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Lesson Learned: Well Logging Analysis to Interpret Shallow Connection Between Two Wells in Dieng Geothermal Field, Indonesia

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ABSTRACT

Loss of annular integrity in a well can create a loss of zonal isolation, significantly impairing a geothermal well's productive capability and efficiency. Effective remedial action must be based on a clear understanding of the underlying causes. Without this information, repair or control is, at best, a matter of informed guesswork or trial and error. Well-1 and Well-3 are two production wells on the same pad in Dieng Geothermal Field, Indonesia. In early 2019, both wells were offline with 0 psig of WHP (Well Head Pressure). During the production period, Well-1 WHP is mimicking the Well-3 WHP. This response continues even though Well-3 was down because of casing integrity issues. The chemistry analysis of a fluid sample from Well-3 indicated casing leakage. The relationship between both wells shows that the connection was not located in the feed zone area but in shallow depth. To get a better understanding, an integrated investigation was carried out, starting from MTD (Magnetic Thickness Detection) to PTS (Pressure/Temperature/Spinner) logging in shut-in, injection, and transient conditions. In conclusion, the results were satisfactory as, based on the integrated investigation, the leakage location that connects both wells in shallow depth can be determined. These investigation results play a significant role in creating an effective and efficient remediation program in both wells.

1. INTRODUCTION

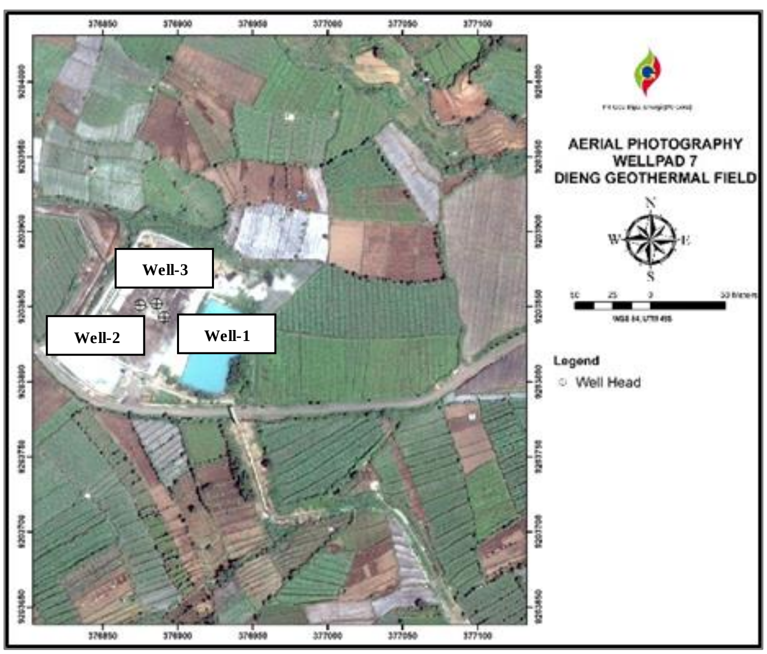

Figure 1: Location of Well-1 and Well-3.

Dieng Geothermal Working Area, located in Central Java Province, Java Island, Indonesia, is one of the geothermal fields operated by PT Geo Dipa Energi (Persero) (GDE) since 2002 with an electricity generation capacity of 60 MWe. Well-1 and Well-3 are two production wells for Dieng Geothermal Power Plant Unit 1, located in the same well pad (Figure 1). Well-1 has not been operated since 2012, while Well-3 still produces steam with about 14% of total power generation. The decrease in Well-3 performance started in September 2018, even though several heating-up programs were conducted (Figure 2).

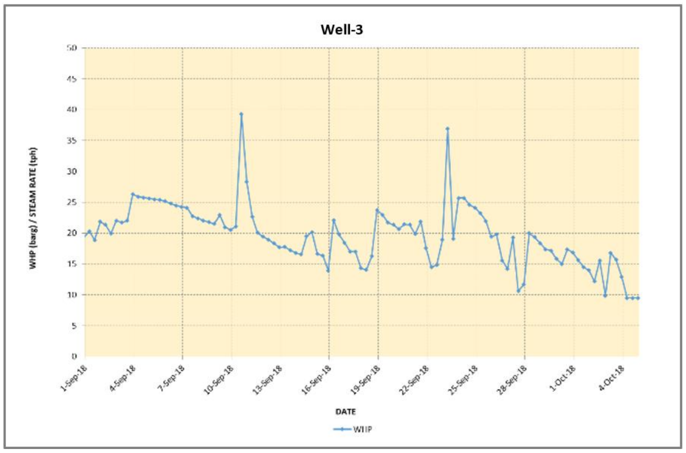

Figure 2: WHP and production profile of Well-3.

1.2 Casing Leakage Indication

1.2.1 WHP Response Analysis

Since September 2018, several air compression stimulation programs have been performed to improve production. On 11-12 October 2018, WHP slowly dropped from 187 psig to 136 psig during air compression (Figure 3). The indication of a production casing issue was confirmed after air compression stimulation on 22 October 2018, when WHP experienced a drastic decline from 480 psig to 350 psig (Figure 4).

