of the mud weight, which causes tensile failure (Pasic et al., 2007).

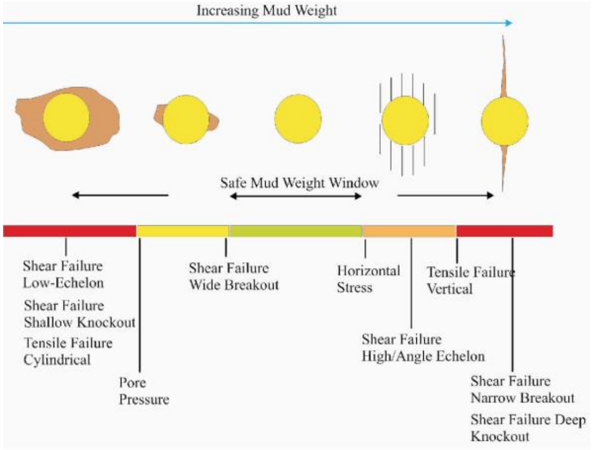


Fig. 7. Effect of mud weight on the stress in wellbore wall (Pasic et al., 2007)

3. Methods

This research was conducted using qualitative and quantitative methods using log data, numerical data, drilling data and graphic data which were reviewed objectively. In this research, 1D geomechanical modeling was made using software, namely Techlog. With the help of this software it will assist in processing and calculating geomechanical parameters such as pore pressure, fracture pressure, elastic properties, rock strength, and in-situ stress. After the 1D geomechanical modeling is formed, wellbore stability analysis can be carried out so that recommendations for safe drilling mud can be determined for planning or developing drilling in Field Z. The data collection method in this Research was obtained from companies located in the Kutai basin area. The data collection used in this Research came from well logging data and drilling data. The following is the data that has been obtained, where the mark (V) indicates the well has the data listed and the mark (X) indicates the well does not have the data.

Table 1
Research Data Availability

Data	Sumur Z	Keterangan
Gamma Ray	V	Mandatory
Density / RHOB	V	
Sonic DT Compressional Slowness	V	
Sonic DTs Shear Slowness	X	
Resistivity	X	
Neutron Porosity / NPHI	X	
Caliper Logs	X	
Trajectory / Deviation for Offset and Plan Well	X	
Equivalent Circulating Density / ECD Log	X	Validation
Formation Pressure Point (MDT)	V	
Image Logs (FMI, UBI, etc)	X	
LOT / XLOT	V	
Rock Mechanics Laboratory Core Test Result	X	
Mud Weight	V	

4. Results and Discussion

The research location is in the lower Kutai basin, Sanga Sanga working area, Field Z well Y. The formation of the 1D Geomechanical model aims to determine the mechanical properties & stress regime, predict the weight of drilling mud that is safe to use, and analyze the stability of the well. In this Research using the Techlog software to assist in processing logging data to create 1 dimensional geomechanical model.

4.1 Zonations

Determination of lithological zones is a very important factor in analyzing 1D geomechanical models, because each zone has different criteria and this can affect the calculation of 1D geomechanical model parameters. In this Research, the division of zones was carried out based on lithological zones, where there are two lithologies, such as sandstone and shale. This zone division was carried out using RHOB logs and GR logs which were then re-validated using shale volume data obtained based on GR logs. The RHOB log and GR log data are used to create a data crossplot, from which the data is restricted by using sandstone criteria obtained from the literature. From the literature, the criteria for sandstone are based on log GR is greater than 15 API and less than 55 API while from log RHOB is greater than 2.2 g/cm3 and less than 2.6 g/cm3. The results of the data are then validated using shale volume data obtained at 0.35. The results of determining the lithology zone can be seen in Figure 8 below:

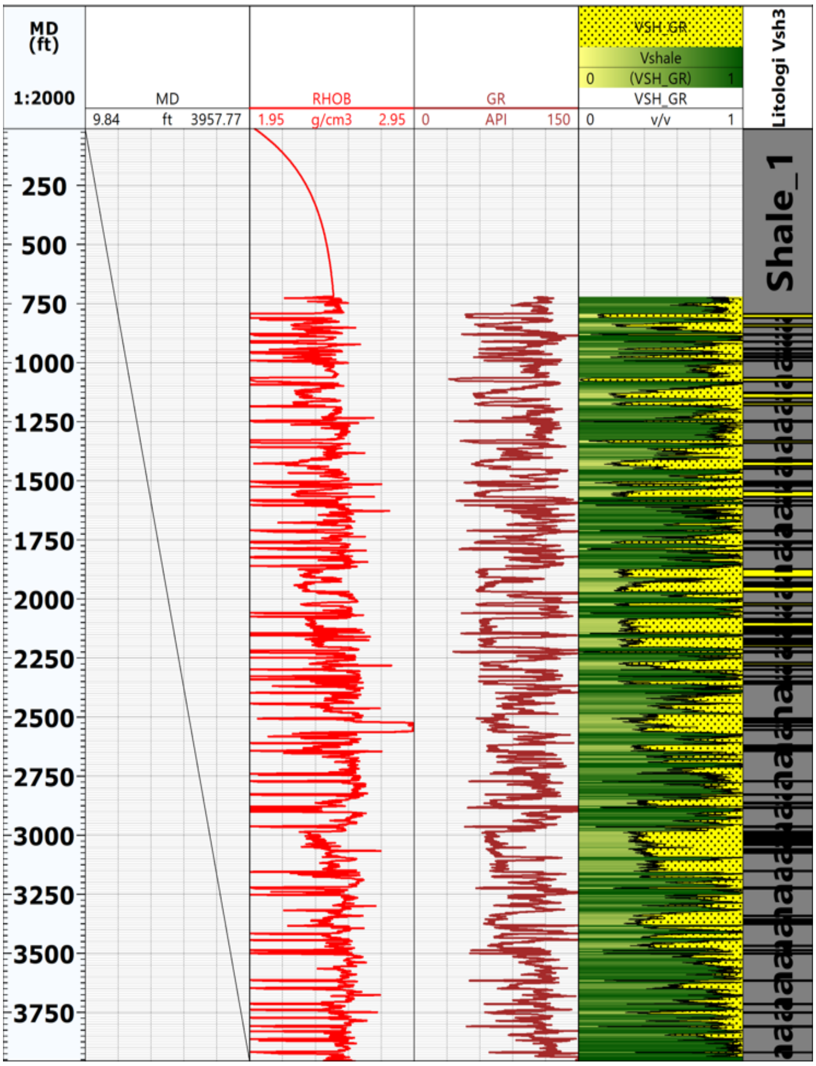


Fig. 8. Lithology Zone

Note :	
▨	Shale
🟨	Sandstone

4.2. Pore Pressure

Pore pressure is very important because it has an effect on determining the stability of the wellbore. Calculation of pore pressure can be done using the Eaton method. Calculation of pore pressure by the Eaton method can be carried out using resistivity logs and sonic logs, but with limited data in this Research, the logs used are only sonic logs. The Eaton method uses a trandline called the Normal Compaction Trand to determine the pressure conditions in the well. Based on the calculation results that have been obtained, there is an increase in pressure at a depth of 2850 ft which continues to increase with increasing depth. From these indications at a depth of 2850 ft overpressure has occurred. The results of calculating the pore pressure can be seen in Figure 9 below:

