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The Kamojang Geothermal Field: 25 Years Operation

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ABSTRACT

Kamojang is the first Geothermal Field in Indonesia, and it is known as one of vapor dominated systems in the world. It first started producing steam in 1978 in order to generate electricity for its own use through a 250 KW monobloc unit. The first commercial operations of 30 MW started in 1982. Subsequently, an additional 110 MW started commercials operations in 1987. Further, a 60 MW unit is now under preparation to be constructed, and it is expected to be on line in 2006. In addition, the possibility of having another 60 MW unit is now being evaluated.

The current rate of mass withdrawal shows the unbalance of discharge and recharge induce decreasing of water level to deeper parts of reservoir. And, the 22 years continuous commercial production has led to slight decline in the well head pressure and temperature within the active production sector. As a result, 80% of 31 productive wells tend to approach superheated condition. The re-injection programmed may have slowed down this entire phenomenon, especially that of the reservoir being superheated.

1. INTRODUCTION

The Kamojang geothermal field is one of the world's few developed dry steam reservoir. It is located in an area of high elevation, 40 km south east of Bandung, Indonesia (figure 1).

The Field, which is operated by PERTAMINA -a state owned oil company, has been producing steam to supply PLN'S 140 MW since 1982.

The exploration had begun under a New Zealand's government aid in 1974. Since then five exploration wells were drilled down to 700 m throughout the Kamojang Area.

Pertamina continued from 1975 and developed the first geothermal field, with the initial state of development producing 30 Mwe, utilizing steam from 6 wells.

Commercial operations started to peak in 1987 from 30 MW to 140 MW capacities and supplied from 26 wells. To date 77 wells have been drilled within an area of 14 km2 (figure 2). The additional 60 MW power plant is scheduled to start commercial operation in 2006. This paper presents the result learned from Kamojang geothermal steam field management workshop held at Kamojang in 1999 and the five years latest additional information about Kamojang.

2. POTENTIAL RESERVE

A reservoir area of 14 km2 has been estimated from DC Schlumberger sounding (Hochstein, 1975) and a further field delineation of up to 21 km2 has been determined from CSAMT studies (Pertamina, 1990).

The first two exploration wells drilled are producing dry steam from shallow feed zones with temperature of 237°C at about 600 m depth (Sudarmaji, et.al., 1995). The Kamojang geothermal reservoir is dominated by vapor with temperature of 235 - 245 °C and pressure of 34 - 35 bar abs. The potential resources calculated using volumetric analysis suggest a power potential of 150-250 MWe (Pertamina Kamojang, 1999) within the reservoir area of 7,52 km2 – 12,5 km2. Individual calculation had also been made. Fauzi, 1999, calculated proven reserve from reservoir area of 8,5 km2- 15 km2 and suggested a power of 140 MW to 360 MW for 25 years utilization. Sanyal S.K and Sudarman (2000) estimated that proven reserves ranged from 210 to 280 MW for 30 years. The most likely power potential lies between 180 to 250 MWe for 25 years operation, which has been proven by drilling wells. To date, the field producing steam is equivalent to 140 MW electric.

3. TWENTY-TWO YEARS OF COMMERCIAL OPERATION (1982-2004)

3.1 Reservoir Response

The continuous commercial operation from 1982-2004 is characterized by a slight decline in the wellhead pressure and silica scale in the gathering systems. The natural states of the Kamojang geothermal field characterize typical vapor dominated systems. The Kamojang reservoir has water saturation in the order of 25-35 %. It mostly produces 100% steam. Values of permeability thickness of production area range from 500 to 140.000 m Darcy meter where the productive wells display values greater than 4900 m Darcy (GENZL, 1992).

The non-condensable gas content in the discharging fluid is less than 1% by weight, mostly CO2, and very low to nil chloride content.

The general distribution of permeability (K) is subdivided in 3 zones, i.e. high K-zone, moderate K-zone, and low K-zone (figure.3).

