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Exploration Drilling Project in Sokoria Geothermal Field

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ABSTRACT

Aside from the uncertainty in probing a prospect, geothermal exploration drilling is costly and can make or break an exploration, appraisal, and eventual development of a geothermal resource. This paper articulates 5-wells exploration drilling project in Sokoria Geothermal Field during 2017-2018 including preparatory activities, execution of the drilling campaign, and drilling results. A key objective of this paper is to bring a new perspective about the challenges in drilling exploration wells in Indonesia. This paper wishes to show that drilling exploratory geothermal wells does not necessarily need to be expensive, does not always need years to prepare, and can be managed by an effective slim drilling organization. The average cost of the exploration wells was significantly lower than the average cost of geothermal wells in Indonesia. The first exploration well was spudded within the same year the concession was acquired. All of these were achieved despite a slim drilling organization and the remoteness of the location.

1. INTRODUCTION

Sokoria Geothermal Field is located on Flores Island, East Nusa Tenggara Province, Indonesia. It is accessible from Jakarta through flights with stopover(s) in Bali or Kupang, with connections to the city of Ende (Figure 1). The site is located approximately 25 km from Ende, which takes approximately 1.5 hours by car. Sokoria is the second concession acquired by KS Orka in 2016 through its subsidiary PT Sokoria Geothermal Indonesia (SGI). The first concession (Sorik Marapi) was acquired through another subsidiary PT Sorik Marapi Geothermal Power. In the vicinity of Sokoria Geothermal Field, there are two other geothermal concessions, namely Ulumbu and Mataloko Geothermal Fields. They are being developed by PLN, the state-owned power company of Indonesia. The presence of manifests such as fumaroles at moderate to high elevations, as well as its association with the surrounding volcanic activities become the key indicators for the presence of highly active hydrothermal systems on the Island.

Figure 1. The map of Sokoria and its surrounding geothermal fields.

SGI intends to develop 30 MW power plant in Sokoria at different stages of 5 MW each with the commissioning of the first unit in March 2019. Each year, an additional 5 MW will be commissioned until 2024 except in 2021 as part of its contract with PLN. [s1]

The first well in Sokoria has to be completed before mid-December 2017 to meet the commissioning target and the contractual area requirement, which specifies the first exploration well must be completed before the aforementioned time period. Failure to meet this requirement may risk that the contractual area withdrawn by the government. Timeline wise, this is a very tight schedule as the concession itself was only acquired by PT SGI on January 2017.

2. DRILLING PREPARATION

2.1 Drilling Team Organization

PT SGI constructed a very slim drilling team dedicated to managing Sokoria drilling project. The full team was established on April 2017, consisting of one Drilling Engineer, one Junior Drilling Engineer, and led by one Drilling Operation Manager. This team was tasked to cover the entire task of the drilling campaign, which includes well design, drilling engineering, drilling operation, contracting & procurement, logistic, and cost controlling.

There are always pros and cons in having a slim drilling team. The benefits are fast decision-making process, clear information distribution among decision maker, clear responsibility and accountability, and cost effective in terms of human resources. The cons, on the other hands are reduced quality in administrative process, fewer quality checks, and personnel work-overload.

2.2 Drilling Contract Structure

There are four known type of drilling contract structures: discrete, bundled service, semi-IPM, and IPM. The team, for this project, has chosen the bundled service contract type. Some advantages with bundled service are less contracting process required since several drilling services (8 services in this case) are handled by one company and also better pricing from the vendors due to the economics of scale. The eight services bundled for this project are Directional Drilling, Drilling Fluid, Cementing, Mud Logging, Fishing Services, Drilling Rental Tools, Wireline, and Drilling Bits.

The remaining drilling services, such as Air Drilling, H2S, Heavy Equipment Rental are managed through a direct contract by PT SGI. Drilling Rig, in this case, was also directly contracted and separated from other services.

Contracting process was initiated in May 2017 and was entirely completed by June 2017 (around two months' time), with a total of 15 drilling contract concluded.

As for the material, main material procurement for geothermal drilling are casing, wellhead & valve, liner adapter, and casing accessories. All these are managed individually through a direct procurement process. Material lead time was a key challenge especially in a very tight schedule condition.

