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Feed Sharing Limit for Geothermal Wells in Bacon-Manito, Philippines

Eden G. Baliatan-Sernadilla, Julius John T. Dimabayao, Christine Marie R. Espartinez and Madelaine C. Cerio

Energy Development Corporation, One Corporate Center, Julia Vargas cor. Meralco Ave, Ortigas, Pasig City, Philippines

baliatan.eg@energy.com.ph, dimabayao.jt@energy.com.ph, espartinez.cmr@energy.com.ph, cerio.mc@energy.com.ph

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ABSTRACT

The point-to-point separation between wells that intersect similar feed zones is crucial during well-design preparations to eliminate the risk of production interference. When feed sharing occurs, the total output from the new well becomes less than expected. In some cases, this may lead to output decline of the adjacent wells.

To eliminate or reduce risk of feed sharing, a minimum point-to-point separation of ≥ 300 m between wells along common feed zones has been implemented in designing Energy Development Corporation (EDC)-owned geothermal wells as adopted from a previous drilling interference study from one of its fields. However, given a finite resource area and the need to drill more wells to maintain and manage steam supply requirements to power plants, this separation has become a challenge to achieve. Therefore, it is the aim of this study to establish an optimum point-to-point separation along common feed zones for Bacon-Manito (BacMan) geothermal wells by assessing well production data from Pad 1 where a collapsing production well D is suspected to be sharing feed zones with other wells.

The calculated optimum separations are validated for future well design considerations. Factors that possibly enhance or reduce feed sharing such as fault characteristics and reservoir rocks that are specific for the Bacon-Manito geothermal field are also identified. The methods utilized in this study will be further assessed for applicability in other EDC geothermal fields where optimum point-to-point separation as not yet been established.

1. INTRODUCTION

Exploration in BacMan geothermal field started in 1977 with several geoscientific surveys being carried out over an area of 200 km^2. However, commercial exploitation only began in 1992 when the BacMan-1 FCRS was commissioned. To date, the field has a total installed capacity of 140 MWe.

Geothermal wells in BacMan derive its hot fluids from volcanic-hosted reservoir and are typically being channeled to the surface thru faults and fractures. Some of these wells obtain fluids from common feed zones hence the occurrence of production interference or feed sharing. It is the tendency of wells to share from the same feed zone such that instead of adding more to the total yield, the new well is just sharing with the output of the existing wells. In some cases, this leads to output decline of existing wells. When this occurs, it did not only fail to augment the steam supply of the power plant but it also has a negative impact to the business economics due to the costly price of drilling a geothermal well.

In 2016, a study on production interference was done in EDC's Leyte geothermal field where responses of existing wells upon cut-in of new wells were observed and analyzed. It is noted that feed sharing often occurs in wells with < 100 m separation along common feed zones but does not always result to total output decline. For areas that are productive with highly permeable feed zones, production interference does not pose a concern. The study suggested an optimum separation of ≥ 100 m along common feed zones. However, a ≥ 200 m separation is recommended for long term sustainability (Amora et al. 2011, Amora et al., 2011, Amora and Uribe 2016).

During well design preparations, a minimum point-to-point separation of ≥ 300 m between wells along common feed zones has been implemented in designing EDC geothermal wells as adopted from previous drilling interference study from one of its fields. However, given a finite resource area and the need to drill more wells to maintain and manage steam supply requirements to power plants, this separation has become a challenge to achieve. This study aims to establish an optimum point-to-point separation for BacMan geothermal wells along common feed zones. Data such as output-, mass flow- and steam flow- trend over time were assessed for wells in Pad 1 where Well D is suspected to have interference among its nearby wells. This separation will then be used as the new basis for designing future wells to ensure that the risk of feed sharing will be reduced or eliminated. Factors that possibly enhance or reduce feed sharing such as feed zone characteristics and reservoir rocks that are specific for the BacMan geothermal field are also identified. The methods utilized in this study will be further assessed for applicability in other EDC geothermal fields where optimum point-to-point separation has not yet been established.

