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EXPERIENCE WITH SHALLOW WELLS IN TANZANIA

Background

Well before international conferences such as "Habitat" in Canada (1976) and the "Water Conference" in Argentina (1977) set new policies and targets that strongly backed rural water supply programmes, in fact as far back as 1971, the Tanzanian government embarked on an ambitious programme to provide water for everyone by 1991.
Whereas the original target was to
- provide a source of clean and dependable water within reasonable distance of each village by 1981
- provide a piped water supply to the rural areas by 1991 so that all people would have "ease of access" (less than 400 metres) to a public water point, the sheer magnitude of this task in combination with financial limitations forced the government to reassess the programme and to focus attention on attaining the 1991 goal. Furthermore the emphasis shifted from piped supply to shallow wells with hand pumps (ref. 1,2).

Comparison of water supply systems

There were several supply possibilities to choose from, for instance surface water or groundwater supplies, pumped supplies or gravity supplies, etc.
With few exceptions surface water is bacteriologically unsafe, may contain high sediment loads seasonally, and as a matter of standard practice will require more or less complicated treatment, thus resulting in high investment and operating costs.
Next to springs, which are mainly found in hilly or mountainous areas and even then in limited numbers, shallow wells and boreholes constitute the most reliable groundwater sources.
The construction of boreholes, relatively narrow-diameter wells of greater depth (more than 30 to 50 metres), requires machine-powered equipment. Even for the simplest type of drilling equipment, the percussion rig, high initial expenditure and skilled personnel are required, while its operation remains entirely dependent on the availability of fuel and spare parts.
Shallow wells do not have these disadvantages, as their construction requires a minimum of skill and no mechanized equipment. Furthermore, manually operated pumps are generally sufficient for their exploitation.
In boreholes the water table is often so deep that manually operated pumps cannot be used. Unless pumps can be powered by wind energy (requiring a very stable and constant wind pattern and/or huge water storage capacities) or solar energy (as yet requiring high capital outlays, though a solar pump is at present under test at the Morogoro compound) a conventional pump, generally diesel-driven, will have to be used. Although such pumps can be very reliable, their continued use presupposes the availability of skilled pump operators, skilled maintenance technicians and adequate fuel and spare parts.
As a rule not all these requirements will be met, especially in rural areas of developing countries.
A comparison of development and recurrent

Table 1. Cost estimates of alternative water supply systems (in TShs)(ref.1)

	Development cost per person	Operating cost per person
Well without hand pump	65	3
Well with hand pump	100	3
Borehole; diesel pumped; 90 m	276	8
Borehole; diesel pumped; 70 m	254	8
Surface water supply; gravity; short transmission main	162	8
Surface water supply; gravity; long transmission main	320	8
Surface water supply; diesel pumped	365	12
Dam; diesel pumped	504	14

Note: 1 TSh = £ 0.06 = US$ 0.12

Table 2. Cost estimate for rural water supply programme 1979-1991

Type of supply	Percentage of population supplied	Population supplied (millions)	Unit cost per person (TShs)	Total development costs (millions of TShs)
Gravity supply	15%	3.0	900	2700
Surface water (pumped)	23%	4.6	700	3220
Boreholes	12%	2.4	700	1680
Shallow wells	50%	10.0	80	800
total	100%	20.0	-	8400

costs for the various water supply options (table 1) shows the attractiveness of shallow wells from an economic point of view.
Experience in Tanzania shows that the actual development costs for shallow wells and boreholes or surface water supplies are even farther apart, with shallow well schemes costing about one-tenth of the alternative options.
Using these updated cost figures and the division of supply expected to be found in Tanzania by the year 1991, table 2 shows the expenditures up to that year.
It is assumed that, due to the population growth and the need to rehabilitate or replace existing water supply systems, a total of 20 million people will have to be provided with water supply facilities within this period.
In order to realize this ambitious programme, annual development funds of approximately TShs 700 million should be available. With the total donor contributions at present amounting to approx. TShs 300 million annually (for the rural water supply sector) it is clear that it will be extremely difficult to attain the goals. It is also clear that shallow wells are by far the most attractive solution, economically, since half the rural population would be supplied with water for less than ten percent of the total costs. The most recent government policy has thus been to encourage the construction of shallow wells wherever feasible. Other water supply options should only be tried when the construction of shallow wells is unfeasible due to water quality, subsoil conditions, etc.