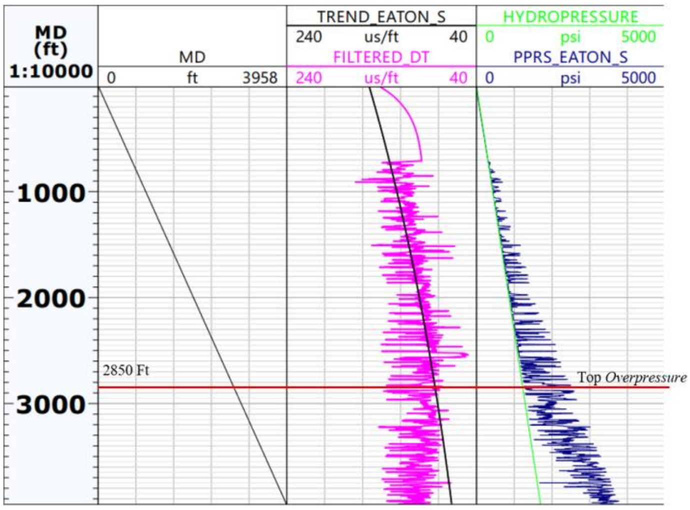


Fig 9. Pore pressure using Eaton method

4.3. In-Situ Stress

In-situ stress is divided into three conditions, namely vertical stress, maximum horizontal stress, and minimum horizontal stress. The results of the in-situ stress calculation can be used to determine the stress regime that occurs in the formation.

In this Research, the vertical stress was calculated using the density log using the extrapolation method. Figure 10 shows the vertical stress value which continues to increase with increasing depth, because the value obtained is the value of the load above it plus the load at that depth, which is called overburden. Therefore the vertical stress can also be said to be overburden pressure. To validate this value, based on the literature, the normal vertical stress gradient value is equal to 1 psi/ft.

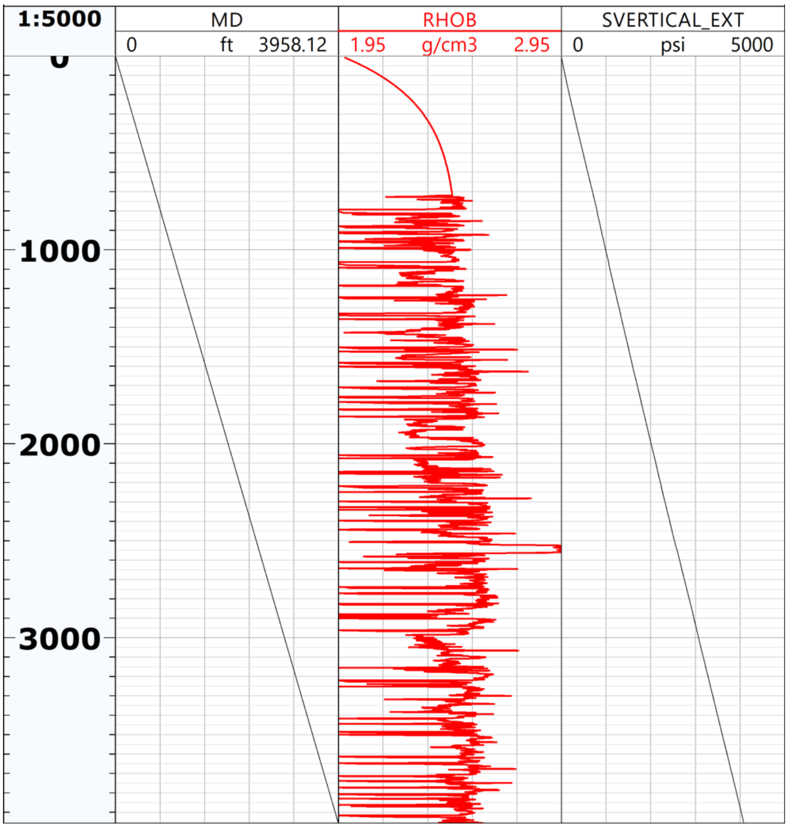


Fig 10. Vertical Stress Data

The calculation of horizontal stress in this Research using a poro-elastic approach where the input parameters are Poisson's ratio, Young's modulus, vertical stress, and pore pressure. to adjust the horizontal stress value, it is necessary to use the strain/epsilon value, where in this Research the values were divided into two, it is the maximum and minimum values. The maximum epsilon value (εH) in this Research was 0.0003 and the minimum epsilon (εh) was 0.00015. These values are obtained based on calibration carried out using data leak off test (LOT). Figure 11 shows the magnitude of the maximum and minimum horizontal stress values where the values obtained for both the maximum and minimum horizontal stress are not much different. With the two horizontal stress values that are not much different, the formation in the well can be said to be isotropic. Figure 12 shows the distribution of horizontal stress data where the maximum horizontal stress value is 0.83 psi/ft and the minimum horizontal stress value is 0.81 psi/ft.

