Attachment F: Wytch Farm - Elements of Successful ERD Program

From: www.schlumberger.com "*Extending Reach Drilling: Breaking the 10-km Barrier*"

The main technical hurdles to the success of long ERD wells are: 1) reducing torque and drag of the drill pipe, 2) controlling fluid circulation to clean cuttings from the hole while avoiding excessive fluid pressure that could compromise the physical integrity of the hole and result in loss of fluid via unintentional fractures, and 3) maintaining directional control of the drill pipe so it reaches the intended target. Solutions to problems in any one of these areas are not simple because methods to mitigate technical challenges in one area often have adverse consequences in others. One factor, drillstring rotation, is part of the solution to all the major problems in most ERD well applications. Floating the casing into the hole can also play a key role in addressing torque and drag issues in ERD wells.

Guiding a wellbore accurately through the production zone at great distances would be virtually impossible without geosteering. Geosteering involves taking petrophysical measurements at or near the drill bit and relaying the information in real time to the drilling team. The team can then adjust the drill bit direction to aim the well path optimally through the producing oil or gas formation. The result is that smaller targets can be drilled successfully at greater distances.

Wytch Farm ERD Drill Pad in Ecologically Sensitive Location in England

The use of ERD at Wytch Farm was driven by environmental and economic as well as technical objectives. Simply put, the well was drilled because it economically tapped additional reserves more than 10 km from the surface wellsite. These reserves lay in a section an oil reservoir which extends offshore beneath Poole Bay on the southern coast of England. Wytch Farm is western Europe's largest onshore oil field, but roughly one-half of its 467 million bbl of oil extends offshore. The field sits near a nature preserve and is in an area of outstanding natural beauty frequented by tourists. Thus, any development plan had to be aesthetically pleasing with minimal effect on the area. The development plan also had to adhere to stringent environmental regulations.

The initial plan developed by project developer British Petroleum (BP) called for construction of an artificial island with conventional directional wells at a cost of $330 million (see Figure 1 upper graphic). The Figure 1 lower graphic depicts how ERD would be applied to achieve the same objective while eliminating the need for a second drilling pad.Development of the offshore reserves with ERD wells was projected to cost less than half as much at an estimated $150 million and would better protect the environment. Figure 2 shows the trajectory of an actual 11-kilometer well at Wytch Farm.

Figure 1. Conventional Directional Drilling and ERD Comparison, Wytch Farm

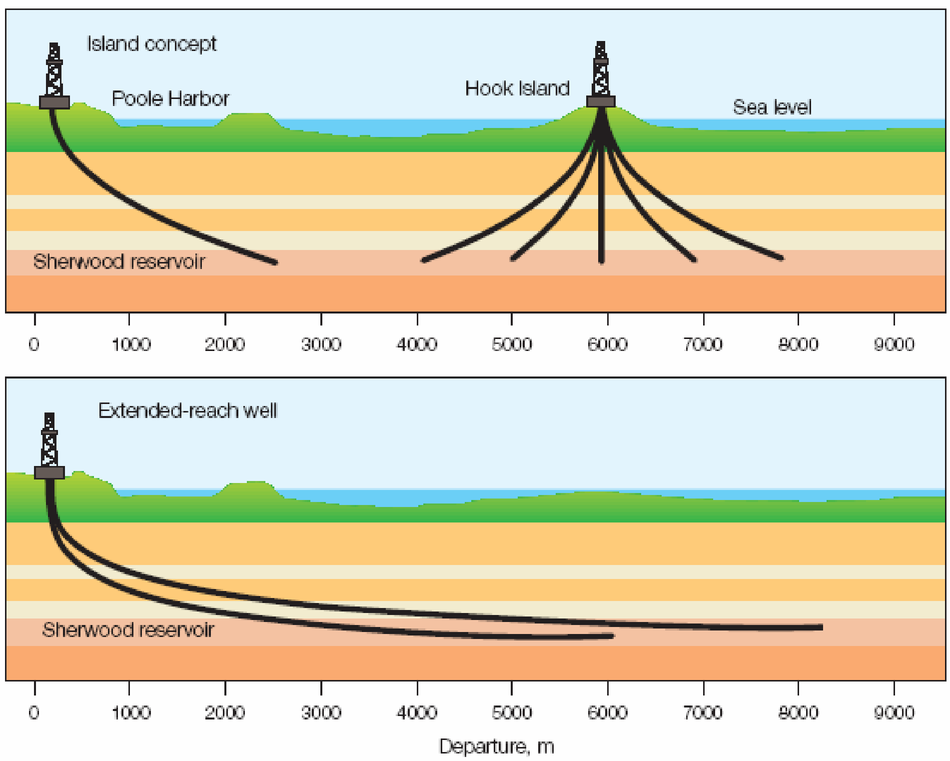
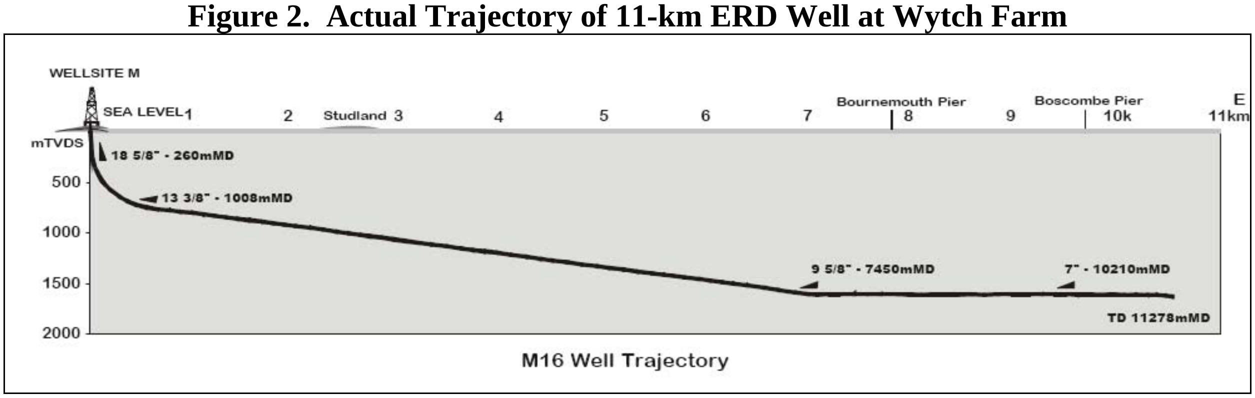


