PROCEEDINGS, 25th Annual PNOC-EDC Geothermal Conference
Manila Diamond Hotel, Philippines, March 10-11, 2004

SUSTAINABILITY OF THE BACMAN GEOTHERMAL FIELD

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ABSTRACT

Results of the geochemical monitoring of the field for the last ten years showed that most production wells have attained a relatively stable chemical discharge with time. There was also an absence of detrimental reservoir processes as experienced in other PNOC-EDC geothermal fields such as injection returns, cold ground water intrusions and acidic inflows. Most often, reservoir related problems encountered occur near well bore and at very manageable levels. This paper aims to present that the current reservoir management strategy and with the existing geochemical monitoring scheme all point out to a stable and sustainable resource.

1.0 INTRODUCTION

The Bacman Geothermal Production Field is located near the southern tip of the Bicol Peninsula in Luzon Island, some 500 kilometers southeast of Manila, Philippines. The field derives its steam from three adjacent production areas composed of several production and injection wells (Fig. 1). It has three generating power plants – Bacman-I Palayang Bayan, and Bacman-II Cawayan and Botong. The first unit of the 110-MWe (2x55MWe) Palayang Bayan power plant was commissioned in September 10, 1993 and the second unit followed in December 12, 1993. The 20-MWe Cawayan modular power plant was commissioned in March 15, 1994 while the 20-MWe Botong power plant started commercial operation in April 27, 1998.

The Bacman-I Palayang Bayan power plant, since commissioning in 1993 was often operated below its rated capacity because of various mechanical problems. It was only able to load up to 110-MWe from April to June 1995. After this, due to plant problems, the average load of the two turbines was less than 45 MWe. In February 2000, Unit 2 was totally cut-out for repair because of excessive turbine vibration.

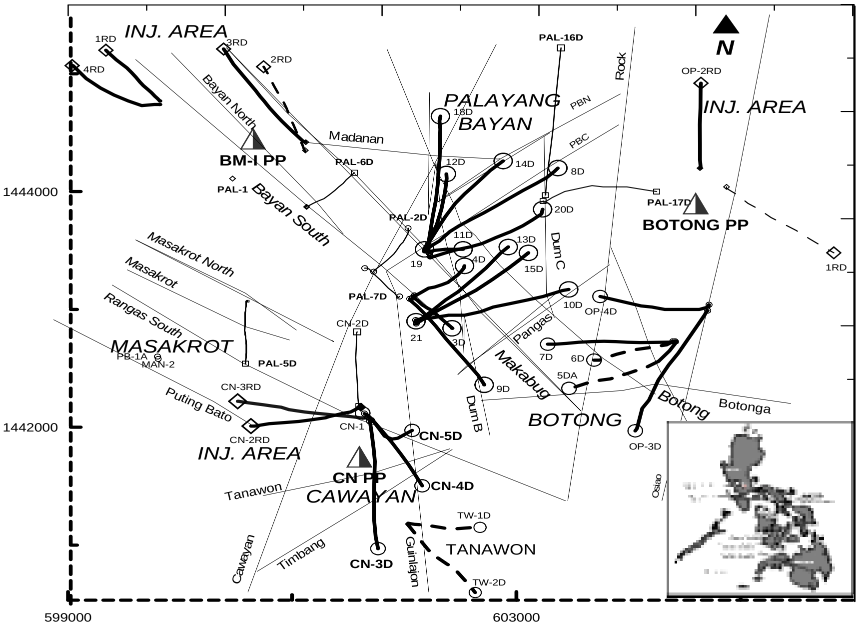

Figure 1. BGPF well location map and major structures.

The Cawayan and Botong power plants have been operating at full capacity, except during preventive maintenance schedule and repairs.

2.0 BACKGROUND

Full-scale extraction of the field commenced in February 1993 when most production wells were put on full-bore discharge prior to power plant commissioning. During commercial operation, when the power plant was under-loaded, a number of wells, especially the big producers, were either shut or put on bleed or throttled conditions to minimize steam wastage. Due to this situation, the long-term response of the field at full-scale extraction has not been fully assessed. However, substantial data have been gathered to evaluate the sustainability of the resource during full operations.

This paper summarizes the over-all response of the field, the operational problems encountered, and their impact on the sustainability of the resource.