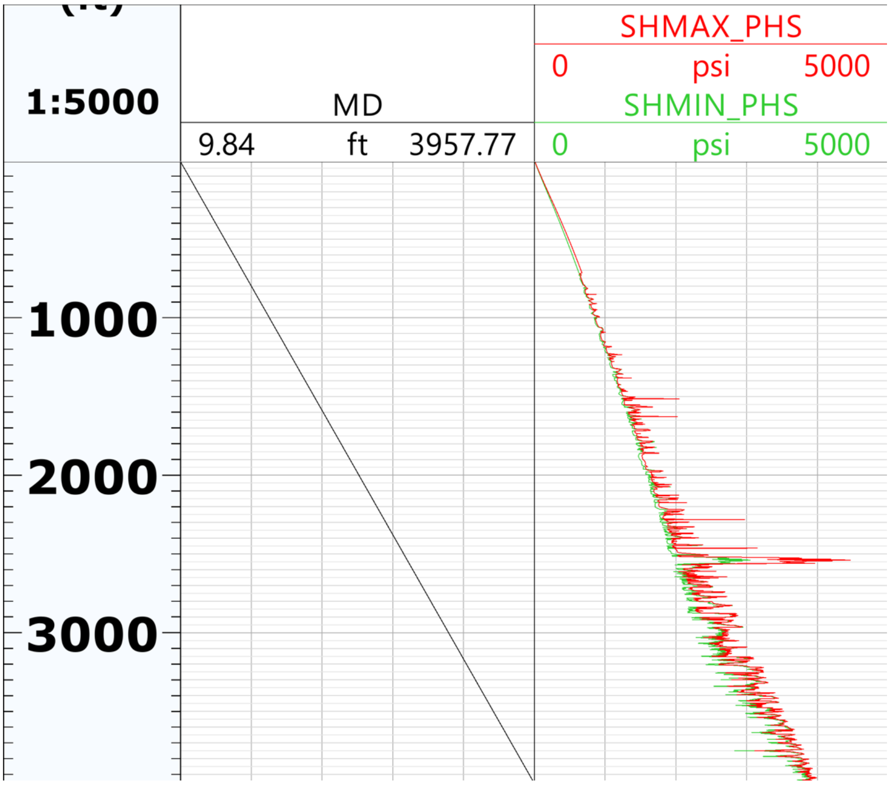
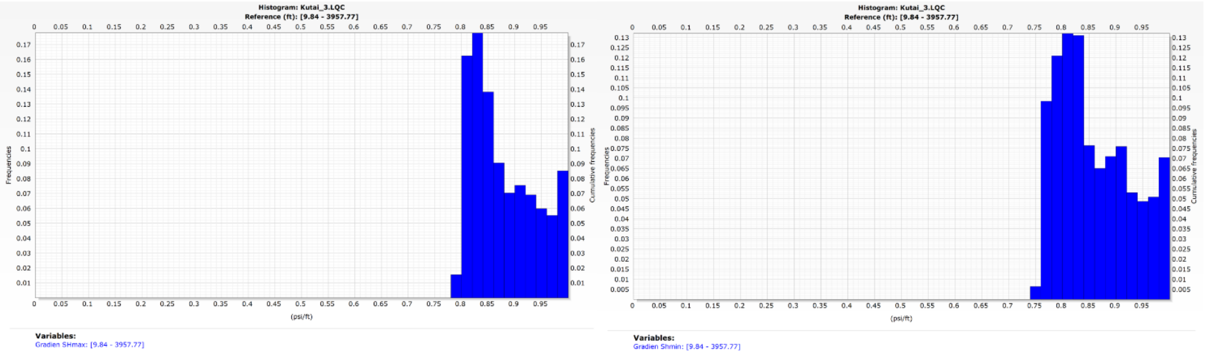


Fig 11. Horizontal stress data



(a)

(b)

Fig 12. Gradient histogram horizontal maksimum (a) & minimum (b)

4.4 Stress Regime

The stress regime can be determined using the result value of in-situ stress. Figure 13 show the in-situ stress log data, from these logs it can be seen that, in general the stress regime that occurs is the normal regime, where the vertical stress value is greater than the horizontal stress value and the maximum horizontal stress is greater than the minimum horizontal stress (Sv>SHmax >Shmin). However, at certain depth intervals there are different stress regimes such as at depth intervals of 2524 ft – 2561 ft where the maximum horizontal stress value has the largest value followed by the minimum horizontal stress then the vertical stress (SHmax>Shmin>Sv), so that at these depth intervals the stress The regime is called the reverse stress regime or what is called a thrust fault.

