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Drilling Effectively in The Target Zone Using A Smart Alert System to Reduce Non-Productive Time in Geosteering Operations

Yustian Ekky Rahanjani and Budhi Nugraha

Petrolink
Sona Topas Tower-5th floor, Jend. Sudirman Street Kav. 26, South Jakarta, Indonesia.

Corresponding author: yustian.rahanjani@petrolink.com

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ABSTRACT - This paper discusses the benefits of using a smart alert system for the detection of geological boundaries and how this system enhances decision making during geosteering operations. Monitoring multiple wells in a high-operation environment is a big challenge for geosteering operations. Using managed by exception (MBE), an integrated smart system that produces an alert when the well deviates from the target zone while drilling, is a solution which can greatly improve operational efficiency. Real-time drilling data is processed through the integrated alert system by a set of algorithms that can recognize when the drill-bit goes out of the reservoir. This is based on logging while drilling (LWD) characteristics. The smart system can then recommend if an adjustment in inclination is required to keep the best contact with the reservoir. This creates a seamless geosteering workflow. Geologists and petrophysicists can now leverage a comprehensive understanding of real-time data infrastructure, log formats, and data processing. This fosters effective communication about reservoir condition. We believe MBE setup significantly improves geosteering efficiency and encourages others to utilize the power of real-time data analysis.

Keywords: geosteering, drilling, smart alert, efficiency, real-time data.

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INTRODUCTION

This paper examines a proof of concept demonstrating the successful implementation of a smart alert system aimed at reducing non-productive time (NPT) during geosteering operations. NPT, defined as the period when drilling halts or the penetration rate significantly drops (Moazzeni et al. 2010), encompasses various scenarios such as lost circulation, kicks, stuck pipes, wellbore stability issues, formation breakdown, slow rate of penetration (ROP), and other drilling and formation challenges. For instance, as illustrated in Figure 1, an analysis of over 200 recent development wells in the Maroun oil field revealed that 10% of rig time was spent on hole conditioning due to instability, while 3% was consumed by fishing operations to

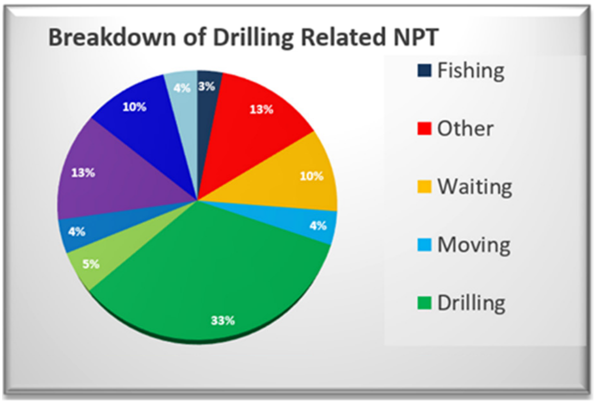

Figure 1. Time breakdown diagram of drilled development wells in Maroun oil field (Moazzeni et.al. 2010).

retrieve stuck pipes. These issues incurred significant costs in rig time without advancing drilling progress, underscoring their operational inefficiency.

Further investigation indicated that monitoring multiple critical parameters during geosteering can exacerbate NPT, as geologists must navigate multiple user interfaces to monitor log readings. This paper will specifically highlight scenarios where timely interventions enabled operators to mitigate hidden lost time associated with monitoring numerous wells by consolidating information into a single interface for decision-making purposes. This study is the first to quantify NPT reduction via smart alerts in geosteering, building on (Alsanie et al. 2017) integrated workflow model and extending recent work on AI-driven drilling optimization (Benzine et al. 2024). Previously, Rahanjani et.al. (2018) have observed NPT while calculating reservoir footage during geosteering operations.

Furthermore, this study will outline best practices for seamlessly integrating a smart alert system into existing geosteering workflows. It will explore considerations such as data acquisition methods, data quality control measures, integration with existing software platforms utilized for real-time monitoring and decision-making, and the training and support required for effective implementation. This study is based on a foundational concept introduced by Rahanjani et al. (2020), which emphasizes the potential of real-time calculations as a future development for leveraging real-time data in geosteering operations.

In conclusion, drilling effectively in the target zone with a smart alert system holds tremendous potential for reducing non-productive time in geosteering operations. By leveraging advanced data analytics and real-time monitoring capabilities, the geosteering geologists can identify which reservoir zone they are in, enabling them to take immediate corrective actions. The successful integration of a smart alert system can lead to improved wellbore placement, enhanced operational efficiency, and optimized hydrocarbon recovery. Through this paper, we aim to provide valuable insights into the benefits of utilizing a smart alert system in geosteering operations and offer guidance on its seamless implementation.