The continuous commercial operation from 1982 to 2004 shows decline in wellhead pressure (from about 3%/year to 9%/year), which is a direct reflection of declining reservoir pressure that depends on reservoir permeability zone. The largest decline happened in well KMJ-39, which lies in the low K-zone. The lowest decline is shown in KMJ-18, which is located in the high K-zone. It indicates that decline is closely correlated to the reservoir permeability. Therefore, all wells at Kamojang can be expected to decline at annual harmonic rate of 4,2% starting 1988 and after 15 years of production, the reservoir pressure declined by about 5 Kscg (Sanyal S.K et.al, 2000).

Furthermore, the initial well head pressure in the east sector has not changed during production period (figure.4), giving the high level of confidence to develop additional 60 MW in 2006.

3.2 Casing Design

There are at least 5 periods where different type of casing design from 76 wells were drilled. In the period of 1926–1928, before PERTAMINA took over the field, there were 5 exploration wells that were drilled by The Dutch, with depth of 66 – 128 m with unknown casing design.

From 1974–1975, PERTAMINA & GENZL drilled another 5 exploration wells with depth varying from 536 – 753 m. These wells were completed by slim hole casing from 13 3/8 inches of stove pipe to 4½ inches of production casing.

The third period is 1976 – 1979. During these years, ten development wells have been drilled by PERTAMINA & GENZL with depth of 935 to 1800 m. Those wells used semi standard casing diameters from 18” stove pipe to 7” production liner.

The forth period is 1979 – 1986. These years are characterized by the change of 18” stove pipe to 20” casing design. Total depth varied from 1150 m to 2200 m. These wells had been drilled by PERTAMIN of total 25 wells.

The last period is 1986 – present. During these years, 28 wells of directional and delineation wells were drilled up to 1003 – 2200 m using standard casing design comprises of 30” diameter of stove pipe, 9 5/8” production casing and 7” production liner. One of newest two big hole wells were drilled in 2002 using 9 5/8” production liner.

3.3 Gathering System

To support 140 MW power plants, the steam transmission pipe lines are divided in to 4 supported pipe line (PL) called PL-401 (Ø 32”); PL-402 (Ø 24”); PL-403 (Ø 40”) and PL-404 (Ø 40”). Designed pressures are up to 10 bars, which are feed into a PLN'S commence interface with PLN’S pipe line at the header. The turbine inlet pressure and temperature are 6,5 bars and 161,9 °C respectively. Steam flow in each PL is controlled manually, and is supplying 2,5% greater than power plant demand. The excess of steam is controlled automatically by butterfly vent valve into vent structure under normal operating condition. In order to reduce the excess steam from vent structure, since 1998, PERTAMINA controls the steam supply from 4 main production wells by using automatic control valve. This advance control system enables the well to immediately stop and reduce the excess steam at vent structure up to 2%. SCADA System is installed and developed in 2003 by adding transmitter in those control valves. This continuous venting is due to the gathering system design of turbine with steam consumption rate of 8 tones/hour/mega watt average at power plant operating at 6,5 bar inlet pressure.

The wellhead used in Kamojang production wells comprises of WP 3000 Psi, 900 class. This high-pressure class of wellhead can be reduced into 600 class (WP 2000) corresponding to 35 bar (abs.) of WH pressure as it is used in KMJ-73, KMJ-74 and KMJ-76, but KMJ-75 as a big hole used WP 3000 Psi, 900 class.

4. STEAM FIELD MANAGEMENT STRATEGIES

In 2000, the Kamojang geothermal field has been in operation for 18 years. The steam production is predominantly from two sectors within the proven field. These sectors show high K-zone over KMJ-18 and KMJ-30 and low K-zone in the north.

The continuous commercial operation from 1982 to 1993 is characterized by decline in reservoir pressure by about 1 to 2 bars with corresponding temperature decline of 2° to 4°C. In 2002, the annual well productivity decline was also about 2 – 3 % after 20 years of commercial operation.

The decline rate is calculated to increase by about 6,4 %. The resource risk associated with productivity decline is relatively low even after a capacity expansion from 60 MW to 200 MW (Sanyal S.K. et.al, 2000).

