Anti-Collision and Kick Tolerance Analysis of Development Wells in Gelama Merah Field

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***Abstract* — The Gelama Merah (GM) oil and gas field off the coast of Malaysia plays a crucial role in the country's energy sector. This study explores the strategies used in Gelama Merah to prevent collisions and manage sudden pressure increases (kicks) during drilling. Advanced techniques like the IPM kick tolerance calculator and the Ellipse of Uncertainty model are used to ensure drilling safety and minimize risks. The results show that these measures effectively protect drilling operations, providing valuable lessons for future drilling activities in the region.**

Keywords— kick tolerance, anti-collision, Gelama Merah, Gelama Merah.

I. Introduction

In the vast industry of oil and gas exploration and production, optimizing drilling operations is essential for meeting energy needs. The Gelama Merah field in Southeast Asia showcases this need for balance. The field holds promising resource potential, but the complex geological landscape presents obstacles to extraction.

The Gelama Merah oil field is geologically complex, posing challenges to drilling engineers. The field has faulted structures and diverse reservoir formations, requiring innovative approaches, specialized knowledge, and meticulous planning to unlock the reservoir's full potential while overcoming subsurface obstacles.

In the complex interaction between science and engineering in drilling operations, two crucial elements play a central role such as preventing collisions through robust anti-collision strategies and analyzing how drilling structures withstand impacts, known as kick tolerance analysis. These two pillars ensure safe and efficient drilling, guiding well trajectories to avoid accidents and protect against potential risks.

In the Gelama Merah drilling area, where numerous wells are closely spaced, preventing collisions is crucial. To ensure safe and successful drilling, effective anti-collision strategies are essential. These strategies involve using advanced directional drilling techniques, real-time monitoring systems, and surveying methods. By harmonizing these elements, these strategies aim to maintain the integrity of existing wells, allow for new drilling without interference, and optimize reservoir management.

In Gelama Merah, assessing a well's tolerance to kicks becomes crucial for safety and efficiency while drilling. In the unpredictable world of drilling, with varying fluid dynamics and formation pressures, it's essential to predict, identify, and manage kicks - unexpected fluid inflows - to prevent disasters. By understanding kick tolerance, not only do we boost safety, but we also optimize drilling operations, reducing downtime, and maximizing cost-efficiency.

II. Literature Review

A. *Anti-collission*

A drilling well may stray from its intended course throughout the operation for a variety of reasons, such as riser inclination errors, vertical well section inclination errors, instrument faults, or human error. A bore collision might then result from any of these.

Collisions between wellbores drastically lower output and may lead to well abandonment, which can result in severe financial loss. This kind of accident, if not managed appropriately, may result in serious environmental contamination, harm to people, or even death (Liu et al.,

2012) Accordingly, research on wellbore collision prevention has enormous practical implications for the drilling sector (Guan et al., 2010). It is vital to keep the spacing between bores within a suitable range and to monitor it in real time to better manage the collision problem. By doing this effectively, accidents are avoided, and safe drilling is ensured.

Vibration monitoring, which may be broadly classified into two categories: casing vibration monitoring and Measurement While Drilling (MWD) vibration monitoring, is a set of techniques used to prevent wellbore collisions. The well casing head vibration signal is measured on the ground via the casing vibration monitoring method. It is feasible to ascertain whether there is a risk of a collision with the drilling well by analyzing this signal.

The finished target well is equipped with an acoustic sensor as part of the MWD vibration monitoring system. To avoid collision, the approximate distance between the drill bit and the sensor is computed by tracking variations in vibration.

The MWD vibration monitoring method only has a small range and significantly lower accuracy due to certain limitations, such as the minimum distance being determined only when the sensor moves in accordance with the drill bit, vibration caused by the drill bit or drill rod colliding with the wellbore interfering with the vibration as monitored, and vibration transmission damping quickly and being subject to formation (Guan et al., 2010). Simply put, there are currently no effective ways to provide borehole distance sensing for the purpose of preventing wellbore collisions.

