Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Steam Production from the Expanded Two-Phase Region in the Southern Negros Geothermal Production Field, Philippines

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Keywords: sustainability, field management, Southern Negros Geothermal Production Field

ABSTRACT

The Southern Negros Geothermal Production Field (SNGPF) in Central Philippines, has been supplying steam to the 112.5MW (3x37.5) power plant in Palinpinon 1 and the 80MW (4x20) modular plants in Palinpinon 2 in the last 27 and 17 years, respectively. Field exploitation has induced field wide reservoir changes that constantly affected the capability to sustain steam supply to the power plants. Pressure drawdown and injection returns were the two major processes that controlled prevailing reservoir conditions at any time during the production period, together with mineral deposition and cool acidic fluid inflow albeit at lesser extent.

Extensive monitoring of the physical and chemical changes in reservoir fluid properties facilitated the careful understanding of reservoir response to exploitation. This also led to the timely formulation and implementation of reservoir management strategies and well interventions that effectively addressed the various problems affecting steam supply. Most important of these strategies were the transfer of the bulk of injection load away from the Puhagan area towards Ticala and Malaunay sectors in Palinpinon 1, and the controlled brine injection into specific injection wells known to have strong communication with the production sector. The full load operation of Palinpinon 1 plant and the commissioning of the modular plants in Palinpinon 2 also considerably promoted the expansion of the existing shallow two phase zone that became the potential source of additional steam to the Palinpinon geothermal power plants.

Steam production from this highly two-phase region has been proven viable initially in 2004 with the commercial re-utilization of the once-acidic well NJ6D and the recovery in 2006 of the commercial outputs of pre-maturely decommissioned wells, PN21D and PN17D affected by injection returns early in the production stage. This was followed by the successful conversion of in-field injection wells, PN6RD and PN9RD into producers in 2008. To date, a total of 63 kg/sec of additional steam equivalent to 25.0MW is realized from the contribution of the two phase region. In addition, future make-up wells are now also being considered to be drilled in the area.

1. INTRODUCTION

The Southern Negros Geothermal Production Field (SNGPF) is located in the southern tip of the peninsular arm of the Negros island in Central Philippines (Figure 1). The field consisted of two production fields, namely, the Palinpinon 1 in the Puhagan area and Palinpinon 2 in the Nasuji-Sogongon area. Development began in Palinpinon 1 in 1981 after a 1.5MW pilot plant installed in September 1980, proved the viability of a commercial geothermal production. On May 1983, the 112.5MWe Palinpinon 1 geothermal power plant was commissioned by National Power Corporation (NPC), the government's power utility arm. Ten years later, the 80MW Palinpinon 2 modular plants were installed by NPC after establishing that the Palinpinon resource can still support additional capacity. Four 20MWe modular units (one each in Balasbalas and Nasuji areas, and two in Sogongon sector) were commissioned between December 1993 and January 1995. To this day, the field has a total installed geothermal capacity of 192.5MW.

Gradually, the Palinpinon 1 Geothermal Power Plant increased its power generation to full load capacity in 1991 expanding its power supply to meet the electricity needs not only of the host province of Negros Oriental but also that of the neighbouring islands of Panay in 1991 and Cebu four years later in 1995. To date, the field has a total installed plant capacity of 192.5MWe.

After 25 years of continuous exploitation, the rated installed capacity of Palinpinon 1 power plant can no longer be attained due to the increased inefficiencies of the power plant coupled with reservoir pressure drawdown and injection returns. The need therefore to optimize steam production has become crucial; more so as the demand for additional power has been seen to increase each passing year. Tapping the expanded two phase zone induced by pressure drawdown as a result of the continuous exploitation of the geothermal resource has been proven successful in augmenting steam supply to the power plant. Moreover, EDC has recently acquired the power plants from NPC in October 25, 2009 through competitive bidding supervised by Power Sector Asset and Liabilities Management (PSALM).

2. SOUTHERN NEGROS GEOTHERMAL PRODUCTION FIELD CONCEPTUAL MODEL

The initial conceptual model of the field developed, was based on pre-exploitation pressure and temperature data, well discharge data, geochemical and geological data (Urbino et al, 1988). The reservoir model indicated that a cooling intrusive rock beneath a dormant Cuernos de Negros volcano heats-up fluids at depths to temperatures >320°C, and recharge the reservoir in two upflow areas. The major upflow is located south-southwest of Puhagan area while the minor one occurs in the Sogongon area. The reservoir was initially liquid-dominated with localized two-phase zones at the shallow levels. These were detected in exploratory wells drilled in the Puhagan, Ticala, and Nasuji-Sogongon areas. The existence of these two-phase zones was manifested by the excess enthalpies of the discharge fluids. Shallow production well OK-2 in central Puhagan, for instance, produced fluids with a maximum enthalpy of 1819 kJ/kg during discharge testing in 1978.