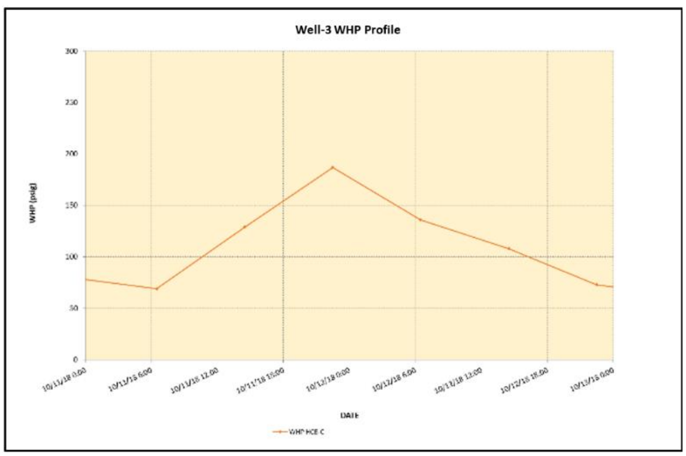

Figure 3: Well-3 WHP profile during air compression stimulation on 11-12 October 2018.

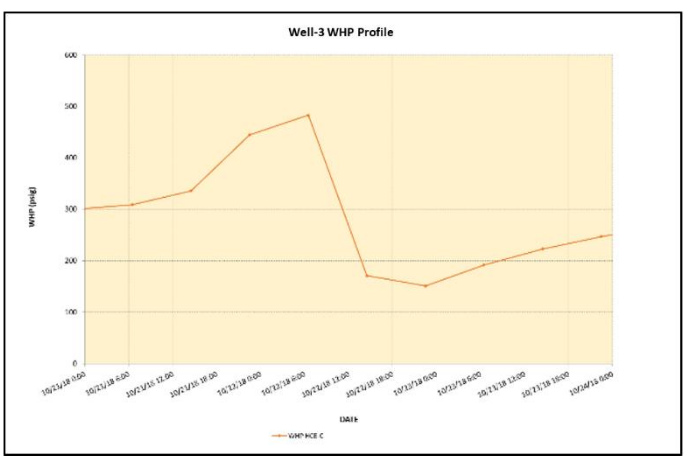

Figure 4: Well-3 WHP profile during air compression stimulation on 22 October 2018.

Based on all the phenomena of WHP hereinabove, fluid channeling or networking at production casing is suspected. The compressed air was lost to the formation through the leakage depth. Geochemistry data need to be reviewed to strengthen the possibility of casing leakage.

1.2.2 Fluid Chemistry Analysis

Table 1 shows low Cl content in several sampling results in 2018. High Cl values appeared in January and February (13,000 ppm), while Cl values were very low in October (7,000 ppm). It indicates some mixing of geothermal fluid inside the wellbore.

Table 1: pH dan Cl data of Well-3 (Dieng Unit Chemical Laboratory Data, 2018).

No.	Date and Time	WHP (psig)	Point Sampling	Cl (ppm)	Well Status
1	04/01/2018 09.50	383	Outlet separator	13.471	Online
2	05/02/2018 10.03	600	Outlet separator	17.423	Online
3	02/10/2018 16.00	151	Outlet separator	8.456	Online
4	08/10/2018 14.00	300	AFT	7.540	Bleeding
5	08/10/2018 14.30	229	AFT	7.399	Horizontal discharge
6	10/10/2018 09.37	180	AFT	7.047	Horizontal discharge
7	10/10/2018 11.30	90	AFT	10.571	Horizontal discharge
8	18/10/2018 17.15	69	AFT	7.347	Horizontal discharge
9	18/10/2018 17.48	85	AFT	6.997	Horizontal discharge
10	18/10/2018 19.54	84	AFT	8.397	Horizontal discharge
11	22/10/2018 09.30	290	AFT	11.275	Horizontal discharge
12	26/10/2018 09.55	60	AFT	6.342	Horizontal discharge
13	26/10/2018 09.56	60	AFT	6.342	Horizontal discharge
14	26/10/2018 10.00	54	AFT	6.695	Horizontal discharge

Brine sampling analysis was conducted to check Mg content in November 2018. Brine sampling results in December 2016 were used as a comparison. Table 2 and Table 3 show both brine analyses. Mg content in December 2016 was at a normal level, about 0,1 mg/L. It represents that no surface water entered the Well-3 wellbore. However, Mg content in November 2018 was high, about 13 mg/L. There was a possibility of geothermal fluid and surface water mixing in the wellbore.

Table 2: Brine chemistry data of Well-3 in 2016 (Geoservices Laboratory Analysis, December 2016).

Chemical Compound	Unit	Result
pH (25^oC) in lab		3.6
Boron (B)	mg/L	200.0
Dissolved Silica (SiO_2)	mg/L	806.0
Dissolved Sodium (Na)	mg/L	7,550.0
Dissolved Potassium (K)	mg/L	1,686.0
Dissolved Calcium (Ca)	mg/L	349.0
Dissolved Magnesium (Mg)	mg/L	0.1
Ammonium (NH_4)	mg/L	5.6
Bicarbonate (HCO_3)	mg/L	<1.0
Carbonate (CO_3)	mg/L	<1.0
Chloride (Cl)	mg/L	13,163.0
Sulfate (SO_4)	mg/L	50.0

Table 3: Brine chemistry data of Well-3 in 2018 (Geoservices Laboratory Analysis, November 2018).

Chemical Compound	Unit	Result
Dissolved Silica (SiO_2)	mg/L	396
Dissolved Calcium (Ca)	mg/L	207
Dissolved Magnesium (Mg)	mg/L	13
Bicarbonate (HCO_3)	mg/L	3
Chloride (Cl)	mg/L	4810
Sulfate (SO_4)	mg/L	674
Total Silica (SiO_2)	mg/L	401
Total Calcium (Ca)	mg/L	211
Total Magnesium (Mg)	mg/L	16

Visually, there is also an anomaly in the brine color after air cap stimulation on October 22, 2018. The brine is reddish (Figure 5-a) and different from the brine color in normal conditions (Figure 5-b).

