Shallow Wells

Second Edition

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Shallow Wells

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DHV

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This publication has been prepared by DHV Consulting Engineers as the second part of the final report on the Shinyanga Shallow Wells Project. This bilateral technical aid project of the Governments of the United Republic of Tanzania and the Kingdom of the Netherlands was executed by DHV Consulting Engineers, in cooperation with ILACO International Land Development Consultants and ONV Organisation of Netherlands Volunteers.

Preface

This publication is based on the experience gained with the construction of some 750 shallow wells in the Shinyanga Region of Tanzania, East Africa.

These wells were constructed during the execution of the Shinyanga Shallow Wells Project which was carried out as a bilateral project of the Governments of the United Republic of Tanzania and the Kingdom of the Netherlands, in the period October 1974 to June 1978.

The quantity of literature on the subject of constructing shallow to medium-depth wells is rather restricted. Therefore compiling the experience gained in Shinyanga may be a useful means of providing information on this subject to the relevant authorities in other Regions of Tanzania, and in general to anyone planning to construct shallow or medium-depth wells in developing countries.

The methods described in this publication may not be applicable in every case for two reasons: firstly they are based on the conditions prevailing in a sparsely populated area in East Africa, near Lake Victoria, and secondly the set-up has been based on a production capacity of approximately 20 shallow wells per month, which poses special problems that may not be encountered in smaller scale projects. Nevertheless, it is felt that the information given may be helpful in that it shows in which direction the solution for specific problems may be sought.

December, 1978.

In the second edition the experience gained during the first phase of the Morogoro Wells Construction Project has been incorporated. This project, which started in July 1978, is the second wells construction project to be carried out within the framework of the Netherlands-Tanzanian technical cooperation.
Especially the chapters on the Kangaroo pump and costs incorporate major revisions.
Costs quoted refer to prices ex-factory Morogoro/Shinyanga, at the price level of July 1979.

December, 1979.

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Part 1

Introduction

Chapter 1. **Why shallow wells**

Throughout the world the conviction is growing that the availability of sufficient quantities of clean, potable, water should be considered one of the basic human rights. As a consequence many governments and international organizations are executing programmes for implementation and expansion of water supply systems. These are often aimed primarily at supplying the urban population with water, since a lack of water and the resulting unhygienic and insanitary conditions will be felt most strongly in these concentrated settlements, where 'natural' water sources may be less easily available and, moreover, may be polluted as the result of the concentration of human activities.

Nevertheless increased attention is being paid to the water supply in rural areas where - especially in developing countries - the vast majority of the entire population live. Here the prevailing conditions often dictate other solutions for the water supply problem than in urban areas, however, as:

- the income and paying capacity of the population will generally be lower
- the population will often be more dispersed
- highly skilled personnel will hardly be available and, moreover, may show a preference for moving to urban areas with better job opportunities
- the availability of spare parts for pumps, engines, and other machinery may pose problems, which will be aggravated in areas with a less developed infrastructure.

Several possibilities can be distinguished:

- surface water supplies vs. groundwater supplies
- piped supplies vs. individual supplies
- pumped supplies vs. gravity supplies

With only a few exceptions surface water (in rivers, lakes, pools) is bacteriologically unsafe, contains high sediment loads, and as a matter of standard practice will require more or less complicated treatment. The ensuing investment costs, energy costs, chemical costs, and the need for trained, skilled operators result in a general preference for groundwater over surface water.

Groundwater may be obtained from springs, wells or boreholes. Springs can offer excellent water supply opportunities, but are generally found in hilly or mountainous areas only, and may require long pipelines in order to bring the water to the people. For larger and concentrated settlements this may be a feasible solution, but for a more dispersed population the investment costs may still be prohibitive, the more so when pumping is necessary to transport the water.

For less concentrated settlements other means of abstracting groundwater will thus have to be found, e.g. boreholes and wells.

Deep groundwater often has an excellent quality but may still pose problems:
- for the construction of boreholes special equipment is necessary, with skilled operators, especially for deeper boreholes
- only aquifers with a high transmissivity are suitable
- the groundwater table may be so low that using hand pumps is virtually impossible and engine-driven pumps have to be chosen. Not only are the running costs vastly increased in that case, but the provision of spare parts may now become a critical factor as these are - as a rule - not manufactured locally.

Most of these difficulties are overcome when shallow to medium-depth wells are used:
- simple tools and unskilled labour are sufficient
- also aquifers with lower transmissivity can be used, since dug wells possess a certain storage capacity
- the use of hand pumps is now possible in any case, so running costs are vastly reduced

Furthermore investment costs are lowest for shallow wells as compared to other possibilities. For Tanzania the investment costs for various rural water supply possibilities are as follows:

Investment costs per capita in Tanzanian shillings (1979)*

	with handpump	with motordriven pump and simple distribution system
shallow well	60	550
borehole (25 m deep)	140	700
small reservoir	400	850

* TShs 8.00 = 1 US$ (1979)

In view of the above it will not be surprising that more and more shallow wells are being chosen as one of the best ways of tackling the enormous task of supplying the world's rural population with water. On the other hand shallow wells should not be considered the panacea for this problem. In certain cases shallow wells will simply not be possible, for reasons of soil conditions, danger of pollution, etc., whereas for larger concentrated settlements piped water supply systems may be required, for which other possibilities may be more attractive.

Chapter 2. **Where to locate shallow wells**

The decision to locate a shallow well at a certain site will generally be based on two kinds of considerations. The first, which may be called 'technical' is

3. Supplied through hand pumps . . . .

4. . . . . public taps . . . .

5. . . . . or in other ways

rather obvious: the site should be suitable for making a shallow well, i.e. it should be accessible, the soil type should permit the construction of a well and, most important of all, there should be good-quality water in sufficient quantity.
The second kind of considerations is less clearly defined. Socio-economics and politics may play an important role here. Much depends on the authority or person who provides the funds for construction.

When the (local) government is in charge of well construction, priority lists of villages where wells are to be located may be available. If not, such lists can be drawn up, taking into account (per village or settlement)

- existing ('natural') water supply sources
- quality of this water
- absolute or relative lack of water
- development potential of the village
- earning capacity and per capita income of the villagers
- size of the village/settlement
- industrial or trade activities

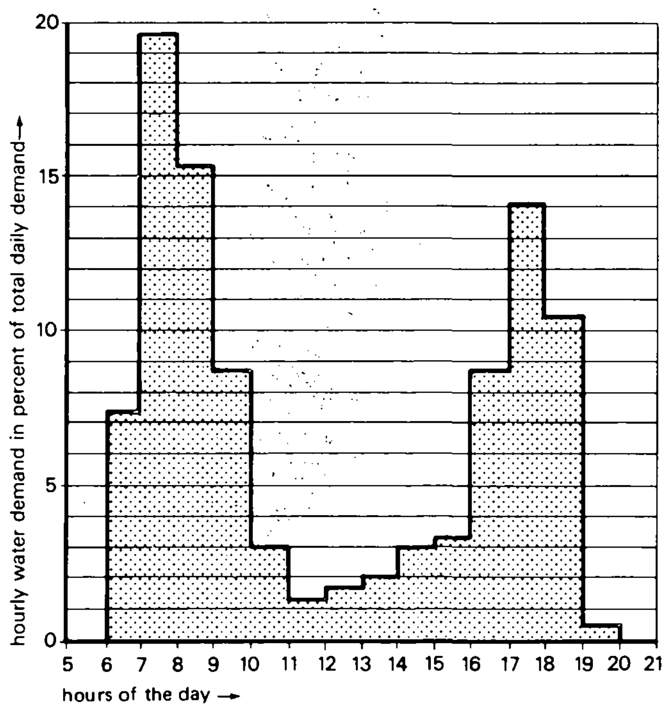


Fig. 1. Fluctuation of water demand over the day (rural communities, East-Africa)

Political considerations, such as stemming the flood of rural population to the larger cities, or concentrated development of certain rural areas, may also be important in deciding where shallow wells should be located.

6. . . . . take their recourse to water from pools and the like

Chapter 3. **How many wells**

The number of shallow wells which are needed for a certain village depend on the following factors:

a. The number of villagers, at present, and in the future
b. The distance between the houses and the well. In Shinyanga at present the aim is to restrict the maximum distance to 1-2 kilometres.
c. The maximum number of people that can be supplied through one well.

Experience in many parts of the world shows that when water is supplied through hand pumps - whether on shallow wells, boreholes or small reservoirs - through public taps or in other ways where the water has to be carried home, the consumption per head will not exceed approximately 25 litres/day. During the execution of the Shinyanga Shallow Wells Project the capacity of shallow wells has regularly been investigated. The results show that the capacity of the pumps is the critical factor. For hand pumps with piston diameters of 7.5-10 centimetres (3-4 inches) capacities of 1200 to 2000 l/h were found, based on one full stroke per second and an effective pumping time of 75%.
If it is assumed that the pump is used continuously over 10 hours per day, the total volume of water pumped would be 12 to 20 cubic metres, which is equivalent to the daily water demand of some 500 to 800 people. In practice, however, the collection of water is more or less concentrated in 2 peak demand periods: one in the early morning and one in the afternoon (fig. 1), which reduces the effective well capacity, limiting the number of consumers to approximately 250 per well according to experience.

The number of wells required is found by dividing the (actual or future) number of villagers by 250. Then, after the hydro-geological survey has been carried out and well sites have been selected (see Part 3) the distances between the houses and the wells are checked. In dispersed settlements the criterion of one well per 250 inhabitants may lead to maximum walking distances in excess of 1-2 kilometres. In such cases additional wells may have to be constructed, just to reduce the maximum walking distance. As a consequence the number of people per well is reduced, but investment costs per capita are increased.

In Shinyanga Region in a number of cases so-called 'rainy-season wells' were constructed. For some villages it appeared to be impossible to find shallow wells with a perennial supply of water within the adopted maximum walking distance of 1-2 km. In such cases wells were constructed as close to the village as possible, and additional wells (the rainy-season wells) were built at strategic points within the 1-2 km radius. These wells gave good-quality water during the larger part of the year, but fell dry in the second half of the dry season. In this way an attempt was made at accustoming the population to using good-quality water only: in the wet season through the nearer, non-perennial wells and in the dry season through the rather far-away perennial wells. It was felt that otherwise in the wet season people would object to the obligatory walk to the perennial wells and would resort to the more readily available, but polluted, water from pools and the like. In the dry season the latter do not exist any more, and the perennial wells then constitute the only source of water available.

Part 2

Setting up a wells construction project

Chapter 4. **General**

When the occasional well has to be constructed a special set-up will hardly be necessary and the manpower and materials which happen to be available will be the decisive factor in organizing the work.
However, if one aims at a regular wells construction programme, thorough thinking will have to be done about the organization and set-up.

One decision has to be taken first - which is of utmost importance - viz. whether to set up a fully separate body or to incorporate a wells construction organization in an existing body such as a public works or water supply department. It is obvious that a small-scale wells construction project will benefit most from cooperation with or integration in an existing organization.
The larger the project is, however, the more advantageous a separate organization may become. The organizational set-up as employed in Shinyanga, which - though housed on the same compound as the Regional Water Engineer's office - was completely separate, will be used as an example.

Chapter 5. **Organization**

A possible organization outline of a wells construction project is shown in fig. 2. The organization is assumed to be fully self-supporting.
Basic elements are the hydro-geological section, which selects the well sites, the construction section, which actually constructs the wells and the administration and project management. Vehicles and drivers as well as vehicle maintenance and the maintenance of mechanical equipment are classed under the transport and mechanical section.
The production section supplies special items which are centrally made, such as hand pumps (when these cannot be purchased locally), concrete rings and covers or burnt or cement bricks for lining the wells (if necessary and if centralized production is preferred), filter pipes (slotting of plain p.v.c.-pipes), etc.
It will be clear that the production section and the transport and mechanical section may be omitted in the case of integration in an existing organization.
In the next chapters each section of the project organization will be described, however, as if it were a fully independent set-up.

Chapter 6. **Personnel**

The number of staff to be employed on a wells construction project will, as a matter of course, depend on the size of the project. The following table is based on the Shinyanga Shallow Wells Project with an output of 20 wells per month.

Project management		:	1 person(s).
Hydro-geological section		:	8 ,,
Wells construction section		:	37 ,, (incl. 20 self-help labourers)
Production section:	- concrete factory	:	17 ,,
	- pump factory	:	7 ,,
	- filter construction	:	2 ,,
	- general workshop	:	5 ,,
Transport and mechanical section	- transport staff	:	3 ,,
	- drivers	:	30 ,,
	- vehicle workshop	:	6 ,,
	- maintenance	:	13 ,,
Administration:	- administration	:	3 ,,
	- stores	:	10 ,,
	- miscellaneous	:	3 ,,
Total		:	145 persons

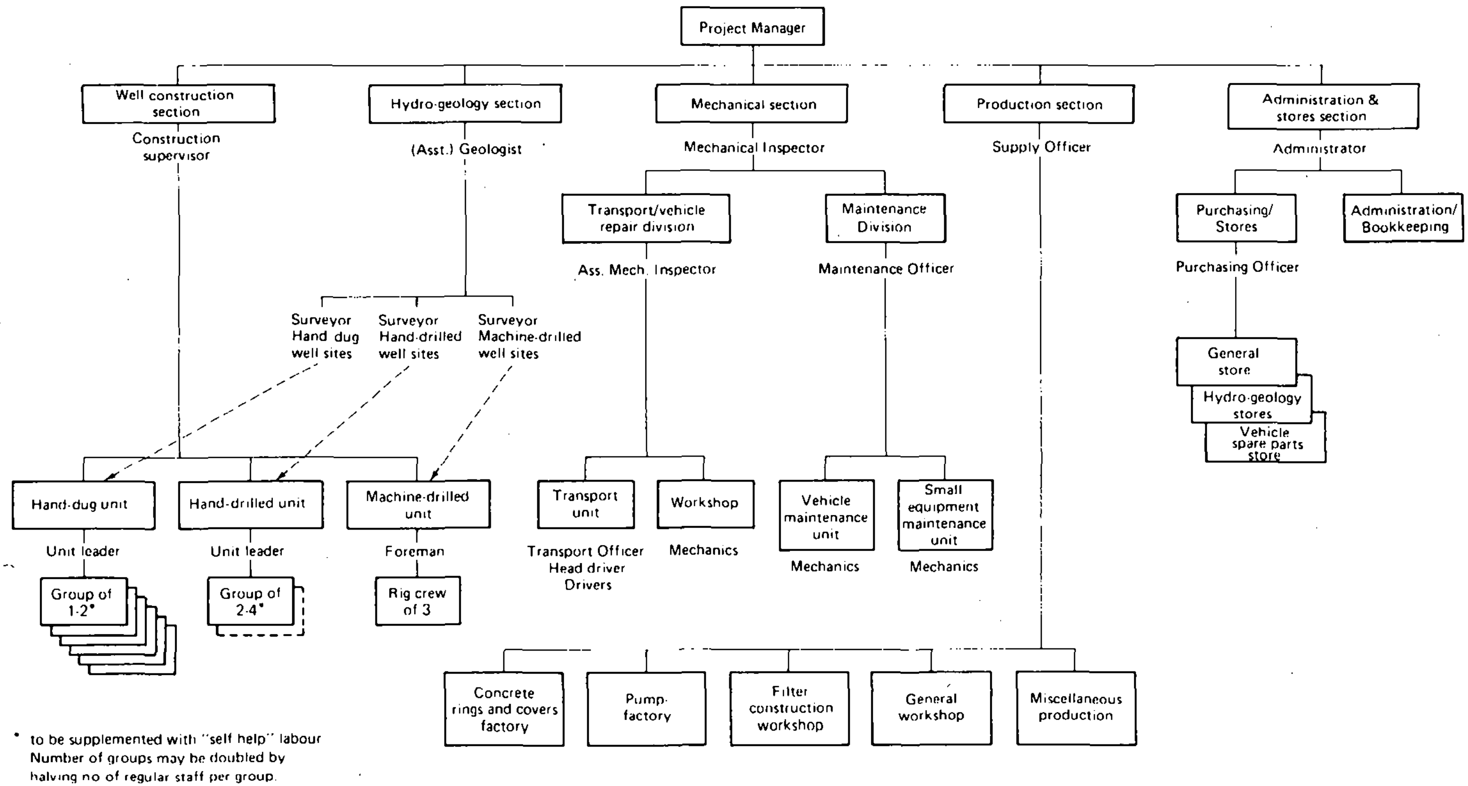


Fig. 2. Organization schedule of a wells construction project

Chapter 7. **Space requirements**

The space required for a project with a production capacity of 20 wells per month is illustrated in fig. 3, which shows the compound of the Shinyanga Shallow Wells Project.

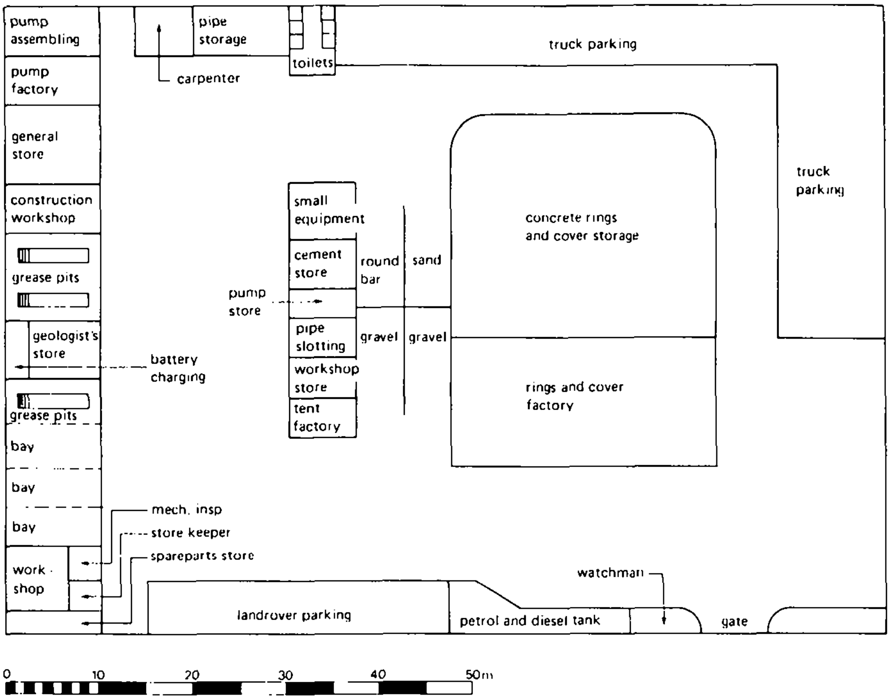


Fig. 3. Layout of Shinyanga Shallow Wells Project compound

The overall size of the compound is 95 × 65 metres, subdivided as follows:

- concrete rings and covers factory and storage	1330 m^2
- mechanical workshop	39 m^2
- vehicle spare parts store	25 m^2
- garage	298 m^2
- geologist's store	48 m^2
- general store	80 m^2
- pump factory	150 m^2
- pipe warehouse	70 m^2
- small equipment workshop	42 m^2
- cement store	35 m^2
- construction workshop	50 m^2
- secondhand materials, scrap	21 m^2
- parking area	900 m^2
- toilets and showers	35 m^2
- roads, etc.	3050 m^2

Note: the offices, with a total surface area of 150 m^2, are not included. They were available in the Regional Water Engineer's offices and included:

- project manager's office
- administration office
- geo-hydrology office
- construction office

7. Site should be accessible . . . .

8. . . . . and not within 100 m from cattle pools

Part 3

Selection of well sites

Chapter 8. **Preparatory investigations**

Before embarking upon a regular wells construction programme, it is advisable to collect and study data which could give information on groundwater availability. It is important to get some insight into:

- the general geology of the area
- recharge areas
- the occurrence of shallow aquifers
- the yielding capacity of these aquifers
- the hardness of the soil layers
- the chemical and bacteriological quality of the groundwater
- rainfall and evaporation data

Information may furthermore be obtained from

- geological and topographical maps
- aerial photographs
- drilling logs
- existing water supply installations

Generally the available data will not be sufficiently detailed to enable the selection of well sites on that information alone, and an additional field survey will be necessary.
When choosing the location for a future shallow well, various factors have to be considered:

- several general requirements have to be fulfilled for a proper functioning of the well
- sufficient good-quality water should be available
- the type of subsoil should enable the technical realization of a well.

In the following paragraphs the general requirements are be first dealt with. Simple guidelines based on geological and topographical conditions then indicate the area on which to centre field investigations. Then a description follows of the field surveys, the survey equipment to be used, and the planning of the field survey.

Chapter 9. **General requirements**

A suitable shallow well site has to meet the following requirements:

a. It should be within walking distance (1-2 km) from the relevant village
b. It should be accessible by truck during the construction phase, and accessible for the villagers throughout the year

c. It should not be within 100 m of cattle pools, latrines and other health hazards, and preferably be upstream of these.
d. It should be safeguarded against flooding. Especially near rivers the location has to be chosen so that the well is not threatened by any meandering action of the river. Furthermore the danger of flooding of low-lying areas should be taken into account.
e. The subsoil should not render the construction of a well impossible. It is not feasible to make shallow wells in rocky materials, even if these contain sufficient quantities of water in crevices, interstices etc.

If one or more of these conditions are not fulfilled, the site should be rejected, even if sufficient water is available. Exceptions may be made in some cases, when alternative solutions cannot be found. If no suitable well site can be found within the adopted maximum walking distance either the larger distance has to be accepted or the village has to be moved closer to the available water sources. Likewise non-accessibility by truck may be remedied by building a road or by accepting that the construction equipment is transported by human labour over part of the way.
Furthermore, latrines, cattle pools and the like can be removed, filled up, etc.

Chapter 10. **Geological guidelines for the selection of shallow well sites**

A. *Soil conditions*

Groundwater is present as water filling the pores between the grains of a waterbearing layer or aquifer. The larger the pores of an aquifer, the easier the water can flow through it. In this respect emphasis should be put on the difference between pore volume and pore size; generally the pore volume of clay exceeds that of sand, but most of its pores are so small that water cannot leave the clay or only leaves it very slowly.

Hence: ***layers of sand and gravel are the best aquifers***

In limestone areas rock solution may have taken place (karst phenomena), creating holes which may have sizes as big as large caverns and into which entire rivers may disappear, only to surface again as wells kilometres further on. At first sight karst phenomena seem very wayward: in order to make reliable predictions about the availability of exploitable groundwater a clear insight in the geological structure of the area is a necessity. An important factor to take into account is that - contrary to sand - karstified limestone does not possess any filter properties at all, so:

In karstified limestone the danger of pollution of ground water from the surface is relatively great

An important group is the crystalline rocks. These are composed of the crystals of various minerals. Well-known examples are granite and basalt. In their non-weathered condition these rocks hardly contain any pores at all. Yet both can eventually contain exploitable amounts of groundwater.
Weathering reduces granite to sand which is often very coarse, and contains the original rock crystals. In flat areas the weathering layers - the thickness of which may amount to dozens of metres - often have not been moved and still occupy their original position on top of the bedrock, while they have sometimes been covered with a thin top layer. Thus:

In granite areas the weathered rock may contain good aquifers

Basalt is very fine-grained and weathering reduces it to a material which is too fine-grained for groundwater exploitation. Basalt is formed through the solidification of fluid lava, on land or under water. Under certain conditions contraction phenomena occur, resulting in fractures - often in polygonal patterns - which cause the well-known vertical basalt pillars. The volume of these fissures may amount to several percent of the total rock volume, and providing that conditions are also favourable in other respects, groundwater exploitation from basalt may be feasible.
In cases like this where a 'watertight' soil type becomes an aquifer because of fissures, fractures, cracks and cleaves, the expression 'secondary permeability' is used, as compared to primary permeability for porous layers such as sand and sandstone. The size of a well should be many times the average distance between the waterbearing openings in a layer, thus:

Wells in basalt are much more expensive (because they have to be larger) than in sand, gravel or sandstone

B. *Topography*

Climate and topography determine whether a potential aquifer is indeed waterbearing.
In mountainous areas the exploitation of groundwater on tops and steep slopes will generally not be possible because erosion removes the weathering products which might form potential aquifers. In these areas surface reservoirs might be used for water collection. At the transition from a permeable to an impermeable layer springs may be found.
Valleys in the mountains are partly filled with erosion products. At the transition from mountain slope to valley bottom the mountain streams first deposit coarser materials, the finer being deposited farther away from the mountain slope (see figure 4), hence:

In mountainous areas the best aquifers are found along the edges of the valleys

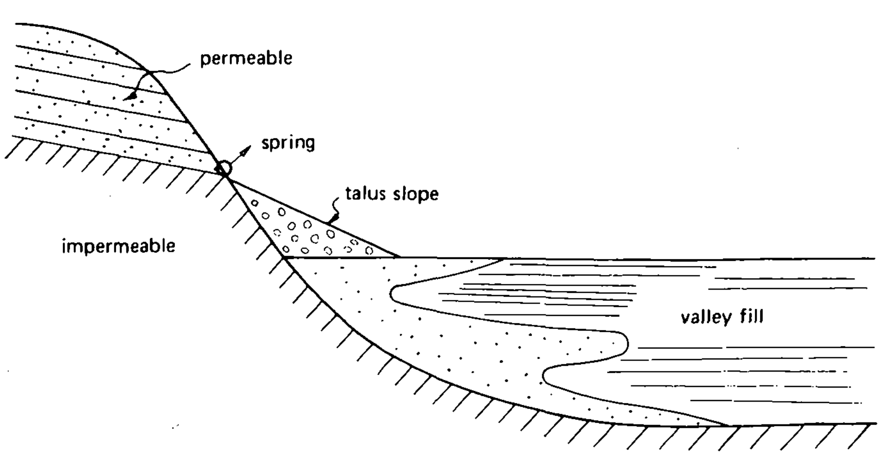


Fig. 4. Schematic geological section

Further downstream most river valleys increase in width and many rivers eventually pass a flat coastal plain before debouching into the sea.
In the mountains the use of surface water should be considered, as the mountain streams can often be dammed relatively easily, the water is clean and groundwater may be difficult to find.
In the middle and lower course of the river the use of river water is less obvious. Its quality is often doubtful or even bad, certainly at low flows, and the distance between the river and the consumer may be prohibitive.

The composition of the subsoil in a wide river valley is almost invariably very complicated because during its existence the river has constantly changed its course while filling up the valley (fig. 5).

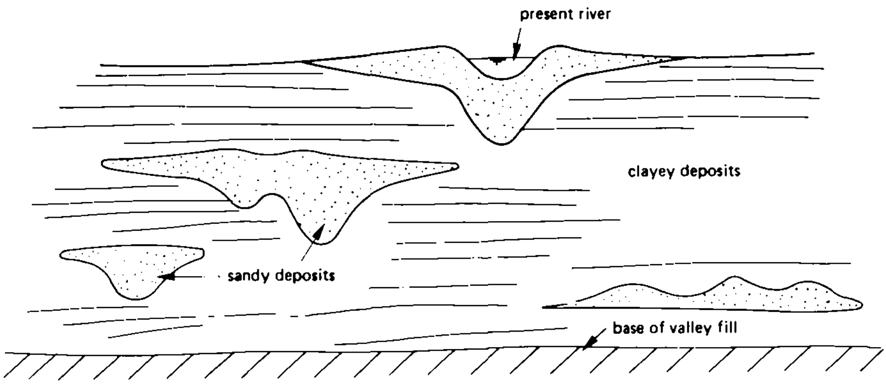


Fig. 5. Schematic geological cross-section over river valley

The proportion of sandy and clayey deposits depends on the river gradient. This means that generally the percentage of clayey deposits is increasing in a downstream direction. The schematic cross section shown in fig. 5 should be found near the mouth of the river.
When a river floods its surroundings the coarser materials are deposited first, the finer sediments farther away. Thus the best aquifers are found under the river bed and in the riverbanks. At high water levels these are fed by the river. The latter acts as a drain, however, at low water levels.
In some areas the river bed may even fall dry during part of the year. Exploitable quantities of water may then still be found under the river bed.

In wide river valleys the sandy deposits under the river bed and in the banks of existing and 'buried' rivers offer good opportunities for groundwater exploitation.

A walk along the river yields information whether the river is eroding or depositing. Old river deposits may be found in this way. When bedrock is exposed in the river bed the river is apparently eroding, but still old bends (cut-off meanders) of the river may offer opportunities for shallow wells.
The deeper sandy river deposits cannot be observed from the surface. In order to find these potential aquifers exploratory drillings or wells will have to be made.

Although river areas often are the most promising, depressions may also be suitable for the construction of shallow wells. The topography and character of the topsoil gives some indication of the recharge capacity. Outcropping granite hills in connection with small dry valleys and depressions are promising areas, whereas flat mbuga clay areas are unfavourable because of the low recharge capacity and high evapotranspiration rate. It should be realized, however, that in weathered granite old remnants of the mother rock are present, which often hamper drilling progress.

Crushed zones at faultlines are very good waterbearing layers (fig. 6). Faults can best be observed on aerial photographs, geological maps and topographical maps. Except for the rift zones, faultlines can hardly be observed in the field. Closer to the sea the possibility of finding saline groundwater increases. In arid areas the salt content of the groundwater, even at a great distance from the sea, may be several times as high as that of seawater, in extreme situations resulting in vast salt plains. In such areas exploitation of suitable groundwater is out of the question.

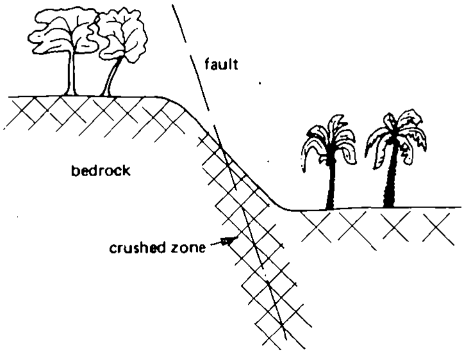


Fig. 6. Schematic geological section over fault zone

C. *Climate and vegetation*

The influence of the climate has already briefly been dwelt upon in the last paragraph. Especially in areas with (very) little rainfall groundwater is essential for life. In those areas damming rivers in order to create reservoirs is generally useless as the evaporation may well exceed the rainfall. Thus underground storage should be used, as provided by the coarser layers in and under the river beds.

Hence: ***In arid regions groundwater may be the only permanent water source. Especially the coarser river sediments may offer good opportunities for aquifers.***

Vegetation such as banana trees, date palms, bulrush, sugar cane, etc. indicates the presence of shallow groundwater (0-5 m). On the other hand the vegetation may indicate that the water is brackish or saline (salt water grass).

Chapter 11. **Surveying**

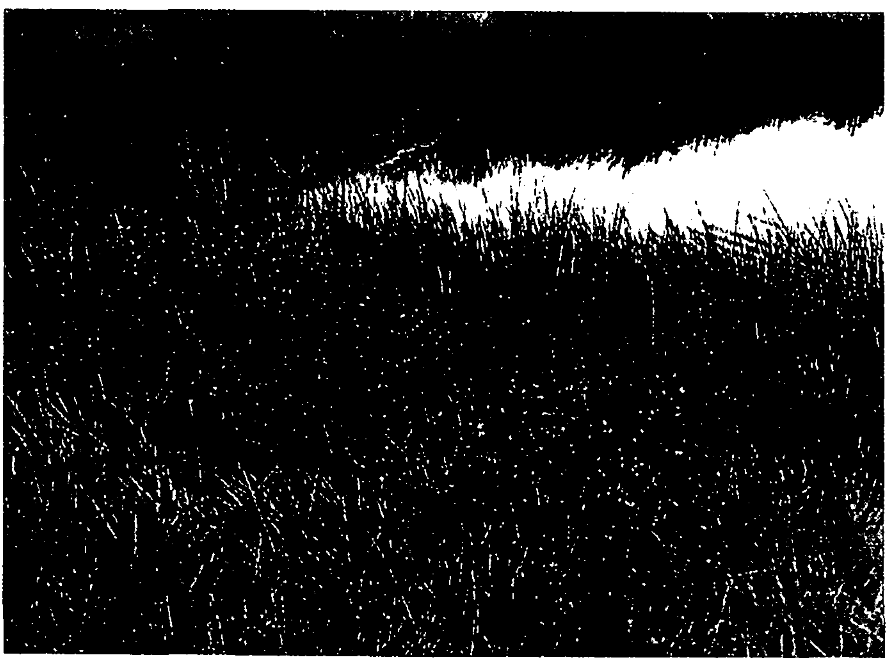
If the over-all planning allows it, the survey activities should be carried out at

the end of the dry season. The groundwater is at its lowest then, thus reducing the risk of constructing wells which will not last throughout the dry season. A survey for selecting sites for shallow wells consists in fact of two parts. During the first, possible sites are selected, based on the preparatory investigations. Thus a spot is found which should be promising for shallow well construction. The assumption is checked in the second part of the survey in order to establish whether a waterbearing layer is actually present and suitable for well construction.
An answer is sought to the following questions:

- Will the yield of the well be sufficient, also at the end of the dry season?
- Is the aquifer protected from pollution?
- Which construction method is most suitable?

Thus the following information has to be collected:

- the aquifer material
- the thickness of the layer
- the depth of the layer and what kind of overlying material is present (protection from pollution and expected influence of water level fluctuations)
- the water level in the aquifer and how far will it have dropped at the end of the dry season
- the yield of the aquifer
- the quality of the water



 9. Salt water grass

A. *Initial selection of sites*

1. In collaboration with the regional authorities a priority list is drawn up of villages which have to be supplied with shallow wells.
2. In these villages, with the aid of ward heads and village leaders, information is gathered about promising areas for shallow wells. The sites to be given first attention are the springs, pools and rivers which supply the village people with their drinking water.
   Before a more detailed survey of the site is carried out, a check is made on the general requirements mentioned in chapter 9. If these are complied with, the following checks are made.
3. Does the pool or spring dry out in the dry season?
   If the pool or the spring dries out during the dry season a more detailed survey, by means of drilling boreholes, is required. Also it is advisable to ask where the people fetch drinking water in the dry season. Mostly this will be farther away.
4. Does the water meet the (inter-)national water quality standards?

If the selected location meets all requirements mentioned above a detailed investigation is carried out.

B. *Survey methods*

A wide variety of methods is being used all over the world to determine the presence of water in the subsoil, including exploratory drillings, aerial surveys, seismic and geo-electrical methods, etc. Several of these are primarily aimed at giving some insight in the water availability within a very limited period of time, and require sophisticated, sometimes extremely expensive, equipment and highly specialized personnel.
For developing countries these methods do not seem appropriate, however, especially when aiming at low-cost water supply for as large a part of the population as possible. In the Shinyanga Region the aim has, therefore, been to devise a low-cost survey method with equipment that is as simple as possible and that can be operated and maintained by local personnel. Although it has as yet not been possible to accomplish this task completely, the survey method described in the following paragraphs is believed to be a step in the right direction. It is a combination of hand-drilling and machine-drilling with a strong emphasis on the former.

C. *Detailed investigation*

After the preliminary choice of potential well sites has been made, a detailed investigation is carried out, comprising

- test drilling
- yield test
- water quality check
- recording of information

10. Lightweight set (from left to right: various bits, bailer, handle + extension rods, casing pipe and clamp)

11. Bayonet coupling lightweight set

A. *Test drilling*

In most cases test drilling is carried out by hand. Only when the soil structure does not allow hand-drilling a simple motor drill can be used, especially when a certain target of investigated locations per time unit has to be reached.

Hand-drilling

Hand-drilling is a comparatively cheap and simple method of investigation. Hand-drill tools are in general sturdy and need little maintenance as no motor or other complicated equipment is involved. Lightweight hand-drill sets can be purchased abroad. Hand-drills can also be made locally. Operating the equipment is not complicated. A few weeks of training is sufficient to operate hand-drills properly under different conditions.
Hand-drills offer the best possibilities of getting accurate lithological descriptions. There are, however, limitations to the depth which can be reached by hand-drilling. The limits are caused by the hardness of the different soil types and the perseverance of the operators.
Under the conditions met in Shinyanga and Morogoro the capacity of hand-drills turned out to be the following:

- Easy drilling: clay, loam, and sand above and below the groundwater table. Maximum depth: 20 metres.
- Laborious drilling: clay, loam and sand mixed with coarse gravels, highly cemented layers, heavily weathered granites.
- Drilling impossible: laterite crusts, cemented layers, weathered granites and other materials containing boulders or coarse gravels.

The perseverance of the operators and their interest in the work are very important factors in reaching sufficient depth by means of hand-drills.

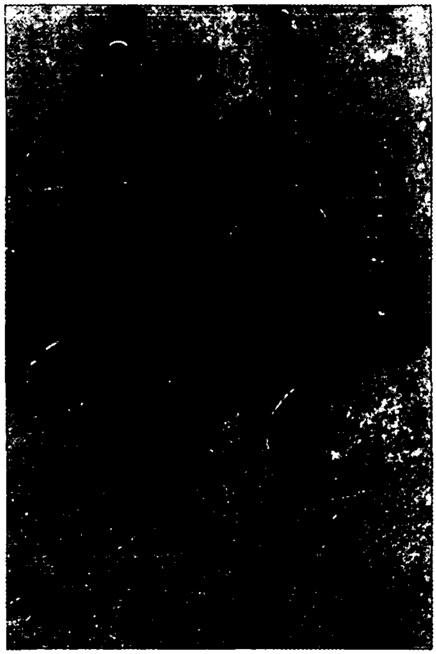
A complete survey set, suitable for investigations down to 15 m, comprises the following items:

1. *hand-drilling equipment*

a. lightweight set:	2 Handles + 15 extension rods of 1 m each 2 Edelmann combination bits of 7 cm diameter 2 Edelmann combinations bits of 10 cm diameter 2 Riverside bits of 7 cm diameter 1 Riverside bit of 10 cm diameter 1 Screw auger of 4 cm diameter 1 Bailer of 63 mm diameter
b. heavyweight set:	1 Cross piece with 4 handles 15 Extension rods of 1 m each 2 Spare cross pieces 2 Riverside bits (elongated) of 7 cm diameter 2 Riverside bits (elongated) of 10 cm diameter
c. casing pipe	15 ABS casing pipes of 90/75 mm diameter, length: 1 m each

2. pump set
3. water analysis set
4. transport box

12. Operated by one man



13. Combination bits (empty)

14. Combination bit (full)

15. Riverside bits

For hand-drilling two sets of equipment are used: a lightweight set with bayonet couplings, which can be operated by one man (see photo 12), and a heavyweight set which is operated by four persons. The purpose of the various bits is as follows:

- Combination bit.

The auger body of this bit consists of two blades, the ends of which are forged into the auger's end. Upwards the blades diverge gradually up to the desired diameter. Depending on the width of the blades the auger is suitable for clay, sand or coarse sand. The blades of the combination bit have an average width so it can be used in all soils.

- Riverside bits.

The auger body of these bits is a tube with two blades welded at the bottom. The sharp extremities of the blades point at an angle downwards, a little outside the tube. The blades are spoonshaped so that the soil is steadily pushed into the tube. This bit is suitable for use in hard, stiff soils and in all kinds of materials below the water level.

- Screw auger.

This bit is made of a steel strip, forged in a spiral form. The diameter is only four centimetres. With this bit hard layers can be broken loose and the material brought out with other auger types afterwards.

- Casing.

