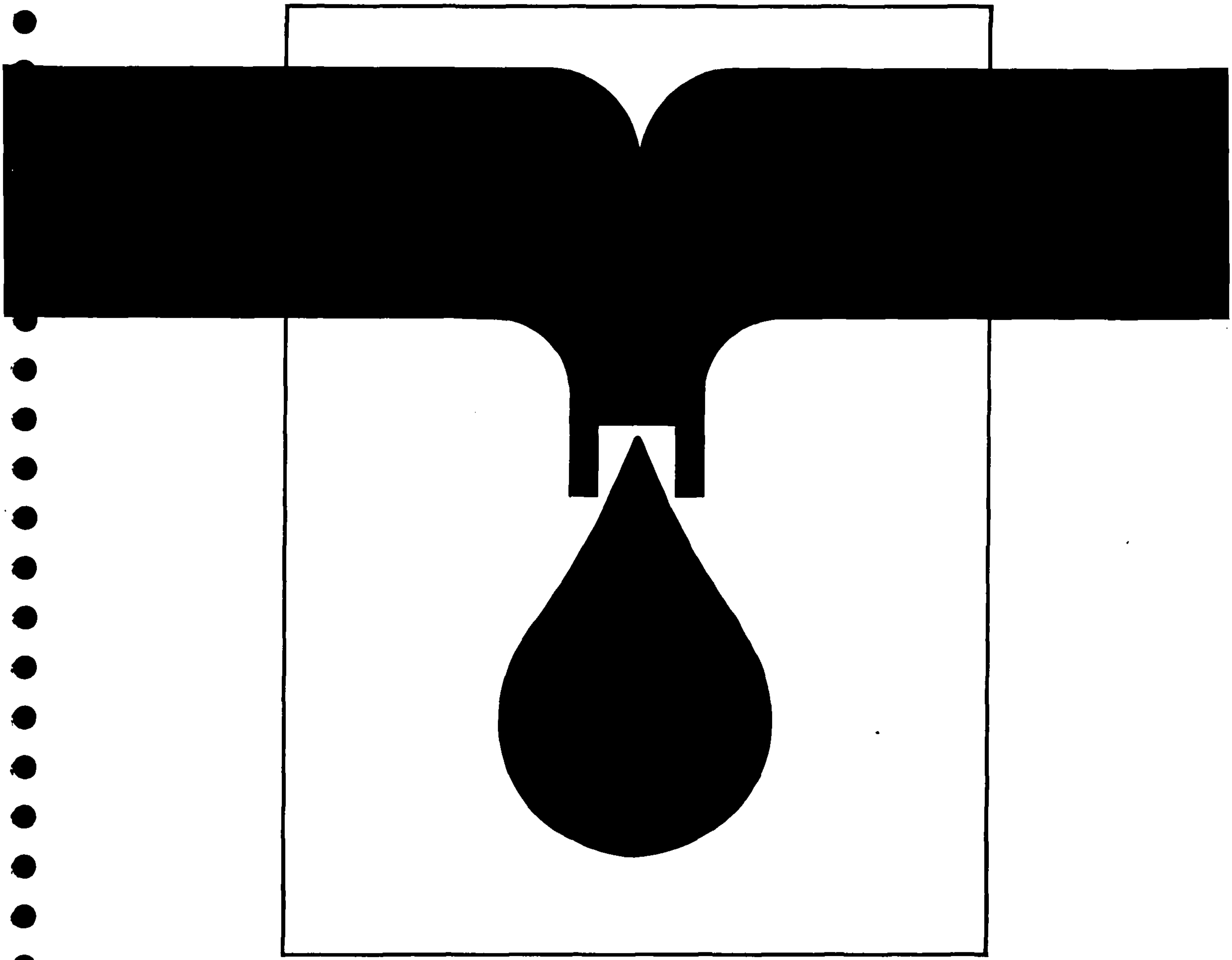
TRAINING MODULES
FOR
WATERWORKS PERSONNEL



Basic Knowledge

1.1

The function and technical composition of a watersupply system

Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and – if possible – low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

Our grateful thanks are due to

Prof. Dr.-Ing. H. P. Haug
and
Ing.-Grad. H. Hack

for their committed coordination work and also to the following co-authors
for preparing the modules:

Dipl.-Ing. Beyene Wolde Gabriel
Ing.-Grad. K. H. Engel
Ing.-Grad. H. Hack
Ing.-Grad. H. Hauser
Dipl.-Ing. H. R. Jolowicz
K. Ph. Müller-Oswald
Ing.-Grad. B. Rollmann
Dipl.-Ing. K. Schnabel
Dr. W. Schneider

It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

Dr. Ing. Klaus Erbel
Head of Division
Hydraulic Engineering,
Water Resources Development

Eschborn, May 1987

Title: The Function and Technical Composition of a Water-supply System

Table of Contents: Page

0. Introduction

The water resources available for human use are very limited. If the total existing volume of water were not steadily renewed by natural means, it would not suffice to maintain the world's human and animal populations for a very long time.

The natural renewal of water resources rests on the fact that nature keeps its water in a constant state of motion. Since that motion is cyclic, it is referred to as the water cycle or hydrologic cycle. Saltwater evaporates, travels through the atmosphere, and precipitates over land, from where it returns to the ocean via numerous avenues (fig. 1).

The hydrologic cycle has no beginning and no end.

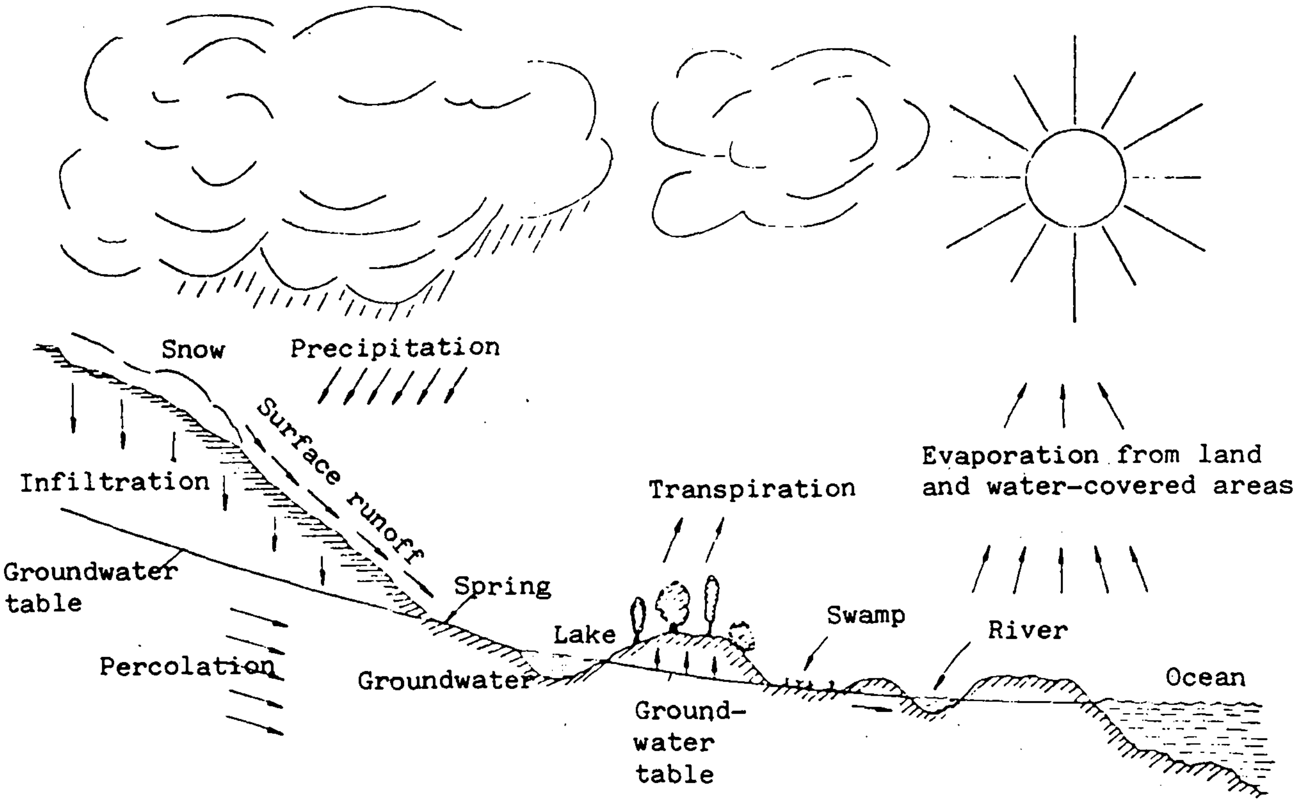


Figure 1: The water cycle

1. Water resources

The following types of water resources are exploitable:

- precipitation
- surface water
- groundwater
- spring water
- dune water

While precipitation falls practically everywhere, water supplies resting on that basis must be considered very unreliable, because rain, snow, etc., are distributed very unevenly - and unforeseeably - around the year. In addition, the very nature of rainwater is such that it cannot always be used for human consumption in its natural state. Consequently, groundwater and surface water are regarded in following as the two most essential water resources.

1.1 Groundwater

Groundwater is the water that runs into and fills the cavities in the earth's crust, and which is only subject to the force of gravity, i.e. hydrostatic pressure.

Groundwater is always on the move. It flows less rapidly than surface water and always strives to reach the parts of the earth's crust that can absorb it and help it to move farther on. Such areas are called water-bearing strata or aquifers. The water penetrates down to an impermeable layer and then flows in the direction which offers the least resistance.

Aquifers are always bordered by an impermeable layer at the bottom and either a permeable layer (sand, soil, etc.) or an impermeable layer (clay, rock, etc.) at the top. When a water-filled stratum is covered by a permeable layer, so that the groundwater table can fluctuate, the groundwater table is referred to as being "unconfined". The groundwater flows freely - i.e. free of hydrostatic pressure - along the existing slope.

If a well is sunk into such a stratum, the water level in the well will correspond closely to the level of the water table (fig. 2).

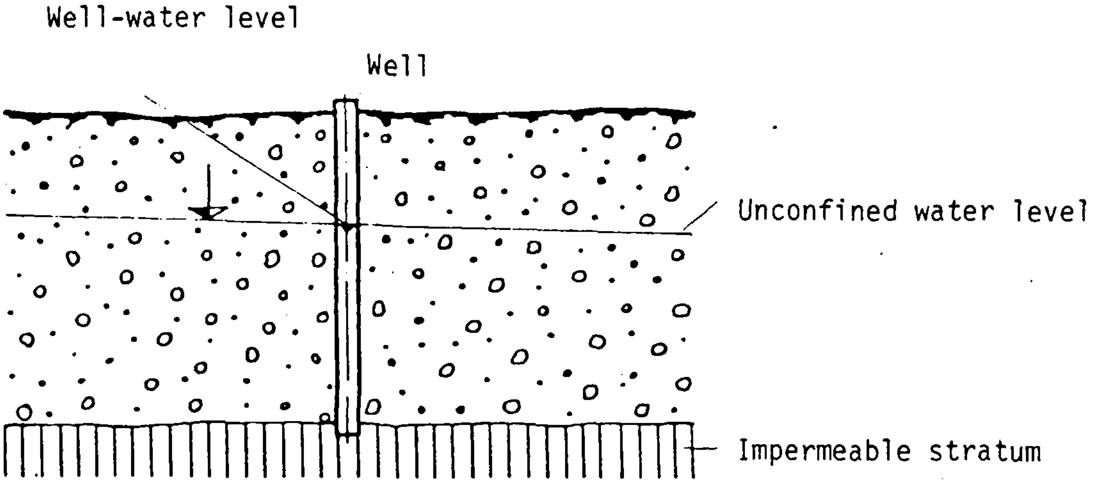


Figure 2: Water-bearing stratum with unconfined water table

If, however, the water-bearing stratum is covered by an impermeable layer, the upward flow of water may be limited, and the groundwater comes under pressure. In such cases, the groundwater is referred to as "confined" (fig. 3).

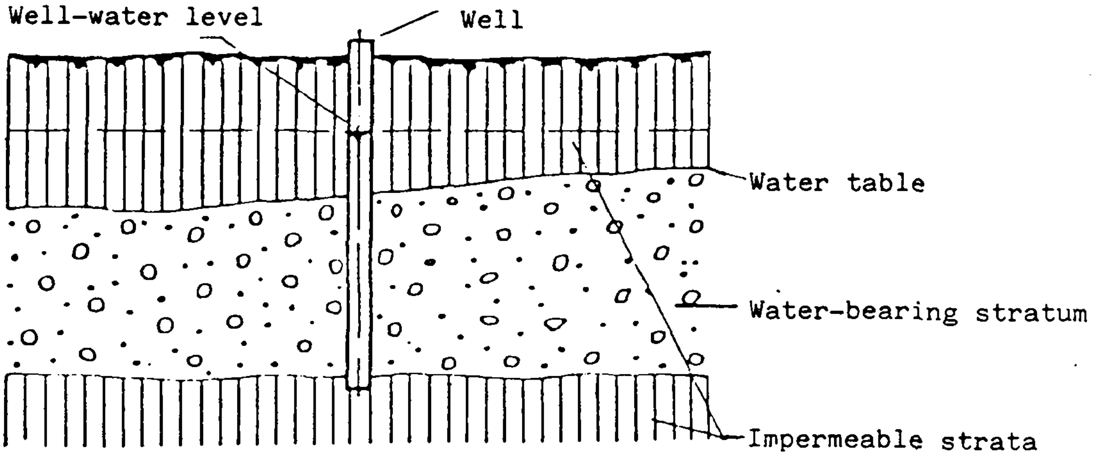


Figure 3: Water-bearing stratum with confined water table

If a well is drilled in such as layer, the water level in the well will stand higher than the confined water table. In rare cases, it can even rise above the level of the surrounding terrain, in which case the groundwater is said to be artesian.

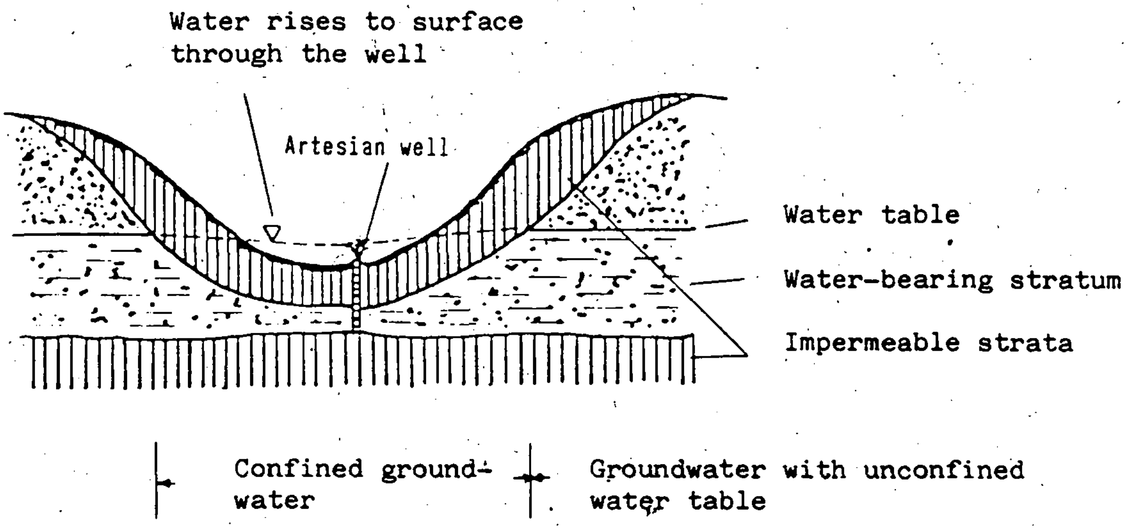


Figure 4: Water-bearing stratum with artesian water table

When a water-bearing stratum leads up to ground level, a spring appears. Springs are reliable, economic providers of drinking water.