2.3 Drilling Infrastructure

Key infrastructures needed to allow drilling geothermal wells area are sufficient road access, well-pad with all its supporting facility (water pond, cutting pit, drainage system, etc), and the water supply system. The entire drilling infrastructure works were managed by the Civil team of PT SGI.

One of the key challenges in the infrastructure is the water supply system. The main water source is located around 12 km from the well-pad, with elevation approximately 350 m below the well-pad elevation. Five pump stages were required to flow water from the source to the well-pad, in a series design. This means if one pump stage is down, then the entire water delivery system will be down. Given this condition, sufficient pump back up and proper maintenance are critical for continuous operation.

3. DRILLING EXECUTION

This section will describe how the team manage the operation during the drilling execution, including how the team handles some of the main challenges in drilling geothermal wells.

3.1 Drilling Logistic

Due to the remoteness of the location and minimum shipment schedule, sufficient drilling equipment and material must be carefully prepared. There are several ways to ship equipment to the rig site location in Ende, i.e. by dedicated LCT/barge or thru trucking & regular vessel. Each alternatives has different cost and time frame; therefore, every logistic movement must be carefully planned.

3.2 Drilling Software

For drilling project-management type of purpose, the software being used are mainly in-house developed. For daily drilling report, Excel spreadsheet was used. The data however were later extracted into an integrated database for analysis and easy visualization. All the figure shown in Section 4 of this paper are the taken from this integrated database.

As for drilling-parameter data, another database was created to integrate all mud-log data from all wells. A data visualization software was later used. The maximum utilization of data has really helped the team to improve the performance from time to time. Figure 2 below show example of visualization of drilling mechanic data from all wells.

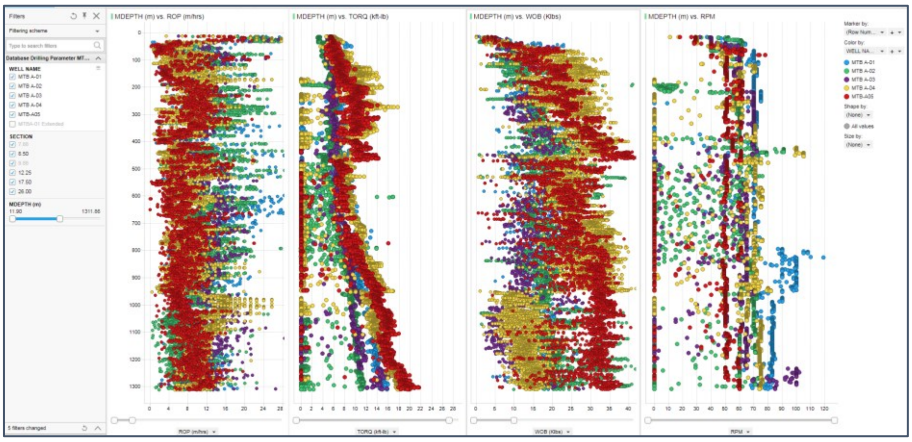


Figure 2. Data visualization of drilling parameter of all wells.

The utilization of this visualization software was later extended for other purposes, such as monitoring mud chemical utilization, cement chemical composition of each well, and so on. Figure 3 shows the data of utilization of KOH on each well in Sokoria. Having this database, utilization of other chemicals can be easily displayed instantly.

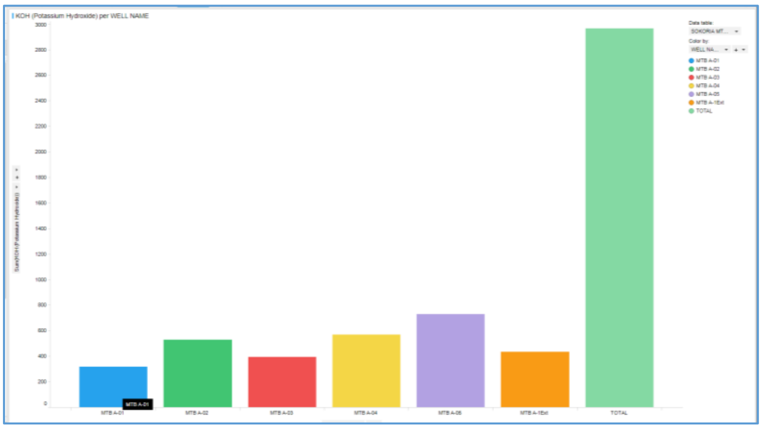


Figure 3. Data visualization of utilization of KOH of all wells

In the future, there is a plan to integrate also subsurface data, such as PTS data. This will eventually create a comprehensive database for the company.