The turbines show high efficiency with an average capacity, ability and load factors of 85%, 90% and 97,5% respectively (Sudarman, et.al, 1995). Even though, turbines require over haul job every year to remove silica deposit within turbine blade and in the steam pipe.

4.1 Production Strategies.

The field has been generating 30 MWe since 1982 supplied by steam at optimum well head pressure of about 15 to 17 bars to feed 6,5 bars inlet pressure plant. At the start generating 140 MWe in 1987 with total of 26 wells initially producing 1315 tones/hour steam and gradually decreasing to about 1086 tones/hour in 1993 giving an average decline of 2 – 3 % (Sudarmaji, et.al, 1995). The minimum feed of three Mitsubishi Condensing turbine units of 1 x 30 MWe and 2 x 55 MWe are 1100 tones/hour steam. Therefore, up to the year 2000, six make-up wells have been drilled to keep constant flow rate of steam fed to the plant.

In 2000, the anticipation of major increase in mass may caused further decline in pressure. They were three deep unproductive wells that have been used as re-injection wells to cope with the total field production.

Another scheme of maintaining the reservoir pressure is to operate different productive wells alternately.

The effect of this process in the operating of the field is manifested in the stabilization of output of producing wells and increase of wellhead pressure. The immediate response is the recovery of mass production corresponding to increase in the steam out put.

4.2 Reservoir

The Kamojang wells were drilled either straight or directionally using standard completion casing size of 9 5/8” and 7” perforated liner with average production of 7 MW . Even a well bore simulation study revealed that large hole configuration of 13 3/8” casing and 9 5/8” perforated liner in the east and north sectors are capable of producing more steam of 2 (on average) times greater than that of using standard size well of 7” liner (Kris Pudyastuti, 1994). However, until year 2000, the wells in Kamojang were still drilled by conventional method. The wells with standard completion had been drilled in the east sector of Kamojang to support a 60 MW turbine units. In 2002, one big hole well was also drilled to campaign more steam producing and to support the 60 MW plant. The results of this last big hole well produced 65 ton/hour of steam.

For the efficiency, the steam transmission is designed to be inter connected with 140 MW steam transmission pipe line. Steam flow in this new gathering is planed to be controlled by DCS (Distributed Control System) integrated with 140 MW transmission steam pipe line. This connecting system might reduce the in efficiencies flexible system PL-401 to PL 404.

To monitor the reservoir performance, well head static pressure is one of the parameters measured during well testing and reservoir monitoring programs. Down hole measurement is also done for this purpose by using a conventional mechanical tools of Kuster gauge. It also monitors pressure and temperature continuously for accuracy using electric digital wire line logging.

A tracer transient tests use deuterium as natural tracer, tritium and methanol as artificial tracer. They have been performed to observe the pattern of fluid flow in the reservoir. This tracer tritium was injected from injection wells of KMJ-15 in 1983 and 1992. The results indicated a flow pattern of injected water from these wells to the southwest and north east part of the field and for 5 to 6 years time flow to the west through NE-SW normal fault and NW-SE lateral fault (Abidin. Z. et.al. 2000). The trium was also injected in KMJ-46 in 2003. It is still monitoring to the present day.

Pressure interference tests are effective for establishing reservoir connectivity and for estimating inter well transmissivity, and they should also be part of the monitoring programs.

Therefore, a data management is conducted to collect even pressure build up data, well productivity history, well deliverability data, productivity and reservoir performances

Other engineering techniques such as application of flow meter log (SPT survey) might also be considered.

4.3 Re-injection Strategies

Up until today, five deep unproductive wells have been used for re-injection wells. Three of them are located in the center of the field and low permeability zone but the other two are in medium permeability. This re-injection does not give yet the impact to maintain the productivity. On the other hand, KMJ-33, KMJ-18, KMJ-40 gave a good response from re-injection to minimize the decline of productivity. In addition, water re-injection also can contribute steam in to productive reservoir.

