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LOW-COST TUBEWELLS FOR DEVELOPING COUNTRIES

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SUMMARY

The suitability and methods of construction of different types of low-cost tubewells are considered in this paper. Emphasis is given to shallow tubewells with bamboo strainers and cavity wells because of their suitability in less developed countries. The process of fabricating bamboo strainers is discussed, as are the two low-cost methods of drilling shallow tubewells, namely the hand-operated rotary method and the sludging method. The method of cavity development in cavity wells is also described. Finally, the comparative economics of shallow and cavity wells for accessing groundwater under typical conditions prevailing in India are given.

1. INTRODUCTION

Whereas heavy duty deep tubewells are used almost exclusively in most developed countries for tapping groundwater for irrigation, both shallow (light duty) and deep (heavy duty) tubewells are used in less developed countries for accessing groundwater. In India, deep tubewells are in the main constructed by government agencies, and a tax is levied on the water supplied to the farmers. The high initial investment of approximately Rs 200,000* per well makes it almost impossible for the average individual farmer or small-holder in India seriously to consider the construction of a deep well for his personal use. It is mainly for this reason that shallow tubewells are now gaining popularity among farmers in many less developed countries, India among them. The yield of a deep tubewell is about 50 l/s compared with 10 l/s for a shallow tubewell, but the initial investment for the latter is only about Rs 10,000 including the cost of the pumpset. Recent developments in its construction technology have made the modern low-cost shallow tubewell an even more attractive proposition.

* 1 US dollar = Rs 10.00 approximately

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2. SHALLOW TUBEWELLS AND CAVITY WELLS

2.1 *Strainer and cavity wells*

Shallow tubewells fall into two distinct categories: *strainer* wells and *cavity* wells. In the former different types of strainers, namely agricultural brass strainers, PVC strainers and bamboo strainers can be used. The particular type of shallow well to be chosen in a given situation is generally determined by the nature of the formation and its occurrence, characteristics of the covering layer, and of course economics. These wells work satisfactorily when the water-table is at a depth of 5 metres or less from the ground level. However, when the prevailing conditions do not permit this and providing that the depth of the water-table does not exceed 7·5 m, shallow wells can still be constructed by installing the pumping unit below the ground level to lower the suction depth to 6 m or less.

In a shallow tubewell the pipe/strainer diameter is generally small, ranging from 75 to 100 mm. The suction end of the horizontal centrifugal pump, which is installed on the ground surface, is connected to the top of the tubewell by means of a hose pipe using a tee-joint and check valve fittings. Because the suction head of the pump is equal to the depth of the water-table and head losses which occur during pumping, it is important in the case of shallow wells that the depth of the water-table does not exceed 6 m.

In a strainer well, blank mild steel or galvanized iron piping is placed in the aquiclude, and the aquifer is tapped by means of strainers. Wells of this type can be successfully constructed in locations where the aquifer is composed of medium-to-large sand, or sand mixed with gravel. A satisfactory level of discharge is obtained when the thickness of the aquifer is at least 10–12 m and, in order for the well to be economically viable, the aquifer should start from within a depth of about 40 m from the ground level.

Strainer wells can be constructed even when 12 metres or so of the depth of the aquifer is separated into 2 or 3 zones by intruding layers of clay. Also, when the thickness of the aquifer is large, shallow tubewells can be partially penetrated by tapping only the top 12–15 m of the aquifer depth.[1] In some places the depth of the aquiclude is found to be only 10–20 m, with an aquifer of large thickness occurring below that. In such places the cost of the strainer alone constitutes a major proportion of the total cost of installation, and it is in cases such as this that costs can be substantially reduced by substituting bamboo strainers for brass strainers.