3.3 Managing Lost Circulation

Whenever encountering lost circulation situation, which is common in geothermal, the team chose to continue blind drilling with water. The confidence rose after drilling the first well, when it was known the formation stability is sufficient. Has this not been the case, another mitigation plan might need to be executed, such as dropping cement plug, drilling with mud, etc.

Continuing blind drilling with water, particularly in this Sokoria drilling project, has brought several benefits especially in terms of cost efficiency, in addition to less damage to reservoir formation, significant saving in mud material, and saving in rig time has contributed significantly to overall cost saving of the project.

3.4 Managing Stuck Pipe

Two stuck pipe incidents occurred in the campaign; yet in both cases the drill string was successfully freed. Utilization of aerated drilling has helped in freeing the stuck pipe. No BHA was left in hole during the entire drilling project.

3.5 Managing Blind Drill

During drilling the reservoir section, where lost circulation has occurred, directional motor (mud motor and MWD) were removed from the BHA and only rotary BHA is used. Hence this reservoir section is drilled with very minimum control of the BHA, and no trajectory monitoring as there was no directional survey. To optimize the trajectory despite the condition, lessons learned from previous well must be carefully evaluated to understand the formation and the BHA behavior in the formation. This will help to continuously improve the BHA design and also the drilling parameter.

4. DRILLING OPTIMIZATION

Prior and during the drilling operation, SGP team encountered problems that required the team to do some changes in order to improve and optimize the operations. Some of the main optimizations are highlighted below.

4.1 Well Design

For the first three wells of Sokoria, MTB-A01, A02, and A03, the well was drilled with a standard hole design. The team decided to change the well design to big bore for the A04 and A05 well. Although the overall cost of the two wells is higher, the risk of drilling with this design is lower. This is partly because with the bigger hole size, there is bigger annular diameter for hole cleaning. Drilling will also have a higher chance to reach the target depth because 9-7/8" section hole becomes a contingency option.

4.2 Infrastructure Improvement

During the drilling of MTB-A01 and A02, operation experienced a significant amount of loss waiting for water supply. The total NPT hours added up waiting for water is 222.5 hours. After the second well, the water delivery system was improved. Previously the water supply pipe is made of HDPE materials, which has a low burst pressure. This requires a number of small water pump stations between the water source and the rig. Following the water supply problem, the pipeline was changed into steel pipes, which has a higher burst pressure. This reduces the number of water pumps needed and also increases the maximum capacity of the flow line. Figure below shows the reduction of water pumps from 10 to 7 pump stations. The reduction of pump stations also reduced the number of maintenance and operator, typically locals, needed to monitor the pump station. After this optimization, the project did not experience any further NPT due to waiting for water.

