Low Cost Water Supply

for

Human consumption
Cattle watering
Small scale irrigation

September 1985

Part 1:
Survey and Construction of Wells

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Survey and Construction of Wells

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The instruction manuals "Low Cost Water Supply"

Part 1 – Survey and Construction
Part 2 – Pumping Equipment

have been prepared by DHV Consulting Engineers

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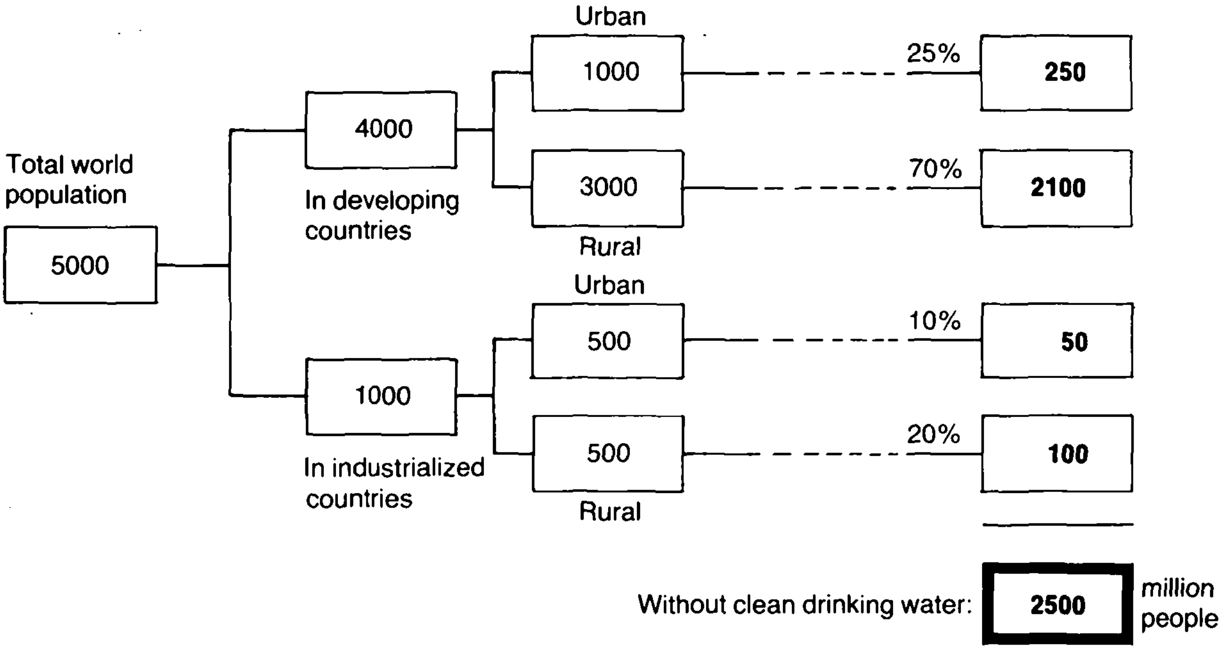


Total world population (in millions of people) in 1985 without clean drinking water

1. Low cost water supply for rural areas

1.1. Why low-cost water supply?

According to the World Health Organization, 80 percent of all sickness in the world can be attributed to inadequate water and sanitation. It is for that reason that the United Nations proclaimed the period 1981 - 1990 to be the International Drinking Water and Sanitation Decade.

The particular goal of the decade (ratified at the United Nations Water Conference of Mar del Plata, 1977) is to provide all the world's population with adequate access to safe water and to hygienic latrines by 1990.

There are at present more than 4000 million people in the developing countries, about 75 percent of whom live in rural areas.
While three-quarters of the townspeople have reasonably safe water, less than 30 percent of those in rural areas have clean water. The remaining 2100 million still rely on traditional, and generally inadequate or unsafe, water sources.

In the past, water supply systems in developing countries have been constructed using the same technologies as more industrialized countries. The emphasis has, therefore, traditionally been on high-capital, centralized pumping systems with elaborate distribution networks. In addition to high construction costs, these systems required operation and maintenance expenses that were often not within the paying capacity of the villages concerned.
In many cases, therefore, the central government that had installed the system was also faced with the maintenance costs, and scarcity of funds led to a multitude of poorly maintained, and often inoperative, water supply systems.

The cost of providing traditional water supply systems to the people that do not have access to clean water would be staggering: approximately $ 200 000 – $ 500 000 million for the decade period.
Therefore, and certainly under the influence of the world-wide recession of the early eighties, various countries and donor agencies have shifted their emphasis, away from the traditional capital-intensive projects, to low-cost, locally maintainable systems.
It is for that reason that this brochure will be confined to low-cost water supply systems, thereby focusing on durability of the systems as well as on ease of maintenance.

Roughly 50% of the world population has no acces to clean drinking water.

1.2. Which water will be used?

There are three categories of water that may be available:

rainwater
groundwater (springs, wells, boreholes)
surface water (lakes, rivers)

Each category has its own advantages and disadvantages, as described below:

RAINWATER:
advantages: – available almost everywhere
– no pumping or abstraction works required
– generally of good quality

disadvantages: – annual rainfall may be too low for practical use
– often available during restricted periods only, necessitating extensive (and expensive) storage facilities
– water quality may become unacceptable in industrialized areas (air pollution)

GROUNDWATER:
advantages: – generally good water quality
– water bacteriologically safe
– water availability hardly depending on season

disadvantages: – presence of sufficient quantities of groundwater not always easy to determine
– often pumping required
– water may contain excessive salts, iron, hydrogen sulphide, etc.
– moderate to high construction costs involved

SURFACE WATER:
advantages: – availability of water can easily be determined, without sophisticated surveys

disadvantages: – normally requires (extensive) treatment as well as pumping

Taking into account the abovementioned advantages and disadvantages, of which especially the expensive rainwater storage and surface water treatment pose considerable obstacles for rural water supply, the favoured water source will normally be groundwater.

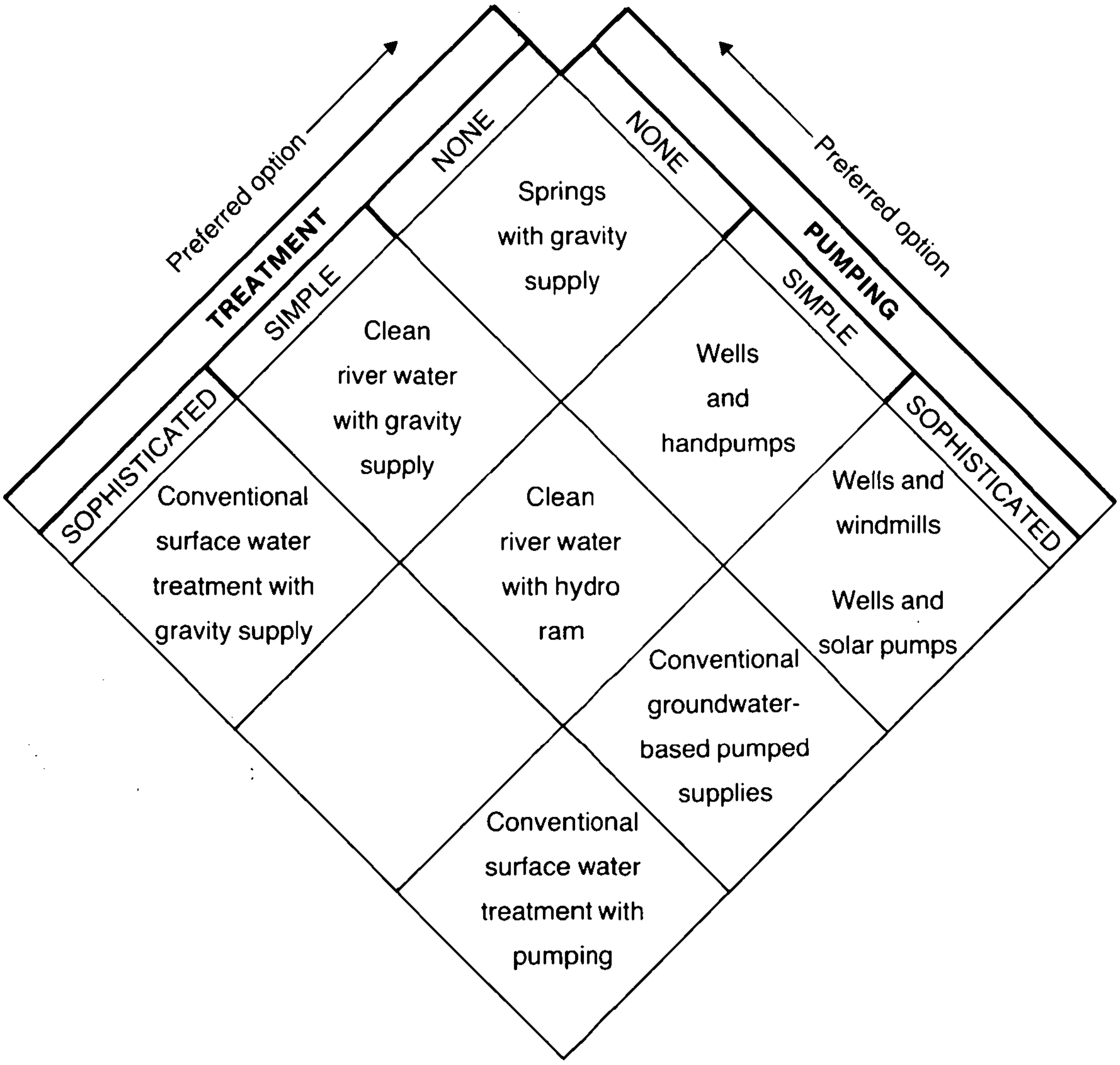
Groundwater is the most attractive source of water.

1.3. Which water supply is the most attractive, and why?

In the previous paragraph a preference for groundwater has already been indicated. More generally speaking, the selection of the most appropriate water source should take into account the following factors:

* availability of water
* least-cost solution concerning: – treatment (preferably no treatment at all)
  – pumping (preferably no pumping at all)

This is visualized in the matrix on the next page.


Preferred option
TREATMENT
SOPHISTICATED
SIMPLE
NONE
Preferred option
PUMPING
NONE
SIMPLE
SOPHISTICATED
Springs with gravity supply
Clean river water with gravity supply
Wells and handpumps
Conventional surface water treatment with gravity supply
Clean river water with hydro ram
Wells and windmills
Wells and solar pumps
Conventional groundwater-based pumped supplies
Conventional surface water treatment with pumping

Thus, in order of decreasing suitability for rural water supply in developing countries, the various systems are as follows:

Water supply system	Type of water source
Springs with gravity supply	groundwater
Wells with hand pumps	groundwater
Wells with windmills	groundwater
Clean river water, with gravity supply	surface water
Wells with solar pumps	groundwater
Clean river water, with hydro-ram	surface water
Conventional, groundwater-based pumped supplies	groundwater
Conventional surface water treatment with pumped supply	surface water

Whenever possible, a gravity supply based on natural springs is an excellent choice for rural water supply, but their availability is generally confined to mountainous or hilly areas.
Also systems relying on clean surface water are normally found in mountainous areas only.

For most cases groundwater, other than from natural springs, may thus be the most appropriate water source, with the emphasis on relatively low-cost solutions, such as shallow or medium-depth wells.

The remainder of this brochure will, therefore, be devoted to the construction of those types of wells.

Shallow or medium-depth wells mostly the least cost water supply.

1.4. How many wells, and where?

Water for how many people?

The principal purpose of wells is to provide water for human consumption (drinking, food preparation) and for other household uses (cleaning, washing, laundering), for which an average of 20 - 30 litres per person and per day is sufficient. As in most cases the water will have to be carried home, a higher per capita water consumption would involve a larger number of trips to the well, which is not normally done.

For reasons of hygiene, wells must be covered and fitted with a pump, which in most cases will be a hand pump. The critical factor for the production capacity of a well is thus normally the hand pump.

The yield of an SWN hand pump (see Part 2 "Pumping Equipment") with a stroke of 16 cm, at 2000 strokes per hour, is:

cylinder Ø 4"	2.5 m^3/h
cylinder Ø 3"	1.4 m^3/h
cylinder Ø 2.5"	1.0 m^3/h
cylinder Ø 2"	0.6 m^3/h

Thus, at 6 pumping hours per day, a hand pump with a 4" cylinder could supply water to approx. 750 people, while even with a 2" cylinder a pump could provide water for 200 people.

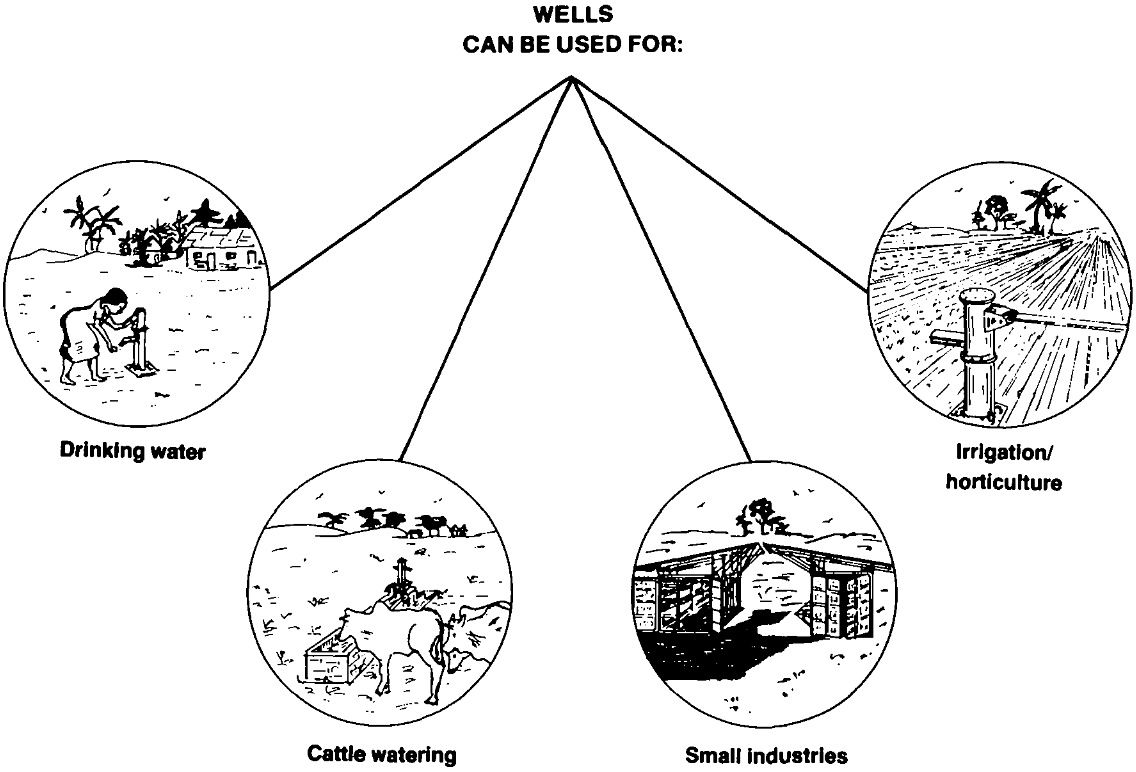
In view of the sometimes large distances between houses in rural areas of developing countries, an average of one hand pump for 250 people is a realistic assumption.

One hand pump is sufficient for approx. 250 people.

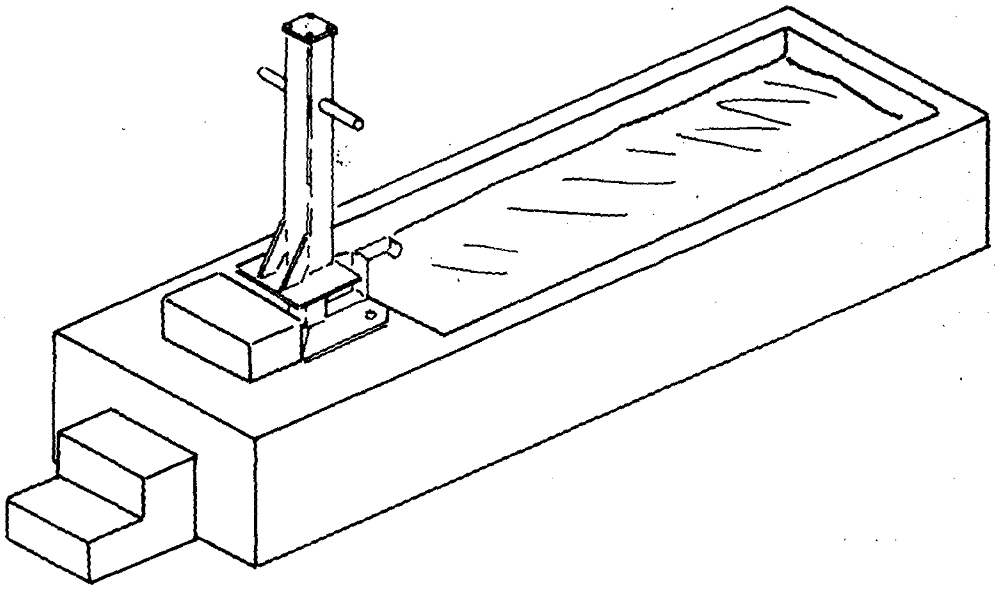
For what other purposes is water required?

Shallow and medium-depths wells may be used to advantage for:

- watering cattle
- watering crops
- providing water to hospitals, schools, etc.

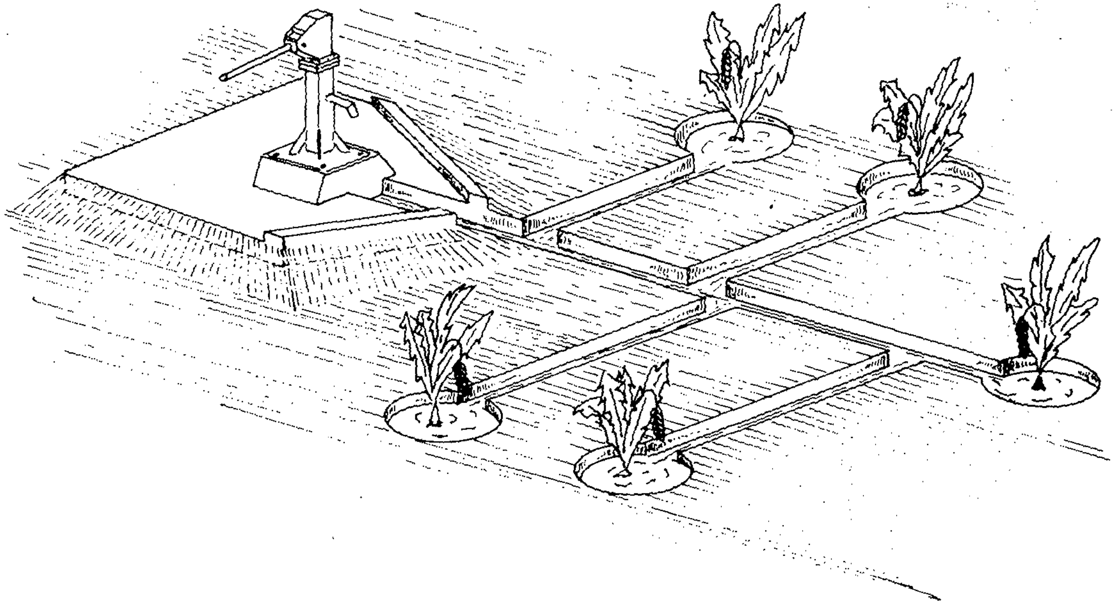


Cattle watering:
A Kangaroo pump equipped with a 3" cylinder can provide sufficient water for up to 600 heads of cattle (at 12 hours' pumping per day, and an average water demand of 40 l/day per head of cattle).
A cattle trough with a net length of 6 - 8 m would be required to water such a number of cattle.



Crop watering:
Wells can be used for watering vegetables, trees, etc.:

vegetables	– tomato, onion, mchicha, beans, pepper, okra, eggplant and cabbage;
tree nurseries	– coconut, citrus and mango;
others	– banana and papaya.



The size of the plot that can be watered depends on the type of pump and the water requirements of the particular crop.

HAND PUMP (max. output 6 m^3/day):

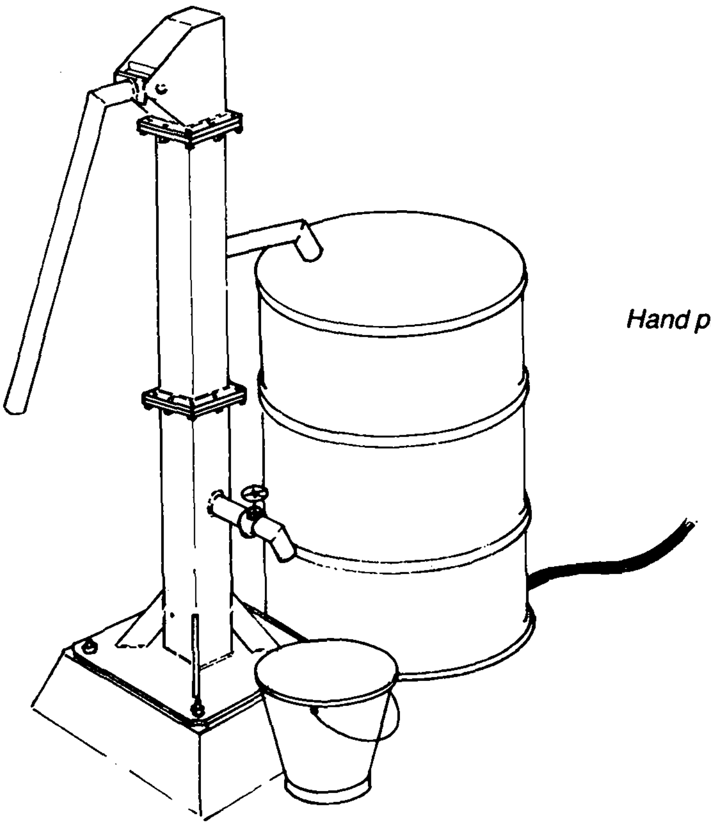
Daily water requirements (litres/m^2)	Max. area to be irrigated	Size of garden (approx.)
4	1500 m^2	40 x 40 m
6	1000 m^2	32 x 32 m
8	800 m^2	30 x 30 m
10	600 m^2	25 x 25 m

KANGAROO PUMP (max. output 12m^3/day):

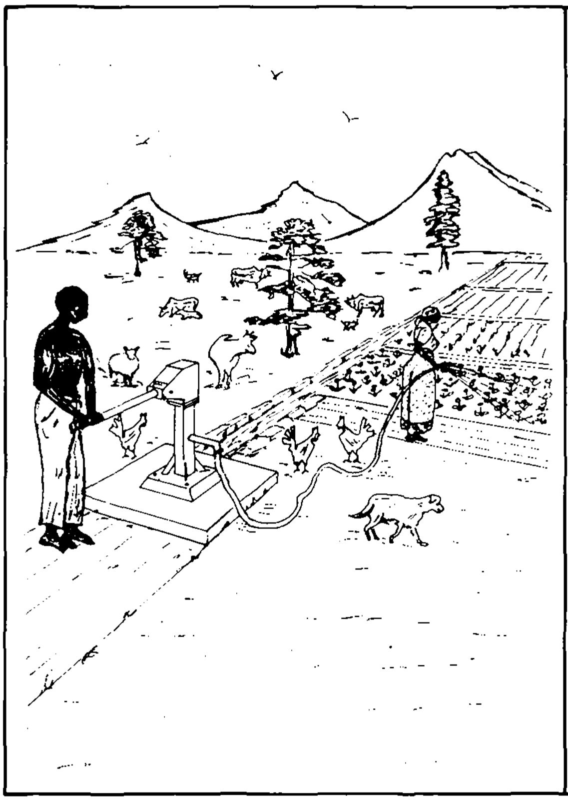
Daily water requirements (litres/m^2)	Max. area to be irrigated	Size of garden (approx.)
4	3000 m^2	55 x 55 m
6	2000 m^2	45 x 45 m
8	1500 m^2	40 x 40 m
10	1200 m^2	35 x 35 m

Pumping methods for irrigating a plot can be:

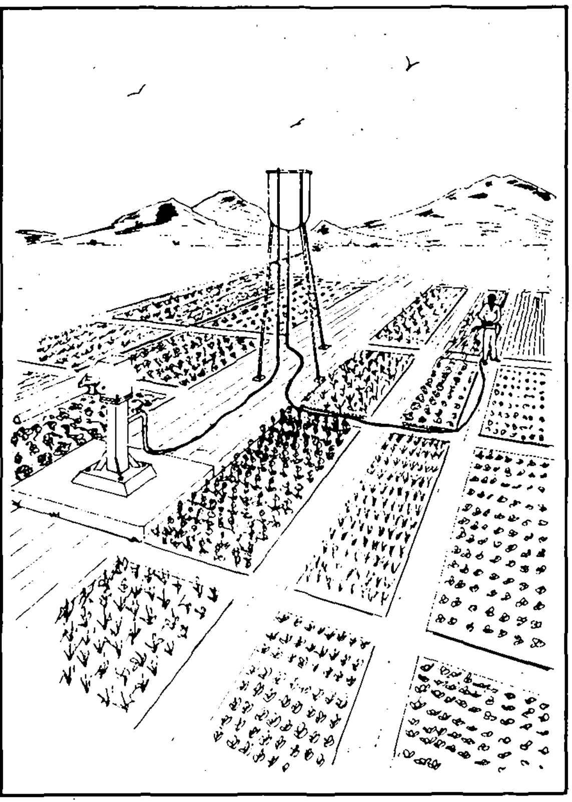
- non-sophisticated, free-flowing through furrows
- with SWN 80/SWN 81 pump, with extended superstructure
- with kangaroo pump on raised pedestal, free-flowing
- with pressure pump, with hose and/or storage tank



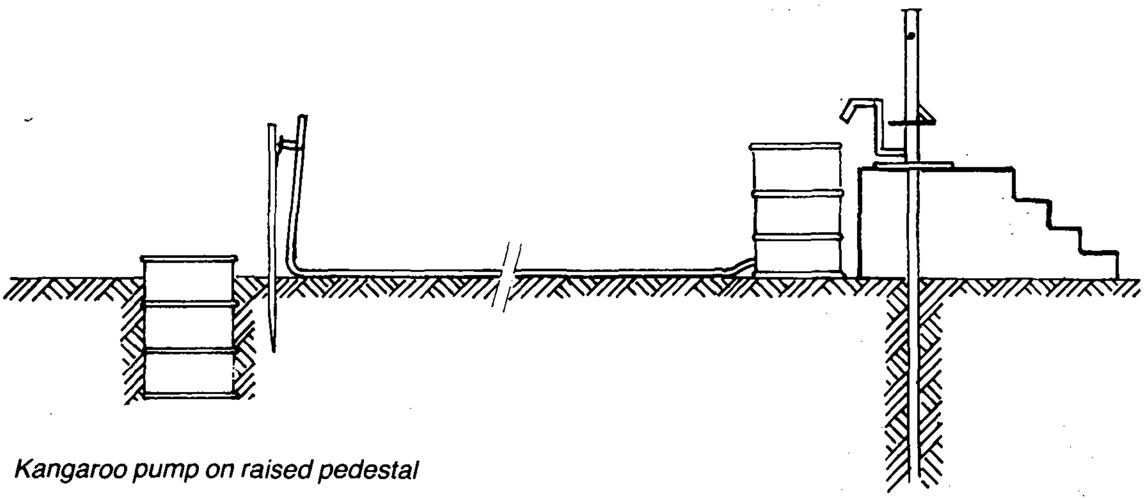
Hand pump with extended superstructure



Pressure pump with hosepipe

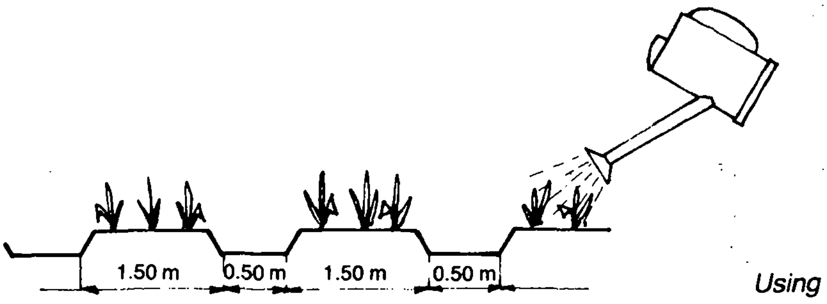


Pressure pump with water tank

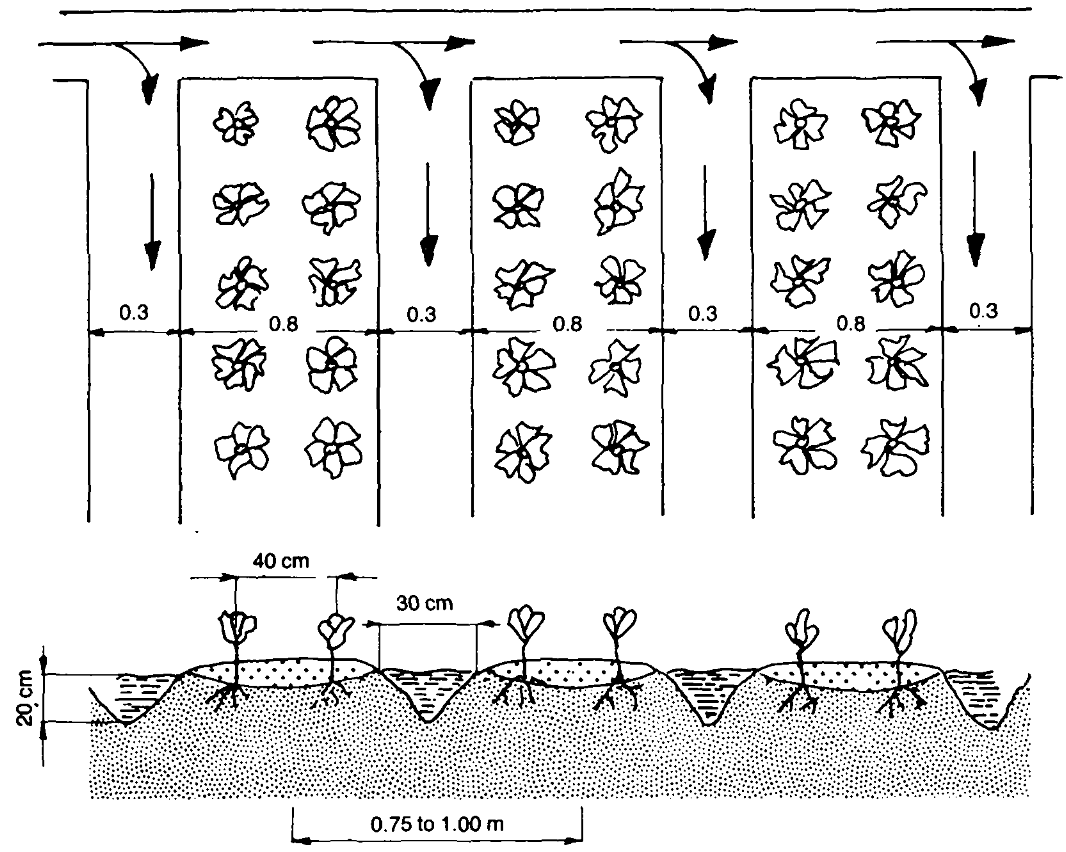


Kangaroo pump on raised pedestal

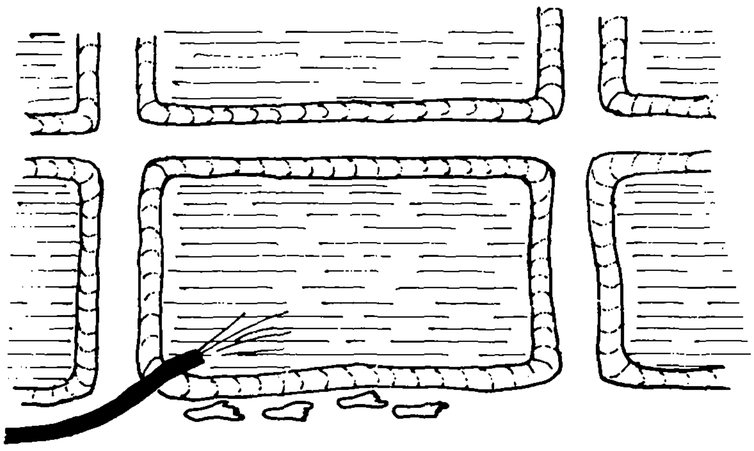
The following irrigation methods lend themselves for small-scale application:



Using watering cans



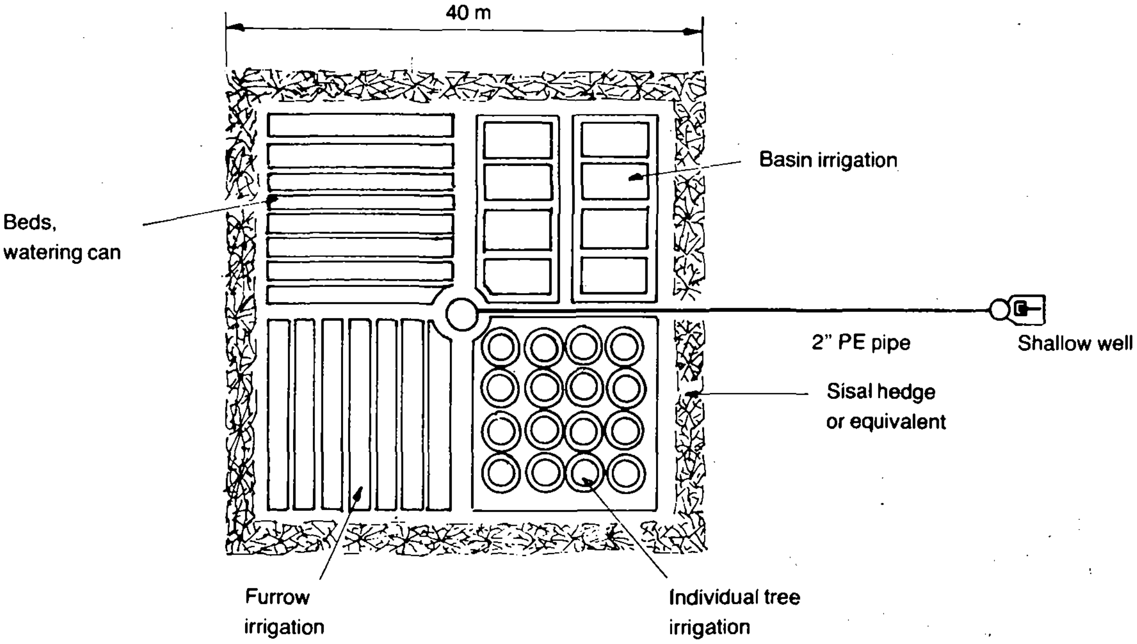
Furrow irrigation



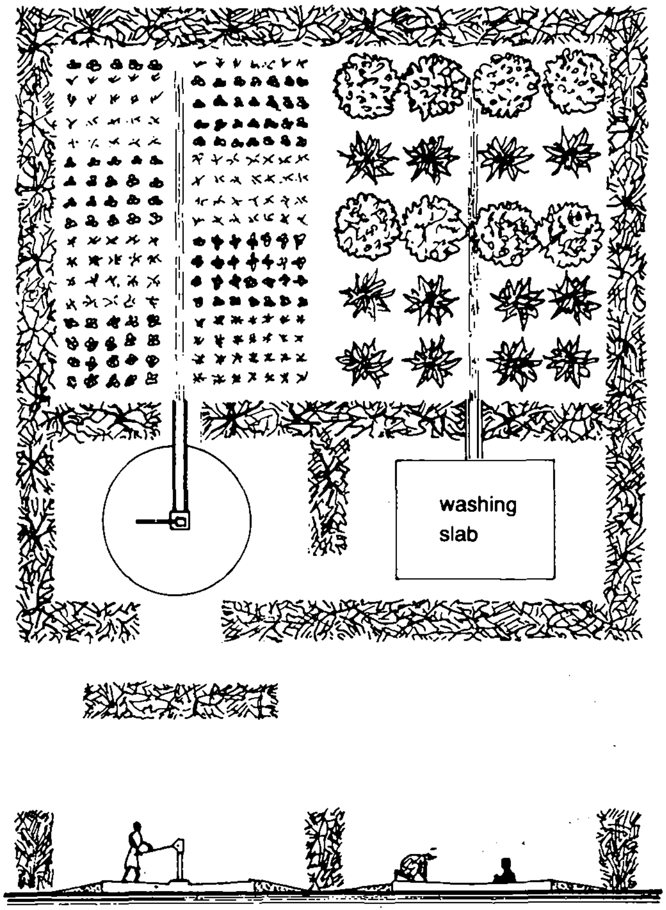
Basin irrigation

Irrigation of individual trees, etc.

