

Significant Improvements in the 2018-2019 Wayang Windu Drilling Campaign

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ABSTRACT

Star Energy Geothermal (SEG) has just finished its 2018-2019 Wayang Windu Make-up Well Drilling Campaign. A comparison with the 2015-2016 Drilling Campaign indicates that the recent campaign has better drilling performance in terms of drilling days (32 % improvement in ft./day) and drilling cost (40% improvement in \$/day) while also meeting the production target.

A key factor that contributed to the above performance is the reduction of stuck pipe incidents, especially that the Wayang Windu reservoir has multiple layers of a very reactive clayey formation. Another factor that contributed to the better performance is the ability to monitor in real-time the drilling parameters enabled making quick decisions to prevent the stuck pipe incidents and other untoward incidents. An in-house Drilling & Completions (D&C) Team enabled sharing of information, Best Practices, and Lessons Learned in drilling SEG's three geothermal assets. In addition, the in-house D&C Team allowed the use of an Integrated Drilling Service (IDS) Contract with two separate big sub-contracts, namely, drilling rig and services for better cost monitoring and avoidance of double handling cost and payment of taxes.

1. INTRODUCTION

1.1. Wayang Windu Geothermal Field

The Wayang Windu Geothermal Field is one of the three geothermal assets operated by SEG and produces 227 MW. Together with the Salak (377 MW) and Darajat (271 MW) Geothermal Fields, which were acquired in late 2016, SEG produces 875 MW of electricity making it the biggest geothermal producer in Indonesia.

The first Unit (110 MW) at Wayang Windu was completed in 1999, and has been producing at full capacity since 2000. At the time of its installation, Unit 1 was the largest geothermal turbine in the world. In March 2009, Wayang Windu Unit 2 commenced operation at 117 MW from a single turbine/generator (Wayang Windu Geothermal Asset, 2019).

Located at Pangalengan City, West Java Province, Indonesia, Wayang Windu Geothermal Field is hot water-dominated geothermal resource. Steam comes from production wells completed to about 4,700'-8,000' Measured Depth (MD).

1.2. Drilling Challenges at Wayang Windu

To maintain steam supply for Units 1 and 2, the 2018-2019 Wayang Windu Drilling Campaign was planned to obtain at least 64 kg/s of steam, and additional information about the brine reservoir. This campaign drilled four wells at two different pads, namely, MBA and MBD. Both of these pads are located at the northern portion of the geothermal field, a proven productive area in Wayang Windu.

During the planning phase and based on offset wells, the main challenge in drilling at Wayang Windu is to successfully drill the reservoir section without getting the pipe stuck. Several potential obstacles to drill the reservoir section were identified: most of the reservoir is in soft formation (i.e., tuffs), there are layers of very reactive clay formation (herein called Tuffaceous Silstone or TS), and there is high drilling fluid loss rate when drilling through fault/feed zones.

From the previous drilling campaigns at Wayang Windu, there was increased Rate of Penetration (ROP) when drilling through the soft formation. As ROP increases, the amount of rock cuttings produced also increased; thus, making hole cleaning challenging. It was planned to determine a maximum ROP that balances penetration speed and lifting the rock cuttings away from the Bottom Hole Assembly (BHA) to avoid the pipe getting stuck.

The TS is a formation in Wayang Windu that contains a high percentage of smectite, one of the main swelling clays. Once encountered during drilling, the water diffuses into the TS and swells the formation in ~48 hours (Kingston and Morrison, 1997). When the TS swells, it limits the drill string movement and drilling fluid circulation that may lead to stuck pipe.

Based on the offset wells report, at Wayang Windu, the liquid level in the well being drilled dramatically decreases as a feed (or fault) zone is encountered. The explanation of this phenomenon is that the feed zone acts as a pathway for the drilling fluid in the wellbore into the formation. The liquid level decreases until a certain pressure equilibrium is reached. The suspended rock cuttings, which were previously distributed in the liquid column, tend to get packed with the new liquid level. This packed rock cuttings limits the drill string movement and may cause the pipe to get stuck.

The rest of this paper presents a comparison of drilling performance between the 2015-2016 and 2018-2019 Wayang Windu Drilling Campaigns. The 2015-2016 Wayang Windu Drilling Campaign was used as a benchmark for the sake of continuous improvement.