B. Kick tolerance

According to Watson et al. (2003), kick tolerance is the highest kick intensity a well can withstand before experiencing decreased circulation at the final casing seat. It is not desirable to take a kick during drilling or finishing operations on a rig site. Because of the underlying over-pressured formations and comparatively smaller fracture gradients, the danger is higher in deep water situations. The possibility of a subterranean blowout, which may be extremely expensive to prevent, exists if the formation fractures or breaks for any other reason.

Toop (2011) asserted that safe well design and drilling depend on accurately determining kick tolerance. A drilling campaign that ends with the operator business losing well control might cost them money and damage their image. It's interesting to note that no technique appears to be provided by the International Association of Drilling Contractors (IADC) Drilling Manual or the American Petroleum Institute (API) publications.

Early kick detection is essential for deep water well management, according to several studies. The idea presented in this research study is predicated on the idea that a closed wellhead increases bottom hole pressure due to a volume of kick fluid entering the well. As a result, the subject's tolerance allows them to withstand the kick without losing control.

It is necessary to compute the kick tolerance of each well in advance. There might be disastrous results if the kick tolerance is not accurately calculated as a function of the well design that is being built. The Deepwater Horizon Disaster, as reported by Cheng et al. (2013), is one of the most notable examples of a serious failure in the deepwater oil and gas drilling business. The computation of kick tolerance depends on having precise knowledge of the fracture gradients and pore pressure in the wells.

Due to the numerous variables that must be considered when drilling a well, the kick tolerance idea for the wells is one that needs to be carefully considered. To be utilized for pre-drill pore pressure and fracture pressure forecasts of the future wells, a post-well study should be conducted for each well and the corresponding pore pressure and fracture gradient data made accessible.

C. Development wells in Gelama Merah

There are two stages of the GM Area Integrated Field Development Project: GM Main, GM Tengah, Gelama Merah, GM Tepi, and GM Ujong. The construction of GM Main Field is regarded as Phase 1 in the development of the entire GM Area.

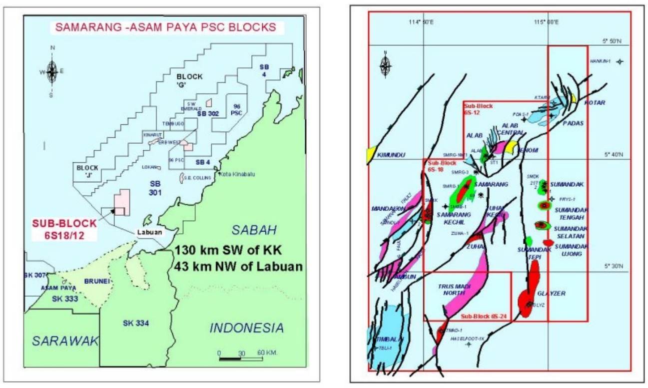

Figure 1 Topography Map of Samarang - Asam Paya & GM Field Development Area

In October 2006, the GM-A (GM-A) platform, a four-legged, 28-slot platform, was successfully built at the location. Due to the unconsolidated production section, poor productivity indices, and low critical drawdown of the GM-A Development area, a full-scale review was conducted to support the project's use of open hole completion. The idea was first presented during the creation of GM-A to raise the wells' productivity index, which raises oil production rates in addition to lowering CAPEX. According to research, the idea is the best use of creativity and technology to overcome the low reserve wells that are allotted to the GM fields. In GM-A formations, observations from offset exploration wells point to the absence of cementation characteristics. Found in the GM-1, GM-2, SMTP-1, and GM-2ST1 wells are friable core samples, friable cuts, and friable side wall cores. These observations lead geologists to classify the hydrocarbon-bearing strata in GM-A as unconsolidated formations. Therefore, during production, these formations run the danger of catastrophic sand collapse.