Example of plot, irrigated by means of a shallow well



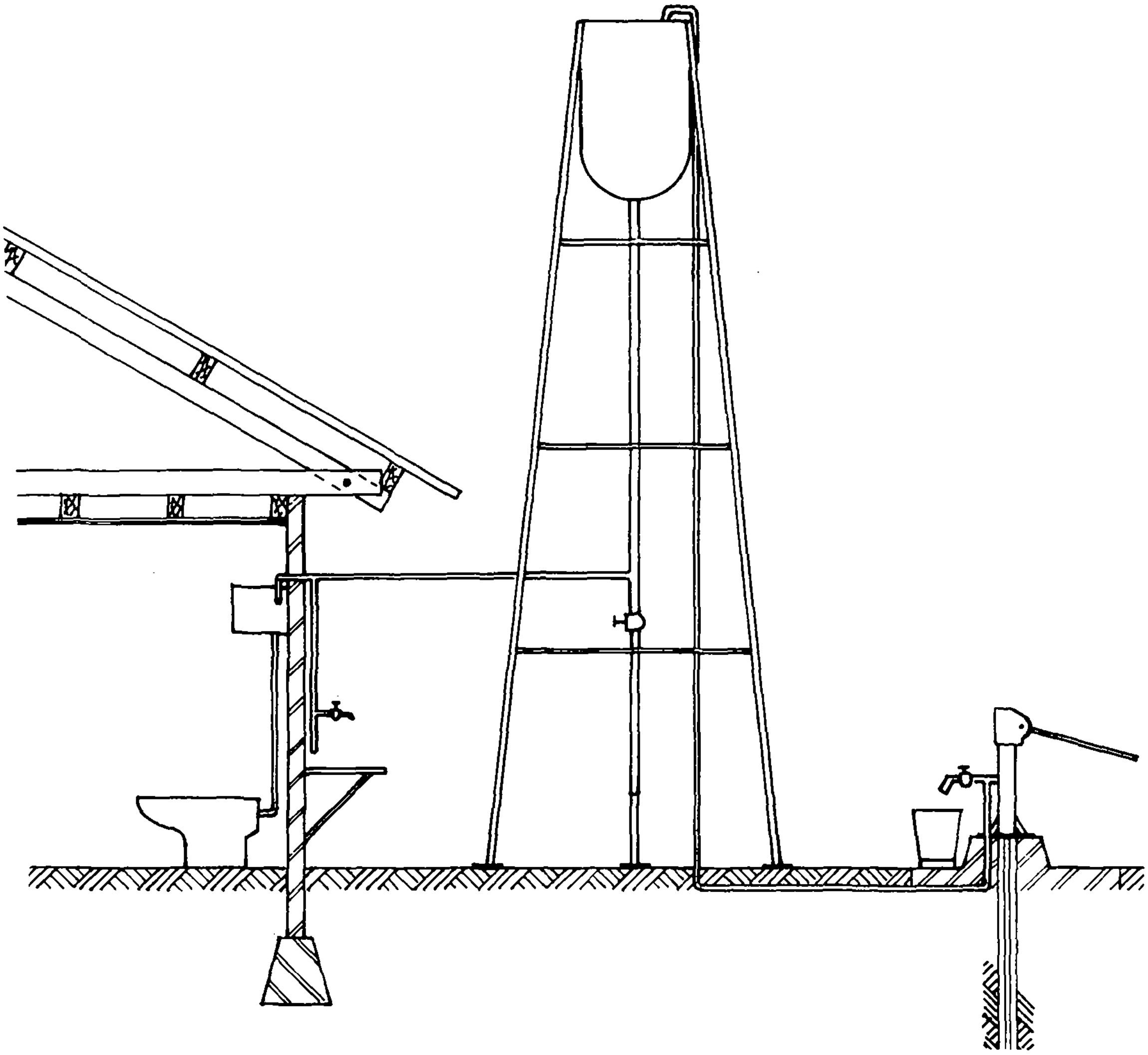
Pump attendant's garden



Often a well that is primarily used for water supply, can also be used for watering a small plot owned by the pump attendant, outside the hours when the villagers collect their water.
In this way the pump attendant can obtain some extra income, which will stimulate him/her to maintain the well and pump in an optimal manner.

Providing water to hospitals, schools, etc.

Wells for hospitals, schools, and other institutions can best be wells that are used for that specific purpose only. When water under a certain pressure is required, roof tanks may be used, to be filled by means of a hand-operated pressure pump (see Part 2: "Pumping Equipment").



How many wells are needed?

The required number of wells for any given village can be found by;

- dividing the total population by 250 (take into account some allowance for population growth)
- adding wells for horticultural or cattle watering purposes
- adding wells for hospitals, schools and similar institutions

1.5. Socio-economic conditions

Wether or not a well will be successful, depends on the following considerations:

a. Do the villagers appreciate the selected well site, or do they prefer another site?
b. Are the villagers prepared and able to contribute to the investment cost in cash or in kind, and who is going to organize this contribution?
c. Are spare parts for the pump available in the country and can it be arranged that these parts will become available to the villagers?
d. Is someone in the village willing and able to maintain the pump? (after training, if necessary). How will he/she be paid?
e. Is anybody living in the vicinity, preferably an older man or a woman, prepared to carry out daily supervision as well as the clean-up and small repairs at the well?
   What will be the compensation for this job?
f. Are the villagers prepared and able to save money for the recurrent costs of the well, being approx.:

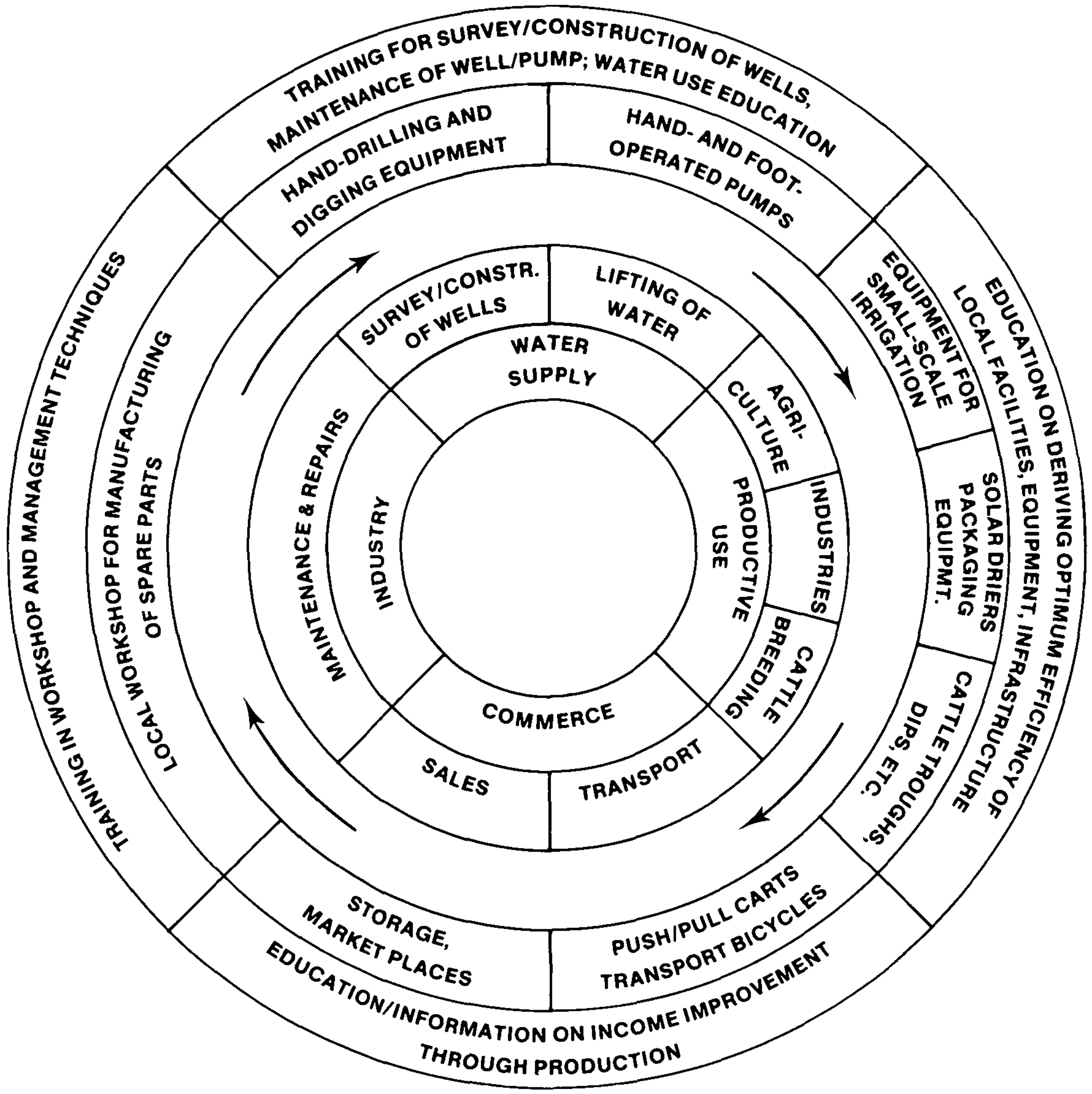
$ 75 - $ 150	per year for maintenance
$ 50 - $ 100	per year for depreciation of the pump
$ 75 - $ 150	per year for depreciation of the well
$ 200 - $ 400	per year in total for the well ($ 0.80 - 1.60 per person)

g. If a financial contribution towards the maintenance has to be paid, who will organize this and where will the money be kept?
h. Does anybody or any organization in the village have sufficient authority to ensure fulfilment of the necessary arrangements?

If it is not possible to organize an effective financial contribution towards the construction and maintenance of a well for drinking water only, possibilities for the construction of an **irrigation well** may be considered.

In this case the following questions will have to be answered:

a. Do possibilities exist for small-scale irrigation in the direct vicinity of the village?
b. Is the possible owner of such an irrigation well prepared to:
   - contribute to the direct investment costs?
   - maintain the construction?
   - allow villagers to fetch drinking water from the well?
c. How much can the villagers be asked to pay per bucket or per person each month?
d. Who will check this payment?



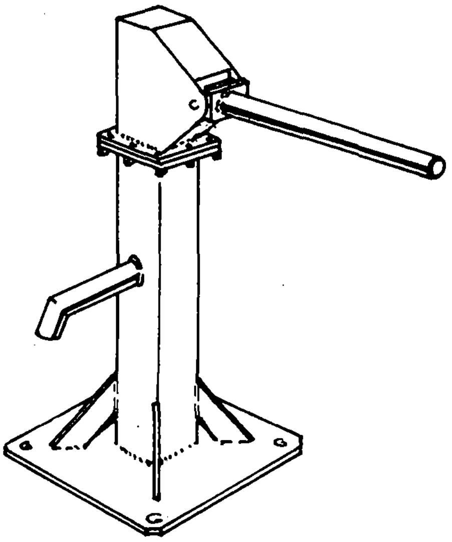
Water can play an important role in the stimulation of community development, but in order to do so, it must not stand alone. It should be linked to a number of additional activities that are all interlinked and working together in raising the level of the community's development, self-suffiency, in come, etc., as illustrated in the diagramme above.

In many cases the possibility to make **productive use** of water (for agriculture or cattle watering - for instance), so that income is generated for the owner,is a prime requirement to ensure that wells and pumps are maintained properly. This, in turn, assures that water is continuously available also for domestic use.

Additional inputs as shown in the diagramme must be of a nature and at a level that correspond with the level of self-sufficiency of the community. They must be realised simultaneously and without omissions, in order to guarantee success.

2. How to find a suitable site for a well?

2.1. General requirements (partly depending upon use of well)



5 conditions:

1. **capacity**
   500 litres per hour for a ring well
   1000 litres per hour for a tube well
2. **quality**
   bacteriologically safe
   only low concentration of salts
   without bad taste or odoor
3. **situation**
   - 100 metres from toilet or septic tank
   - above flood level
   - at reasonable distance from the village
4. **accessibility**
   throughout the year for users and maintenance personnel
5. **productive use**
   possibility for:
   - small scale irrigation
   - cattle watering
   - cattle dip
   - fish pond

2.2. General hydrogeological considerations

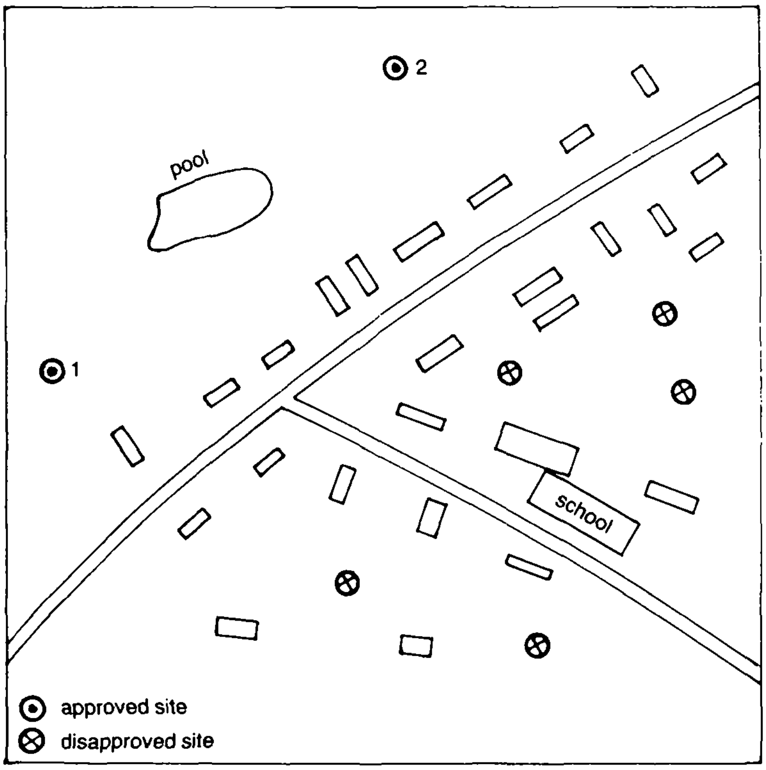
- Layers of sand and gravel are the best aquifers.
- In karstified limestone the danger of pollution of groundwater from the surface is relatively great.
- In granite areas the weathered rock may contain good aquifers.
- Wells in basalt need to be larger, and are therefore much more expensive, than wells in sand, gravel or sandstone.
- In mountainous areas the best aquifers are found along the edges of the valleys.
- In wider river valleys the sandy deposits under the river bed and in the banks of the existing and 'buried' rivers offer good oppurtunities for groundwater exploitation.
- In arid regions groundwater may be the only permanent water source. Especially the coarser river sediments may offer good opportunities for aquifers.

2.3. Collection of information

- Collect (hydro-)geological information, e.g. well logs of wells and boreholes that are situated nearby, and any other useful information that may be supplied by geological, hydrological, water supply and/or irrigation departments.

- Interview the local population:
  - Make a sketch of the area where most people are living (scale 1 km = 10 cm).
  - How many people are living in this area?
  - Where do the people fetch the water?
  - Is that water available throughout the year?
  - Are there complaints regarding the quality of the water?
  - Indicate on the sketch where well sites may be possible.

- Which locations are suitable for digging water holes?
- Are there any existing wells or boreholes?
  If so, collect all available information about these:
  - depth of well/borehole
  - at which depth was water struck when the well/borehole was constructed?
  - water depth
  - does the water level fluctuate seasonally?
  - does the well/borehole ever fall dry?
  - is the water quality good?
    If not, what is the problem?
- Are there any sites where no wells may be constructed because of socio-cultural or religious taboos? (sacred places, etc.)



Typical sketch of village with well sites

2.4. Survey methods for well siting

Next to collecting information, as indicated above, the following steps are important:

- Study aerial photographs.
- Study the area and its vegetation.
  Banana trees, date palms, bulrush, sugar cane, etc. indicate shallow groundwater (0-5 m); other types of vegetation may indicate brackish or saline water (salt water grass).
- Carry out test drillings.

If well sites are surveyed in alluvial sediments, the activities as mentioned above are sufficient. Hand-drilling can be carried out easily, and checking the availability of groundwater in this way, though possibly requiring a number of hand-drillings to find one approved well site, is feasible.

In case wells have to be constructed in (weathered) rock formations, more sophisticated investigations such as geo-electrical surveys are warranted, in order to minimize the number of test drillings (which are much more costly in this case).

A typical survey would now consist of:

- Determining approximate locations of faults and linaments, from satellite images and aerial photographs.
- Vertical electrical resistivity soundings, each oriented parallel to the strike of the fault, at 5 locations on a line perpendicular to the fault; at 200 m and 100 m from the fault (at either side) and at the fault itself. Thus the resistivity of the various vertical zones, the expected depth to groundwater and the weathered/transition zone are determined.
- Horizontal resistivity profiling and
- Electromagnetic profiling, to provide additional geological information and the exact location of the fault.
- Test drilling at the most promising locations

For the typical geo-electrical activities specialized equipment as well as knowledge is essential. Furthermore data processing by computer may have to be used to speed up the determination of larger numbers of suitable well sites.
Wether geo-electrical profiling is used or not, test drillings are necessary to finally check the availability of water at the selected site. If posssible, test drilling should be continued until a second aquifer is struck, as the upper aquifer - unless it is covered by an impermeable layer - is subject to contamination from above. On this aquifer a pumping test is carried out, with a hand-operated pump, and the water quality is checked. If both the yield and the water quality are sufficient, the site is marked for future construction of a well.

If no suitable second aquifer can be found, however, the upper aquifer may have to be tapped.
In that case the well should be surrounded by a concrete slab of sufficient extent, to minimize the danger of contamination.

Details of the survey procedure and the equipment used are given in paragraphs 5.1. and 6.1., respectively.

3. How to make the well(s)

3.1. Types of wells, and construction methods

Wells can be categorized according to their

depth
- shallow wells (up to several tens of meters)
- deep wells (of at least 80 to 100 meters)
- wells of intermediate depth

diameter
- large-diameter wells (so that at least one man can descend into the well during construction)
- small-diameter wells, also called tube wells
- combinations of the above, e.g. large-diameter wells with smaller diameter above the groundwater level

construction method
- driven wells
- jetted wells
- bored/drilled wells (either by hand or by machine)
- dug wells (either by hand or by machine)

finishing
- open wells (water abstracted with bucket and rope)
- covered wells (water abstracted with (hand)pumps, etc.)

Although almost any combination is theoretically possible, there is only a limited number of options that have found wide-spread application in practice:

The **large-diameter** dug well, generally of no more than medium depth, either open at the top, or covered and fitted with a hand pump.

The **small-diameter** well of normally larger depth, machine-drilled; or of somewhat smaller depth and constructed in any of the above-mentioned ways.
Because of their size, these wells are of necessity covered and fitted with a pump.

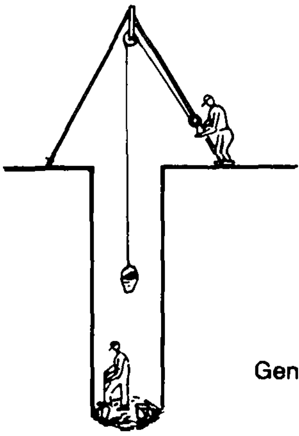
Small and large-diameter wells each have their own advantages and disadvantages, as shown on the next page.

RELATIVE ADVANTAGES AND DISADVANTAGES OF SMALL AND LARGE DIAMETER WELLS

	SMALL	LARGE
EQUIPMENT REQUIRED for construction	– Specialized equipment such as augers and bailers required. – No dewatering of well is necessary.	– Hardly any specialized equipment is absolutely necessary. However, speed of construction improves when using specialized equipment. – Special dewatering equipment is normally required.
for raising water	Pumps or special small-diameter well buckets are necessary.	Ropes and buckets are frequently used if top of well is open; otherwise the same equipment is used as for small-diameter wells.
COST OF CONSTRUCTION	Lower, because relatively litte material is required, and less man-hours.	– Higher, because much more material is required. Especially lining materials (e.g. concrete rings or aggregates and moulds) may require costly transportation. – Number of man-hours involved is larger.
SPEED OF CONSTRUCTION	Higher (approx. one week per well)	Lower (approx. one month per well, or more)
HYGIENIC ASPECTS	Potentially good, especially when a hand pump is used.	Potentially good when the well top is covered and a hand pump is used; poor when top of well is open. Bucket and ropes may be dirty, thus contaminating the well.
SAFETY during construction	Negligible danger during construction	Danger of cave-in may be eliminated by proper construction. Danger of something dropping in well always possible. Handling heavy well lining rings is dangerous for unskilled labourers.
during use	Danger during use negigible	Raising the well lining to well above ground-lever can minimize danger of people falling in. Negligible danger in case of covered wells.
MAXIMUM NUMBER OF PEOPLE ABLE TO USE THE WELL CONCURRENTLY	*Normally one; two in case of duplex pumps.*	*In open well: three to six, depending on well* diameter; in covered well: same as with small-diameter wells.
RATE OF DISCHARGE POSSIBLE	Theoretically/Potentially better: – more than one aquifer can be tapped – well can be made almost any depth below static water level. – good possibility of putting filter construction in material of high permeability.	Theoretically less: – well yield increases less with larger diameter than with larger depth. – depth to which well may be excavated below static water level is more limited than with small-diameter wells.
SKILL REQUIRED well construction	– Little, in case of hand-operated augers (can be taught within one month). – Much, in case of sophisticated drilling equipment (several years).	Much. Well sinking is a difficult job, which takes up to 2 years to master.
water raising	Must be able to maintain and repair pump and/or small-diameter well buckets.	Little skill required in case of open wells; otherwise: same as with small-diameter wells.
RELIABILITY well	Excellent (see "rate of discharge possible")	Somewhat less, as depth is more limited. Poorer aquifers may be tapped, however, and water stored in the well overnight.
water raising	Somewhat less, as for pumps a certain local maintenance and repair potential is required.	Somewhat better in case buckets are used; otherwise: same as for small-diameter wells.
ABILITY TO STORE WATER (Important when permeability of aquifer is low)	Negligible	Larger as diameter and depth below static water level are larger.
LIMITATIONS ON WHEN WELL MAY BE CONSTRUCTED	None, except accessibility of site (may be problematic in rainy season)	– Well to be constructed preferably at time of year when water level is at its lowest. Otherwise: – high-capacity dewatering equipment required, or: – well constructed in stages: major part at any convenient time; lower part of well when groundwater level is at its lowest.

3.2. What type of well is the most appropriate?

The four most common types of wells/well construction are outlined below:

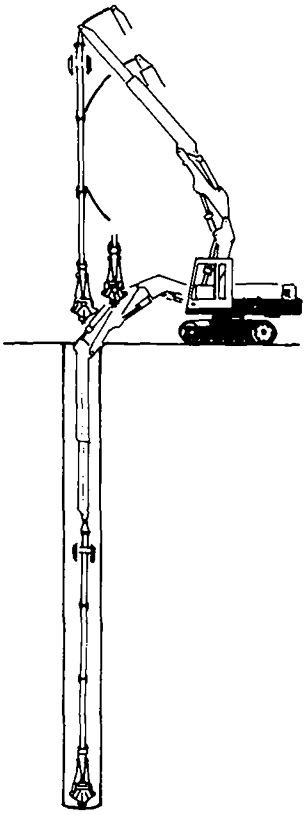


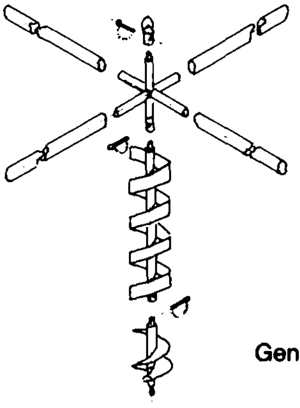
Hand dug
- hand tools for Ø 1000 - 1500 mm
- possible in very hard soils
- lining required in unstable formations
- dewatering equipment required

General : long construction time, relatively small investment

Mechanically dug
- hydr. clam-shell for Ø 500 - 1000 mm
- not possible in hard soils
- casing required
- possible to depths of – 20 m

General : short construction time large investment



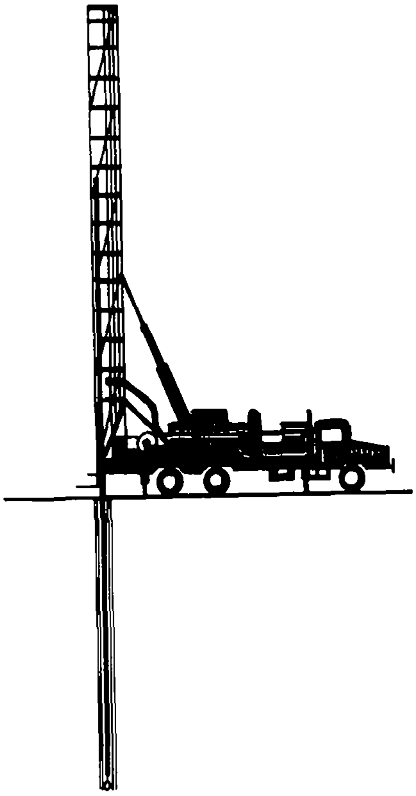


Hand drilled
- auger/bailer for Ø 150 - 300 mm
- not possible in hard soils
- casing required
- possible to depths of – 25 m and sometimes more

General : short construction time, small investment

Machine drilled
- drilling tools for Ø 150 - 400 mm and more
- suitable for very hard soils
- possible to depths of up to 150 m and more

General : short construction time, very large investment



Which of these methods is the most suitable under certain circumstances, depends on a number of factors, such as:

Depth to the water table
When the aquifer is at greater depth, hand-dug wells may take a very long time to be completed. Greater depths also require greater skills and are more dangerous for the workers below.
Machine-digging is possible to limited depths only. Thus, drilled wells are preferred for tapping deep aquifers.

Yield of the aquifer
In case of poor aquifers it may be necessary to construct wells with a certain storage capacity: those wells then will be slowly replenished overnight, so that the available quantity of water is larger than the day-time yield only.
In these cases large-diameter, dug wells are required. As the required output per well is determined principally by the pump that has been fitted on it, and consequently the number of users of the well is in the order of 250 (see paragraph 1.4.) even a small-diameter well often has a yield that is more than sufficient, even without any storage capacity.

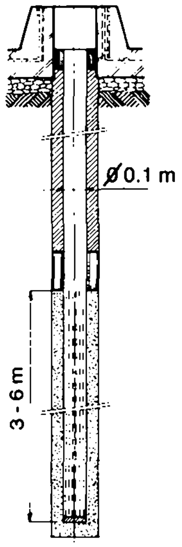
Availability of building materials
Large-diameter wells normally require a lining of brick, concrete or a similar material, which may not be readily available, and often requires expensive transportation.
Small-diameter wells require much less material, in the shape of a steel or plastic casing/filter pipe only. Even if it is not locally produced, the purchase and transport cost of this pipe is relatively low.

Availability of sophisticated equipment/spare parts versus availability of manpower
Mechanically-dug wells or machine-drilled wells require the use of relatively sophisticated equipment, that costs a considerable amount of foreign currency to obtain and to operate.
Also trained manpower and spare parts should be readily available for these methods to work.
If manpower is in short supply and wages are high, the use of sophisticated machinery may be necessary to keep overall costs down. When labour is abundantly available, however, manual digging or drilling will be more cost-effective.

As a rule, developing countries have labour much more readily available than hard currency, so that the emphasis will be on **hand-dug** and **hand-drilled** wells. The depth of the well and the choice between large- en small-diameter wells will normally be dictated by local circumstances.
As will be explained later, constructing large-diameter wells is generally dependent on mechanical (thus: vulnerable) equipment, which small-diameter wells are not. Therefore, if local conditions permit, *the construction of wells by* ***manual drilling*** *is to be preferred.*

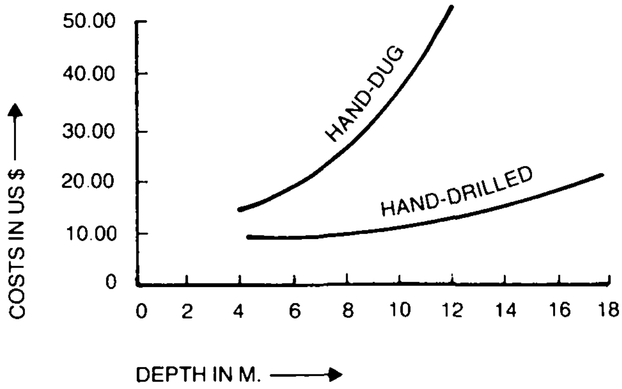
3.3 Hand-drilled wells

A typical hand-drilled well



- Is drilled perfectly vertical.
- Consists of a thick-walled PVC casing of at least 100 mm internal diameter (minimum suitable for lowering a 3" pump cylinder). The lower 3 - 6 m of the PVC casing pipe is slotted, slot size 0.5 mm, to guarantee a sufficient inflow of water, even when a substantial part of the slots would be clogged.
- Has a gravel pack with a minimum thickness of 30 mm around the filter, 3 - 5 mm gravel size, and a sealing layer of clay or cement on top of this gravel pack above the slotted pipe, but still within the impervious layer, to prevent pollution from above.
  It is provided with a strong PVC or wooden bottom plug underneath the filter.

Dewatering dug wells during construction often causes severe ploblems and thus hand-drilling has gained a solid foot-hold in practice.
Because generators and motor pumps are no longer required, initial expenditure can be brought down and also the overall costs per well are lower than for dug wells, as shown in the figure below. Cost savings are considerable in transport, labour and well materials. Time saving is tremendous.



Costs of shallow wells

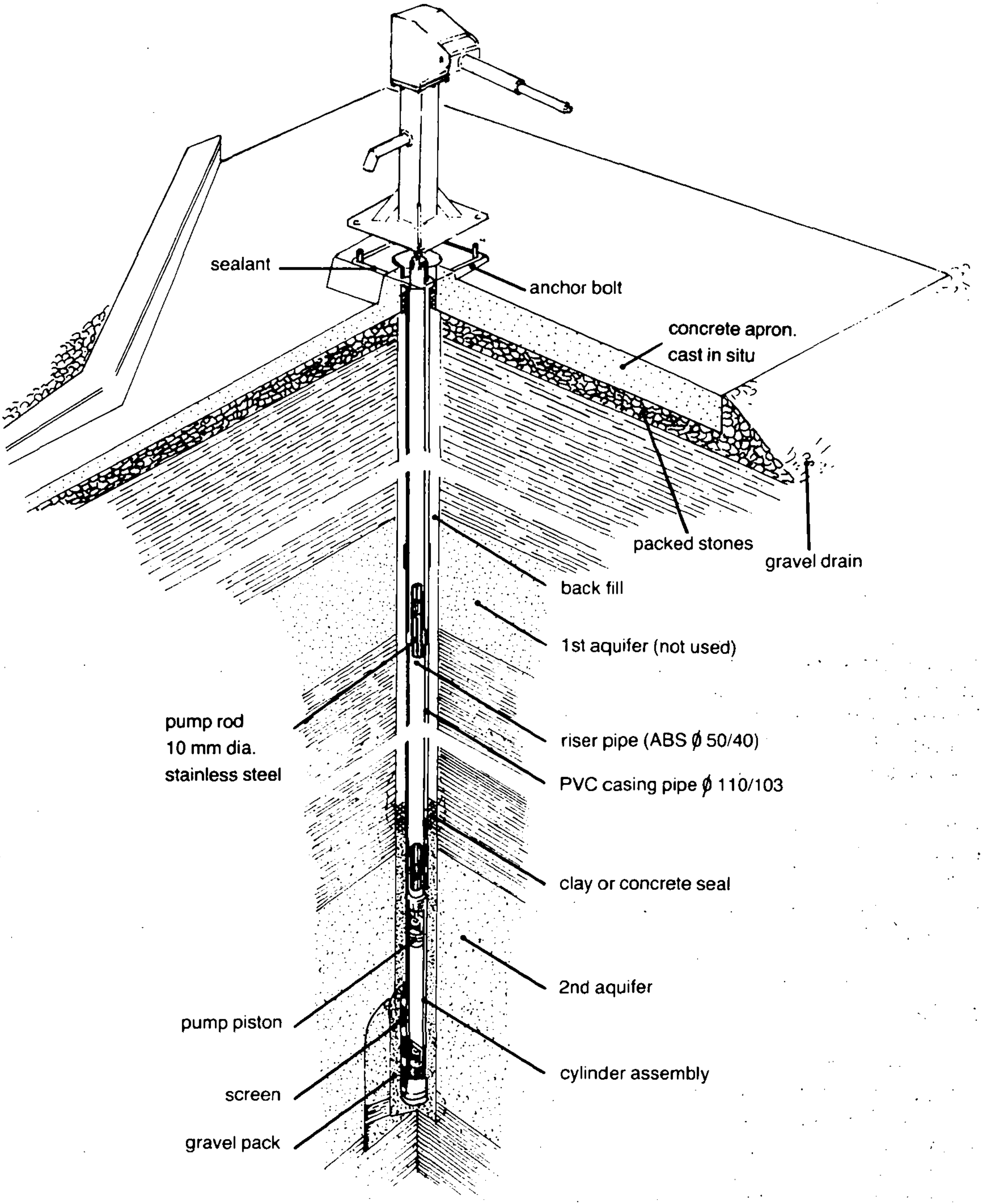
The steep incline in the graph of the hand-dug wells cost for wells over 6 m deep, is caused by the fact that deep well pumps will then have to be used, while the dificulty of digging the well is increasing more than proportionally with the depth of the well.
The requirement of better aquifers for small-diameter wells (according to experience the yield during test pumping should be 1000 l/h or more, rather than 500 - 1000 l/h as for dug wells) generally does not present large problems.

Hand-drilling equipment (manual augering equipment) consists essentially of a continuous flight auger with various bits of two diameters (the smaller to be used inside a temporary casing), a cross piece for turning the drill, bailers, casing pipe, etc.
Apart from the fact that this drilling equipment is manually operated there is no principal difference with the conventional augering of boreholes. When the borehole is at the required depth a slotted PVC pipe is lowered into it (a combination of screen and casing), a gravel pack is put around the screen, the temporary casing pipe is removed and the well is finished with a pump foundation, apron and hand pump.

The advantages of the use of hand-drilling equipment over hand-digging, such as:
- reduced construction time per well, or: a higher output per construction group
- reduced costs per well
- no need for using motorized equipment that would require trained operators as well as fuel and (imported) spare parts
- the possibility to repair the drilling equipment wherever welding facilities are available
- the possibility to work with virtually untrained personnel, without safety hazards render the hand-drilling method one of the most appropriate ways of constructing shallow to medium depth wells for rural water supply in developing countries.

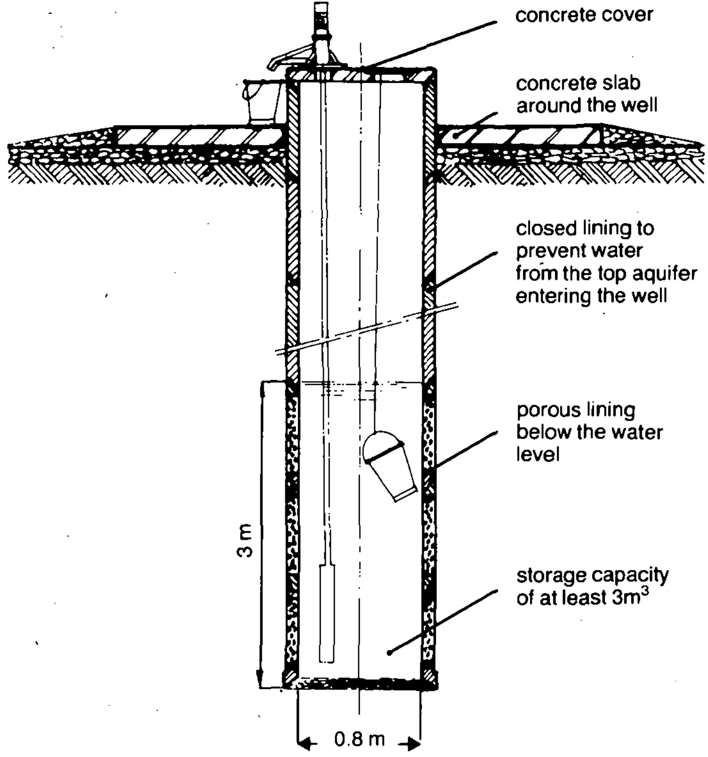
After construction there is hardly any difference between dug and drilled wells: in both cases a concrete slab is cast on top of it, and a hand pump mounted on the well.

A detailed description of the hand-drilling procedure and necessary equipment is given in paragraphs 5.2. and 6.2., respectively.



Typical hand-drilled shallow well

3.4. Hand-dug wells



A typical dug well

- Is lined with a hard and corrosion resistant material, preferably with concrete rings.
- Has a sufficient internal diameter (approx. Ø 1.25 m) to allow people to work inside, for cleaning or deepening the well.
- Has been dug through to at least 3 m below the top of the aquifer, so that approx. 3000 litres of stored water will be available in the early morning, even with a poor aquifer.
- Is provided with a 10 cm thick layer of gravel at the bottom.
- Has an impermeable concrete slab around it, of which all seams and cracks are filled, preferably with bituminous kit.
- Is completely covered at the top, to prevent pollution of the well from outside.

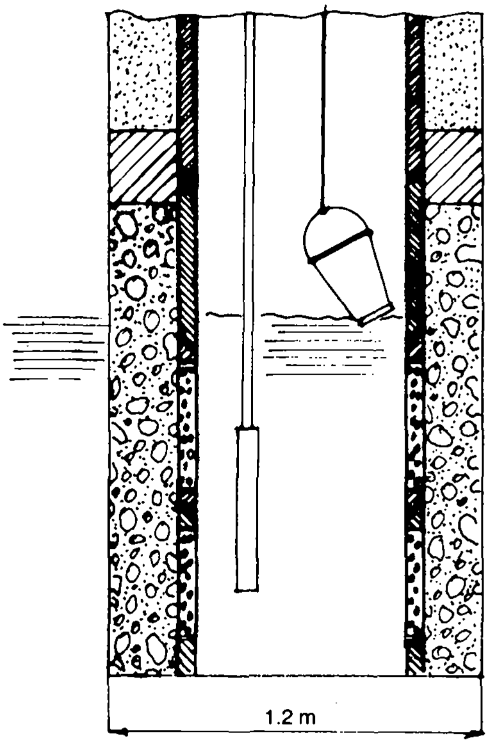
Large-diameter wells may be the only feasible solution when the aquifer characteristics are poor. Even then the effect of increasing the well diameter on the well yield is very limited, and an increase in yield may better be obtained by extending the depth of the well (if the aquifer is thick enough). *The real important asset of a large-diameter well is its storage capacity: overnight, the well is filled* up to the groundwater level, and during the day the well volume plus the direct inflow during the day hours can be abstracted.

