THE AMERICAN OIL & GAS REPORTER®
SEPTEMBER 2006
The "Better Business" Publication Serving the Exploration / Drilling / Production Industry

Technology, Prices Awaken Old Fields

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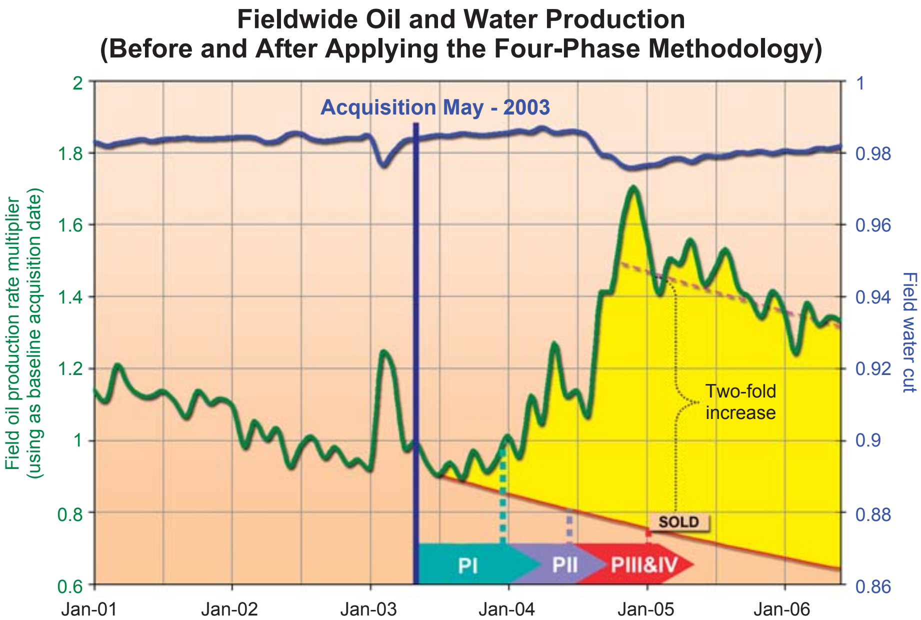
GOLDEN, CO.–Mature fields hold nearly two-thirds of the known conventional reserves, and yet many of these old fields are neglected, experiencing a steady decline in production rates and profits, presumably awaiting new technology or higher prices. But the simple fact is, both the technologies and the commodity prices needed to reawaken mature fields are in place today. The missing ingredients likely are attention from multiple disciplines, a belief in the power of the technological advancements made in recent years, and a corporate commitment to investing in mature producing properties.

There is little agreement on how much oil is left in the world. Technical, economic and political differences between different regions make it difficult, if not impossible, to validate the reserve estimates. However, the consensus is that most of the easy oil already is being produced, and that nearly two-thirds of the remaining conventional reserves are in mature fields. Decreasing oil discoveries, increasing demand and low risk of mature fields compared with nonconventional resources have highlighted the importance of these older producing assets.

Awakening mature fields is often challenging because of a lack of available qualified professionals, combined with the fact that most of the information about the field is stored on paper. This often includes a voluminous, fragmented well and field data set compiled by multiple operators with their own nomenclatures, storage processes, procedures and philosophies. These records need to be unraveled.

FIGURE 1



To make things worse, there can be pressure from lending institutions and corporations eager to show large and immediate returns without allocating capital or time for testing or evaluation work. Apparent short-term "savings" in manpower and data processing lead to an increased risk of failure and an inability to tie gains or losses in field value to specific activities. This lack of documentation and understanding has perhaps the biggest negative impact on the independent reserve evaluation engineer or potential joint venture partner who has little to justify the reserve volume that the operator believes exists.

Reawakening Project

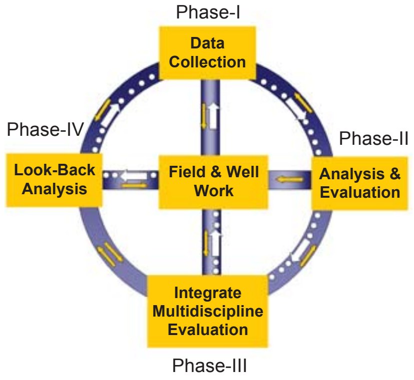
A successful reawakening process consisting of an in-house, four-phase methodology was applied to a 60-year-old oil field in the Northern Rockies that previously had been operated by several companies–including three majors. The economic benefits over a period of two years proved that patient and data-driven operators are not an extinct species, and that they can be significantly rewarded for the application of appropriate procedures and solutions (Figure 1).