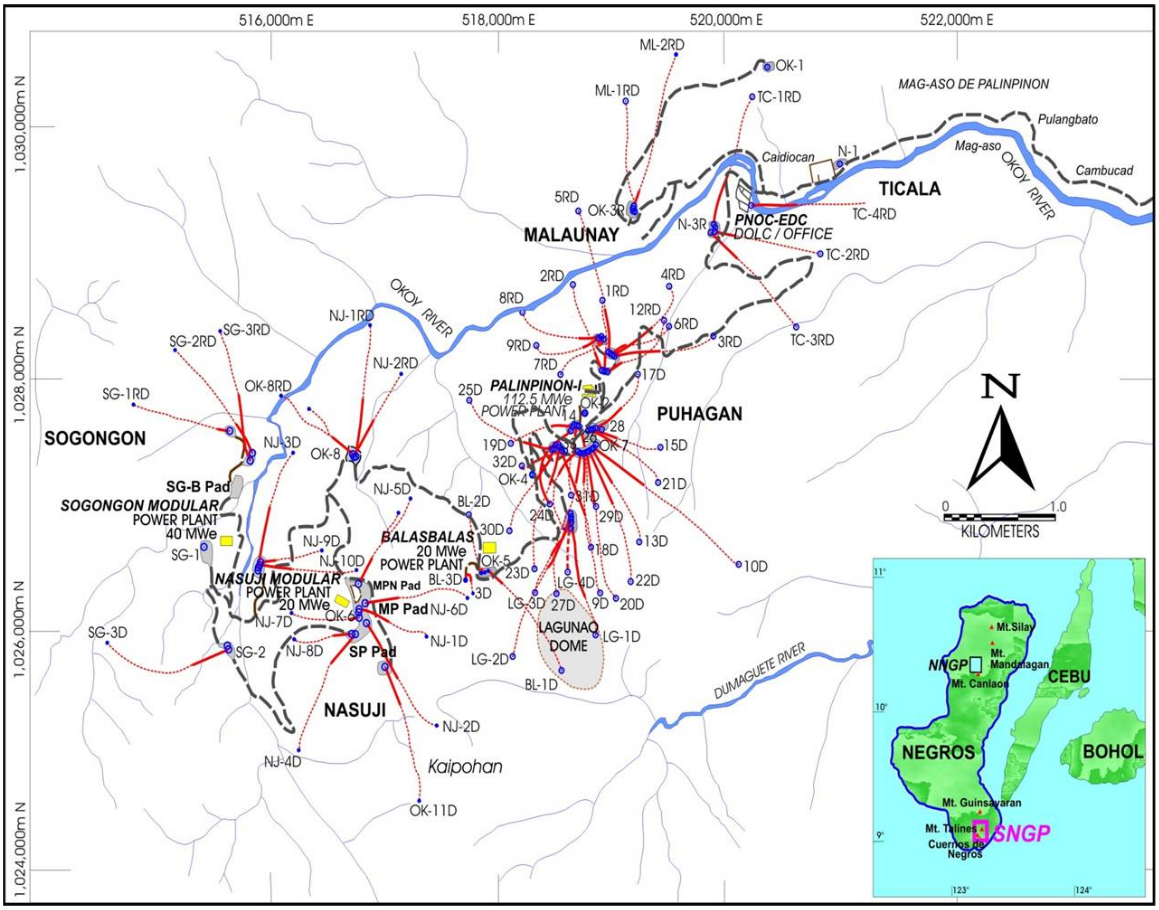

Figure 1: Location and structural map of Southern Negros Geothermal Production Field (SNGPF) showing areas of localized steam/two-phase cap. (With permission from SNGPF GeoServices Department)

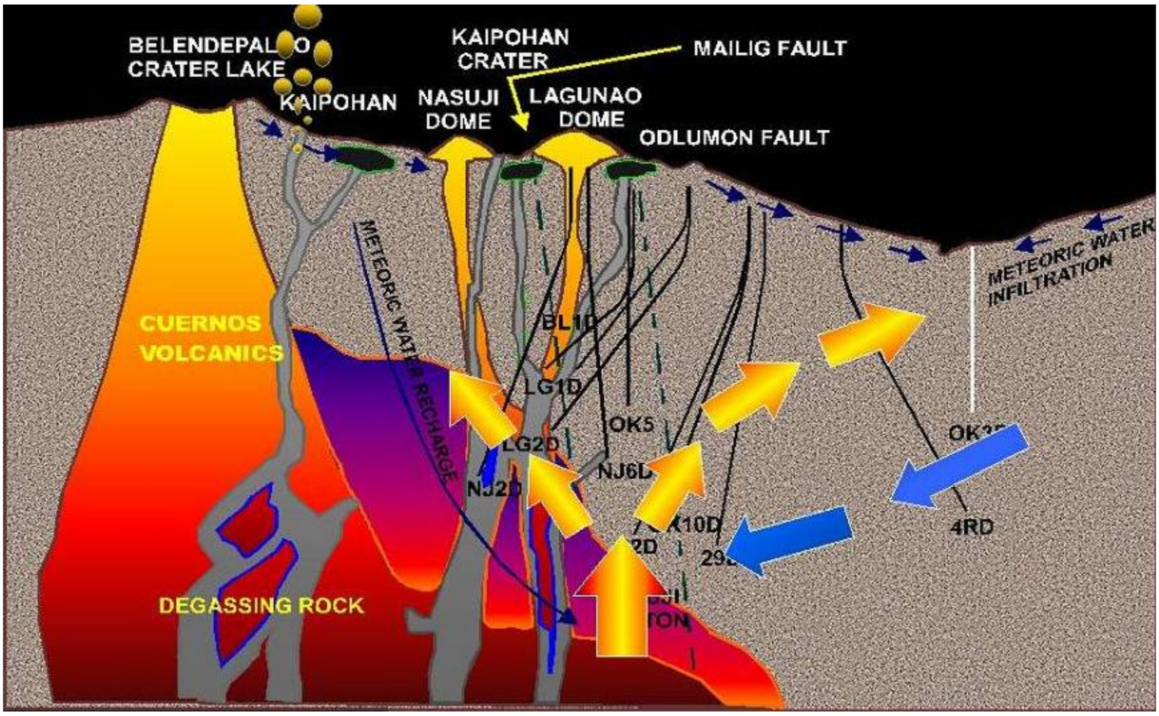

Figure 2: Conceptual model of the SNGPF reservoir (After Pamatian, et al., 2003)

