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Rural Water Supply from Shallow Aquifers in Ethiopia - Strategy and Alternative Technologies

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RURAL WATER SUPPLY FROM SHALLOW AQUIFERS IN ETHIOPIA

- Strategy and Alternative Technologies

by

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TABLE OF CONTENTS

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ABSTRACT

Consistent with the international trend in developing countries, it is envisaged that low-cost technologies will play the major role in rural water supplies in Ethiopia. Hand-dug wells will probably continue to be the main such technology basically because of its storage characteristic which makes it suitable for low yielding aquifers on the plateau. Hand augered wells may also prove suitable in a lot of areas. Another potentially beneficial technique is the construction of small diameter boreholes in hard rock areas for handpump installation. Such boreholes can be economically constructed using small rigs.

Whatever technology is used, the desired objective of significant health improvement would not be achieved unless the improved source is properly maintained and used. Maintenance considerations should, therefore, be central to any effective strategy. In areas with great water need, but no maintenance possibilities, open wells should be considered. The objective would then be saving energy and time. In projects where health improvement is the goal, if absent, maintenance capability should be built up as part of the project, and health education incorporated. With present limitations of resources, such projects can be undertaken better in a concentrated way as pilot projects covering limited areas rather than as dispersed activities in a national programme.

1. INTRODUCTION

The International Water and Sanitation Decade (1981 - 1990) is underway. One major area that is getting attention in the Decade activities is the use of low-cost technologies. This seems to be the only practical way to serve the hundreds of millions of people in the developing countries with improved water supply and sanitation, which presently are without them.

Consistent with the international trend, the emphasis in Ethiopia also has been on simple technologies recently. Handpumped well is the important technology in this category. Unlike surface water, ground water does not usually require any treatment for domestic use. It seems this fact has always been appreciated in rural water supply development in the country. What is new is the recent acceptance, however reserved, of simple technologies by the water authority. The reason for this acceptance lies in the general international trend favoring low-cost technologies for the rural areas of developing countries and the oil crisis. But only a start has been made in the area of low-cost technologies. The brave new world of Schumacher *, "Small is Beautiful", has yet to flourish in the Ethiopian scene, despite the fact there are strong arguments for it considering the low socio-economic development of the country and scattered habitation pattern. Traditions die hard, specially so when the change calls for shift from big to small, from relative sophistication to simplicity.

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* Schumacher is a well known British economist who promoted the idea of "intermediate technology" for the developing world in the mid-1960's and later (1973) elaborated his thoughts in his book "Small is Beautiful".

Just what are some of these advantages of simple technologies?

- Less cost: Usually the overall cost of simple technologies is much lower than the alternative more complicated ones.
- Savings in foreign exchange: Ethiopia, like most non-oil producing developing countries is acutely short of foreign exchange. Supplies based on relatively sophisticated technologies, such as motor-run-pump schemes, require heavy investment in equipment initially; but more important are the recurrent costs for fuel and spare parts needed for operation and maintenance, which are all in foreign exchange. Actually, the dramatic rise of oil prices during the last decade is perhaps the most significant single event that forced countries, including Ethiopia, to look seriously into alternative technologies.
- Labour intensive: Simple technologies such as well digging, spring development and infiltration drains require more labour than alternative boreholes drilled by rigs. Unskilled labour is just one important factor that the country is not short of.
- Suitable for community participation: Nowadays it is widely reorganized that community participation is a good strategy in rural water supply not only because it may be cheaper, but more importantly, through participation the community may develop a sense of responsibility and ownership that is vital for proper operation and maintenance of the system.

Experience in simple technologies in Ethiopia has been almost limited to dug wells. In this area some improvement in construction methods and some degree of standardization has been achieved. As found out from the recent field visit, however, there is a lot of opportunity in further developing dug well construction methods, and in introducing and developing other low-cost techniques. But the most difficult problem, however, is related to maintenance and water use.

There is very little, if any, experience in other simple ground water abstraction methods. To meet the challenging demands of the Decade all possibilities should be explored and appropriate technologies should be adopted.

In this study, possible technologies for handpump operation and other related technologies used for abstraction of ground water from shallow aquifers are considered. (Shallow aquifers are here understood to mean those from which water can be normally drawn for domestic use using handpumps, say upto 50 metres.) To limit the subject of discussion, normal fracture or tubular springs from which the water issues at a point and can be "capped" are not included. Though interesting and of importance in many semi-arid areas of Ethiopia, the whole subject of sub-surface dams is also excluded for the same reason.

"Shallow" up to 20m

The various technologies are compared, the emphasis being on the "why" than on the "how". For each technology, its applicability and limitations are discussed in the Ethiopian context. Based on this, the experience gained in Ethiopia and internationally in such rural water supply technologies, and basic considerations of the objectives for rural water supply, a strategy for level of service, coverage pattern and timing is suggested. In discussions of technologies, a heavy draw is made on experience in Hararghe Region where more of these ideas have been tried. Two appendices are also included: one deals with recommendations for field trial during the on going practical research in shallow wells construction in Hararghe, and the second, summaries the findings from the recent field visit undertaken in relation with this study.

2. BACKGROUND

2.1 The land and its people

The relief, geology, climate and habitation pattern have great bearing on the rural water supply development in Ethiopia.

Ethiopia with estimated population of 32 million people covers some 1,2 million km^2, more than the combined area of Finland and Sweden. It has highly varied relief, with elevations ranging from below sea level to over 4500 m above sea level. The central part, where most people live, is mainly an upland country with rugged landscape which makes land transportation difficult. This area enjoys generally moderate climates and good rainfall. There are also extensive lowlands, mainly in east and south-east which are arid and semi-arid, and sparsely populated by mainly nomadic people.

The vast majority of the population lives in rural areas and the dominant habitation pattern is scattered. According to the estimates made during preparation of the Decade plan in 1980 about 83 % of the total population lives in small nucleated settlements of less than 500 people or in dispersed homesteads (EWRA, 1980). This fact has great significance in the choice of suitable technology for rural water supply.

2.2 Geology and hydrogeology

The plateau section is covered by in-situ weathered soils of varying thickness underlaid by thick layers of volcanic rocks. Extensive sedimentary rocks appear in the south-east. Old crystalline rocks have been exposed in the south, north and western periferies. The Rift Valley, which divides the plateau into two parts, is composed of recent volcanics and lactustrine deposits. Alluvial deposits along some major rivers in the plains, alluvial fans and scree below mountains and the rift escarpment are also of some hydrogeologic importance.

Detailed knowledge about the hydrogeology of the country is limited, but some general remarks can be made. Yields of boreholes on the plateau are low to moderate. The lacustrine and fluvial deposits in the Rift valley give good to high yields. The yields in the sedimentary rocks deposits are also variable with low to good. Borehole depths range from 40 m to over 250 m the average being about 100 m. Very many communities depend on dug wells for water supply.

Rough estimation made from UN report (1973) and available statistical data in the Ethiopian Water Works Authority (EWWCA) indicates that possibly about 2000 boreholes have been drilled in the country over the last thirty years. Though the figure is very small compared to the area of the country, considerable useful hydrogeological data could have been obtained from these. But in most cases available data is very scanty.

Ground water quality is generally good on the plateau. High fluoride content is common in the Rift Valley, and salinity is a problem in the south-eastern low lands, the Red Sea coast and parts of the Rift Valley.

2.3 Water supply

Rural Water Supply Development

Improved water supply for rural areas in Ethiopia dates back to early 1950's when the government started engine-run borehole supplies for communities that were hard pressed for water.

The communities were sometimes small road-side towns on the plateau, but mainly administrative outposts in such semi-arid areas as the Ogaden and Southern Ethiopia. At the same time some pond construction work was undertaken in such semi-arid areas as Borena, Southern Ethiopia, mainly for stock watering.

There was little else done in this field for the next twenty years, except perhaps few schemes based on such simple technologies as spring capping and improved dug wells equipped with handpumps undertaken by the then Gondar Public Health College, schools and non-governmental organizations, such as the missionaries.

The next landmark in rural water supply was the new interest aroused about the activity by the devastating effects of the drought that started in early 1970's. This combined with the advent of the Ethiopian Revolution which, reversing the previous trend, emphasized rural development has greatly accelerated the pace of rural water supply activity. But a lot remains to be done. Latest statistics from the EWWCA indicates that the coverage for improved water supply in the country is only 5,5 %.

The development since mid-1970's has not only been in increased rate of output in water schemes, but also a shift in emphasis of technology choice, favoring simple technologies, as noted earlier. Again according to statistical data from EWWCA, now about 150 boreholes and 400 handpumped wells are constructed and about 45 springs are developed every year.

Organization

At present rural water supply activity (design, construction, operation and maintenance) is undertaken by the Ethiopian Water Works Construction Authority (EWWCA) through its eight Regional Offices. Under a recent legistlation the maintenance component would go to a separate body, Water Supply and Sewerage Authority. Both these authorities, plus two others - Water Resources Development Authority and the National Meteorological Services Agency - reposible for water resources studies and meteorology respectively, are now organized under the National Water Resources Commission (fig 1).

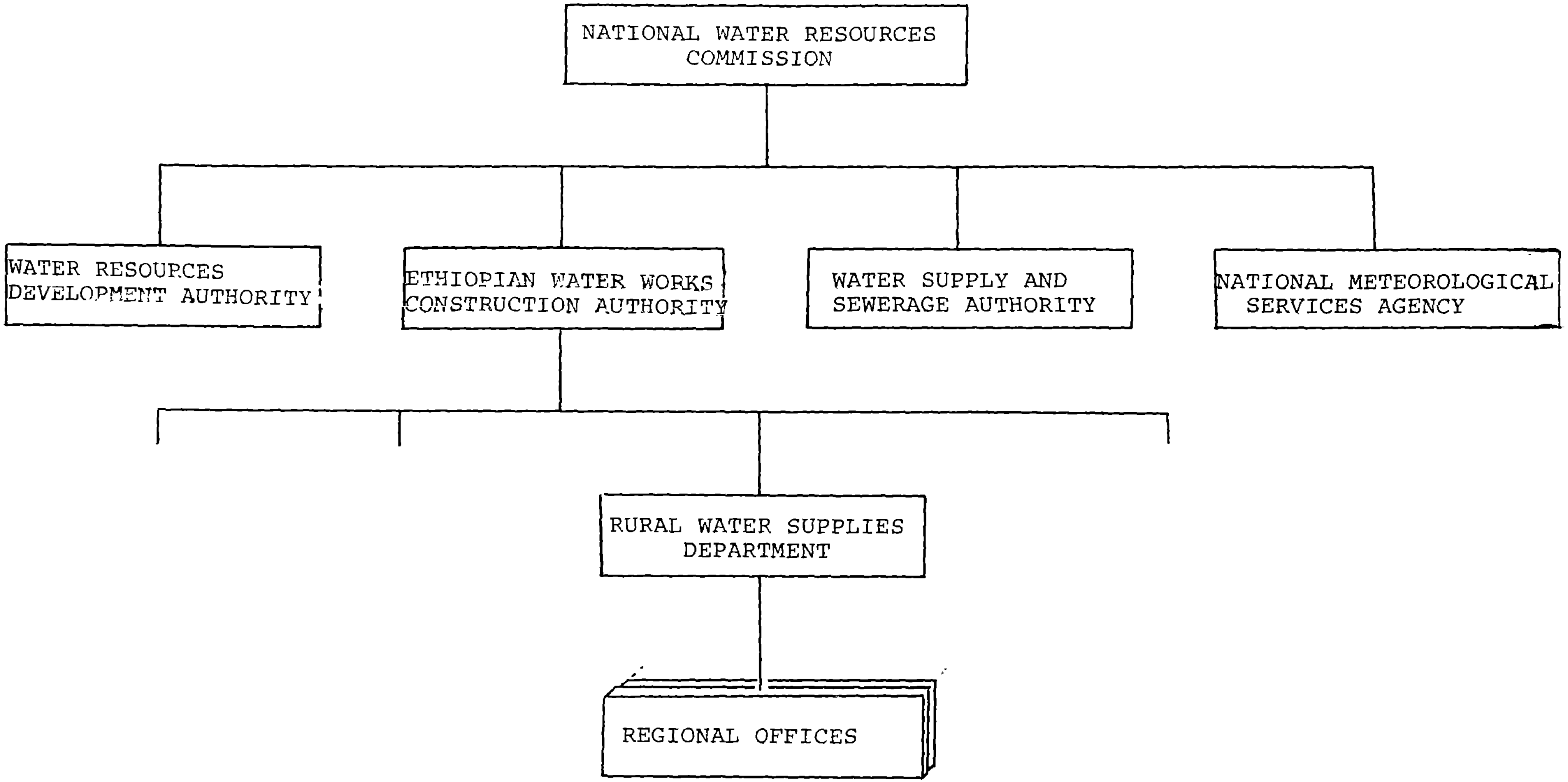


Fig 1. Organizational set-up of rural water supplies in Ethiopia within the National Water Resources Commission.

An EWWCA Regional Office is responsible for quite a large area: over 100 000 km^2 and inhabited by at least 2 million people. It is thought sub-regional offices would be started as activities increase. Already this is happening in two regions.

Non-governmental organizations like missionary groups and OXFAM are also engaged in limited rural water supply activities mainly relying on simple technologies.

Rural people in Ethiopia are now organized under legally constitued peasant associations, whose task among other things, is to undertake local development activities within its jurisdiction. This body creates good contact point in the rural areas for the water authority. Because of the existence of such favorable organizations in rural areas and the increased emphasis put on community participation and simple technologies, both by the government and donor agencies, some form of community participation is now becoming quite common in rural water supply construction. But to be effective it has yet to improve in quality and quantity. Community participation has to be based on genuine collective desire and include all phases of the water supply: planning, construction, operation and maintenance.

3. COMPARISON OF TECHNOLOGIES

3.1 Hand-dug wells

Traditional wells

Hand-dug wells have been used for water supply in different parts of Ethiopia for centuries. A typical well is a circular unlined shaft sunk into basically stable soils which may have a collapsing top layer supported by masonry or wooden crib wellhead. Such wells have been sunk manually in some parts of the world upto 120 m depth (Watt et al., 1979). In Ethiopia it is not uncommon to find wells upto 40 m, though most common depths range from 5 m to 20 m, naturally varying from one area to another. Perhaps the simplest wells are temporary shallow water holes excavated into sandy river beds in semi-arid areas only to be filled up with sand during a flood or the walls collapse.

The diameter of wells can also vary a lot. Traditional wells are commonly about 90 cm in diameter. Some hand-dug wells of 10 m diameter and over are sunk for irrigation and human use in India (Watt et al., 1979). Experience indicates the minimum diameter for two people to work in is 120 cm (Hofkes, E.H., 1981) but a single person can apparently manage in a well of 80 cm diameter (Rantala, M., 1980).

Most hand-dug wells in Ethiopia are privately owned and cater for a family's or two water need. In some rare cases hand-dug wells have been traditionally used for irrigating cash crops such as pepper as in Inseno area, Central Region, or for watering livestock in such places as the semi-arid regions of Borona, Southern Region.

On the other hand, some communities opted for long distance water haulage though ground water existed at shallow depth under their feet. It is interesting to note that when improved wells were first constructed in the semi-arid area around Sabure, Central Region, in 1979, the users' initial reaction was less than enthusiastic and are said to have claimed that "the underground water is ment for the dead ancestors, not for the living" (Ahmed Ibiro, personal communication). In this case, however, the old belief was quickly forgotten when it became apparent that clean water could be obtained closeby instead of the alternative drudgery of haulage over kilometers from a perennial river.

Water is usually drawn manually using buckets or sections of car tyre tubes from such traditional wells. In some cases donkeys and even camels draw the rope holding the water container over some sort of pulley contraption. In nomadic areas relatively large quantities of water are drawn from wells for watering livestock by skillfully passing gourds from hand to hand by people standing on small platforms built along the well shaft, usually inclined. The burden of such tiresome work is lessened by the accompanying traditional work songs.

Traditional wells still play an important role in water supply in Ethiopia, as witnessed by numerous villages and small towns across the country that still rely on them for their water supply. These wells do solve the problem of water availability and quantity in most cases, but their construction and water drawing method make them highly susceptible to gross pollution by parasites and bacteria. Most of these wells do not have raised headwalls which create additional safety hazard from falling in.

Well pollution

Dug wells have a tendency to be polluted easily. Such pollution has three possible routes: the well mouth, the wellhead and the ground water as illustrated in Fig 2. Poorly located open wells are subjected to pollution through all the routes. Pollution may take place through the mouth during water drawing or it may be airborne if the well is not covered. Polluted surface water may get access to the well through again the mouth or by seeping along the wellhead, if not properly sealed. The well may also be polluted if it is located close to a high concentration of pollution source such as a latrine or animal pen. But it is interesting to note that the safe distance from bacterial pollution source may be surprisingly small: 15 m for unconsolidated sand and silty formations (Lewis, W.J. et al., 1980).

On the other hand, pollution may be carried to distant wells in fissured rocks or limestone formations. In the Ethiopian case dug wells are usually sunk in unconsolidated formations for which the presently recommended minimum distance of 30 m from a bacterial pollution source should suffice. In areas with non-uniform formations no definit limit could be set. According to Andersson (1983) a limit of 100 m is the nearest latrine was used in Shinyanga project, Tanzania, "to eliminate possible pollution hazards".

These well pollution issues mentioned in relation with dug wells apply also to other types of wells, except for the facts that it is easier to make reliable sanitary seal for narrow diameter boreholes than for dug wells; and secondly, the deeper the aquifer is the less the likelihood of its pollution.

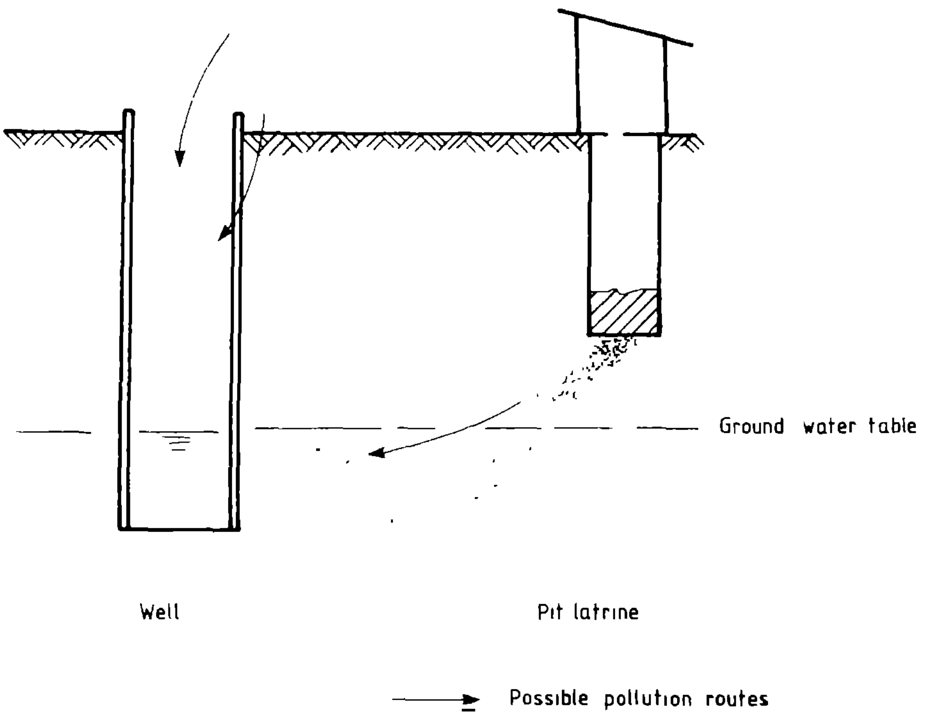


Fig 2. Possible pollution routes for a dug well.

Improved wells

For the supply of safe water, improved wells should have:

- water tight well lining and backfill at least on the upper few meters to prevent surface water from seeping into the well,
- well apron and drainage to lead away surface and split water,
- well cover and a non polluting water drawing device such as a handpump, and
- a location safe distance away from a pollution source.

Concrete, masonry or bricks could be used for well lining. In practice, masonry and brick lining could be cheaper where the materials and the necessary skill are available, and ground conditions are favourable. The construction does not require special equipment, except ordinary mason's tools. Bricks are not readily available in most rural areas of Ethiopia. Improved masonry lined wells could be appropriate in a lot of areas, especially for self-help projects where special equipment and skills are hard to come by. Actually there are some few cases where such well improvement methods have been used in Ethiopia. A small self-help project assisted by missionaries in the Chencha area, Gamu Gofa Region, seems to have worked well.

Concrete lining with precast rings is however more suitable for the construction of large numbers of wells by some organization like a water authority. Equipment and construction elements such concrete rings and covers can be standardized, digging and manufacturing of rings can go side by side, difficult conditions such as caving soils can be better handled.

Precast concrete ring lining can be done by "dig-and-line" where the rings are lined after the completion of the excavation (fig. 3). This is possible in somewhat firm ground that allows at least temporary unlined excavation. Fig. 4 shows the other and more safer method of the "caissoning" whereby the excavation continues inside a stack of rings that sinks by its own weight. Precast concrete rings are also especially suitable for deepening of wells by the "telescoping" method (fig. 5). This may be required if a well goes dry due to the lowering of the ground water table during the dry season.

These factors make lining with precast concrete rings more flexible and faster, and thus cheaper, than other lining methods specially if construction is being done with mobile crews with considerable field expenses.

