CALCULATING RESERVOIR FOOTAGE IN REAL-TIME: A WAY TO REDUCE NON-PRODUCTIVE TIME DURING DEVELOPMENT DRILLING

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ABSTRACT

Horizontal drilling is one of the critical stages during development drilling where the reservoir footage could be the important key performance indicator.It is utilised by the reservoir management to identify how much footage of the well bore has been steered in the sweet zones. This information will also be used in making decisions for any extension of total depth of a well from the intial plan. Manual computation of the reservoir footage usually consumes a lot of time as the geologist has to first intrepret the reservoir depth looking at the log charecteristics. This leads to non productive time and sometimes even leads to a pause in the drilling operations until the information is aquired by the reservoir management team in order to call the total depth of the well. In this era, all oil operators are looking to optimise their operations with new techologies and cost effective methods. This initiative was brought up after a survey that takes into account the struggle of geologists to calculate the reservoir footage manually while handling multiple horizontal wells at the same time leading to delays that impact critical decision making of drilling.The paper primarily focuses on presenting an innovative solution that calculates the real-time reservoir footage using a set of real-time calculators and algorithms then compares the results with manual calculation to define the error.

We piloted a case study of this innovation with the LWD logging data such as gamma ray, resistivity, density and input them to a set of processes in the analysis engine and algorithm. The output was displayed in the realtime chart along with other logs that enabled users to make decisions in realtime.

To analyze the results we did a manual calculation by classifying the reservoir based on the log characteristics and compared the results. It showed only a reasonable error that is less than 1%.

INTRODUCTION

In the present situation of the oil and gas industry, when the commodity's price is unstable, many operators are trying to keep their profit in stable margins. One of the ways to achieve this is reducing the non-productive time which is related to operational costs.

Non-productive time (NPT) is defined as time where drilling is ceased or penetration rate is very low (Moazzeni et.al. 2010). There are several cases for NPT such as: lost circulation, kicks, stuck pipe, wellbore stability issues, formation breakdown, slow ROP, and another drilling and formation problem. As an example (Figure #1), time breakdown analysis was shown of more than 200 development wells which were drilled in recent years in Maroun oil field. It shows 10% of rig time was spent on hole conditioning due to hole instability. Also 3% of the rig time was used up for fishing due to stuck pipe issue. These issues spent the cost on rig time basis meanwhile no drilling progress was made. This situation wasn't beneficial for the operation.

Further observation shows that manual calculation reservoir footage could contribute to the NPT. Reservoir footage is the total length of the reservoir during horizontal drilling which is used by the asset or geosteering geologist as one of the factor to decide well total depth (TD) compared with the target they have. If the reservoir footage hasn't reached the target meanwhile the well is in good shape, they may instruct to continue drilling. But, if there's no more possibility to find the reservoir zone, they will stop the well. This paper focuses on the manner to reduce non-productive time due to reservoir footage calculation on development drilling (geosteering) operation after finding the fact that manual computation of the reservoir footage usually consumes a lot of time as the geologist has to first interpret the reservoir zone looking at the log characteristics and calculate the total length of the pay zone manually. If this calculation could be automated, the geologist's job would be eased, especially if they handle multiple horizontal wells and save the time they usually use to calculate reservoir footage.The result of real-time reservoir footage calculation is a complement of logging while drilling (LWD) depth display for geosteering.

GEOSTEERING

The basic concept of geosteering is to place and maintain the well in the target zone(s), drilling a smooth trajectory that follows the path of the productive zone (Calleja, 2010) (see Figure #2).An ideal geosteering project requires two kinds of substantial components which consists of data and integrated systems.

Geosteering Data

The required data for geosteering consists of real-time WITSML (Wellsite Information Transfer Standard Markup Language) LWD data, survey data, and static data which covers offset wells data, formation grids, and drilling plan.

