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Full Coring Drilling Operation Analysis to Improve the Exploration Drilling Performance of Geothermal Slimhole

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ABSTRACT

The exploration phase comes intending to prove the presence of a geothermal system underneath the earth's surface. The resource proving process can only be confirmed by conducting drilling activity. Several alternative well sizes known in the geothermal industry are big hole, standard hole, and slimhole. Drilling rigs used in slimhole drilling are generally designed in advance to have coring abilities. As we know, the use of a full (mineral) coring rig is usually only done for mining activities. Full coring is a drilling technique carried out to the planned depth by taking samples in rock cores without open hole drilling. This makes the full coring rig adaptable for a slimhole rig and optimizes the mineral coring drilling performance in the X field. This paper also aims to determine the ROP (m/hr) for drilling duration estimation. The drilling performance analysis is based on the daily drilling reports of Rig X (full coring rig with NQ depth rating of 1800 m). The offset wells to be analyzed are X-1 well, X-2 well, and X-3 well (12 wells).

1. INTRODUCTION

Field X is a mining field that operates using a full coring rig. In this field, it was found that there was geothermal potential where there was a surface manifestation that identified the potential for geothermal below the surface. The surface manifestations include clusters of hot springs, fumaroles, and alteration areas. The hot springs have a temperature between 37 ° C and 80 ° C. The estimated reserves of 60-70 MWe and hot springs in the area of XY, which are of the sulfate type reflect the up-flow geothermal system that needs to be followed up by drilling a temperature incline of 250 m or around 1000-1500 m to prove the potential for steam and heat at that depth. The only data source used as a reference for the exploration drilling plan is the daily drilling report data from the full coring rig. The number of wells recorded was 12 wells. Well X-09 is the deepest well, with a depth of 1407.7 m, and X-04 with the lowest depth is 80.85 m. The study of this paper is to see the performance of the full coring rig for each well by looking at and analyzing the Productivity Time and Non-Productive Time. The full coring rig itself has similarities with slimhole drilling. Namely, the routes used are PQ, NQ, and HQ. From this data, an estimate of the ROP (m/h) for each well and each section can be obtained. Knowing one of these drilling parameters is expected to help further drilling performance.

2. OBJECTIVES

This study aims to analyze and calculate the performance of a full coring rig. The analysis carried out is an analysis of days vs. depth, rate of penetration (ROP), the time distribution of productive time & non-productive time, and the last one is to know the potential hole problem to optimize for further drilling and adaptation to slimhole drilling.

3. CORING AND SLIMHOLE DRILLING OPERATION

3.1 Full Coring Rig

One of the methods of exploration drilling in coal or mining is full core. A full core is a drilling technique carried out to the planned depth by taking samples in rock cores without open hole drilling. Core drilling (Coring) aims to obtain a representative sample for geotechnical purposes, determine coal quality, and other tests to provide excellent and sufficient information from a drilling hole.

Figure 1. Core sample extracted by full core drilling operation during coal exploration in Kuala Kuayan

The rock core sample is shaped like a tube, and the size will be following the drilling pipe used. Sampling is usually per 1.5 m or 3 m, depending on the length of the pipe used.

3.2 Slimhole Drilling

3.2.1 Definition

There is no formal standard that classifies wells (especially geothermal well) based on their diameter. Society of Petroleum Engineers (SPE) defines a slim hole well as a well with a casing size less than 7" for 90% of its depth, while ISOR defines a slim hole well as a well with a final diameter less than 6" (Thorhallsson, 2016). However, the most commonly used definition is that any well with a wellbore diameter less than 6" is considered a slimhole well (Schlumberger, 2020; Mackenzie et al., 2017). Apart from wellbore diameter, in the geothermal industry worldwide, there are three types of well commonly used for exploration based on their objectives and depth: 1) temperature gradient well, 2) deep slimhole well, 3) conventional/standard/big well (Mackenzie et al., 2017). Table 1 summarizes the typical depth and objectives for the well configuration commonly used for geothermal exploration.

Table 1. Typical well configuration used for geothermal exploration (modified from Mackenzie et al., 2017).