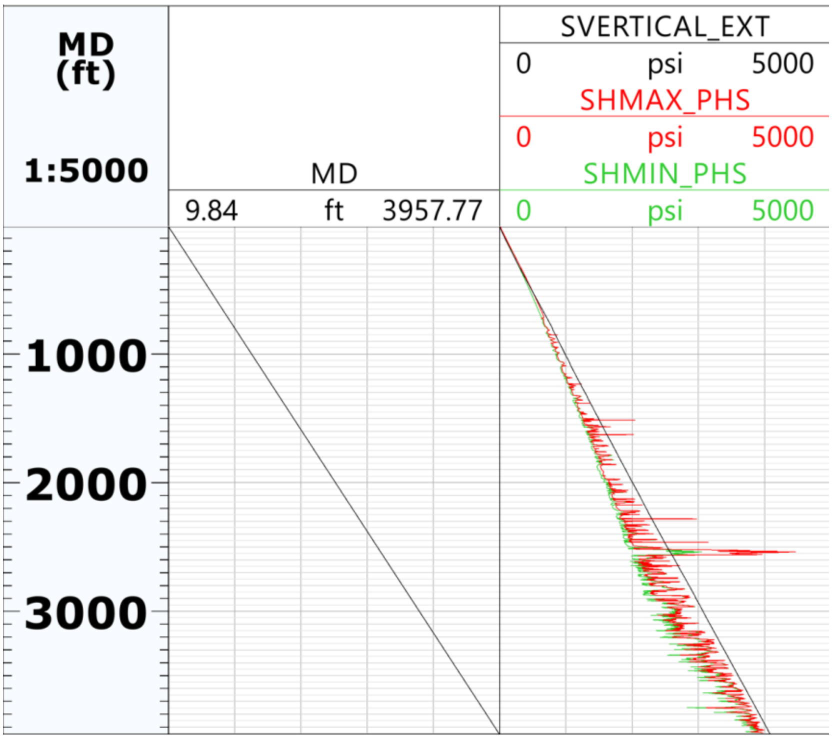


Fig 13. In-situ stress log data

4.5 1 Dimension Geomechanical Model

1D Geomechanical Model is needed to analyze the stability of the wellbore which is useful for knowing what happens to the well, in addition to predicting the safe mud weight window and failure in each well. To determine the stability of the wellbore requires several parameters such as pore pressure, elastic properties, rock strength, and in-situ stress. Each parameter has an effect on the failure factor in the formation. rock strength will determine the value of the shear strength of the rock. If the rock strength is greater, then the rock has a large shear strength value so that it can withstand the impact of shear stress, but if the shear stress strength exceeds the shear strength it can form shear failure, whereas if the tensile stress strength exceeds the tensile strength it can form a tensile failure. the presence of shear and tensile failure will have an impact on the wellbore such as: pipe sticking, fracture, hole collapse, lost circulation, enlargement of the wellbore, and others. In addition, the values obtained from pore pressure, in-situ stress, and elastic properties will affect the value of the safe drilling mud weight window.

Figure 14 shows 1D geomechanical model. each mechanical property has an influence on the geomechanical results. If Young's modulus, friction angle, and UCS increase while the poison ratio decreases, then the range of drilling mud weight in the results of geomechanical model will increase, and vice versa. Based on the figure, shear failure occurs at every depth interval with sandstone lithology, while tensile failure does not occur in this well. This is effected by the value of the weight of the drilling mud where at the depth before the overpressure occurs the weight of the drilling mud is 9 ppg to 12 ppg while in the overpressure zone the drilling mud increases from 13 ppg to 16 ppg.