Presently precast concrete ring lining using "sink-and-line" method is the standard procedure in EWWCA. During the past few years of experience, some standardization of equipment has been achieved, and improvements have been made. But the full potential of the method has not yet been exploited as the

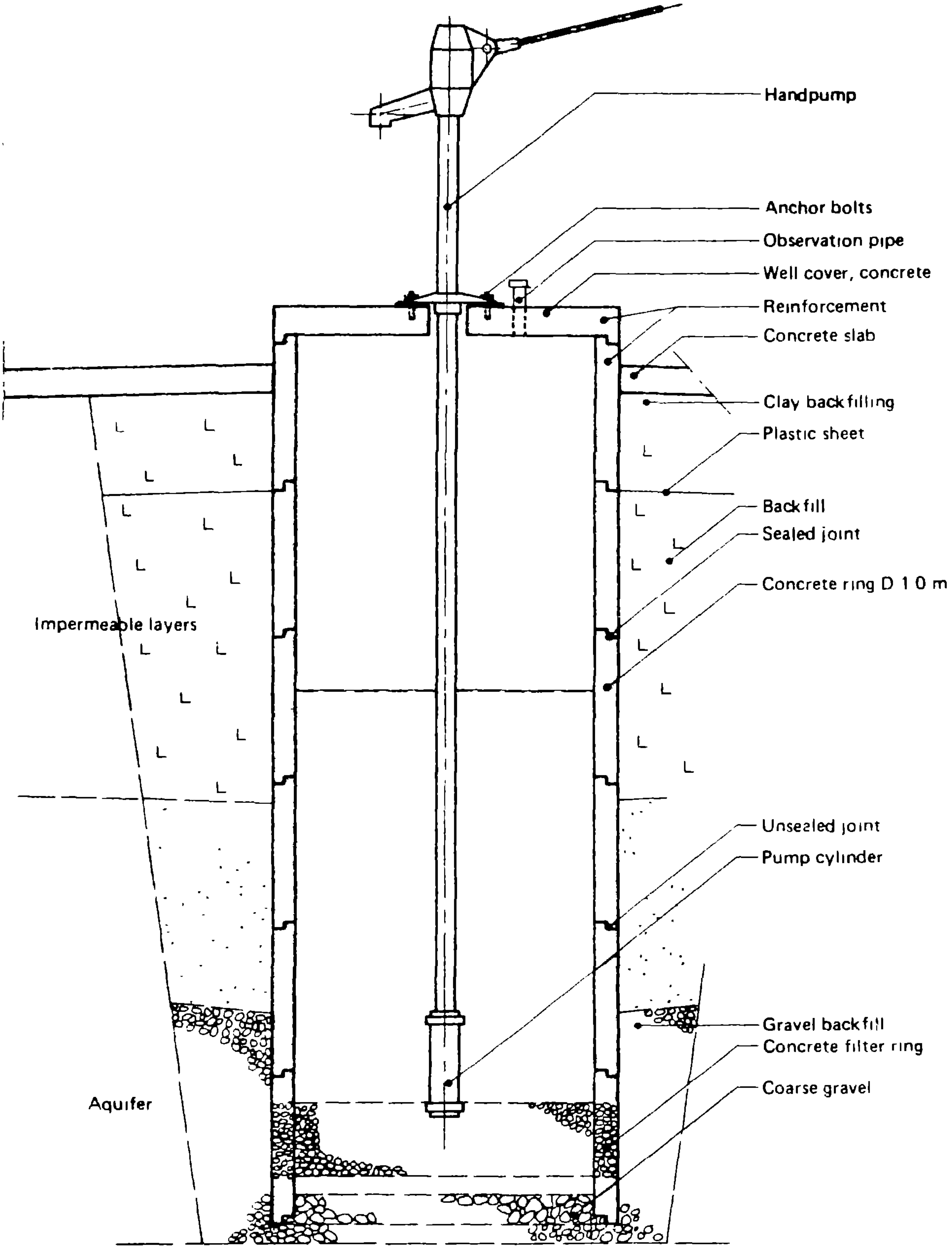


Fig 3. Shallow ringwell (Rantala, M., 1980)

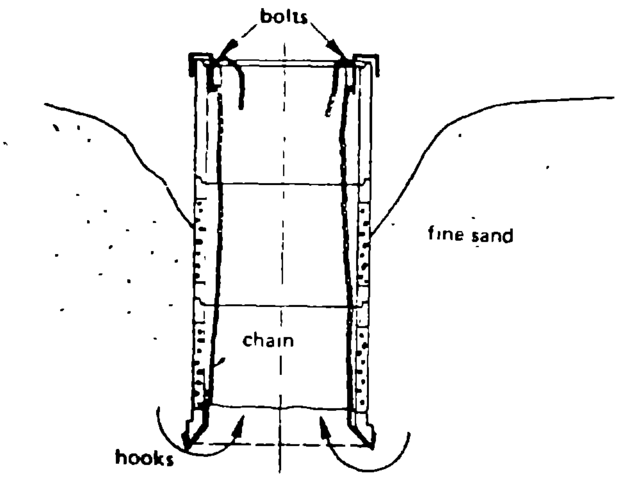


Fig 4. Preventing uneven setting of well rings during caissoning. (DHV Consulting Engns., 1978).

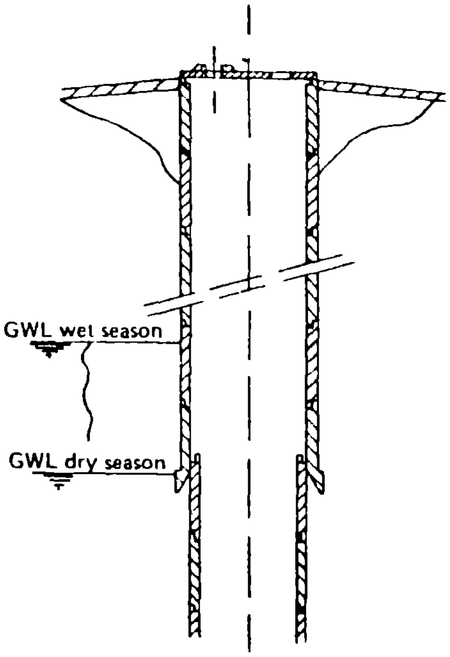


Fig 5. Telescoping for deepening dry wells. (DHV Consulting Engns., 1978)

number of abandoned wells in difficult soil conditions and drying of wells due to fluctuations of the ground water table indicate. It is hoped the familiarization of "caissoning" and "telescoping" methods could help alliviate these technical problems.

The other method of concrete lining is "in-situ lining", whereby concrete is poured behind shutters set up in the well. This method, though assures sanitary seal of the wall, is slow and it is difficult to prevent wastage of concrete.

Usually lining of a dug well is the most expensive part of the construction. Reduced diameter wells (fig. 6) are used to bring down the cost. They are constructed by first digging a normal, open well, placing a screen and casing in the middle, and then backfilling with gravel at the aquifer zone and the rest with excavated material. Such reduced diameter wells have been constructed extensively by UNICEF-assisted projects in Ethiopia, specially in Bale Region. The output per construction crew has been higher than for lined wells. Some wells were afflicted with the same problem of drying up as lined wells and others did not have enough yield due to reduced storage capacity. Problems of apron distortion and/or cracking due to the settlement of back-filled material was noticed in some wells. From the wells that were visited during the study tour, 85 % of those with yield problem, and all with apron subsidence or major cracking problems were reduced diameter wells (Appendix 1).

The problem of inadequate yield usually indicates unsuitable site. In case of lack of an alternative site the situation could be improved by providing storage at the bottom and backfilling the rest (fig. 7). In this case, however, the lining of the bottom storage section requires the same equipment as for normal ring wells. Special care have to also be taken to adequately reinforce the burried reinforced concrete cover placed over the storage section.

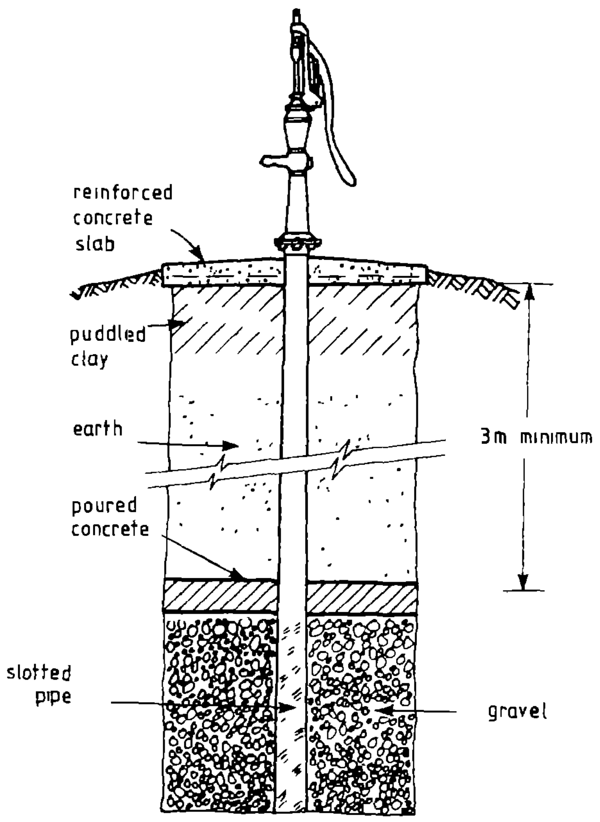


Fig 6. Reduced diameter well
(After Cairncross and Feachem, 1978).

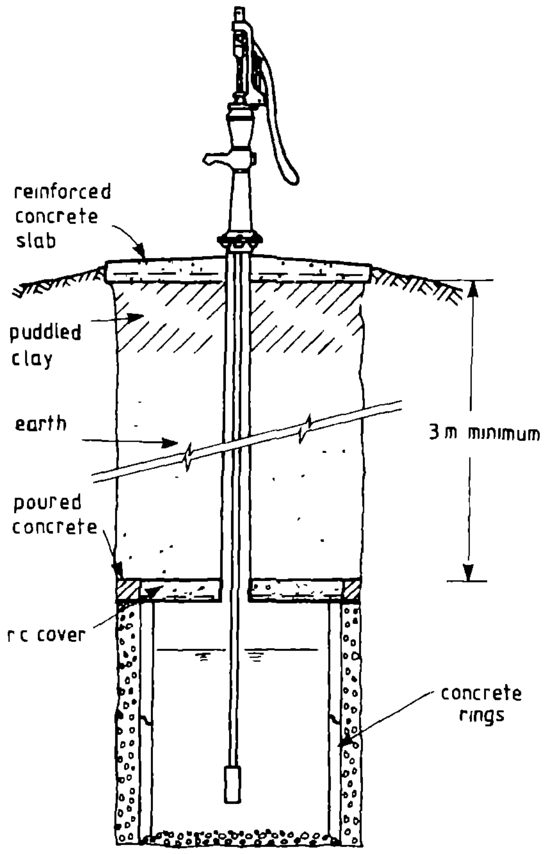


Fig 7. Reduced diameter well with storage.

Characteristics of hand-dug wells

Dug wells can be sunk almost in any type of formation including hard formations where explosives could be employed to break the rock. This technique has not been tried in Ethiopia as explosives and skills for handling them are not readily available. But some wells have been sunk through hard formations using only chisel and sledge hammers. Such construction is slow and can only be justified in special cases such as breaking boulders of limited size or constructing large diameter well for supplying sizable population from low yielding aquifer where a normal machine drilled borehole would not have adequate yield. One such construction was successfully completed for the town of Inware in Central Region. A large diameter well was sunk through weathered basaltic rock. The well will be equipped with an engine pump for distribution to the town. Here, repeated hydrogeological investigations had failed to locate suitable site for a borehole. Leaving beside such exceptions, dug wells are usually sunk in Ethiopia in soft formations manageable with a normal pick and a shovel.

Dug wells can usually be sunk to only limited depth below the ground water due to interference of inflowing water with the digging operation. In aquifers of moderate transmissivity it is difficult to go more than two meters below the ground water table. This limited penetration of the aquifer has two consequences. Dug wells may dry up during the dry season due to ground water table flactuations and they have low yield due to limited drawdown. This is why it is preferable to sink dug wells at the end of the dry season when the ground water table is low.

On the other hand, dug wells provide storage and allow the well to be pumped at higher rates than its yield during peak demand hours. This is an important characteristic in areas of low yielding aquifers of limited thickness where tube wells may fail to meet the demand. Though no systematic study has been made, field experience indicates that low yielding aquifers of clayey formations and weathered rocks are quite common in many parts of the Ethiopian plateau where the majority of the population lives. In these areas, privately owned low yielding wells may provide enough water for individual families, but it can be quite a different matter to use them as public wells. The demand from a public well can be quite high (fig. 8). Careful site selection, preferably based on local knowledge and/or test wells could be required before construction begins. Selection of suitable well type, construction period and close supervision during construction are also indispensable if problems of low yielding wells or drying up of wells are to be avoided. 16 % of all the wells for which data was collected during the recent field visit had yield problems. The percentage rises to 35 % if only wells in Bale are considered. In this case, it was most probably due to the inappropriate use of reduced diameter well method in some cases with low yielding aquifers, where adequate storage would have been required.

Fig 8. A scene at a public well.

Generally hand-dug wells are cheaper than machine drilled wells but more expensive than hand drilled wells. The cost of dug wells increases very rapidly with depth. Fig. 9 shows comparison of construction costs for dug and hand drilled wells (DHV Consulting Engn., 1981). The sharp rise in dug well cost starting at 6 m depth is explained by the use of motorpumps for dewatering starting from that depth. Excavation becomes also much more difficult as the depth increases.

Much more significant than the advantage in absolute cost of dug wells over machine drilling in countries like Ethiopia is its much lower proportion in foreign exchange cost. Whatever foreign exchange cost there is in dug well construction, it mainly comes from transport, which can still be kept to a minimum by better planning and logistics.

Risk of pollution may be higher for dug wells than for tube wells tapping the same aquifer. Sealing of the wellhead is more difficult and surface pollution might have an easier access. But there is no reason why a properly located and constructed well should be unsafe.

Construction of dug wells entails some safety problems but overall it is easy and people in most parts of Ethiopia are familiar with the basics and therefore existing skills in rural areas are relatively easily adaptable to improved sanitary well construction techniques.

A provision can be made in a dug well to use a bucket for drawing the water if a handpump fails. This can be quite important under conditions of unreliable pump maintenance and where there is no alternative water source within a reasonable distance.

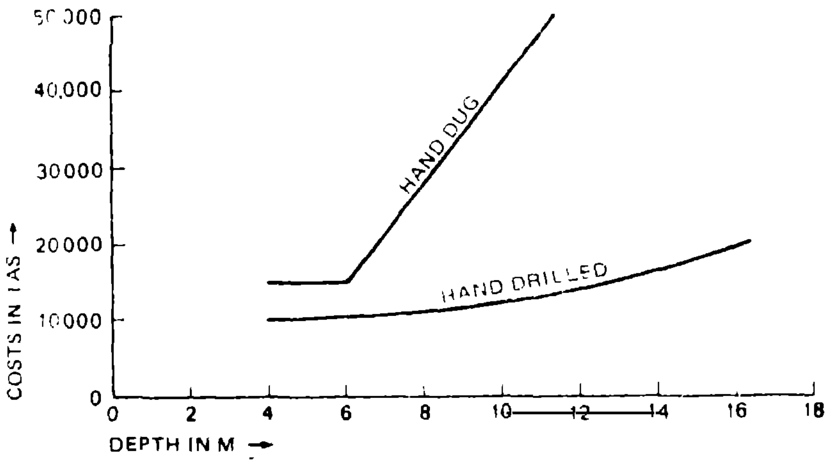


Fig 9. Comparison of shallow well costs (DHV Consulting Engn., 1981).

3.2 Augered wells

Augered wells are sunk by rotating a various types of auger bits through unconsolidated material (fig. 10). The bit cuts and collects the material which normally is periodically pulled out for removal. While using continuous flight spiral auger in clayey soil the material moves out at the same time as the rotation proceeds.

Augered wells can be sunk quite easily in soft clay and sandy soils. It is a bit more difficult but still possible, in fine clay, weathered rocks, but impossible in formations with boulders, heavily cemented soils and, of course, hard rock. Different soil types are handled by interchanging the bits. Temporary casings are used for support in caving soils. In augering below the ground water in sandy aquifers, the broken material may not come up the spiral or taken out with the auger. In such cases, periodic bailing might be necessary to remove the broken material. In sand aquifers the well is completed as a normal borehole with gravel packing.

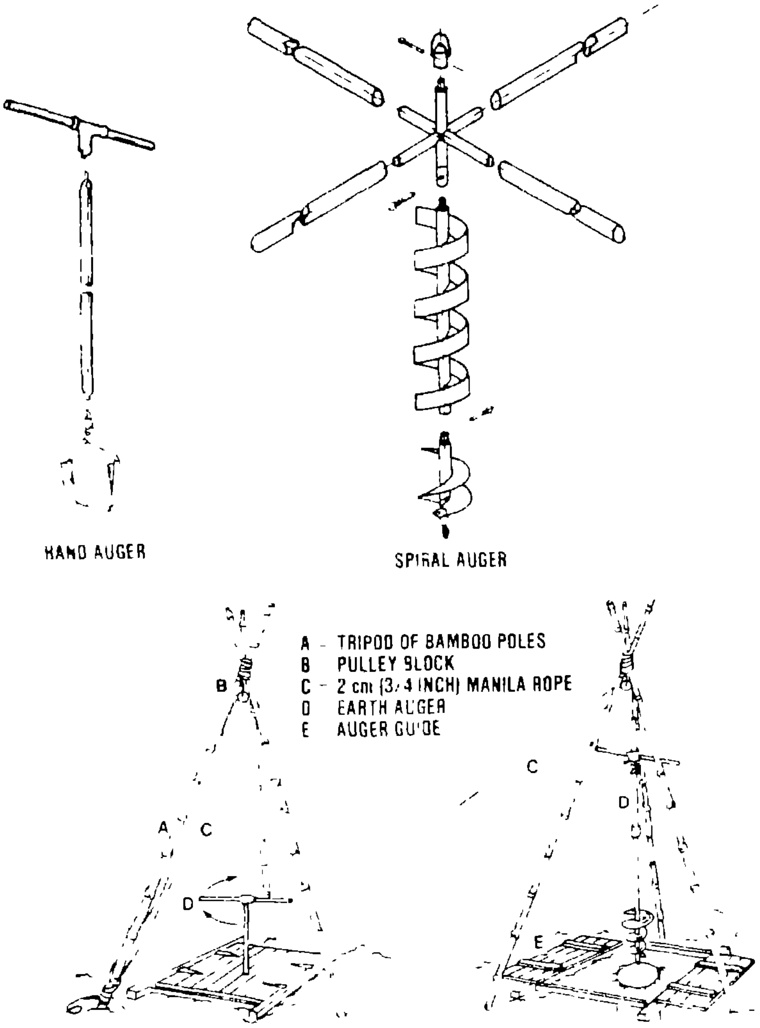


Fig 10. Hand drilling equipment (Hofkes, 1981).

It is generally thought that requirement for borehole intake design can be relaxed if it is ment for handpump installation. According to Arlosoroff (1983) preliminary findings in Malawi indicate that poorly designed borehole intakes contributed to frequent pump failures due to cylinder cup and leather wear. Careful screen/gravel pack design is necessary. Though the ideal design of selecting screen size and gravel pack material for every well on the basis of sieve analysis is not necessary and economically unjustifiable for such boreholes, some locally applicable practical design would be required. Satisfactory results were obtained in almost all aquifers in Morogoro Shallow Wells Project in Tanzania by using a gravel pack seived between the practical measurement of 1,2 mm (mosquito gauze) and 4,6 mm (coffee tray wire) for use with screens of slot size 0,6 - 0,8 mm. (Blankwaardt, R., 1980)

According to Tanzanian experience, hand augered wells have been used more and more as alternative to dug wells in areas where ground condition were right. The main reasons are shorter construction time, which here means less cost as well. The following rate was said to be the average output (DHV Consulting Engn., 1981):

Hand drilling group: 1 foreman + 1 assistant + 5 dailies
output: 40 - 50 wells per year
Hand-dug group: 1 forman + 1 assistant + 5 dailies
output: about 8 wells per year

In Tanzania, upto 30 cm diameter boreholes are hand drilled 10 to 15 m depth (Blankwaardt, R., 1980). In some other parts of the world, even larger diameter boreholes of upto 90 cm diameter have been drilled using a team of horses and special augering equipment (Wagner, E.G. et al, 1959).

In Ethiopia there is no experience with hand drilled auger wells. Machine augering with a light rig has been tried, however. Boreholes upto 30 m depth were sunk fast in suitable formations like in the lacustrine deposits of Lake Zwai. The auger rig, however, was found unsuitable in the Robe area of Bale Region due to apparently wide spread boulders in the soil. Dug wells were successfully constructed at some of the same sites later on.

Though it would affect drilling efficiency, ground water inflow does not hamper augering as in dug wells. Caving of aquifer material is less as no dewatering is necessary and such unstable walls can be supported by temporary casing in any case.

Besides the suitability of the formation for augering, a main requirement for an augered well, like for any other small diameter well without storage, is that the aquifer has to be at least of medium transmissibility. The minimum yield during test pumping that was acceptable for hand-drilling in Morogoro and Shinyanga Projects in Tanzania was 500 l/h while it was 200 l/h for dug wells (DHV Consulting Engn, 1981). For the same two project areas in Tanzania, the authors report that 50 % of the sites were suitable for hand-drilling in Shinyanga while the percentage was as high as 98 % for Morogoro.

Similar or bigger variability in suitability of sites for hand-drilling is to be expected in Ethiopia, but still it is probable that major parts of the Rift Valley, alluvial deposits along major rivers and the low land plains below the mountains, and possibly some, though limited, part of the plateau would be suitable for hand-drilling. Because of some of the above mentioned advantages and because of its wide applicability next to hand-dug wells, systematic field trial of the method with possible adoption as an alternative to dug wells is warranted.

The advantages of hand augered wells as compared to dug wells are:

- less influenced by flactuations of the ground water as the well can penetrate the aquifer adequately
- reduced construction time per well
- reduced construction cost per well
- no need for dewatering equipment evolving machines and fuel cost
- safe method in which virtually untrained local labor could be used.

3.3 Driven wells

Driven wells are constructed by hammering down into the ground a pipe fitted with a perforated well point at the end. One such arrangement is shown in fig. 11.

Well points are particularly suited for soft sandy formations. They can be driven or pulled fast in such formations. They can also be driven through compact soils. They cannot be driven, however, in hard rocks or hard-pan strata or heavy bed of clay. The friction between the pipe and the wall limits the depth to 10 - 15 m. Diameters of pipes are also small for the same reason, ranging from 3 cm to a maximum of 10 cm, with 5 - 8 cm being most common. (Hofkes, ed., 1981)

Normally pump cylinders have diameters greater than 5 cm and they cannot be installed in small diameter well points.

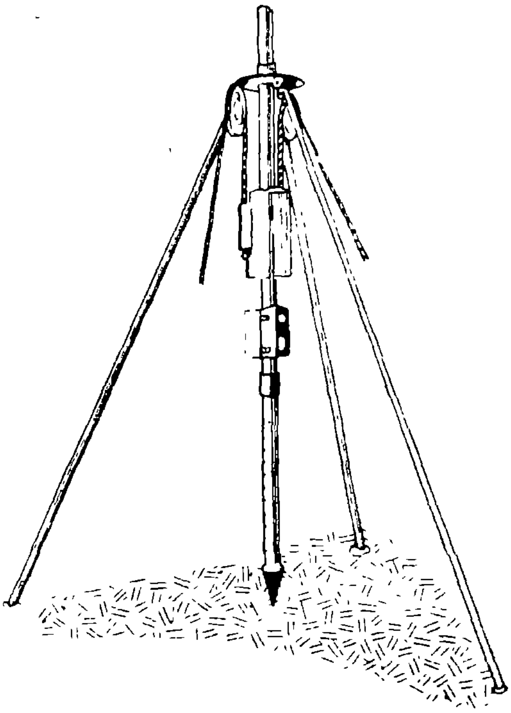
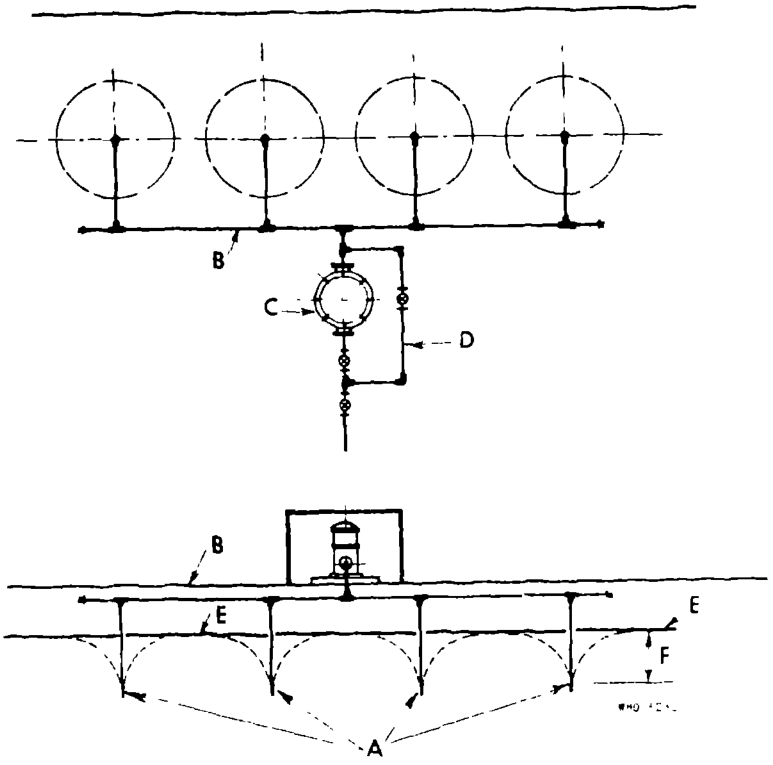


Fig 11. Well driving arrangement. (Hofkes, 1981)

Another disadvantage of driven wells is that the well point may be clogged as it is driven through clayey formation, and it may be difficult to remove after installation. The solution might be to use protective sliding joint, or the well point has to be driven through aquifer section after the upper part has been auger drilled.