A two-fold increase in oil production resulted from implementing new technology to capture, analyze and integrate data and solutions in this mature field. Only one-third of the recommended well work activity had been completed by the time the field was sold for almost three times its purchase price. Today, the field still produces at twice the oil rate, with less water, than the baseline forecast.

It is a standard procedure worldwide to rank projects on the basis of benefit and risk associated with field size, characteristics and location. As a consequence, more resources wisely are allocated to high-priority assets, while the less glam-

FIGURE 2

Methodology Developed to Awakening Mature Fields



orous or low-priority assets receive whatever is left. Historically, mature fields have usually fallen into this second group, where newer employees studied them, if they are studied at all.

Frequently, especially during periods of low oil prices, these assets were sold or activity restricted just to the point of retaining the lease(s), while personnel were transferred or downsized to cut costs. Those who lived through this cycle knew it was best to keep their distance from these types of fields. As a result, technically complex or small to medium fields historically received intermittent attention and fewer resources than bigger and less complex fields. These assets now require more resources and time to understand, but they can also hold a surprisingly high volume of untapped reserves in comparison to those that have been closely scrutinized.

A screening tool for finding mature fields with a great deal of remaining potential is to look for those that received an exhaustive technical study in the 1970s or 1980s. Such a study can keep people believing for decades that anything worth pursuing would have been found in that evaluation, which was conducted with the technical tools from 20-30 years ago. A number of key advancements have been made since that time including the advent of personal computers, which greatly increase our ability to compile, organize, correlate and interpret data.

Four Distinct Phases

The methodology for awakening mature fields is divided into four distinct step-by-step phases: data collection, analysis and evaluation, integrated multidiscipline evaluation, and look-back analysis (Figure 2). The first step involves collecting, transferring and analyzing data to understand the current status of the field and past and current field responses to historical activities. In the next three stages the engineers, geologists and field personnel analyze the information from single-discipline perspectives, and then meet for collaborative, multidisciplinary discussions that increase their understanding of the physics controlling the reservoir and well performance.

Multiple projects are considered and prioritized for each well, and the results later are documented for use in subsequent field activities. As the processes continue, new information is collected from the ongoing activity to evaluate their results and the economic impact on the field. Thus, the team re-evaluates several projects and focuses only on those activities that generate the highest benefit to the operator.

The first phase is the longest and least productive phase in terms of fieldwork recommendations, but it is the most important phase of the project. This phase consists of data collection, organization and evaluation, and in the case study mature field in Wyoming, included scanning more than 125,000 pages of data. Field data, well histories, well bore diagrams, production data, perforation histories, well logs, deviation surveys and any type of well work were all scrutinized, cleaned and transferred to an in-house electronic database that was customized to handle the types of data collected and generate the evaluation displays.

A significant advantage the team had over previous operators was the application of existing low-cost computer resources to organize, sort, correlate and display decades of data. Figure 3 displays the main window of the in-house database software. The following list shows the types of data that can easily be accessed from the main window of the database:

- Well bore diagrams and well histories;
- Detailed well information;
- Monthly and cumulative production and injection volumes;
- Deviation surveys;
- Well logs;
- Perforation and completion histories;
- Production, completion and well work activity versus time plots; and
- Fluid level data.

The software gives engineers the flexibility to filter data using engineers' specific criteria, and display and correlate production data with perforation, completion, geologic intervals, stimulation, hydraulic fractures, reperforation, pump change or update, or any combination of activities.