Overpressure occurred in this wellbore. The overpressure is known based on the increasing pore pressure value, and on the other hand the window/range of the effective stress value gets smaller with increasing depth. The impact of this overpressure causes the kick limit value to increase with increasing depth, thus making the mud weight window smaller. This condition is validated by the history of drilling mud weight where in the history of drilling mud weight continues to increase with increasing depth, it even increases rapidly at a depth of 2600 ft, indicating that overpressure zones are starting to occur at that depth. The reduction in the mud weight window can be seen from a depth of 2850 ft where the overpressure zone has occurred. By reducing the mud weight window, events such as kicks are prone to occur in these wells. After the wellbore stability analysis has been carried out, a safe drilling mud weight values can be determined.

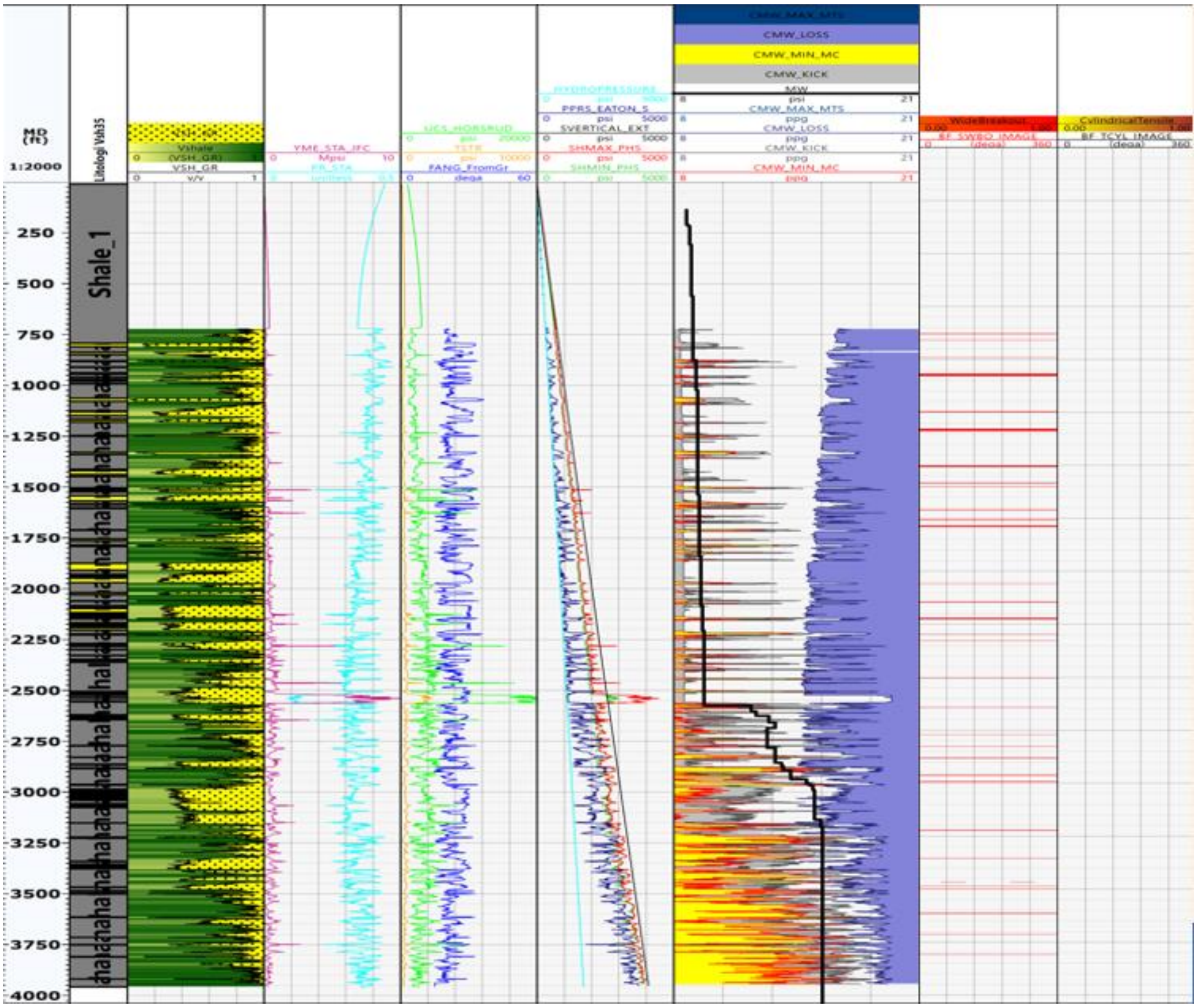


Fig 14. 1D Geomechanical Model Well Y

4.6 Safe Mud Weight Window

The weight of the drilling mud can affect the stability of the wellbore, therefore an accurate prediction is needed to determine the drilling mud weight in order to prevent damage to the well. Figure 15 shows the predicted of drilling mud weight window that is safe to use in well Y. The determination of the safe drilling mud weight is considered based on the values of fracture pressure, share failure and the column where the kick occurs which can represent the value of pore pressure. The results show that at a depth of 300 ft – 2560 ft the safe weight of drilling mud is 10.2 ppg, at intervals of 2560 – 2876 ft the safe weight of drilling mud is 12.8 ppg, then at depth