

Appendix C: Directional and Extended-Reach Drilling

Directional drilling is a drilling technique whereby a well is deliberately deviated from the vertical in order to reach a particular part of the reservoir. Directional drilling technology enables the driller to steer the drill stem and bit to a desired bottom hole location. Directional wells initially are drilled straight down to a predetermined depth and then gradually curved at one or more different points to penetrate one or more given target reservoirs. This specialized drilling usually is accomplished with the use of a fluid-driven downhole motor, which turns the drill bit (Gerding, 1986). Directional drilling also allows multiple production and injection wells to be drilled from a single surface location such as a gravel pad or offshore production platform, thus minimizing cost and the surface impact of oil and gas drilling, production, and transportation facilities (see Figure 5.3). It can be used to reach a target located beneath an environmentally sensitive area and may offer the most economical way to develop offshore oil fields from onshore facilities.

The limitations of directional drilling are primarily dependent upon maximum hole angle, rate of angle change, and torque or friction considerations. In directional drilling, it is now common for the horizontal displacement of the bottom hole location to be twice the total vertical depth (TVD) of the well. That is, a well with a vertical depth of 7,000 feet could have a bottom hole horizontal displacement of 14,000 feet from the drill site. However, in a shallower well, such as one in which a potential target is two miles away from the drill site but only one mile deep, directional drilling would be much more difficult, risky, and costly (Schmidt, 1994).

Direction drilling may be limited by the type of geology or rock through which drillers must drill in order to reach the desired target. Coal and shale deposits tend to expand or collapse the well bore and cause the drill string to get stuck. This is more likely to happen in wells that take longer to drill where the downhole formations are exposed to the drilling mud and drill string longer before well casing is cemented into the hole. Small subsurface faults are difficult to locate prior to drilling, and if the drill bit crosses a fault, the type of rock being drilled may suddenly change and a new geologic reference must be established. During this intermediate period in the drilling operation, the driller will not be sure if the desired geologic target is being drilled or could be intersected again (Schmidt, 1994). Stuck pipe can also occur in directional wells when the borehole becomes oval shaped from the drill pipe constantly laying on the downside part of the well bore. The pipe gets lodged in the groove cut on the bottom of the hole. The most common cause of hole collapse is the chemical difference between in-formation saltwater and the water in drilling mud. This is especially common when drilling through shale. Ions in the water in the mud have a tendency to transfer to the shale, the shale expands, and small sheets slough off into the hole, causing the pipe to get stuck (Gerding, 1986).

Subsurface collisions with neighboring wells can be problematic when drilling multiple boreholes from one surface location. A collision with a producing well could result in a dangerous situation. Anticollision planning begins with accurate surveys of the subject well and a complete set of plans for existing and proposed oil and gas wells (Schlumberger Anadrill, 1993).

Perhaps the greatest limitation on directional drilling is cost. For certain reservoirs, directional drilling technically may be possible but is not always economically feasible. Factors that may prohibit the use of directional drilling, such as the position of oil or gas deposits in the geologic structure relative to the drilling rig, the size and depth of the deposit, and the geology of the area, are all important elements that determine whether directional drilling is cost effective (Winfree, 1994). The environment and the cost of multiple pads or locations are also considerations in determining the cost-effectiveness of directional drilling.