3.0 GEOCHEMICAL RESPONSE

After several years of exploitation, the general response of the reservoir based on chemical and physical changes can be classified into four processes (See, 2001), spread across the field (Fig. 2): (1) boiling and mixing with low boron fluids from PAL-6D area, (2) boiling and vapor formation, (3) mixing with Masakrot fluid from the Western part of the field, and (4) dilution with cooler acid-SO_4 fluids from shallow feedzones in Cawayan area. The reservoir responded rather distinctively in each particular area of the field. Except for the last process, the response was mostly beneficial to the resource as indicated by the relatively stable chemical and physical trends. The processes are best represented by the HTQuartz vs. Clres (Fig. 3), and TQuartz vs. Cl/B (Fig. 4) cross plots. In Figure 4 recent trends showed data clustering towards the end-member mixing fluids indicating stable reservoir processes. In both plots, no mixing trend towards the injection fluids could be discerned.

4.0 FIELD DRAWDOWN

Pressure monitoring at non-commercial well PAL-7D showed that the biggest rate of decline

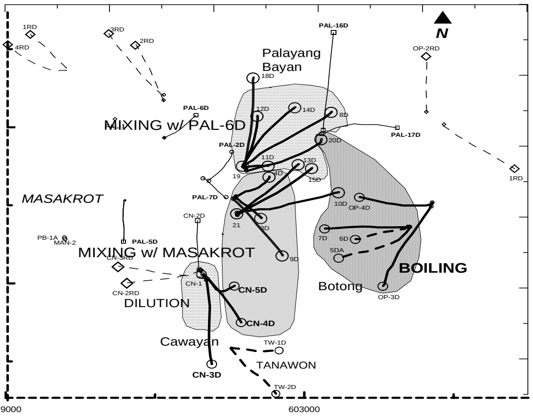

Figure 2. Reservoir processes

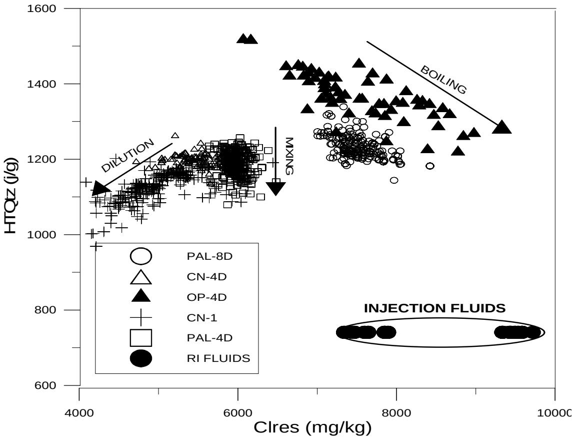

Figure 3. Crossplot of HTQuartz vs. Clres

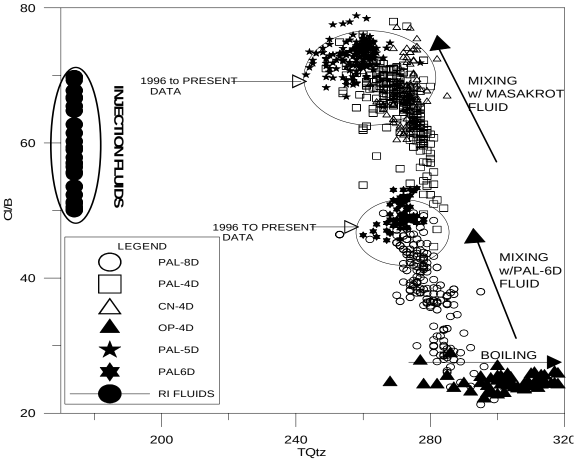

Figure 4. TQuartz vs. Cl/B ratio

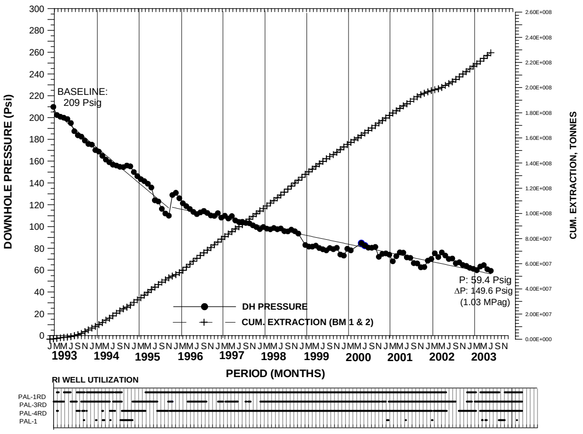

Figure 5. PAL-7D Interference Test (RRMD Data)