Driven wells are very popular in the Western Hemisphere, South-East Asia and the Orient (Wagner, E.G. et al., 1959). There is not much experience with this method in Ethiopia. It was shortly tried in the compact sandy soils of Lake Zwai area in 1979, but developed too high friction before reaching the aquifer which was 10 - 15 m deep.

The yield from a well point is usually small ranging from 360 to 3600 l/h (Hofkes, E. ed., 1981). If located in a sandy aquifer and properly developed should yield enough for a handpump operation. But for large supply under similar circumstances, a well point system could be installed (fig. 12).



A	Well points properly spaced so that there is no interference between their circles of influence
B	Pumping header with allowance for future expansion in both directions
C	Pump
D	Priming line
E	Water table
F	Draw-down

Fig 12. Well-point system (Wagner, E.G. et al., 1959).

Though not tried so far, such a system would not be suitable for rural water supply in Ethiopia because it is rather expensive and is based on a central suction pumping with its attendant maintenance and operation problems.

3.4 Jetted wells

Tubewells can be constructed quite fast by jetting water from the end of a pipe, dislodging formation material by the erosive action of the water and transporting it up with the flow.

Jetted wells are well suited for sandy deposits. Clay and hardpan material are difficult to excavate using this method. Gravely materials require high water velocity and large amounts of water. Again boulders cannot be handled.

Generally jetting is done using a jetting pipe inside a permanent or temporary casing. Water flows in through the jetting pipe and back between the annular space between the pipe and the casing carrying the excavated material. The casing is rotated to increase the rate of descent as the excavation proceeds. Alternatively, the water may be pumped through the casing itself with the backflow between the casing and the wall.

Small diameter wells can be sunk using manually operated lift and force pumps (fig. 13). Such wells have been sunk successfully upto 60 m in West Bengal, India (Wagner, E.G. et al., 1959).

Larger wells with 100 - 200 mm (4 - 8 in) casing can also be jetted using high capacity pumps and more elaborate head-frames for handling casing and jetting pipes.

Large quantities of water are required for jetting wells. In areas with limited water supply the water may be circulated using settling ponds. At any rate, jetted wells, specially the ones with large diameter, require so much water and are suited only to sandy formations that they are generally feasible in river valleys.

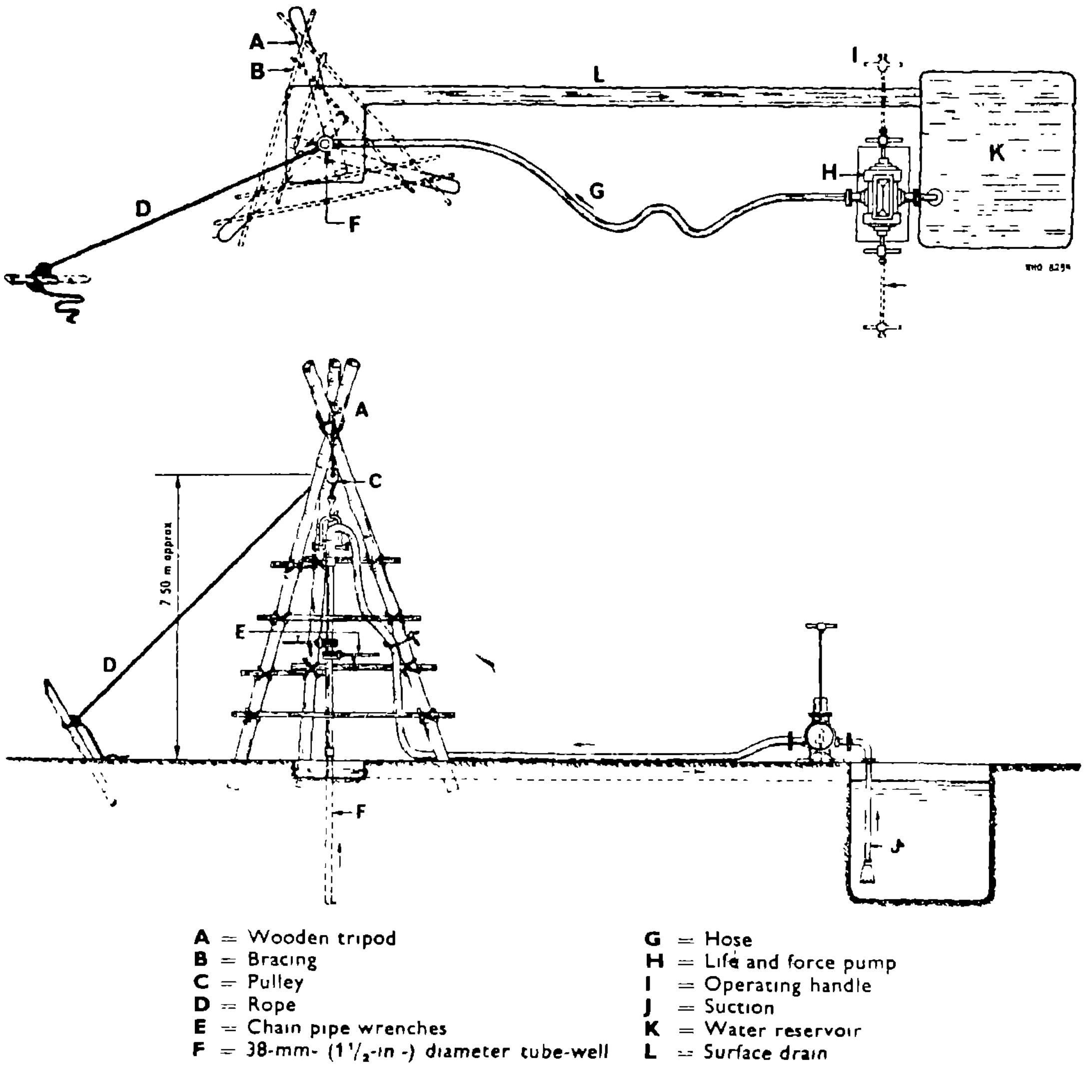


Fig 13. Tube-well jetting (Wagner et al., 1959).

Compared to driven wells, jetted wells are even faster, allow installation of plastic casing and screen, deeper depth can be attained and no clogging problem of well screens occurs. On the other hand, the requirements for suitable site are a bit more stringent.

There is no experience with jetted wells in Ethiopia. The combination of formation type requirement and the need for the availability of water limit its application to only some areas such as the banks of rivers with alluvial sandy deposits or near lakes. Even in most of those cases some form of water transportation to the site would be required. Therefore, this method can be considered unsuitable for the Ethiopian conditions

3.5 Infiltration galleries

Infiltration gallery is a horizontal ground water collection method as opposed to vertical collection means such as boreholes. Ditches that intercept the ground water, burried porous drains or tunnels all come under this definition (Hofkes, E.H. ed., 1981).

Ditches are commonly used for land drainage, and because of their obviously high pollution risk they are not considered for domestic water supply. Tunnels can be constructed in consolidated ground formations. They are suited for fractured formations where the water supply demand cannot be met by dug wells or boreholes. Infiltration drains are constructed in unconsolidated formations.

Both ditches and inflitiation drains require the excavation of trenches to the required depth and their cost increases very fast with depth. Therefore practical drain placement depths are generally limited to 5 to 8 m below ground level (Huisman, L., 1978N).

Important considerations in the design of infiltration drains are the internal diameter of the pipes, drain length, pipe slope and the depth at which the pipes and the gravel pack material are burried below the ground water table.

The aim of proper design is to:

- abstract adequate water,
- avoid clogging of the drain openings and gravel pack by deposition of iron and mangense deposits if they are present in the water, or by the entrainment of the particles due to high entrance velocities,
- avoid the sedimentation of silts that may enter the pipe despite the gravel pack.

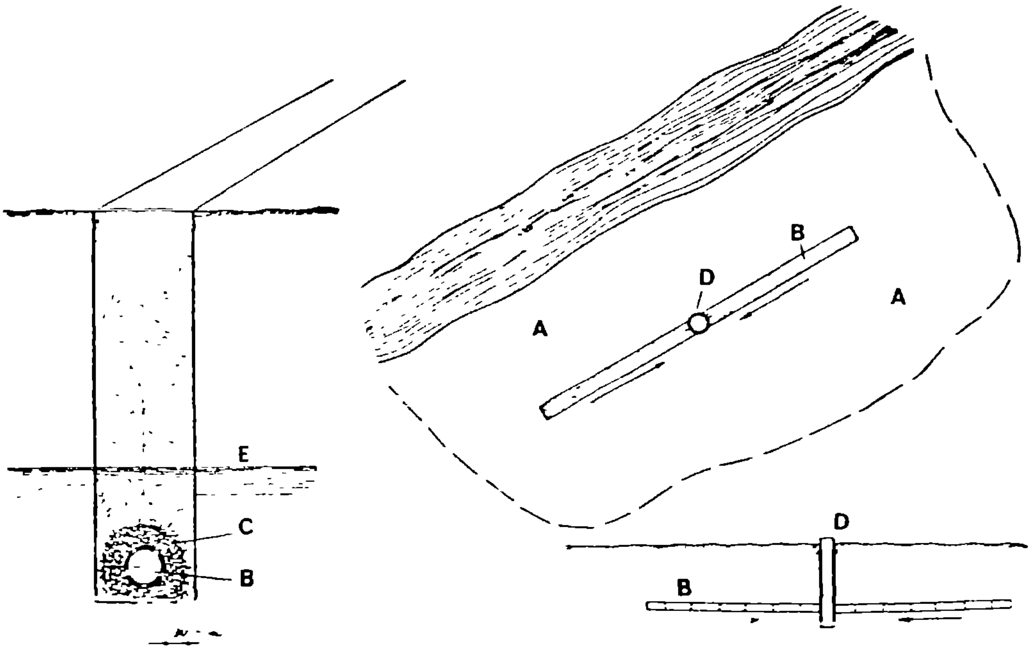
The depth at which the drains are burried should allow for the abstraction of adequate quantities of water even at the end of the dry season when the water table is low. For this purpose, the minimum depth of ground water below the top of the gravel pack is recommended to be 0,5 m. If the ground water contains iron and manganese this minimum depth below ground water has to be increased to 2 - 3 m to prevent the clogging of the drain by iron and manganese deposits. Allowing for say 1 m of drop of ground water table at the end of dry season and an additional 1 m for drawdown, the depth of placement of the top of the drain has to be at least 2,5 m below existing ground water table. Similarly, this depth has to be increased to 4 to 5 m below existing ground water table if the ground water contains iron or manganese. Generally the infiltration drains are suitable only in places where the ground water table is shallower than 6 metres. In practice, it is recommended to construct infiltration drains at the end of the dry season to facilitate construction and ensure that the drains are burried adequately below the ground water table.

Silts may enter the drain and get deposited blocking the drain in due time despite the gravel pack. A minimum water velocity required to flush any accumulating silt is 0,5 m/s. But if the velocity exceeds 1 m/s, the friction losses may be too high and the water may be drawn along the length of the drain (Hofkes, ed., 1981). Experience in drainage engineering using drains indicates that siltation problem is less for firm clayey formations than for sandy formations (IILRI, 1974). Plastic sheets can be used to cover the gravel pack to prevent the downward movement of particles from disturbed backfilled material.

Given the flow rate, using a recommended drain slope of 1:150 (WHO, 1976) and recommended velocities, the diameter of the pipe can be picked.

In practice, the yield per meter of gallery, and thus the total length of the gallery needed to meet the water demand, has to be determined by pilot test. The pilot test could be part of the final construction. According to experience in SE Asia, yields of 900 to 1800 l/h/m length of gallery could be used for preliminary design purposes in cases of galleries tapping sub-surface hill springs (WHO, 1976).

Infiltration drains can be applied for water supply in a number of situations in Ethiopia. They can be used for major water supplies from banks of rivers or the river bed itself in areas where boreholes are not feasible because of low yield or unacceptable quality of ground water. Fig. 14 illustrates drains burried on the bank of a river.



A = Sand bank beside river
B = Perforated pipe
C = Graded filter

D = collection/pump well
E = Water table

Fig 14. Infiltration gallery in riverbank. (Wagner et al., 1959)

Infiltration drains can also be used in areas with shallow ground water where substantial amount of water is required for piped distribution but borehole is not feasible due to low yield arising from thin aquifer thickness or poor transmissibility. Such cases are quite common on the Ethiopian plateau. One such supply was for the village of Adele in Haraghe Region. Boreholes in the broad valley below the village had low yields due to poor transmissibility. Infiltration drains with a cross pattern and a central collector well/pumped well in the shallow clay-silt aquifer solved the problem. But due to the rather too shallow depth and the fact that the valley is a popular grazing ground and located below the village, it would be instructive to study the bacteorological quality and nitrate content of Adele water supply.

Another case was for Gursum town, again in Haraghe. Previously water supply for the town was from open dug wells in nearby a broad valley. Boreholes were thought not feasible due to small aquifer thickness in the weathered upper part over massive non fractured granite bedrock. Infiltration gallery with branched drains was used here. An interesting positive development during this project was the terracing and reafforestation scheme undertaken on the steep hill slope above the site to augment recharge as the catchment area was very small and rainfall rather scanty. The side benefits of soil conservation and possibilities of future wood supply for firewood and construction material for the town are equally important in this denuded landscape.

A related method but even with much more potential for application in the Ethiopian uplands, is using infiltration drains for tapping seepage or sub-surface springs below hills. Such areas may have flowing seepage springs or appear as green patches even during the dry season, and usually appear where there is a break on the slope of the land. Commonly local people dig wide pot holes in such areas to serve both as a storage and a water drawing point as the material is commonly clay-silt with low transmissibilities.

Infiltration drains with storage and public tap down slope in feasible cases gives a reliable gravity water supply where no pumping is involved. Similar supplies have been successfully installed for Kobo and Karamile in Haraghe. In both cases large storage structures were built over the seepage area with public taps some 50 m downstream. The source would have been better protected and possibly less costly due to suitability for construction if the reservoir had been placed outside the seepage area. Fig. 15 illustrates proper spring catchment lay-out using infiltration drains. In a case like Karamile where the supply point is only 50 m downstream, the inspection chamber could be left out, its purpose being served by the reservoir.

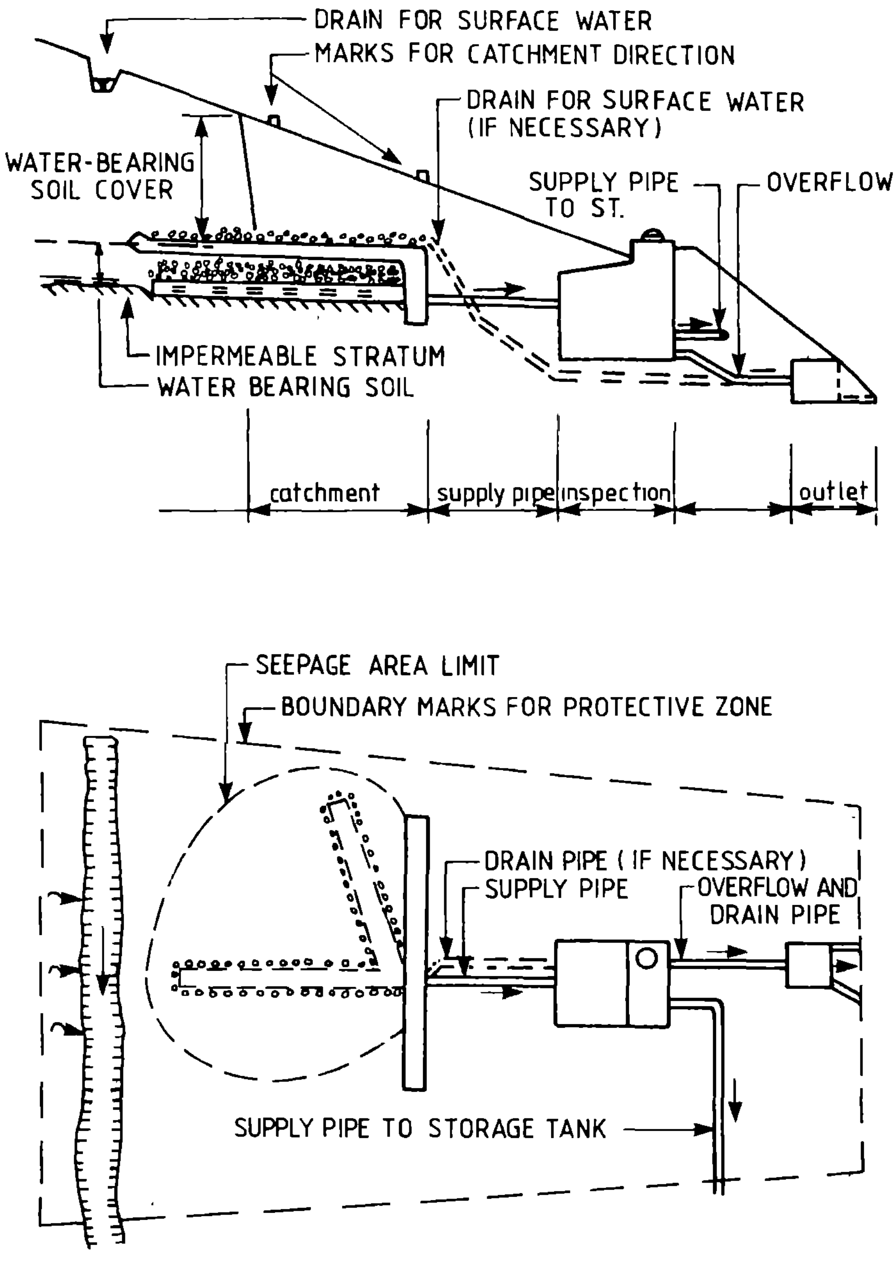


Fig 15. Tapping sub-surface spring (After Helvetas, 1980).

Cases of highly saline water underlying shallow fresh ground water is quite common along the Red Sea Coast and may also be encountered in the Rift Valley lowlands and Ogaden Areas of Hararghe. When the community is scattered and the water demand is low normal shallow wells could be used for improved supply in such areas. If large quantities of water are required for distribution, an infiltration gallery would be preferred to borehole as the required large quantity could be abstracted with a small drawdown and thus avoids the extraction of highly saline water. The drawdown for a borehole yielding the same amount of water would be much higher (fig. 16).

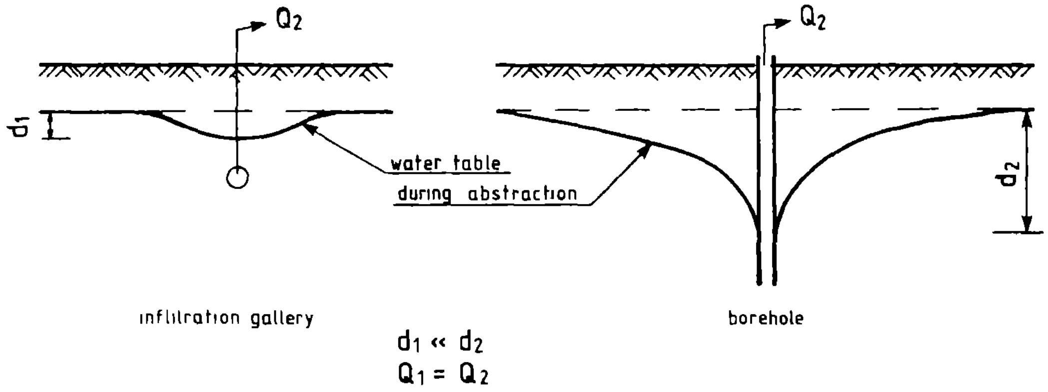


Fig 16. Comparison of the drawdown of an infiltration gallery and a borehole.

3.6 Radial collector wells

Radial collector wells are large diameter wells from which preforated pipes are placed horizontally for ground water abstraction. High capacity wells can be constructed in sand gravel aquifers by placing pipes of 0,15 m to 0,50 m diameter and 15 m to over 100 m length from collector well of diameters varying 1,5 m to 4 m or more (Hofkes, 1981). Fig. 17 illustrates such a well.

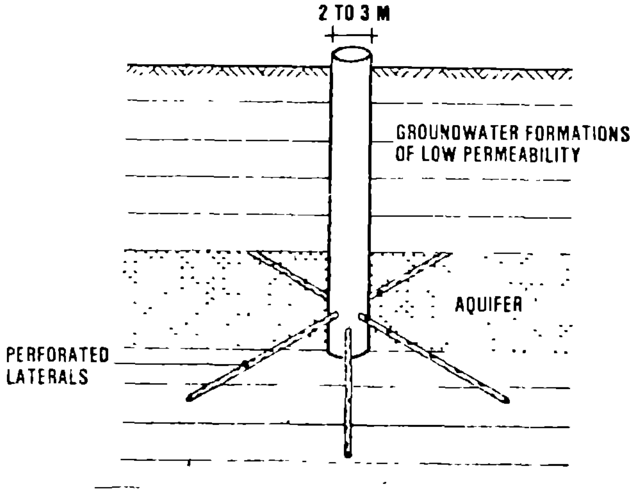


Fig 17. Radial collector well in thin aquifer. (Hofkes, ed., 1981)

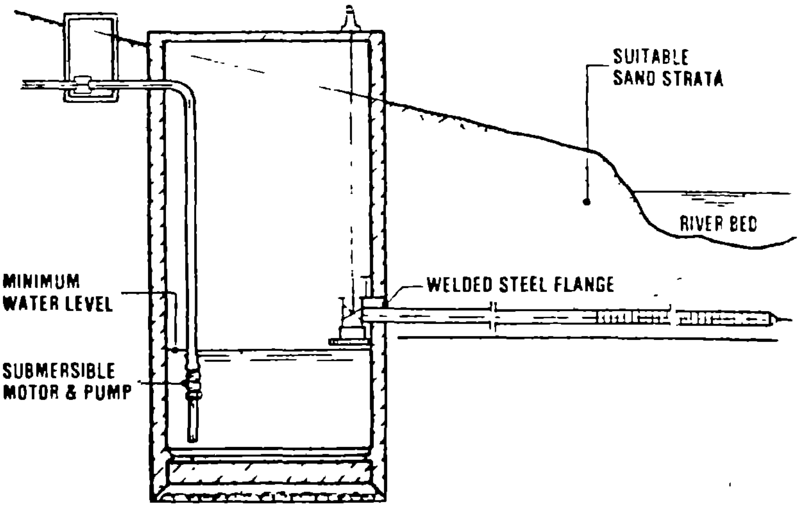


Fig 18. Radial collector well in a riverbank. (Hofkes, ed., 1981)

The usual application of radial wells is in cases of thin and deep aquifers in which vertical wells would not have enough yield, or infiltration galleries are not practical because of the depth. Radial wells could also be used to abstract fresh water floating upon underlying saline water.

There is no experience of radial wells in Ethiopia. High capacity radial wells require special equipment and skill and, in any case, generally there is no need for such wells in rural areas of Ethiopia. If feasible, horizontal jacking of perforated pipe few meters from dug wells could be used to increase the yield of the well. Similarly, the technique could have some application in some cases when drawing water from a river bed sand deposit is required (fig. 18).

Table 1 summarizes the characteristics of the different manually constructed graound water recovery methods.

Table 1.
Comparison of characteristics of manually constructed ground water recovery methods.