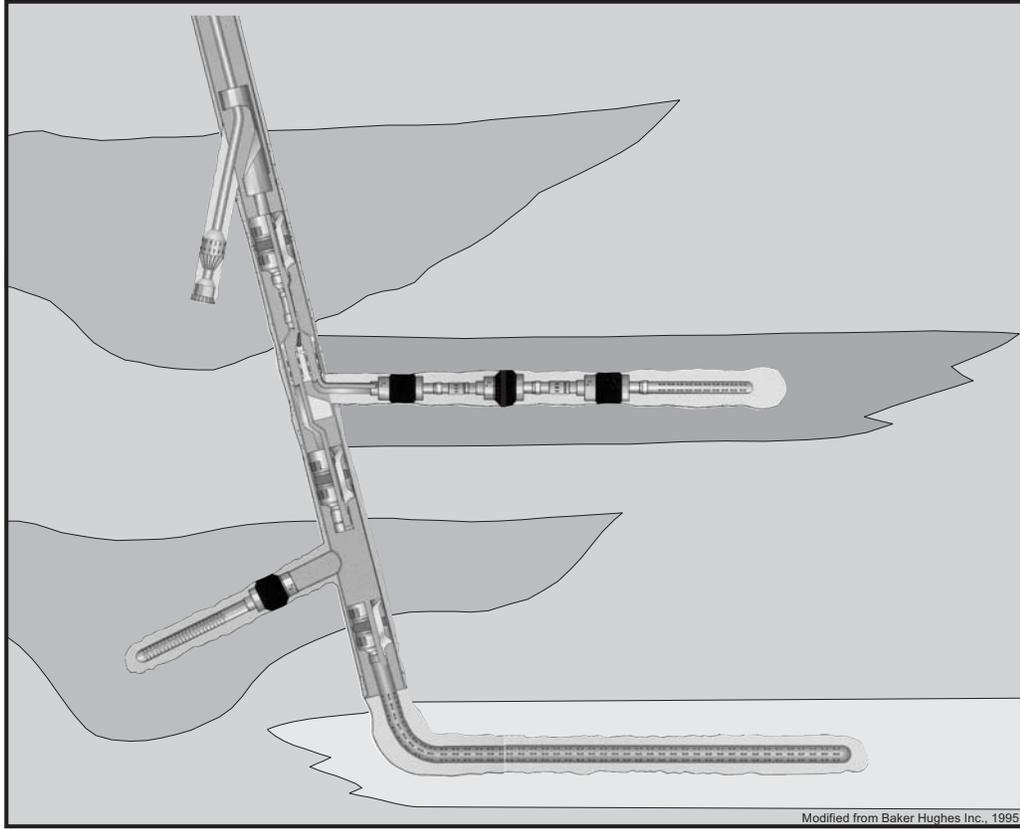
Horizontal drilling, a more specialized type of directional drilling, allows a single well bore at the surface to penetrate oil- or gas-bearing reservoir strata at angles that parallel or nearly parallel the dip of the strata. The well bore is then open and in communication with the reservoir over much longer distances. In development wells, this can greatly increase production rates of oil and gas or volumes of injected fluids (Winfrey, 1994). Horizontal drilling may involve underbalanced drilling, coiled tubing, bit steering, continuous logging, multilateral horizontals, and horizontal completions. Lateral step-outs are directional wells that branch off a main borehole to access more of the subsurface. Conditions for successful horizontal wells include adequate prespud planning, reservoir descriptions, drillable strata that will not collapse, and careful cost control (PTTC, 1996).

Extended-Reach Drilling (ERD) has evolved from simple directional drilling to horizontal, lateral, and multilateral step-outs (see Figure E.1). ERD employs both directional and horizontal drilling techniques and has the ability to achieve horizontal well departures and total vertical depth-to-deviation ratios beyond the conventional experience in a particular field (Gerding, 1986). ERD can be defined in terms of reach/TVD (total vertical depth) ratios (Judzis *et al.*, 1997). The definition of an ERD well depends on the results of existing drilling efforts in a particular oilfield (Gerding, 1986). Local ERD capability depends on the extent of experience within specific fields and with specific rigs and mud systems. “ERD wells drilled in specific fields and with specific rigs, equipment, personnel, project teams, etc. do not necessarily imply what may be readily achieved in other areas.” (Judzis *et al.*, 1997).

Possible challenges to successful ERD include problematic movement of downhole drillstring and well casing, applying sufficient weight to the drill bit, buckling of well casing or drillstring, and running casing successfully to the bottom of the well. Drillstring tension may be a primary concern in vertical wells, but in ERD, drillstring torsion may be the limiting factor. Running normal-weight drill pipe to apply weight to the bit in ERD can lead to buckling of the drill pipe and rapid fatigue failure. Conventional drilling tools are prone to twist-off because of unanticipated failure under high torsional and tensile loads of an extended-reach well (JPT, 1994). Torque can be significantly reduced with the use of nonrotating drill pipe protectors (Payne *et al.*, 1995). Advanced equipment for an ERD well may include wider diameter drill pipe, additional mud pumps, enhanced solids control, higher capacity top-drive motors, more generated power, and oil-based drilling fluids (Judzis *et al.*, 1997).

