CHALLENGES IN PROVIDING A RELIABLE WATER DISTRIBUTION SYSTEM FOR GEOTHERMAL DRILLING OPERATION IN INDONESIA

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ABSTRACT

Geothermal drilling activities, both in the exploration and development stage, require a significant amount of fresh water supply. The water consumption generally increases during drilling into the reservoir zone, which consists of fractures and faults allowing higher chance of lost circulation event. Continuous water supply with sufficient flow rate, to be circulated into the hole, is very critical during drilling because it serves many purposes. When the water distribution into the well is interrupted or stopped completely, drilling activity must be ceased to avoid any potential downhole problem due to lack of water or mud circulation. Unfortunately, in Indonesia, providing fresh water for drilling operation is often not an easy task. Most geothermal prospects in Indonesia are located in fertile mountainous areas that have low rainfall and are inhabited by people, thus the available sources of fresh water are often used for irrigating rice fields. This condition forces geothermal developers to use other water sources with low (acidic) pH that often located far from the existing road. Additionally, the surface contour from the water source to the drilling pad is often extremely uneven.

This paper discusses various potential challenges, both technical and non-technical, in securing fresh water supply for geothermal drilling operations in Indonesia. Several solutions or mitigations based on literature studies and authors experience are also summarized in this study.

1. BACKGROUND

In geothermal drilling, the production zone is usually a loss zone (Finger & Blankenship, 2010). This means curing the loss zone is not preferable as it might harm the well productivity. Therefore, it is almost a certainty that at some point, the drilling must be continued even in the event of loss circulation.

The loss circulation will reduce the cold fluid column inside wellbore, reducing hydrostatic pressure. Apart from causing stuck pipe, this condition can also lead to steam blowout due to the fluid inside wellbore is getting hotter and flashes, with no sufficient water column to prevent the steam from rising to the surface. Therefore, the continuous and reliable water supply for geothermal drilling is very critical for the success of geothermal drilling, both in terms of drilling performance and also in terms of safety.

2. OBJECTIVES

The purposes of this paper are as follow:

- Give overview of typical quantity of water and water supply infrastructure required for geothermal drilling in Indonesia.
- Discuss potential technical and non-technical challenges in securing fresh water supply for geothermal drilling operations in Indonesia. The potential mitigation options for those challenges is also discussed.

Literature review and case study from authors' experience were used to give an overview and examples of some of the challenges commonly faced in securing water supply for geothermal drilling.

3. WATER QUANTITY FOR DRILLING

3.1. Typical Well Design in Indonesia

The current typical geothermal well in Indonesia use big bore type (13-3/8" production casing with 10-3/4" production liner) as shown in Table 1 (Hartono, 2019) and Figure 10. Note that the big bore well offers more flexibility to step down the liner size in case of drilling problem as the big bore well can be stepped down twice up to 7" liner. However, this larger well diameter means more water is required to drill the well.

Table 1. Typical big bore geothermal well design in Indonesia.

Section	Hole Size	Casing Size	Typical Depth (mMD)
Conductor	36" / drilled using Auger	30"	30-60
Surface	26"	20"	300-500
Production casing	17-1/2"	13-3/8"	400-1400
Production liner 1	12-1/4"	10-3/4"	1100-2000
Production liner 2	9-7/8"	8-5/8"	1500-2500
Production liner 3	7-7/8"	7"	2000-3000

3.2. Water Quantity Estimate

The amount of water required for drilling varies from well to well, depends on well size and drilling condition, but may vary from 260-1200 gpm (Putranto, Iswara, & Bismoyo, 2018). The 1200 gpm is the typical maximum flowrate required for standard/big bore well as shown in Figure 10. To estimate the water required for drilling, this study use big bore well with the total measured depth of 3,000 m or around 10,000 ft (Figure 10) and the total drilling duration of around 65 days.

As loss circulation is quite common in geothermal and difficult to predict, two scenarios are used to estimate the amount of water required for drilling:

3.2.1. <u>Scenario 1: Attempt to cure loss in 26” and 17-1/2” hole</u>

This scenario assumes that in 26” and 17-1/2” hole section any loss circulation encountered will be cured prior to continue drilling. It means that there will be no blind drilling to be conducted in surface and production section, while in the reservoir section (12-1/4”) the drilling will be carried out even when encountering total loss circulation.