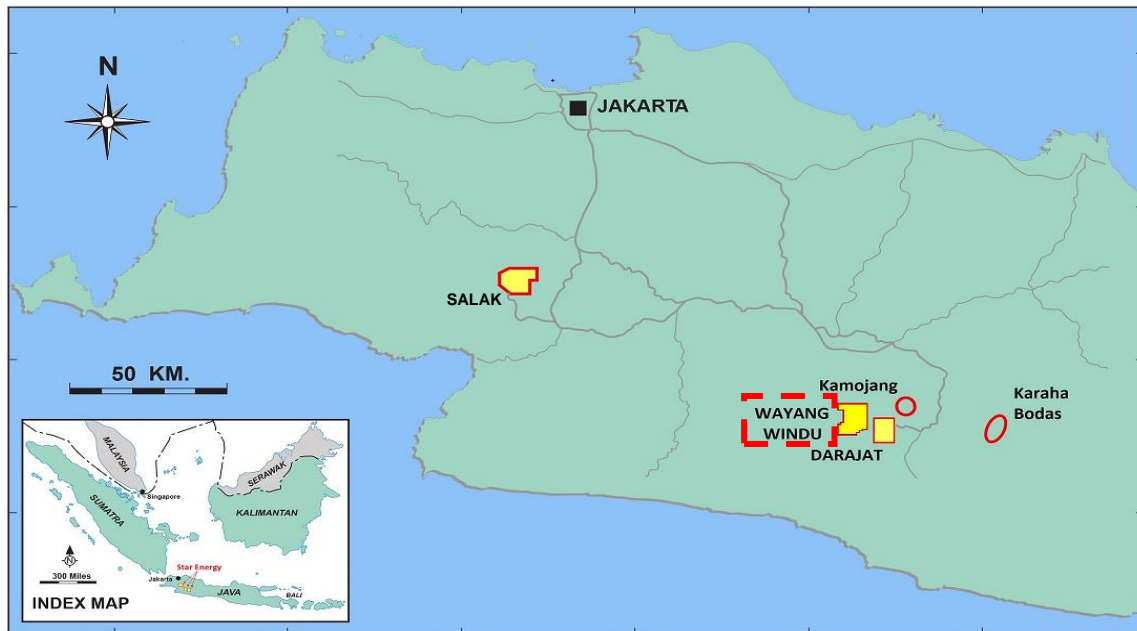


Figure 1: Map showing the location of the geothermal fields operated by SEG, namely, Wayang Windu, Salak, and Darajat. Also shown are the other geothermal fields in West Java, Indonesia.

2. INNOVATIONS DURING THE WAYANG WINDU DRILLING CAMPAIGN 2018-2019

2.1. In-house Drilling & Completions Team

During the 2015-2016 drilling campaign, SEG only had a single geothermal asset, Wayang Windu Geothermal Field; hence, it was considered inefficient to have a permanent Drilling & Completions (D&C) Team when drilling operation happens every five years. A Project Manager from SEG led the drilling campaign and with the coordinate with the Integrated Project Management (IPM) Team that was led by Schlumberger. Figure 2 shows the organization set-up during the 2015-2016 drilling campaign where six (6) Drilling Engineers (reporting to a Drilling Engineering Manager) developed the individual well plans supported by the Drilling Operations and Safety, Health, and Environment (SHE) Teams. Not shown in this diagram is the Procurement and other Support Teams.

