[PS]Horizontal Well Journey: Enhance Oil Recovery and Flatten the Oil Production Decline in the Gulf of Thailand*

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Abstract

Horizontal wells have played an increasingly important role in the oil production of the Gulf of Thailand (GoT). The number of the horizontal wells accounts for 5% of the total oil wells. However, they deliver 30% of the GoT oil production with the best horizontal wells producing more than 1,000 BOPD. There are two main types of reservoir where the potential benefits of horizontal wells are observed: thin reservoirs and contact reservoirs. Horizontal wells drilled in thin reservoirs provide larger and more efficient drainage patterns leading to increased overall reserves recovery. In addition, Horizontal wells drilled in contact reservoirs helps to reduce the amount of water and/or gas coning within the reservoirs.

Operating strategies Horizontal Well Standard Operating Procedures (SOP) have been developed to ensure consistency in optimizing ultimate recovery. Inflow Control Devices (ICD) are commonly installed to balance inflow throughout the length of completion. A horizontal well surveillance project was initiated to gain better understanding of horizontal well performance in the Gulf of Thailand. This additional data will be analyzed to create a more robust operating strategy for the future. Horizontal Well Community of Practice (CoP) has also been initiated to disseminate knowledge and promote innovative application of horizontal well technology in Chevron Thailand. Through the CoP, continuous improvement in horizontal well design and operation will continue to flatten the production decline in the Gulf of Thailand.

Horizontal Well Journey

Enhance Oil Recovery and Flatten the Oil Production Decline in the Gulf of Thailand

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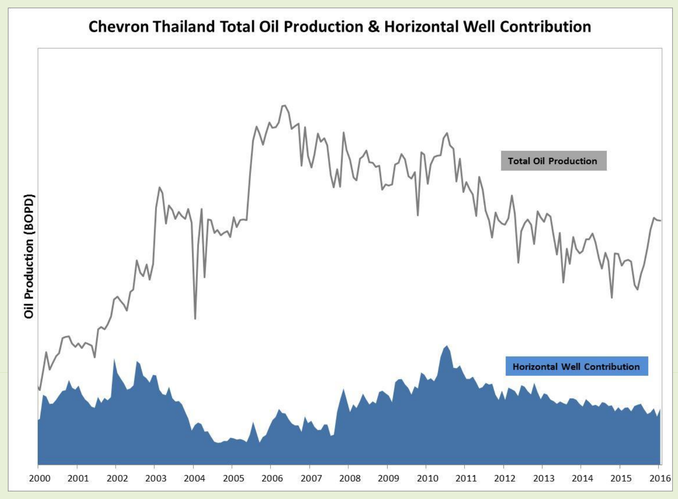
Gulf of Thailand (GoT) Horizontal Well

Horizontal wells have played an increasingly important role in the Chevron oil production of the Gulf of Thailand (GoT). The number of the horizontal wells accounts for 5% of the total oil wells. However, they deliver 30% of the GoT oil production with the best horizontal wells producing more than 1,000 BOPD.

There are two main types of reservoir where the potential benefits of horizontal wells are observed: thin reservoirs and contact reservoirs. Horizontal wells drilled in thin reservoirs provide larger and more efficient drainage patterns leading to increased overall reserves recovery. In addition, Horizontal wells drilled in contact reservoirs helps to reduce the amount of water and/or gas coning within the reservoirs.

