INFRASTRUCTURE PREPARATION OF GEOTHERMAL ENERGY DEVELOPMENT IN INDONESIA

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ABSTRACT

Indonesia has around 29.2 GWe of potential geothermal energy distributed in 276 locations along the volcanic belt running from Maluku to Sumatera. Most of the geothermal concessions are at the development phase hence drilling activities are expected to commence in the near future. In line with this, infrastructure preparation has to commence at the soonest possible time. Geothermal developers in Indonesia have to cope with some hurdles and obstacles regarding soil works in this infrastructure preparation phase. Geotechnical hurdles can happen any time and may have serious ramifications on the geothermal exploration and development activities In order to address this matter, site assessment can be implemented prior to site selection. The data gathered during site assessment can help the developers choose the best strategy for designing the infrastructure. Site selection has to be consistent with the initial development plan on which the permit was based. Lack of information regarding the geothermal project site could lead to problems. Hence data gathering should be undertaken in the early stages of the project. Mitigation of the risks should be considered as a part of the geothermal development. Information about the site candidates correspond with the steam source information will significantly reduce the risks resulting from geotechnical hurdles.

1. INTRODUCTION.

Indonesia has abundant sources of geothermal energy which are related to both extinct and active volcanic systems that are distributed throughout the archipelago. There are around 29.2 GWe of geothermal energy potential distributed in 276 geothermal locations along the volcanic belt running from Maluku to Sumatera. This makes Indonesia the potentially the largest user of geothermal energy in the world (ESDM, 2011).

Indonesian geothermal prospect selection for exploration studies were based on earlier reconnaissance surveys by geochemists and geophysicists. Indonesia is a geologically complex region located at the intersection of three major tectonic plates and bordered by tectonically active zones characterised by intense seismicity and volcanism resulting from crustal subduction (Brophy *et al*., 2011). Brophy *et al*. (2011) explain that geothermal concessions in Indonesia are predominantly associated with the volcanic chain that extends along the central and southern portions of the islands of Java, Bali and Flores, and along the south western margin of Sumatera.

The potential of geothermal areas in Indonesia are classified into five categories by “Standard Nasional Indonesia” (Indonesian National Standard) SNI 13-5012-1998. These are: speculative resource, hypothesis resource, probable reserve, possible reserve and proven reserve, as given in Table 1.1. Those categories depend on the stage to which the resource investigation has progressed.

Table 1.1: Indonesia’s geothermal energy potential (Kementerian ESDM RI. (2011))

Resource		Reserve		
Speculative (MWe)	Hypothesis (MWe)	Probable (MWe)	Possible (MWe)	Proven (MWe)
8,905	4,391	12,756	823	2,288
13,296		15,867		
45.57%		54.43%		

Despite the large potential which is listed in the Table 1.1, only 1,226 MWe of geothermal energy capacity have been developed (ESDM, 2011). This is just a small fraction of the total potential of the country and a large portion still remains to be developed from other geothermal areas.

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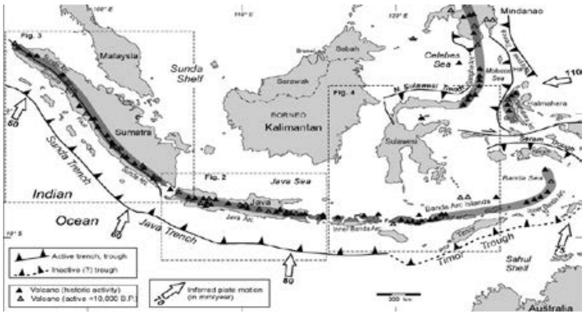

Figure 1.1: Principal geographical features of Indonesia showing plate tectonic structure and location of active volcanic arcs, source Hamilton, (1979); Simkin and Siebert (1994); Hall (2002) (as cited in Hochstein and Sudarman, 2008).

As shown in Figure 1.1, Hochstein and Sudarman (2008) showed that development areas of geothermal energy in Indonesia tend to lie on the slopes of volcanoes with high elevation. Furthermore, about 80% of the geothermal concession and geothermal prospects in Indonesia are associated with active volcanoes (Wahjosoedibjo and Hasan, 2012). Consequently, landslide hazards are widespread and pose a serious problem for geothermal development.

Indonesia has a geothermal energy development program which targets a generation capacity of 4,600 MWe by 2016, then increasing further to 9,500 MWe by 2025 (Brophy *et al.*, 2011). In order to achieve this goal, many geothermal exploration activities which could lead to development have been initiated. Part of these geothermal exploration activities is the infrastructure construction for drilling activities.