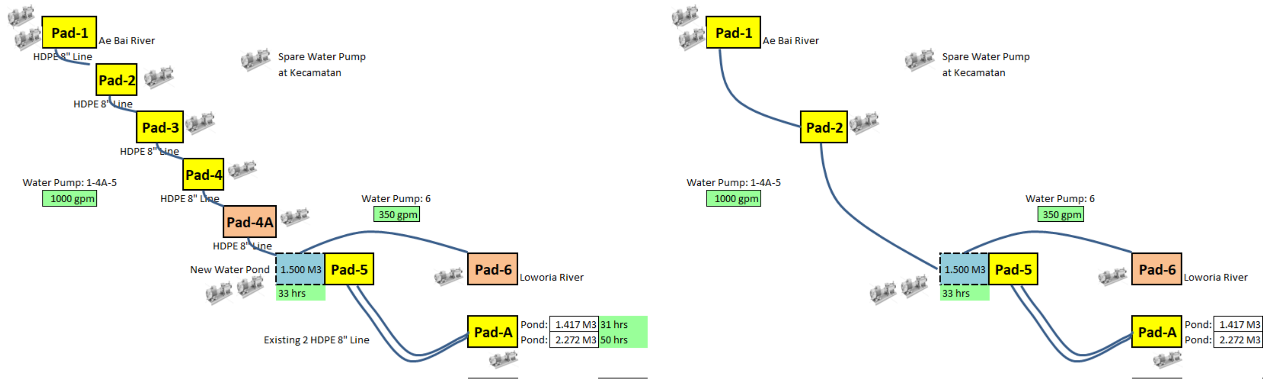


Figure 4. Water flow line using HDPE material (left) and flow line after changing to steel pipeline (right)

4.3 Drilling Equipment

Other than the NPT relating to water supply, during drilling MTB-A02, drill pipe parting occurred. Several pressure drops also occurred, which costed the rig some downtime to investigate. This costed the operation team a total of 272 hours of downtime in order to fix and fish the tools that fell into the hole. After investigation, it was found that the main cause is because the pipes were not coated with IPC (internal plastic coating) and since the water source was very corrosive (pH < 2.5), the pipe quickly corroded. To fix this, the team changed the pipes with those that has IPC from the fourth well onward. No similar incident occurred after the change.

4.4 Material Selection

This paper will focus on the material selection for the casing and wellhead, the two most critical components of a well. Based on field experience, engineering studies, and published papers, the recommended and most suitable production casing grade is L-80. This casing grade have a proven lifetime of 30 years and will be able to withstand the pressure and temperature of geothermal well production. For the rest of the production liner, K-55 grade casing will be sufficient because it will not be exposed or contain any pressure during production.

As for the wellhead, ANSI 900 valve was used in combination of API 6A 3M wellhead sets. This is proven to be sufficient for this geothermal application.

4.5 Drilling Operation Efficiency

Operational efficiency was improved from well to well, lesson learned was always captured for future improvement. Several significant operational efficiency improvements including: continue drilling blind with water during loss circulation instead of pumping cement plug as the formation is proven to be competent. This really save rig days and material.

5. DRILLING RESULT

This section will discuss the drilling performance result. The key performance matrixes are drilling days per well, drilling NPT, and drilling cost.

5.1 Drilling Days

The overall Sokoria drilling campaign took 320 days to complete. The first well of Sokoria Geothermal Field was MTB-A01, which was spudded on 8 October 2017; while the last well, MTB-A05, was completed on 24 August 2018. In average, each well took approximately 45 days to complete, excluding the time taken during rig move, with an average of 2100 mMD depth drilled.

Aside from MTB A-01 that was extended/deepened and MTB A-02, which encountered problems and required the well to be side-tracked at depth 1485 mMD, the rest of the wells did not encounter any major problems that required re-drilling or side-tracking.

The overall timeline of the drilling days can be seen in the figure below.

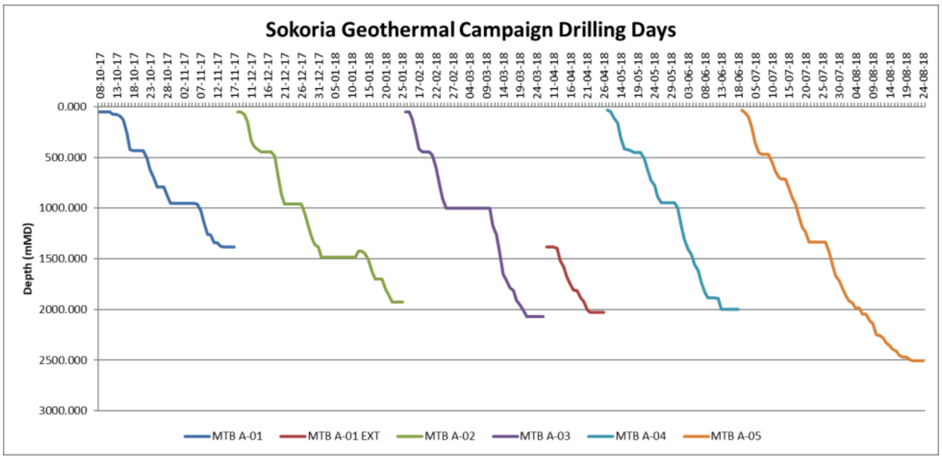


Figure 5. Sokoria drilling Days versus Depth.