Real-time LWD and survey data should come from the tools. The minimum requirement to classify or characterize reservoir zone is triple combo tools which consists of gamma ray, resistivity, and density-neutron-photoelectric (PEF) sensors plus imaging tools. The lithology of reservoir could be determined by the gamma ray and density-neuton-PEF tools as lithology has unique value ranges for these parameters. Meanwhile, the resistivity tool could determine the fluid type. However, the geologist could recommend to management to add additional tools depending on the reservoir character. As an example, Kanfar (2012) used formation pressure while drilling (FPWD) and nuclear magnetic resonance while drilling (NMR-WD) tools to avoid the well passing low permeability zone and tar mat. Additional criterion has been added about the minimum mobility data of the reservoir as a guidance to use the tools during the geosteering. Besides real-time LWD data, the geologists also need survey data to find out where the wellbore position is spatially, henceforth, they will be able to give an instruction about well inclination to the directional driller (DD).

Static data required for geosteering consists of the offset wells data, formation grids, and drilling plan. The geologists require offset well data to be compared with current active geosteering wells. This will help the geologist to get a description about the reservoir geometry so they can predict the reservoir position ahead and advise the well inclination to reach it. The offset wells data also gives a petrophysical reading guidance for the current active wells so geologist can define if the wellbore position is inside the payzone or not.

Formation grids are required with the same function as offset wells data with less resolution to review the well position stratigraphically in general. And the drilling plan will give guidance for the drilling aspect especially about the position azimuthally and dog leg severity.

Integrated System for Geosteering

Alsanie et.al (2017) introduced an integrated real-time system for geosteering projects. This is a model of an ideal real-time system to manage the geosteering project workflow in real-time. As shown in Figure #3, it consists of a complex combination of applications required to merge the available information scattered over the vast storage network. All of non-WITSML data will be converted to WITSML data to fulfill the requirement of the data type for visualization and any calculation. The system consists of:

1. All of the real-time and static data required which we have mentioned
2. Surface grids converter which is designed to read the formation grid in the subsurface model and convert it with reference to actual datum and horizon information.
3. Offset well data converter which reads various kinds of historical well's non-standard data logs as a data source for correlation display.
4. Real time and static data visualization which allows the geoscientist to evaluate the data and perform geosteering operations. This consists of a cross section display, correlation display, and single logs display.
5. Data store to collect all kinds of WITSML data.
6. Communication facility such as chat. This will be used by the user to give instructions to the directional driller about the well inclination they have to achieve.

Within this system, a solution could be designed between the WITSML Real-Time Data Store and visualization part. We set-up a data analysis engine to process the WITSML LWD log with the algorithm and put the result in the widget within a single logs display. However, the user has flexibility to change the cut-off and range within the algorithm considering the different petrophysical characteristic of the reservoir.

RESERVOIR FOOTAGE ALGORITHM

The reservoir footage calculated in real-time is a temporary reservoir length which was used to be analyzed and calculated by the geologists soon after their well reached total depth (TD) or in the middle of drilling operation when they needed to evaluate the operation. Each reservoir has its petrophysical value range or cut-off. Let's say a clean sand reservoir will have a gamma ray value below *a* gAPI, resistivity value between *x* ohm.m and *y* ohm.m, and porosity above *b* ,the data rate average of the real-time data is *n*, and reservoir footage is F, the formula could be arranged as below:

$$F = n * \forall\ (x\ \Omega.m < R < y\ \Omega.m,\ GR < a\ gAPI,\ \phi > b\ v/v,\ \ldots\ldots\ldots, etc\ldots) - n$$

R = resistivity
GR = gamma ray
Φ= neutron porosity
n = data rate average
F = reservoir footage

Any petrophysical parameter can be used depending on the sensitivity level of the petrophysical parameter to recognize the reservoir or payzone. The logic was deployed as an algorithm to filter the LWD WITSML (depth log) data and calculate the length of value filtered by the algorithm through data analysis engine.

As mentioned previously, each reservoir has its petrophysical value range or cut-off, hence the users of this system may need to consult with the petrophysicist regarding the range and cut-off of petrophysical parameters they are going to input inside the algorithm. Additionally, the users need to consider the abnormality of the petrophysical reading such as the anisotropy or the reading difference based on the well inclination and parameter polarization.

Furthermore, an implementation is required to verify the result of this method, to find the error and confirm the reliability of the algorithm. This will be done by comparing the manual calculation and real-time calculation result through the implementation.