Shallow-well programmes under execution

At present several projects that aim at constructing shallow wells in larger numbers are under way.
Two such projects form part of the Netherlands-Tanzanian bilateral assistance programme: the Shinyanga Shallow Wells Project and the Morogoro Wells Construction Project. The first was executed from end-1974 to mid-1978 and the second was carried out consecutively, employing a large part of the first project's expatriate staff.
In the course of the Shinyanga project a wells construction organization was set up, capable of siting and constructing an average of 20 shallow wells per month, i.e. the production capacity that is required per Region in order to attain the 1991-goals.
Well construction methods were developed in Shinyanga, special equipment was designed, and the local staff was trained to the extent that the project could be continued as a fully Tanzanian operation from July 1978 onward.
The success of this project may be illustrated by the fact that, with a total production of some 750 wells up to July 1978, the Tanzanian staff succeeded in adding another 169 wells within one year, despite the severe constraints imposed by the hostilities between Tanzania and the former Ugandan regime.
In Morogoro a wells construction organization is now operating which again has an output of 20 to 25 wells per month, but with greater emphasis on the training of staff and the supply of equipment. Personnel from other Regions in Tanzania is trained, mainly at Morogoro, but also at Shinyanga, and the Morogoro workshop provides hand-drilling equipment, Kangaroo pumps and miscellaneous items to these Regions upon request.

Finding a suitable well site

The first step in the construction of a shallow well is to find a suitable site. Obviously a geohydrologic survey would give the best results, but the cost and the time available render anything but the quickest and simplest methods impracticable.
Geoelectrical surveys were carried out at the beginning of the Shinyanga project, but the results were of hardly any value and the surveys were discontinued in favour of large-scale test drilling with small-diameter drilling equipment.
Initially, light machine drills (approx. £ 6000 apiece) and trailer-mounted machine-drills (£ 25 000) were used, but the first were abandoned in favour of hand-drilling equipment. The trailer-mounted machine-drills are reserved for the cases where hand-drilling cannot be used.
A typical hand-drilling set consists of Edelmann and riverside bits of 7 and 10 cm diameter, a screw auger, bailer and extension rods and handles, and costs approx. TShs 41 500 (ex-Morogoro), including 15 metres of casing pipe and a test pump.
The final adoption of a well site is based on the results of a simple pumping test with a hand pump. Experience in Shinyanga shows that a test yield of 200 litres per hour is the minimum requirement for a large-diameter well

(1.25 m dia.), whereas for a drilled well of 0.15 m dia. the negligible storage capacity requires a minimum test yield of 500 l/h.

Well construction methods

The traditional way to make a shallow well is to dig it by hand, which is simple, requires very little investment and only unskilled labour.
Programmes that require a large number of wells to be finished within a fixed period impose their own restrictions, however.
When laterite layers are encountered, as is the case in the Shinyanga and Morogoro Regions, the time-consuming method of using hammer and chisel may be technically possible, but still requires so much construction time that it hampers the progress of the entire project. Jackhammers may then be used. Petrol-driven jackhammers produce exhaust gases that are hazardous for the well sinkers, pneumatic jackhammers require huge capital outlays and electrically-driven jackhammers require generators, with the ensuing fuel supply and maintenance problems. The latter type has been used in Shinyanga but eventually the project resorted to the hammer-and-chisel method or percussion drilling.
Especially when the aquifer recharge is large, digging a well to the required depth may be impossible because of the inflowing water. Then two different methods can be followed: either the pit has to be dewatered during construction, or digging is continued as far as possible, after which the well is completed, to be deepened in the dry season, if necessary.
The first option requires the use of pumps during construction.
Suction pumps are simplest, but can be used only for water tables down to 7 m; for deeper wells lift pumps are required. Especially with larger inflows, machine-driven pumps are required, preferably electrical pumps, whereby great attention should be given to avoiding all risk of electrocution of the well diggers.

The problems encountered with the supply of spare parts and of fuel have resulted in a re-assessment of the dug well concept.
In a number of cases dewatering of the pit during construction resulted in washing out the sandy aquifer material from between horizontal clay layers; these subsequently collapsed and sealed off the aquifers. Therefore a method which did not require dewatering of the well was reverted to: hand- or percussion drilling. The Morogoro project uses hand-drilling almost exclusively.

