The Walnut Bend Field:

Rejuvenate a Mature Field Through Reservoir Management

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GENERAL

Location

The Walnut Bend Field is located approximately 65 miles north of Dallas in Cooke County, Texas. The field was discovered in 1938 by Sinclair. ARCO is the operator of Unit 1 and Unit 2 along with 10 other 100% working interest leases. Most of the current production comes from Unit 1 and Unit 2. Figure 1 shows the field map.

Geology

Accumulation in the Walnut Bend Field in all horizons is due to the presence of the Walnut Bend anticline, which was first uplifted and truncated during Post-Ordovician time. The truncated structure was overlapped by fluvio-deltaic Pennsylvanian sediments until at least the end of Strawn time. Although accumulation is due to the presence of the anticline, production from the individual reservoirs in the Walnut Bend Field is largely dependent upon a combination of structure and existing stratigraphic environment. Figure 2 shows a type log for the field. Production in Unit 1 is from the Winger Pool at a depth of 4600 ft. subsea. The Winger reservoir is located on the eastern flank of the Walnut Bend anticline and covers 3 square miles, or about half of the total area of the field. Unit 2 consists of a large number of separate Pennsylvanian sands. These are grouped into three major fields: The Atkins field which overlies the Winger, the Regular field, and the Hudspeth field.

Production

The current production from the Walnut Bend Field is 1400 BOPD and 30,000 BWPD. Figure 3 shows the production history of the field. To date, the cumulative production is over 99 MMBO, which is about 43% of the original oil-in-place. The field has been waterflooded since the early 1960's. The WOR versus cumulative production plot is shown in Figure 4. A continuous program of recompletion and shut-in high WOR wells has resulted in approximately 3 MMBO of incremental reserves.

COST ANALYSIS

Five Year Trend

As typical of most mature waterfloods, one of the problems which plagues the Walnut Bend Field is its high operating costs. Figure 5 shows the net operating cost trend for the past 5 years. From 1986 to 1990, the net annual lease operating expense (LOE) exhibited a gradual decrease from $3.3 MM to $2.9 MM. In 1991, the LOE jumped to $3.8 MM, a $900 M increase over 1990 LOE. Although the LOE increase was the result of one time environmental expense and out of period adjustment, it nevertheless caused concern and precipitated in a rigorous cost study.

Cost Structure

Excluding the one time expense items, the different components which made up the LOE are illustrated in Figure 6. Electrical power and fuel is by far the largest component - it accounted for 41% of the normal LOE. Company supervision and labor is the next largest component. At 19%, the labor portion of the LOE is higher than either routine repair (17%) or subsurface expense (16%). Chemicals (4%) and facility allocation (3%) made up the rest of the LOE.

Since power and fuel is the largest component of LOE, it is naturally the first target for LOE reduction effort. Power and fuel along with chemicals made up the "fluid handling" or variable cost component of LOE - they are directly related to the volume of fluid processed. By reducing the volume of fluid (produced water), it follows that the fluid handling cost should decrease. Company labor, routine LOE, subsurface expense, and facility allocation could be categorized as the "fixed" well cost component of LOE - they depend more or less on the number of active wells in the field.

In 1991, the Walnut Bend field produced 1315 BOPD, 42,307 BWPD and incurred $1.424 MM in power cost and $149 M in chemicals. Therefore the handling cost per barrel of fluid produced is $0.099/bbl. The Walnut Bend Field had 208 active wells (including injectors) which incurred $479 M in routine LOE, $440 M in subsurface expense, and $532 M in labor to operate. Thus the fixed well component of the LOE is $582/well-month.

COST REDUCTION STRATEGIES

The profitability of a mature field can be improved by reducing operating expense and/or increasing oil production. At Walnut Bend Field, both objectives can be accomplished by implementing the following strategies:

- o Cost Management
- o Technology
- o Organization Synergism

Cost Management

Cost management is the crucial strategy to reduce the cost structure. It entails the efficient use of expense money: In time of budget constraint, it does not make sense to spend a dollar to squeeze out that last penny of profit. We can not keep a marginal well producing - not when the money to operate that well can be used for other projects such as recompletion or stimulation that generate more profit. Therefore it is important to pay attention to the individual well economics.

Using the total fluid production of each well and the fixed and variable cost components, the daily profit margin of each well could be calculated:

$$\text{Profit Margin} = \text{Revenue} - \text{Expense}$$
$$= (\$/BO)(BOPD)(NRI) - WI[(BFPD)(\$/bbl)+(\$/\text{Well-day})+BOPD(\%Tax)]$$

The individual well contribution to the total field production is shown in Figure 7. The wells are plotted from most profitable to least profitable. Since the most profitable wells typically have high oil cut, the cumulative daily oil production curve shows a large increase in the beginning and gradually flatten out as higher water cut wells are added. The cumulative water production curve shows the reverse trend where the curve increases sharply at the end due to the addition of high WOR wells. Figure 7 also shows that the first 50% of the active producers contributes over 80% of the field total oil production but only 50% of the water production.