Analysis And Evaluation

The second phase focuses on independent geologic, reservoir and production engineering analyses and evaluations of the field. Although this phase is shorter than the previous phase, it provides the basis for understanding the physics that

FIGURE 3

Main Window of the In-House Database

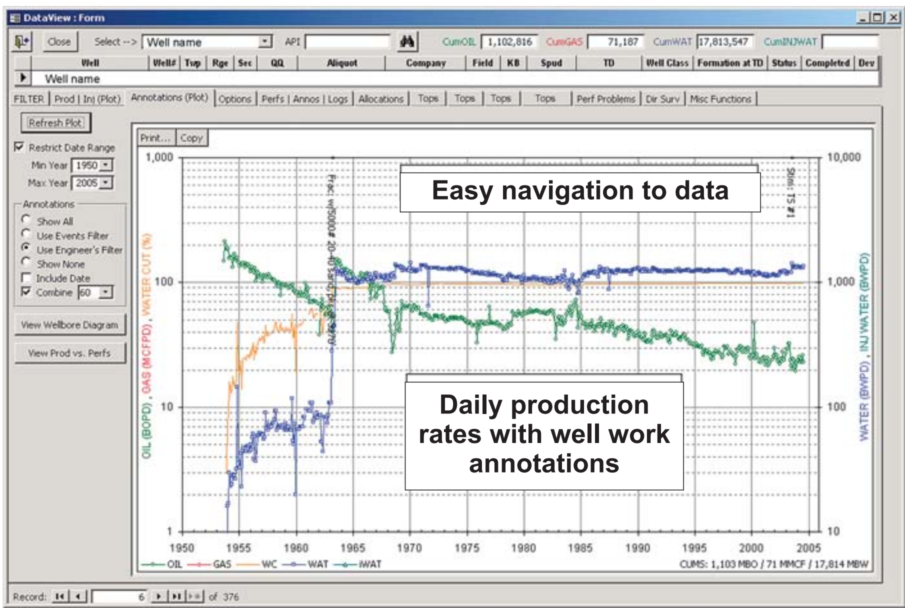
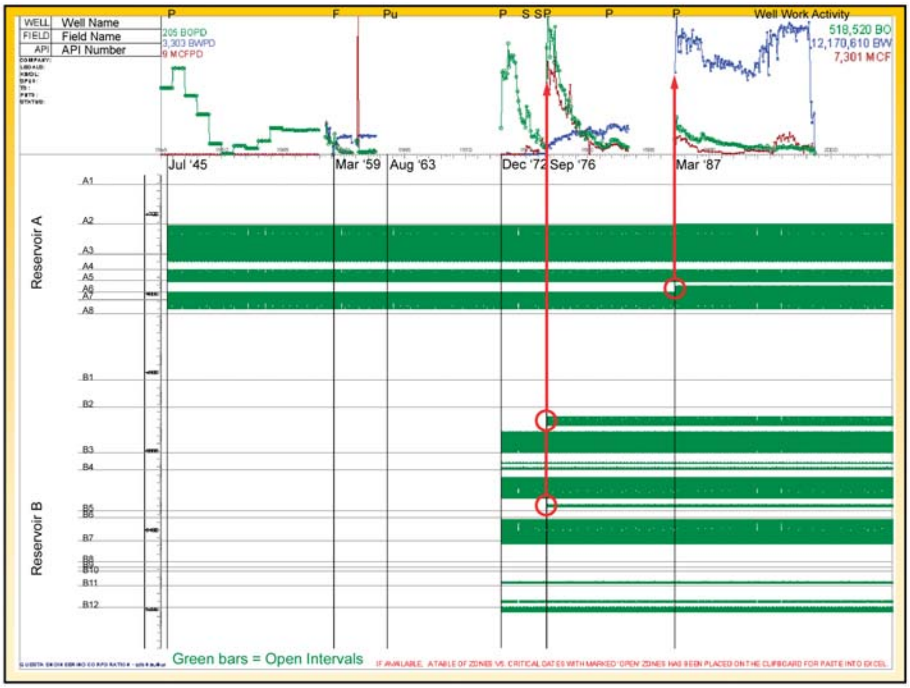


FIGURE 4

Historical Effect of Perforation, Completion and Workovers on Well Production



controls reservoir performance from single-discipline points of view.

The geologic study provided a consistent structural and stratigraphic framework for the field by reviewing 2-D seismic data, well logs and core data. Tops and other properties of each productive interval were entered into the database to correlate perforation history, production history, geologic intervals and production response. All geologic data also were used to construct a numerical reservoir model.

The multidisciplinary team started by solving a common problem in old fields with a long and commingled production history: What was the original oil in place, and what are the remaining reserves in each geologic interval? The answers to those questions then drove the team to investigate how to improve recovery on those intervals with higher remaining reserves and lower development risk. Fluid characterization, seismic interpretation, well log analysis results, production data, completion history, perforation history and fluid-rock data were integrated by the team to build a 3-D model of the field.