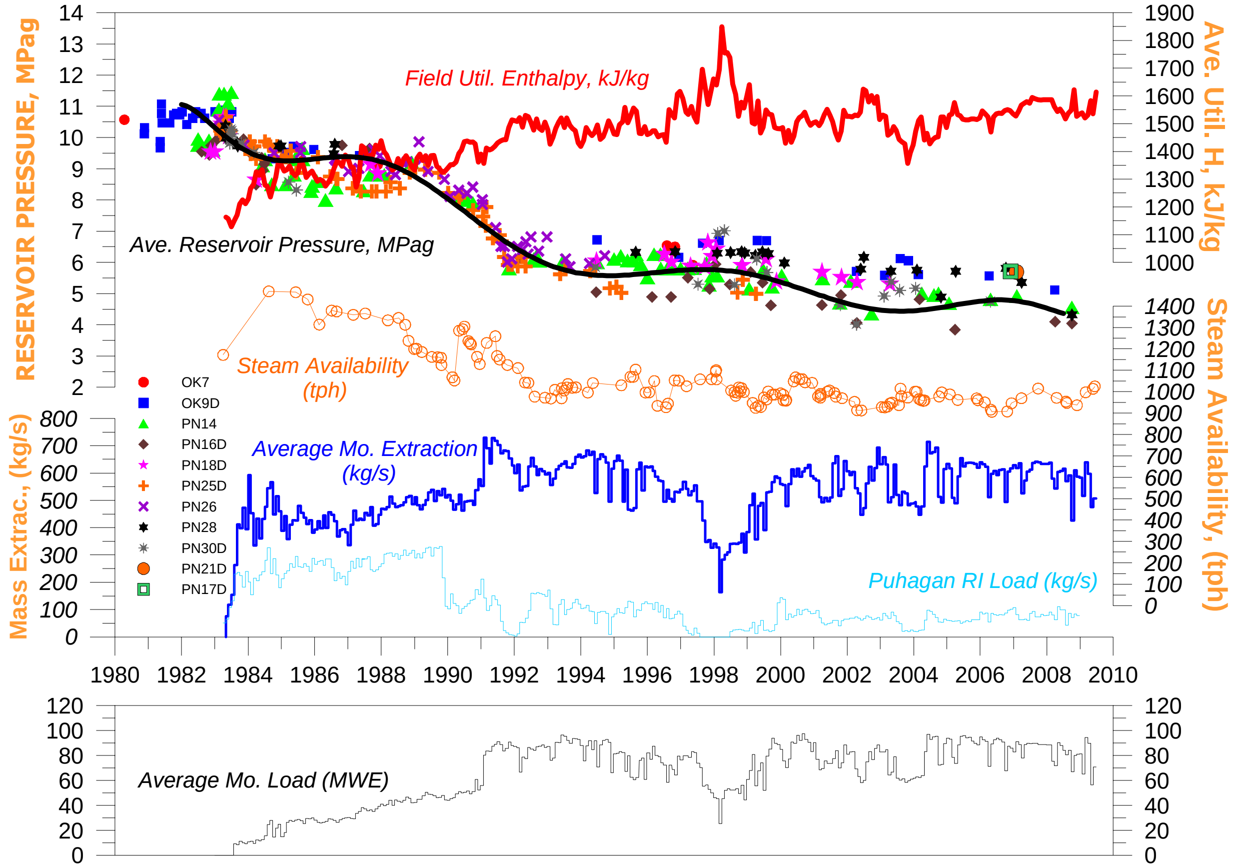

Figure 3: Palinpinon 1 field trends and power plant loading

The present hydrological model of the Southern Negros geothermal system shown in Figure 2 indicates two outflow zones (Pamatian et al, 2003). One occurs towards the northeastern sector through a narrow conduit into the outflow area in the lower elevations of the Okoy Valley and the other towards the western sector to the Nasuji-Sogongon area through a much broader channel. Fluid flow in the system is mainly controlled by geologic structures such as faults, contact zones between lithologic units and sedimentary formations. However, major permeability is provided by faults mapped in the area, namely the NE trending Nasuwa, Ticala, Puhagan, and Odlumon Faults and the NW trending Nasuji and Sogongon Faults. These structural faults and their splays, while playing major role in the hydrological flow of the system, also provided good communication channels between the production and injection sectors.

Understanding the fluid flow mechanism in these structural faults enabled the formulation of appropriate strategies that effectively manage the exploitation of the resource. Moreover, it provided vital information that facilitated in promoting the expansion of the shallow two phase zone into what these had become at present.

3. RESERVOIR RESPONSE TO FLUID EXTRACTION

Pressure drawdown and injection returns have been the two major and most often, opposing reservoir processes dictating the exploitation of the Palinpinon geothermal field (Amistoso, A.E., et.al. 1997). Power plant load demand as well as field management interventions, i.e. well utilization and brine injection strategies, have been observed to influence pressure drawdown and injection returns more than any other factors in shaping prevailing reservoir conditions. Pressure drawdown has been seen to promote the expansion of the two-phase zone while effects of injection returns inhibit it.