Dug wells

In Shinyanga most wells were hand-dug (fig. 1a; ref. 4), with a lining of unreinforced concrete rings. These rings (1.25m int.dia.; 1 m height) were of no-fines concrete at aquifer level and of plain concrete at other levels. The well rings were manufactured centrally, at a cost of approx. TShs 300 apiece, and trucked to the site. There the well was dug manually as deep as possible without lining. Then rings were lowered into the well, using a simple tripod and winch, and digging continued as a caissoning process.
In the initial stages of the project mechanical well digging with a hammer grab was tried out, but failed to give satisfactory results.
When the wells had been dug to the required depth and the concrete rings put into their final position, the space between the rings and the undisturbed soil was backfilled with coarse sand or gravel and a concrete or clay seal employed just above the aquifer level, in order to block seepage. On top of this seal the original soil material was backfilled up to the ground level, the well opening itself was covered with a concrete cover-cum-pump-stand and the area around it with a concrete apron, cast in situ.
For wells with deep-lying aquifers the diameter of the concrete rings above groundwater level was sometimes reduced to save on cement and transport (fig. 1b).

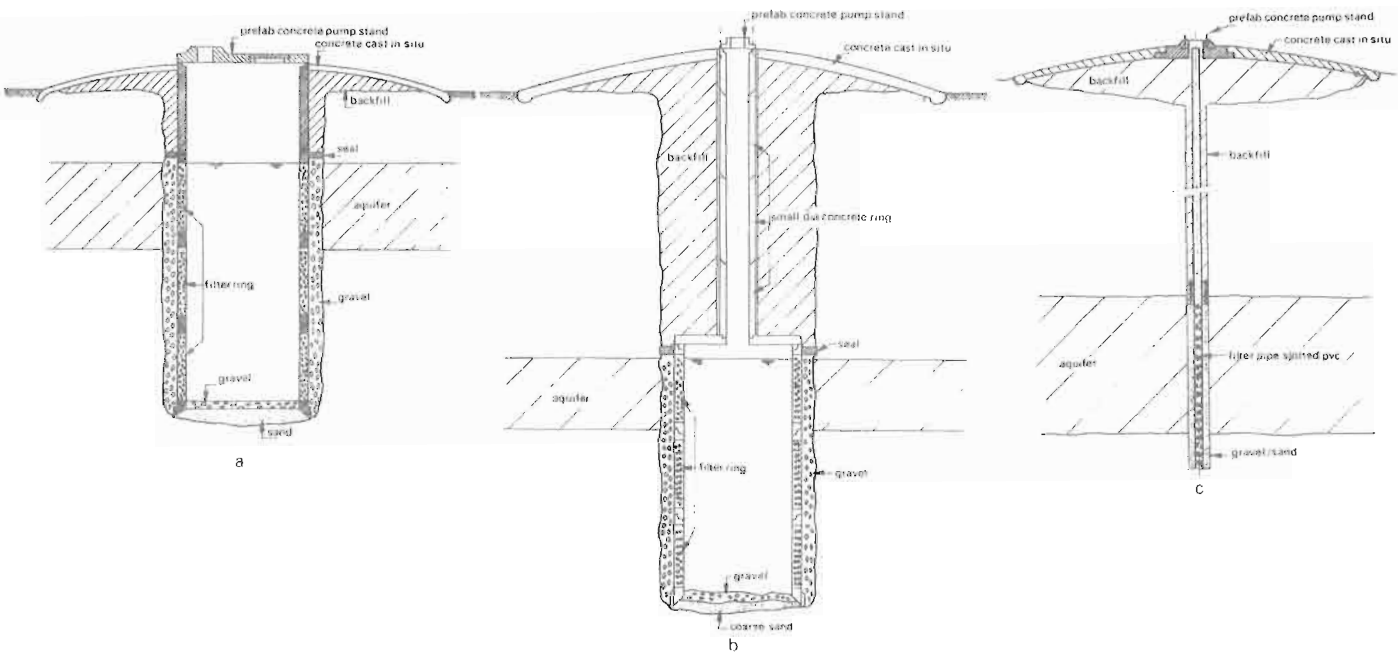

Fig. 1 Shallow well types

Hand-drilled wells

As already mentioned, dewatering the dug wells sometimes caused severe problems and by the end of the Shinyanga project hand-drilling had gained a solid foot-hold.
Because generators and pumps were no longer required, initial expenditure could be brought down and also overall costs per well turned out to be lower than for dug wells. The requirement of higher aquifer transmissivity (yield during test pumping: 500 l/h rather than 200 l/h as for dug wells) was met at the vast majority of the well sites. Thus for the Morogoro project the emphasis has been on hand-drilled wells (fig 1c) from the start.
Hand-drilling equipment consists essentially of a continuous-flight auger with various bits of 30 and 23 cm dia. (the latter to be used inside a casing), a cross piece with four handles for turning the drill, bailers, casing pipe, etc. (fig. 2).
It costs approx. TShs 105 000 per set (ex-Morogoro).
At the beginning of the drilling operation the cross piece with handles, a continuous-flight auger and a bit are connected and hung from a cable that runs through a pulley block in top of a tripod. A crew of 4 to 6 people, most of whom are employed on a semi-self-help basis, screw the drill down for approx. half a metre. The drilling assembly is then lifted, soil is removed from the auger, the assembly is lowered again, and this process continues, with or without a casing, until the required depth has been reached. Depending on the soil type a regular auger bit, conical auger bit, riverside bit or bailer is used. When the hole is at the required depth a slotted pvc pipe is lowered into it, a