2. STUDY AREA

The BacMan geothermal field, one of the geothermal fields of the Energy Development Corporation, is located in southern Luzon Island, Philippines (Figure 1). It is situated in a 25,000 hectares reservation area within the Pocdol Mountains between the towns of Manito, Albay and Sorsogon City, Sorsogon in Bicol Region (Espartinez and See 2015). The Pocdol Mountains is part of the northwest trending Bicol Volcanic Arc and underlain by intercalated altered andesite lavas and tuff breccias with occasional limestones, calcareous clastics and sedimentary breccias (Santos and Dimabayao 2011).

The structures within BacMan geothermal field are largely influenced by two major tectonic features, the left-lateral strike-slip Philippine Fault and the west-dipping Philippine Trench**.** Lagmay et al. (2005) provided a comprehensive assessment of the regional structural setting of the Bicol Basin where BacMan is located. Structural analysis suggests that the Bicol Basin is controlled by a maximum horizontal stress (σ_1) oriented in an east-northeast direction (Lagmay et al. 2005).

The BacMan field has been proven to be a geothermal system that is structurally controlled. Within the field, the most prominent regional trend is an extension of the San Vicente-Linao Fault (Ferrer et al. 1986), a northwest trending transtensional splay from the Philippine Fault. This extension is locally known as the BacMan Fault Zone and confirmed to be one of the most permeable structures in the field.



Figure 1. Bacon-Manito geothermal field is located at the southern Luzon, Philippines.

Several wells were drilled to sustain the installed capacity of BacMan. A total of 6 wells were drilled from Pad 1 (Figure 2) since 1984. Most of the wells drilled through intercalated volcanic deposits in the upper parts and through compacted sandstones near the bottom. The latest well drilled was Well D in July 2011, which intersected three feed zones. Other wells in the pad such as Well A, Well B and Well C on the other hand intersected four to five feed zones. Discharge fluid of Well D suggests that it is liquid saturated as opposed to its nearby wells which have two-phase component. Hence, Well D output was lower.

During the medium term discharge (MTD) until its recent activities, Well D showed cyclical behavior, with mass flow and enthalpy peaking and falling at irregular intervals (Lagamayo and Dimabayao 2017). Production interference with nearby wells may have contributed to this cyclic behavior.

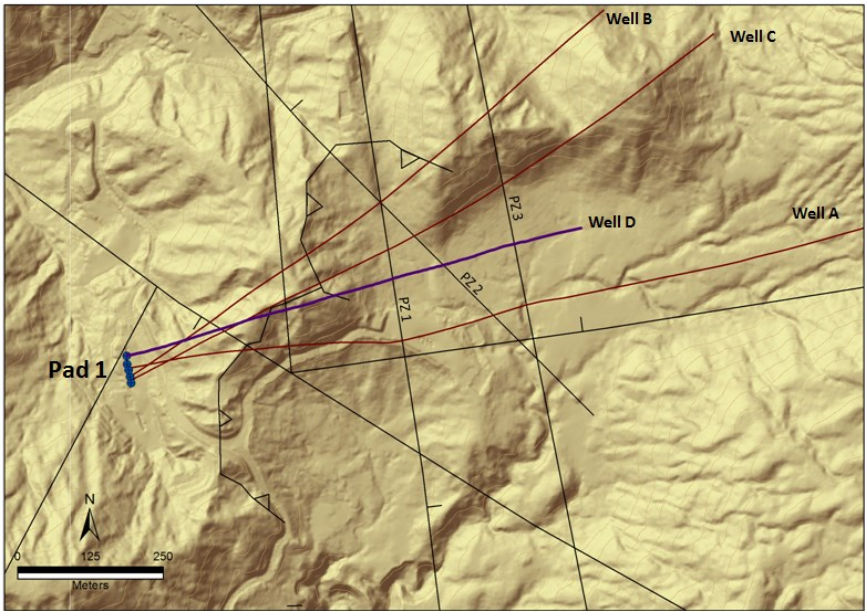

Figure 2. Location of Pad 1 with the well tracks of Wells A, B, C in red line and Well D in purple line. Black solid lines are the faults in the area which corresponds to permeable zones.