Characteristics	Construction Methods					
	Dug well	Hand augered well	Driven well	Jetted well	Infiltration drains	Radial well
Formations						
Hard rock	+	-	-	-	+	-
Weathered rock	++	+	-	-	++	-
Hard clay	+++	++	-	-	+++	-
Soft clay	++	+++	+	+	+	+
Sand, gravel with boulders	++	-	-	-	++	+
Sand, gravel without boulders	++	++	+++	+++	++	+++
Ground water table level						
< 5 m	+++	+++	+++	+++	+++	+
5 - 10 m	+++	+++	+++	+++	+	+
10 - 15 m	+++	++	++	++	-	+++
15 - 50 m	++	-	-	+	-	++
Simplicity of construction	++	++	+++	++	+	+
Safety during construction	+	+++	++	+++	+	+
Suitability in water-scarce areas	+++	+++	++	-	+++	++
Availability of potentially suitable habited areas in Ethiopia	+++	++	+	-	++	+
Suitability for community participation in construction	+++	++	+	+	++	++
Experience so far in Ethiopia	+++	+	+	-	+	-

+++	well suited/very positive
++	suited/positive
+	manageable/less positive
-	unsuited/negative

3.7 Mechanically drilled wells

Methods

Mechanical drilling methods and equipment are quite varied. Perhaps only four are of some interest in the Ethiopian case: augering, cable-tool drilling, direct circulation hydraulic rotary drilling, direct circulation air rotary drilling.

Mechanical auger drilling has already been mentioned in connection with hand augering method.

Cable-tool percussion drilling

In cable-tool percussion drilling heavy string of drilling tools is rythmically lifted and dropped. The drilling bit at the end breaks and crushes hard rock or loosens the material if soft. The broken material is mixed with water to form slurry which is periodically removed by a bailer or a sand pump (fig. 19). Water for the operation is added into the borehole if not flowing in from the formation. Cable-tool machine is simple. But the greatest disadvantage of the method is that it is very slow. It is well suited for hard formations drilling to great depths, but loose formations can also be managed by driving casing tubes at the same time as drilling progresses to prevent caving.

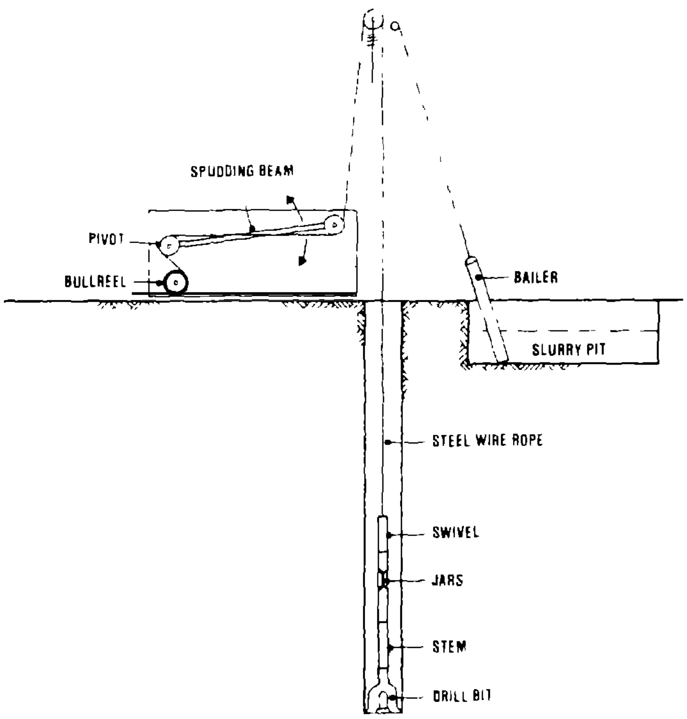


Fig 19. Cable-tool or percussion drilling rig (Hofkes, 1981).

Direct circulation hydraulic rotary drilling

In hydraulic rotary drilling penetration is achieved by abraising and crushing the formation material by a drill bit attached at the end of hollow rotating drill pipe. In direct circulation mud rotary drilling the cuttings are flushed out by drilling fluid, usually clay based, pumped through the drill pipe and coming back in annular space around it (fig. 20). Large quantities of water are required in this method, a drawback in water scarce areas. The method is superior to cable-tool drilling in loose material and soft rock formations.

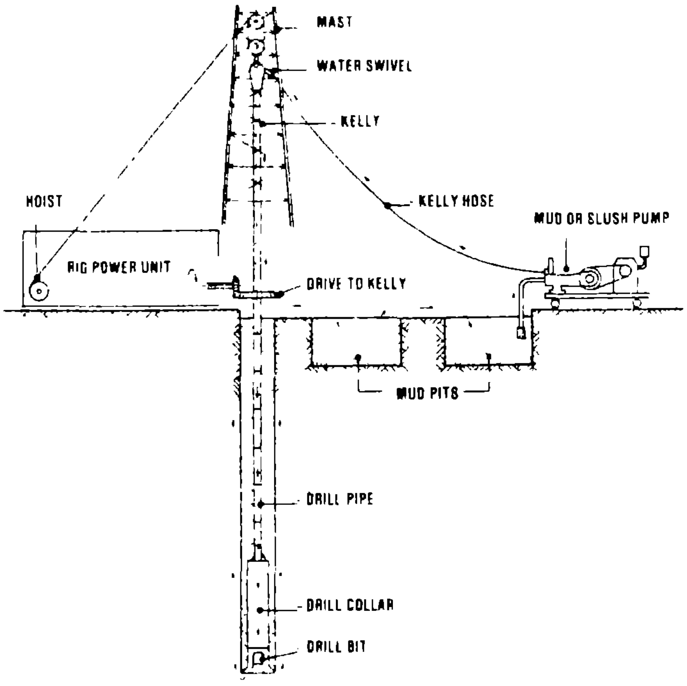


Fig 20. Normal direct circulation rotary drill (Hofkes, 1981).

Direct circulation - Rotary drilling (air)

In this method, a tungsten carbide tipped bit, operated by pneumatically powered rock drill, rapidly strikes the rock material while slowly rotating, chipping away pieces of solid rock which are carried up by flushing medium (air, water, mud or foam).

The rock drill can be either top hammer or a down-the-hole hammer, DTH. The main difference between the two methods is that in the latter the drill is of such small diameter that it can follow the bit in the hole (fig. 21). This fact also gives DTH better flushing characteristics and smaller compressor capacity requirement due to less energy losses during transmission between hammer and bit. Efficiency for top hammer decreases for holes of more than 125 mm (5 in) diameter, while the smallest diameter for DTH is limited by the diameter of the hammer, restricting its use for exploration drilling. However, lightweight DTH rigs, intended for handpump wells, which drills 4 to 4½ " diameter wells in hard rock have been developed recently (Appleton, B., 1983).

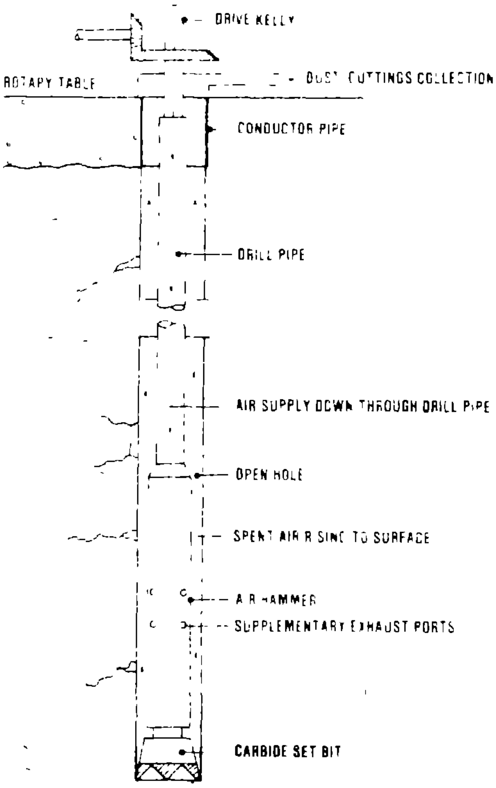


Fig 21. "Down-the-hole" hammer drill (Hofkes, 1981).

Air rotary drilling is well suited for hard rock areas . It is very fast and does not normally require water. However, the efficiency is very low in soft formations and below ground water. To manage caving formation, these rigs have to also be equipped with a conventional mud pump.

Characteristics of the four drilling methods are summarized in table 2.

Table 2. Comparison of characteristics of some mechanical drilling methods

Characteristics	Mechanical drilling methods			
	Augering	Cable-tool drilling	Direct circulation (mud) rotary drilling	Direct circulation (air) rotary drillin
Ability to drill through different formation types:				
Soft	+++	+	+++	-
Soft with boulders	-	+	+	-
Hard with fissures	-	+++	+	+++
Hard without fissures	-	+++	+++	+++
Alternating hard and soft formations	-	+	++	-
Speed of drilling	++	+	++	+++
Suitability for small diameter wells	++	+	+	+++
Simplicity of operation	+++	++	++	+
Availability of needed skilled manpower in Ethiopia	+	+++	+++	+
Simplicity of machine for maintenance/repair	++	+++	++	+
Suitability in water-scarce areas	+++	++	+	+++
Costs (capital + running)	++	+++	++	+

+++ very positive
++ positive
+ less positive
- negative

Ethiopian conditions

Considerable experience exists in EWWCA in using cable-tool percussion and direct circulation hydraulic rotary rigs. Recently some air rotary rigs have been introduced, but the performance fell far below expectations. Such rigs were apparently too sophisticated for the circumstances - little repair possibility locally, need for varying material and accessories to effectly deal with changing geologic conditions, deficiency in operators' skill.

Water well rigs used by EWWCA are generally high capacity for drilling production wells with depths more than 150 m, with some cable-tools capable of handling upto 300 m. And since these wells were ment for engine-run pumps, the smallest casing used for such wells are generally 150 mm (6 ") diameter so as to enable the installation of the pumps.

With present emphasis on rapid expansion of rural water supply, handpumped wells would be one key technology. Since low yields of 15 l/m would be adequate for handpumped wells and handpumps can be easily installed in 100 mm (4 ") diameter wells, high capacity traditional water wells would not be required. In any case, increasing the diameter of a well does not increase yield much. Wells of 100 - 110 mm (4 - 4½ ") diameter going upto 50 to 70 meters would be all that is needed. Such wells can be drilled with smaller rigs than the ones in the present EWWCA fleet.

Such small rigs would have some important advantages over the larger rigs for constructing handpumped wells:

- lower costs - both initial investment and running costs due to lower fuel consumption - lower power and lighter transport requirement,
- faster mobility and access to more areas - very important in the Ethiopian case - generally rugged terrain, narrow roads and bridges.

If the number of dry holes is to be limited, however, such rigs have to be used in areas where the hydrogeology is fairly well known and the ground water table is within their range of drilling.

Under favorable conditions, the cost of such tube wells can be remarkably low. In India, for example, where tens of thousands of such handpumped tube wells are being constructed each year, a typical 50 m deep tube well fitted with India Mark II handpump is claimed to cost only USD 1200 (Gray, 1983) - difficult to believe in light of experiences elsewhere. Appleton (1983) also reports that in one recent rural water supply project in Kenya's West Pokot Region, a team with lightweight down-the-hole hammer drilling rig was completing two wells per week at depths upto 120 m and fitting them with handpumps. It should be remembered that this was achieved under field conditions in a remote area.

It is possible that in many inhabited areas of the Ethiopian plateau, adequate yields for handpump operation can be obtained from shallow depth small diameter boreholes tapping the underlying volcanic rock aquifers. In many such hard rock aquifer cases machine drilling would be the only practical well construction method. Even in soft formations where the ground water table is deeper than 20 m and large number of wells are needed, the advantages of drilling with a lightweight rig (speed, probably less cost, deeper penetration of aquifer) could outweight the important advantages of hand digging or hand drilling (savings on foreign exchange and local employment/participation).

4. STRATEGY

4.1 Strategy basis

In order to devise a viable strategy for rural water supply, for any undertaking for that matter, it is first essential to clearly define its objectives and understand the existing problems.

4.1.1 Objectives of rural water supply

The widely recognized objectives of rural water supply are:

- to improve the health status of the population,
- to save the energy and time spent by women and children on the daily drudgery of water carrying
- to stimulate socio-economic development in rural areas.

Health improvement

To appreciate how some diseases can be controlled by the proper use of improved water supplies, it is necessary to understand their mode of transmission. Bradley (1977) has classified water-related diseases into four categories which relate them directly to water.

a) Water-borne diseases - infections spread through water supplies, e.g. cholera
b) Water-washed diseases - due to poor personal hygiene, e.g. trachoma
c) Water-based diseases - transmitted through aquatic invertebrate animal, e.g. schistosomiasis
d) Water-related insect vector - infections spread by insects that depend on water, e.g. malaria

In table 3 the four categories are shown with relevant preventive strategies.

Table 3. The four mechanisms of water-related disease transmission and the preventive strategies appropriate to each mechanism. (Feacham, 1977).

Transmission mechanism	Preventive strategy
Water-borne	Improve water quality Prevent casual use of other unimproved sources
Water-washed	Improve water quantity Improve water accessibility Improve hygiene
Water-based	Decrease need for water contact Control snail populations Improve quality
Water-related insect vector	Improve surface water management Destroy breeding sites of insects Decrease need to visit breeding sites

Perhaps the most important group in the case of Ethiopia are diarrhoeal diseases, which are transmitted by faecal-oral route and thus both by water-borne and water-washed modes of transmission. Therefore, for the control of this group of diseases both good quality and adequate quantity of water are required.

On the other hand, another important group of diseases, infections of the skin and the eyes, is water-washed. Here water availability and hygienic way of life is more important than water quality. Therefore, it could be argued that, for example, in areas with only prevalent skin diseases water availability is more important than water quality.

Recent literature reviews of evaluations of the impact of improved water supplies on health by Hughes and Mc Junkin (cited by Lindskog, Per and Ulla, 1983) have shown that on several cases improved water supplies and hygiene have effect on diarrhoeal diseases. It should be noted that such positive impacts on health were not observed in all cases.

The mere provision of a well with a handpump is not enough. The improved water has to be always available, used in a proper way without contamination between "tap and mouth" for all purposes, including personal hygiene. Schultzberg (1983) mentions about a water quality study made in Botswana where the need for health education was exemplified: "About 70 % of the tube well samples were free from feacal coliforms and less than 6 % of the samples had feacal coliforms in excess of 100 per 100 ml. The water quality in the standpipe taps was not significantly different whereas the count in household jars exceeded 400 in all cases and 2000 for about half the samples."

In another in depth study made in Lesotho (Feachem et al., 1978), no reductions in water-related diseases were observed, even in villages where generally safe piped water supplies were used, when compared with villages without improved supplies. Since hygienic practices in the villages did not improve along with the introduction of improved water supplies , the researchers felt this to be the major cause for the lack of health impact - again stressing the need for health education.

Apart from such empirical findings, based on current knowledge of tropical epidemiology, Feachem (1977) postulates that "Probably without exception low-income communities in hot climates suffer from high morbidity due to non-water-borne faecal-oral infections and to the water-washed infections." He indicates that in faecal-oral category, much of the diarrhoeal diseases (a major cause of infant mortality and morbidity in the developing world) may be non-water-borne. Such non-water-borne faecal-oral infections and the other water-washed category of the skin and eye infections can all be reduced by "increasing the quantity, availability and reliability of the water supply almost irrespective of its quality." The clear implication here is that under conditions of severly limited resources of the low income communities in developing countries, water supply design should focus on increased quantity, availability and reliability. The same sentiment has been aptly put recently by Feachem as cited in World Water (1983), "the health impact of the Decade will not be achieved by simplistic policy of supplying clean water. Only carefully designed programmes which integrate water quality improvements with improvements in water availability, sanitation and hygiene education will achieve substantial reductions in the transmission of water- and excreta-related infections."

For the governments in developing countries and the donor agencies, the main justification for rural water supplies is expected health improvements. But it may not be so from the users' point of view.

Saving energy and time

Experience in Ethiopia (Makonnen et al., 1983; VIAK, 1977b), like elsewhere in the developing world (Kauzeni, 1983; Andersson, 1983; Falkenmark, ed. 1982), indicates that though water is a felt need of many communities, this is rarely due to health reasons. It is almost always linked to the amount of drudgery involved in carrying water from traditional sources. The further away the traditional source is from the village, the greater the enthusiasm they show for improved supply closeby. A community with a polluted surface water source closeby has usually other needs of higher priority, such as a school for their children or a clinic. Inferior water quality is perceived only by their senses: odour, taste or sight.

Stimulation of rural development

It is conceivable that the time and energy saved by implementing improved supply may be used by rural women for productive activities such as gardening, weaving, etc.

Water supply may also directly improve production. In some rare cases, the water is used for small irrigation. During the recent field visit in Ethiopia, two such cases were noticed near handpumped wells. In one case in Bale substantial commercial vegetable gardening was being done by a cooperative. Livestock watering at improved supply is more common if alternative source is far away. In the case of dairy farming based on high grade cows the economic advantage of using safe water source may be quickly realized by farmers. Such dairy farmers in the high potential areas of Kenya were eager to have and willing to pay for improved supplies (VIAK, 1977a).

Successful water supply programme in which peoples' participation has been high may encourage other development work in the area.

4.1.2 Problems

Only problems that have direct bearing on whether or not a completed scheme is achieving the desired objectives are considered. It has already been noted that rural water supply schemes may not achieve their objectives because either they are poorly constructed (e.g. no sanitary seal), or are often out of service (lack of maintenance) or are not used properly. In this context, main problems of handpumped water supplies in Ethiopia are related to community selection criteria, complementary inputs, standardization, supervision, and above all, maintenance.

Community selection

Usually new water supplies are provided for communities that have been identified as water needy which in many cases means the women and children have to fetch water from sources several kilometres away during the dry season. Often the request for water supply comes from the peasant association and priority is decided on by the Regional office in consultation with the Regional Administration, again often on "water need" criteria. Other important factors in the decision process are accessibility, balanced distribution of improved supplies within the Region and degree of technical feasibility. Though these selection criteria are reasonable and consistent with the overall objectives of balanced project allocation within the country and meeting the needs of the most needy first, they have adverse effects on construction costs and quality and maintenance systems.

In any given years' programme, sites are selected which are widely dispersed, may be hundreds of kilometres apart. Small construction crews are moved from site to site, sometimes coming back to the same site after a year or two.

Such widely dispersed small construction works raise supervision and maintenance costs immensely and aggravate the problem of supplies. Some of these problems could be alleviated by better detailed planning but basically the attempt to meet requests for water supply from widely dispersed areas in the Region during a year's programme will meet with only limited success at best because of the big logistics and supervision problems which are beyond the present financial and managerial capabilities of the Region.

Complementary inputs

Studies about rural water supplies (White et al., 1972; Saunders, R.J. et al., 1976) have repeatedly stressed the need for complementary inputs in health education and sanitation. In Ethiopia such complementary inputs are generally lacking. The exception to this would be the Bale settlements where an attempt is being made at integrated developments in water supply, health education and sanitation, among other fields, by various organizations. In these areas the people seem to be aware of health benefits of improved water supply, but they do not always seem to act on it as envidenced by, for example, the soggy areas around most water points due to bad drainage. During the recent visit, however, it was observed that at least in one case the people were willing to put more effort in getting water from improved handpumped well supply than to get it from a near by river with clean water. From the reason they gave for this choice, it appears that the health education message has sunk in. In the author's experience, in similar situation elsewhere in the country, the river water would have been preferred.

Standardization

Standardization in the construction of numerous repeated rural water supply schemes helps achieve acceptable construction quality under conditions of non-optimal supervision, craftsmen become familiar with the work in a short time (Hartman, 1983), and facilitates operation and maintenance (limited types of spares).

Some construction works, such as infiltration galleries, are mainly site specific and therefore cannot be fully standardized.

Attempts are being made in Ethiopia to limit the type of handpumps, but, for example, still about five different types of pumps are used in Bale Settlements. The problem of providing spares for all is obvious.

For ring wells, the well diameter is now standardized but the same is not true for well cover, hard standing and drains which, in a lot of cases, could be improved.

Supervision

No amount of standardization will achieve required construction quality without some degree of effective supervision. Lack of effective supervision is evidenced by varying quality within the same area. This is specially important in parts of the construction which cannot be observed easily after work completion, such as adequate excavation into the aquifer and sanitary seal for wells and infiltration drains. A number of cases were observed where the joints between the top rings in a dug well were not sealed. Some of these shortcomings seem to come from lack of appreciation of their importance by the field crew rather than negligence. Some supervision and practical field training from better informed individuals could have solved the problem.

A problem closely related to effective supervision is that it is difficult to get better trained people interested in the detail of simple technology schemes. They find it unchallenging, unrewarding and fear a deadend in their professional development. The result has been although there are some dedicated field technicians, these are not generally supported by people who can benefit from existing domestic and international experience and improve designs, properly document work done and make supervision.

Maintenance

Handpumped well water supplies have distinct characteristics which give it both its strengths and weaknesses. That the system is simple and of limited capacity (200 - 300 people per pump) means it is particularly suitable for rural setting where the population lives in small groups. Under rural conditions in Ethiopia, better service level could be achieved with handpumped wells than wells with motor-run pumps because such wells provide water for bigger population but they have only one public water point near the well. On the other hand, a bigger number of handpumped installations (5 to 15 times more) would be required to serve the same population as that which could be served by a motor-run pumped well. This is one important factor that makes the maintenance of handpumps, specially centralized maintenance, very expensive and difficult due to unbearable transport costs.

Maintenance is by far the biggest problem of handpumped well supplies in Ethiopia. This may well be the case also for other water water supply systems, though obtaining and distributing fuel for operating motor-run pumps may sometimes be just as difficult.

At present, maintenance is centralized at the Regional level. Maintenance crews go out on call for repair jobs of motors, generators, motor-run pumps or civil works related to distribution systems. Rarely do such maintenance crews engage in works involving handpumped wells and till now there are no separate crews organized only for handpumped wells. Whatever repair work done on handpumped wells, is usually undertaken by the construction crew. Some reasons for this state of affairs may be:

- An out-of-service large scheme attracts more attention than an equivalent number of simple schemes, and therefore, present maintenance crews and resources at the disposal of Regional Offices are fully occupied in maintaining large schemes.
- Since there are no detailed completion reports and exact locations for the numerous handpumped wells in a given area, it becomes easier for construction crews to do the repair work.

There is hardly any preventative maintenance. In fact from the data obtained during the field visit, it is clear that even inoperative pumps go unrepaired for a long time. Out of the 31 handpumps that were out of service during the recent field visit, 60 % had been in disrepair for over six months.

No village level maintenance is practised yet. It was originally intended to try such maintenance system in Bale settlements where the locally manufactured simple plastic handpumps were to be installed in depths less than 10 m. The village level maintenance aspect of the project was never followed through due to mainly undue emphasis on new construction and lack of detailed planning and clearly delegating responsibilities. Almost all of the simple locally made pumps installed earlier were in disrepair during the present visit. The construction crew is now installing more sturdy pumps out of necessity.

It is rare to find rural water supply projects where a serious effort is made to prepare the community for proper operation and maintenance of the system when the construction work is completed. But presently, one large gravity spring scheme is underway with SIDA's assistance in the Huruta area of Arsi Administrative Region where every effort is being made to achieve this community participation in all phases of the project, including operation and maintenance. Emphasis is being put in training women. It is hoped a lot can be learnt from the experience of this unique project in the country.

There is some indication, at least in some sites, that villagers do care for their pumps. They apparently perceive misuse, specially by children, as the major cause for handpump failure, and consequently it was noticed that in some sites they use guards, lock the pump or the fence for certain periods of the day. This positive trend of users trying to care for their handpumps could be turned into full scale village level maintenance with proper training, organization and back-up service in spare parts, tools and occasional major repairs from the Regional Offices.