Type of Well	Typical Depth	Objective(s)
Temperature gradient	200 – 800 m vertical depth Typically drilled above the reservoir	● Confirm the presence of clay cap ● Confirm temperature ● Validate the conceptual model.
Deep slimhole (Prod. Casing 2-3/4" – 7")	~500 – 2,000 m vertical depth Typically drilled through clay cap and reach the reservoir	● Confirm adequate temperature for commercial production (**primary objective**) ● Test productivity (**secondary objective**).
Conventional/Standard/Big hole (Prod. Casing 9-5/8" – 13-3/8")	~1,500 – 3,000 m vertical depth	● Provide comprehensive testing of resource productivity ● It might be used for production or injection.

Thermal gradient well generally implemented not for exploration but to confirm the presence of clay cap and the temperature. Slimhole Well applied for drilling operation to reach the reservoir target. This well type is utilized to confirm the reservoir's temperature, commercial production, and productivity test. Whereas the Conventional or Big Hole Well is implemented to reach the subsurface data and is commonly used for production or injectivity requirements.

Apart from the related necessity and applications, there are also differences in casing design or well configuration between Deep Slimhole Well, Standard Hole Well, and Big Hole Well. This is clearly shown in figure 2.

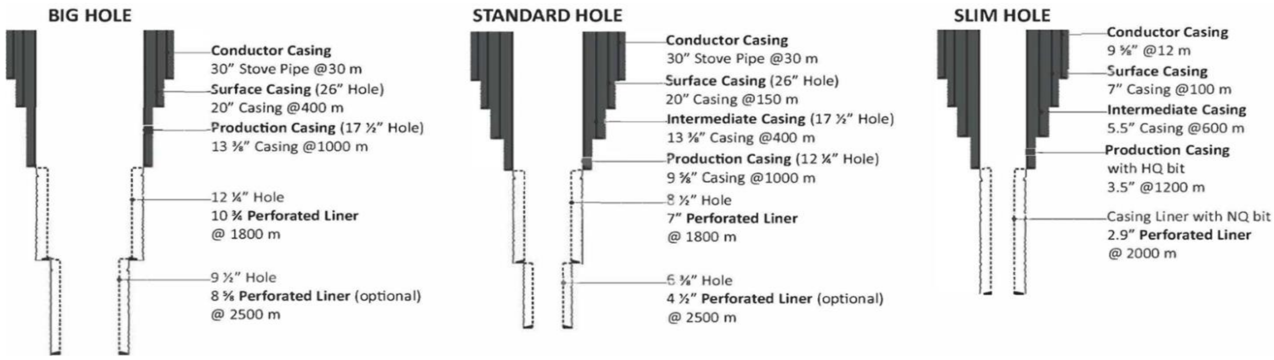

Figure 2. Typical well configuration for big, standard, and slim holes (Purba et al., 2019).

3.3 PT NPT Explanation

3.3.1 PT (Productive Time)

Productivity can be defined as a multiplier of effectiveness and efficiency if both of their value increase will also increase the sum productivity. Besides, the efficiency of a process is a measure of the resource consumed to run the process. Meanwhile, effectiveness is defined as a scenario where actual throughput is at least equal to but ideally larger than expected throughput.

Increasing the asset's productivity during its "productive time" can reduce the non-productive time as well. An asset with higher productivity will cost less to operate, resulting in shorter drilling campaigns and increasing the ROP.

3.3.2 NPT (Non-Productive Time)

Non-productive time (NPT) is an unexpected event outside of the original plan of a drilling project. Hence, it does not have any standards or clauses in its measurement. Rabia (2001) defines NPT as the time taken for any routine or abnormal operation that is carried out due to a failure or an event that causes the drilling operation to stop. The most frequently recorded NPTs in the field during a drilling operation are reaming, stuck pipe, loss, and equipment problems. The repetitive occurrence of an event usually marks NPT due to a specific cause, and hence in most cases, it could consume a long time and duration.