3.1 Pressure Drawdown

The average reservoir pressure in Palinpinon 1 reckoned at 1000 m below sea level, gradually declined during the early stages of commercial operation from 1983 to 1989 but dropped abruptly after the bulk of brine injection was shifted away from the Puhagan production sector in 1989 and after the power plant went on full load operation in 1991 began to stabilize at 6.0MPag in 1994 (Figure 3)

Lower mass extraction during prolonged two-unit operations of the power plant in 1997–1999 and in 2003–2004 due to preventive maintenance of turbine-generator units allowed the reservoir to recover briefly inducing marginally operating (low WHP) production wells, e.g. PN33, PN29D and PN13D to contribute back to the Fluid Collection and Recycling System (FCRS). Stable reservoir pressure was attained since 1996 and has been maintained up to the present with the implementation of appropriate field management strategies. At present, the average reservoir pressure had been drawn down by as much as 6.0MPag despite injection of as much as 60% of the waste brine.

Even before the commissioning of the 80 MW Palinpinon 2 modular plants, the average reservoir pressure in this sector declined by about 3.0MPag since 1990 to 2000 and gradually moving towards the current Palinpinon 1 reservoir pressure (Figure 4). The pressure decline occurred at the same time the reservoir pressure in Palinpinon 1 started to drop in 1990, confirming that both sectors share the same reservoir source. The rate of pressure drawdown increased further albeit slightly when mass extraction was increased by 67% when the Balasbalas module was commissioned in April 1995.

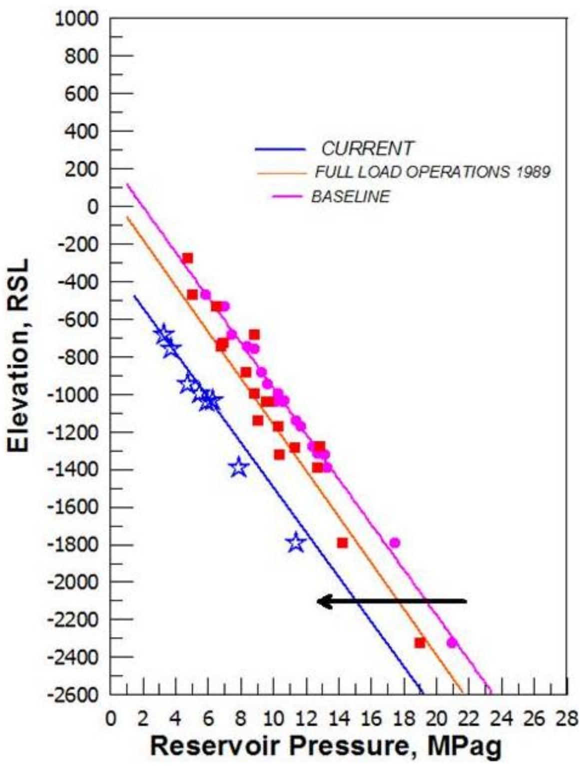

Figure 4: Shift of hydrostatic lines due to pressure drawdown in Palinpinon

Since commissioning, the modular plants have been operating at full load except in the Balasbalas module where plant load had been below the rated capacity of 20MW due to steam supply shortfall as a result of pressure drawdown and mineral blockage at the wellbores. Pressure drawdown has also affected steam production in some production wells in Palinpinon 2, i.e., SG2, and SG3D in the Sogongon sector which tapped the shallow two-phase. However, outputs in production wells NJ9D and NJ10D drilled in central Nasuji sector remained unchanged notwithstanding the increased boiling of reservoir fluids.

3.2 Injection Returns

As the Palinpinon reservoir is exploited, the pressure differential between the production and injection sectors increased and drove the injected brine (~160°C) back to the production area. The breakthrough times of the injected fluids to the production sector vary considerably from injection well to injection well. Experience showed that injection flow rates and the permeability of the structural faults that convey this fluid are the two major factors that significantly influenced the arrival time of the injection fluids to the production sector. In Palinpinon 1 for example, the Puhagan, Ticala and Odlumon faults have been identified to channel injection fluids back to the production sector.

Tracer tests conducted both in Palinpinon 1 and Palinpinon 2 confirmed the interconnection between the production and injection sectors in Puhagan. Hermoso and Mejorada (1997) gave details of the results and established direct communication of a certain injection well to usually multiple production wells. Monitoring of the chemical parameters of the injected brine, i.e. injection line chloride, reservoir chloride and carbon dioxide confirmed the positive effects of shifting the bulk of injection away from the Puhagan production sector. Pamatian, et.al.(2003) also showed that injection line chloride dropped from 11,000 ppm to an average of 9,000 ppm when injection load in the Puhagan injection sector was reduced.

Injection mass front could progress into thermal breakthrough that cools the feed zones of the affected wells. Thermal declines among affected Puhagan wells range from 5°C to 30°C based on actual downhole measurements and $TSiO_2$ geothermometry (Hermoso and Mejorada, 1997). By experience, thermal fronts as a result of injection load of over 50 kg/s into PN5RD could reach the south western Puhagan production sector in about two weeks causing decline in well outputs. Similarly, albeit on a longer period, injection load of over 130 kg/s into TC3RD could cause thermal fronts in the south-eastern Puhagan production sector in about three months.

In the case of Palinpinon 2, communication from injection wells, NJ2RD and SG2RD to some production wells have been properly documented by separate tracer tests as summarized in PNOC EDC (1995) and recently reported by Maturgo, et.al. (2006). Mass fronts have reached as far as NJ3D to the North, in OK5 farther to the West and in NJ5D to the Northeast. Wells NJ3D and NJ5D manifested temperature and output declines including NJ8D in central Nasuji. The tracer test conducted in the Palinpinon 2 area in 2005 revealed that as much as 25% of the injected brine in NJ2RD and SG2RD return to nearby production wells through NW-SE and NE-SW trending faults within a year. This was later confirmed in a simulation study conducted by Esberto in 2003.