(a) (b)

Figure 5: Brine color after horizontal discharge.

Based on wellhead pressure data and fluid chemistry, further investigation is needed to confirm the casing integrity to determine the occurrence of surface water intrusion into the wellbore. MTD survey is a method that can provide qualitative and quantitative results for all casing layers.

2. PROGRAM INVESTIGATION

Several investigation programs were carried out to obtain conclusive results regarding the condition of the Well-3. The types of well investigations commonly carried out in geothermal are shown in Figure 6.

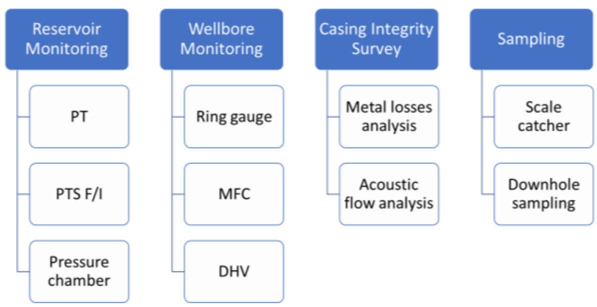

Figure 6: Common type of well logging in geothermal.

2.1 Wellbore Clearance Survey

On October 30, 2018, a result from a well clearance investigation (three different sizes of ring gauge: 5”, 3” and 1-7/8”) showed that the remaining clearance is smaller than 1-7/8” or 4.8 cm at 1,406 mMD of depth which at about 77 m above TOL 9-5/8”. Some scales were carried out to the surface. The sample is reddish, like oxidized metal (Figure 7).

Figure 7: Scales in 5” ring gauge.

2.2 Casing Integrity Survey

The MTD is a 1-11/16″ OD corrosion measuring instrument primarily run through tubing with the ability to inspect tubing and the casing behind it simultaneously. Comprised of two different measurement sensors, the MTD provides an average metal thickness measurement for three barriers and identifies individual defects in each string. Integral gamma ray and wellbore temperature sensors allow accurate correlation and identification of temperature anomalies that may indicate holes or unexpected fluid flow. The objective of performing a casing integrity survey is to find the indication of leakage in the production casing. Investigation of the Well-3 using an MTD survey was performed on November 7, 2018, in the injection condition with 150 gpm of freshwater injection at 1.38 psig of WHP.

The MTD tool logs down temperature data at a speed of 50 mpm. Figure 8shows the temperature and gamma-ray profiles along the wellbore.

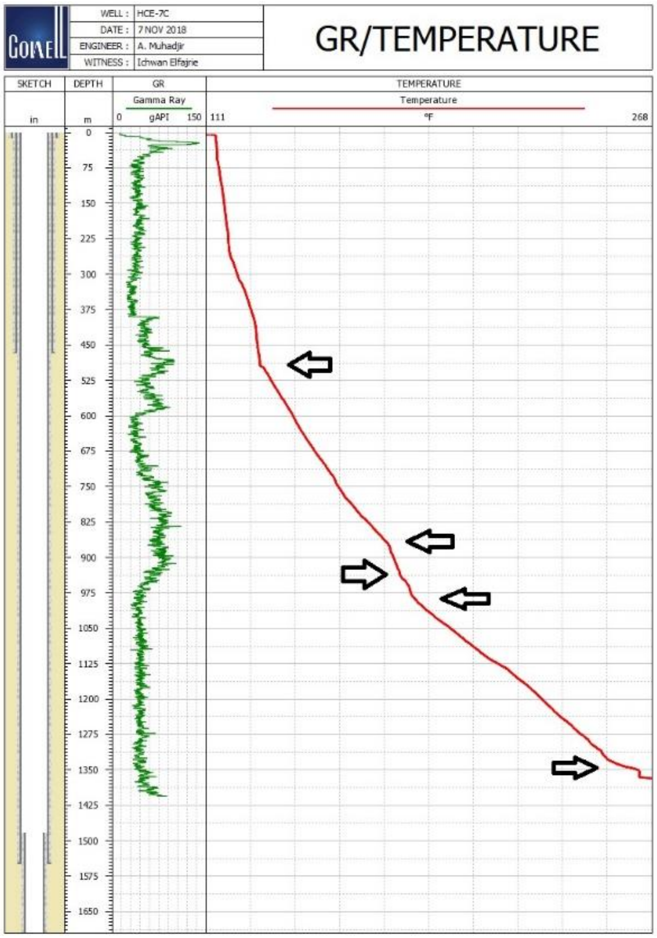

Figure 8: Temperature and gamma ray profile vs. depth.

The arrows in Figure 8 show the temperature change points that indicate changes in water flow. Drastic temperature slope changes occur at a depth of around 1,300-1,375 mMD where the temperature jumps from 250°F to 420°F. It is suspected that water injection loss into the formation occurred. The following are the results of the analysis in question:

- Anomaly at about 500 mMD
- Anomaly at between 850 and 1,000 mMD
- Anomaly at 1,350 mMD
- With OD of 1-11/16", MCD at 1,389 mMD

After reaching maximum depth, the MTD tool starts recording metal losses data to the surface at a speed of 2 mpm. Figure 9 (a-e) show the several locations where indicate intensive corrosion in the 13-3/8" casing. Table 4 gives a metal losses grade definition.