Casing consists of ABS or glassfibre reinforced polyester tubes of one metre each, fitted together with coarse threads. They have to be used when sandy layers below the water level tend to collapse. The lowest part of the casing tube is fitted with slots to enable test pumping. Before the casing is placed drilling is done with the Ø 10 cm bits; afterwards drilling is continued with the Ø 7 cm bits inside the casing.

- Bailer.

The bailer, or pulse auger, is a 60 cm long tube fitted with a valve at the bottom. It is used inside the casing for penetrating saturated sand layers by moving it up and down.

- Sample box.

A sample box is a coverless long and narrow wooden box divided into a number of compartments. During the drilling a sample of each 50 cm is placed in the box to prevent mistakes in the description.

16. Heavy hand-drilling survey equipment

17. Cross-piece, heavy hand-drilling survey equipment

The costs of one complete set of survey equipment, including transportation costs, are:

	TShs	US$ *
a. lightweight set	16,500	2,050
b. heavyweight set (optional)	(16,500)	(2,050)
c. casing pipe	18,500	2,350
d. pump set	6,000	750
e. transport	500	50
	41,500	5,200

* Conversion rate 1 US$ = TShs 8.00 (1979)

As a rule at least 600 drillings can be carried out with this equipment without major repairs or maintenance problems.

Machine drilling

Machine drilling can be a necessity in larger projects, giving information about layers which cannot be reached with hand-drilling equipment but are good aquifers. Information about deeper layers also helps considerably in obtaining insight in the geological conditions of an area.

18. Light machine drill

19. Trailer-mounted machine drill

The advantages of machine drills are very obvious and hardly need any discussion. However, the disadvantages are also very obvious.

A machine drill is an expensive and complicated piece of machinery which has to be purchased abroad. It needs skill in handling and maintaining. A large stock of spares has to be available to ensure reliable operation.

Another disadvantage of a rotary machine drill is that the samples reach the surface in mixed-up condition, or not at all.

Making a proper lithological description of a rotary drilling requires extensive experience, while often additional geo-electrical measurements will have to be carried out. Interpretation of the results of these measurements is again specialized and complicated work.

The approximate cost of simple machine drills, complete with accessories, as shown on photos 18 and 19 amounts to

	US$
light machine drill	12,500
trailer-mounted machine drill	60,000

Larger machine drills will generally not be feasible for the siting of shallow to medium-depth wells and often even for deeper boreholes their usefulness in developing countries is questionable.

In small scale surveys for shallow well sites hand-drilling equipment will be sufficient in most cases. In a larger scale project which has to reach a produc-

20. Drilling with heavyweight set

21. Drilling within casing

22. Depositing samples in sample box

23. *The casing is lowered by turning and pressing it downward when the bailer is lifted*

24. *The bailer is emptied*

tion target, or where all the villages have to be supplied with wells a simple machine drill will in most cases be indispensable.

Drilling procedure

Depending on the situation, holes are drilled in a certain pattern (see next paragraph) in order to find out details about the extent and depth of the aquifer and the most promising well location. In the first instance only hand-drilling equipment is used, machine drilling being restricted to those cases where hand-drilling is hampered by hard layers.
Drilling starts with the lightweight set and a Ø 10 combination bit. To keep the borehole clean no bit should ever be filled for more than three quarters. The outcoming material is laid out neatly in rows, each row representing a full metre of depth. After every 50 cm a sample is deposited in the sample box. When the soil is too hard or mixed with gravels the riverside Ø 10 can be used. If no progress is made, first a small hole is drilled with the Ø 7 riverside. Afterwards the hole is reamed with the Ø 10 bit.
When the water table is passed and the hole starts caving in a casing has to be placed. The casing is lowered by turning (clockwise only) and pressing it downwards at the moment the bailer or a full auger is lifted. When the caving layer is passed the casing should be pressed into the underlying clay layer to prevent sand from entering the hole. Drilling can be continued with Ø 7 bits. When a second layer is met which tends to cave, water is added to the hole. In this way the water pressure within the hole increases, thus preventing caving.

If this does not work out the casing has to be pressed on into the second water-bearing layer.
When a hole gets deeper than 5 metres, the drilling rod has to be disconnected during lifting to prevent bending of the extensions.
If no progress is made anymore with the lightweight set, the heavyweight set has to come into action. Intermittent use of the different bits normally gives the best results. When during one hour of drilling no progress has been made the drilling can be stopped and another hole must be tried or drilling has to be resumed with a machine drill.

Location of test drilling site

There are four types of sites requiring different investigation approaches:

a. pools and springs on slopes
b. river banks
c. river beds
d. wet places

a. *Pools and springs*

Five hand drillings are executed per site, as shown. Based on the results of these drillings a location with the thickest and most suitable water bearing layer is chosen.

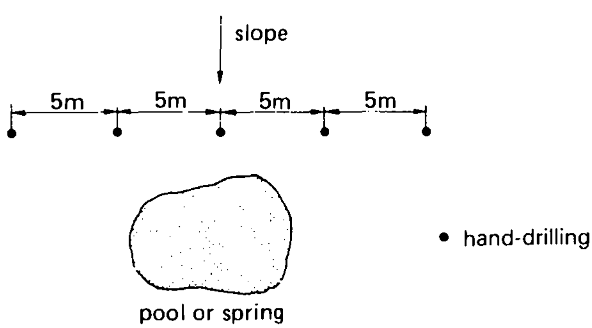


Fig. 7. Survey pattern near pool or spring

b. *River banks*

In places where an old river bed is found in a river bank 10 or 12 hand drillings are executed as shown. The choice of the final well site is made in the same way as under (a).

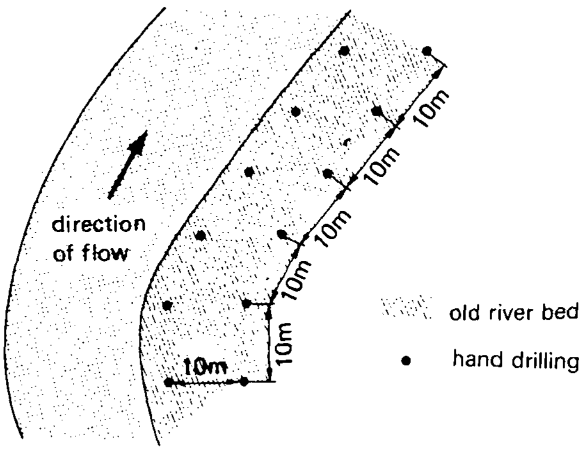
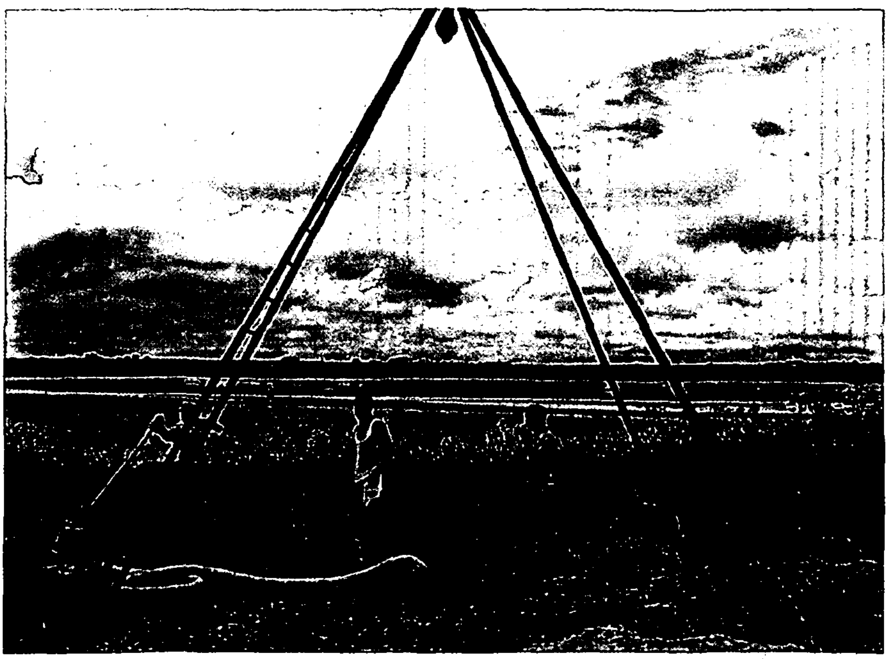


Fig. 8. Survey pattern on river bank



25. Well site in a river bank

c. *River beds*

If no possibilities for constructing a shallow well in the river bank exist, the river bed itself is investigated by making a large number of hand drillings. The distance between the drillings is about 5 metres, or more as the river bed is wider. Some 50 drillings are needed to be able to choose the best location for a well.

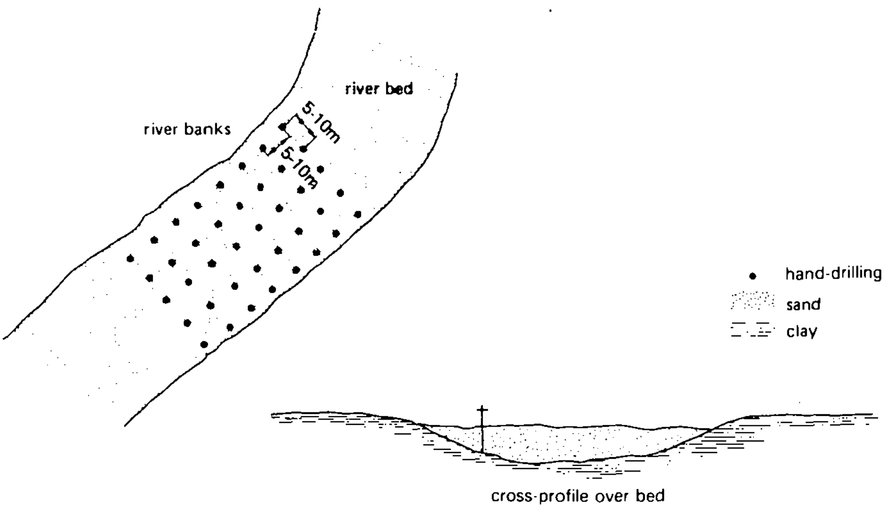


Fig. 9. Survey pattern in river bed

d. *Wet places*

Locations with shallow groundwater, which are often good sites for shallow well construction, are so-called 'wet places'. Vegetation such as banana trees, bulrush, sugar cane etc. may indicate shallow groundwater.
A survey is necessary to indicate whether there is groundwater of good quality and at which location the thickest aquifer occurs. A possible survey pattern is shown below.

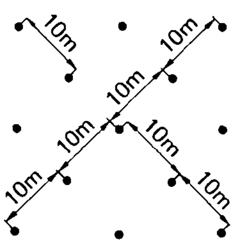
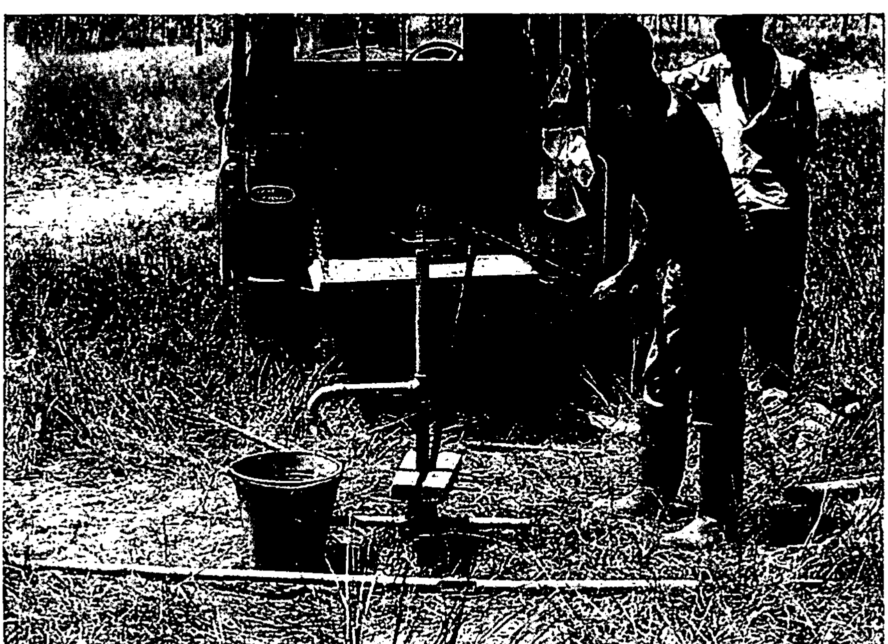


Fig. 10. Drilling pattern in wet places

E. ***Yield test***

A full-scale pumping test would be ideal for establishing the safe yield of a well. In many cases it will not be possible to carry out such a test, however, if only for the lack of a suitable pump.

26. Simple pump for executing yield tests

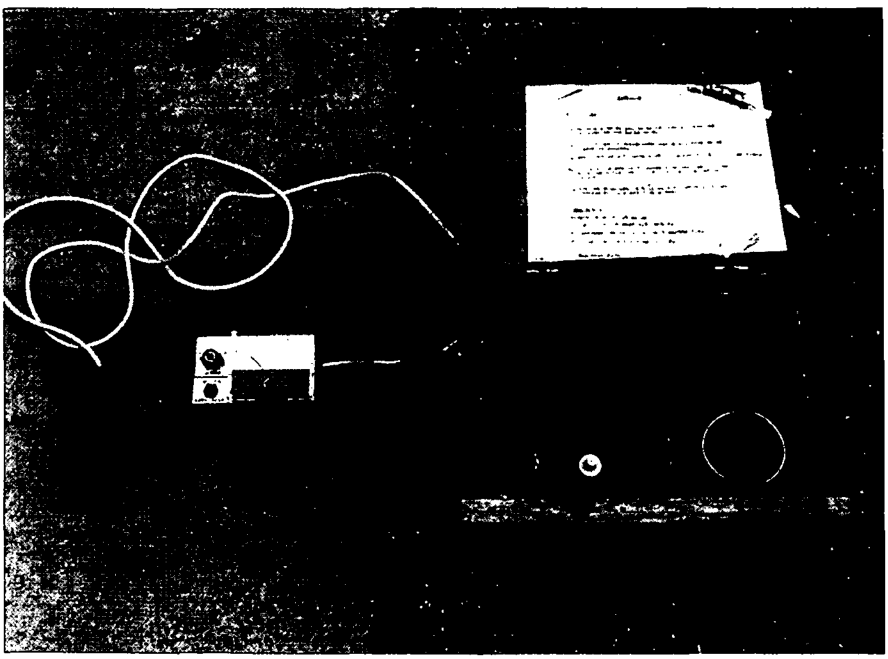


27. Test pumping on survey borehole

In order to get some insight in the yield of the test borehole a kind of step drawdown test is carried out. A simple, locally made, hand operated pressure pump is lowered in the hole. The depth at which the pump is operated is adjustable by adding 1-m extensions to pump rod and rising main. In principle the pump should be situated as deep as possible.
After the initial water level is written down the test can start. Hand pumping is continued for an hour. Every 10 minutes the yield (e.g. number of buckets filled per minute) and the water level are recorded. From the 40th until the 50th minute pumping is done as intensively as possible in an attempt to double the yield during these 10 minutes. A model test form is shown on page 43.
Interpretation of the results of this test should as a matter of course be different from, and more cautious than in the case of a fullscale pump test. Equilibrium levels, for instance, may not have been reached in the limited time available. The future shallow well, on the other hand, will also be equipped with a hand pump only, which will certainly not be used more intensively than the test pump, so a certain degree of reliability will be present.

F. ***Water quality check***

A superficial check of the water which can be carried out already during the preliminary phase of the survey may indicate its suitability as drinking water. At the end of the yield test a water sample is taken. Major constituents may be checked by means of a field kit, especially when experience shows that



28. Simple equipment for water quality tests: conductivity meter (l.) and fluoride analysis kit (r.)

SHINYANGA SHALLOW WELLS PROJECT

Borehole test form.

District ....

Ward ....

Village ....

S.W. No / B.H. No ....

Operator ....

Date ....

Quantity of water in one bucket ....

Pumplevel ....

Initial waterlevel ....

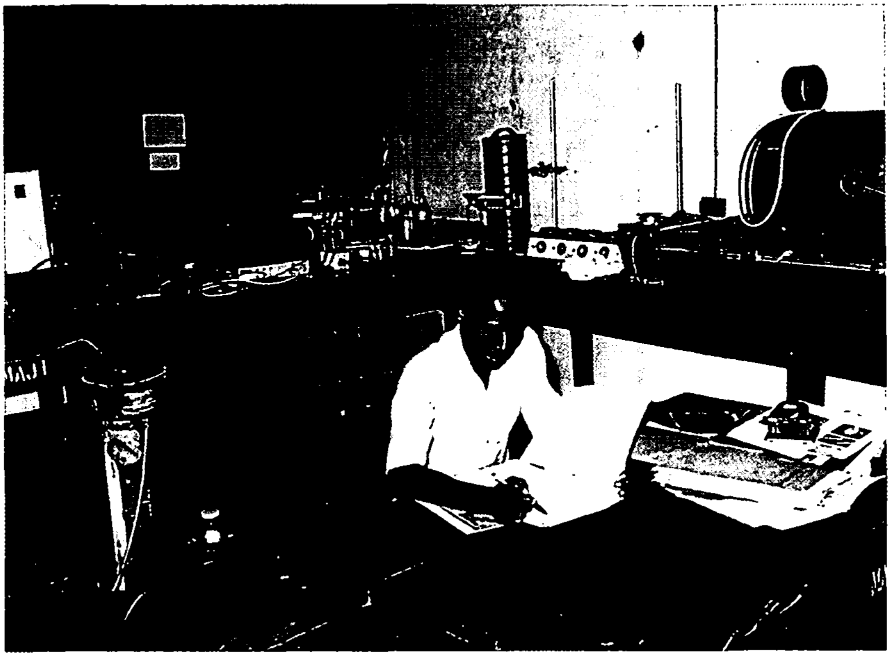
Time start pumping t0 ....

Time stop pumping t60 ....

	Waterlevel	No of buckets
t 0	....	....
t 10	....	....
t 20	....	....
t 30	....	....
t 40	....	....
t 50	....	....
t 60	....	....
REMARKS:	....	....

INSTRUCTIONS:

- Carry out pumping test for one hour.
- Measure the waterlevel after every 10 minutes. When the pump sucks air go on pumping slowly, but note this under remarks.
- Pump as intensive as possible from the 40th to the 50th minute. Try to double the number of buckets in this 10 minutes to get the maximum drawdown.
- Note all deviations, if they occur, under remarks.



29. Special water laboratory

generally only a few may exceed the established water quality limits. It may be better to execute more extensive analysis in a special laboratory, although field test kits for the analysis of a large number of constituents are available. Water quality standards may differ from country to country, often following - with individual variations - the International Drinking Water Standards of the WHO, which are summarized below:

International standards for drinking-water (World Health Organization)

Toxic substances

Substance	*Maximum allowable concentrations mg/l*
Lead	0.05
Arsenic	0.05
Selenium	0.01
Chromium (Cr hexavalent)	0.05
Cyanide	0.2
Cadmium	0.01
Barium	1.0
Radionuclides (gross beta activity)	10 μμ/l

Components hazardous to health

Substance	*Maximum allowable limit*
Nitrate as NO_3	45 mg/l
Fluoride	1.5 mg/l

Chemical substances affecting the potability of water

Substance	*Max. acceptable concentration*		*Max. allowable concentration*	
Total solids	500	mg/l	1500	mg/l
Colour	5	units*	50	units*
Turbidity	5	units**	25	units**
Taste	unobjectionable		—	
Odour	unobjectionable		—	
Iron (Fe)	0.3	mg/l	1.0	mg/l
Manganese (Mn)	0.1	mg/l	0.5	mg/l
Copper (Cu)	1.0	mg/l	1.5	mg/l
Zinc (Zn)	5.0	mg/l	15	mg/l
Calcium (Ca)	75	mg/l	200	mg/l
Magnesium (Mg)	50	mg/l	150	mg/l
Sulfate (SO_4)	200	mg/l	400	mg/l
Chloride (Cl)	200	mg/l	600	mg/l
pH range	7.0-8.5		Less than 6.5 or greater than 9.2	
Magnesium + sodium sulfate	500	mg/l	1000	mg/l
Phenolic substances (as phenol)	0.001	mg/l	0.002	mg/l
Carbon chloroform extract (CCE: organic pollutants)	0.2	mg/l	0.5	mg/l***
Alkyl benzyl sulfonates (ABS: surfactants)	0.5	mg/l	1.0	mg/l

* Platinum-cobalt scale.
** Turbidity units.
*** Concentrations greater than 0.2 mg/l indicate the necessity for further analyses to determine the causative agent.

Bacteriological Standards

Classification		*MPN/100 ml coliform bacteria*[a]
I.	Bacterial quality applicable to disinfection treatment only	0-50
II.	Bacterial quality requiring conventional methods of treatment (coagulation, filtration, disinfection)	50-5000
III.	Heavy pollution requiring extensive types of treatment	5000-50 000
IV.	Very heavy pollution, unacceptable unless special treatments designed for such water are used; source to be used only when unavoidable	greater than 50 000

[a] When more than 40% of the number of coliform represented by the MPN Index are found to be of the faecal coliform group, the water source should be considered to fall into the next higher category with respect to the treatment required.

A simple check which can be carried out without any equipment is the following:
the water should neither smell nor taste salty, sour, soapy or bitter, so should in fact be almost tasteless. Furthermore it should be clear and colourless after standing for a few minutes. A milky white colour may be acceptable in lateritic areas only. In general the water must not contain any visible living organisms like worms etc., nor the remnants of plants or other visible debris. The concentration in water of a number of chemicals can be indicated by simple means like litmus-paper, indicator papers or colorimetric comparators. In that case, as a first indication, the investment costs per type of check are approx. Dfl. 150.— (US$ 75.—) with chemical costs per check amounting to Dfl. 0.40-0.50 (US$ 0.20-0.25).

If a large number of analyses per sample is required, more expensive equipment is needed, e.g. a portable water-laboratory, costing approx. Dfl. 2,800-4,800 (US$ 1,400-2,400). Chemical costs per check are the same as mentioned above.

Chapter 12. **Recording of information**

During the drilling major and minor soil constituents, gradation and consistency of the material and water content are logged against the depth on a form as shown on page 48. The abbreviations to be used on this form are given on page 49. For machine drills also the drilling speed is recorded. As mentioned before, soil samples of each 50 cm depth are put in sample boxes.

Once the drilling is finished a sketch is prepared of the village and the situation of the various boreholes.

A complete survey report of a site consists of:

- village sketch
- situation sketch
- borehole description form(s)
- pumping test form

30. Filling out test drilling log

TEST DRILLING LOG

Map sheet : .... Village : ....

Bore hole no. : .... Ward : ....

Date : .... District : ....

Drilled by : .... Drilling method : ....

Depth in cm	Major part	Colour	Gradation/ consistency	Minor part/s	Water content				Drilling speed			
					dr 1	m 2	w 3	wb 4	sl 5	md 6	q 7	bu 8
000–050												
050–100												
100–150												
150–200												
200–250												
250–300												
300–350												
350–400												
400–450												
450–500												
500–550												
550–600												
600–650												
650–700												
700–750												
750–800												
800-850												
850-900												
900–950												
950–1000												

Well clogging yes/no Depth of waterlevel

Water sampling yes/no Remarks:

Pumping test yes/no

These forms give the basic information needed to determine the suitability of a site for construction.

The survey report is then studied either centrally (for larger projects) or on the spot.
Village and situation sketches give information about:
- distance of the site to the village
- pollution hazards
- erosion hazards.

Legend for abbreviations to be used on test drilling log

Major parts		Colour	
clay	= cl (smaller than 2 μ)	blue	= bl
loam	= lm (between 2 and 50 μ)	brown	= br
sand	= sd (between 50 and 2000 μ)	yellow	= ye
gravel	= gr (between 2 and 60 mm)	grey	= gr
stones	= st (larger than 60 mm)	black	= blk
sandstone	= sd.st	green	= green
laterite	= lat	white	= wt
calcrete	= cal		
granite	= grt	*Minor parts* -	*As major parts*
		few	= few
Gradation		very	= ve
fine	= fn (sand 50-200 μ)	layers	= ls
medium coarse	= md.cs (sand 200-600 μ)		
coarse	= cs (sand 600-2000 μ)	*Water content*	
		1	= dry
Consistency		2	= moist
soft	= sft	3	= wet
loose	= ls	4	= water bearing
dense	= ds		
hard	= hd	*Drilling speed*	
weathered	= wed	5	= slow
sticky	= stk	6	= moderate
		7	= quick
		8	= bumping

Borehole description forms:

- aquifer material, thickness and depth of the layer
- the different descriptions together with the situation sketch give insight in the extent and shape of the aquifer
- the water level is of importance to get an idea about the part of the aquifer that still bears water at the end of the dry season.

Pumping test form:

From the pumping test form two things can be found out. The actual yield

during pumping is represented by the total amount of buckets times the content of one bucket, which gives the yield in litres per hour.
From the drawdown of the water level during pumping it can be seen whether this actual yield is also the maximum yield.

Except for aquifers in river beds it is preferable that the aquifer has an overlying layer of at least 2 m, as a certain protection against seepage of spoil water back into the well. Moreover shallow aquifers are likely to dry out rather easily.
Piezometer readings which were carried out for one year in the Shinyanga Region of Tanzania showed groundwater level fluctuations to be related more to the topography than to aquifer characteristics. A succession of an excessively dry and excessively wet season enabled the observation of maximum water level fluctuations, which were found to be as follows:

	max. water level fluctuation
wide river beds	1.00 m
river banks*	1.50-1.75 m
valley bottoms and plains	1.40-1.70 m
slopes**	0.70-1.85 m
deep, confined aquifers	many metres

* The smaller the banks, the larger the fluctuations.
** The steeper the slope, the smaller the fluctuations.

In Shinyanga Region two main types of wells are used: a well without storage capacity (0.15 m dia. slotted pvc pipe with coarse sand/gravel pack) and a larger-diameter well with concrete rings (1.25 m internal diameter) (see chapter 15). The minimum yields required for these wells are 1000 l/h and 750 l/h, respectively, so theoretically the required test yields (for a 0.10 m dia. borehole) should equal a minimum of 900 l/h and 400 l/h, respectively.
In practice pumping and filter conditions during test pumping are far from ideal, so for practical purposes the following criteria are used:

1. test yield equals 200 l/h or more: 1.25 m dia. well possible
2. test yield exceeds 500 l/h: 0.15 m dia. well possible.

These criteria are not rigid, however. Also important are:

a. drawdown-yield ratio
b. aquifer depth and thickness
c. expected groundwater fluctuations

Last but not least, field experience is required in order to be able to judge the suitability of a potential well site.
When a potential well site has been approved by the hydro-geological section it is also determined whether a small- or large-diameter well can be constructed. This depends not only on the expected yield of the well, but also on the soil types encountered. These may, for instance, hamper drilling (small-diameter) wells because of the presence of boulders, but still enable the digging of larger-diameter wells. A flow sheet showing the steps taken in a well survey is given in fig. 11.
Data of the approved well are entered on a shallow well card (see page 53), on

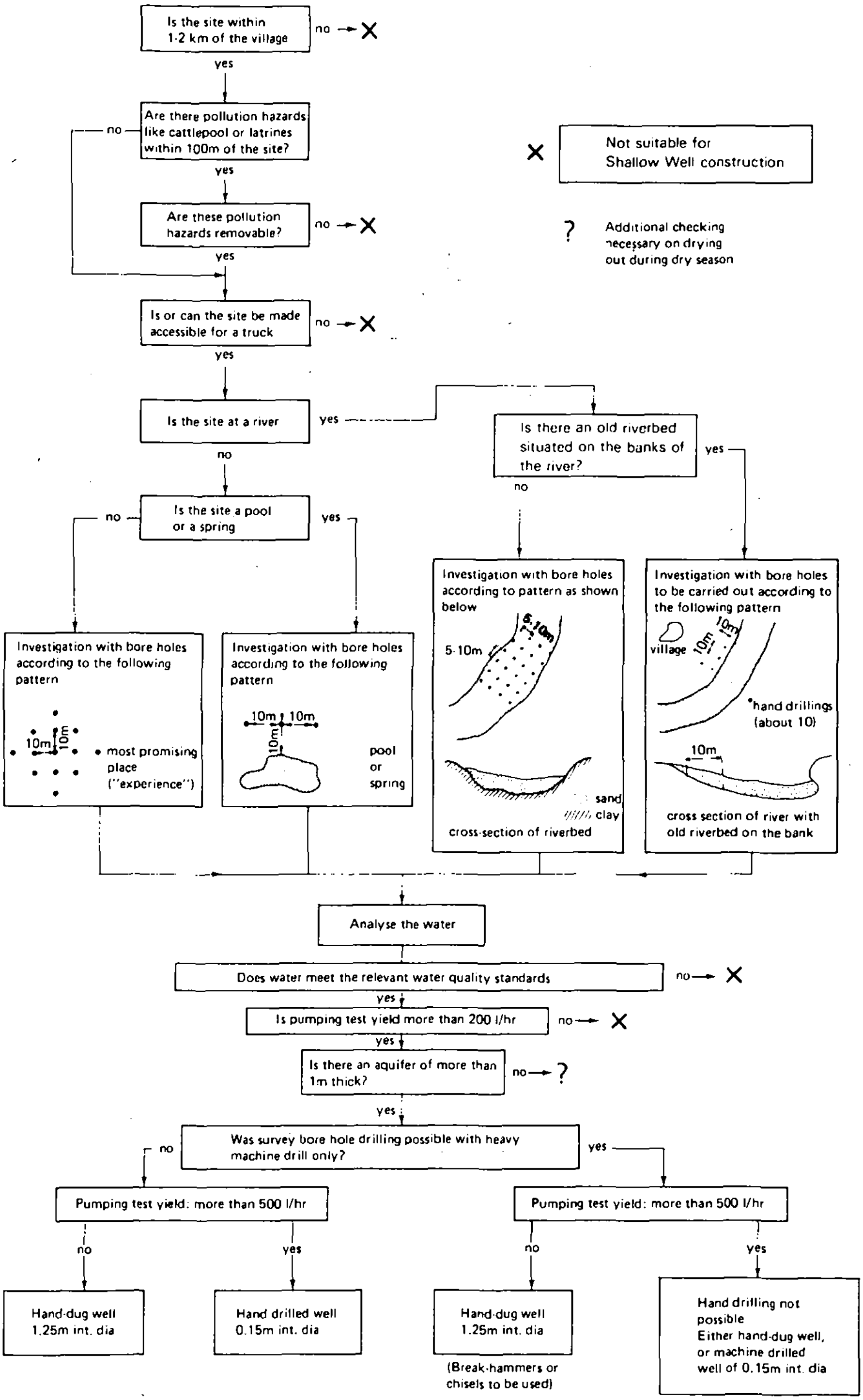


Fig. 11. Flow sheet shallow wells site investigation

which also construction data are recorded later on. The reverse of the card is used for recording the results of maintenance visits.

Chapter 13. **Planning and budgeting a shallow well survey**

Finding a good shallow well site is very important. Therefore, a good survey is also important. The survey, however, is a cost-increasing factor which needs to be planned and checked accurately.
Generally only a limited amount of money is available and surveying will often be (falsely) judged to be a costly commodity which can be omitted. This intensifies the need to keep survey expenses under control.

A planning will have to be set up, which includes:

- time planning	- which area to be surveyed in which period?
- personnel planning	- how many sites to be surveyed per surveyor per week - how many sites to be surveyed, hence: how many surveyors needed (+ drivers, cars, assistants and supervisors)
- materials planning	- survey and camping equipment. Hand- or machine drills?
- transport planning	- how many cars available? How many surveyors can be transported?

Often the number of available cars and/or trained staff will be a critical factor in planning. The planning results - taking into account all factors mentioned - will indicate a certain level of running costs. These can then be calculated by means of a form as shown on page 55.

Included in the running-cost calculation are:

- wages and salaries of staff
- additional field allowances
- cost of hired local labour ('self help')
- running cost of machine drills (fixed rates per machine-hour)
- transport cost (fixed rate per km)
- supervision (in Shinyanga approx. 10%)
- miscellaneous incl. repairs, etc. (in Shinyanga approx. 15%)

NR:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

SHALLOW WELL TYPE: *Hand dug/Mechanically dug well**

REGION: SHINYANGA
DISTRICT:
WARD:

DIVISION:
VILLAGE:

LOCATION: Co-ordinates :

Start of hydro-geological survey : / /19
Hydro-geol. code number :
No self help/self help started on : / /19
Construction started on : / /19
Construction finished on : / /19
Pump installed and well disinfection on : / /19
Take over on : / /10

Inner well diameter : m
Depth of well : m
Avge. water height : m
Avge. storage volume : m^3
Hydro-geol. survey group :
Construction group :
Construction supervisor :
Aquifer type :
Well dries up in dry season : Yes/No.

*** delete whatever is not applicable**

WATER ANALYSIS

sample collected on (data)	laboratory number	date of lab. analysis	Conductivity (micromhos / cm at 25 °C)	pH	F^-	NH_4^+	E. coli	Remarks

LITHOLOGICAL DISCRIPTION

Depth	Drilling discription	Humidity

WATER LEVEL:

PERIODICAL CHECK - UP

Date of check/repair	Controlled/repaired by	well dry?	general impression of			pump repaired	Remarks/Action taken
			well cover	well surrounds	pump		

SHINYANGA SHALLOW WELLS PROJECT

P.O. Box 168,
SHINYANGA

COST CALCULATING FORM, SURVEY

Month .... Supervisor / Surveyor ....

Car ....

Area .... No approved sites ? ....

Transport : total: .... km x 2.7 Shs/km = ...

Motor drill : total: .... machine-hours x 10 Shs/hr = ...

Self help : total: .... men x .... days x 10 Shs/day = ...

Camp watchman : .... days x .... Shs/day = ...

Wages : surveyor : per month : Shs 600

Driver(s) : .... men x Shs 400 = ...

Drill operator(s) : .... men x Shs 400 = ...

Others : .... men x Shs ..... = ...

Total wages per month = ... = ...

Night allowance : .... men x Shs 200/month = ...

Sub-total: = ...

Supervision : Sub-total = ...% = ...

Stores : Sub-total = ...% = ...

Total costs : ....

Total no of sites : ....

Average survey costs per site : ....

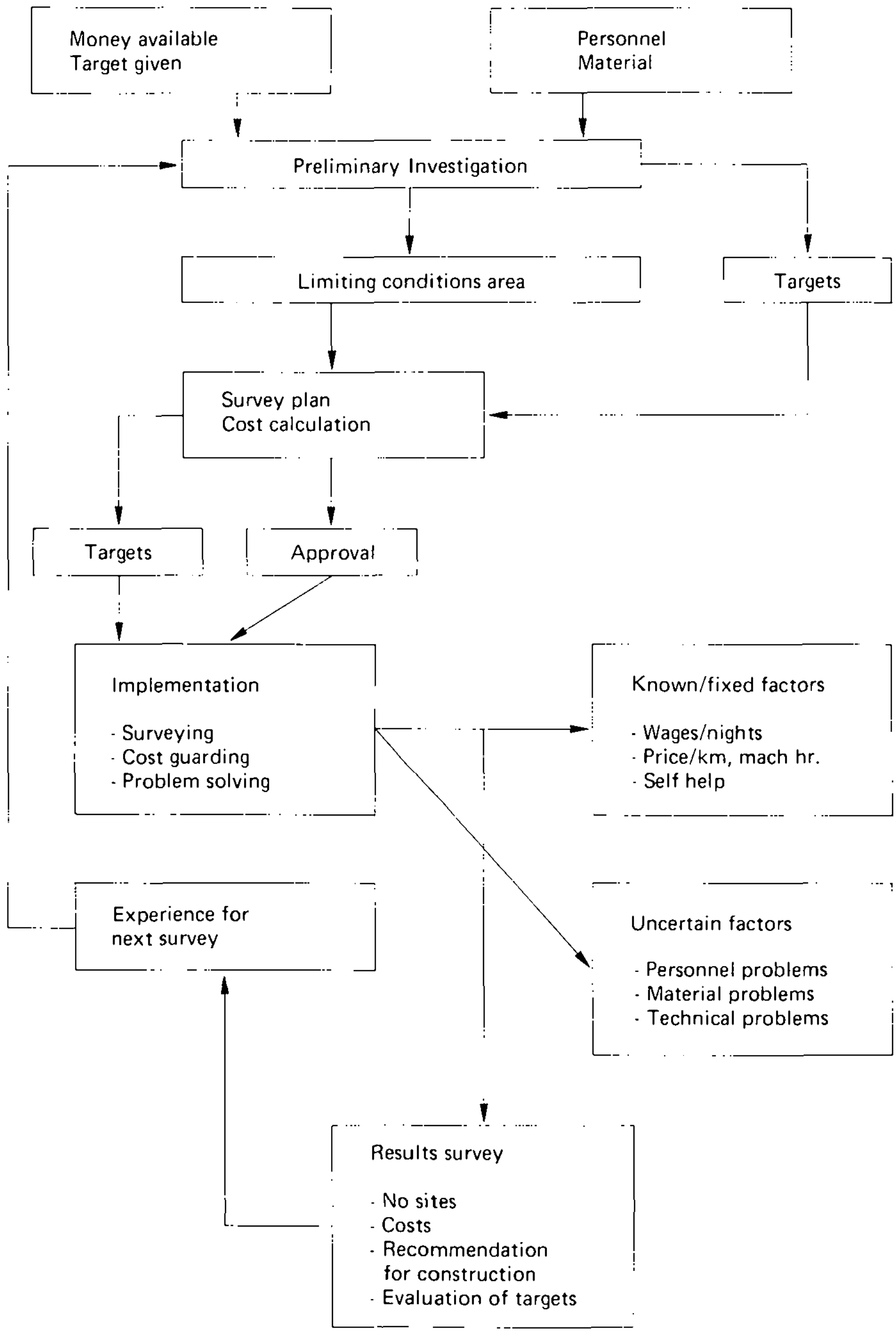


Fig. 12. Steps to be taken in planning a survey

From the number of well sites which has to be established per month, average survey costs per site can be calculated. In Shinyanga these amounted to TShs 1,500 (US$ 200) per site (1978), based on survey groups operating independently from construction units. Each group, consisting of a surveyor and a driver, locally supplemented with 2 or 3 'self help' labourers, produced an average of 2 suitable well sites per week.
For projects of smaller size it may be beneficial not to have survey groups operating as independent units but to incorporate them in the well construction groups, thus at least saving on transportation expenses and numbers of vehicles.

A flow sheet indicating the steps to be taken in setting up a survey planning is given in fig. 12.