The benefit of mature oil fields operated by multiple companies with different philosophies and strengths is that they offer a more diverse history from which one can gather better practices and lessons learned. Using some rather unique visualization tools enhanced the ability to separate the successful and failed past work activity, as well as to find the most and least productive intervals.

An "all in one" display also was prepared for production data, interval completion history, stimulation history, production techniques, and well work history versus time. Figure 4 provides an example of using this tool. In this particular case, two intervals perforated in 1976 made an important contribution to oil production. Investigating on a well-by-well basis to determine whether this response was an isolated case or a general response helped determine the remaining potential for this type of work in the field. In the same example, a small interval perforated in 1987 significantly increased water production. Identifying those intervals on a well-by-well basis helped lead to water shut offs that significantly reduced water production costs for the field.

Additionally, the evaluation of historical stimulation and completion techniques helped to identify optimum workover procedures and to understand what current stimulation technology would be most beneficial. This systematic approach was combined with the improved understanding of reservoir fluid flow characteristics, saturation distributions and structural features. This work led to a large prioritized list of recommendations for the field with many wells having multiple recommendations to address opportunities in individual reservoir layers.

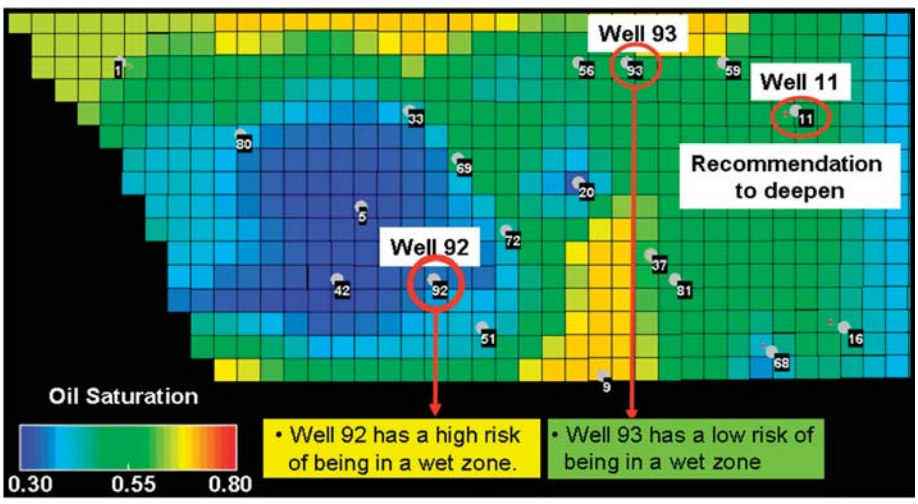
The first and second phases of field activities had a combined success rate of 36 percent. Success was defined as positive net present value using a 10 percent discount rate.

Reservoir Description

During the third phase, the pieces of the puzzle were put together to develop a description of the reservoir that was consistent with the findings and perspective of the individuals from each discipline. Throughout this process, the team was able to greatly improve its understanding of why certain current and past

FIGURE 5

Oil Saturation Map of the Reservoir Before Drilling Wells 92 and 93



activities had either failed or succeeded. It also allowed the team to design specific solutions for current wells and broader solutions for each reservoir.

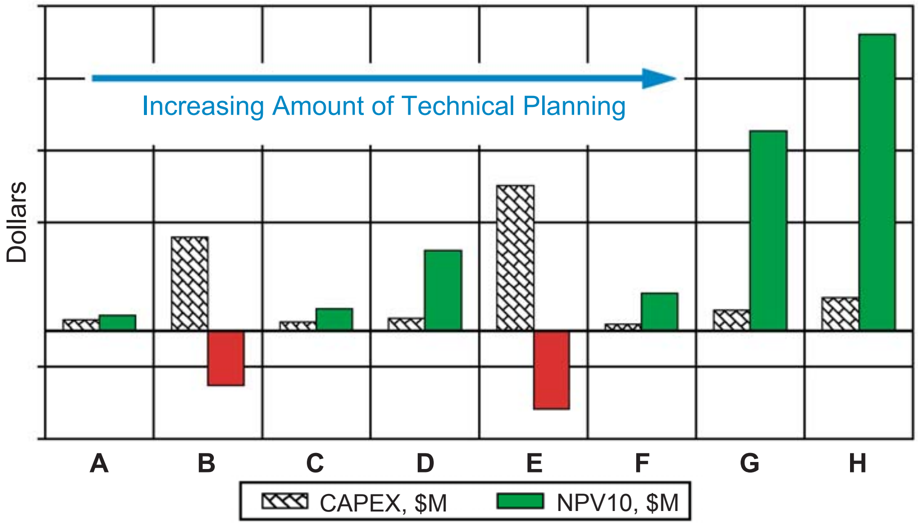
This phase was the most effective stage of the project, owing to the higher benefit produced per dollar invested in fieldwork, as evident in Figure 1. Clearly, better understanding led to better recommendations. Phase III recommendations had a success rate of 100 percent; that is, they all produced a positive NPV 10.