The deepest well drilled in this campaign is MTB A-05 with 2505 mMD depth.

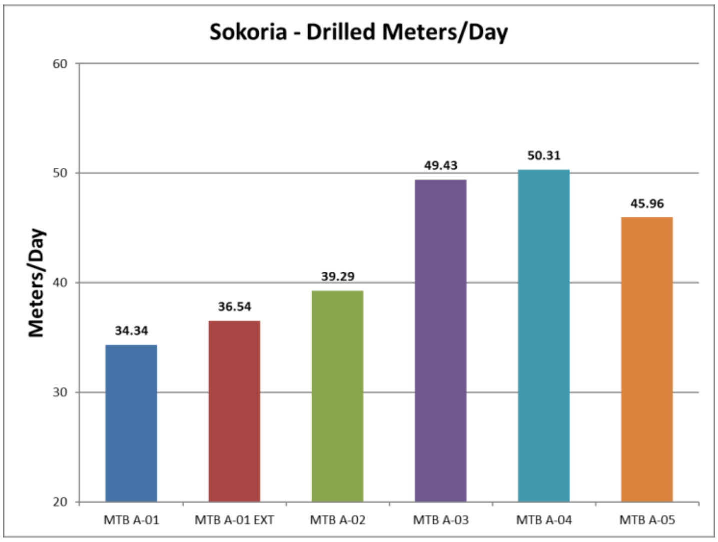


Figure 6. Sokoria drilling meters/day.

The average meters/day drilled in this project is 42 meter/day.

5.2 Drilling NPT

For most drilling campaigns, one of key metric to measure drilling performance is often the non-productive time (NPT). NPT is the amount of time spent dealing with trouble during the drilling operation. NPT for this project is defined as the sum of planned hours encountering trouble and the unplanned hours encountering trouble.

Figure 7 shows the Time versus Depth data for each well with its NPT distribution.

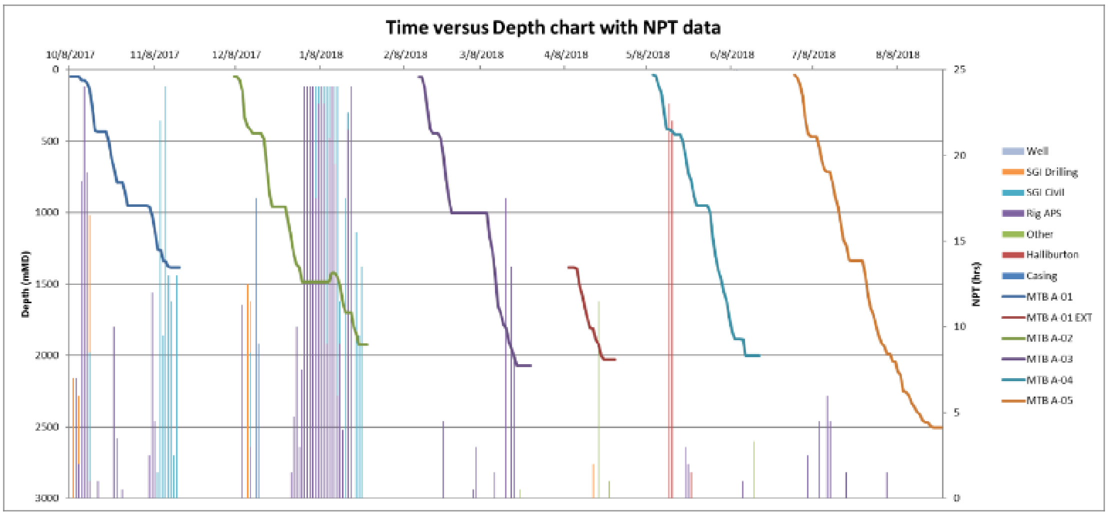


Figure 7. Sokoria Drilling Days versus Depth with NPT Plot.