4.4 Scaling

The scale analysis from steam pipeline is known mainly as silica. The scale might have also been formed and blocked the wells at depth (e.g. KMJ-18, 41, 51, 67, 11, 14, 17, 26 and KMJ-27) and affect the reservoir within its surrounding.

The action taken to address this problem was to operate steam flows at higher WHP (at least 15 bar), acidizing and hydro blasting of the blockages tagging its maximum clear depth, and work over operation. In the gathering facilities, silica scale is cleaned by using chemical inhibitor (chemical light bolt 103) and neutralized by agent for coating white powder component. It also uses scale remover liquid (SR 982 liquid).

Work over and acidizing have been found to be effective in recovering the out put of each well. The use of chemical inhibitor is being considered due to the cost effectiveness compared to drilling more make up wells.

5. CONCLUSIONS

Up to 2004, The Kamojang geothermal field has been in operation for 22 years. Within this time span, it is attributed to minor change in the system. Some wells which are located within low K zone showed a significant change of reservoir pressure due to increase in mass extraction. However the stability of these well' flow rate can be maintained by proper re-injection strategy. Thus, the goal is to ensure sustainability of the field for full generating capacity by employing the technologies and right reservoir management.

6. ACKNOWLEDGMENT

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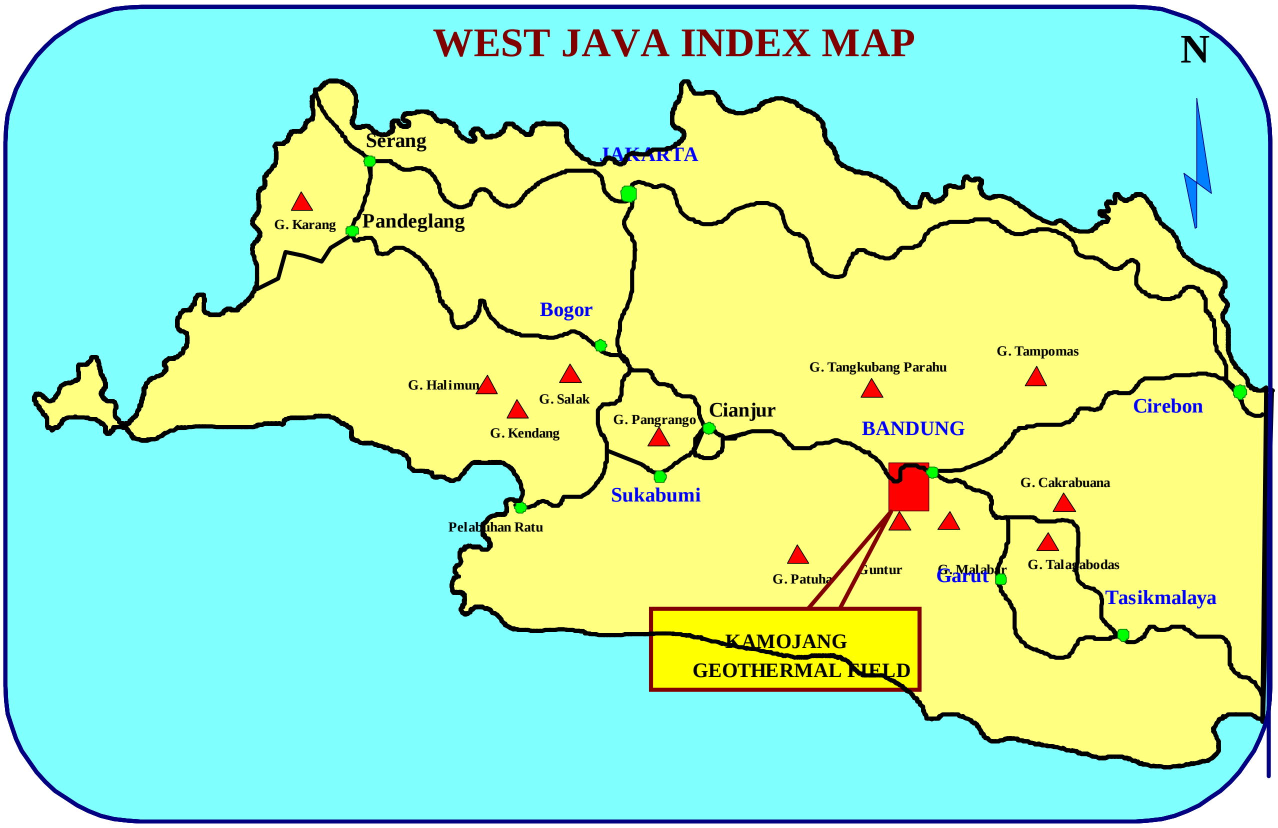