III. Background

A. Gelama Merah

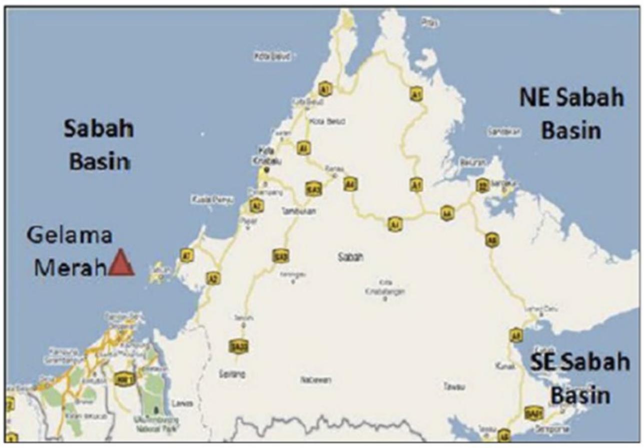

Figure 2 :Map of Sabah Basin, North-East Sabah Basin and South-East Sabah Basin, and the location of Gelama Merah within Sabah Basin

Gelama Merah's position within the Sabah Basin is seen in Figure 1. The Samarang oil field lies next to the Sabah basin. Samarang Field and the Labuan Gas Terminal are around 72 km apart, and Samarang Field and Gelama Merah are roughly 17 km apart. At a depth of thirty feet, the shallow reeds encircle Gelama Merah. Additionally, 12 km of dense Neogene sediments that were deposited in shelf slope and deep marine settings may be found in this basin. Gelama Merah is in the northwest of the Sabah Basin's East Baram Delta (EBD) Province. Most of the hydrocarbons in the Sabah Basin are in rollover anticlines connected to growth faults resulting from deltaic activity, complex faulted anticlines formed by wrench tectonics, and other fault-related closures. The field's depositional environment is deltaic, suggesting a shallow marine environment with a water depth of around 42.8 m from the Mean Sea Level (MSL) to the Seabed. The most notable feature in this area is the large Champion-Padas megastructure, which is made up of the macrostructures of Padas, Samarang, and Timbalai.

IV. Methodology

A. Anti-collision

A cutting-edge software is available to help plan and carry out directional drilling, which is where wells are deliberately bent to reach specific targets like oil or gas deposits. This software uses a model called the Ellipse of Uncertainty - Wolff deWaardt, which is very advanced and helps with directional drilling.

The Ellipse of Uncertainty (EOU) is a method used in directional drilling to visualize how much the wellbore's path may vary from the intended path. It considers uncertainties such as the direction of the drill bit, the properties of the rock formations being drilled through, and the drilling settings. The EOU shows the possible range of positions the wellbore could be in at any given point in its trajectory, helping to plan for any potential problems.

The Wolff deWaardt Model, developed by Wolff and deWaardt, enhances the Extended Offset Unit (EOU) by mathematically determining its dimensions and orientation. It utilizes parameters including wellbore inclination, azimuth, and drilling conditions to consider factors such as tool face control, rock properties, and equipment capabilities. By incorporating these factors, the model predicts potential wellbore deviation with greater precision, aiding in operational planning and decision-making during drilling operations.

Equipped with the Ellipse of Uncertainty - Wolff deWaardt Model, drilling professionals can predict the probable path of the wellbore. This visualization helps them decide and plan in real-time, adjusting steering corrections, wellbore placement, and integrity management. Additionally, the model helps reduce risks like wellbore crashes, formation damage, and operational issues, making directional drilling safer, more effective, and more likely to succeed.

The software uses an advanced algorithm to consider factors related to the well path and nearby wells. It creates a 3D model showing planned and existing well paths and any possible collision areas. The EOU (Elapsed Operations Unit) is added to the model, allowing us to visually see how the wellbore may deviate.

The software uses advanced calculations to find where the planned well's drilling path (EOU) might cross the EOUs of nearby wells. These intersections indicate possible collision points where the wells could meet. The software checks the distance, angle, and positions of these points to estimate the possibility and seriousness of any potential collisions.

Using this analysis, drilling engineers and operators can see images and reports that show where there are risks of collision. This information helps them make decisions about where to place the wellbore, how to adjust the drilling direction, and what the overall drilling strategy should be. By finding and dealing with collision risks as they happen or while planning, the software makes drilling operations safer, more reliable, and more efficient.