Groundwater renewal occurs naturally by the inflow of infiltrating surface water. It can also be achieved artificially by way of river water seepage.

Groundwater is the water resource with the best protection against contamination. Its normally high quality serves as a standard for good drinking water. It is usually regarded as especially suitable for use in meeting the potable-water requirements of local populations.

1.2 Surface water

The term surface water is used to define the water in rivers, lakes, reservoirs and the ocean.

Since surface water picks up all kinds of contamination as it flows along the surface of the earth, it nearly always has to be treated and purified before it can be used as drinking water.
River water is subject to strong seasonal fluctuation regarding its degree of silt, contamination and its temperature. In addition, the quality of river water is usually so severely impaired by domestic sewage water, industrial wastewater and shipping activities, that it can only be regarded as potable after being purified. Water from lakes and reservoirs is better suited than river water for use as drinking water, because it is usually less severely contaminated.

Reservoirs that are fed by relatively clean and pure spring water provide good drinking water.

Due to the high cost of desalinizing salt water, it is rarely used as a source of drinking water.

2. Water requirements

2.1 Quantitative demand

The purpose of a central water supply system is to provide its users with ample and reliable amounts of hygienically safe drinking water.

The quantitative demand for drinking water within the service area is one of the most important factors to be considered in planning and calculating a central water supply facility.

The water requirement may be defined as the estimated quantity of water that has to be delivered by the central water supply system at any given time.

The quantitative demand can only be ascertained properly, if the following factors are known:

- number of residents within the service area
- climatic data
- economic structure
- standard of living and customs of the local population
- extent of sanitary equipment in the homes to be serviced
- type of sewage disposal
- distance to the nearest water supply
- public facility consumption
- price of water
- quality of water
- supply pressure

The overall demand for water within a given service area comprises the following fractional requirements:

- Consumers
  a) local population: minor consumers such as households, gardens, small businesses and farms
  b) major consumers such as big businesses, special consumers and industries.
- Internal requirements of the waterworks
- Public-sector consumption in public buildings, services, institutions, etc.
- Losses
- Firefighting requirements

Tables 1 and 2 list the approximate consumption figures to be used in calculating the total water requirement (water losses included).

Table 1: Average water consumption as a function of the type of water supply system

Type of water supply system	Daily per-capita water consumption in liters
- Communal water supply (village well, public taps)	
. involving a considerable distance (≥ 1000 m)	7
. involving a medium distance (500 - 1000 m)	12
- Village well within walking distance (≤ 250 m)	20
- Standpipe within walking distance (≤ 250 m)	30
- Outdoor tap (near to house)	40
- Private indoor connection	
. with one tap	50
. with several taps	150

Table 2: Average water consumption as a function of the type of use

Use	Water consumption
Day schools	15- 30 liters/student and day
Hospitals	220-300 liters/bed and day
Small hotels	80-120 liters/overnight stay
Restaurants	65- 90 liters/seat and day
Mosque	25- 40 liters/worshiper and day
Movie theaters	10- 15 liters/seat and day
Office buildings	25- 40 liters/person and day
Railroad and bus stations	15- 20 liters/user and day
Animal husbandry	
. cattle	25- 35 liters/head and day
. horses, mules	20- 25 liters/head and day
. sheep	15- 25 liters/head and day
. swine	10- 15 liters/head and day
Poultry	
. Fryers	15- 25 liters/100 head and day

Since the water requirement is not a measurable quantity (like water consumption), but can only be estimated for the future, the local population development must also be predicted as closely as possible, i.e. the annual population growth rate must be accounted for in sizing a waterworks for a particular length of service.

The internal requirement of a waterworks means the amount of water needed for sand washing, flushing out the distribution network, etc. It normally amounts to 1 - 2 % of the overall consumption figure. Water losses are the amounts of water that cannot be accounted for after being fed into the distribution network. Depending on the type and condition of the water supply system, water losses may range as high as 10 % of the overall consumption figure, whereby poor construction and maintenance can even result in losses far in excess of 50 %.

Depending on the design basis of the water supply system, a fire-fighting water supply may also have to be considered.

Proper sizing of individual components such as the storage tanks and piping requires knowledge of the anticipated annual and daily fluctuations in water consumption. For a small town, a typical daily-consumption profile would look something like that shown in figure 5:

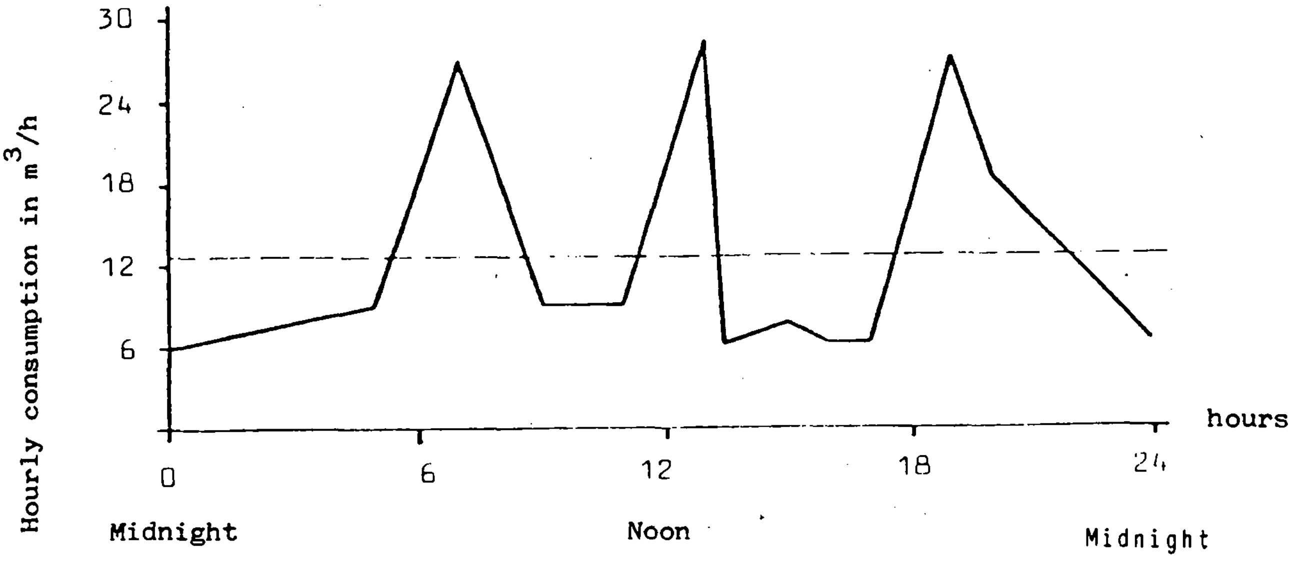


Figure 5: Fluctuation in the daily water consumption of a small town (5000 inhabitants, daily per capita consumption: 60 l)

2.2 Meeting the demand

Whether or not a particular water supply system will be capable of meeting the demand for water in its service area depends primarily on two factors: the quality and amount of available water, and the level of the demand itself. If the demand intermittently exceeds the supply, the system cannot be regarded as adequately efficient. A possible remedy in such a case would be to provide some means of storing the natural water supply. The job of a good waterworks is not limited to just meeting a steadily rising demand for water, but should also include efforts to prevent that demand from getting out of hand.

3. The technical composition of a water supply system

A waterworks constitutes a basic public utility that provides a vital supply of water for daily cleaning requirements and to the benefit and sustenance of humans and animals alike. Consequently, not only economic factors, but hygienic aspects as well, are of decisive importance in the planning, construction and operation of any waterworks.

The main components of a water supply system are the water procurement equipment, the water treatment facilities, the pumping stations with their suction and delivery pipes, the storage tanks/reservoirs, and the distribution network. All of those components must be designed to accommodate the local situation with regard to terrain, water resources and consumption levels. Under very favorable circumstances, some of the main components of the water supply system i.e. the water treatment facilities, pumping stations and/or storage tanks/reservoirs, can be dispensed with altogether.

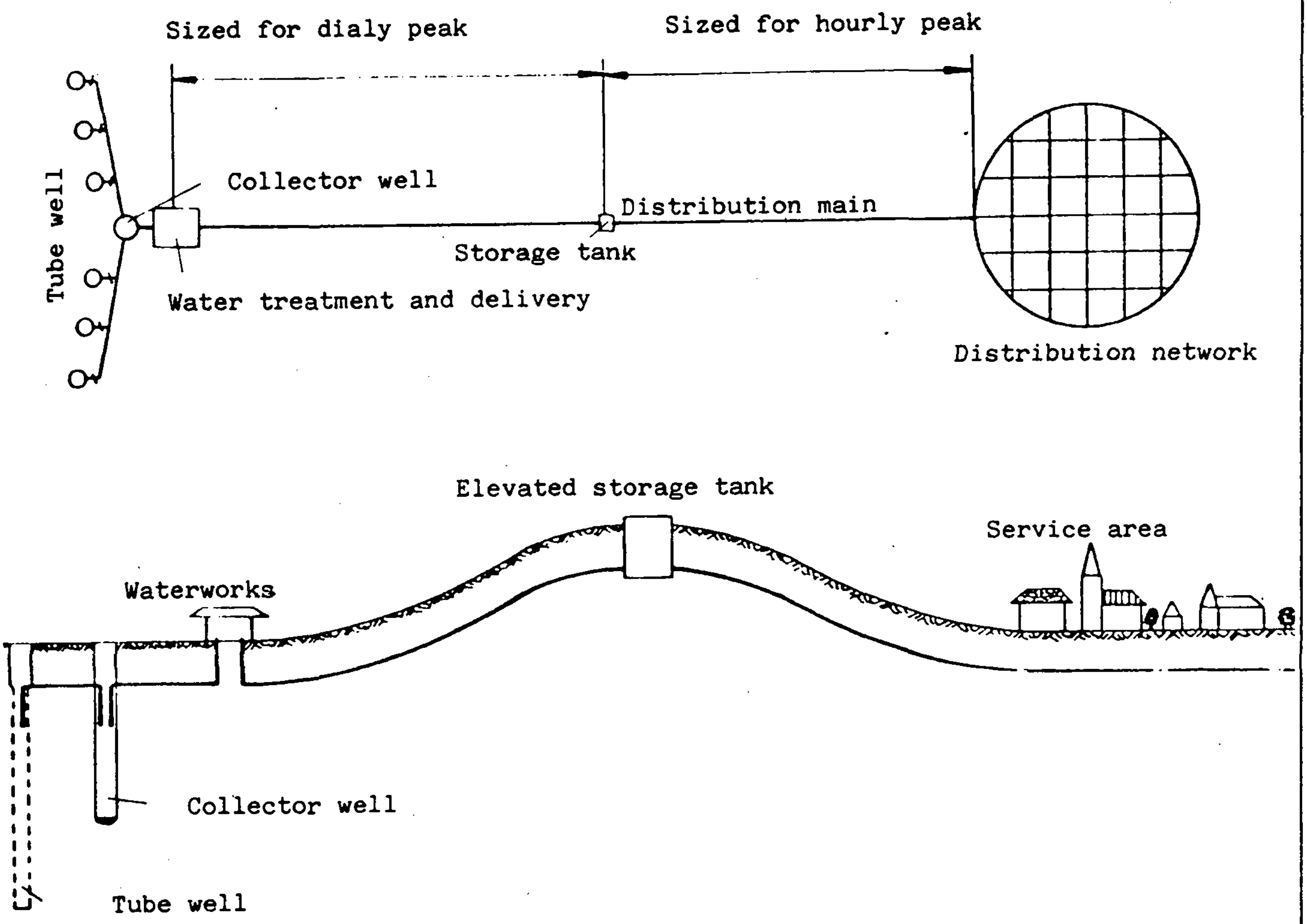


Figure 6: The technical composition of a water supply system

The main components may include any of the following elements:

1) Water procurement

   Well shaft, tube well (vertical and horizontal), water catchment (river, lake or dam), cistern

2) Water treatment

   Equipment for flocculation, filtration, sterilization, removal of iron and/or manganese, deacidification, softening, decolorization, etc.

3) Pumping stations

   Pumps and drive units, pipework, control and instrumentation equipments

4) Water storage

   Elevated water tank, water tower, underground water tank, compressed-air vessel

5) Piping

   Intake pipe (siphon or suction pipe) leading from the collector well or surface water source to the pump(s), delivery pipe from the pump to the water storage facility, distribution main from the storage facility to the water supply network

6) Water supply network

   Distribution lines throughout the service area

The size of the individual elements depends on the amount of water to be collected, treated and delivered. Since the water storage facility normally has to be able to compensate for fluctuations in consumption over a 24-hour period, it follows that all of the water-procurement, water-treatment and water-pumping elements must be sized for the peak daily demand, while the distribution main and the supply network must be large enough to handle the peak hourly demand of the users connected to them.

4. Water procurement

The procurement or collecting facilities must be selected to fit the water-resource situation. The most widespread types of collecting systems are:

Collecting groundwater

- Vertical taps
  - . Abyssinian driven wells (ram pumps)
  - . dug wells
  - . drilled wells (tube wells)
- Horizontal taps
  - . groundwater galleries
  - . groundwater drifts
  - . horizontal filtering wells
- Spring tappings

Collecting surface water

- River water extraction
- Lake or reservoir water extraction

Collecting precipitation

- Rainwater catchment

4.1 Collecting groundwater

The type of tap depends on the amount of water required and on the hydrogeological situation. The main distinction is made between vertical and horizontal taps.

Vertical taps are employed both as private water supplies (rural) and in centralized systems (municipal). Abyssinian driven wells and dug wells are at least as important as drilled wells in rural areas. By contrast, municipal water supplies come almost exclusively from drilled wells.

Abyssinian driven wells are a good solution in rural areas with a high water table (5-10 m below the surface) as long as the ground is sandy or gravelly. They are driven - hence the name - with a hammer or ram and consist of a ram filter that is fitted with a ram shoe and connected to a pipe. The filter has a diameter of between 2.5 and 10 cm, the most popular diameter being 5 cm or less. Driven wells offer the advantage of quick installation.