The cavity well, which is also a shallow tubewell but without a strainer, is constructed either in a confined or semi-confined aquifer. Originally developed in India, the cavity well is now gaining popularity in that sub-continent.[2] When properly designed and constructed, these wells are more economical than strainer wells. It is mainly for this reason that they have great potential for extensive application in many less developed countries. In practice cavity wells are suitable for locations in which the aquifer is overlain by a layer of stiff clay at least 5 metres thick, so that the cohesive property of the clay prevents the possible collapse of the cavity once it has been formed. Strainer wells cannot be constructed when the aquifer consists of fine sand to a depth of only 3 metres or so; but cavity wells can be very successful in such formations.

2.2 *The bamboo strainer*

Plate 1 shows the skeleton of a bamboo strainer partially wrapped with coir rope, as well as one which is complete. Perhaps the most important aspect of the bamboo strainer is the low technology involved which permits its fabrication by village artisans at a low cost. It is to be noted, however, that an alternative strainer whose skeleton is made of mild steel rods instead of bamboo is also available in some village markets in India. Although these skeletons cost a little more than their bamboo counterparts, they need only to be wrapped with coir rope for making them into complete strainers.

A bamboo strainer can be fabricated by following these steps in this order:

(a) Make bamboo strips, 30–40 mm wide and 5 metres long, from whole bamboos.
(b) Fix the bamboo strips on circular mild steel rings 25 mm wide and 75–100 mm in diameter, spaced

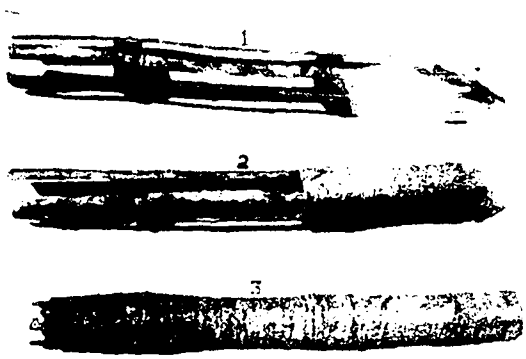

Plate 1. Fabrication of the bamboo strainer; (1) Bamboo skeleton; (2) Bamboo skeleton partially wrapped with coir rope, and (3) Complete strainer

500 mm lengthwise along the strips, to generate the shape of a hollow cylinder. This is done by drilling six equally spaced holes of 6·4 mm diameter on the periphery of each ring. Through these holes the bamboo strips are then secured by means of GI nuts and bolts.

(c) Fit to each open end of the hollow cylinder a mild steel short piece 300 mm long, its diameter being equal to that of the steel rings. The manner in which they are fitted is similar to that of the rings. The outside end of the short piece is threaded to facilitate its joining with another strainer or a pipe.

(d) Tightly wrap the cylinder (skeleton) thus formed with coconut coir rope of 3 mm diameter. The bamboo strainer is now complete.

3. METHODS OF CONSTRUCTION OF SHALLOW TUBEWELLS

In most formations two methods are generally employed for the construction of shallow tubewells, namely the 'rotary' method and the modified percussion method commonly known as the 'sludging' method. Depending upon the type of formation, depth of aquifer, availability of technical know-how and the time available for construction, either of these methods can be employed when bamboo strainers are used.

3.1 *The rotary method*

In the rotary method, shown schematically in Figure 1, the liquid traditionally used in India for drilling is water mixed with cowdung. The mixture of mud and cowdung makes the liquid sufficiently