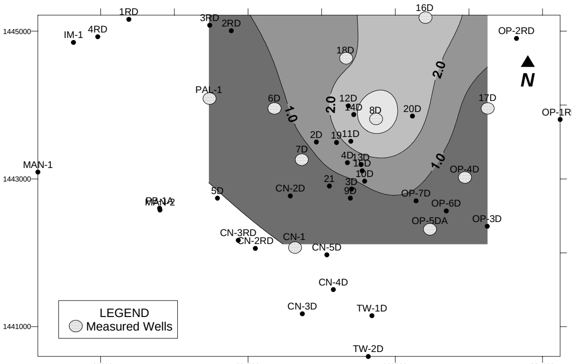

Figure 6. BGPF field drawdown distribution (in MPag).

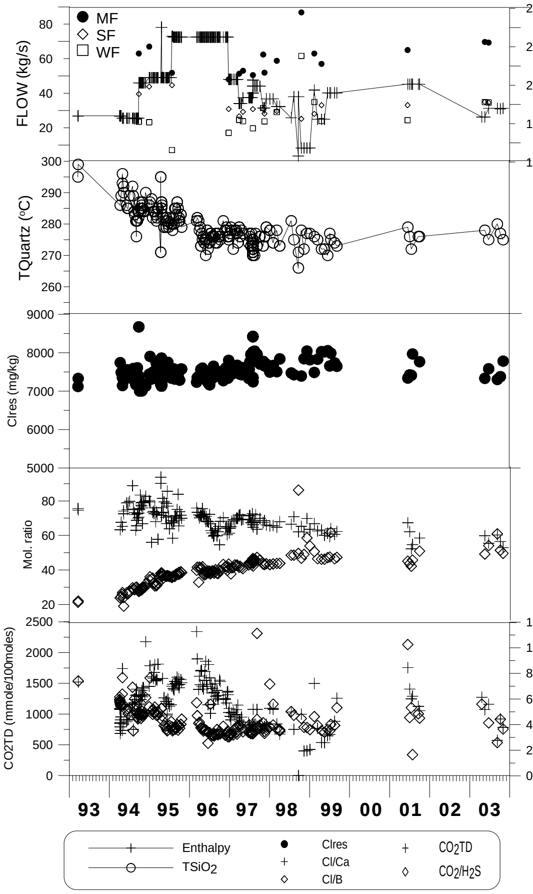

Figure 7. PAL-8D chemical trends with time

in downhole pressure at 2.70 psig per month occurred from 1993 to late 1995 (Fig. 5). During this period the most significant chemical change among the production wells were also observed. From 1996 to present, the pressure drop has stabilized at a much slower rate of 0.67 psig per month. Total pressure drop at PAL-7D from 1993 to present was relatively low at 149 psig or 1.03 Mpag.

The biggest drop in downhole pressure in the field (Fig. 6) was measured at 4.27 Mpag in July 1998 at well PAL-8D (Fajardo, 2003). However, chemical trends would show that this drawdown was stabilized by the inflow of recharge fluid, and presumably, even in the absence of new downhole measurement, has not declined neither further nor expanded to other parts of the field as indicated by the chemical trends.

5.0 CHEMICAL AND PHYSICAL TRENDS WITH TIME

Chemical and physical trends with time of selected wells reflect the over-all response of the field, and also provide a basis for predicting the future response of the field. The chemical trends with time of all wells have stabilized as exhibited by the following representative wells:

PAL-8D. The initial trends with time of PAL-8D (Fig. 7) showed the most drastic response among the production wells in terms of chemical and physical changes. During the first three years of extraction, the well increased in discharge enthalpy from about 1500 j/g to almost pure steam at 2500 j/g. Declining trend in TQuartz with corresponding increase in Clres and CO_2TD was also observed, typical of a well experiencing massive boiling due to pressure drawdown. At first, it appeared that the drawdown would spread in the area; however, as the Cl/B ratio and other chemical parameters

