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Improved Availability of 5MW Collapse-prone Mahanagdong-B Well in Leyte, Philippines, since 2014

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ABSTRACT

Mahanagdong Geothermal Field in Leyte, Philippines, is supplying steam to 2-unit Mahanagdong-A (120MW) and 1-unit Mahanagdong-B (60MW) operations. Mahanagdong-B production wells are also supplying to Mahanagdong-A via steam line interconnection (SLI) to augment its steam available. However, there were identified Mahanagdong-B wells that are prone to collapse resulting to decline in Mahanagdong steam availability. These wells are assessed to be affected by peripheral inflow and cold fluid injection (peripheral inflow/RI returns) from the west which have led to thermal decline and collapsing of wells, thus not being able to attain the higher operating wellhead pressure (WHP) requirement.

One well in Mahanagdong-B sector, was one of the recorded collapsing wells in 2014 caused by peripheral inflow/RI returns resulting to 5MW loss in Mahanagdong steam availability. Numerous well discharge attempts were conducted in 2014-2016 but all failed to sustain well discharge and was out of service since. Resource management initiatives and low-pressure operation projects were implemented in 2017-2018 to optimize steam generation. In 2018, the well was included in the Leyte cut-in and recovery program as one of the existing production wells that were out of service for years. The program aims to recover and cut-in all idle production wells using the available resources for additional steam supply to sustain the Mahanagdong 3-unit operation. The well was able to successfully discharge and sustained cut-in contributing additional 5MW since 2018. Well availability is observed to have improved and became more reliable after commissioning of the low-pressure operation and eliminated cold fluid injection in the west. Lowering the separation pressure allows the pressure of newly-recovered well to withstand the two-phase header pressure and continuously flow within the system and stabilized. On the other hand, elimination of RI cold injection leads to thermal recovery and improvement of well enthalpy.

1. INTRODUCTION

Leyte Geothermal Production Field (LGPF), located in the eastern part of Visayas region of the Philippines, is divided into two geothermal resources, the Tongonan and Mahanagdong fields. As illustrated in Figure 1, Mahanagdong Geothermal Field is situated in the southeast section of LGPF. Mahanagdong is subdivided into two sectors to sustain the 2-unit Mahanagdong-A (120MW) and 1-unit Mahanagdong-B (60MW) operations. A steamline interconnection (SLI) was also installed to have flexibility in steam distribution between the two Mahanagdong sectors.