Table 4: Grade definition of MTD results.

Grade	Max_ML	Corrosion Level	Diagnosis & Recommendations
A	0-5%	Negligible	Within tool accuracy calculation. Generally not a matter of significant concern.
B	5%-10%	Light	This is on the threshold of accurate detection and may indicate onset of localized corrosion activity.
C	10%-20%	Moderate	This grade may be associated with higher level of corrosion activity and/or with possibility of critical damage across a localized area. Further evaluation and if required, remedial action may be considered if means and access to this tubular is available.
D	>=20%	Intensive	Generally, this is associated with integrity issues in that part of the tubular. Peak corrosion activity in one depth has a higher probability of penetration damage of the tubular. Remedial action after further evaluation is recommended.
E	<0%	Special Joint	Associated with joints that have a higher weight or electro-magnetic permeability.

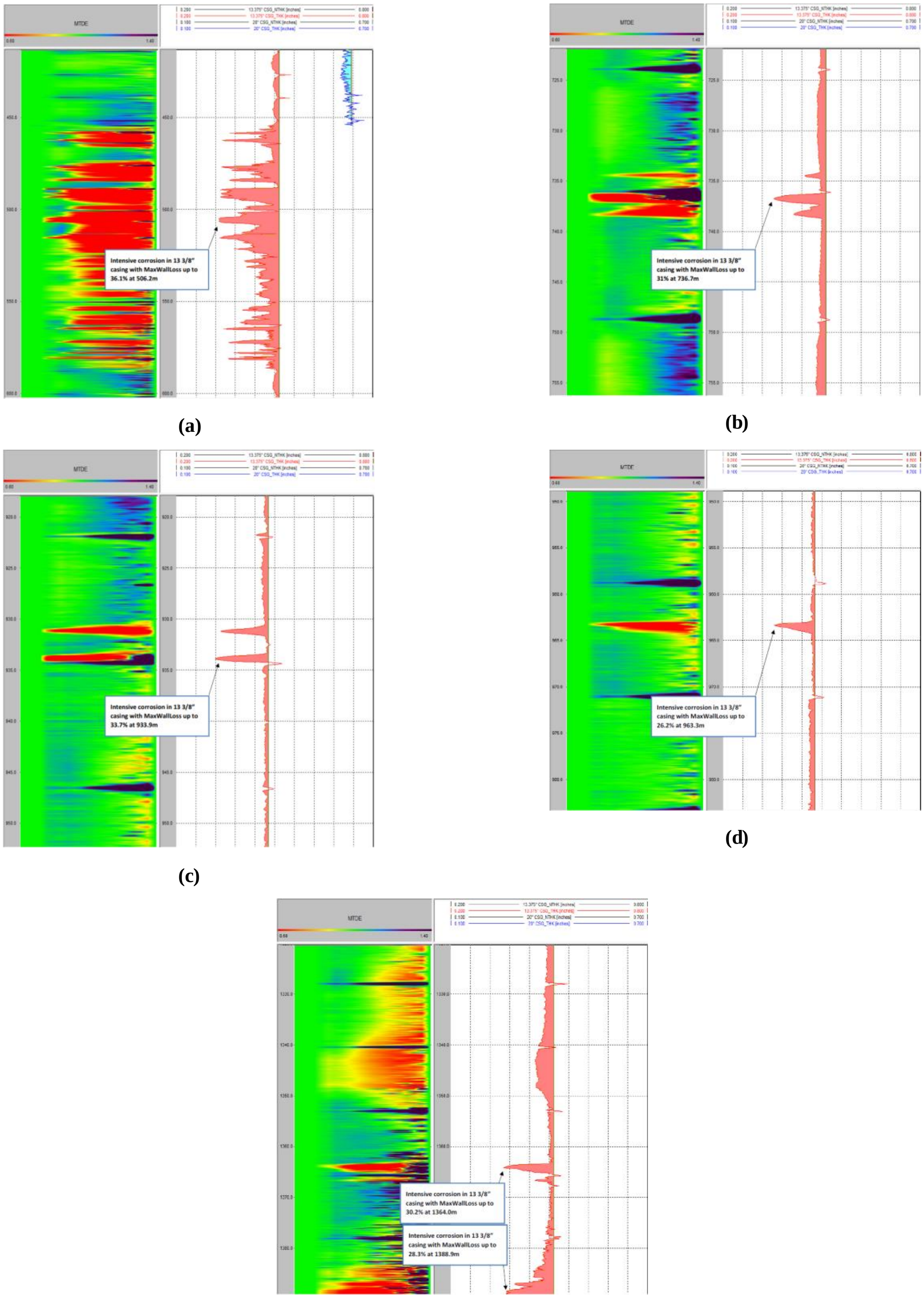

Figure 9: MTD results.

Figure 10 shows a resume of wellbore condition after several investigations.