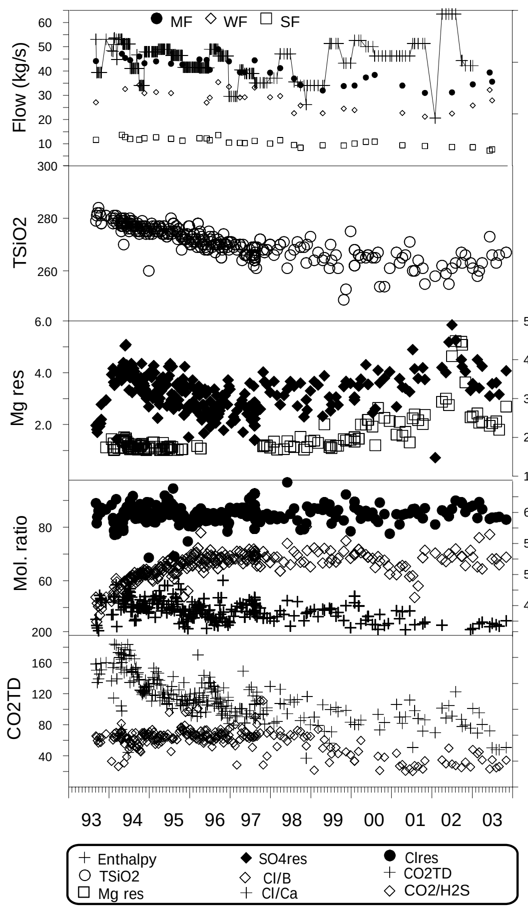

Figure 8. PAL-4 chemical trends with time

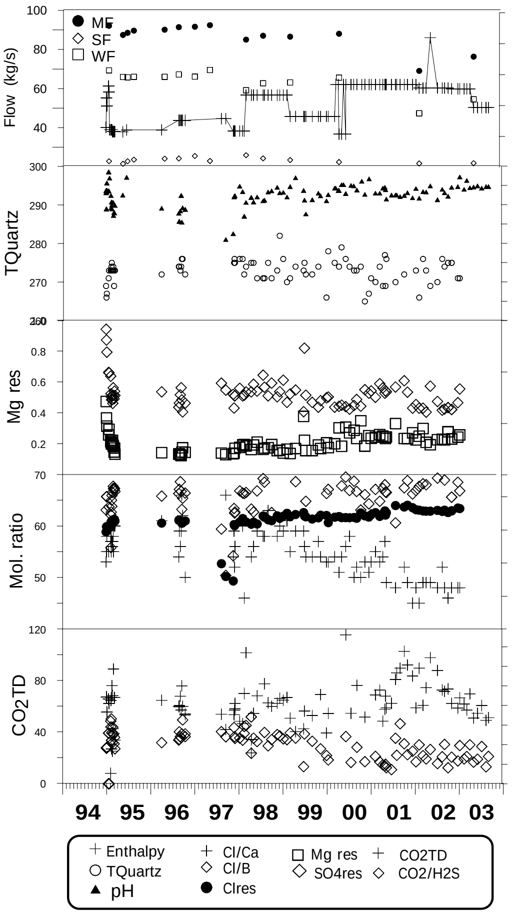

Figure 9. CN-4D chemical trends with time

would show, a low-boron recharge fluid from the western part of the field, as shown in Figure 4, entered the well. This recharge prevented the expansion of pressure drawdown and eventually stabilized the well up to the present time. TQuartz has eventually stabilized at about 275°C with no indication of a declining trend, while other chemical parameters remained stable. To date, the well continues to provide about 15 MWe of power.

PAL-4D. During the initial stage of exploitation, well PAL-4D showed an increasing trend in the Cl/B ratio, decline in CO_2TD, decline in TQuartz, but relatively stable discharge enthalpy (Fig. 8). The response of PAL-4D is typical of the wells in the area. The chemical changes are due to the immediate influx of recharge fluid from the Masakrot area indicating the open channels or conduits of recharge fluids. The Masakrot fluid did not bring detrimental effects except for the drop in temperature as indicated by the TQuartz. Furthermore as the recent chemical trends would indicate, the mixing process appeared to have attained a steady state condition. TQuartz has stabilized at about 265°C. Other chemical parameters such as Clres, SO_4res, Cl/B and Cl/Ca ratios have also stabilized. Fluctuation in Mgres is due to a cold inflow inherent in the well that contributes if the well is throttled.

CN-4D. The chemical trends with time of CN-4D are typical of the wells in Cawayan area. Chemical and physical parameters like discharge enthalpy, TQuartz, Clres, SO_4res, Mgres, and pH are relatively stable (Fig. 9). The relatively low concentrations of SO_4 and Mg, as well the neutral pH are indications that no acid inflow is present in the discharge fluid.