3. METHODOLOGY

Evaluation of production interference involves assessing the effects of newly cut-in wells to the output of existing wells. Changes in water flow or steam flow in existing wells as recorded by Bore Output Measurement (BOM) and Tracer Flow Tests (TFT) are evaluated over time. The tests and evaluations are ideally done immediately upon cut-in and over the course of a short period of time to avoid the effects of other reservoir processes. If a decline in mass flow is observed in existing wells, common feed zones are determined and separations are calculated. Factors that enhance or reduce feed sharing are also assessed. Figure 3 below shows the ideal process flow for monitoring and evaluating production interference.

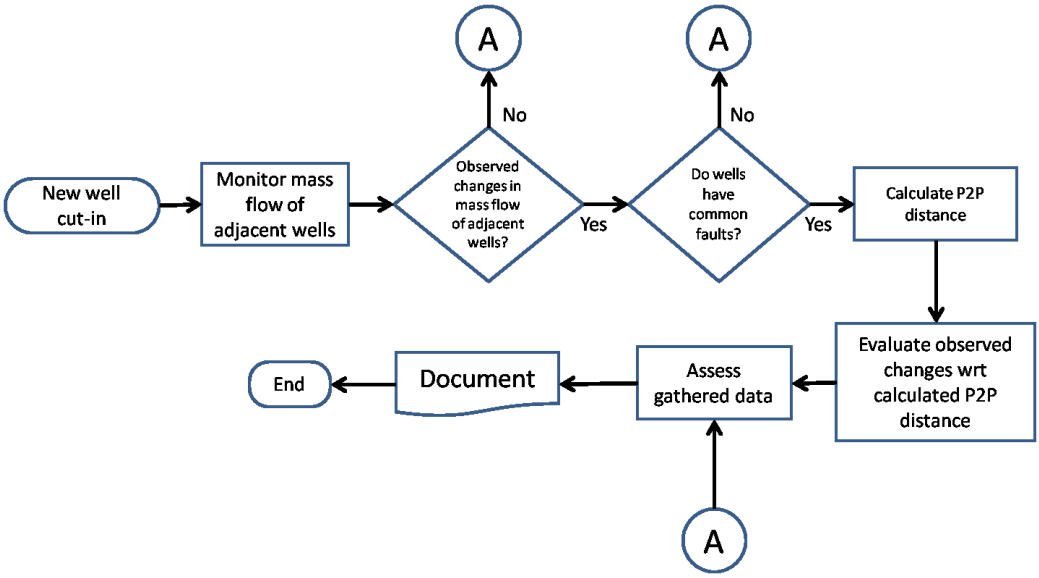

Figure 3. Ideal process flow in monitoring production interference.

However, for the case of BacMan, since there are no recent drilling activities, only the available data have been evaluated for feed sharing. Moreover, due to limited activity within the field for the past years, well-parameters sampling was less frequent. Evaluating the existing data was more complicated because other factors that may affect the output of wells such as RI returns, reservoir boiling, etc also need to be investigated to isolate the cause.

4. WELL D DRILLING IMPACTS

During drilling of Well D, adjacent wells were regularly monitored for total suspended solids (TSS) on the brine. Data showed that there was an increase in TSS of adjacent wells with Well A being the most affected. The well had an abrupt change of TSS from 14.4 ppm to 257 ppm in just one day. However, effect in Well A was also transient and the well recovered after drilling of Well D. Wells C and B were shut during Well D drilling as a precaution (Dimabayao 2012).

After drilling of Well D, TSS sampling was still continued on some wells with muddy discharge brine samples. Well C post-drilling TSS had the highest recorded value at 2007 ppm while Well A post-drilling TSS value was 344 ppm. These were suspected to be residual drilling fluids from Well D which indicated an apparent structural connection among these wells (Dimabayao 2012).

Bore output measurement (BOM) after drilling of Well D revealed that some of its adjacent wells exhibited output decline while Well C became non-commercial for some time after it was shut. Well C was the most affected not only in TSS values but also in output decline. Moreover, Well D produced lower output than expected upon cut-in.