Part 4
Well construction

Chapter 14. **Choice of construction method**

The Shinyanga Shallow Wells Project has shifted its emphasis during the years from hand-dug to hand-drilled wells. It started with hand-dug wells, lined with non-reinforced concrete rings of 1.25 m internal diameter. For special applications a hammer grab (0.58 m external diameter), hung from a light mobile crane, has been in use for some time, to be replaced later by heavy hand-drilling equipment. During the latest stage also a simple percussion rig has been in use.
Making hand-dug wells is a simple method, requiring very little investment. When the recharge of the aquifer is large, however, difficulties may be encountered in dewatering the pit sufficiently in order to make hand-digging possible over the full depth. Thus preference was given to hand-drilling, which also requires only limited investments, while not necessitating dewatering of the hole. The equipment which is used cannot penetrate hard layers, however. In such cases either full-size hand-dug wells are required, in which the hard layer can be removed by chisel and hammer or by electric or pneumatic jack-hammer, or heavier, motor-driven drilling equipment will have to be used. In that case relatively simple equipment such as a percussion rig should be preferred.
According to the experience gained in Tanzania the cost ratio for wells is roughly as follows: hand-drilled wells: hand-dug wells: percussion rig wells = $1:1\frac{1}{2}:2$.
Thus if no problems are expected hand-drilled wells should be preferred if the aquifer recharge is sufficient. If the aquifer recharge is less, but still sufficient for a larger-diameter well, a dug well should be used. If hard layers are encountered hand-drilling may not be possible any longer. Hand-digging will become much more expensive now because of the time-consuming chiseling through the hard layers and/or the use of expensive jack-hammers. Thus percussion rigs could then be preferred for making the wells. Again only if the recharge of the aquifer is sufficient for small-diameter wells. If not, hand-dug wells are the only solution, irrespective of the higher costs.
For the construction of only one well or a limited number of wells hand-digging may be the most attractive solution because investments can be very small.
Thus hand-digging is the method which is used most frequently, especially in countries where human labour is relatively inexpensive.

Chapter 15. **Well types**

The following well types are distinguished (fig. 13)
a. dug well with constant diameter over full height
b. dug well with reduced diameter in upper well section
c. drilled well.

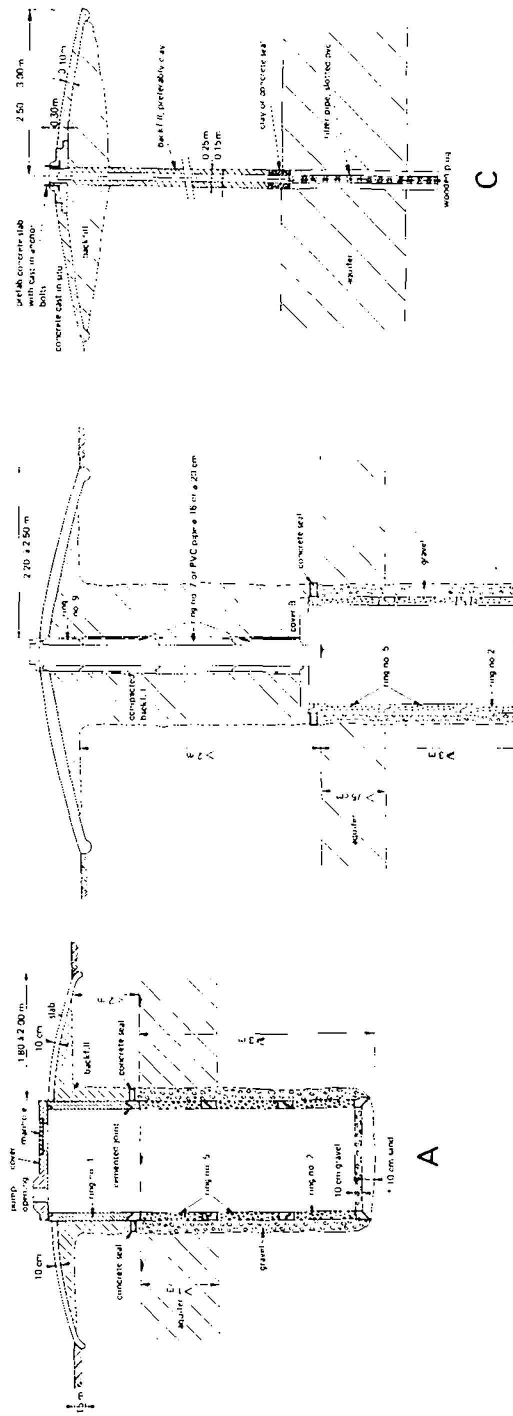


Fig. 13. Main shallow well types

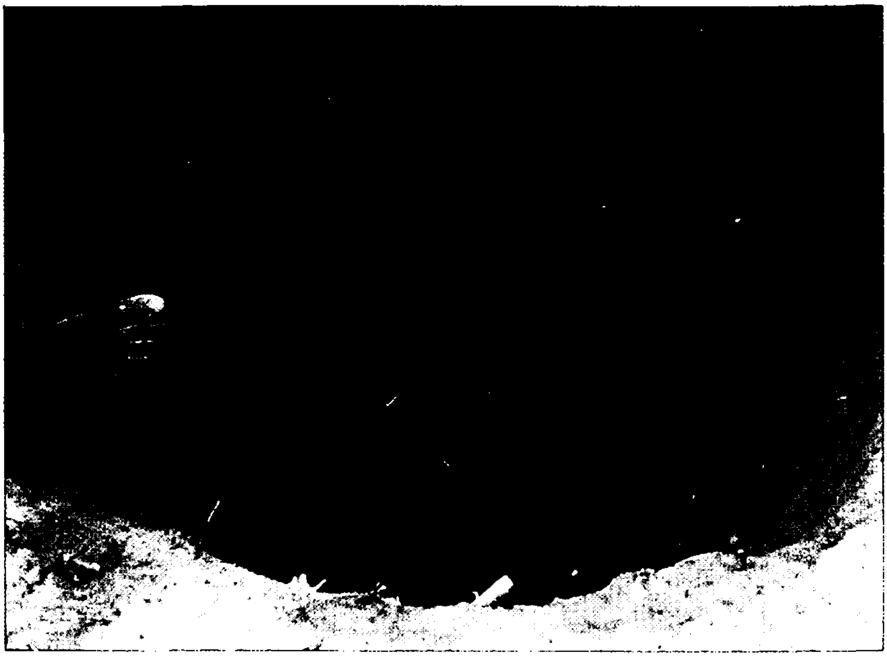
Drilled wells will not require a lining (any casing needed during construction is removed afterwards), but dug wells may need a lining over at least part of their height.

Various methods of lining may be used, such as:
1. sinking prefabricated concrete rings by digging the soil material away from underneath (caissonning)
2. constructing lining in situ. The lining consists of:
   a. concrete poured in situ (shuttering/moulds erected in pit)
   b. brickwork cemeted in situ (burnt clay bricks, cement blocks, etc.)

In Shinyanga the large number of wells to be constructed made brickwork lining too slow and expensive. In situ lining would require a large number of moulds with the ensuing handling problems. Thus it was preferred to centralize the production of well rings in Shinyanga town and use the caissonning method. The fabrication and handling of well rings and covers is dealt with in chapter 21.

A. *Dug well with constant diameter over full height (type A)*

When soil conditions permit, digging the well is continued without any lining as far as possible. Well rings are lowered into the pit then and digging is resumed in the caisson method, i.e. the soil material is carefully removed from under the rim of the ring, which gradually sinks as a consequence.
In several cases lining is not necessary over the full height. In Shinyanga Region often rather hard layers were found several metres below ground level, while the top layers were so soft and loose as to require lining from the beginning. In those cases lining can be restricted to the upper part of the well only (fig. 14, A1).
A variation on well type A1 is one in which the aquifer itself is also a soft layer, again requiring a lining. In that case the upper part of the well is lined with concrete rings of 1.25 m internal diameter, the middle part is unlined and the bottom part of the well is lined with concrete rings again. These have to be passed through the regular lining of the upper part so the external diameter of these rings should not exceed 1.20 m (fig. 14, type A2).
Telescoping a smaller-size lining through the regular lining is also used in rehabilitating existing wells which turn out to fall dry in the dry season (fig. 14, A3). This kind of construction can also be used for completely different reasons. Especially when the transmissivity of the aquifer is large, digging a well in the wet season may be continued to a limited depth only because of difficulties in removing the inflowing water. When seasonal groundwater level fluctuations are large, the result may then be that the well falls dry in the dry season. Since it is not possible to dig deeper in the wet season without expensive additional equipment, while digging all wells during the dry season is not possible either in larger projects, the following method is sometimes used. Wells are dug and lined as deep as possible during the wet season. In the dry season the groundwater level sinks and wells can be dug out further, until the desired level. For the additional excavation concrete rings of 1.20 m external diameter are telescoped inside the existing lining, down to the required depth.



31. As far as possible the well is dug without a lining (here a jack hammer is used on a hard layer)

32. Digging is continued after the well rings have been put into position

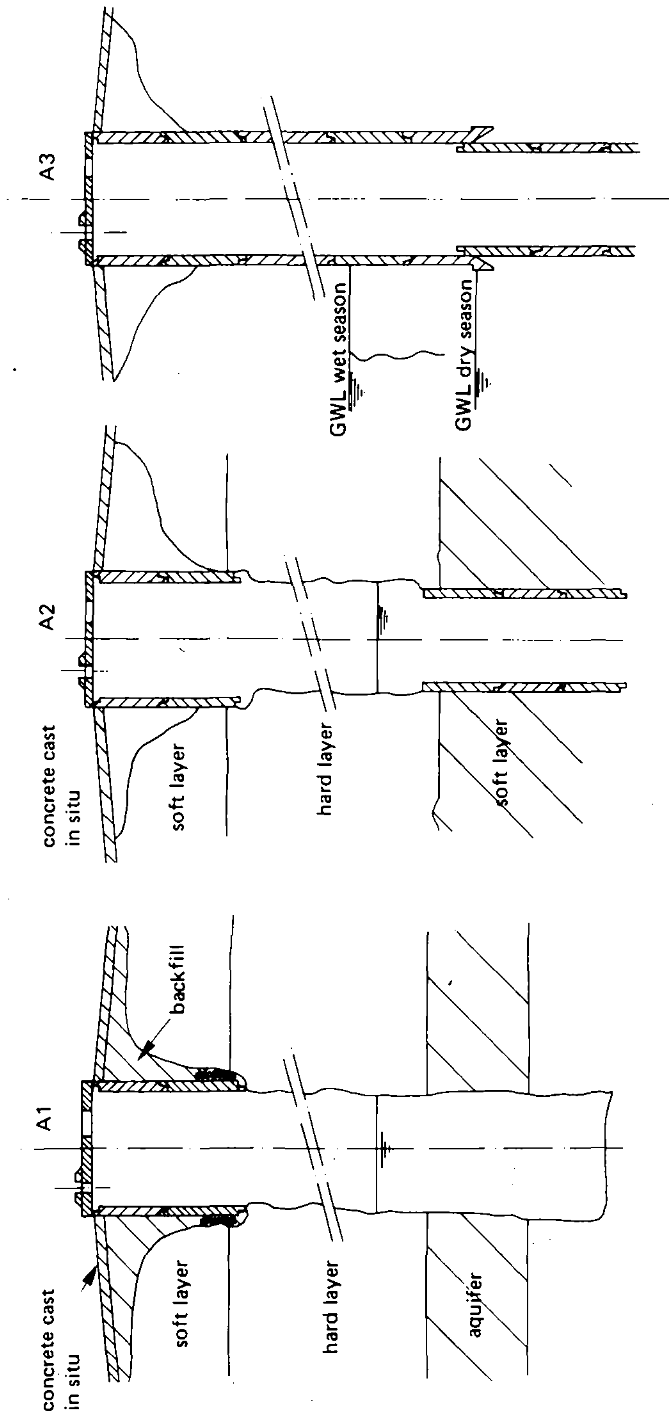


Fig. 14. Alternative solutions for well type A

B. *Dug well with reduced diameter in upper well section (type B)*

Often the aquifer is found at a depth of more than two metres. This is particularly so when the aquifer is weathered bedrock (granite or quartzite). In this case and also when laterite or gravels are found at a depth of less than two metres but with the water level at a depth of more than two metres, the following (cheaper) construction method may be considered. After digging to the required depth the filter rings are put into position in exactly the same way as in standard well construction, up to the upper boundary of the aquifer.
On top of the upmost filter ring a prefabricated reinforced concrete cover, with a hole in the centre, is put into position. On top of this cover smaller-diameter rings or PVC-pipe with sufficient diameter to enable a pump cylinder to pass through can be used.
Again the space between the filter rings and the undisturbed soil is filled with gravel up to the top of the aquifer and a concrete seal is poured on top of it. The reinforcement (3/8" dia. rods every 10 cm) of the concrete cover is necessary to carry the weight of the backfill on top of it.
After backfilling the rest of the hole and compacting the soil a concrete slab is built around the smaller-diameter rings. The diameter of this slab - which is cast in place - should be about 4.50 m. Bolts, to which the pumpstand can be fastened, are cast in. The exact position of the bolts can be ascertained by using a mould as dummy for the pumpstand. The slab must be reinforced with steel mats in order to avoid cracking due to setting of the backfill. To restrict this setting as far as possible attention should be paid to the proper compaction of the backfill. This can be done by ramming after each foot of fill and by using water.

C. *Drilled well (type C)*

Drilled wells have some advantages over dug wells:

- dewatering the pit is not necessary, thus saving on pumps, etc.
- water pressure inside the borehole can be maintained, reducing the danger of caving-in or washing-out of the aquifer into the borehole
- generally the drilling takes less time than excavation by hand.

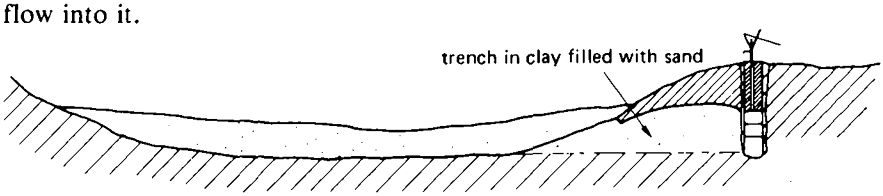
On the other hand a drilled well will have a (much) smaller diameter than a dug well and thus hardly possesses any storage capacity. This implies that the transmissivity of the aquifer should meet certain minimum requirements (in Shinyanga Region: test yield should exceed 500 l/h).

Wells can be drilled with simple hand-drilling equipment or motor-powered drills or percussion rigs. From the point of view of investment costs hand-drilling should be preferred, with percussion rig drilling as a (more expensive) alternative. The hand-drilling method is further discussed in chapter 18.
In Shinyanga the diameter of the borehole is 25 cm. The pvc filter pipe itself has a diameter of 15 cm.

D. *Special application: river well*

In general the river bed consists of sand, which in Shinyanga can have a depth of 1 to 3 metres in the middle of the river. This sand layer is underlaid by mbuga clay which rises up to the surface at the river banks.
Since it must remain possible to reach the pump during the wet season, when

the water level reaches its highest point, the pump must be situated at a sufficiently high level on the river bank.
Due to its low permeability, clay is not a good aquifer. For this reason a special provision should be made to transport the water from the well to the side of the river.
To achieve this, a trench with a width of about 1 m is dug from the middle of the river through the mbuga clay to the bank. The bottom of the trench is at the same level as the deepest lying mbuga clay in the river.
On the bank a standard hole is dug in the clay, one or two filter rings are placed in the lower part and, on top of these, fully concrete rings up to the surface. Then the hole is connected to the trench, after which both the trench and the open space around the rings are filled with sand from the river. On top of the sand in the trench a clay seal should be placed to prevent contaminated water from seeping through the sand into the well. In the method described above, the river aquifer is in fact extended to the well, allowing the water to flow into it.



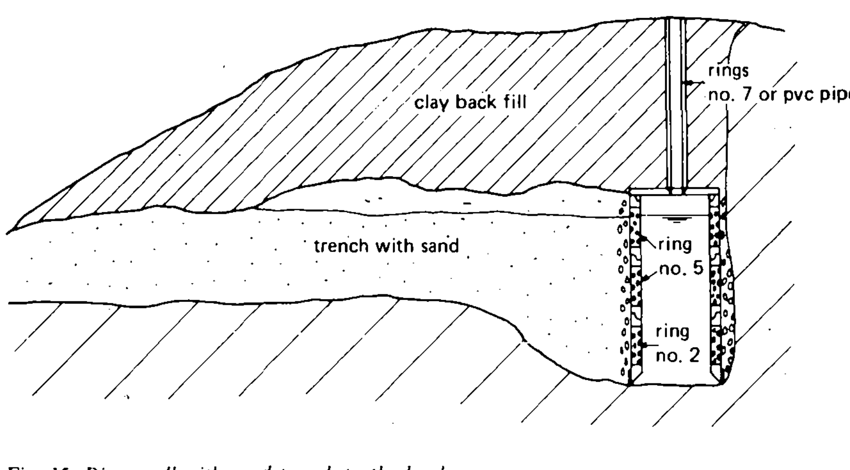


Fig. 15. River well with sand trench to the bank

As an alternative solution a drilled well can be used, situated in the river bank, as the river sand is generally coarse, resulting in a high transmissivity of the aquifer.
Various different methods have been tried in Shingyanga. In one of these the suction pipe of the hand pump was extended to a well consisting of filter rings in the middle of the river (fig. 16). It proved impossible to safeguard this second well sufficiently to prevent it from being washed away, even when the entire construction was buried in the river bed, without any protruding parts. Other alternatives proved equally unfit and/or more expensive and have been rejected in favour of the method described above.

33. River well with trench to the bank

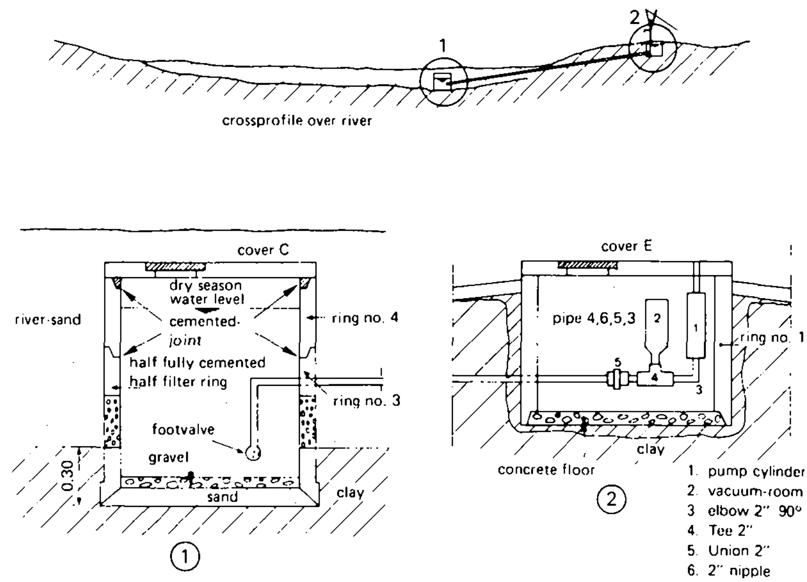


 Fig. 16. River well with rings in river and pipe to the bank

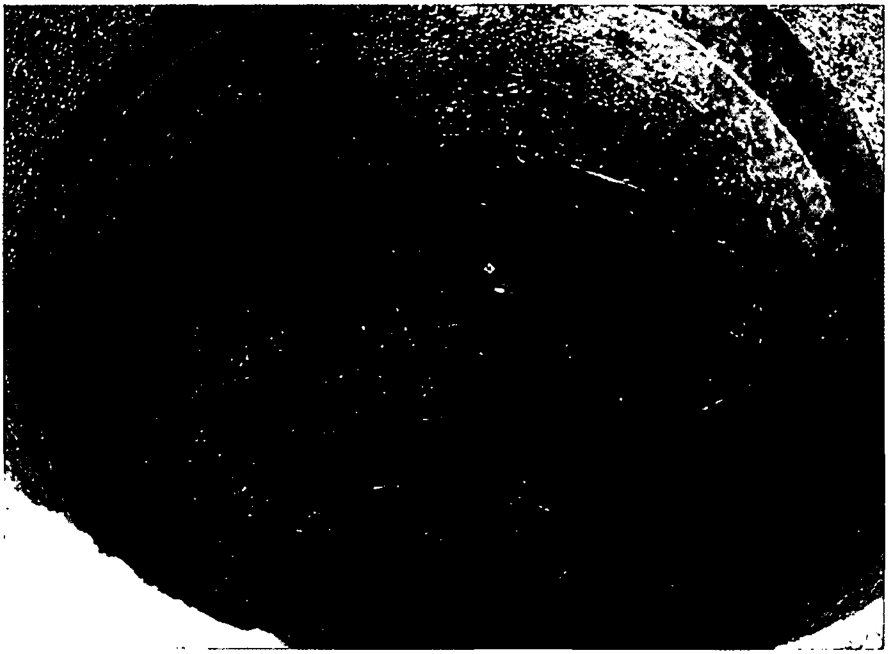
Chapter 16. **Construction of a hand-dug well**

When the final location for the well has been chosen - after careful interpretation of the investigation data - the necessary equipment is brought to the site:

3 spades
3 pointed pick-axes
2 jembe pick-axes
1 heavy hammer (5 kilograms)
2 hammers (2 kilograms)
4 chisels 9″ or 12″
1 bucket with at least 15 m rope
1 tripod with 2-tons winch and pulleys
1 hand pump
1 plumb
1 measuring tape

A circle with a diameter of 1.80 m (6 feet) is staked out with the investigation borehole as the centre. This circle indicates the hole which has to be dug. The earth is removed with spades after the harder soil has first been loosened with pick-axes. The soil is deposited some 4 metres from the hole on the higher side. The lower side will be reserved for draining excess water afterwards. Digging will continue until it is no longer possible to throw the soil out of the

34. Tripod erected over shallow well site



35. Hard soil is loosened with pick-axes first

36. A bucket is filled with soil and pulled up

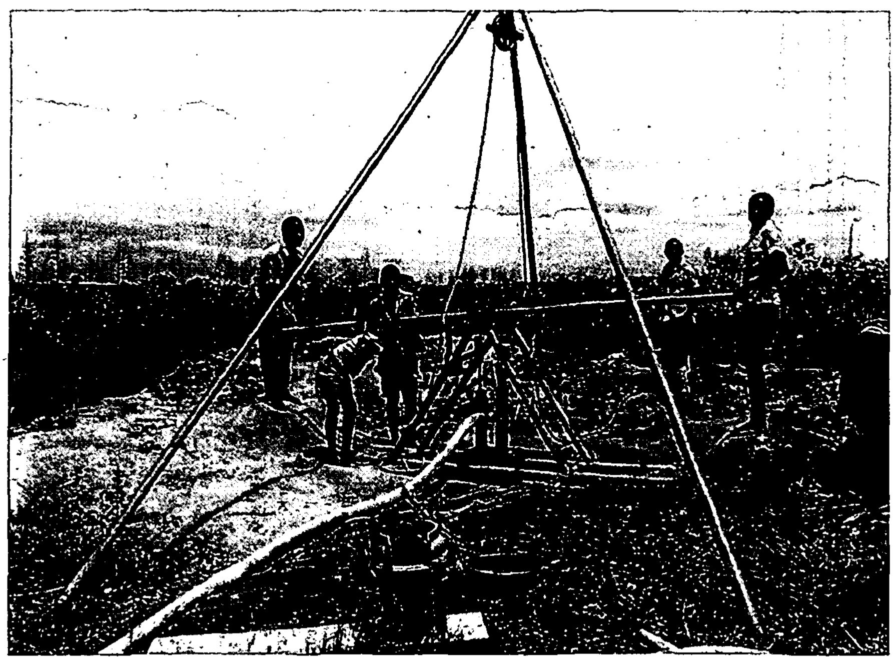
37. A simple but sturdy membrane pump

hole. A small tripod is then erected over the hole, consisting of three 2″ diameter pipes of about 3-5 m length, joined at the top by a bolt. A pulley is fastened to the bolt so that a bucket can be lowered on a rope.
The bucket is to be filled with soil, pulled up, emptied etc.
The vertical alignment of the well is checked with the plumb and line and digging continues until either the desired depth is reached or digging has to be stopped for fear of the hole caving in (in looser soil). In the latter case it is necessary to line the well before digging can be continued.
As soon as water seeps into the hole it must be removed. At first this can be done with the bucket, but as the inflow increases one or more hand pumps will have to be used. A sturdy pump, like a membrane or plunger pump, is preferable as it is less easily damaged by stones and sand than, for instance, a centrifugal pump. A simple but sturdy membrane pump is shown on photo 37. Special attention should be paid to the suction hose which may not be damaged in any way and should have an airtight connection to the pump.
Motor-driven pumps, while facilitating the work, require fuel and increased maintenance and are more difficult to maintain than hand-operated pumps. The membrane pump as shown on photo 37 has to be placed at ground level, which implies that the depth to which the pit can be drained is limited to approx. 7 m below ground level. Thus for larger depths other types of pumps have to be used. In Shinyanga good results have been obtained with hand pumps which are based on the Shinyanga pump as described in chapter 25A. Single as well as double-acting hand pumps are used (see photos 40 through 43). Rising main and pump rod can be assembled in sections, while a flexible suction hose is attached to the pump cylinder. In this way the suction level of the pump can be adapted to the progress of the excavation.

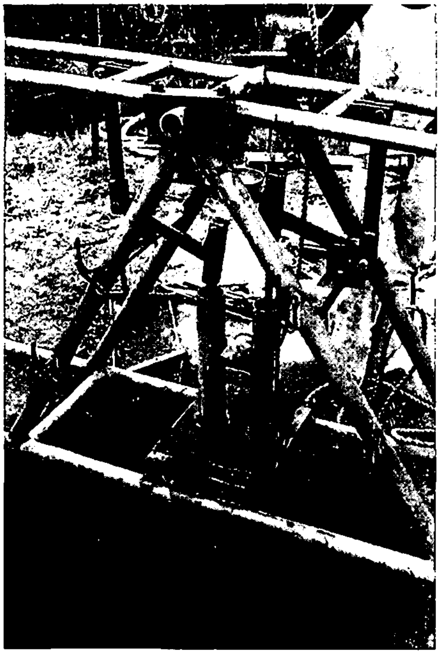
38. Motor-driven centrifugal pump. When the pump is placed above water level the suction hose should be connected air-tight to the pump

39. Electrical plunger pump (right) with generator. For water levels deeper than 7 m below ground level neither this pump nor the one shown on photo 38 can be used

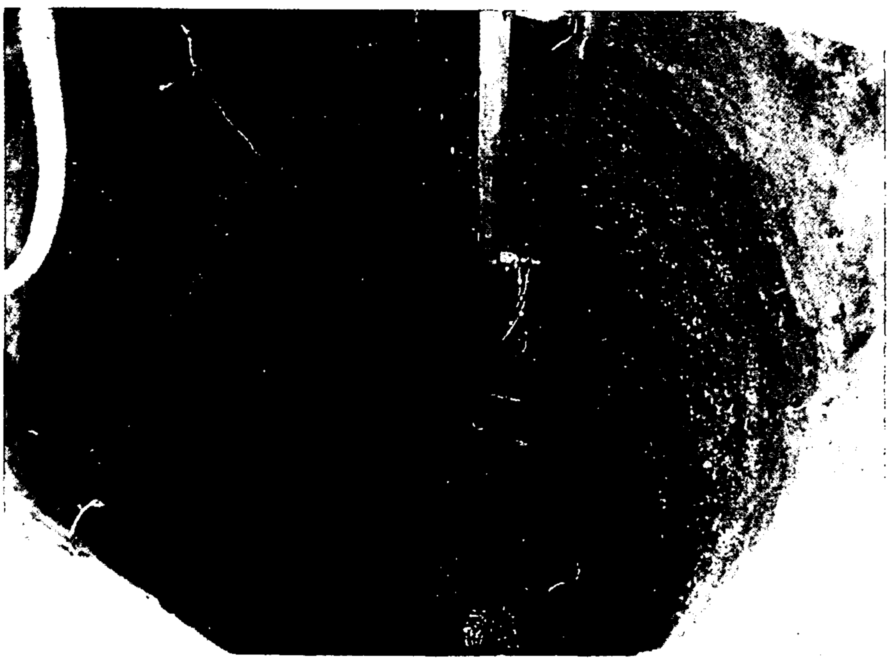
40. Single-acting hand pump. In background frame for positioning pump over well opening is visible



41. Double-acting hand pump, according to principle of old-fashioned fire-fighting hand pump



42. Double-acting hand pump, used during construction of wells (detail of superstructure)



43. Substructure of double-acting hand pump. Note flexible suction hoses which are attached to cylinders (yellow)

A. *The depth of the shallow well*

In Shinyanga Region the depth of a well, which is theoretically not restricted, is limited to a maximum of about 10 metres for practical reasons.
In general the depth is governed by the required storage capacity necessary to provide water for 200 to 300 people. This water is drawn during certain times in the morning and evening, so peak-storage is required.
Two other possibly limiting factors for the necessary storage capacity are the discharge capacity of the aquifer and the capacity of the pump mounted on the well.
The pump used in Shinyanga Region has a capacity of about 1.2 litres per stroke. However, the replacing and cleaning of buckets restricts the net pumping time. Experience has taught that a storage of about 3 m^3 is sufficient in Shinyanga Region circumstances.
For the depth required in these circumstances the following two general guidelines can be given.

1. The depth is sufficient when the empty hole is recharged to a water depth of about 3 m after one night.
2. In principle digging must go on right through the aquifer down to the next solid layer. For example, when going through an aquifer which consists of sand, digging should be continued to at least about 30 cm into the underlying clay, or other solid layer.

Practical reasons for accepting a limited depth, as exception to the rules given above, are:

- The capacity of the aquifer is not sufficient to recharge the well with at least 3 m^3 during one night. In such a case, a storage capacity equal to the overnight discharge capacity of the aquifer is sufficient. In fact the well is deep enough when the water level in the hole reaches the original water level after one night of recharging. However, a well with a storage capacity of less than 3 m^3 is considered an unsuccessful well and should be abandoned. A proper well test with a pump would have prevented the choice of this location.
- The capacity of the aquifer is larger than the capacity of the pumps (e.g. plunger pumps) which are used to empty the hole during digging. When the available pumps are not able to lower the water level in the hole sufficiently so that digging becomes impossible, the well can be finished with the reasonable certainty of meeting the recharge and storage requirements (see photo 44).

B. *Completion of the well*

When the necessary rings, a well cover, some 8 bags of cement, and a load of sand and gravel have been delivered at the well site, the well construction can be completed.
In Shinyanga Region concrete rings are used to line the wells. Since their weight is about 1200 kilograms their handling needs special attention; this is discussed in chapter 21.
The first ring to be sunk (the cutting ring) is rolled to the well and on top of the 5.50 m sling, which is then fastened around somewhat higher than the middle of the ring but nog higher than about 30 cm (1 foot) below the ring edge. The tripod has been positioned in advance next to the well opening, the tackle cable hanging about 1 metre from the edge of the hole. The ring is

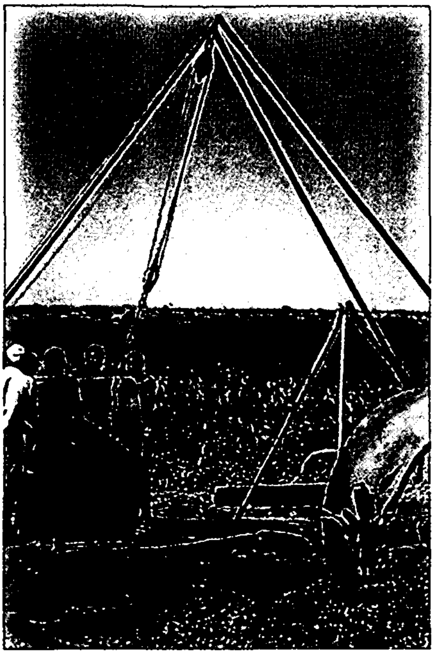
44. Well with excessive recharge. Two pumps are used to remove the water (see suction hoses at left)

rolled to a position 1.50 m from the well edge with its top facing the opening of the well. Next, the ring is pulled slightly upwards and thus moved slowly to the edge of the well opening, hanging somewhat askew due to the eccentric position of the sling.

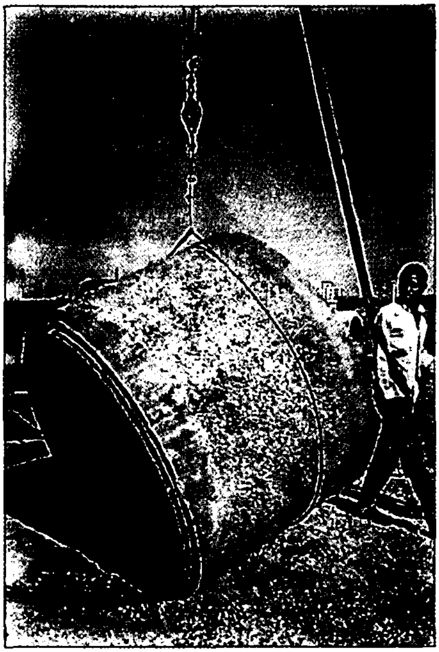
The bottom of the ring is now man-handled towards the edge of the well, while at the same time the tackle is pulled away from the well and the tackle rope is paid out. During this operation the ring must be carefully guided to prevent it from turning sideways, thereby pulling the tripod down. From a standpoint behind the winch the tackle cable must be seen to hang exactly between the two pipes of the double leg to which the winch is fastened.

Thus the well ring is put in a horizontal position right next to the well. The position of the tripod is now changed in such a way that the tackle is exactly over the centre of the hole. Then the 7 m long sling is fastened around the ring again, as described before. A rope is attached to the pulley hook and by pulling the tackle cable upwards, at the same time paying out the rope, the ring is carefully hoisted into position over the well. It is essential that the guide rope be attached to the hook of the tackle. The ring will be pulled askew if the guide rope is fastened around the ring, and this will prevent it from being lowered properly. Now the ring, hanging horizontally above the well, can be lowered to the bottom of the well or stacked on top of a ring already placed.

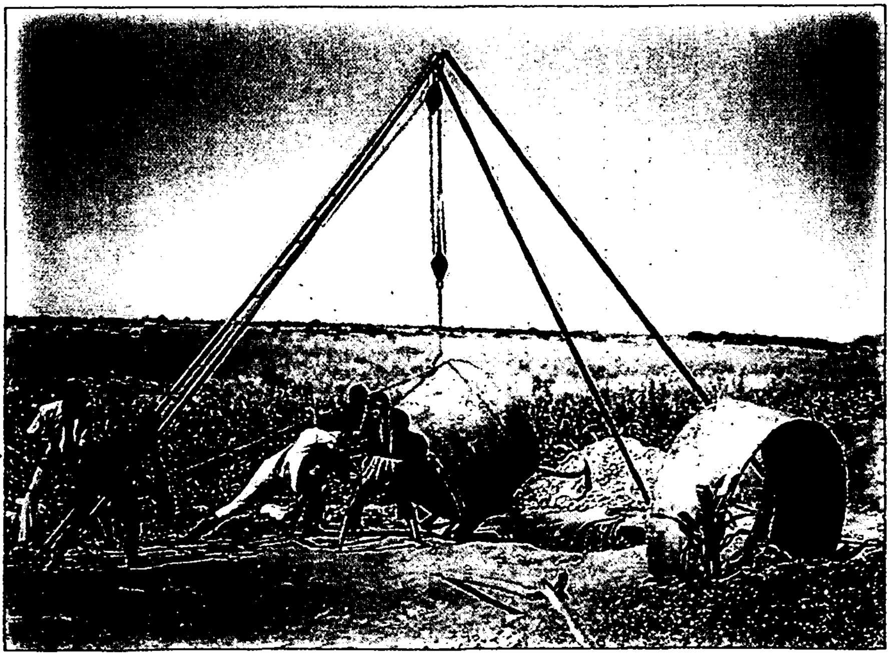
When lowering a cutting ring or first ring, its position is checked with a water level after it has reached the bottom. If it is not exactly horizontal, the ring can be lifted slightly, some soil removed from underneath, etc., until it is exactly level.