intervals of 2876 ft – 3150 ft safe drilling mud weight is 14,5 ft, at depth intervals of 3150 ft – 3480 ft safe drilling mud weight is 16.1 ft and at depth intervals 3480 – 3957.77 ft safe drilling mud weight is 17.8 ppg, then based on figure 14, the red line is the maximum drilling mud weight and the blue line represents the minimum drilling mud weight.

Table 2
Safe Mud Weight Window

Interval Kedalaman (ft)	Berat Lumpur Pemboran (ppg)		
	MW Min	MW Max	MW Opt
300 – 2560	8,8	11,5	10,2
2560 – 2876	12	15,2	12,8
2876 – 3150	13,4	15,4	14,5
3150 – 3480	14,8	16,6	16,1
3480 – 3957,77	16,5	18,4	17,8

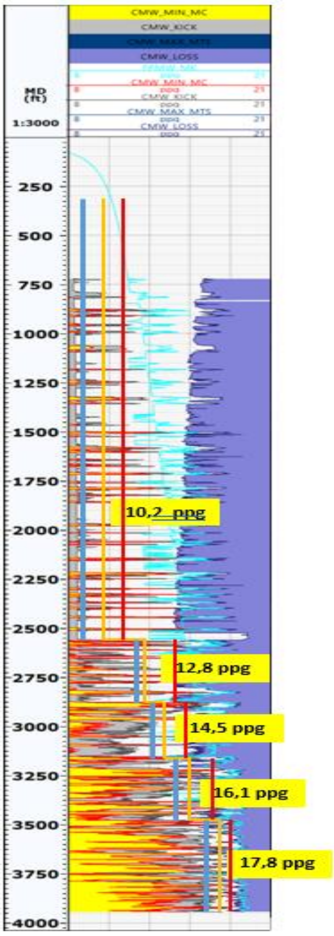


Fig 15. Prediction Safe Mud Weight Window

5. Conclusion

Determination of well stability in Field Z well Y uses calibration data of drilling mud weight. The data is useful for adjusting predictions of failure in wellbore. The results of the well stability model in this Research are that at every depth interval with sandstone, Shear Failure will generally occur. The factor that causes this to happen is the pressure value exerted by the weight of the drilling mud is lower than the value of shear failure.

After the well stability analysis has been carried out, the determination of the safe drilling mud weight can be carried out in this research. In this research the recommended safe drilling mud weight is 10.2 ppg starting from a depth of 300 ft – 2560 ft, then 12.8 ppg at a depth of 2560 ft – 2876 ft, then at a depth of 2876 ft – 3150 ft the recommended mud weight is 14 .5 ppg, then 16.1 ppg at depth intervals of 3150 ft – 3480 ft, and at depth intervals of 3480 ft – 3957.77 ft the recommended drilling mud weight is 17.8 ppg.

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