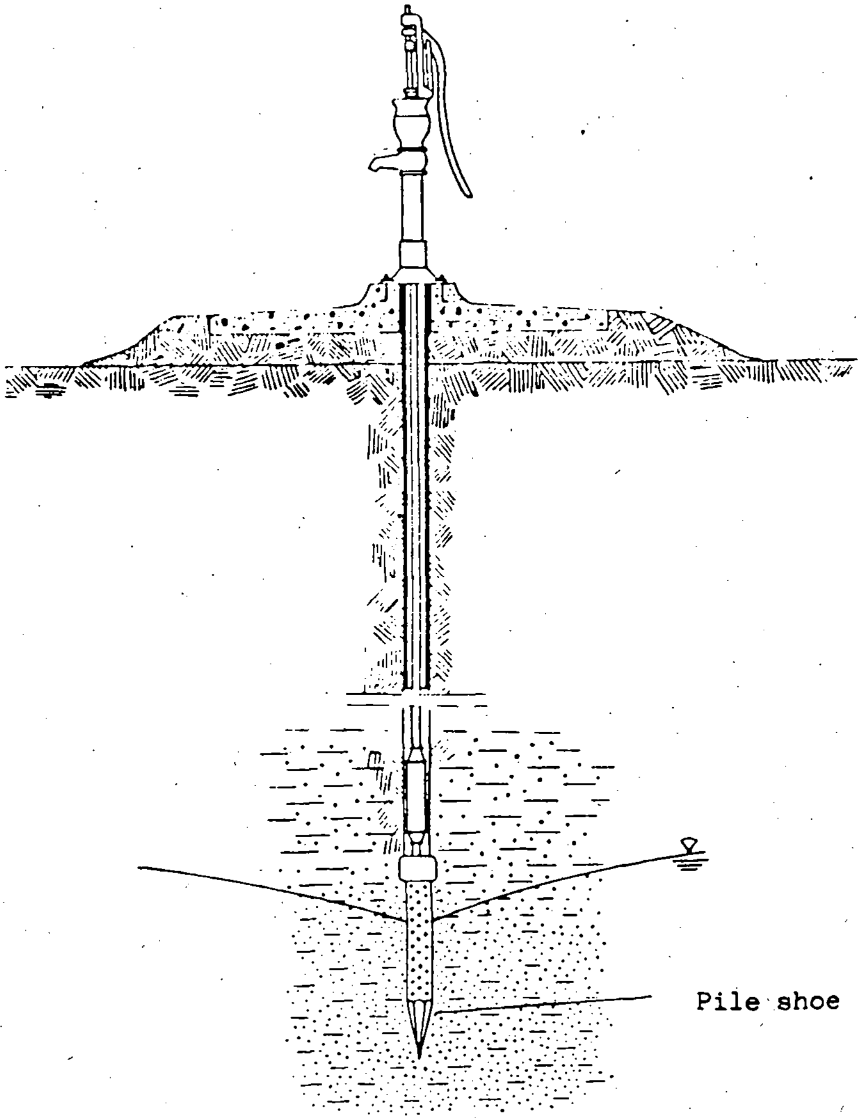


Figure 7: Abyssinian driven well

Dug wells have a diameter of at least 1 meter and extend down to below the water table. The walls are protected against collapse by means of masonry, shaft rings etc. The water collecting at the bottom is raised with the aid of a pump or bucket. Dug wells require stable ground, and the water table must not be too deep down. In soft ground, such wells have to be reinforced to prevent a cave-in.

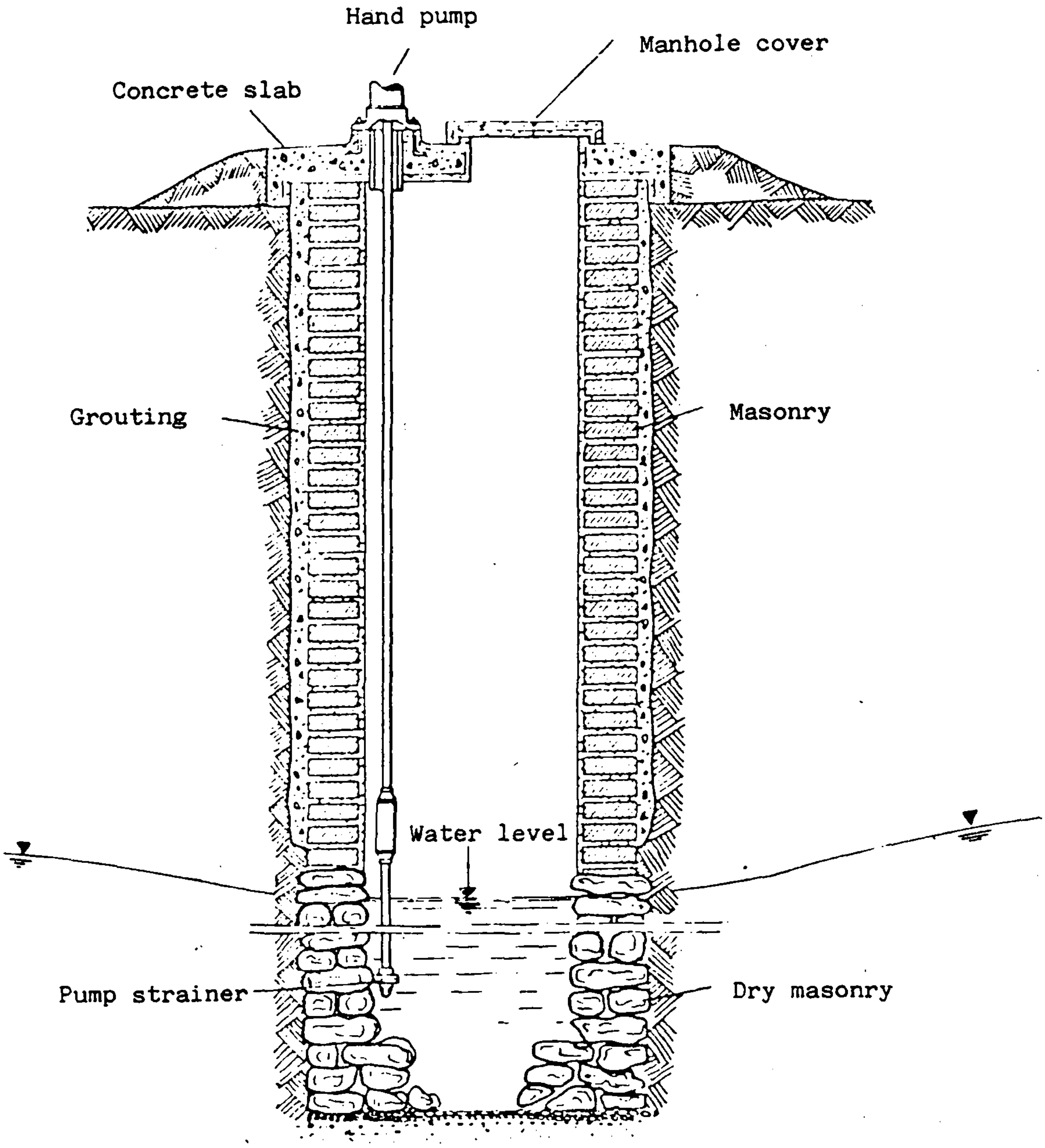


Figure 8: Dug well

Drilled wells can be used to reach great depths. Depending on the intended depth and diameter of the well, various - sometimes quite complicated - techniques have to be employed in constructing it. Manual drilling is only adequate for shallow wells with small diameters. All such wells are closed off at the top with a well head or chamber. The type of pump to be used (deep-well or borehole pump) depends on the depth of the water table.

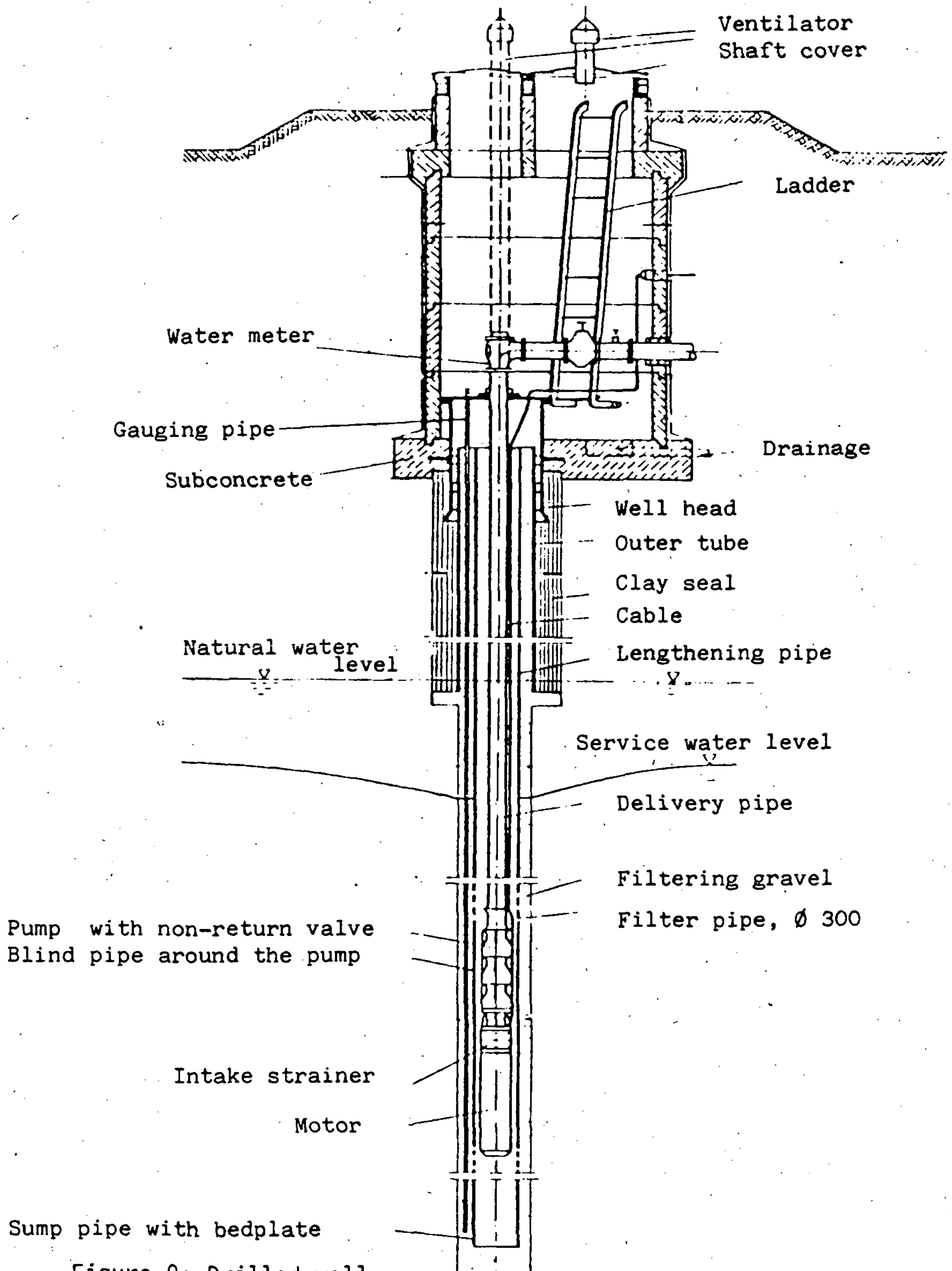


Figure 9: Drilled well

Horizontal taps are normally used for water-bearing strata of limited thickness. They lead to a vertical collector shaft with a diameter of 1.6 - 5.0 m. The horizontal filter pipes are either buried (shallow taps) or pressed into the water-bearing stratum.

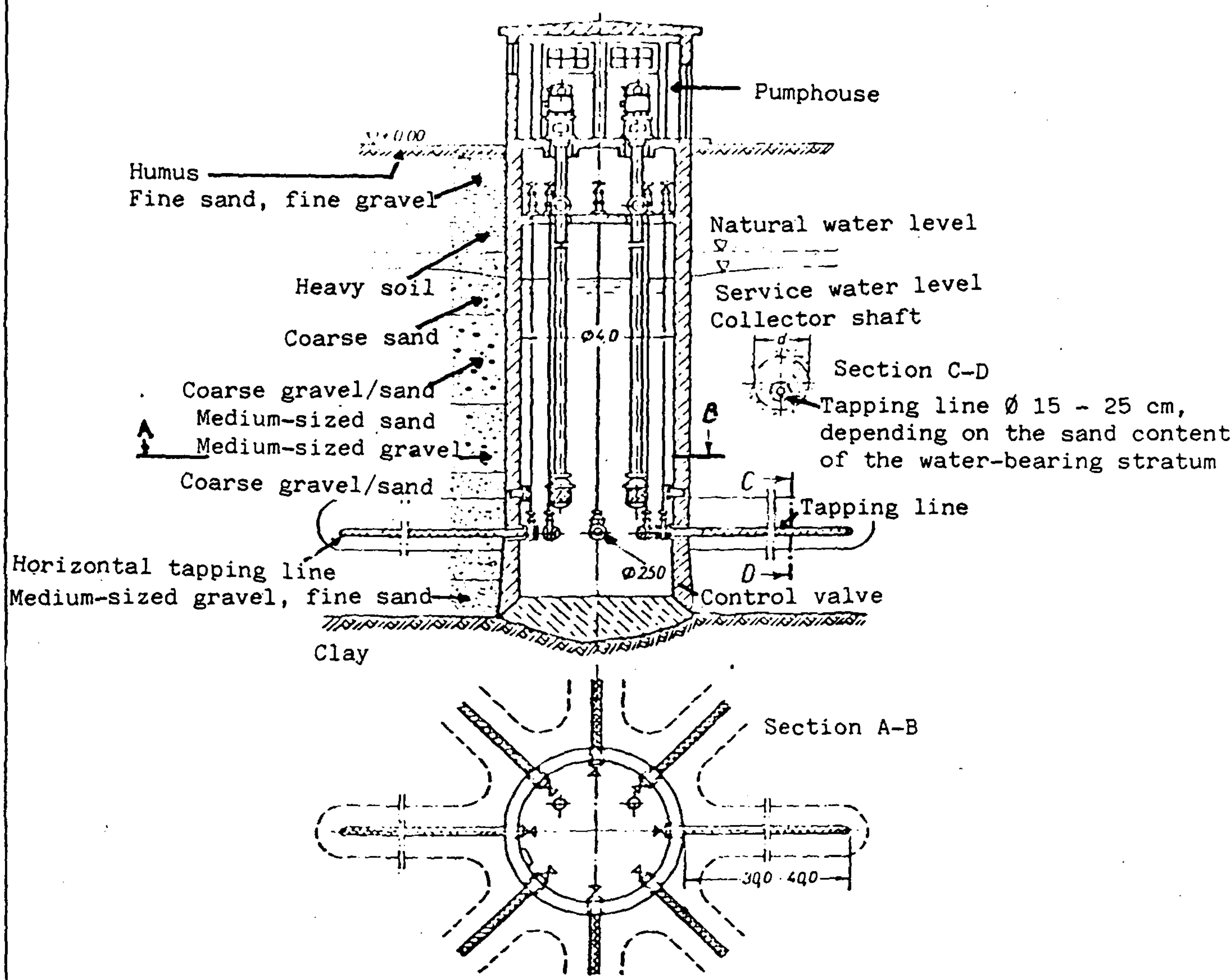


Figure 10: Horizontal tap

Spring taps differ according to the type of spring involved. They must be specially adapted for each different spring. The spring tap must have adequate cover (3.0 - 4.0 m) and back-up prevention. Care must be taken when digging to ensure that the impermeable bottom layer is not damaged.

