Case study: Offshore, Malaysia

Integrated Well Services, alliance partner rejuvenate brownfield, extend field economic life by 20 years

Discovered in the early 1980s, Field-D reached its peak production in the early 1990s, topping 19,000 BOPD (3020 m^3/d). By the late 1990s, however, production began a steady decline, bottoming out at 4,000 BOPD (635 m^3/d) in the early 2010s. The sharp decline is attributed to the reservoir depletion mechanism without any support.

The field is a complex, compressional-extensional structure with varying fluid contacts. The field is laced with more than 800 interpreted faults, making block-to-block transmission more challenging. Small compartments contribute to rapid pressure and rate decline while the thinly laminated sands are easy to miss in seismic studies—increasing the risk of bypassed hydrocarbons.

Various service companies attempted to mitigate the declining production over the years but the depleted pressures kept dwindling the production and the decline could not be arrested. At the lowest production rate, only about 30% of the dual conventional strings with straddled zones in the field remained active and the artificial lift systems were under optimized for sustainable recovery. Based on declining baseline production and increased facilities operating costs, the field was expected to become uneconomical by 2020.

Faced with declining production and no plan for increased oil recovery, the operator established a contract with Baker Hughes for a solution that would rejuvenate the field and enhance recoverable reserves and production of hydrocarbons to extend Field-D's economic life.

Aligning the well plan

Baker Hughes, drawing on its extensive production portfolio and expertise, assigned responsibility of the project to the Baker Hughes Integrated Well Services (IWS) team. Combining project management expertise, a comprehensive technology portfolio, and superior service delivery, IWS was tasked to optimize the project performance and extend the field's productive life.

IWS and the operator created an alliance comprised of integrated multi-disciplinary teams, emphasizing a collaborative work environment that followed an upstream process management system and aligned the various business drivers through a risk-reward model between both companies.

Additionally, the alliance members agreed that:

- The plan must fully exploit all the conductor slots on the platforms, thereby adding more wells per slot to enhance recoverable reserves.
- An integrated solution was required to develop the multiple, stacked reservoirs with variable pressures and saturation profiles to avoid early inactivation and extend the field's productive life.

Designing the solution

In order to boost production, the operator first needed to zero in on where the recoverable reserves were

Challenges

- 30-year-old depleted reservoir without any IOR/EOR
- Conventional well were limiting the life of the well
- Insufficient artificial lift
- Excessive and unplanned deferments due to aging facilities
- High operating cost per barrel

Results

- Extended field economic life by >20 years
- Delivered incremental reserves >50% compared to total reserves drained
- Increased incremental oil production >90% of total production
- Improved active strings from 30% to 60%
- Upgraded facilities to reduce unplanned production downtime from >10% to <5%
- Reduced field operating costs, with new oil coming in at lower costs and reducing unit production cost
- Achieved a perfect health, safety and environmental (HSE) performance (more than 6 million safe man-hours and counting)

located in the compartmentalized formations, and drew on the robust reservoir modeling portfolio of Baker Hughes. This portfolio provided in-depth subsurface intelligence that reduced uncertainty and clarified the field planning.

The teams also emphasized specific design areas of concentration to achieve success:

- Facilities—All facilities would receive an upgrade to enhance the fluid-handling and lifting capability.
- Reservoir—Water injection would be commissioned to improve the recovery through pressure maintenance and sweep.
- Chemicals—Tailored chemical solutions would be developed to address deliquification, enhanced oil recovery (EOR), and stimulation.

With a better understanding of the reservoir and a modified well design, the consolidated teams developed a multi-phase approach to re-energize the field.

Executing predictable performance

The first step towards field reactivation was to stop the production decline and improve marginal recovery. Phase 1 of the project consisted of nine wells, including oil producers and water injectors that were being used to initiate secondary recovery. This segment of the plan incorporated a smart completion concept with a permanent downhole monitoring system and hydraulically controlled flow control valves.

Phase 1 successfully managed to arrest the production decline but it was just the beginning. With Phase 2 in sight, the target was to reverse it back to the 1990's peak.

Drawing on the lessons learned in Phase 1, Phase 2 was conducted with the goal of maximizing the existing production and recovery via eight new infill drilling wells. In four out of the eight oil producers, the team opted to deploy the electrical inflow control valves (ICV) to address the formation complexity, pressure, and production challenges.

Reaching new reservoirs with technology

Historically, Field-D has produced from the primary oil-bearing reservoirs located at a shallower depth while the potential of the deeper formations remained untapped due to limited data availability. Exploration at this depth was considered unfeasible because of its associated higher risks, such as tight reservoirs, watered-out sands in deeper reservoirs, and more complex geology.

IWS and the operator took the initiative to drill deeper along the trajectory of wells planned for the shallower prospects to appraise new deeper horizons. Phase 2 quantified the future production potential of the deeper horizons.

Comprehensive formation evaluation was vital prior to developing the deeper plays and appraising/developing the existing sands. The **FASTrak™ fluid analysis sampling and testing service** and the **RCX™ Sentinel focused sampling service** are just two examples of services used to provide fluid characterization and pressure data. In addition, an alternative geological model was proposed from the geological analysis carried out from the facies and log expression. This geological model showed where additional healthy reserves were located and enabled high-pressure gas in deeper sands to support the lifting of wells. **Remote Operations Services (ROS)** teams performed much of the data analysis to avoid delays due to travel restrictions during the COVID-19 pandemic.

As a result, six out of the eight wells in Phase 2 were drilled to the middle of the deeper horizon where significant oil and gas reserves were discovered. The hydrocarbons flowing from these intervals added more than 50 MMSTB of oil in a 35-year-old brownfield—providing production flow expected to last for at least 30 years.

Revitalizing a brownfield

As of 2021, the alliance has implemented more than 30 new technologies and initiatives to help deliver on the project's goals and continues to innovate as new challenges present themselves—driving efficiencies and increasing production. At each stage, both Baker Hughes and the operator reaped the reward of a continuous improvement curve, applying new lessons learned to existing and future segments.

Today, the tangible results speak for themselves as the incremental oil production constitutes more than 90% of the total production. The active strings percentage has improved from 30% to 60% with a plan to reach 80% within ten years. Through facilities rehabilitation, unplanned field deferments were cut in half. Field operating costs were substantially reduced as well, with new oil coming in at lower costs, to further reduce the unit production cost. And, through the combination of new wells and production enhancement campaigns, the team more than doubled the operator's incremental reserves.

When the collaboration began, the real threat was that the economic limit of Field-D would be reached in 2017. By collaborating with the Baker Hughes Integrated Well Services team and tapping their technology and expertise, the field's life has been extended by at least 20 years and, with the prospects of new, deeper wells producing at virgin pressures, the operator can expect new phases of development even beyond the life of the contract.