A 3-D dual-permeability/dual-porosity sector model was created to simulate a representative sector of the field. Simulation results were used to correct some minor interpretation problems and identify future opportunities. The numerical model was tested by running the model and using data until 1997, the year when the last two wells in the field were drilled. The objective of this technique, called "bootstrapping" in other disciplines, was to test the model's ability to predict the results of the last two wells without using any data from these wells.

Figure 5 displays the results of the simulation just before the last two wells (well nos. 92 and 93) in the field were drilled. The simulated oil saturation map suggested that Well No. 92 had a high probability of being an underperformer, and that Well No. 93 had a high probability of being an above-average producer. These predictions were compared with actual cumulative values for each well and with the average per well in this reservoir. Actual results supported simulation predictions and provided a higher degree of confidence in the numerical model.

FIGURE 6

Correlation Between Investigation Time/Incremental NPV 10 for Different Projects



In fact, from the same saturation map, the team recommended deepening Well No. 11 to produce from an area that former operators believed was below the field's water/oil contact. Well 11 was deepened and produced 100 percent oil for almost six months. The well was suc-

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cessful in that it proved that there still were multiple opportunities for infill drilling–even in a 60-year-old field! Unfortunately, the field was sold before many other projects like Well 11 could be completed.

Look-Back Analysis

The fourth and final phase is refining the process, incorporating best engineering practices, and applying the process to ongoing field studies for the current project along with documenting it for future field evaluation projects. Each well operation, no matter how small, was analyzed to determine its economic benefit. This was done by projecting production and cash flow from each operation and comparing it with the cost of the operation.

The process of collecting, examining and categorizing field work at each stage provided a basis for examining how much study was needed to ensure the economic success of a particular type of field activity. A positive correlation between evaluation time spent and the resulting economic effect is shown in Figure 6. The amount spent (CAPEX) since acquisition, and the resulting incremental NPV 10, is illustrated for each type of well work activity. Field activities that generated a negative incremental NPV 10 either were eliminated or put aside for further study.

The amount of technical evaluation work applied in designing each field activity increases moving toward the right in Figure 6, with a corresponding left-to-right trend of improving incremental NPV 10. A positive cash flow was generated from some types of field activities that received only a relatively small amount of study, such as repairing downhole equipment failures. Feedback on the individual types of activity significantly helped the operator decide which projects to continue while the field was still under evaluation, because the investors did not want to shut down well work during the technical studies.

In fact, the success of the Phase I well work created some pressure to accelerate field activity and scale back the studies, but management was firm in continuing the technical evaluations. The positive correlation between the amount of technical work and the field activity results supported this decision. Additional dramatic evidence was provided by Phase III field activity.

A major third-party reserve evaluation company conducted a baseline reserve study at the time of acquisition and completed subsequent studies 12 months and 18 months after acquisition. Its reports indicate a 31 percent increase in proved-developed reserves and a 36 percent increase in proved nonproducing reserves between the second and third evaluation. Factors that increased proved reserves were the sustained improvement in the oil decline rate, the jump in oil production rates, the drop in water production, and the documentation showing the ties between reservoir understanding and reservoir responses.

Awakening mature fields is an economically attractive alternative that can increase oil production from conventional resources if patient and data-driven operators and investors provide the resources for improvement. Such resources include qualified personnel to apply appropriate procedures to capture data, understand the field, transfer technology, and adapt and evaluate solutions. Past limitations in technology and product prices created the current, sizable opportunities for further development in mature fields. ❐