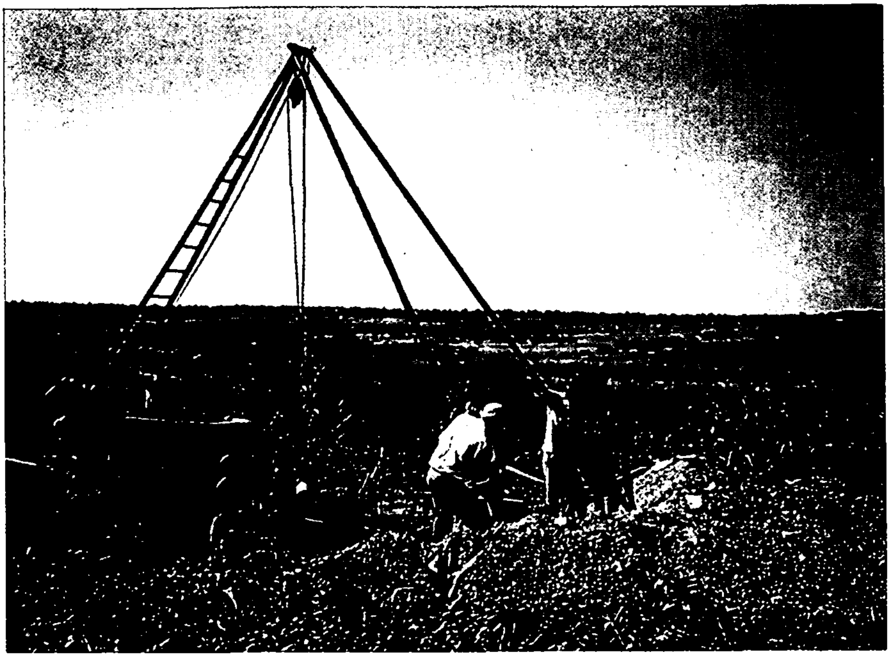
45. A concrete ring is rolled to the well and the 5.50 m sling is fastened around it. The tripod is positioned next to the well opening



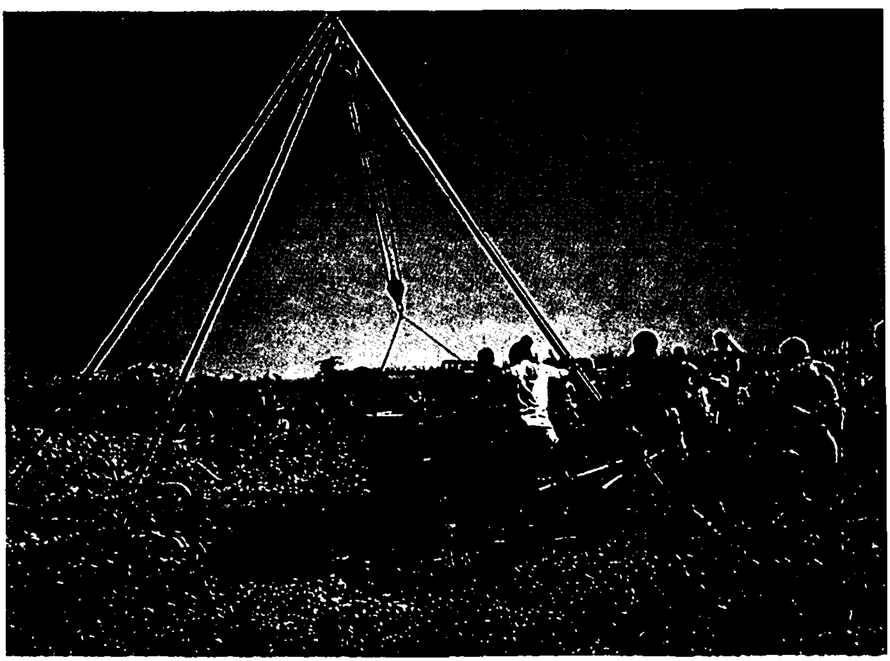
46. The ring is pulled up (eccentrically) and turned over



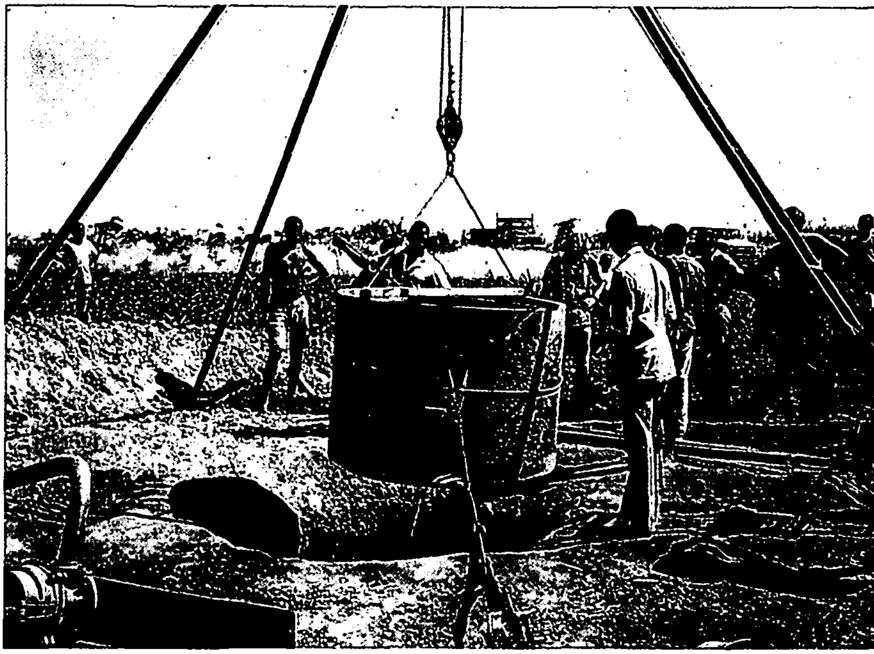
47. The bottom of the ring is pushed towards the well edge and the tackle rope is paid out, until the rings rests on the ground in horizontal position



48. The tripod is repositioned so that the tackle is exactly over the centre of the well

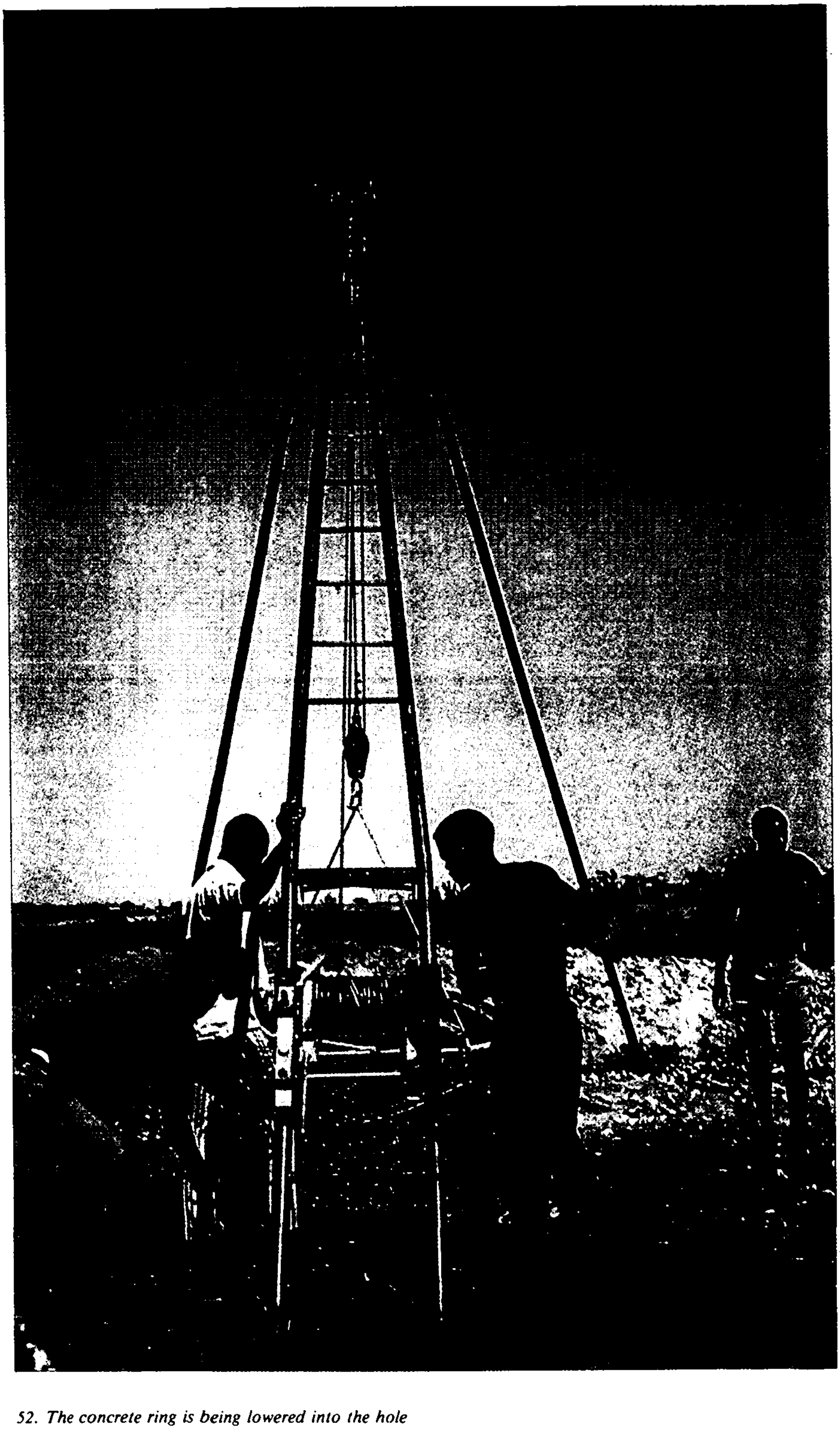


49. The ring is hoisted into position over the well

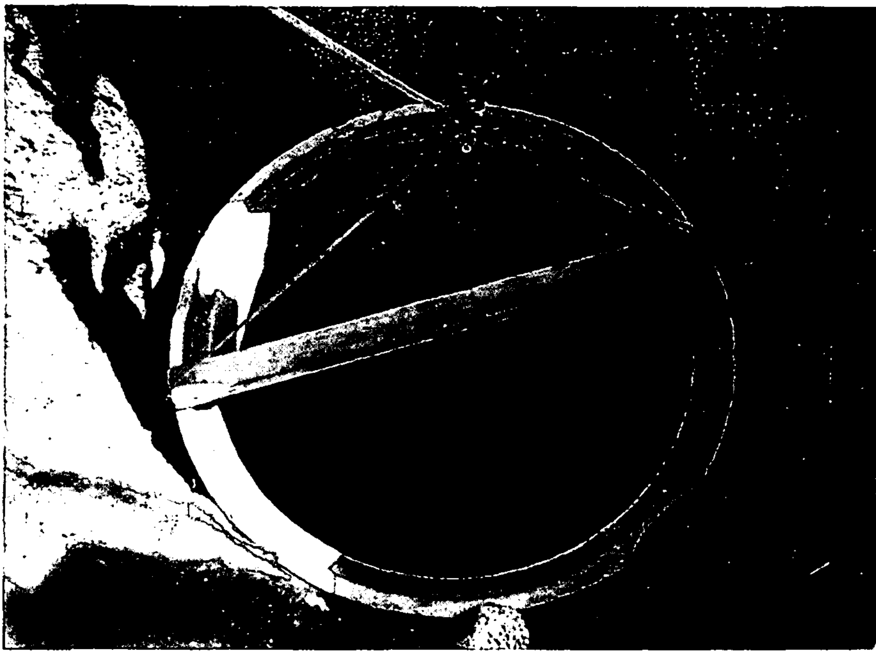


50. The ring is hanging horizontally: ready to be lowered

51. The guide-rope around the ring is repositioned to prevent askew lowering



52. The concrete ring is being lowered into the hole



53. The result

The lowest rings, up to just above the aquifer, are so-called filter rings, with walls of a high permeability to enable the water to flow into the well. Above the aquifer the ring walls consist of mass concrete and the ring joints are closed with cement to prevent contaminated surface water from entering the well.
If the depth of the hole does not match a whole number of rings, a top ring with a height of 50 cm can be used.

The bottom of the well is finished off with a sand and a gravel layer, both with a thickness of about 10 cm, to filter water which possibly flows into the well from underneath the rings (fig. 17).
A cover, with cast-in bolts to fasten the pump, is put on top. The cover should be positioned in such a way that the pump hole is at the downward sloping side of the well. The connection between cover and ring should be sealed with cement mortar.
Then the space between the undisturbed soil and the outside of the filter rings is filled with coarse sand up to the upper boundary of the aquifer. Some concrete is poured on top as a seal against seepage of contaminated surface water into the well.
The remainder is filled up with earth.
A concrete slab with a width of about 1.50 m is then cast around the well cover. The thickness of the slab is increased at its edges to offer more resistance to damage, and the edge is embedded in the ground.
A small platform is built under the pump opening, to facilitate the placing of buckets under it.
To drain the spill water properly, a gutter is created by constructing two sills on

the concrete slab, which run towards one another to form a lip at the edge of the slab. From there a small drain can be dug.
Finally the pump can be mounted and after the disinfection of the well everything is ready for pumping the water for public use.

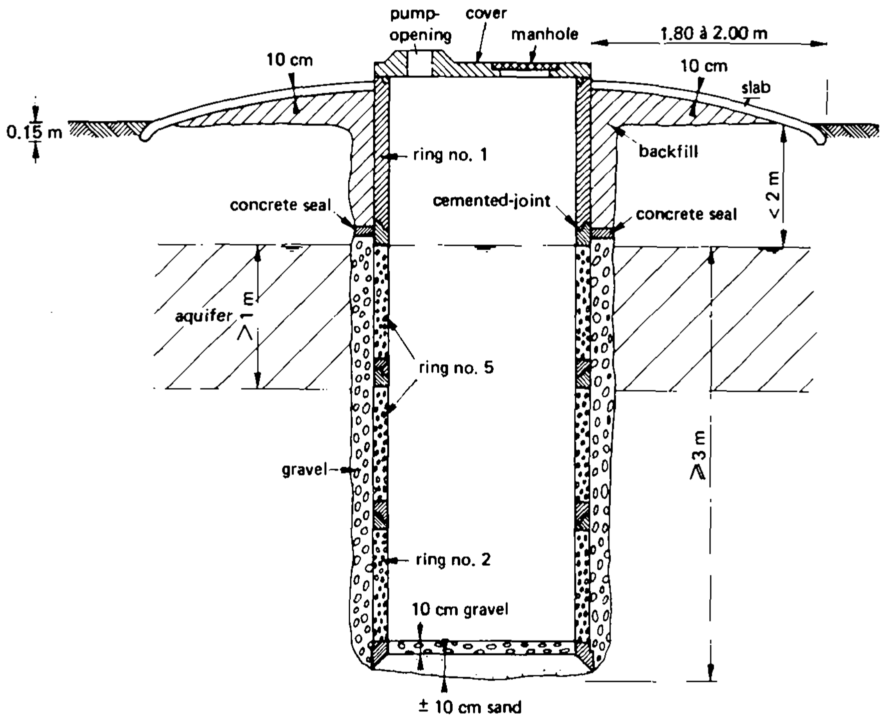
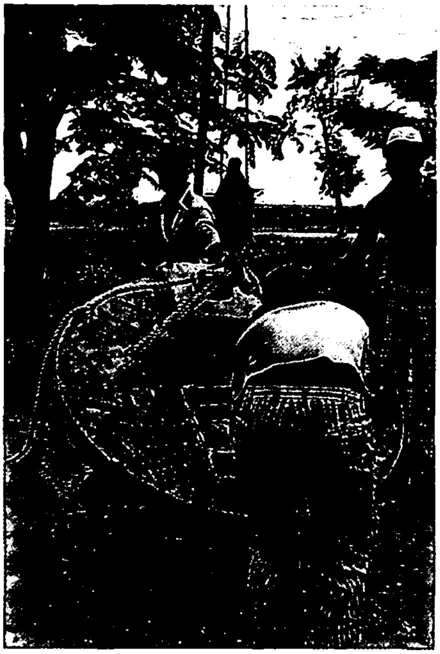


Fig. 17. Standard well (type A)



54. The cover is put on a completed well (here with concrete block masonry)

55. A watertight connection is made between well rings and cover

C. *Wells in loose soils*

In well construction, good sites are often found in areas overlaid with sandy soils and in old riverbeds. When a hole is dug in these soils it is not possible to maintain vertical walls, due to the inconsistency of the sand which will cave in till its natural slope, about 30°, is reached. Digging a hole to a depth of 5 to 10 m with walls under such a slope would require an enormous amount of extra digging. To overcome this problem the sequence as employed normally in Shinyanga, namely digging a hole and lowering the concrete rings afterwards, is replaced by simultaneous digging and sinking of the rings. In this way the hole is immediately lined and caving in of its walls is prevented.
This method - which is described in detail below - should preferably be avoided in view of the difficulties to be expected. When the transmissivity of the aquifer is sufficient, drilled wells should be constructed in these situations.
The sinking procedure is as follows:
A filter ring with cutting edge is put around the investigation borehole. Digging is started inside the ring which lowers itself as the sand is dug away underneath the cutting edge. When the ring has been completely lowered into the ground another ring is stacked on top of the first one. Digging inside is continued and rings are stacked upon each other till the required well depth is reached.
A carefully prepared borehole description is very important since this should give the necessary information about the total number of rings to be lowered, and about how many of them must be of the filter type and how many of the fully concrete type.

D. *Difficulties to be expected*

If the above described method of digging and lining the wells simultaneously is adopted, some specific difficulties may be encountered, depending on the geologic features of the site.
If digging has to be done in sand, with its loose character, a serious problem can occur when the well has reached a depth of about one metre below the natural water level. By then, the difference in water level in and outside the well causes a high entry velocity of the water coming into the well underneath the cutting edge of the lowest ring (fig. 18). Considerable amounts of sand enter the rings with this water and, in the case of fine or medium sand, stream inwards as quicksand. The quicksand can sometimes fill up the whole lower ring within a few seconds. The higher the difference between the outside and inside water level, the more serious this problem becomes, and consequently, the more difficult the digging and sinking of rings becomes.

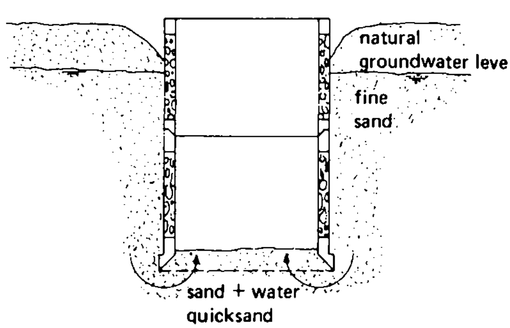
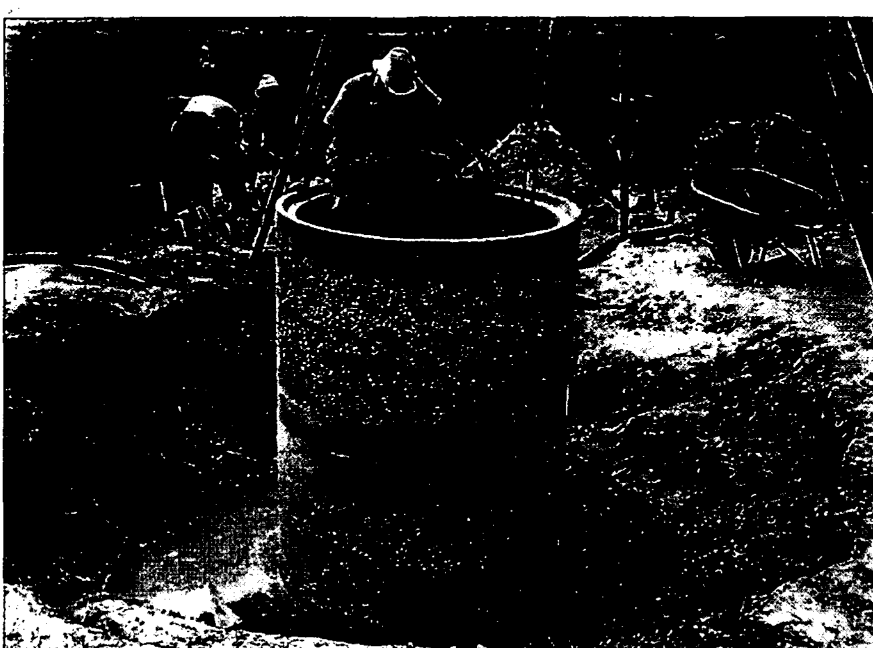


Fig. 18. Entering of sand and water underneath the cutting edge

Experience has taught that one should not try to construct a well in a layer of fine or medium sand that is more than about 3 metres thick, since at this depth it is no longer possible to continue digging against the sand entering from underneath, which means the rings cannot sink any farther.
It is always required that the lowest ring is founded at least 30 cm into any stable layer like clay or weathered bedrock, in order to prevent the sand from entering the completed well.
For these reasons a shallow well should not be sited at a place where a loose layer of more than 3 metres must be dug through, unless drilling is possible. Sand entering the well underneath the cutting edge of the lowest ring has the side effect that the surface around the rings caves in (photo 56).
This does not raise extra problems as long as the tripod can be erected over the hole to stack the rings on top of each other. When the threat of more caving in appears to make this impossible, all the necessary rings should be stacked on top of each other in advance, even if this means stacking above ground level. Information about the total number of rings to achieve the final required depth comes from a proper borehole description. It is advisable to add one ring to this total number to be on the safe side.

Another effect resulting from the above described features is the setting of the sand around the rings, building up pressure against the ring walls. The more time the sand has to set, the higher the pressure against the ring walls will be. If digging and lowering the rings is continued after a period in which this setting could take place, the following situation may be encountered.



56. Cave-in of sand around the rings

Firstly, due to the ground-pressure the friction between the rings and the walls increases so that, although the lowest ring sinks when digging is restarted, the others do not follow, leaving a gap between the lowest and the other rings. Sand may enter through this gap. Usually after a while the upper rings will sink, however not always exactly on top of the lower one. The gap which is left should be closed with cement. The second effect is the sudden entry of masses of sand due to high ground- and water-pressure. The water and sand turn into quicksand when shaken by the restarting of digging and sinking.
A possible way of preventing all this is to connect all rings together before sinking, by means of hooks and chains (see fig. 19).
When a well is to be constructed in a thick layer of fine to medium sand a digging tactic should be designed carefully on the basis of the borehole description. If this is done properly much extra work can be prevented.

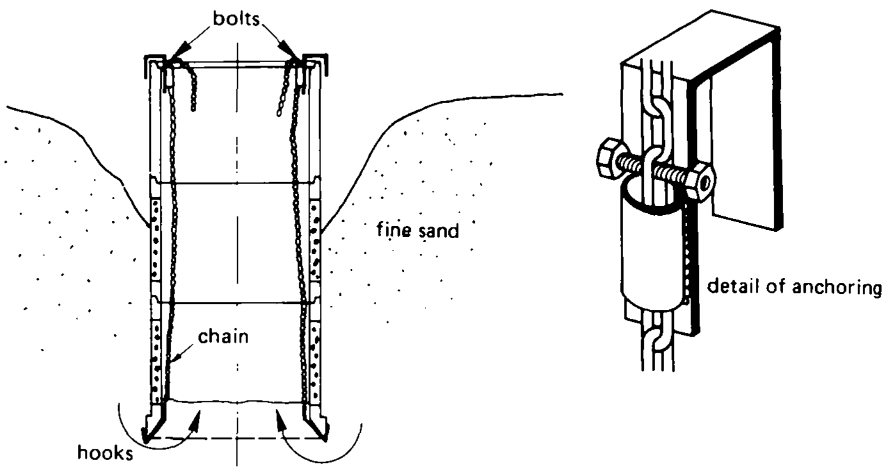


Fig. 19. Preventing uneven setting of well rings

For example, a well is to be dug through a layer with a thickness of 3 m of fine sand, with the water level at a depth of 0.5 m. The sand layer is underlaid by clay.
Digging in sand can achieve a maximum depth of 2 metres per day. For digging through a layer of 3 m the following sequence of digging and sinking is suggested.
The first day, one filter ring with cutting edge is lowered carefully with the least possible shaking of the surrounding soil. After this, everything is prepared for the lowering of two other rings, one filter ring and one fully concrete ring.
Next day these rings are lowered in one day till the clay is reached. The disadvantages of shaking the ground, which may cause an increase of the amount of sand which enters the ring underneath, are thus kept to a minimum. If two rings are placed on the first day, there is a real chance that the lower ring will suddenly be filled with quicksand when digging is restarted after a night in which setting and building-up of ground pressure could take place, and it will be very difficult to get the last ring into the ground.
It is important to dig as much as possible without removing the water from the

hole. When digging becomes impossible, remove only as much water as is absolutely necessary.
Next day, after the clay layer is reached, digging and sinking should be continued till the rings are lowered at least 50 cm into the clay, this in order to provide the required storage (3 m below the water level in the aquifer, i.e. the sand layer).
The problem can be partly avoided by first sinking a steel casing, smooth at the outside, of a diameter larger than the rings. Due to its thin cutting edge the steel casing will sink easier. Once it is dug into the stable layer underneath the sand the concrete rings can be put in position. A filter pack is brought in and the steel casing is pulled out by means of jacks which are supported by beams on top of the rings (fig. 20). Filter material or backfill is added during the pulling out of the steel casing.

In coarse sand the quicksand problem does not occur. Furthermore the transmissivity will be high enough then to warrant the construction of drilled wells.

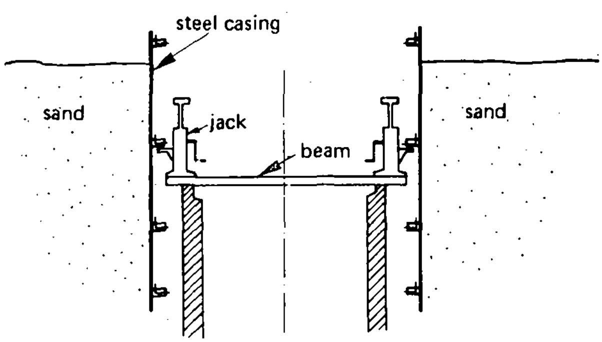


Fig. 20. Removing steel casing with jacks.

In the Shinyanga Region one district often showed alternating layers of fine sand and thin layers of clay. The caissonning method as described above and especially the difference in water pressure inside and outside the concrete rings caused the sand to be washed away from between the clay layers. The latter then caved in thereby closing off the aquifers (fig. 21). In situations like this the well has to be finished quickly, for instance with the use of the steel casing mentioned above, and preferably a construction method should be chosen which does not result in a lowering of the water table inside the well, e.g. by using hand-drills, percussion rigs, etc. Even then it may still be advisable to add some water to the well during operations, thus increasing the water pressure inside the well, and preventing sand from being washed into the well.
The occurrence of a sandstone layer in or under the sand layer may influence the number of filter rings to be used. Sandstone can be a very good aquifer. Often it acts as a sort of collector drain in the sand layers. If a clear indication of the existence, depth and thickness of a sandstone layer can be derived from a borehole description of a well site, it may be advisable to use a filter ring in the well only at the depth of this layer. In this way all the water is forced to pass the sand layer before being collected in the sandstone layer and entering the well. The result is very clean water in the well.

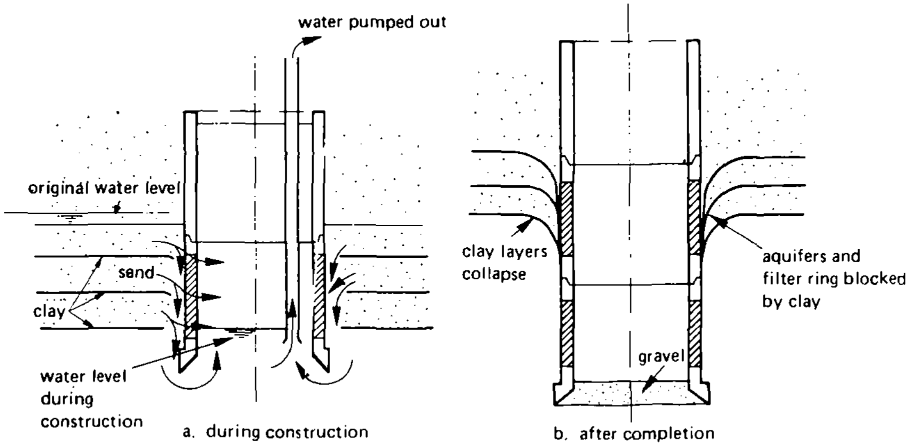


Fig. 21. Blocking of aquifer and filter rings by collapsed clay layers.

A general problem in sinking concrete rings in loose soil is the chance of sinking askew. There are various reasons for this.
If the hole caves in more on one side of the rings than on the opposite side, the result will be different ground pressures at both sides, which may cause sinking askew.
As long as the rings have not sunk more than about 2 metres, correction of the askew position can be attempted. If the consistent layer (clay, weathered bedrock) is not too deep (approximately 2 m) the best way is to dig as fast as possible without pause until firmer layers are struck. If, however, the clay, quartzite or bedrock is at greater depth an attempt can be made to correct the position of the rings as follows (see fig. 22).

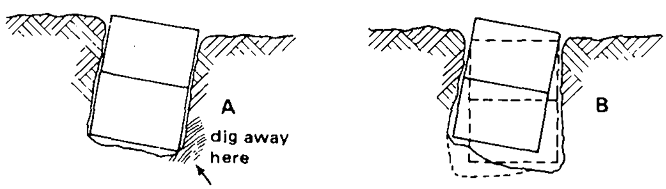


Fig. 22. Correction of askew well.

If the rings are in the position indicated in fig. 22A, the soil is dug away as much as possible at the highest side of the ring, extending halfway around the ring. Then the digging is continued on the lowest side trying to have the sand cave in on that side as much as possible. Thus a partial cavity is formed which may allow the ring to be returned to the vertical position.
After more than two rings have been lowered into the sand, it is hardly possible to correct the slant of the rings.

Sinking askew can also occur when a harder or stiffer layer than the sand layer is reached, and this layer is not completely horizontal.

The ring sinks easily - more or less by its own weight - in sand, whereas in the more consistent layer sinking can only be achieved by digging away underneath the cutting edge.
In such a case digging should concentrate on the consistent layer while the ring sinks by itself through the sand. This way of digging must be continued till the whole cutting edge is dug into the consistent layer. Such a layer may consist of sandstone which sometimes occurs as a thin layer within the sand layer or on top of the clay or weathered rock underlying the sand. It also may be clay, calcrete, laterite or bedrock.

However, when for one reason or another the rings are sunk askew, the well cover on top of the upper ring must always be laid down horizontally, since this is going to support the pump and people will have to stand on top of it. This can be achieved by cutting the edge of the upper ring horizontally. The cover should never be positioned horizontally by means of building up the edge of the upper ring with fresh concrete, because such concrete will shrink and crack, resulting in loosening of the cover. Contaminated spill water may enter the well through the openings created in this way. When placing the cover, the pump-hole in it must be so positioned that when the pump is mounted, the rising main with the cylinder does not touch the concrete rings.
The pump itself is installed in such a way that the spill water can be drained away at the lower side of the pump platform, so it does not flow around the well, thereby making the surrounding area muddy.
No serious difficulties will be encountered in finishing a well constructed under the circumstances described above.
To prevent setting of the backfill in the hole around the rings created by caving-in, the soil should be soaked sufficiently during filling.
Finally, in case for one reason or another the consistent layer is not reached - because of the impossibility of sinking the rings any deeper with the available tools - but sufficient water is flowing into the well, it may be decided to complete the well anyway. This can be done by pouring a thick layer of gravel onto the bottom of the well. However, there will always be the possibility of sand entering the well from underneath, filling it up to such a height that the pump cannot be used anymore, because the cylinder is full of sand.
It is advisable not to complete such a well till the concrete rings are fully set, which may take as much as a year. Meantime the well can be used as an open well with an extra (half) ring added to prevent accidents.

Chapter 17. **Construction of hand-dug wells in limited numbers**

If one or only a limited number of wells have to be constructed, investments should be kept down as much as possible. No separate survey groups will be established, but surveying and construction are executed by the same unit. Survey equipment is reduced to a lightweight set with two bits only: an open clay auger, possibly with flaps for gravel, and a riverside bit. Where casing would normally be used, it is best to just dig and see in this case, as purchasing the full survey set would increase costs too much.

Two main types of construction are important:

1. construction in soils which show a tendency to cave in (running sands)
2. construction in non-caving-in soils

The latter solution should be chosen where possible.

A. *Construction in caving-in soils*

When caving-in occurs from the beginning it is imperative to sink the lining (caisson method). Rings are constructed and sunk by digging inside them. Sinking should be continued as long as possible. When the amount of water entering the well makes further digging impossible, construction is stopped temporarily and resumed in the dry season (see chapter 15, B).
Construction of the ring may be done in a way similar to that described in chapter 21, with a simpler - and as a consequence less durable - set of moulds. Moulds are made of 3 mm thick mild steel sheets, with a height of approx. 60 cm. The diameter of the moulds can be the same as described in chapter 21, i.e. 1.25 m external diameter for the inner mould, and 1.45 m internal diameter for the outer mould. The sheets are bolted together, whereby the nuts are welded on the concrete side and the bolts screwed in from the other side. Bolts should not protrude from the nuts on the concrete side. Threads should be as coarse as possible.
The sheet metal of the inside mould can be shaped by means of rolled angle or channel iron (e.g. 25 × 25 × 3 mm angle iron) inside the sheeting, preferably with a cross piece. The angle irons forming the cross piece should be lapped and bolted together in pairs to facilitate dismantling (see fig. 23). The rolled angle or channel iron can be butted, and fixed with a strap and two bolts.

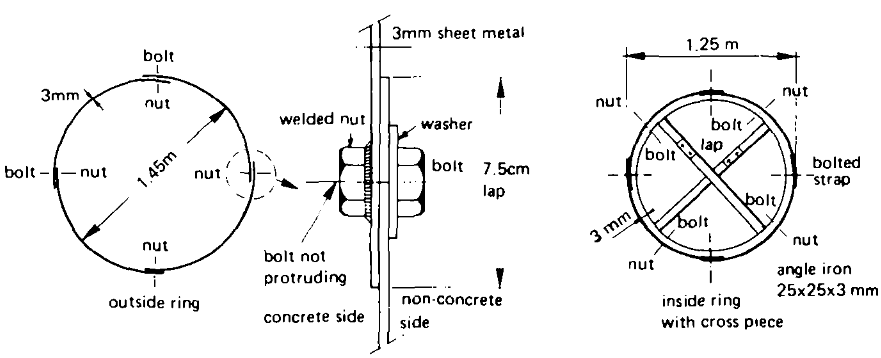


Fig. 23. Details of simple mould for concrete rings.

Pouring concrete into the mould has to be done carefully, a little at a time, no more than 10 cm at a go, taking care that the distance between the inner and outer mould is the same all around. The higher the concrete comes, the more stable the sheets will become. Concrete should *not* be poured on one side only without taking care of the other. A degree of skill will soon be obtained, however.

After one night standing the sheets are loosened, cleaned and fixed again and put on top of the first ring. To facilitate fitting small pieces of angle iron can be welded on the concrete side of the sheets, to rest on the concrete of the finished ring (see fig. 24). The new ring is poured on top.

The next day only the outer mould is removed and, with the inner mould in place, the concrete rings are sunk by the caisson method until the upper rim of the topmost ring is approx. 15 cm above the ground. Then the next one or two rings are cast, etc.

In the way described here, full concrete rings as well as filter rings can be made, similar to the ones described in chapter 21, A.

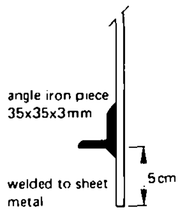


Fig. 24. Auxiliary angle iron supports.

B. *Construction in non-caving-in soils*

When the soil does not show any tendency to cave in, first the well is dug, after which a lining is put in. This lining can be made in the same way as described for caving-in soils, by making concrete rings at ground level and lowering them into the well, or by lining in situ. In the latter case there are again several possibilities. Concrete rings can be cast in situ, by using only the inner mould mentioned above. Bricks or cement blocks can be stacked along the circumference. At the aquifer level the bricks/blocks should be stacked without mortar, taking care that the vertical joints are firmly together and that the space between the stacked bricks and earth wall is filled with coarse sand which is well watered down in layers not exceeding 30 cm.
As soon as the top of the aquifer is reached the bricks/blocks are mortared into place, to seal off any spill water. Between the mortared blocks and the earth wall a concrete ring is cast (approx. 25 cm thick), the space above which is filled back, preferably with clay, well tamped down at 30 cm-intervals. In the case of a deep-lying aquifer it is possible again to reduce the quantity of lining materials by reducing the diameter of the upper part of the lining (see fig. 25).

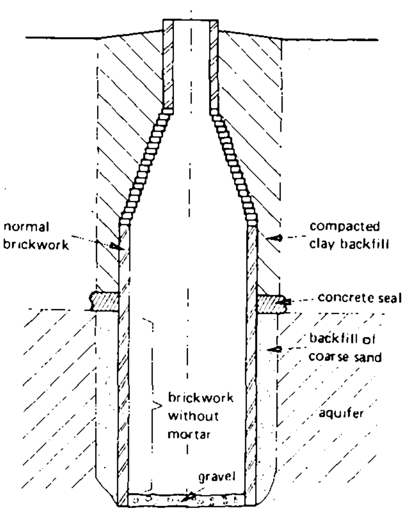


Fig. 25. Well with in-situ brick lining.

Chapter 18. **Construction of a hand-drilled well**

The average cost of a hand-drilled well with a diameter of 25 cm is approximately two-thirds of that of a hand-dug well of 1.25 m internal diameter. Since the transmissivity of the aquifer is often high enough to warrant a drilled well, the possibility of hand-drilling wells should be checked before embarking on hand-digging. The hand-drilling equipment used in Shinyanga enables drilling 25 to 30 cm dia. boreholes by hand to depths of 15 to 20 metres. In clay and sandy soils the process is relatively easy. If gravel and small stones are found, and in semi-cemented layers such as soft sandstone, weathered granite and weathered laterite, hand-drilling is still possible, though rather time-consuming. In layers with big stones and boulders and in heavily cemented soils hand-drilling is not possible.

A. *Hand-drilling equipment*

In Shinyanga 2 sizes of drills were used, with 30 and 23 cm diameter respectively. The 30 cm dia. drills were used without casing, while the 23 cm diameter drills were used inside a 10″ (25 cm) dia. casing.
A full set of hand-drilling equipment comprises the following:

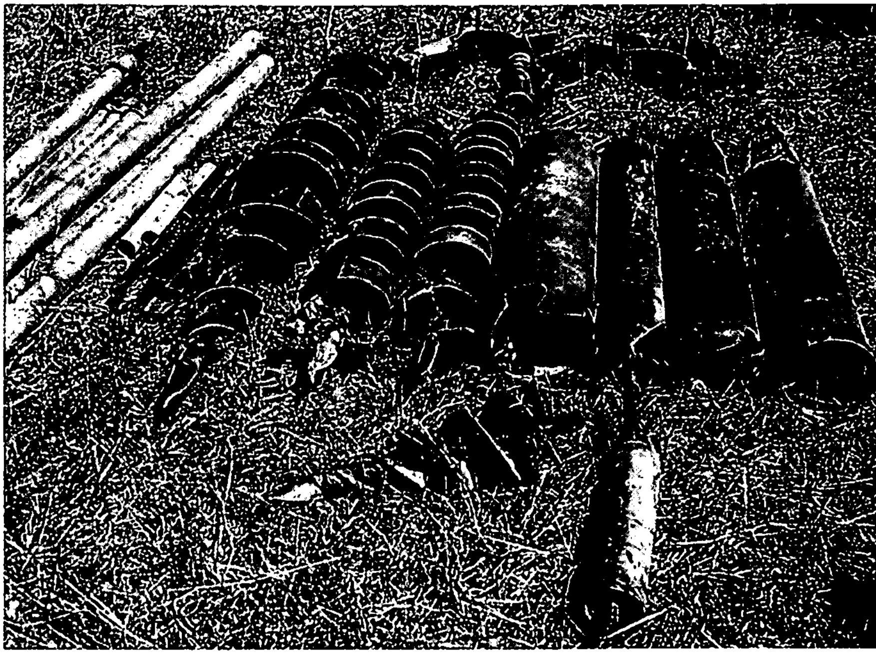
- heavy cross-piece with 4 handles and hexagonal shank/socket couplings
- various extension rods of 0.5, 1, 1.5, 2 and 3 m lengths
- auger bits of 30 cm dia. and 23 cm dia.
- conical auger bits of 30 cm max. dia. and 23 cm max. dia
- continuous flight augers of 30 cm and 23 cm dia.
- riverside bits with hinged flap, of 30 cm dia. and 23 cm dia.
- sand bailers of 20 cm dia. and 18 cm dia.
- casing pipes of 25 cm internal dia. with separate cutting ring, casing clamps, etc.; casing pipe made of steel or glass fibre-reinforced polyester, of 1.25 m length
- steel tripod with one double leg, winch, pulley-blocks, steel cable, etc.
- toolset, incl. pipe wrenches, cutters, spanners, level, jacks, etc.

The cost of a complete set, ex-Morogoro Wells Construction Project workshop (Tanzania) is approx. TShs 105,000 (US$ 13,125).

Auger of 30 cm dia.: Normally drilling is started with the 30 cm diameter auger bit. Connected to this bit is a continuous flight auger to increase the soil storage capacity and support the auger bit in the hole. A 10 cm high rim is welded to the outer edge of the flights to increase the capacity of lifting sandy materials from below groundwater level. Again centering the drill in the borehole is improved hereby and damage to the borehole walls is reduced to a minimum. This auger set is especially suited for moist clay and sand, and also for gravelly soils.

Auger of 23 cm dia.: is used, again in combination with a continuous flight auger of the same diameter, to drill through clay, and gravelly clay, inside a casing.

Conical auger bit is used in stony, layered soils. Its relatively small point allows it to progress in situations where a regular auger bit is stopped, and the layered material is 'screwed' loose. Again the bit should be attached to a continuous flight auger for support.



57. Hand-drilling equipment. From left to right: extension rods, continuous flight augers with conical and normal auger bits, riverside bits and bailers

Riverside bit is used in hard, dry clay and in gravelly soils, as well as in semi-cemented layers. This bit only cuts at the outside, leaving the soil collected in the inside practically undisturbed.

Bailer is used especially for lifting sand from below the groundwater table. Generally this will be done in combination with a casing. The bailer, hung from a steel cable attached to the pulley block of the tripod, is deposited on the bottom of the borehole. Next the cable is pulled away horizontally by means of a long rope, the bailer is thus lifted over approx. 1 m, the rope is released and the bailer dropped. This sequence is repeated until the bailer is full. The bailer is removed from the borehole, emptied, and the entire operation repeated. During bailing the water level inside the casing should not be lower than that outside, to prevent sand from being washed in. For the same reason the diameter of the bailer should be relatively small, in order to prevent excessive suction inside the casing. Thus a 18 cm dia. bailer is used inside the 25 cm internal dia. casing. A 22 cm dia. bailer proved to cause too much suction in this case.