OP-4D. Well OP-4D represents the deep fluid in Botong area. Its chemical response to exploitation, which is boiling and vapor formation, is typical in the area. This has been shown in the HTQuartz vs. Clres cross plot (Fig. 3), as well as in the increase in discharge enthalpy. Trends with time of chemical parameters such as TQuartz and TNaKCa, Clres, SO_4res, Mgres as well as Cl/B and Cl/Ca ratios have shown relative stability (Fig. 10). As in other wells in the area, the chemical trends do not indicate intrusion of unwanted fluids or any detrimental reservoir process.

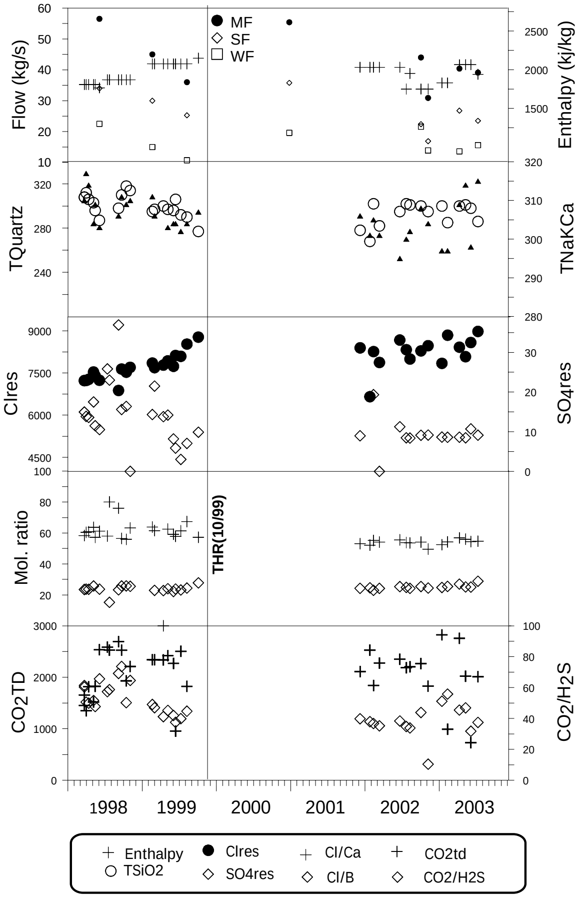

Figure 10. OP-4D chemical trends with time

6.0 OPERATIONAL PROBLEMS ENCOUNTERED

6.1 Non-Condensable Gases

One characteristic of the Bacman field is the wide variation in CO_2 concentration that range from about 100 to 3000 mmoles/100moles at total discharge (Fig. 11). The high-end values could sometimes lead to a relatively high percentage of non-condensable gas at the power plant interface. However, this is being addressed by effective well utilization and combinations, proper steam mixing before the interface, and in case of drilling new wells, targeting well-track towards the low gas areas of the field.

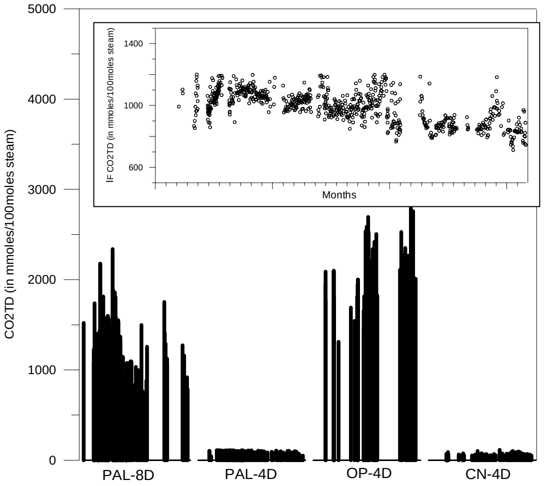

Figure 11. CO2TD contents of some Bacman wells

6.2 Acid-Sulfate Intrusion and Anhydrite Deposition Inside the Wellbore

This process, affected a number of production wells, two on a massive scale. In most cases the acid fluids enter the well bore below the casing shoe at shallower feed zones. Once inside the wellbore the high-SO_4 fluid mixes with the deep fluid to form anhydrite deposits (See, 1995). As the mineral deposits grow, this progressively isolates the hotter, neutral, deeper fluids until the discharge fluid becomes acidic, dilute, and cooler. The chemical trends with time of well CN-1, as well as its casing profile exemplify this process (Fig. 12a). The well was eventually blocked by anhydrite and mechanically cleaned by means of a drilling rig. Remedial measures have been adopted to address this problem. These include maintaining the wells at full-bore condition to prevent downflow, deepening the production casing shoe of new wells to avoid acid feed zones, calcium chloride injection during drilling, and use of corrosion-resistant casing at acid depths. Some of these measures are best illustrated in Well CN-4D where the production casing shoe was deepened at 1495.5 mVD, and corrosion-resistant casings were used at acidic depths (Fig. 12b) identified from drill cuttings through petrological analysis.