A cumulative daily profit and expense curves can be constructed as shown in Figure 8. The daily expense curve is not a straight line since it is a function of the number of active wells and the volume of fluid produced. The daily expense curve does not sum up to the total field expense since it does not include the fixed cost portion of the active injectors. Figure 8 shows that the first 37% of the producers contributes over 90% of the field profit margin. The daily profit curve actually peaks at about 100 wells and decrease thereafter, which means that only the first 100 wells are profitable and the rest can be shut in without affecting the profitability of the field. The saving in operating costs from shutting those high WOR wells can be significant however. As high WOR producers are shut-in, ineffective injectors would also be shut-in to expedite additional facilities consolidation. Battery consolidation would streamline current operations by having fewer facilities to operate and reducing potential environmental hazards.

Technology

Technology is a leveraging strategy to get more cheap oil production from a mature waterflood. Under certain circumstances, the pulsed-neutron log (Schlumberger TDT or Halliburton TMD) can be used to identify behind pipe oil reserves. Walnut Bend Field, with its ideal reservoir characteristics (multiple pay zones with porosity > 12%, water salinity > 200,00 mg/l TDS) and numerous existing wellbores, is the perfect application for the pulsed-neutron log. After working closely with logging service personnel to improve interpretation technique, we have successfully utilized the pulsed-neutron logging technology to fuel our recompletion program. The emphasis in the future will be to combine the logging program with better geologic interpretation to improve the success rate (i.e. number of recompletions/number of wells logged). Figure 9 shows the pulsed-neutron log of well #26-25. The log indicates favorable oil saturation in the interval from 4564-75' and shows that the existing perfs from 4722-28' have watered out. This well produces 75 BOPD and 44 BWPD after the recompletion.

Computerized reservoir management is another area where technology can help to improve oil production and reduce costs. Without using computer, reservoir management at the Walnut Bend Field is a significant challenge due to the large number of wellbores and the multiple completion intervals. Using the computer as a tool to visualize well performance, we can optimize water injection, eliminate water cycling, and identify recompletion or stimulation candidates.

Organization Synergism

Organization synergism is the strategy to foster continuous improvement. Organization synergism requires the pro-active involvement from all levels: pumpers, engineers, geologists, drilling and production supervisors all working together. The key to success is open communication between the various entities. Frequent brainstorming sessions at the field location provide the opportunity for everyone to contribute cost-cutting ideas. Knowlege and information must flow freely between the team members so that everyone can stay involved. The contribution of the service contractors must not be overlooked either. They play an important role in keeping cost down and quality up.

RESULTS

The results of implementing the cost cutting strategies are encouraging. Figure 10 shows weekly average production of the field before and after the program was initiated. The drop in oil production following the shut-in of high WOR wells was quickly replaced by the increase in production from the recompletion program. Water production was cut by 10,000 BWPD. Shutting-in high WOR wells reduced monthly electrical usage by 400,000 Kwh and saved over $13,000 a month in electrical cost alone. The computer based reservoir management program and the improved teamwork made the 27 well recompletion program in a six month period possible. This is a substantial increase over the previous 3 years when on average 8 wells were recompleted each year.

CONCLUSIONS

The Walnut Bend Field provides a case study on how to improve the profitability of mature fields. Technology can provide the tools for better reservoir management. Cost management allows the field to remain profitable through the understanding of cost structure. And most important of all, it takes teamwork and the personal involvement of the team members to make the process possible.

ACKNOWLEDGEMENTS

We express our gratitude to the other members of the Walnut Bend Asset Team. Without their contribution, this work would not be possible. We also thank the management of ARCO Oil and Gas Co. for the permission to publish this work.