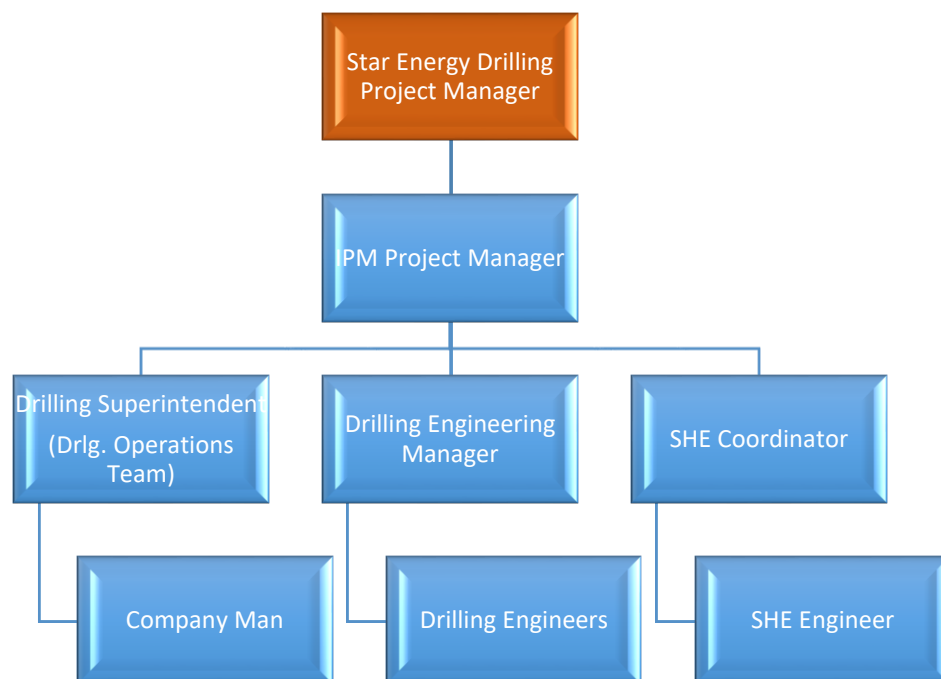


Figure 2: Diagram showing the drilling organization during the 2015-2016 Wayang Windu Drilling Campaign.

With the acquisition of the Darajat and Salak assets, SEG started to manage three geothermal assets and decided to maintain a permanent D&C Team to undertake the periodic make-up well drilling in the three geothermal assets, and help in drilling Star Energy's oil and gas assets. A Project Drilling Engineer was assigned to manage a drilling campaign project, usually several wells, per geothermal field. The other Drilling Engineers support the Project Drilling Engineer while assigned to develop the plan for the next drilling campaign of the other assets. Figure 3 shows the organization of the SEG D&C Team.

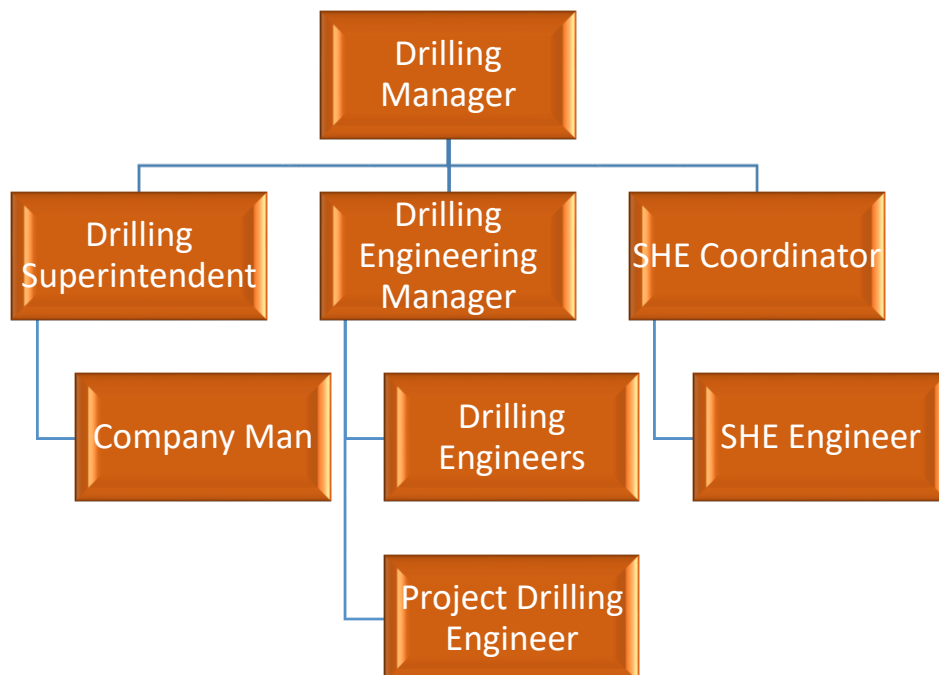


Figure 3: Diagram showing the SEG D&C Team during the 2018-2019 Wayang Windu Drilling Campaign.