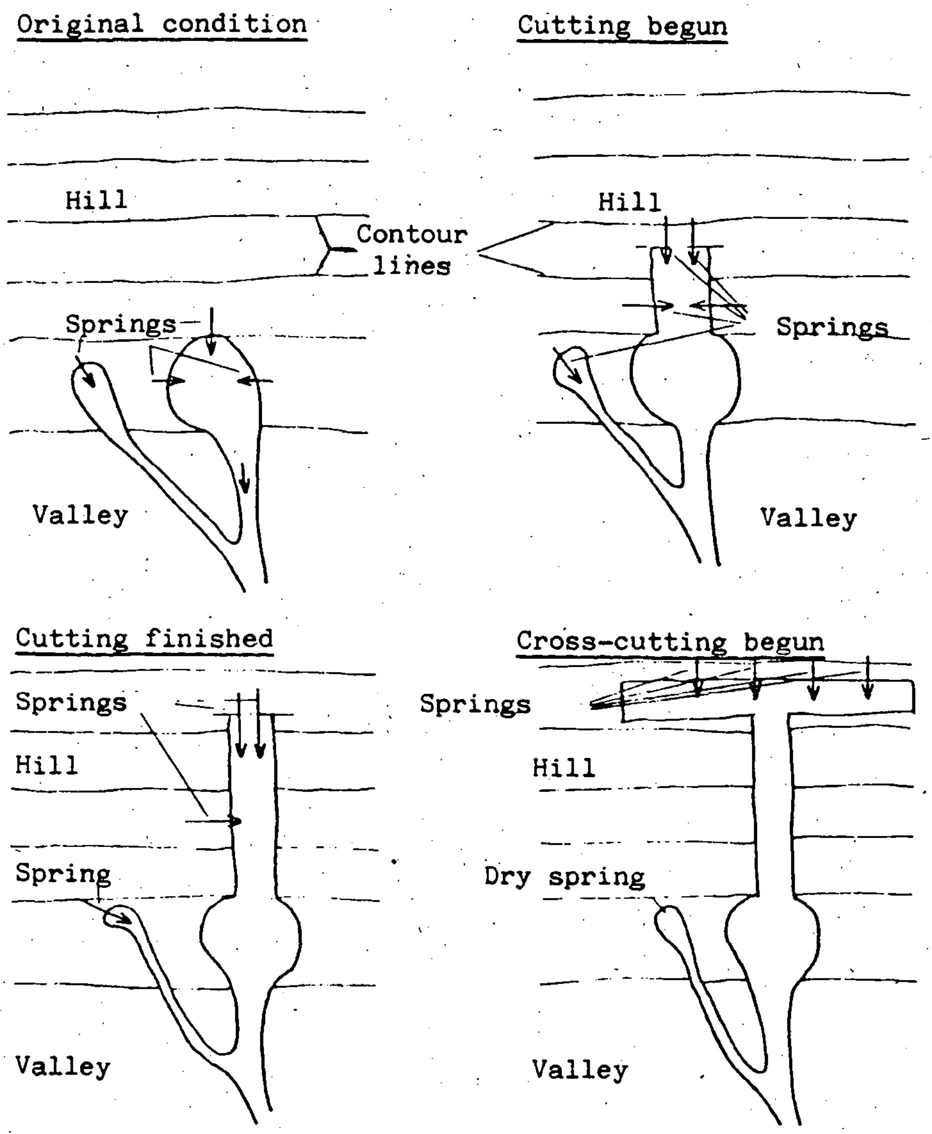
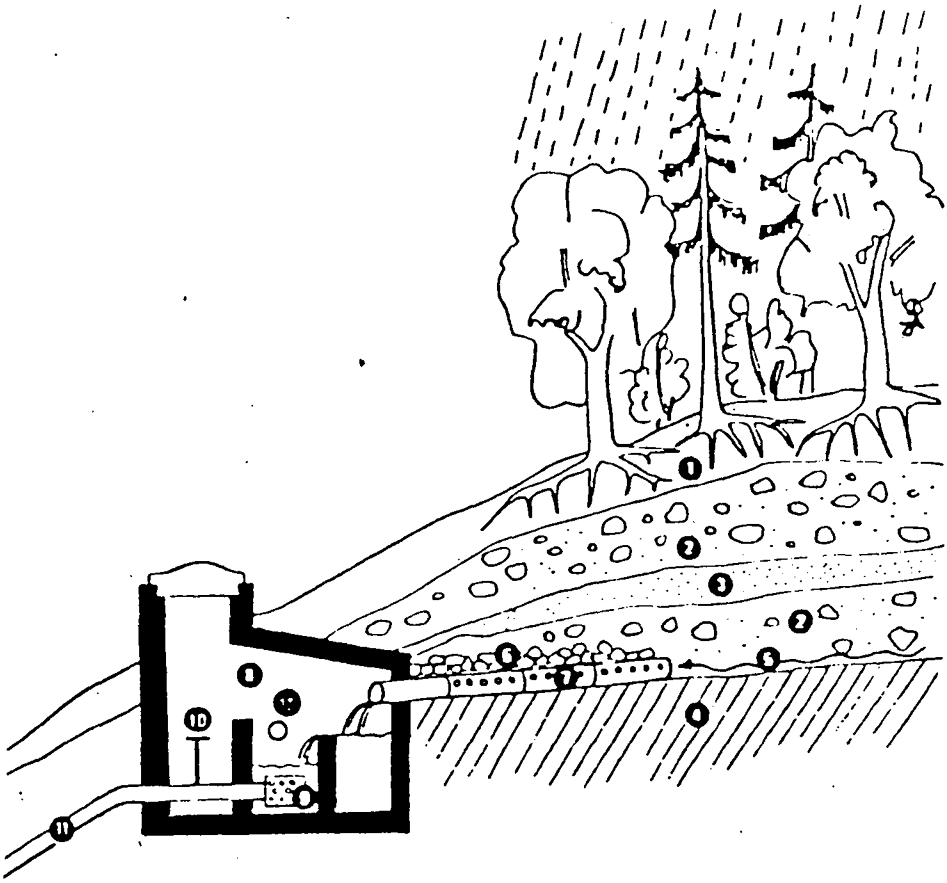


Figure 11: Tapping a contact spring



Legend: 1) humus, 2) sand and gravel, 3) sand, 4) loam or rock, 5) water, 6) layer of rock, 7) seepage tube, 8) well chamber, 9) strainer, 10) control valve, 11) delivery line to reservoir, 12) overflow

Figure 12: Spring tap

4.2 Collecting surface water

Surface water is procured by way of intake structures or catchments. Various types of surface water are extracted or collected in different manners.

When river water is exploited, care must be taken to ensure that the extraction point is located far enough upstream of towns, docks and other potential sources of contamination.

The intake structure (surge tank) should be installed at a point where the water is in constant motion and carries little sediment. That usually means that it will be located either on the outer radius of a bend or on a straight stretch of river. During high water, the inner radii of bends normally collect large amounts of sediment and sandy matter. The intake structure must be designed to provide water of adequate quality all year round - even during dry spells, when the water level is low - and to withstand high water undamaged.

If the water table tends to fluctuate considerably, the extraction points should be flexibly arranged so that they can be adjusted to extract at the required depth.

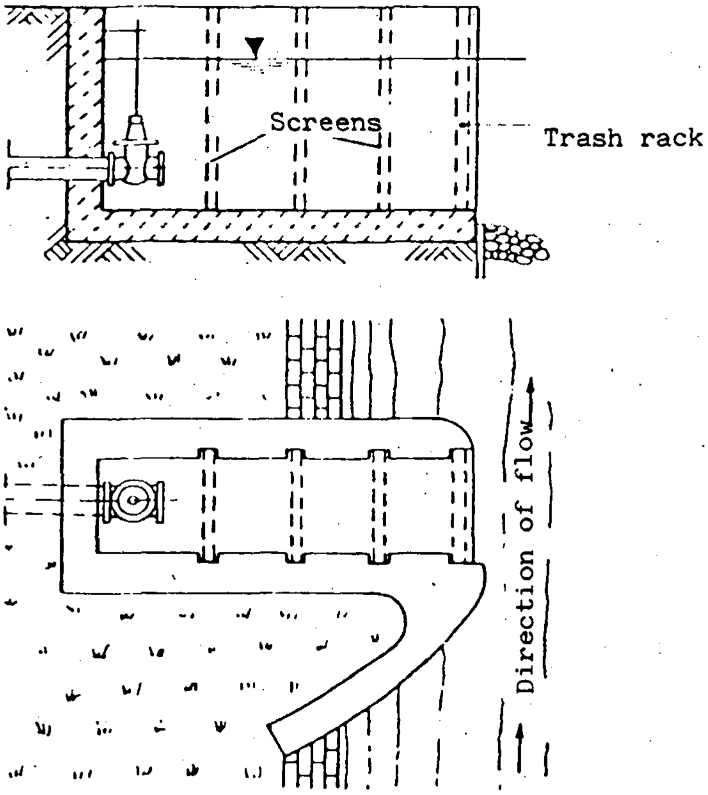
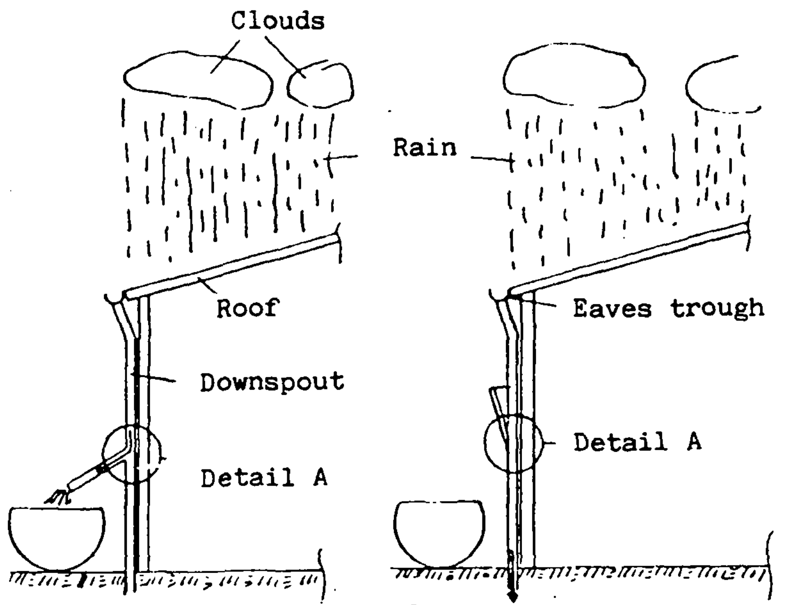


Figure 13: River water intake structure

4.3 Collecting precipitation

Figure 14 illustrates a typical rainwater collecting arrangement.



1. Unwanted rainwater flows into a catch vessel

2. Clean rainwater flows into the underground cistern

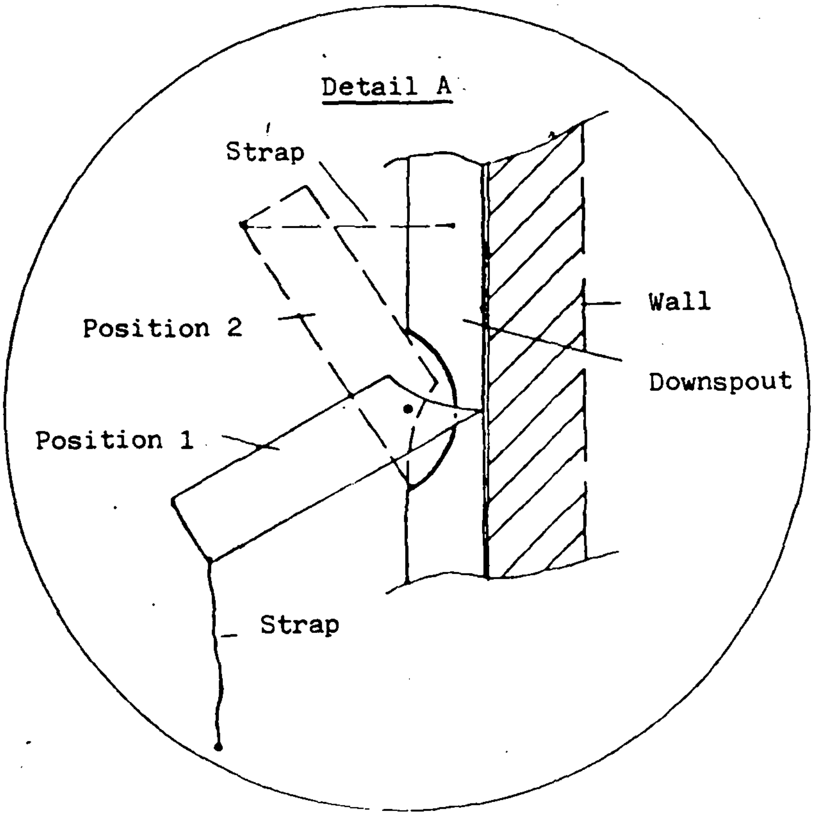


Figure 14: Rainwater catchment

5. Raising water

Wherever people need water, they are confronted with the problem of raising it from one level to another. That task can be accomplished by various means, i.e. with water-drawing implements (buckets lowered into a well) or, in modern waterworks, by pumping it through a potable-water network to the individual users.

The use of buckets and the like has, understandably, waned and is now largely restricted to rural areas with no central water supply, where shallow dug wells with a near-constant water level are still in use. However, hand or foot-operated pumps that can raise water from a depth of 50 - 60 m have gradually become much more popular in such areas (figs. 15 and 16).