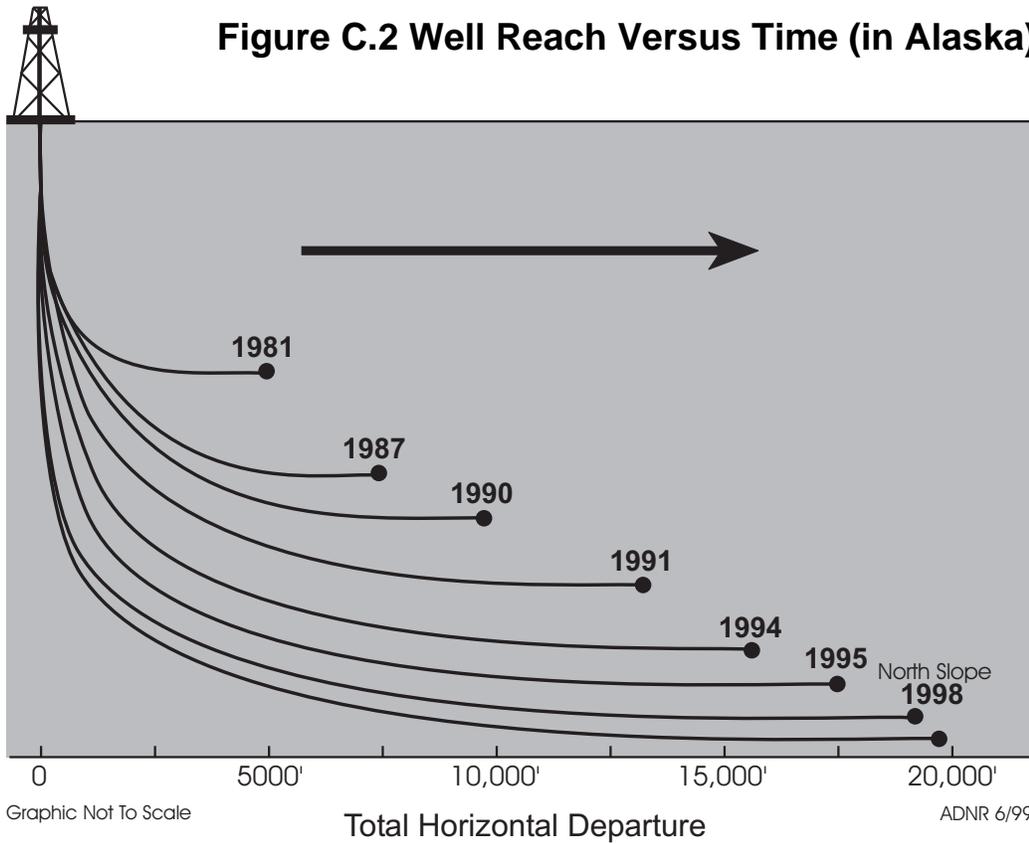
ERD requires longer hole sections, which require longer drilling times; the result is increased exposure of destabilizing fluids to the well bore (JPT, 1994). Oil-based muds are superior to water-based muds in ERD (Payne *et al.*, 1995). Water-based muds may not provide the inhibition, lubrication or confining support of oil-based muds (JPT, 1994).

Figure C.1 Multilateral Wellbore



Multilateral_Wellbore_ppt.cdr

Figure C.2 Well Reach Versus Time (in Alaska)



Drillstring design for ERD involves: (1) determining expected loads; (2) selecting drillstring components; (3) verifying each component's condition; (4) setting operating limits for the rig team; and (5) monitoring condition during drilling. Economic and related issues in drillstring planning include cost, availability, and logistics. Rig and logistics issues include storage space, setback space, accuracy of load indicators, pump pressure and volume capacity, and top-drive output torque. Drill hole issues include hole cleaning, hole stability, hydraulics, casing wear, and directional objectives (Judzis *et al.*, 1997).

The working relationship between various components of a drill string must be analyzed carefully. Conventional drill stems are about 30 feet long and are made up of a bit, stabilizer, motor, a measurement-while-drilling (logging) tool, drill collars, more stabilizers, and jars. Typically there are more than 1,600 parts to a drill string in a 24,000-foot well. A modern drill string can be made up of hundreds of components from more than a dozen vendors. These components may not always perform as anticipated and may not meet operational demands of drilling an extended-reach well (JPT, 1994).

In a few cases, ERD technology has been used instead of platform installation off the coast of California, where wells are drilled from onshore locations to reach nearby offshore reserves. ERD has been instrumental in developing offshore reserves of the Sherwood reservoir under Poole Bay from shore at Wytch Farm, U.K. The original development plan called for the construction of a \$260 million artificial island in the bay (JPT, 1994). ERD also has been used successfully in the North Sea, in the Gulf of Mexico, in the South China Sea, and in Alaska (Milne Point, Badami, Point McIntyre, Alpine, and Niakuk fields) (Judzis *et al.*, 1997).

Although a 6.6-mile horizontal displacement was accomplished in 1999 at Cullen Norte 1 well in Argentina (Halliburton, 1999), horizontal displacements (departure from vertical) of 0.5 to 2 miles are typical. In October 1998, BP set a long-reach record for horizontal directional wells in the U.S. with a displacement of 19,804 feet in the Niakuk field (see Figure E.2). Despite its \$6 million price, the well represents a cost saving over the other drilling alternatives, such as construction of an offshore artificial gravel island (AJC, 1996).

Exploration wells within the license area may be directionally drilled because of a lack of suitable surface locations directly overlying exploration targets. However, until specific sites and development scenarios are advanced and the specific conditions of drill sites are known, the applicability of directional drilling for oil and gas within the license area is unknown. It is anticipated that most development wells will be directionally drilled because of the cost savings realized in pad construction and required facilities.

Many surface use conflicts can be avoided through directional drilling and ERD. However, some reservoirs are located or sized such that directional drilling cannot eliminate all possible conflicts.