FIELD REPORTS

IMPROVING YIELDS OF OPEN WELLS IN CONSOLIDATED ROCKS USING EXTENSION DRILLING TECHNIQUES

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Introduction

In the consolidated rock areas of many developing countries, hand-dug open wells are commonly used to provide water for village drinking supply, and agricultural irrigation. In India consolidated rocks crop out in over two-thirds of the country (Figure 1) and there are roughly several

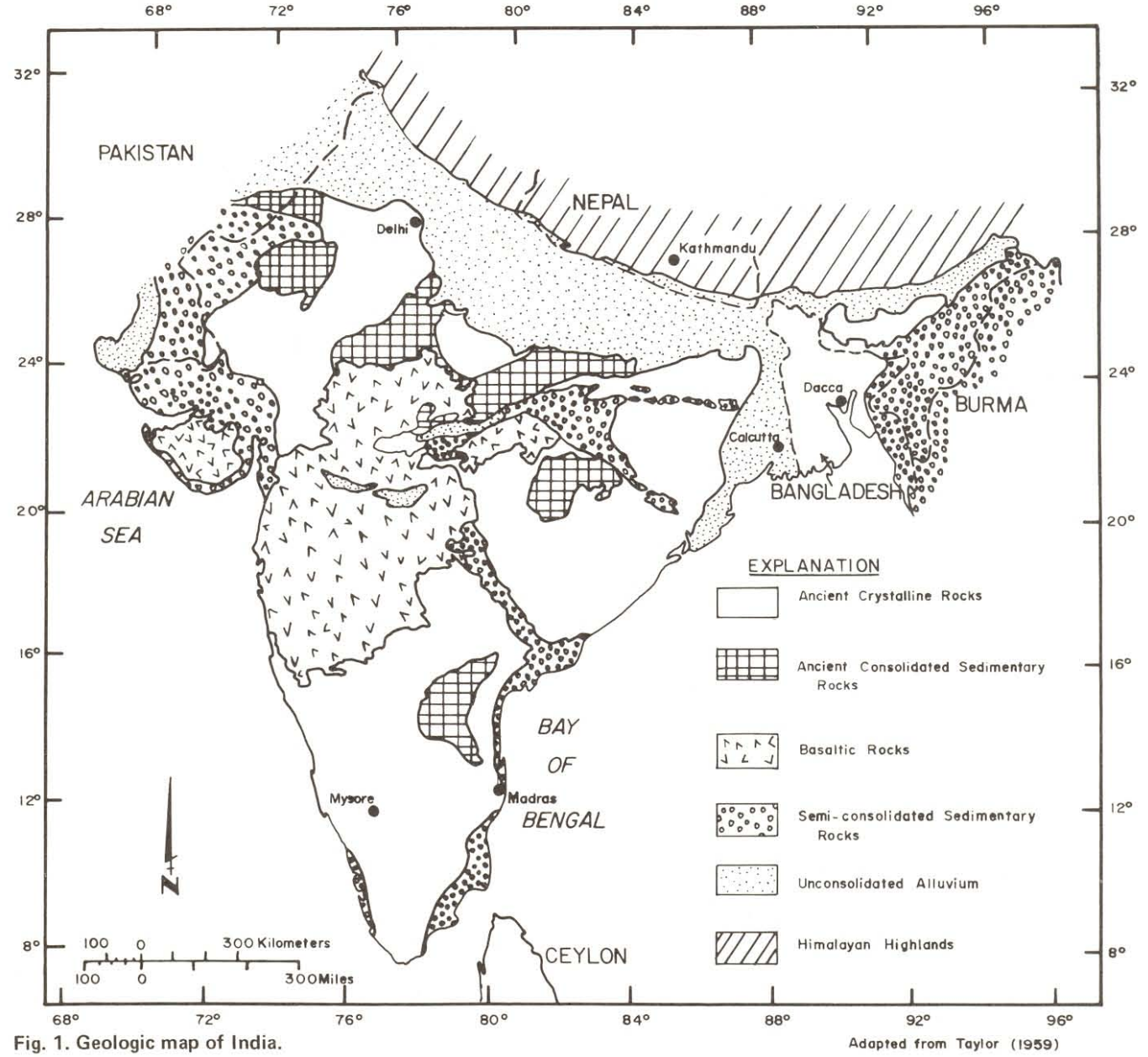

Fig. 1. Geologic map of India.

Adapted from Taylor (1959)

million hand-dug open wells in these consolidated rock areas. These wells are generally constructed using local technology and materials and are usually affordable by farmers owning medium-sized and small farms [1 to 10 acres (0.4 to 4 hectares)]. Tube wells or bored wells are generally too costly for such farmers.

The diameters of these open wells range from a few feet to more than 50 feet (15 meters). Well depths range from 20 feet (6 meters) to more than 100 feet (30 meters) and are often determined by the depth to water-bearing strata, seasonal fluctuations of water levels, depth to the transition from weathered rock to hard rock, and available indigenous equipment. Open well yields are quite variable and range from a few gpm (gallons per minute) to more than 50 gpm (190 liters per minute).

In recent decades demands for increased food production have been met in part by increasing the acreage under irrigation. This has resulted in a need for improving well yields in areas which are dependent on open wells for irrigation-water supply. In India, extension drilling or long-hole drilling techniques have been used since the mid-60's as a method for improving well yields in open wells in consolidated rock areas. The technique consists of drilling 1.5- to 2.0-inch (37.5-mm to 50-mm) diameter holes near or at the bottom of a well in vertical, horizontal or angled directions. Since existing centrifugal pumps or other local indigenous methods are used for pumping these open wells, this technique is most successful where, during pumping, water flows into a well from these small-diameter holes. The more appropriate areas in the ground-water flow system for applying this technique are ground-water discharge areas.