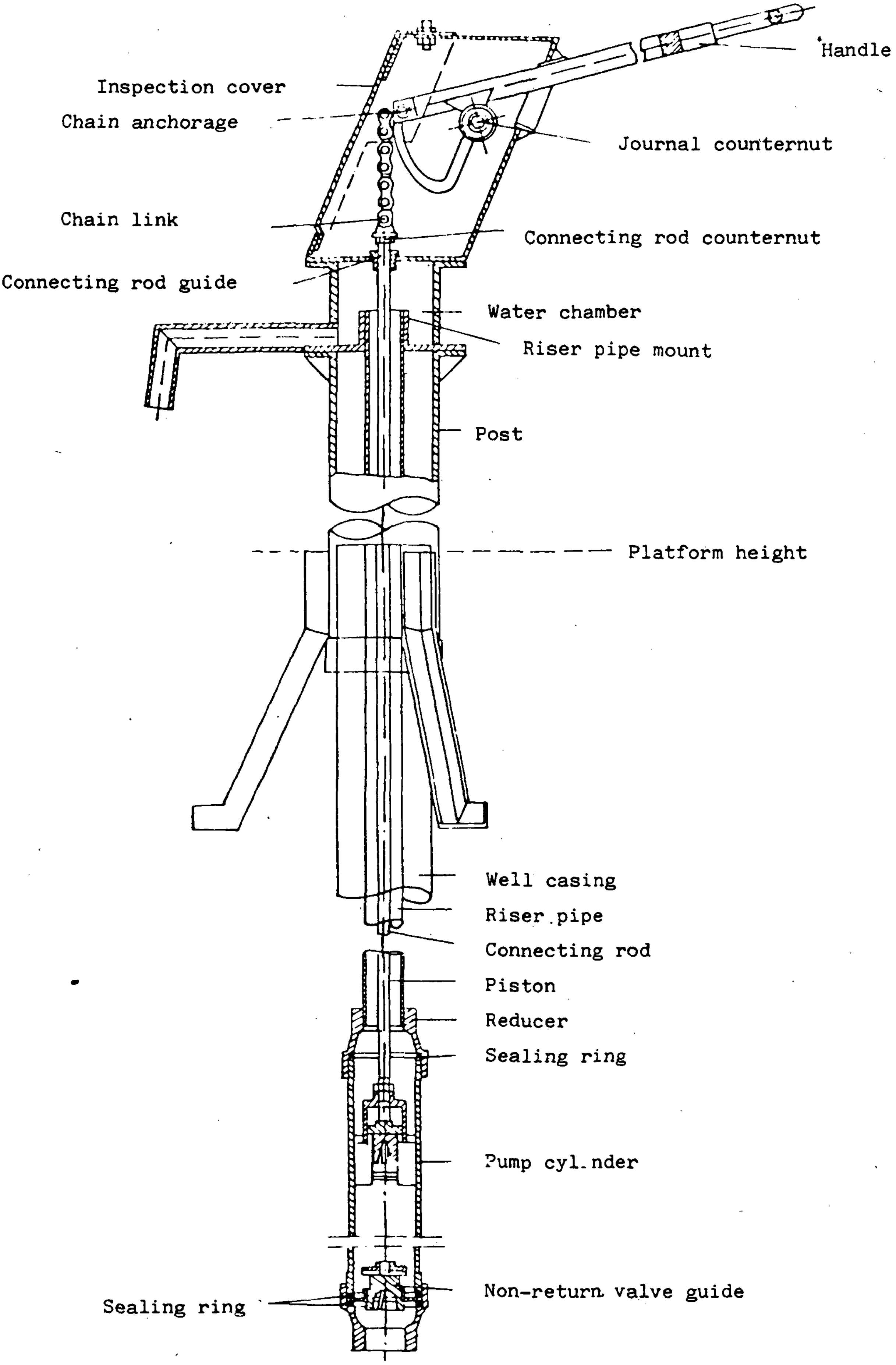


Figure 15: Modern hand pump

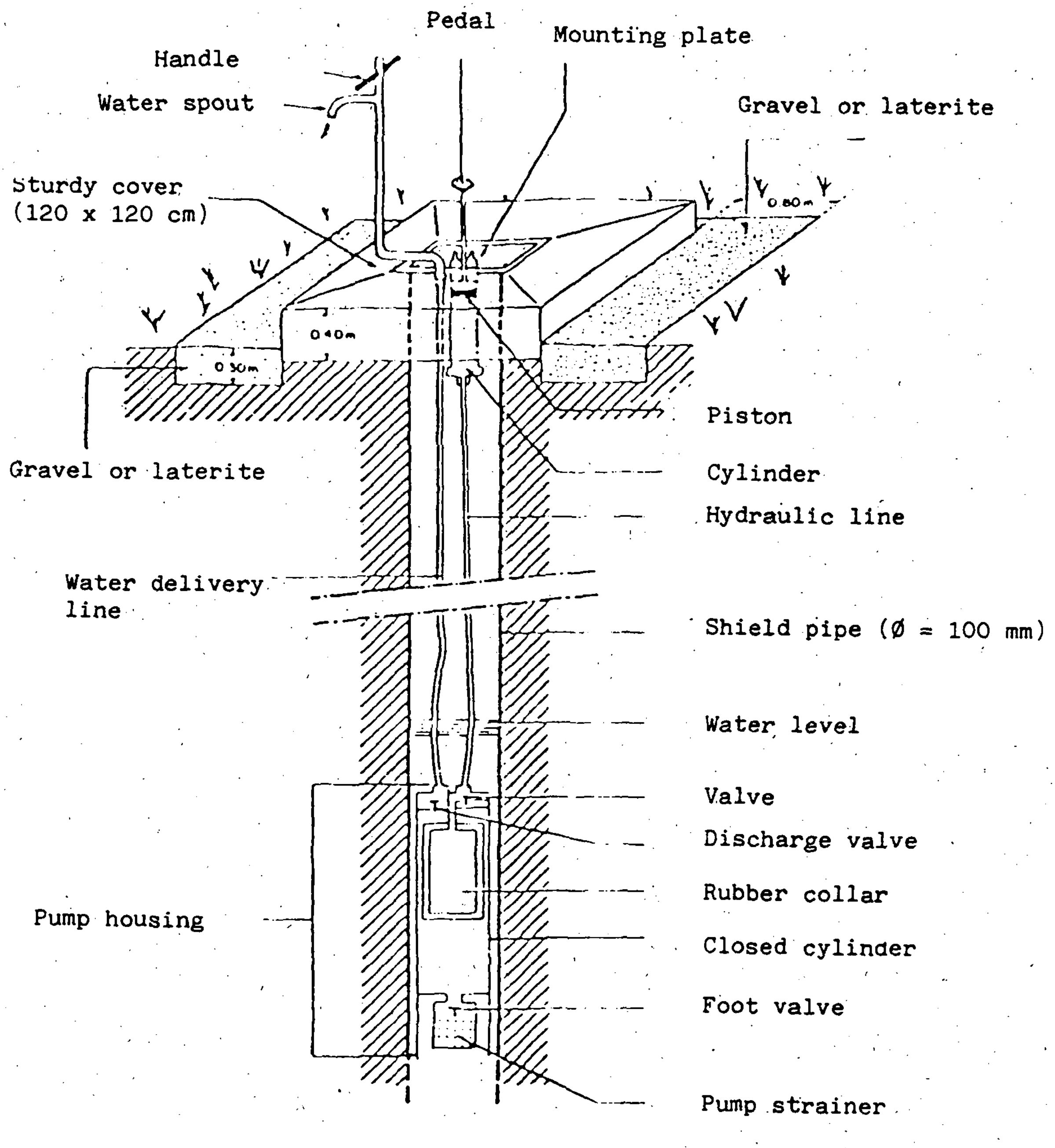


Figure 16: Function of a foot-operated reciprocating pump
(Vergnet pump)

The most commonly employed type of pump is the centrifugal pump, in the form of either a rotary pump or a turbopump, the latter type being used most frequently as an underwater or borehole pump.

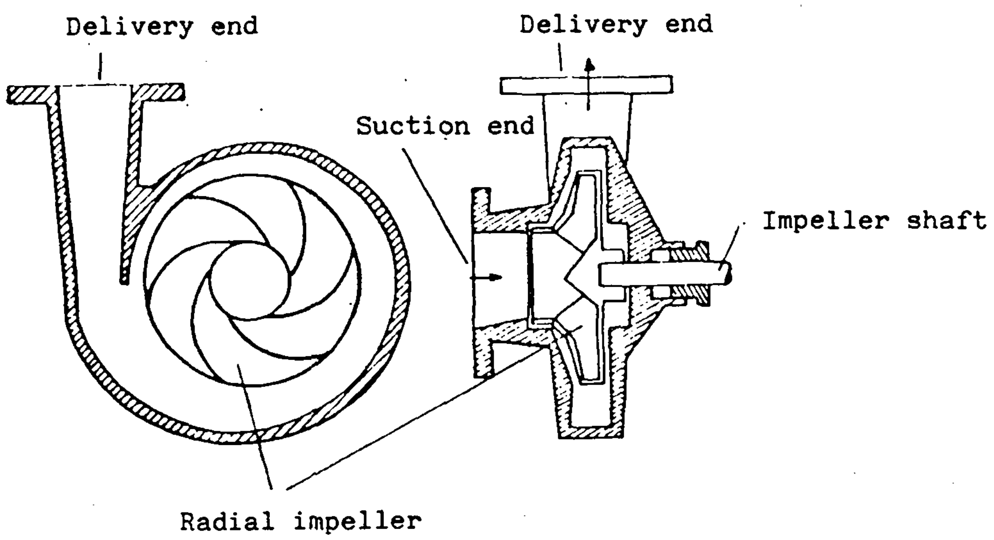


Figure 17: Front and lateral sections of a centrifugal pump

A pumphouse is usually provided in order to protect the pumps and associated equipment from damage.

The pumping station illustrated on the following page (figs. 18a and 18b) is represented by a plan view and a sectional view showing the essential components.

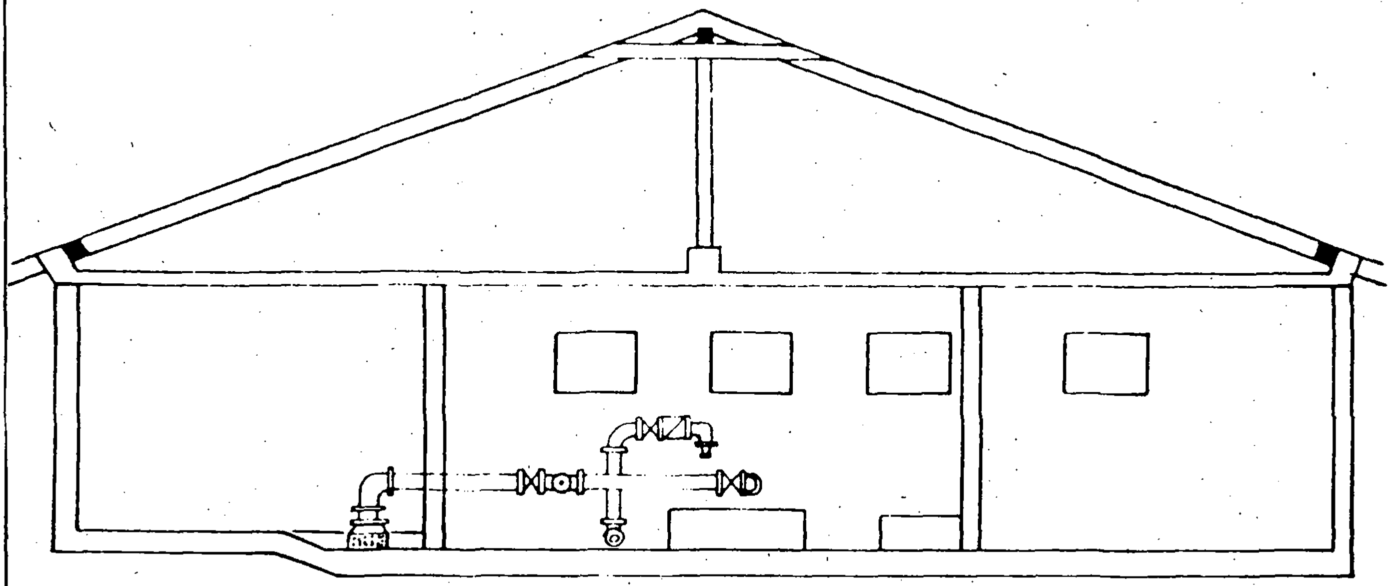


Figure 18 a: Sectional view

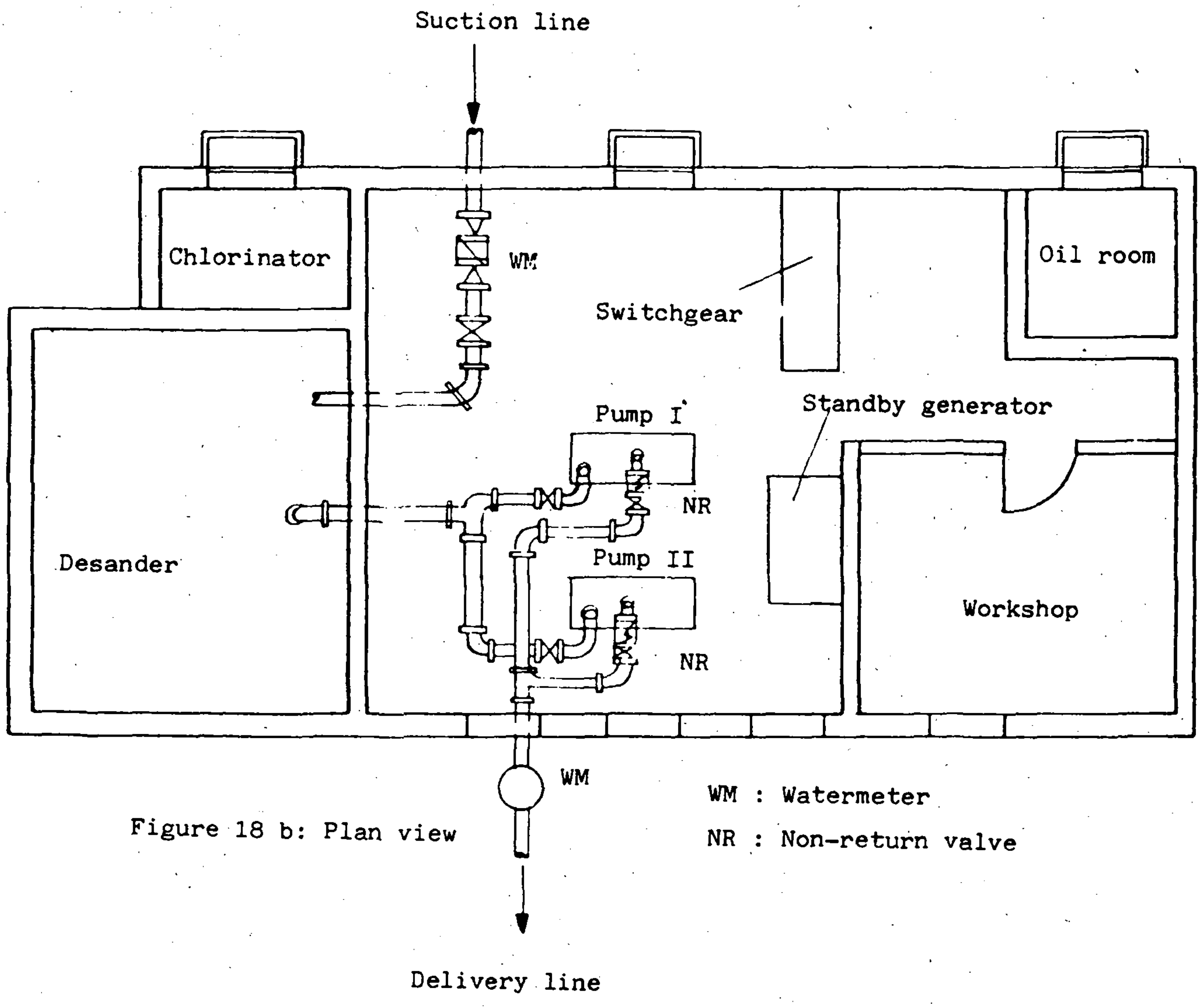


Figure 18 b: Plan view

WM : Watermeter
NR : Non-return valve

Figure 18: Schematic drawing of a pumping station

6. Water quality

Natural cycling of water subjects it to numerous bacteriological, biological, chemical and physical changes.

In selecting water-catchment or extraction points for a centralized water supply system, attention should be paid to locating such points that yield natural-state water capable of meeting the standards for potable and/or service water.

The following table compares the quality of groundwater and surface water.

Groundwater	Surface water
Components	
Gases: . oxygen (O_2), usually in low concentration, . Carbon dioxide (CO_2) in various amounts, . Hydrogen sulfide (H_2S), occasionally Salts: primarily - . Chlorides, . Sulfates, . Nitrates, . Carbonates, of alkalies, alkaline earths and other metals such as iron and manganese Organic decomposition products of humic acid (occasionally)	Surface water that has not been contaminated with foreign substances contains the same components as groundwater, though the oxygen and carbon-dioxide contents are more exposed to the effects of sunlight and the interactions of biological transformation. In addition, it contains: . Ammonium compounds, nitrites and phosphates in the form of natural metabolic products, . Humates (yellow-to-dark-brown color), . Dust, loam, clay, iron compounds, animal and plant residue: cause turbidity . Plankton: sometimes causing "fishy" or algous odors, . Germs (usually high counts; cause of infectuous diseases)
Characterization	
. Near-constant physical and chemical quality; . Cool, uncolored, clear, no strange odor or taste; . Appetizing, aesthetic and generally satisfactory from the standpoint of hygiene	. Subject to atmospheric influence; . Variable quality according to sensory criteria such as: temperature, color, turbidity, odor, taste; . Inhabited by lower/higher-order organisms; . Liable to contamination by plants, animals and humans

As already indicated, groundwater is usually more suitable than surface water as a potable water supply for the population of a given service area. The table comparing the properties of groundwater and surface water contains the parameters that determine the quality of natural water. Those parameters are:

1) The physical condition: temperature, color, clearness, odor and taste;
2) The chemical condition: hydrogen-ion concentration (pH), carbon dioxide concentration (carbonation), oxygen/hydrogen-sulfide/iron content;
3) Manganese content
4) Ammonium-compounds content
5) Nitrites content
6) Nitrates content
7) Chlorides content
8) Sulfates content
9) Phosphates content
10) Hardness
11) Calcium/carbonic-acid ratio
12) Oxidizability
13) Bacteriological nature

Any natural-state water can be classified according to the above parameters. Hydrological surveys and analyses are necessary in order to document the quality parameters (see also module 0.3).

