Horizontal Wells—an Economical Water Development Option

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Availability of adequate water for livestock is a prerequisite for good range management. Dispersal of good quality water is also essential for obtaining optimum forage use, a vital ingredient to insure maximum livestock production. Throughout the history of the range livestock industry, securing reasonably priced water developments at suitable locations has been a continual problem for livestock producers. Improving the flow of springs and seeps has alleviated scarcity of water in some areas. However, many of these developments are wasteful, resulting in exhausting the water supply or destruction of the natural barrier which retains the ground water. Conventional spring developments are often contaminated by animals and other forms of surface pollution. The horizontal well virtually eliminates the disadvantages of conventional spring development techniques (Welchert and Freeman 1973), because it is a cased borehole with simple plumbing fittings to control water flow.

Development of Horizontal Drilling Techniques

The introduction of horizontal wells is possibly the most exciting range water development system in the previous 50 years. Horizontal wells are "relatively inexpensive, efficient, reliable, sanitary and maintenance free." Further, this technique permits the development and use of "relatively small, trapped water supplies that go undeveloped in conventional vertical well drilling," according to Welchert and Freeman (1969). Water yields of only 0.25 gallon per minute (gpm) may be adequate in many areas, depending on livestock numbers, length of grazing period, and location and quantity of other water supplies.

Horizontal wells were first extensively developed on the San Carlos Apache Indian Reservation in Arizona (Welchert and Freeman 1969). According to those authors, the innovator and authority for this system of water development was A.W. "Bud" Smith of Crestline, California. Smith drilled 53 horizontal wells on the San Carlos from 1967 to 1969, with 45 successful wells developed, using a rig of his own design. An estimated 1,500 horizontal wells were drilled in Arizona during the next 10 years (Altimonte 1980).

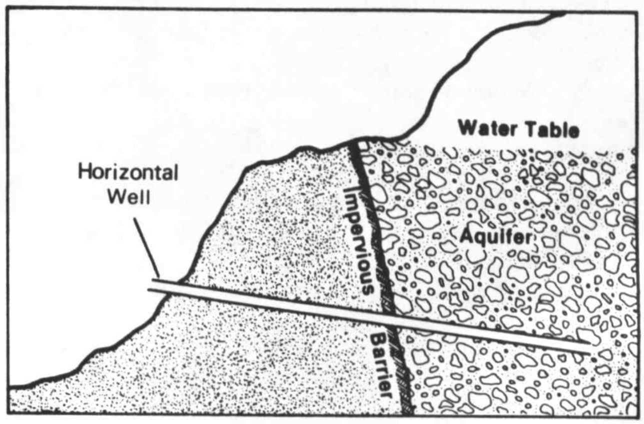
In 1972, the horizontal drilling technique was introduced in the Davis Mountain area of western Texas when A.W. Smith moved his drilling rig to that area (Jacoby 1973). According to Jacoby, the horizontal drilling method opened a new era of water development in western Texas because much of the area is suited to its use.

Altimonte (1980) described the successful horizontal well drilling accomplishments of Glen Sevey in the Pacific Northwest using a rig purchased from A.W. Smith. Well length, flow, and drilling time of 20 successful horizontal wells developed on the Fremont National Forest were documented. Horizontal wells provided water for drinking and shower facilities at a 150-unit campsite in the Modoc National Forest of northwestern California. Drinking water was also made available for 150 to 200 skiers per day at the Warner Canyon ski area in southern Oregon by a horizontal well which produced three gpm (Altimonte 1980). Horizontal wells have many potential uses in public and private recreation areas.

Recently, a Montana geologist noted that many successful livestock water developments have been developed with horizontal drilling equipment in eastern Montana (Mark Koffler, Ashland, MT., personal communication). Montana, North Dakota, South Dakota, Nebraska, and Wyoming have potentially thousands of sites that could be developed with horizontal drilling equipment. Yet, there are only two known horizontal drilling rigs in this vast region despite nearly two decades of successful horizontal well developments in the western United States and many foreign countries.