METHODOLOGY

Geosteering is a technique used to effectively position and control a well within the desired target zone. This process involves drilling a precise path that aligns with the productive zone (Calleja 2010) (refer to Figure 2). To achieve successful geosteering, two essential components are required: data and integrated systems.

Geosteering Data

The data needed for geosteering includes real-time wellsite information transfer standard markup language (WITSML), logging while drilling (LWD) data, survey data, and static data. This can also include offset well data, formation grids, and the drilling plan. Real-time LWD and survey data are obtained from LWD and measurement while drilling (MWD) tools. The minimum requirement for classifying or characterizing the reservoir zone is triple combo tools that consist of gamma ray, resistivity, and density-neutron-photoelectric (PEF) sensors, along with imaging tools. The gamma ray

Figure 2. Geosteering display shows process involves drilling a precise path that aligns with the productive zone.

and density-neutron-PEF tools can determine the lithology of the reservoir by identifying unique value ranges for these parameters. The resistivity tool helps determine the fluid. Depending on the reservoir characteristics, additional tools may be recommended by geologists to management. For example, Kanfar (2012) used formation pressure while drilling (FPWD) and nuclear magnetic resonance while drilling (NMR-WD) tools to avoid passing through low permeability zones or tar mats. Additional criteria can also be added regarding minimum mobility data of the reservoir as guidance for tool usage during geosteering.

In addition to real-time LWD data, geologists require survey data to determine the spatial position of the wellbore and to provide instructions on well inclination to directional drillers. Static data required for geosteering includes offset well data, formation grids, and drilling plans. Offset well data is compared to the active geosteering wells to understand reservoir geometry and predict future positions. It also provides guidance on petrophysical readings to determine if the wellbore position is within the pay zone or not. Formation grids serve a similar purpose as offset wells, but with less resolution in reviewing well positions stratigraphically. The drilling plan provides guidance on aspects such as azimuthal position and dog leg severity during drilling operations.

An integrated system for geosteering

Alsanie et.al (2017) proposed an integrated real-time system for managing geosteering projects. This system serves as a model for efficiently handling the workflow of geosteering projects in real-time. Illustrated in Figure 3, it incorporates various applications that are necessary to consolidate the scattered information from different sources within the storage network. Using visualization and calculations, it ensures that all non-WITSML data is converted into WITSML data.

The key components of this system include: 1). Real-time and static data: As previously mentioned, this includes all the required data such as LWD data, survey data, offset well data, formation grids, and drilling plans; 2). Surface grid converter: This application is designed to read formation grids from subsurface models and convert them based on actual datum and horizon information; 3). Offset well data converter: This application reads historical well logs with non-standard formats to serve as a source correlation; 4). Real-time and static data visualization: Geoscientists can evaluate the collected data and perform geosteering operations using tools like cross-section displays, correlation displays, and single log displays; 5). Data store: All types of WITSML data are collected and stored in this designated space for easy access; 6). Communication facility: A chat feature enables users to provide instructions regarding the desired inclination to directional drillers.