Equipment Requirements

Small-diameter horizontal, vertical, and angled holes can be drilled to depths of 50 feet (15 meters) using a drilling system comprised of a jack hammer, $\frac{7}{8}$-inch diameter (22-mm) drill rods, and 1.5- to 2-inch (37.5-mm to 50-mm) diameter tungsten carbide cross bits. The system is pneumatically powered. The drill rods are hollow and air is passed through these rods to flush cuttings from the hole. A water swivel arrangement can also be used where high-pressure water is passed through the drill rods to flush cuttings from the hole.

Figure 2 depicts a typical drilling operation in an open well. Two or three men usually work in the well while one man remains on top to lower equipment into the well and to look after the compressor. Basic equipment requirements for this type of operation are listed in Table 1.

Drilling Methodology

The first operation, before actual drilling, is to dewater the existing open well using a sump pump. If there is silt or sand on the bottom of the well, then a sludge pump can be utilized to remove these materials. Next, the drilling equipment is lowered into the well and set up to begin drilling. If a vertical hole is to be drilled, then a few feet of 2.5-inch (62-mm) diameter casing are installed.

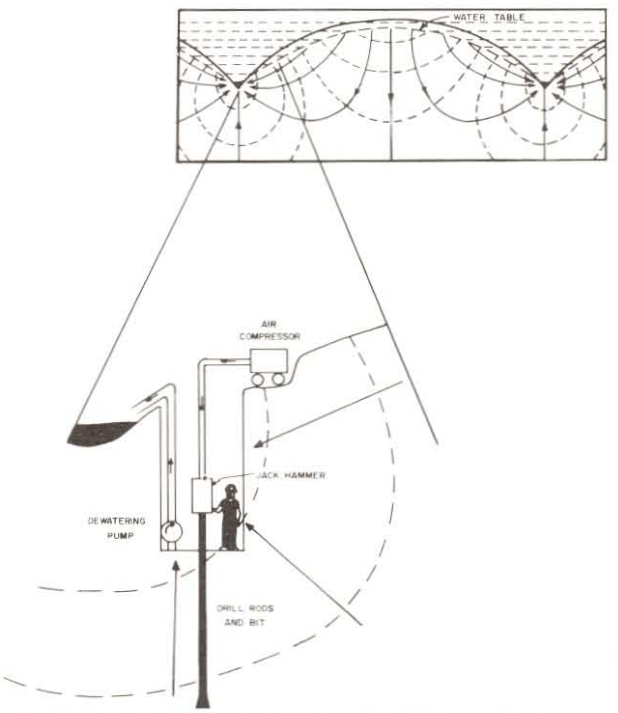

Fig. 2. Schematic diagram depicting flow pattern in a shallow ground-water flow system and a typical drilling operation in an open well.

Table 1. Basic Equipment Requirements for Extension Drilling Operation

Item No.	*Equipment Description*	*Technical Specifications*
1.	Air compressor	150 to 300 cfm (cubic feet per minute), 100 psi (pounds per square inch)
2.	Jack hammer	
3.	Drill rods	$\frac{7}{8}$-inch diameter, 2- to 4-foot lengths
4.	Tungsten carbide cross bits	1.5 to 2.0 inches in diameter
5.	Double acting reciprocating pump	100 psi, 5 to 10 gpm
6.	Sump pump	
7.	Sludge pump	
8.	Winch and ladder	
9.	Three different assemblies for holding the jack hammer and drill rods in vertical, horizontal, and angled positions	

After this, drilling is carried out using 1.5- to 2-inch (37.5- to 50-mm) diameter bit. A water flushing system is generally preferred as the drill bit has a tendency to jam if air is used to flush cuttings. All the components of this drilling system are pneumatically powered, and the only power source needed is an air compressor.

Hydrogeology

This technique has been used to improve well yields in a variety of geologic formations in India; namely crystalline rocks, basalt, and consolidated sedimentary rocks (Figure 1). Most open wells are constructed at relatively shallow depths [30 to 50 feet (9 to 15 meters)] in water-table or unconfined aquifers. Generally depths are determined by depths to fresh rock, and seasonal fluctuation of water levels.

In the consolidated rock areas shallow water-table aquifers are generally characterized by local ground-water flow systems, where a local system has its recharge area at a topographic high and discharge area at a topographic low which are adjacent to each other. Figure 2 depicts the flow and potential lines in an idealized local ground-water flow system.

The optimum location for drilling in open wells in shallow water-table aquifers is at topographic low areas or ground-water discharge areas where hydraulic potentials increase with depth. In such areas if water-bearing fractures are encountered during vertical drilling, the hydraulic potential often exists for water to flow into a well. Also fracturing is often more intensive in topographic low areas and there is more likelihood of encountering fractures during drilling in such areas.

Technology and Economics

In some developing countries, the equipment required for this type of drilling operation are either manufactured or are available locally and are fairly easy to maintain and repair. Drilling costs in India are approximately $1.00/foot and the average cost of drilling 2 to 3 holes in a well ranges from about $50 to $75 per well. These costs are generally within the capability of farmers owning medium to small size farms.