Injection breakthrough causes cooling of the production zones precluding the expansion of the two-phase zone and in worst cases induce downflow from the upper permeable zones that suppress feed from the deeper zones. As such, both mass flow and enthalpy deteriorate as in well OK7 where output dropped from 7 MWe to only 1.3 MWe after its mass flow and enthalpy declined. In 1989, PN26 ceased to produce commercially and was cut-out from the system (Malate and O'Sullivan, 1991). Production wells PN17D and PN21D also became non-commercial and were decommissioned in 1993 and 1996, respectively. By 1997, six of the 25 producers in Palinpinon 1 became non-productive and the field lost about 39 MWe of steam capability. In Palinpinon 2, wells NJ5D and NJ8D in central Nasuji and NJ3D in northern Nasuji manifested similar trend. A combined steam flow of around 50 tons per hour (TPH) had been lost from these wells, equivalent to about 6 MW.

4. RESERVOIR MANAGEMENT STRATEGIES IMPLEMENTED

Several reservoir management strategies were implemented to address the adverse effects of injection breakthrough at the same time promote pressure drawdown to allow expansion of the shallow two-phase zone. Foremost among these are the major shift of the bulk of injection farther away from the production sector, drilling and utilization of high enthalpy wells (Orizonte, R.G., et.al., 2000) and the controlled injection of brine into known injection wells that have high communication with the production sectors.

4.1 Shifting Injection Away from the Production Area

The compact design of the Palinpinon 1 steam field required disposal of waste brine into infield injection wells drilled near the Puhagan production sector early in its commercial production. Shortly after commissioning, massive injection breakthrough had been experienced causing substantial declines in well outputs prompting the shift of the bulk of injection farther away towards the Ticala and Malaunay sectors starting in 1989. The reduced injection load in Puhagan to 100 kg/s induced output recoveries in a number of production wells. Subsequently, the two-phase condition at the upper permeable zones of some production wells expanded as pressure drawdown intensified inducing production from the deeper zones. The mass flow of well PN29D recovered from 28 to 66 kg/s while its enthalpy increased from 1058 to 1408 kJ/kg increasing the steam flow from 17.6 to 82.5TPH. Similar improvement was observed in well PN19D when its lower feedzones contributed to the discharge. Over-all, steam supply to the power plant had improved.

Despite the transfer of the bulk of injection, thermal breakthroughs were still observed in several wells which are hydrologically connected to injection wells N3R and TC3R through Ticala Fault. These injection wells were later decommissioned and re-drilled to target other faults as in the case of the latter. By mid-1997, injection at the Puhagan area was totally eliminated. This induced excessive pressure drawdown in the southern and south western sector of the production area. Although the enthalpies of the wells increased, their mass flows significantly declined resulting to decline in steam outputs. The total transfer of injection away from Puhagan area therefore, had not been entirely beneficial to the reservoir system.

4.2 Drilling and Utilization of High Enthalpy Wells

This strategy was adopted in Palinpinon 1 to increase steam production without increasing the volume of separated brine. Wells with high discharge enthalpies were given priority in utilization in lieu of the more watery wells during low plant loads. Some of these wells are OK2, PN30D and PN32D. Although the steam capability of the field was improved, it was not enough to sustain full load operation. Thus, make-up wells were drilled to tap the shallow two-phase fluid. Big hole PN33 was drilled in 1993 in central Puhagan area while LG2D within the upflow zone at the Lagunao area. Both wells produce dry steam with brine flow of less than 5 kg/s. Production well LG2D could have replaced at least four low priority low enthalpy wells and reduced the total Palinpinon 1 brine load by about 84 kg/s (Amistoso, 1993) had the well not been lost during its work-over in 1995. Production wells LG3D and LG4D were later drilled as replacements and were put on-line the system before the end of 1996.

Prioritization of high enthalpy wells proved effective at the time when effects of injection breakthrough were prevalent in the production sector however, with the three-unit operation of the Palinpinon 1 power plant, discharge of all production wells into the FCRS cannot be avoided. The injection breakthroughs associated with the increased mass extraction during full load had been controlled with the commissioning of TC3RD and TC4RD into the system. Maximum utilization of all production wells in Palinpinon 1 has since been continued to the present.

4.3 Controlled Injection

Balancing the effects of pressure support as against pressure drawdown as a strategy to sustain steam production requires the controlled injection of waste brine in some injection wells in Palinpinon 1 as well as in Palipinon 2. Reaching this balance had involved a complex process in determining the optimum or preferred injection load that took into consideration, among others, the selection of the injection wells to be used and the mechanism of how brine injection into this well can affect steam production.

In the case of Palinpinon 1, it has been established that a load of about 50 kg/s and not more than 130 kg/s in PN5RD and TC3RD, respectively could provide pressure support to the wells in the southern and south western sectors of the field without adverse effects to the production zones. Knowing the injection breakthrough times and identifying the specific production wells that will be affected enabled the implementation of short-term interventions to address operational constraints, thus providing operational flexibility. Excessive load in PN5RD for example would drastically affect the outputs of wells PN24D, PN30D and PN23D in south western Puhagan in just two weeks while higher loads in TC3RD would affect PN22D, OK9D and PN20D at the opposite side of the production field albeit at a longer period of time of at least three months. Cold brine injection at SG3RD in Palinpinon 2 has been limited to 50 kg/s to minimize effects of injection returns to the production sector. This injection strategy has been implemented up to the present.