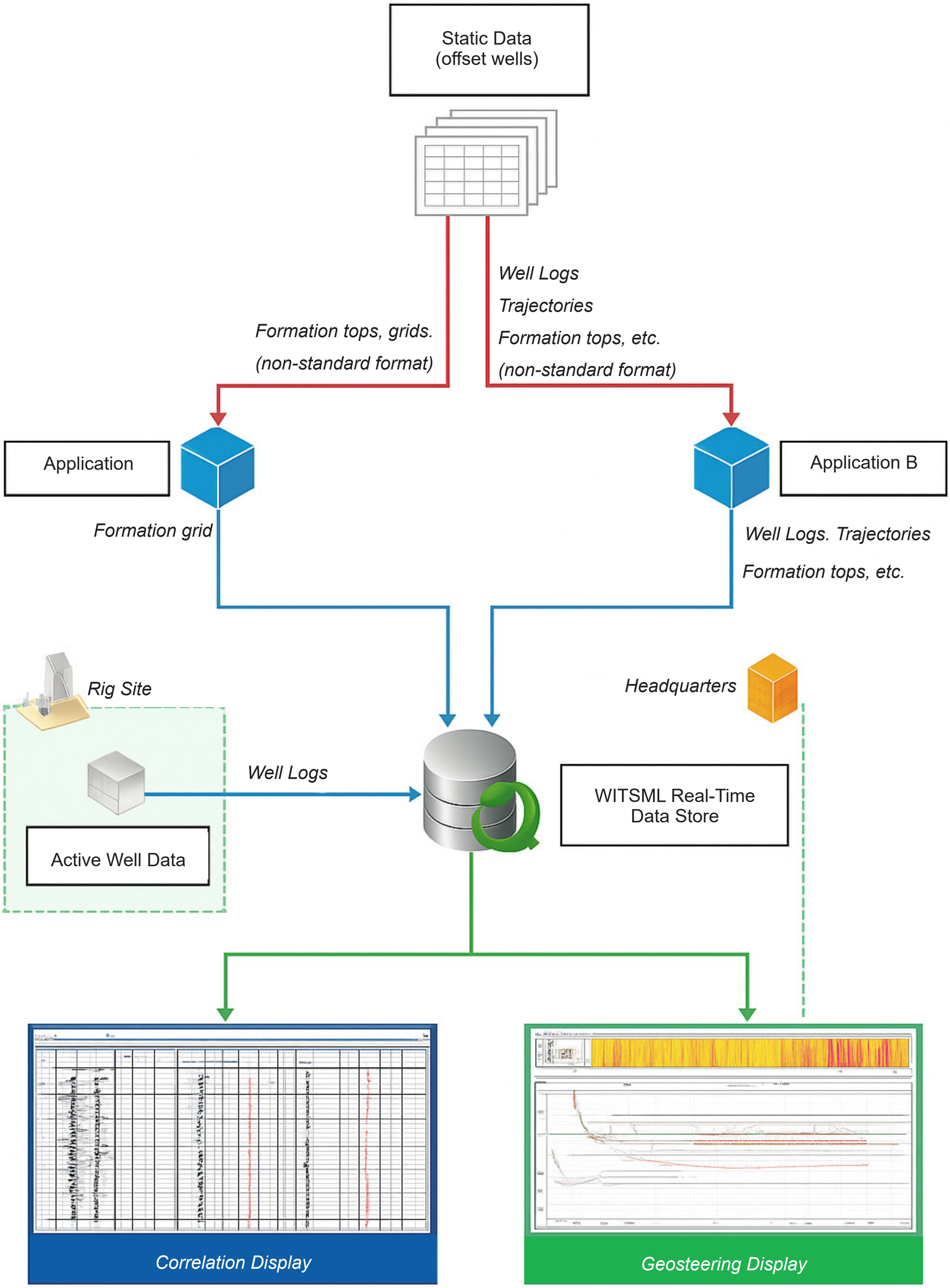

Figure 3. Integrated real-time system for geosteering (Alsanie 2017).

Within this system framework, a solution can be developed between the WITSML Real-Time Data Store and the visualization component by implementing a data analysis engine that processes WITSML LWD logs using specific algorithms. The results can then be viewed within a single display. Users have the flexibility to adjust cut-off values and ranges within these algorithms to account for variations in petrophysical characteristics of reservoirs.

Smart alert

Employing a smart alert system during the simultaneous monitoring of multiple wells in highly operational conditions has the potential to minimize non-productive time in geosteering operations. MBE notifies the geosteering operators when the drill string deviates from the targeted zone. To illustrate this concept, the PetroVue manage by exceptions (MBE) application, administered by Petrolink, serves as the smart alert manager in this scenario. Like the closed-loop automation in SPE-22564-MS, MBE's rule engine processes real-time data to trigger alerts, enabling proactive responses akin to their bit-life optimization (Elgamal, A. et al. 2025). This approach is akin to the method applied by Bambang Widarsono, who used fuzzy logic as a tool to estimate the production potential of a sand layer (Widarsono et al. 2004). Widarsono's technique is capable of handling overlapping, imprecise, and linguistic data such as terms like 'low', 'medium', and 'high'. Alerts are generated based on real-time data from logging while drilling (LWD) logs, which are processed through a logic connected to the alert system. For example, if a reservoir zone is characterized by a gamma ray (GR) reading of less than 30 gAPI, an alert can be triggered when the GR reading exceeds or equals 30 gAPI. The smart alert system is comprised of three main components: the engine, the rule management system, and the user interface (UI). Data is ingested into the engine through a Trigger, which converts external data into the engine's internal model, if required. The Trigger then forwards this data to a configurable process known as a Flow. Within the flow, decisions are made regarding how to handle the incoming data. It assesses conditions and generates output accordingly. Flows incorporate actions which process the output generated by the flow. These actions encompass various functionalities, such as creating alerts within the alert flow. Furthermore, the alert mechanism itself possesses actions that dictate responses to specific alerts (please refer to Figure 4). A simulation was conducted to implement a smart alert system using test data during a geosteering operation within a carbonate reservoir. The reservoir was characterized by over 30% porosity, a low Rate of Penetration (ROP) below 100 feet per hour, and resistivity above 30 ohm.m. As depicted in Figures 7 and 8, the smart alert system triggered a notification when the ROP fell below 100 feet per hour. A simple algorithm on the alert was set as