MANUAL AND REAL-TIME CALCULATION WORKFLOW

With the conventional technique to evaluate the success of horizontal well drilling (geosteering), the geologists will do quicklook interpretations once the well reaches planned total depth. They will review if the gamma ray value below the cut-off, resistivity value within the range he considered, and the neutron porosity log showed good porosity above the threshold or any other parameter which fulfilled the reservoir criterion. Once all of the reservoir zones are found, they will calculate the total length of the reservoir as reservoir footage. If the reservoir footage reached the target and there's a possibility to find the reservoir zone, the geologist may decide to extend the well but if there's no possibility, they will stop the well and call TD. The process to get the reservoir footage considering all the criterion will spend quite a bit of time at least 30 minutes.

Meanwhile, when a set of real time data calculators and algorithms were used, the required LWD log just needed to be deployed there and the reservoir footage result will be produced in real-time during drilling. This will ease the geologist's job as they will get the result of reservoir footage as soon as they want. If they get it faster, they will save non-productive time to make the decision to continue drilling or not. In this case, it's flexible to use any kind of LWD log, cut-off, and range by inputting them to the algorithm through the widget as we're aware that each reservoir has its own petrophysical characteristic. Figure #4 and Figure #5show the workflow model of manual and real-time reservoir calculation using gamma ray, resistivity, and neutron porosity log.

IMPLEMENTATION

As an example, this system was implemented on a horizontal well which was drilled inside the clastic reservoir. With the relatively good porosity, the geologist requested us to filter the gamma ray and deep resistivity log to define the reservoir footage in real-time. The geologist had no issue with porosity as it's quite good and the reservoir is thick enough. They were considering the fact that there's a huge resistivity contrast between the reservoir and the lithology above the reservoir and oil water contact (OWC) issue.

As shown on Figure #6, the well started entering target entry as per gamma ray signature around 3700 m MD (Measured Depth) and immediately built the inclination to track the reservoir upper boundary, meanwhile the TD point was decided at 4800 m MD. . The reservoir criterion was defined as the resistivity will be between1.2 Ω.m and 5000 Ω.m and gamma ray cut-off as 100 gAPI as requested by the geologist. Once the algorithm was ready, the WITSML depth log was deployed to our data analysis engine and it started filtering and calculating the log reading. The result of real-time reservoir footage was 1077.75 m and the manual footage was 1069 m from 1100 m geosteering footage. There's 8.75 m difference on the result, so we can see that there's 99.2 % accuracy of the calculation.

Initially there is a difficulty as the difference between the data points had huge diversity, so the interpolation inside the data was required through our data analysis engine to reduce the diversity of the data rate. This is important as this will be multiplied with the data number to define the reservoir footage. This problem should be considered to do the improvement on future practice. Furthermore, the result was displayed as shown on Figure #7.

FUTURE IMPROVEMENTS

As this is kind of a continuous study, all various scenarios need to be considered as any condition might happened such as:

1. Calculating the reservoir footage if we have multiple reservoir targets.
2. Calculating the reservoir footage if we have bad quality data and doing data interpolation to fix it.
3. Calculating reservoir footage if there is a huge diversity on data rate.

As a recommendation, machine learning and statistical models could be applied to this solution so it will be adaptive to any kind of condition which can not be solved by the current solution.

CONCLUSION

With the error margin of less than 1%, real-time reservoir calculation could save non-productive time from manual calculation and interpretation by the geologist. This will ease the geologist's job especially if they handled multiple development wells in the same time. If the non-productive time could be saved, the user will be able to make decisions faster and more focused on chasing the reservoir target.

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ABOUT THE AUTHORS

Yustian Ekky Rahanjani joined Petrolink in 2013. He is currently working as Real-Time Data Specialist with Petrolink International, Ltd. in Al-Khobar, Saudi Arabia since 2013 supporting real-time data operations for Saudi Aramco, Geosteering Operation Center (GOC) currently. He gained a BSc in Geology in 2012 from Universitas Gadjah Mada.