These definitions of NPT suit the objective in which they are used. According to Rabia's (2001), NPT is useful as a performance index and a measure of how well the time is utilized in useful activities. As an illustration, the highest expense in a drilling operation is the daily rig rates. If the operation happened to stop due to problems, the daily rig rates would still run as usual. This is a time when the operation is referred to be non-productive

4. CASE STUDY

The data used to do the analysis is the Daily Drilling Reports (DDR) of X1 – X12 Well that was drilled by using "Y" Full Coring Rig. The X1 – X12 wells are sorted based on the well's name, not the time when it was drilled. In some cases, the wells only have partial DDR data. The X1 Well only has DDR of its HQ section and X4 & X12 Well only has the PQ section. Nevertheless, this partial data is included in the calculation to support the heterogeneity of the data to be analyzed.

Table 2. General Well Information Drilled by "Y" Full Coring Rig

Well Name	Total Depth	Drilling Duration	PQ sec. Duration	HQ sec. Duration	NQ sec. Duration
	m	days	days	days	days
X1	1,060.50	13.63	-	13.63	-
X2	1,204.00	55.68	31.88	13.48	10.32
X3	1,201.50	37.13	19.46	4.80	12.87
X4	111.30	3.13	3.13	-	-
X5	1,601.00	45.42	15.10	12.02	18.29
X6	1,124.00	41.82	24.19	17.63	-
X7	1,001.00	27.52	18.98	8.54	-
X8	1,407.70	60.21	23.81	36.40	-
X9	607.80	16.98	16.98	-	-
X10	1,124.00	32.46	15.73	16.73	-
X11	1,200.00	40.81	21.83	18.98	-
X12	80.85	4.00	4.00	-	-

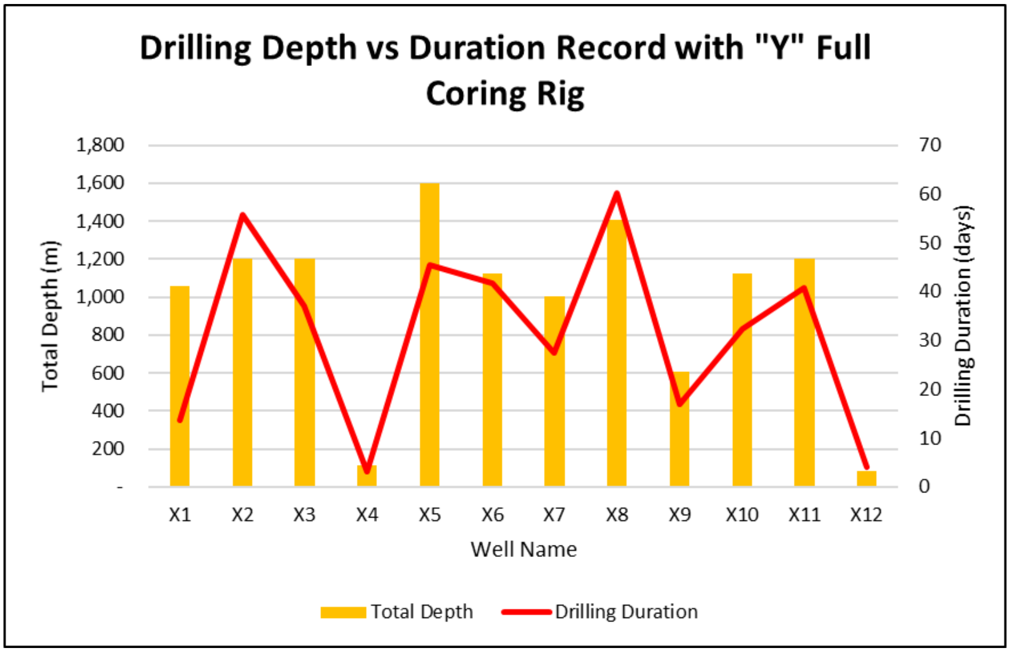

Figure 3. Drilling Depth vs Duration Record with "Y" Full Coring Rig

4.1 DvD

One of the results of the drilling analysis process is the Days vs Depth chart. In this analysis using 12 (twelve) offset wells in Field X, data of completion time and well depth from all wells will be plotted in the form of the Duration (days) vs Depth (mMD) graph as shown in Figure 4. The graph shows the total completion time for each well in Field X by considering the NPT that occurs during operation. This graph also shows that the occurrence of NPT mostly begins to appear at depths below 200 mMD.