The water should satisfy the following criteria, i.e. it should -

. be free of pathogenes (infection-causing germs),
. have no contents that could pose an immediate or potential danger to human health,
. be extensively clear (no turbidity or color),
. contain no salts,
. have no components that could cause or develop an objectionable odor or taste,
. have no components that could cause corrosion or incrustation of the water-supply equipment or soil the clothes washed in it.

7. Water treatment

To the extent that the quality of the water from the available source fails to meet the requirements placed upon it, some form of treatment will be necessary.

The techniques employed in water-treatment facilities are based on the following fundamental principles:

1) Straining via trash rack and strainer (+ microstrainer for surface water),
2) Sedimentation via desander, settling basin,
3) Flotation of lightweight substances (grease, oil, suspended matter) with the aid of modifiers,
4) Chemical precipitation by oxidizing soluble compounds to produce insoluble compounds (iron, manganese) with the aid of aerators or oxidizers - oxidation of organic matter - softening with lime and soda,
5) Ion exchange, e.g. calcium and magnesium for sodium,
6) Gaseous exchange via aeration (spraying, atomizing, injection of air),
7) Physical absorption of odorous or gustatory substances onto active charcoal,
8) Filtration: slow and fast sand filters
9) Chemical stabilization: e.g. by phosphate injection,
10) Disinfection: chlorination, ozonization, etc.

Various methods have been developed for improving the quality of water. The most significant of those methods are listed in the following table.

Objective	Process
Temperature control	1. aeration 2. colling shafts 3. underground storage of surface water 4. variation of the intake depth in reservoirs and lakes
General improvement	1. Decolorizing a) chemical flocculation, sedimentation, fast-sand filtration b) slow-sand filtration ~~c) lime-soda softening, settling~~

Objective	Process
	2. Clarification a) chemical flocculation, sedimentation, fast-sand filtration b) slow-sand filtration c) lime-soda softening, settling 3. De-odorizing, improving the taste a) aeration b) chemical flocculation, sedimentation, fast-sand filtration c) lime-soda softening, settling d) sterilization
Sterilization	1. Chlorination 2. Ultraviolet irradiation 3. Ozonization 4. Electrocatadyne process
Deacidification	1. Processes aimed at eliminating aggressive carbonation a) aeration b) addition of quick lime (in large-scale facilities and soft water) c) filtration through calcined dolomite (magro) d) filtration through marble 2. Processes aimed at forming a protective layer a) addition of orthophosphate or silicic acid b) filtration through calcined phosphate
Deferrization (iron extraction)	1. Closed-cycle filtration with air interchangers a) gravel/sand filters b) magnofilters 2. Open-cycle aeration with subsequent filtration 3. Precipitation

Objective	Process
Demanganization	1. Manganese exchange filters 2. Aeration and filtration through brownstone-containing material 3. Biological processes (manganese-consuming bacteria)

Other processes include softening, degassing and deoiling. The suitability or unsuitability of the various approaches can be recognized on the basis of the following table:

Table 3: The effects of various water-treatment processes

Problem	Aeration	Chem. flocc. and settling	Lime-soda softening and settling	Slow-sand filtration	Fast-sand filtration with (C)	Disinfection
(a)	(b)	(c)	(d)	(e)	(f)	(g)
Bacteria	0	++	(+++)1,2)	++++	++++	++++
Coloring	0	+++	0	++	++++	0
Turbidity	0	+++	(++)(2)	++++(3)	++++	0
Odor/taste	++(4)	(+)	(++)(2)	++	(++)	++++(5)
Hardness	+	(--)(7)	++++	0	(--)(7)	0
Corrosion	+++(8) ---(9)	(--)(10)	(11)	0	(--)(10)	0
Iron/manganese	+++	+(12)	(++)	++++(1,2)	++++(12)	0

0 = no improvement; + = improvement; - = aggravation

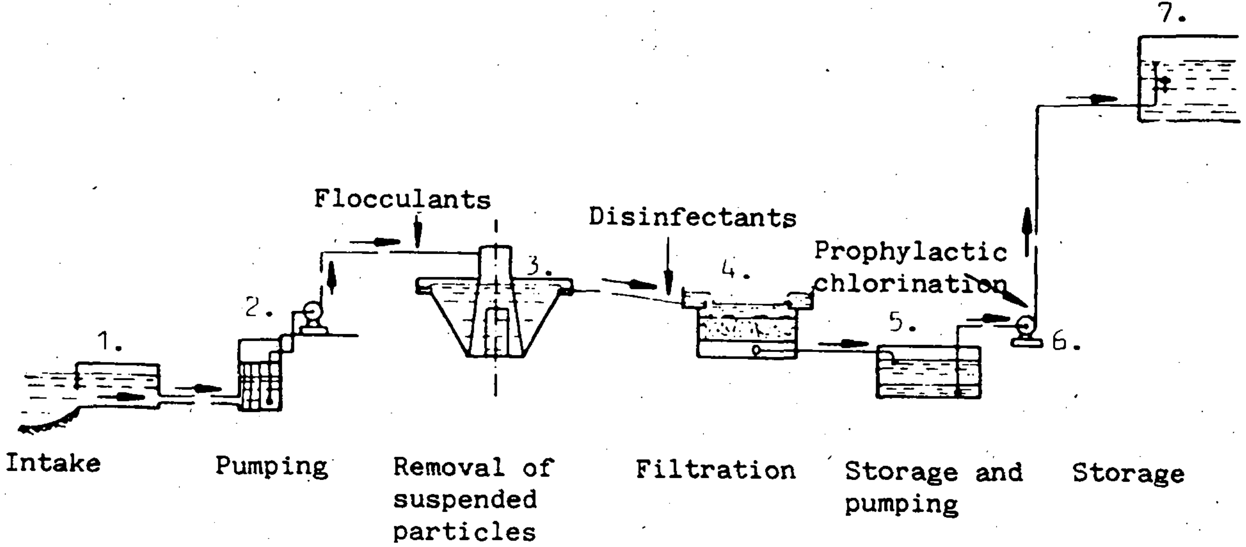
See following page for comments on table 3.

Notes on table 3:

1. If very high pH results from the addition of excess calcium
2. By way of inclusion in the precipitation
3. Filters clog up rapidly, if turbidity is excessive
4. No effect on chlorphenols
5. To the extent that breaking-point chlorination or superchlorination with subsequent dechlorination is employed
6. If (5) is not used to combat a high concentration of odorous or gustatory matter
7. Some flocculators replace carbonate with sulfate
8. Due to the elimination of carbon dioxide
9. By adding oxygen to remedy a low oxygen concentration
10. Some chemicals release carbon dioxide
11. Effects vary; some metals corrode in high-pH water
12. After aeration

Depending on the quality of the available water, water treatment may consist of several different processes, each requiring its own structure.

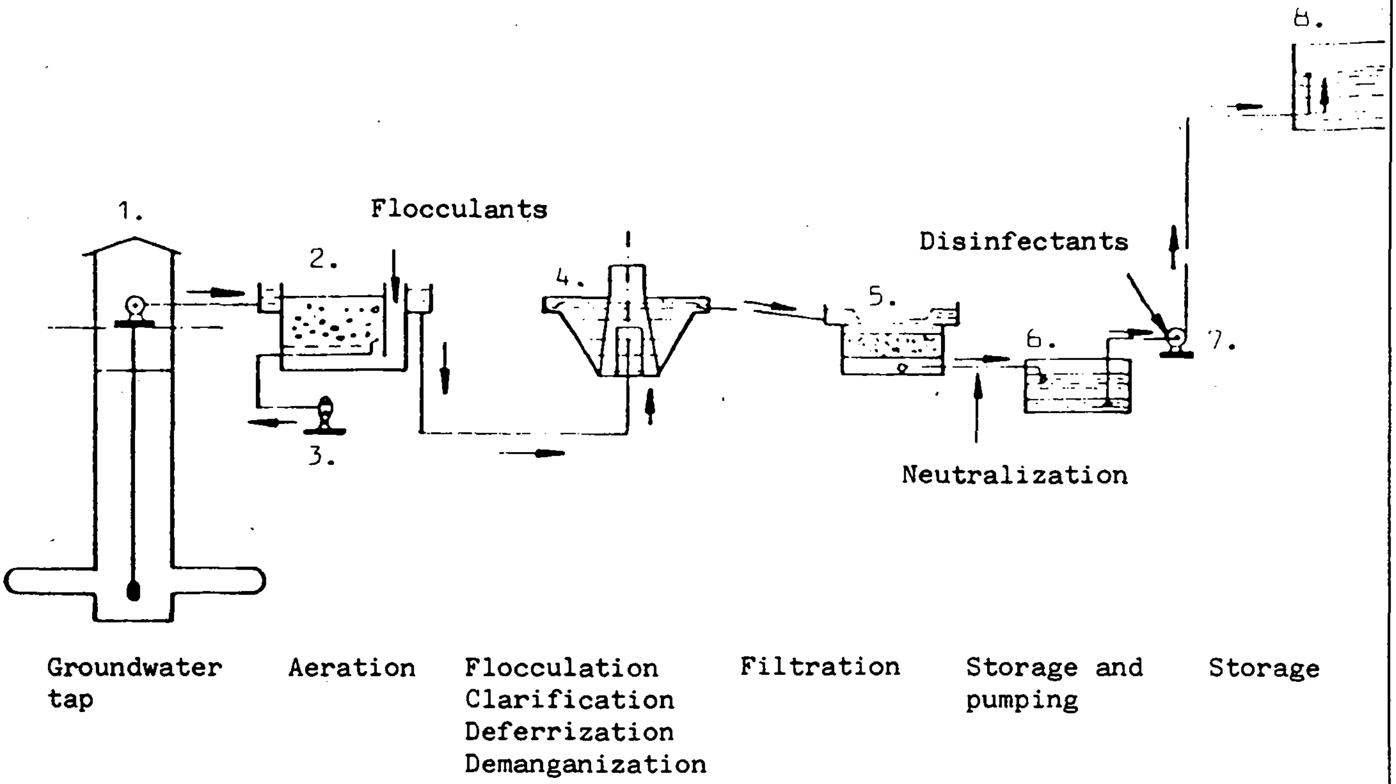
Two examples - one for surface-water treatment and one for groundwater treatment - are shown in figures 19 and 20.



1. Raw water intake
2. Aeration tank/ pumping station
3. Clarifier
4. Filter tank
5. Pure water tank
6. Pure water pump
7. Elevated storage tank

Figure 19: Surface-water treatment plant

The example for surface-water treatment in figure 19 is a rather basic arrangement aimed primarily at removing suspended matter (sediment and deposits). If surface water is also exposed to industrial contamination, its treatment becomes more complicated.



1. Raw-water pumping station
2. Aerating tank
3. Aerator
4. Clarifier
5. Filter tank
6. Pure water tank
7. Pure water pump
8. Elevated storage tank

Figure 20: Groundwater treatment plant

Whenever groundwater contains excess amounts of manganese, iron and/or carbonation, it has to be aerated (fig. 20), whereby the iron and manganese are oxidized, and the excess carbonation is degassed. The flakes of iron and manganese are eliminated in the filter tank. Aftertreatment adjusts the pH level to 7.0 (neutral). The last step consists of prophylactic disinfection by way of chlorination.

8. Water storage

8.1 Duty and function of storage facilities

The water-consumption rate within a given service area varies widely according to the time of day and only very rarely coincides with the momentary water intake rate. Consequently, water storage facilities are needed as a means of compensation for unavoidable changes in demand and supply. In addition to compensating for a varying demand, a water storage facility also:

- provides a uniform service pressure
- ensures a standby supply to bridge short-term operational disturbances
- provides a supply of water for fighting fires
- enables pressure zoning
- serves as a settling tank for unwanted suspended particles.

8.2 Types of water storage facilities

Water storage structures are normally designed either as <u>elevated</u> (or high-level) tanks in the form of earth-covered tanks or water towers or as <u>underground</u> (or low-level) tanks. Special versions include fire tanks and hydraulic accumulators (pressure reservoirs).

Figure 21 shows a water-supply system that includes both a high-level and a low-level tank.

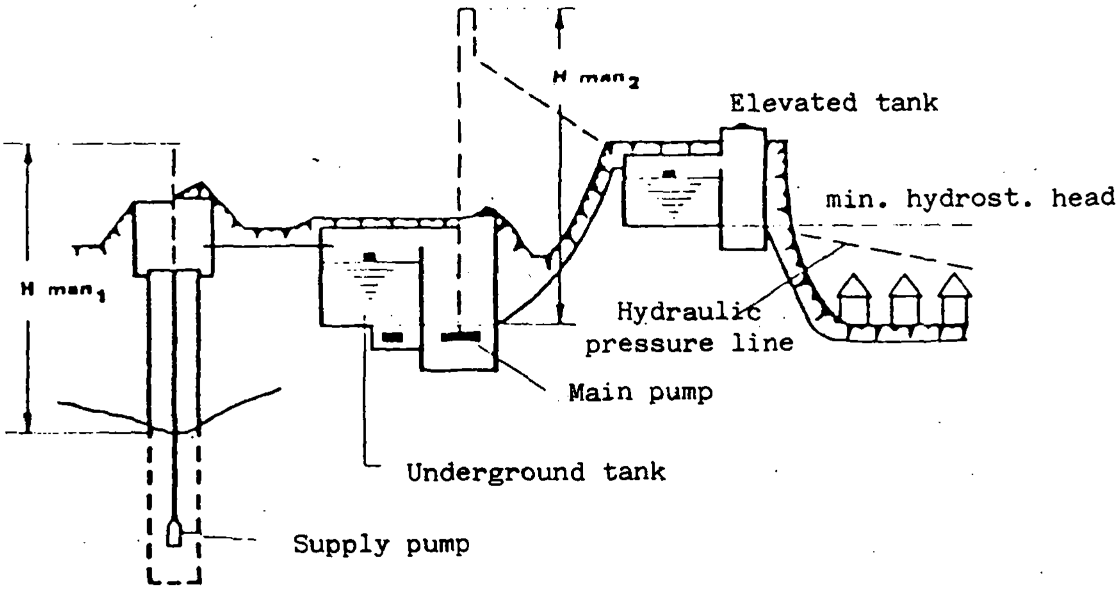


Figure 21: Water supply system with high-level and low-level water storage tanks

8.2.1 Elevated water tanks

Elevated water tanks are characterized by a supply-water level that is located higher than the water supply points served. Thus, the water runs to those points under gravity, and a certain supply pressure is guaranteed. Such tanks must be installed at a suitably elevated location. They can be located either in front of or behind the service area (as seen from the direction of water flow).

Elevated water tanks operate on one or the other of two principles: in-line supply or auxiliary supply.

In-line tanks are situated between the pumping station and the service area. The discharge head of the pure-water pump is practically independent of the momentary consumption level. The supply pressure in the service area is independent of the pump's delivery rate, and the stored water volume is continously replenished.