Figure.1 : Location map of Kamojang, West Java Indonesia

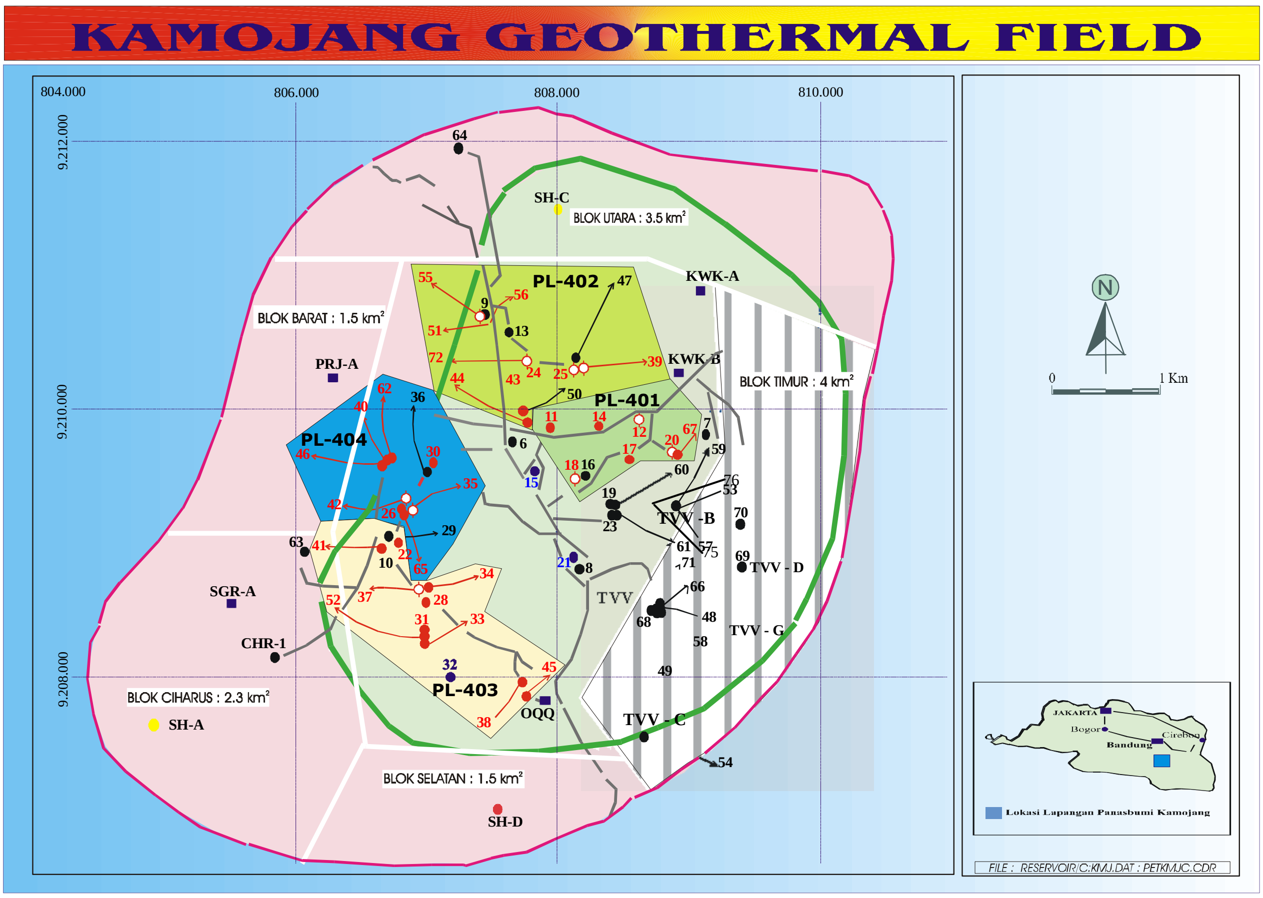

Figure 2 : Map of the Kamojang Field showing boundary of the prospect, well bores, and development of east sector.