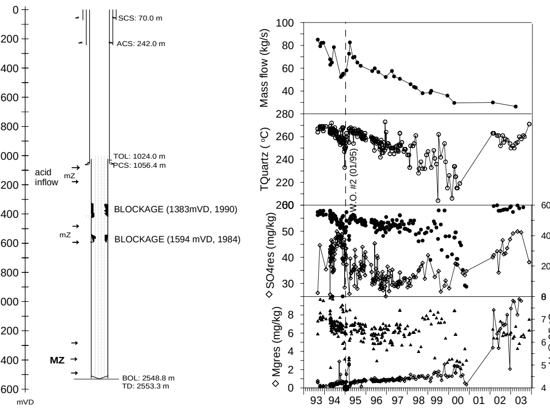

Figure 12a. CN-1 anhydrite blockage profile and chemical trends with time.

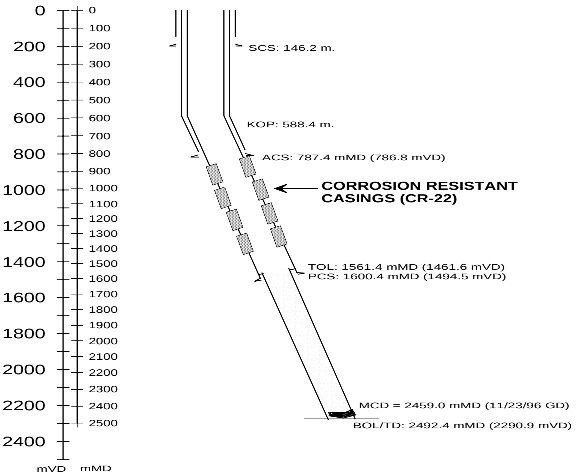

Figure 12b. CN-4D casing profile and location of corrosion-resistant casing.

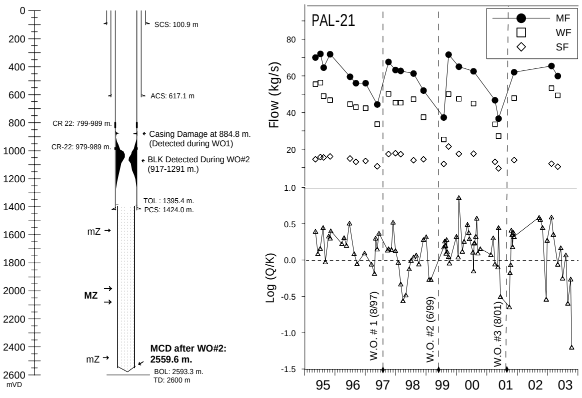

Figure 13. PAL-21 calcite deposit profile, log (Q/K) calcite and physical parameters trends with time.

So far, these acidic, high-SO_4 fluids are confined in a small, shallow portion of the field and the newly drilled wells have been spared from such problem.

6.3 Calcite Deposition Inside the Wellbore

Another problem encountered was calcite deposition inside the production casing. This has caused one production well, PAL-21 to collapse at a regular but relatively long interval of about twenty-one to twenty-eight months (Fig. 13). The well has been characterized to be supersaturated with respect to calcite based on speciation program. So far, this problem is being addressed by regular mechanical clearing using a rig, which is the cheapest option at present. Other options such as dosing with chemical inhibitor is also being evaluated.

6.4 Calcite Deposition in Two-Phase line

The mixing of two two-phase fluids from two production wells caused this problem. One fluid is a super-heated steam, and the other a high-enthalpy two-phase fluid with a small water fraction. Their mixing in a two-phase header line causes the boiling of the water component (Solis *et al.*, 1999) and induced calcite deposition that eventually blocked the two-phase line. This problem was addressed by the construction of an over-sized drain pot along the phase line (Fig. 14). This modified drain pot scrubs-off the water component of the two-phase fluid prior to mixing with the superheated steam (Fragata *et al.*, 2003) and thus minimize calcite deposition.