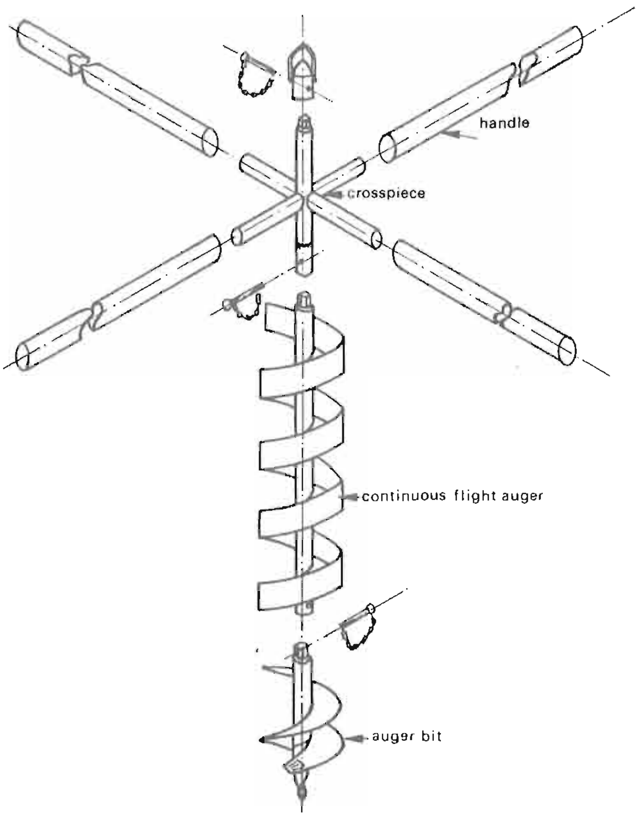

Fig. 2 Heavy hand-drill

gravel pack is put around the pipe, and the well is finished in essentially the same way as a dug well. The slotted pvc pipe is imported or manufactured locally from plain pvc pipe (cost ex-Morogoro: TShs 450 per length of 3 m).

Hand pumps

Traditionally, bucket and rope are often used for drawing water in larger-diameter wells. Not only is contamination of the ground water almost certain in these cases, but for smaller-diameter (drilled) wells the use of buckets is impossible.
From the beginning of the Shinyanga Shallow Wells Project it has been intended to use hand pumps on the shallow wells.
For a long time the "Shinyanga" pump was the only type used in this project.
It is a modified version of the "Uganda" or "Unicef" pump used in East Africa and consisted as far as possible of standard pipe fittings, so that construction and maintenance could be easily carried out locally.
The cylinder assembly is completely different from the orignal versions, however, having a pvc or ABS cylinder, a commercially available manchet-type piston and brass piston and foot valves. In the course of time the assembly has undergone repeated modifications, aimed at improving the reliability and -especially - reducing the maintenance requirements of the pump. The same train of thought has led to the replacement of the Shinyanga pump by the Kangaroo pump, at least for the Morogoro project.
A number of considerations, one of these being that centralized maintenance of pumps and wells in an area as sparsely populated as rural Tanzania is extremely costly, have led to a shift in policy. The most important criterion is no longer that pumps should be built up from locally available materials, but that they should require as little maintenance for as long a period as possible. By constructing a pump head that acts in the same way as a pogo stick, the vertical movement of the pump piston is transferred directly to the pump head, without any levers or hinges that require lubrication (fig. 3). Elimination of the wooden parts of the superstructure, which might be stolen for firewood, adds to the life expectancy of the pump.
At present the costs of the Shinyanga and Kangaroo pump heads are TShs 1500 and TShs 2200 respectively; the cost of a 3" cylinder assembly is TShs 1250.