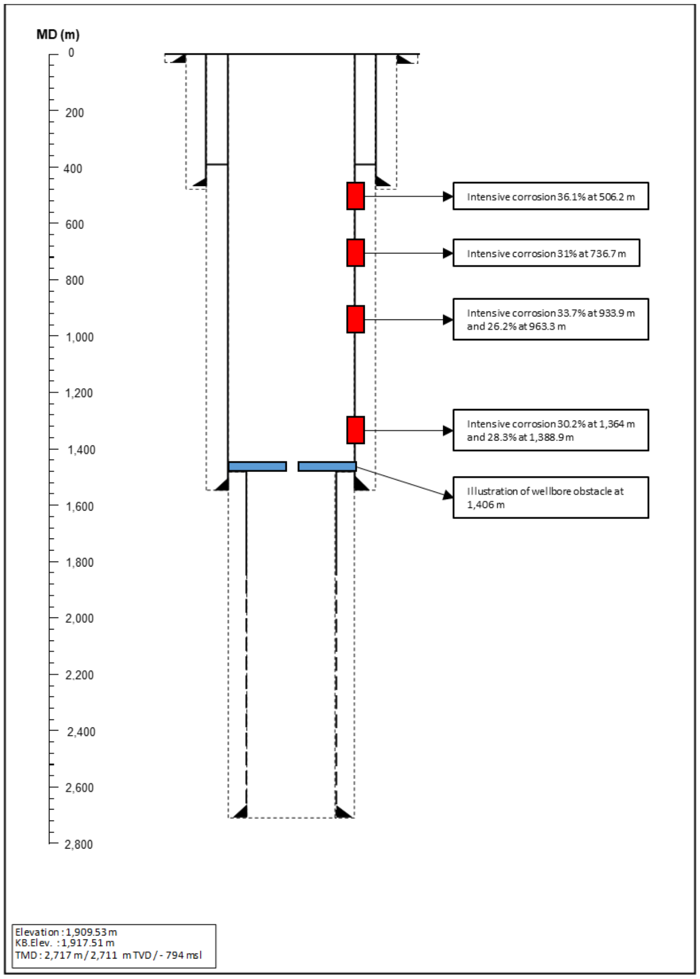

Figure 10: Well-3 wellbore condition.

4. CONNECTION BETWEEN WELL-1 AND WELL-3

Well-3 WHP changes following maneuver in throttle valve opening. In the meantime, the WHP of Well-1 also changes while its throttle valve opening remains unchanged. Well-1 WHP profile, which "mimics" the WHP of Well-3, continues even though the well is in a shut-in condition. Figure 11 shows the profiles of both wells since May 2018, where the Well-1 is in shut-in condition, and Well-3 is in flowing condition.

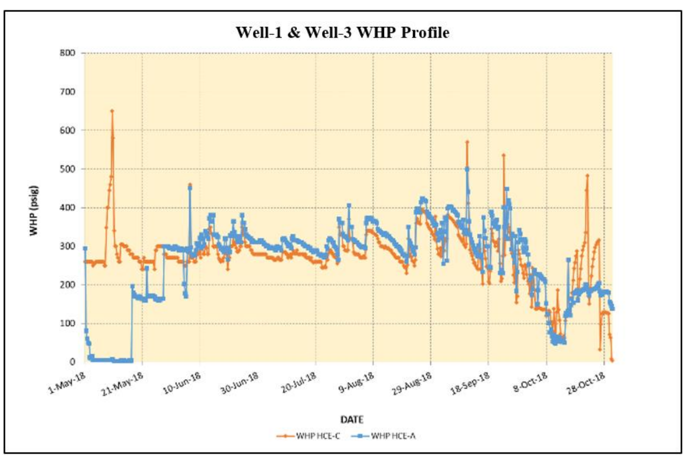

Figure 11: WHP profile of Well-1 (static condition) and Well-3 (flowing condition).

The quick response of WHP changes between both wells shows that the connection between them does not represent feed zone interference. This condition strongly indicates that Well-1 and Well-3 are connected at shallow depths.

Based on history, there were three workovers after the completion of Well-1. The objective of the first workover was to overcome the leak in production casing 13-3/8" at 227 mMD. TLC (Total Loss Circulation) at 129 mMD of depth during drilling indicates an aquifer at a shallow depth. The distance between these two wells is quite close, where the wellhead space is 8 m. Figure 12 shows its magnitude to a depth of 750 mMD. It is suspected to be a leakage position that results in a connection between Well-1 and Well-3.

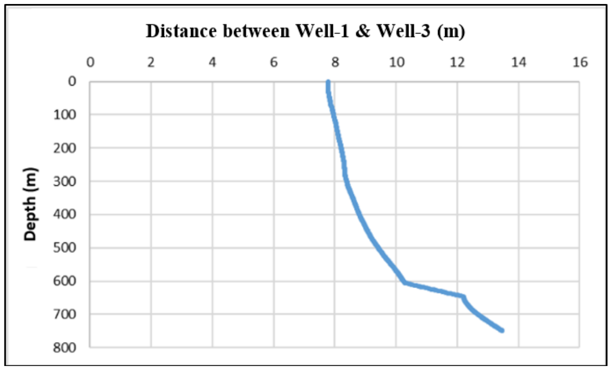

Figure 12: Distance between Well-1 and Well-3 vs. depth.

Further investigations, PTS shut-in and PTS injection, were performed for both wells. The objective of PTS investigations in shut-in conditions is to obtain baseline conditions and monitor the pressure and temperature response in transient conditions after injection is stopped. During injection, a PTS investigation was executed to determine the lateral flow at the suspected leakage depth.

PTS logging on the Well-1 was carried out for three days, followed by PTS logging on the Well-3 for the next three days. The following is the sequence of investigations carried out at each well:

1. PTS logging in shut-in condition
2. PTS logging in injection condition (300 gpm of fresh water)
3. PTS logging in transient condition (1 hour after injection stopped)
4. PTS logging in shut-in condition while another well was injected with 300 gpm of fresh water

Quality check on spinner data was carried out by analyzing samples of spinner rotation at a certain depth at three cable speeds during log down and log up. Figure 13 and

Figure 14 show the analysis for these two wells. The measurement results in the Well-1 show that the data at a speed of 5 mpm cannot be used, while all measurement data in the Well-3 is of good quality so that it can be used.