For the 26” and 17-1/2” section, the amount of water is calculated as follow:

Volume required = (Hole volume + Active system*) x 300%

The active system (mud tank and surface piping) is assumed to have the total volume of 2,000 bbls or around 318 m^3, while the 300% excess volume is the typical mud volume prepared by the mud engineer on the site.

For the 12-1/4” section, it is assumed that half of the hole section will encounter total loss and will be drilled blind. Therefore, the total volume required for drilling 12-1/4” section is as follow:

Volume required = ½ drilling duration x flow rate

Half of the 12-1/4” drilling duration is around 10 days, with the assumed flow rate required is 1,200 gpm. The result for this scenario is shown in the Table 2:

Table 2. Water quantity estimate for scenario 1.

Hole Section	Water Required
26”	1,416 m^3
17-1/2”	1,563 m^3
12-1/4”	69,173 m^3

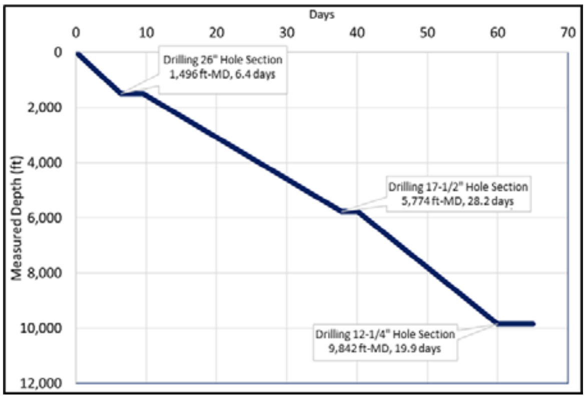

Figure 1. Typical time-depth curve for 3,000 mMD well.

3.2.2. <u>Scenario 2: Blind drilling along the half of each hole section</u>

The second scenario assumes that half of each hole section will encounter total loss circulation, thus there will be no fluid return to the surface. The result for the second scenario is shown in Table 3.

Table 3. Water quantity estimate for scenario 2.

Hole Section	Flow rate	Water Required
26”	1200 gpm	20,931 m^3
17-1/2”	1200 gpm	92,230 m^3
12-1/4”	1200 gpm	69,173 m^3

In practice, it is highly unlikely that the total loss circulation in 26” section will not be cured, as the drilling fluid pumped to the well has the potential to contaminate the groundwater. The utilization of aerated drilling also has the potential to reduce the amount of water to be used as there might be some fluid return to the surface.

3.3. Water Properties Requirement

The water is used for both drilling fluid and cementing. Therefore, the water properties are important to ensure that the drilling fluid and cementing can perform as designed. Apart from water compatibility with mud and cement, the water used or discharged from drilling activities should have no adverse effect to the environment. The typical water properties for drilling are as follow (Alamsyah, et al., 2020):

1. Should not contain any toxic materials such as Mercury [Hg], Fluorine [F], Boron [B], Arsenic [As], Cadmium [Cd], Aluminium [Al], Lead [Pb], etc. due to environmental concern;
2. The dissolved metal such as Fe, Cu, Pb, Zn, and Ag content should not be greater than 75 ppm;
3. The pH of the brine should be more than 5;
4. The density of the brine should not be greater than 8.5 ppg at a temperature of 25 ^oC;
5. The brine temperature should not be more than 40 ^oC;
6. Total hardness (Ca^{2+} and Mg^{2+}) content should not exceed 100 ppm.

Those requirements above mean that no untreated geothermal byproducts such as brine (or condensate in some cases) to be used as base fluid for drilling fluid and cement. It is better to have fresh water for drilling purpose, even then the water properties should be carefully monitored, as in volcano hosted geothermal system in Indonesia the water sources sometimes have very low pH (Putranto, Iswara, & Bismoyo, 2018; PT Geo Dipa Energi, 2019).