Among the five wells, MTB-A02 has the highest NPT hours, totalling to 518.5 hours, which was due to drilling rig drill pipe parting and SGI water supply problem. This NPT is one of the key contributing factors to MTB-A02 slow drilling rate (39.29 m/day). The NPT for the three wells following MTB-A02 is significantly lower due to the optimization done at MTB-A02. This leads to the relatively higher meters/day rate for MTB-A03 onwards (Figure 6).

NPT was the lowest for MTB A-01 EXT, with 14.5 hours in 647 mMD drilled and followed by MTB A-05 with a depth of 2505 mMD and 20.5 hours of NPT. In terms of NPT, the best performing well was MTB-A05, which was the deepest well in Sokoria with very low NPT hours. Figure 8 shows the total NPT hours for each well.

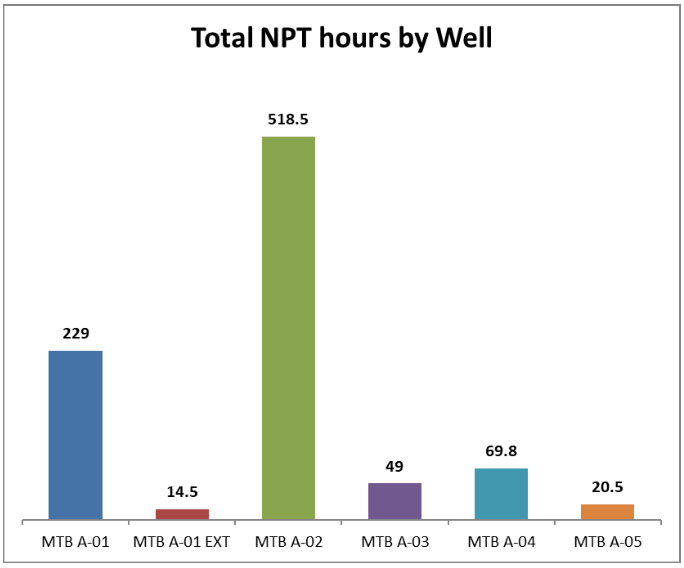
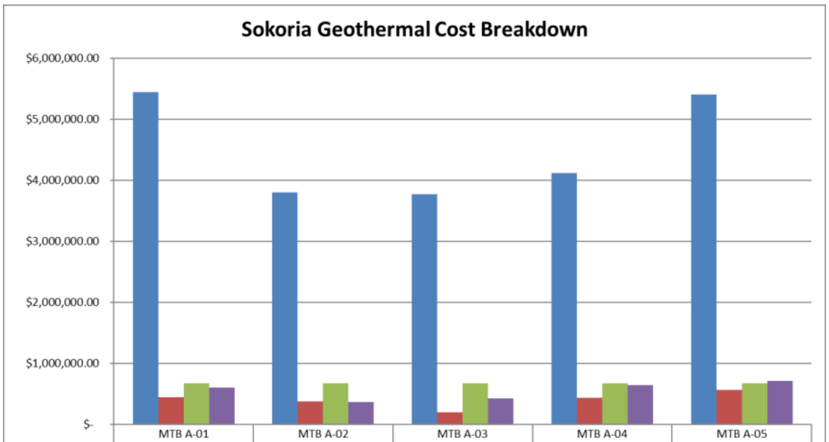


Figure 8. Sokoria drilling NPT by well.

One of the major NPT causes in the Sokoria drilling campaign relates to the availability of water supply. This contributes to 25% (222.5 hrs) of the total NPT hours and was solved after the MTB A-01 well. Water supply shortage becomes very critical during drilling at PLC/TLC condition, because drilling at PLC/TLC condition requires a continuous significant amount of drilling fluid for hole cleaning and well control.

5.3 Drilling Cost

This section of the paper outlines the overall drilling costs of Sokoria drilling campaign. The total cost calculation for each well takes into account all of the direct costs associated with drilling a well. These include the actual drilling costs, charges during interwell period, inventory costs, and mobilization and demobilization costs. The mobilization and demobilization costs for rig and services are split evenly across all the wells. The diagram below illustrates the summary of total costs for each well in Sokoria drilling campaign.