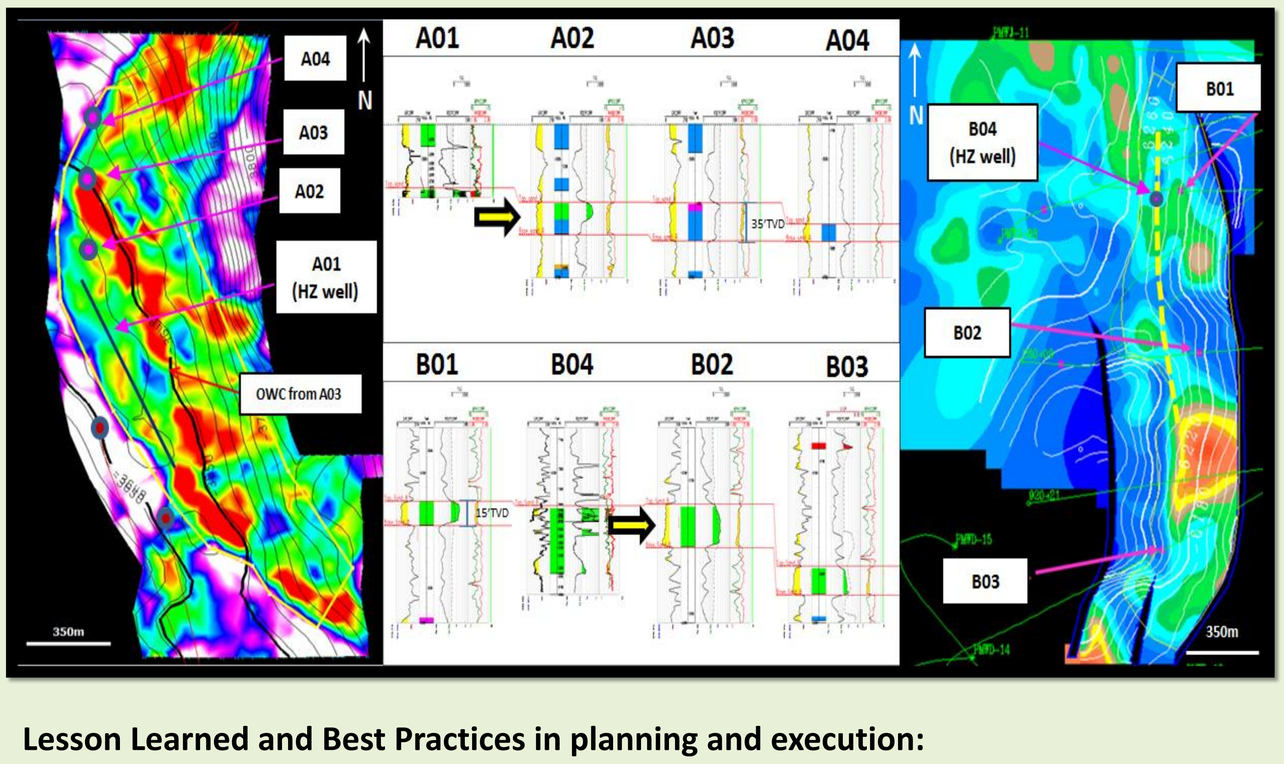
The recovery factor of horizontal wells ranges from less than 10% up to around 50% with the average at around mid-20%. This is a significant improvement from the recovery factor of deviated wells; the average is around 10%. Technology, innovation and best practices have been essential to improving the overall recovery factor. Based on lookback data, there are two main categories of low performers: well placement and operating strategy.

Well placement is optimized using Rotary Steerable System (RSS) combined with the fast-paced/real-time monitoring. RSS has also helped to improve the rate of penetration compared to the use of conventional direction tools such as mud motors. However, the use of RSS generally results in longer lead-time and Non-Productive Time (NPT)



Horizontal Well Planning and Execution Guideline

The depositional environment in the Gulf of Thailand in is fluvial channel deposits. Reservoirs in the northern part are deposited from relatively thick, highly amalgamated, more continuous and homogenous reservoirs. They are interpreted as braided stream deposits. On the other hand, reservoirs in the southern part are relatively thin, pocket like and more heterogeneous. They are interpreted as point bars and distributary channel deposits. Due to the differences in reservoir characterization in northern and southern parts of the basin, as illustrated in Figure below, horizontal well planning and execution guideline has been established to maximize overall recovery.