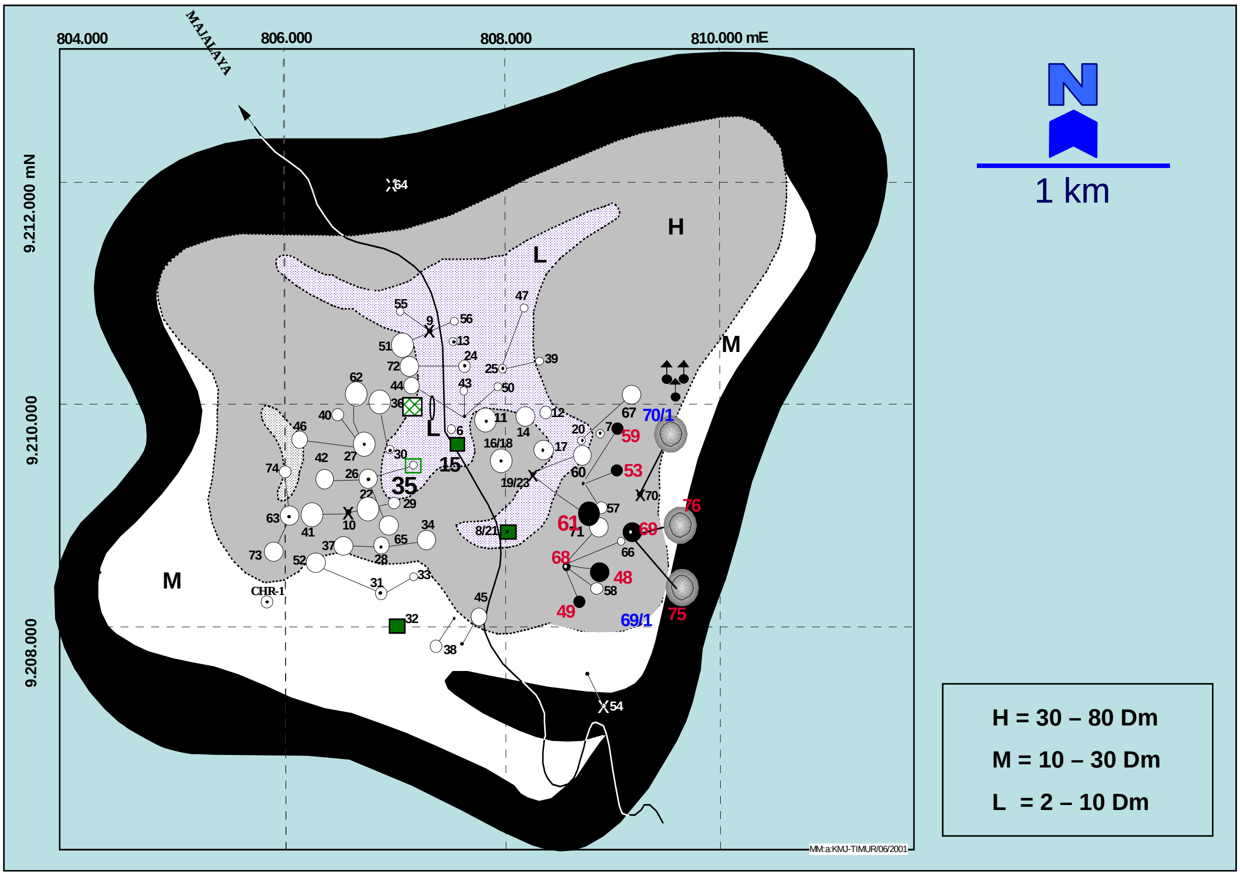

Figure.3 : Permeability structure over the KF ; constructed from surface geo-electrical data, borehole data and production data