$$ROP <= 100 \text{ and } NPHI <= 30 \text{ and } RESD <= 30 \qquad (1)$$

Where ROP stands for Rate of Penetration, NPHI stands for Neutron Porosity, and RESD stands for Deep Resistivity. The user decided to use deep resistivity as it is less affected by mud invasion and more sensitive to reservoir fluid contacts.

This prompted the geosteering geologist to proactively adjust the inclination from 88 degrees to 88.95 degrees starting at 6099.5 feet Measured Depth. Consequently, the drill string remained within the reservoir for approximately 644 feet ahead (Figure 5, Figure 6, and Figure 7).

RESULT AND DISCUSSION

The managed by exception (MBE) smart alert system demonstrated significant value during geosteering operations in a carbonate reservoir. The system successfully identified a critical deviation when the rate of penetration (ROP) dropped below 100 ft/hr at 6,099.5 ft Measured Depth (Figure 6). This early detection enabled geologists to proactively adjust the well inclination from 88° to 88.95°, maintaining optimal reservoir contact for an additional 644 feet of drilling (Figures 6-7).

The time efficiency gains were particularly noteworthy. Traditional monitoring methods required geologists to manually review multiple data interfaces, consuming approximately 35 minutes per incident (Table 1). In contrast, MBE's automated alerts reduced this decision-making window to just 20 minutes - a 43% improvement in operational response time. This improvement stems from the system's ability to continuously monitor three key parameters: ROP (≤100 ft/hr), neutron porosity (NPHI ≤30%), and deep resistivity (RESD ≤30 ohm.m), with deep resistivity specifically selected for its reduced susceptibility to mud invasion effects.

An important secondary benefit emerged from the system's comprehensive alert history feature (Figure 8). This audit trail documents all system alerts and subsequent operational responses, creating a valuable knowledge base for post-well analysis. The ability to review and analyze these historical alerts provides opportunities to refine future geosteering strategies and threshold parameters.

While the current implementation has proven effective for monitoring ROP and formation evaluation parameters, the system architecture could potentially be expanded to incorporate additional drilling parameters. Such enhancements might further optimize geosteering decisions and potentially deliver additional efficiency gains in future operations.

Implementation and future improvements

Another advantage of utilizing the smart alert system is the creation of an alert history within the user interface, enabling the team to review past decisions and audit operations. This facilitates the development of improved guidelines and operational planning through post-audit analysis (please refer to Figure 8).

Future improvements in implementation could involve employing specific algorithms within the data analytics engine to process real-time drilling parameter data and generate code numbers indicating particular drilling events, such as changes in trip tank gain or washout. Smart alerts could then be configured to notify operators of these events, enabling proactive adjustments to drilling parameters for optimization purposes.