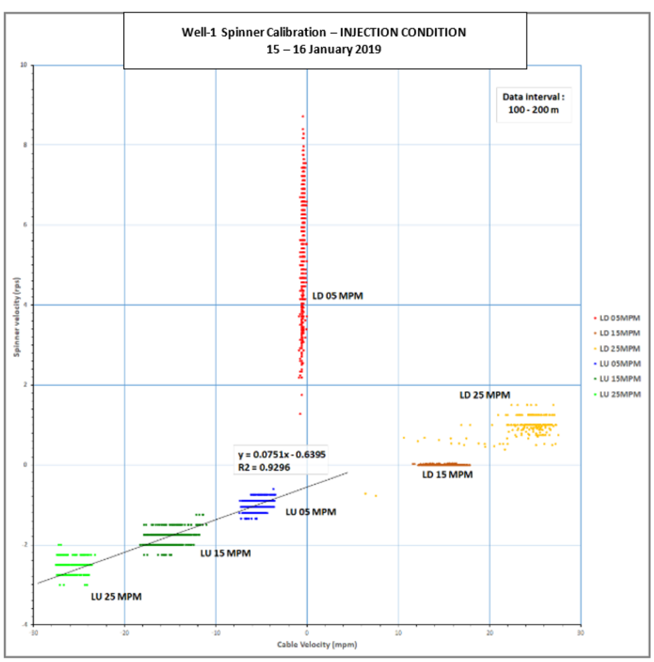

Figure 13: Well-1 spinner calibration crossplot.

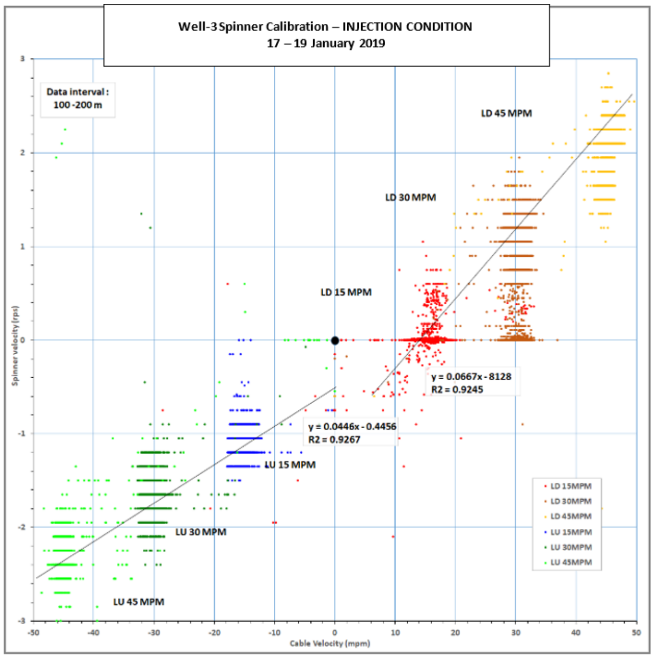

Figure 14: Well-3 spinner calibration crossplot.

The results of the PTS analysis on the Well-1 show that there is a hole in the 13-3/8" casing with the following details:

- Depth 122 m
  - Temperature reading: There is a significant increase in temperature at a depth of 100 – 122 m. This zone may be a permeable layer that becomes hot because there is crossflow activity in the Well-3, which, during production, results in hot fluid flowing into the reservoir and heating it.
  - The spinner reads that there is flow activity during shut-in conditions at a depth of 122 m (leak point in the casing) to 135 m (peak liquid in the well at shut-in). Water flowing from 122 m falls to the top of the liquid at 135 m, causing the PTS spinner to rotate.
- Depth 355-360 m.
  - Temperature during Transient conditions shows a significant temperature difference between 355 m and below 360 m.
  - The spinner does not show changes during injection conditions because the dominant flow of injected water flows downwards.

Calculations based on spinner data are as follows. The flow of the casing leak at a depth of 355-360 is relatively small, not detected by the spinner; almost all of it flows down the obstruction at 513 m.

The results of the PTS analysis on the Well-3 show that there is a hole in the 13-3/8” casing with the following details:

- Depth 475-500 m
  - Above a depth of 475 m, spinner data shows the fluid flow velocity in the casing is 19 m/min, and below 500 m, it is 9 m/min. 52.6% of the injected water flows through casing leaks in the 475 – 500 m interval.
  - Temperature reading: There is a significant increase in temperature at a depth of 475 m, indicating that some of the cold-water injection flow has shifted out of the casing.
- Depth 1,365 -1,370 m.
  - Temperature during Transient conditions shows a significant temperature difference between 1365 and 1375 m. The potential is that water coming out of the 13-3/8” casing at a depth of 1365 – 1370 m enters the permeable zone at a depth of 1365 – 1375 m.
  - The spinner shows there is a contribution of injection flows out of the 13-3/8” casing at 1365 – 1370 m. Above a depth of 1365 m, the water flow speed in the well is 9 m/min; below 1370 m, it is 6.5 m/min. 13.2% of the injection water flows out of the hole at this depth, and 34.2% flows downwards.

