4-6 WATER TREATMENT

4-6.1 GENERAL

It is obvious that rural water supplies should be designed to safeguard the quality of the natural water selected. It should always be the policy of a responsible engineer to restrict the use of water treatment under rural conditions to only those cases where such treatment is absolutely essential and where correct plant operation and maintenance can be secured and supervised. The design engineer should also vigorously oppose the use of treatment processes which the community concerned can ill-afford to procure, operate and maintain with meagre financial resources. This explains in part why a careful study, based on engineering and economic analysis may have to be made to compare, in doubtful situations, the relative merits of water treatment against those of long pipelines bringing untreated water from distant springs, wells, etc. Experience shows that whenever possible it is wise to make a large investment in order to eliminate operational and maintenance problems.
(partly from "Water Supplies for Rural Areas and Small Communities" WHO)

Furthermore, all the water supplies constructed in the Technical Section of CD/SATA-Helvetas apply to the WHO Standards of untreated water (see chapter 2-2). We consider this water quality as sufficient for any rural water supply. In a future step chlorination can be introduced easily.

Treatment stations (sedimentation and slow sand filters) are normally calculated for continuous flow over 24 hours in stage I (see 4-1.2).

4-6.2 SEDIMENTATION

4-6.2.1 General definition

Definition: Sedimentation is the removal of suspended particles heavier than water by gravitation settling.

Natural existence: In the rainy season the erosion of the land by run-off from rain-storms carries vast amounts of soil into streams and other water-courses. Some of the eroded particles are heavy enough to settle when flood waters subside, often to be picked up again and be redeposited further downstream during successive floods until eventually reaching the ocean.

Influence on water supplies: such suspended particles prevent water supplies from working continuously because they block pipes and filters, reduce the capacity of storage tanks and the water quality. Therefore, these particles have to be removed immediately after the catchment.

Methods of sedimentation:

The undesired suspended particles are removed from raw water by sedimentation in a special tank. There are three kinds of sedimentation:

- Plain sedimentation: The impurities are separated from the suspending fluid by gravitation and natural aggregation of the particles.

- Coagulation: Chemical substances are added to induce or hasten aggregation and settling of finely suspended matter, colloidal substances and large molecules.
- Chemical precipitation: Chemicals are added to precipitate dissolved impurities out of solution by changing them into insoluble substances.

Plain sedimentation would be used where water contains much suspended matter and particularly in warm climates, where higher temperatures lower the viscosity of the water permitting thus more effective sedimentation. The plain sedimentation requires less and simpler maintenance than the other methods of sedimentation. Therefore, only this method is employed by CD/SATA-Helvetas for rural water supplies in Cameroon.

All the following remarks refer to plain sedimentation.

4-6.2.2 Design of sedimentation tanks

Sedimentation tanks are designed to reduce the velocity of the water flow so as to permit suspended solids to settle out of the water by gravity.

The raw water (of rivers) contains impurities of three physical kinds:

- Particles large enough to be strained out of the water or which will settle gravitationally in still water (sedimentation)
- Particles of microscopic or colloided form which will not settle in still water and are too small to be strained out (filtration is required to remove these substances)
- Substances held completely in solution, i.e. dissolved in the water can be removed by chemical treatment only.

a) Factors affecting sedimentation efficiency:

- settling velocity
  - mass density of suspended particle
  - shape density of suspended particle
  - mass density of the fluid
  - viscosity of the fluid
- drag force
  - shape of suspended particle
  - velocity of the fluid
  - viscosity of the fluid
  - mass density of the fluid
- concentration of suspended solids in the fluid (settling hindered by wall effect)

The only factor which is altered by plain sedimentation is the fluid velocity. The smaller the size of the particles removed, the smaller is the velocity of the fluid. The reduction in flow velocity needed depends on the nature of the sediment and the required efficiency of sedimentation (e.g. gritty, granitic or volcanic sediments being heavier, need less flow velocity reduction to deposit them than fine lateritic top-soils.

The efficiency depends also on design:

- inlet and outlet have to be constructed so that short-circuiting is prevented;
- agitation of settled solids from the sludge zone has to be prevented. Hence certain relations between length and depth are needed.

The required efficiency of a sedimentation-basin will depend on the need to prevent blockage of the sand-filters (following). Further details have to be determined by observation and research on similar existing installations.

b) Calculation of the required dimensions

The dimensions of a sedimentation tank can be calculated from the surface load and the period of detention.