Disadvantages of large-diameter wells in general (as compared to small-diameter wells) are:

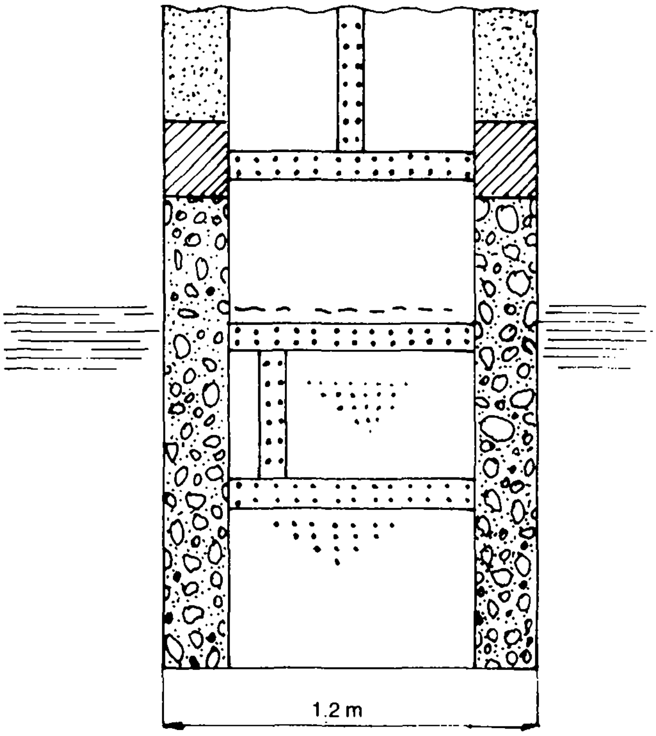
- greater efforts and longer construction time are required
- the inflowing water must be pumped out of the well during construction, often making the use of motor pumps necessary and causing caving of the aquifer into the well. This may result in the top impermeable layer collapsing into the aquifer, thus preventing water from entering into the well.
- safety hazards during and after construction are greater
- it is more difficult to prevent contamination
- the rate of inflow for the effort involved is generally lower.

Whereas small-diameter wells have casings, screens and gravel packs in the same ways as traditional boreholes, large-diameter wells are generally dug by hand or by any mechanial means. They are normally provided with an internal lining to prevent the walls from collapsing and surface water from entering and contaminating the well.

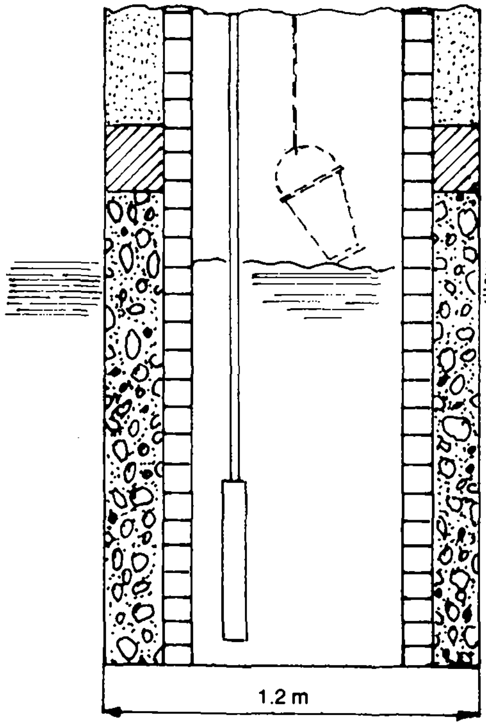
TYPICAL LINING MATERIALS



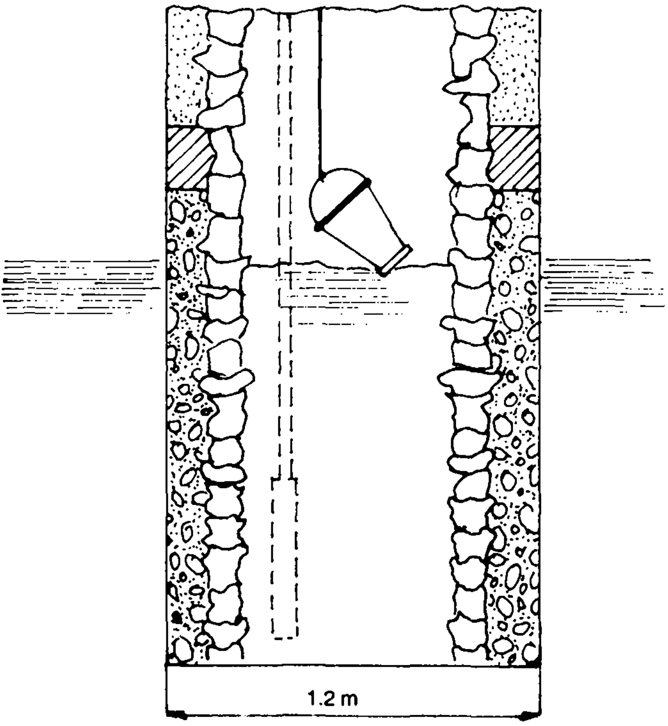
Concrete rings



Polyethylene sheets



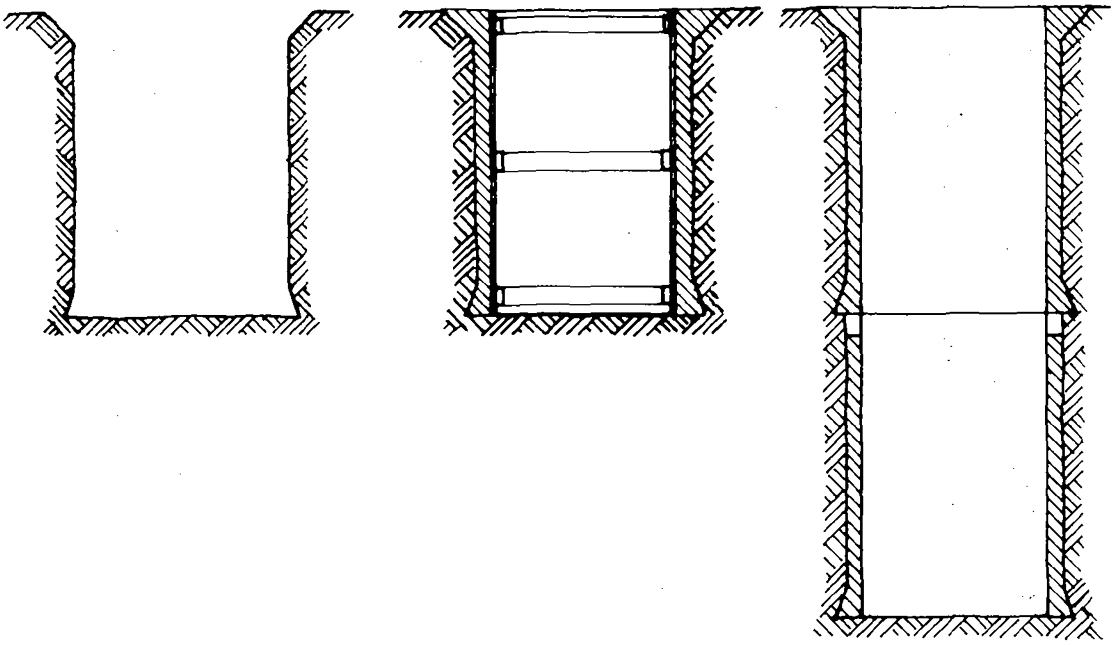
Brickwork



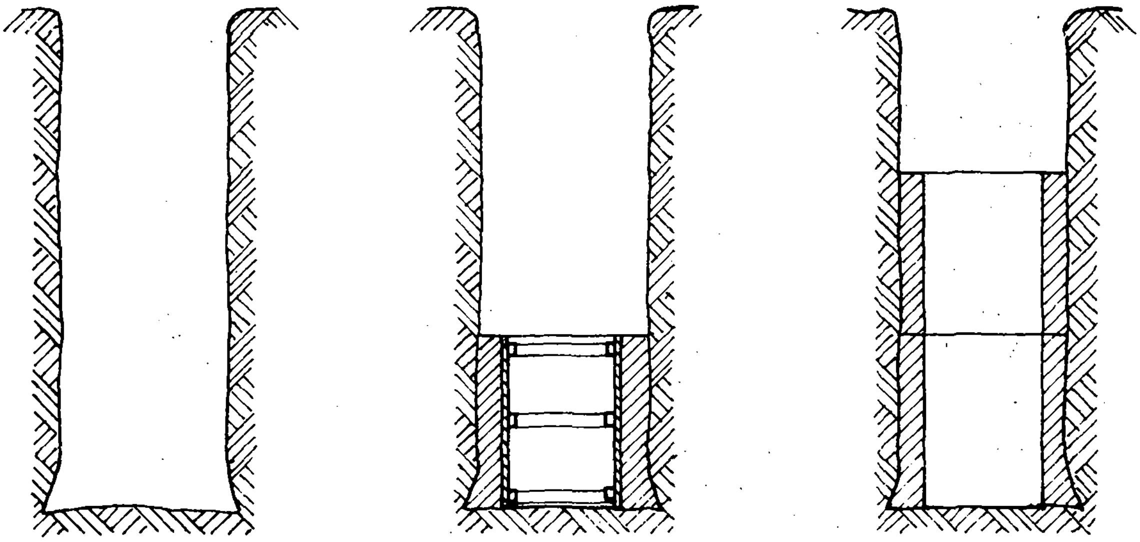
Stone masonry

There are three main systems for lining a well:

A. Alternately deepen and line the well shaft.
Possibilities for lining are:
1. (reinforced) concrete, cast in place
2. concrete trowelled into grid of reinforcing rods
3. brick or stone on concrete footing, anchored into sides of excavation.



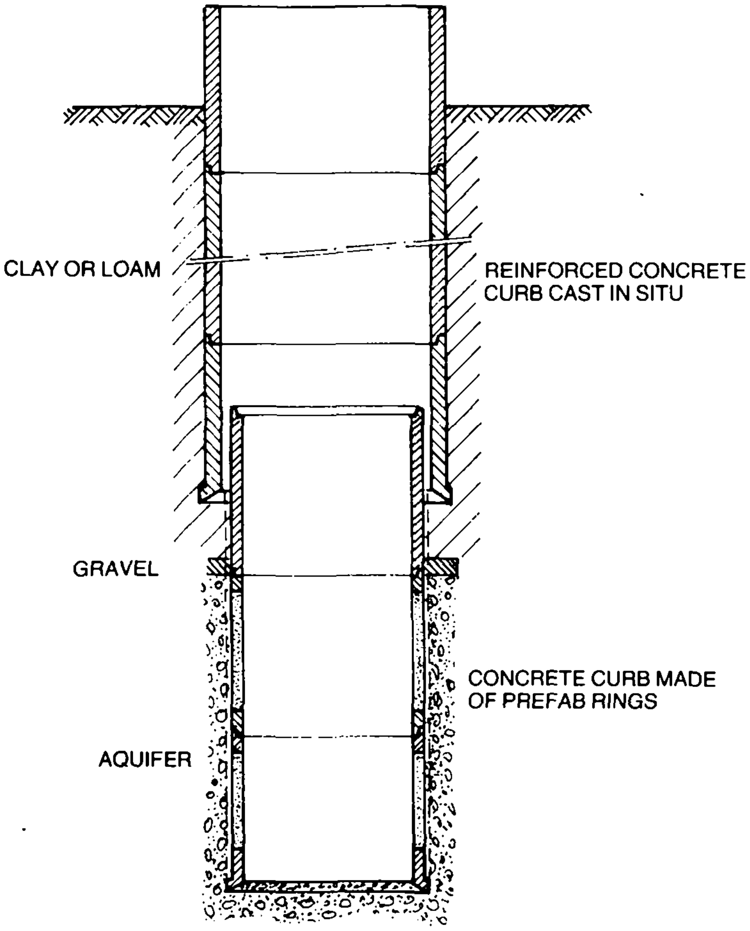
B. Excavate to the water table, and then build lining upward
(the unlined shaft in this case may be a safety hazard)
Possibilities for lining are:
1. reinforced concrete cast in place, or concrete rings
2. brick or stone on concrete footing
3. timber cribbing or other wood construction



C. Sink a pre-formed cylindrical lining by undermining

Possibilities for lining are:

1. precast concrete caisson rings
2. brick or stone on reinforced concrete or steel cutting ring
3. prefabricated steel caisson
4. vertical planks supported by horizontal rings



Methods A and B must be used in conjunction with the caisson method (C) to finish the well, but have the advantage that the well depth may be virtually unlimited.

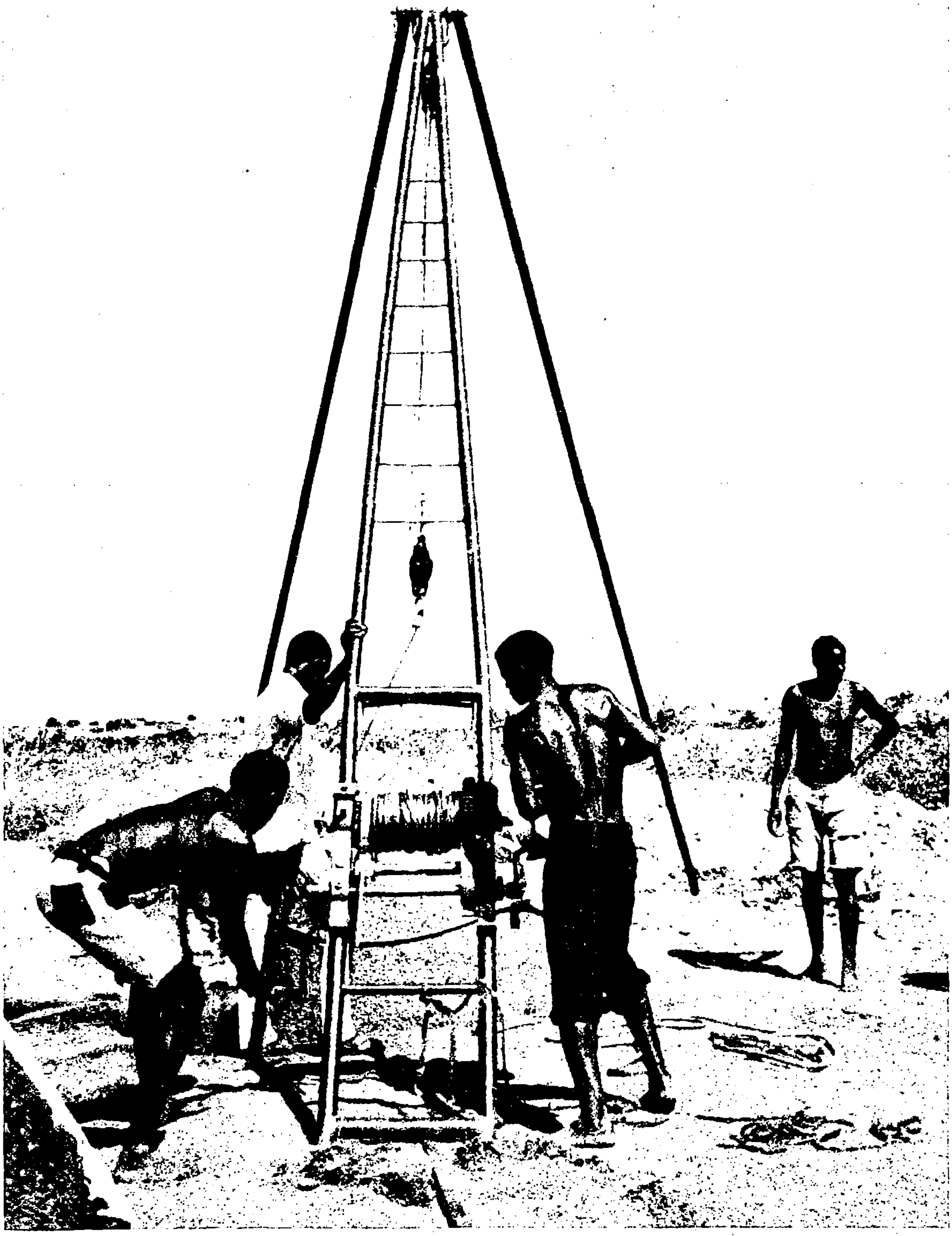
Caissoning over the entire depth, as is the practice in many projects, offers various advantages:

- the equipment required is simpler
- the amount of steel reinforcing rods for the concrete is reduced
- practically all construction work can be done at the surface
- advance site preparation and production techniques can speed up the work considerably.

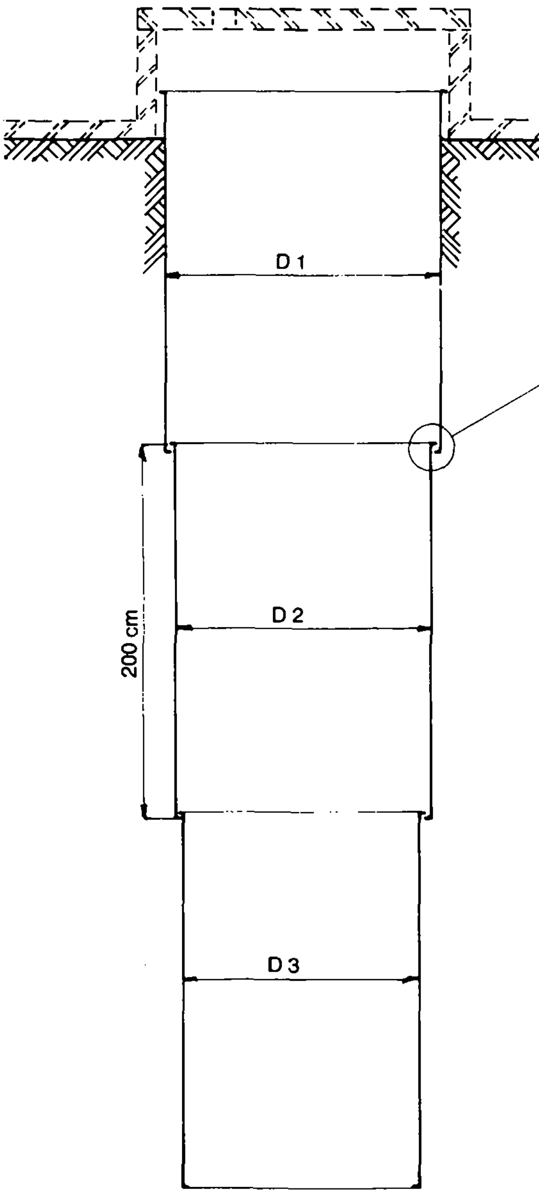
The method also has several disadvantages, however:

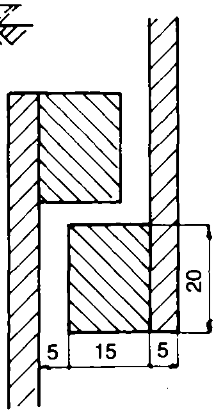
- it is difficult to keep the shaft vertical
- boulders and large stones can cause the caisson to tilt
- the friction between lining and shaft wall is irregular, as a result of which stresses are set up that may cause slipping, jamming or opening of construction joints.

A possibility to overcome these problems, is the use of a - temporary - steel caisson, that is sunk in the way indicated under method C, and in which a lining of concrete, brickwork or stones is then built according to mehtod B.
Thereafter the temporary steel lining is pulled up, and the annular space around the remaining lining filled (with sand/gravel at the filter rings and clay or similar material further upward).



P.E. AS LINING MATERIAL

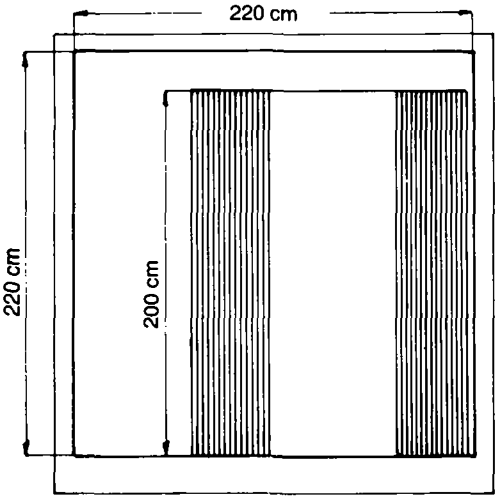




Various diameters of the PE rings.

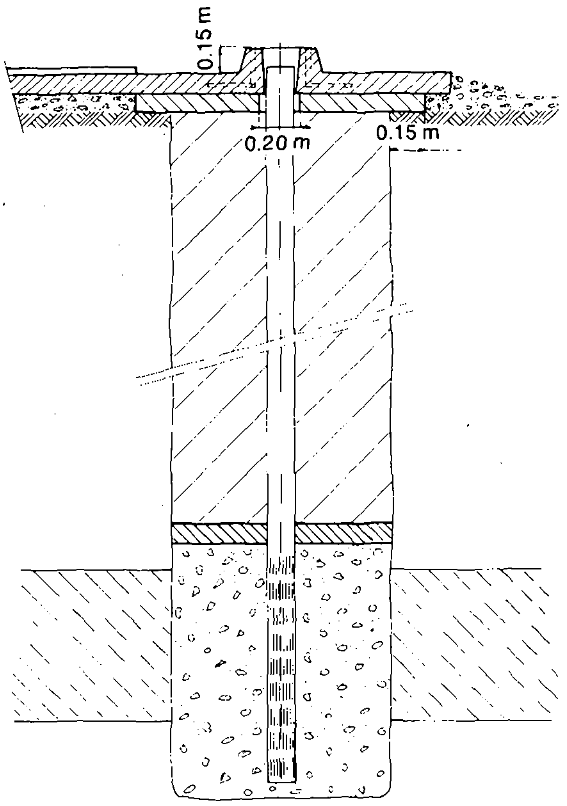
D 1 = 150 cm.
D 2 = 145 cm.
D 3 = 140 cm.
D 4 = 135 cm.
D 5 = 130 cm.
D 6 = 125 cm.
D 7 = 120 cm.
D 8 = 115 cm.
D 9 = 110 cm.
D 10 = 105 cm.
D 11 = 100 cm.
D 12 = 95 cm.
D 13 = 90 cm.
D 14 = 85 cm.
D 15 = 80 cm.

PE lining for a well of 30 metres depth. (during container transport)

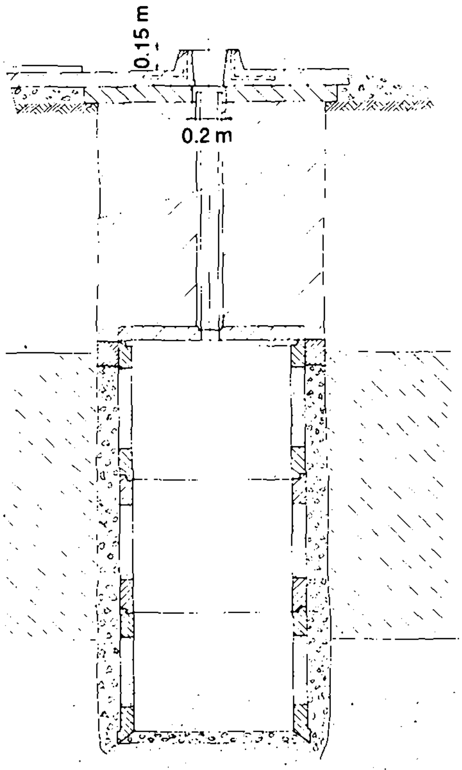


One of the disadvantages of large-diameter wells, viz. their costly lining, can be reduced considerably by either of two methods:

- reduce the well diameter just above the highest groundwater table. Thus the total storage capacity of the well is maintained at a considerably reduced cost of the lining.
- place a PVC casing/filter pipe in the center of the well and backfill with small stones, coarse gravel or stone chippings.
  The total cost of the well is thus reduced considerably, whereas the net storage capacity can still be as high as 40 to 50 percent of the gross well volume.



Backfill well



Ring well with reduced upper diameter

Typical costs of 12 m deep wells are as follows:

hand-drilled well	:	$ 3000
hand-dug well (with backfill)	:	$ 4000
hand-dug well (with concrete rings)	:	$ 5500

A detailed description of the hand-digging procedure and the equipment used is given in paragraphs 5.3. and 6.3., respectively.

4. Who owns or maintains the well?

A matter which has been more or less overlooked in the past, but is justly receiving growing attention is the question of ownership of wells/pumps, as it directly influences the operation and maintenance, and thereby the success of the water supply system.

4.1. Privately-owned wells / Community-owned wells

Privately-owned wells as a rule have cost their owner a certain investment that he or she will want to safeguard. The operation and maintenance of private wells will thus normally not be a problem. This is even more so with wells that are put to a directly productive use, as a malfunction there would result in an interruption of production and, thereby, a loss of income for the owner.

Community wells, on the other hand, have sometimes been 'dumped' on their users by a government that has been sincerely concerned about the health and material well-being of the population, but unable to spare the funds and/or manpower for having the actual well construction accompanied by a full-fledged community participation or extension programme.
However, except in those rare cases where sufficient funds are available to have the operation and maintenance carried out by a centralized government organization, the active cooperation of the villagers will be indispensable for reducing the cost of operation and maintenance to an affordable level.
Thus at least some degree of community participation will be required.

The construction of wells should go together with an information and training programme for operation and maintenance, which involves all people concerned:

- users
- mechanics
- attendants/caretakers
- village leaders

Subjects covered in such a programme should include:

- use of the pumps
- maintenance
- repair (small and large)
- where are spare parts available?
- responsibilities
- productive use of water
- health, etc.

In addition, radio broadcasts, newspaper campaigns, stickers, etc. an be used for popularizing key issues regarding water supply.

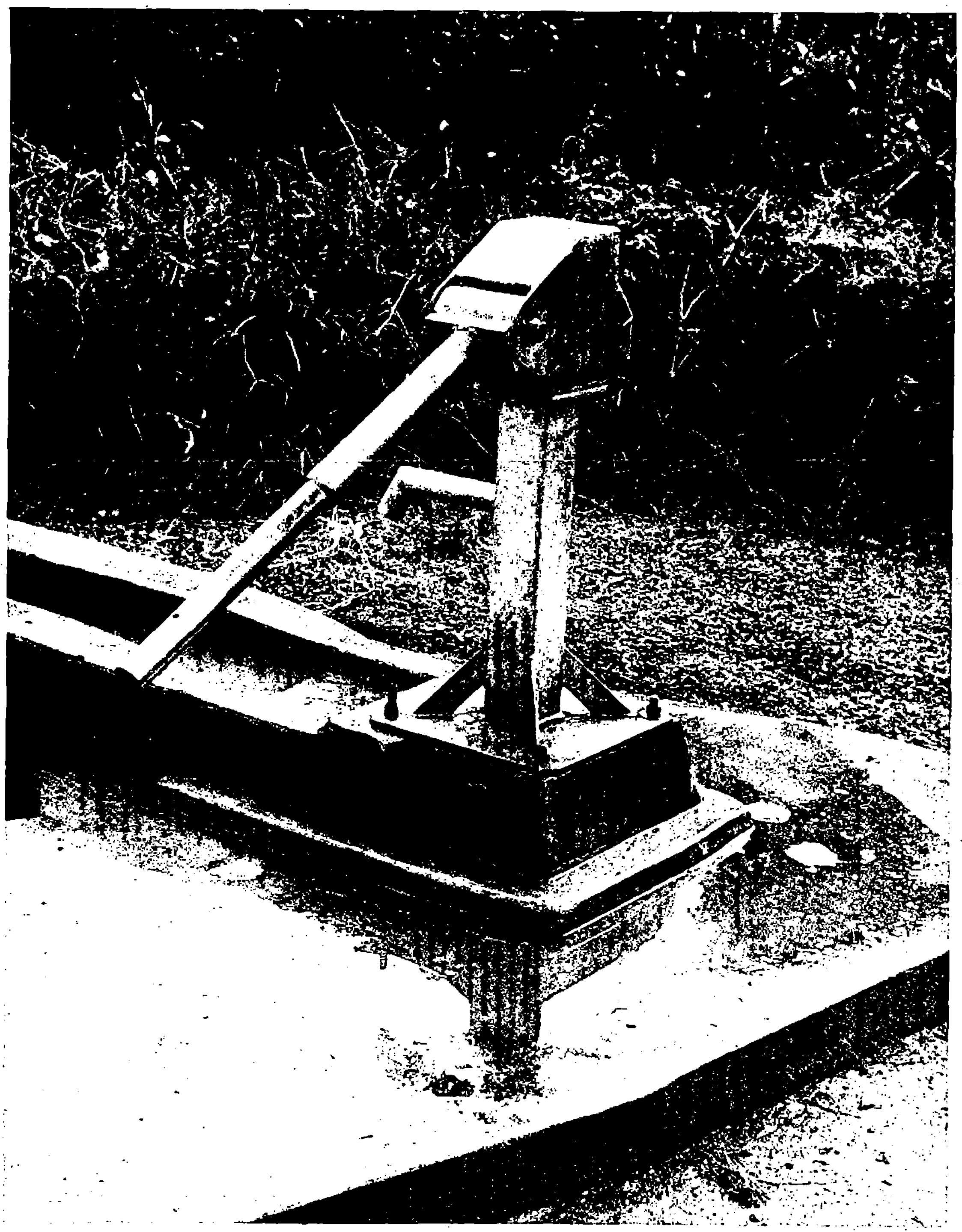
4.2. Incentives for local maintenance

Possibilities for guaranteeing a proper (preventive) maintenance of wells, pumps and their direct surroundings are:

- construct wells in those villages only, where the population has specifically requested wells
- have the local population contribute to the construction (in cash or in kind, though the possibility of the latter may be rather restricted in practice), so as to accomplish some sense of ownership.
- have the local population appoint a paid pump attendant for maintaining one or more pumps and wells
- sell or rent the well to someone who is willing and able to commercially exploit the well and sell water to the villagers at a predetermined rate (which should of course be acceptable to all parties concerned), thereby being responsible for the upkeep of the well

- appoint an - unpaid - pump attendant, who is allowed to use the well - outside the hours of normal water collection - for watering his or her private plot or cattle, or use the water in another, directly productive way, thereby establishing a more direct relation between the degree of maintenance of the well, and personal income.

Which of these options might be feasible, and wether or not additional community participation or extention programmnes would be necessary, depend entirely on the local circumstances, political situation, etc.



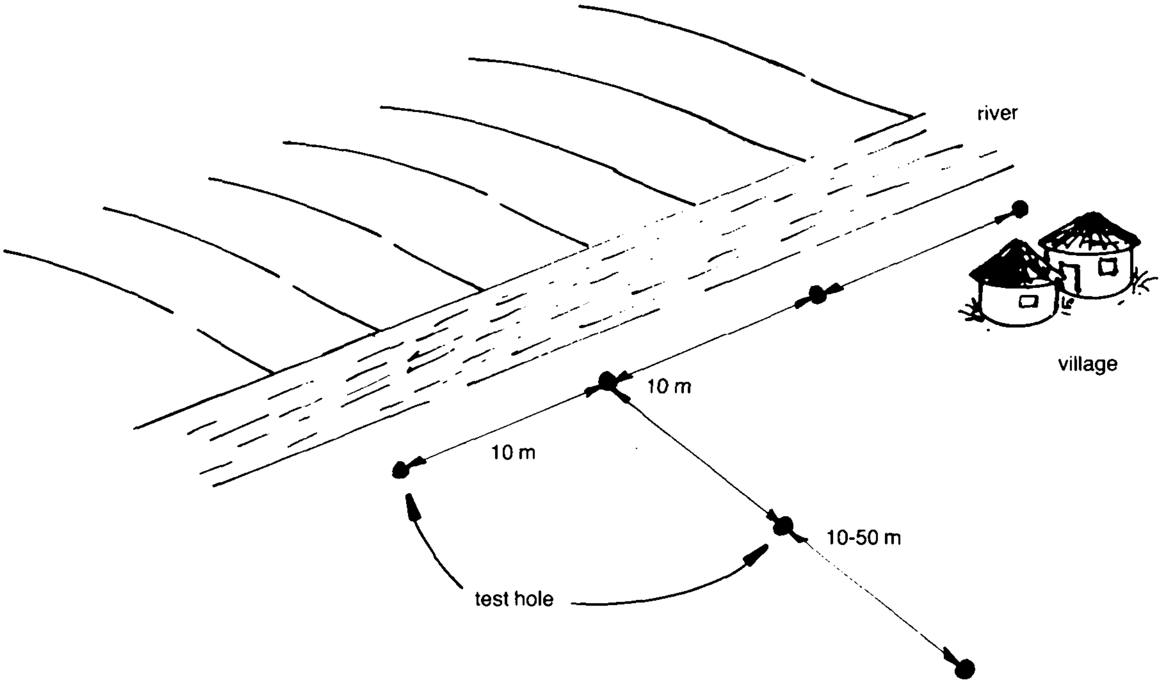
5. Construction methods

5.1. Survey by hand-drilling

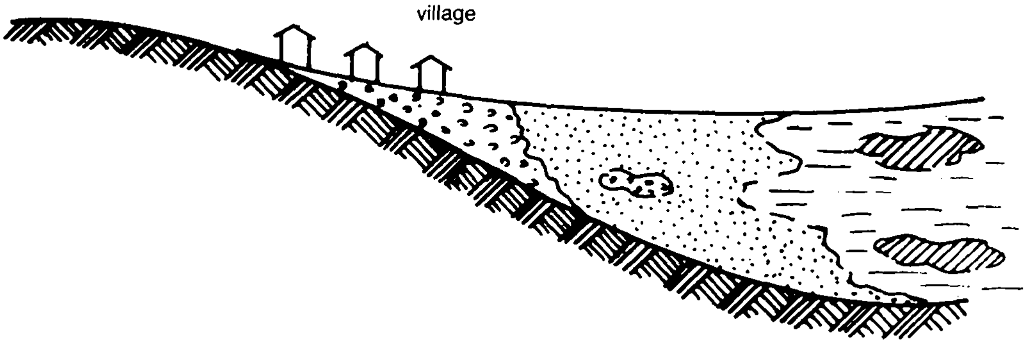
5.1.1. Selection of test drilling sites

Test drilling is done at promising well sites only.

Near rivers: Test holes must be drilled at approx. 10 m from the river bed, in a line parallel to the river.
Whenever a promising aquifer has been found, a new test hole can be tried, closer to the village, in a straight line between the successful test hole and the village.

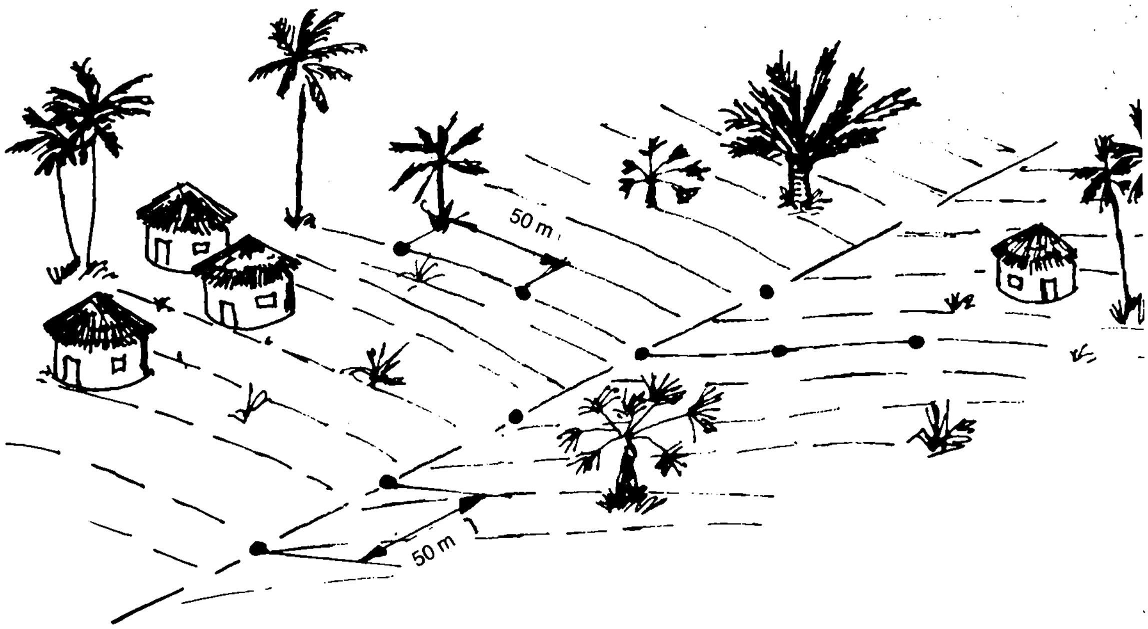


In foothills: Try to find a good site in the low, flat area.
Thereafter, try to find a good site closer to the village, in a straight line between the last successful hole and the village itself.



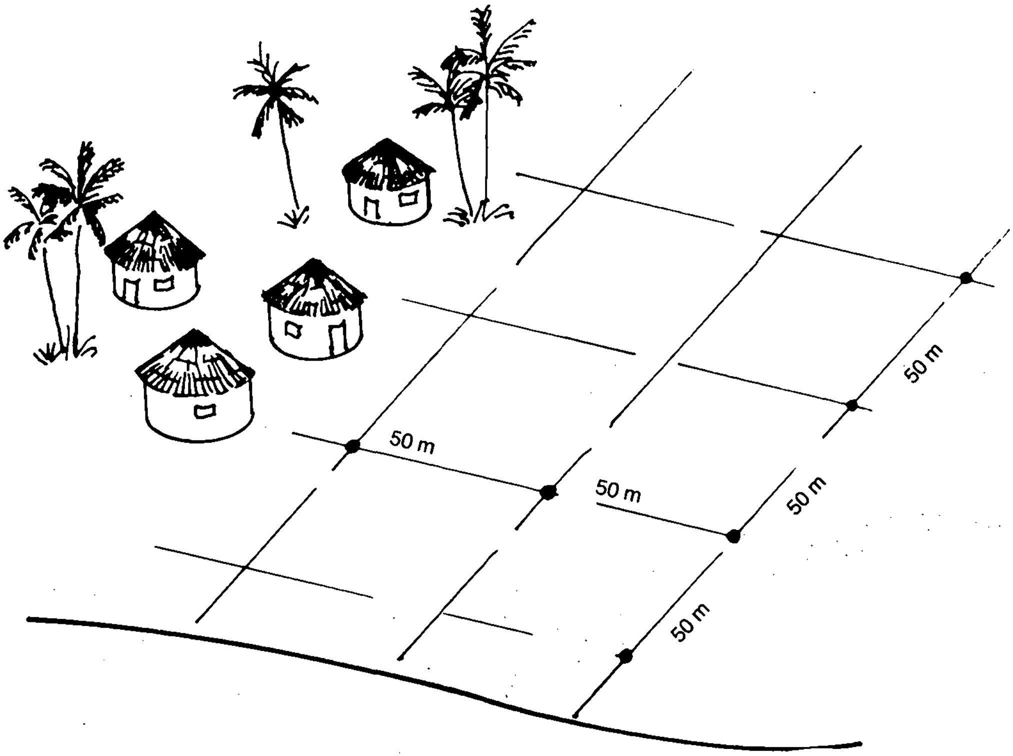
In dry valleys:

If the width of the valley is not more than 100 - 200 m, drill test holes in one line across the valley and one line along its axis. Distances between drillings must be approx. 50 m.