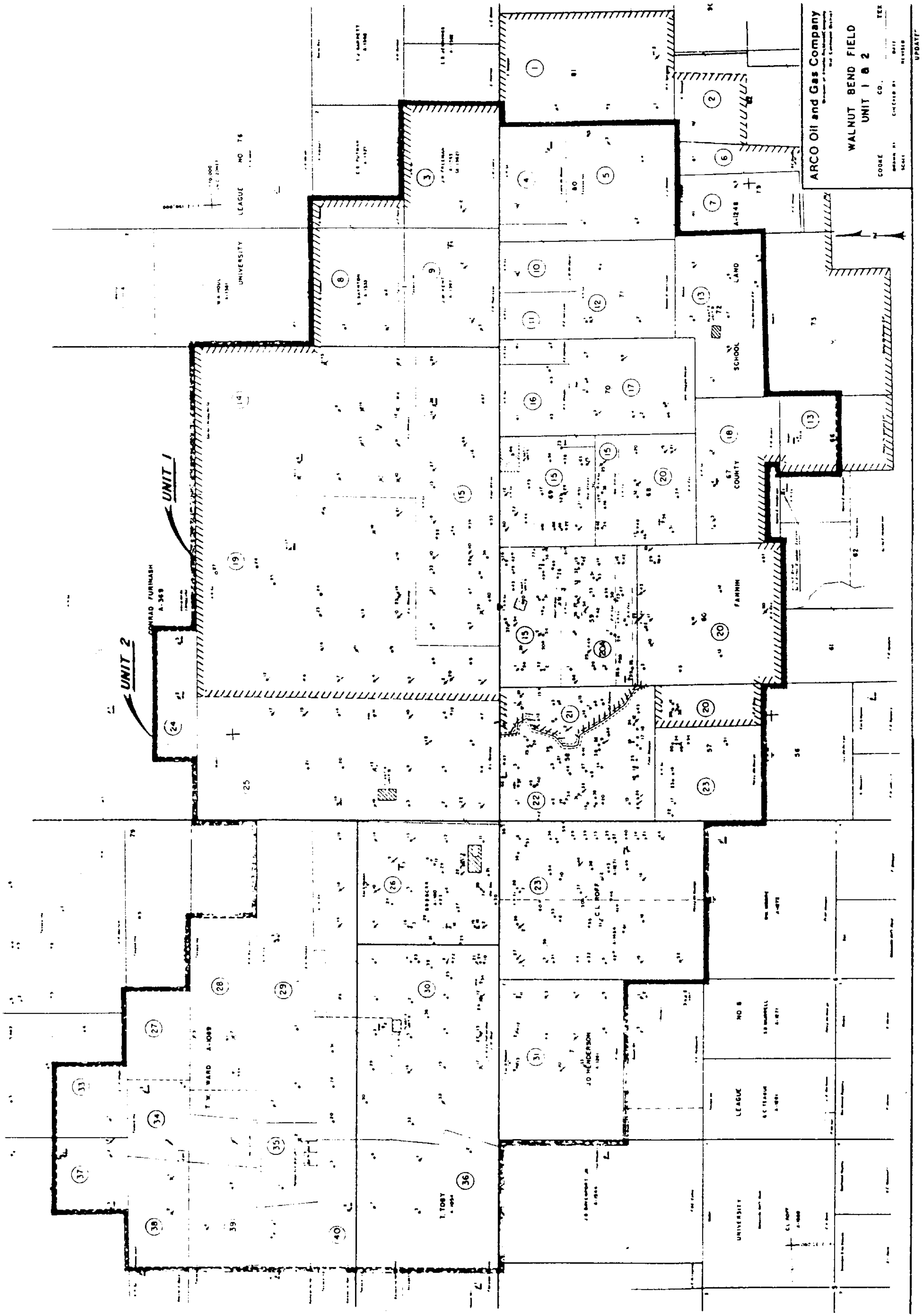
ARCO Oil and Gas Company
WALNUT BEND FIELD
UNIT 1 & 2
UNIT 1
UNIT 2
SCHOOL
LAND
COUNTY
FANNIN
UNIVERSITY
LEAGUE