Ragesh Nair started his professional career in Petrolink Saudi Arabia as a field engineer in 2009 after completing his Bachelors degree in Computer Applications. During his tenure with Petrolink he has on more than one occasion proved his versatility and talent and met the expectations of the company in coordinating different projects and leading several assignments in Saudi Arabia as well as overseas. He has successfully completed a six month assignment leading the operations team in Petrolink UK. While working as a realtime coordinator in Saudi Arabia in 2013 he also helped set up the nascent Indian operations in Petrolink India where he stayed for a year as an Acting Operations Manager to build up the new team there. He is currently working as a Senior Operations Coordinator in Saudi Arabia and also leading the Geosteering wing of Petrolink Saudi.

Budhi Nugraha started his professional career as Software Developer and System Analyst after he graduated as Bachelor of Computer Science from Bogor Agricultural Institute in Indonesia in 2005. He has been involved in many software development projects in various industries like manufacturing automotive, banking, insurance, agriculture and oil industry. He joined Petrolink initially as developer analyst, and due to his involvement in the development of real-time application, then he became a real-time specialist. His experience in Petrolink as specialist in Real-Time and Static Data Management has led him to be the training instructor for Petrolink Operations team in multiple countries, including Saudi Arabia. Now he is managing Real-time Operations of Petrolink Saudi Arabia and is enjoying his 13th year in oil industry.

Teguh Ferianto is Senior Operation Coordinator in Petrolink International, Ltd. After graduated as Bachelor of Computer Science from Bogor Agricultural Institute in 2003, his career started as software developer in Waindo Spectra Indonesia, a GIS Company. Later, he moved to Petrolink International, Ltd. in 2005 and given a challenging position as Distribution Team Leader. Due to his effort in various kinds of project in Saudi Arabia to develop and test the real-time and static data application for drilling operation to support Saudi Aramco clients, he was given new position as Senior Operation Coordinator till now.

FIGURES

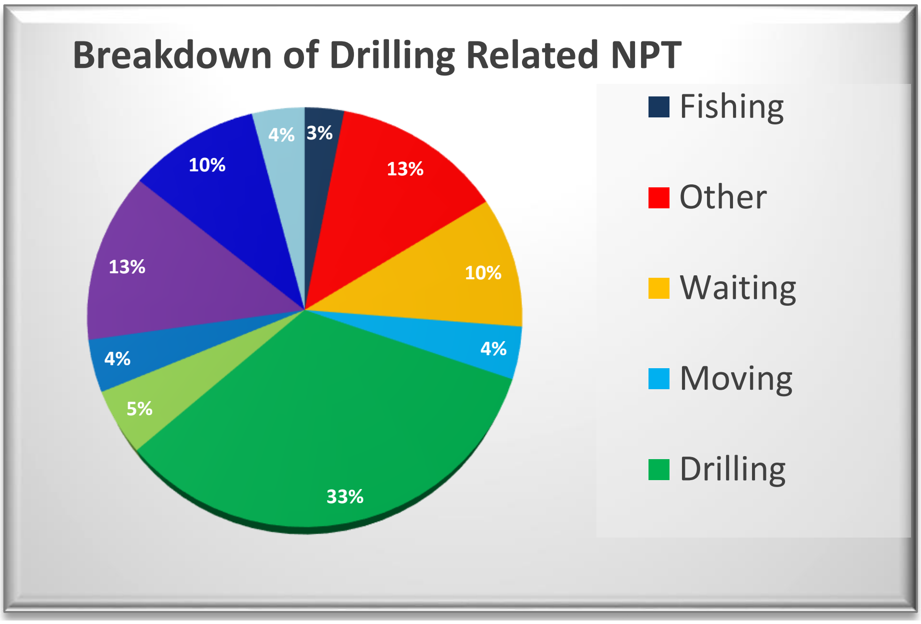

Figure #1: Time breakdown diagram of drilled development wells in maroun oil field (Moazzeni et.al. 2010)