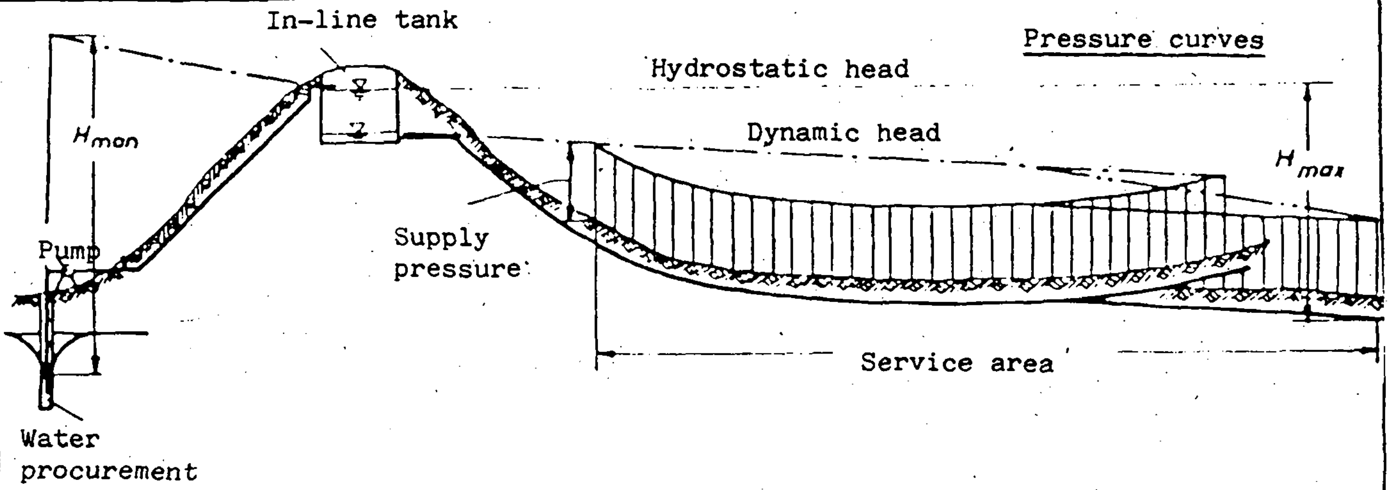


Figure 22: In-line water storage tank

The in-line water storage tank must be installed so far above the service area that the minimum supply pressure is still available when the water level is at its minimum and the consumption rate is at its maximum.

In the case of an auxiliary supply tank, the service area is located between the pumping station and the elevated reservoir. As long as consumption is relatively low, the pump supplies the water directly to the users, and any excess water flows into the storage tank (mode I). During periods of maximum consumption, both the pump and the tank feed into the supply network (mode II), often involving noticeable fluctuations in the supply pressure. Since not all of the water has to be pumped up to the level of the supply tank, less electrical power is required for operating the system.

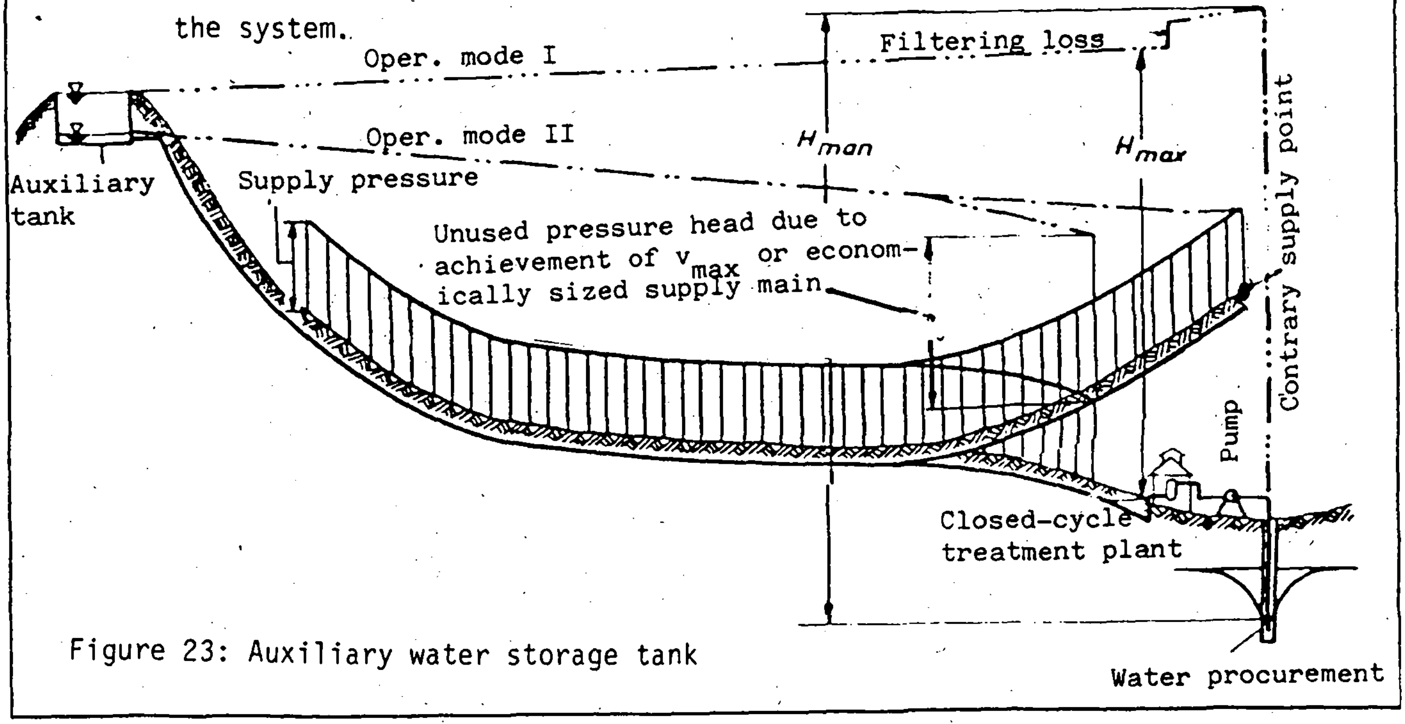


Figure 23: Auxiliary water storage tank

8.2.2 Underground water tanks

Underground water tanks are characterized by a supply-water level that is too low to provide an adequate supply pressure in the distribution network without the aid of pumps. Thus, most underground water tanks are in the form of suction tanks arranged ahead of the pumping station and always "upstream" of the service distribution network (as seen from the direction of water flow).

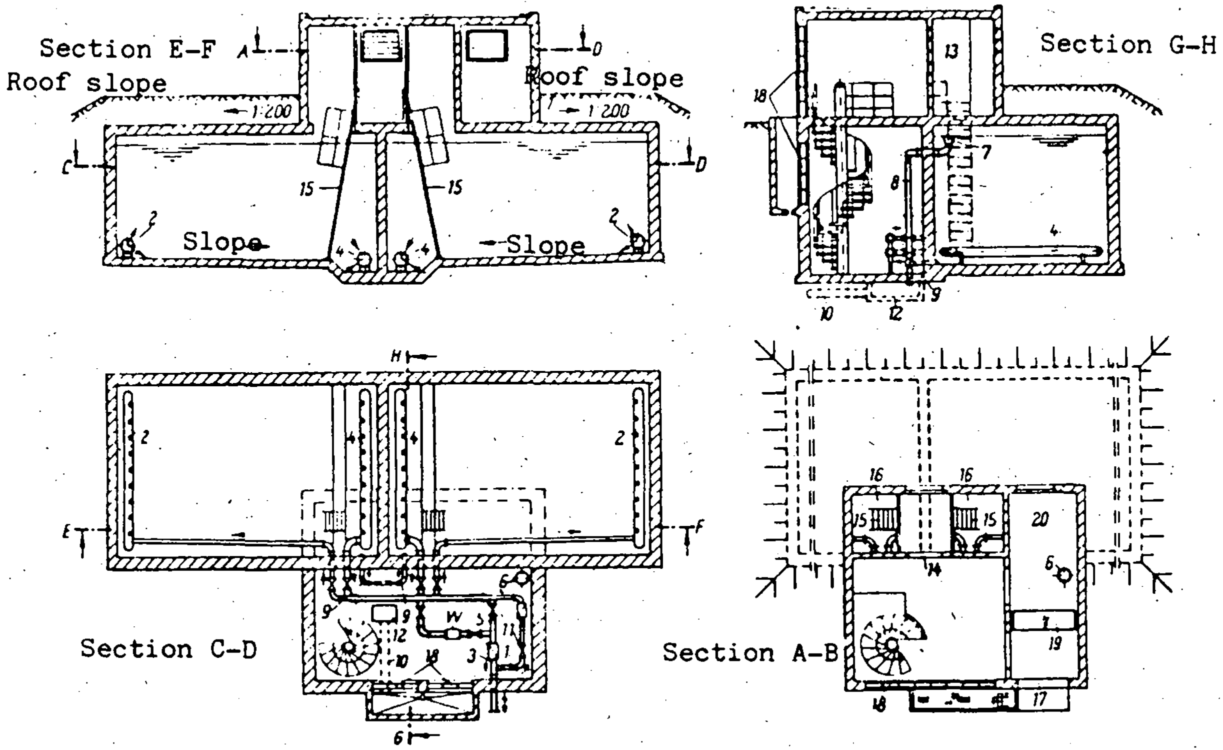
In small service areas, an underground water tank can serve as a reservoir for fire-fighting water.

8.3 Structural design basis for water tanks

The following important aspects should be considered for the construction of water tanks:

- good flow-through characteristics and economically efficient type of construction, whereby a rectangular shape is favorable over a round shape in less-developed countries, since the latter requires complicated formwork;
- division into at least two separate chambers, so that at least one chamber stays in service during cleaning or repair work;
- guaranteed renewal of all water, i.e. the intake and outlet must be arranged in such a manner, that the water in all parts of the tank is renewed within as uniform a time span as possible;
- artificial lighting instead of windows or vault lights in order to prevent the growth of algae;
- accessibility of pipes, valves and accessories, i.e. installation in a separate service/control room, if possible;
- provision of control gear to prevent overfilling or complete emptying of the tank;
- expansion capability for additional water chambers at some later date.

Figure 24 shows an example of a rectangular underground tank serving as an auxiliary reservoir.



1. Intake pipe
2. Distributing pipe
3. Extraction line
4. Extraction header
5. Water-meter bypass
6. Water-level indicator
7. Overflow funnel
8. Overflow line
9. Drain
10. Drain line
11. Stop valve
12. Drain chamber
13. Tank ventilation
14. Vent access
15. Tank access (ladder as per applicable safety regulations)
16. Tank inspection port
17. Control room access
18. Lighting for control room
19. Switchgear cabinet
20. Service room

Figure 24: Underground water storage tank

In rural areas, where rainwater is used as drinking water, storage is usually effected in cisterns. As a rule, such cisterns are for individual users (farms, etc.).

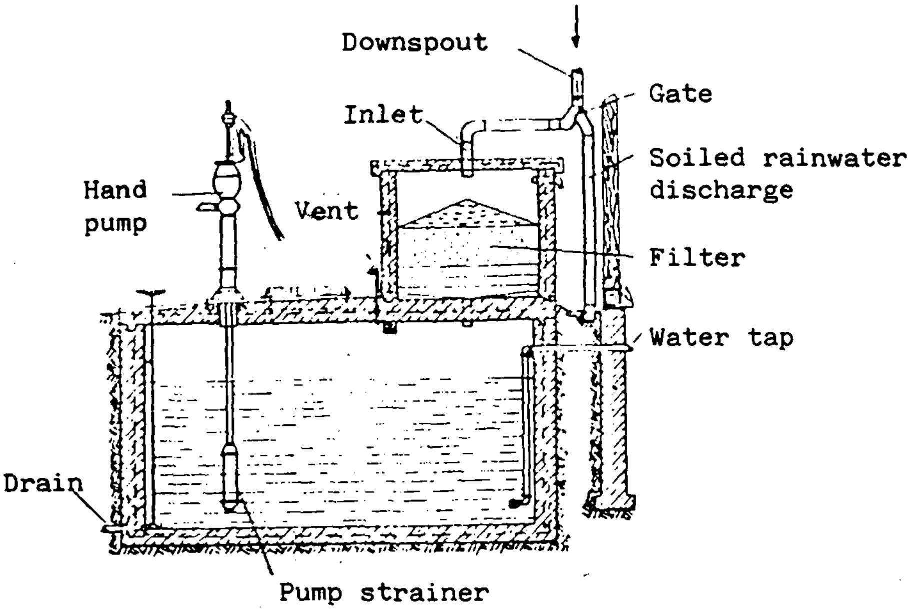


Figure 25: Cistern

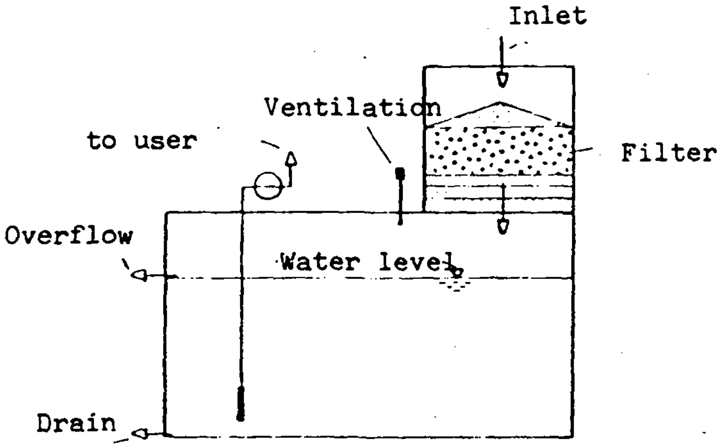


Figure 26: Schematic drawing of a cistern

9. Distribution of water

At the end of the treatment and conveyance chain (procurement - pumping - treatment - storage), the water still has to be distributed. The distribution system is intended to ensure that all users within the service area are provided with a safe supply of water.

Water distribution is effected almost exclusively through piping.

Differentiation is made between the following basic types of piping and service functions:

- Feed lines
  These pipes do not actually distribute the water, but only convey it - with no extraction along the way - to the water treatment facility, the storage tank, or the distribution network.
- Distribution mains
  These are the trunk lines from which the supply lines (but, as a rule, not the connection lines) branch off. They are only necessary in large networks.
- Supply lines
  These lines make up the actual distribution network. They carry water to the branch connections for the individual public and private consumers.
- Connection lines
  These are the pipes leading from the supply lines to the water meters.
- Tap lines
  These are the lines leading to the individual points of use, i.e. faucets and the like.

In a hydraulic sense, differentiation is made between gravity-feed and pressurized piping. Gravity-feed lines are always laid with a natural gradient, while pressurized lines can be either sloping or pump-fed.

The use of gravity-feed lines is normally restricted to areas with appropriate terrain formation, and then only as feed lines from the water extraction point to the water treatment facility and storage tank.