3.4. Water Transfer Infrastructure

Geothermal well generally has larger hole sizes and volumes, therefore the pump and pits/ponds to store the water is generally bigger than for oil well of comparable depth (Finger & Blankenship, 2010; Purba, Adityatama, Umam, & Muhammad , 2019). As shown in the Table 2 and Table 3, the quantity of water required for drilling is very high and it is highly unlikely that the water pond on the pad can accommodate it. Hence, instead of relying on the water pond on the well pad, it is important to have a capable water transfer system from the water source (rivers, lake, etc.) that can continuously supply the water at 1,200 gpm in case of the total loss condition. This is especially challenging as in most geothermal field in Indonesia, the water source is generally far from the well site and has very high elevation difference. Providing adequate water transfer system for geothermal drilling can be cost intensive.

NZS 2403:2015 dictates that the water supply used should have redundancy and backup equipment, and if there is only one set of water supply pumps available, the geothermal company should provide additional water storage and necessary piping to feed the water to the rig site. The water storage should be able to feed water to the rig site with the following requirement:

- Feed the water to the rig site at the rate adequate to quench and control the well;
- Have an adequate capacity that allows continuous quenching of the well for a period of no less than 12 hours.

Note that NZS only dictates the water storage should be enough to provide continuous quenching of the well, not necessary to continue the drilling. The inadequate water supply might stop the drilling and prolong the drilling operation, thus increasing the total drilling cost (Adityatama, Purba, Muhammad, Wiharlan, & Pasmeputra, 2020).

4. CHALLENGES IN PROVIDING RELIABLE AND ADEQUATE WATER SUPPLY FOR DRILLING

Geothermal prospect areas in Indonesia is mostly volcano hosted with high relief terrain (Umam, Muhammad, Adityatama, & Purba, 2018). This poses unique challenges as the well pad is located in mountainous area, with the water source situated far and in the lower elevation. The geothermal areas in Indonesia are also generally located in the protected forest, making the environment and social issue become critical.

4.1. Water Source Location

The distance and elevation difference of well pad and water source is proven to be very problematic for the geothermal developer, as it might require a lot of booster pump to be able to provide adequate water supply.

4.2. Water Usage by Local Community

Even if there are the fresh water source for drilling, it is likely that the water is also being used by the local community. Authors' experience in some geothermal drilling preparation planning shows that this might not be an issue during rainy season but will become a serious problem during dry season. However, if the flowrate of the water source is also limited even in the rainy season, the geothermal company will be unable to obtain water from that source at all. This is especially true for eastern parts of Indonesia such as southern part of Sulawesi and Nusa Tenggara islands, which are classified as equatorial savannah with dry winter climate (Putranto, Iswara, & Bismoyo, 2018). These areas are typically having very little freshwater sources such as lake or river available throughout the year.

4.3. Low pH Water

As the fresh water with neutral pH water is most likely have been used by the local community, the remaining options are to utilize the water source with less preferable properties, such as low pH. This kind of water source is less likely to be used by local community, as it might cause health problem. The source of this acidic water can be from volcanic crater lake, or river with low enough pH (<4).

Even though this water source might be used without any problem with the local community, but it requires certain precautions to avoid any damage or problems in drilling equipment. A proper treatment is required to increase the pH of the water and the pump should use a corrosion resistance material for the liner and/or impeller.

4.4. Case Study

4.4.1. <u>Ijen, East Java</u>

Slimhole drilling campaign in East Java was conducted in 2016-2017 period. The water source for drilling is located 17 km from the well pad site and transported by truck. This caused problem as during total loss circulation, the drilling had to be stopped if the water pond had been emptied and the truck had not arrived yet (Sunarso, 2020).

The decision to invest in construction of water transfer facility from the water source was complicated at the moment, as the field is still in the exploration phase. The requirement to invest a high amount of capital for water supply infrastructure should be carefully considered with regards to the potential drilling problems or even steam kick or blowout.

4.4.2. <u>Way Ratai, Lampung</u>

Way Ratai is a geothermal field located in Lampung Province, Sumatra. During authors' experience in surveying the water supply and the well pad area, the water source is located at 9.83 km from the furthest well pad, with 317 m elevation difference (Figure 2 and Figure 3).