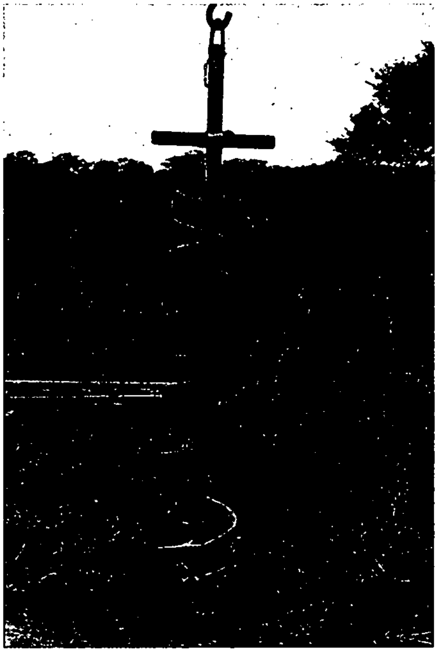
B. ***Hand-drilling procedure***

The tripod, placed on oversize foot plates, is erected over the well site. Then the following drilling equipment is assembled: one 30 cm dia. auger bit + continuous flight auger + cross piece. The assembly is hung from a cable attached to the pulley block, and the four handles (5 cm dia. pipe) are connected to the cross-piece. Then 4 to 6 people screw the drill down over approx. 0.40 m. The drilling assembly is then lifted by means of the tripod-mounted winch and the

soil material is removed from the auger. This sequence is repeated, while extension rods are added with increasing borehole depth. When the soil gets harder the riverside or conical auger bits are used. Often the most successful way is to use the various bits alternately.
When the total length of extension rods exceeds 5 m a continuous flight auger has to be inserted half-way, in order to centre the drilling rod.

As soon as sand is struck below groundwater level the borehole will tend to cave in and a casing has to be inserted. The first casing pipe has a cutting ring at its underside. The water level inside the casing is raised - whenever possible - to some 50 cm over normal groundwater level and bailing is started. When the bailer is lifted, the casing pipe is turned around and vibrated, to let it sink vertically.

When clay is reached again, bailing is stopped and drilling is continued inside the casing, with 23 cm dia. bits, until the desired depth is reached.



58. Auger bit, continuous flight auger and cross-piece hung from the pulley

59. Handles are attached to the cross-piece

60. Drilling is started

61. The full auger is pulled up . . . .

62. . . . . and pushed away from the borehole opening . . . .

63. . . . . to remove its contents

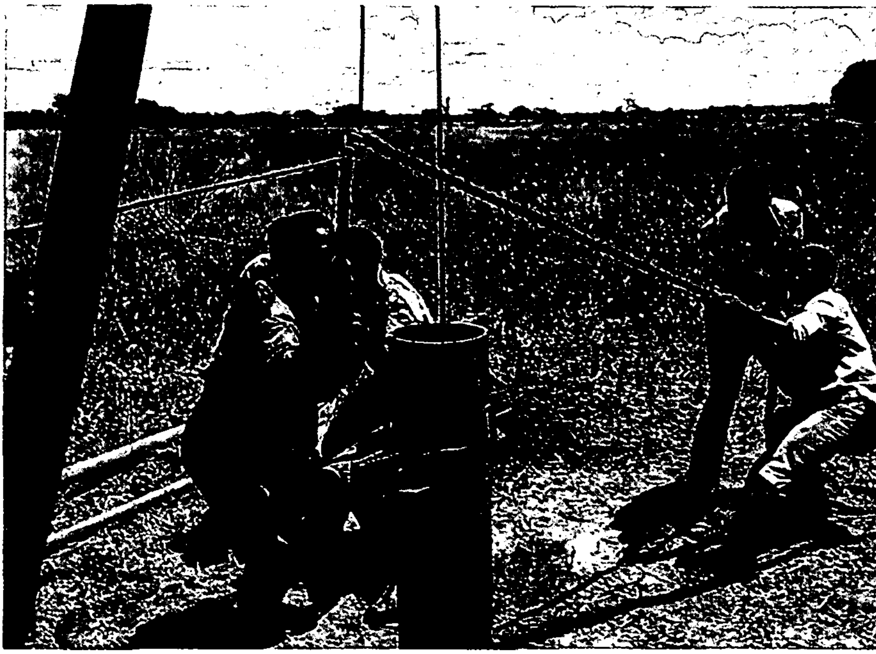
64. A riverside bit is being emptied

65. A new extension bar is connected

66. A casing pipe is screwed into the soil

67. A new section of casing pipe is going to be connected after the protective ring has been removed from its threaded end

68. A bailer is lowered in the borehole



69. Bailing

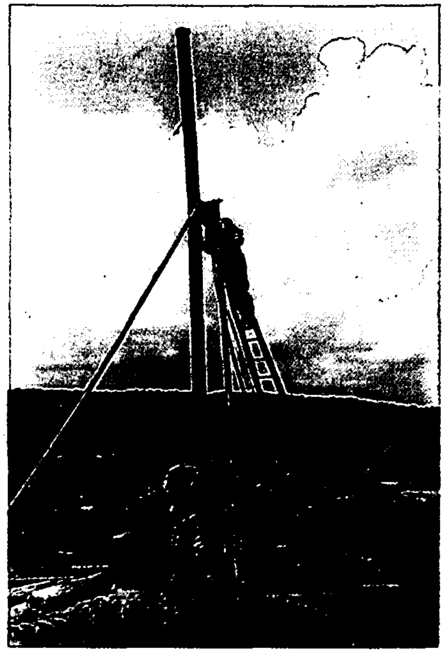
70. The bailer is emptied

C. ***Finishing the borehole***

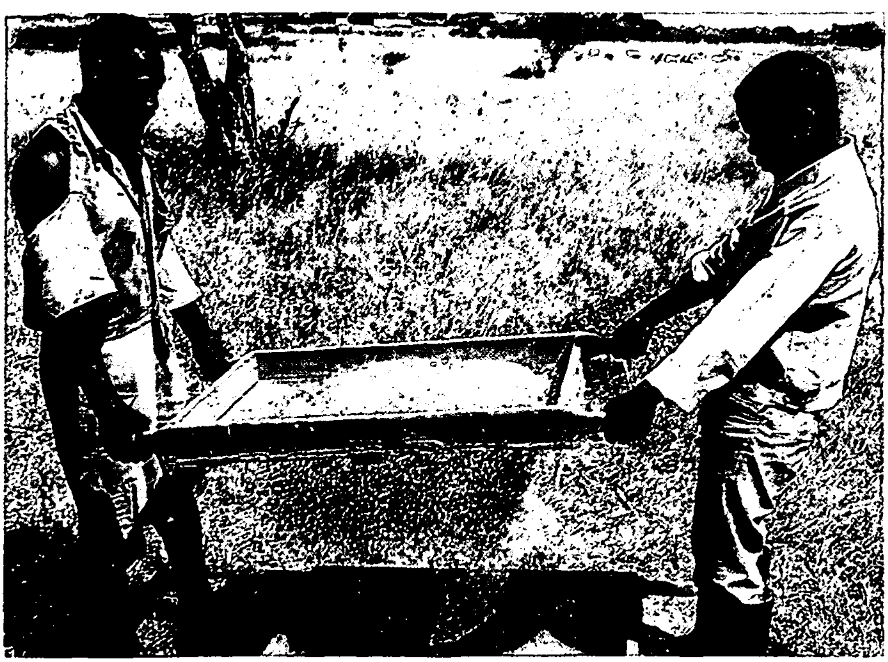
As soon as the final depth has been reached, the pvc filter pipe is cut at the exact length (i.e. the depth of the borehole + 0.15 m), a wooden plug is inserted in the bottom of the pipe and the latter is lowered in the borehole.
In rather coarse sands and in boreholes that do not tend to cave in, a filter pack of 2-4 mm sand/gravel is constructed, while in finer aquifers the filter material should also be finer. The filter sand can be sieved with standard sieves. If these are not available, mosquito gauze, wire mesh, etc., can be used to construct makeshift sieves which approximate the desired sizes as closely as possible. After a layer of approx. 50 cm of filter gravel has been added, the casing pipe has to be pulled up over roughly the same distance before filter gravel is added again. This sequence has to be repeated every 25 to 50 cm, and each time the depth has to be sounded.

When the entire casing pipe has been removed, the filter is pumped clean and the well capacity can be determined through a pumping test. Generally the water is clean only after about 2 to 10 m^3 of water have been pumped out.
Should the well prove to have an insufficient capacity the filter pipe can be recovered. A plug, hanging from a steel cable, is lowered to the bottom of the filter pipe and gravel is poured on top. Then the entire filter pipe is pulled up with the winch, while by vibrating the pipe and/or turning it, the friction is largely removed.

71. The pvc filter pipe is cut off at the required length

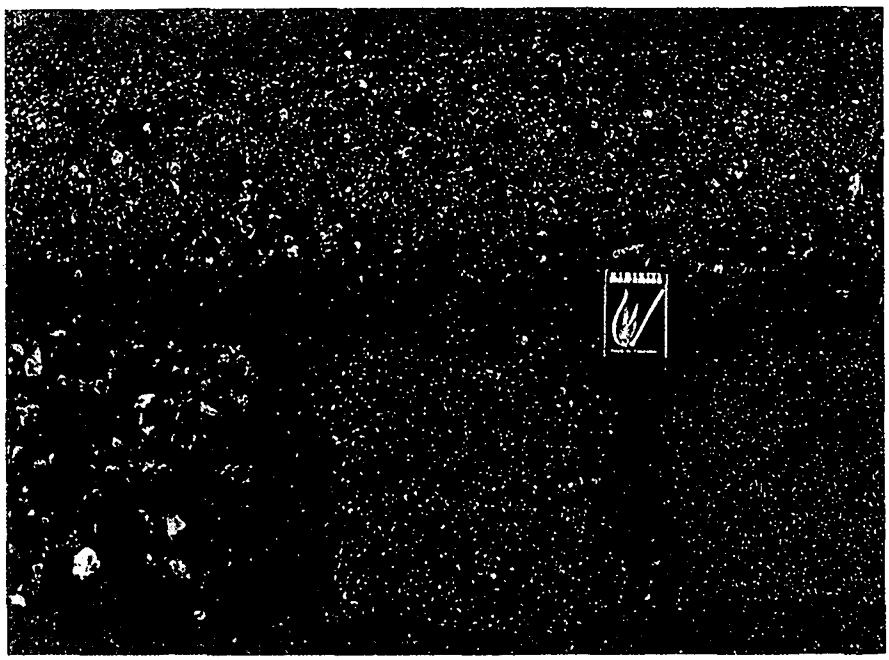


72. *The filter pipe is lowered in the borehole*



73. *Sieving sand from a river bed for filter material*

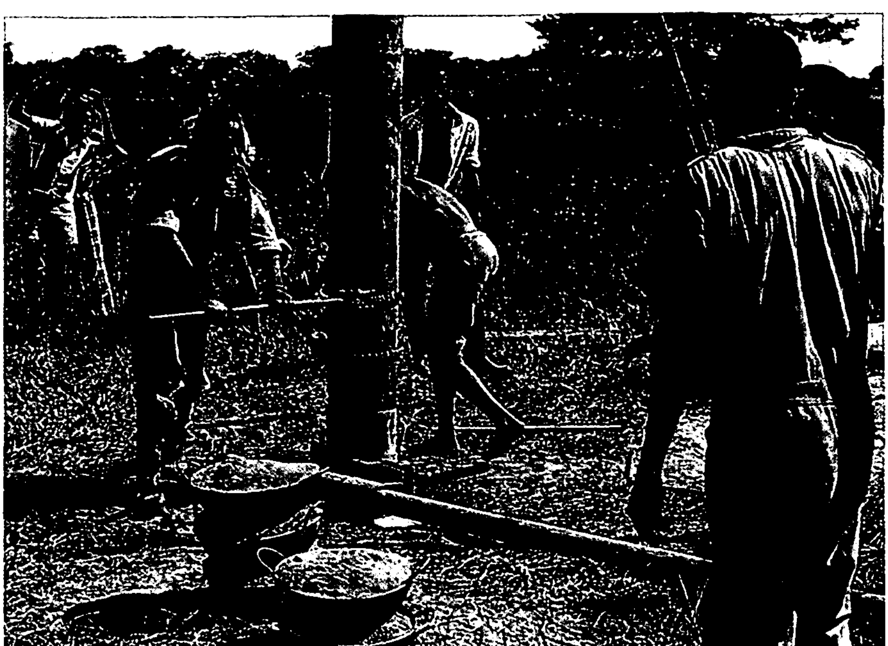
74. *Makeshift sieves*



75. *The original material (above) and the result after sieving (below)*

76. *The pvc filter pipe is closed with a wooden plug*

77. *The filter material is poured between filter pipe and casing*



78. *Section-wise removal of the casing. Note the 'karai' with filter material on the foreground*

In a borehole which does not tend to cave in and thus does not need a casing, a pumping test can be carried out without a filter pipe being placed. In that case work and materials can be saved if the capacity proves not to be sufficient.

Normally, however, the yield test of the survey test drilling should offer a sufficiently reliable indication of the well capacity to prevent the construction of wells of a too limited capacity.

If the well capacity is sufficient the top few metres of the borehole are backfilled with clay and tamped. Next the ground level around the well opening is raised slightly to form a low mound in order to facilitate draining of spill water. A prefab concrete cover (type G, see chapter 21A) with cast-in anchor bolts for the hand pump stand is put over the well opening in such a way that the concrete cover is free from the top of the pvc filter pipe. Around the well cover a reinforced concrete apron is constructed, similar to that for hand-dug wells (see fig. 26).

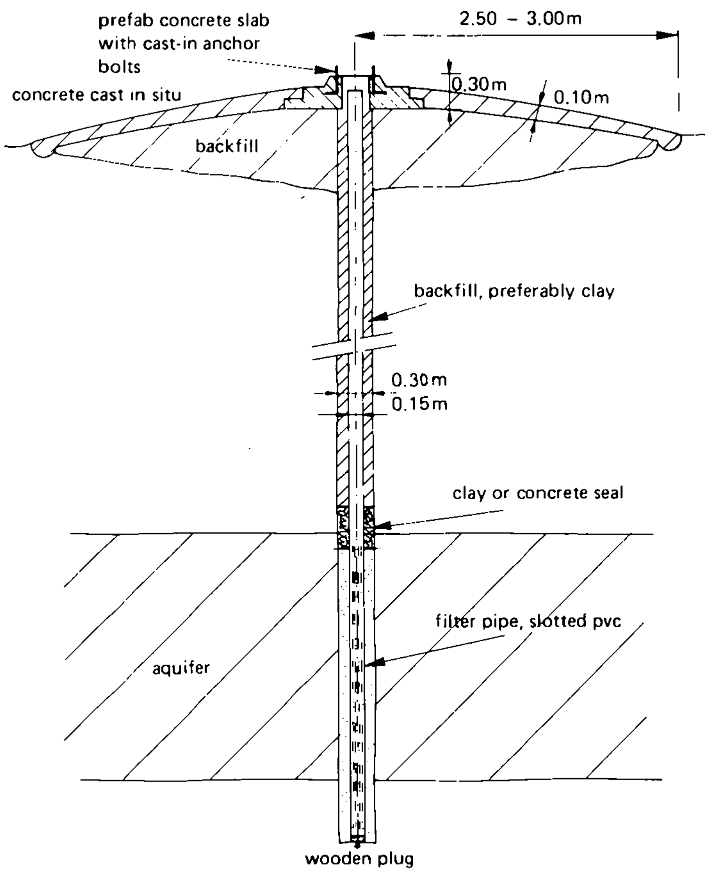


 Fig. 26. Drilled shallow well

79. Mechanical well digging with clam shell

Chapter 19. **Mechanical construction of wells**

In the Shinyanga Shallow Wells Project two types of mechanical well-construction have been applied:

a. mechanical well digging
b. mechanical well drilling.

A. *Mechanical well digging*

In Shinyanga mechanical well digging was done with a clam-shell of limited diameter, operated from a simple crane (see photos 79 + 80). The clam-shell was used inside a 65 cm dia. steel casing, in situations where coarse sand and plenty of water made hand-digging virtually impossible without heavy pumping equipment. After the soil had been dug away from within the casing down to the required level a 15 or 20 cm dia. pvc filter pipe and rising main were placed and the well backfilled in much the same way as described above for the hand-drilled wells. Using the clam-shell has not been entirely successful, however, as it developed the habit of - partially - closing itself at the very moment it should be wide open, i.e. just before impact. Since the sites suitable for the clam-shell proved to be also suitable for hand-drilling, mechanical digging was abandoned in favour of hand-drilling.

80. Clam-shell

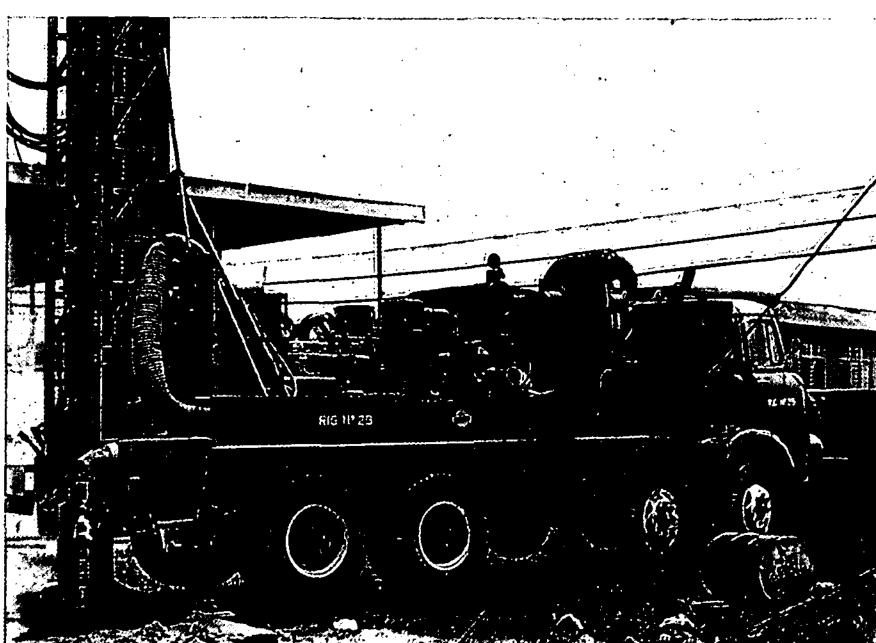
B. *Mechanical well drilling*

Mechanical well drilling is approximately twice as expensive (on an average) as hand-drilling. Since the results are essentially the same, mechanical well drilling is used only in those situations where hand-drilling would be too laborious or even impossible. Thus mechanical well drilling is restricted to weathered rock and fissured zones at shallow depths, hitherto difficult to exploit due to depth and hardness of material.
Investment costs of rotary or percussion rigs that fit the requirements, i.e.:

minimum hole diameter required	30 cm (12 inches)
minimum hole depth required	15 m (50 ft)
minimum weight of percussion tool	1,000 kg (1 ton)
minimum rotary torque	750 kgm (5000 lbs ft)

amount to some Dfl. 150,000 to 600,000 (US$ 75,000-300,000). This means: The cost of mechanical drilling equipment is 7.5 times the cost of hand-drilling equipment. It will be clear, therefore, that this type of mechanical equipment will be useful in large-output projects only, where targets have to be met irrespective of soil constitution.

Apart from the fact that a machine-driven drill is used with different drilling bits or even a percussion bit, the drilling proces is essentially the same as in the case of hand-drilling, and the well itself is finished in exactly the same way.



81. Heavy motor-driven rotary drill

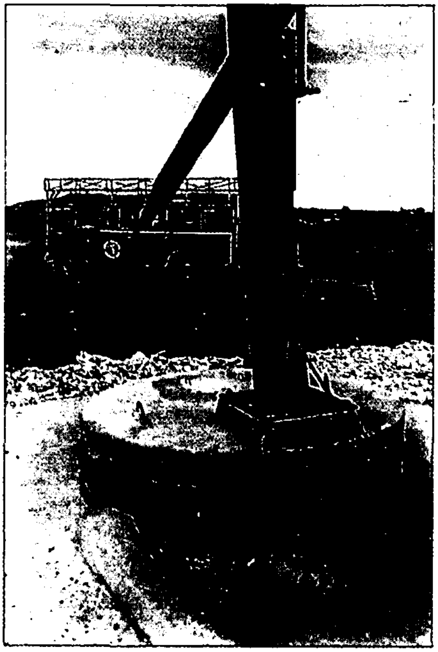
82. Percussion rig. Less complicated than rotary drilling rigs, but still requiring skilled operators

Chapter 20. **Rounding-off well construction**

A. *Prevention of pollution*

When finishing the well head care should be taken to minimize the possibility of waste water contaminating the well. Thus a concrete or clay seal is used just above groundwater level to block the path of seepage water entering along the outside of the well rings (dug well) or pvc pipe (drilled well). Also the connection between cover plate and concrete apron and/or uppermost concrete well ring is cemented in such a way as to form a watertight connection (see also photo 55). The apron itself has the shape of a low mound, thus facilitating the drainage of water from it.
When the ground surface is not level, the well cover is put in such a way that the hand pump is mounted at the downslope side, causing spill water to drain away from the well head. Concrete brims on the apron guide the spill water to a gutter and further to a drainage area or pit (see photos 83 and 84).
When the soil is level a drain filled with coarse gravel is made along the circumference of the apron, again collecting spill water and guiding it to the drainage gutter.
Unhygienic conditions near the well head should be prevented. The local population should be persuaded to throw away the water used for rinsing buckets, etc. at the designated drainage area, instead of just anywhere near the pump. In that way muddy wet places - which can form breeding places for insects - are avoided. Preferably well sites should be surrounded by a fence or special vegetation, which makes it impossible for cattle to enter and pollute the well area.
The most important contribution to guarantee a non-polluted well is the fact

83. *A gutter guides the spoil water to a drainage area*



84. *Detail of well superstructure. Note horizontal platform for buckets*

that it is covered, and a closed handpump mounted. Thus accidental pollution of the well is virtually impossible, in contrast with open well heads where objects may be dropped in the well, and pollution through buckets – which have been left on the ground before or in between use – is far from imaginary.

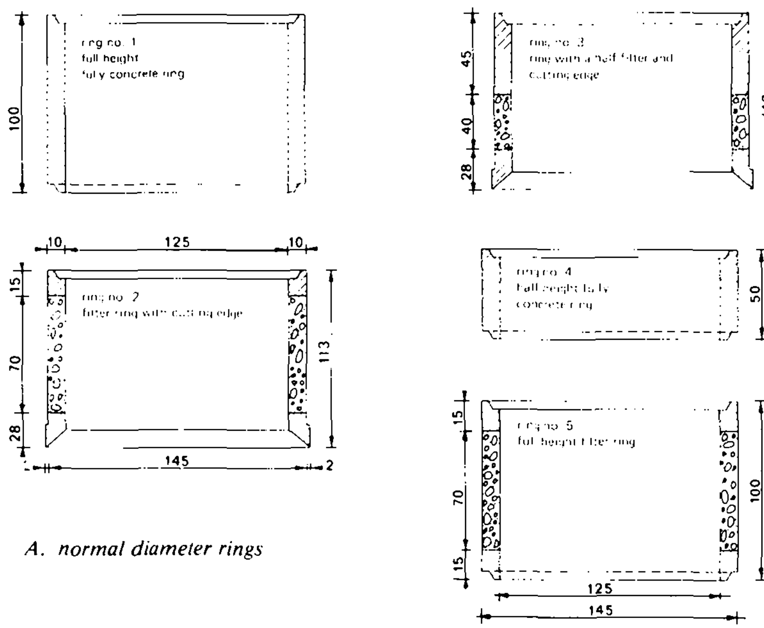
B. *Disinfection of the well*

As labourers handle the rings and stand in the well during its construction, it cannot be assumed that the groundwater is still bacteriologically safe. After the pump has been mounted (see chapter 27) the well is therefore disinfected with tropical bleaching powder (25-35%).
The amount needed for this purpose is 100 gr of bleaching powder per m^3 water in the well. So if the water volume in the well is 4 m^3, 400 grams of bleaching powder must be added.
The powder is dissolved in water (about 100 grams of bleaching powder to one bucket of water) and then poured into the well. The water in the well must be well agitated to ensure good mixing; this is accomplished by pumping the water around with a motor pump. The strongly chlorinated water is now left in the well for at least 12 hours. During this time the water should not be used, so it will be advisable to remove the pump handle or in any other way immobilize the pump.
After 12 hours the pump handle is connected again, the water is pumped to waste and the chlorine content is regularly checked with a simple comparator. The pumping is stopped when the chlorine content has dropped below 0.7-1.0 mg/l.

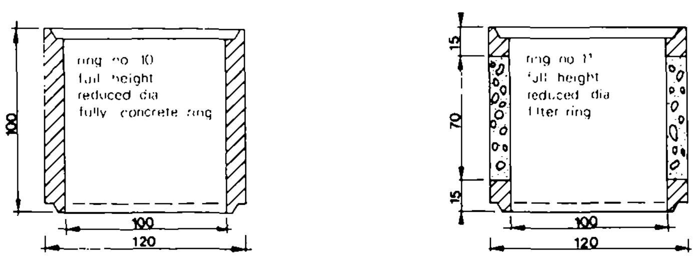
Chapter 21. **Construction and handling of well rings and covers**

A. *Well rings and covers; types and manufacturing*

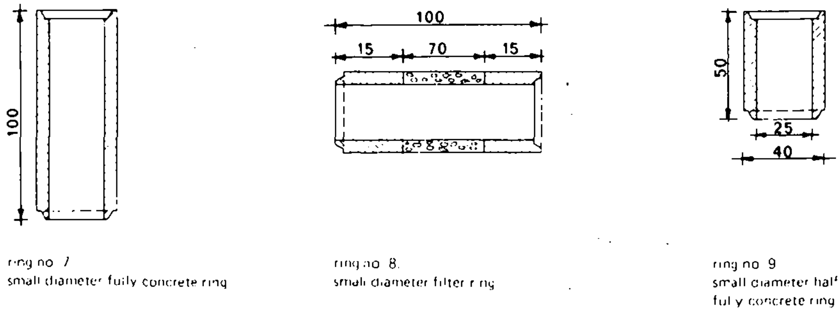
As mentioned before, in Shinyanga Region concrete rings are used for lining the hand-dug wells. The rings are manufactured centrally, in Shinyanga, in three diameters. These are the 145 cm external diameter ring, which is most generally used, the 120 cm external diameter ring - used for caissonning inside the normal lining only - and the 40 cm external diameter type, used in the construction of wells with a deep lying aquifer. In all diameters two main types are manufactured with different properties: fully concrete rings of a one part cement/three parts sand/four parts gravel mix, and so-called filter rings of the same mixture but without sand (one part cement/four parts gravel).
Gravel has to be sieved (6 mm-18 mm). If it contains organic or clay particles these have to be washed out before using the gravel for concrete.
Sand can be obtained from a river bed.



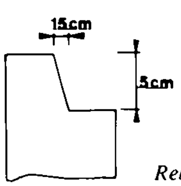
A. normal diameter rings



B. reduced diameter rings



C. small diameter rings



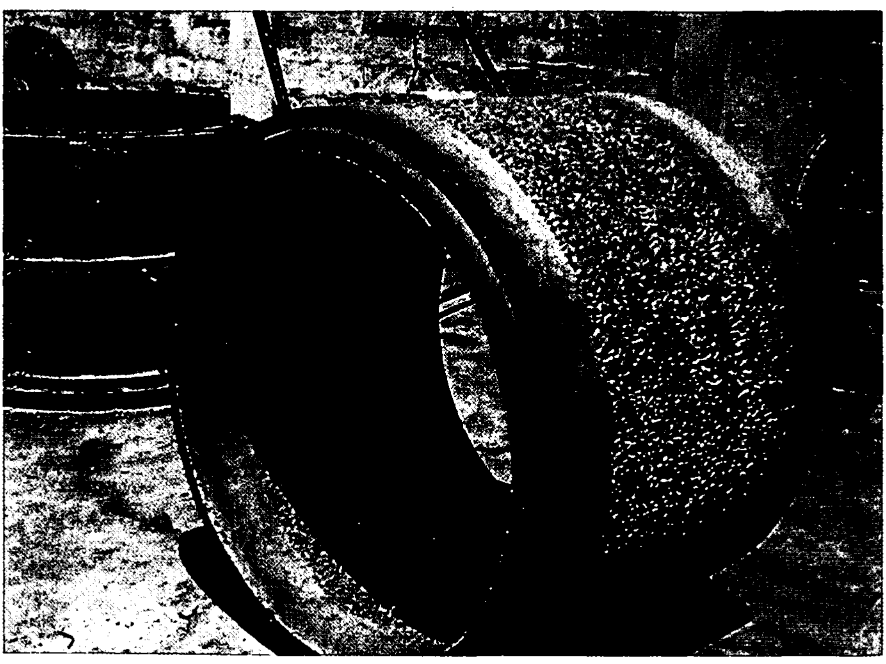
Rebate in top and bottom of well rings

Fig. 27. Different types of well rings

Each type of ring with a certain diameter and wall property has a number as follows (fig. 27):

Ring number	1 :	full height, fully concrete ring
,, ,,	2 :	filter ring with cutting edge, to be sunk as the first ring of a well
,, ,,	3 :	ring with a half filter and cutting edge, to be used as the first ring of a river well
,, ,,	4 :	half height fully concrete ring
,, ,,	5 :	full height filter ring
,, ,,	7 :	40 cm diameter fully concrete ring
,, ,,	8 :	40 cm diameter filter ring
,, ,,	9 :	40 cm diameter half height fully concrete ring
,, ,,	10 :	120 cm outside dia. fully concrete ring
,, ,,	11 :	120 cm outside dia. filter ring

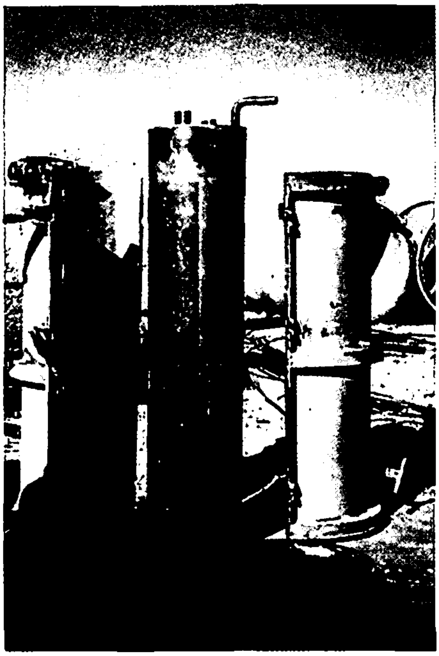
All rings are provided with rebates in top and bottom, except the ring with cutting edge, which has a rebate at the top only. Rebates are 5 cm × 5 cm with a sloping centre. Thus rings cannot shift in relation to each other when being sunk.
To keep the rebates in filter rings strong, 15 cm of the top and bottom of the rings, as well as the cutting edge for cutting rings, are poured of mass concrete. The full height rings are 1 m high (with cutting edge 1.13 m), thus 70 cm of filter height is available per filter ring.
One reinforcement bar of 6 mm diameter is placed in the first 10 cm from the top as well as from the bottom, leaving the larger part of the ring without any reinforcement. This has proved to work out very well in practice, since no breakage - either in transport or during or after construction - has occurred.
The concrete is mixed with a mixer and, after being poured into the moulds, compacted by hand with wooden stampers. The moulds can be removed within a three hour period and are then available for re-use, except for the bottom rebate mould (or cutting edge mould). So extra bottom moulds are necessary.
To be able to remove the moulds within a three hour period, the amount of water added to the cement, sand, and gravel should be limited as far as possible. The concrete should be just workable for pouring and proper compaction.
The moulds shown on photos 85, 86 and 88 are constructed in such a way that they can be removed without damaging the fresh concrete. First the wedge in the inner mould is lifted, after which the inner mould itself can be hinged inwards, and taken out.



85. Filter ring, with mould in background

86. Inner and outer moulds for regular size rings (1.45/1.25 m diameter)

87. Rings with reduced diameter (1.20/1.00 m). Moulds, with ring inside, are positioned at right



88. Moulds for small-diameter rings (0.40/0.25 m dia.)

Then the connections between the two outer half moulds are loosened so that they can be removed from the concrete ring.
In this way, using three moulds, six rings can be manufactured per day. The following daily sequence of events is then kept:

- remove the moulds from the rings poured on the previous day
- pour three new rings
- allow to set for one hour to an hour and a half
- remove the moulds (except the bottom mould)
- pour three new rings

After one night (approx. 12 hours) the rings are lifted and the bottom moulds removed. When rings have hardened for at least 48 hours, they are pulled over on their sides by means of a sling and rolled away to cure. After four days of curing they can be transported to the site by truck.

In Shinyanga regular, heavy-duty moulds have been used for 145 cm dia. and 40 cm dia. rings only. The 120 cm dia. rings were planned to be used incidentally only, so makeshift mild steel moulds have been used for these rings (see photo 87).

Well covers can be made in various types (fig. 28):

cover B_1: cover with central hole for pvc pipe for wells with reduced diameter in upper section

,, B_2: ditto, with central hole for concrete pipe

,, C : cover with manhole only, for buried river wells

,, E : cover with pumphole and cast-in bolts for the pump stand, and a manhole

,, G : cover with pumphole and cast-in bolts for the pump stand, for drilled wells only

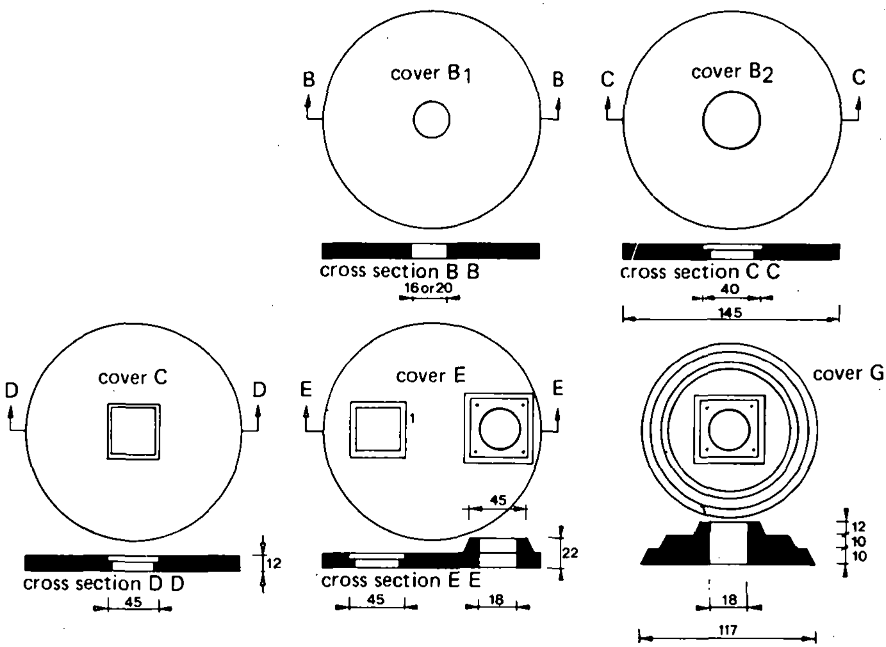


Fig. 28. Different types of well covers

89. *Mould and covers for dug wells*

90. *Mould and cover for drilled wells*

B. *Handling of concrete well rings*

Since the weight of each ring is about 1200 kilograms, special equipment is necessary to handle them. As they are easily damaged the handling should be done carefully.
If the rings have to be moved over short distances they can be rolled over without damaging them.
Loading and unloading from a truck and the sinking in the well hole involves lifting and turning over the rings. Because of their weight this cannot be done by hand.

The tripod

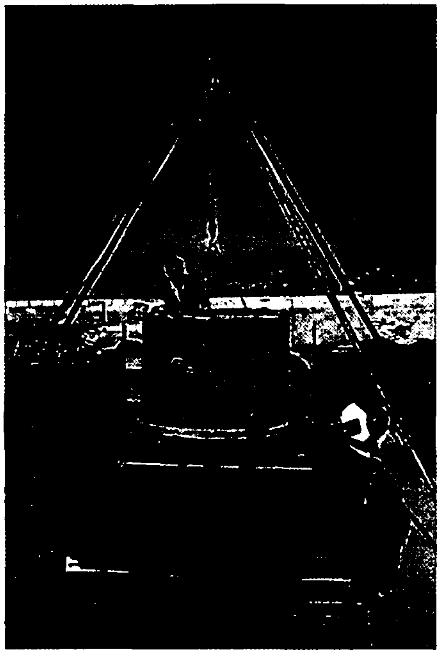
For lifting the rings a tripod is used, consisting of two legs of approximately 6 metres long and one double leg of the same length on which a winch is fastened. A cable is wound around the winch and run through a double pulley fixed in the top of the tripod and through a single pulley to which a hook is attached.

For safety reasons the tripod must be erected extremely carefully.
The legs must be positioned in such a way that they cannot slide away and that the cable hangs down exactly in the middle of the tripod.
Theoretically, for stability the centre of gravity of a mass hanging on the hook must always stay between the planes formed by the three legs of the tripod. More practically, attention should be paid to the following when erecting the tripod:

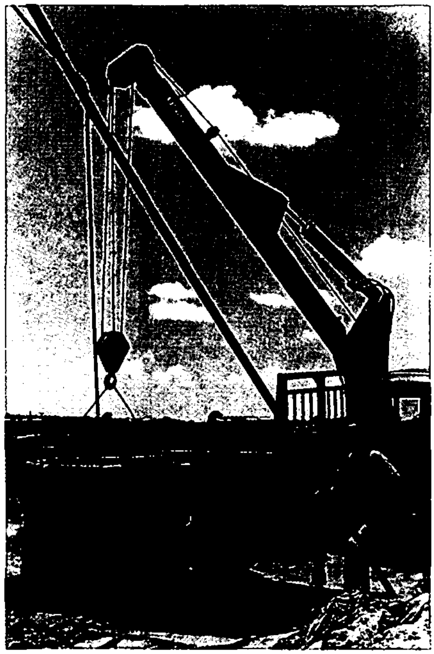
- the feet of the legs must all be put at the same level
- both the single legs must stand at the same distance to the double leg with the winch
- the distance between the feet of the single legs must be about 4 metres
- from a standpoint behind the winch, the cable must be seen hanging exactly between and parallel to the legs of the double leg.

Loading of a ring on a truck

When the tripod has been properly erected over the ring, a wooden beam of 1.45 m length is laid over the ring, and a sling is put around the ring at about half its height.
The length of the sling, which has an eye at one end and a hook at the other, is about 7 m.
The hook is pushed through the eye to form a loop which is laid around the ring, and then the hook is fastened to the other side of the loop (fig. 29).
The beam prevents the upper part of the sling from crushing the top of the ring.
To prevent the sling from cutting into the beam, its ends are reinforced with steel plates.
Pieces of plywood of about 0.10 × 0.25 m can be put between the ring and the eye and hook, respectively, to prevent these from damaging the concrete ring walls.
The sling is then fastened to the tackle cable, and when this cable is pulled upwards, the sling tightens around the well ring and the ring is lifted.
Then the truck backs up underneath the well ring, which is lowered onto it.
Before loading the rings onto the truck a wooden floor is put on top of a 5 cm layer of sand in the cargo space of the truck, in order to absorb shocks during transport and to assure equally distributed support.