4.2 Strategy recommendations

4.2.1 The need for strategy

From previous discussions it is obvious that successful rural water supply programme where substantial health benefits are likely to be realized is more than the construction of wells. It requires changes in peoples' hygienic behavior and that the schemes are not only constructed but most importantly kept operational and used. But all of these minimal requirements are not usually fulfilled, though considerable resources are going into the sector. More and more schemes are being constructed each year while considerable numbers are going out of service at the same time. Though no general water quality studies are made, it is probable that most improved sources are quite safe at the tap, but the same cannot be said while it is inside the home. Marked changes in the quantity of water used is not noticed after installation of improved sources, but we expect significant impact on health, specifically reduction in the water-washed diseases, only if per capita use increases due to appropriate changes in personal hygiene practices. The minimum amount of daily per capita consumption necessary for significant health improvement is not exactly known. The lowest estimate for the amount is about 20 l/c/d (White et al., 1972), while studies in Ethiopia (VIAK, 1977a; Makonnen, 1983) show that the average consumption even for improved sources is only about 10 l/c/d.

At the same time, according to Bradley (cited by Pacey, 1977) water consumption does not increase significantly unless the fetching distance is reduced to the point where water is supplied within each house. This view is based on field observations. But one can imagine that with effective health education people would increase their consumption to the minimum required for personal hygiene even if the water point is at some reasonable distance from home. Indeed this was indicated to be the case in the Lesotho study (Feachem et al., 1978). But it is unlikely that such "reasonable" distance can be more than half a kilometer. The implication is that to achieve significant health impact we have to also supply the water closer to habitation areas than is generally the case in Ethiopia at present. If it could be done, reducing the fetching distance is also what the users want, though for the different reason of saving energy and time as discussed earlier.

We have also seen how the present policy of community selection priority based mainly on water need and fair project distribution, though well intentioned, thins out the limited available resources and consequently, quality of construction suffers, and more importantly, proper maintenance becomes difficult, if not impossible. Moreover, promoting genuine community participation and provision of complementary inputs are also difficult in such widely distributed projects. It is therefore inconceivable that significant health benefits would accrue under these conditions.

Therefore, at this early stage of expanded rural water supply programme in Ethiopia, one has to look back and see if endeavors are likely to meet the objectives, and if not, what can be done to improve the situation and get the maximum benefits out of limited resources. A strategy based on defined objectives, which takes into consideration the present level of socio-economic development and available resources is called for.

4.2.2 Defining objectives

A strategy for the rural water supply sector based on shallow wells and suitable for the Ethiopian situation is suggested here. Similar strategy could be devised for other water supply techniques.

Two levels of objectives are considered under three different cases. Level I has the objective of mainly saving the time and energy expended in water carrying, while level II aims at all the objectives, emphasizing health benefits.

Case I/Level I: Communities with strong expressed water need due to large distances to traditional sources, or too small water quantity, but where sustained maintenance of schemes is unlikely in the near future. The objective for water supply here would be saving energy and time, specially to liberate women and children from the drudgery of water carrying.

Case 2/Level II: Temporary concentration of people due to some disasters, such as drought, where the chance of epidemics is very high. The major objective of water supply in such cases would be health benefits.

Case 3/Level II: Communities where the likelihood of sustained maintenance is good due to:

- existing capabilities within the community and/or the water authority, or
- definit plans to build up these capabilities as part of the overall water supply project for the community. Again the main objective here would be health benefits.

Most communities that are provided with water supply today in Ethiopia are case one, with only one difference. The tacit objective is health benefit and consequently attempts are made to provide bacteriologically safe water at first, but schemes go out of service after a short time, or become polluted (handpumped well deteriorating to an open well), or remain inoperative for long periods after breakdowns.

Case 2 situation is critical from the health point of view and therefore it calls for as good quality and quantity of water as practical to supply. Fortunately, such emergency situations usually attract enough resources that not only construction but also operation and maintenance of the system is possible, at least for the period the emergency lasts.

The overall approach in the proposed strategy is to concentrate on developing the national capabilities for case three (maintenance capabilities) while at the same time providing some form of water supply for case 1 (no maintenance capability) where it cannot be postponed, and cover case 2 (emergency) as such situations arise.

With the limited resources available the capability for case 3 - capabilities for proper maintenance supplemented by sanitation and health education programme - are unlikely to be achieved in projects dispersed all over the country. Concentration in limited selected areas seems the only rational strategy at present, despite its conflict with the commendable general policy of fair project allocation throughout the country. According to Lindskog (1983), one reason for the relative success of rural water supply programme in Malawi is "the concentration of the programme to few focal areas."

4.2.3 Level 1/Open wells

In case 1, where the traditional source is distant and the likelihood of sustained maintenance is low, generally improved water supply should be delayed till the maintenence possibilities are good unless supplies with high reliability such as a spring gravity systems are possible.

If the water need is overwhelming and the ground water table is shallow open wells should be considered as an interim solution. Such cases are found usually in the lowland areas where the semi-nomadic people live. In one such case in Awara Melka area, handpumped ring wells were constructed four years ago. Not a single handpump was working during the recent visit and the water was being drawn through the manholes (fig. 22). Locally manufactured PVC pumps were used.

Fig 22. Here the handpump stand is given another duty after the pump broke down: securing the rope while drawing water using a container.

The open well should be constructed properly with the necessary sanitary seal, apron and drain as it can be easily upgraded in the future by cleaning, pump installation and disinfection only. A raised wellhead could control the transmission of guinea worms, if they do exist, reduce general pollution by preventing split water from going into the well, and also provide safety for users and animals. The required wellhead can be constructed by jointing an extra concrete ring at the top. This could easily be removed during the upgrading (fig. 23).

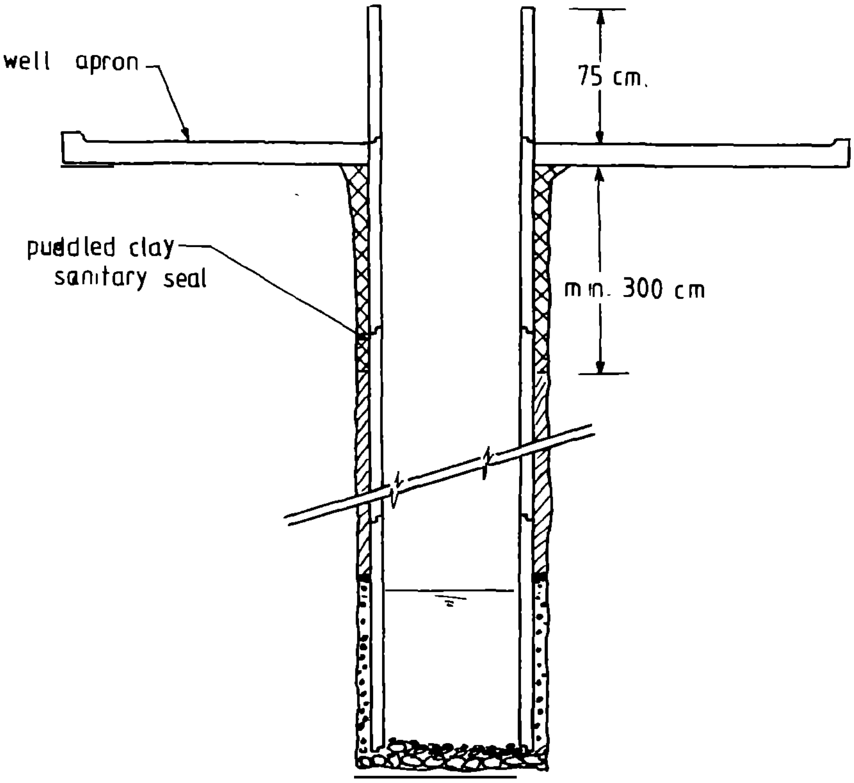
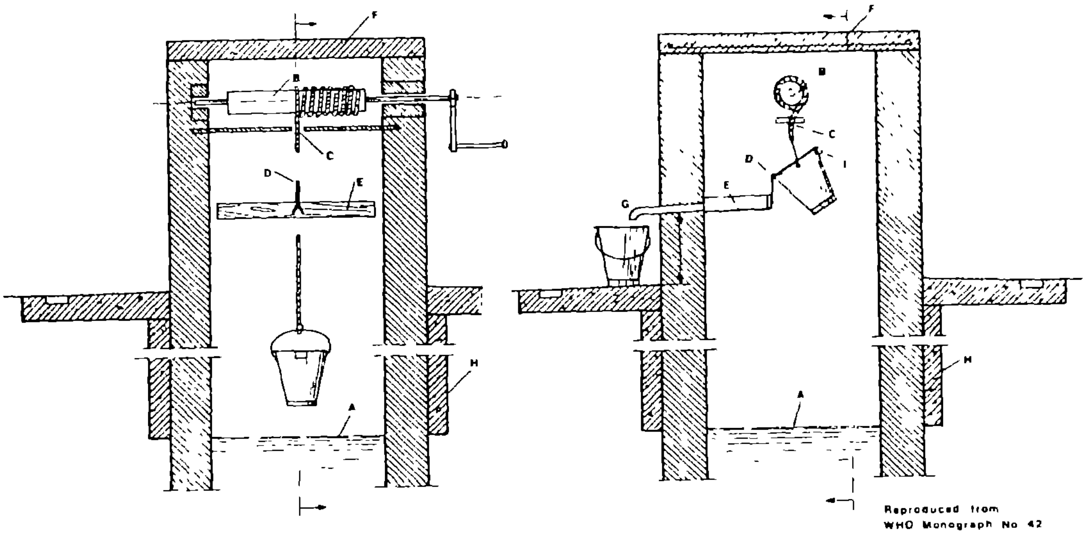


Fig 23. An improved open well.

Water supplies from such carefully sited and constructed open wells can be theoretically quite safe if care is taken not to pollute it during the water drawing process. Some things can be done to minimize pollution. Air borne pollution can be prevented by covering. When not in use, the bucket and rope can be hanged away from children and the ground. These steps are usually taken already by private well owners in Ethiopia. With a little bit more investment, one can think of a completely covered superstructure with some mechanical contraption such as a winch permanently installed inside (fig. 24). The author feels however such devises are probably at least just as costly and difficult to install and maintain as handpumps when put on public wells.



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WHO Monograph No 42

A = Water level in well
B = Windlass
C = Guide hole for rope
D = Stop hook
E = Trough

F = Tight cover, removable
G = Discharge opening
H = Compacted clay or concrete grout

I = Weight attached to top side of bucket to make it tilt when bucket is lowered onto water surface

Fig 24. A sanitary rope and bucket well (McJunkin, 1977).

Some small communities in China use open wells with public buckets (IDRC, 1981). It was found out that the bacterial quality of water from such dug wells, though not upto standard, was a vast improvement over untreated water. Even in China, however, where discipline and awareness of health benefits of improved water among rural people is believed to be higher than in most developing countries, the bacterial water quality difference between handpumped wells and open wells was significant.

In the late 1950's when the Government of India embarked on rural water supply schemes under the National Water Supply and Sanitation Programme the initial stress was on improving wells by preventing outside contamination. First roofs over wells and then covering wells leaving only small opening for drawing bucket were used, but the pollution could not be prevented (Garg, 1978). Further development was the use of automatic chlorination for these wells by hanging pots filled with bleaching powder inside the well water. This method did not work also due to costs and organization problems related to periodic replacement of the pots. It was also found difficult to control the concentration of chlorine as per requirements, despite some technical progress in pot chlorination.

The performance of open public wells in Ethiopia cannot be expected to be any better. During a water quality survey in the country, VIAK (1977a) found out that open wells were highly polluted.

Such actual experiences around the world lead us to the conclusion that public open well used under prevailing rural conditions cannot be considered bacteriologically safe. It would solve the problem of water availability and reliability. Theoretically, if the well is close to habitation area, properly constructed and relevant health education is given, it could have significant positive health impact by reducing water-washed diseases, including the component of diarrhoeal diseases that could be checked by proper hygienic practices. But it would be unrealistic to expect effective health education in such areas.

Therefore, a correct attitude to the use of open wells would be required under present circumstances. Some authorities in rural water supply (Wagner, E.G. et al., 1956; Pacey, A., 1977; Hofkes, E.H., 1982b) realize this and approve the use of open wells in some situations. On the other hand, some government policies like in Tanzania (DHV Consulting Engn., 1981), Ethiopia and other bodies like WHO (Hofkes personal communication) seem to consider handpumped wells as a minimum level of service to be provided to rural people at present. Such policies may have definite positive impact in prodding water authorities to build rapidly their maintenance capacities and provide safe water. But the general application of policies, emphasizing quality at the tap irrespective of situations, leads to wastage of resources. In addition, numerous inoperative pumps lying around would create a general disillusionment with such water supplies. The worst case is when a traditional well has been "improved" by complete sealing of the well by such method as reduced diameter construction and a handpump installed in areas where there are little maintenance possibilities. When the pump fails, the people have to dig a new well or opt for distant sources. Exactly this had happened in the Zwai area, Ethiopia.

Moreover, there seems to be some contradiction in rural water supplies policies that in some difficult situations, accept ponds and cisters without any treatment or measures against contramination but does not accept open wells in similar grounds like in Ethiopia. Despite the policies, it has not been practically possible to completely avoid open well supplies. They are now usually provided as "temporary" measures till handpumps are available. One such project (Jovanovic, D., 1977) was undertaken in Haraghe 1976/77 when eighty open wells were provided in semi-arid drought stricken areas of Haraghe and were latter provided with handpumps. The pumps subsequently went into disservice in most cases. It is argued here that if at all wells have to be dug somewhere, the condition for pump installation has to be maintenance capability, rather than handpump availability. Experience indicates that maintenance should not just be taken for granted.

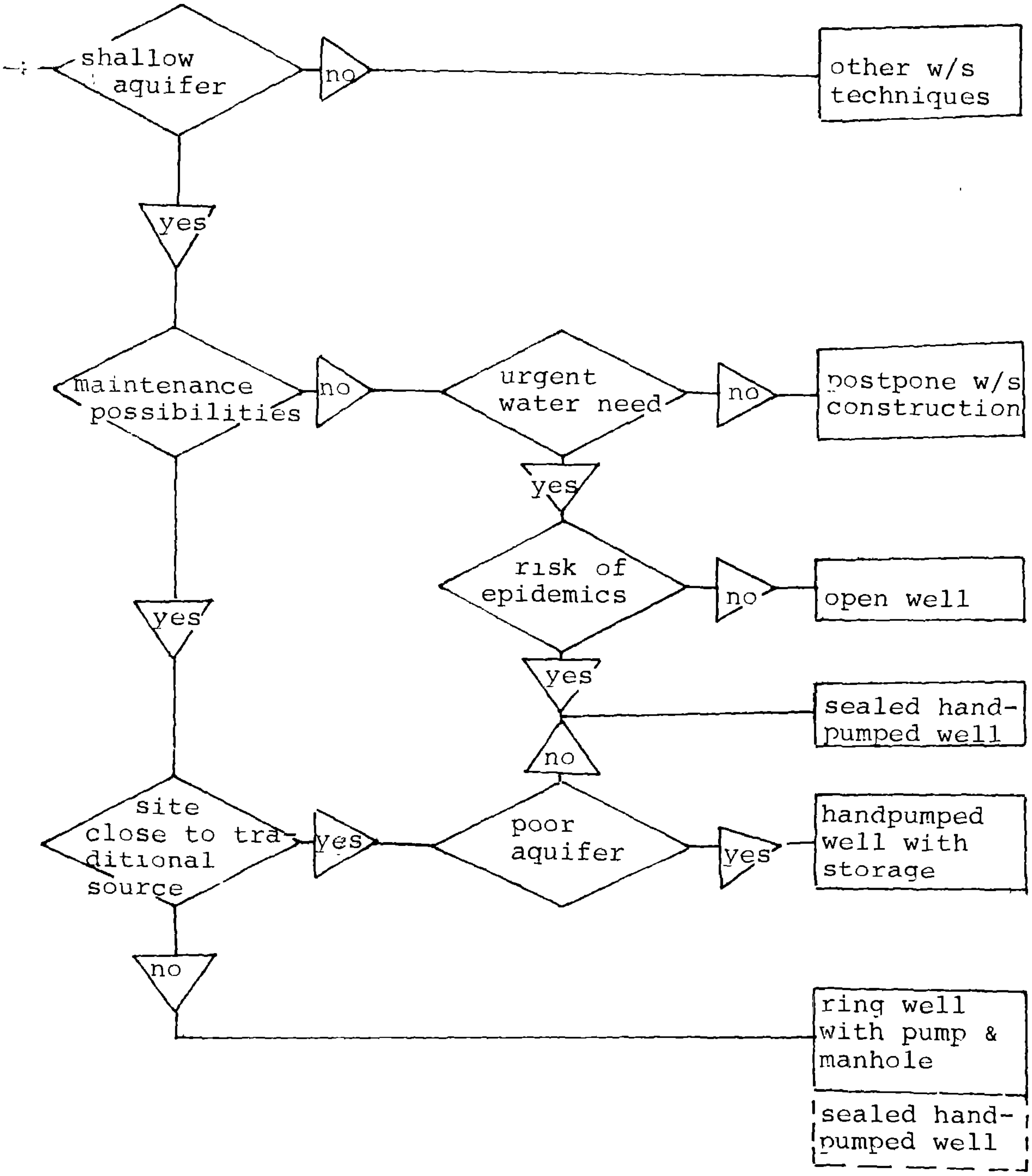
4.2.4 Level 2/Handpumped wells

In case 2 (emergency situations with large concentrations of people) carefully sited and constructed handpumped wells can be used for water supply. The reliability of such supplies can be increased by providing more handpumps than strictly required by the demand. In the case of dug wells this can be economically accomplished by installing two handpumps in a well.

In case three, where capability for maintenance exists or is to be built as part of the project, again handpumped well with increased reliability by providing extra handpumps, are suggested. The emphasis here is on maintenance capability and health benefits. Both are easy sounding but difficult to realize in rural situation of Ethiopia, and therefore a concentrated effort emphasizing quality over physical output is suggested until good performance standard is achieved. To accomplish this two approaches are foreseen for the immediate future:

- pilot projects and
- rehabilitation works.

Fig. 25 shows what type of shallow wells should be constructed depending on the different situations of maintenance possibilities, water need, risk to public health, aquifer type and distance from traditional sources. Basically depending on the maintenance possibilities three types are envisaged:



Note: ⬚ = in conditions of reliable maintenance

"sealed" well = well without manhole

w/s = water supply

Fig 25. Algorithm for decision in shallow well water supplies in Ethiopia.

- open wells: no maintenance possibility
- ring wells with manholes and handpumps: some maintenance possibility but not reliable, and no alternative source within reasonable distance during the dry season
- sealed handpumped well: good maintenance possibility (without manhole)

4.2.5 Pilot project

The overall aim of the pilot project for handpumped wells in Ethiopia would be to increase the national capacity for implementing successful water supply projects based on handpumped wells and serve as a model for other areas. The specific goals of the pilot project should be to:

- introduce, develop or adopt appropriate techniques for siting and constructing handpumped wells,
- introduce and develop appropriate maintenance system for such projects,
- train field technicians.

Such a project should be undertaken with maximum community participation in all phases of the project: planning, construction and, specially operation and maintenance. It should be supported by a programme of health education preferably directly linked to the project, and, if possible, a sanitation programme.

Although the need for complementary input, specially sanitation and health education is generally accepted, in Ethiopia, like in most other developing countries, the implementation of such programme has been difficult because of dispersed responsibilities within different government bodies, lack of resources, disproportionate emphasis on new construction and may be lack of experience in how to go about it.

In the proposed pilot project, attempt should be made to implement all the necessary inputs for successful rural water supply in a concentrated way in a given area. Complementary inputs from other bodies such as the Ministry of Health would be necessary for significant impact on health. But here all the necessary inputs possible from the water authorities and the community to make the supplies at least functionally viable and fully utilized would be considered. The needed inputs are correct planning, good construction, health education regarding water use and sustained maintenance with emphasis on community participation in all phases. Some inputs, specially health education, look outside the responsibilities of water authorities; but some of information regarding health benefits of improved supply and correct water use should be and could be passed on in the process of community mobilization. This is particularly important considering the practical difficulties of achieving coordinated inputs from different Ministries, though Kauzeni (1983) notes that at least in a pilot project in Tanzania such coordinated approach has been very effective in community participation.

Techniques

Some deficiencies and limitations of presently employed handpumped well construction techniques in Ethiopia have been already mentioned. Techniques that need to be introduced and developed are for:

- Constructing dug wells in caving soils: here caissoning using precast concrete rings on cutting shoe seems the best choice because of its relatively better construction speed.
- Deepening dry wells: telescoping again using precast concrete rings can be used.
- Improving well yield - horizontal jacking of perforated pipe could be tried. Tunneling could be tried in some areas of firm ground. Horizontal

and vertical drilling at the bottom of wells in fractured hard rock areas seem to have been successful in India (World Water, 1982). Similar situations may be encountered in Ethiopia.

- Tapping aquifers in hard rock areas: dug wells in hard rock areas are not common in Ethiopia due to construction difficulties but there are many areas on the plateau with low yielding shallow aquifers in the hard rock. Therefore, the capacity for well digging in hard rock areas could be useful. For this purpose, jack hammer-compressor units could be tried. The compressor can also be used for dewatering purpose. Use of explosives is not recommended due to difficulties in getting explosives and problems of safety and security.

  Hard rock aquifers can, of course, be tapped by machine drilled tube wells as well. In hard rock areas with shallow aquifers handpumped small diameter tube well supplies drilled using smaller rigs, vehicles and crews than in conventional drilling have proven highly cost-effective method in India (Appleton, B., 1983), Malawi (Charnock, G., 1983) and other places. Two important requirements for the Ethiopian condition are that the rigs have to be transportable over difficult terrains and poor roads, and secondly, they have to be flexible enough to cope with any type of formation. Even in hard rock areas in Ethiopia, layers of unconsolidated materials formed in between the successive lava flows, are often encountered.
- Improve the construction of well superstructures: improvements in construction of well head, well apron, well cover and drain are necessary to achieve sanitary seal to prevent well pollution by surface water, to avoid pools of split water where mosquitoes may breed and to enhance user convenience.

Maintenance systems

Maintenance systems can be:
- centralized
- village level
- combination of the two.

Experience around the world (Arlosoroff, S., 1983; Hofkes, E.H., 1982) indicates that in the long-run the transport costs for centralized maintenance with mobile crews regularly visiting large numbers of pumps dispersed around the countryside would be prohibitive. Completely self-supported village level maintenance, though desirable cannot be envisaged now due to problems of spare parts availability, initial costs of equipping pump caretakers for complete overhaul of the pump and relatively high level of training required. A combination of village level and government agency maintenance looks the better alternative. First, it may encourage sense of ownership and self-reliance within the village. Secondly, it would be less costly than completely centralized maintenance system. Hofkes (1982) gives the estimated maintenance costs from the government budget, based on experience in Shinyanga and Morogoro Regions, as follows:

centralized	25 %	of	initial	pump	cost/yr
village	12 - 15 %	"	"	"	"
de-centralized (combination)	6 %	"	"	"	"

Obviously, the more the villagers take the maintenance responsibility the less the burden on the government, and hence the more its capability to reach areas not yet served.

The participation of the villagers in maintenance may be at first limited to preventative maintenance of the pump superstructure - greasing, tighting bolts - and regular cleaning of well surrounding and repair of fences to keep out animals from the immediate surroundings of the wells.

In the pilot project a combination of village level and central mobile crew maintenance system is foreseen. The exact mix of responsibilities depend on the pump type, well depths and organizational capabilities of the community. But the project should aim at organizing a minimum of preventative maintenance of pump superstructure and upkeep of well surroundings at the village level. To achieve this pump caretakers have to be trained as part of the project and community level organization, "water committee" established, and mobile crews set up for back-up service and major repairs. The mere inclusion of intensions for establishing maintenance in the terms of reference would not suffice. Definit progressively increasing budget and work programme with realistic targets have to be worked out for maintenance systems as is normally done for construction work.