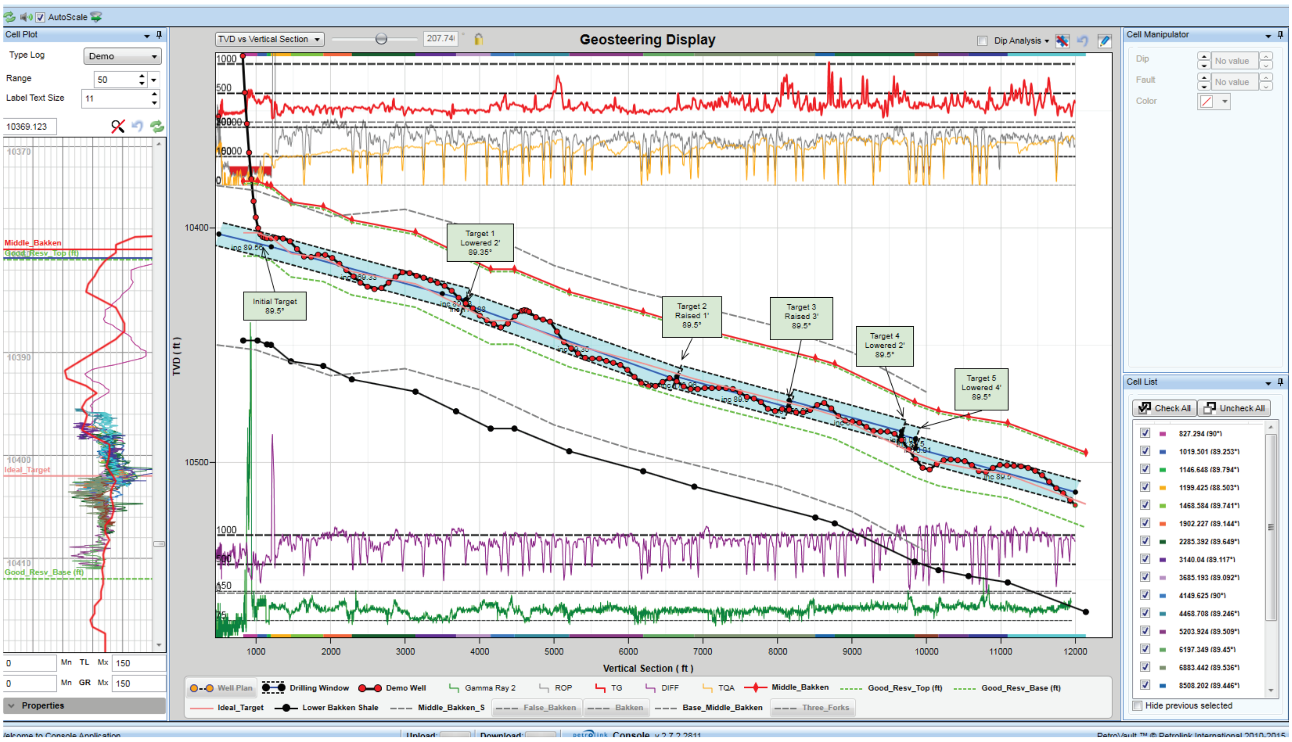

Figure #2: Illustration of geosteering (Property of Petrolink International, Ltd)