Monitoring of steam flow over time of wells in Pad 1 revealed that when Well D was cut-in, there was no net gain of output in the pad (Figure 4). Consistent with the effects during drilling of Well D, Well C appeared to be the most affected among the wells after cut-in as shown in the deflection of its steam flow in 2011. It is also apparent in the graph that the output of Well C did not recover and the output of Well D only made up for the loss in Well C.

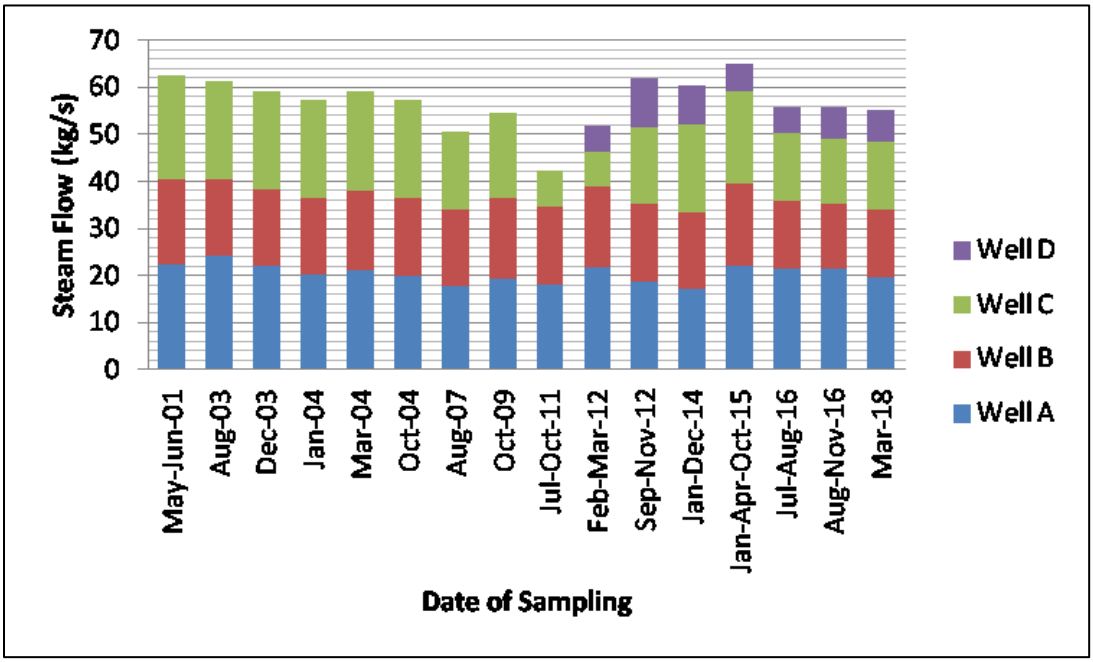

Figure 4. Steam flow over time of Pad 1 wells show a deflection in the output of Well C in 2011 during drilling of Well D.

Comparison of structures intersected by Well D and its adjacent wells A, B and C showed that the wells were tapping three common permeable zones at varying depths within the production zone. These depths were identified based on drilling data and pressure-temperature-spinner logs. Figure 5 shows location of the feed zones with respect to the well track. Using Pythagorean theorem, the point-to-point separations along the permeable zones were calculated between well D and its adjacent wells (Table 1). Data showed that the separations are closest in Well B (131m) and Well C (140m).