Training

The pilot project should be used to give practical training in well site surveying, well construction and maintenance to increase the national capacity for rapid and expanded well/handpump programme implementation. Training would be given both to new recruits and existing technicians to upgrade their skill level.

Related projects

Presently there is a practical research programme in shallow wells construction underway in Haraghe Region in Ethiopia. The objective of this programme is to improve existing methods and introduce better techniques in shallow wells construction methods and familarize the techniques through demonstration. This project would, no doubt, contribute to improved techniques and is one good way of strengthening the handpumped well programme. However, within its present terms of reference, funds and staffing it cannot accomplish the more comprehensive aim of the pilot project suggested here. A new shallow well project should include a definit plan to institute maintenance systems and basic health education.

4.2.6 Rehabilitation work

Out of the 87 handpumped wells visited during the recent study tour 36 % were inoperative and another 32 % were in bad condition. Since more inaccessible areas were not visited due to shortage of time, the overall picture can be even more grim. In the meantime some 200 handpumped wells are being constructed each year in the eight Regions with little improvement in the maintenance capacity. It is felt that Regions with large number of wells out of service could benefit the population more by rehabilitating old wells than constructing new ones. The rehabilitation phase should also be used for building the maintenance capacity, installing standard pumps, learning from past construction mistakes and collect and record data on wells. The following main processes would be required for successful rehabilitation work that would have positive long-term results.

- Survey communities and assess causes for failure, need and extent of rehabilitation in collaboration with the community.
- Establish maintenance crew in the region or sub-region.
- Establish "water committee" and "pump caretaker" for communities where rehabilitation work is to be undertaken.
- Rehabilitate the schemes.
- Give on-the-job training to pump caretakers and instruct them in basic health education. Establish line of communication with the Regional or Sub-regional Office.
- Prepare and distribute simple maintenance instructions to pump caretakers and maintenance technicians.
- Collect, update and record well data.

During the rahabilitation work where feasible, past construction shortcomings should be corrected, such as putting well identification numbers and providing drains.

It is to be noted here that rehabilitation work should not be understood as a simple assignments of maintenance crews to do major repair work. It should be carefully planned and supervised by competent people, taking into consideration not only the hardware components of pumps and wells, but also the software part of users and organizations.

4.2.7 New construction in the Regions

Ideally new construction work of handpumped wells in the Regions should proceed after the maintenence system has been operational and rehabilitation work has been undertaken. However, in practice, it might not be possible to suspend new construction work. Safe water supply has to be provided to critical areas such as Case 2. All that can be done in such cases, is to increase reliability of the water supply by installing enough sturdy pumps.

In the Regions which have successfully undertaken the rehabilitation work, the construction of new wells can proceed following the same approaches as in the "Pilot project" described earlier.

4.2.8 Other measures

Standardization

With regard to standardization, one important area is the type of handpump. Presently about five different types of pumps - Mono, Monyo, Consallen, Boswel, India Mark II, EWRA - are used in EWWCA programmes. Ideally only two types of pumps for different depth ranges should be used all over the country. Practically this may not be possible now due to preferences by some donors to import from home countries and the absence of such universally acceptable and appropriate pumps. At present, as a minimum requirement the number of pumps used in each Region should be restricted to two. The overall choice of pumps should also be restricted to the sturdy pumps that have been already selected until, on overall counts, far superior pumps come up. The benefits of standardization and familiarity far outweights the marginal benefits that would be gained from introducing a slightly better new handpump type, even if such pumps were available. In any case there is no reliable basis to make such fine comparison at the moment.

At present, the UNDP/World Bank Handpump Testing Project is underway (Anlosoroff, S., 1983). A group of handpumps have been selected for field trial after preliminary screening during rigorous laboratory tests in UK. Presently extensive field test is underway in a number of developing countries on the selected handpumps. The project is expected to give reliable information to make rational selection from handpumps available in the market. It would also come up with appropriate designs for handpumps that could be locally manufactured in developing countries and could be maintained by villagers, so called "VLOM Pumps" (Village Level Operation and Maintenance). The results of this project should be studied and used for final standardization of pumps at the national level and possible local manufacture.

The present practice of installing two or more pump types in a given site for "trial" purposes seems counterproductive. Pumps that have been installed on experimental basis should be in sites so designated and where proper evaluation could be done. Such pumps should be replaced by the standard pumps after the evaluation period.

Another area for standardization is for construction of different types of wells. The existing standard design is for normal ring well only and it needs improvements. Some design ideas that could be incorporated in standard designs after field trial are suggested in Appendix one which deals with proposals for practical research project in Hararghe. It is also hoped that this practical research work in shallow wells construction would alleviate the technical problems in this field discussed earlier.

Record keeping

In general record keeping in rural water supply needs much improvement. Hydrogeologic, installed equipment types and maintenance and repair records are all very important for planning and implementation of future projects, and for evaluating and properly running existing ones. For shallow wells identification of wells by numbers and recording of information has to start now. At present whatever information that exists seems to be in the heads of the construction foremen. The idea should be to collect as much essential information as possible with the least paper work. Some proposed forms for data collection are included in Appendix one.

Manpower

Assignment of better trained people in Regional offices so that they work closely with and supervise activities in simple technologies for limited period of time, could contribute to rapid development of these technologies. The limited period assignment would expose more professionals to the peculiarities of such technologies and help sustain their interest during the assingment as they would not perceive it as a deadend in their professional development.

If rural water supply had lacked respectability in the past this is particularly so for simple technologies within the sector now. The situation can be changed by such measures as highlighting the challenges for improvement in the technologies presently employed in the country, proper incentives and limited period assignment, mentioned above. The role played by such organizations as UNICEF, OXFAM, SIDA and UNDP in overcoming the long stablished bias against simple technologies in Ethiopia is commendable.

The call for different types of manpower (planners, designers, supervisors, construction crew, maintenance crew, community Participation Promotors) to visit villages, all for the provision of water supply, makes schemes expensive. In practice, one or more of these are missing due to lack of resources. Under conditions of limited resources it may be possible to combine some of these functions. Here it is suggested that individuals with technical aptitude and social skills be carefully selected to be "water extension workers" with the duties of scheme maintenance, community mobilization and rendering of basic health education pertaining to proper water use. Since the maintenance of schemes, community participation and health education should all be on going processes, such an arrangement could be feasible and economical. In any case, it would be better to have, for example, three crews of fully operational "Water Extension Workers" (WEW) in a Region than three maintenance crews and a community participation promotor which are always having problems of transport and funds. Moreover, the idea of WEW as outlined above, may encourage the badly needed community participation in operation and maintenance (instead of the present situation of over emphasis in construction) better than the alternative arrangement of having separate crews.

This arrangement does not obviate the need for complementary inputs by other organizations such as the Ministry of Health. It is only an attempt to make the inputs from the water authorities as comprehensive and goal oriented as possible.

5. SUMMARY

Simple technology water supply systems, such as handpumped wells are recent phenomenon in the Ethiopian scene; and though a good start has been made the full potential is not yet explored.

Considering the geologic and hydrogeologic conditions, generally some ground water abstraction methods are technically more suitable than others, but other considerations may be more important than technical feasibility when specific rural water supply projects are considered.

> Dug wells are well suited to most parts of the plateau, where the majority of the people live, because of the low yield of aquifers.
>
> The introduction of augered wells and driven wells could be beneficial in some areas with better yielding aquifers and more homogenous material.
>
> Jetted wells are not considered suitable for Ethiopian conditions because of its water requirements during construction.
>
> Digging wells in hard rock areas with jack hammer-compressor units is another technology that has good potential for application. In suitable areas, large diameter wells for water supply to towns can also be constructed using this technique.
>
> Introduction of small rigs that can be maneuvered over the difficult terrain and able to drill fast through alternating hard and soft formations would be one cost-effective method of rural water supply in Ethiopia. Using the present high capacity rigs for this purpose would be uneconomical.

> Gravity supplies should always be considered. For example, infiltration drains can be used more often than now as simple gravity supply from hill-side subsurface-springs.

Maintenance is the main constraint in successful hand-pumped water supplies; and, therefore, maintenance considerations should be at the core of any successful programme.

> Areas where maintenance of schemes are unlikely but the water need is great, if technically feasible, could be supplied with open wells for an interim period maily to solve the problem of water availability. Coupled with effective health education and small fetching distances that could enable to increase consumption, theoretically even such water supplies of dubious quality can have some health benefits by controlling water-washed diseases. However, in this particular case, it would be unrealistic to expect delivery of effective health education in a situation where even simple water supply systems cannot be maintained.
>
> To achieve the desired health benefits from water supplies based on shallow wells in Ethiopia, the main trust should now be to improve and/or develop well construction methods and maintenance systems in a well staffed and well funded pilot project(s) covering limited representative area(s). The pilot project could also be used for giving on-the-job training for field technicians and it would also serve as a model for future expanded activities in other areas.

Those Regions which at present have large numbers of inoperative pumps should first do rehabilitation work and build up their maintenance capacity before expanding the construction work.

In those critical areas where safe water supply could not be postponed, scheme reliability can be increased by installing sturdy pumps and in such numbers that are more than strictly required by the demand.

Rural water supplies cannot be effective by improving only the hardware technologies. Health education has to be given and community participation has to be secured during all phases of the project, including operation and maintenance so that the community feels responsible for its water supplies.

"Water Extension Workers", whose task combines maintenance of schemes, promotion of community participation and health education, can be trained by carefully selecting individuals with both technical aptitudes and social skills. Such a strategy could be practical and more cost-effective than setting up independent crews.

Standardization of equipment and techniques facilitates construction, operation and maintenance. Ultimately it saves money while ensuring acceptable quality.

In the long-run handpumps in the country should be standardized to one type, may be with two variations for different depth ranges. At present, such standardization is not only desirable but also possible at least on Regional basis, and it is should be instituted and strictly adhered to.

> Despite initial difficulties of qualities and possibility of higher financial costs, local manufacturing of pumps is desirable because of better availability of spares and fostering of local industry. Research and development work for local manufacturing of pumps could more fruitfully concentrate on adapting well tried pumps for full or partial local manufacturing, rather than in trying to innovate completely new designs.
>
> Other areas that can benefit from standardization are well diameters, sanitary seal for wells, construction of well apron, drain and cover.

Though a simple process, it has been difficult to institute technical and cost data recording in the past. Persistent effort should be made to improve the situation.

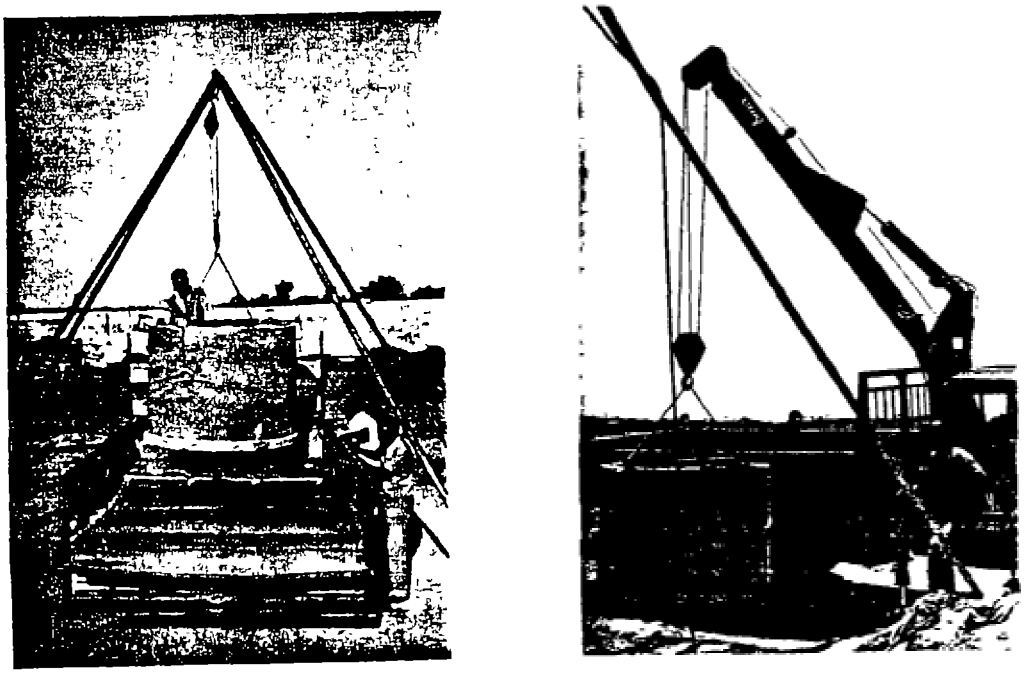
Motivated and more competent people have to work closely with the field personnel in simple technology activities at least on assignments of limited duration, if centrally approved standards and procedure are to be fully implemented and further improvements are to be made based on local conditions. The necessary conducive atmosphere have to be consciously created for these often neglected technologies with a still lingering bias against them.

A. PROPOSED SHALLOW GROUND WATER RECOVERY METHODS FOR FIELD TRIAL IN THE PRACTICAL RESEARCH, HARAGHE REGION

Proposed construction methods are those that have not been tried so far or well established in the water supply activity of the Region, or those that need improvement. (Original proposal put forward in October 1983 are herein revised after the field visit and consultation.) The methods are:

1. Some shallow wells construction aids
   - for lifting concrete rings (fig. 26)
   - for driving perforated pipe horizontally from a collector well (fig. 27)
2. Dug-well construction - caissoning method
3. Dug-well construction - telescoping method
4. Ring well with a raised manhole
5. Installation of two handpumps over a well
6. Well apron with drain
7. Handpump with extension pipe
8. Drainage water disposal
9. Wash basin
10. General lay-out of handpumped well
11. Improving traditional well
12. Infiltration galleries
13. Radial collector well
14. Driven well
15. Augered wells
16. Making seives from material available in domestic market for:
    - preparing gravel pack material for a standard screen
    - preparing graded gravel for infiltration galleries

1. Some shallow wells construction aids



a. Loading of ring on truck with tripod.

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

c. Sling for lifting a concrete ring horizontally.

d. Sling for turning over a concrete ring.

Fig 26. Lifting concrete rings. (DHV Consulting Engn., 1978)

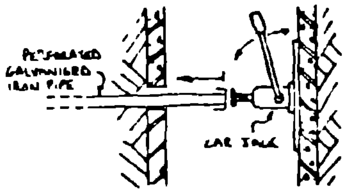


Fig 27. Driving perforated pipe. (Watt, S.B. and Wood, W.E., 1979)

2. Dug-well construction: caissoning method

a) For sinking standard standard ring well in caving formations (fig. 4)

Required: concrete rings O.D./I.D. = 120/100 cm
" " " " = 145/125 cm
or cutting rings " " = 125/100 cm
" " " " = 150/125 cm
optional

b) For sinking special large diameter wells

Required: R.C. or stone or brick or concrete block masonry well lining built on R.C. cutting edge (fig. 28 - fig. 31)

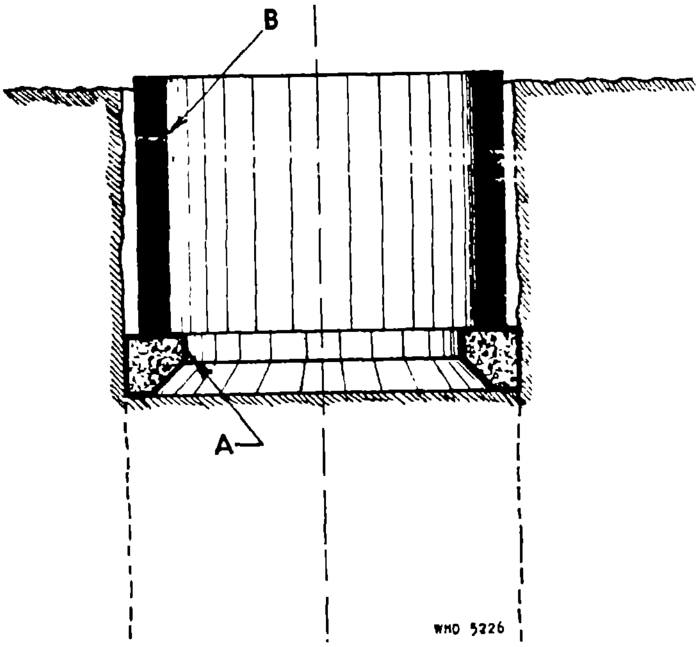


Fig 28. Dug-well: casing descending with excavation. (Wagner et al., 1959)

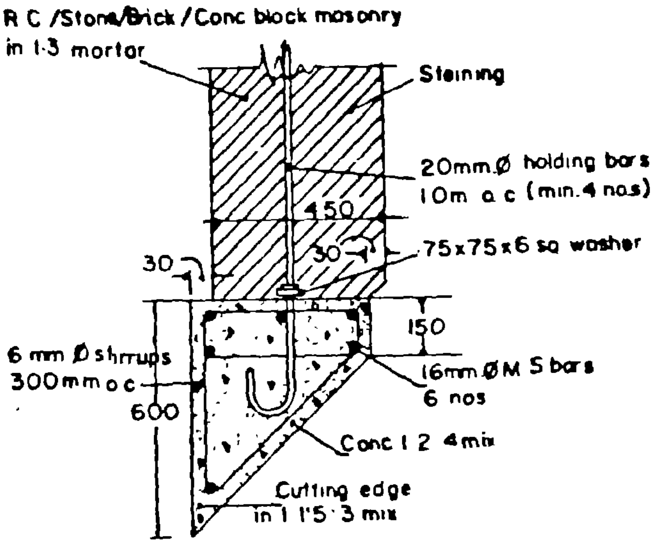


Fig.29. R.C. cutting edge for well up to 3 m Ø. (WHO - SE Asia, 1976)

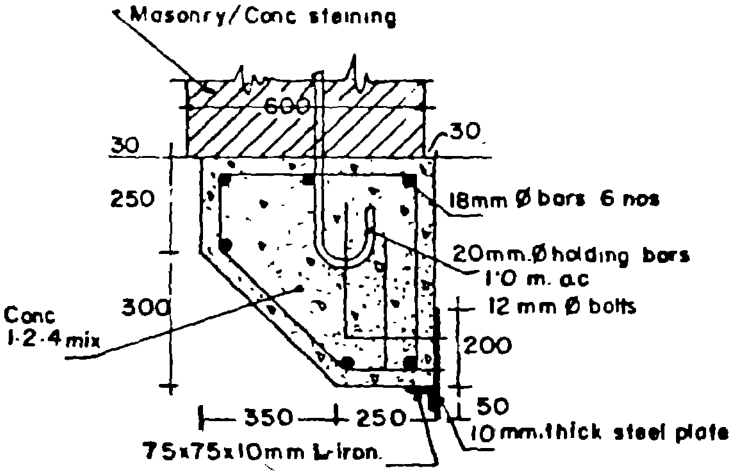


Fig 30. R.C. cutting edge for well diameter > 3 m. (WHO - SE Asia, 1976)

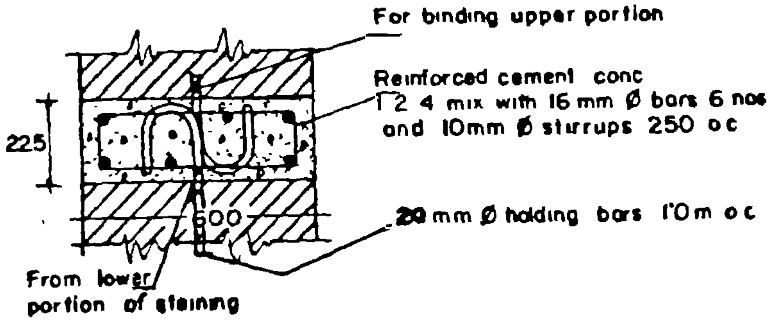


Fig 31. Detail of steining ring. (WHO - SE Asia, 1976)

3. Dug-well construction: telescoping method

Main items required:

- concrete rings O.D/I.D = 120/100 cm or 95/75
- " " " " = 125/145 cm or 120/100

Application:

- in deepening dry wells (fig. 32)
- in lining soft top layer and soft acquifer while leaving unlined hard middle layer (fig. 33)

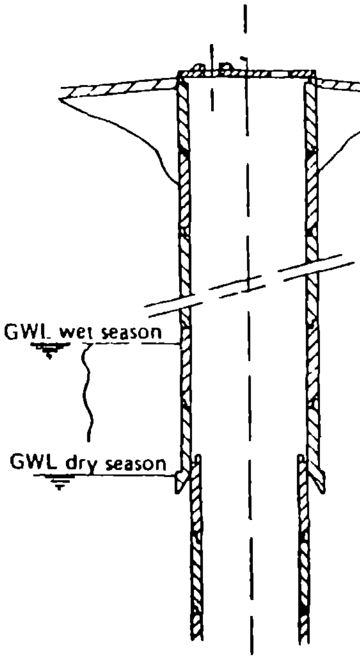


Fig 32. Telescoping for deepening dry wells. (DHV Consulting Engn., 1978)

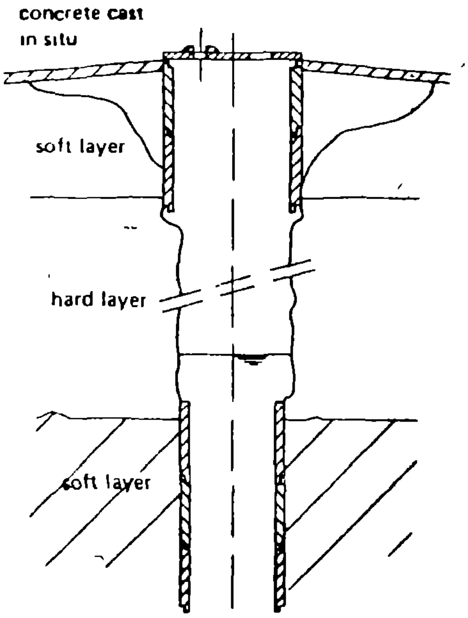
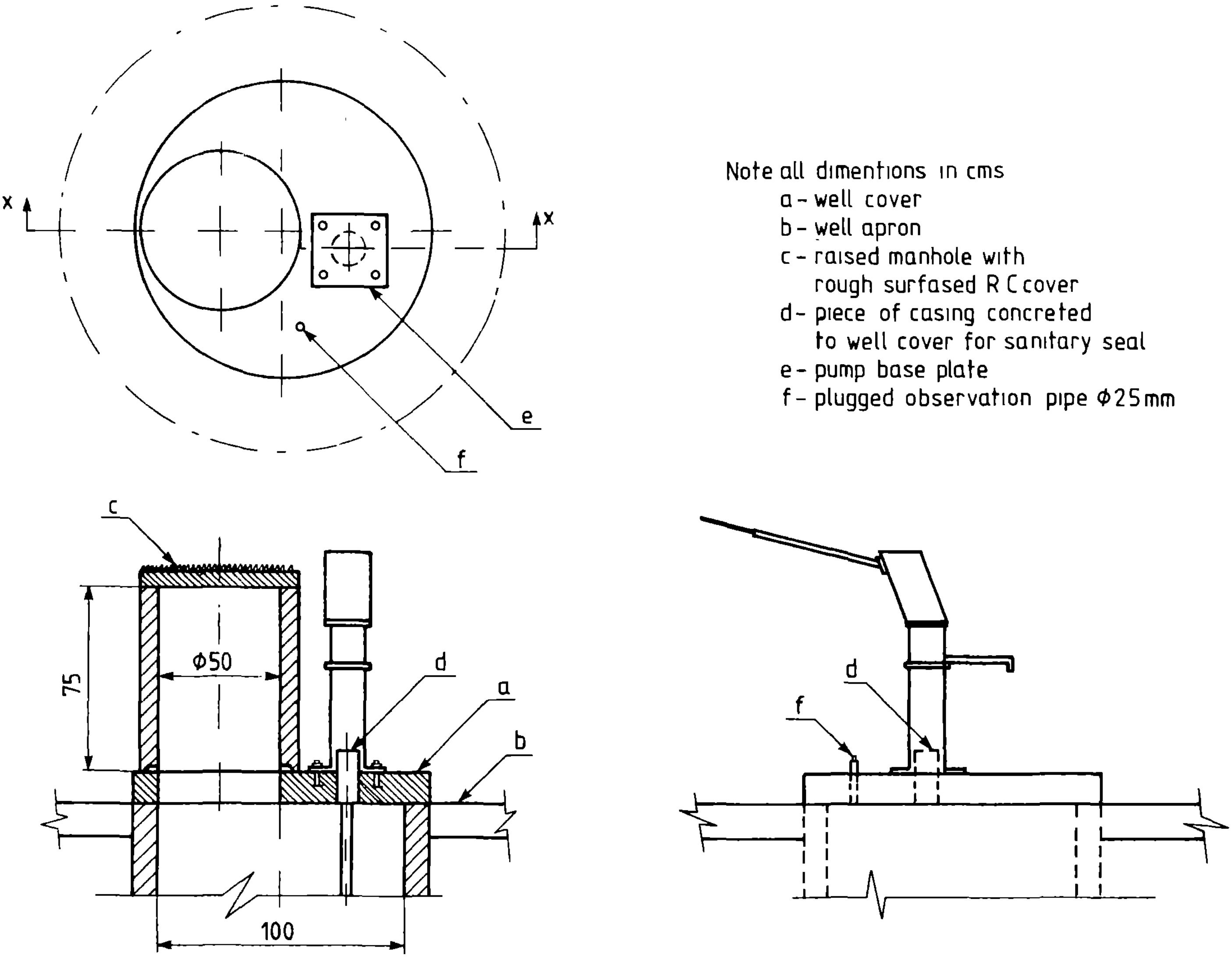


Fig 33. Telescoping in alternate soft and hard layered formations. (DHV Consulting Engn., 1978)

4. Ring well with a raised manhole (fig. 34)

The manhole could be used as an alternative for drawing water when the pump is inoperative.