5. STEAM PRODUCTION FROM THE TWO-PHASE ZONE

With the implementation of the above mentioned reservoir management strategies, the two-phase condition at the shallow levels of the reservoir identified in the conceptual model of the Palinpinon geothermal field had expanded considerably after 25 years of exploitation in Palinpinon 1 and 15 years in Palinpinon 2. The vertical expansion of the steam or two-phase cap is reflected by the change in the water levels of the Palinpinon wells. Water levels had dropped from a baseline data of 200 mMSL to -600 mMSL and -700 mMSL in central Puhagan, and in Nasuji - Sogongon areas, respectively. This can also be seen as a shift in the hydrostatic lines drawn to represent the wellbore pressures at the control points measured at different stages of the exploitation of the field (Figure 4). The extent of the lateral expansion of the two-phase horizon of the Palinpinon 1 field was estimated based on volumetric calculation by Amistoso, et. al. (1993). From localized areas, it has widened encompassing almost the entire Palinpinon 1 field, following the north-easterly outflow tongue of the system estimated to cover an area of 4.93 km^2 with a power potential of 35.5 MWe-years (Figure 5). In the case of Palinpinon 2, the extent of the lateral expansion can be only be surmised from the recent wellbore data as the volumetric calculation is yet to be updated. Production from this two-phase zone has been proven by shallow wells OK2 and PN33 in central Puhagan, and by SG2 in Sogongon sector, and just recently by well NJ6D which had become commercial in the Palinpinon 2 sector.

Recognizing the potential of this expanding relatively dry component of the geothermal resource, the following steam optimization strategies had been proposed and implemented to sustain and augment supply to the power plants. Excess steam flow in Palinpinon 2 as a result of the additional steam production from this two-phase zone has been estimated to support additional plant capacity of around 20MWe.

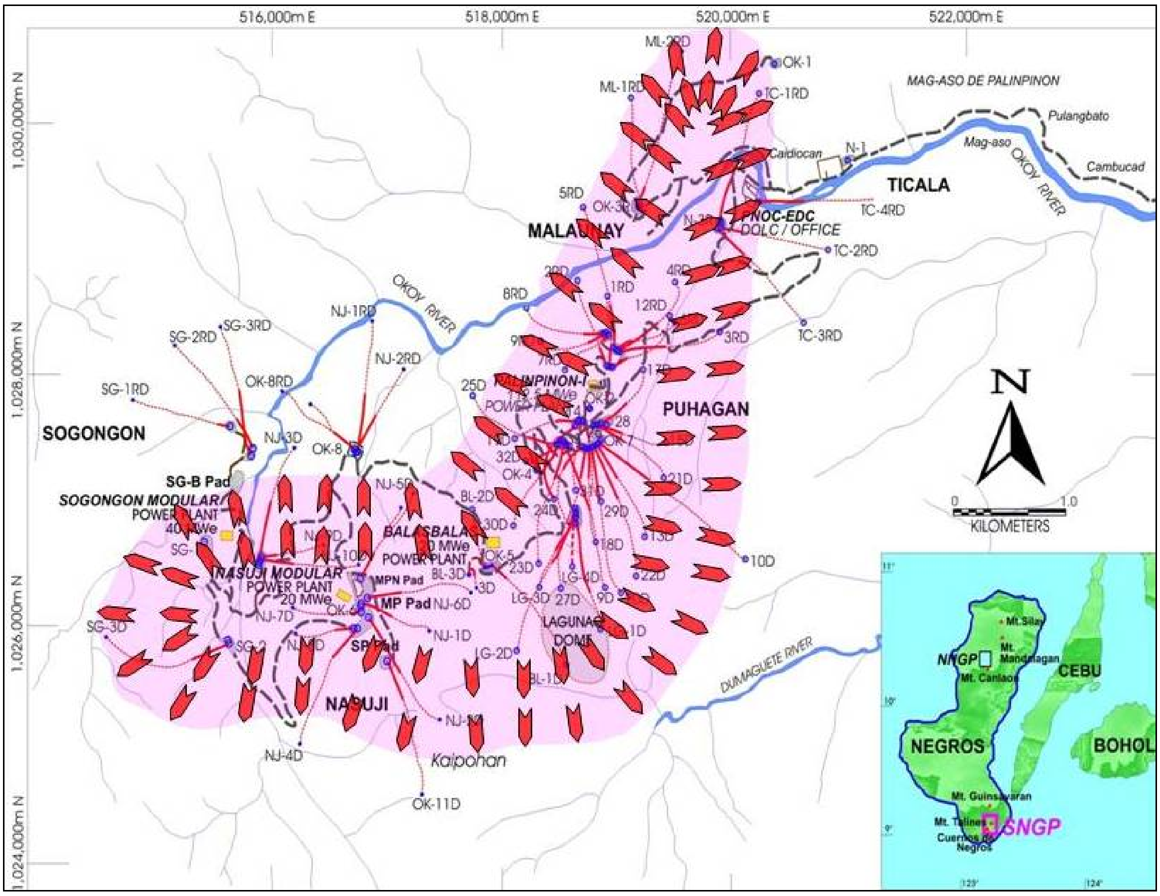

Figure 5: Estimated aerial expansion of the steam/two-phase cap in Palinpinon 1

5.1 Revival of Pre-maturely Decommissioned and Acidic Wells

The massive injection breakthroughs affecting steam production in the early stage of the commercial operation of the 112.5MWe Palinpinon 1 geothermal power plant caused the pre-mature decommissioning of PN21D, PN17D, PN26 and OK7 in 1989 to 1996. Over 10 years after their shutdown, these wells were recommended for re-utilization to augment steam supply in Palinpinon 1 (Aqui et al., 2005). The significant drawdown and the reduced effects of injection returns in the production sector had justified their workover and acid stimulation. The remedial jobs were carried out and were completed respectively in November 2006 and July 2007.