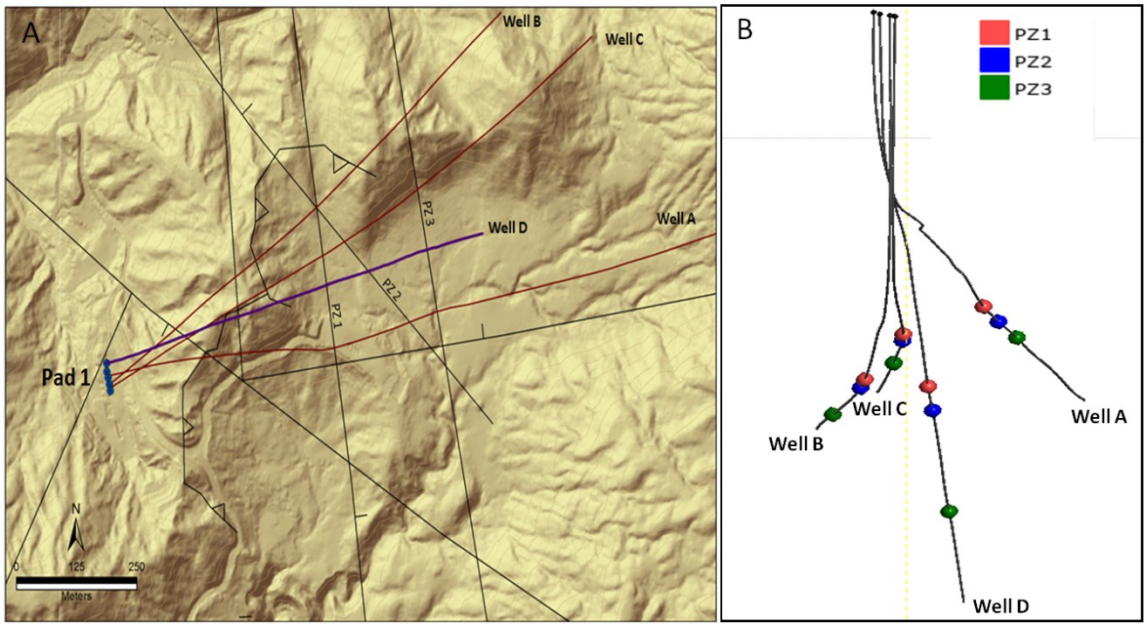

Figure 5. A. Plan view of Pad 1 showing well track. B. Section view of wells in Pad 1 showing feed zones.

WELL D Permeable Zones	P2P (m) WELL A	P2P (m) WELL B	P2P (m) WELL C
PZ 1	256	131	140
PZ 2	274	158	186
PZ 3	518	343	391

Table 1. P2P separation along common permeable zones.

5. DISCUSSIONS AND CONCLUSIONS

Based on the calculated point-to-point separations along common feed zones, it is expected that the wells most susceptible to feed sharing with Well D are Well B and Well C. These are the wells with lowest separations ranging from 131-186 m along common feed zones. The likely conduits that the wells are sharing from are PZ 1 and PZ 2 given that these zones have the lowest separations and were encountered within the intercalated volcanic deposits. The primary permeability of the intercalated volcanic deposits might have enhanced the connectivity of the feed zones. On the other hand, PZ 3 had longer separations between wells and was encountered within the compacted sandstones hence likely to be less permeable. Based on the orientation of the three structures, the northwest-trending PZ 2 is possibly the most permeable owing to the prevailing regional stress regime in the area.

Furthermore, the cyclic and collapsing nature of Well D can be attributed to the lower number and less permeable zones compared to its adjacent wells. There appears to be a preferential flow of fluid to more permeable wells. However, it is not yet established whether there is a gain in output in other wells when Well D flow ceases.

In designing future in-field wells in BacMan, it is recommended that the optimum point-to-point separations along common feed zones be >250 m to minimize or prevent feed sharing. This value is based on the closest separation in Well A where the effects of drilling Well D were only transient. However, these findings can still be further improved with more data.

In addition, production interference can be evaluated better if done immediately upon cut-in of a newly drilled well. Parameters of adjacent wells should be sampled on a more frequent interval such as on a monthly basis. This way, minor changes will be easily detected. It is therefore recommended to conduct a more detailed interference monitoring when a new well is drilled in BacMan.

The calculated optimum separations are validated for future well design considerations. Factors that possibly enhance or reduce feed sharing such as fault characteristics and reservoir rocks that are specific for the Bacon-Manito geothermal field are also identified. The methods utilized in this study will be further assessed for applicability in other EDC geothermal fields where optimum point-to-point separation has not yet been established.

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