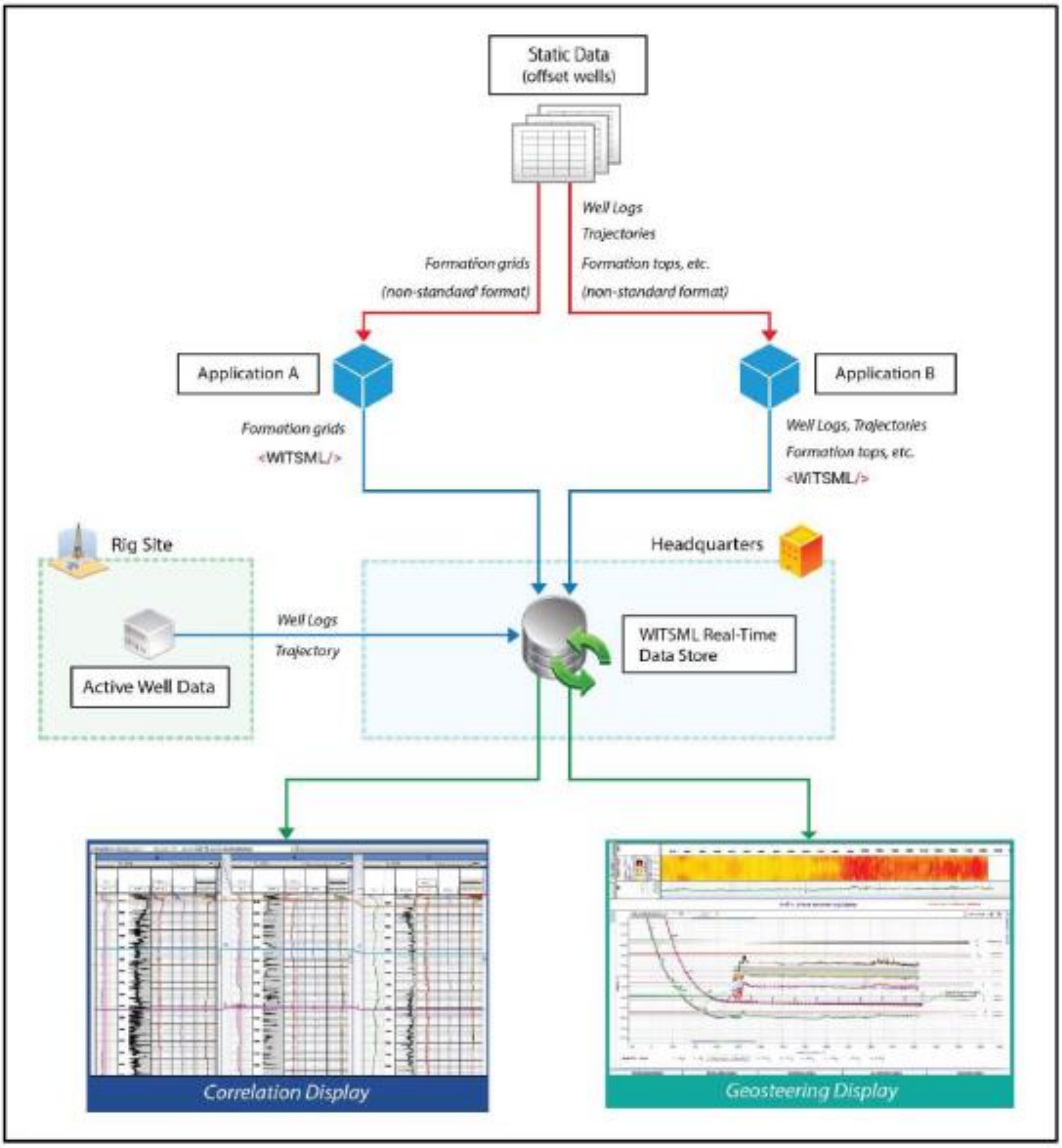

Figure #3: Integrated real-time system for geosteering (Alsanie 2017)