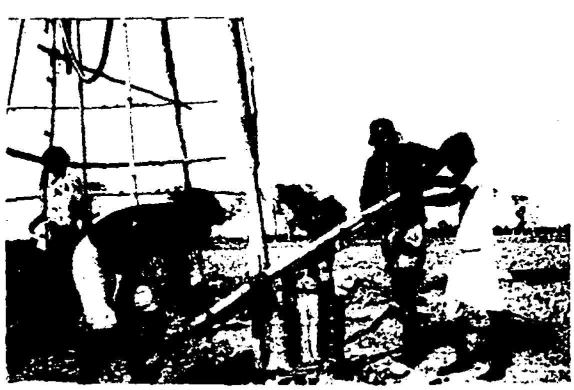

Plate 2. A view of the plunger pump

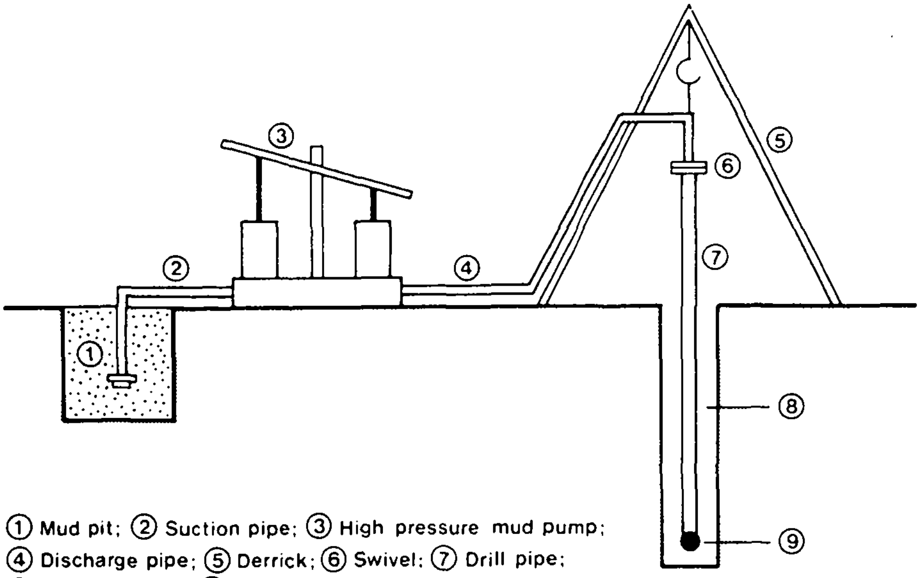

Figure 1. Schematic diagram showing hand-operated drilling rig for shallow tubewells

viscous so that the cut material can be easily lifted without any danger of the drilled hole caving in. A hand-operated double-acting plunger pump is used for circulating the slurry. This special plunger (Plate 2), which can be manually operated by 2–4 persons, is capable of dealing with a viscous liquid under high pressure. The pressurized liquid is forced in through the pipe, and it escapes along with the cut material through the annular space between the pipe and the drilled hole (Figure 1).

A hole of 50 mm diameter is initially drilled using a 50 mm diameter cutter fitted to a mild steel pipe 6 metres long and 37·5 mm in diameter. The pipe is supported by a chain pulley (Plate 3) suspended from a bamboo tripod, and this particular arrangement permits the lifting and lowering of the drill pipe to be performed by just one person. The cutter is operated by rotating the pipe by one or two persons with the help of a chain wrench. From the samples of the well log, collected during the initial stages of drilling, the location of the aquifer is determined for the placement of strainers and blank pipes at suitable depths in the drilled hole. All the pipes are retrieved one by one on completion of first drilling. Drilling is then resumed with the 100 mm diameter cutter (Plate 4) for enlarging the hole diameter to 100 mm, or to 200 mm if required. In fact, a hole of 200 mm diameter is necessary for a bamboo strainer which is normally constructed with internal and external diameters of 100 mm and 150 mm