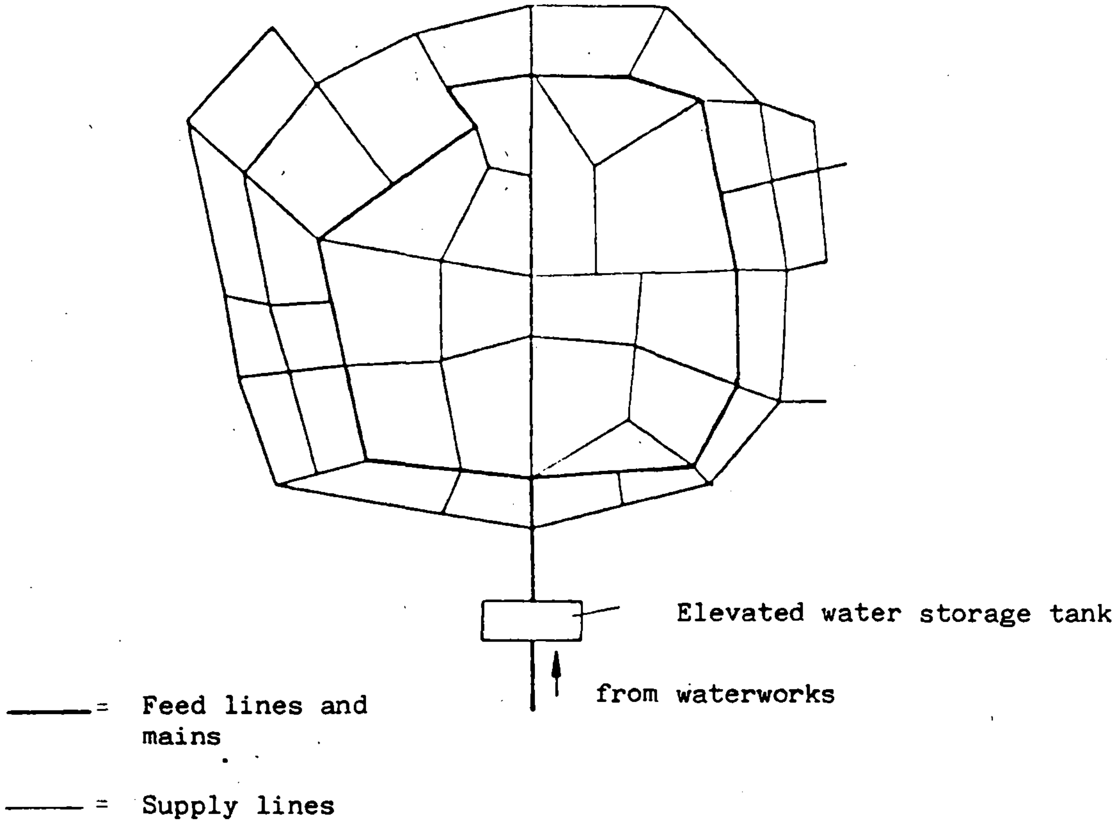


Figure 27: Intermeshed ring main system

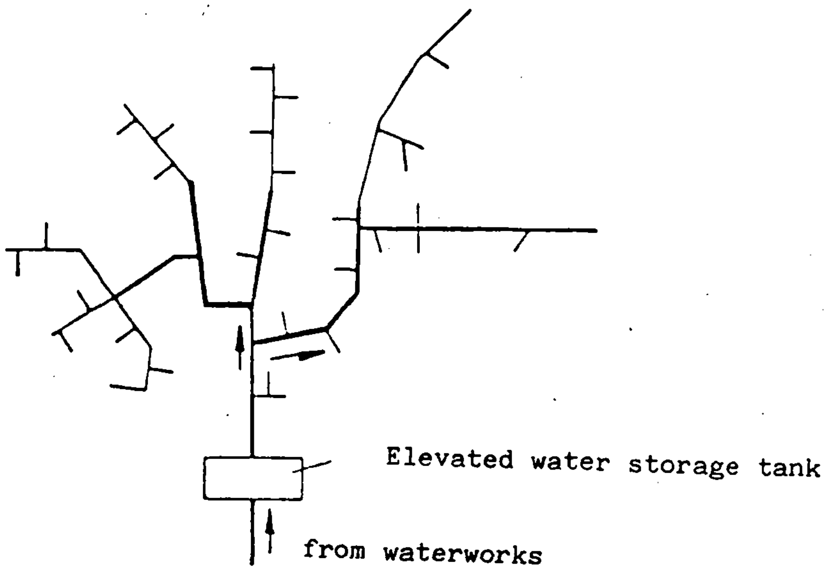


Figure 28: Radial distribution network

Depending on the service conditions and external stress, the pipes may be made of cast iron, steel, reinforced concrete, asbestos-cement or plastic.

Upon completion of all pipework, the result is a pipe network.

There are two basic types of pipe networks (see figures 27 and 28): radial networks and intermeshed ring-main systems.

In a radial distribution network, the supply lines branch off from the mains like the branches of a tree. The distribution mains lead to various central points within the service area. The main disadvantage of a radial network is that in case of a ruptured pipe, all consumers located behind the point of rupture receive no water until the pipe is repaired. Also, during periods of low consumption at the ends of the branches, the water in the pipes stagnates, and its quality may suffer as a result (germination).

An intermeshed ring-main system avoids those disadvantages. The ends of the branch lines are intermeshed, so that all points of the system can be supplied from either direction. In case of a pipe rupture, only the broken line need be isolated, and the remainder of the service area still receives its water (even if on a makeshift scale).

9.1 Valves and accessories in water-supply piping

The valves and accessories that are installed in pipe networks are for:

- isolating part of the network for cleaning or repair work,
- automatically closing off the distribution mains and feed lines in case of a pipe rupture,
- controlling the flow rate and reducing the supply pressure.

The most important valves and accessories are:

Pressure reducing valves and pressure relief chambers. These are for limiting the pressure in the network.

Their use is recommended wherever the maximum tolerable system pressure might be exceeded. Such fixtures can also be used to divide the network into various pressure zones.

Booster stations are required when certain major consumers need a higher water pressure than the rest of the network's consumers. All that is needed is to install a standard-type underwater pump in the appropriate branch line.

Compressed-air vessels (hydrophor facilities) help maintain the proper supply pressure in cooperation with the pumping stations. They serve as a sort of control mechanism intended to protect the piping and its internals from the effects of pressure transients. They are used in systems that cannot be equipped with storage facilities (water towers or elevated storage tanks) at a sufficient altitude above the service area.

Water meters are used to measure water consumption. There are different kinds of water meters for different network designs and flow rates.

A section of a piping layout is shown in module 2.11. Figure 29 on the following page is a sectional view of a typical water supply connection and the associated valves and accessories.

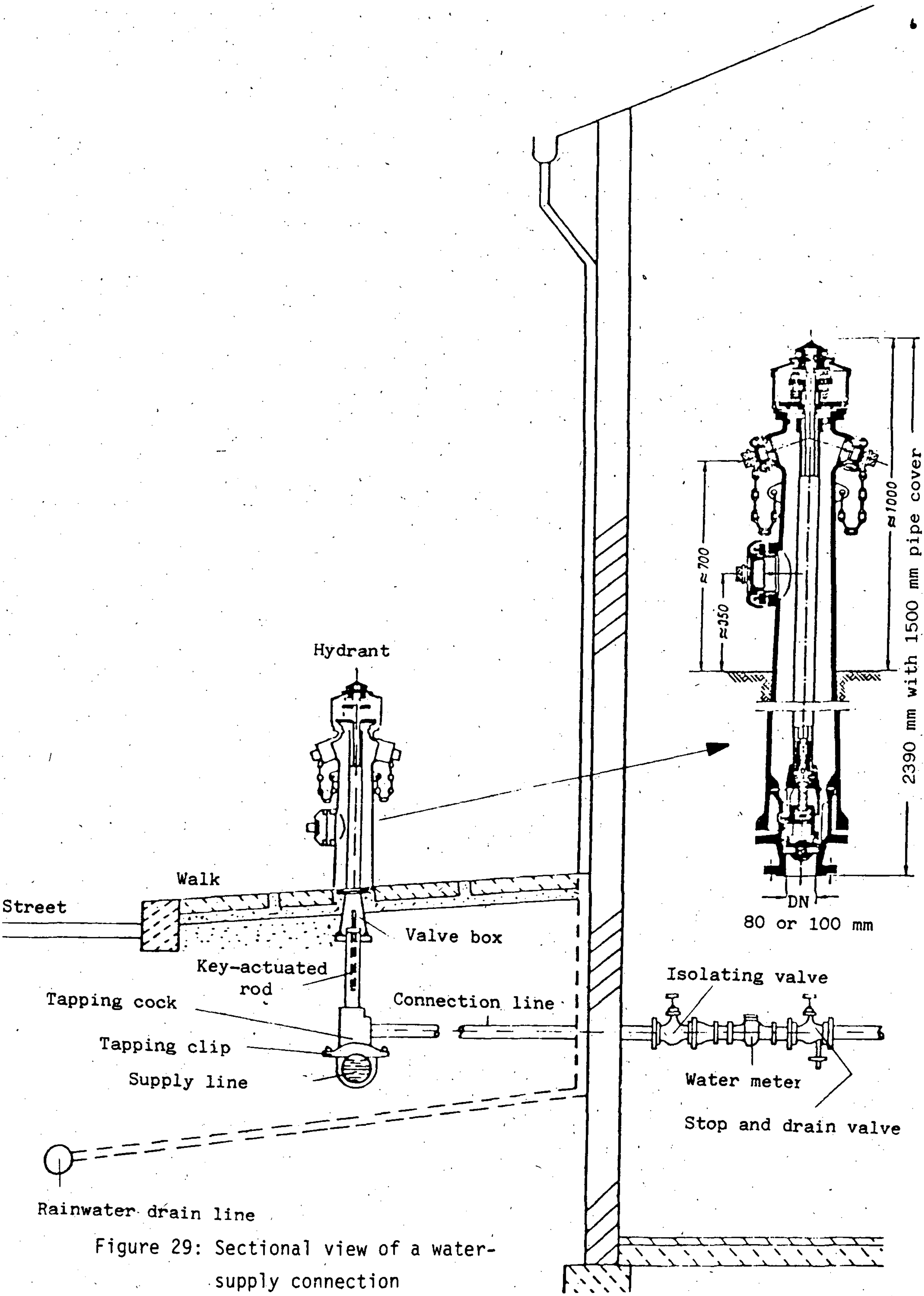


Figure 29: Sectional view of a water-supply connection

10 List of references

The literature consulted in the preparation of module 1.1 is listed in following:

a) Benton, W. Inc.	Encyclopaedia Britannica
b) Bieske, E. jr.	Leitfaden für den Brunnen- und Wasserwerks- und Rohrleitungsbau II, Verlag Rudolf Müller, Cologne, 1973
c) Boese KG (Pumpen-Boese)	Technical Information
d) Bretschneider, Lecher, Schmidt	Taschenbuch der Wasserwirtschaft, Verlag Paul Parey, 6th edition, 1982
e) Brix, Heyd, Gerlach Hünerberg	Die Wasserversorgung, Oldenbourg Verlag, Munich, 1963
f) Dahlhaus, Damrath	Wasserversorgung, Teubner Verlag, Stuttgart, 1978
g) Degrémont	Degrémont Handbuch, Bauverlag Wiesbaden/Berlin, 1974
h) Fair, Geyer, Okun	Water Supply and Wastewater Removal, John Wiley & Sons Publishing Co. Inc., New York/London/Sydney, 1966
i) Kittner, Starke, Wissel	Wasserversorgung VEB Verlag, Berlin, 1975
j) Ruhruniversität Bochum	Skript Siedlungs-Wasserwirtschaft I + II
k) Schocklitsch, A	Handbuch der Wasserversorgung, Teil I, Springer-Verlag, 1962
l) Schweizer Vereinigung für Gewässerschutz und Lufthygiene	Lehrerdokumentation Wasser, Zurich, 1982
m) Techn. Hochschule Darmstadt	Skript Wasserversorgung, I + II, 1975
n) Wagner-Lanoix	Water Supply for Rural Areas and Small Communities, WHO, Geneva 1959
o) World Water	July 1980

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
Dag-Hammarskjöld-Weg 1 + 2 · D 6236 Eschborn 1 · Telefon (0 61 96) 79-0 · Telex 4 07 501-0 gtz d

The government-owned GTZ operates in the field of Technical Cooperation. Some 4,500 German experts are working together with partners from some 100 countries in Africa, Asia and Latin America in projects covering practically every sector of agriculture, forestry, economic development, social services and institutional and physical infrastructure. – The GTZ is commissioned to do this work by the Government of the Federal Republic of Germany and by other national and international organizations.

GTZ activities encompass:

- appraisal, technical planning, control and supervision of technical cooperation projects commissioned by the Government of the Federal Republic of Germany or by other authorities
- advisory services to other agencies implementing development projects
- the recruitment, selection, briefing and assignment of expert personnel and assuring their welfare and technical backstopping during their period of assignment
- provision of materials and equipment for projects, planning work, selection, purchasing and shipment to the developing countries
- management of all financial obligations to the partnercountry.

The series **"Sonderpublikationen der GTZ"** includes more than 190 publications. A list detailing the subjects covered can be obtained from the GTZ-Unit 02: Press and Public Relations, or from the TZ-Verlagsgesellschaft mbH, Postfach 36, D 6101 Roßdorf 1, Federal Republic of Germany.

TRAINING MODULES FOR WATERWORKS PERSONNEL

List of training modules:

Basic Knowledge

0.1 Basic and applied arithmetic
0.2 Basic concepts of physics
0.3 Basic concepts of water chemistry
0.4 Basic principles of water transport
1.1 The function and technical composition of a watersupply system
1.2 Organisation and administration of waterworks

Special Knowledge

2.1 Engineering, building and auxiliary materials
2.2 Hygienic standards of drinking water
2.3a Maintenance and repair of diesel engines and petrol engines
2.3b Maintenance and repair of electric motors
2.3c Maintenance and repair of simple driven systems
2.3d Design, functioning, operation, maintenance and repair of power transmission mechanisms
2.3e Maintenance and repair of pumps
2.3f Maintenance and repair of blowers and compressors
2.3g Design, functioning, operation, maintenance and repair of pipe fittings
2.3h Design, functioning, operation, maintenance and repair of hoisting gear
2.3i Maintenance and repair of electrical motor controls and protective equipment
2.4 Process control and instrumentation
2.5 Principal components of water-treatment systems (definition and description)
2.6 Pipe laying procedures and testing of water mains
2.7 General operation of water main systems
2.8 Construction of water supply units
2.9 Maintenance of water supply units Principles and general procedures
2.10 Industrial safety and accident prevention
2.11 Simple surveying and technical drawing

Special Skills

3.1 Basic skills in workshop technology
3.2 Performance of simple water analysis
3.3a Design and working principles of diesel engines and petrol engines
3.3b Design and working principles of electric motors
3.3c –
3.3d Design and working principle of power transmission mechanisms
3.3e Installation, operation, maintenance and repair of pumps
3.3f Handling, maintenance and repair of blowers and compressors
3.3g Handling, maintenance and repair of pipe fittings
3.3h Handling, maintenance and repair of hoisting gear
3.3i Servicing and maintaining electrical equipment
3.4 Servicing and maintaining process controls and instrumentation
3.5 Water-treatment systems: construction and operation of principal components: Part I - Part II
3.6 Pipe-laying procedures and testing of water mains
3.7 Inspection, maintenance and repair of water mains
3.8a Construction in concrete and masonry
3.8b Installation of appurtenances
3.9 Maintenance of water supply units Inspection and action guide
3.10 –
3.11 Simple surveying and drawing work

*Deutsche Gesellschaft für
Technische Zusammenarbeit
(GTZ) GmbH*

*P. O. Box 5180
Dag-Hammarskjöld-Weg 1+2
D 6236 Eschborn/Ts. 1
Telephone (06196) 79-0
Telex 407501-0 gtz d
Fax No. (06196) 79-1115*