Identifying Drilling Sites

Most persons with experience on rangeland can recognize potential sites for horizontal drilling by the presence of water-loving plants or a seep (Welchert and Freeman 1969). Trapped ground water tends to occur in two types of hillside, water-bearing formations: the dike and the contact type



Dike spring formation (from Welchert and Freeman 1973.)

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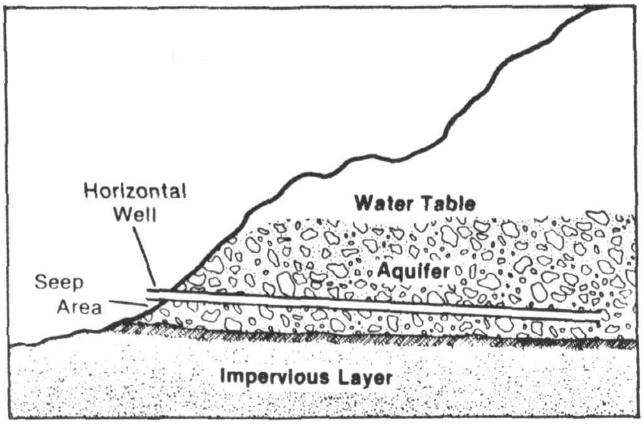


Contact-type spring formation (from Welchert and Freeman 1973).

(Altimonte 1980). The dike spring is formed behind a geologically tilted, impervious barrier. Horizontal drilling attempts to drill through this barrier at a point below the seep to tap the water supply.

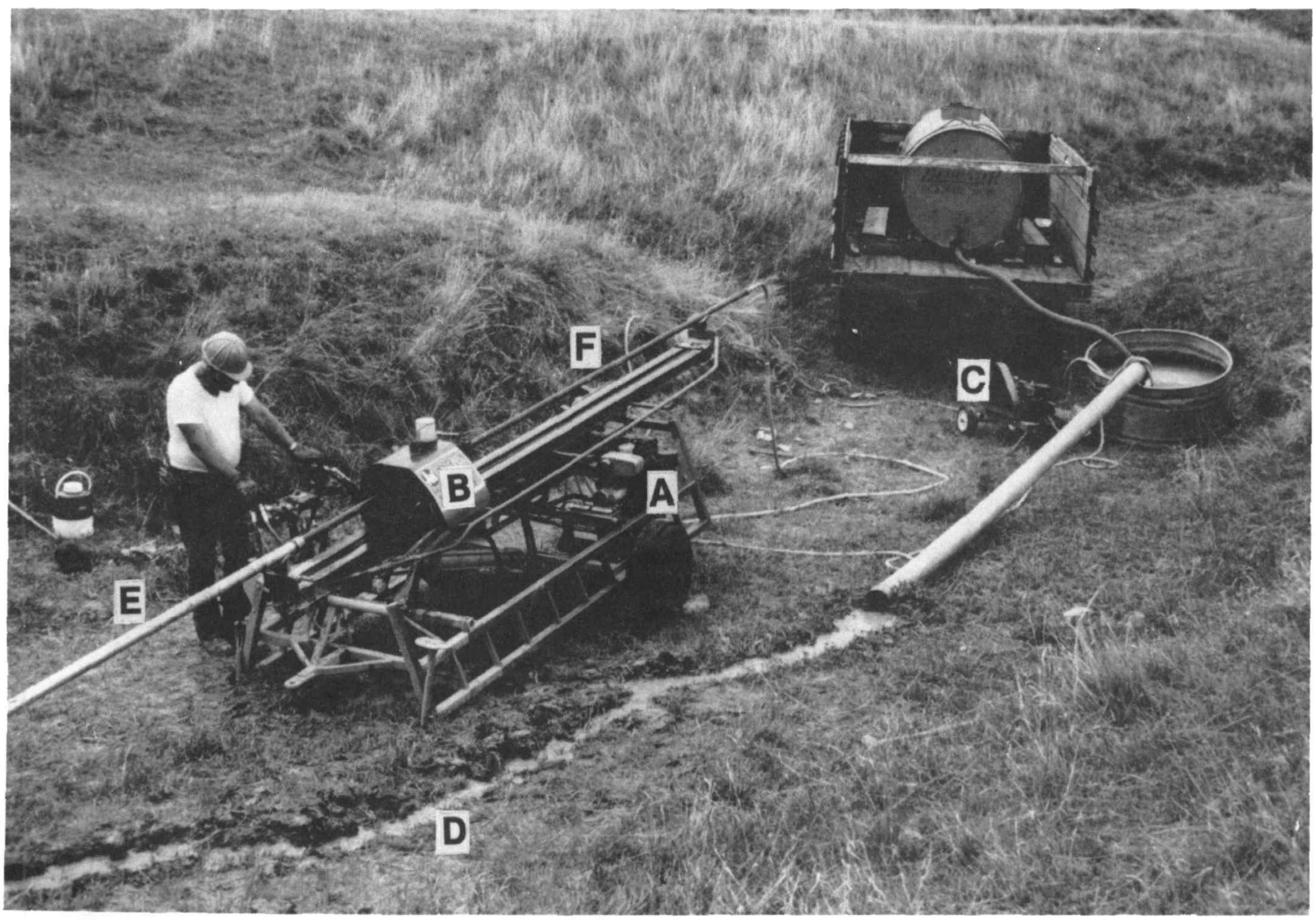
The contact formation consists of ground water perched above an impervious layer such as shale. Water seepage, if present, is generally just above the outcropping of the impervious layer. Developing this type of water source can be more difficult, since drilling into the impervious layer will probably not contact the ground water.