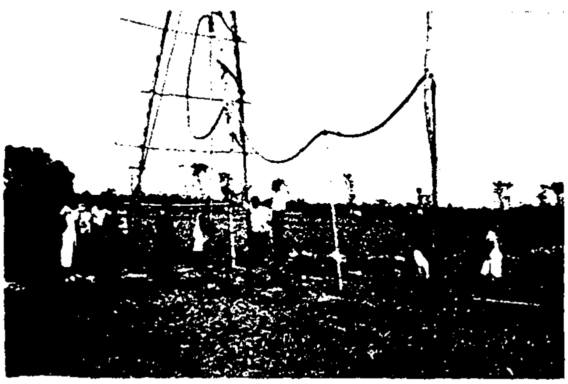

Plate 3. Drilling operation in progress for a shallow tubewell

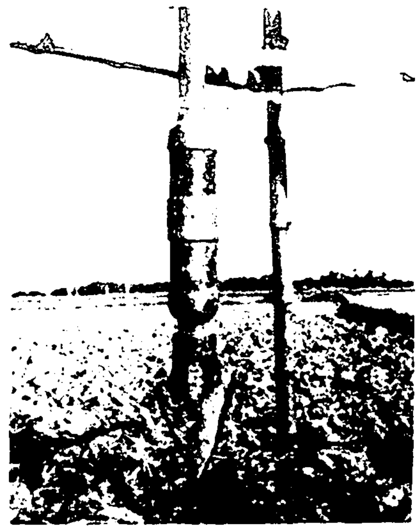

Plate 4. A view of the cutter for drilling 100 mm diameter hole

(170 mm at the steel rings), respectively. After drilling the hole of the required diameter, pipes and the cutter are retrieved. During the lowering process, which then commences, a mixture of mud and water is circulated to facilitate lowering and for preventing the possible collapse of the drilled hole. At first the part of the aquifer drilled into is provided with either a brass or a bamboo strainer, while the aquiclude is provided with a mild steel pipe. Once lowering is complete, the annular space between the strainer-pipe and the hole wall is filled with coarse and clean sand and, simultaneously, clean water is circulated through the tubewell with the plunger pump. Finally, the bottom of the tubewell is closed with a plug cutter of conical shape, which is placed by dropping it into the well from the top.

For the development of the tubewell thus constructed, it is first connected to a 37·5 mm hand pump through a tee-socket arrangement.[1] The hand pump is operated for 4–6 hours, by which time sufficient flow will have taken place to make its operation easier. A diesel pump, normally of a rating of 5 HP, is then used for further development. Initial discharge from the tubewell is low and contains a relatively large amount of sand. Gradually, however, the amount of sand in the effluent decreases as the discharge increases. In practice an intermittent procedure is adopted for achieving best results; in this the pump is temporarily stopped for a few minutes after operating for sometime, and then restarted. Although the sand content shows a temporary increase following a restart, it usually disappears after intermittent pumping in this way for about 24 hours.

3.2 *The sludging method*

In some regions of India a modified version of percussion drilling, known as the 'sludging' method, is employed extensively. An important advantage of this method is the very small capital investment which the hardware needed entails. Basically, the method consists of the lowering and lifting of a 37·5 mm diameter steel pipe, fitted with a socket at the bottom. Lowering and lifting can be done by one or two persons using a lever arrangement. Drilling operation is controlled by just one operator who, by placing his palm over the top end of the pipe, alternately opens and closes that end with his palm during the downward and upward motions of the pipe, respectively.

The mechanics of the process are similar to that of an impulse pump, with the palm acting as a valve. The cut material escapes along with the water during the downward motion of the pipe. Water, placed in a nearby pit, enters the annular space between the bore wall and the pipe. The initial diameter of the hole is subsequently enlarged by further drilling with larger diameter sockets, fitted to 37·5 mm diameter pipes. Well logs are kept, as in rotary drilling, for locating the aquifer. The lowering and development processes are similar to those of the rotary method described in Section 3.1.

4. CONSTRUCTION OF CAVITY WELLS

The manner in which the drilling of the bore hole of a cavity well is started is identical to that of a strainer tubewell and, depending upon the type of formation, either the rotary or the sludging method can be adopted. During second drilling for the enlargement of the bore diameter, a well pipe of diameter 75 or 100 mm is directly used.[3] Drilling is continued upto a depth where a layer of clay, 2–3 metres thick, is present above the aquifer. A wooden plank is then placed over the top of the pipe, and it is hammered with a heavy mallet to ensure that the pipe is secured tightly against the clay layer. Pipes of 37·5 mm diameter are inserted into the tubewell which is then connected to the aquifer by means of sludging. Quantities of sand from the aquifer usually escape through the pipe during further sludging, and this creates a small cavity within the aquifer. A hand pump is then connected to the 37·5 mm diameter pipe, and pumping is continued until clear water is obtained and the hand pump runs freely—a process which may take 8–12 hours to complete. The hand pump and the 37·5 mm diameter pipe are then lifted, a tee is fitted on to the top of the cavity well pipe, and the final development of the cavity well carried out with a 5 HP diesel pump.