Figure 1

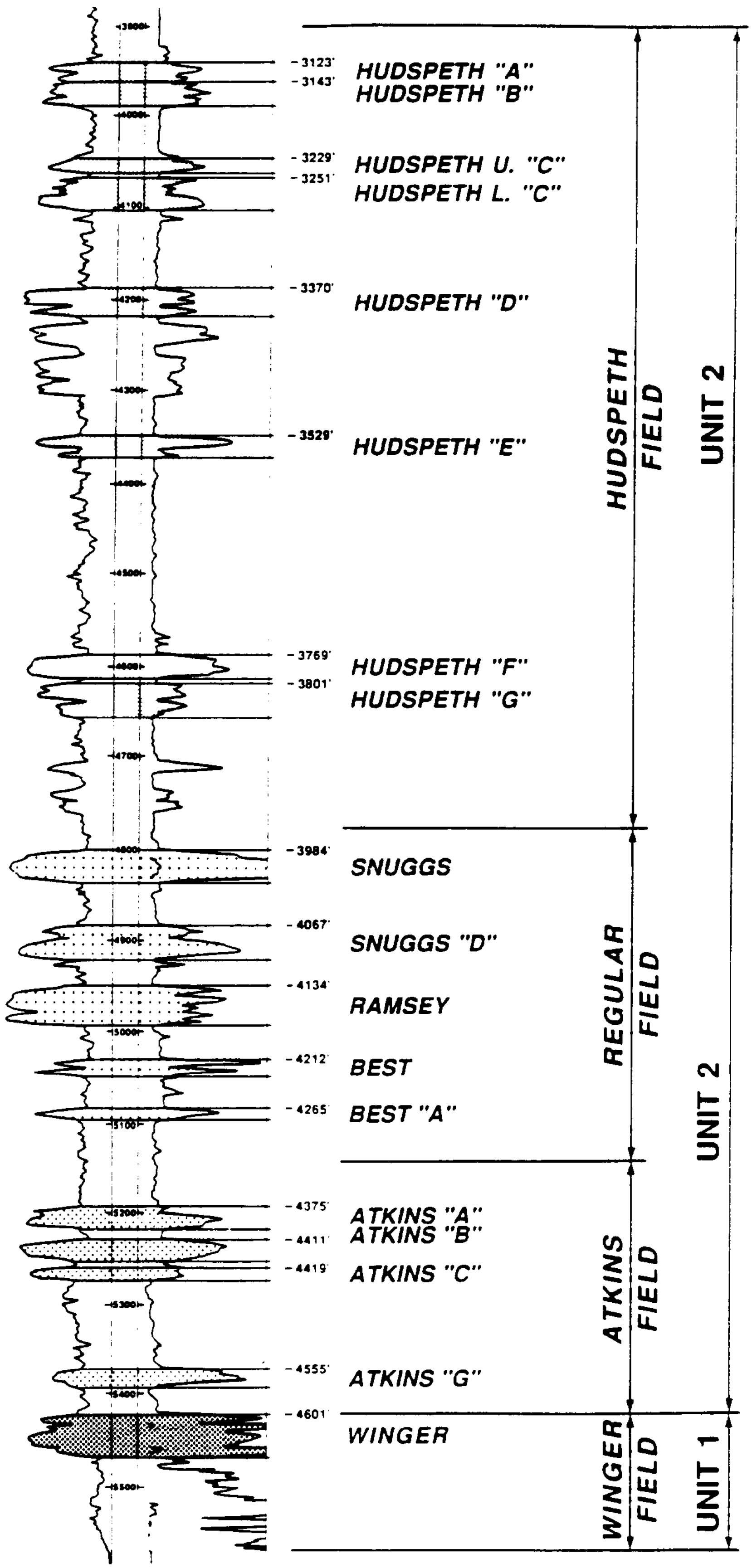

Figure 2 - Walnut Bend composite log

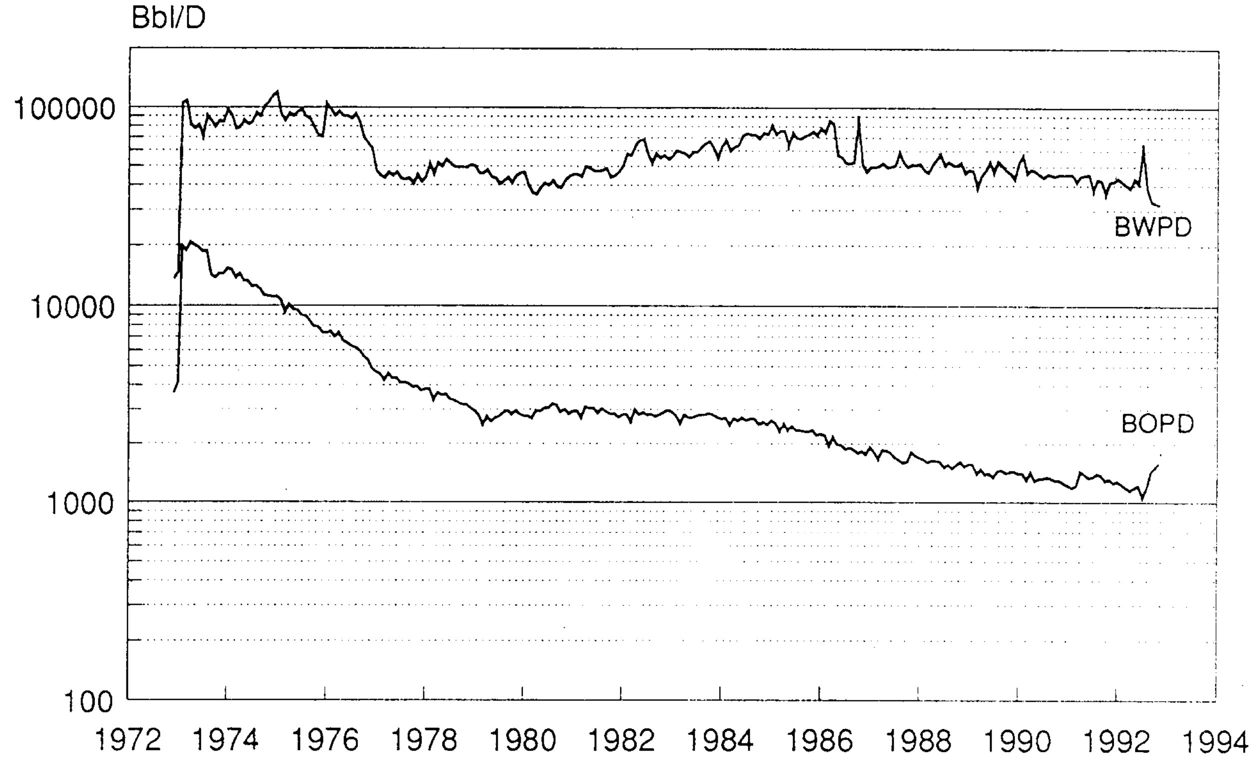

Figure 3 - Walnut Bend