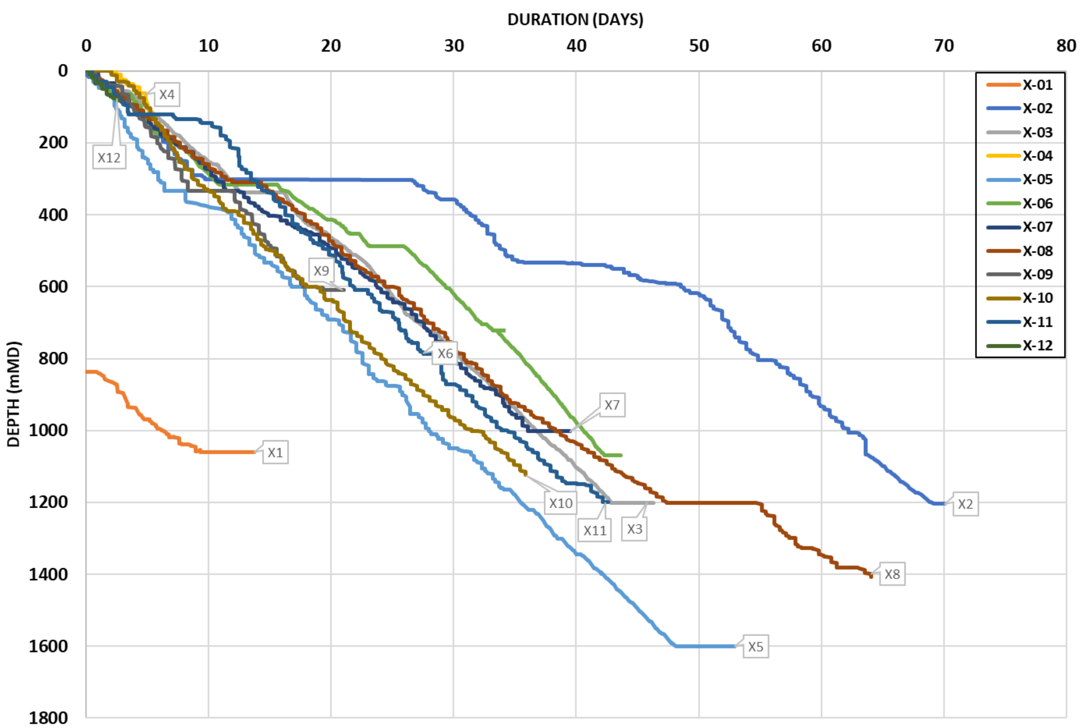

Figure 4. Day vs Depth with NPT in Field X

Well X-05 owns the deepest well depth. However, the most prolonged drilling duration is owned by well X-02. This is due to many NPT activities with a long duration that occurred when drilling the X-02 well. At well X-02, there were several times stuck, with remedial action reaming, but like at a depth of about 500m reaming could not solve the stuck problem. So, Re-drill activities are taken to overcome this.

Even though in Figure 4, all wells do not have the same well depth, through comparison of duration between "with NPT" and "without NPT", it can be seen that the deeper the hole, the wider the variation that occurs. This can be considered an early indication that in Field X (offset wells), the difficulty of drilling increases as the well is deeper.

4.2 PT NPT

Figure 5 shows the result of Productive Time (PT) and Non-Productive Time (NPT) distribution of the drilling operation of 12 wells in X Field. Based on the results, drilling operations were successful, with a productive time percentage reached 63%. However, the percentage of non-productive time was still high at 37%.

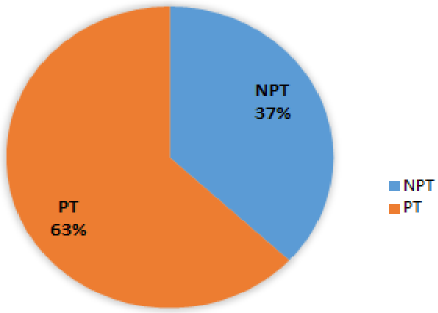

Figure 5. PT NPT Distribution

4.3 NPT Breakdown

Here is the Non-Productive Time (NPT) Breakdown from the results of 12 wells that had been drilling in X Field. Based on the PT and NPT Distribution, Non-Productive Time taken 37% of drilling time or 6145.25 hours. There was 12 drilling hazard that happened in X Field. Figure 6 explains the details of the proportion of drilling problem occurred in X Field.