In the plains:

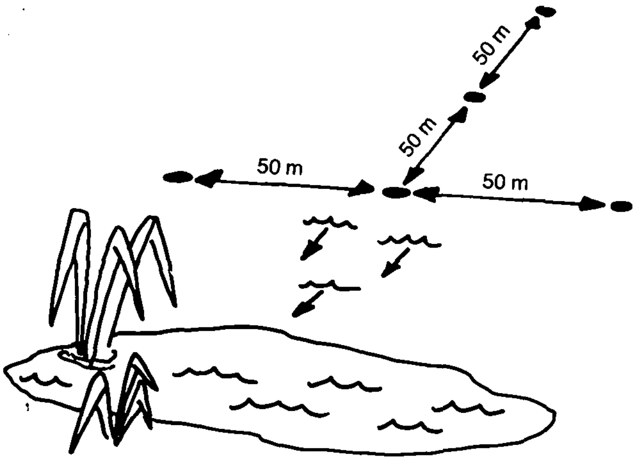
If the village to be provided with water is situated in the plains, test drilling can only be more or less at random.
Carry out test drillings all around the village, taking into account any planned extension of it.
In this situation it is even more important to collect information from the local population first.



In sloping terrain:

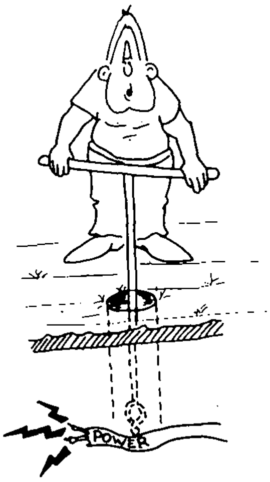
Carry out test drillings in a line perpendicular to the direction of slope.

Near pool, lake or wet area: First determine if, and from which side, the pool, lake or wet area is fed by aquifers. Then cary out test drillings at the upstream side.



5.1.2. Test drilling procedure (survey)

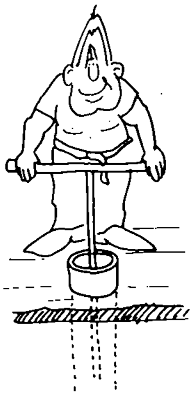
Check the equipment:
- see that no items are missing
- check welds and connections; have (almost) broken connections repaired first
- check the outer diameter of the drilling bits; replace or repair bits that have w0rn out
- check casing pipes for cracks, etc. Do not use cracked casing pipes
- smoothen damaged thread with a file
- check connections of test pump riser pipe; repair damaged thread
- check action of foot valve; replace foot valve in case it does not close tight (for bailer as well as for test pump)



Drill a test hole
Do not drill in the immediate vicinity of power lines.

Do not drill close to trees:
- the drill may get stuck between the roots
- even if drilling would be successful, roots may later penetrate the well screen and (partly) block the well.

Clear an area of approx. 2m x 2m around the drilling site, and remove high grass.

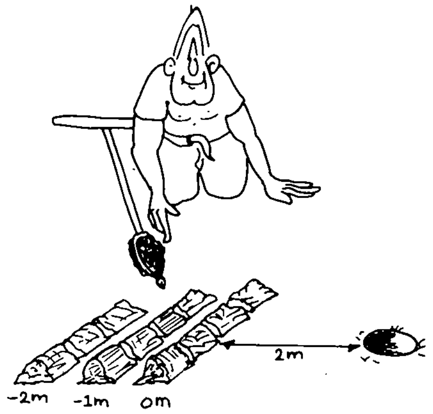


While drilling, maintain vertically.

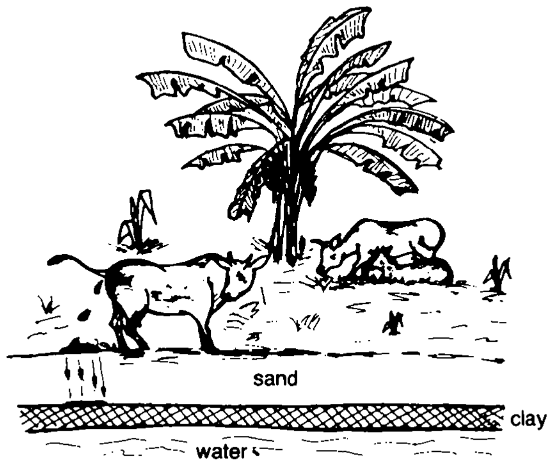
Normally start drilling with the riverside bit, Ø 10 cm.
Put the drill in a vertical position and turn it a few times around, while maintaining a downward pressure. Ensure that the drill remains exactly vertical.

The number of turns that are required to completely fill the drill bit depends on the soil composition and the vertical pressure exerted on the drill.
However ......

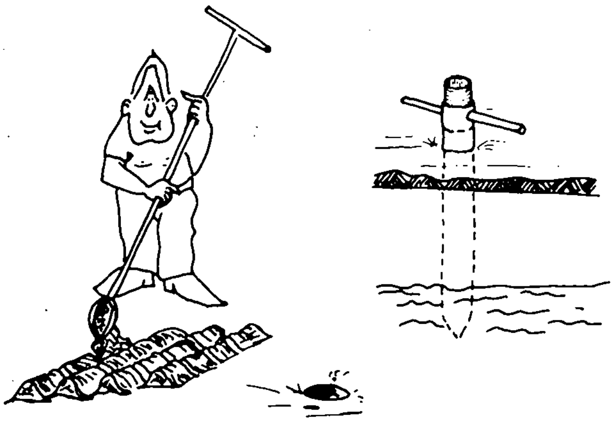
When drilling in clayey soil never completely fill the drill bit, because it would then act as a piston in the borehole. This might lead to a collapse of the borehole, and the drill may not be removed except with the greatest of effort.



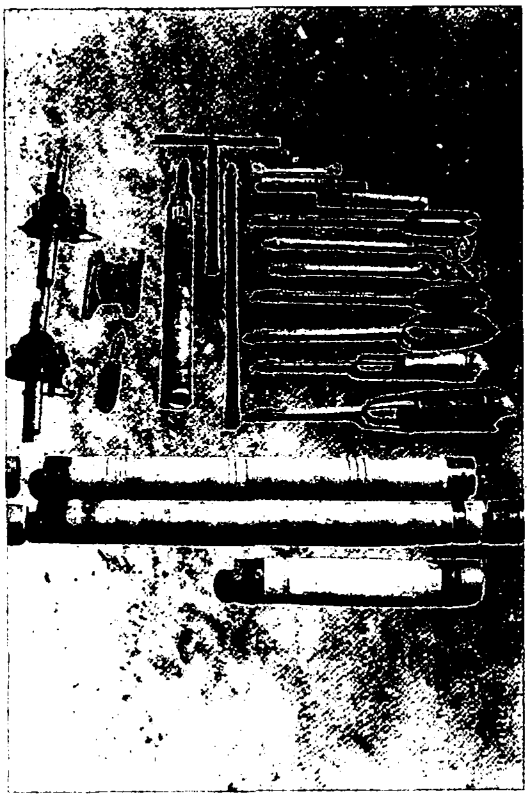
Take soil samples every meter and arrange them neatly in a row, next to the borehole.



Try to find an aquifer that is covered by an impermeable layer (at least one layer of clay) to prevent contamination of the groundwater from above.



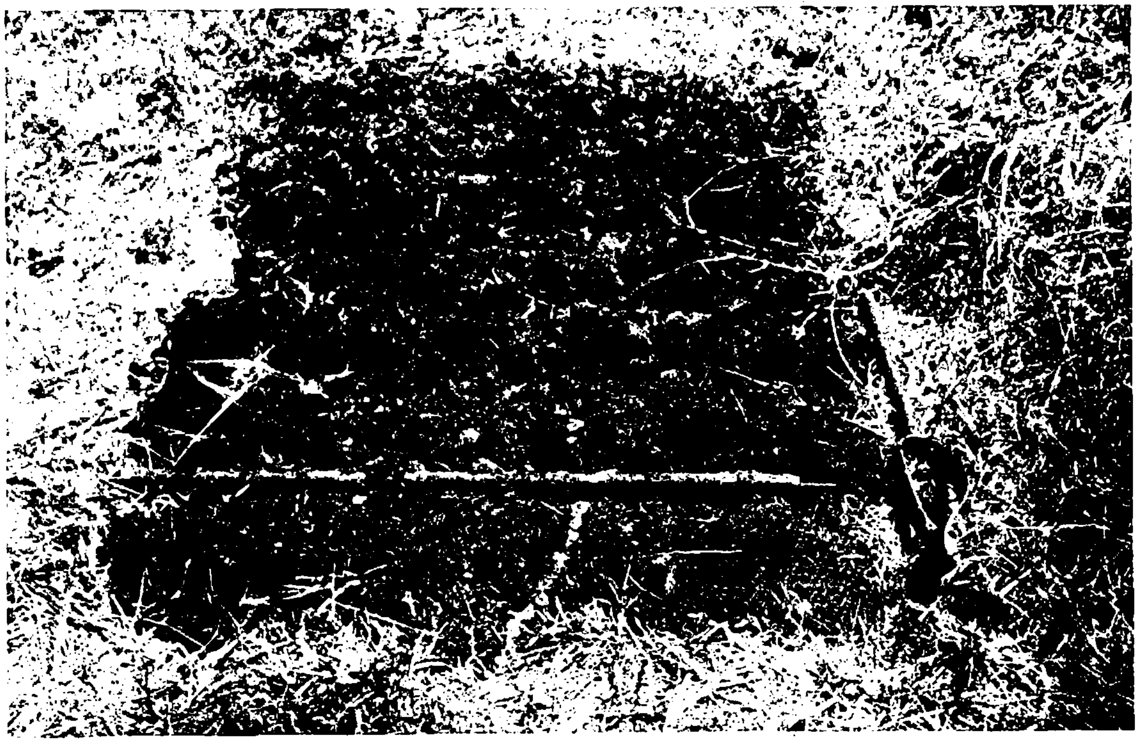
As soon as an aquifer is struck, insert a casing in the borehole to prevent it from collapsing. The casing hanger should be fixed to the top of this section of casing. After the casing has been positioned, continue drilling inside it, with 70 mm diameter bits.

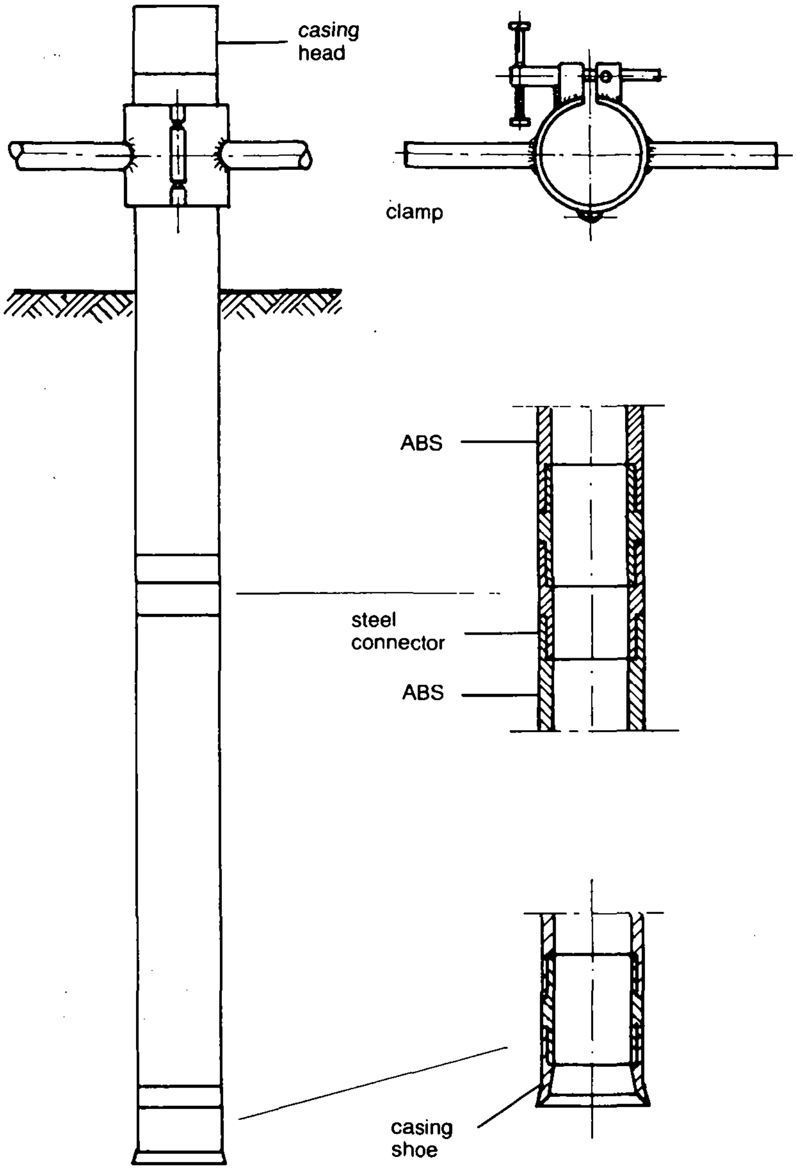


Hand-drilling survey equipment

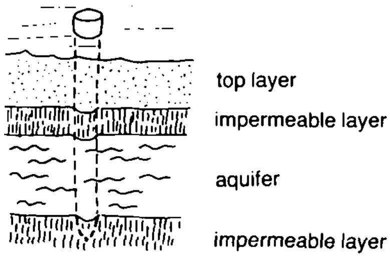
Survey by hand-drilling

Soil samples



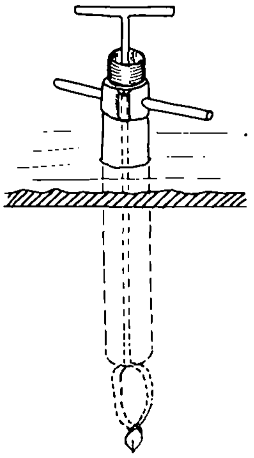


Casing for survey drilling 90/76 mm



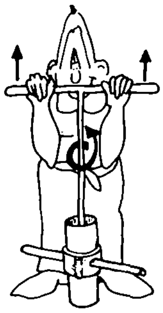
Continue drilling until an impermeable layer below the aquifer is struck. The thickness of the aquifer should not be less than 1 m in case of confined aquifers.

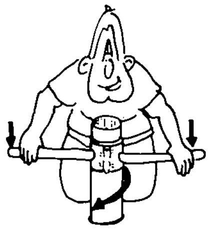
In situations where there is no impermeable layer on top of the aquifer, the latter should be at least 2 m thick.



When drilling inside a casing, never drill deeper than approximately one bit length below the casing.

Otherwise, the deeper part of the borehole might collapse on top of the bit, so that this would get stuck.

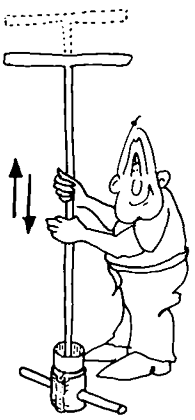




Immediately after pulling up the drill (in a rotating manner), press down the casing (also rotating).

To make working with casing pipes easier, it is essential that the borehole is straight and vertical.

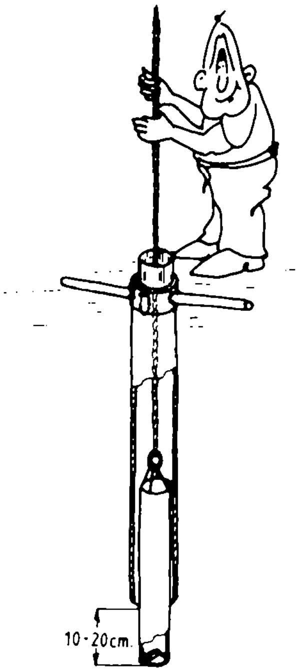
In a slanting borehole problems must be expected with the installation of casing pipe.

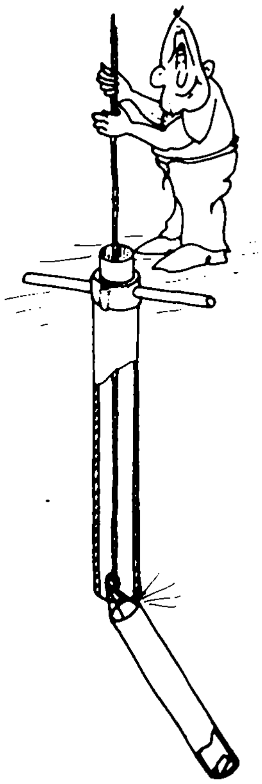


When the soil contains so much water that drilling with auger bits is no longer successful, use a bailer to continue deepening the borehole.

Bailing is only successful when the borehole contains some water. This may have to be added to ensure progress.

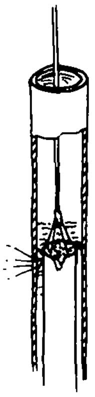
Bailing must be done by frequently lifting and droping the bailer. The vertical amplitude need not be more than 10 cm



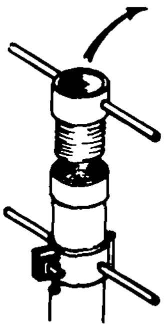


Take care that bailing is not carried out more than 10 - 20 cm below the casing shoe, as the hole might collapse and the bailer get stuck.

By bailing much water is normally removed from the borehole. In some cases this will cause caving in through the bottom, because of the difference in water pressure between the borehole and the ground. To prevent this, pour water in the hole before taking out the bailer.

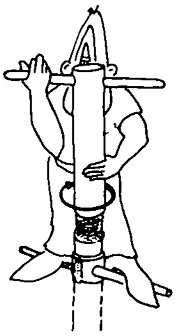


Prevent the bailer from overflowing inside the borehole:
sand might be washed in the space between the bailer and the casing, and the bailer might get stuck as a consequence, making it next to impossible to retrieve.



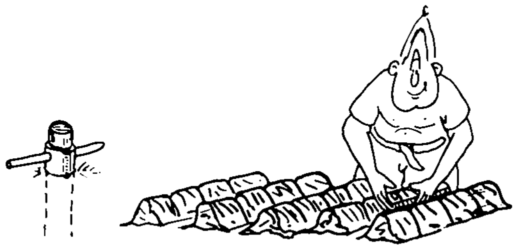
When the casing clamp at the top of the first section of casing has almost reached the ground, it is time to connect a second section of casing.

Attach a casing clamp just below the female end of a new casing section, and remove the thread protector from the female end of the first section and the male end of the new section. Then connect the new section of casing to that already in the borehole.

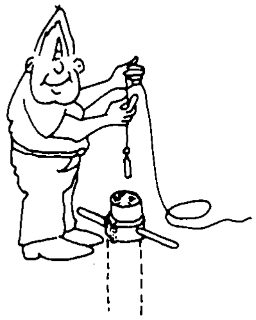


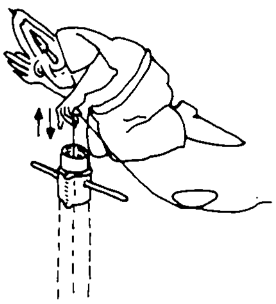
Place one foot on the casing clamp of the lower casing section during connection, to prevent it from being turned around. Remove the casing clamp after both casing sections have been joined.

When the test drilling has been completed, make a borehole description of the test hole, using the symbols as shown on page 105.



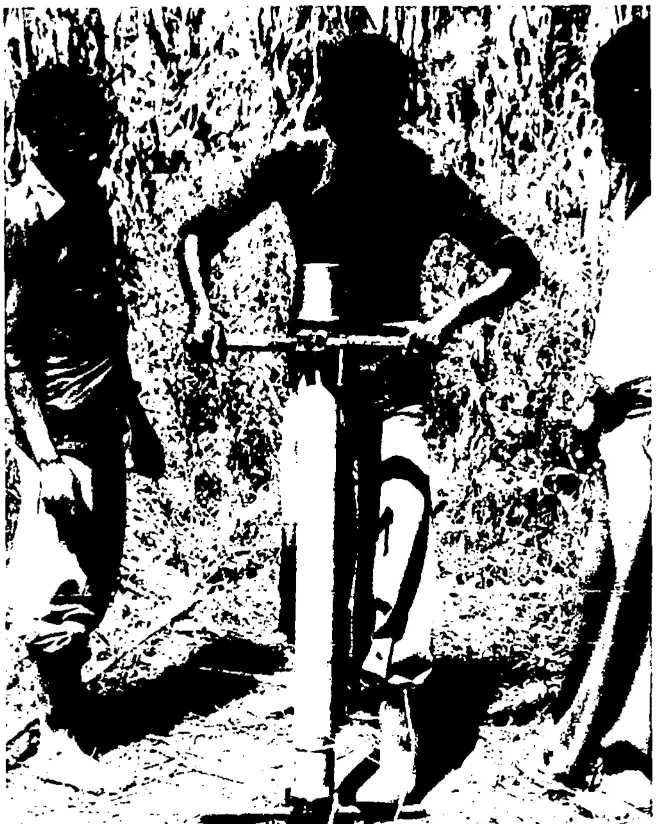
Remove the drilling equipment from the test hole. During lifting, the drilling rod must be disconnected in lenghts of not more than 3 m, to prevent bending of the rods/extensions.





Measure the water level with a water level indicator (acoustic signal).

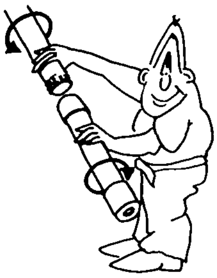
Measure the total depth of the borehole, with a weighted rope.



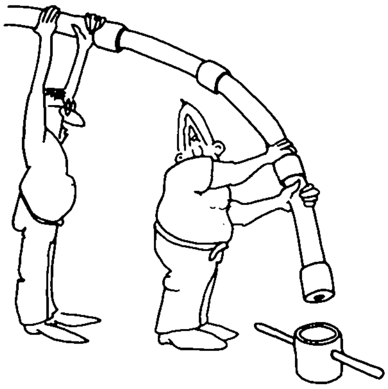
Placing the casing

Removing the augering string while pressing down the casing

Carry out a pump test:

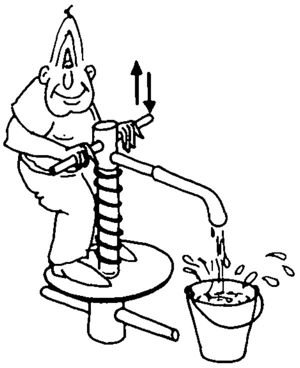


Connect a number of riser pipes for the test pump, until their combined length equals the total depth of the borehole minus 1.50 m.

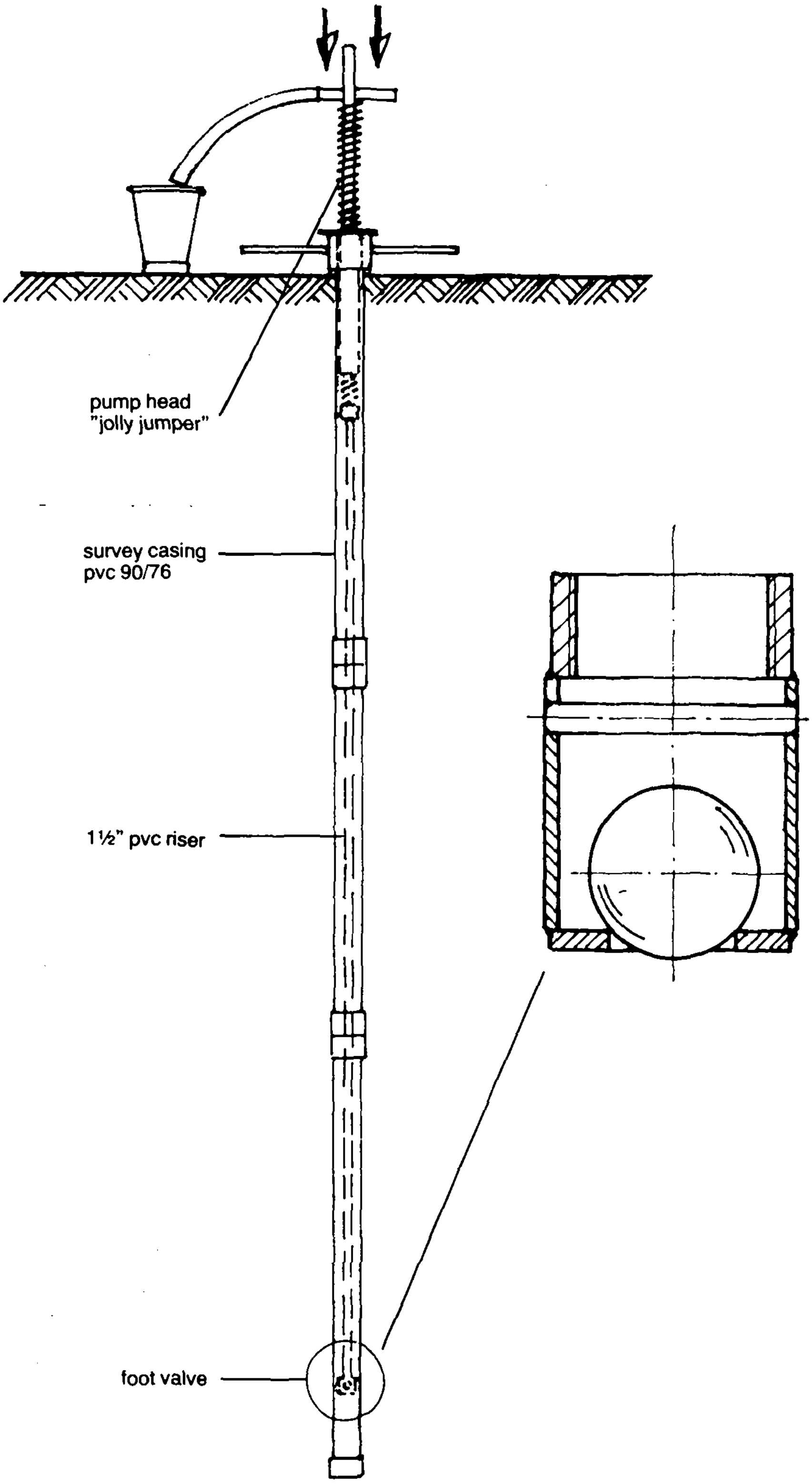


Check that the bottom section of the riser pipes contains the foot valve. Do not use wrenches or similar tools for jointing the riser pipes.

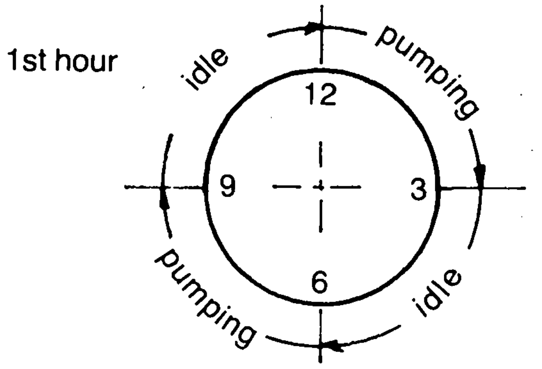
Lower the riser pipe assembly into the test hole (do not drop!) and connect it to the test pump.



Lower the test pump until its foot plate rests on the casing clamp. Start pumping by moving the pump body up and down, as if using a bicycle foot pump.



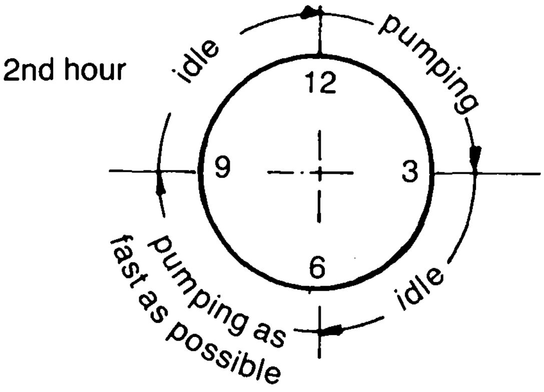
Well capacity testing



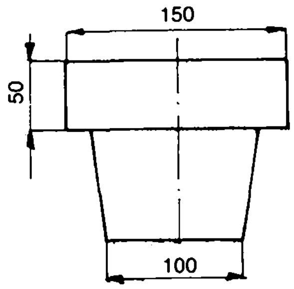
First pump 5 bucketsful of water from the test hole, to develop it.

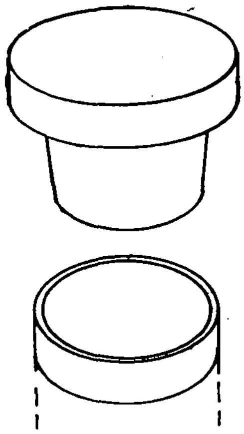
Collect a water sample and check the water quality.

For 2 hours carry out a pump test, pumping with 15 minutes intervals. During the test, measure and record the yield, water level and - if possible - the electrical conductivity of the groundwater just before and after each pumping cycle.
At the end of the pump test, once more determine the electrical conductivity, taste, smell and colour of the water. Enter the results on the borehole description form overleaf.



Remove the casing sections one by one: after pulling up the topmost section by the casing clamp, connect another casing clamp to the second section and disconnect the first section.
Attach a thread protector to the underside of the first section and remove the casing clamp. Then fix the thread protector to the top of the first casing section.





Repeat this procedure until all casing sections have been removed from the test hole.
If construction of the well is not carried out immediately afterwards, place a marker or bench mark at the test hole site, if the site has proven to be successful (see paragraph 5.1.3.).

SURVEY AND WELL LOG FORM

BOREHOLE No. 432/1
Date : 03-09-1985
District : Arawara
Village : Bonanza
Location : Calorama

Depth in cm below ground level	Grain size	Lithology	Colour	Type of auger	Water content		
					dry	medium	wet
0 - 50	–	cl	blk	cl	×		
50 - 150	–	cl	blk	cl	×		
150 - 250	–	cl	br	cl	×		
250 - 350	–	cl	br	cl	×		
350 - 450	–	cl	br	cl	×		
450 - 520	–	cl	ye, br	cl		×	
520 - 620	fn	slt	ye	rd			×
620 - 750	me	sd	or	rd			×
750 - 880	=	cl	or/red	rd		×	
880 - 1000	fn	sd	or	ba			×
1000 - 1220	cs	sd	ye	ba			×
1220 - 1300	–	cl	gy/ye	cl		×	

PUMP TEST

t min.	No. of buckets	EC	F⁻ mg/l	Colour	Taste	Odour	Water level
t_0	—	350	1.5	clear	none	none	- 6.
t_{15}	15/15 min						- 6.80
t_{45}	15 "						- 6.90
t_{75}	14 "						- 6.90
t_{105}	14 "	400	1.5	clear	none	none	- 6.90

1120 lt/h

RECOMMENDATIONS FOR CONSTRUCTION

Total well depth	Hand-dug	Hand-drilled	Depth of screen	[✓ APPROVED]
12.50 m		×	900 - 1200	DISAPPROVED

5.1.3. Criteria for approval of well sites

Approval or rejection of a survey test well depends on:
a. the yield of the pump test
b. the appearance, colour, odour, taste and E.C. of the groundwater
c. the location of the test well
d. the hydrogeology of the site

Re a
If the pump test yield is more than 1000 litres per hour, the well is suitable for construction as a hand-drilled well of limited diameter (see paragraph 3.3.).

If the yield is between 500 and 1000 litres per hour, the survey will be continued at this site to try and find a well (usually in the same aquifer) which will yield more water. In case such a well cannot be found, the test hole with the highest yield may be selected for constructing a hand-dug well.

Re b
If, during the pump test, the electrical conductivity of the groundwater remains constant and below 2000 µS/cm, the well can be approved.

If, however, during the pump test the E.C. increases considerably without surpassing the 2000 µS/cm limit, this may be an indication that after a prolongued withdrawal the water might become too saline. In such a case the survey should be continued, to find a safer location.

When the salinity of the water is high already during the pump test, as indicated by an E.C. of more than 2000 µS/cm, the well site cannot be approved for drinking water purposes or irrigation.

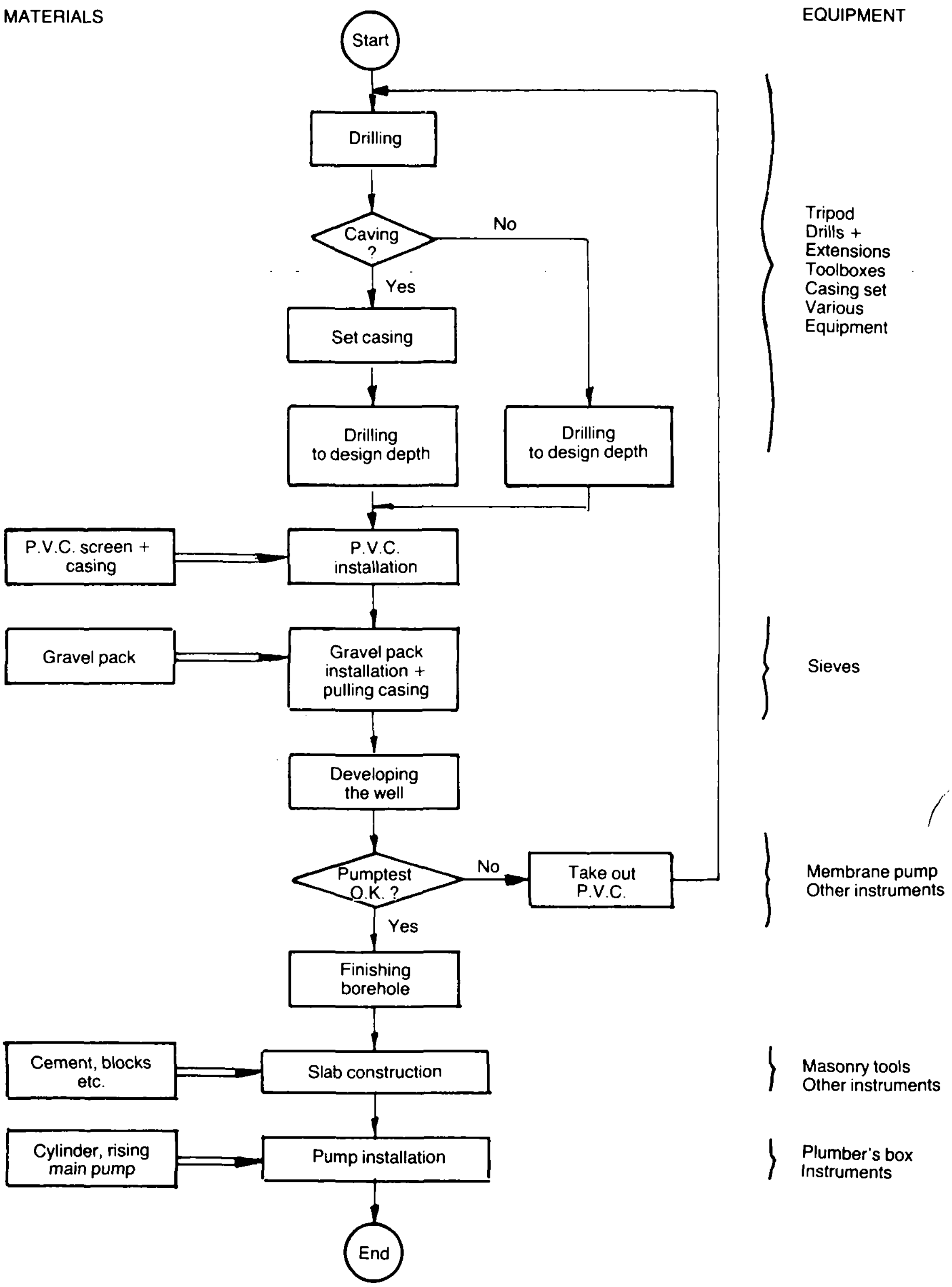
Sometimes the E.C. of the borehole water, as measured during drilling exceeds 2000 µS/cm, whereas the E.C. drops considerably during test-pumping.
In such a case it is safe to approve the well. Salts sometimes have a tendency to get concentrated in clays, and when drilling through clays the water in the borehole may get mineralized temporarily by these salts. When such a well is pumped, water will be drawn from the aquifer and the E.C. of the borehole water will quickly approach that of the aquifer itself.

Re c
The location of the well site is very important, and many factors have to be taken into consideration:
- the well site has to be within walking distance from the community for which the well is meant
- the location of the well has to be discussed with the future users because otherwise the well might not be used at all, and certainly if alternative, traditional water sources can be found closer to the community
- the well site must be accessible on foot throughout the year
- the site may not be subject to flooding during the rainy season
- the location must be such that there is no danger of contamination of the groundwater
- the location should not be in a depression, but rather on a slope or elevation, so that spill water and rain water will always drain away from the well.

Re d
When surveying a well site by means of test driling, gradually insight is gained into the hydrogeological conditions of the site.
This knowledge has to be used to evaluate the extent of the aquifer and its recharge possibilities, in order to ensure a continuous supply of water throughout the year.