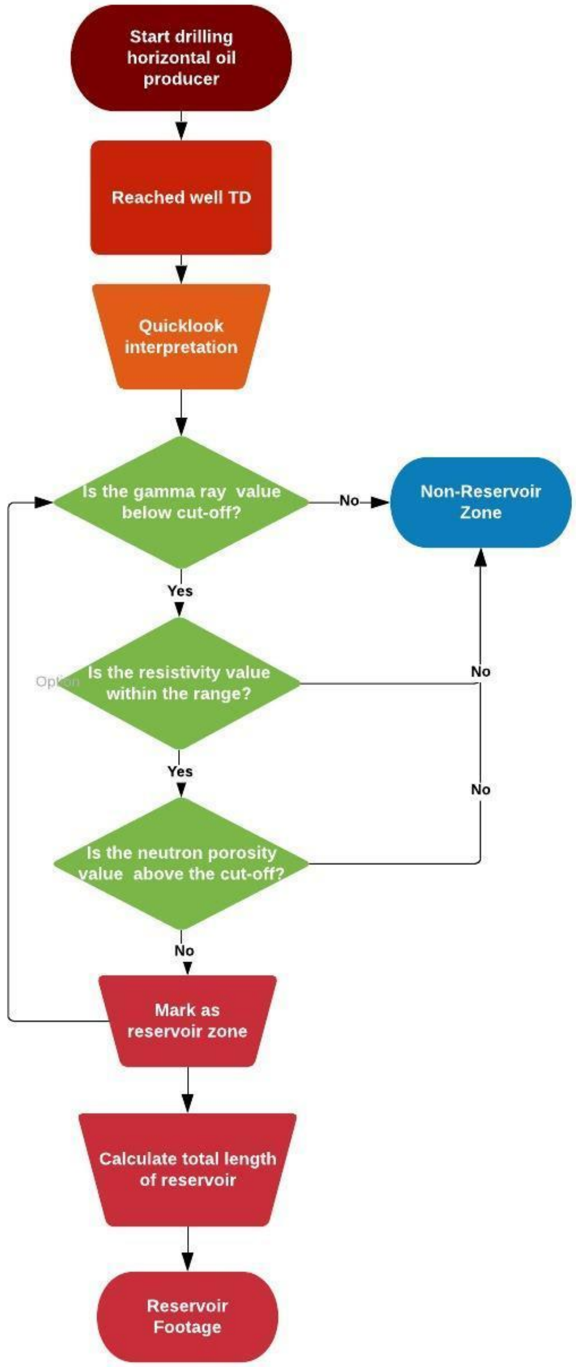

Figure #4: Manual reservoir footage calculation workflow.

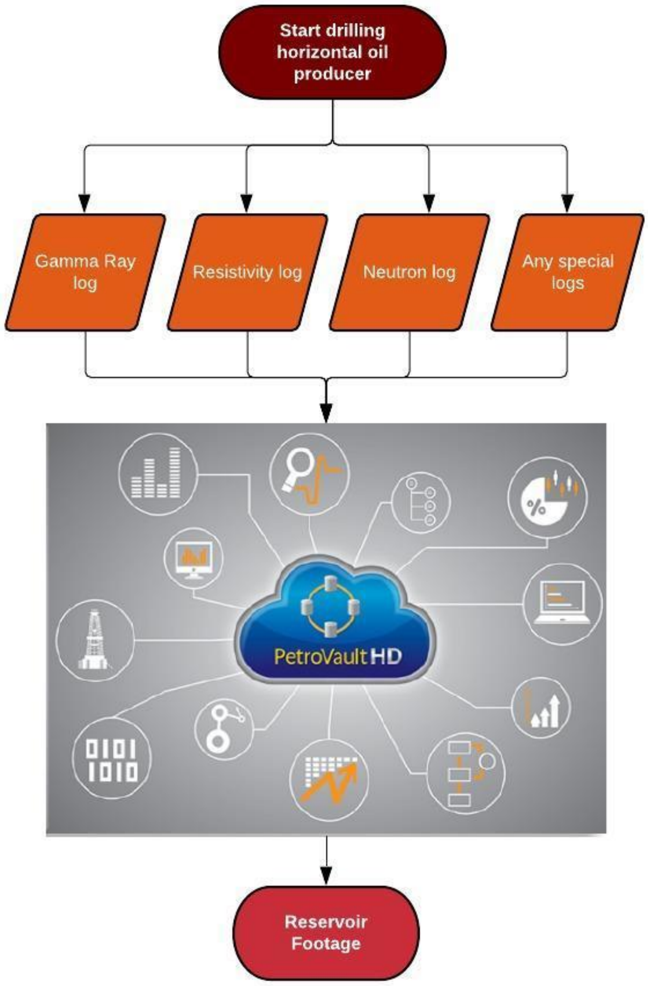

Figure #5: Real-time reservoir footage calculation workflow.