91. Loading of ring on truck, with tripod



92. Truck with hoisting device. Easier, but more vulnerable

After the ring has been transported to the well site, it is unloaded by the same procedure in reversed order. As the trucks normally cannot back up to the very edge of the well itself, the ring, after unloading, will have to be placed close to the well, turned over on its side, and rolled to the well. Therefore another sling (length about 5.50 m) - with an eye at each end - is put around the well ring in the same way as before, the remaining eye now being fastened to the tackle rope (fig. 30).

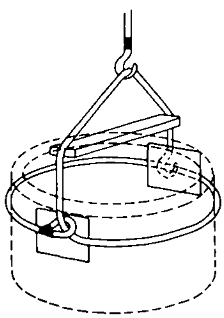


Fig. 29. Sling for lifting a concrete ring horizontally

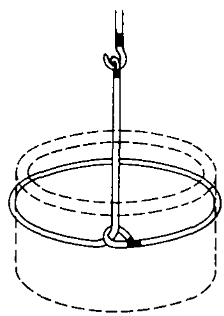


Fig. 30. Sling for turning over a concrete ring

By pulling the tackle rope upward the ring is turned over, the sling can be unfastened, and the ring rolled away to the well site.

The sling should be put around the ring in such a way that the eye through which the other eye is pulled is positioned on the winch side of the ring, or exactly opposite to it.
If the sling is put around the ring with the sling coming up at either side - as seen from the winch side - the ring may pull down the tripod while it is being lifted.
Even when the sling is properly attached, the ring must be guided by hand to prevent it from turning around and pulling down the tripod.

C. *Organization of concrete ring and cover production*

In Shinyanga the set-up of the 'concrete factory' was as follows:

Staffing:	1 foreman
	6 concrete workers
	10 casual labourers
Equipment:	1 concrete mixer
	3 moulds for 1.45/1.25 m rings
	1 mould for 1.20/1.00 m rings
	1 mould for 0.45/0.25 m rings
	1 mould for covers B, C or E
	1 mould for cover G_1
	1 tripod + winch
	1 gravel washing assembly

The daily capacity amounted to: 6 rings 1.45/1.25 m + 1 cover B/C/E + 1 cover G. The material needed per unit is shown on page 118.

Average production costs in Shinyanga were:

1.45/1.25 m ring (no. 1, 2, 3, 5):	TShs 260.— apiece *)
1.45/1.25 m ring (no. 4):	TShs 130.— apiece
1.20/1.00 m ring (no. 10, 11):	TShs 100.— apiece
0.45/0.25 m ring (no. 7, 8):	TShs 50.— apiece
Cover for dug well (E):	TShs 200.— apiece
Cover for drilled well (G):	TShs 100,— apiece

*) based on 1978 price level (TShs 7.50 = US$ 1.00).

Raw materials needed for concrete ring and cover production

Description	Cement (bags)	Sand (karai)*	Gravel (karai)*	Soft wire	Reinf. bars $\frac{3}{4}$"	Bolts $\frac{5}{8}$"	Nuts $\frac{5}{8}$"
Ring no. 1	3	32	12	0.90 m	12 m	—	—
Ring no. 2	3	13	32	0.90 m	12 m	—	—
Ring no. 3	3	24	21	0.90 m	12 m	—	—
Ring no. 4	1.5	16	8	0.90 m	12 m	—	—
Ring no. 5	3	12	32	0.90 m	12 m	—	—
Ring no. 7	0.5	8	3	0.90 m	2.5 m	—	—
Ring no. 8	0.5	4	8	0.90 m	2.5 m	—	—
Ring no. 10	1.5	15	8	0.90 m	8.5 m	—	—
Ring no. 11	1.5	6	15	0.90 m	8.5 m	—	—
Cover E	1.5	16	8	3.76 m	36 m	4	4
Cover G	1.5	12	8	—	—	4	4

* 1 karai = approx. 10 litres (see photo 78)

Material	Unit	Costs (TShs) **
Cement	Bag	40.00
Sand	Karai	0.35
Gravel	Karai	1.20
Reinf. bar $\frac{1}{4}$"	Length	15.00
Bolt $\frac{5}{8}$"	Each	3.50
Nut $\frac{5}{8}$"	Each	4.00

** based on 1978 price level (TShs 7.50 = US$ 1.00).

Chapter 22. **Production of pvc filter pipes**

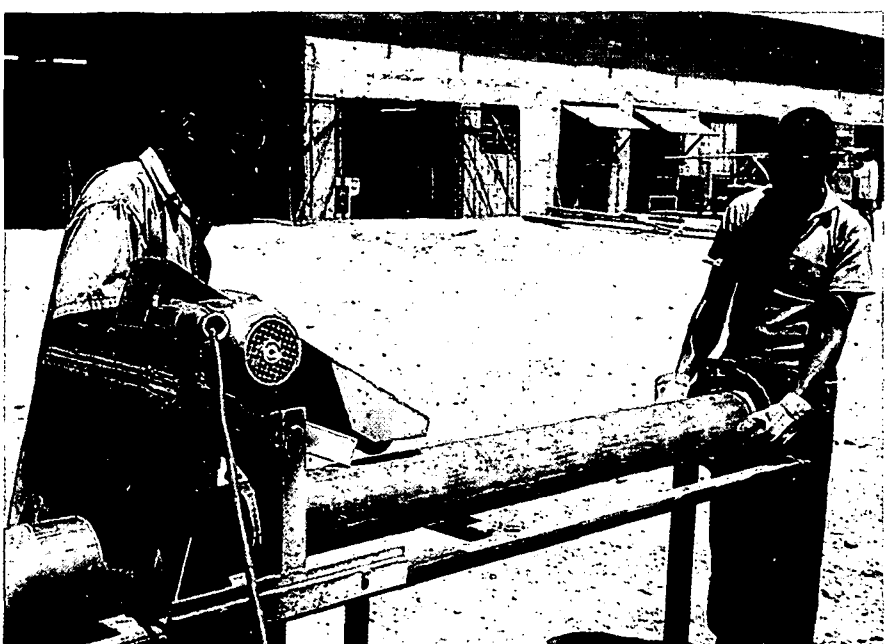
Sometimes ready-made pvc filter pipes can be purchased locally, but in most cases they are not available. Photos 93 through 97 show the preparation of filter pipes at the Shinyanga project compound. Plain pvc pipes could be obtained locally, so a pipe slotting machine was developed and built in Shinyanga. Two parallel circular saw blades (80 mm diameter, 0.7 mm thick) are used for cutting parallel slots in longitudinal direction in 3 m-long sections of pvc pipe. After slotting has been completed for a number of pipe lengths, pipe sockets are made on the spot. One end of each pipe is immersed for some time in hot oil, until the pvc has become soft and deformable. This end is then pushed over a piece of regular pipe, the pvc expands and the socket is formed. Hereafter it is cooled with water until a rigid socket has been obtained.

In Shinyanga two labourers were engaged in producing filter pipe, with an output of 6 metres of slotted pipe per day.

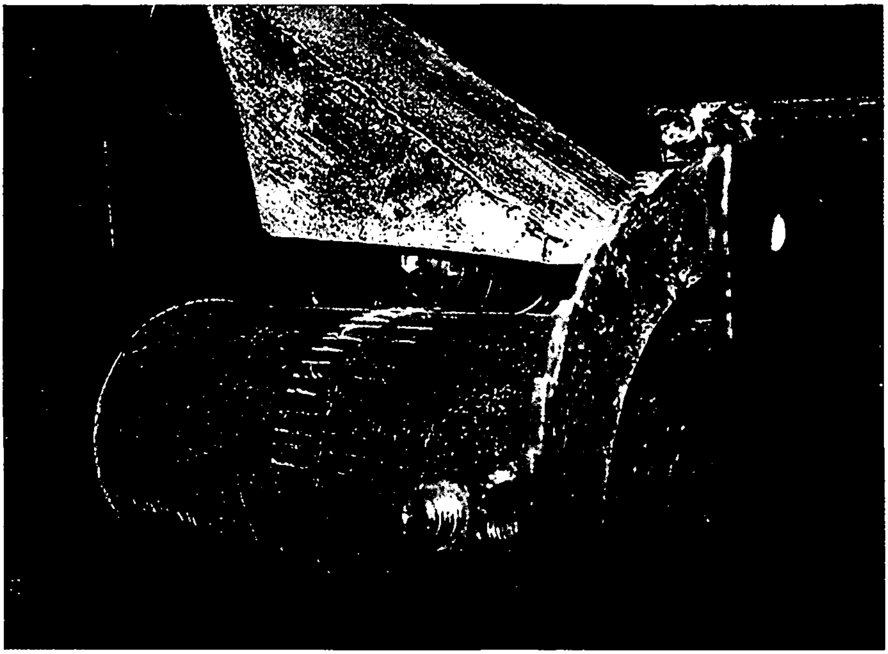
The equipment consists of one slotting machine (photo 93) and one stove (for making the sockets).

The costs of 150 mm dia. pvc pipe ex Morogoro Wells Construction Project compound is:

slotted pipe in 3 m-lengths	:	TShs 450.— per length
plain pipe in 3 m-lengths	:	TShs 350.— per length



93. Slotting machine for pvc pipe



94. *Detail of pipe slotting machine. Note twin saw blades*

95. *Heating pipe end*

96. *Heated pipe end is pushed over cold pipe, to form socket*

97. *Home-made pipe socket*

Chapter 23. **Wells production capacity and equipment**

Experience in Shinyanga shows that it takes an average of slightly more than three weeks for one group of well sinkers (see organization schedule on page 19) to construct and finish one hand-dug well. Of course the depth of the well and the type of soil materials encountered have a strong influence on the actual time to construct a particular well.
Furthermore the availability of more sophisticated equipment such as jack-hammers, motor pumps, etc. will accelerate construction. This equipment will - on the other hand - increase the dependence on fuel, imported spare parts, require the presence of skilled mechanics, etc. and the over-all effect may well be that construction is sped up only at the cost of higher expenditure per well. In case the importation of spare parts is hampered - for instance through scarcity of foreign currency - machine-powered equipment is a disadvantage rather than an asset.
Thus in Shinyanga the tendency has been to shift from hand-dug wells with much machine-powered equipment (generator, electrical jackhammer, motor pump) to hand-dug wells with simple equipment (hammer and chisel replacing electric jackhammers; double-acting hand pump replacing motor pump).

In Shinyanga hand-drilled wells are finished at a rate of 4½ per group and per month, as an average or: about one per group and per week. No machine-driven equipment is used. Only when soil conditions become too unfavourable for hand-drilling, machine-drilling may be tried. The total time needed per well will not change substantially by using drilling rigs because a more awkward transportation will take an additional time which is roughly equal to that gained in the drilling process itself. Since only locations with hard soils are reserved for machine-drilling, there will still be a substantial saving in time, as compared to the situation when laborious hand-drilling or hand-digging would be the only alternative.

Part 5

Hand pumps

Chapter 24. **Requirements for hand pumps**

A hand pump to be used on shallow wells in developing countries should meet several requirements:

a. The pump should be as simple as possible, hardly requiring any maintenance.
b. Costs per pump should be as low as possible.
c. The pump should be made, as far as possible, from locally available materials so that it can be repaired - and preferably also manufactured - locally.
d. The pump should be a lift pump. Not only do suction pumps need priming - which may cause difficulties as either no water is available or polluted water may be used, contaminating the well itself - but a suction pump would only operate to depths of at most seven metres, whereas many wells will be deeper.

In Shinyanga two types of pumps were used:

1. the Shinyanga pump, based on the 'Uganda' pump as introduced into Tanzania by UNICEF, but with modified superstructure and entirely different cylinder assembly,
2. the Kangaroo pump, of which cylinder and rising main are identical to those of the Shinyanga pump, but with a completely changed superstructure, further minimizing maintenance requirements because of the absence of a pump handle.

The Morogoro Wells Construction Project, which may be considered the follow-up of the Shinyanga Shallow Wells Project, uses Kangaroo pumps exclusively, whereas in Shinyanga from July 1978 onward only Shinyanga-type pumps have been produced.

Pump cylinders of 3 different diameters are used: 4″, 3″ and 2″, with the emphasis on 3″. Based on one full stroke per second and an effective pumping time of 75%, the pumps have the following capacity:

4″ cylinder, approximately 2000 l/h
3″ cylinder, approximately 1200 l/h
2″ cylinder, approximately 600 l/h.

98. Shinyanga pump

99. Kangaroo pump

Chapter 25. **Pump superstructure**

A. *Shinyanga pump*

The Uganda pump had to be strengthened and improved because regular and good maintenance in the villages was and still is virtually non-existent. Instead of costly brass pump cylinders, which had to be imported, a pvc cylinder is used. The piston has been replaced by a manchet type commonly used as a standard piston in hydraulic and pneumatic installations. Parts of the pump such as piston valve, bottom valve, and the connections of pump rod and rising main initially consisted of standard pipe fittings. Later on, however, the increasing emphasis put on maintenance-free operation has led to the adoption of different materials.

Three diameters of pumps are used - all with the same pump head - for the following depths:

4″ cylinder up to approximately 10 metres
3″ cylinder up to approximately 20 metres
2″ cylinder up to approximately 30 metres.

The Shinyanga pump is shown in 'exploded view' in fig. 31. Its manufacture is illustrated in photos 100 through 109.
A list of materials is given in the table below.

Specification of materials for Shinyanga pump superstructure

Description	Number	Length*	Width	Height	Thickness
Iron sheet	—	400	400	—	7.8
Flat iron	—	2080	50	—	8
Flat iron	—	280	25		8
Angle iron	—	1760	65	65	6
Round bar ⅝″ dia.	—	2080			
Round bar ½″ dia.	—	780			
Round bar ⅜″ dia.	—	1000			
Galvanized iron pipe 3″ dia.	—	800			
Galvanized iron pipe 2½″ dia.	—	570			
Galvanized iron pipe 2″ dia.	—	680			
Galvanized iron pipe 1″ dia.	—	460			
Galvanized iron pipe ½″ dia.	—	1950			
Bend 90° 1″ dia.	1				
Reducing socket 3″× 1½″ **)	1				
Flange ½″	1				
Cap ½″	1				
Steel bolt ¾″	2				
Nut ¾″	4				
Nut ⅝″	20				
Nut ⅜″	6				
Timber: handle 4″×3″× 7′	1				
upright 6″×4″×5½′	1				

* When not indicated otherwise measurements are in mm.
** Later replaced by 1½″ flange.

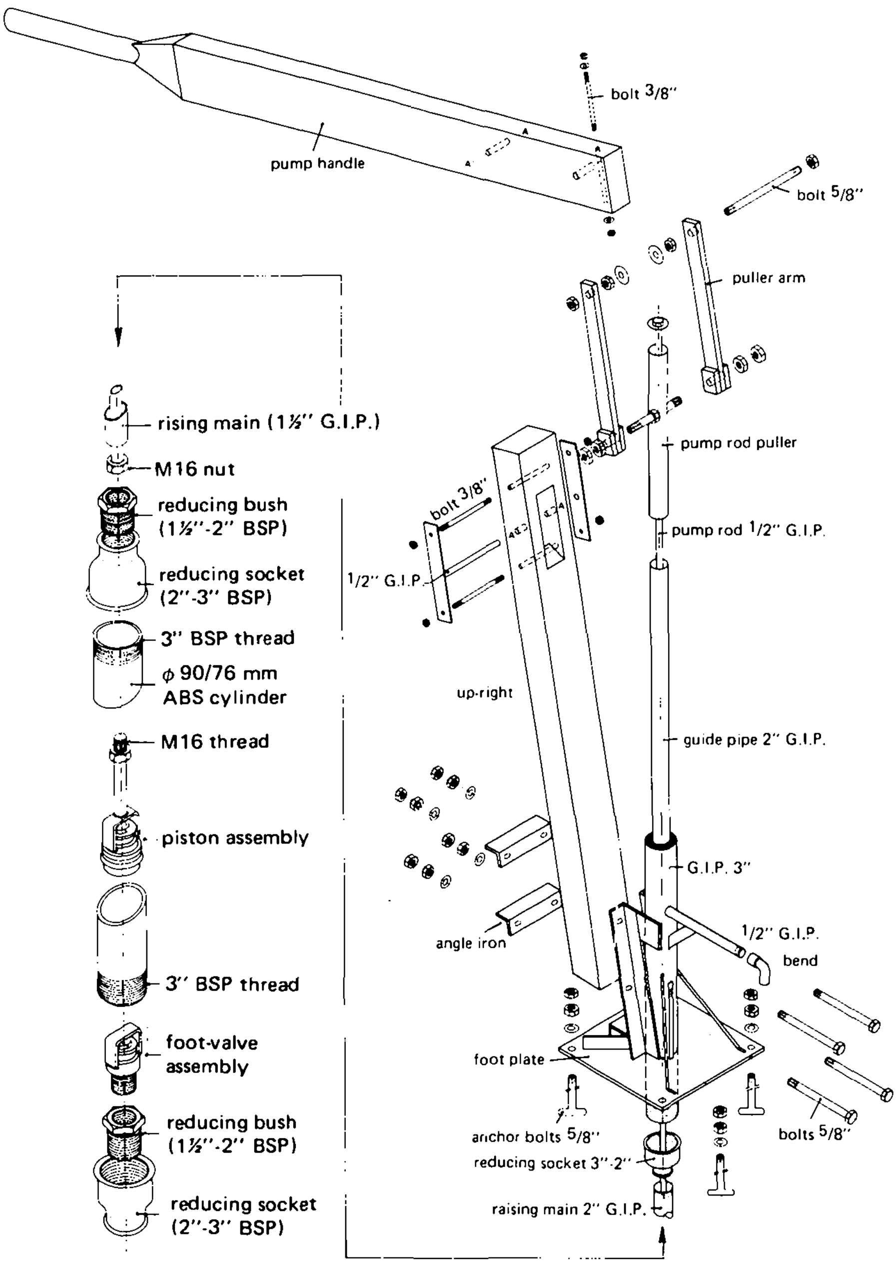
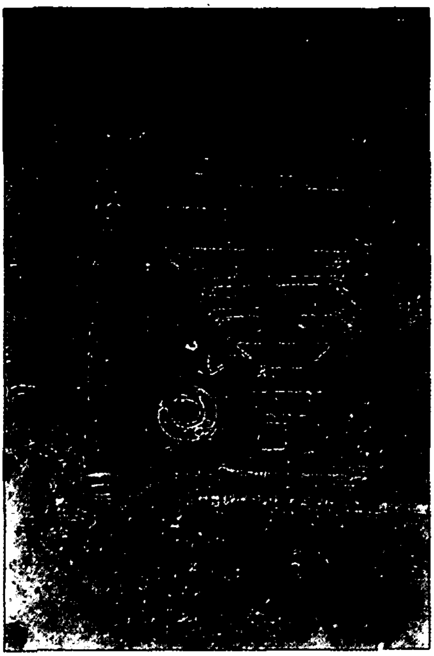


 Fig. 31. The Shinyanga pump

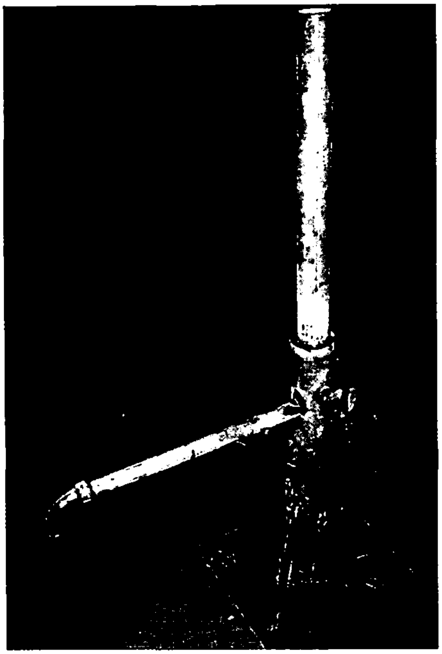


100. Parts for Shinyanga pump superstructure

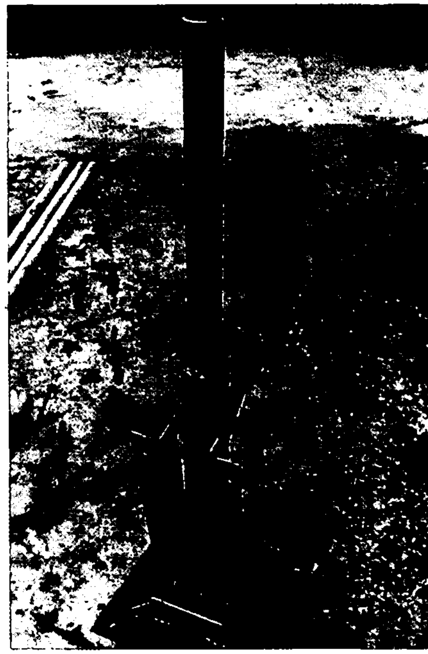
101. Welding . . . .

102. . . . . checking . . . .

103. . . . . and welding again



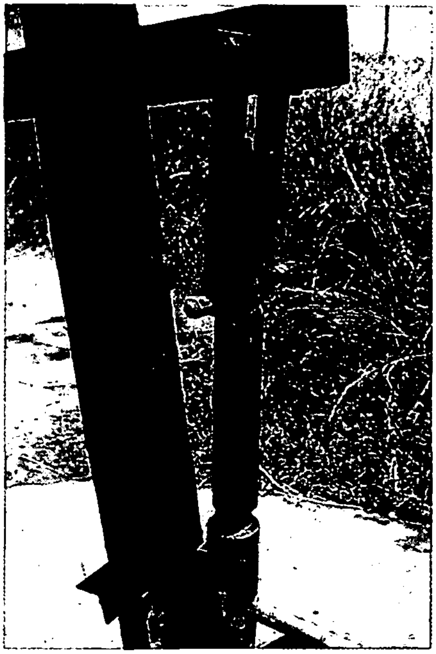
104. The result, before . . . .



105. . . . . and after painting

106. The up-right is mounted

107. . . . . and the handle put through the hole in the upright



108. Connection of handle to pump rod puller

109. Connection of up-right to pump stand

B. *Kangaroo pump*

The Kangaroo pump (fig. 32) is the result of an attempt to further minimize maintenance by eliminating hinge points - which have to be greased or lubricated - and the wooden parts of the pump superstructure (pump handle and upright), which might be stolen and used as fuel for cooking.
The pump head consists of a set of pipes within which a spring is fitted. The spring is loaded by depressing the footplate. The energy for the upward stroke of the pump - which is the pumping stroke - is delivered when the spring unloads itself.

The pump, invented by the Shinyanga Shallow Wells Project and further developed by the Morogoro Wells Construction Project, has a spring pressure which allows water to be pumped:

from a depth of 6 metres with a 4″ cylinder,
from a depth of 10 metres with a 3″ cylinder,
from a depth of 20 metres with a 2″ cylinder.

The pump head has no hinges and the wear and tear on the pipes is minimal, which results in a maintenance-free period estimated at ten years.

The composition of Kangaroo pump heads is illustrated in photos 110 and 111.

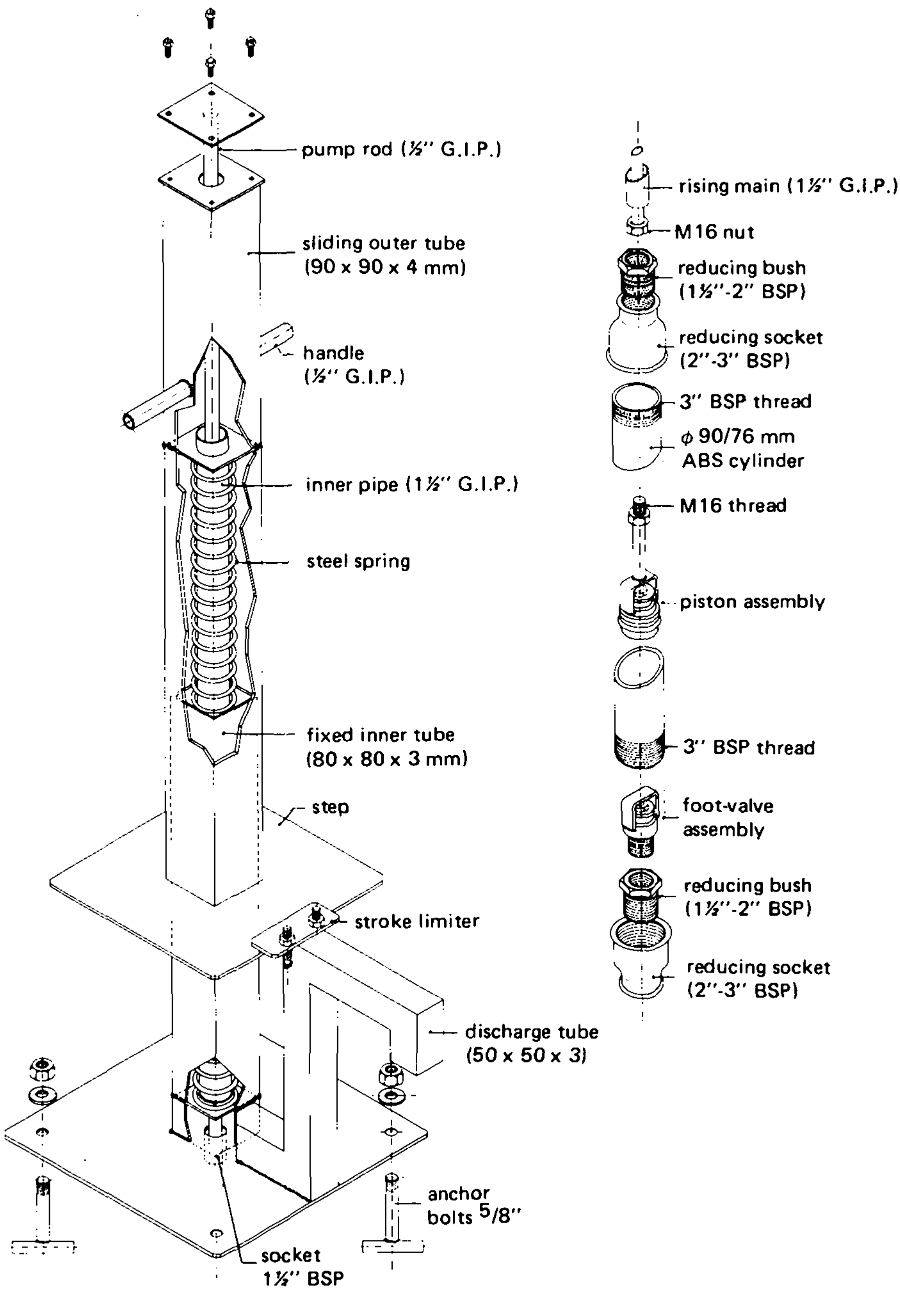
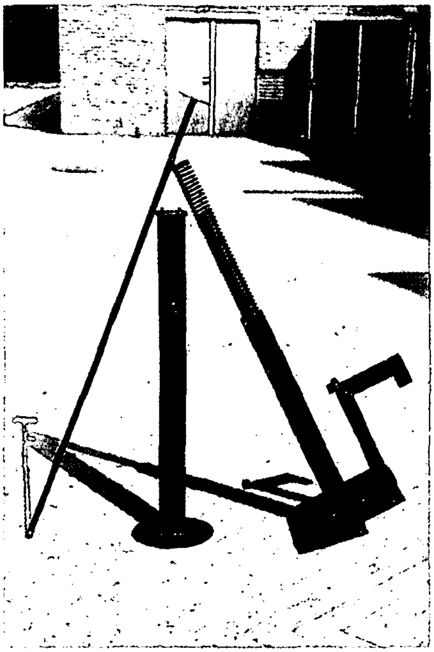


Fig. 32. The Kangaroo pump



110. Components of Kangaroo pump head

111. Finished Kangaroo pump

Chapter 26. **Pump cylinder and piston**

The development of the pump cylinder and piston is illustrated in figs. 33 through 35. The target was and is to construct a pump cylinder/piston assembly with negligible maintenance requirements, composed of parts which can be bought over the counter anywhere. Hence the initial set-up employed pvc pipe for the cylinder jacket, with standard galvanized iron pipe, and gas-pipe or pvc sockets, reducers, etc.

Preference for a simple foot-valve and less favourable experience with flap valves led to the adoption of a conical reducer 4″-2″ at the bottom end of the cylinder. A rubber ball was used as ball valve. In order to restrict the length of the stroke of the ball - and, therefore, the closing time of the foot valve - a counterweight was soon added to the ball. A pvc reducer was chosen first, to minimize wear and tear of the ball. As a consequence the reducer had to be cemented to the cylinder itself, implying that the whole assembly had to be replaced if one of the component parts became defective (fig. 33A).

A solution was sought to increase exchangeability of the various parts by using screwed-on malleable fittings (4″-2″ reducers) at both ends of the cylinder. This resulted in a weakening of the cylinder jacket, because thread had to be cut in it, while wear on the ball valve increased (rubber/steel contact instead of rubber/pvc).
A solution which gives good results is a cylinder built up from a straight piece of pvc pipe and two malleable flanges with a circular groove in which the pipe fits. The assembly is kept together by three screwed bars. Both flanges have an

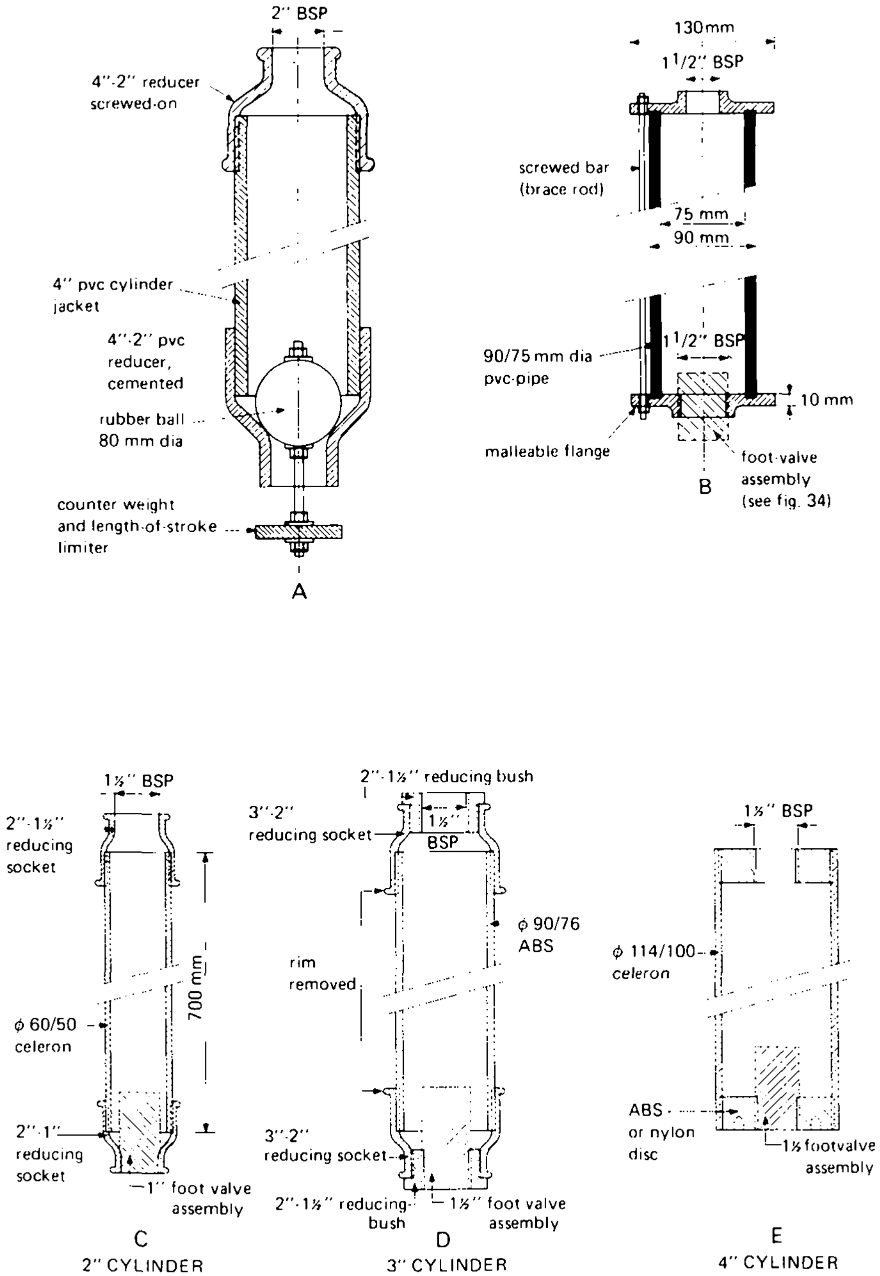
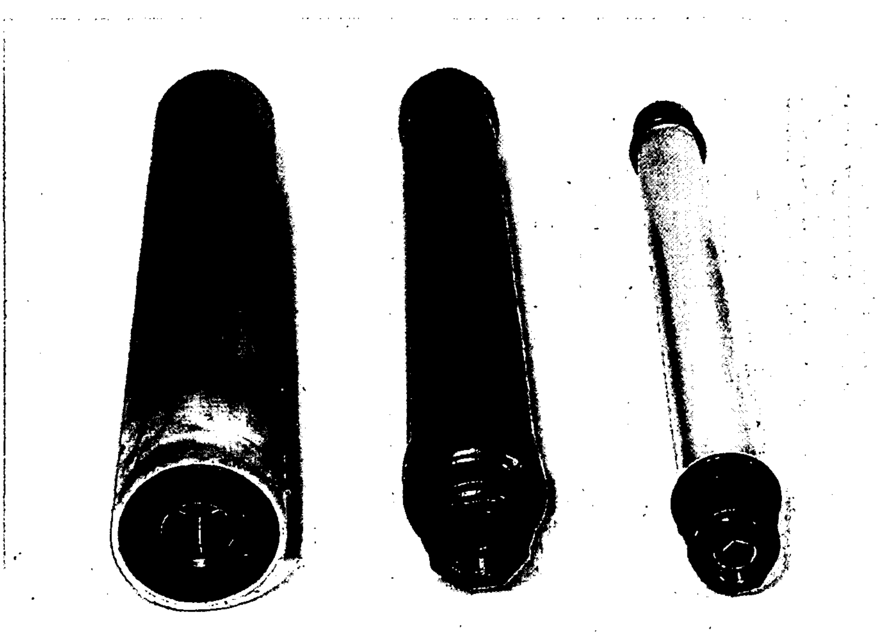


 Fig. 33. Development of pump cylinder

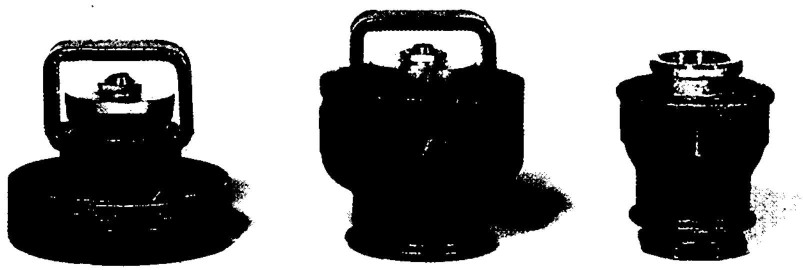
opening with 1½" BSP thread (fig. 33B). The rising main is screwed into the upper flange, while the foot-valve assembly fits in the bottom flange as shown in fig. 34D.

The modification favoured at present uses high-quality pipes, with fittings screwed either onto or into the pipe, so as to minimize the external diameter of the cylinder assembly.
The standard plastic pipe sizes only fit the standard piston sizes for 3" pipes. In this case 90/76 mm dia. ABS or hostalit pipe is used, onto which 3"-1½" reducer sets are screwed. In the bottom reducer set the standard 1½" foot-valve assembly is fitted (fig. 33C). For the 2" and 4" cylinders celeron* pipes with diameters of 60/50 mm and 114/100 mm, resp., are used, with the inner pipe diameters machined to exact values. On the 2" cylinders a 2"-1" reducing socket is fitted at the bottom and a 1" dia. foot-valve assembly is screwed into this socket. At the top a 2"-1½" reducer is fitted, to receive the pump raiser.
The 4" cylinder has internal thread at both ends, so that ABS or nylon discs can be screwed into the cylinder. All discs have a central hole with 1½" BSP thread. The standard 1½" foot-valve assembly is screwed into the bottom disc, whereas the rising main is fitted into the top disc.

* a phenol-formaldehyde-coated fibre compound



112. Pump cylinders (4", 3" and 2" dia.)



113. Foot-valves for 4", 3" and 2" cylinders.

The advantage over solution B is that the outer diameter of the cylinder is reduced (from 130 mm to 105 mm for a 3″ cylinder, thereby markedly increasing the play within a standard 160/147 mm pvc filter pipe), whereas the cost is lower.

Fig. 34 shows the development of the foot-valve. The conception of a rubber ball as the ball valve was abandoned when flat malleable flanges were adopted (see above). A stainless steel SKF ball of 40 mm diameter was chosen instead. A standard 2″ BSP cap with a 30 mm dia. hole drilled in its centre was screwed on the flange (fig. 34A) and a bar welded over the ball to limit its stroke. The distance between the ball and the inside of the 2″ socket which was welded to the flange allowed the ball to roll around and bounce against the socket, thereby damaging the latter. On one occasion the ball was even forced completely through the cap opening. To overcome this problem a chromium-nickel-molybdene steel ring was inserted in the cap, with a rubber ring as a buffer in between (fig. 34B).

In order to limit the number of parts a solution was sought whereby the foot-valve assembly would be identical to the piston valve. Thus a 2″-1½″ reducing nipple was welded onto the Cr.Ni.Mo-steel ring with the stainless steel ball inside. Four 3 mm dia. spacers were welded on the inside to reduce the play of the ball. A bar of 5 mm dia. was welded over the ball, to prevent it from blocking the entire opening during the downstroke (fig. 34C).