5.2. Manual drilling of wells

The flow chart below indicates the steps to be taken for manually drilling a well.



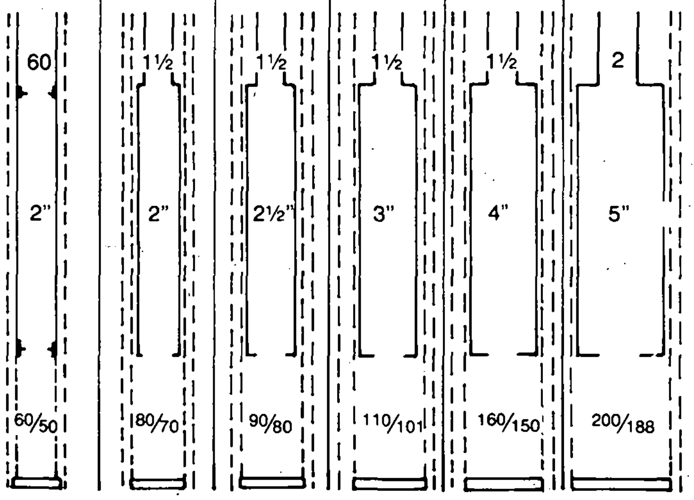
Flow chart of construction of a hand-drilled well

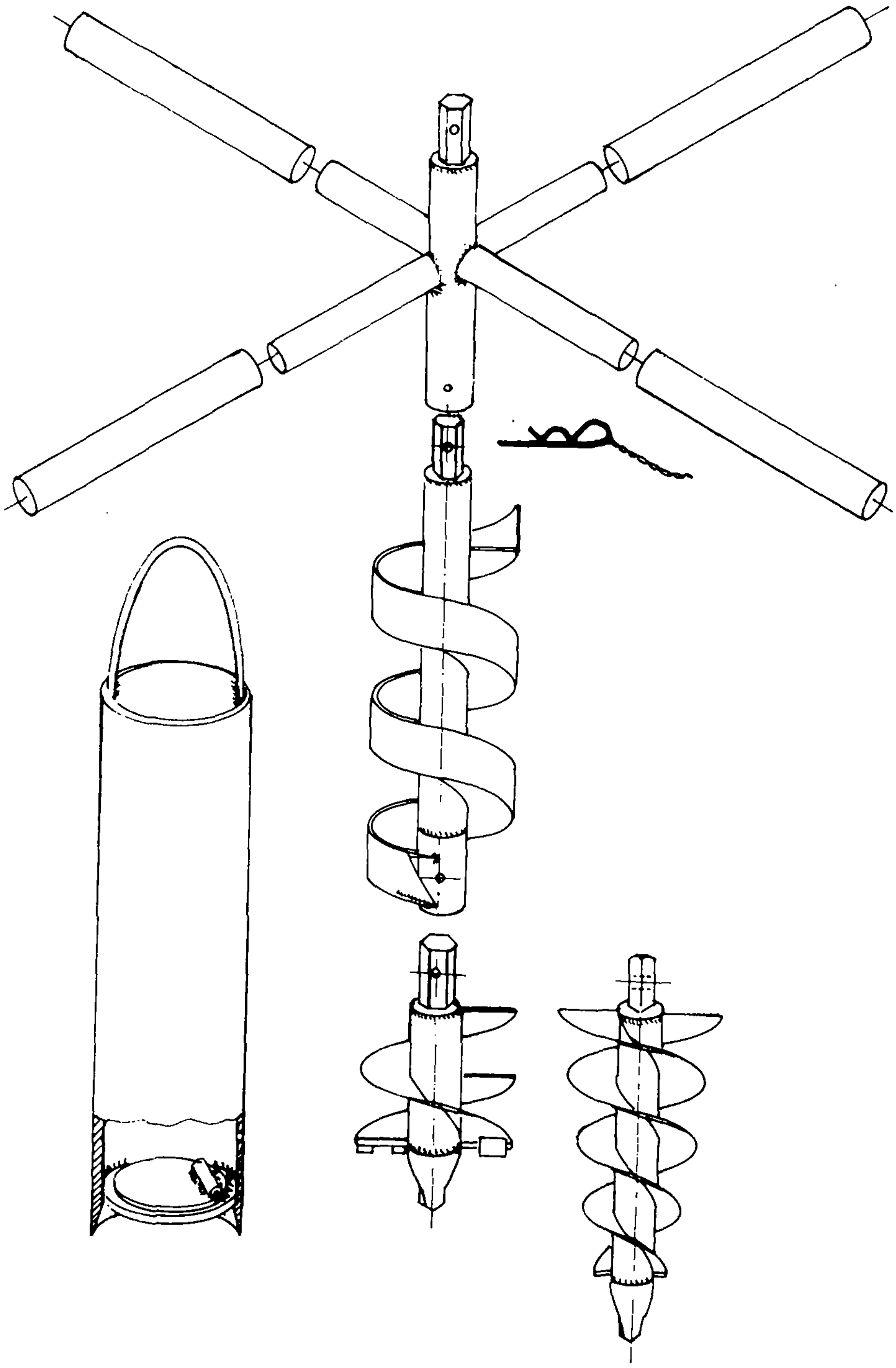
Based on the survey data the main characteristics of the borehole are determined:
- total depth to be drilled to
- length of screen to be installed, and length of standard (pvc) riser pipe required
- required diameter of the borehole, size of gravel pack material, etc.

The size of the pump cylinder is often the factor that determines the size of the borehole (see table below).

HAND DRILLING EQUIPMENT (SIZE IN MM)

type equipment	3"	4"	5"	6"	8"	10"
borehole drilling						
auger dia. (mm)	100	140	150	180	230	300
chisel dia. (mm)	30	40	45	50	55	60
rod dia. (mm)	Ø26	□30	□40	Ø76	Ø76	Ø76
coupling	conical	square	square	hex.	hex.	hex.
tripod		x	x	x	x	x
lifting equipment		pulley	pulley	winch	winch	winch
weight 25 m drilling rod (kg)	50	75	100	165	175	185
numbers of drillers	1	2	4	6	8	8
casing						
drilling pipe dia. (mm)	90/76	125/106	140/128	165/150	220/200	275/250
weight/m[1] ABS casing (kg)	6	10	15	20	25	35
weight/m[1] steel casing (kg)	10	18	25	36	45	55
casing drilling						
augers dia. (mm)	70	90	120	130	180	230
bailer dia. (mm)	63	80	100	120	150	165
weight of bailer (kg)	3	6	7	9	12	25
transport						
weight of set, complete (kg)	200	500	700	1000	1200	1500
means of transport	bicycle	bicycle	LR	LR + tr.	LR + tr.	truck
inside diameter casing	76	106	128	150	200	250
riser	60	1½	1½	1½	1½	2
cylinder	2"	2"	2½"	3"	4"	5"
filter	60/50	80/70	90/80	110/101	160/150	200/188

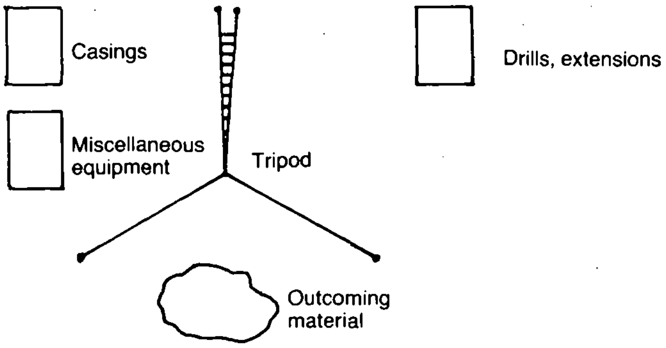




Heavy hand-drilling equipment

5.2.1. Hand-drilling procedure

- Check the equipment:
  - see that no items are missing
  - check welds and connections; have (almost) broken connections repaired first
  - check the outer diameter of drilling bits; replace or repair bits that have worn out
  - smoothen damaged thread with a file.
- Do not drill in the immediate vicinity of power lines.
- Do not drill close to trees.
- In the immediate neighbourhood of an approved test hole (see paragraph 5.1.2.) clear an area of approx. 10 m x 10 m, and remove high grass.
- Set up the tripod and lay out the equipment in an orderly manner.



Plan of a construction site

- Select the correct size of drilling equipment (see table on page 57). Important factors are:
  - the maximum size pump cylinder that will be installed and, consequently, the size of the PVC casing/filter pipe
  - the thickness of the gravel pack, which should be at least 4 - 5 cm.

Hand-drilling in progress

The drilling equipment is essentially the same as that for the survey. The only difference is that it is several sizes larger and heavier. The equipment is hoisted and lowered by means of a pulley system, hung from a tripod with winch and cable. All separate parts, however, have been designed in such a way that they can be handled easily by one or two men.

- Mount a cross piece with handle bars on top of the (extended) drill, so that the drill can be turned into the soil by manpower. Usually 4 to 8 men are required to do the job, depending, of course, on the soil conditions.

The soil conditions also determine what type of drill has to be used.
Three types of drilles are available:

1. auger bit and flight auger, mainly used for clayey and silty materials, possible mixed with sand
2. conical auger bit, used to penetrate and crush very hard and dry clay layers
3. riverside bit, for use in layers which contain a lot of gravel or stones

Of all three types two sizes should be available: the larger for drilling without casing, and the smaller for use inside the casing.

- Normally, start drilling with the auger bit and flight auger. While keeping the drill vertical, turn it around, maintaining a downward pressure.

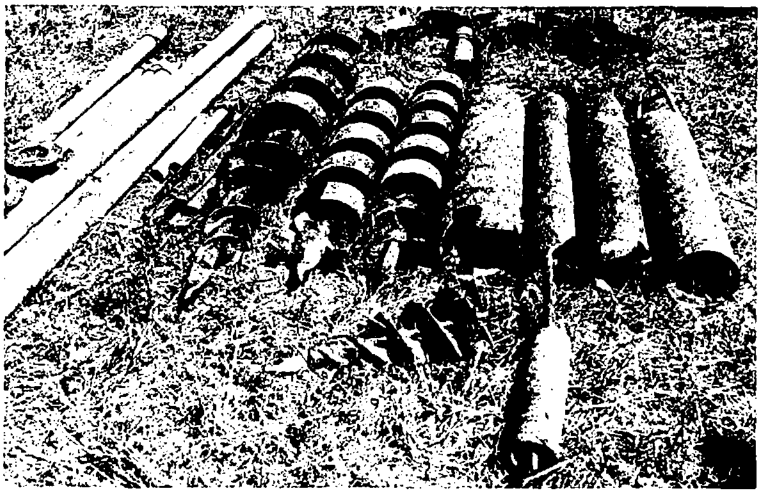
When drilling, maintain verticality. This is very important, as field experience has shown that many problems with pump rods and risers are caused by non-verticality of the borehole.

When the drilling assembly has been turned into the soil for approx. 40 cm, lift it by means of the winch.

Pull the auger to one side, empty it and clean it provisionally; then resume drilling.

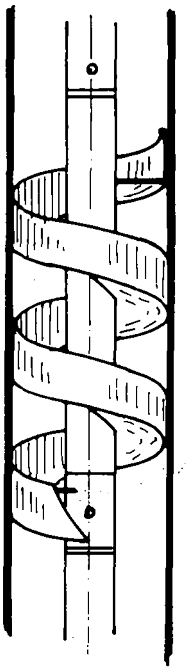
230 mm auger drill

Cleaning auger drill

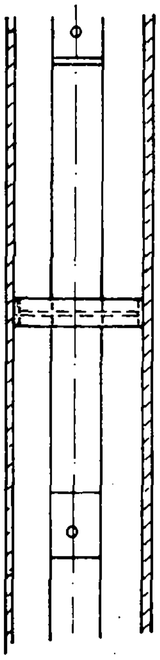


Drilling bits and augers for hand-drilling wells

- Take soil samples every meter, and arrange them neatly in a row next to the borehole.
- When the drilling has progressed so far that the cross piece and handles are within 50 cm from the ground, a drilling rod must be fitted between the flight auger and the cross piece.
  Then drilling is resumed and additional drilling rods inserted whenever necessary.
- When the total length of drilling rods exceed 5 m, a continuous flight auger or a drilling rod with centering device must be inserted half-way, to center the drilling rod assembly.



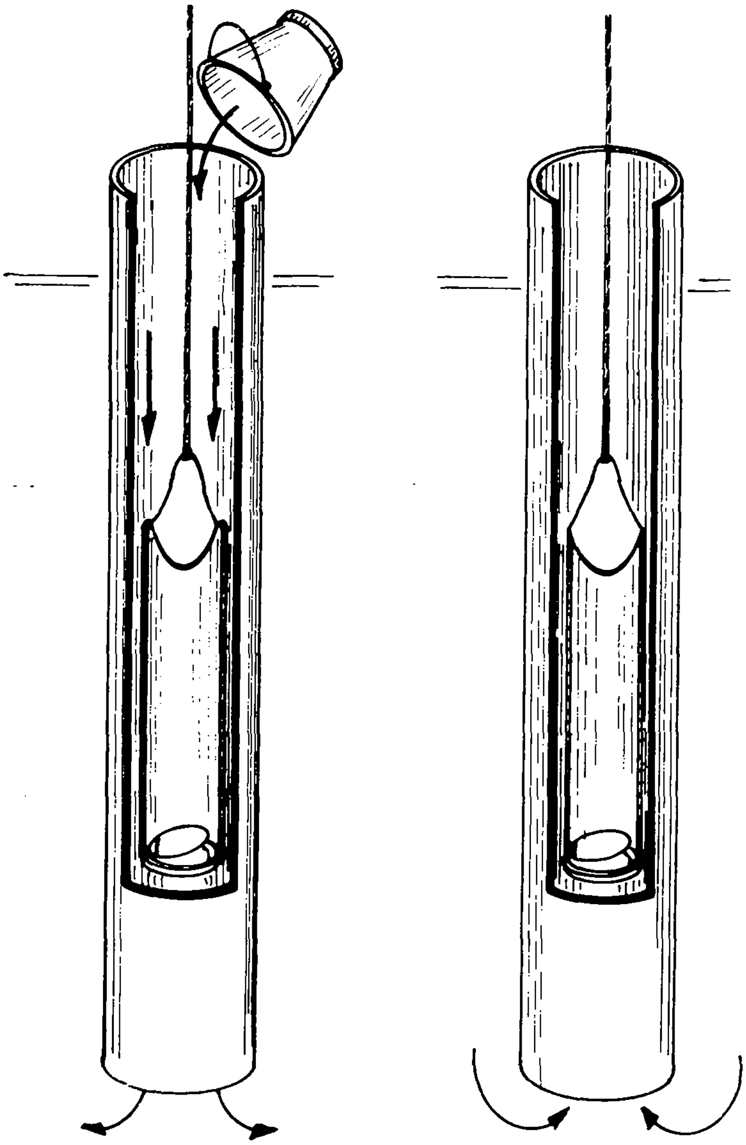
in borehole



in casing

- As soon as sand is struck below groundwater level, the borehole will tend to cave in.
  Insert a casing in the borehole, to prevent it from collapsing. The thread protector at the top of this section of casing also acts as a casing hanger.

After the casing has been put in position, continue drilling inside it, with the smaller-size bits and augers indicated in the table of drilling equipment on page 57.



Whenever possible, continue drilling until an impermeable layer below the aquifer is struck or a minimum depth of 6 m below the top of the aquifer has been reached. The thickness of the aquifer should normaly be at least 1 m in case of confined aquifers; otherwise at least 2 m.

Immediately after pulling up the drill, press down the casing while turning it around. To make working with casing pipes easier, it is essential that the borehole is straight and vertical.
In slanting boreholes problems must be expected with the installation of casing pipe, as with pumping equipment that will be installed on them later.

When the soil contains so much water that drilling with auger bits is no longer successful, use a bailer to continue deepening the borehole.
Bailing is only successful when the borehole contains some water. This may have to be added to ensure progress.
Bailing must be done by frequently lifting and dropping the bailer. The vertical amplitude need not be more than 10 cm.

Take care that bailing is not carried out more than 20 - 30 cm below the casing shoe, as the hole might collapse and the bailer get stuck.

By bailing much water is normally removed from the borehole. In some cases this will cause caving in through the bottom, because of the difference in water pressure between the borehole and the ground.
To prevent this, pour water in the hole before taking out the bailer.

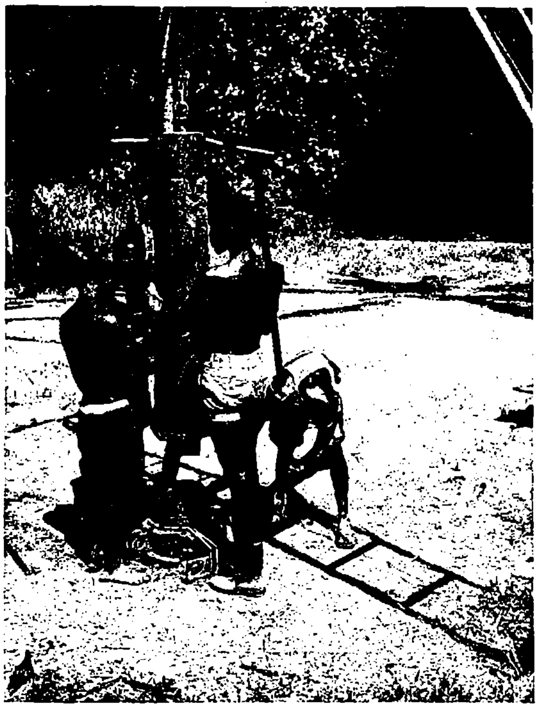
- Once the aquifer has been reached, drilling **must** be continued, to prevent the casing getting stuck or the borehole becoming filled with sand due to caving.

- Prevent the bailer from overflowing inside the borehole:
  sand might be washed in the space between the bailer and the casing, and the bailer might get stuck, making it next to impossible to retrieve.

- When the top of the first section of casing has almost reached the ground, the casing clamp is fixed around the casing, and the thread protector/casing hanger is removed.

Then the thread protector is removed from the male threaded end of the new casing section, and this section is connected to the casing that is already in the borehole.
After both casing sections have been joined, attach the casing clamp to the top of the new section.

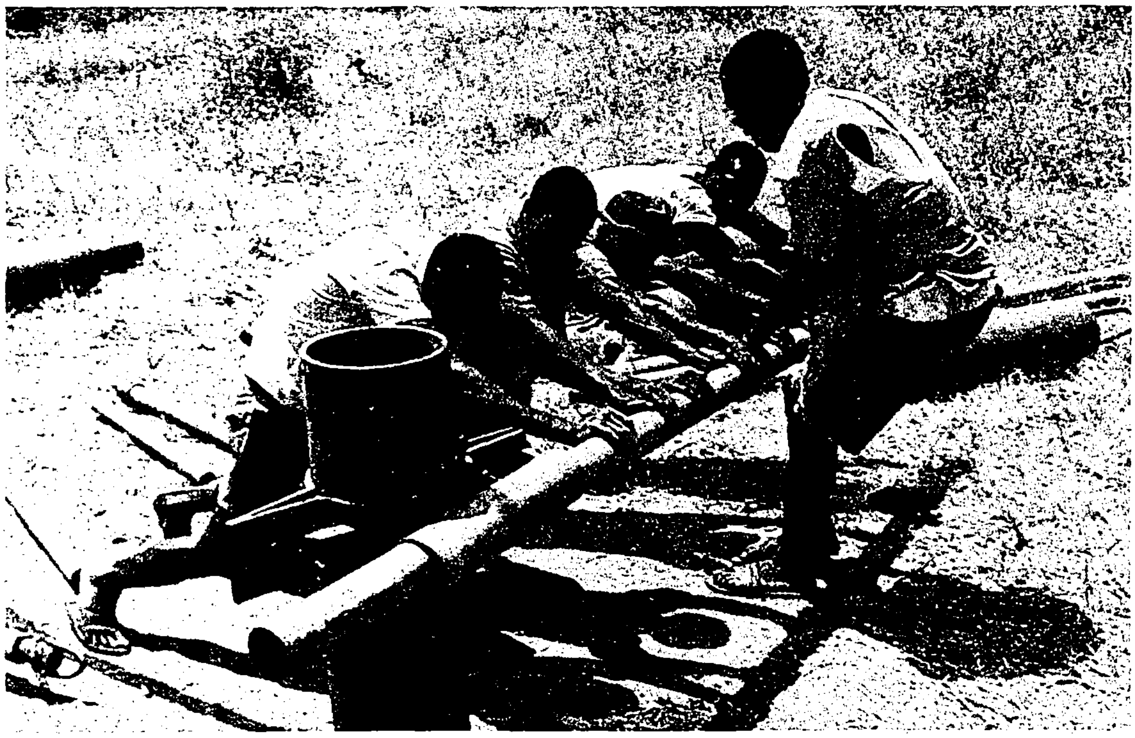
- When the drilling has been completed, make a borehole description. Use the symbols as indicated in the list of page 105.



Installation of casing

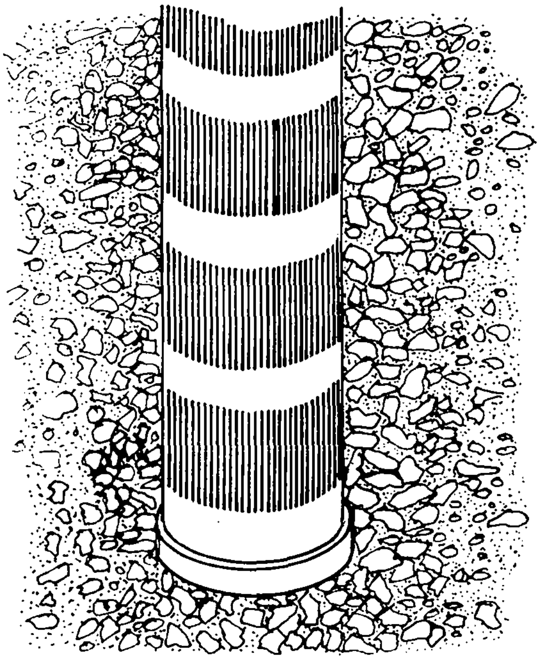
Emptying the bailer

Pressing down the casing



5.2.2. Installation of well screen and gravel pack

- Remove the drilling equipment from the borehole.
- Measure the water level with a water level indicator (acoustic signal).
- Measure the total water depth, using a weighted cable.
- Prepare the PVC filter/casing pipe: cut off the pipe at the correct length (i.e. the depth of the borehole + 15 cm), while ensuring that the pipe is slotted over the entire length that will be in contact with the aquifer, but not too far beyond it.

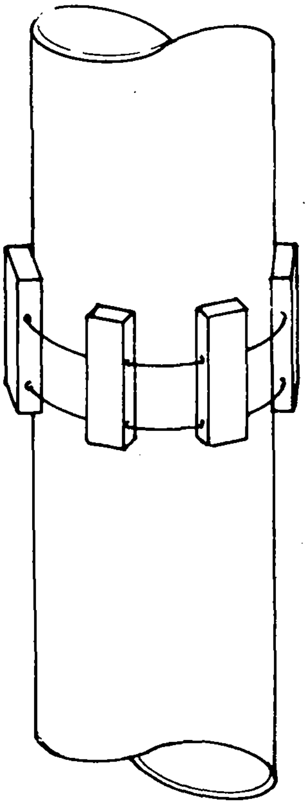


Slotted PVC, surrounded by a gravel pack, is used as a screen. It is important that there is a good tuning of the slot size, the size of the gravel in the gravel pack, and the grain size of the aquifer itself. The following criteria must be used:

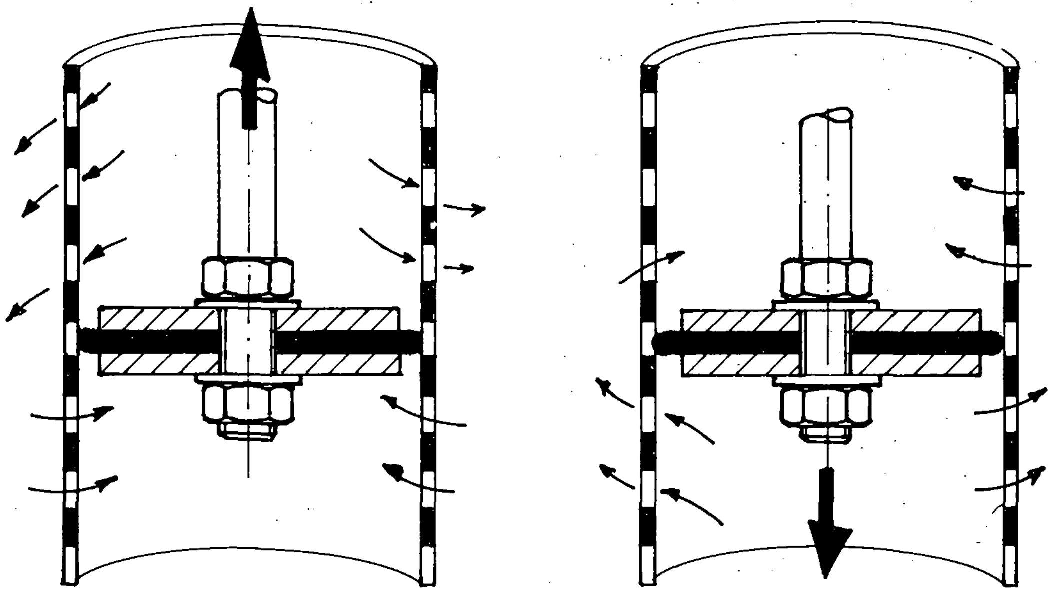
- there must be enough slots to obtain low entrance velocities
- the gravel must not clog the slots
- the gravel pack must act as a filter for the surrounding aquifer material
- the gravel pack must be coarse enough to let the finest aquifer particles pass, for good develoment of the well.

The combination of a slot size of 0.6 - 0.8 mm, and a gravel pack sieved between the practical sizes of 1.2 mm (mosquito gauze) and 4.6 mm (coffee tray wire) appears to guarantee a long life of the well in almost any aquifer.

- Bind small wooden blocks around the PVC riser pipe, with steel wire, to center the pipe in the borehole, thus guaranteeing a correct thickness of the gravel pack.
  The spacers should be fastened around the riser/filter pipe not farther than about 6 m apart.
- Install the screen. Normally the whole assembly of PVC pipe is placed in the borehole at once, sealed off at the bottom with a wooden plug. For deeper wells the PVC pipe may have to be inserted in sections. The lower sections are kept in place with a wooden clamp, to enable the top section to be attached. Screens and casings are available in standard lengths of 3 metres.
- Pour the gravel pack into the borehole, until the space around and 0.50 m above the screen is completely filled. This must be done in combination with pulling out the casing. It must be done very carefully, because a small mistake at this stage may spoil the whole performance of the well afterwards.



5.2.3. Developing the well



- Before the borehole is further backfilled, first develop the aquifer. The reason for this is that the aquifer material directly adjacent to the borehole is always somewhat affected during the drilling. A plunger consisting of two steel disks, with a piece of rubber in between, is connected to a rod, and moved up and down for about half an hour, in and out of the water of the borehole.
  This causes a strong current through the slots of the screen, the gravel pack and the surrounding part of the aquifer. The stronger this current is, the more fine materials are taken out of the aquifer, thus creating a higher permeability in the aquifer around the borehole.
  After the development a pumping test is carried out.
  This method can also be used when the yield of an existing well is going down because the slots in the screen are clogged. If, after developing, the yield is still low, the cause will often be the aquifer itself.
  Sometimes a thin clay layer has been formed at the inside of the borehole.
  This can be removed by intermittent pumping, for which a high-capacity membrane hand pump can be used when the water level is not below 7 m, and a SWN 80/81 hand pump for deeper water levels.

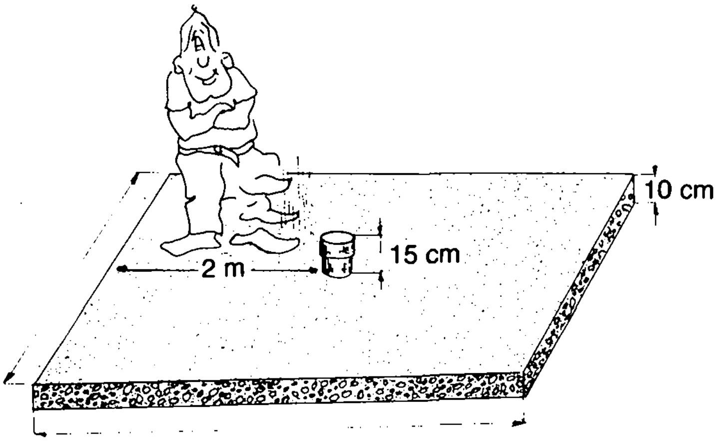
- When the water has lost its initial brown colour (caused by fine soil particles), carry out a pump test with the same pump for half an hour.

If the yield of the well is sufficient (more than 100 l/h), finish the borehole with a clay seal (if necessary) and backfill material.

If for some reason the well yield is not sufficient, the well wil have to be redrilled. In that case take out the PVC, clean it and use it again later.

5.2.4. Finishing of tube wells

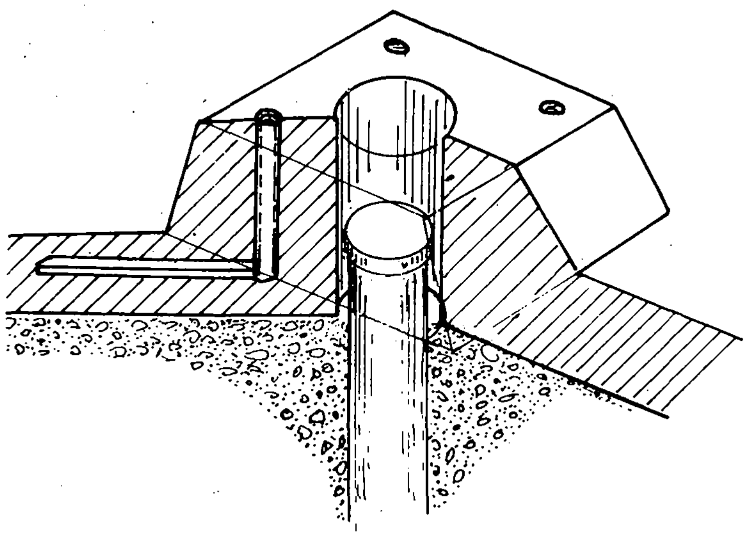
Keep the tube well closed so that children cannot throw stones into it.



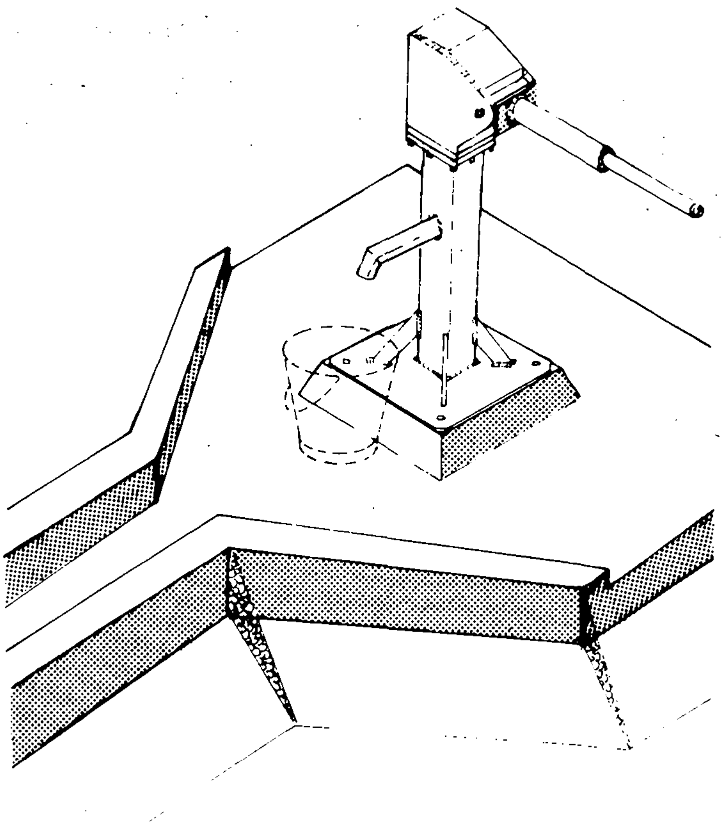
Flatten an area of approx. 2 x 2 m around the tube.
Then spread a layer of gravel or rubble and sharp sand (approx. 10 cm thick) and compact well.
Saw the PVC tube off at about 15 cm above the floor.

Fit screw anchors (or anchor bolts) at the underside of the top plate of the central mould section.

Check verticality of the borehole als follows:
connect the correct number of pump rod/riser assemblies and the cylinder, and lower in the borehole. Connect top section of rising main with special flanged steel socket to the central mould section and fit special pump rod puller to uppermost pump rod section.
Check that piston can freely move up and down. If this is not the case, the borehole cannot be used with a handpump and may have to be abandoned.



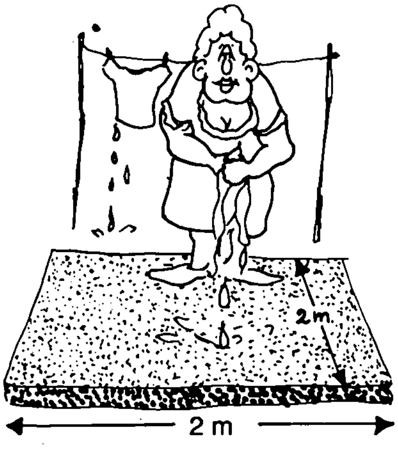
Install the remaining sections of the mould for the well slab/pump stand.
Make sure that the drainage gutter is directed towards the most low-lying area and that the mould is positioned in such a way that the slab surface is sloping in the same direction.
(slope approx. 5%)

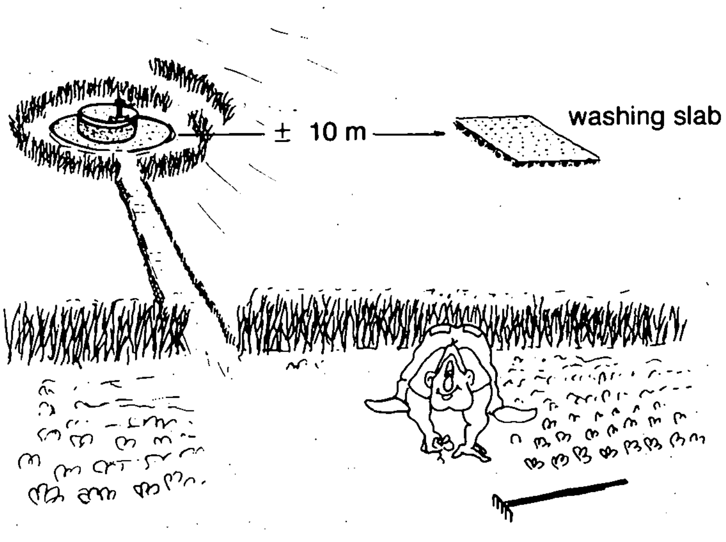


The concrete slab should be at least 10 cm thick and slightly reinforced.

Make a concrete washing slab of approx. 2 x 2 m (0.10 m thick) at a distance of about 15 m downhill and away from the well.

The slabs should be left to harden for at least two weeks before the pump is installed.