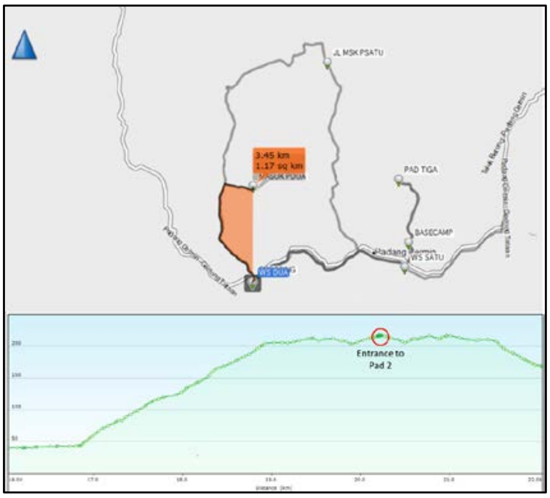

Figure 2. Water source to the well pad 2 distance.

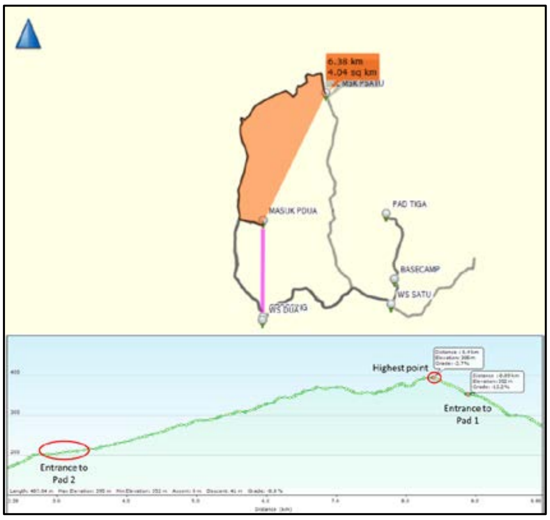

Figure 3. Water source to the furthest well pad distance.

One potential problem identified during site survey in Way Ratai was that the water source is adjacent to the community settlement. This can become an issue as the developer will put water pump in those areas and will disturb the local community (Figure 4). The geothermal developer has to install a pump house to reduce the noise and even pay some compensation for the disturbance to the local community. In Way Ratai context, the water pipeline is most likely to be built across the provincial road that require other permits to the local government and community. Failure to do so may cause the water supply infrastructure construction and/or operation to be stopped by locals, further delaying the whole project.

4.5. Sokoria

Sokoria is situated in Flores Island, Nusa Tenggara. As shown in Figure 11, Flores Island is classified as savannah dry winter climate. Finding a reliable water supply was proven to be quite challenging due to the following reasons:

- The river with neutral pH has a small flow rate (300 – 600 gpm) and is used by the local community, so it cannot be used by the developer.
- The remaining river that is not being used by the community has very low pH of 2 and is located at around 8.5 km with 300 m elevation difference (Figure 7). However, this water source has a relatively high flowrate (8000-9000 gpm).

The summary of the water sources candidates for drilling in Sokoria is shown in Table 4. Figure 5 shows the water supply survey in one of the rivers with preferable properties (neutral pH). However, the flow rate is very small (~300 gpm) and will not be enough to support drilling activity. Moreover, the water is also used by the local community. On Figure 6, the river has an adequate flow rate, but with a pH of 2.

Figure 4. One of the river assessed in Way Ratai. Note that the river is located directly behind the settlement.

Table 4. Potential water supply candidates in Sokoria.