Field total production

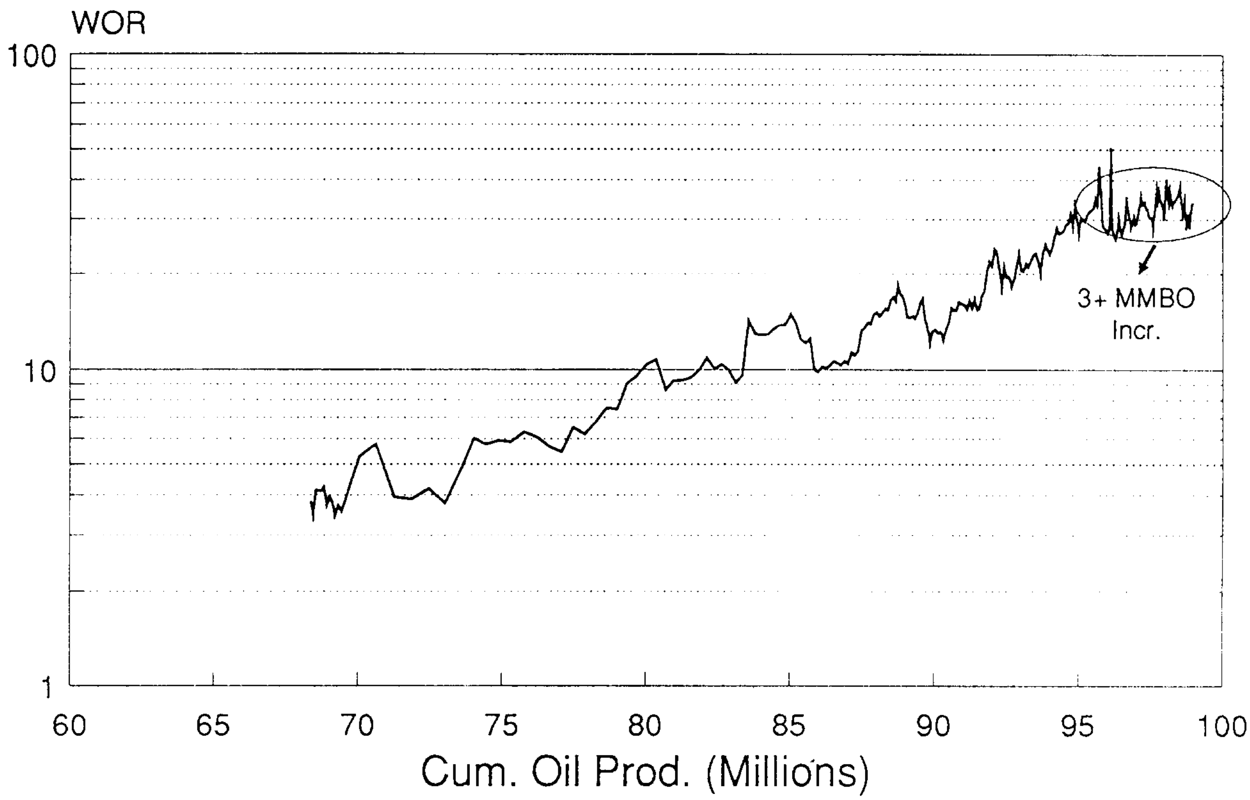

Figure 4 - Walnut Bend Field WOR vs. cum. oil

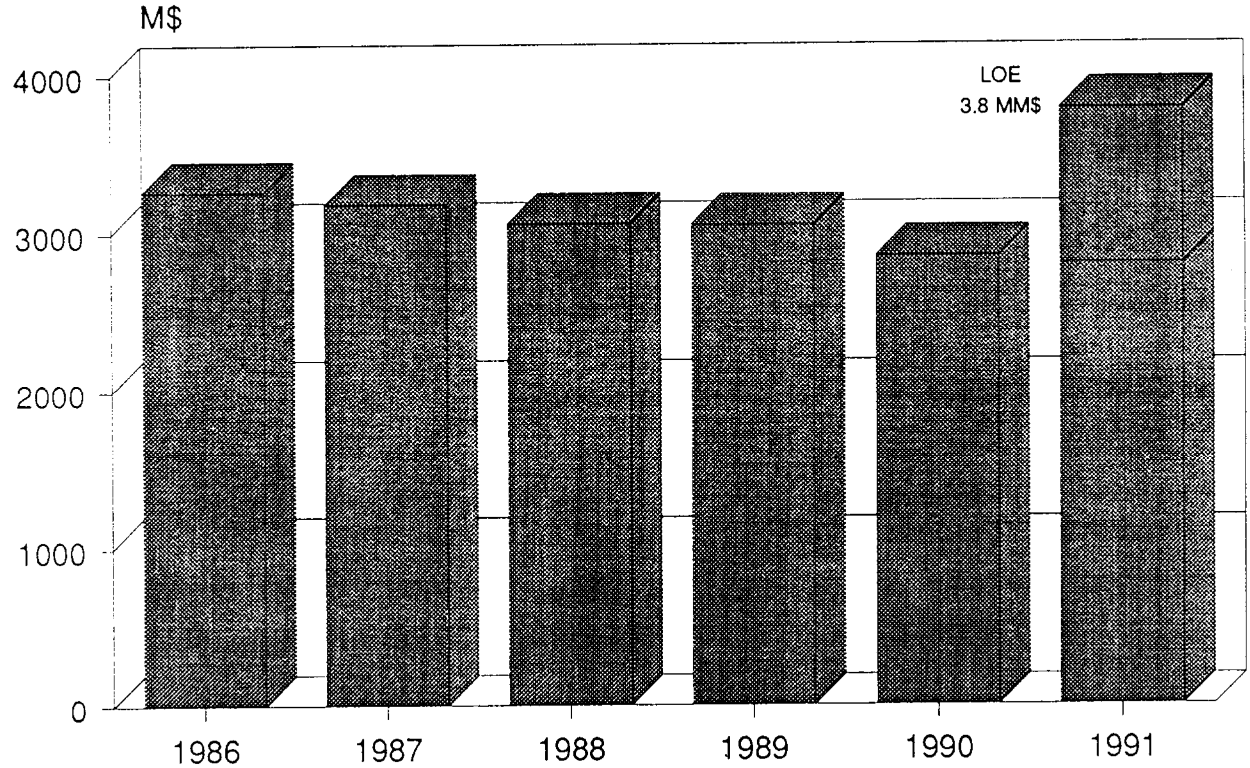