Figure 2. Actual Trajectory of 11-km ERD Well at Wytch Farm



From: Society of Petroleum Engineers Paper No. 59204, *To the Limit and Beyond - The Secret of World-Class Extended-Reach Drilling Performance at Wytch Farm*, IADC/SPE Drilling Conference, New Orleans, February 2000.

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A significant factor in the decision to use of ERD at Wytch Farm was the success of other companies, particularly Unocal Corp. in the Point Pedernales field in southern California. In the late 1980s, collapsing oil prices prompted Unocal to design and drill ERD wells from an existing platform rather than set a second platform. For Unocal, ERD wells achieved several objectives: 1) eliminated the high capital cost of a second platform, 2) intersected more of the formation with near horizontal wellbores, and 3) demonstrated conclusively that such difficult wells could be drilled and completed economically.

The use of ERD wells results in less surface disturbance because fewer wells are needed and surface sites have a smaller footprint. In developing Wytch Farm field, BP sought to maximize oil recovery as economically as possible with the least disturbance to the environment and the surrounding community. Drilling from small surface sites instead of an offshore location helped accomplish this goal. BP established a partnership with local communities and regulatory authorities to ensure that the natural beauty of the Poole area remained unspoiled. More than 300 formal meetings and countless informal discussions were held with local authorities, government departments, environmental and conservation organizations, and the general public to ensure that the views of area residents would be considered in the development of the field.

The area around the oil field forms part of the Dorset Heritage Coastline and includes areas of special scientific interest, a wildlife special protection area, a wetland birds site and a national nature reserve. The surface site is designed to blend into the environment, and equipment is painted in earth-tone colors to minimize visual impact. All lighting is judiciously placed and pointed downward. Strict noise regulations are imposed and ensure minimal disturbance. An extensive impermeable containment ditch surrounding the site can hold any fluids from potential accidents.

Teamwork and Planning

An extended-reach well requires extensive planning and involves the commitment and direct participation of the operator, rig contractor and all service providers. The evaluation, design and planning of Well M-11 lasted more than a year, from March 1996 until drilling began in May 1997. Close cooperation and a smooth working relationship were essential for such a challenging, high-profile project as Wytch Farm.

Contractors were paid on a day-rate basis with total well performance incentives to be shared among all participants, further encouraging teamwork and ensuring alignment of goals. Contractor senior representatives have offices close to one another within the operator's office complex in Poole. This setup fosters a close but informal "roundtable" arrangement. Communication barriers have disappeared, and everyone on the project has the same goals—to drill the wells efficiently, correctly and economically. Decisions are made and involve both the operator and contractors. For such a system to work effectively, a high degree of trust and openness is necessary among personnel of all rank.

Typically, the first one or two wells of any project incur the greatest time and cost as the learning curve begins. Efficiency and performance improve rapidly on subsequent wells as team members work together more efficiently and technology is applied more effectively.

This was true on the directional wells drilled at San Martin 1 and San Martin 3 at Camisea. A description of the well drilling efficiency improvements realized during the San Martin drilling program is available on the Schlumberger website under "drilling case studies."