Post workover shut surveys in well PN21D (Figure 6) indicated that the upper feed zone at 1250-1400 mMD has indeed become two-phase. Its water level had dropped by about 800m to a current depth of 600 m below sea level. Moreover, the temperatures at the deeper zones are higher compared to the 1985 values indicating recovery from the effects of injection breakthrough. The well was discharged last December 2006 and results showed that its commercial output was regained. As shown on Table 3, the current mass flow has not significantly changed compared to the baseline value in 1988 but the corresponding enthalpy is higher. This indicated that there is additional feed into the well to compensate for the effects of pressure drawdown, and this may be a two-phase feed coming from the upper zone. Compared to the output prior to its decommissioning in 1995, both mass flow and enthalpy have improved, an indication that the well has fully recovered from injection breakthrough.

In well PN17D, perforation was conducted at the cased-off section from 1272 mMD to 1530 mMD where a two-phase zone existed based on downhole surveys. Interestingly, this section has substantial permeability as suggested by the partial and total circulation losses recorded during drilling. Post workover shut surveys showed that the water level (liquid-two-phase interface) is also at ~600 m below sea level. The temperature profile (Figure 6) indicated liquid and two-phase fluids entering the well at the perforated section (1350 mMD). The heavier liquid fluid downflows and exits at the still severely cooled major zone at 2000-2050 mMD. The relatively strong downflow from 2100 mMD noted during the 1989 survey has apparently disappeared as temperatures at 2400-2800 mMD recovered indicating that the well has also recovered from injection breakthrough. PN17D was flowed last July 2007 and yielded positive results. Its commercial output of 4MWe was regained as summarized in Table 1. Comparison of the current and the previous data confirmed the expansion of the steam/two-phase horizon to this area.

Production wells PN21D and PN17D were put on-line to the system on December 2006 and August 2007, respectively. The successful revival of these wells increased the field steam capability by about 8MWe. The wells have since been utilized without significant deterioration in output to date. Just recently, PN26 was worked over and stimulated to restore its productivity. However, the well was not able to regain its commercial output most likely due to a casing problem encountered towards the end of the workover operation. Restoration of the productivity in OK7 was not pursued as the well was significantly damaged during its last workover.