Lesson Learned and Best Practices in planning and execution:

- Always account for possible TVD error in a planning phase
- Single well penetration target is feasible where the amplitude extraction is reliable
- Understand driving mechanism is the key to success
- Where appropriate, use RSS tool to optimize well placement and better geosteering (smoother well bore and ABI (At Bit Inclination) tool)
- Do not deviate from the original plan without good reasons
- Keep clear and concise communication between geosteering and offshore teams
- Smooth well geometry and tortuosity is critical for running completion successfully

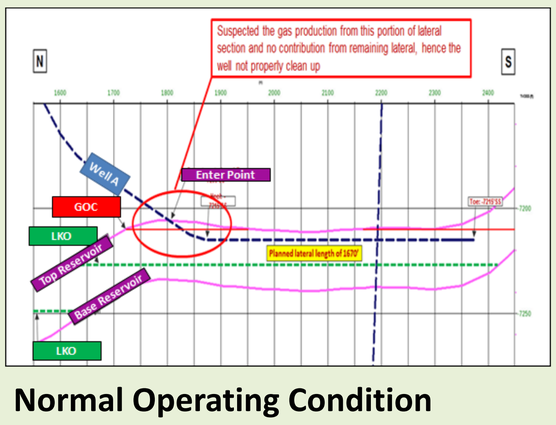
Example of a horizontal well placement in a strong water drive reservoir with existing gas cap (15ft TVD of oil column) : The horizontal well was placed at GOC (+/- 1ft TVD) to maximize overall recovery from strong aquifer support. The lateral section was drilled with mud motor, resulting in medium tortuosity well path along the GOC. The well path could be improved by using RSS.

Operating strategies Horizontal Well Standard Operating Procedures (SOP) have been developed to ensure consistency in optimizing ultimate recovery.

Horizontal Well Production Guideline

Time to Production

Prior to putting the HZ well on production, ensure the swell packer elastomer elements are completely swelled (if applicable) as according to manufacturer guideline. The timing for the swelling duration is depending on various factors including the size/type of the packer, as well as the reservoir temperature. It is also essential to ensure a well is properly clean-up. Example of a case without a proper clean-up is show below; a well produces a lot of gas from day one. It is suspected



that the lateral section was not properly cleaned up (the gas is from the GOC). It is recommended to open up the choke and monitor gas rate and GOR trend to ensure the well is properly clean-up. It is also recommended to monitor the BS&W on chloride contents analysis to differentiate formation water to completion fluids

Normal Operating Condition

In the normal operating condition, the design for off take rate is depending on :

- ICD design rate (if applicable)
- Drive mechanism (water drive, gas cap expansion etc)
- Distance from the OWC and/or GOC

Horizontal Well Stimulation

If the IP rate of the horizontal well is far below the expectation due to productivity impairment, the well should be considered for clean up or stimulation (normally with CTU). The fist step is to identify potential causes. Common ones are:

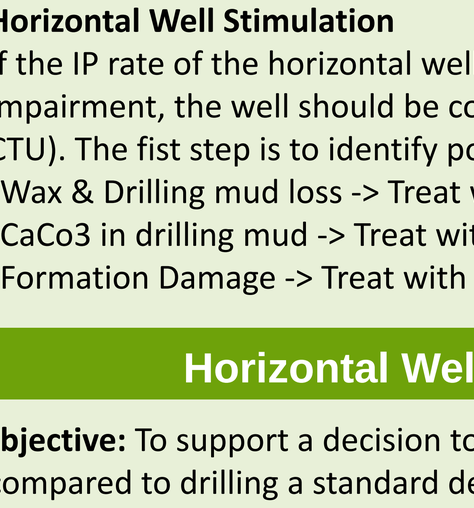
•Wax & Drilling mud loss -> Treat with NVSO
•CaCo3 in drilling mud -> Treat with HCL
•Formation Damage -> Treat with HF + HCL

Horizontal Well Economics Screening Tool

Objective: To support a decision to drill a horizontal well into a particular reservoir (compared to drilling a standard deviated well). Key components are

- Horizontal Well Production Rate Model
  - Initial Rate
  - Abandonment Rate
  - Effective Decline, %Ramp-Up, %Plateau and % Decline
- Horizontal Well Recovery S-Curve
- Economics Model

Horizontal Well Community of Practice (CoP)



Goals: Develop a sustainable CoP to:

- Share best practices and lessons for GoT
- Serve as a connection point for both experienced and new employees working on horizontal wells
- Identify opportunities to further apply this technology to efficiently develop our resources

Frequency: Quarterly meetings (L&L)