The results of the PTS analysis on the Well-3 also show that there is a hole in the 20” casing at a depth of 310 m with the following details:

- MTD (Magnetic Thickness Detector) data in November 2018 shows significant metal loss at this depth.

- Temperature data during shut-in conditions shows local heating at a depth of 300 m. It is very likely correlated with the presence of a permeable zone at 300 m where when this well was producing, there was hot fluid flow into the zone through a 13-3/8" casing leak at 475-500 m, flowing upwards through the 13-3/8" annulus and out to the 20" annulus through the hole at 310 m.

The conclusion of the analysis of the connection between two wells is shown in Figure 15 and Figure 16.

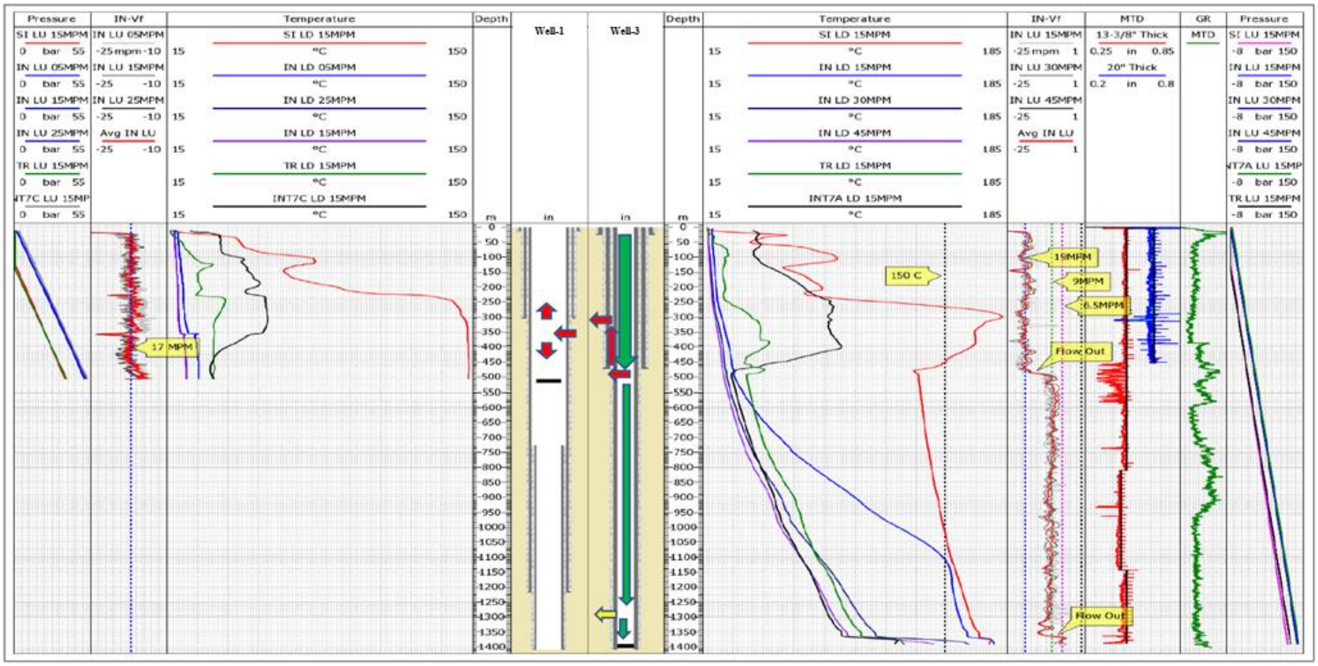

Figure 15: Well-1 and Well-3 PTS log conclusion (Well-1 shut-in and Well-3 injection).