Equipment and Drilling Technique

The drilling rig designed by A.W. Smith weighs about 1,900 pounds and is supported on a single axle with 13-inch wheels. It can easily be towed to drilling sites with a pickup, yet is light enough to be transported to extremely inaccessible sites by helicopter. Most 3- or 4-wheel all-terrain vehicles are able to tow the rig to a drilling location.

A 16-hp air-cooled engine (letter A on photo) powers a hydraulic system which provides the rotation and thrust to the drill stem through the chuck. The chuck (B), which turns the drill stem, slides forward and backward along a 16-foot steel I-beam-type carriage. The 1 1/4-inch extra strength (schedule 80) steel drill pipe (F), in standard 21-foot or shorter lengths, is secured in a "donut" between the thrust bearing and rear of the chuck. The operator controls thrust and rotation of the chuck with two hydraulic valves.

A portable two-cylinder, double-acting water pump (C) powered by a 5-hp engine circulates water at 3 to 6 gpm through the drill pipe. Water circulation flushes cuttings back through the annular space around the drill pipe and cools the drill bit. A continuous flow of return water is absolutely essential to prevent the drill bit from plugging or binding. Return water (D) is channeled to a small holding pond or tank and recirculated. Usually sufficient water is available at



Horizontal well drilling equipment in operation.

or near the drilling site, but if not, 100 to 300 gal must be transported daily.

Drill bits consist of two tungsten-carbide blanks welded into notches in a standard 1 1/4-inch pipe coupling. Modifications of this "standard" bit have been designed to drill through various geologic formations. Commercial diamond drill bits are available for drilling through extremely hard rock. The outside diameter of the bit must not exceed the inside diameter of standard 2-inch galvanized pipe used in casing a horizontal well.