WDS	Location	Latitude	Longitude	Elevation (masl)	Elevation difference to MTB A wellpad (m)	Road Distance to MTB A wellpad (m)
WDS-01	Nua Sada/Pancoran Wawotune	8°47'13.59"S	121°46'5.34"E	1160	100	1,175
WDS-02	Tecoleco	8°47'15.73"S	121°46'8.42"E	1111	51	1,100
WDS-03	Pancuran Mbujaria	8°48'29"S	121°46'38"E	990	-70	6,595
WDS-04	Loworia (Sokoria)	8°47'40.79"S	121°46'16.40"E	858	-202	3,746
WDS-05	Loworia (Roa)	8°46'10.6714"S	121°43'59.581"E	740	-320	13,700
WDS-06	Aebai (Roga)	*to be confirmed*	*to be confirmed*	686	-474	11,546

Flowrate (GPM)	26-Oct-16	3-Nov-16	4-Nov-16	31-Mar-17
WDS-01				
Timed-gravimetric/Volumetric	2.5			
WDS-02				
Area velocity (floating object)	62.2			
Area velocity (flowmeter)		57.7		
WDS-03				
Timed-gravimetric/Volumetric	8.3			
WDS-04				
Area velocity (floating object)	228.5	896.8		
Area velocity (flowmeter)		659.9		
WDS-05				
Area velocity (floating object)			8,735.2	
Area velocity (flowmeter)			9,725.0	
WDS-06				
Area velocity (floating object)				9,136.7
Area velocity (flowmeter)				6,479.5

Figure 5. Flow rate measurement and survey for fresh water supply in Sokoria.

Figure 6. Flow rate measurement on of the rivers. The flow rate is adequate but has a pH of 2.

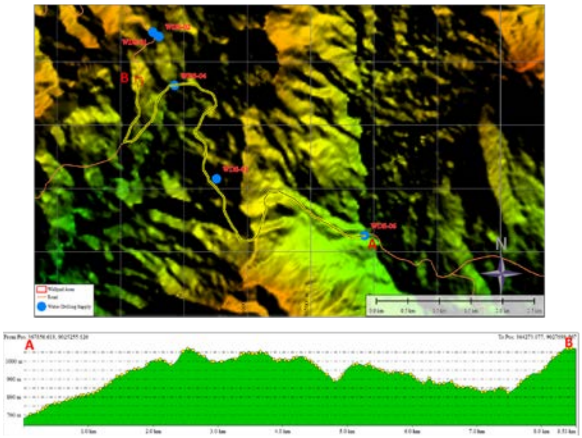

Figure 7. The distance and elevation profile of the acid river with the well pad.

4.6. Dieng

Dieng is a geothermal field in Central Java highlands at an elevation of 1800-2100 m above sea level. The field was initially developed in the 1990s. Currently, most of the plateau is intensely cultivated and there are a lot of villages and farms nearby the geothermal facilities (Hino, Itoi, Tanaka, Pambudi, & Khasani, 2013). In 2020, further development for Dieng Unit 2 is currently underway.

The problem with a brown field such as Dieng is that there are already a lot of settlements nearby, thus the water is also used by local community. Other water sources in the vicinity of geothermal facilities are acidic lake such as in the Merdada pond (Table 5).

Table 5. Surface water bodies nearby Dieng Geothermal Facility (PT Geo Dipa Energi, 2019).

Water Body	Characteristics & flow rates	Suitability for drilling
Merdada pond	Acidic water, important irrigation water source	Not suitable
Warna pond	Acidic water	Not suitable
Pengilon pond	Acidic water	Not suitable
Cidolok river	Main river in the project area; 80-120 L/s average flow rates; main water source for farmland irrigation. Water extractions point already constructed	Suitable, with extraction restrictions (max. 20L/s during normal operation, no extraction during dry season)
Tulis river	2.5km from project area; 100-150 L/s average flow rates; important water source for farmland irrigation; water extraction points already constructed.	Suitable, with extraction restrictions (max. 20L/s during normal operation, no extraction during dry season)
Urang river	Very low flow rates	Not suitable

The average annual rainfall on the Dieng Plateau is around 260 cm, however, during dry season it can be as low as 3-8 cm per month. The potato agriculture in Dieng relies exclusively on the precipitation as the freshwater aquifer is very deep in Dieng (PT Geo Dipa Energi, 2019). The underground sources on the Dieng area is also prone to high H_2S content.

As the agriculture industry is very important for the local community, Cidolok and Tulis river cannot be extracted during dry season, thus further complicating the drilling planning for Dieng Unit 2. To address this issue, other water sources should be identified. Several alternatives identified are:

- Utilising condensates from Unit-1 (can be up to 30 L/s flow rate). However, the water properties should be considered whether it requires further water treatment or not.
- Utilising brine from production well. This requires a complex water treatment plant as the geothermal brine contains a very high amount of dissolved solid and even heavy metal (Alamsyah, et al., 2020).