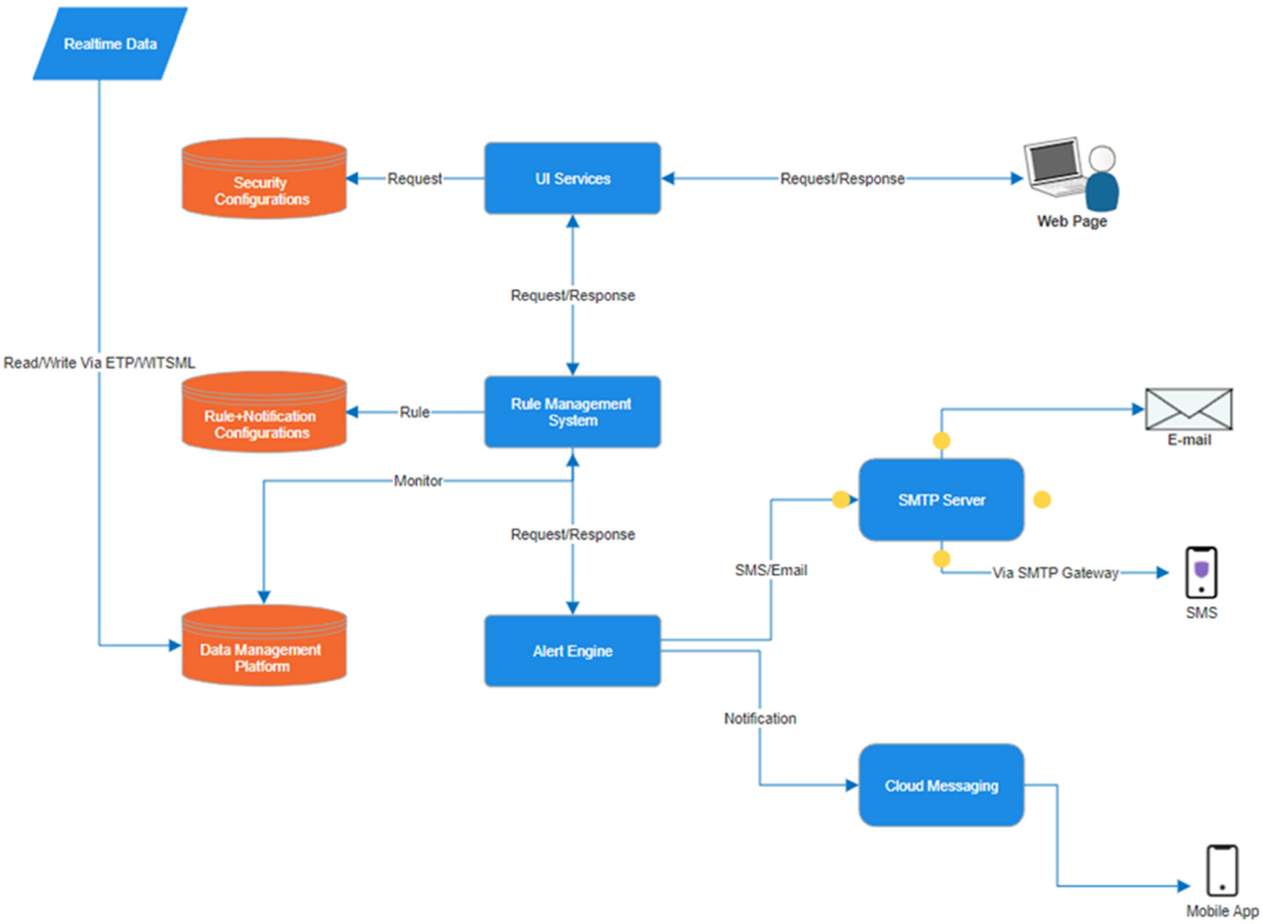

Figure 4. Smart alert workflow diagram shows how the alert was generated from each component's interactions.

Figure 5. When ROP reached below 100 ft/hr, the geologist adjusted the inclination to be higher.