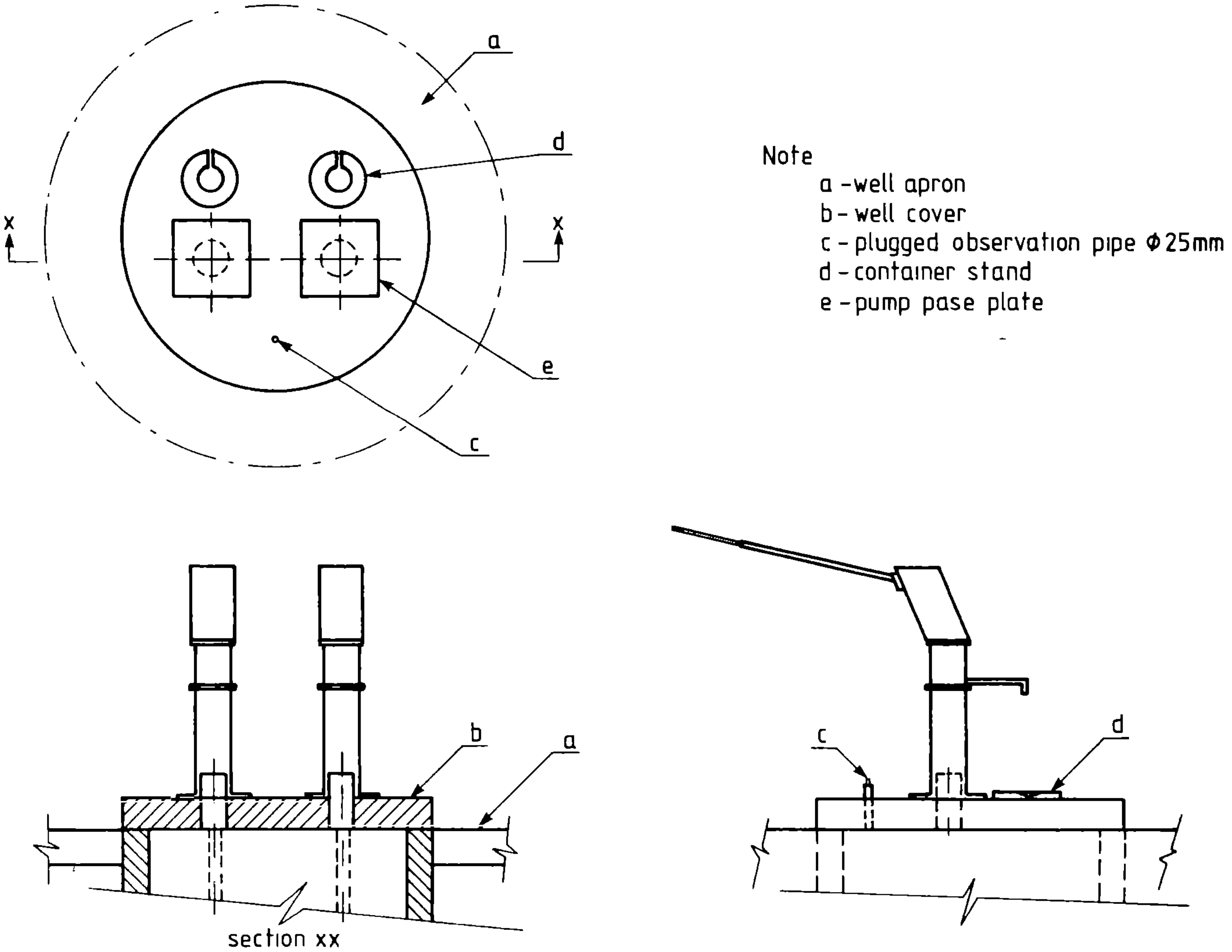


Note all dimentions in cms
a - well cover
b - well apron
c - raised manhole with rough surfased R C cover
d - piece of casing concreted to well cover for sanitary seal
e - pump base plate
f - plugged observation pipe Φ25mm

Fig 34. Ring well with a raised manhole.

5. Installation of two handpumps over a well (fig. 35)

Increases safe water supply reliability and improves user convenience by lessening possible queuing time during peak demand periods.



Note
a -well apron
b- well cover
c - plugged observation pipe Φ25mm
d - container stand
e - pump pase plate

Fig 35. Two handpumps over a ring well.

6. Well apron with drain (fig. 36)

Purpose: to lead away split water and serve as platform during operation.

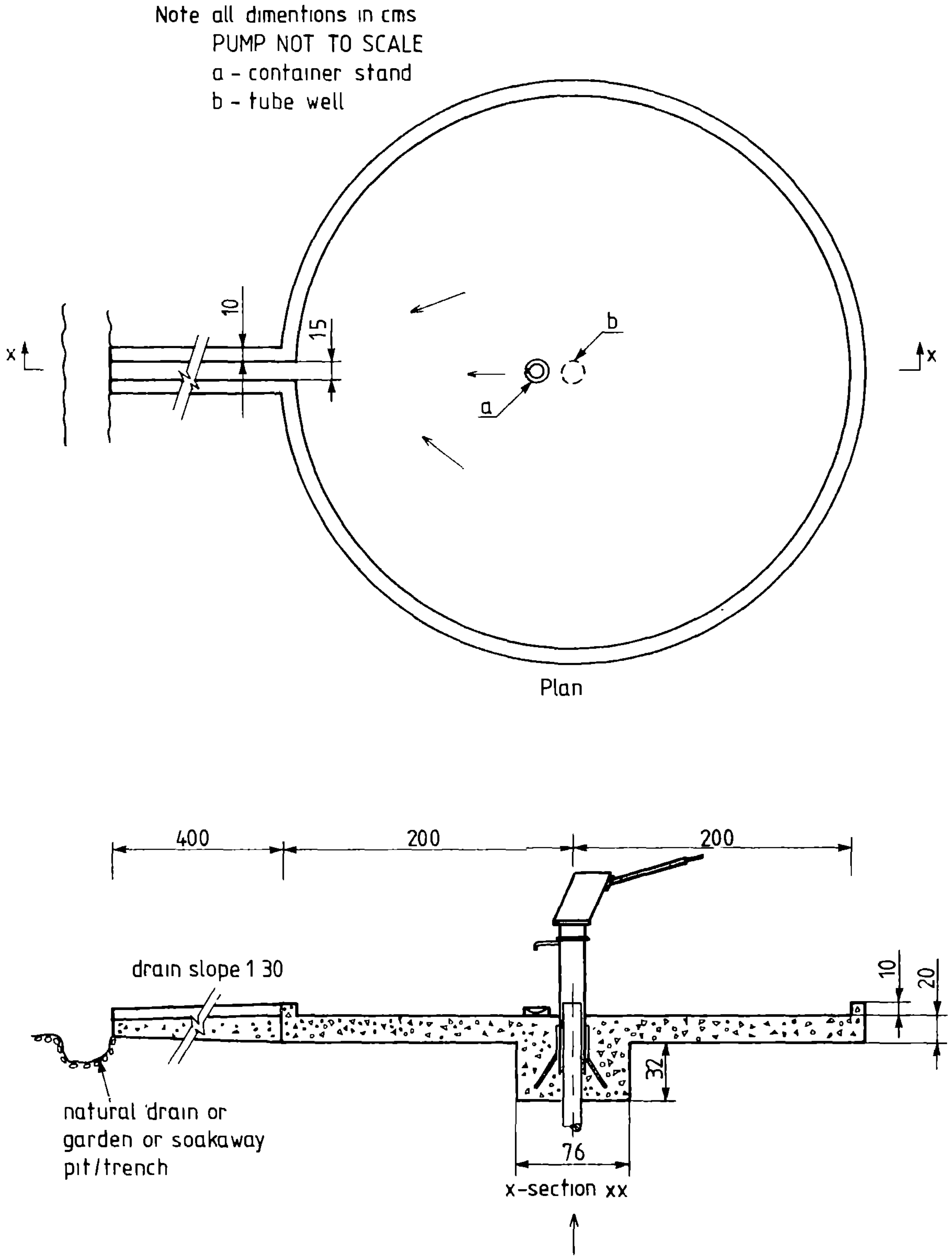


Fig 36. Circular well platform and a drain for a handpumped tube well.

7. Handpump with extension pipe (fig. 37)

Another method of controlling well pollution from split water. The raised container stand can easily be connected to a small cattle trough by gravity flow.

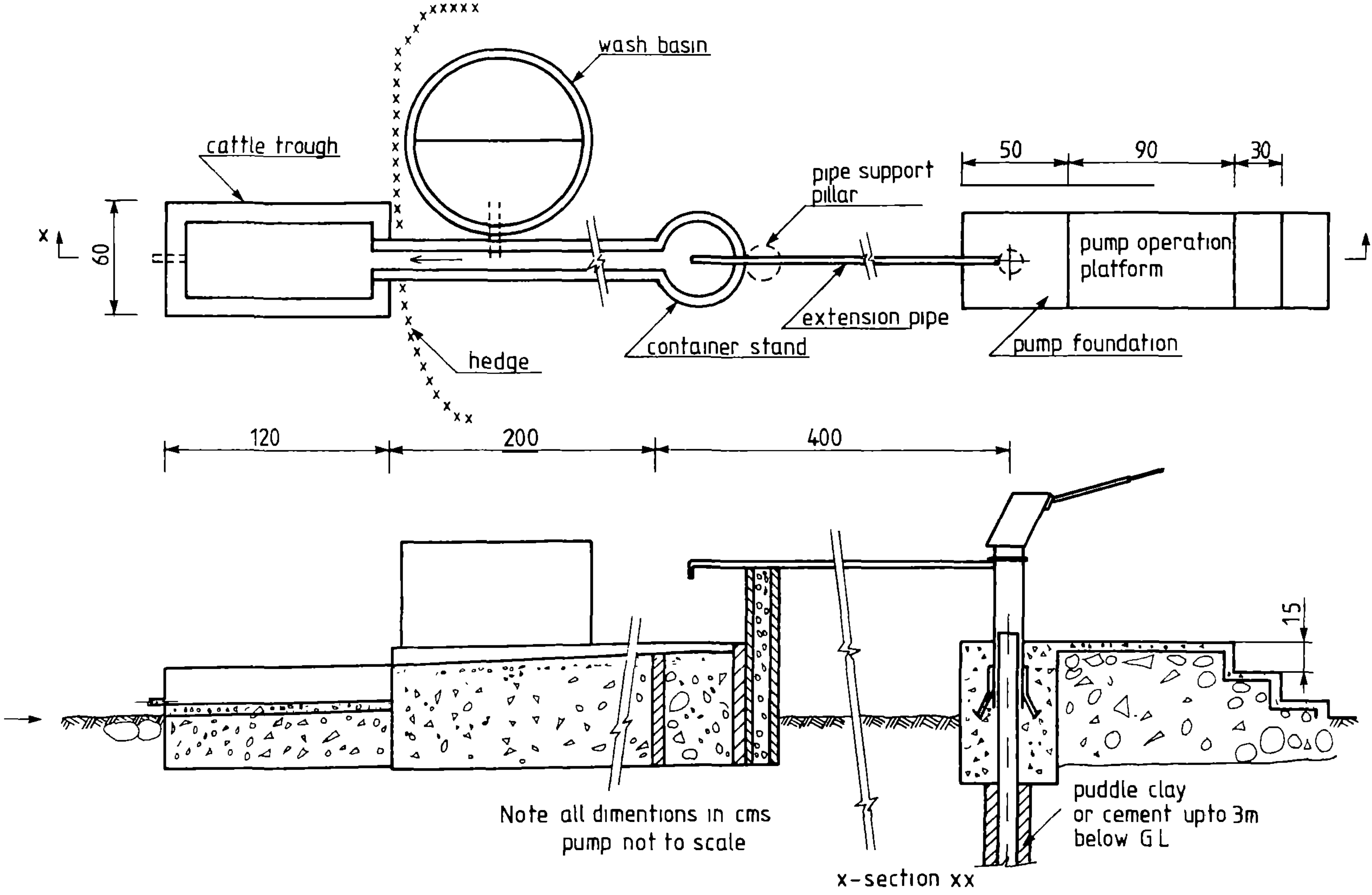


Fig 37. Handpump with extension pipe.

8. Drainage water disposal

Application:

- in flat areas, specially in center of villages

Methods:

- soakage pit in sandy or sandy loam soil (fig. 38)
- soakage trench in clayey soil or where the ground water table is close to surface (fig. 39)

Important for good performance:

- silt trap, screen, plastic sheet or tarred paper over stone ballast to prevent top soil from entering soakage area (dried grass or "chid" may be experimented also) + mound over pit or trench.

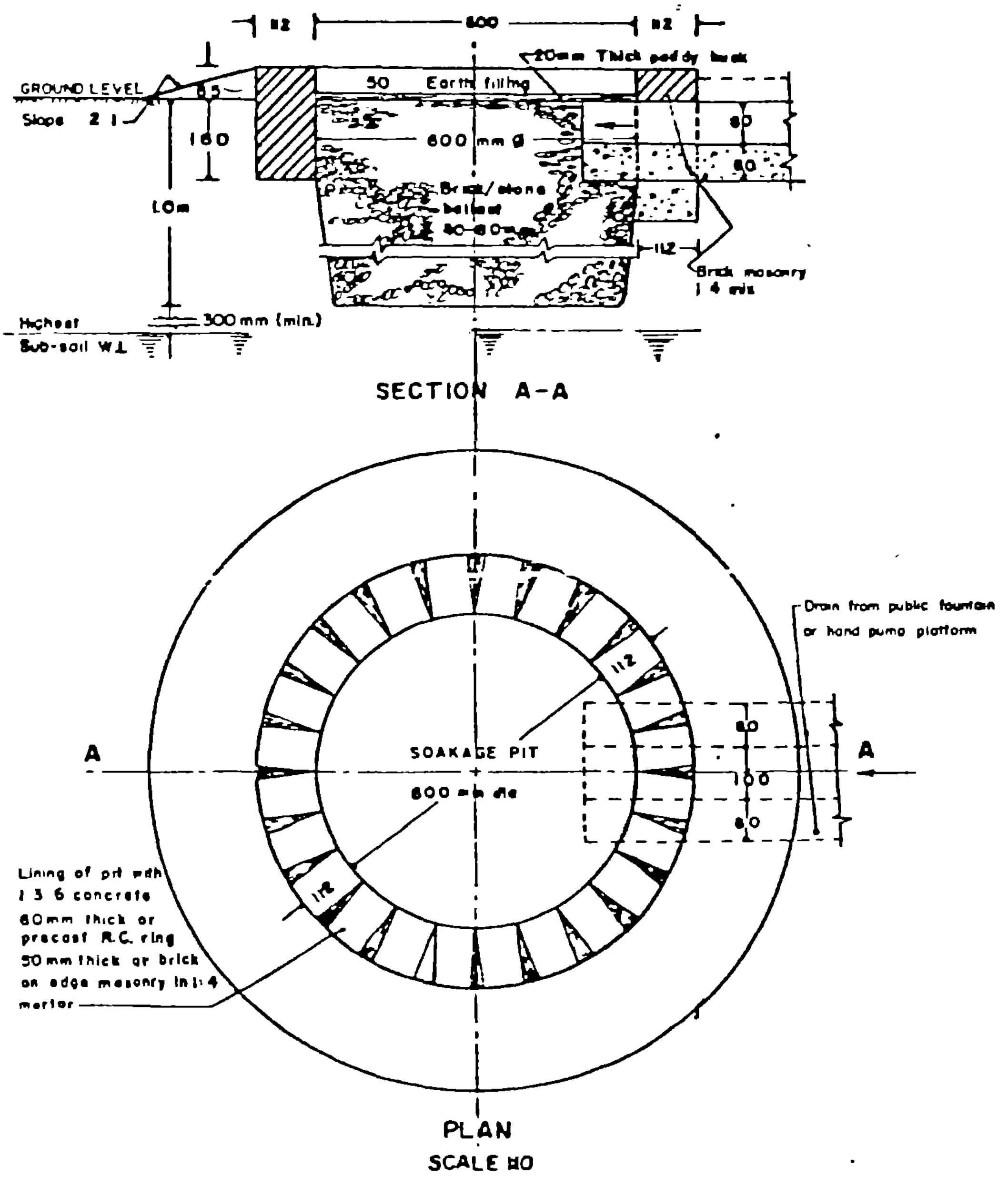


Fig 38. Soakage pit. (WHO - SE Asia, 1976)

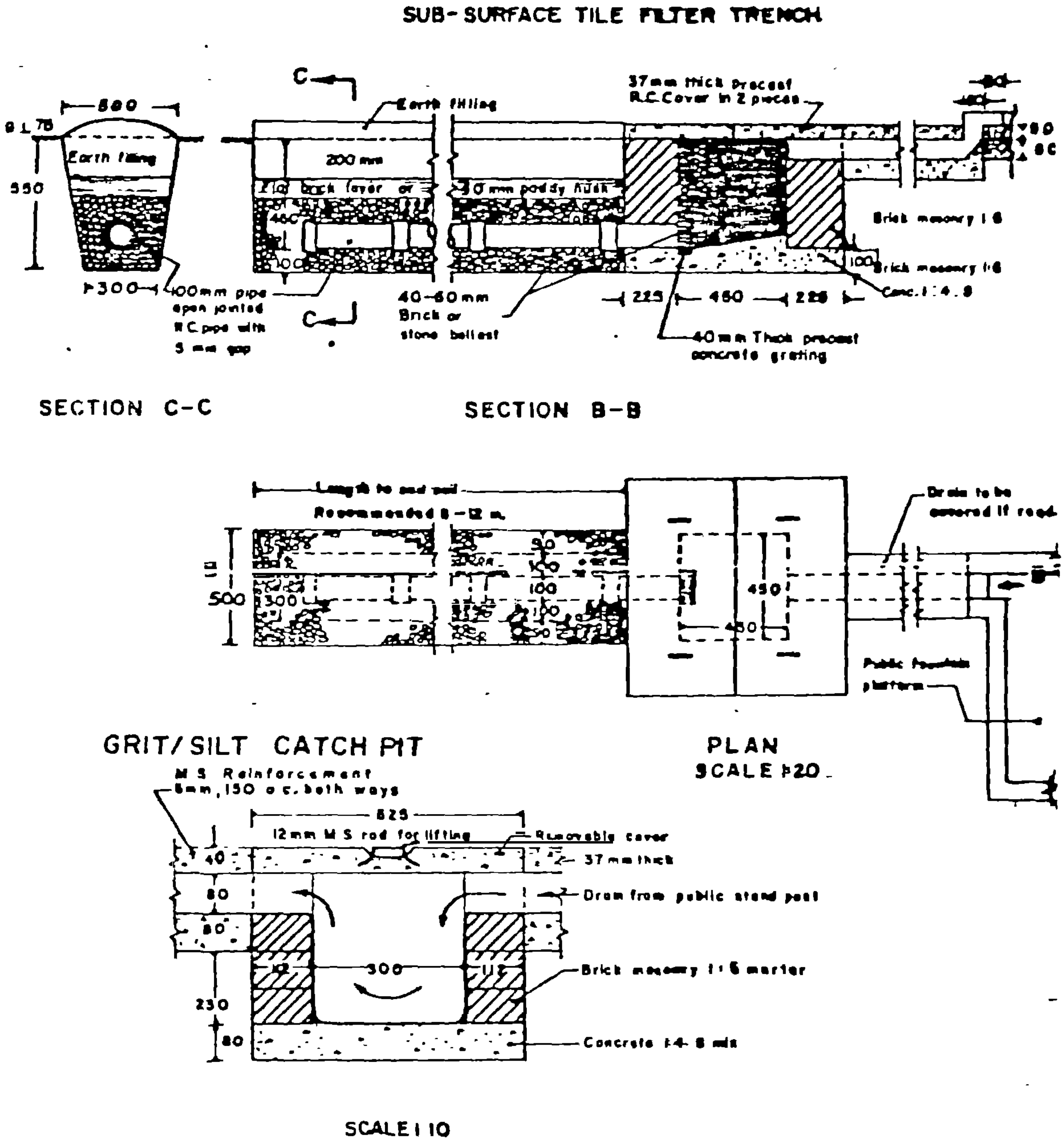
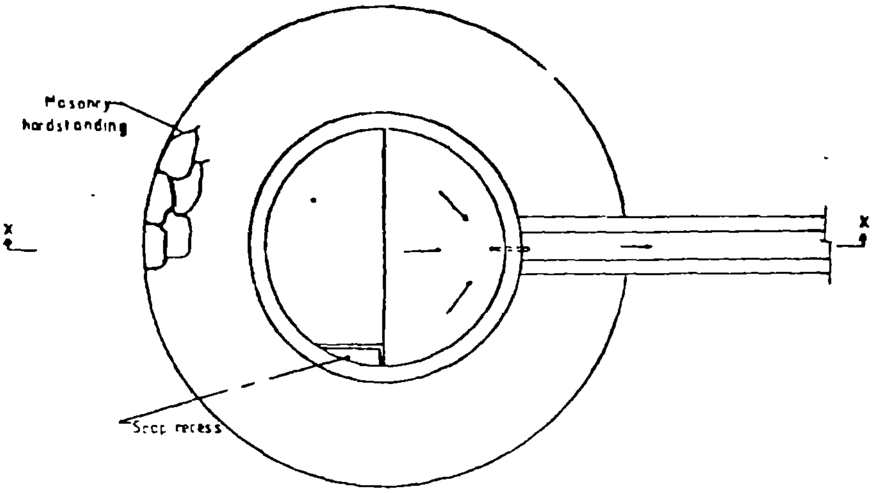


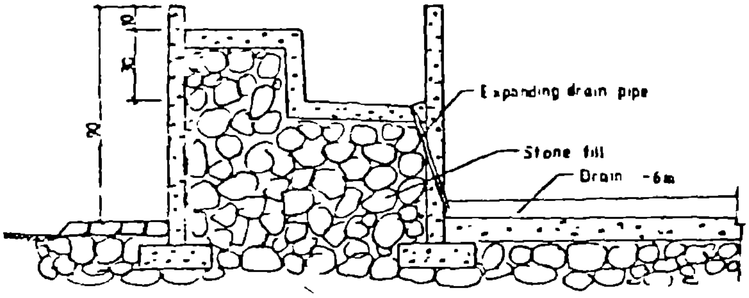
Fig 39. Soakage trench. (WHO SE Asia, 1976)

9. Wash basin

A simple wash basin may be constructed from a normal concrete ring of 1 m x 1 m (fig. 40).