5. POTENTIAL MITIGATION OPTION

From the case study and literature review, typically water is in a short supply in the geothermal prospect area, while it is very critical for geothermal drilling for well control and prevent other drilling problem. Therefore, it is important to identify and provide water sources alternative to ensure enough fresh water for drilling. This study identifies several alternatives that can be used to ensure reliable water supply for drilling. Those alternatives can be used separately or in combination, depends on the water requirement and the actual condition on the drilling site.

5.1. Construct Robust Water Transport Infrastructure

After all water sources are identified and mapped, it is important to ensure that the water transfer system is properly built. Case study in Ijen showed that having a transfer pump with a pipeline is preferable instead of transporting the water using tank truck to ensure continuous water supply. The flowrate of the water source, distance and elevation difference between well pad and drilling site should be accurately measured to prevent any issues during operation (e.g. lack of booster pump due to higher head loss than expected). The pipeline specification and pump material should be carefully taken into account during engineering design process, as some water source might have lower pH and can be detrimental to pump and pipeline.

5.2. Drill Ground Water Well

If possible, drilling a water well can be an interesting proposition as it may not necessarily interfere with local community. However, authors' experience so far in geothermal projects in Indonesia never found any geothermal drilling that used artesian well.

5.3. Construct Water Treatment Plan for Acidic Water

In Eastern parts of Indonesia with equatorial savannah dry winter climate, the only viable water sources are the acidic volcanic crater lake with very low pH. To address this, Putranto et al., (2018) proposed a water treatment for acidic lake water with NaOH dosing (Figure 8).

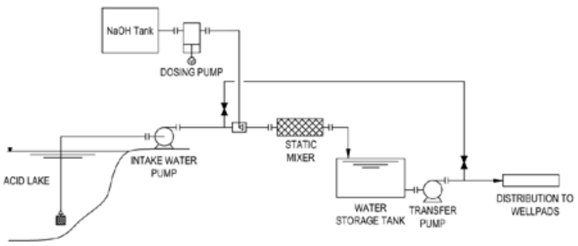

Figure 8. Water treatment system for acidic lake water proposed by Putranto et al., (2018).

This extra water treatment plan will surely require extra capital in the exploration phase. Therefore, its economic viability should be assessed first whether it is more economic to provide water treatment plant or other alternatives such as long pipeline and series of pumps.

5.4. Water Treatment Plant for Produced Brine

For a brown field with existing power plant unit such as in Dieng, the produced brine generally offers enough flowrate to cover drilling fluid requirement. However, it is most likely containing a lot of dissolved solid such as silica and other heavy metals, making it unsuitable to be used directly for

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drilling. As with acidic lake water treatment plant, the brine can be treated first to remove dissolved solid and heavy metals, with reverse osmosis as one alternative (Figure 9).

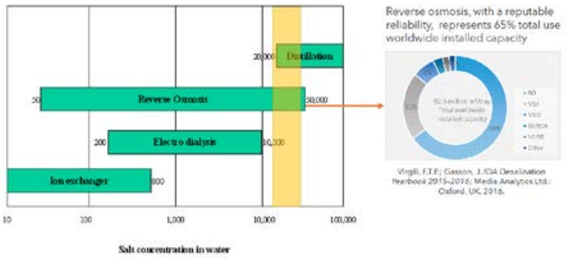

Figure 9. Typical water treatment type based on Dieng brine properties (LKFT UGM, 2019).

5.5. Ensure Good Communication with the Locals

Most of geothermal prospect area in Indonesia are located near people's settlement. Any installation of water transfer infrastructure such as Water Pump Station (WPS) and pipelines will surely disturb the local community in the form of noise, obstruction in the roads, etc. Ultimately, the water extraction from surface water sources such as river and/or lake can also be detrimental if the water is used by the locals for agriculture purposes such as in Dieng and Sokoria.