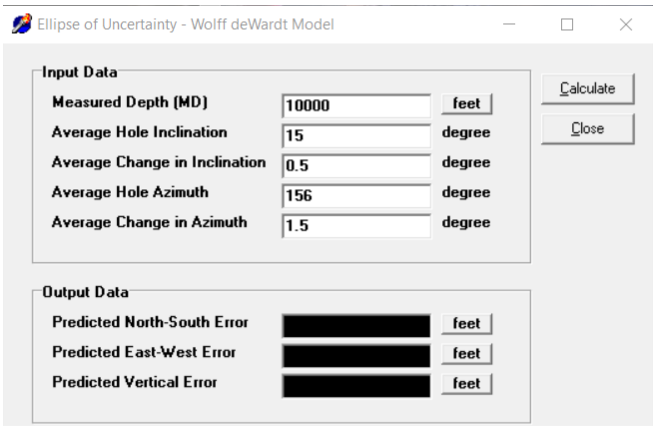

Figure 3 Input Data for Anti-Collission Calculation

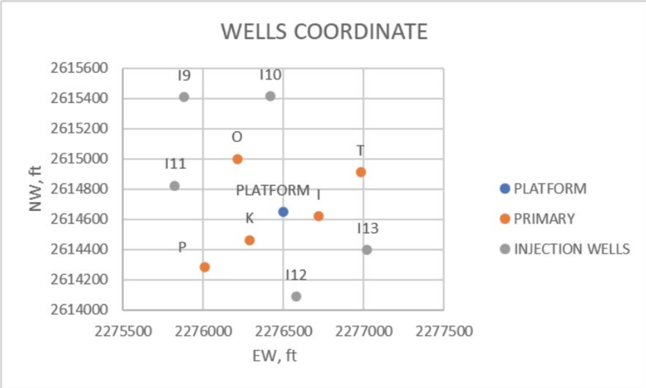

Figure 4 The coordinate for all wells plotted in Excel

B. Kick tolerance

The IPM (Integrated Pore Pressure Management) kick tolerance calculator is essential in the oil and gas sector. It helps estimate and regulate the likelihood of uncontrolled releases of formation fluids (e.g., oil, gas, water) into the wellbore during drilling. These incidents, known as kicks, pose risks such as blowouts, loss of well control, and threats to worker and equipment safety.

Using advanced mathematical formulas, the IPM kick tolerance calculator calculates the maximum amount of reservoir fluids that can safely enter the wellbore during drilling. It considers factors like the weight of the drilling fluid, the pressure of the underground fluids, the shape of the wellbore, and the properties of the drilling fluid. This ensures that drilling operations can proceed safely within acceptable limits. The IPM kick tolerance calculator can determine the Maximum Allowable Mud Weight (MAMW), the maximum thickness of drilling mud that can be used without damaging the formation. By entering information about the formation pressure, well depth, and mud composition, the calculator calculates the MAMW and advises on the correct mud weight to use during drilling.

The IPM kick tolerance calculator goes beyond just calculating kick tolerance. It also considers different stages of drilling, including when casing is installed and when intermediate sections are being drilled. By doing this, it evaluates the well's ability to handle formation fluid influxes at various points in the wellbore. This information is crucial for planning the well and making decisions during the drilling process. To determine the ability of the wellbore to resist a kick, the software assesses various factors: 1) Formation pressure at both ends of the casing shoe 2) Depth of the wellbore 3) Properties of the drilling fluid The software calculates the highest pressure that the wellbore can safely handle at each end of the casing shoe. This maximum allowable pressure helps prevent uncontrolled fluid entry into the wellbore (known as a kick). Using formation pressure and related data, a software program determines how much pressure can be safely increased at the bottom of the hole before it reaches the formation pressure. This limit is called "kick tolerance" and factors in safety margins to account for unexpected events and changes during drilling.

The software displays the results of the kick tolerance calculations for both ends of the casing shoe in two formats: graphs and tables. This visual representation helps drilling engineers and operators understand the results. It also enables them to make informed decisions about drilling operations, reducing the chances of kicks, and ensuring the safety and success of their drilling efforts.

The IPM kick tolerance calculator is a powerful tool that helps oil and gas drillers improve their safety and efficiency. It helps them calculate how much pressure their drilling system can withstand before a blowout occurs, allowing them to make informed decisions and adjust their procedures accordingly. By using this calculator, drillers can minimize the risk of uncontrolled gas or oil releases, ensuring the well-being of workers and the environment.