As the D&C Team was involved in the three geothermal assets, it had better access to information, Lessons Learned, and Best Practices from previous drilling campaigns in each asset. In addition, the D&C Team was able to develop Standard Operating Procedure (SOPs) specific to each geothermal field. During the planning of the 2018-2019 Wayang Windu Drilling Campaign, the D&C Team developed a Well Design Procedure and Drilling Operational SOPs to optimize drilling time and maintain well control while preventing stuck pipe incidents based on specific experience and subsurface information from Wayang Windu specific (Figure 4).



Figure 4: Diagram showing revised well design document and operational procedures for the 2018-2019 Wayang Windu Drilling Campaign.

2.2. Live Monitoring of Drilling Parameters

During the 2018-2019 drilling campaign, SEG utilized Schlumberger's Real-Time Decision Centre (RTDC) to enable live monitoring of drilling parameters. The data collected from the sensors in and around the rig in the field are shown in real-time through the RTDC. With real-time data, all personnel involved in the drilling operations are enabled immediate situational updates and take necessary actions to avoid any well control or stuck pipe events. By having the monitoring screen in SEG's Jakarta office, each stakeholder (e.g., Well Decision Team, Business Partners, etc.) can participate in ensuring that the drilling process goes smoothly. Furthermore, the drilling data can be accessed thru the smart phone as shown in Figure 5. With this feature, any stakeholder is able to watch live the drilling parameter away from the office 24 hours daily.

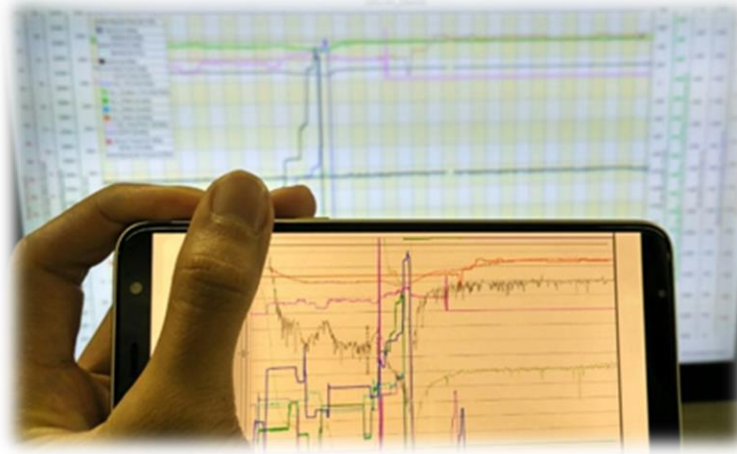


Figure 5: Photo showing the RTDC display in the smart phone (Kusuma et al., 2019).

An important feature of the RTC is its ability to plot the selected offset well's drilling parameters side-by-side with real-time drilling data in a single display. This feature allows a quick analysis if the current well is encountering anomalous drilling conditions.

Figure 6 shows an example comparison between actual (red line) and an offset well (green line). The left chart shows that torque in the current well is less than the offset well's although the current well is more erratic; thus, the perception is that the current well's condition is better than when the offset well was drilled. The right chart shows the drilling mud returns and that the offset well encountered Total Lost Circulation (TLC) after ~3900 ft. suggesting that the current well may encounter the same. This "advanced" information can help in better planning the preparations in case TLC is encountered in the current well being drilled. If not anticipated, losing mud circulation can lead to a stuck pipe incident. SEG's Best Practice when encountering TLC for the first time is to pull the drill string as far as possible (at least a full stand) to avoid the BHA getting packed with the rock cuttings.