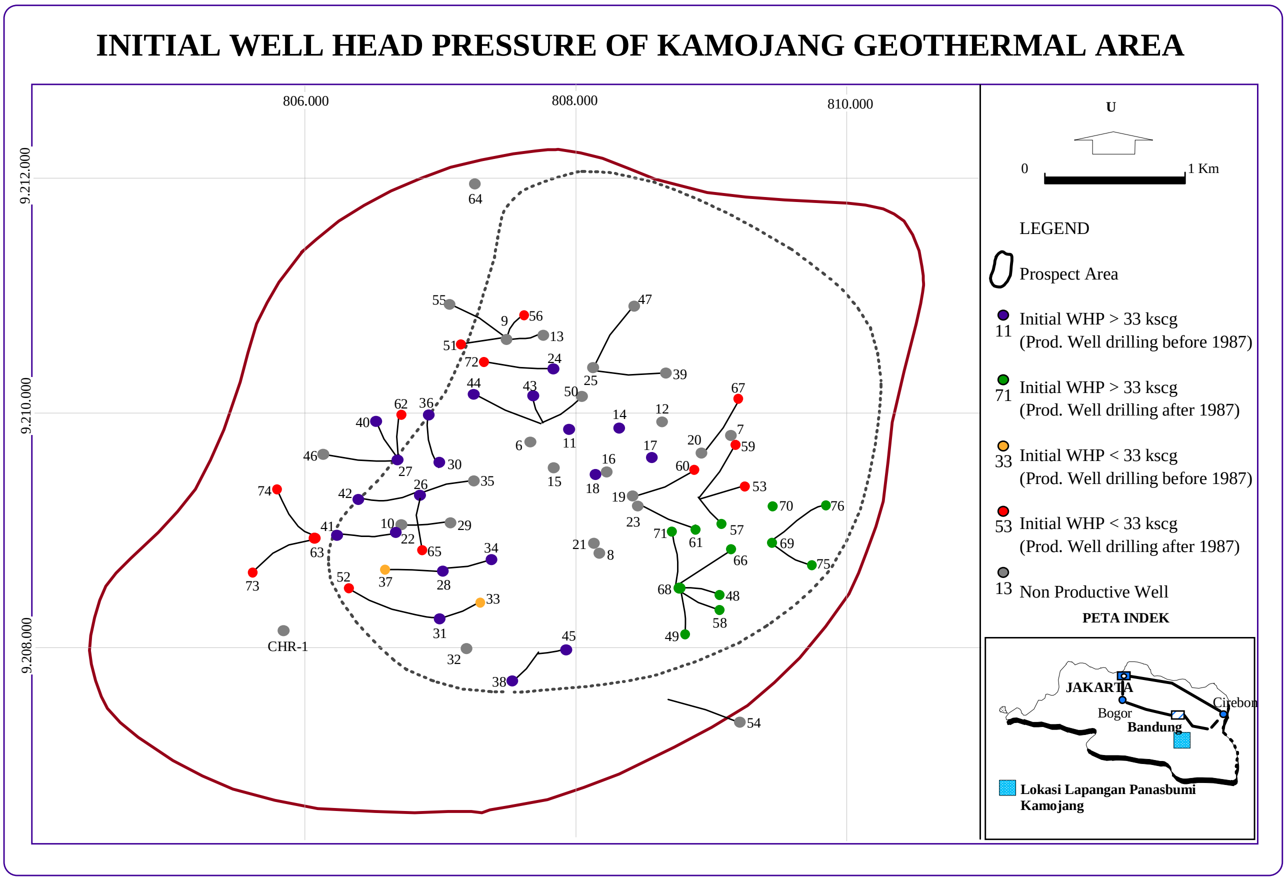

Figure.4 : Initial well head pressure