Table 1 Casing Setting Depth

Type of Casing	Depth, ft
Conductor	656.17
Surface	1862.68
Intermediate	3958.24
Production	4900.00

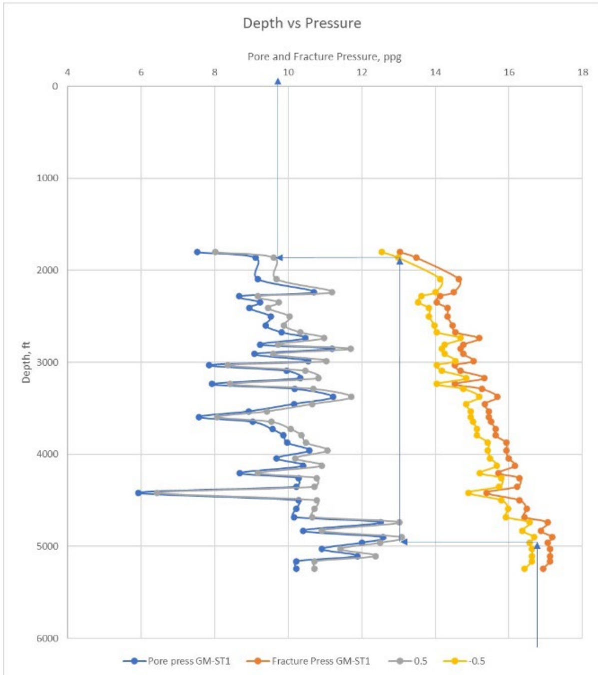

Figure 5 Pressure Profile

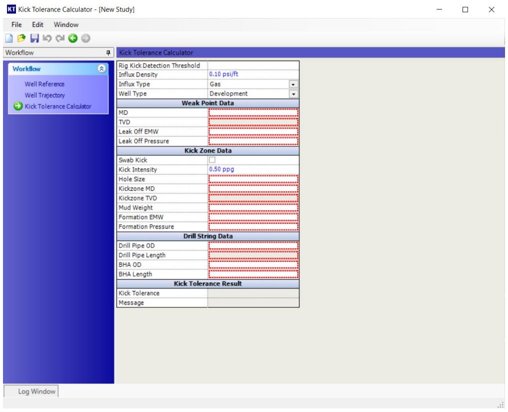

Figure 6 Input data for kick tolerance calculation

RESULTS AND DISCUSSION

C. Anti-collision

Table 2: Anti-collision Results

Pair	Distance (m)	Error (ft)	Separation Factor	Remarks
9I-11I	586.76	139.68	4.20	SAFE
9I-10I	537.46	155.07	3.47	SAFE
9I-O	526.59	90.98	5.79	VERY SAFE
10I-O	459.09	127.84	3.59	SAFE
11I-O	429.91	112.45	3.82	SAFE
O-K	745.32	75.69	9.85	VERY SAFE
O-I	542.71	51.24	10.59	VERY SAFE
K-I	331.39	63.18	5.25	VERY SAFE
I-12I	472.96	168.97	2.80	SAFE
I-P	457.09	34.55	13.23	VERY SAFE
12I-P	548.52	164.79	3.33	SAFE
12I-13I	539.59	307.69	1.75	SAFE
P-T	393.04	54.40	7.22	VERY SAFE
P-13I	375.76	173.27	2.17	SAFE
GM-1 - T	457.90	93.87	4.88	SAFE

The analysis of potential collisions in the Gelama Merah field offers important information about the position and safety between wells. Each pair of wells was examined considering factors like the distance between their paths, possible errors, and separation ratios. This analysis aims to determine the likelihood of a collision.