Figure 5 - Walnut Bend Field operating cost trend

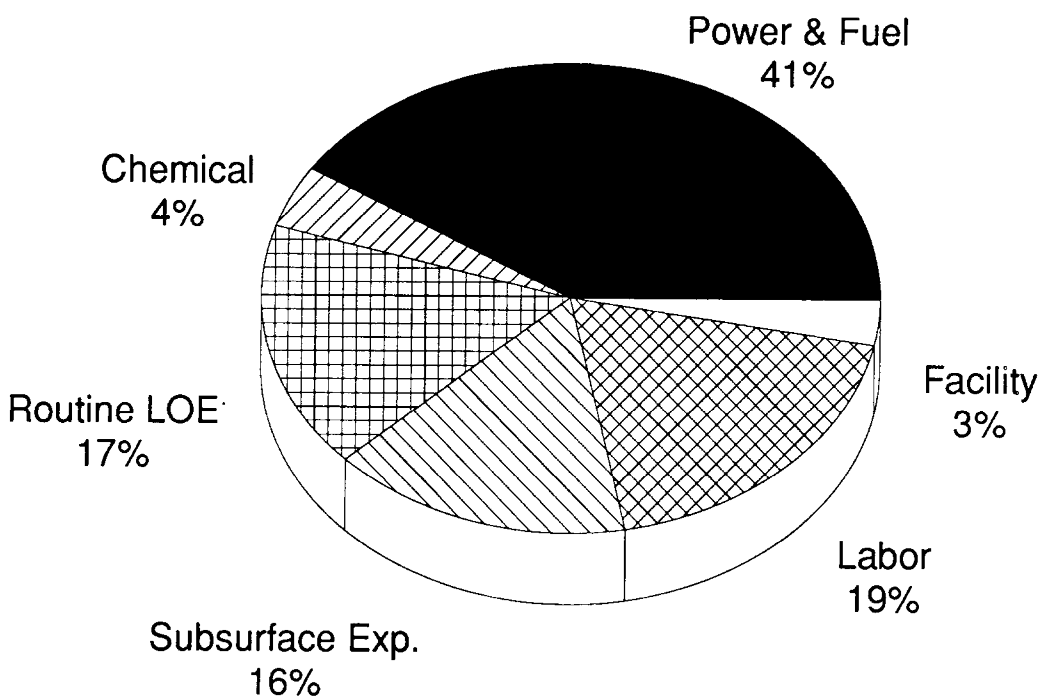

Figure 6 - Walnut Bend Field operating cost breakdown