"Surface load" is the settling velocity of the particles in the water:

$$S_L = \frac{\text{quantity of water per h}}{\text{surface of tank}} \qquad \frac{m3}{m2 \times h} = \frac{m}{h}$$

In the reverse we can calculate the necessary surface as follows:

$$S_n = \frac{\text{quantity of water per h}}{\text{surface load}} \qquad \frac{m3/h}{m/h} = m2$$

The capacity or volume of the basin can be calculated with the quantity of water per hour and the period of detention:

$$V = (\text{quantity of water per h}) \times (\text{period of detention})$$

$$\frac{m3}{h} \times h = m3$$

The surface load and the period of detention varies widely because of the kind of material to be retained, the stage of extension considered, and the treatment added after passing the sedimentation (e.g. granitic and volcanic soils bring heavier material than lateritic top-soils so the surface load can be bigger and the period of detention shorter or vice-versa).

The figures below should only be taken as <u>an approximate value:</u>

S_L = surface load max. = 0.6 m/h
(0.6 m/h is the settling velocity of a silt grain with a diameter of 0.01 mm)

t = periode of detention = 4 - 6 h

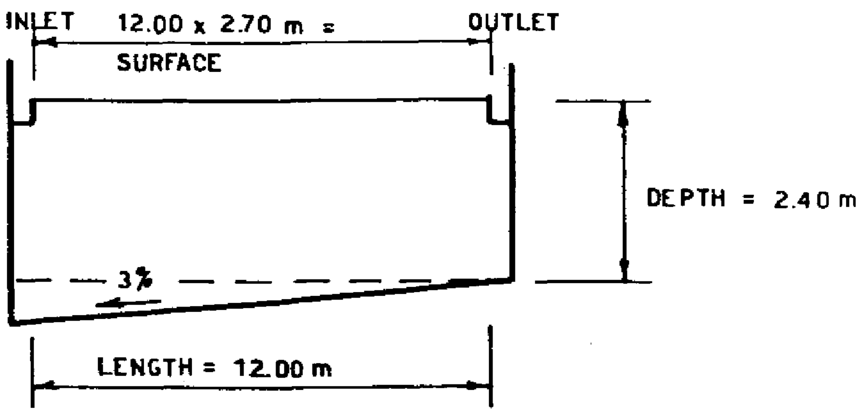
d = depth of tanks 1.50 m - 2.50 m (2.50 should be the maximum)
relation between length and depth 5:1 up to 10:1

The effect of sedimentation varies only with the surface load and not with the depth of the tank.
The smaller the surface load the better the sedimentation.

Example:

quantity of water	= 20 m3/h	
surface load	= 0.6 m/h	
period of detention	= 4 h	
relation between length and depth	5 : 1	
therefore:		
necessary surface Sn	$= \frac{20.0 \text{ m3/h}}{0.6 \text{ m/h}}$	= 33.3 m2
capacity V	= 20.0 m3/h x 4 h	= 80 m3
depth	$= \frac{80.0 \text{ m3}}{33.3 \text{ m2}}$	= 2.40 m
length	= 5 x 2.40 m	= 12.0 m
width	$= \frac{33.3 \text{ m2}}{12.0 \text{ m}}$	= 2.70 m

length = 12.00 m   width = 2.70 m   depth = 2.40 m

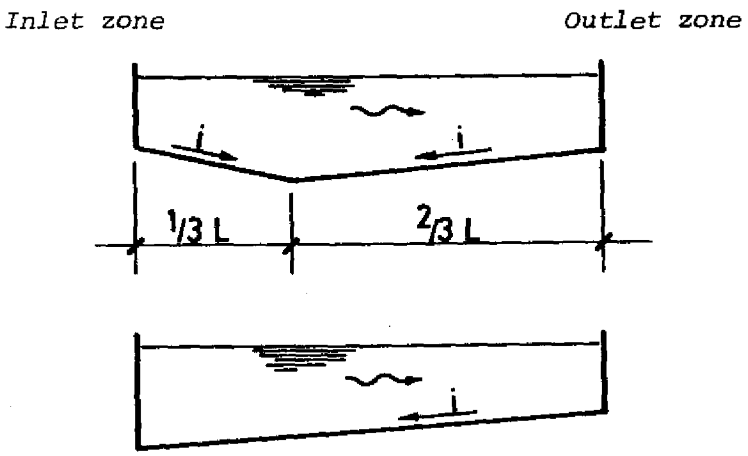


4-6.2.3 Construction details

Rectangular sedimentation tanks are most commonly used in Cameroon because their construction is easier than that of circular tanks. Therefore, all the following construction details are with reference to rectangular tanks.

a) Slope of the tank bottom

The cleaning of the sedimentation tank is much easier if its bottom has a slope of min. 3%.