The rig is positioned so the drill stem has a minimum downward slope of 1/2 to 3/4-inch per linear foot. Sometimes it is desirable to begin drilling for the first few feet with a section of 2-inch pipe (E). This pipe then serves to support the 1 1/4-inch drill stem when distance between the rig and point of contact is greater than about six feet. The drilling rate varies with type of material being drilled, sometimes varying from hard shale or rock to sand in the same hole. In most shale and soft rock materials the rate will range from 3 to 9 inches per minute. Hard rock, such as dense basalt, hard shales, and some gravel beds, can reduce the drilling rate to 1/4-inch per minute.

Completing a Horizontal Well

The search for water ends when a clear flow is detected in the darker-colored water flowing out of the borehole. The section of drill stem outside the hole is uncoupled while leaving just enough drill stem protruding from the hole to serve as a guide for the 2-inch galvanized casing. Next, a 1 1/4-inch rounded plug and pick-up guide is threaded into the protruding end of the drill stem. The plug forces pumped water to flow between the outside wall of the drill stem and the inside wall of the casing when the latter is drilled into place. A 21-foot section of casing is inserted through the thrust bearing, a 2 1/2-inch "donut", and through the chuck. After threading on a 2-inch bit, the casing is guided over the exposed (but plugged) end of the drill stem. Using normal drilling procedure with water was first located. Depending on well length, several sections of casing may be required. One to three feet of casing must protrude from the borehole to permit threading of plumbing hardware.

When the casing is in place, the drill stem is removed and inserted along the left side of the casing where it will serve to transport the cement grout to the annular space around the casing. Paper is packed tightly around the drill stem at the point where it enters the soil to keep the grout in the ground. The casing is now ready to be cemented in place. A cement grout, using one to two sacks of plastic cement mixed with water, can be prepared in a 5-gal bucket. It is mixed to the consistency of heavy cream, then poured into an 18-gal pressure tank. Water pressure from the portable pump forces the grout from the tank through a high pressure hose into the drill stem and into the annular void around the casing. Cementing the casing takes only 15 to 30 seconds and is completed when grout flows out the casing. The drill stem is removed, the hole packed tightly with more paper, and the cement grout allowed to set overnight.

The next day the 1 1/4-inch drill stem is inserted into the casing to drill out the grout. Drilling can be continued to extend the hole further into a water-bearing formation. When drilling is stopped the drill stem is removed and 1 1/4-inch perforated PVC is inserted the full length of the well (or from the last few feet of 2-inch casing to the end of the borehole).

Plumbing fixtures include a gate valve, vacuum relief valve, and necessary fittings, all threaded on a tee at the end of the casing. The relief valve is at the highest point of the system and prevents a vacuum from developing in the well if water flow exceeds recharge. Fine particles could also be drawn into the well if a vacuum occurred. Pipe or hose can be fitted to the tee to distribute water to a float valve at the livestock watering site. The horizontal well is an "automatic" system because the outlet is below the elevation of the water table which provides a sufficient head to create an artesian-type of flow.

Expected Water Yields

The yield of water needed for livestock is relatively small, especially if water is adequately distributed within a grazing unit. As little as 0.7 gpm will furnish approximately 1,000 gal per day, or enough to water about 100 cattle (Greenfield 1967). Every drilling site has a different potential for water yield. Drilling success and development costs vary with each site, and these factors also depend on the experience of the driller. On the San Carlos Apache Indian Reservation in Arizona, success was defined as a yield of more than 0.25 gpm (Welchert and Freeman 1970). Water yields from 45 successful wells ranged from 0.25 to 60 gpm, and most ranged from 3 to 10 gpm. Curl (1972) cited flows ranging from 0.25 to 20 gpm from horizontal wells in western Texas. Jacoby (1973) reported an average flow of 10 gpm at "more than a dozen" horizontal wells developed in the Davis Mountain area of western Texas. Water flows ranged from 0.25 to 18 gpm. On the Fremont National Forest in Oregon, yields on 20 wells completed in 1979 ranged from 0.25 to 42 gpm, with an average of 4.8 gpm (Altimonte 1980).