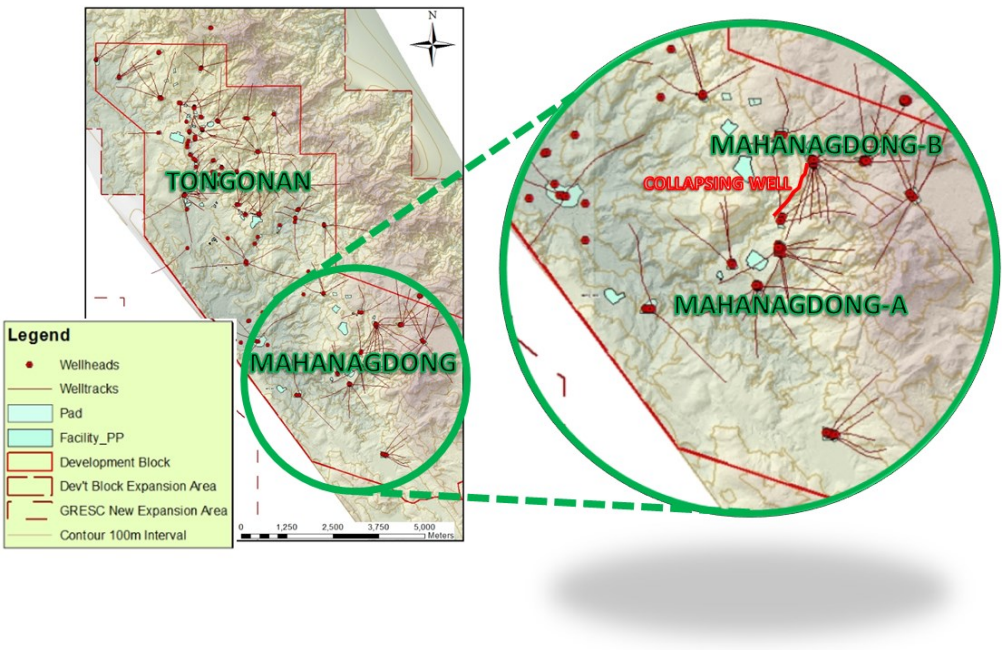

Figure 1: Location Map of the 5MW collapse-prone Mahanagdong-B well in Leyte Geothermal Production Field

With Mahanagdong's continuous mass extraction since 1980, reservoir pressure drawdown is expected until such time that the hydrological flow of peripheral waters and injection sink is preferential towards the production sector. Two injection sinks situated in the south and north areas have already infiltrated the Mahanagdong-A and Mahanagdong-B production wells, respectively. On the other hand, encroachment of peripheral water is also coming from the west affecting the productivity and sustainability of the field. This peripheral inflow/RI returns caused thermal degradation in some of the production wells through time as shown in Figure 2 where the central part of the field is observed to have lower temperature based on quartz minerals (Tqtz) ranging from 240°C to 260°C from a higher baseline of 280°C. As a result, fluid enthalpy declined that could lead to collapse of well.