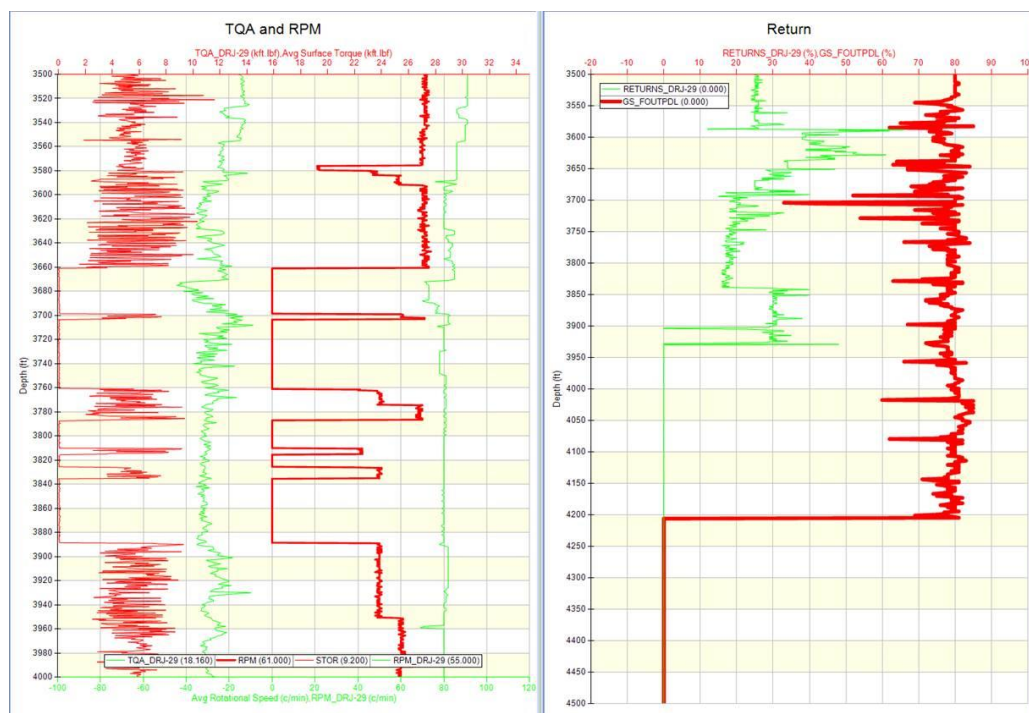


Figure 6: Drilling parameter comparison of offset well (green curves) and real-time drilling data (red curves).

One of our best practice to avoid stuck when we first get TLC is to pull the drill string for minimum one full stand. The example of this best practice shown from RTDC monitor can be seen from below figure.



Figure 7: Picture showing a TLC indication. Explanation for the multicolored lines: bottom hole pressure is purple triangle, Stand Pipe Pressure (SPP) is green curve, drilling fluid rate is blue curve, air flow rates is purple curve, hook load is grey curve, and block position is yellow curve.

Figure 7 shows plots of bottom hole pressure (triangle) and Stand Pipe Pressure (SPP; green curve) as measured by the Pressure While Drilling (PWD) tool while the blue and the purple lines indicate the drilling fluid and air flow rates, respectively. The grey and yellow lines represent the hook load and block position. At 7:02 and at the same fluid and air flow rates, both the SPP and bottom hole pressure suddenly decreased suggesting that a major feed zone was encountered and accepted all of the drilling fluid in the wellbore. The Field Supervisor took the proper action to pull the drill string to keep the BHA from getting stuck with rock cuttings that were settling at the bottom of the hole.

To have better rock cutting distribution and avoid stuck pipes, SEG's Best Practice when drilling the reservoir hole section under TLC is to back ream every 15 ft. of drilling new formation (or shallower when necessary). During back reaming, the drill string torque is observed. By having the ability of compare with the previous back ream, the Field Supervisor can decide to conduct another back reaming especially if the torque is considered higher than the previous back reaming operation (Figure 8). An additional back reaming operation can stabilize the torque and keep the rock cuttings distributed within the open hole section.