6.5 High Silica in Brine

The very high silica content and saturation index of the separated brine at Botong could clog up the injection pipelines within weeks. This problem was addressed through the use of a chemical inhibitor injected in the two-phase line (Fig. 15). So far, this method has been effective in controlling silica deposition to manageable level.

7.0 SUMMARY AND CONCLUSION

The response of the reservoir to exploitation was rather beneficial. Relatively hot recharge fluids provided pressure support that prevented the occurrence of a field-wide drawdown or the entry of cool peripheral waters. No injection return has

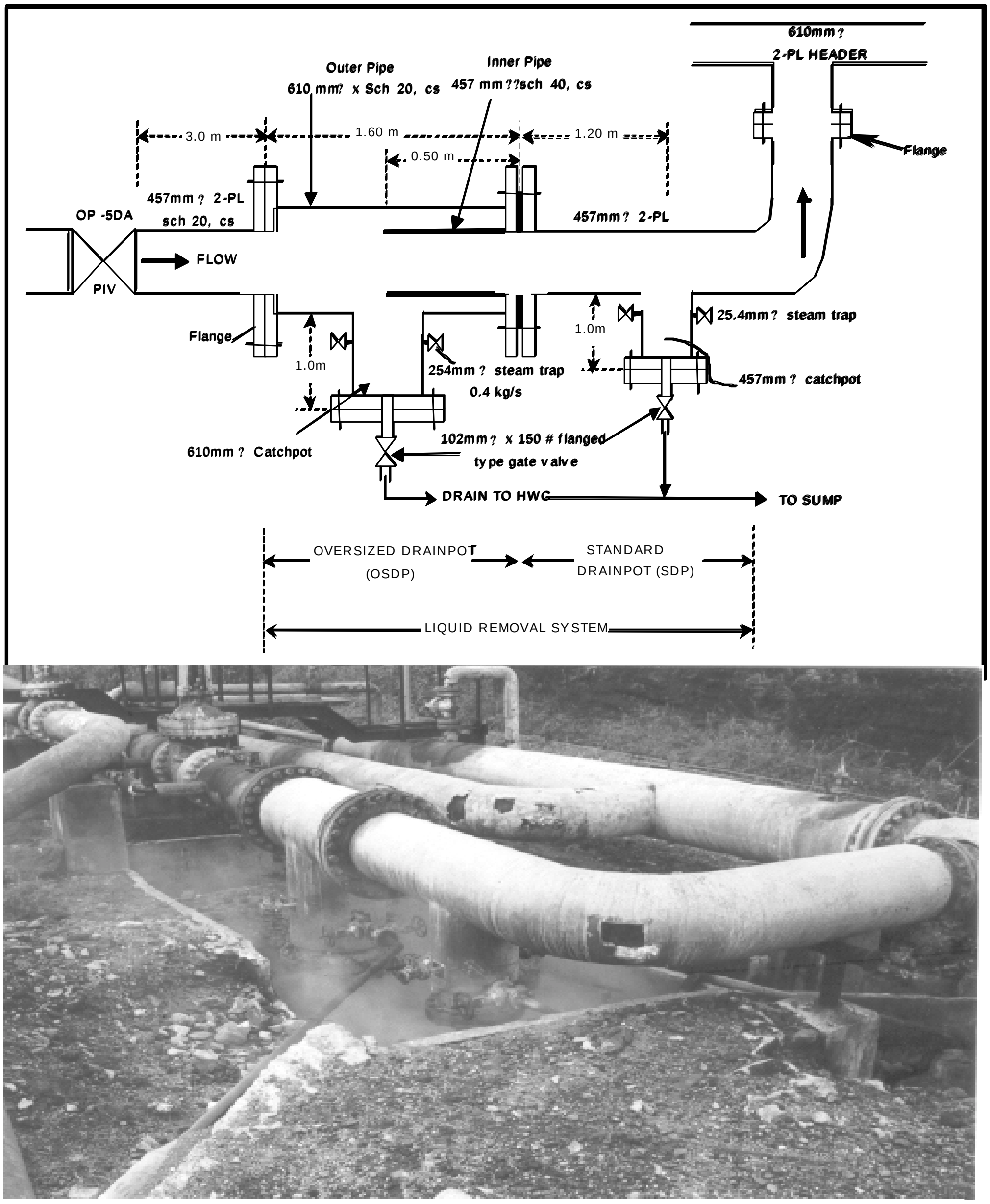

Figure 14. Schematic diagram and actual picture of the Botong over-sized drainpot (from Fragata *et al.*, 2003).

so far been detected in the production wells. The present chemical and physical trends have shown stability since 1996. Operational problems encountered are mostly wellbore or superficial in nature and have been addressed with practical solutions. These observations all point out to a conclusion that the resource is sustainable even at full operations.