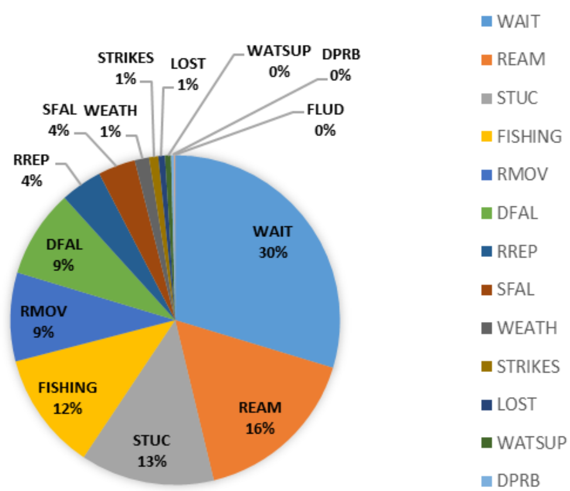

Figure 6. NPT Breakdown of the 12 total wells

For this project, there were five drilling problems out of the total that had the most influence. The first is the WAIT code, which means the waiting process in this drilling project, where it took 1823.5 hours or 30% of the total NPT time. The second is REAM Code, which means reaming process. These problems took time 16% of the total NPT time or 1017.5 hours.

The third problem is STUC code, which means stuck condition when drilling operations. This problem had 807 hours or 13% of total NPT time, and the fourth is FISHING. This code means fishing in drilling was on this project, took 12% of total NPT time or 713 hours. Moreover, the last is RMOV Code or Rig Move. This problem has happened before drilling activity in general. This problem took time 9% portion of total NPT time or 534.5 hours duration.

Table 3. TOP 5 NPT based on NPT duration in 12 wells

NPT	Duration (hr)	Percentage (Compared to NPT Time)
WAIT	1823.5	30%
REAM	1017.5	16%
STUC	807	13%
FISHING	713	12%
RMOV	534.5	9%

4.4 ROP and Completion Time Rate

ROP (Rate of Penetration) is the time needed to drill one meter length of formation in a well section. Thus, ROP can be expressed as the total length of a section divided by the time to drill/coring (adding the section depth) the section of the well. Any operations that did not add depth, such as taking a survey, cementing, and solving some drilling problems of the well, will not be included in the ROP calculation.