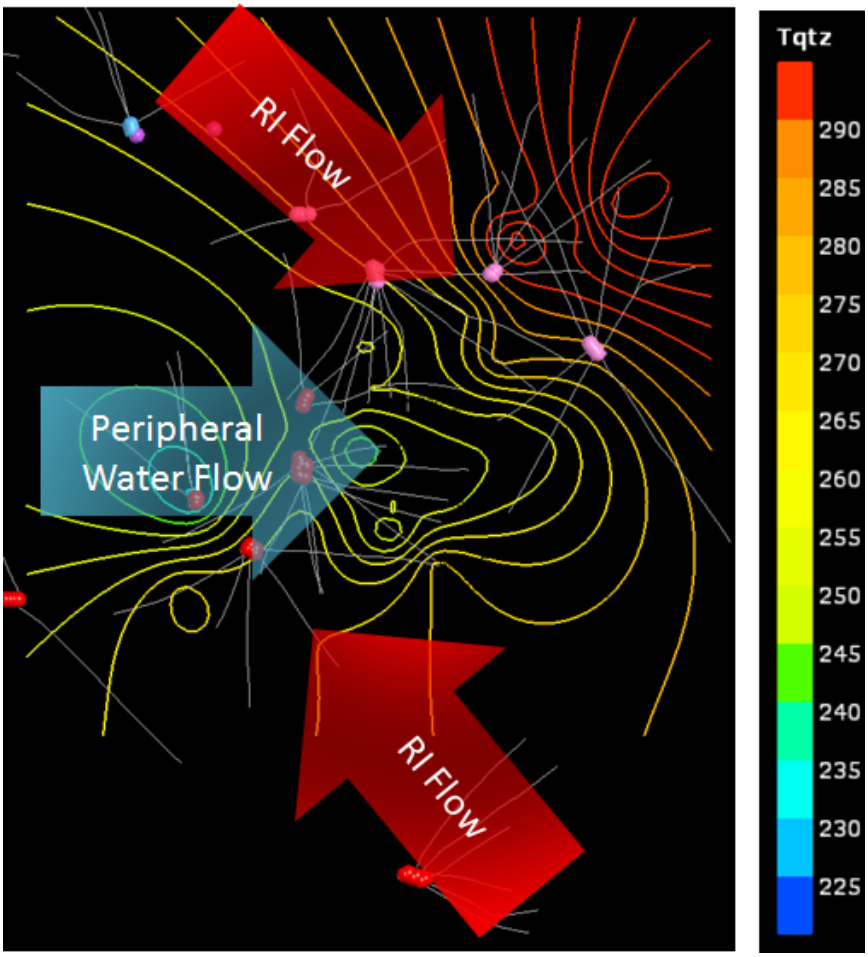

Figure 2: Mahanagdong Temperature Contour and Hydrological Flow Model

A 5-MW Mahanagdong-B well drilled in 1996 which was affected by peripheral inflow/RI returns has started to collapse in 2014 and continuously recorded series of well collapse thereafter. Well had difficulty in attaining the required higher operating pressure (WHP) and left idle for 4 years, which translated to about 175GWh loss. This paper will discuss the reservoir process that affected the operation of the well and how it has sustained its discharge starting in 2018.

2. BACKGROUND AND WELL EVALUATION

2.1 Mahanagdong-B Well Profile and Chemistry

Mahanagdong-B well was drilled in July - September 1996 with a total depth of 2400mMD/2176mVD and production casing shoe set at 1462.5mMD/1337mVD as illustrated in the well casing profile of Figure 3. Post-drilling parameters was quite remarkable, producing steamflow of 14kg/s initially at WHP of 1.3MPag. It was a mid-enthalpy well supplying an average of ~12kg/s steam to Mahanagdong-A and Mahanagdong-B Power Plants. As shown in Figure 4, well was stable from 1997 – 2005 until there was an observed change in the well parameters. Well enthalpy started to decline and mass flow has increased. Reservoir chemistry also showed a decline in reservoir chloride (Clres), Tqtz and total discharge carbon dioxide (CO2TD) which all leads to an indication of cooler fluid inflow. This has resulted to the continuous decline in enthalpy and Tqtz through 2014 and worsened with the onset of collapsing episodes. Both parameters dropped to 1150kJ/kg (vs 1450kJ/kg) and 260°C (vs 280°C), respectively.