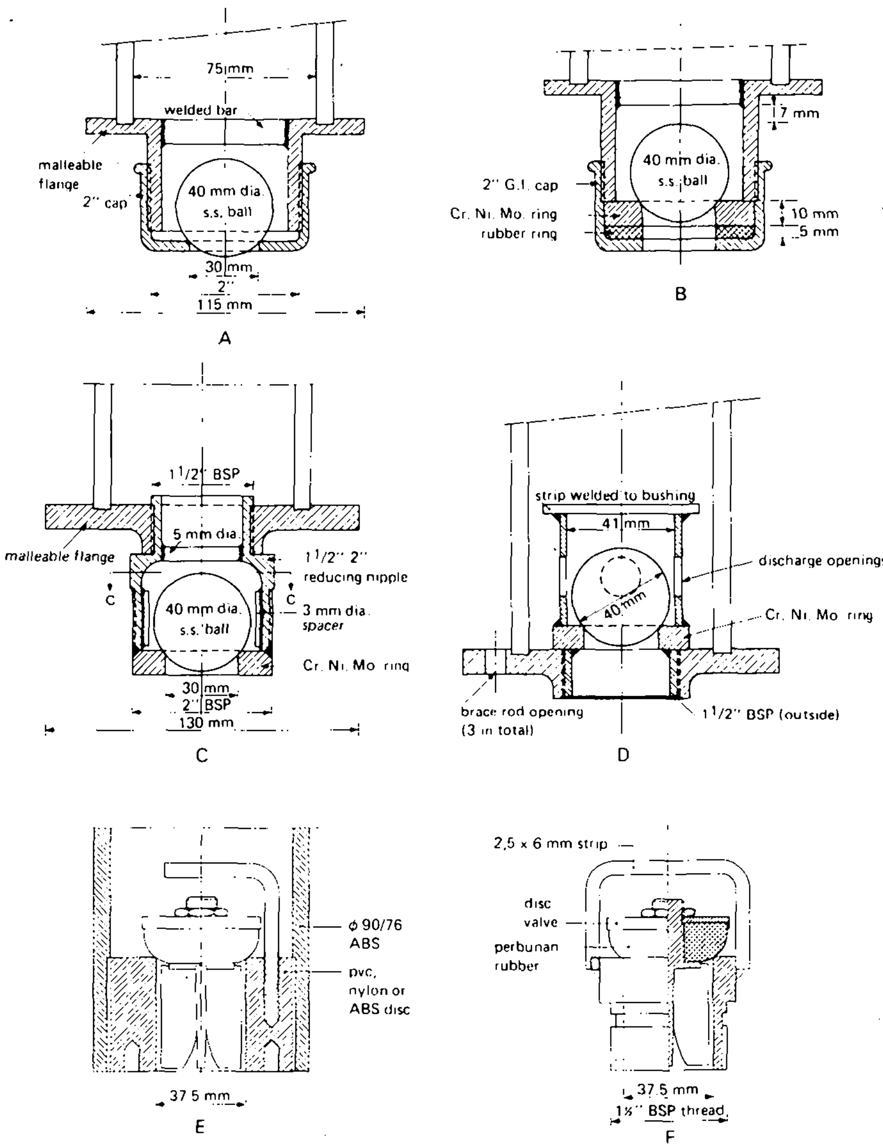
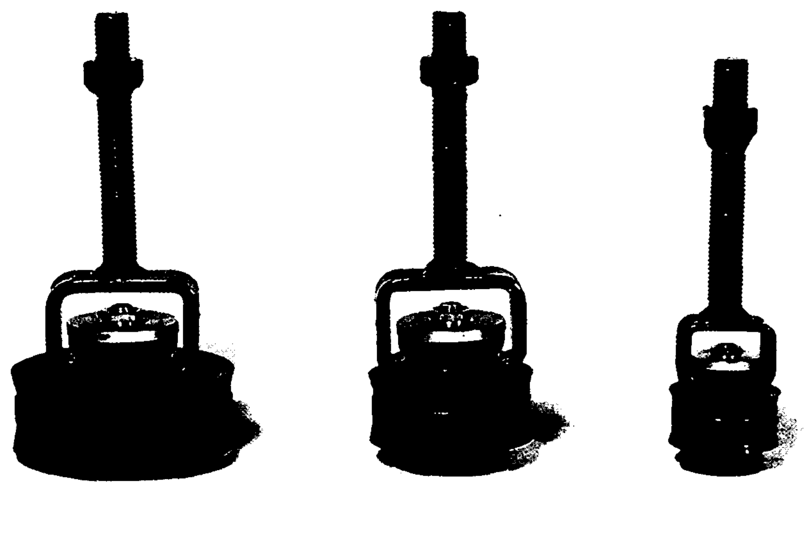


Fig. 34. Alternative constructions of foot-valve assembly

In the solutions mentioned so far, the horizontal play of the stainless steel ball had to be reduced by means of inserting spacers. The total cross-sectional area between the ball and the 2″ socket should be large enough, however, not to offer too much resistance to the flow.

By putting the foot-valve assembly inside the cylinder - on top of the foot flange instead of underneath - the problem could be overcome (fig. 34D). The 40 mm dia. ball was enclosed in a 41 mm inside dia. bushing. A strip was welded on top, to limit the vertical play of the ball. Discharge openings cut in the sides of the bushing allowed water to enter the cylinder as soon as the ball was lifted from its seat (the Cr.Ni.Mo-steel ring).

Better results than with a ball valve could be obtained by using a commercially available winged disc valve, made of brass and perbunan rubber. This valve is now the core of a valve assembly which further consists of two machined parts made of mild steel (fig. 34E). An alternative solution, possible for 3″ and 4″ cylinders only, is shown in fig. 34F. Choosing this solution would mean again abandoning the idea of interchangeability between foot valve and piston valve assembly.



114. Piston assemblies for 4″, 3″ and 2″ cylinders.

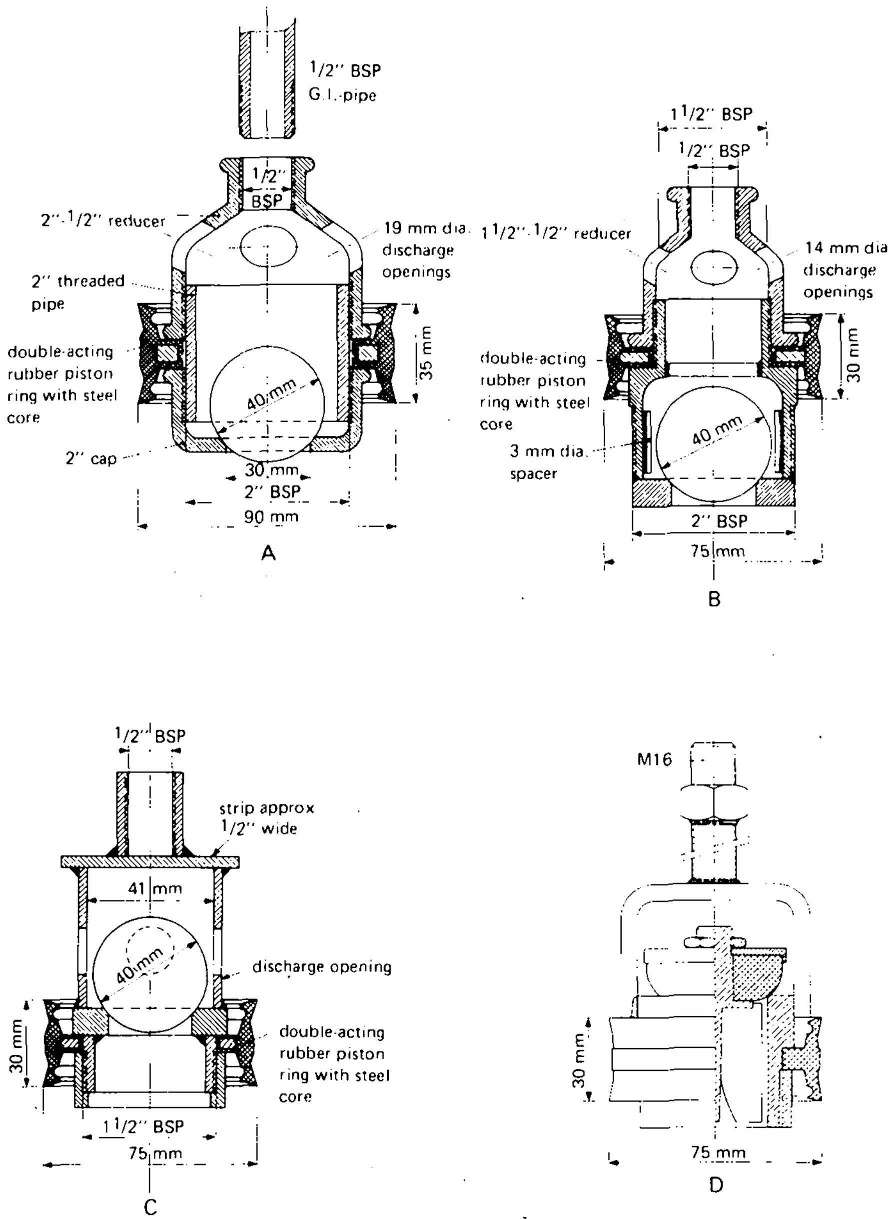


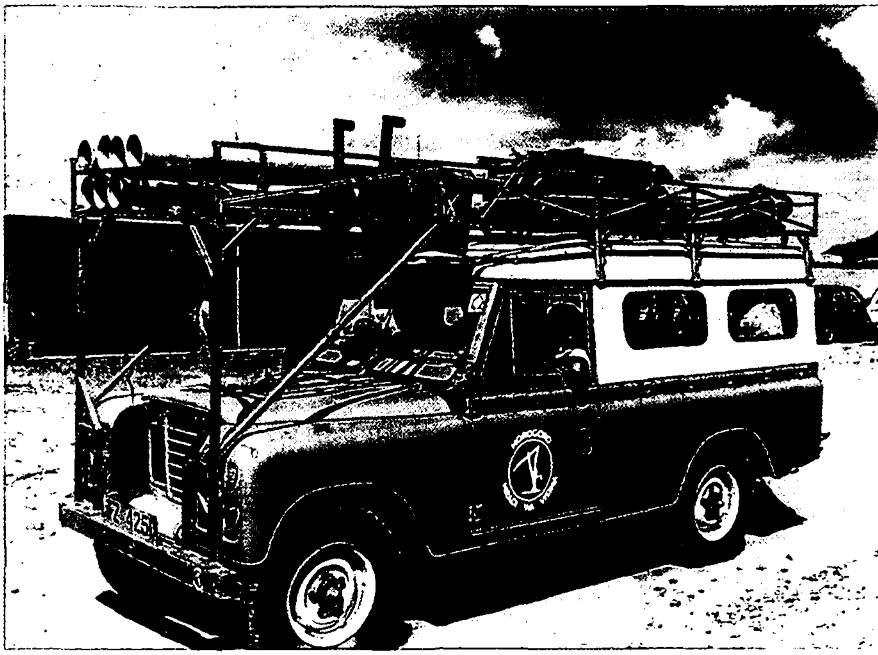
Fig. 35. Development of pump piston

The development of the pump piston is shown in fig. 35. Started originally with a valve similar to that of the foot-valve as shown in fig. 34A, the same problems were encountered and again a hardened steel ring was inserted (fig. 35A). A 90 mm diameter double-acting standard rubber piston ring was used, after the hole in its centre was reamed to the required size (a 2″ BSP threaded pipe should fit inside).

Figs. 35B and C show a development identical to that of the foot-valve assembly in figs. 34C and D. In the modification used at present (fig. 35D) the piston assembly is composed of the entire foot valve assembly (fig. 34D) with a M16-threaded bar welded on top to receive the ½″ pump rod. The piston ring is fixed to the assembly by means of a steel ring with internal thread.

From figs. 34 and 35 it can be seen that the original standard cylinder of 4″ dia. has been replaced by a 3″ dia. cylinder, with a 75 mm piston. Not only are 3″ dia. pistons sufficiently large to yield at least one litre per stroke, but they are also applicable for greater water depths than 4″ dia. pistons would be. The latter would require too much force. For very shallow, or deep, water levels 4″ and 2″ dia. cylinders are used. For small-scale irrigation use (very shallow groundwater) even 10″ dia. cylinders have been used. Their composition is similar to that of the standard 3″ dia. cylinder described above.

115. Storage of Kangaroo pumps at Morogoro yard



116. Transport of pvc pipes, pumps, etc. on specially designed 1½ ton roofrack

At first the ordinary ½" gas pipes used for pump rods were connected with plain sockets. Later on the connection was improved by welding M16 nuts to the pipe ends, cutting the same thread inside the pipe ends also and fixing a piece of M16-threaded bar in one end, thus creating a 'bolt' and 'nut' end on each pipe rod.

Chapter 27. **Mounting of hand pumps**

When the digging or drilling of a well has been finished, the depth of the well is measured and a hand pump set can be ordered. In Shinyanga complete sets consisting of pump superstructure, rising main and pump rods - in sections with spigot and socket - and the pump cylinder assembly are prepared at the pump factory. The length of the rising main and pump rods is fixed so that after they have been put together their length equals the depth of the well - taken from the top of the well cover - minus 1 m.

At least three people are needed to mount a hand pump, i.e. a pipe fitter and two assistants, with the following equipment and materials:

a. pipe cutter 2″ and ½″
b. two pipe wrenches 3″
c. two spanners ⅝″
d. hacksaw
e. file
f. trowel
g. bucket
h. rope (about 15 m)
i. cutting oil
j. machine oil and grease
k. bituminous paint
l. cement
m. sand.

Furthermore it is very useful to have the special clamp available shown in photo 123; this clamp, which consists of two wooden beams with two bolts, can easily be made by hand.

At the well site first the rising main and pump rod are assembled and connected to the cylinder assembly. In case of re-assembling after a pump check the cylinder has to be built up first (see photos 117 and 118). Bituminous paint is put in the circular grooves in the cylinder flanges and the pvc cylinder jacket is pressed in the groove of the bottom flange. Next the piston assembly, to which one short extension rod has been jointed, is pushed in the cylinder opening; the top flange is slid over it and fastened to the bottom flange with three thread bars.

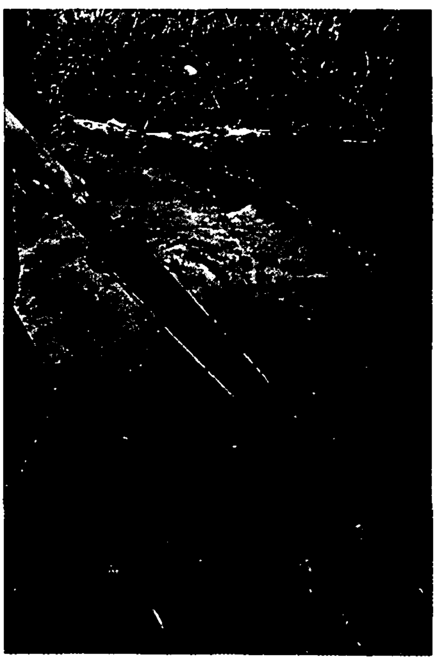
117. Bituminous paint is applied to the groove in the bottom flange

118. The pump cylinder is assembled

119. An extension rod is connected to the pump rod

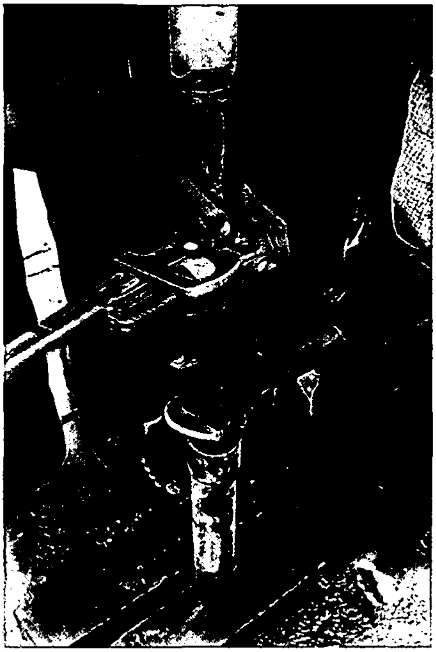
120. Bituminous paint is applied to the thread of the rising main

121. And the rising main and pump cylinder are connected



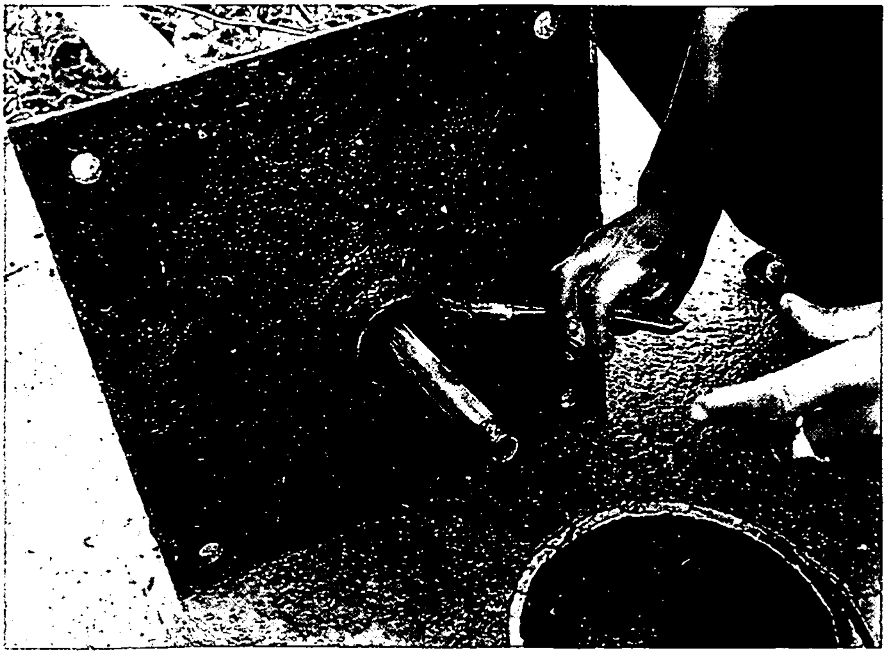
122. The assembly is lowered in the well

123. A wooden clamp prevents the assembly from falling into the well



124. As long as required, pump rods and . . . .

125. . . . . rising mains are connected



126. Again bituminous paint is added (to the thread on the underside of the pump stand and pump rod)

127. Pump rods are connected. (The lower one is fixed. The upper one is turned by turning the pump superstructure)

128. The pump superstructure is screwed into the rising main

129. The footplate is bolted to the cover plate

130. The finished pump

Another ½" extension rod is jointed to the pump rod next, after the bare threaded end has been covered with bituminous paint. Then a section of the rising main is screwed into the top flange, again after bituminous paint has been applied to the thread. As the next step the whole assembly is lowered in the well opening and secured with a wooden clamp, after which new sections of pump rod and rising main can be added. The clamp is released, the assembly lowered and fixed with the clamp again, etc. until the required length of rising main and pump rod have been connected. Then the pump rod is pulled up slightly and fixed with a pipe wrench.

The pump superstructure is now positioned over the well opening and the pump rod connected to the part fixed with the pipe wrench, by rotating the complete pump superstructure, while the lower part of the pump rod is held in position with the pipe wrench. (Note: the pump rod section - which is part of the pump superstructure - should be in its fully downward position. For a Kangaroo pump this will mean that the upper part of the pump should be secured in that position with soft wire (see photo 131).)
The pump head is next connected to the rising main by again rotating the entire superstructure. Then a thin layer of cement (1 cement : 1 sand) is put on top of the cover, under the footplate, the footplate is slid over the 4 anchor bolts and secured with double nuts.

131. Kangaroo pump fixed in fully-down position with soft wire

Chapter 28. **Production of hand pumps; costs**

Originally, the pump superstructures for both the Shinyanga and the Kangaroo pumps were completely manufactured at the project yard in Shinyanga. The wooden handles for the Shinyanga pump were manufactured in a special carpentry workshop. A staff of 4 (1 foreman and 3 carpenters) repaired and maintained wooden equipment parts, supplied boxes, etc., and produced an average of 2 sets of pump handle + upright per day.
The pump factory itself had a staff of 7 (1 foreman, 1 welder and 5 plumbers). Its equipment consisted of a boring machine - the use of which was shared with the general workshop - welding equipment, a set of stocks and dies, a pipe cutter, and various moulds used for assembling the pump stands.
The maximum output capacity was 30 pump sets per month.
After the direct Dutch involvement in the Shinyanga Shallow Wells Project was terminated in July 1978, the Shinyanga factory restricted itself to the production of Shinyanga pumps, whereas the Morogoro Wells Construction Project uses Kangaroo pumps exclusively.

Prices for these pumps ex-factory Morogoro/Shinyanga are:

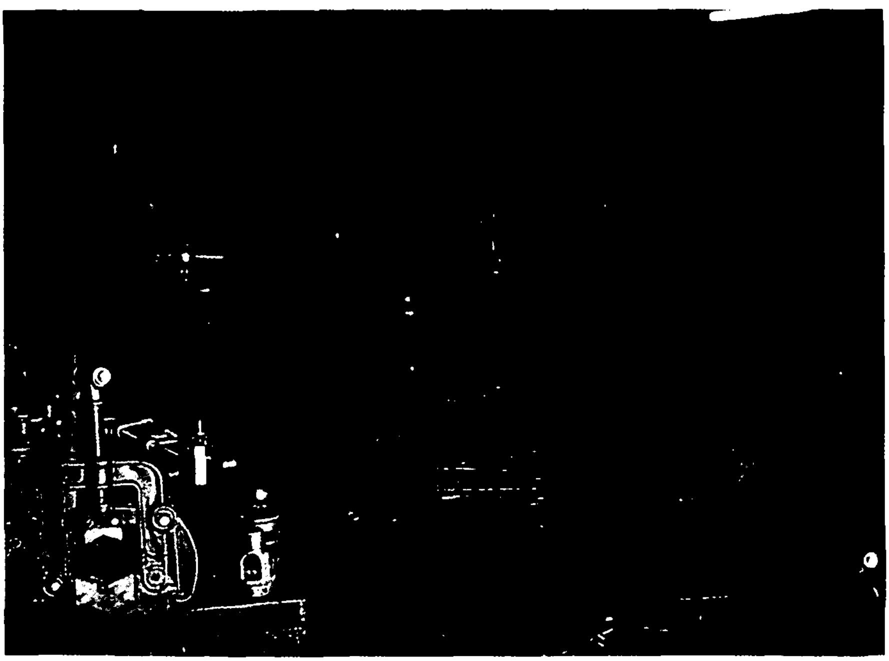
Shinyanga pumphead complete	TShs 1,500.— *)
Kangaroo pumphead complete	TShs 2,200.—
3″ deep-well pump cylinder	TShs 1,250.—

Including rising main, pump rod, transport and labour, total costs per installed pump will amount to approx. TShs 5,000.—.

*) TShs 8,00 = US$ 1.00 (1979).

132. Up-rights are made in carpentry workshop

133. Wooden parts of pump superstructure are oil soaked in drums which are dug into the ground



 134. Pump factory

Part 6
Maintenance of wells and pumps

Chapter 29. **Maintenance targets**

Ideally a well, once constructed, should continue to give good-quality water for a lifetime, without any repairs, supervision, etc. Unfortunately such wells have never been built yet and a certain degree of regular supervision and maintenance will be required to ensure a trouble-free operation. Nevertheless, in designing and building a well and pump the ideal of maintenance-free operation should be kept in mind, in order to reduce maintenance costs in practice as much as possible. The distances between wells may be such that even a modest attempt at centralized supervision and maintenance will incur expenses that are prohibitive in practice.
In many countries - especially when still developing - due to financial limitations in regard to government funds, attention is mainly focused on the construction of wells whereby maintenance after construction is given second priority.
Although the aim should be to leave a maintenance-free structure behind in each village, in practice problems will still occur, like:

- cracked concrete slabs and covers
- loosened anchor bolts
- broken pump rods
- broken or split handles
- hinge points worn out
- bolts and nuts stolen
- wooden pump handle and upright stolen and used as fuel for cooking
- contamination of well and surroundings.

Parts which frequently give rise to defects should be modified on grounds of the experience of the maintenance groups. For the pump superstructure this means that no wooden parts should be used and the number of hinge points, bolts and nuts reduced to a minimum. This train of thought has led to the development of the Kangaroo pump, which is designed to be maintenance-free for a period of approximately 10 years (chapter 25 B).
Defects in the concrete work nearly always prove to be the result of bad execution (slab too thin), or poor concrete quality (not enough cement). These faults must be blamed on insufficient supervision during the construction phase.

In general, in Shinyanga E-coli were found in half the bacteriological check-ups. The causes are usually:

- cattle in the immediate vicinity of the well
- inadequate drainage of spilled water
- sources of pollution (latrines, ponds etc.) upstream of the well

Measures to combat these causes are often rather unsuccessful.
Cattle can be kept at a distance by means of thorn barriers etc. However, the cooperation of the local population is important. Instruction on the importance of keeping the immediate vicinity of the pump clean is therefore necessary. Latrines and ponds located within a distance of 100 m upstream of the well should be removed.
Securing the cooperation of the local population in maintaining and guarding the wells is essential. Much can be done to ensure a long trouble-free operation by keeping cattle away, keeping the well and its immediate surroundings clean, and preventing children from using the well as a playing ground.

Regular well maintenance checks should comprise:

- periodical inspection and repair of well and pump structure
- periodical examination of the chemical and bacteriological quality of the water.

Often the latter is considered to be superfluous and restricted funds may indeed prevent water quality checks from being executed as part of the maintenance package.
During the survey stage water quality checks were executed (chapter 11F), so an overall picture of the local water quality has been obtained. Unless major changes in water quality are envisaged, contamination from the outside - thus mostly of an organic nature - will be the principal factor to be taken into account. As long as all water is boiled thoroughly before consumption, the effect of not checking the quality of the water will, therefore, be of minor importance.

Chapter 30. **Maintenance organization**

The possibilities for setting up a maintenance organization depend mainly on the available funds, and to a somewhat lesser extent on the available manpower. In this chapter two alternative solutions will be described:

- centralized maintenance, with 2 complete check-ups per well and per year, as practised during the initial stage of the Shinyanga Shallow Wells Project
- decentralized maintenance with responsibilities delegated to the villagers, and decentralized repair groups.

A. *Centralized organization*

The well maintenance organization consists of 3 sections, under the direction of a supervisor:

- check-up section, divided in a number of identical groups, each operating in a specific area.
- laboratory section, comprising a centrally located laboratory with the necessary staff.
- repair section, consisting of 3 to 5 labourers and a foreman.

The work of the check-up group comprises:

- Inspection of the parts of the pump above ground level, and carrying out any necessary repairs.
- Dismantlement of the lower parts of the pump if these are not operating effectively. If the pump cylinder is out of order, it is replaced and forwarded to the central workshop for repair.

- A bacteriological investigation to establish the number of E-coli bacteria. This test must be carried out in the field directly after sampling, as the bacteria quickly die off, so that later testing gives unreliable results. The sample is placed in an incubator under conditioned circumstances for one day and then examined in the group's portable water laboratory.
- A chemical investigation to establish the ammonia content. This test is also carrried out in the field to ensure reliable results.
  As there is a fully equipped central laboratory, the determination of the remaining constituents is carried out there. The samples required are taken by the check-up group.
- Disinfection of the well if E-coli bacteria have been found.

The work of the laboratory section comprises the determination of all relevant components in the water samples taken by the check-up groups, and during the survey.

The work of the repair section comprises the repair of the concrete surroundings of the pumps and of the filter construction enclosing the well rings, after the necessity to do so has been reported by one of the check-up groups. All data on the construction, repairs, maintenance and water quality of each well are registered on cards (see page 54).

Every six months each hand pump is taken apart.
This maintenance programme consists of the following activities:

- unfasten the pump stand, rising main, pump rod and remove the pump unit
- pump the well dry with a motorpump and remove all dirt, insects and garbage
- disinfect the well with 50 grams of bleaching powder. As soon as the well is filled up again with about half a metre of water, pump this water around and spray the highly concentrated liquid over the entire ring and cover
- check and/or repair the pump cylinder, all pipe connections, hinge points, bolts and nuts, the cover and the concrete slope
- after these activities the water is pumped out again and the cylinder and superstructure are installed
- information is given to the village authorities about the condition of the well.

B. *Decentralized organization*

Maintenance costs can be greatly reduced, although at the cost of lower maintenance standards, by laying the first responsibility for maintaining the wells with the villages themselves. A village may appoint 1 or 2 men or women to receive a basic training on well maintenance and be appointed pump attendants. Their activities should include:

1. daily activities
   - check operation of the pump
   - control bolts and nuts to be tightened
   - clean the slab
   - clean the spoil gutter
   - surround the well with minyara or thorns to prevent cattle from entering the area of the well
   - prevent the well from being used as a working area
   - prevent the well from becoming a children's playing ground

135. Bolts and nuts have to be tightened after some time

136. Hinge point of pump handle is greased

137. Hinge points of pump rod pullers are greased

2. monthly activities
   - check damage, rotting of wood, insects in wooden handle etc.
   - grease or oil all pivot points and oil the wooden handle and upright
   - inform maintenance office if capacity or quality of the water has diminished
   - check concrete slab and repair the cracks with some mud or stones

Furthermore on a higher government level, e.g. on district level, maintenance offices are installed. A District Maintenance Officer supervises maintenance and is in charge of the check-up groups in his district. Major repairs are executed by a repair section as described for the centralized organization.

As an - less expensive, though less ideal - alternative, is to have only one trained pump mechanic at district level (again being called District Maintenance Officer), who is warned by representatives from the various villages when their pump or well is in need of repair.

The District Maintenance Officer's task is to check the village maintenance, to help with the larger repairs and to see to the provision of spares, and to keep records on all wells in the district.
He is responsible to the central organization, where he can also obtain the spares required and can request help for major repairs. In Shinyanga the District Maintenance Officers each have a motorcycle available on which a large box can be mounted for tools and spares.

C. ***Frequency of maintenance. Costs.***

Experience in Shinyanga Region shows that one check-up group can complete 300 well checks per year. A frequency of 2 checks per well and per year has proved to be feasible, which fixes the number of wells that can be controlled by one group at 150. The distance between the wells plays an important role, however, and for wells in less sparsely populated areas than Shinyanga Region the capacity per group may be considerably higher.

If the centralized maintenance set-up is chosen the costs per well in a situation comparable with Shinyanga Region (more than 700 wells over an area of 50,000 square kilometers) amount to TShs 1,200 to 1,700 *) per year, without chemical or bacteriological analysis being performed.

In the case of decentralized maintenance the costs will be reduced markedly, but still amount to approximately TShs 400.— per well check i.e.:

transport costs	TShs 145.—
materials	TShs 170.—
salaries, etc.	TShs 30.—
sundries	TShs 55.—
Total per well check:	TShs 400.—, or: TShs 800.— per well per year.

Costs may be further reduced by introducing a system whereby the villages are charged, possibly for the construction, but in any case for the maintenance of their wells. The wells would then become the property of the villages, which will buy the spares needed from the District Maintenance Officer.
As the costs for spares are estimated at TShs 350.— per well per year, this method would mean that the cost of maintenance only would be not more than TShs 2.— per head per year.

*) TShs 8.00 = US$ 1.00 (1979)

Part 7

Logistics and administration

Chapter 31. **General set-up**

In Part 2 the general outline of the organization of a wells construction project has been sketched. Various parts of the organization have been discussed in greater detail in Parts 3 through 6. The remaining departments - transport and mechanical section, administration, etc. - are discussed in the following chapters. It will be clear that each individual situation will result in special requirements, so that no generally applicable recipe for the organizational set-up can be given. Thus the following chapters comprise an indication only, based on a self-supporting wells production organization with an average output of 20 wells per month. Details are given of the manpower and equipment of the various units as encountered within the Shinyanga Shallow Wells Project.

Chapter 32. **Vehicles, organization and maintenance**

The organization of the Mechanical Section is shown in Fig. 36.

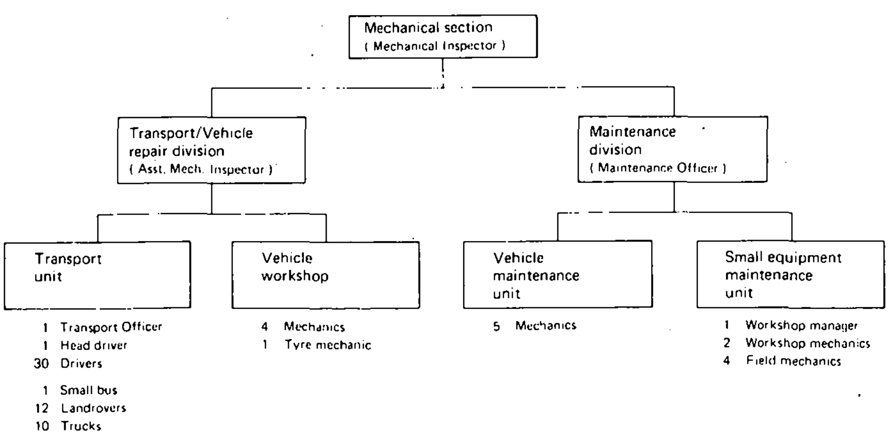


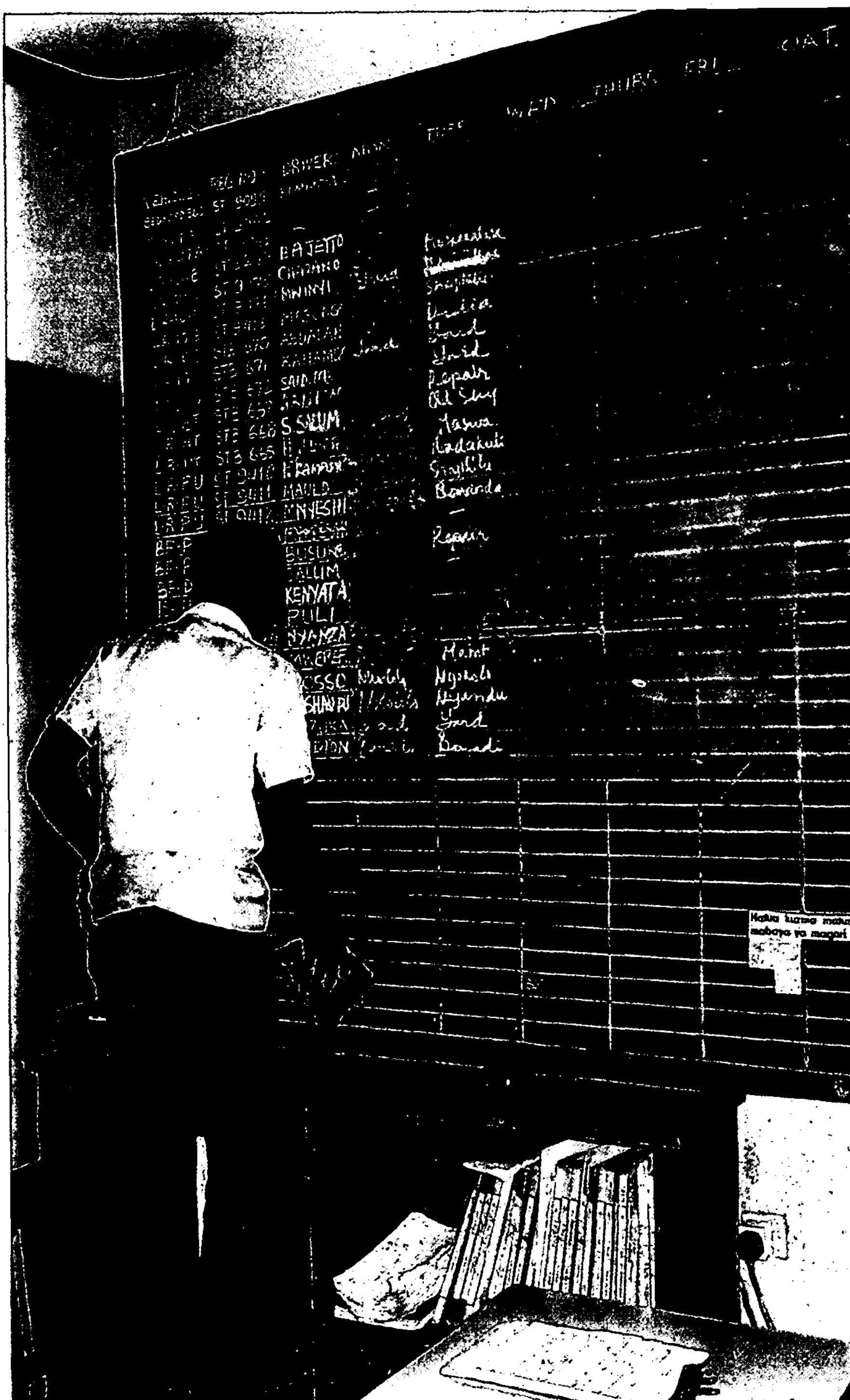
Fig. 36. Organization of Mechanical Section, Shinyanga Shallow Wells Project

An important criterion for establishing a Transport/Vehicle Repair Division is the type and the number of vehicles that is going to be used. Experience generally shows that the provision of spare parts is one of the most time-consuming and critical activities within the entire set-up. The aim should be:

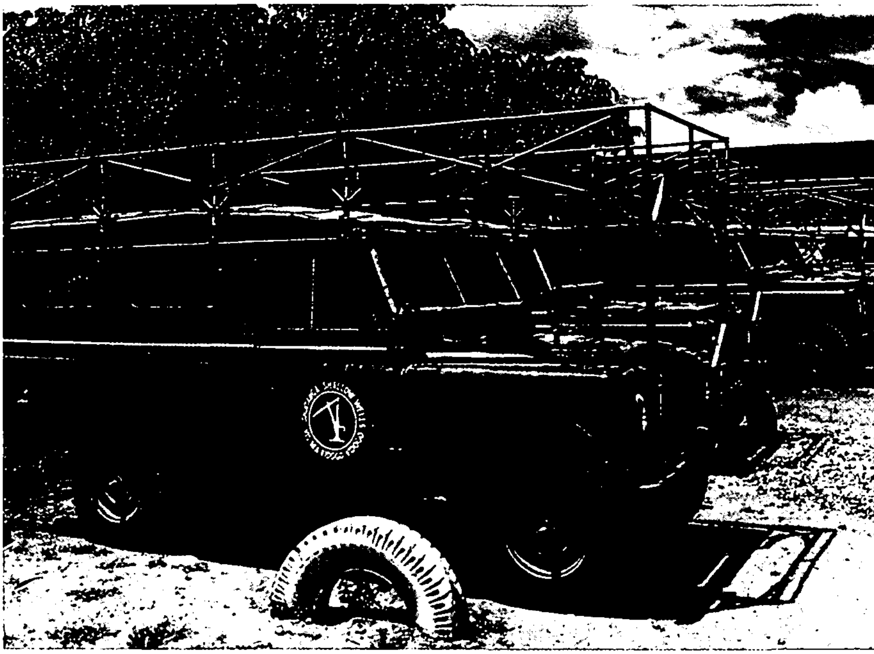
a. to restrict the number of different vehicle types to a minimum, thereby vastly reducing the number of spare parts that should be in stock.
b. to choose only vehicles that are widely used in the country concerned and of which spare-parts should be easily obtained locally.
c. to choose vehicles that are appropriate to prevailing conditions, e.g. 4-wheel drive etc.

The number of vehicles to be employed is of course a function of the desired output of the project and the available funds.
The principal task of the Transport/Vehicle Repair Division and Vehicle Maintenance Unit is to keep the vehicles in running order. As some 23 vehicles are regularly employed in the Shinyanga Shallow Wells Project, with a total monthly kilometrage of 70,000, this is a large and crucial task.
Weekly the Transport Officer makes a planning for the use of the various cars by the other units. The use of a certain car is then authorized by a staff member from the relevant unit, who fills in the Transport/Plant Works Ticket and Log (page 177). The date, destination and reason for the journey are entered and the signature of the authorizing officer put behind it. The driver shows this form to the Transport Officer who then writes out a gate pass (page 178) for the relevant car, after having checked the validity of the signature on the Transport/Plant Works Ticket and Log. The driver has to check the condition of his car and the presence of the standard equipment from the check list which is indicated on the gate pass. In case repairs are needed or equipment missing he has to report this to the Transport Officer.
The gate pass is checked for the Transport Officer's signature by the gate watchman, who allows no car to leave through the gate without a valid gate pass.

At regular intervals the vehicles are overhauled by the Vehicle Maintenance Unit, which also repairs small defects. Larger repairs, e.g. those caused by accidents, are performed by the vehicle workshop, however. The time spent on any repair as well as the fuel, oil and spare parts used are recorded on job cards (page 179). The job cards, together with the Transport/Plant Works Ticket and Log - on which the issue of fuel is recorded - give an impression of the performance of each car.