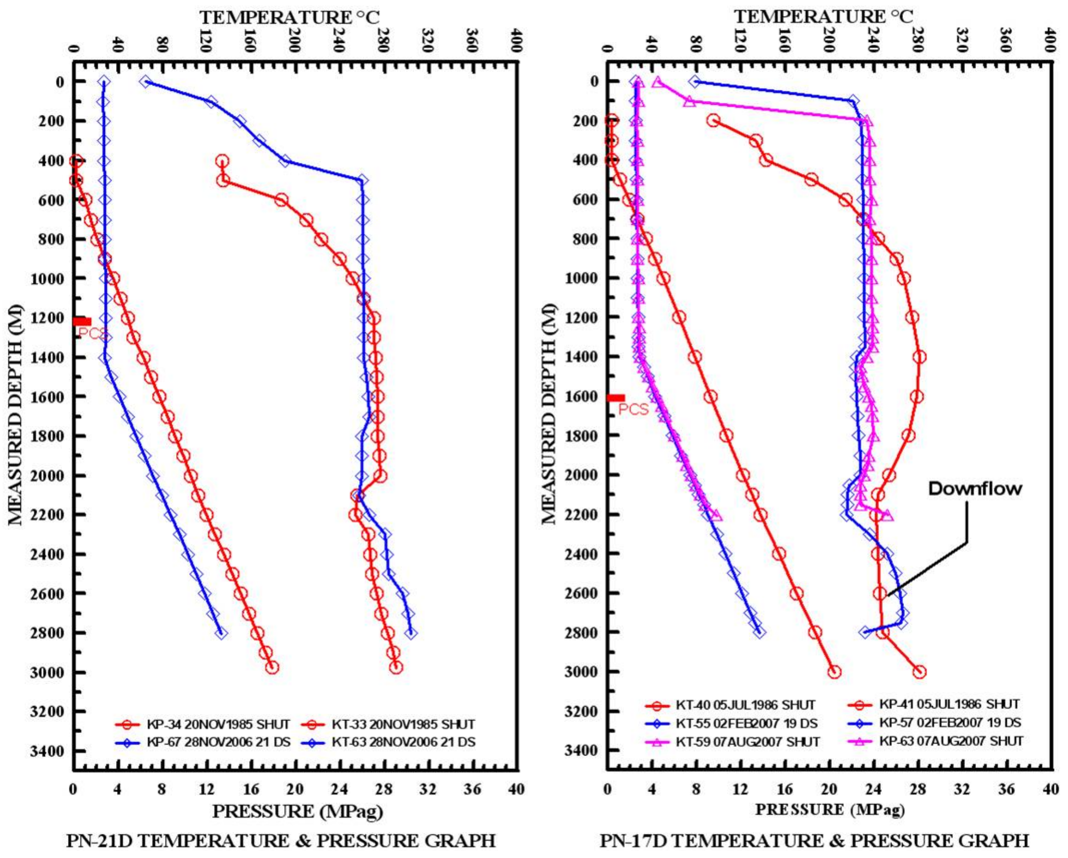

Figure 6: Post-workover downhole temperatures and pressures in PN21D and PN17D

Well NJ6D drilled towards the southeastern Nasuji sector in Palinpinon 2 was initially unsuitable for commercial production due to its acidic discharge. With the expansion of the two-phase region, the acidic horizon had receded and eventually disappeared as field had drawn down. Discharge testing in 2004 proved the near neutral discharge of NJ6D, increasing the steam capacity of this sector by as much as 10MW and confirmed the field wide extent of the two-phase expansion. The same manifestation has been observed in BL1D in the Balasbalas sector. The well was initially feeding from an acidic source at the upper permeable zone causing corrosion and erosion of the casing as well as the surface equipment, i.e. wellhead assembly and the branch lines conveying the two phase fluids to the FCRS. A 15-meter section was totally eroded causing an open hole in the 7-5/8 inch production liner while a thinned-out section occurred at the vicinity of the kick off point (KOP) section of the well. The well was shut for safety reasons but was recently re-utilized after recent discharge testing in 2007 indicated that the well is already discharging relatively dry steam and after the production liner of this well was “sleeved” to improve the casing integrity of the well. The well was cut-in back to the OK5 Modular plant in December 2008 with an output of at least 5MWe.

5.2 Conversion of Puhagan Injection Wells to Producers

The positive results of the workover and acidizing jobs in PN21D and PN17D strengthened the earlier recommendation to convert selected Puhagan injection wells into production wells to further augment the steam supply for Palinpinon 1 plant (Aqui et al, 2005).

Injection well PN6RD, drilled towards the north-eastern part of the Puhagan sector and within proximity to production well PN17D was initially tested in July 2007. The well discharged relatively dry steam of about 6.7 MWe. This output was later confirmed and sustained during the extended discharge test conducted from December 2007 to January 2008.

The Puhagan injection wells PN7RD, PN8RD and PN9RD although drilled in the northwest flank of the field, are also closest to the production area with established good communication to producers through common geological structures intersected. The three wells have high shut-in pressures of 2.16 MPag, 1.51 MPag and 2.68 MPag, respectively and still have exploitable temperatures at depths ranging from 220°C to 260°C. PN8RD did not sustain discharge due to a blockage just below its production casing shoe (PCS). Well PN7RD on the other hand sustained discharge when flowed but gave a cyclic non-commercial discharge output likely due to the mineral blockage within the production liner. Well PN9RD sustained discharge when tested producing at least 3 MW at the wellhead. As expected, the well’s discharge was liquid dominated confirming that the two-phase condition at this part of the reservoir had not expanded significantly.

Table 1. Bore Output Measurements of PN21D and PN17D after Re-Commissioning.

	WHP (MPag)	**H** (kJ/kg)	**MF** (kg/s)	**WF** (kg/s)	**SF** (TPH)	**MWe**	**Date Tested**
PN21D	0.69	1511	34.2	17.7	48.7	4.8	28Sep07
PN17D	0.64	1395	27.0	15.3	32.9	3.3	17Aug07

Table 2. Bore Output Measurements of NJ6D and BL1D.

	WHP (MPag)	**H** (kJ/kg)	**MF** (kg/s)	**WF** (kg/s)	**SF** (TPH)	**MWe**	**Date Tested**
NJ6D	0.82	2547	25.4	2.6	82.1	10.0	11Feb04
BL1D	0.9	2712	12.3	0.2	43.0	5.3	8Dec08

Table 3. Bore Output Measurements of Puhagan Injection Wells After Conversion to Production Well.

	WHP (MPag)	**H** (kJ/kg)	**MF** (kg/s)	**WF** (kg/s)	**SF** (TPH)	**MWe**	**Date Tested**
PN6RD	1.03	2722	15.8	0.4	55.6	5.5	23Jan08
PN9RD	0.79	1280	36.8	27.0	35.8	3.6	10Mar08

CONCLUSION

After more than 20 years of continuous exploitation of the Palinpinon Geothermal field, the timely implementation of appropriate resource management interventions has been successful in achieving a balance between the two major reservoir processes, pressure drawdown and injection returns, expedient in promoting the expansion of the two-phase region at the shallow levels of the resource for steam production.

The current Palinpinon field management strategy has been geared towards tapping this two-phase fluid to sustain and optimize operations of the power plant. The successful re-utilization of pre-maturely decommissioned wells after more than ten years of shutdown and conversion of some infield injection wells in Puhagan into producers and the commercial steam production from the once acidic well NJ6D in Nasuji had proven the merits of this strategy. Evaluation and discharge testing of the other Puhagan injection wells have been undertaken to explore the possibility of converting these into producers. Three of these, i.e. PN7RD, PN8RD and PN3RD have indicated high potential.

Consequently, steam production in the Palinpinon geothermal field has improved with the relatively dry feed contribution from the expanded two-phase region. A total of about 32MWe has been added to the power generation capacity of the power plants in a span of four years since 2004. Moreover, steam production from the two-phase region has been beneficial in managing the exploitation of the Palinpinon reservoir reducing brine load disposal and hence, minimizing problems posed by injection returns.

ACKNOWLEDGEMENT

The authors wish to thank EDC management for the permission to publish this paper.

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