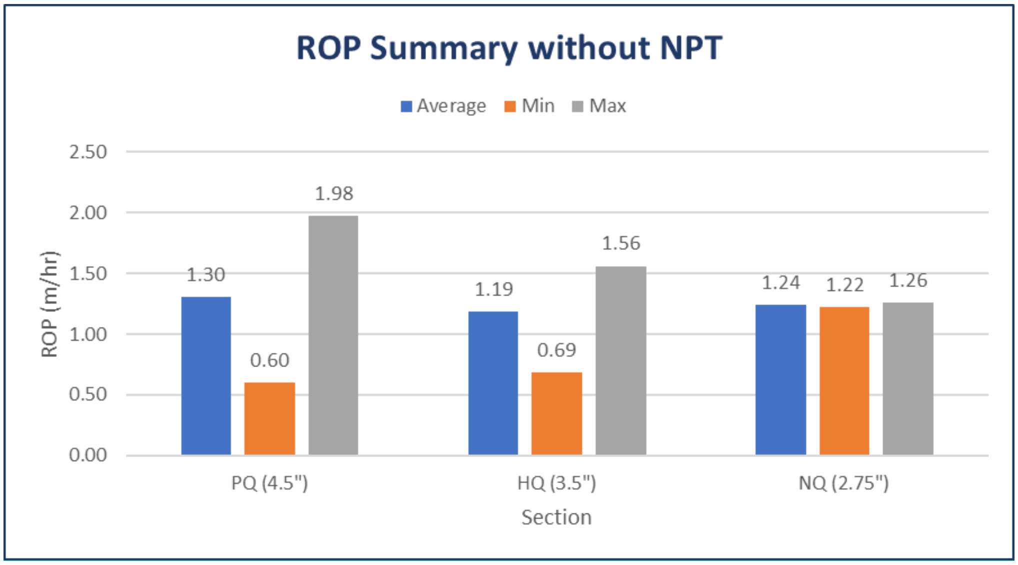

Figure 7. ROP Summary of All Wells without NPT

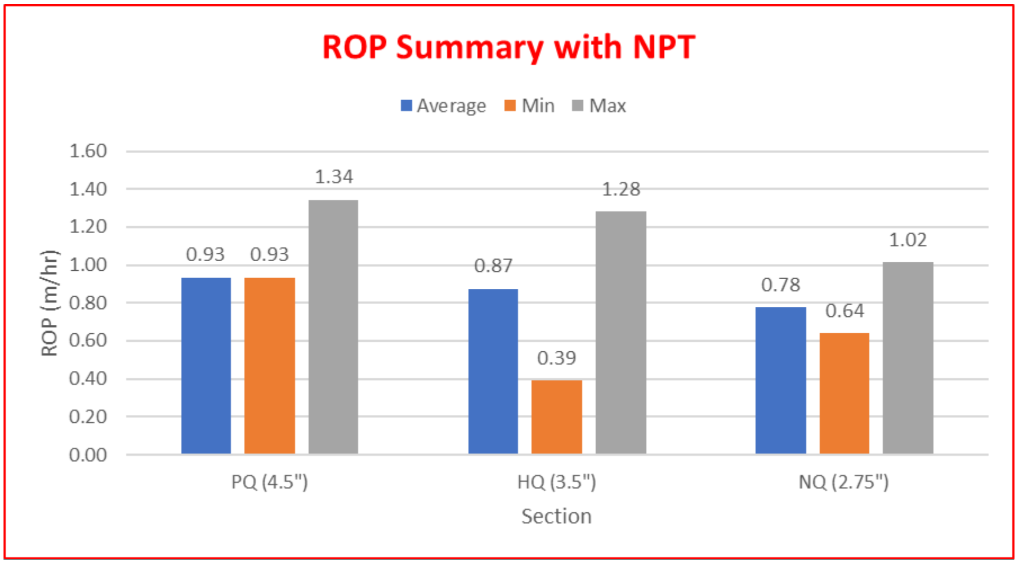

Figure 8. ROP Summary of All Wells with NPT

While CTR (Completion Time Rate) is the rate of time needed to finish/complete a section of the well. The CTR formula is the total length of a section divided by the time to finish a section. All operations to finish the section will be included in the calculation, whether adding the depth.