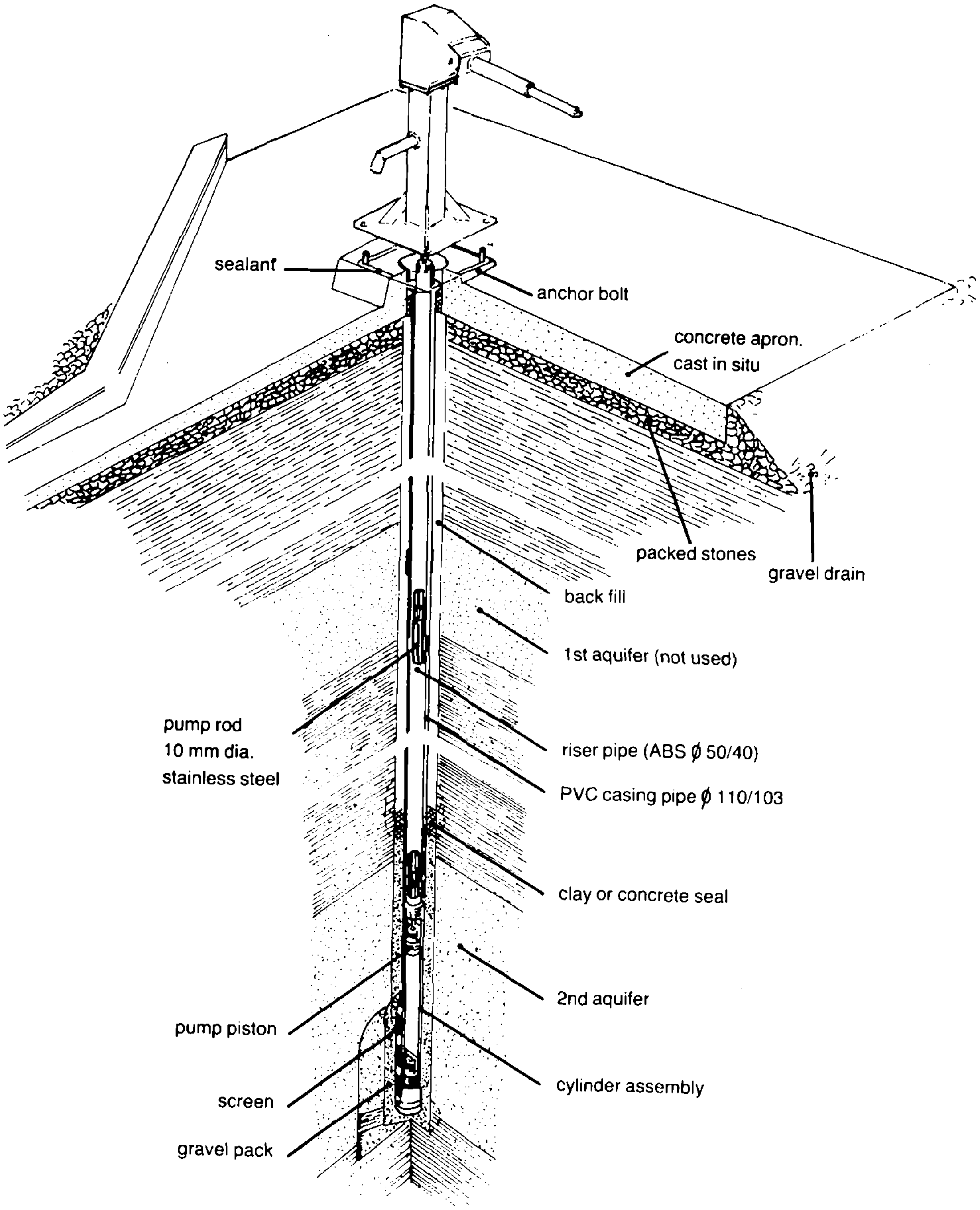




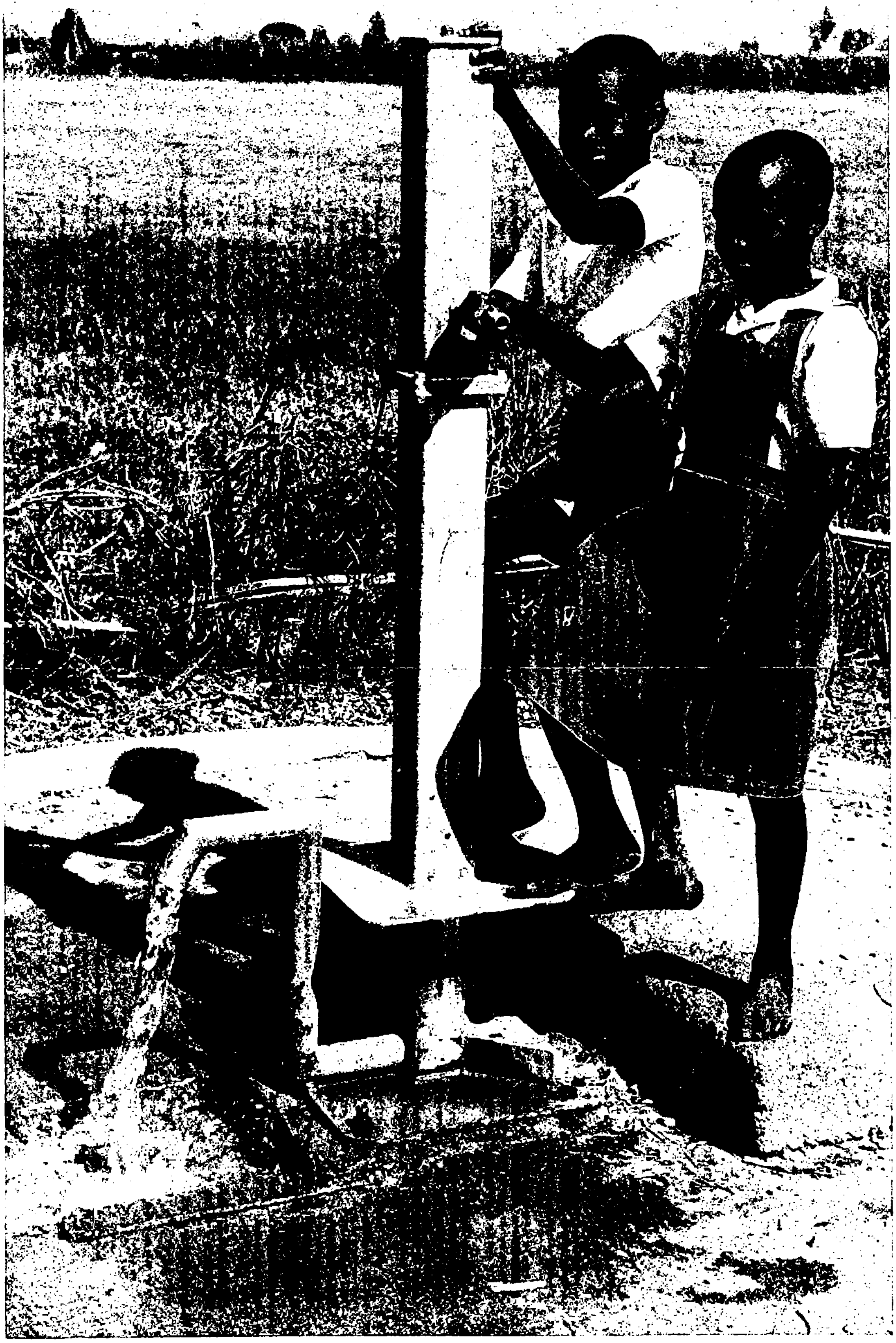
If possible, a properly constructed fence should be provided to keep out cows and goats.

Allow the pump attendent to lay out a garden and use the spill water.

Give the villagers clear instructions about the use of the well.



Standard assembly of a shallow well fitted with a deep well cylinder



Kangaroo hand pump mounted on drilled well

5.3. Construction of dug wells

5.3.1. Procedure common to ring wells and backfilled wells

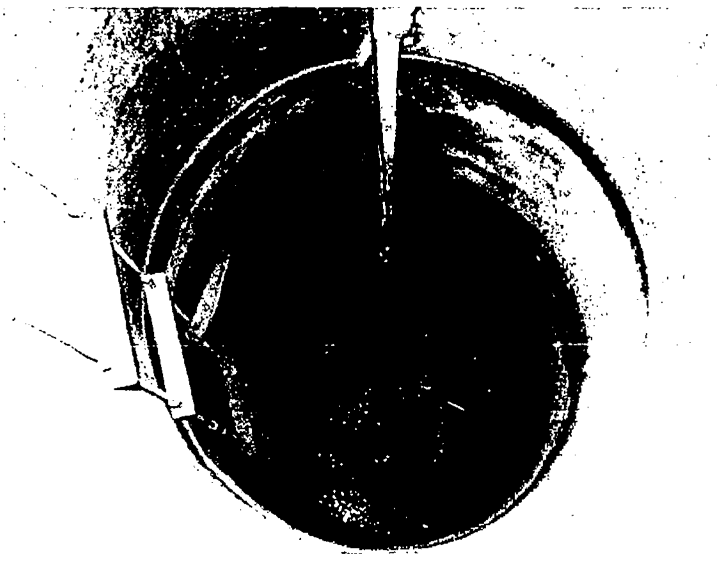
- Check the equipment. Repair or replace worn items.
- Do not dig in the immediate vicinity of (underground) power lines.
- Do not dig close to trees.
- Clear an area of approx. 10 m diameter around the approved test hole, and remove high grass.
- Stake out a circle of the required diameter (1.5 to 2 m), with the test (survey) hole as its centre. The circle indicates the hole that has to be dug.
- First loosen the harder soil with pick-axes and remove the earth with spades. Deposit the soil some 4 metres from the hole, at the high side. (Reserve the lower side for draining excess water afterwards).
- Continue digging until it is no longer possible to throw the soil out of the hole. From then onwards, a second man lifts the soil out of the well by means of a rope and bucket, either by hand or using a small tripod and pulley or winch.

Depending on the consistency of the soil, approximately 1.5 to only 0.3 m can be dug per day, and on the average some 2 to 6 weeks may be required to reach the groundwater table.

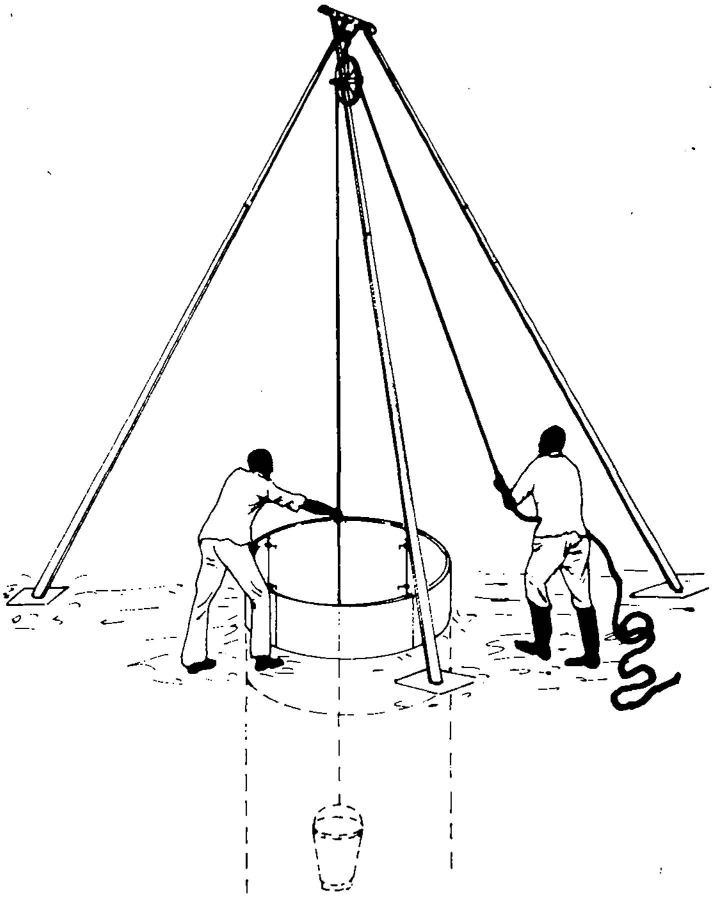
Under certain circumstances, e.g. when digging in hard formations without a soft top soil, it may be possible to dig the entire well without any lining.
When digging in softer formations, however, and especially during the rainy season when the top soils are saturated with water, digging without a lining becomes very risky, and concequently a lining will have to be selected.
Also after reaching the water table in a hand-dug well under construction, the use of a lining may become necessary.

The choice may then be between a temporary lining of for instance steel sheets, or a permanent lining of for instance concrete rings.

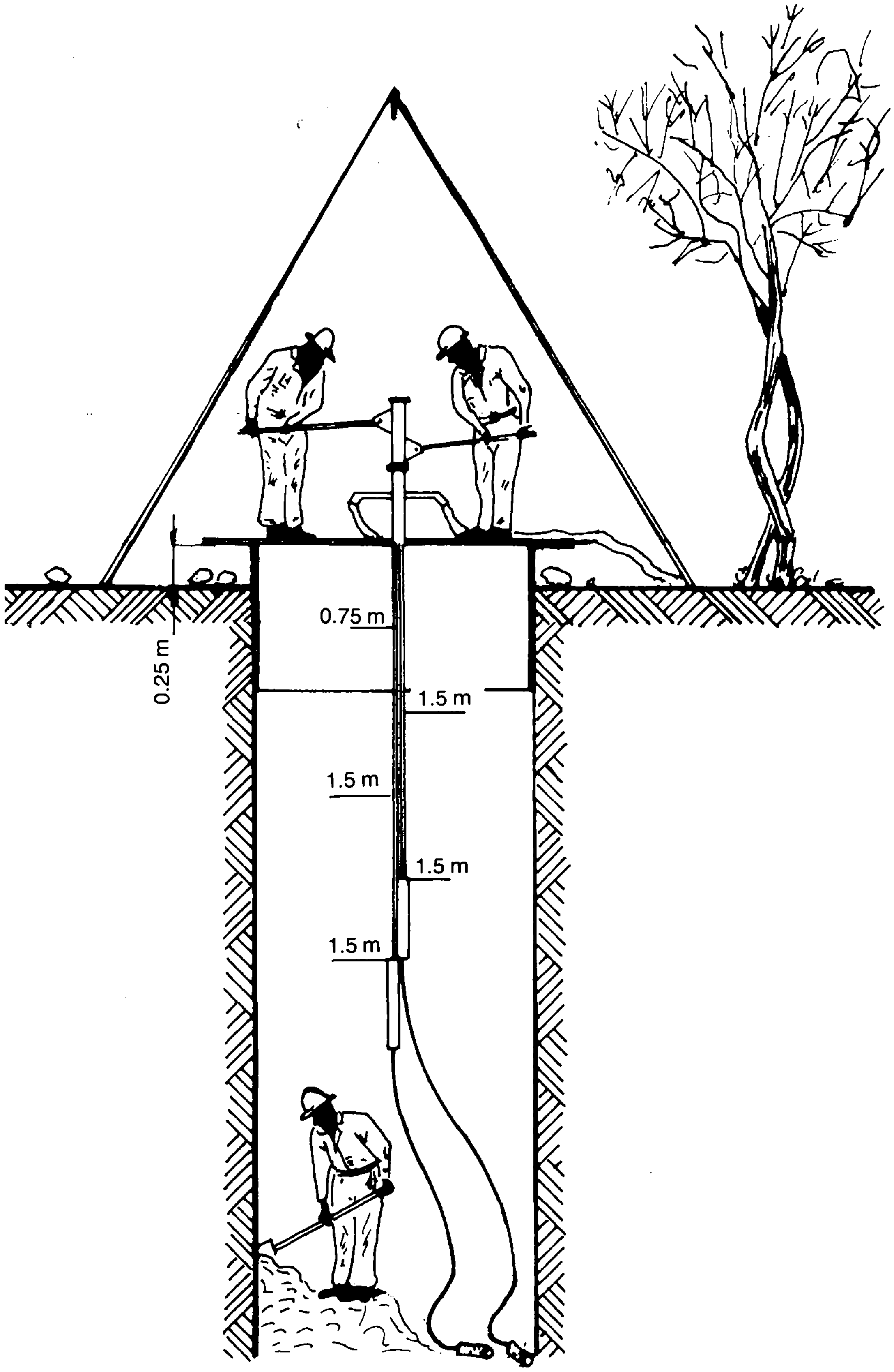
In view of the high cost of concrete rings, the first method is to be preferred whenever the quality of the aquifer allows having wells with a reduced storage capacity (see paragraph 3.2.).



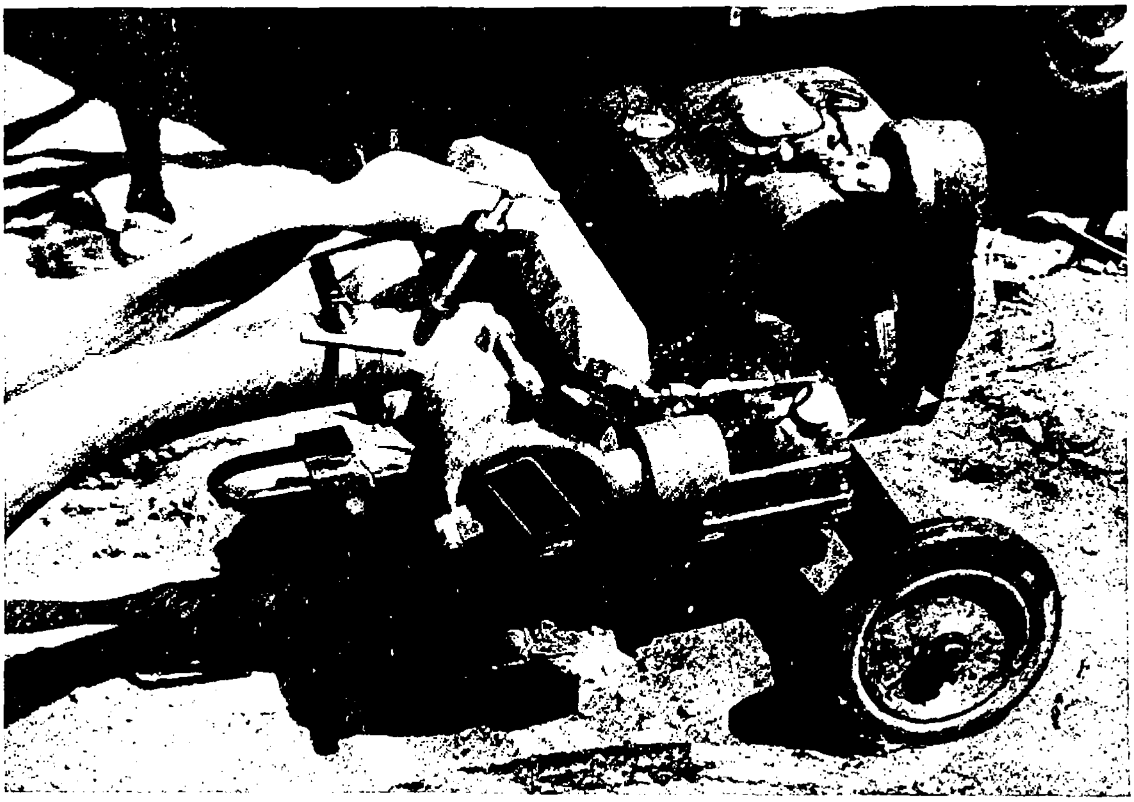
Hand-digging in progress



Exessive inflow of groundwater necessitates the use of motor pumps



Dewatering during digging



Small motor pump, applicable for water depths less than approx. 7 m

- During the first few days after reaching the water table, remove inflowing water by emptying the hole with a bucket on a rope. When, however, the inflow of water becomes stronger and removal of it with a bucket becomes impossible, install a SWN 80-type hand pump (see Part 2 "Pumping Equipment") with a 3" cylinder in the hole and have one or two extra labourers operate the dewatering pump(s).

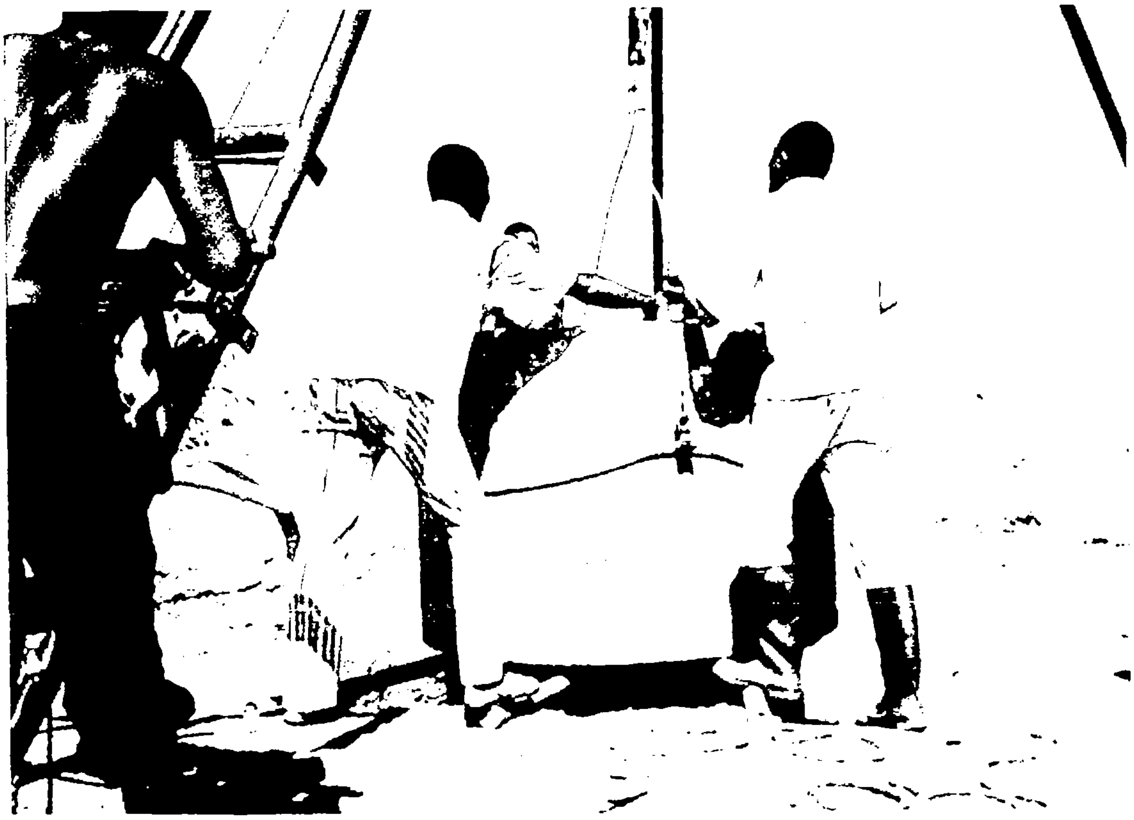
As digging proceeds, lower the pump intake opening by extending the rising main and pump rods of the pump. At this stage of the construction, usually every morning 1 to 4 hours may be required to pump out the water that has accumulated during the night.
In case this delay is considered unacceptable, or when the inflow of water increases even further, the installation of an additional hand pump, of a duplex pump or of motor-driven pumping equipment may become necessary.

The use of motor pumps should be avoided whenever possible, however, as is implies the use of fuel and spare parts that may not be available in the rural areas.

It is problems with motorized dewatering equipment, and the large amounts of foreign currency required for its upkeep, that is partly responsible for the sometimes very high cost of shallow wells, and has led to the recommendation to use hand-drilled well construction methods whenever possible.

A SWN 80 pump used for dewatering a hand-dug well.

Concrete (porous) rings, used as a permanent lining for hand-dug wells.



- If possible, continue digging until a depth of 3 m below the dry-season water level has been reached.

During the stage of construction where the inflow of water becomes abundant, digging usually proceeds at a rate of only 0.3 - 0.5 m per day, and in practice a minimum of 2 weeks may be required to bring the well to a sufficient depth.

- Start the completion of the well once a sufficient depth below the dry-season static water level has been reached.
  Basically there are 3 ways to complete the well:
  a. install a PVC tubing in the well, and backfill it with a gravel pack around the PVC filter (see paragraph 5.3.2.)
  b. install concrete rings, with porous rings at the bottom of the well (see paragraph 5.3.3.).
  c. install porous concrete rings below the groundwater table only, and continue upward with PVC or asbestos-cement pipe (see paragraph 5.3.4.)

5.3.2. Constructing a back-fill well

This method can be used when:
- digging without a lining is possible, or
- a temporary lining can be used, and
- a limited storage capacity is sufficient.

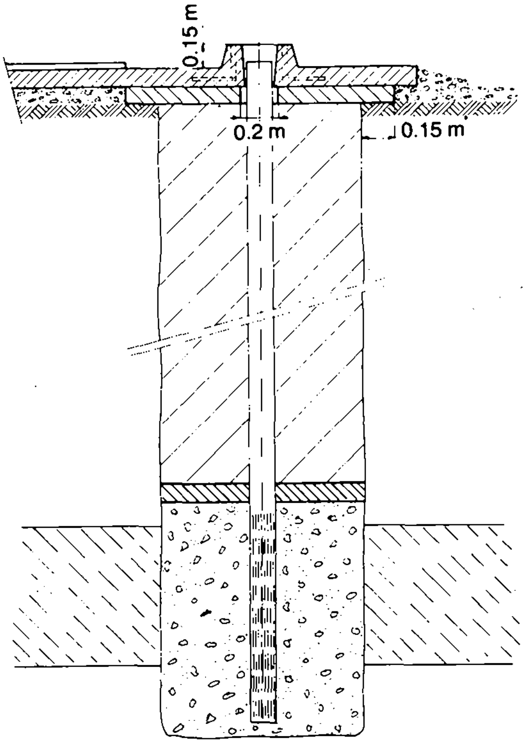
(N.B.: Check wether hand-drilling might be possible, as this could offer a lower-cost solution).

The sequence of activities is now as follows:

- Connect PVC filter pipes and blind pipes of sufficient lenght and keep them ready, at the construction site.

- Remove the dewatering pump(s).

- When a temporary lining has been used, carefully remove the lining.



At the same time, pour a 5 - 10 cm thick layer of fine gravel (1.5 - 3 mm) on the bottom of the well, to prevent fine aquifer particles from entering the well through the bottom.

- With one man in the well, and another on top of the tripod, place the string of PVC pipes in the centre of the hole, and secure its position at the surface, e.g. by tying it to a cross bar or to the support of the dewatering pump(s).
- Start pouring gravel around the filter section of the PVC pipe, while making sure that the PVC pipe remains vertical .
  Pour the gravel carefully, from small containers, so as not to damage the filter pipe.

Experience with 6 - 10 mm crushed stone chippings has shown that this material, when used for backfilling, has an effective porosity of approx. 50%, which is still quite high and, therefore, allows a reasonably large storage volume.

When the PVC filter is completely surrounded by gravel, add another 0.5 m to allow for some setting of the gravel.

- Install a cement layer of approximately 0.3 m thickness on top of the gravel, to seal the aquifer from the upper layers and to prevent contamination of the well.
- Once the cement has dried, backfill the hole with the original soil, making sure that the PVC casing is straight and vertical and that the loose material is sufficiently compacted in the hole.
- Place a pre-cast reinforced concrete cover over the hole, with a diameter that is at least 0.3 m larger than that of the hole itself.
  This cover is then resting on the undisturbed soil, and even when some compaction of the backfill occurs, this will not effect the well.
  The cover must have a central hole in it, of approx. 20 cm diameter, to allow the PVC pipe to pass through it.
- At this stage install a temporary pump on the well and develop and clean the hole for a day or two by pumping.
- Construct a standard slab, using the concrete cover as a base.
- Before installing a permanent pump, pour 10 litres of bleach into the well and allow it to stay in it for at least 24 hours.
- After installation of the pump, have the well surroundings taken care of by the well owners, e.g. by digging a trench and/or putting gravel around the well and planting an euphorbia hedge.

5.3.3. Constructing a ring well

Because of the relatively high costs of completing a well with concrete rings, use this method only when the yield of the aquifer is very low and the maximum storage capacity must be obtained, or when a temporary casing cannot be used and the caisson method with concrete rings had to be used already during the construction phase.

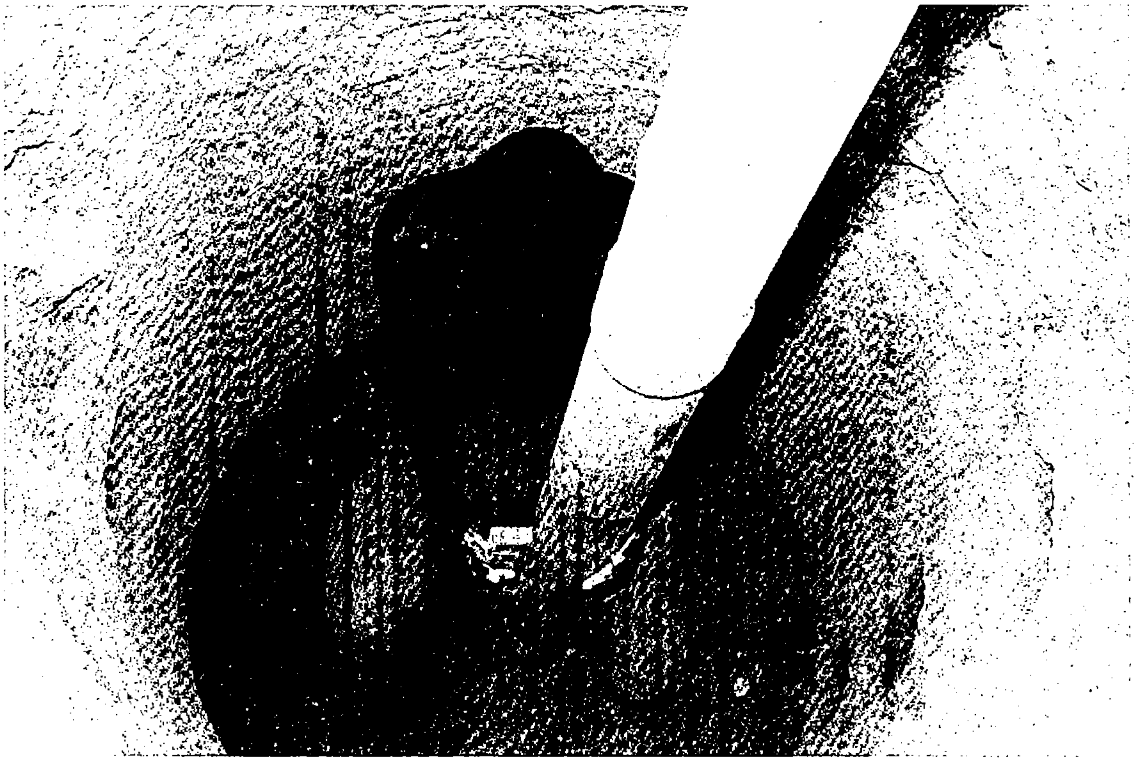
The sequence of activities is as follows:

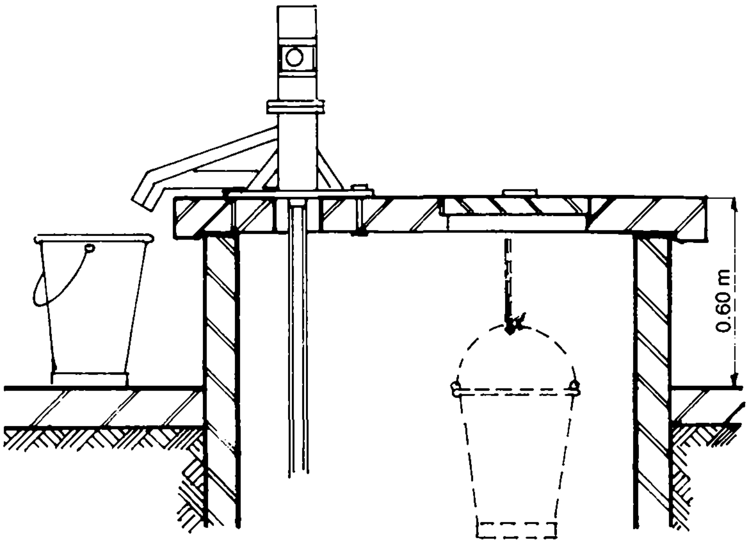
- As soon as the walls of the well start caving in, or appear unstable otherwise, lower the first rings into the well. These should be porous rings of the "no-fines" concrete type.
  The bottom ring should preferably have a cutting edge.
  For handling concrete well rings see paragraph 6.3.3.

Installation of the string of PVC

Pouring of gravel around the PVC filter

Keeping the PVC vertical during backfilling



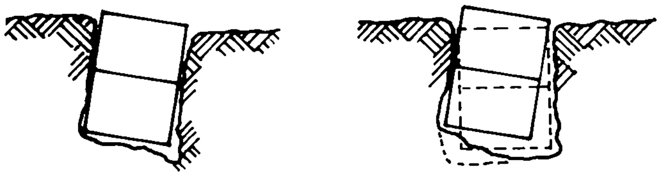


- Install so many rings that the top ring is partly above ground. Only those rings that will eventually be at least partly below the top of the aquifer must be porous rings. All other rings must be full-concrete rings.

- Continue digging inside the well, removing the soil from within and from underneath the cutting edge of the lower ring. The string of rings will then sink because of its own weight.

During digging, maintain verticality.
If, in loose soils, the hole caves in more on one side of the rings than on the opposite side, the result will be different ground pressures at both sides, which may cause sinking askew.
As long as the rings have not sunk more than approx. 2 m, attempt correcting as follows.
If the consistent layer (clay, weathered bedrock) is not too deep (approx. 2 m) the best way is to dig as fast as possible, without pause, until firmer layers are struck.

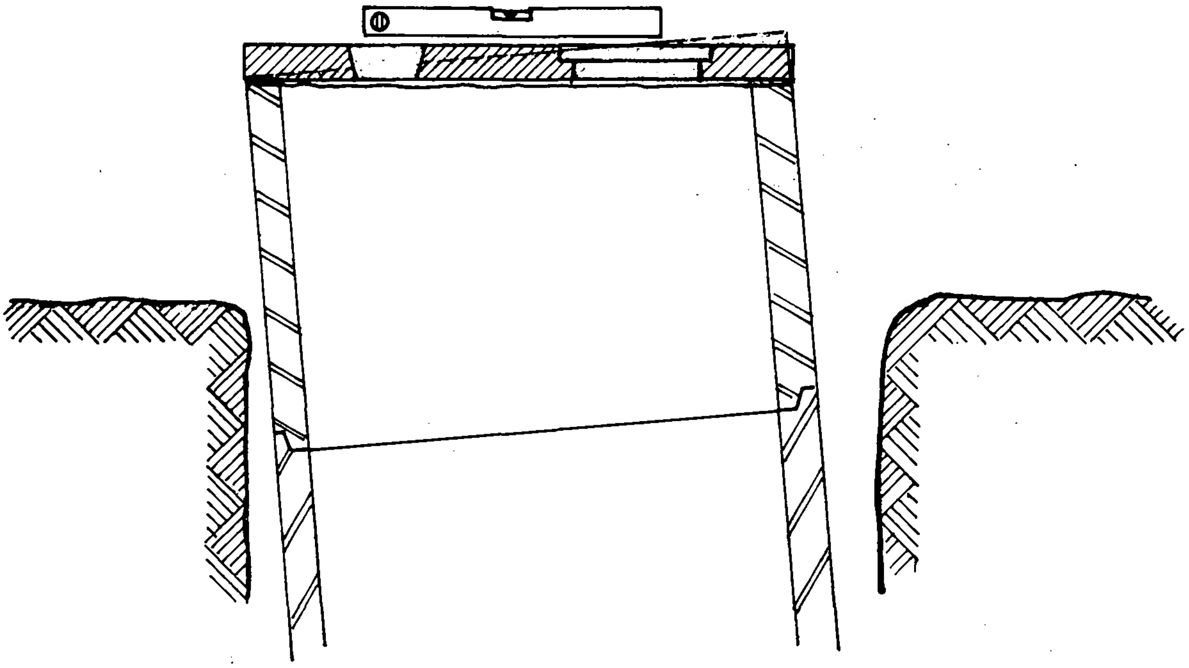
If, however, the clay, quartzite or bedrock is at greater depth, try to correct the position of the rings as follows.



If the rings are in the position as indicated above, dig away the soil as far as possible at the lower side, underneath and next to the rings. This must be done as soon as the rings start sinking askew. Next, remove soil from underneath the highest point of the rings, and try to slide the rings back into a vertical position.

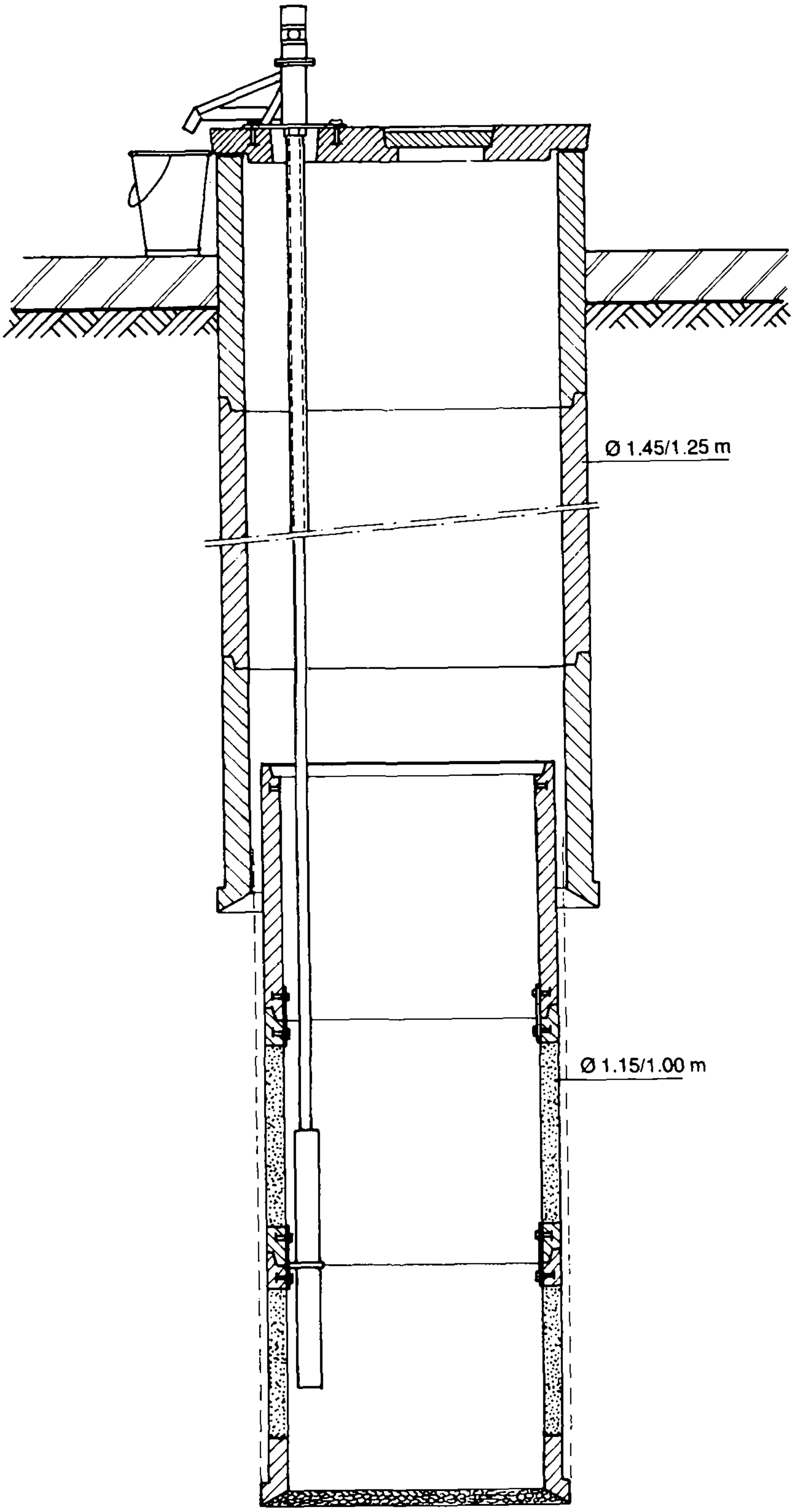
Once more than 2 rings have been lowered into the well, it becomes very difficult to correct the slant of the rings.