Therefore, it is crucial that the geothermal developer build and maintain a good relationship with the local community and inform the potential impacts that might rise from the drilling activity. Sometimes, it is necessary to give compensation for any discomfort the people suffer due to the water supply infrastructure construction and operation.

6. SUMMARY

This study has given a brief overview of the importance of having a reliable water source in geothermal drilling, the typical estimate quantity required, and the requirement for the water transfer infrastructure needed. Generally, the water quantity required during total loss circulation cannot be 100% accommodated by the water pond constructed in the well pad. Therefore, it is important to have a reliable water transfer infrastructure instead to ensure continuous water supply for drilling.

Several challenges that might be encountered in finding and securing water sources for drilling are as follow:

- The fresh water source might be located very far from the well pad and the elevation difference is very high. This might cause expensive investment in building water transfer system due to requirement of having a lot of pumps and pipeline.
- The fresh water with neutral pH water is most likely have been used by the local community, the remaining options are to utilize the water source with less preferable properties, such as low pH.
- Even if there are the fresh water sources available for drilling, it is likely that the water is also being used by the local community. In the dry season extracting water from this source is unlikely.

To address the difficulties in securing water supply for geothermal drilling, the following alternatives can be used:

- Construct robust water transfer infrastructure with enough redundancy.
- Drill ground water (artesian) well if possible.
- Construct water treatment plant for water from acidic volcanic lake.
- Construct water treatment plant for produced brine if possible.
- Maintain a good relationship with local community.

Each of those options can be done in conjunction with each other alternatives. Further technical and economic feasibility study should be conducted to assess whether the selected option is the most cost-effective but still guarantee drilling success.

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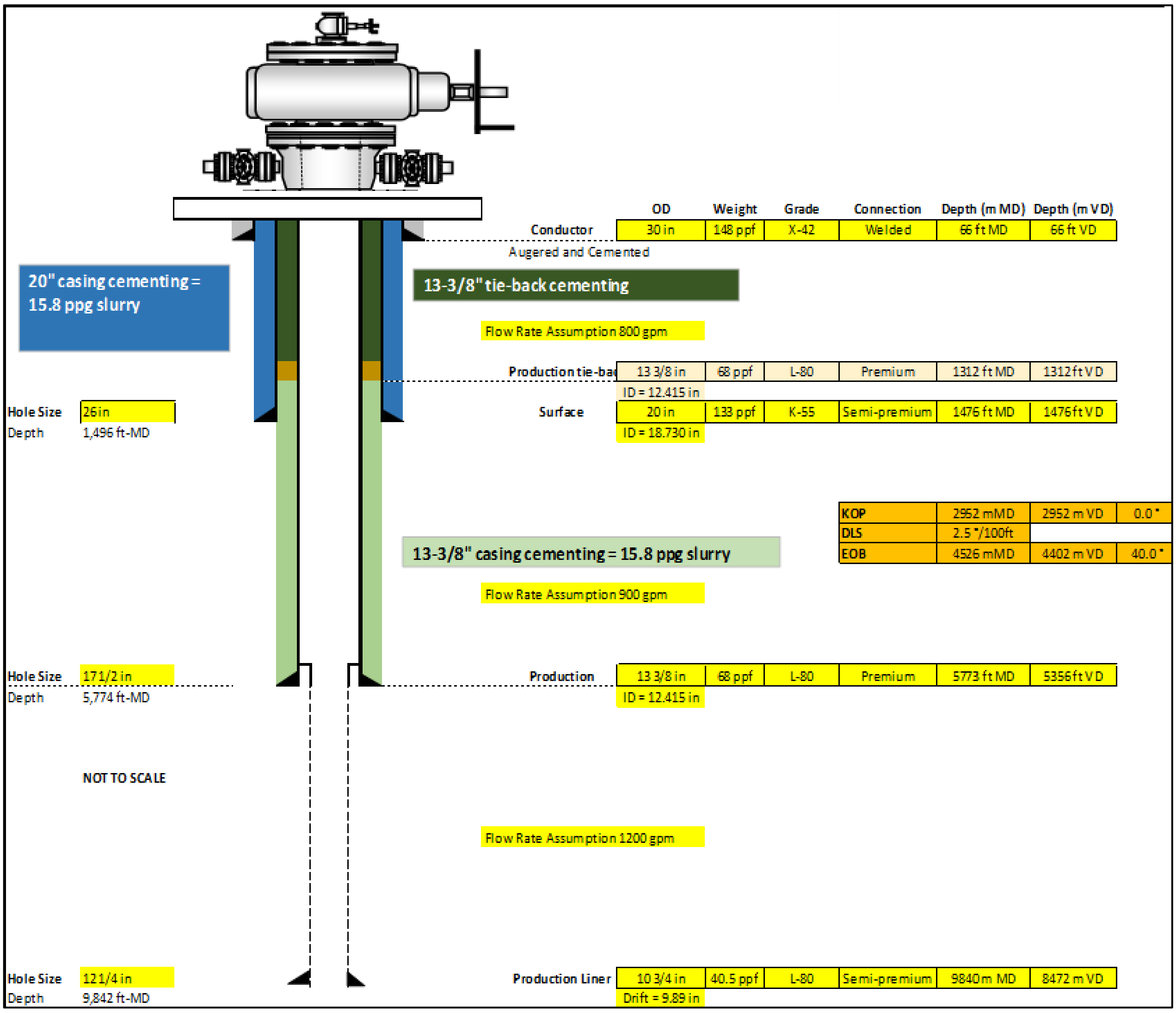