At the commencement of pumping with the diesel pump, the discharge obtained is small and mixed with a relatively large quantity of sand. However, as pumping is continued, the amount of sand gradually decreases while the discharge increases in volume. The final development of the cavity well may take 2–5 days depending upon the type of formation. In total 6–12 m^3 of sand comes out during the development process, and this creates a cavity about one metre deep within the aquifer.

Table 1. A typical cost analysis of different types of shallow wells

Item	Quantity	Cost per unit (Rs)	Total cost (Rs)
Brass strainer well			
GI pipe (75 mm diameter)	36 m	60·00	2160·00
Brass strainer	14 m	75·00	1050·00
Sockets	13 Nos.	6·00	78·00
Plug cutter, sand packing and development	Lumpsum		200·0
Cost of hand drilling	50 m	15·00	750·00
			Total = 4238·00
Bamboo strainer well			
Mild steel pipe (75 mm diameter)	10 m	30·00	300·00
Bamboo pipe/strainer	40 m	15·00	600·00
Sockets	9 Nos.	6·00	54·00
Plug cutter, sand packing and development	Lumpsum		200·00
Cost of hand drilling	50 m	15·00	750·00
			Total = 1904·00
Cavity well			
GI pipe (75 mm diameter)	32 m	60·00	1920·00
Sockets	6 Nos.	6·00	36·00
Drilling and sludging costs	36 m	15·00	540·00
Development	Lumpsum		400·00
			Total = 2896·00

5. ECONOMICS OF SHALLOW TUBEWELLS

Table 1 shows a typical comparison of the costs of installing shallow tubewells with brass and bamboo strainers, and a cavity well. This analysis, based on the conditions to be found in rural India and the cost regime of 1982, clearly shows, as we might have anticipated, that a shallow tubewell with bamboo strainers offers the least-cost option; and that the cost of GI pipes dominates the total costs of both cavity and brass strainer wells. Another important advantage of the bamboo strainer tubewell is that the strainer can be fabricated locally by village artisans. This is an important consideration, especially in deep rural communities for whom communication with suppliers and technicians in distant towns, as well as transportation, is often difficult. However, these advantages of the bamboo strainer tubewell should be seen in the context of its average service life of 7 years, which compares with 12 years for one constructed with GI pipes and brass strainers.

Nevertheless, the balance of advantage would appear to lie with bamboo strainer tubewells, or cavity wells, for two reasons: first, the technology involved is appropriate to the rural communities of India—communities who have for centuries used bamboo as an important local construction material and still continue to do so. Secondly, because it is the cheapest to construct, the bamboo strainer tubewell is within the financial resources of many more farmers than the other types could be.

6. CONCLUDING REMARKS

A programme of work was undertaken to evaluate the technical feasibility and economic viability of bamboo strainers and cavity wells for accessing groundwater in rural India. The results of that study, reported in this paper, show that shallow tubewells with bamboo strainers, which can be fabricated by village artisans at low cost, offer a very satisfactory alternative to other types of tubewells requiring high initial investment which is beyond the financial resources of the average Indian farmer.

Formations consisting of fine sand are not suitable for strainer wells; low-cost technology has been developed for the construction and successful application of cavity wells in such formations. The cost of a cavity well works out at about 70 percent of that of a brass strainer well for the same depth of aquifer.

Because of the low but appropriate technology involved, both the bamboo strainer well and the cavity well would appear to have considerable potential for successful application in the rural communities of India and other less developed countries.

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