Even when, for whatever reason, the rings are sunk askew, the well cover on top of the rings must alweays be laid horizontal, since it is going to support the hand pump, and people will have to stand on it.
Therefore, cut the edge of the top ring horizontally.



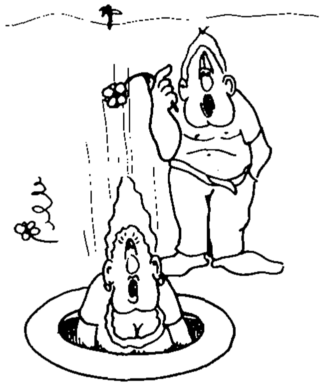
- Never build up the top of the topmost ring with fresh concrete in an attempt to make the slab horizontal, as this concrete will shrink and crack, as a result of which the cover will become loose and contaminated spill water can enter into the well.
- After having reached the desired depth, fill the opening between the rings and the undisturbed soil with gravel or crushed stone chippings, up to approx. 30 cm above the top of the aquifer.
- Cast a concrete or clay seal on top of the gravel or chippings, around the rings.
- Backfill the remaining space around the rings, using the original soil.
- Clean the bottom of the well.
- Pour a 5 - 10 cm thick layer of fine gravel (1.5 - 4 mm) on the bottom of the well, and cover this layer with a 10 cm thick layer of coarser gravel or stone chippings, for stabilization.
- Place a pre-cast concrete cover over the well and complete it as described on page 81 and further.

Under certain conditions it may be advantageous to have the top well rings of a larger diameter than the lower well rings. In this way there is ample room for digging through the (drier) upper layers of soil, whereas less expensive, and lighter, rings are used when the aquifer is reached.
Potential benefits are also the reduced friction of the string of well rings, as only a part of them (viz. – the smaller – diameter rings) are being sunk at a time, and the possible savings in transport costs because the sizes of rings can be 'nested'.



Finishing of large-diameter wells

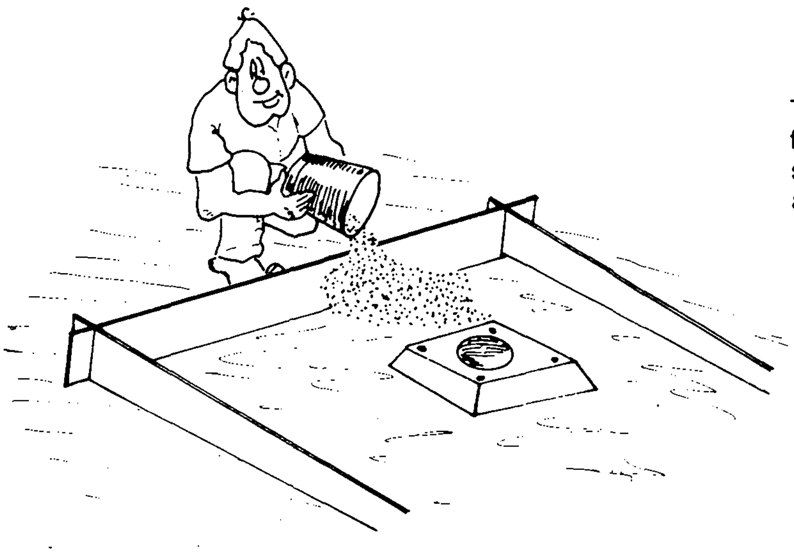
Open wells at ground level are extremely dangerous for people and animals.



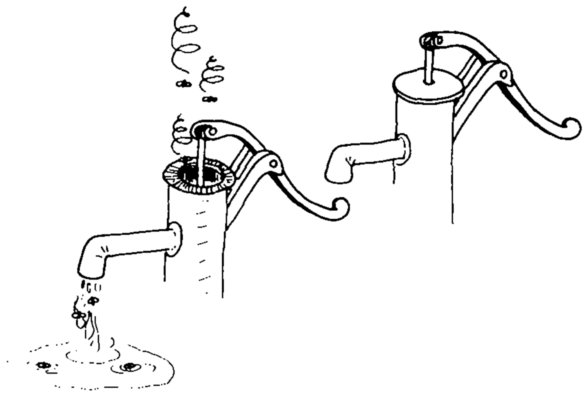
Open wells must be be built up to about 50 - 60 cm above the ground.

Using dirty buckets and ropes pollutes the well.

So cover the well with a concrete slab (10 - 12 cm thick) and erect a hand pump on this slab.



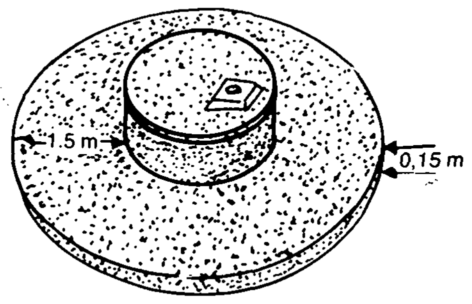
To avoid problems, the pump foundation (with anchor bolts) should be cast at the same time as the well cover.

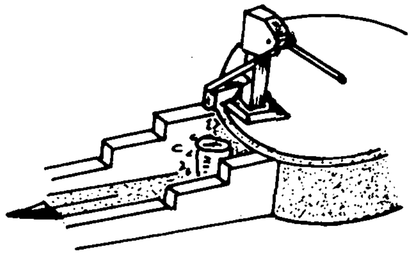


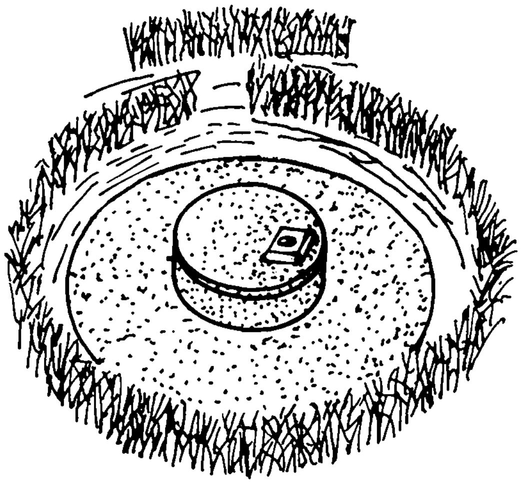
The hand pump must not have any slots or other apertures through which dirt can enter and pollute the well.

Place the pump in such a way, or make the spout so low, that the water falls exactly into the bucket.

The distance between bucket and spout must not be more than 30 cm.







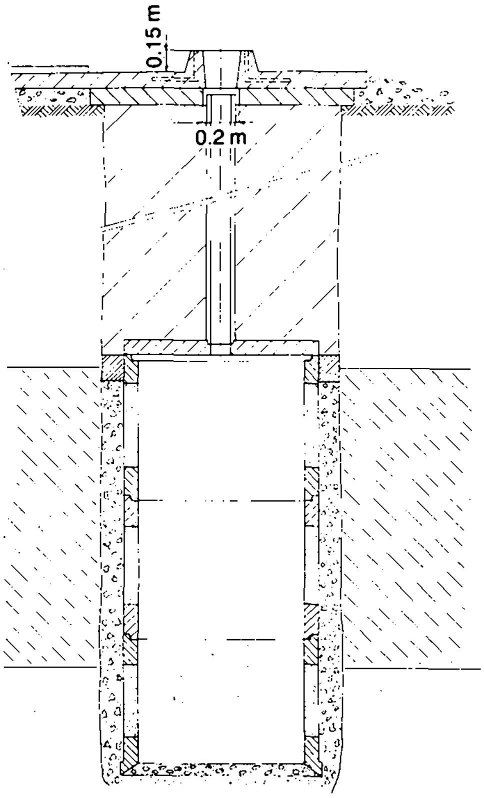
The pump (spout) should be placed on the lower part of the well site, so that spill water runs away from the well.
Make a good, strong discharge gutter so that the surroundings of the well remain dry.

Build a strong fence around this paved area (to keep out cows etc.) and let the pump attendant make a garden at the end of the gutter.

Make a *concrete slab right* around the well. It should be about 1.50 m wide and 0.15 m thick and lightly reinforced at top and bottom.

5.3.4. Constructing a ring well with small-diameter top section

A possible way of reducing the cost of rings and transport is to reduce the well diameter above the static water level.
By using this method the storage capacity of the well is maintained, at lower cost.
Essentially it is a combination of the completion methods as described in paragraphs 5.3.2. and 5.3.3.



6. Survey and construction equipment

6.1. Survey drilling equipment

6.1.1. Overview of equipment

The most important parts of a hand-operated suvey set, suitable for drilling to a depth of approx. 25 m, are:

SURVEY SET, FOR INVESTIGATIONS DOWN TO 25 METRES
(measures in mm, unless indicated otherwise)

1) drilling equipment; conical thread connection:

handle	Ø 26 x 600	2
extension rod	Ø 26 x 1000	25
open clay auger	Ø 100	2
open clay auger	Ø 70	2
riverside auger	Ø 100	1
riverside auger	Ø 70	1
spare bits riverside	Ø 100 (set)	1
spare bits riverside	Ø 70 (set)	1
bailer	Ø 63	1
spare valve for bailer	Ø 63	1
wrench/catcher for conical thread connectors		2

2) casing, high impact PVC/ABS 0 90/76:

casing head	Ø 90/76	1
casing pipe	Ø 90/76 x 500	1
casing pipe	Ø 90/76 x 1000	24
casing pipe, slotted	Ø 90/76 x 1000	3
casing clamp	Ø 90	2
casing shoe	Ø 90/76	1
steel brush		1

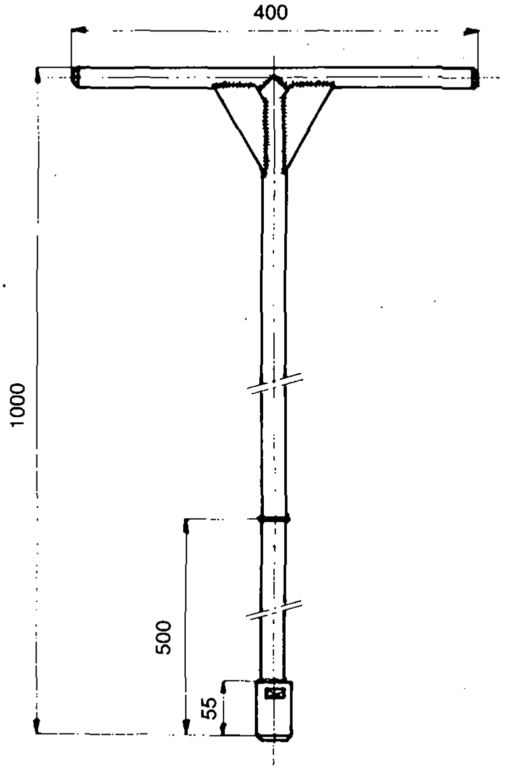
3) well capacity and water quality control set:

Pumphead "jolly jumper"		1
riser pvc quick coupling,	Ø 1½" x 500	1
riser pvc quick coupling,	Ø 1½" x 1000	25
electric conductivity meter		1
water-level meter, 25 m		1
plastic bucket (20 litres)		1
screw driver, flat		1
foot valve, quick coupling		1

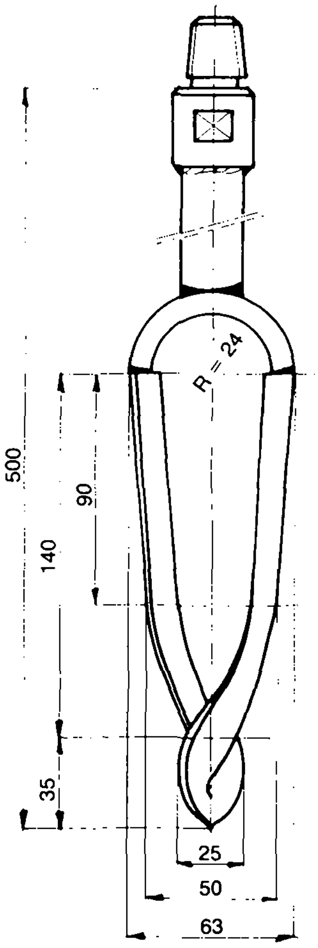
4) general equipment:

measuring tape 50 m	1
ruler 2 m	1
tent, complete, 2 m x 3 m	2
camping chair, table and lamp	2
camping/safari bed, mattrass	2
steel box 1200 x 450 x 400	2
steel box 800 x 450 x 400	2
transport bicycle, heavy duty type	2

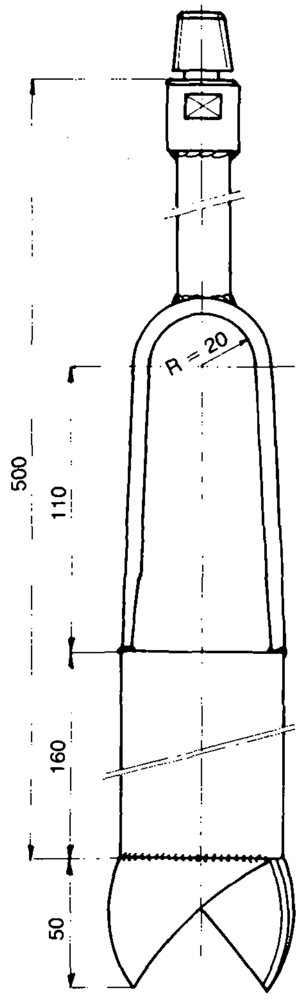
6.1.2. Hand-drilling equipment



Handle and extension rods
During the drilling operation, the drilling bits are connected to one or more extension rods and a handle, all made of steel tube. (26 mm outside dia.; 2 mm wall thickness).
The handle, extension rods and bits are provided with conical thread protectors.



Open clay auger
The body of this bit consists of two blades, the ends of which are forged together. Upwards the blades diverge gradually up to the desired diameter.
Depending on the width of the blades, the auger is suitable for clay, silt or sand.
The blades of the combination auger have an average width, so that it can be used in many types of soil.

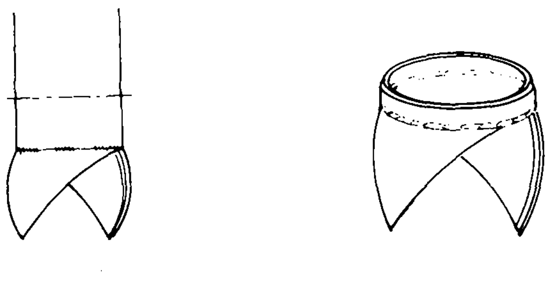


Riverside auger

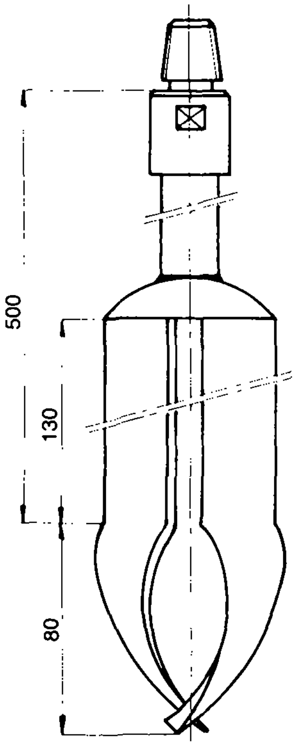
The body of this auger is a tube with 2 blades welded to its bottom. The blades are spoon-shaped so that the soil is steadily pushed into the tube.
This auger is very suitable for use in hard, stiff soils, in sand and in soils mixed with gravel.

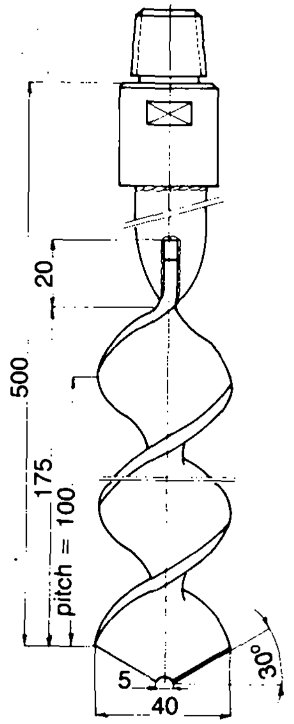
Stone auger

If the gravel content of the soil is so high that the riverside bit is not yielding adequate results, the stone auger can sometimes be used to lift large stones that block the drilling progress.



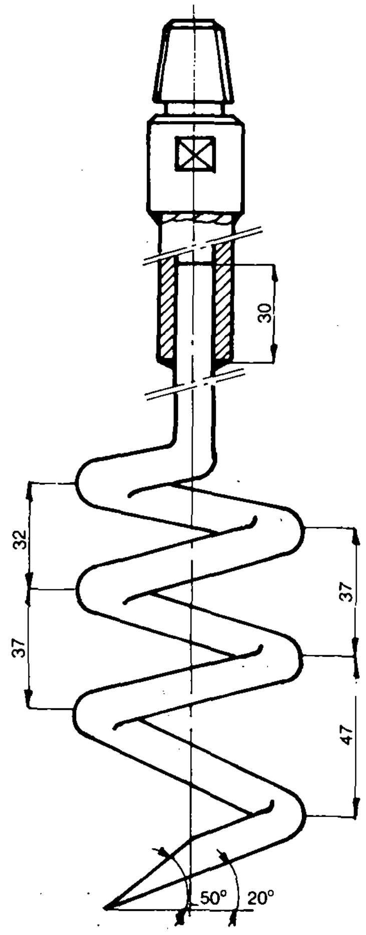
Spare bits are available, to be welded to the bit body after the worn bits have been sawn or cut off.

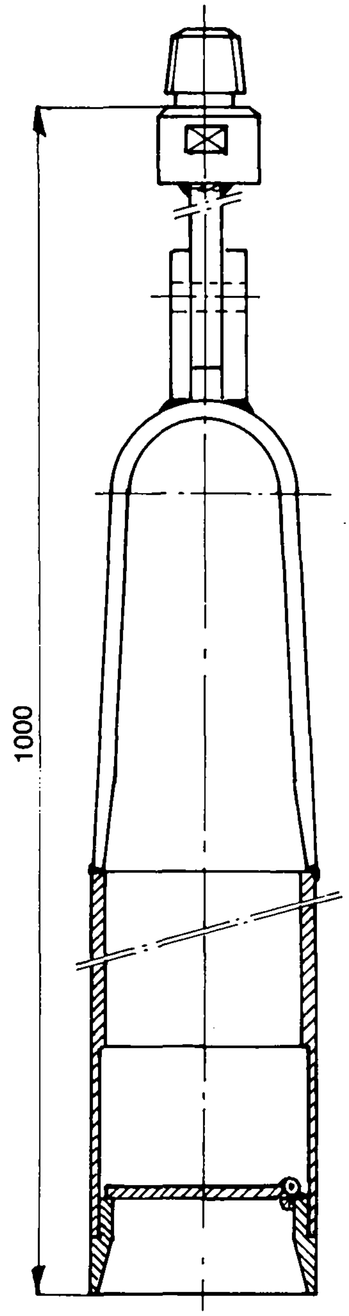




Spiral auger
This auger is made of a steel strip, forged into a spiral. With this auger hard layers, e.g. laterite and calcrete, can be broken up and the material brought out with other auger types afterward.

Stone catcher
This auger is made of a round iron bar, forged in the shape of a spring. It can be used to remove large stones from the borehole and also as a fishing tool for equipment, lost in the borehole.





Bailer

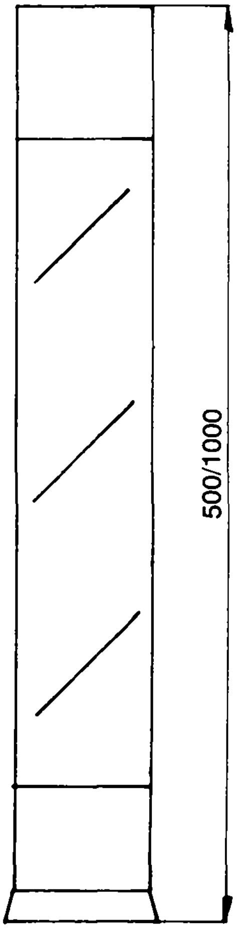
The bailer or pulse auger is a tube with a valve at its bottom.
It is used inside the casing for penetrating water-saturated sand layers, by moving it up and down.

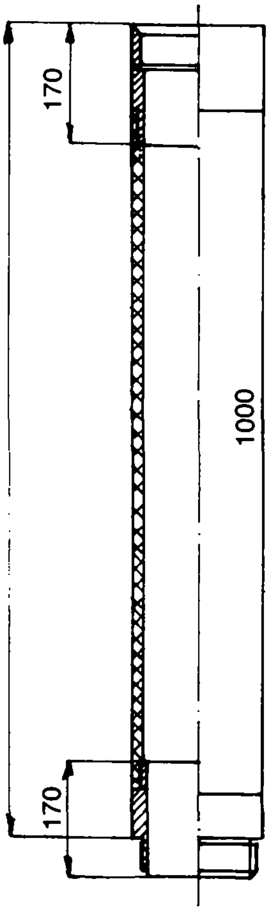
6.1.3. Casing set

Casing pipe

The casing pipes (90/76 mm outside/inside dia.) have a net length of 500 or 1000 mm each. They have a male thread at one end; a female thread at the other. Both are protected against damage by PVC thread protectors. The thread itself is square, thus being better wear-resistant and allowing for an easier disconnection of the pipes.

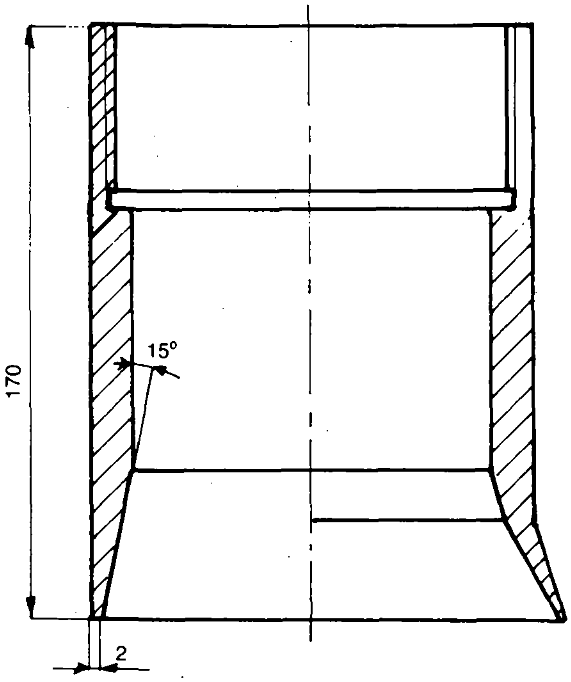
Two casing pipes of each set have fine slots, so that they can act as filter pipes, allowing water from the aquifer to enter the borehole. This facilitates the use of a bailer and allows test pumping without having to remove the casing pipes first.

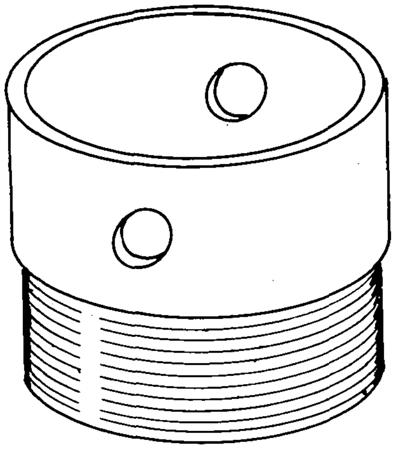




Casing shoe

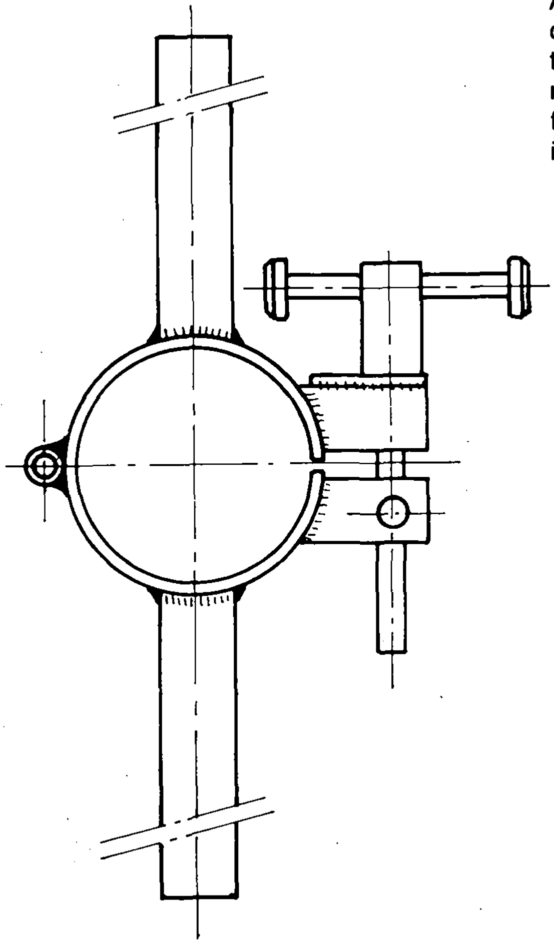
To the first casing pipe to be used in a borehole, a casing shoe must be connected, to facilitate lowering of the casing.





Casing head

A steel casing head is screwed onto the uppermost casing pipe that is in use at any given moment, to protect the thread from being damaged by the drilling bits and rods.

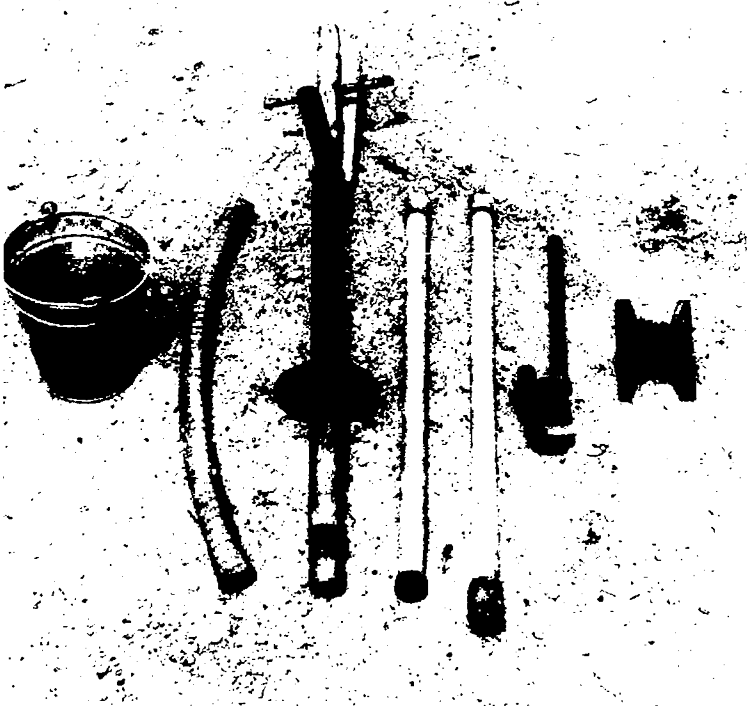


Casing clamp

This device is used to prevent the string of casing pipes from falling into the borehole, when – after completion of the drilling – the casing pipes are disassembled.
It is also used for pressing casing pipes down when necessary, and lifting the pipes after completion of the hole.

6.1.4. Pump test equipment

The test pump shown is an inertia-type of pump. It is essentially an open tube with a spout, to which a number of riser pipes are connected. The lowest riser pipe is provided with a foot valve. A foot plate is inserted between two springs around the top section of the pump. During operation, the foot plate rests on the ground, on top of the borehole, and the entire pump is moved rhythmically up and down, resulting in a pulsating flow of water. The riser pipes have a nominal diameter of 1.5.".



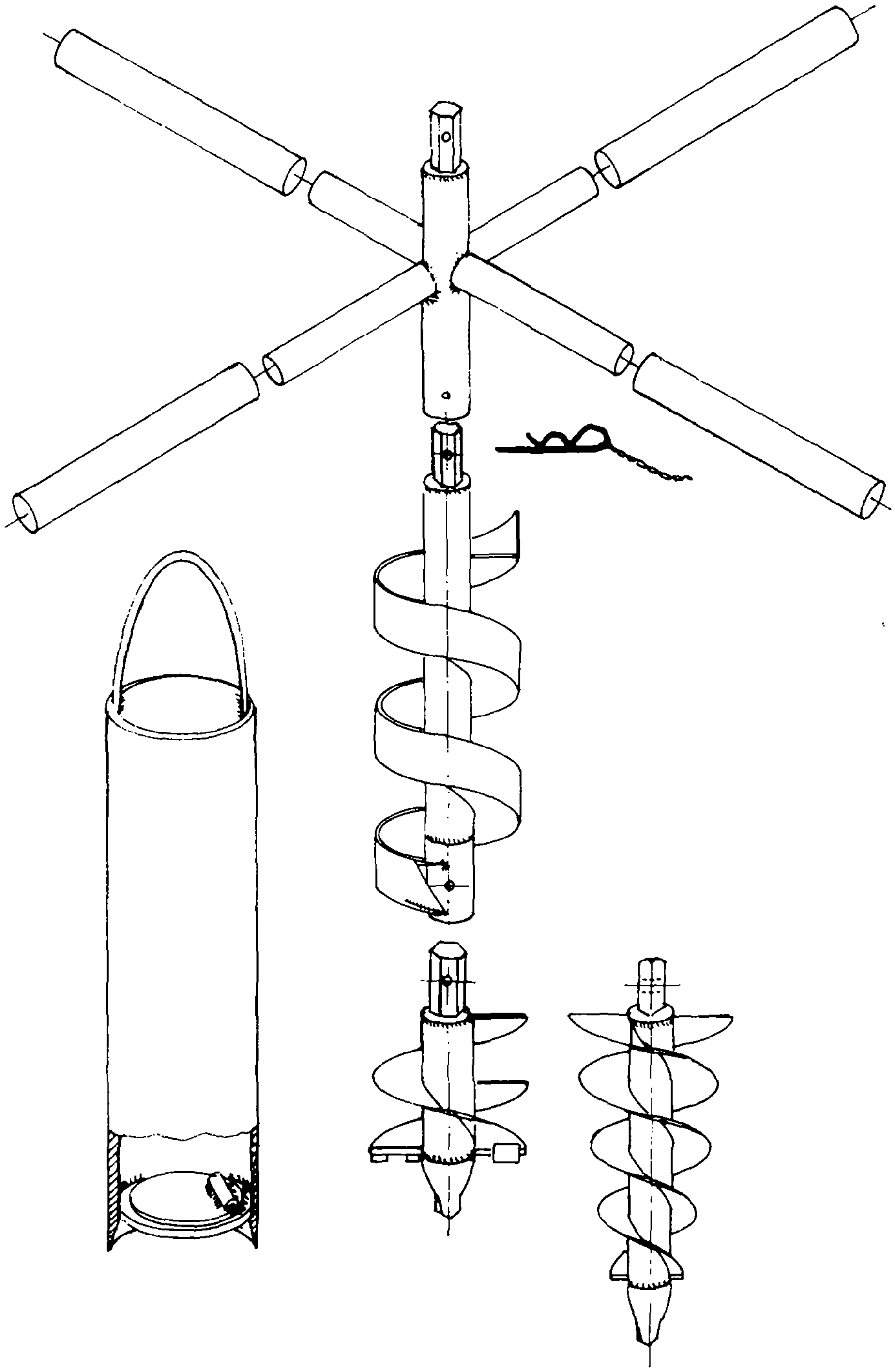
6.2. Equipment for hand-drilling wells

6.2.1. Overview of equipment

The composition of a typical heavy-hand-drilling set (8", see page 57) is shown below:

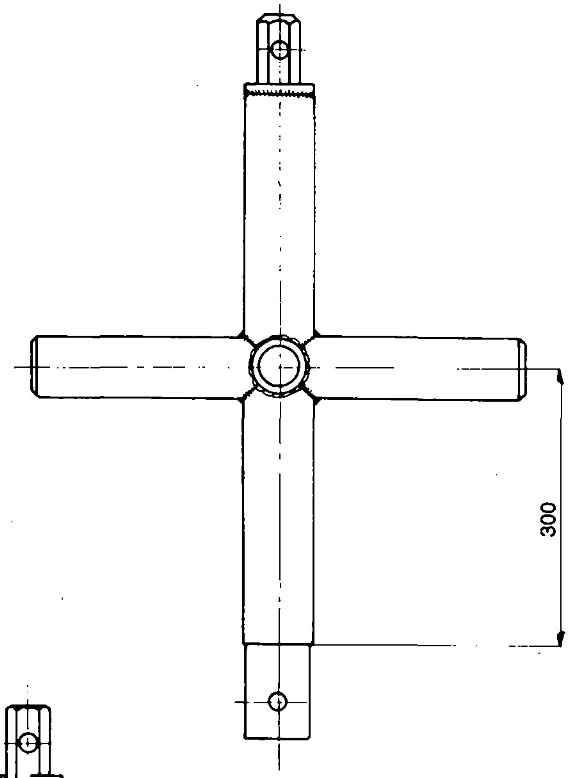
description	size/mm	number
A. Augering set		
bit for flight auger	Ø 230	1
bit for flight auger	Ø 180	1
conical bit	Ø 180	1
flight auger	Ø 230	1
flight auger	Ø 180	1
riverside auger	Ø 180	1
bailer with spare valve	Ø 165	1
drilling rod	Ø 76 x 500	1
drilling rod	Ø 76 x 1000	3
drilling rod	Ø 76 x 1500	5
drilling rod	Ø 76 x 2000	3
drilling rod	Ø 76 x 3000	1
stabilizer	Ø 180 x 1000	1
cross piece complete	Ø 76 x 1000	1
drilling rod catcher		1
bolt M 16 x 80 with chain		40
drilling rod hanger		1
B. Casing set		
casing	Ø 220/200 x 1250	18
thread protectors	Ø 220/200 (female)	18
thread protectors	Ø 220/200 (male)	18
casing shoe	Ø 220/200	1
casing clamp	Ø 30 - Ø 220/200	2
C. Miscellaneous equipment		
lowering pipe	Ø 220	2
chain spanner	Ø 220	2
tripod, complete		1
winch, complete with spare cable	Ø 10	1
pulley block with swivel-hook		1
knives for auger bits	Ø 230	-
knives for auger bits	Ø 180	-
coupling hexagonal for	Ø 76	set
thimbles etc.		set
pulley block with flapdoor		1
swivel-hook	3 tons	1

6.2.2. Heavy-Hand-Drill (HHD) Equipment



Although the equipment is heavier, and for that reason is suspended from a tripod, it is similar, in shape and method of operation, to the survey equipment.

Drilling equipment, when used inside a casing, may get stuck because of soil that gets in between the drill and the casing, even though this may not be noticed by the drilling crew. As continuing with drilling could then result in the casing pipes becoming unstuck, the direction of operation of the drills was selected contrary to that of the casing pipes: the drill is operated counter-clockwise, whereas the casing pipes have normal thread (a clockwise rotation screws them together). As a result of this, a drill that gets stuck in the casing, causes the upper casing sections to turn with it. This is easily seen by the drilling crew, who can stop this by means of casing clamps, before the casing sections down in the borehole get unstuck.

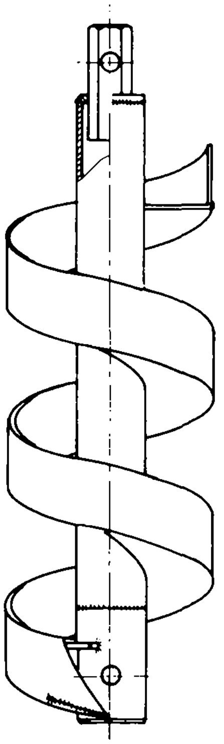


Cross-piece and drilling rods
The cross piece (a special drilling rod of 0.80 m length, on which four 2.5"-dia. pipes can be mounted as handles) is used for turning the HHD equipment around.
When necessary the downward force on the drill can be increased by having people sit on the handles.

The drilling rods are 2.5"-dia. pipes with lengths of:

0.5 m
1.0 m
1.5 m
2.0 m
3.0 m

with hexagonal couplings. These are locked by means of M16 x 80 bolts with R-springs.

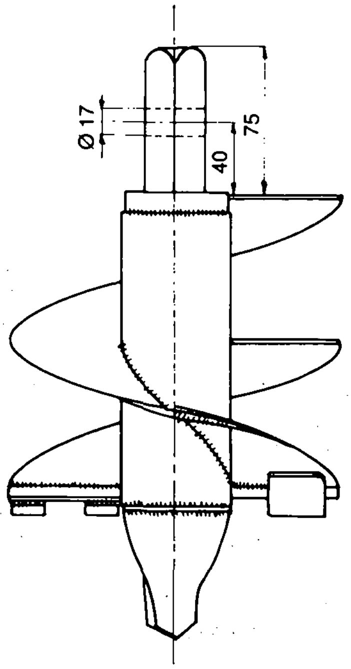


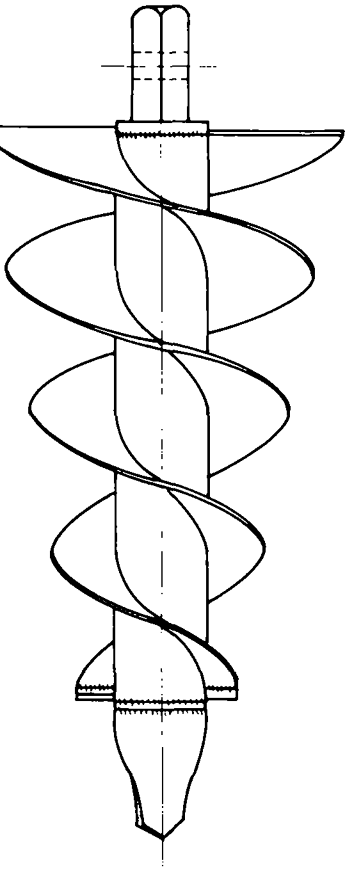
Standard auger bit
The auger bits are normally used in combination with a continuous flight auger, to increase the soil storage capacity.
The bit has 2 spiral-shaped blades around a vertical axis, ending in cutting rims of specially hardened steel. The rims will cut horizontal slices of soil, which are worked up by the spiral into the flight auger.