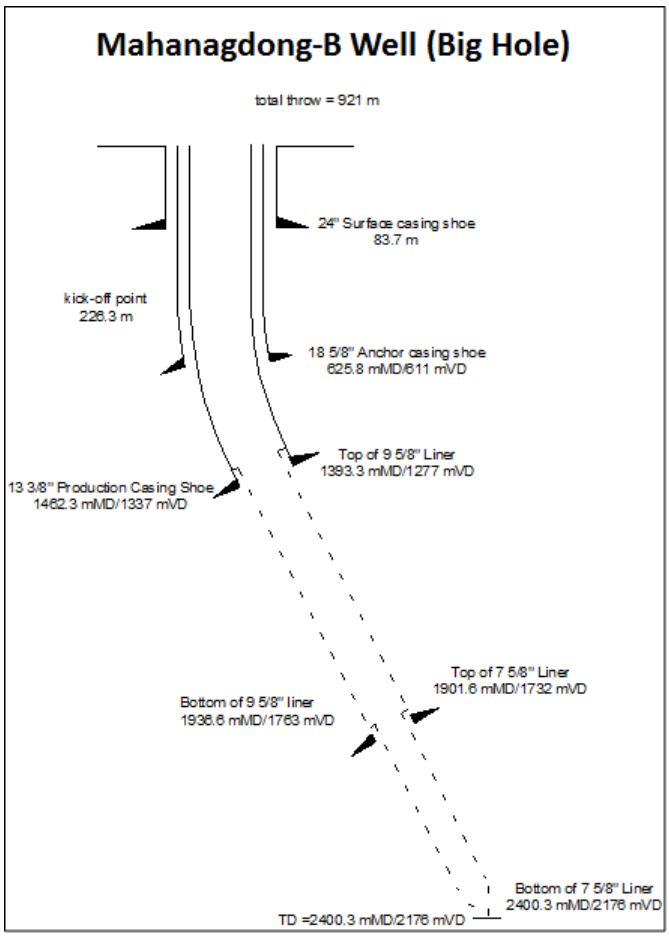

Figure 3: Mahanagdong-B Well Profile

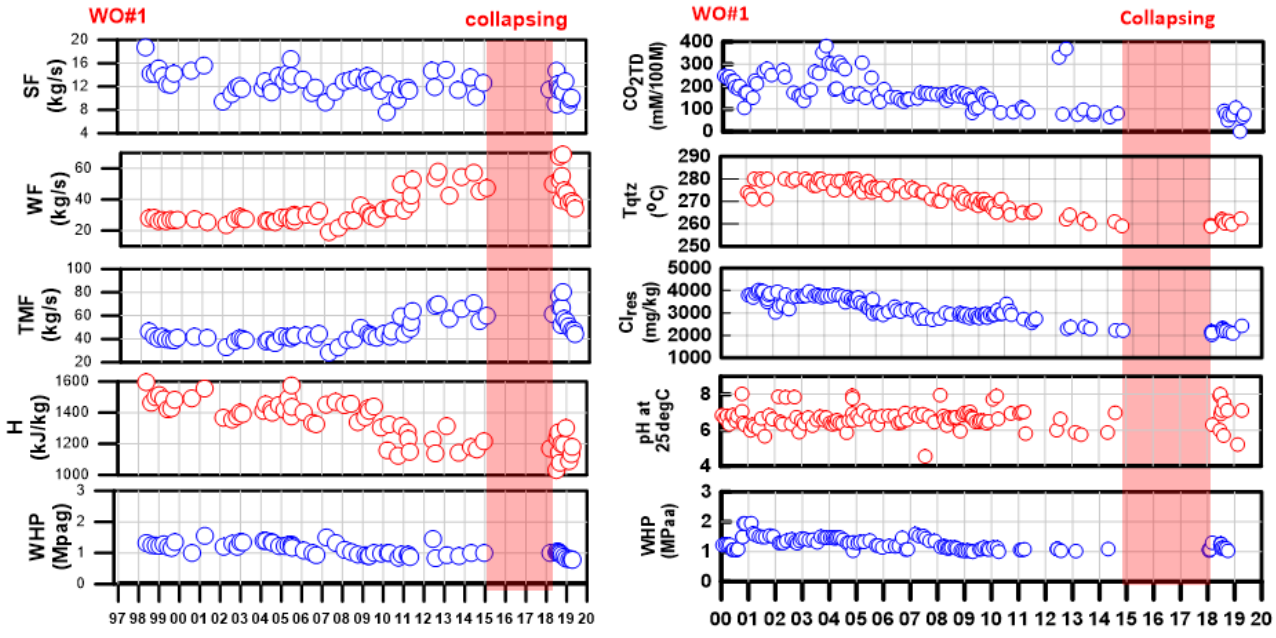

Figure 4: Physical and Chemical Historical Trends of Mahanagdong-B Well

2.2 Characterization of Peripheral Water Inflow

Peripheral water from the west is geothermal fluid diluted with meteoric or steam-heated spring waters. This water has low chloride (Cl), high magnesium (Mg) and high sulfate (SO4) levels with slightly acidic to neutral pH. It is postulated that this water may have percolated within the formations at relatively shallow section and infiltration may persisted at deeper levels through local fault structures with good permeability since it has a temperature of about 170°C (Remoroza and Mismanos, 2015).

2.3 Impact of Peripheral Water Inflow

As established, peripheral water inflow from the west has been induced with the higher pressure drawdown in the central part of the production sector that is attributed to continuous geothermal fluid extraction for commercial operations (Cerio et al., 2016). Impact of this peripheral water inflow was worsened with the additional injection of condensate or mixed condensate and thermal pond fluid into one of the RI well within the area in 2010. In the case with the Mahangdong-B well, its productivity has been greatly affected by this peripheral inflow/RI returns as evidenced by the change in chemical composition of the well's geothermal fluid. All three crossplots in Figure 5 illustrates the migration of data points towards peripheral/RI fluid suggesting that the source of cooler fluid inflow within the well is coming from the west. Well has currently lower enthalpy and is watery causing well to collapse due to quenching effect of peripheral inflow/RI returns.