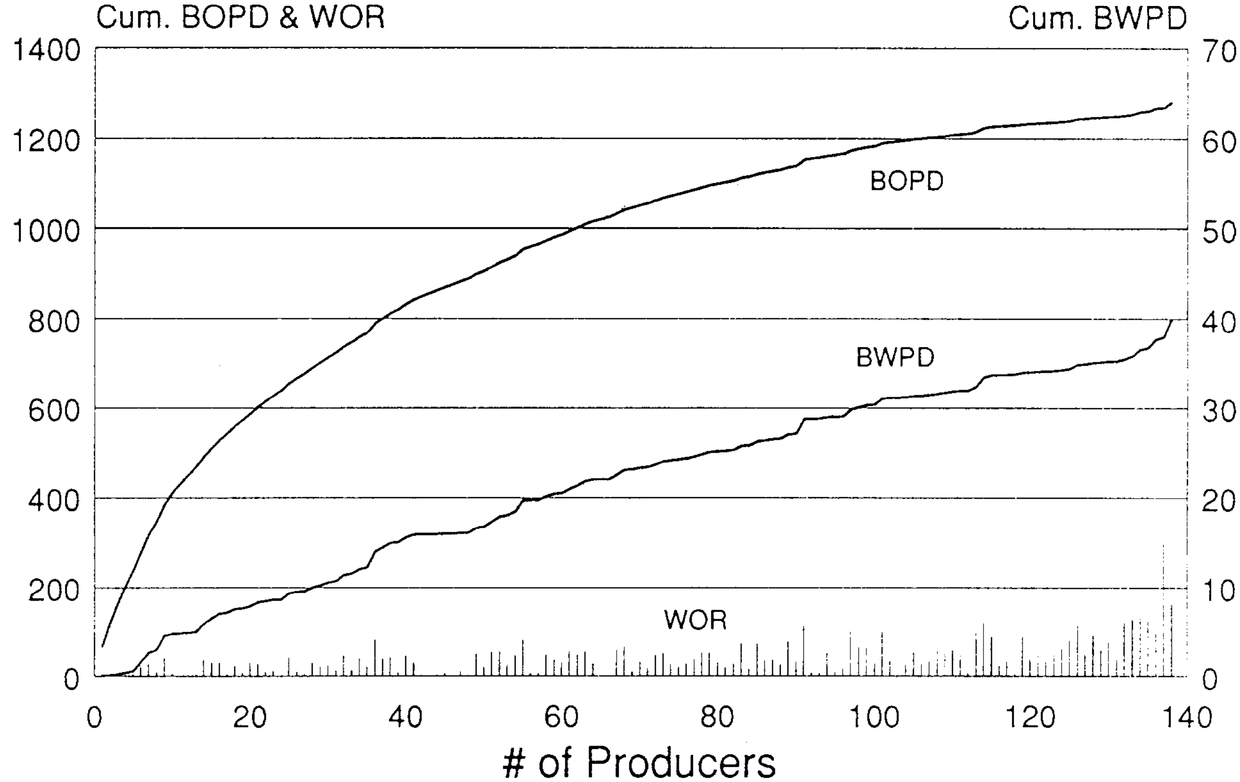

Figure 7 - Walnut Bend Field shut-in analysis

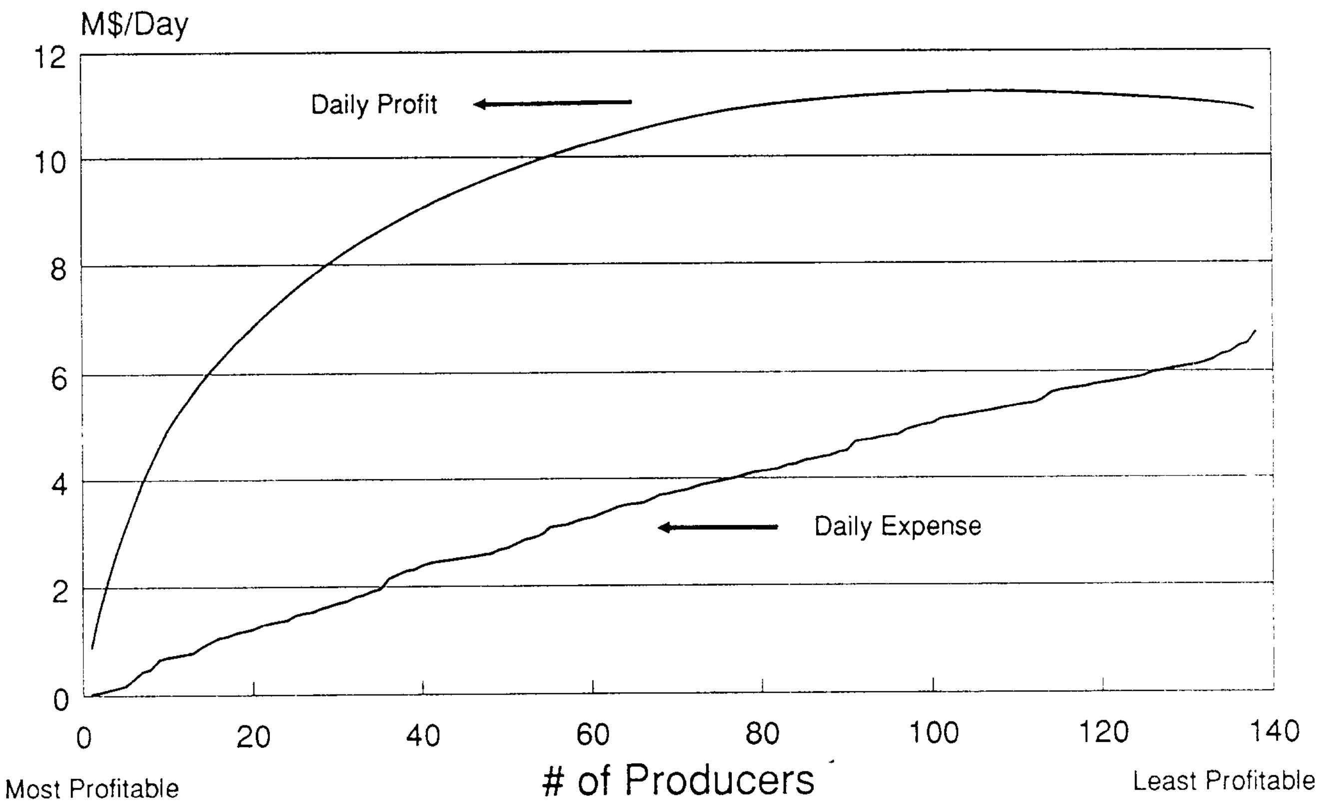

Figure 8 - Walnut Bend Field shut-in analysis