2. GEOTHERMAL DEVELOPMENT ACTIVITIES.

Geothermal systems are developed to utilise heat sources below the earth. DiPippo (2012) noted five important steps should be accomplished during the exploration for geothermal energy, namely: locate the areas underlain by hot rock; estimate the reservoir's volume, fluid temperatures, and formation permeability; predict whether the phase of the fluid from reservoir will be dry steam, liquid or a two phase mixture; determine the chemistry of the fluid; and forecast the electric power potential for a minimum of 20 years. Once a prospect area has undergone the five steps above and with favorable results, one of the next things that developers have to take into consideration is the risk of landslide.

2.1 Phases of geothermal energy development

Developers of geothermal energy in Indonesia have to undergo several stages of development before being able to extract steam from the geothermal reservoir. After the concession is obtained, detailed exploration has to be carried out. The flowchart in Figure 2.1 below shows the typical stages of geothermal development in Indonesia.

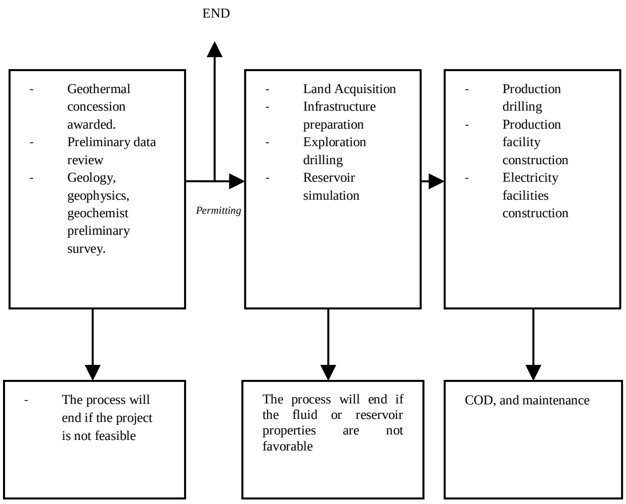

Figure 2.1: Typical geothermal energy development stages in Indonesia (simplified)

As shown in the diagram in Figure 2.1, land acquisition and infrastructure preparation will be undertaken after the developer has obtained the permit from authorities. In the permitting process, the government authorities require that a plan for infrastructure development and land acquisition will be prepared. A developer is then restricted to operate only in the location indicated on the development map. In order to mitigate the risk of the landslide, it is advisable to have the geohazard assessments of the site carried out early and prior to the preparation of the development plans.

2.2 Infrastructure required in geothermal exploration drilling.

In the exploration drilling stage, information pertaining to the underground reservoir and the type of fluid will be acquired leading to an estimate of the megawatt potential of the field. The data gathered from the exploration drilling activities are important for the numerical reservoir simulation studies whose results are part of the important factors considered for the go or no-go decision for the next stage of activity as shown in Figure 2.1 Geothermal well drilling activity involves various pieces of heavy equipment and complex processes, that must be supported with adequate infrastructure.

The geothermal drilling rig consists of the rig itself, as well as supporting contractors and equipment. Since geothermal well drilling locations are predominantly in remote areas, mobilising equipment became a matter of great interest. Drilling rig equipment is normally mobilised by heavy trucks to the drilling location. For example, PT. PGE (Pertamina Geothermal Energy) utilises a land skid-mounted drilling rig with 1500 HP capacity. This is large heavy equipment with a height of 41.45m – 43.28m (136 – 142 ft).

Material supply for drilling activity should be considered as well. The most important drilling material is the drill pipe. Most drill pipe lengths and casings are classified according to API standard range 2 (8.2 – 9.2 m/27 – 30 ft). Fuel is usually supplied daily. For drilling the fuel consumption is 10,000 – 15,000 litres per day.

If the exploration stage proves that development is feasible, more construction activities will follow. For example, the power station and steam gathering system will be built in the area. The load on the road and any bridges will increase, and so temporary roads must be designed with provision for a possible upgrade. The range of infrastructure which is mandatory for exploration activity is discussed below.

2.1.1 Road Access to the drilling location

Road access to the location must be capable of being weighed down by heavy vehicles carrying the above mentioned equipment. Macadam with a layer thickness of 25– 30 cm is enough for temporary roads which are weighed down with heavy trucks bearing 6 X 6 axles. In addition to pavement, vertical and horizontal alignments are also important. The road alignment must be designed in such a way that it is able to accommodate the vehicle's manoeuvres. Usually the slope or vertical alignment is no more than 14 %.