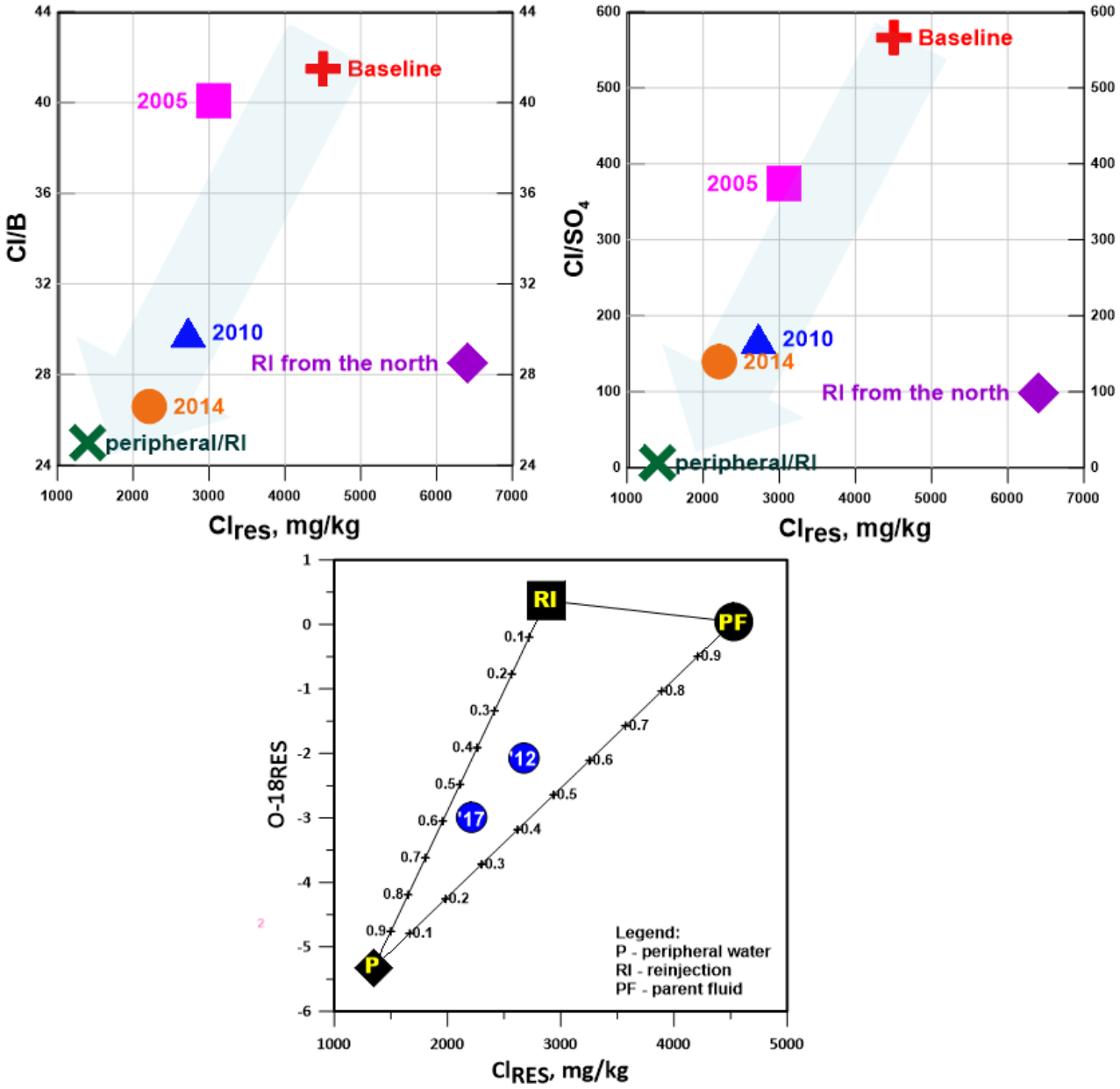

Figure 5: Clres vs Cl/B crossplot (top-left), Clres vs Cl/SO4 crossplot (top-right) and Clres vs O-18 crossplot (bottom)