	MTB A-01	MTB A-02	MTB A-03	MTB A-04	MTB A-05
Drilling Cost	$5,440,271.58	$3,801,046.67	$3,765,367.63	$4,114,423.55	$5,403,307.66
Interwell Cost	$439,515.52	$371,495.13	$193,902.30	$433,990.19	$559,353.09
Mob/Demob	$665,931.14	$665,931.14	$665,931.14	$665,931.14	$665,931.14
Inventory	$600,538.48	$360,981.59	$423,582.25	$639,185.86	$712,979.10

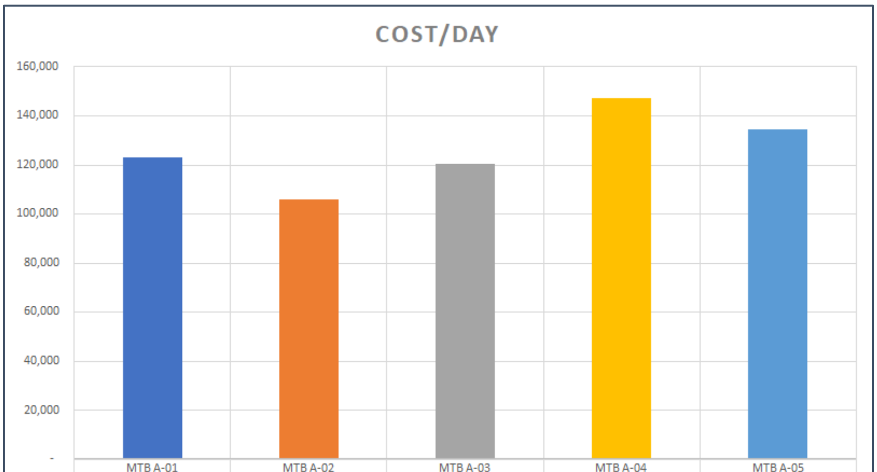
Figure 9. Sokoria drilling cost breakdown by well.

Additionally, from the total cost from each well, Figure 8 outlines the detailed costs from each category of costs, which are the drilling cost, interwell cost, mob and demob, and inventory costs. The actual drilling cost makes up for the largest proportion of all the costs, which is 73.63% of the overall costs.

The well with the highest total cost is MTB A-05 at USD 7,341,571.00, with MTB A-01 following closely at USD 7,146,256.73. It is important to note that the costs for MTB A-01 EXT are included into MTB A-01, which may explain the seemingly inflated figures in the well costs. The well with the lowest total cost is MTB A-03 at USD 5,048,783.32.

MTB A-05 has a very high cost, but low NPT, while MTB A-02 has a high NPT but low cost. One of the reasons of lower cost in MTB A-02 is that the NPT owner was not paid in full due to the amount of NPT hours. It is important that this is stated in the contract between the company and contractor, so company can avoid costly drilling projects.

MTB A-05, on the other hand, has encountered a very hard drilling situation when drilling at depth below 2200m. This requires several bit trips hence adds up to the drilling ti1me.



	MTB A-01	MTB A-02	MTB A-03	MTB A-04	MTB A-05
USD	123,254	106,111	120,439	147,259	134,708

Figure 10. Sokoria drilling cost per day by well.

MTB A-02 has the lowest cost/day compared to the other four wells. Considering that this well has the highest NPT hours, this shows that the NPT owner are not paid in full due to the troubleshoot.