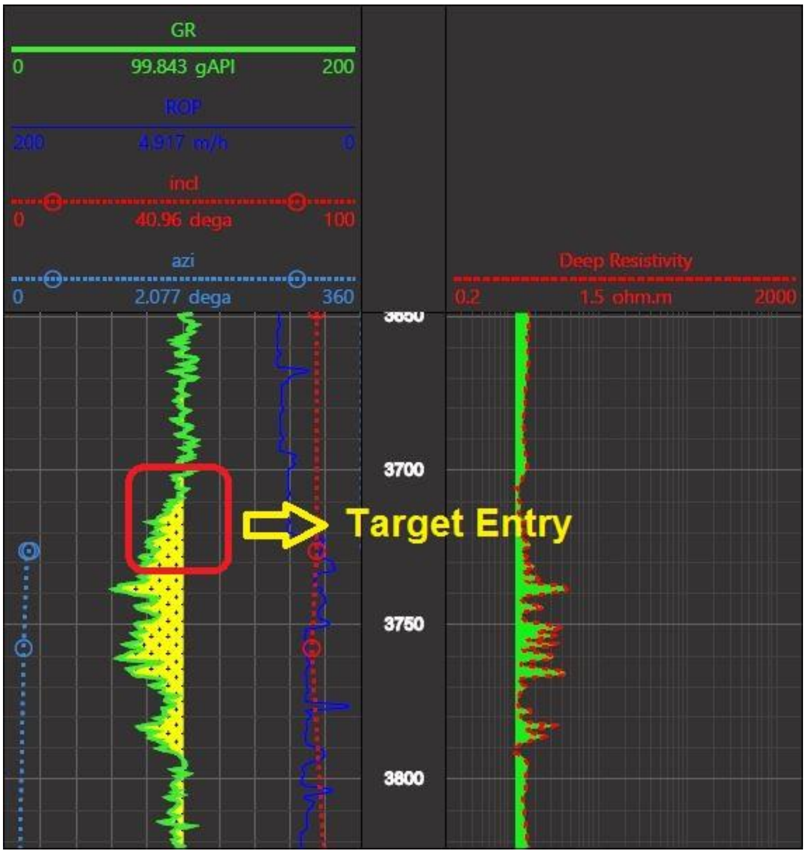

Figure #6: Target Entry

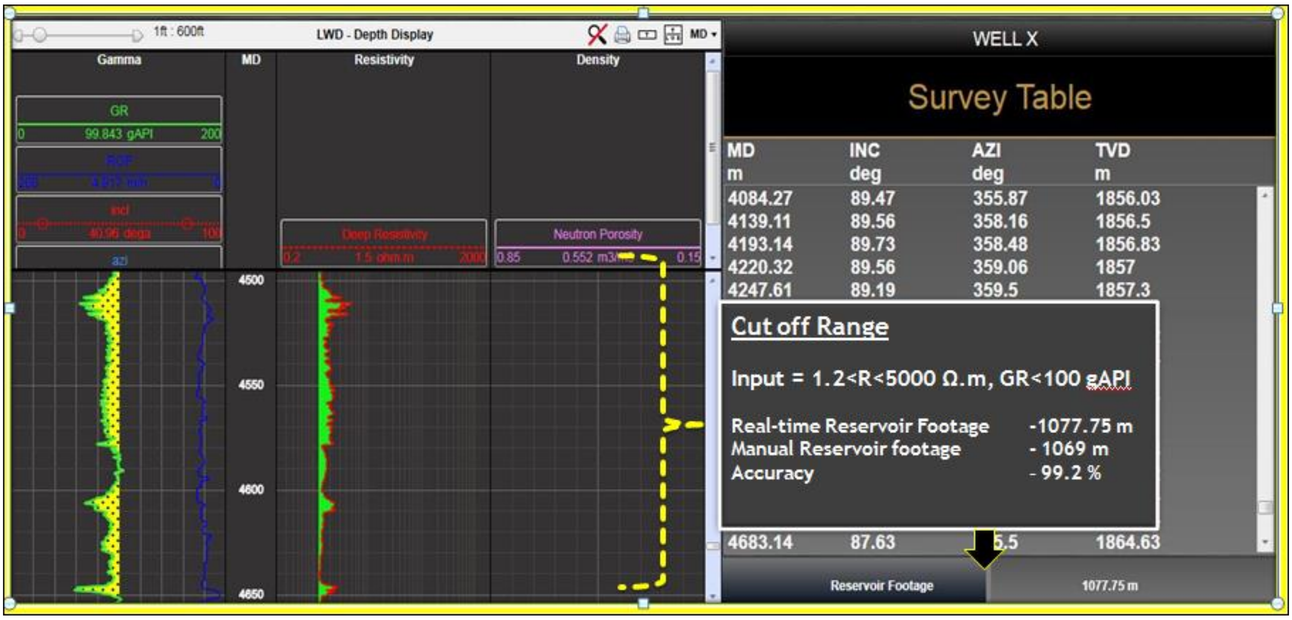

Figure #7: Implementation display