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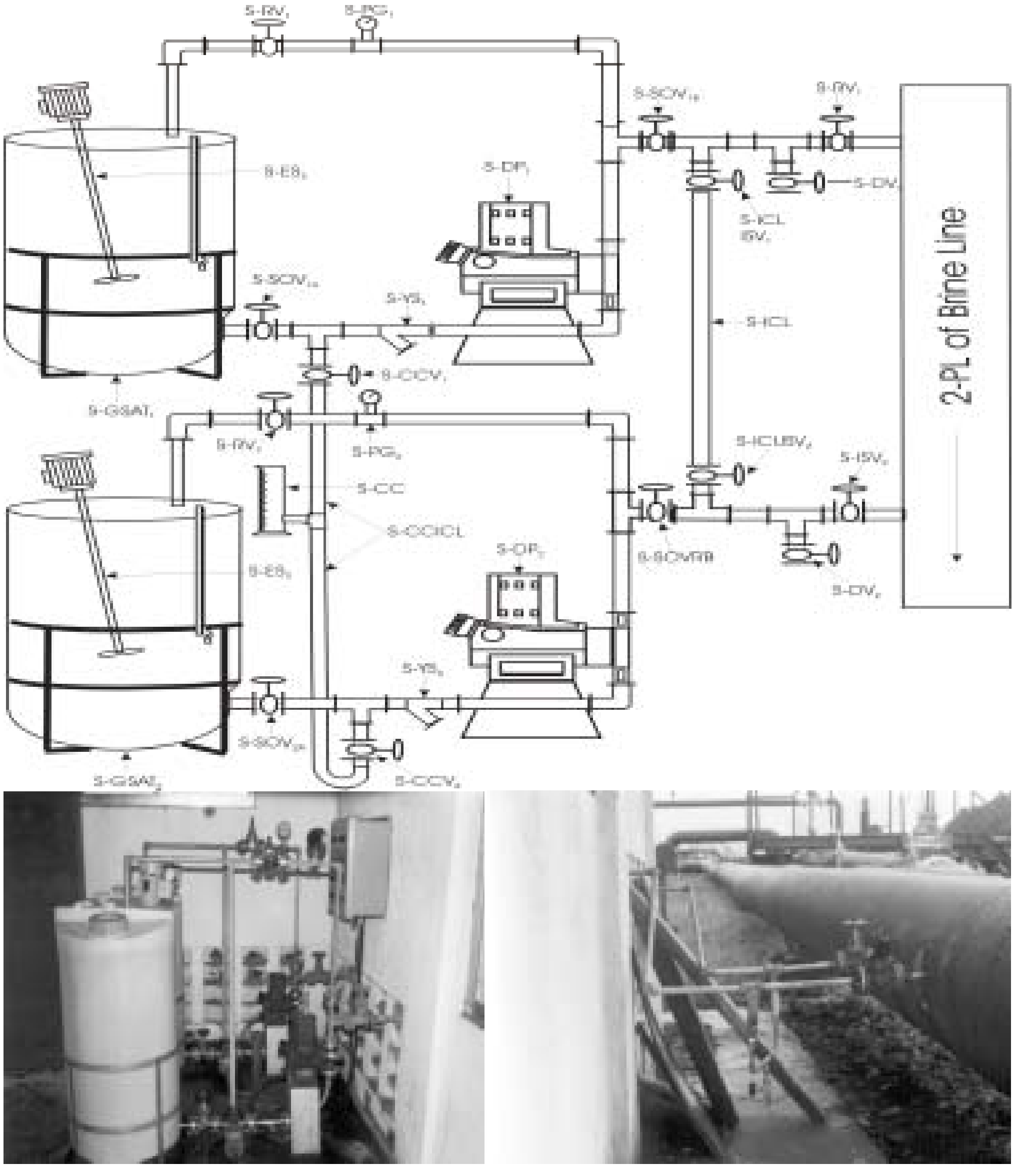

Figure 15. Schematic diagram and actual pictures of the Botong silica inhibition set-up.

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