138. Transport planning



139. Often a great variety of vehicles, ...

140. . . . .including heavy trucks, has to be taken care of

141. Vehicle repair and maintenance

Chapter 33. **Small equipment maintenance**

The activities of the small equipment maintenance unit (SEM) comprise the maintenance and repair of all mechanical equipment except the vehicles.
The work is carried out in the central workshop and in the field for the construction units.

The work in the workshop consists of:

- the monthly complete overhauls
- carrying out major repairs

The work in the field consists of:

- daily care of the equipment
- the weekly overhauls
- carrying out minor repairs
- instructing the labourers in correct operation and treatment of the equipment.

142. Miscellaneous small equipment

The equipment which is maintained by the SEM includes: hand drills, mechanical drills, generators, jackhammers, concrete mixers, wheelbarrows, spades and pick-axes, motor- and hand-pumps.

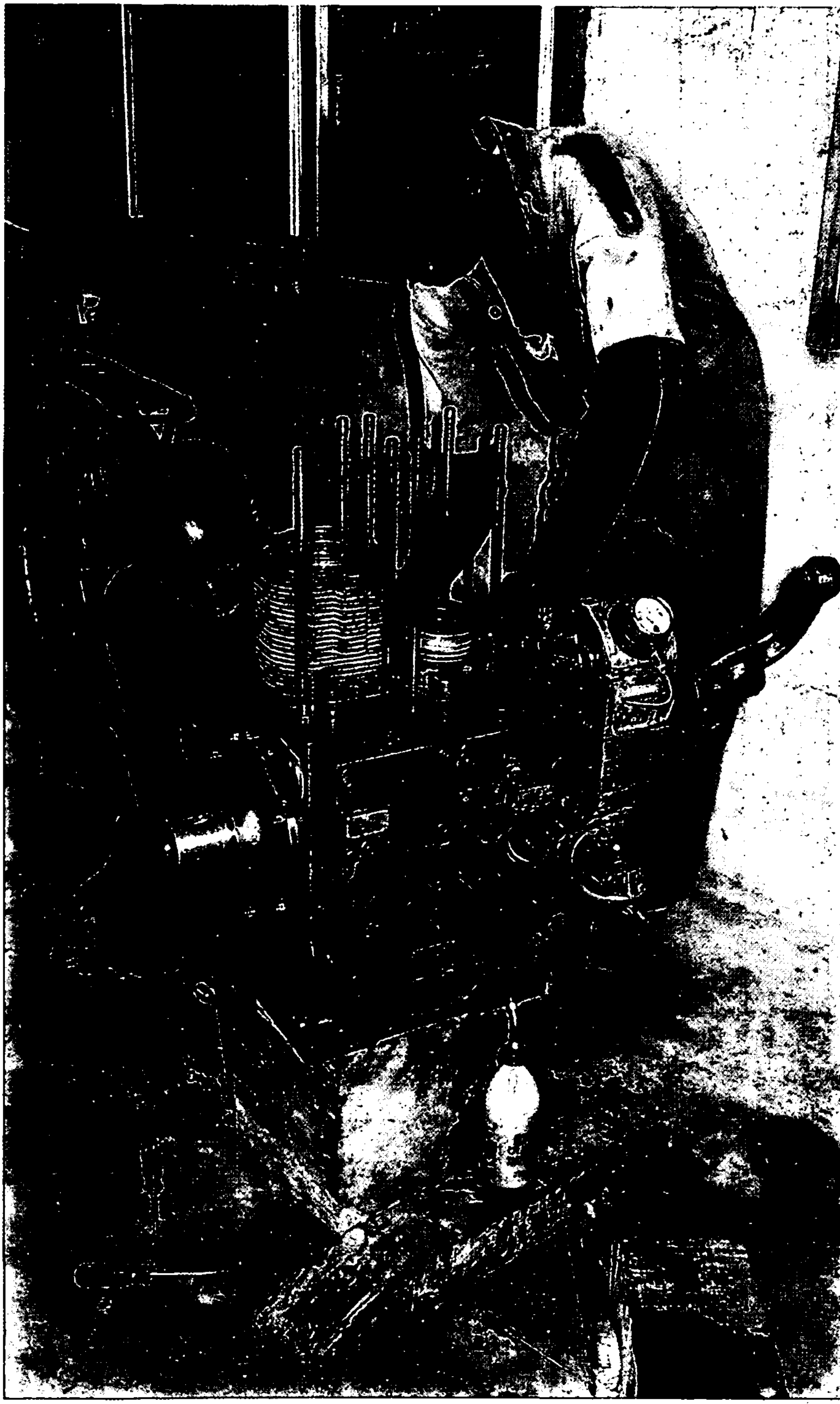
The staff of SEM includes:

1 workshop manager
2 workshop mechanics
4 field mechanics

The field mechanics are attached to the construction units and take care of the maintenance in the field.

This attachment has proved to be very successful because:

- equipment now only has to be transported to the central workshop for maintenance once a month instead of once a week; this results in a considerable time saving
- equipment in the field is better operated and maintained, so that the number of breakdowns and defects has decreased.



143. Overhauling equipment

Chapter 34. **General workshop**

A general workshop is a necessary part of any well construction project. In Shinyanga it produced: survey bits, heavy hand-drilling equipment, tripods, hand pump assemblies for dewatering well pits during construction, certain parts of the camping equipment, etc., while all kinds of repairs on non-mechanical equipment were performed and new equipment developed and tested.

The staff of the general workshop consisted of:

1 welder/blacksmith
1 welder/bench fitter
1 lathe operator
2 labourers

with the following equipment:

1 lathe
1 set of electric welding equipment
1 drill press
1 shearing machine
1 profile rolling machine
1 sheet rolling machine
1 smith's hearth

Chapter 35. **Administration and accounting**

Administration and accounting often have to comply with specific rules, fixed by local or higher government. Methods can be so entirely different, and on the other hand specialized literature on this subject is available in such abundance that a detailed discussion of the various methods which can be applied seems to be less useful. The fact has to be stressed, however, that a good administration and accounting section is a very worthwhile asset to any project, whatever its actual administrative and accounting methods may be.

Generally the following should be included:

- Day to day administration incl. recording of incoming and outgoing mail
- Personnel administration
- Financial administration
- Stores and supply administration

In small-scale wells construction projects the entire administration and accounting may be a one-man job, or even a part-time job. In other situations the wells construction project may be incorporated in an existing (government) organization which already has its own fully-equipped administration and accounts departments.

The stores and supply administration is a department which time and again proves to be crucial in any production project, especially in countries with a less developed infrastructure. Therefore, this department is the only one of which the organization and working methods will be described in more detail.

Chapter 36. **Purchasing and stores**

The operation of a wells construction project depends largely on a regular supply of materials and equipment. In order to complete 20 wells a month, approximately 500 bags of cement and a considerable quantity of piping and fittings are required monthly. Moreover, the vehicles (in Shinyanga: 23) cover a total distance of up to 1,000,000 km per year, consuming approximately 250,000 l of fuel. Last but not least the survey and construction units need to have tools and equipment readily available.

During any project different types of tools and equipment can be used and their effectiveness tested. Standard equipment should be selected on the basis of such experience, of availability and of costs. In the construction of shallow wells and the manufacture and operation of hand pumps, standardization will be necessary for:

- surveying equipment, e.g. hand-drills, bailers, sand pumps
- construction equipment, e.g. hand-drills, tripods, pullies, winches and membrane pumps
- concrete moulds for rings of standard diameter, so that all rings are interchangeable
- hand pumps

A. *Purchasing*

In a project the size of that in Shinyanga (20 wells per month), one purchasing officer should be able to arrange all purchasing.
Wells construction projects will as a rule not be situated near larger cities so that the possibilities of obtaining equipment locally will be limited. Simple equipment like buckets, spades, pick-axes, etc. may be bought locally, but cement and reinforcement steel often have to be obtained farther away, e.g. in the capital, or have to be shipped in from abroad. The same applies to more sophisticated equipment and many spare parts.

From the store (see under B.) the purchasing officer receives instructions by means of order notes or lists of the items to be purchased. The first decision will then have to be the choice of the supplier.
The following factors play a role in the selection of a supplier:

1. *the price of the article* ex-shop, including discounts
2. *the transport charges* from the supplier to the project's location
3. *expenses* to be made during purchasing, e.g. travel cost and lodging for the purchasing officer, etc.
4. *time of delivery.* Depending on the urgency of a particular required item the time of delivery may be the overruling factor, despite higher costs, etc.
5. *reliability of supplier:* reliability of the supplier as to time of delivery, quantity and quality of the article involved. In Shinyanga the delivery of cement has at times been very erratic, and people had to be sent to Dar es Salaam in order to ascertain delivery. This caused delay in the work and led to high purchasing expenses.
6. *'self reliance'.* In view of the continuity of the project it is advisable to use as far as possible articles which are locally available, even if this implies higher costs.

7. *Substitution possibilities.* Often articles which are difficult to obtain can be replaced by others which are obtainable locally and may be just as suitable. A nylon rope may for instance be replaced by a sisal rope, etc.
8. *Possibility of independent local production.* In Shinyanga several items were produced by the project organization itself because:
   - the required articles were not available
   - the price of the local suppliers was far too high.

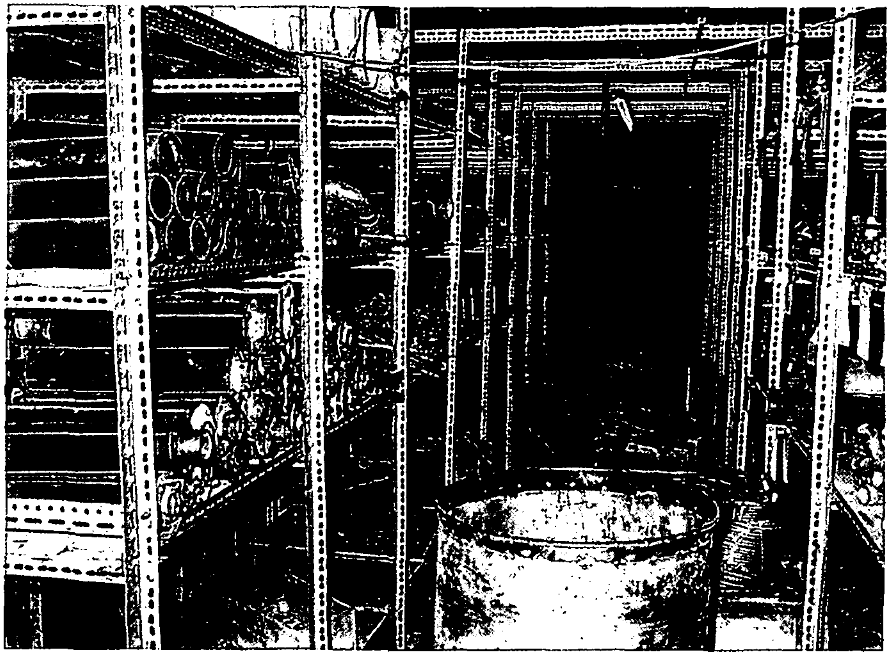
From the above it will be clear that a maximally efficient purchasing policy can only be partly attained. Too many factors are involved, each of which varies in time and in relative importance. Especially the quality of the available means of communication often leaves something to be desired when one is executing a construction project 'out in the bush', and this does not make the process of improving efficiency easier.

B. *Stores*

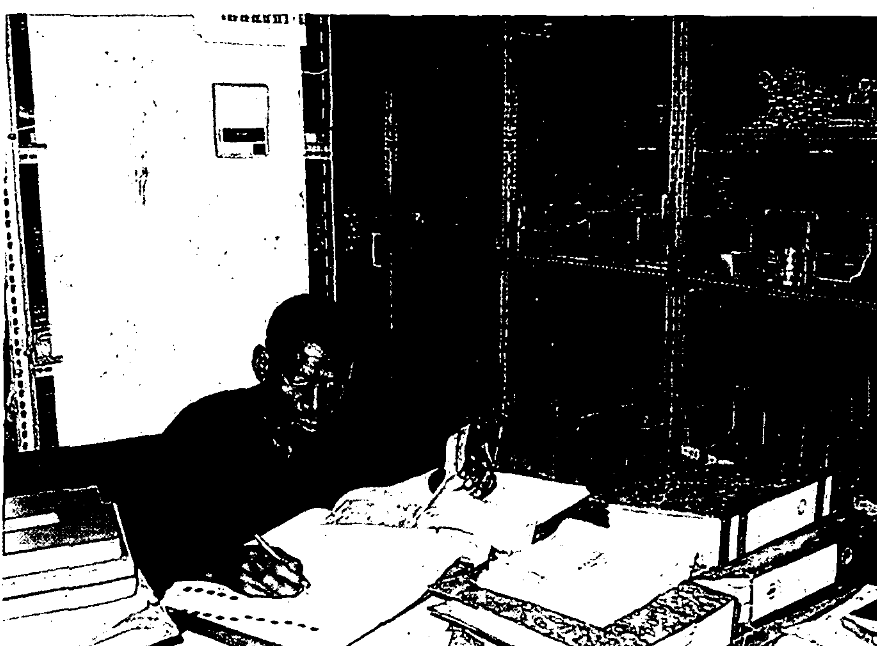
In order to prevent stagnation in the progress of the work a stock of items which are regularly needed has to be available. The size of the stock which should be kept is determined by more than one variable, however. Speed of turnover, time of delivery and cost of keeping a stock of a certain size are important factors.

The cement supply is taken as an example. Monthly 500 bags are used in Shinyanga. Time of delivery is 2 months after the order was placed.
The quantity of cement to be ordered in a single order should be 500 bags, when orders are placed once a month; approx. 125 bags when weekly orders are placed; to become a (theoretical) minimum of some 20 bags if an order for cement were to be placed every day.
It will be clear that a daily supply with 20 bags of cement which is used immediately reduces the required storage space to a minimum. On the other hand the costs of purchasing and freight will be relatively high. However, more important is that the safety margin is reduced to a non-acceptable minimum, i.e. the possibility of the cement not arriving every day - resulting in delays of the work - may no longer be excluded. To overcome this problem a higher stock level can be chosen, or the orders are placed at such a time that when the new articles are delivered, the old ones are not yet depleted. This increases the storage requirements, however, etc.
Theoretically this entire process can be optimized. In practice, however - certainly under rural conditions in developing countries - too many factors are not stable enough to base a proper planning on and stock levels will generally have to be higher than would be necessary in theory.
In Shinyanga the frequency of restocking items was higher than once per week for articles which could be obtained locally; once per two weeks for articles which were purchased in Mwanza (about 3 hours' drive); and once per two months for articles which had to be brought by truck (about 1½ days' drive) or flown in from Dar es Salaam.

In the Shinyanga set-up the entire flow of goods is divided over three store administration units, viz.
a. *the general store,* which keeps records of all non-consumable goods (equipment) and of all consumable goods (materials) other than vehicle spare parts.
b. *the geo store,* which is in fact a sub-store of the general store. It keeps records of the equipment used by the geological section.



144. General store



145. Keeping up with store administration

146. Issuing articles from the general store

c. *the garage store,* which records the flow of all vehicle spare parts

Within these units information is laid down with regard to the incoming flow, the stock present, and the outgoing flow of goods.

The procedures used are visualized in figs. 37 and 38. The forms used are shown on pages 180 through 188.

In order to control the efficiency of the outflow of goods, the following monthly reports are submitted by the stores:

1. for each vehicle the relation between fuel used and kilometres run
2. for each vehicle the cost of repairs or maintenance is calculated on the job card (page 179, 180). From these the average costs of repair or maintenance per kilometre are calculated for each type of vehicles.
3. The total cost of all issues to each department, section or unit is calculated.

The total staff of the stores in the Shinyanga Shallow Wells Project consisted of 9 people:

4 storekeepers
3 assistant storekeepers
2 store hands

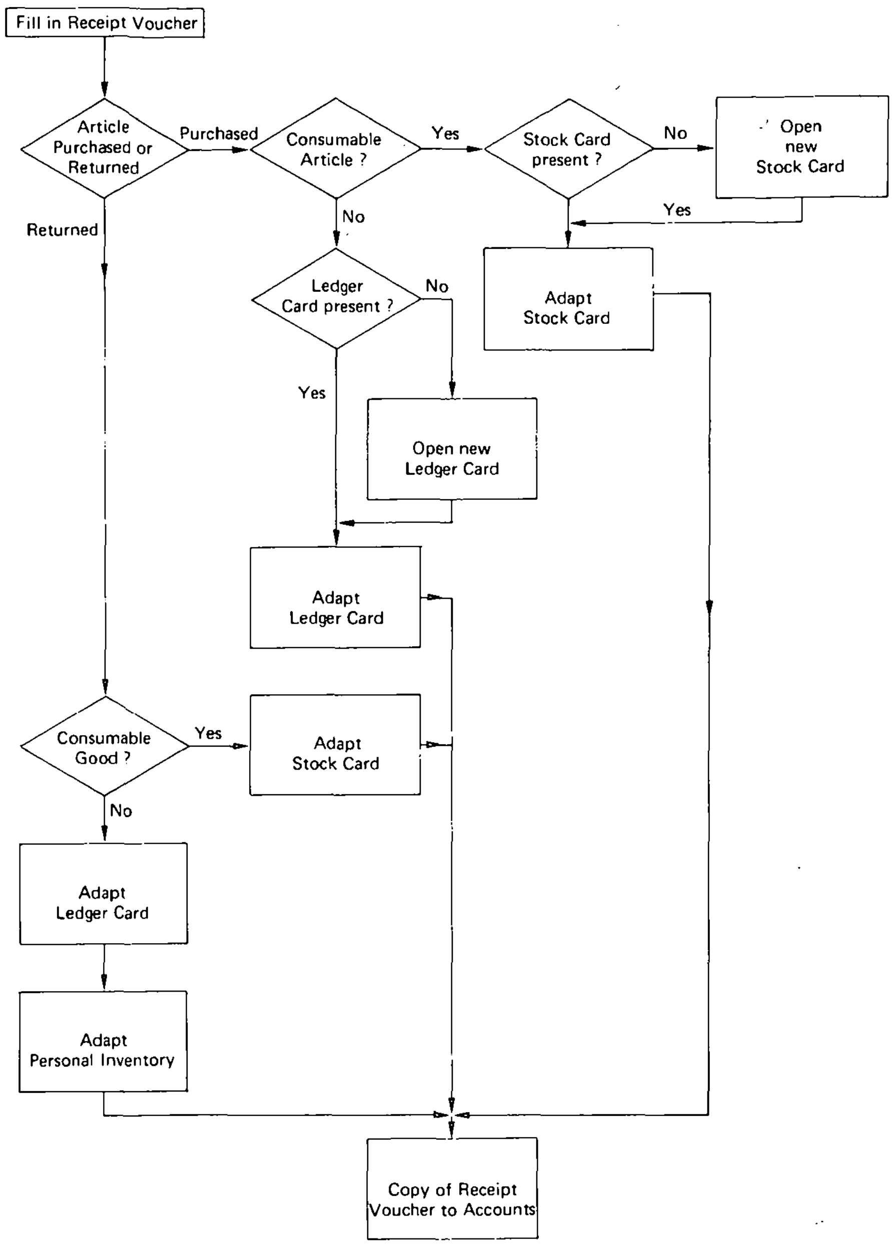


Fig. 37. Stores administration, Incoming Flow

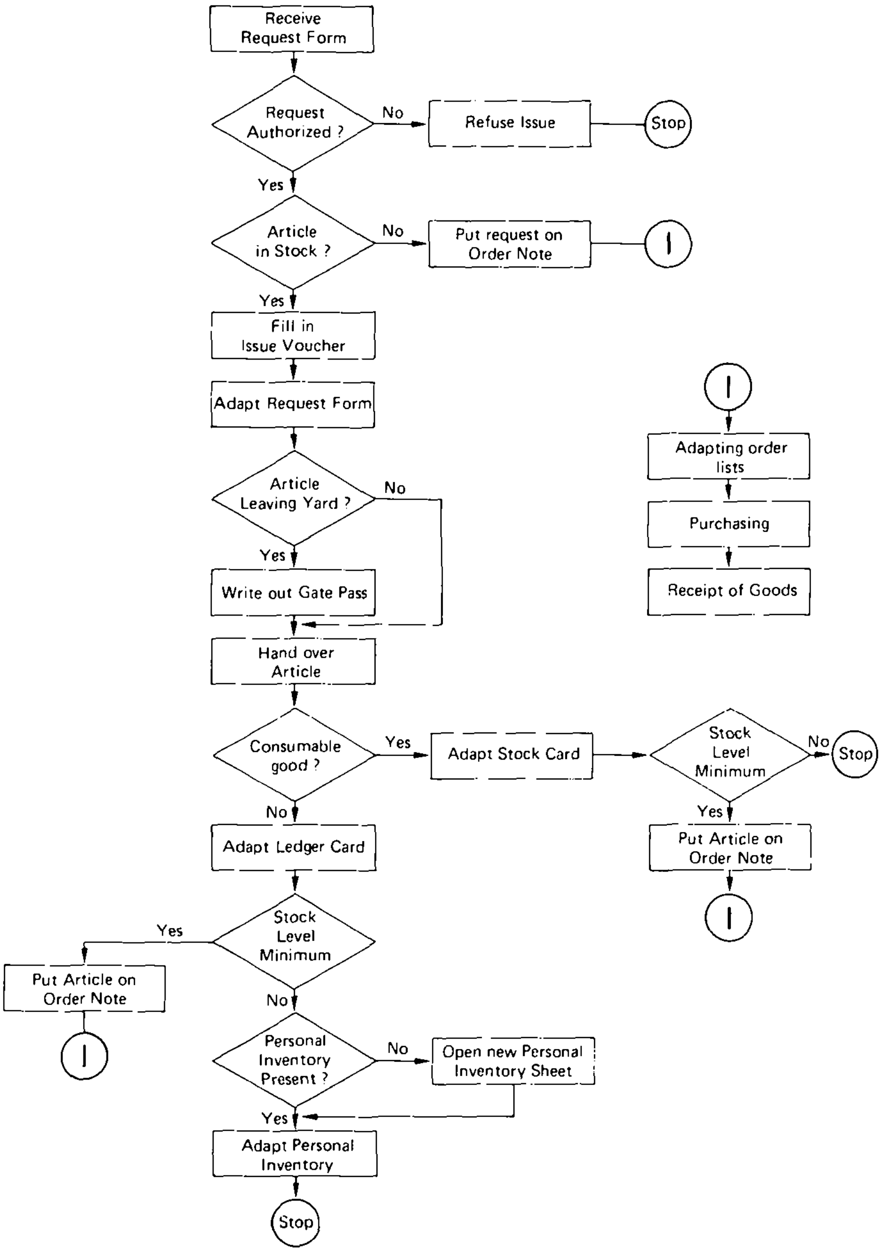


 Fig. 38. Stores administration, Outgoing Flow

Part 8

Costs

Chapter 37. **Introduction**

When a wells construction project is set up, investments have to be made for vehicles, equipment, buildings, etc. (chapter 38). For the duration of the project itself materials and fuel have to be bought, salaries paid, etc. (chapter 39). At the end of the project overall costs per well can be calculated (chapter 40). In chapters 38 through 40 the costs will be discussed as they were incurred in the Shinyanga Shallow Wells Project (ultimo 1974-mid 1978). Where possible, updated cost figures based on the results of the Morogoro Wells Construction Project (July 1978 to present) have been given (price level July 1979). In other projects most probably different figures will be found, so the figures mentioned should merely be considered as an indication.

Chapter 38. **Investment costs**

Total investments made during the Shinyanga Shallow Wells Project amounted to approximately Dfl. 2.65 million, as follows:

	Investment cost	
	in Dfl.*)	in %
Vehicles and vehicle workshop equipment	1,140,000	43.0
Concrete rings, covers and pump factories	95,000	3.6
Survey and laboratory equipment	440,000	16.6
Wells construction equipment	630,000	23.7
Pump installation and maintenance equipment	5,000	0.2
Offices and buildings	335,000	12.6
Administration, stores, miscellaneous	8,000	0.3
TOTAL	2,653,000	100.0

*) Dfl. 2.20 ≐ US$ 1.00 (1978)

Per July 1st, 1978, the project was handed over to Tanzania, after some 750 shallow wells had been constructed. It is assumed that at that time for calculation purposes the salvage value of the buildings should be fixed at 80% of the investment costs, and the salvage value of the remaining investments at 50%. This means that approx. Dfl. 1.2 million investment costs should be apportioned over 750 wells, or: an average of approx. Dfl. 1600.— per well.
If an interest of 8% annually is taken into account, investment costs per well increase to some Dfl. 2500.— per well.

During the Shinyanga project several substitutive working methods have been tried out and developed and as a consequence total investment costs for a similar project might be lower now, with the knowledge available at present.

A compilation of investment costs of various items used in well construction, as well as other costs mentioned earlier in this publication, is shown in the following table.

COST OF MISCELLANEOUS ITEMS

Description	Unit costs *)		
Survey set, complete	TShs	41,500.—	
Drilling machine (survey), simple	US$	12,500.—	
Drilling machine (survey), trailer-mounted	US$	60,000.—	
Water quality analysis set for one type of analysis	US$	75.—	
Portable water laboratory	US$	1,400.—	to 2,400.—
Heavy hand-drilling set	TShs	105,000.—	
Rotary or percussion drilling rig	US$	75,000.—	to 300,000.— and over
Concrete well ring no. 1, 2, 3 or 5	TShs	260.—	**
Concrete well ring no. 4	TShs	130.—	**
Concrete well ring no. 7	TShs	50.—	**
Concrete well ring no. 10 or 11	TShs	100.—	**
Cover for dug well (concrete)	TShs	200.—	**
Cover for drilled well (concrete)	TShs	100.—	**
Cement (per bag)	TShs	45.—	**
Gravel (per truckload)	TShs	240.—	**
Petrol (litre)	TShs	6.50	
Diesel (litre)	TShs	3.10	
Steel mould for cover for drilled well	TShs	6,500.—	
Slotted pvc filter pipe, 150 mm dia. (per 3 m)	TShs	450.—	
Plain pvc pipe, 150 mm dia. (per 3 m)	TShs	350.—	
Shinyanga pump head, complete	TShs	1,500.—	
Kangaroo pump head, complete	TShs	2,200.—	
3″ pump cylinder	TShs	1,250.—	
Complete pump, ex-factory	TShs	4,000.—	(approx.)
Complete pump, installed at well site	TShs	5,000.—	(approx.)

*) prices in TShs are quoted ex-factory MWCP at Morogoro (TShs 8.— = US$ 1.00, July 1979).
**) prices ex-Shinyanga per December 1978 (TShs 7.50 = US$ 1.00).

Chapter 39. **Running costs**

For the Shinyanga Shallow Wells Project the running costs amounted to an average of TShs 300,000 (US$ 40,000) per month. Production being at a level of 20 wells per month, running costs per well amounted to TShs 15,000.
The running costs included all expenses except the investments mentioned in the previous chapter and the salaries of expatriate personnel and regular government staff. The salaries of the vast majority of the staff, who belonged to neither category, are included, however.
Assuming the expatriate staff to be replaced by local staff in government service, monthly salary costs for the 2 categories mentioned are estimated at

approx. TShs 10,000 to 15,000 per month (or: TShs 500 to 750 per well).

Based on several years of experience in Shinyanga the running costs can be broken down as follows (in per cent of total running costs):

Salaries, wages, field allowances, etc.	:	33%
Construction costs	:	30%
Vehicles: repair and maintenance	:	13%
petrol, oil, etc.	:	20%
Miscellaneous	:	4%
Total	:	100%

Maintenance costs have been mentioned before. They amount to:

Centralized maintenance organization	:	TShs 1,200 to 1,700 per well and per year.
Decentralized maintenance organization	:	TShs 800 per well and per year.
Village bears first maintenance responsibility	:	TShs 350 per well and per year.

Including a chemical water analysis will increase those costs by several hundred shilling per well check. Without this analysis maintenance costs per head of the population supplied are TShs 2.— to 8.— per year.

Chapter 40. **Costs per well**

The average costs per well can be calculated from the results of the previous chapters (based on experience in Shinyanga, at price level December 1978):

a. investment costs, apportioned over 750 wells: Dfl. 1600.— to 2500.— per well.
b. running costs: TShs 15,000 per well = Dfl. 5000.— per well.
   additional salaries: TShs 500-750 per well = Dfl. 170.— to 250.— per well.

Thus, total costs for constructing a well were some Dfl. 6800 to 7800 (approx. TShs 20,000 to 23,000, or: US$ 3100 to 3500), or: approx. Dfl. 30 per head (approx. US$ 13/head, or: TShs 85/head).

Per month project calculation forms are filled in (page 189), from which average construction costs for that month can be calculated. Store costs and overhead are both taken into account on these forms. For store costs (including small repairs and replacement of worn out small equipment) 10% is added to the material costs. The overhead over labour, materials and transport is taken at 15%.

From the results of these monthly reports the following conclusions could be drawn:

AVERAGE COST OF WELL CONSTRUCTION (WITHOUT PUMP) PER LINEAR METRE OF DEPTH

	depth up to 7 m	depth from 7 to 15 m
Hand-drilled well	TShs 900/m'	TShs 900-1100 /m'
Hand-dug well	TShs 1300/m'	TShs 1300-3000*/m'
Percussion-rig well	TShs 1700/m'	TShs 1700-2200 /m'

*) Approximate figure. Depending on difficulties encountered, desired speed of progress - hand chisels vs. jack hammers -, amount of drainage required, etc. The cost may be higher or even much higher.

AVERAGE COST OF WELL CONSTRUCTION, CALCULATED FROM RUNNING COSTS (1974-1978; majority of wells hand-dug; TShs 7.50 = US$ 1.00)

Surveying	TShs 1,500	10%
Materials, tools	TShs 4,100	27%
Hand pump	TShs 1,800	12%
Labour	TShs 2,300	15%
Transport	TShs 3,800	26%
Overhead	TShs 1,500	10%
Total	TShs 15,000	100%

It has been mentioned before that depreciation of investments and salaries for expatriate and government staff should be added to obtain the over-all figure for well construction. The break-down then becomes:

Depreciation of equipment, buildings, vehicles	TShs 4,500	22.5%
Surveying	TShs 1,500	7.5%
Materials, tools	TShs 4,100	20.5%
Hand pump	TShs 1,800	9.0%
Salaries, labour	TShs 2,800	14.0%
Transport	TShs 3,800	19.0%
Overhead	TShs 1,500	7.5%
Total	TShs 20,000	100%

For hand-dug wells and hand-drilled wells the relation between materials, labour and transport is as follows:

	Hand-dug wells	Hand-drilled wells
Materials, tools	40%	45%
Labour	23%	19%
Transport	37%	36%
Total	100%	100%

The experience gained so far in the Morogoro Wells Construction Project, which produces hand-drilled wells with Kangaroo pumps only, shows increased investments in hand pumps, with decreasing costs for the materials and tools component.
Total construction costs have remained nominally the same, even though the Tanzanian shilling has slightly devaluated.

AVERAGE COSTS OF HAND-DRILLED WELL CONSTRUCTION (July 1979; TShs 8.— = US$ 1.00)

Surveying	TShs 1,500	10%
Materials, tools	TShs 2,000	13%
Hand pump	TShs 4,000	27%
Labour	TShs 2,000	13%
Transport	TShs 4,000	27%
Overhead	TShs 1,500	10%
Total	TShs 15,000	100%

List of forms used

TANZANIA EM 1(A)

TRANSPORT/PLANT WORKS TICKET AND LOG Sheet No.

Transport/Plant No. Department Station Province Month 19

Date	Nature of Journey: From	Nature of Journey: To	Nature of Journey: Passengers, Load or Reason	Head and Subhead	Authorized by	Details of Journey / Maelezo Kamili ya Safari: Time / Saa za: Out	Details of Journey / Maelezo Kamili ya Safari: Time / Saa za: In	Details of Journey / Maelezo Kamili ya Safari: Kilometre or Hour Meter Reading: Out	Details of Journey / Maelezo Kamili ya Safari: Kilometre or Hour Meter Reading: In	Total kilometres or Hours	Driver's Signature Sahihi Dereva
Total Hours or Kilometres Run Kilometres or Hours per Litre											

In tank at start of month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	In tank at end of month
Litres issued																																
Unserviceable																																

GATE PASS

No. ....

SHALLOW WELLS PROJECT

Car license number ____________ Date ____________

Name of driver ____________ Km-reading ____________

Journey authorized by ____________ Signature of gate keeper ____________

Destination ____________ Time of departure ____________

VEHICLE CHECKLIST

Items	OUT		IN	
	OK	Remarks	OK	Remarks
Petrol/Diesel				
Motor oil				
Cooling water radiator				
Battery				
Brake fluid				
Foot brake				
Hand brake				
Tyre pressure				
Lights				
Horn				
Wipers	X	X		
Instruments	X	X		
Springs	X	X		
Chassis	X	X		
Body	X	X		
Cabin	X	X		
Tyres	X	X		

EQUIPMENT

Items	OUT		IN	
	OK	Remarks	OK	Remarks
Foot pump				
Jack				
Wheel spanner				
Tyre lever				
Spanners				
Screw driver				
Spare tyre				
Pliers				
Puncture repair set				

NOTE:
After return from journey turn over this gate pass to Transport Officer.
When returning after office hours deposit gate pass with gate keeper.

JOB CARD

SHALLOW WELLS MECHANICAL SECTION

Type of vehicle	: ______	Date work commenced:
Registration no.	: ______	______ 19__
Chassis no.	: ______	Date work completed:
Engine no.	: ______	______ 19__
Mileage	: ______	Checked by:
		______

Item no.	Job instruction	Fitter's name	Time		Total time	
			From	To	Normal	Overtime

Total normal time :

Total overtime:

Total costs spare parts	TShs	______
Total costs repair outside	TShs	______
Total costs oil and petrol used	TShs	______
Total costs wages:		
normal time ______ TShs 3/–	TShs	______
overtime ______ TShs 5/–	TShs	______
Total costs transport:		
______ km x TShs 2/50	TShs	______
Sub-total	TShs	______
General labour costs 10%	TShs	______
Total costs repair	TShs	______

Description of part	Sparepart no.	Quantity	Unit costs		Total costs	
		Total costs spareparts TShs				

Type of oil	Quantity	Unit costs		Total costs	
Engine oil					
Gearbox oil					
Differential oil					
Hydraulic oil					
Petrol					
	Total costs oil and petrol				

Job Card, Shallow Wells Mechanical Section (backside)

RECEIPT VOUCHER
(Allocated Stores)

E 012250

I certify that I have received into store and taken on ledger charge the following articles:

Ledger Folio	Article	Unit	Quantity	From whom received (quote Inventory or other reference)	Condition (*)

Date .... *19* .... *Signature of Storekeeper*

1. This voucher should be prepared in duplicate. The original will be retained by the storekeeper and the duplicate handed to the officer depositing the stores.
2. Whenever possible the original voucher will also be signed by the officer depositing the store.

(*) In the column enter either "new", "serviceable" or "unserviceable".

STOCK CARD

Class	Item No	Description	Loc	Price	Unit

Min. stock	Max stock	Order level

Date	Voucher No	Receipts	Issues	Balance	From/To		Voucher No	Receipts	Issues	Balance	From/To

LEDGER CARD ARTICLE ______________________________ Folio No. ______

______________________________ Unit ______________ Bin No. ______

W.D.D. Form 14

ON ORDER				LEDGER							REGISTER							
Date	Indent No.	Qty.	From whom ordered	Date	Voucher No.	From whom received To whom Issued	Unit Price	Receipts	Issues	Total on Charge	Date	Voucher No.	To whom Issued From whom returned	Invtry. No.	Receipts	Issues	Bal. in Store	Total on Issue

REQUEST FORM

SHALLOW WELLS PROJECT
P.O. BOX 168,
SHINYANGA

Date..

To store officer

Please supply/order the following items

Name of job/section..

Signed.. (I.V. nr................)

Item	Description	Re-quired	Re-ceived	Est. costs	Action

ORDER NOTE

Date. .... Nr.: ....

Description Article	Stock	Req.	Rec.	Section	Page Nr. O Book
				Authorised	

To ....

....

ISSUE VOUCHER
TO ....
AT ....

A

LOCAL STORES

REQUISITION/ISSUE VOUCHER

ALLOCATED STORES ONLY

4/912000

Not for use in connection with unallocated stores or local purchase

Date ....

Description of Article	Unit	Quantity		Ledger Folio	
		Required	Issued	Issuer	Receiver

REQUISITIONING OFFICER

....

Signature *Designation* *Station*

ISSUING OFFICER

....

Signature *Designation* *Station*

CERTIFIED

A. Received in good order.
B. Taken on charge in my stores Ledger/for immediate use.
(Delete whichever is inapplicable)

RECEIVING OFFICER

....19.......

Signature *Designation* *Date*

SHINYANGA SHALLOW WELLS PROJECT
GATE PASS

Date: I/V No.

No.	Description	Unit	Quantity
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Signature...

Date	Name	Signature

Article	Quantity	Date return store	Sign store keeper

PERSONAL INVENTORY SHEET

INVENTORY No. ....

Responsible for equipment

Name : ....

Section : ....

TOTAL BALANCES ON ISSUE:

Date	I/V nr.	Folio nr.	Quantity																							
			Issued	Received																				
BALANCES TO BE BROUGHT FORWARD																								

SHINYANGA SHALLOW WELLS PROJECT CALCULATION FORM FOR MONTHLY COSTS OF HAND-DUG WELLS

Month .... 1978 (fictitious example)

General:

	A			B			C		
Labourers + Unit L + Small equipment	10						17		
Wells Finished	5						5		
Total depth	41.0						44.0		
Total metres below 7 m	6.0						9.0		
Average Km dist-Shy-site	125						204		
Number of Trips Shy-site									
Landrovers used for constr.									
Trucks used for constr.	12						95		
Cranes used for constr.	39	38					68	67	38

Labour

	TShs	TShs	TShs
Salaries	4,575		7,900
Nights	2,300		4,000
Self-Help	3,550		5,800
Total Labour	10,425		17,700

Materials:

		Shs	No	TShs	No	TShs	No	TShs
Ring No. 1,2,3,5	each	260	32	8,320			38	9,880
Ring No. 4	each	130	3	390			2	260
Ring 10 11	each	100	–					–
Ring No 7	each	50	–					–
Cover Normal	each	200	5	1,000			5	1,000
Cement	bag	45	53	2,385			75	3,375
Pumps	each	1800	5	9,000			5	9,000
Gravels	Load	240	3	720			2	480
Petrol	Litre	4	157	628			96	384
Diesel	Litre	2.35	108	254			493	1,159
Subtotal				22,697				25,538
Store (10%)				2,270				2,554
Total Material				24,967				28,092

Transport:

	A	B	C
Km Trucks	256		3,493
Km Cranes	3,649		5,181
Km Landrovers			
Total Km	3,905		8,674
Total Transport @ 3/ Km	11,715		26,022

	A	B	C
Total Labour	10,425		17,700
Total Materials	24,967		28,092
Total Transport	11,715		26,022
Subtotal	47,107		71,814
Overhead 15%	7,066		10,772
Total each unit	54,173		82,586
Total hand dug wells			
Total each unit 100 km from Shy	51,478		67,330
Price Comparable standard metre at 100 km from Shy	1,095		1,270

COLOPHON:

Design and layout	:	Studio DHV, Amersfoort, The Netherlands
Printed by	:	GEMA BV, Eindhoven
Lithography	:	Repronika BV, Eindhoven
Photo selection and composition	:	DHV, Amersfoort
Photography	:	DHV, Amersfoort