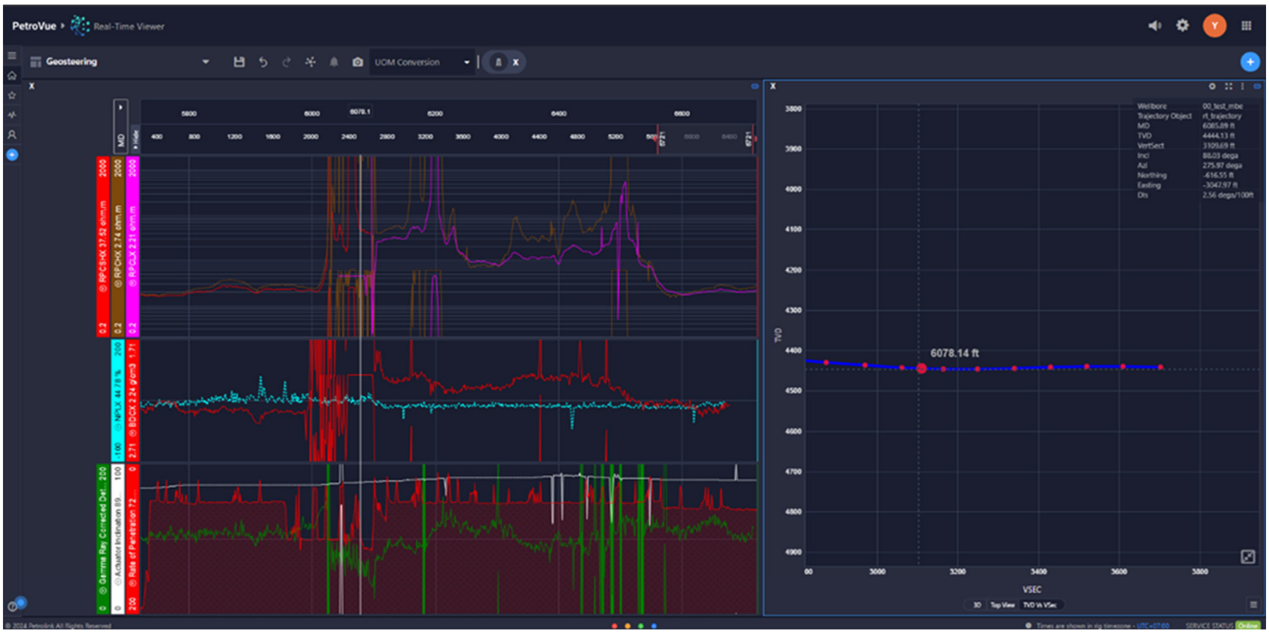

Figure 6. Trajectory station details at 6078.14 feet measured depth show around 88.03 degrees (before the alert was generated).

Figure 7. Trajectory station at 6142 ft was higher to keep the drillstring inside the reservoir zone.

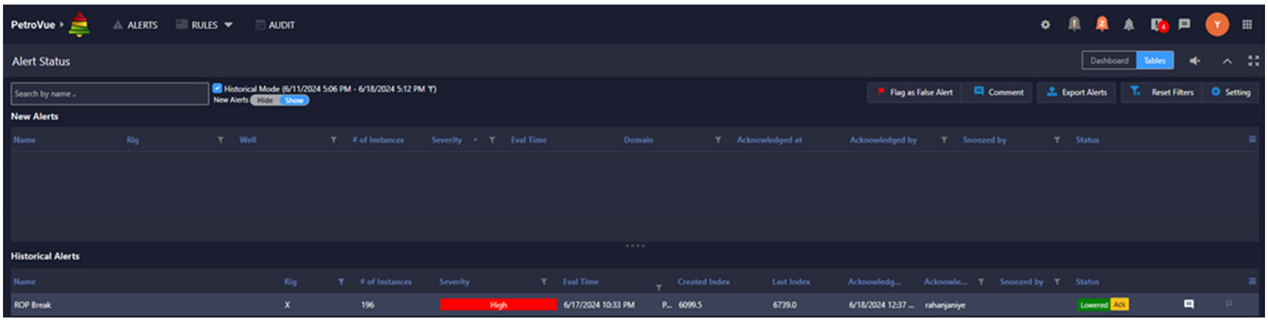

Figure 8. The alert for low Rate of Penetration (ROP) at 6099.5 feet Measured Depth (MD) was recorded in the alert history.

CONCLUSION

The implementation of a smart alert system has demonstrated the potential to reduce non-productive time (NPT) by up to 20 minutes per well during monitoring operations with a single alert. Further advancements in alert sophistication and planning could potentially yield even greater reductions in NPT. This improvement not only simplifies the workload for geosteering geologists, particularly when managing multiple development wells concurrently, but also enhances decision-making efficiency, allowing for a more direct pursuit of reservoir targets. By saving NPT, operators can expedite decision-making processes and maintain a sharper focus on reservoir objectives. For more precise results in the future, particularly in addressing more complex factors such as well control in deviated holes, a drilling simulator developed by Purnomo (2007) may be required to refine NPT reduction strategies (Purnomo et al. 2007).

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GLOSSARY OF TERMS

Symbol	Definition	Unit
LWD	Logging While Drilling	–
ROP	Rate of Penetration	m/hr
Fishing	Taking stuck tools from downhole	–
NPT	Non-Productive Time	–
AI	Artificial Intelligence	–
WITSML	Wellsite Information Transfer Standard Mark-up Language	–
PEF	Photoelectric Factor	b/e
NMR-WD	Nuclear Magnetic Resonance While Drilling	–
FPWD	Formation Pressure While Drilling	–
NPHI	Neutron Porosity Index	v/v or %
GR	Gamma Ray	gAPI
RESD	Deep Resistivity	ohm·m
UI	User Interface	–

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