Maintenance

As mentioned before, in rural Tanzania centralized maintenance of shallow wells would be extremely expensive, possibly costing more than the entire water supply budget. With many piped supplies already out of order due to unavailability of spare parts or fuel, and lack of funds, reduction of the maintenance costs has become of utmost importance, even when implying increased investment costs. In the Shinyanga and Morogoro projects the problem has been approached in two ways: by decreasing the maintenance requirements (e.g. by using Kangaroo pumps) and by decreasing maintenance costs by decentralization of the organization and shifting the first maintenance responsibility to the villages. In this way maintenance costs per head could be reduced to TShs 2 per annum.

Costs

Table 3. Cost of shallow wells

Depreciation of equipment, buildings, vehicles	TShs 5 000
Surveying	TShs 1 500
Materials, tools	TShs 2 000
Hand pump	TShs 4 000
Salaries, labour	TShs 2 000
Transport	TShs 4 000
Overhead	TShs 1 500
Total (hand-drilled well)	TShs 20 000
Total (hand-dug well)	TShs 25 000
Total (machine-drilled well)	TShs 30 000

Thus overall costs per well range from TShs 80 per head (hand-drilled) to TShs 1200 per head (machine-drilled), with hand-dug wells between the two.

Training

With a total of 20 million people to be supplied with water before 1991, at least half of whom may obtain water from shallow wells, the total number of shallow wells to be constructed is between 40 000 and 60 000, or: approximately 250 wells per year for each of Tanzania's 20 Regions. In order to realise this objective, personnel from other Regions is trained at Morogoro. The equipment required, and with which the personnel has been trained to work, can also be obtained at the Morogoro workshop.
Generally speaking the training takes about 2 to 3 months. An average of one well siting/construction crew of 3 people per District (average of 4 Districts per Region) is sufficient to realise the annual target of some 250 wells per Region.

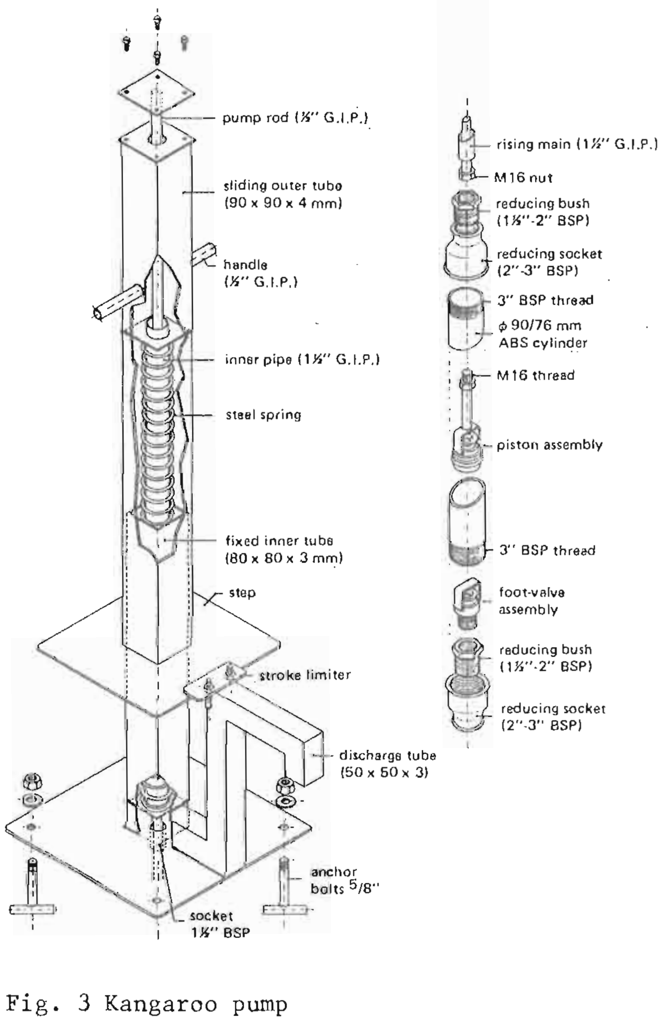

Fig. 3 Kangaroo pump

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