Every aspect of the M-11 well plan underwent a rigorous peer review to identify potential pitfalls and develop contingency plans. Experts from BP and its partners thoroughly analyzed key risks and processes in production reservoir issues, well placement, drilling mechanics, hydraulics and safety. Having outsiders analyze the well plan provided a useful check against existing contingency plans.

Directional Control

Steering by slide drilling is impossible at extreme horizontal distances. Slide drilling means using the weigh of the drill pipe to exert force on the drill bit using some form of motor drive on the drilling rig to rotate the drill string. Experience on early Wytch Farm ERD wells indicated that slide drilling would be practically impossible beyond 8 km. Drilling in the sliding mode results in several inefficiencies that are compounded by extreme distances. The drill bit motor must be oriented and maintained in a particular direction while drilling to follow the desired path. This orientation is achieved through a combination of rotating the drillstring several revolutions and working the pipe to turn it to the desired direction. At 8 km or more, the pipe may need 15 to 20 turns at surface just to turn the drill bit assembly once downhole, because the drillstring can absorb the torque over such a long distance. For the directional driller, this technique is as much art as it is science.

In high-drag situations like long ERD wells, it is difficult to keep torque constant in the lower part of the drillstring, causing difficulty in maintaining drill bit orientation. Another problem with slide drilling in high-angle wells is that cuttings removal suffers from the lack of drillstring rotation. In wells with high drag, the drillstring cannot be lowered smoothly and continuously, which prevents the motor from operating at optimal conditions. In combination, these factors result in a lower penetration rate compared to that during rotary drilling. For ERD wells, not only does the rate of drilling progress suffer, but there is a point at which slide drilling is no longer possible. Continuous rotation of the drillstring results in reduced torque and drag and improved hole cleaning.

Hydraulics and Hole Cleaning

Selection of a drilling fluid must balance a number of critical factors. The fluid must provide a stable wellbore for drilling long openhole intervals at high angles, maximize lubricity to reduce torque and drag, develop proper rheology for effective cuttings transport, minimize the potential for problems such as differential sticking and lost circulation, minimize formation damage of productive intervals, and limit environmental exposure through a wellsite waste-minimization program. A growing industry trend of designing wells to extend casing seats to longer intervals requires the use of oil-base or synthetic-base mud to provide lubricity to help control torque and drag. This trend means larger hole diameters deeper in the ERD trajectory.

With 8- to 10-km extended-reach sections, the circulation rates necessary to ensure adequate hole cleaning in these larger holes are difficult to attain because of increases in annular pressure losses. These pressure losses increase the equivalent circulating density (ECD) at the end of the well. Higher equivalent circulating densities may cause lost circulation, especially in fractured or depleted upper zones. Higher pump rates ensure a clean hole but may lead to lost circulation from higher ECD.

Efficient cuttings transport is one of the primary design considerations for the drilling fluid in an extended-reach well. Hole cleaning is of critical importance when drilling the high-angle tangent sections of extended-reach wells because of the tendency for cuttings to fall to the low side of the well. To obtain the necessary annular velocities for hole cleaning in high-angle and horizontal sections, high flow rates are needed, resulting in greater demands on the mud pumps.

To meet such rates, an existing rig may need to increase the number of mud pumps from two to three, increase the power rating of the pumps from 1600 hp to 2000 hp or more, and increase the pressure rating of the pumps and surface system from 5000 to 7500 psi. A downside to these changes is the increase in capital cost for additional pumps and a doubling of maintenance costs for the higher-pressure equipment.

Pipe rotation is another critical factor in hole cleaning. The objective of the holecleaning program is to improve drilling performance by avoiding stuck pipe, avoiding tight hole on connections and trips, maximizing the footage drilled between wiper trips, eliminating backreaming trips prior to reaching the casing point and maximizing daily drilling progress. The more an extended-reach well can be drilled in the rotary mode instead of sliding, the better the hole cleaning.

Torque and Drag

Torque levels have been closely monitored throughout the extended-reach development program. In extended-reach wells, torque levels are generally more dependent on wellbore length than on tangent angle. Higher-angle wells do, however, tend to reduce overall torque levels, as more of the drillstring will be in compression, and consequently, tension and contact forces around the top build section are reduced.

Casing Flotation

One of the major hurdles to overcome in drilling and completing a 10-km well was running 95⁄8-in. casing to a departure beyond 8000 m. Experience on other Wytch Farm wells showed that running the 95⁄8-in. casing became increasingly difficult with greater departures. Casing design analyses using friction factors from offset wells indicated that drag would be too high to run the planned 8800 m of casing conventionally inWell M-11, even with full weight from the travelling block. Of the options tried, casing flotation proved to be the only method with sufficient potential to get the casing to total depth. In principle, casing flotation is a simple technique. Essentially, casing is not filled as each joint is run into the wellbore, as is done in typical casing operations. The goal is to have the casing close to neutrally buoyant, so it becomes virtually weightless in the mud, and drag is minimal.