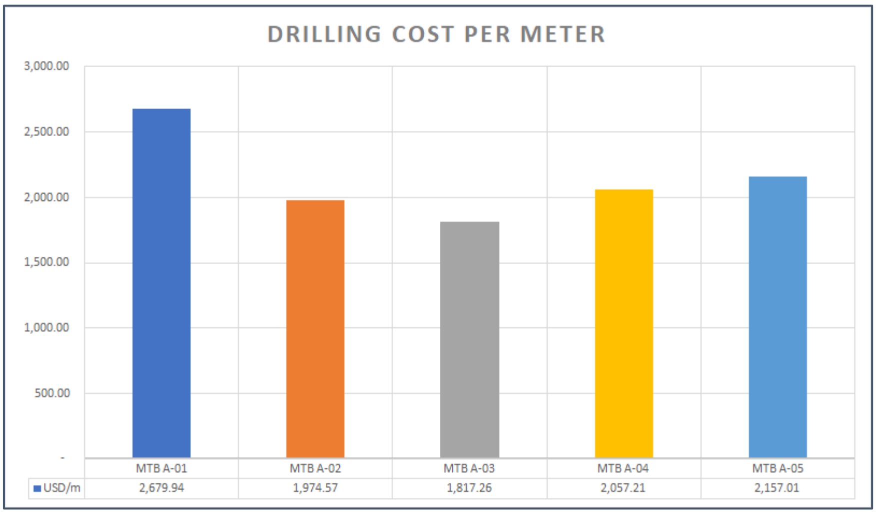


Figure 11. Sokoria drilling cost per meter by well

The diagram above shows the average drilling cost per meter, where the total cost is divided by the total measured depth of the well. The average cost per meter for all wells in Sokoria drilling campaign is USD 2,001.51 per meter. The well with the highest drilling cost per meter is MTB A-01 at USD 2,679.94, while the cheapest is MTB A-03 at USD 1,817.26 per meter depth.

This information can be used as a basis of comparison with drilling campaigns in other fields/projects, and with other contractual structures.

One paper from EBTKE (Purwanto et al. 2018) has collected drilling cost data from various geothermal wells in Indonesia. This data is used as a basis for drilling cost comparison, in terms of drilling cost / meter. The results are shown in below figure.

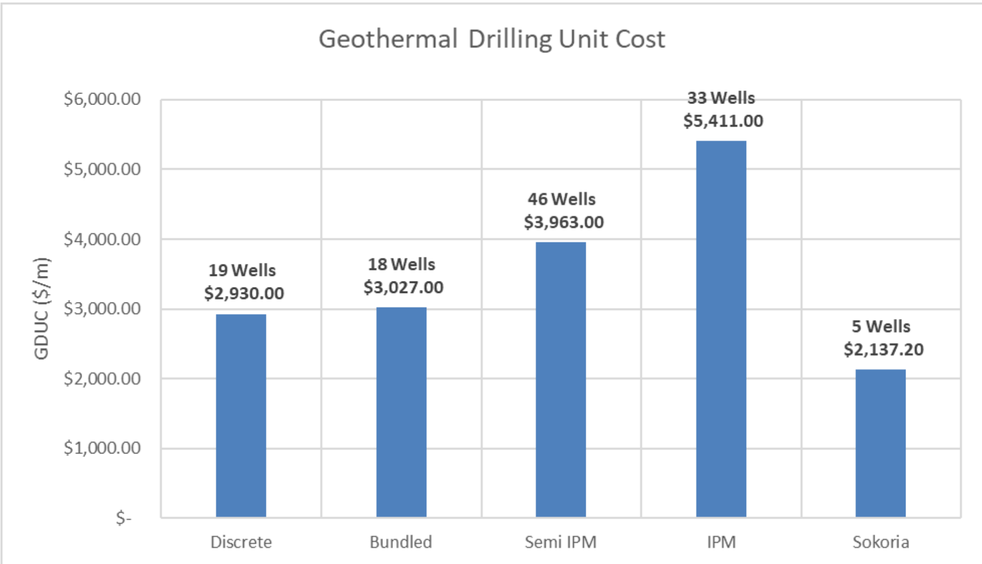


Figure 12. Comparison of drilling cost per meter

Comparing wells cost with bundled-service type contract, PT SGI cost per meter is at 2,137.20 USD/meter while the average in Indonesia is at 3,027 USD/meter.

6. CONCLUSION

This paper has described the voyage of Sokoria drilling project, from drilling preparation, execution, to the drilling result review. Despite the tight time period, remoteness of the location, and the slimness organization of the drilling team, the project was executed successfully in terms of safety, schedule and cost. The drilling project has met the exploration deadline. The drilling cost, in average, was significantly lower than the average of Indonesian's drilling cost.

7. REFERENCE

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