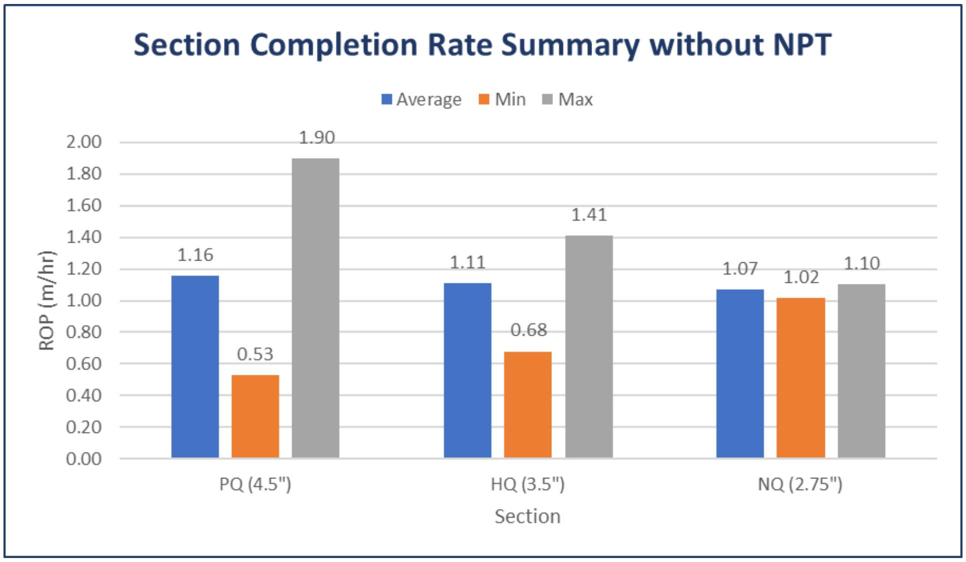

Figure 9. Section Completion Rate Summary of All Wells without NPT

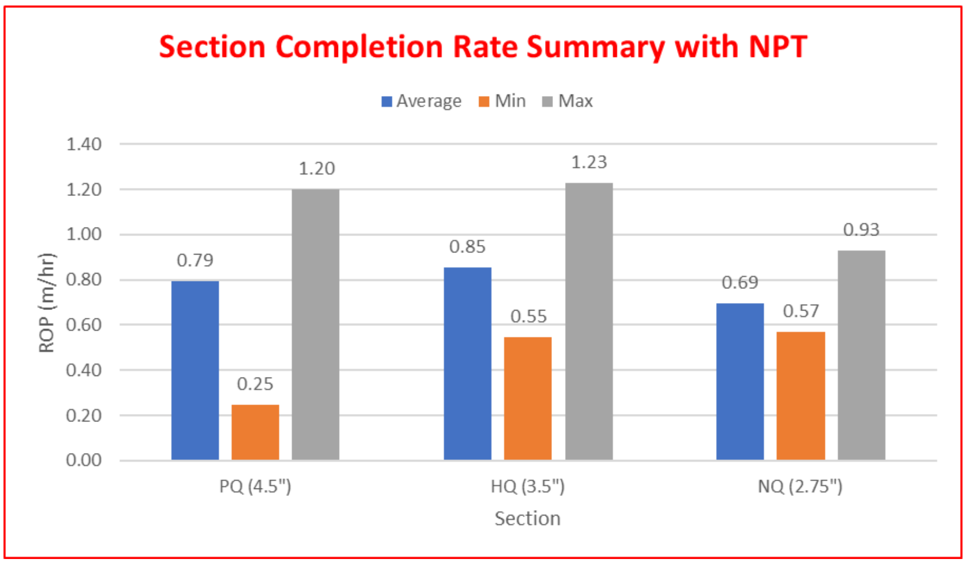

Figure 10. Section Completion Rate Summary of All Wells with NPT

4.5 Prevention & Mitigation Plan of Potential Drilling Problem

a. Wait
More efficient working time scheduling to finish some jobs that can be done at the same time in the same time, thus prevent the waiting time of another job to be done first.

b. Ream
Consider applying other methods to handle pipe stuck. These methods include jarring action or pumping particular chemicals to free the pipe.

c. Stuck
- Optimize viscosity, PV, and YP of mud to maximize cutting lifting
- Hole cleaning circulation before tripping out the string
- Circulate mud 5-10 minutes before adding the new string to clean out cutting around BHA
- Observe the drilling parameter and change of trend routinely
- Optimize ROP and hole cleaning

d. Fishing
Educate the drilling crew to be aware of the equipment that easily dropped into the wellbore. If the fishing operation is caused by the drill string stuck, consider preventing every operation that will exceed the drill string make up torque or maximum torque that can be applied to drilling.

e. Rig Moving
Add some transporters (truck or copper) to cut the moving rig time from one point to another.