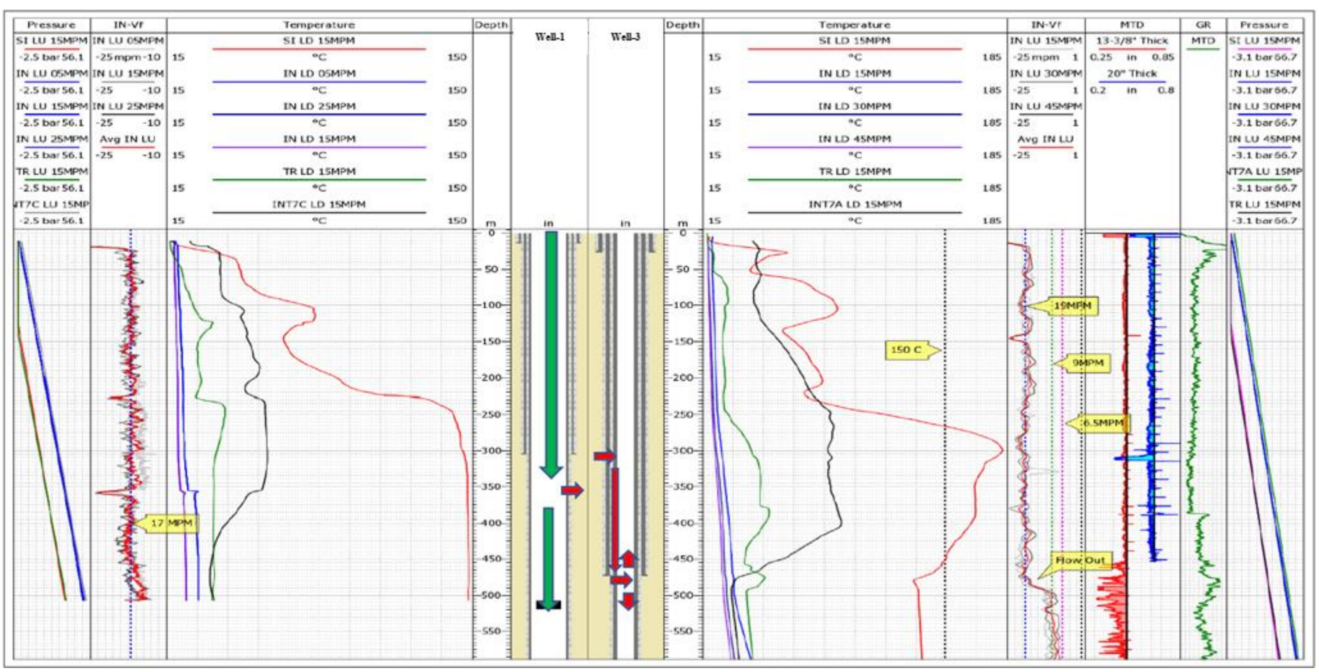

Figure 16: Well-1 and Well-3 PTS log conclusion (Well-1 injection and Well-3 shut-in).

Calculation of water flow into the Well-3 wellbore based on spinner data (Table 5):

Table 5: Flow rate calculation.

Flow calculation	**Imperial**	**Unit**	**Depth (m)**			**Unit**
			0	**500**	**1,370**	
Casing size	13.375	Inch	33.97			cm
Casing ID	12.347	Inch	31.36			cm
Area			772.08			cm^2
Flow velocity			19.00	9.00	6.50	mpm
Flow rate			1.47	0.69	0.50	m^3/min
Flow rate			9.23	4.37	3.16	bpm
Flow rate			387.49	183.55	132.56	gpm
Flow distribution			100%	47.4%	34.2%	%

Table 6 shows flow distribution and Figure 17 is an illustration of a leak that occurred in the Well-3.

Table 6: Flow distribution.

Interval	**Distribution**
Leak at a 475-500 m of depth	52.6%
Leak at a 1,365-1,370 m of depth	13.2%
Downward flow	34.2%
Total	100.0%

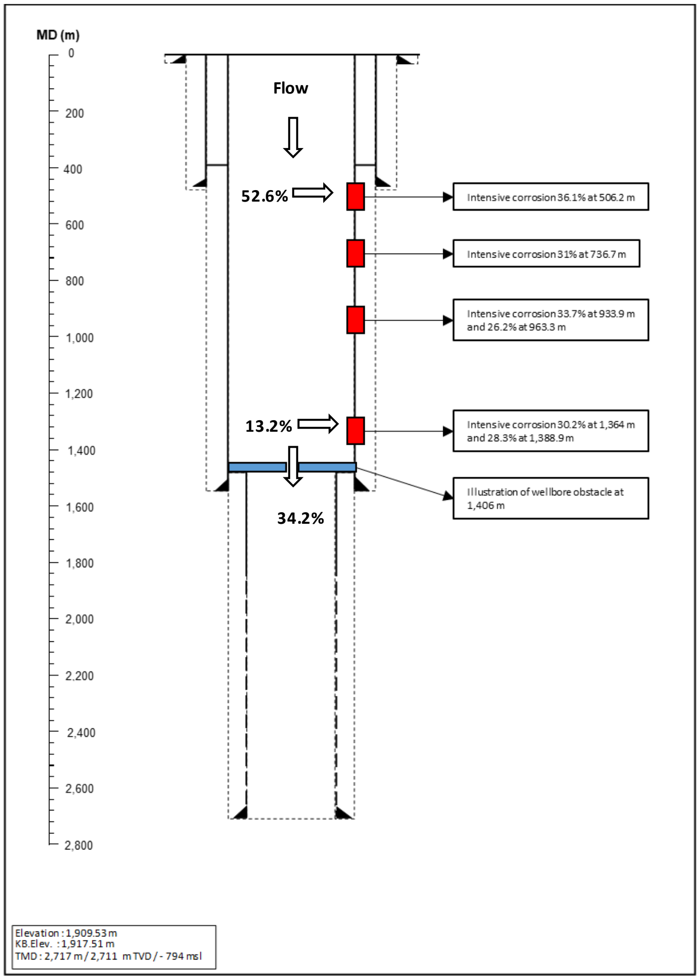

Figure 17: Illustration of a leak in the Well-3 during injection.

5. CONCLUSION

a. Reactivation and remediation priority is carried out on the Well-3 with the following considerations:
- The production potential is more significant than Well-1.
- Access to the well is much deeper than Well-1, up to a depth of 1380 m. It will most likely only be necessary to open casing access 13-3/8” to the top of the liner 9-5/8” at a depth of 1483 m.

- Obstruction in the 13-3/8” casing on the Well-3 is relatively less than the Well-1. Connection between Well-1 and Well-3.

b. Temporarily, Well-1 needs to be plugged with the following considerations:
   - There is communication between Well-1 and Well-3.
   - For remediation of the Well-3, it is necessary to close the potential flow from Well-3 to the reservoir in Well-1 to ensure that the cementing work in Well-3 is not disturbed.

c. Investigation of a problem with a well will be conclusive by overlaying the following data:
   - Geochemistry analysis, including scale sampling inside the wellbore
   - Casing integrity analysis
   - Wellbore clearance survey
   - Pressure & temperature data analysis
   - Spinner analysis

6. ACKNOWLEDGEMENTS

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