1) 9I-11I: There is a 139.68-foot error margin in the distance of 586.76 metres between wells 9I and 11I. There is little chance of a collision between the wells at the separation factor of 4.20.
2) 9I-10I: The separation between Wells 9I and 10I is 537.46 metres, with a 155.07-foot error margin. As the wells have a separation factor of 3.47, there is no risk of a collision.
3) 9I-O: There is a 526.59-meter error margin in the distance between wells 9I and O, which is 90.98 ft. A high degree of spatial separation and a highly safe distance between the wells are indicated by the separation factor of 5.79.
4) 10I-O: There is a 459.09-meter gap between Wells 10I and O, with an error margin of 127.84 feet. A safe spacing between the wells is suggested by the separation factor of 3.59.
5) 11I-O: There is a 112.45-foot error margin in the distance measuring 429.91 metres between wells 11I and O. The separation factor of 3.82 indicates that there is no risk of a collision between the wells.
6) O-K: The separation between Wells O and K is 745.32 metres, with a 75.69-foot error margin. A considerable geographical separation and a highly safe distance between the wells are indicated by the separation factor of 9.85.
7) O-I: There is a 51.24-foot error margin in the 542.71-meter distance between wells O and I. The wells are located a very safe distance apart, with a separation factor of 10.59.
8) K-I: With a 63.18-foot error margin, the distance between Wells K and I is 331.39 metres. The 5.25 separation factor indicates that there should be a fairly safe gap between the wells.
9) I-12I: Wells I and 12I are separated by 472.96 metres, with a 168.97-foot error margin. The separation factor of 2.80 indicates that there is no risk of a collision between the wells.
10) I-P: The separation between Wells I and P is 457.09 metres, with a 34.55-foot error margin. There is a highly safe distance between the wells, as indicated by the separation factor of 13.23.
11) 12I-P: There is a 164.79-foot error margin in the distance of 548.52 metres between wells 12I and P. Given a separation factor of 3.33, there is no risk of a collision between the wells.
12) 12I-13I: The separation between Wells 12I and 13I is 539.59 metres, with a 307.69-foot error margin. Even though there is a little less geographical separation between the wells, the separation factor of 1.75 indicates a safe distance.
13) P-T: There is a 54.40-foot error margin in the distance of 393.04 metres between wells P and T. There is a highly safe distance between the wells, as indicated by the separation factor of 7.22.
14) P-13I: There is a 375.76-meter gap between Wells P and 13I, with an error margin of 173.27 feet. The separation factor of 2.17 indicates that there is no risk of a collision between the wells.
15) GM-1 - T: There is a 93.87-foot error margin in the distance of 457.90 metres between well GM-1 and well T. The wells are placed a safe distance apart, with a separation factor of 4.88.

After analyzing the possibility of collisions, we found that all 10 wells in the Gelama Merah field are far enough apart and don't run into each other. The separation factor is a number that shows how far apart the wells are. Most of the wells are very far apart, with separation factors of more than 5. This shows that the anti-collision plans and procedures used in the Gelama Merah field are effective and keep drilling operations safe.

D. Kick tolerance

Table 3: Kick tolerance Results

Wells		Kick Tolerance (bbl)		
		S1	S2	S3
Primary	T	25.31	83.32	PASS
	O	34.12	80.67	PASS
	K	34.12	94.29	PASS
	P	34.31	43.45	PASS
	I	33.93	76.94	PASS
Secondary	I9	31.61	PASS	PASS
	I10	31.61	116.34	PASS
	I11	31.61	114.53	PASS
	I12	31.61	182.36	PASS
	I13	31.61	190.39	PASS

The kick tolerance evaluation determines how much fluid from underground can enter a well in the Gelama Merah field without causing an uncontrolled release (blowout). It calculates the maximum volume of fluid that can flow into the well at different depths (S1, S2, S3) to make sure drilling activities are safe and the well is protected.

Primary Wells:

1) GM-T (T): The computed kick tolerances for casing shoe depths S1, S2, and S3 are 25.31 bbl, 83.32 bbl, and pass, correspondingly. These findings show that at all analysed depths, well GM-T can safely tolerate formation fluid influxes without running the danger of a blowout.
2) GM-O (O): For well GM-O, the analysis passes with the computed kick tolerances at depths S1 and S2 of 34.12 bbl and 80.67 bbl, respectively. The fact that the kick tolerance at depth S3 is ambiguous indicates that the well is built to securely handle influxes at this level.
3) GM-K (K): With computed values of 34.12 bbl, 94.29 bbl, and pass at depths S1, S2, and S3, respectively, well GM-K exhibits strong kick tolerance throughout all depths. These findings confirm that there is no blowout danger associated with the well's capacity to tolerate formation fluid influxes.
4) GM-P (P): GM-P shows kick tolerances of 34.31 bbl and 43.45 bbl, respectively, at casing shoe depths S1 and S2, both of which pass the analysis. The well's safe design for influxes at depth S3 is shown by the lack of a kick tolerance specification.
5) GM-I (I): With computed values of 33.93 bbl, 76.94 bbl, and pass at depths S1, S2, and S3, respectively, well GM-I exhibits acceptable kick tolerance at all assessed depths. These findings confirm the well's safety and integrity in the event of an inflow.

Secondary wells:

1) GM-I9: This model passes the analysis with a kick tolerance of 31.61 barrels at casing shoe depth S1. The fact that no precise figures are given for depths S2 and S3 suggests that the well was designed to operate safely at these levels.
2) GM-I10: The well demonstrates adequate kick tolerance at depth S1, passing the analysis with a computed value of 31.61 bbl. The well's safe design for influxes at depth S2 is shown by the lack of a kick tolerance specification.
3) GM-I11: In a similar vein, well GM-I11 passes the analysis at depth S1 thanks to its strong kick tolerance, which is determined to be 31.61 bbl. The fact that no precise figures are given for depths S2 and S3 suggests that the well was designed to operate safely at these levels.
4) GM-I12: This model passes the analysis with a kick tolerance of 31.61 barrels at casing shoe depth S1. The well is designed for safe operation down to depths S2 and S3, however no values are given for these depths.
5) GM-I13: This well passes the analysis since it shows a sufficient kick tolerance at depth S1, with an estimated value of 31.61 bbl. The fact that no precise figures are given for depths S2 and S3 suggests that the well was designed to operate safely at these levels.

The analysis of the wells' ability to tolerate sudden fluid influxes shows that all wells in the Gelama Merah field can safely withstand them without causing blowouts. The calculated values that measure this tolerance guarantee the integrity and safety of the wells at various depths. This proves the success of the methods used for drilling and well construction in the field, which have kept operations safe and consistent.

V. Conclusion

The safety of wells in the Gelama Merah field has been ensured through analysis that ruled out any collisions, demonstrating successful spatial planning. Wells have also shown exceptional ability to handle fluid influxes from the formation, preventing blowouts. These findings highlight the field's commitment to safety and efficient operations, creating a positive foundation for future drilling. Adhering to best practices remains essential for maintaining safety and effectiveness in the Gelama Merah field.

REFERENCES

Cheng, R., Wang, H., Shi, L., Ge, Y., Sun, Z., & Tian, H. (2013). Drilling Risk Management in Offshore China: Insights and Lessons Learned from the Deepwater Horizon Incident. All Days. https://doi.org/10.2523/iptc-16726-ms

Eren, T. (2018). Kick tolerance calculations for drilling operations. *Journal of Petroleum Science and Engineering*, *171*, 558–569. https://doi.org/10.1016/j.petWu, Z., Gao, D., & Diao, B. (2015). An investigation of electromagnetic anti-collision real-time measurement for drilling cluster wells. *Journal of Natural Gas Science and Engineering*, *23*, 346–355. https://doi.org/10.1016/j.jngse.2015.02.016

Guan, Z., Liu, Y., Shi, Y., Wei, K., Wang, J., Liang, H., & Zhang, H. (2010). Problems and developing direction of anti-collision technology in the dense well pattern area. *Procedia Engineering*, *7*, 304–311. https://doi.org/10.1016/j.proeng.2010.11.049

G. Liu, Q. Yang, Z. Geng and B. He, "Processing of Wellbore Anti-collision Signal Based on Empirical Mode Decomposition," *2012 International Conference on Control Engineering and Communication Technology*, Shenyang, China, 2012, pp. 440-443, doi: 10.1109/ICCECT.2012.59.

Subramaniam, A. K., Sapian, M. R., & Salmi, N. (2009). Full Field Development With Open Hole Concept at GM-A. *All Days*. https://doi.org/10.4043/19731-ms