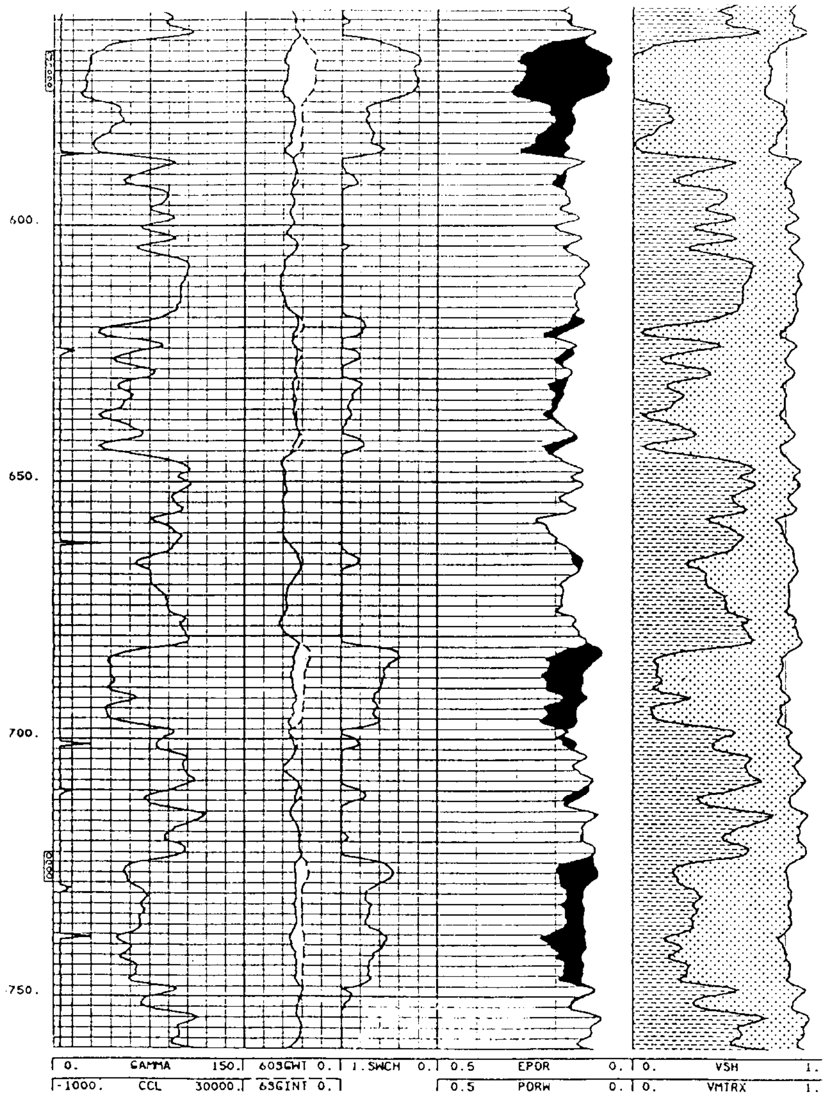

Figure 9

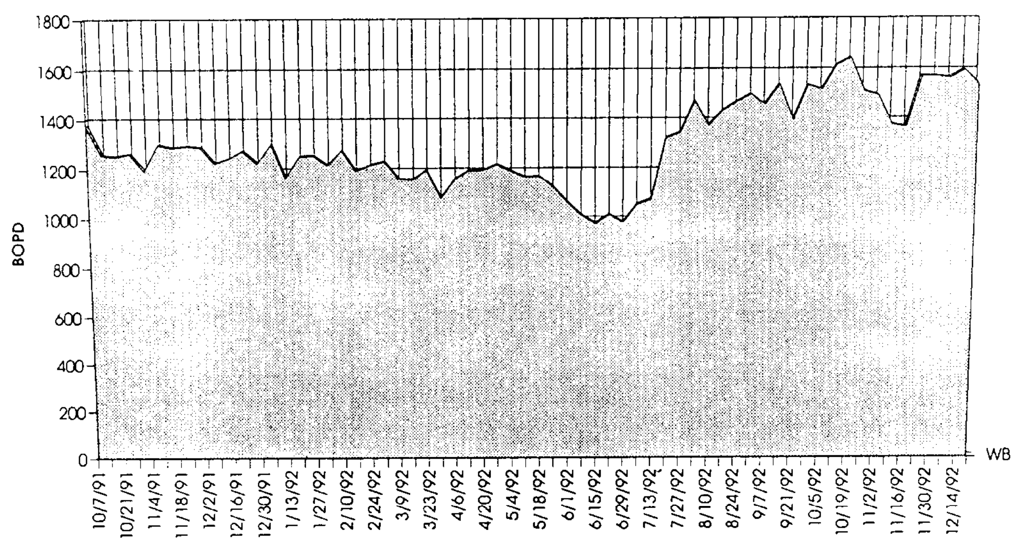

Figure 10 - Walnut Bend Field weekly production