3. PLAN OF ACTIONS AND RESULTS DISCUSSION

Well became commercially unavailable since 2014 and was out of service from 2016-2018 due to frequent collapse and difficulty to attain the required commercial operating WHP during revival discharge at higher pressure operation (HPO). Series of revival attempts through two-phase fluid stimulation from main two-phase header have been executed but all failed to sustain discharge due to observed WHP drop as shown in Figure 6. Discontinued injection within the area has been considered to address the persistent issue of the well since its collapse is attributed to peripheral inflow/RI returns. However, this was a challenge because of limited conveyance of brine and power plant condensates to other injection pads located in the south where it is ~3km far from the production site. Cold RI utilization was successfully terminated in 2017 after completing series of initiatives in order to implement this injection strategy of moving the RI load farther to the southern RI sector.

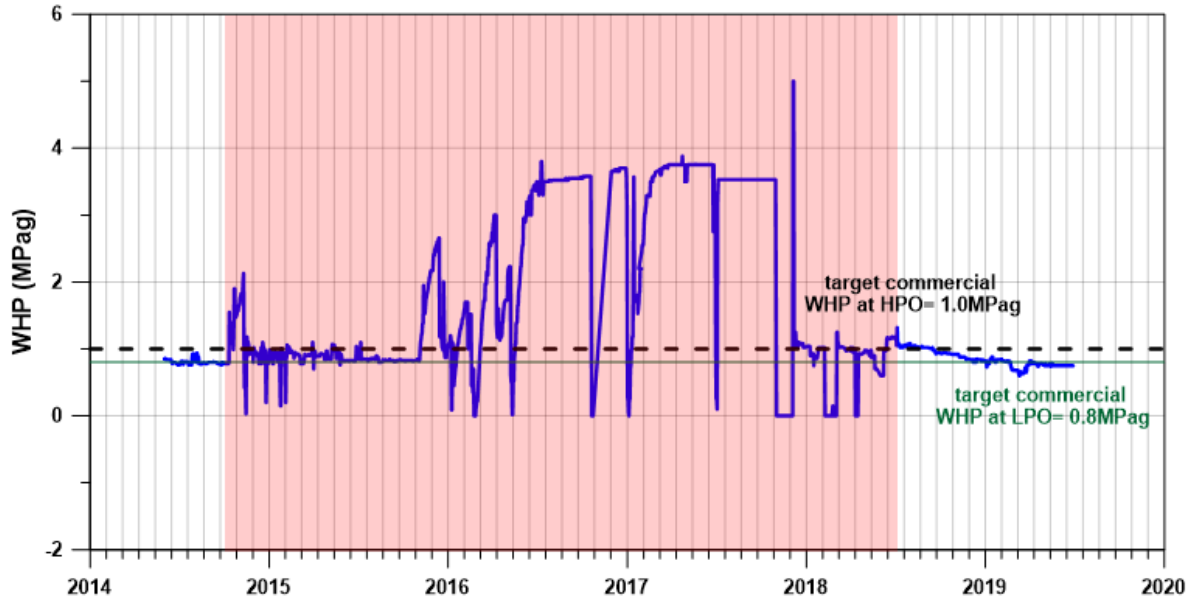

Figure 6: Mahanagdong-B WHP Trend from 2014 to 2019

In 2018, Leyte has organized various programs to achieve and meet the target power generation of the year. Mahanagdong includes two major programs -- the cut-in and recovery program of idle wells, and steam optimization via low-pressure operation. The Mahanagdong-B well was listed among the idle wells scheduled for output recovery as it has high potential to sustain its discharge since the cut-out of nearby RI well. Several discharge attempts were still executed from January to June 2018 until it has successfully sustained discharge and cut-in in July 2018 contributing additional steam supply of 12kg/s to Mahanagdong power plants. Low-pressure operation was then commenced by initially lowering the separator vessel pressure by 1 kscg on the same month and further lowered by another 1 ksc in September 2018. The Mahanagdong-B well has already sustained its production since then and continuously contributes 5MW generation. In regards to the implementation of injection strategy, well showed signs of improvement with its chemical composition indicating that the well is starting to thermally recover (Figure 7).