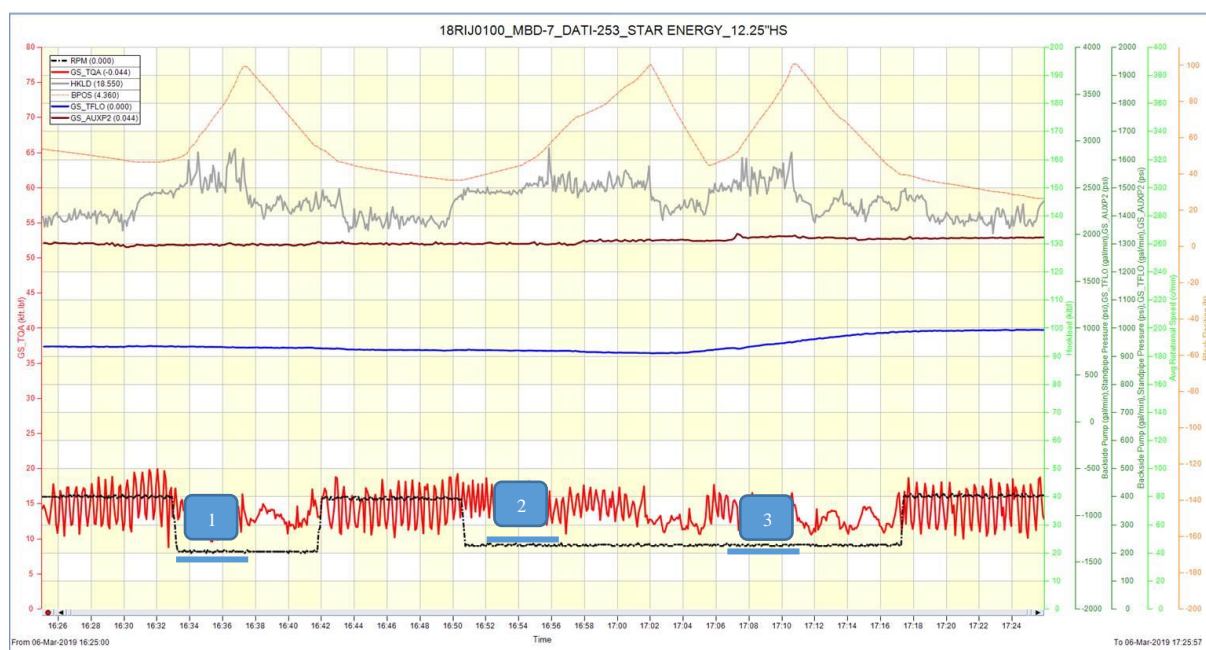


Figure 8: Stabilization of drill string torque with additional back reaming. Explanation for the multicolored lines: torque is the erratic red curve, Revolutions per Minute (RPM) is the black curve, the drilling fluid flow rate is the blue curve, the air flow rate is the yellow curve, the hook load is the grey curve, and the block position is the yellow curve.

In Figure 8, a high in the yellow curve indicates a pair of reaming and back reaming operation which is normally done after drilling 10-15 ft. of new formation. As shown in the squares, there are three back reamings. In the second back reaming operation, the torque was relatively higher to the first reaming; hence, another back reaming was conducted prior to drilling new formation to stabilize the torque. After the torque decreases on the third back reaming, drilling into new formation commenced.

3. RESULTS OF THE WAYANG WINDU DRILLING CAMPAIGN 2018-2019

3.1. Safety Performance and Target Steam Production

Both the 2018-2019 and 2015-2016 Drilling Campaigns were successfully completed with zero fatality, zero Lost Time Injury (LTI), and zero Total Recordable Injury (TRI). At any given time, more than 100 personnel are involved in the day-to-day drilling operation (sometimes in cramped locations); thus, the safety record for the two drilling campaigns is something to be proud of.

In terms of target steam production, Wayang Windu Drilling Campaign 2018-2019 gained 69 kg/s (about 8% more) compared with the 64 kg/s target steam production (Drilling Campaign 2018-2019 Project Team, 2019). Similarly, 2015-2016 Drilling Campaign successfully surpassed its target steam production and gained 100 kg/s or 11% more than the 90 kg/s target (Drilling Campaign 2015-2016 Project Team, 2017).

3.2. Drilling Faster with Less Stuck Pipe Event

The drilling time in both the 2015-2016 and 2018-2019 campaigns were evaluated in footage/day (Figure 9); simply put, a higher daily footage means better performance. The recent drilling campaign averaged about 147 ft./day or about 32% more than the daily footage of the 2015-2016 campaign. This higher daily footage is attributed to the reduction of stuck pipe incidents. The cost per foot drilled during the recent campaign is \$1,178 and about 40% cheaper than the 2015-2016 campaign at \$1,949.