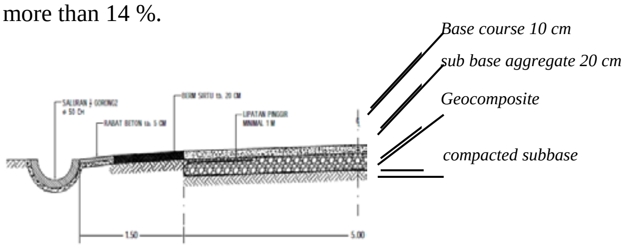

Figure 2.2: Typical road section pavement design for temporary road, Lumut Balai Project 2009, PT. PGE.

Figure 2.2 shows temporary road pavement design which utilises the "*geocomposite*" layer between compacted existing soil and aggregate. *Geocomposite* is a combination of the best features of different materials, usually using geo-synthetic materials such as a geo-textile and geo-membrane. Weather conditions, which are predominantly rainy most of the year in Indonesia, have to be taken into account. The drainage facility has to be capable of preventing water from staying on the road. If this happens, the road pavement will weaken each day and its failure will eventually disrupt the drilling activity.

Road construction must follow the road route described in the map attached to the permit. Occasionally, road construction activities face issues of earth works and soil layer problems. Inappropriate road design will generate difficulties during the rig mobilisation, especially during the rainy season as shown in Figure 2.3. Where bridges need to be built, these must also be designed to be loaded with heavy equipment as stipulated in the standard code.

Figure 2.3: Muddy terrain is a common issue encountered in rig mobilisation during the rainy season.

2.1.2 Drilling Location and drilling crew facilities.

Well pad locations must be paved properly and levelled flat with enough space for the drilling equipment and material supply.

Crew facilities such as portable camps should be ready before the start of exploration drilling. The site for the portable camps require a fence, drainage, waste disposal, and domestic facilities. For activities to be carried out in the middle of the jungle, the safety and security of the crew must be of top priority.

Some important facilities have to be prepared at the drilling location as shown in Figure 2.4 as follows:

1. Area pavement (approximately 120 m X 70 m)
2. Well cellars (well head infrastructure to support the drilling rig)
3. Drainage facilities
4. Water pond
5. Water disposal

Figure 2.4: Drilling location preparation.

2.1.3 Water pump station and drilling water supply pipe installation.

Geothermal well drilling requires vast quantities of water. Sometimes the location of drilling is far from a source of water. In Indonesia, the potential water source needs to be identified early on and indicated on the principal permit documents. Drilling water for several locations is supplied by water pump stations. Pipes for drilling water supply are commonly 15.24 cm diameter (6” diameter) galvanized pipe welded to each other and laid down above ground along the road to the drilling location.

3. SITE ASSESSMENT

After the steam source has been assessed and the feasibility for developement has been determined, the developer needs to determine the location of the exploration wells and the infrastructures necessary to execute the next activities. Before a planner undertakes any design work of facilities for the project, adequate information about the locations has to be gathered first. The main purpose of the site assessment in the early stages of geothermal development is to assist in identifying the best locations for the different facilities that are to be built. The factors affecting the choice of this location include safety.

3.1 Desk Studies as preliminary assessment.

Subsurface information and geotechnical data are always indispensable during the planning and the development stages of any type of site investigation (Sara, 2003). Those data will affect site selection and design and construction of the facilities.

Historical data review is one of the most important steps in the desk study stage. From the historical data, the planner can forecast the risk of similar occurrences in the future. Review of a detailed map is also important at this stage. Instead of using a rough large-scale topographical map, the geothermal developer should utilise a detailed topographical map. Acquisition of this detailed topographical map is commonly difficult for geothermal developers in Indonesia because geothermal concessions are mostly located in rain forest and mountainous areas. In addition, 70% of the 256 geothermal locations in Indonesia that are located in particularly remote areas have not been surveyed in detail yet (Wahjosoedibjo & Hasan, 2012). The conventional way of ground mapping is a possible workaround but this activity is not without challenges. An alternative means to obtain contour maps is the topographical mapping method that uses the Light Detection and Ranging (LIDAR) technology. The importance of this preliminary data is often overlooked in the desire to accelerate the development and as a result of a tight drilling schedule.

Using the information gathered during this phase, planners can make the conceptual geologic models of different candidate locations. This can then be considered during the initial site selection process. From the site conceptual geological model, the detailed map, and other relevant data obtained during this initial stage, the plan of field investigation can be prepared before engineers visit the site that will be investigated. The information gathered from the site assessment phase can be used for further studies and activities in order to prepare the site and to avoid the risk of a landslide in the geothermal location.