i_{min} = 3%

i_{max} = 8%

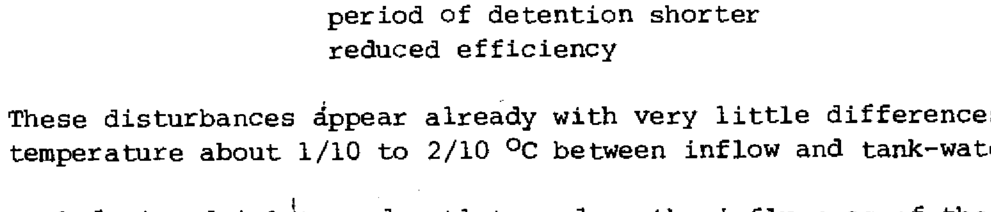
b) Inlets and outlets

It is important to achieve uniform flow of the water over the cross-section. A straight inlet creates an equal straight flow to the outlet and a reduction of the active capacity so that the efficiency is reduced.

Influence of water temperature on the operation of the sedimentation tank:

The operation of a sedimentation tank can be disturbed greatly by the different temperatures of the inflow and the tank-water. Spring-water has a constant temperature but stream-water temperature varies with sunshine as well as with the change of day and night. Simplified the following pattern appears in the sedimentation tank:

night (inflow cold) day (inflow warm)

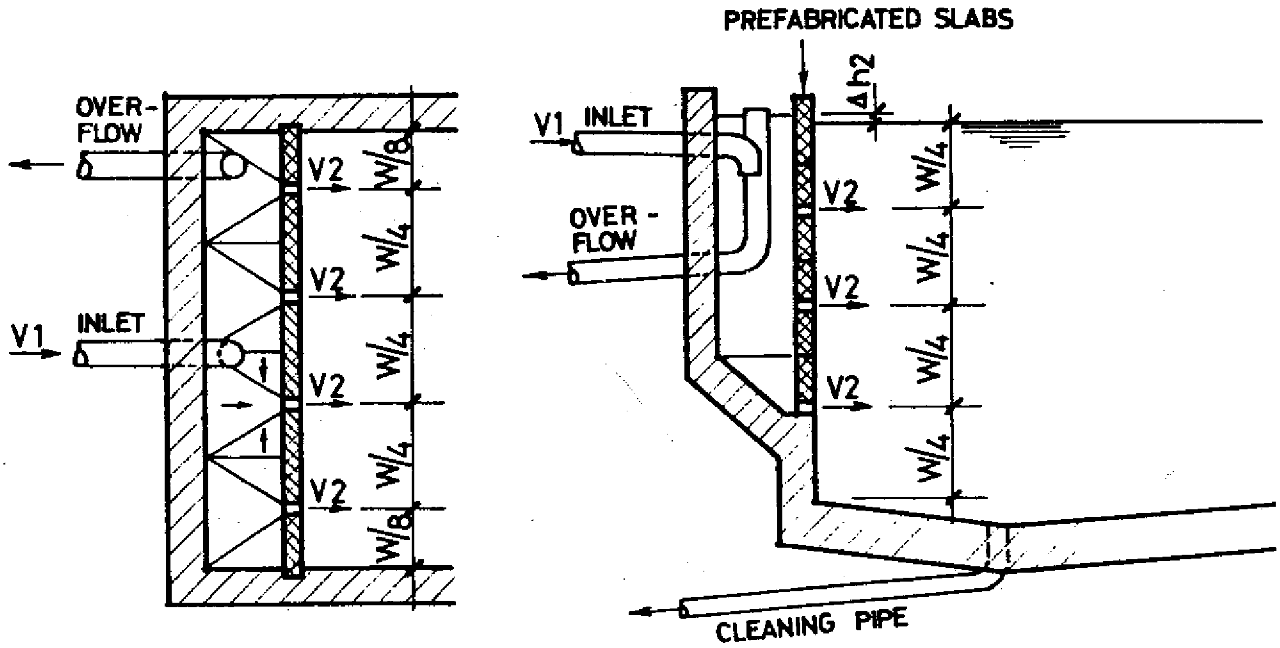


inactive zone
therefore:
period of detention shorter
reduced efficiency

These disturbances appear already with very little differences in temperature about 1/10 to 2/10 °C between inflow and tank-water.

Well designed inlets and outlets reduce the influences of the water temperature.