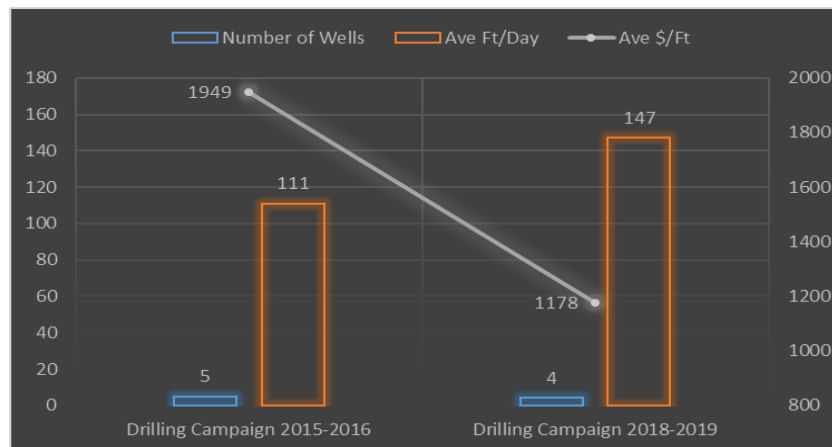


Figure 9: Daily footage comparison between the 2015-2016 and 2018-2019 Wayang Windu Drilling Campaigns.

Figure 10 shows a comparison of the stuck pipe incidents and duration (i.e., days used to get the pipe unstuck) between the 2015-2016 and 2018-2019 drilling campaigns. Note that the stuck pipe incidents during the recent campaign was just a third of the incidents during the 2015-2016 campaign. As explained earlier, the stuck pipe incidents at Wayang Windu are due to the reactive TS, more rock cuttings in the wellbore, and the significant drop in water level when TLC is encountered in the reservoir hole section. The sharing of information between the three assets and use of the real-time monitoring of drilling parameters significantly helped in avoiding stuck pipe incidents.

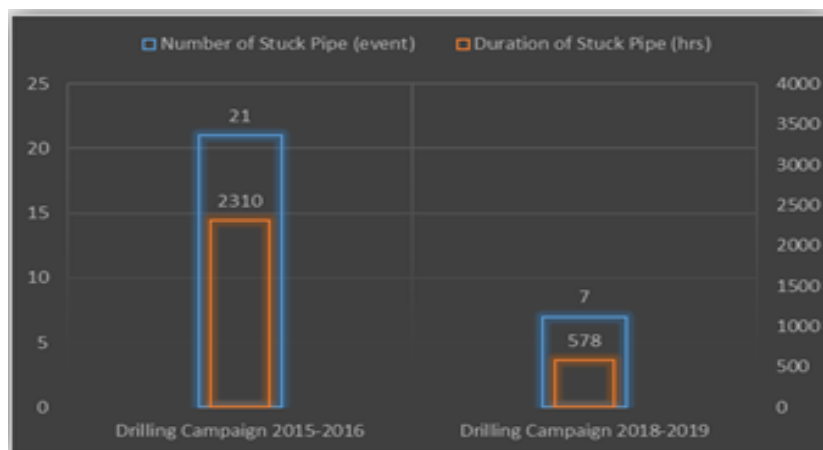


Figure 10: Stuck pipe incidents and duration comparison between the 2015-2016 and 2018-2019 Wayang Windu Drilling Campaigns.

3.3. Performance Comparison on Drilling Cost

From Figure 9, the 2018-2019 drilling campaign enabled a 40% reduction in cost per foot. This was mainly attributed to the different contract structure that was used in the recent campaign. The 2015-2016 campaign used an IPM Contract because SEG did not have an in-house D&C Team then. The 2018-2019 campaign uses an Integrated Drilling Services (IDS) Contract with two different major contracts: drilling rig and other services.