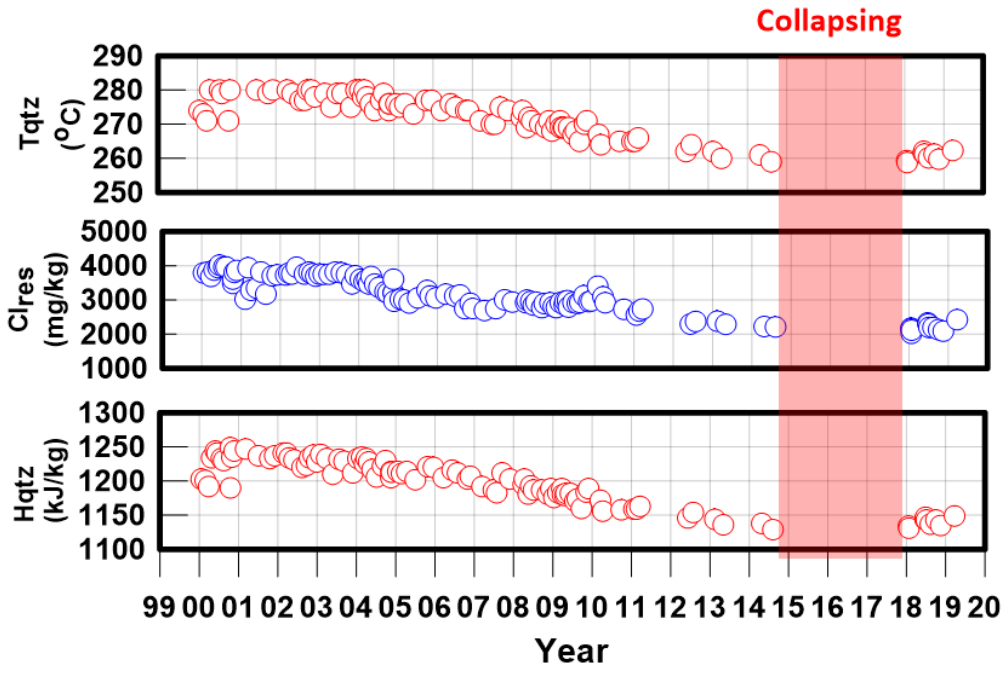

Figure 7: Chemical trend of Mahanagdong-B Well through time (1997-2019)

4. CONCLUSION AND RECOMMENDATION

The injection strategy of discontinuing the utilization of cold RI and low-pressure operation addressed the collapsing issue of the Mahanagdong-B well. Both demonstrated that the root cause of well's incapability to attain the commercial WHP were the peripheral inflow and RI returns. Hence, Mahanagdong is now generating additional 5MW with the successful economical and practical initiatives that have been carried-out.

It is recommended to have a separate low-pressure two-phase line and separator vessels for those wells with low or cyclic WHP. This allows to maximize the utilization of these special wells and to have flexibility with regards to operation. There is also a need to further monitor the well at low-pressure operation which should be considered for future studies because there is still an existing peripheral water inflow that may affect the well's productivity and availability.

REFERENCES

Remoroza, A. I., and Mismanos, J. W.: Peripheral Water Hydrogeological Study: Geochemical Investigation, Energy Development Corporation, Philippines (2015).

Uribe, M. H. C., Dacillo, D. B., Dacoag, L. M., Andrino, R. P., and Alcober, E. H.: 30 Years of Tongonan-1 (Leyte, Philippines) Sustained Production, *Proceedings,* World Geothermal Congress 2015, Melbourne, Australia (2015).

Cerio, M. C., Remoroza, A. I., and Africa, J.: Integrated Conceptual Model of Mahanagdong Hydrothermal Flow in LGBU, Energy Development Corporation, Philippines (2016).