Drilling Costs

The average cost per producing well on the San Carlos Apache Indian Reservation (1967-69 dollars) was $500, including $50 for plumbing supplies. This cost included the dry holes (eight) and "time spent on site preparation and road building." Not included were pipeline and water tank systems. About 32 hours were logged for each producing well, with well length varying from 41 to 270 feet (Welchert and Freeman 1970). The Agricultural Conservation Program in Arizona provided 50% of the drilling cost and casing up to a $2,000 limit, according to Fowler (1971). Similar cost-sharing is probably available in most states for developing springs.

Jacoby (1973) stated that the average cost per horizontal well in western Texas was under $500. Well length ranged from 50 to 180 feet, although some were in excess of 500 feet. He noted that vertical wells drilled for livestock water and fitted with pumps had cost as much as $10,000.

Average drilling time per completed well on the Fremont National Forest in Oregon was about 26 hours, but ranged from 10 to 120 hours (Altimonte 1980). Well length ranged from 33 to 147 feet. Average cost of a completed well in 1979 was about $875, including dry holes, site preparation, and road building.

With increasing costs of fuel, oil, equipment, and labor, today's horizontal drilling costs in the Southwest may be from $30 to $60 per hour. Unique drilling locations on the West Coast are currently billed at $80 per hour (A.W. Smith, personal communication).

The author has limited drilling experience in western South Dakota with a horizontal drilling rig purchased from Smith. The number of wells drilled to date are insufficient to calculate average drilling time, yields, costs, etc. Drilling rates are probably lower in the Northern Plains states because (1) nearly all labor rates are lower in this region, and (2) horizontal well development is relatively new.

Average drilling costs of vertical wells in western South Dakota, currently used by the Soil Conservation Service, USDA, under the Great Plains Conservation Program, range from $18 per foot for 4 to 12-inch casings to $28.50 per foot for larger casings (R.D. Baumberger, personal communication). Many, if not most, vertical wells in this area are 100 feet or deeper. Drilling costs will probably increase after October 1, 1985, when recently enacted legislation requires that the annular void around vertical well casings be filled with cement. The intent of the state law is to prevent surface or subsurface contaminants from entering the water supply.

Those contemplating the purchase of horizontal drilling equipment may be interested in investment costs. Total 1979 investment reported by Glen Sevey for a horizontal drilling rig, miscellaneous materials, and wages was $17,500. He compared those figures with projected costs of $100,000 or more for a vertical drilling system, (Altimonte 1980). His estimated drilling costs, with the horizontal drill rig amortized over three years, were abour $11 per foot, compared with $30 per foot for a completed vertical well in 1978.

Summary

There are many advantages to the horizontal drilling method for developing water for livestock and other purposes. Several were alluded to including efficiency, reliability, water quality, and relatively inexpensive development costs. Horizontal wells require minimal maintenance. The small, lightweight drilling rig can be moved into extremely difficult terrain. The horizontal drilling rig has nearly unlimited potential for providing water for recreationists at campgrounds and other locations as well as for wildlife.

On many range sites, e.g., the Nebraska Sandhills and mountain meadows, shallow vertical wells can reach adequate water supplies. The latest generation of the Smith drilling rig is equipped with a hydraulic ram which raises the chuck and carriage approximately 90 degrees to enable vertical drilling. Maximum drilling depths of about 50 feet are advised, since the rig is of lightweight construction. Shallow vertical wells can supply needed water at several locations on many ranches. Drilling costs with the equipment described should be considerably lower than with conventional, vertical well-drilling equipment.

Water for livestock can, no doubt, be developed with the horizontal drilling technique at relatively low cost in several locations on most ranches. Many range areas also have potential sites for shallow vertical wells. The initial investment of developing added water for livestock will be returned in the form of more efficient use of the range resources and improved livestock production. Horizontal wells may not be the answer to all water problems, but they have tremendous potential for livestock and wildlife water, as well as for human use, in many rangeland areas.

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