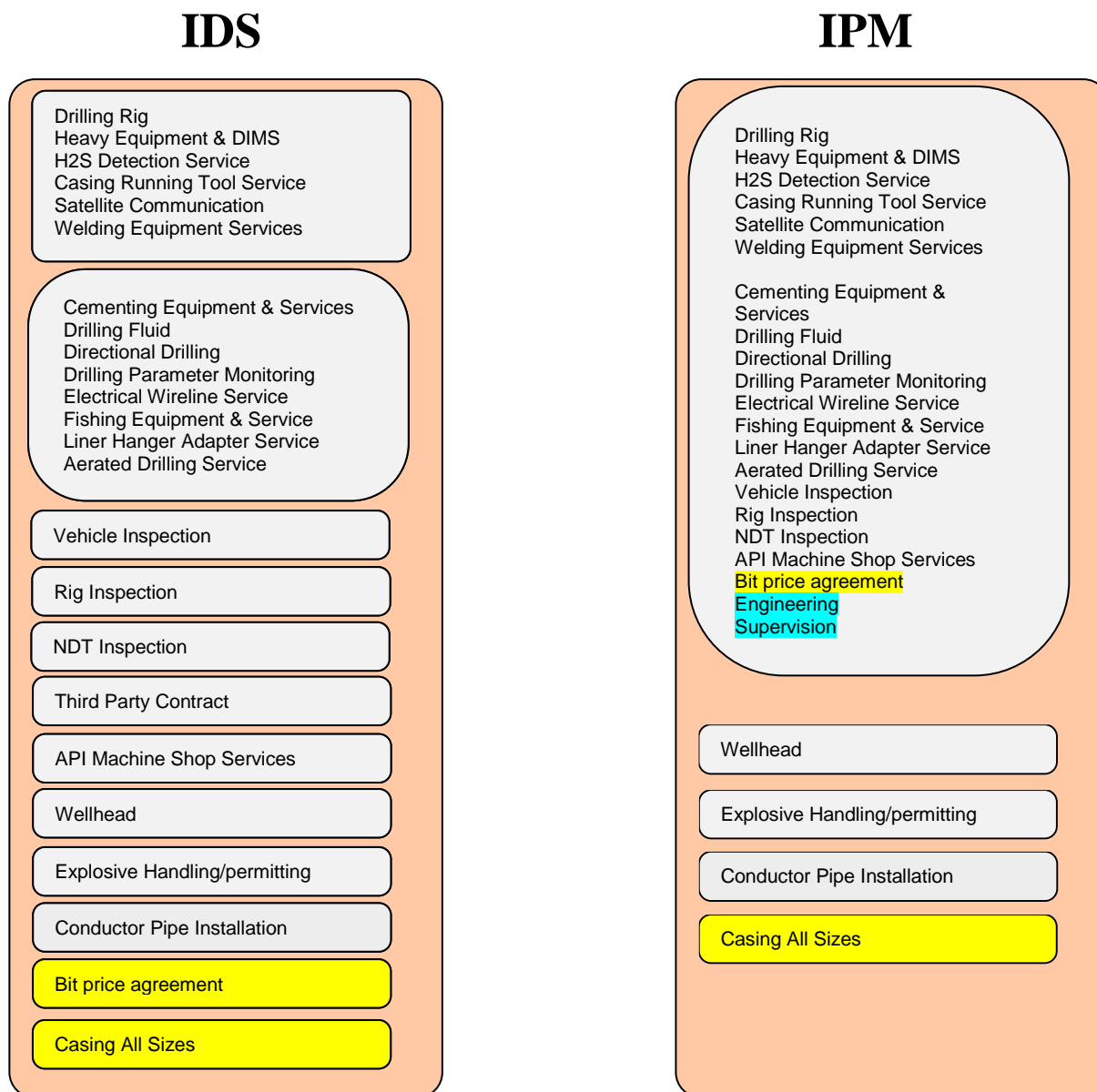


Figure 11: Contract structure of IDS and IPM

Figure 11 shows a comparison of the IDS and IPM Contracts. The yellow-highlighted services are covered by material price agreements while the blue-highlighted services are those that the in-house D&C Team took over. The blue-highlighted service was not available in the IDS as these are the scope of in-house drilling team.

Using the IDS Contract Structure, there will be more contract monitored by SEG. Hence, the monitoring level will be more detail than using single or less number of contract. This will make easier for Drilling Team to identify inefficient spending from the material or services during drilling operation. Also, the IDS Contract eliminated double handling fees and taxes charged to SEG.

Apart from direct commercial benefit, IDS contract structure that have more contract than IPM contract structure has indirect benefit to technical point of view. Having more contract enable drilling team to meet different person in charge with specific expertise. Their expertise is very beneficial to improve the decision quality for any initiative to enhance drilling performance. This condition definitely is better compare to discussing with only one person (the Project Manager) with IPM contract structure.

4. CONCLUSIONS

SEG successfully finished the 2018-2019 Wayang Windu Drilling Campaign with 32% improvement in drilling time and 40% cost savings compared with the 2015-2016 Drilling Campaign. Some of the takeaways during this recently concluded drilling campaign are the following:

- Having an in-house D&C Team enabled sharing of information, Best Practices, and Lessons Learned in the three geothermal assets owned by SEG while executing field-specific drilling operations;
- Real-time monitoring system allowed quick reaction and making informed decisions to avoid stuck pipe incidents; and
- The IDS contract structure is more cost efficient compare to IPM.

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