3.2 Site Investigation

During the initial stages of the site investigations, all relevant data gathered in previous stages should be utilised as base data of the field investigation. Additional data will be collected in this phase to reinforce or confirm the information gathered from the previous phase and iron out some details of the location of interest. A soil investigation is a part of the site investigation process suggested by Fell and Walker (1987).

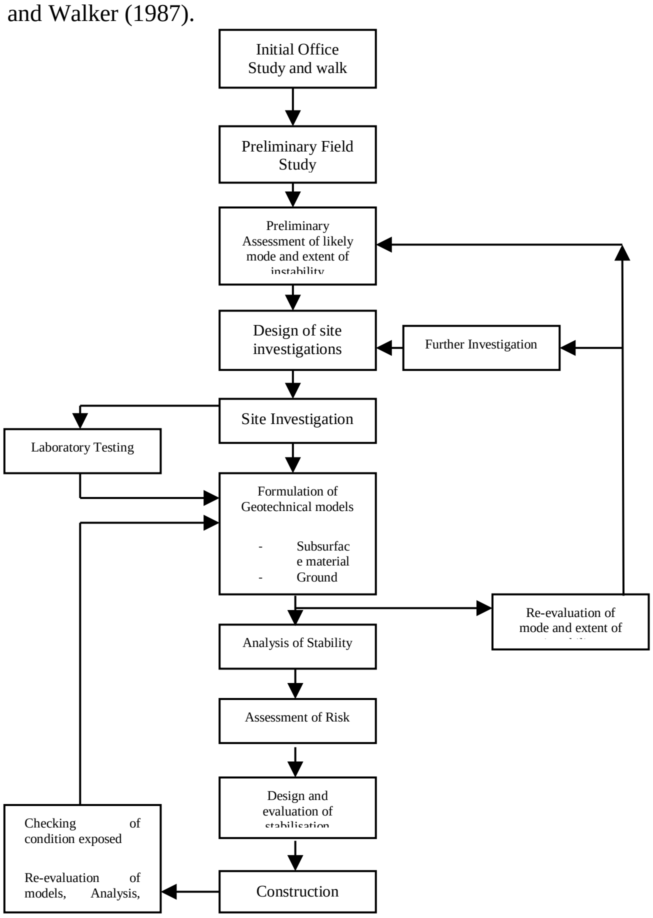

Figure 3.1: Methodology of Study for Slope Instability Problems. (Fell & Walker, 1987).

This process (shown in Figure 3.1) outlines the common methodology that is required during site preparation, especially when the planner designs a site in mountainous topography in which slope instability is of major concern. The scope of soil investigation depends on the type, size and the design of the above-ground construction.

The report of the initial soil investigation can be utilised as benchmark data for monitoring and evaluating the impacts of the construction activity.

3.3 Site Selection

Selecting the site for geothermal development combines information on ground surface stability and the underground steam source. The aim for the geothermal exploration is to locate the area containing high temperature and pressure fluids in the underground reservoir. The location of this high temperature geothermal resource is always the first consideration in site selection. The site assessment carried out in previous stages will provide adequate information regarding potential hazards or failures for the site that will be selected.

From the slope stability criteria evaluation planners can generate a report and the recommendation for the site selection.

4. SUMMARY

Geothermal utilisation as a source of energy in Indonesia started almost a hundred years ago and has continued to grow until today. It has been estimated that less than 5 % of the total number of potential of geothermal prospect have been developed and are producing electricity. Therefore, there is still a huge amount of geothermal potential that is waiting to be utilized. The location of the geothermal concessions in Indonesia brings several challenges. Just like some other geothermal location around the world, geothermal prospect in Indonesia are predominantly located in mountainous areas. This results in a possibility of landslides among other geological hazards. Experience of landslide occurrences in other geothermal areas around the world has proved that they can have serious ramifications for geothermal developments.

Infrastructure preparation and drilling preparation are the initial construction activities in the geothermal development. These construction activities follow after the geothermal exploration activities have successfully demonstrated the existence of an exploitable resource. Geothermal exploration drilling involves heavy equipment. This requires adequate temporary roads so that this equipment can be mobilized to the drilling site. Appropriate well pads are also needed for the rig and heavy equipment.

In order to mitigate landslide risks during geothermal development activities, site assessment is required. Site assessment at the start of the initial phase of geothermal development will provide information that is useful for decision makers to make development plan

5. CONCLUSIONS

Some conclusions can be drawn based on this study as follows:

- Geothermal concessions in Indonesia are predominantly located in mountainous area, associated with volcanoes.
- It is very important for site assessment to be undertaken at the start of a geothermal development.
- In order to mobilise and set up heavy equipment for exploration drilling, appropriate infrastructure, drilling facilities, and well-pad planning are needed.

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