Figure 10. Typical big bore geothermal well in Indonesia (Alamsyah et al., 2020).

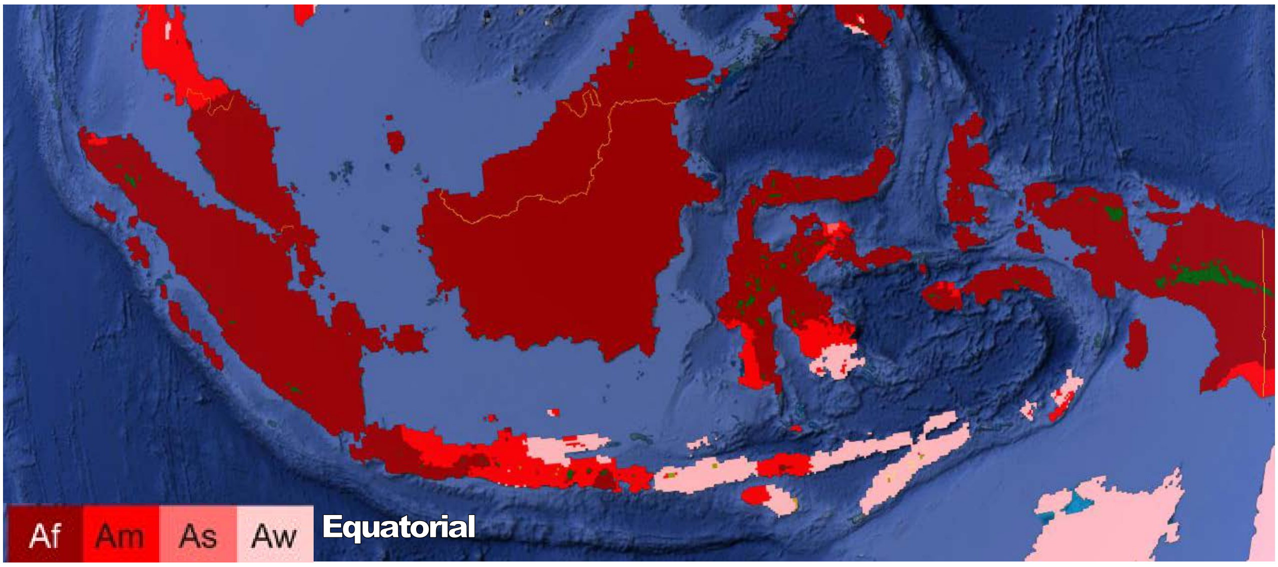

Figure 11. Koppen-Geiger classification of Indonesia area. Note that some eastern part of Indonesia are equatorial savannah dry winter (Putranto et al., 2018)