4.6 Slim Hole Drilling Time Estimates Based on ROP

Based on the average ROP (Rate of Penetration) of X1 – X12 Wells and located in the same field (same formation), the proposed slim hole drilling time can be estimated. All data about the proposed slim hole well schematic is based on the actual proposed well. The required slim hole drilling operations time that is not attended during full coring drilling operation, such as BOP installation, will be assumed as long as the average operation time in the drilling operation of geothermal wells in a field in the same country proposed slim hole drilling. According to the proposed slim hole schematic and table "ROP Summary", below is the Slim Hole Drilling Time Estimates

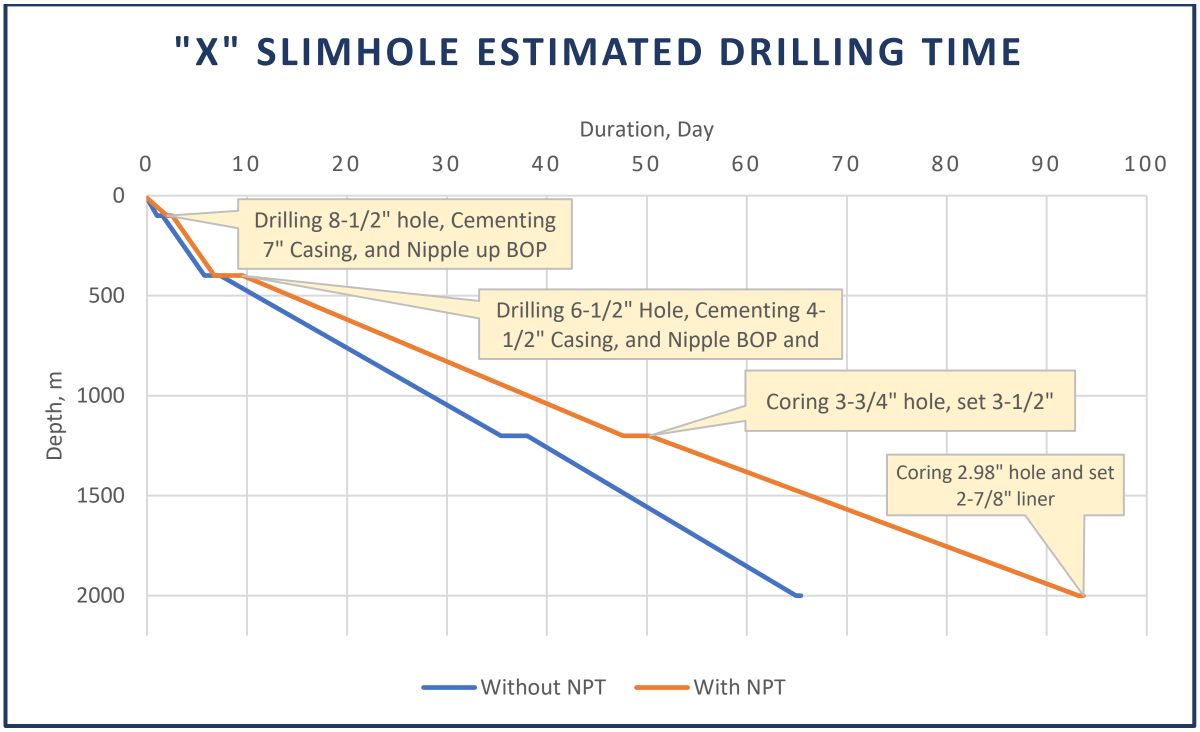

Figure 11. X Slimhole Estimated Drilling Time

5. CONCLUSION

This study involves 12 mining well drilling operations to be analyzed and results in several beneficial analyses to improve Slimhole X geothermal exploration drilling operation. Based on the analysis, the operation of PT (productive time) is 26% higher than the NPT (Non-Productive Time) operation. Although the PT is higher than NPT, the PT should be optimized to be as high as possible for Slimhole X drilling operation. The most frequently occurred NPT operations during drilling those 12 mining wells are WAIT, REAM, STUC, Fishing, and rig moving.

Slimhole X drilling will reach 2,000 m underneath the surface and is estimated to spend 94 days of the drilling operation. The number of days still consider the drilling problems that may happen based on previous analyses. Thus, this drilling time has the potential to be minimized to be 66 days only if the drilling engineers could plan excellent preventive actions to minimize the NPT operation occurrences that historically occurred in the previous mining drilling campaign. Furthermore, good mitigation action execution is necessitated by the company man during the Slimhole X drilling operation. With precise analyses and executions, Slimhole X drilling operation analyzed based on 12 mining well drilled by full coring rig will result in excellent well which completes all the drilling objectives and spends minimum drilling cost.

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