A 10 cm high rim is welded to the outer edge of the flight to increase its capacity of lifting sandy materials. Furthermore the drill will center better, and damage to the borehole walls is vastly reduced.

This type of drill is specially suited for moist clay and sand, and also for gravelly soils.

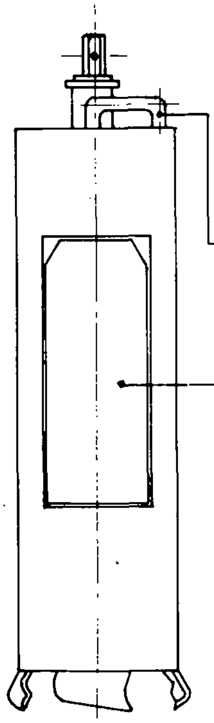
The larger-size auger bit (e.g. 230 mm diameter) is normally used when the drilling is started. The smaller size (e.g. 180 mm) is used when driling is continued inside a casing. The total length of bit + flight auger is 1.30 m.





Conical auger bit

This bit is also used in combination with a continuous flight auger for support in the borehole. Where the cutting blades of a normal auger may start slipping, the sharp point of the conical auger can penetrate such layers. Then the soil is "screwed" loose. For that reason this bit can be used in stoney, layered soils.



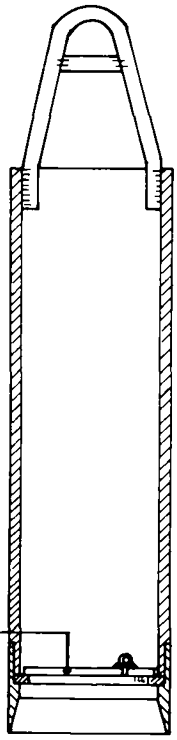
Riverside bit

A riverside bit is a 1 m long, heavy steel pipe with spoon-shaped cutting blades welded to its bottom. The blades only cut at the outside, so that the soil collected inside the bit is practically undisturbed.

This bit is successfully used in semi-cemented layers, such as weathered bedrock (granite, laterite, calcrete), but can also be used for hard, dry clay and for gravelly soils. In such hard soils the drilling speed will be very low, however.

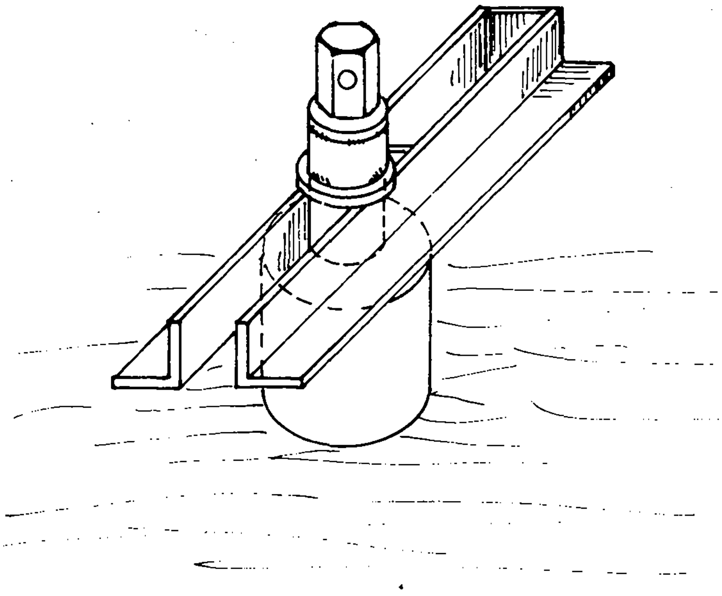
A hinged door is fixed in the wall of the bit, so that the collected soil can be removed easily.

Of the riverside bit again two sizes are required: a larger one for use without casing, and a smaller one for use inside the casing.



Bailer

The bailer is used for the removal of sand from below the water table. It consists of a steel tube of 1 m length, with a flap door at the bottom. An eye is fixed at the top, and the cable of the winch is attached to this with a D-shackle.



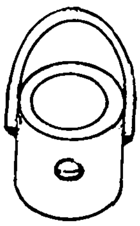
Drilling rod catcher

This device is meant to prevent the drilling assembly from falling into the borehole during coupling or decoupling of the drilling rods.

It is composed of 2 pieces of angular iron welded together with some space in between.

The extension rods can pass untill a steel ring that is welded on the rod rests on the angular irons.

The catcher itself will rest either on the ground or on top of the casing pipe.



Drilling rod hanger

This auxiliary tool is a female connector with a steel eye welded on top. It is used to hang the driling assembly from the hook of the tripod's pulley system.

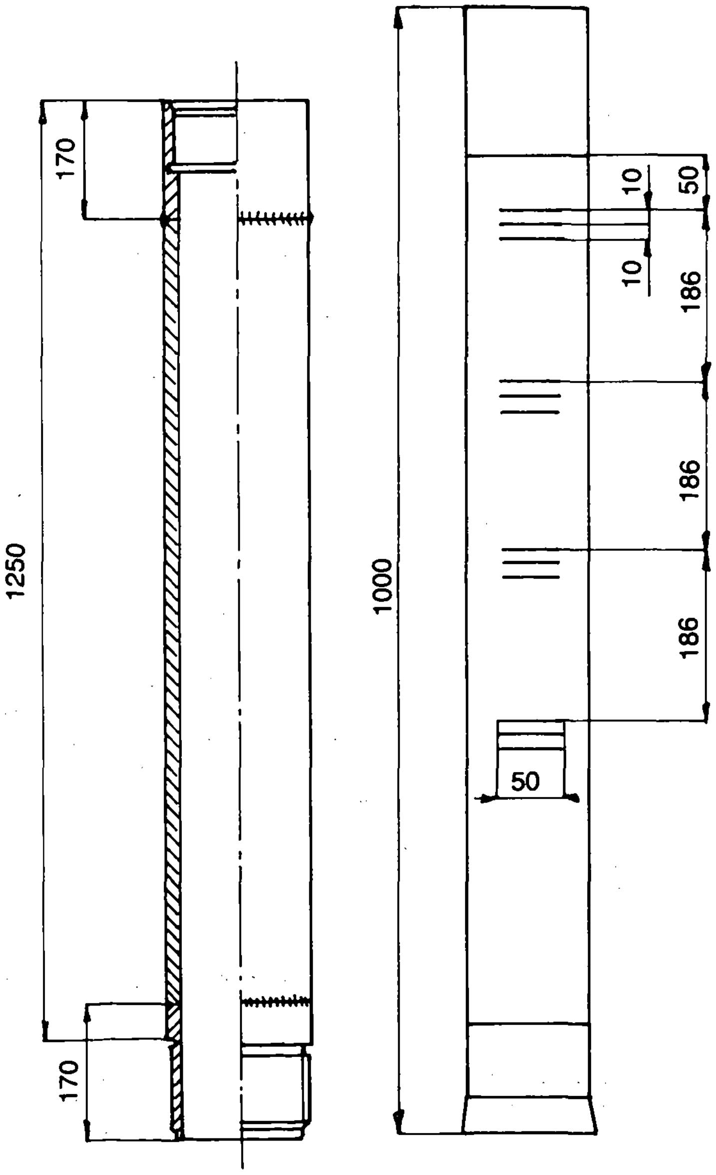
6.2.3. Casing set

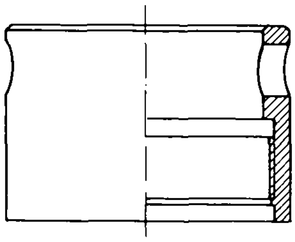
Casing pipe

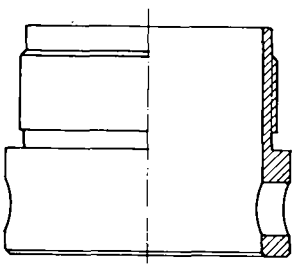
All casing pipes have a net length of 1.25 m each. They have a male tread at one end; a female thread at the other. The thread itself is square, so as to be less vulnerable to damage.

The are made of steel, ABS of PVC, depending on their diameter: 3", 4" and 5" pipes are made of ABS/PVC, and 6", 8" and 10" pipes of steel.

The lower casing pipe has slots (horizontal saw cuts), so that it can act as a filter pipe, allowing water from the aquifer to enter the borehole. This facilitates the use of a bailer and allows test pumping without having to remove the casing pipes first.



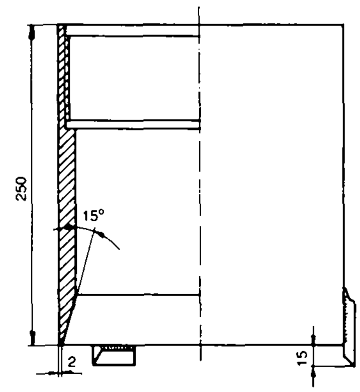




Thread protectors/ Casing hangers

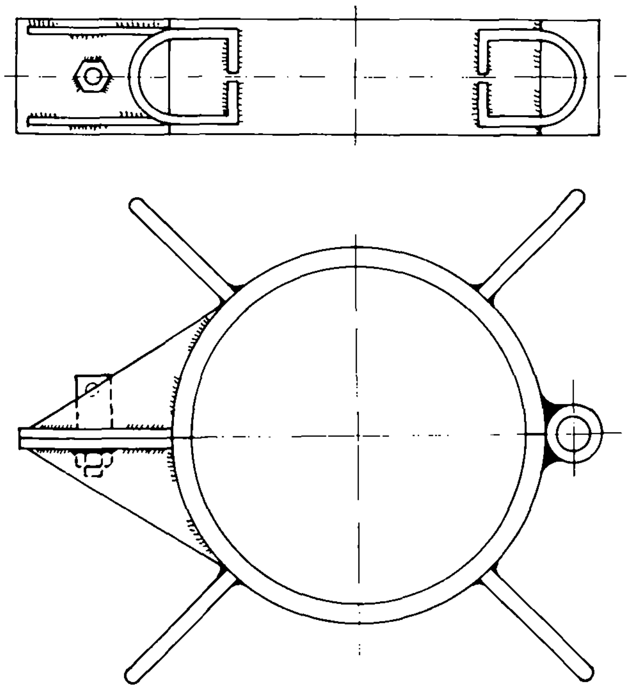
During transport and when the casing pipes are not in use, their ends are protected by female/ male threaded steel rings, so-called thread protectors.

Each unit has two holes drilled in it, through which a steel bar can be put (the casing hanger bar). In that way they can be used for hanging a casing section or the entire casing from the hook of the pulley system, so that the heavy casings can be hoisted or lowered by means of the whinch.



Casing shoe

To the first casing pipe to be used in a borehole, a casing shoe must be fitted at the lower end. This acts as a cutting rim, to facilitate lowering of the casing.



Casing clamp

This is a special tool that will prevent the casing from falling into the borehole during coupling or decoupling of the casing sections.

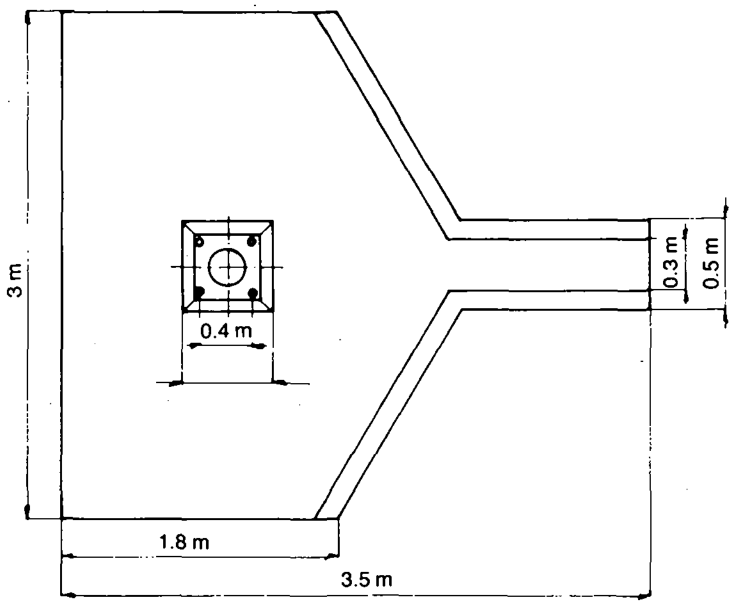
It consists of 2 steel half-cylinders, which can be connected to each other, around the casing, by large bolts.

These are fastened with so-called casing clamp levers.

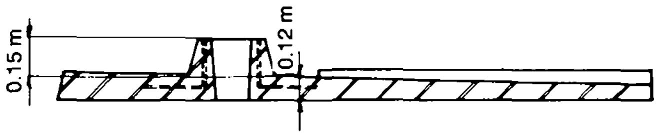
On the sides two eyes are welded, through which a 3-m long pipe of 2" dia. can be inserted. A second pipe of 1.5" diameter is welded inside this pipe, to give it extra strength.

With this pipe the casing can be shaken and turned around during its lowering into, and hoisting up from, the borehole.

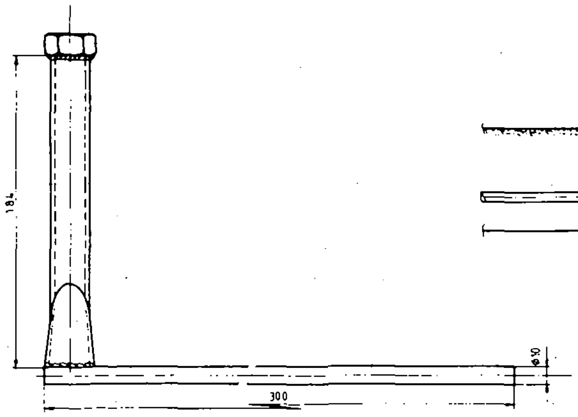
6.2.4. Mould for tube-well cover

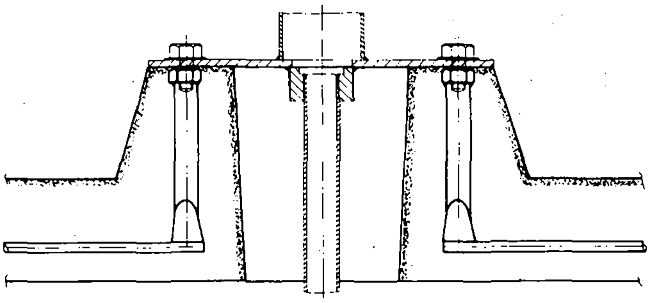


This mould can be used for casting pump stands in which the anchor bolts for the hand pump (or screw anchors) are already fixed at the correct locations.

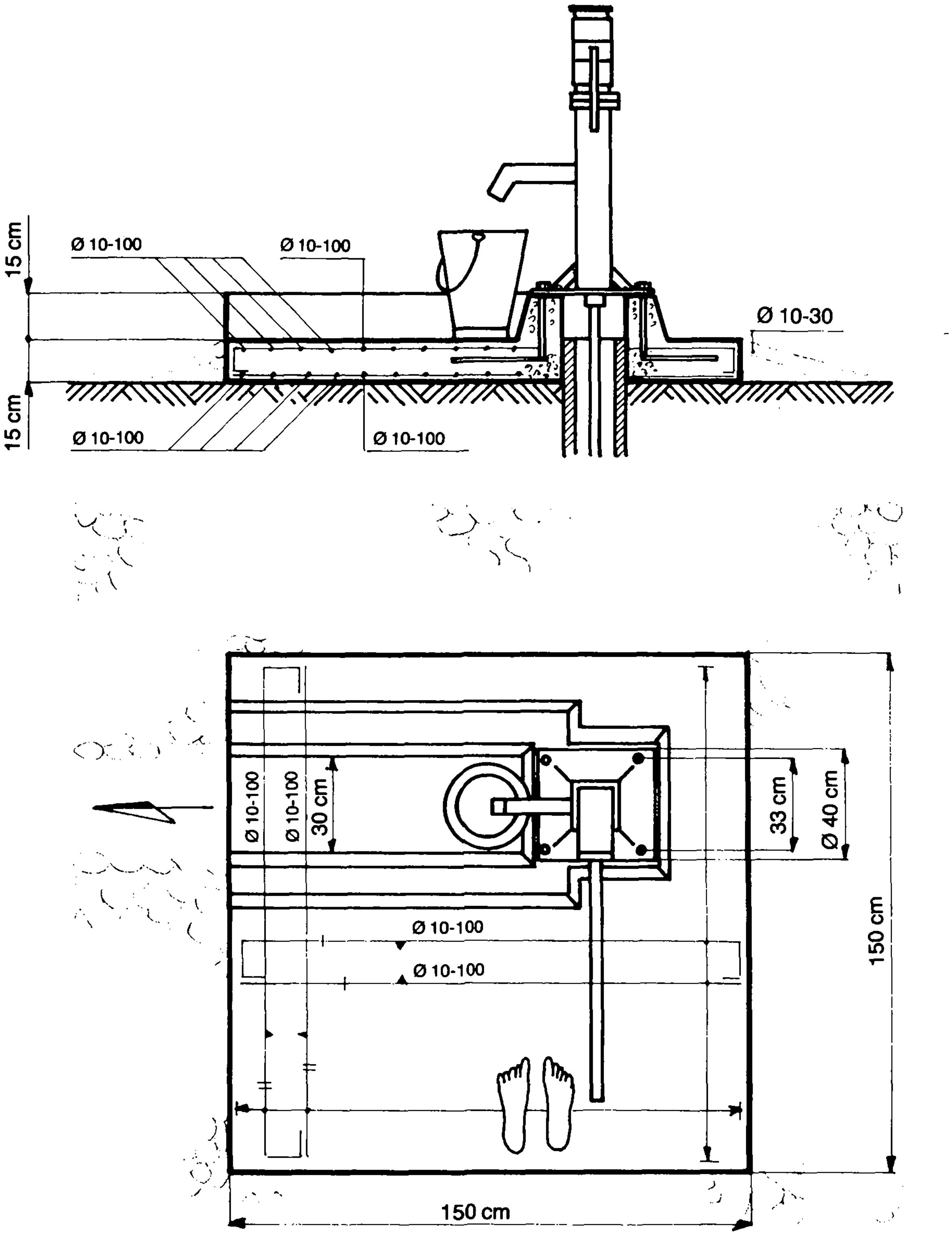


To avoid corrosion of anchor bolts it is recommended to use these with cap nuts only, or to have screw anchors cast in the concrete and fix the pump footplate with G.I. bolts.





Although stainless steel anchor bolts might be used, the adhesion of concrete to stainless steel is often less than desired.
Moreover, such bolts are relatively expensive.



Typical square slab on hand-drilled well

6.3. Equipment for hand-digging wells

6.3.1. Overview of equipment

A typical set of tools for hand-digging shallow wells consists of the following parts:

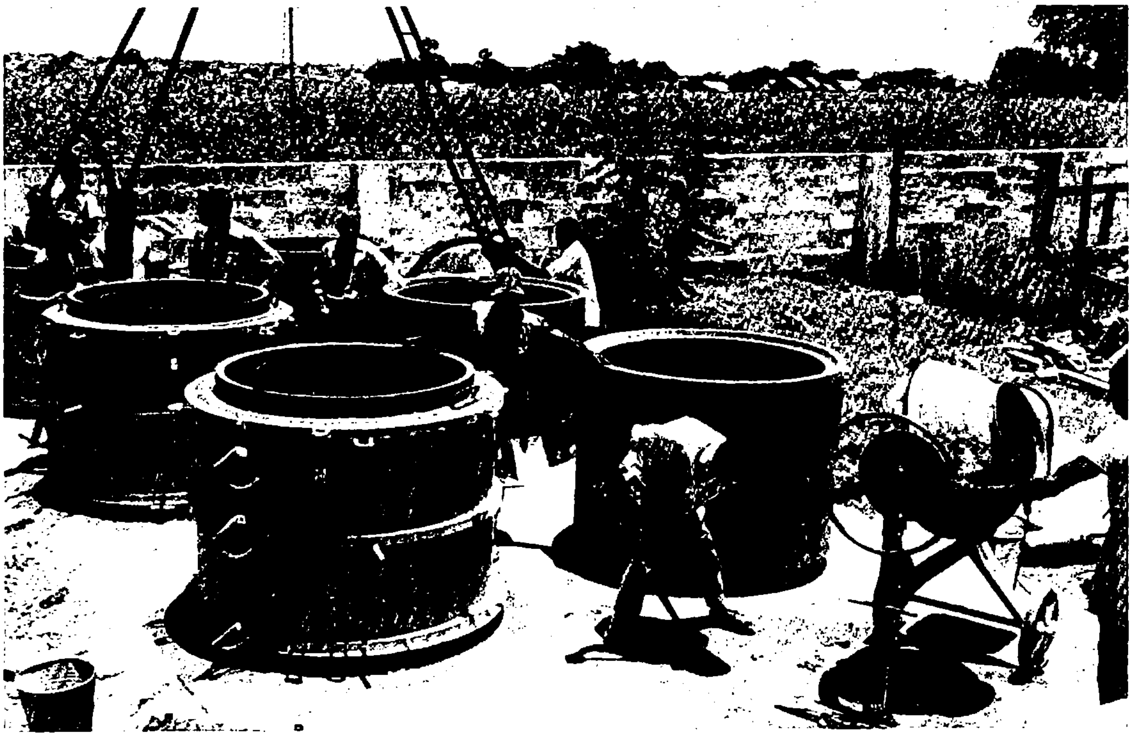
DIGGING SET	**Number**
tripod, capacity 1 ton h = 4 m	1
rope, sisal Ø 30 mm l = 50 m	1
pulley for above with hook and eye	1
pulley, ditto, snatch block	1
safety hook, cap. 2 tons, for rope connection	1
bucket, heavy duty	2
shovel, round point	2
pick, point and chisel end	1
hammer, 3 kg l = 40 cm	2
spare shaft for above	4
hammer, 5 kg l = 50 cm	2
spare shaft for above	4
chisel, flat end, l = 40 cm	4
grinder, hand, with clamps	1
spare disc for above	1
bar, jaw for breaking l = 75 cm	1
helmet, safety	4
rescue device	1
tool box, digging set (800 x 300 x 300 mm)	1

DEWATERING SET

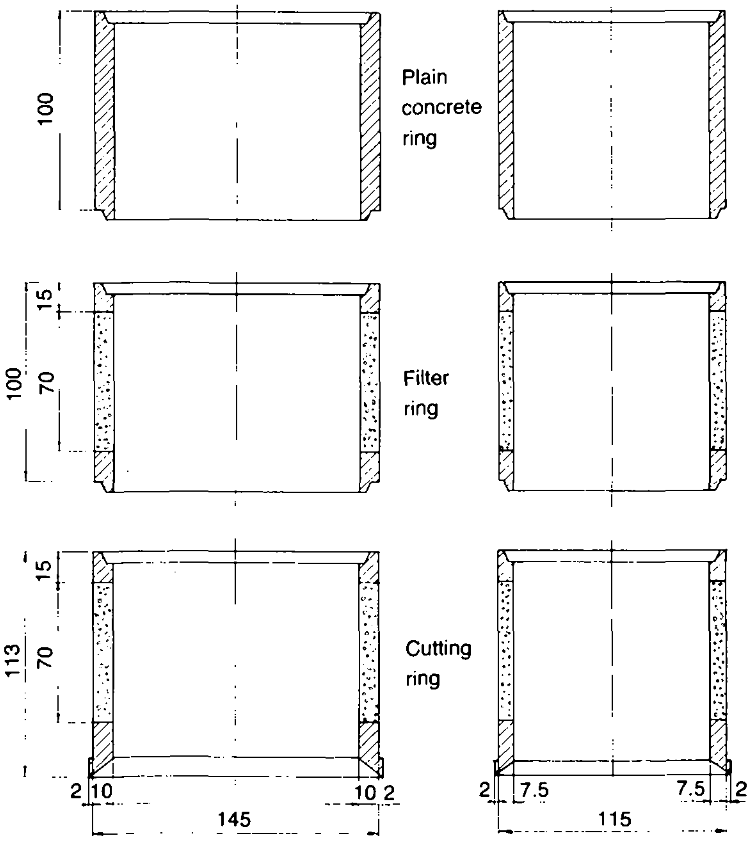
pump support and installation unit	1
pump stand for ring wells	1
pump head SWN 80	1
pump cylinder Ø 75 mm, with 2" hose connection	1
suction hose, Ø 2", rubber l = 5 m	1
strainer, l = 200 mm, with 2 " hose connection	1
clamps for Ø 2" hose	5
riser/rod set l = 2 m	8
riser/rod set l = 1.5 m	4
riser/rod set l = 0.75 m	4
combi wrench for SWN pumps	2
pipe wrench 1½ – 2" pipes	2
adjustable wrench l = 300 mm	1
pliers, combination l = 150 mm	1
screw driver	1
steel brush	1
die, nut, for M 10 st. steel	1
tap, for M 10 st. steel	1
oil, grease, waste cotton	1
tool box, dewatering set (80 x 300 x 300 mm)	1

INSTALLATION SET FOR CONCRETE RINGS	Number
tripod 2 tons, type VRM, cpl with footplates	1
winch, with 33 m of steel cable Ø 10 mm	1
spare steel cable, 33 m Ø 10 mm	1
swivel hook, safety, 3 tons	1
pulley, swivel hook and eye	1
ditto, snatch block	1
thimble for 10 mm steel cable	5
cable clamp for 10 mm steel cable	10
D-shackle, 3 tons	3
double leg chain l = 1.5 m	1
hand chain hoist l = 3 m, cap 1.5 t	1
mould for concrete rings Ø 1450/1250 mm	1
ditto for concrete rings Ø 1150/1000 mm	1
lifting beam for concrete rings	1
cable sling, hook + eye, l = 6 m	1
mould for ring well cover Ø 1450 mm	1
mould for ring well cover Ø 1115 mm	1
adjustable wrench l = 300 mm	2
pliers, combination l = 150 mm	1
screw driver	1
steel brush	1
oil, grease, waste cotton	1
tool box, "concrete rings" (800 x 300 x 300 mm)	1

6.3.2. Additional equipment

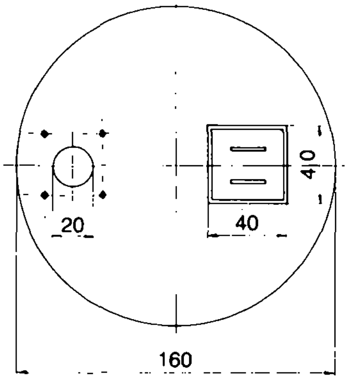


Moulds for conrete well rings

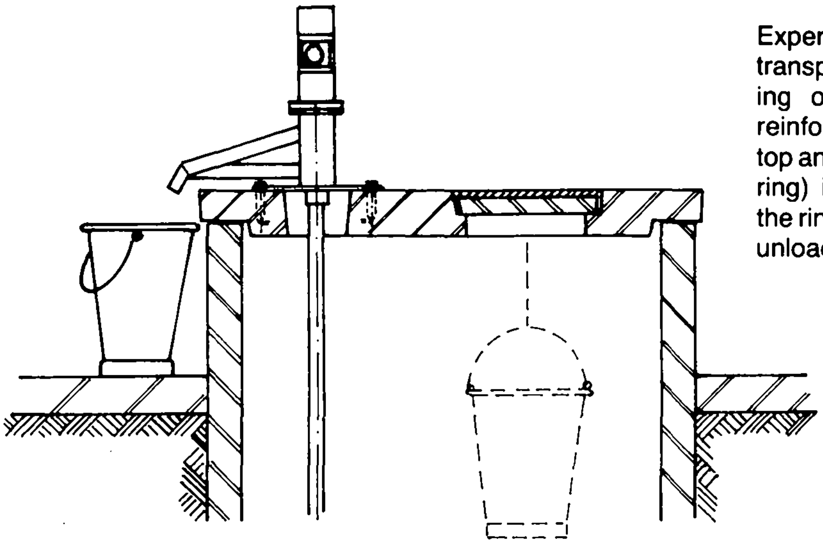


Full-diameter

Reduced diameter



Moulds for well rings and covers
The size of the required moulds are dictated by the dimensions of the concrete rings and well cover.



Experience has shown that a transport reinforcement consisting of 2 hoops of Ø 6 mm reinforcement rods (one at the top and one at the bottom of each ring) is sufficient, provided that the rings are carefully loaded and unloaded (see paragraph 6.3.3.).

6.3.3. Handling of concrete well rings

Since the weight of a typical well ring is between 0.5 and 1 tonne, special equipment is necessary to handle them. As they are easily damaged, this handling should be done with care.

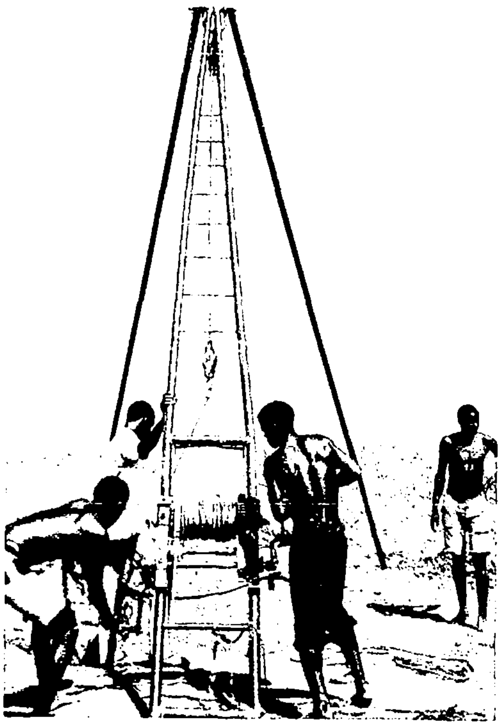
If well rings have to be moved over short distances only, they can be rolled over without damaging them.
Loading and unloading from a truck and lowering in the well itself involve lifting and turning over the rings. Because of their weight, this cannot be done by hand.

Using a tripod
For lifting well rings a tripod can be used, consisting of two legs of approx. 6 m length, and one double leg of the same length, on which a winch is mounted. A cable is wound around the winch and run through a double pulley fixed in the top of the tripod, and a single pulley to which a hook is attached.

For safety reasons the tripod must be erected extremely carefully. The legs must be positioned in such a way that they cannot slide away, and that the cable hangs down exactly in the middle of the tripod.

Attention must be paid to the following practical points when erecting a tripod:

- put the feet of the tripod all at the same level.



Lifting well rings with a tripod

- both single legs must be at the same distance from the double leg with the winch.
- the distance between the feet of the single legs must be approx. 4 m.
- when seen from behind the winch, the cable must hang exactly between, and parallel to, the double leg.

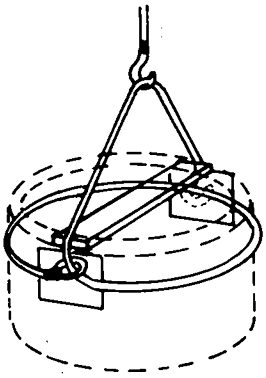
Loading of a ring on a truck

When the tripod has been properly erected over the ring, place a wooden beam (with a length equal to the diameter of the ring + 1 cm) over the ring, and put a sling around the ring at about mid-height. The length of the sling, which has an eye at one end and a hook at the other, is approx. 7 m.
The hook is pushed through the eye, to form a loop which is laid around the ring, and then the hook is fastened to the other side of the loop.

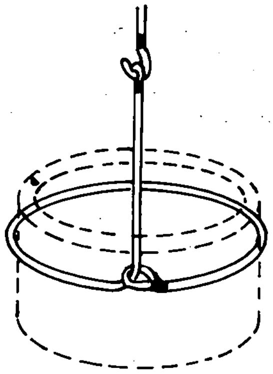
The beam prevents the upper part of the sling from crushing the top of the ring. To prevent the sling from cutting into the beam, its ends may be strengthened with steel plates.
Pieces of plywood of approx. 25 cm x 25 cm are put between the ring, and the eye and hook, respectively, to prevent these from damaging the concrete.
The sling is then fastened to the tackle cable and when this cable is pulled upwards, the sling tightens around the well ring and this is lifted.

Then back up the truck underneath the well ring, and lower this on to the cargo space. (This may be provided with a wooden floor on some sand, in order to absorb shocks during transport.)

After the ring has reached its destination, it is unloaded by using the reverse of the procedure described above.



Sling for lifting a concrete ring horizontally



Sling for turning over a concrete ring

As trucks cannot normally back up to the very edge of the well itself, the rings, after unloading, must be transported to the site itself. Therefore, the ring is turned over on its side and rolled to the well.

Another sling (approx. 5.5 m long), with an eye at each end, is put around the well rings in much the same way as described before, but the remaining eye is now fastened to the tackle rope. By pulling the tackle rope upward, the ring is turned over, the sling can be removed and the ring rolled to the well site.
The sling must be put around the ring in such a way that the eye through which the other eye is pulled, is positioned either at the winch side or exactly opposite it. Otherwise, the ring may pull down the tripod during lifting.
Even when the sling is properly attached, the ring must be guided by hand, to prevent it from turning around and pulling down the tripod.

Sinking and stacking the ring in the well

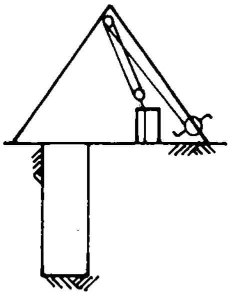
Roll the first ring to be sunk (the cutting ring) to the well and on top of the 5.5. m sling. Then fasten the sling around it somewhat above half-eight, but not less than 30 cm from the top of the ring.

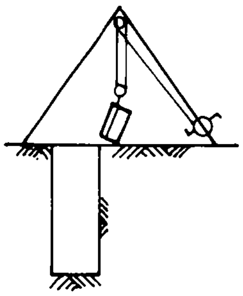
In the meantime position the tripod next to the well opening, with the tackle cable hanging about 1 m from the edge of the hole.

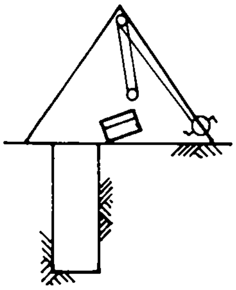
Then roll the ring to a position 1.5 m from the edge of the well, with its top facing the well opening. Fasten the tackle cable to the sling, pull the ring slightly upwards, and in that way move it slowly to the edge of the well opening. The ring will hang somewhat askew, due to the eccentric position of the sling.

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

Thus the well ring is put in a horizontal position, right next to the well.
The position of the tripod must now be changed in such a way that the tackle is exactly over the centre of the hole.



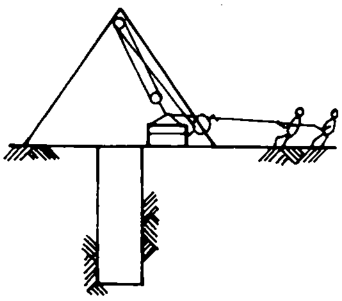


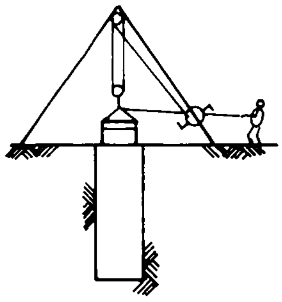


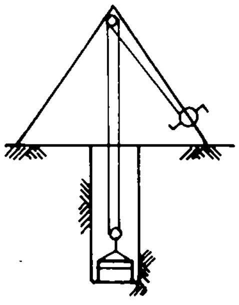
Then fasten the 7 m long sling around the ring again, as described earlier. Attach a rope to the pulley hook and, by pulling the tackle cable upward, while at the same time paying out the rope, carefully hoist the ring into position over the well.
It is essential that the guide rope be attached to the hook of the tackle. The ring will be pulled askew if the guide rope is fastened around the ring itself, and this will prevent it from being lowered properly.

Now the ring, hanging horizontally over the well, can be lowered to the bottom of the well or stacked on top of rings that have already been put into position in the well.

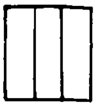
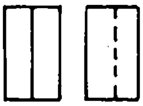
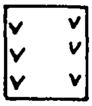
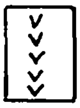
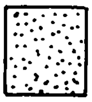
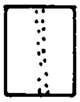
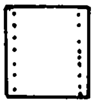
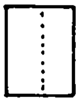
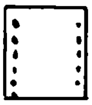
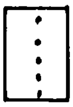
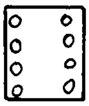
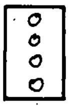
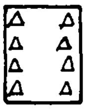
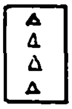
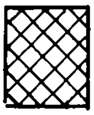
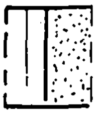
After a first ring has been lowered into the well, check its position with a spirit level. If it is not exactly horizontal, lift the ring slightly and have some soil removed from underneath, until it is exactly level.







7. List of lithological symbols

Symbol		Soil Type	Grain Sizo in µm*	Grada-tion	Consis-tency	Water content
as minor parts	as major parts					
		Clay	2	–	soft sticky dense	dry or moist
		Silt	2 - 20	–		dry, moist, wet or water-bearing
		Sand	20 - 200	fine	soft or loose	dry, moist or water-bearing
			200 - 500	medium		
			500 - 2000	coarse		
		Gravel	2000	round		dry, moist or water-bearing
		Stones		angular		
		Bed Rock			weathered or hard	dry, water-bearing
		Thin clay layers				
		Alter-nating sand and clay layer				

* 1 µm = 0.001 mm

8. Forms

SURVEY AND WELL LOG FORM

BOREHOLE No. ....

Date : ....

District : ....

Village : ....

Location : ....

Depth in cm below ground level	Grain size	Lithology	Colour	Type of auger	Water content		
					dry	medium	wet

PUMP TEST

t min.	No. of buckets	EC	F^- mg/l	Colour	Taste	Odour	Water level
t_0							
t_{15}							
t_{45}							
t_{75}							
t_{105}							

RECOMMENDATIONS FOR CONSTRUCTION

Total well depth	Hand-dug	Hand-drilled	Depth of screen	APPROVED
.... m				DISAPPROVED