PLAN



SECTION X - X

Scale 1 20
dimensions in cm

Fig 40. Wash basin.

10. Proposed general lay-out of handpumped well site (fig. 41)

Two zones are proposed.

- Zone I: to keep away animals from the immediate vicinity of the well, enclosed by a fence preferably made from local thorny brush.
- Zone II: area in which pit latrines and the like are not permitted in order to prevent well water pollution.

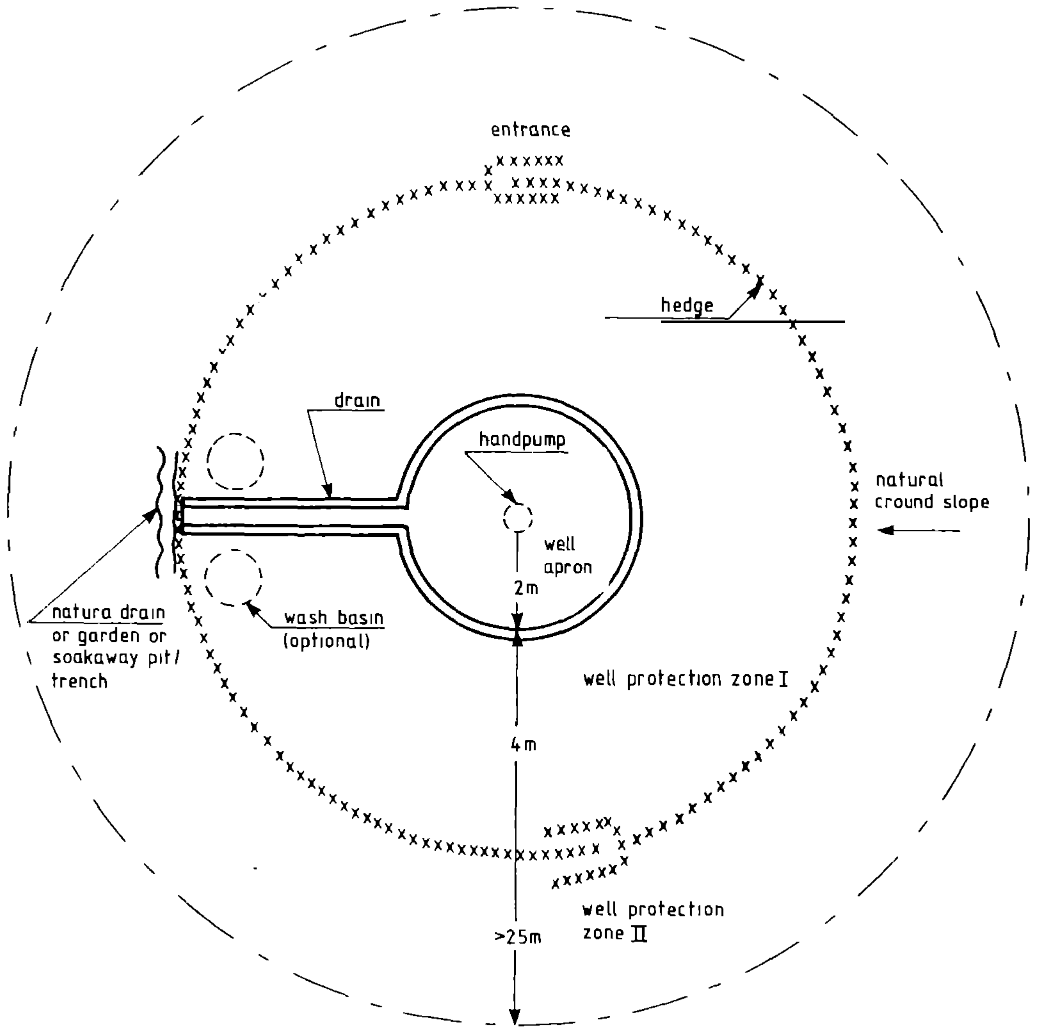


Fig 41. Proposed general lay-out of handpumped well site.

11. Improving traditional well

One method could be lining the top three meters with standard precast concrete rings (fig. 42).

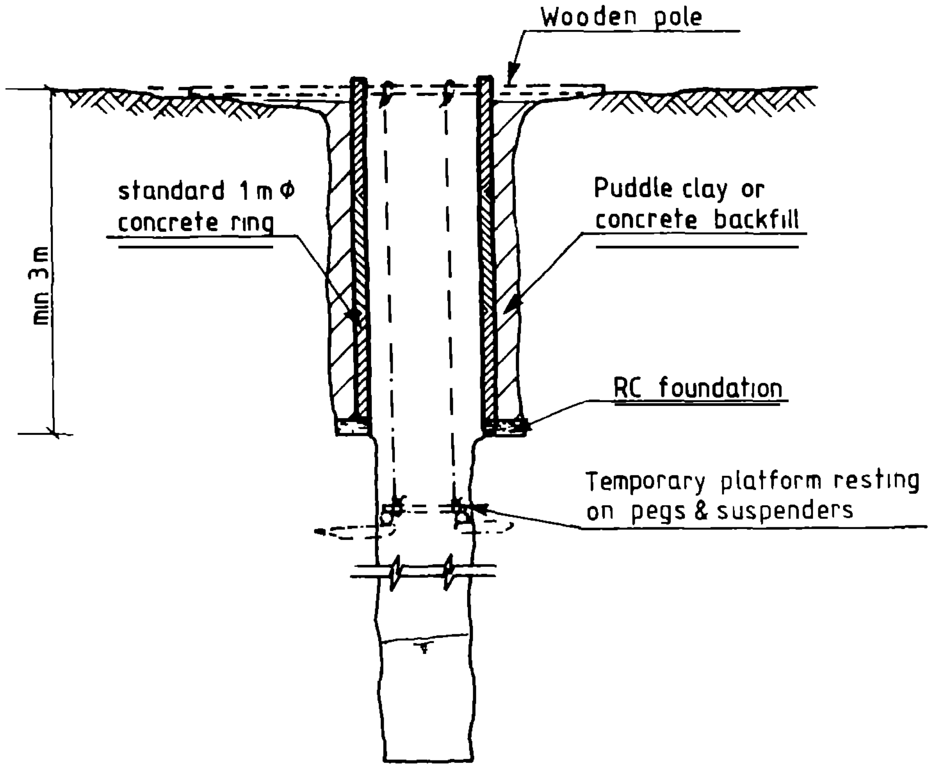
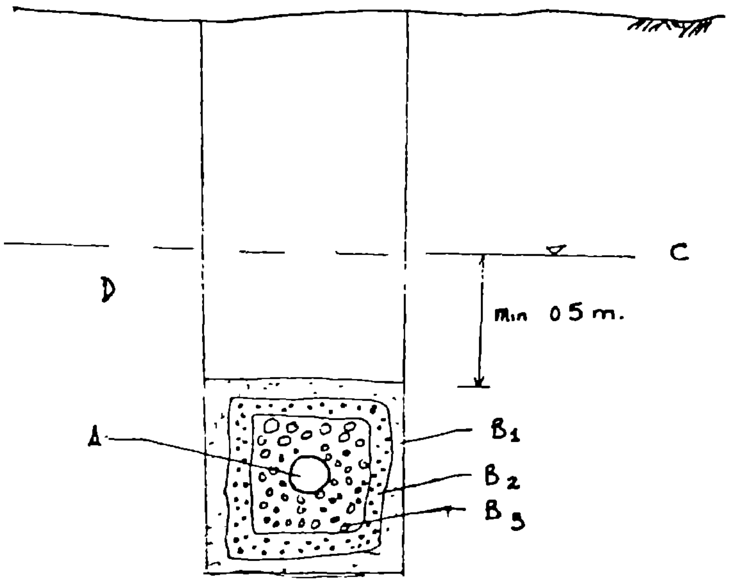


Fig 42. Improving traditional well using precast concrete rings.

12. Infiltration galleries

Possible application: tapping sub-surface hill springs (fig. 15).

Example of gravel pack for an infiltration drain is shown in fig. 43.



A = drain pipe 15 cm Ø with 10 mm perforations at 100 mm o.c.
B_1 = sand layer, grain size 1 - 2 mm, thickness 10 cm
B_2 = gravel layer, grain size 4 - 8 mm, thickness 10 cm
B_3 = gravel layer, grain size 15 - 30 mm, thickness 20 cm
C = lowest ground water table
D = aquifer material, fine sand

Fig 43. Example of gravel pack for fine sand aquifer.

13. Radial collector well

Possible application:
- to increase yield of a dug well in a poor aquifer area (fig. 17)
- to tap filtered water from sand river beds (fig. 18)

14. Driven well

Possible application:
- in sandy aquifers of less than 15 m depth (fig. 11)
- as piezometers in sand dams (sub-surface dams)

15. Augered wells

Possible application:
- in sandy, sand-silt and clay may be weathered gravely material (fig. 10)

16. Making seives from material available in domestic market for

- preparing gravel pack material for a standard screen e.g. for PVC pipe slotted with hacksaw with slot size of about 1 mm, gravel seived between 1,5 mm and 5 mm can be tried
- preparing graded gravel for an infiltration gallery (fig. 43)

B. PROPOSED FORMS FOR DATA COLLECTION: PRACTICAL RESEARCH IN SHALLOW WELLS CONSTRUCTION, HARAGHE REGION

1. Experimental construction daily report

2. Experimental construction well summary data

3. Shallow wells summary sheet

4. Experimental construction cost calculation form

1. EXPERIMENTAL CONSTRUCTION DAILY REPORT

Date .... Construction type ..../scheme No. ....

Village .... Supervisor ....

Labour:		Material and equipment used		Machines used		Work accomplished	
Self-help No.	....	item	quantity	item	hrs	item	quantity
dailies/rate	......./.......	....	....	....	......	....	....
skilled/rate	......./.......	....	....	....	......	....	....
	......./.......	....	....	....	......	....	....
salaried	......./.......	....	....	....	......	....	....
	......./.......	....	....	....	......	....	....
	......./.......	....	....	....	......	....	....

Work condition/reason: difficult ____, fair ____, easy _____/caving soil ____, hard formation _____,
bad weather _____, other ____

Transport service: truck __________ kms Reason ______________________________
4-wheel drive __________ kms Reason ______________________________

Other remarks: ____
____
____

2. EXPERIMENTAL CONSTRUCTION WELL SUMMARY DATA

Location: Map reference ________________ Region ________________ Awraja ________________ Village ____________

Well type: ______________ Well No. ________________ Supervisor ________________________

Depth below G/L ________________ (m.)

SWL below G/L ________________ (m.) on __/__/19__

I.D. __________ (cm)

Aquifer type ________________

Estimated yield ________________ l/hr

Location sketch

Water quality:

Date	Conductivity	F^-	NH_4^+	E.Coli
....	....	......	......	....
....	....	......	......	....
....	....	......	......	....

Lithological Discription:

Depth	Discription
....	....
....	....
....	....
....	....
....	....

Installed pump:

.... on __/__/19__

.... on __/__/19__

Other remarks:

....

....

....

3. SHALLOW WELLS SUMMARY SHEET

Location: Region.............. Awraja .... Woreda .... Village ....

Detail.......................... Map reference ....

Construction Supervisor ....Construction started on........... Construction finished on ....

Well data:

Well No	Well type dug/bored/.	I.D. (cm)	Depth below G/L (m)	Static WL below G/L (m)	Yield estimate (l/hr)	Aquifer type	Water Analysis				Installed pump		Remarks
							F^-	NH_4^+	E.Coli	date	Type(date)	Type(date)	

NOTE: 1. May be used for a group of wells in a village

2. Location sketch to be given on the back - use permanent structures or land features as reference point.

4. EXPERIMENTAL CONSTRUCTION COST CALCULATION FORM

Location: Awraja ________ village ________ Construction type ________

Scheme No ________ Construction Period: From ________ to ________ Supervisor ________

	UNIT	QUANTITY	UNIT COST BIRR	AMOUNT IN BIRR		
LABOUR						
self-help	No					
dailies	No					
	No					
salaries						
per diem						
Total Labour						
MATERIAL						
pump	pcs					
cement	bags					
gravel	m^3					
sand	m^3					
ref. bars	kgs					
diesel	l					
petrol	l					
....	....					
....	....					
Total Material						
EQUIPMENT						
dewatering pump	hrs					
....	....					
....	....					
Total Equipment						
TRANSPORT						
trucks	kms					
4-wheel drive	kms					
Total Transport						
Subtotal						
15 % overhead						
TOTAL						

SOME SHALLOW WELLS DATA FROM THE FIELD VISIT IN ETHIOPIA (NOV., 1983)

The data on shallow wells visited during the study tour (Nov., 1983) are shown in table 3. The summary of the results follows:

1. Out of the 87 handpumped wells visited:
   - pumps working in good order 32 %
   - pumps inoperative 36 %
   - pumps working but badly in need of repair 32 %

2. Different types of pumps used: Mono, Monyo, Consallen, Boswell, Standard I, India Mark II and EWRA.

3. No direct comparison between pumps possible due to differing installation period and working conditions. However, the simple local EWWCA PVC pump had by far the lowest life.

4. Out of 31 inoperative pumps, 20 were in disrepair for over 6 months.

5. 16 pumps had been working for over 2 years without maintenance.

6. 14 wells had yield problems, out of which 2 were ring wells and 12 reduced diameter wells.

7. 19 wells had major drainage problems - cause: both poor maintenence and bad construction. Observation: larger fence area needed to keep away animals - one major cause for muddy well surroundings.

Note:

1. Abbreviations used in table 3

OK1	Handpump in good condition
OK2	Problem with above ground pump structure
OK3	Problem with below ground pump structure
XPump	Pump inoperative
DP	Drainage problem
YD	Problem of low yield

2. Information about well conditions and maintenance that could not be observed at site was obtained by interviewing users or concerned construction supervisors who accompanied the writer during the field visit. Only some information regarding well depth and year of construction was obtained from Haraghe Regional Office records.

Table 3. Summary data of handpumped wells visited

In Hararghe Region

Site area	Well No	Well type	Depth (m)	Year of constr.	Installed h-pump	Time since last maint.	If inoperative, duration pump out of service	Condition/Remark
Woter	1	Ring well	5	1983	India Mark II	<1 month	-	OK1, near open pool, pollution risk
	2	Ring well	9	1983	Monyo	~6 months	-	OK1
	3	Ring well	?	1983	India Mark II	<1 month	-	OK1
	4	Borehole	57	1982	India Mark II	~10 months	-	OK1, DP
Lange Village	1	Backfill	<10	1979	Mono	~1,5 years	-	OK2, OK3, YD
	2	Backfill	<10	1979	Boswell	~1,5 years	-	OK2, OK3, cracked slab, guard used
	3	Backfill	<10	1979	India Mark II	~3 years	-	OK2, OK3, DP, guard
	4	Backfill	<10	1979	Consallen	~6 months	-	OK3, guard used
	5	Ring well	<10	1979	Standard I	~3 years	-	OK2
Kersa	1	Backfill	<10	1979	Boswell	~1,5 years	-	OK2, YD
	2	Backfill	<10	1979	Boswell	~3 years	-	OK2, locked
	3	Improved trad. well	~10	1982	India Mark II	~1 year	-	OK1, original masonry wellhead not sealed

Table 3 cont.

Site area	Well No	Well type	Depth (m)	Year of constr.	Installed h-pump	Time since last maint.	If inoperative, duration pump out of service	Condition/Remark
Kersa Village (cont.)	4	Backfill	<10	1980	Boswell	~3 years	-	OK2, cracked slab, DP, YD
	5	Backfill	<10	1980	Boswell	~3 years	>1 year	XPump, cracked and subsided slab
	6	Backfill	<10	1980	Boswell	~3 years	-	OK2, DP
	7	Backfill	<10	1980	Boswell	~3 years	-	OK2
	8	Backfill	<10	1980	Boswell	~3 years	-	OK2, DP, YD
	9	Backfill	<10	1980	Boswell	~3 years	-	OK2
	10	Backfill	<10	1981	Boswell	~2 years	~10 days	XPump
	11	Backfill	~12	1981	Boswell	~2 years	~2 months	XPump
	12	Backfill	~16	1982	India Mark II	~1 year	-	OK1, locked
Adele	1	Backfill	<10	1978	Boswell	>1 year	~5 months	XPump
	2	Backfill	<10	1978	Boswell	>1 year	~5 months	XPump
	3	Backfill	<10	1978	Boswell	>1 year	-	OK2, OK3, DP, YD
	4	Backfill	<10	1978	Boswell	>1 year	-	OK2, OK3
Eresa/ Logado Mirga	1	Ring well	<10	1982	Consallen	~1 year	-	OK1, DP
	2	Ring well	<10	1982	Standard I	~1 year	~3 months	XPump
	3	Ring well	<10	1982	Monyo	~1 year	-	OK1, DP
	4	Ring well	15	1982	India Mark II	~1 year	-	OK1, DP
	5	Ring well	<10	1982	Boswell	~1 year	~15 days	XPump

Table 3 cont.

Site area	Well No	Well type	Depth (m)	Year of constr.	Installed h-pump	Time since last maint.	If inoperative, duration pump out of service	Condition/Remark
Bati	1	Backfill	<10	1983	Constallen	<1 year	-	OK1, YD, guard
	2	Ringwell	<10	1983	India Mark II	<1 year	-	OK1, YD, guard
	3	Ringwell	<10	1983	Boswell	6 months	-	OK1, YD, guard
	4	Ringwell	<10	1983	Boswell	<1 year	-	OK1, guard
Finkile	1	Backfill	<10	1981	Consallen	>1,5 years	-	OK2
	2	Backfill + storage	<10	1981	Consallen	>1,5 years	-	OK2
	3	Ringwell	<10	1983	Consallen	~6 months	-	OK1, DP
	4	Ringwell	<10	1983	Consallen	~6 months	-	OK1, DP
	5	Ringwell	<10	1983	Consallen	~6 months	-	OK1
	6	Ringwell	<10	1983	Consallen	~6 months	-	OK1
Laga Ambo	1	Ringwell	12	1982	Consallen	~1 year	~6 months	XPump
	2	Ringwell	<10	1982	Consallen	~1 year	-	OK1
	3	Ringwell	<10	1982	Consallen	~1 year	-	OK1

Table 3 cont.

In Central Region

Site area	Well No	Well type	Depth (m)	Year of constr.	Installed h-pump	Time since last maint.	If inoperative, duration pump out of service	Condition/Remark
Sabure area	1 (Sabure)	Ringwell	22	1978	EWRA	>1 year	1 year	XPump, nearby canal water used
	2 (Bolyita)	Ringwell	23	1978	EWRA	>1 year	>1 year	Used with bucket
	3 (Elala)	Ringwell	?	?	Open well	>1 year	>1 year	Used with bucket
	4 (Kebena)	Ringwell	?	1978/79	EWRA	>1 year	~1 year	XPump, nearby canal water used
	5 (Denker)	Ringwell	?	1978/79	EWRA	>1 year	>1 year	Used with bucket
	6 (Hidi)	Ringwell	<10	1980	Open	>1 year	>1 year	Used with bucket
	7 (Wassero)	Ringwell	?	1978/79	EWRA	>1 year	~1 year	Nearby canal water used
Inseno	1	Ringwell	~15	1981	Boswell	>2 years	-	OK2, OK3, DP, guard
	2	Ringwell	~15	1981	Boswell	>2 years	>6 months	XPump
	3	Ringwell	~15	1981	Boswell	>2 years	>6 months	XPump
	4	Ringwell	~15	1981	Boswell	>2 years	-	OK2, OK3, DP-soakaway clogged, guard
	5	Ringwell	~15	1981	Monyo	~2 years	-	OK1, handle stiff
	6	Ringwell	~15	1981	Monyo	~2 years	-	OK1, handle stiff
	7	Ringwell	~15	1981	Monyo	~2 years	-	OK1, handle stiff
	8	Ringwell	~15	1981	Monyo	~2 years	-	OK1, handle stiff

Table 3 cont.

Southern Region, Bale

Site area	Well No	Well type	Depth (m)	Year of constr.	Installed h-pump	Time since last maint.	If inoperative, duration pump out of service	Condition/Remark
Robe Akababi	1	Backfill	<10	1979	Boswell	?	-	OK2, OK3, YD
	2	Backfill	<10	1979	Boswell	?	-	OK2, OK3, YD
	3	Backfill	<10	1979	EWRA	?	-	OK2, DP
	4	Backfill	<10	1979	Boswell	?	-	OK2, YD
	5	Backfill	<10	1979	Boswell	?	-	OK2
	6	Borehole	~10	1982	India Mark II	?	-	OK2, DP, YD
	7	Borehole	~10	1982	India Mark II	?	-	OK1, DP
Shalo	1	Backfill	<10	1983	EWRA	?	-	OK1, near a river
	2	Backfill	<10	1983	EWRA	?	-	OK1, near a river
Sanbitu	1	Backfill	<10	1980/81	EWRA	>1 year	1 year	XPump, YD
	2	Backfill	<10	1980/81	EWRA	>1 year	1 year	XPump, slab subsidence
	3	Backfill	<10	1980/81	EWRA	>1 year	5 months	XPump, cracked slab
	4	Backfill	<10	1980/81	EWRA	>1 year	5 months	XPump, pump base broken
	5	Backfill	<10	1980/81	EWRA	>1 year	-	XPump, pump base broken
	6	Backfill	<10	1980/81	EWRA	>1 year	~1 year	XPump, subsidence

Table 3 cont.

Site area	Well No	Well type	Depth (m)	Year of constr.	Installed h-pump	Time since last maint.	If inoperative, duration pump out of service	Condition/Remark
Sanbitu (cont.)	7	Backfill	<10	1980/81	EWRA	>1 year	~1 year	XPump, subsidence
	8	Backfill	<10	1980/81	EWRA	>1 year	~1 year	XPump, subsidence
	9	Backfill	<10	1980/81	EWRA	>1 year	1 year	XPump, subsidence
	10	Backfill	<10	1980/81	EWRA	>1 year	1 year	XPump, subsidence
Besaso	1	Backfill	<10	1979	Boswell	3 years	-	OK2, OK3, DP, YD
	2	Backfill	<10	1979	Boswell	3 years	-	OK2, OK3, DP, YD
	3	Backfill	<10	1979	Boswell	?	-	OK2, OK3, also used for irrigation
	4	Backfill	<10	1979	Boswell	?	15 days	XPump, YD
Ashuta	1	Backfill	<10	1983	EWRA	3 months	-	OK1, YD
	2	Backfill	<10	1983	EWRA	3 months	-	OK1
Dawe	1	Backfill	<10	1981	EWRA	>1 year	>6 months	XPump
	2	Backfill	<10	1981	EWRA	>1 year	>6 months	XPump
	3	Backfill	<10	1981	Boswell	>1 year	-	OK2, OK3, YD
	4	Backfill	<10	1981	EWRA	>1 year	>5 months	XPump

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