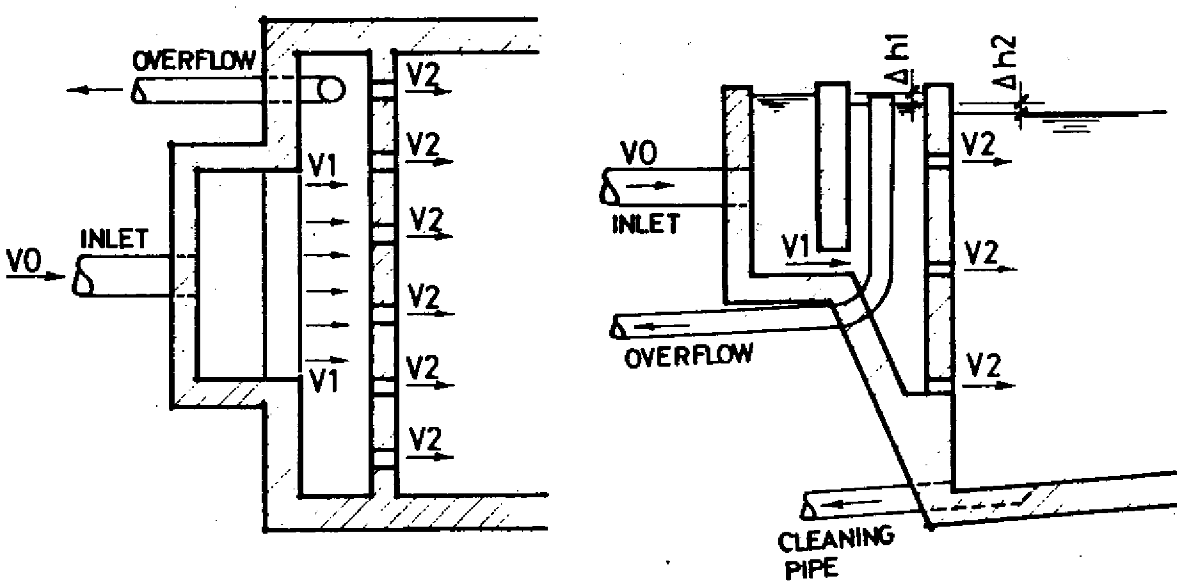
Fig. 42 Inlet: Variant 1



V1 < 1.0 m/s V2 < 0.3 m/s

$\Delta h2 \approx \frac{V2^2}{2g}$ OUTLET LOSS

Fig. 43 Inlet: Variant 2

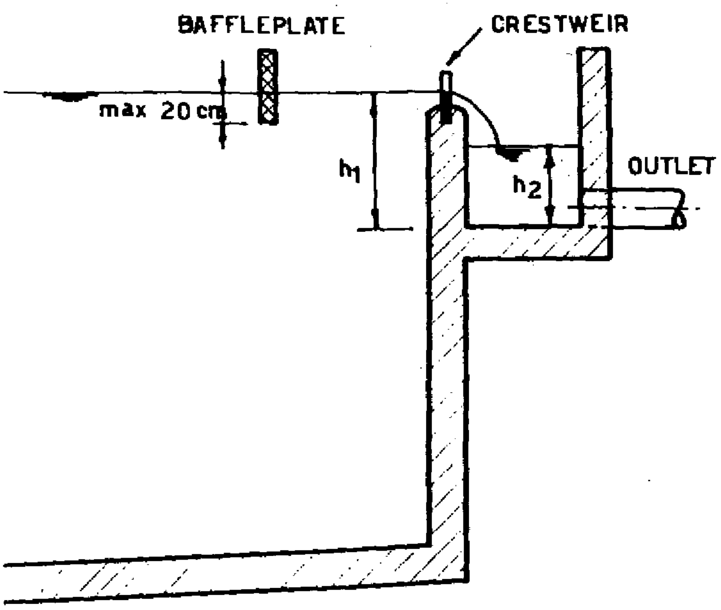


V0 > 1.0 m/s V1 < 1.0 m/s V2 < 0.3 m/s

$\Delta h1 \approx \frac{V1^2}{2g}$ $\Delta h2 \approx \frac{V2^2}{2g}$

A good working inlet shows a horizontal calm watersurface in the gutter

Fig. 44 *Outlet*



The crestweir is necessary to have an equal overflow along the weir

The outlet gutter should always be reasonably deep to avoid submerging the crestweir because there is a considerable slope of the water surface in the gutter

4-6.3 SLOW SAND FILTER

Slow sand filters have been installed in many CD/SATA-Helvetas water supplies with a stream or river as a source. This is due to the fact that these filters can be easily maintained by the communities concerned if they are properly instructed. Also, slow sand-filters show good results in respect of water treatment, and their mode of action is quite simple

Definition: Slow sand filters are filters with a surface charge of 7,25 m3/m2 day (filter velocity 0,3 m/h) or less.

4-6.3.1 Mode of action

The raw water is led gently on the filter bed and percolates downwards. Suspended matter in the raw water is deposited on the surface of the filter bed. This layer of organic and inorganic material increases the friction loss through the bed. The water level therefore rises gradually until it reaches a predetermined value, not more than 100 cm. The bed must then be taken out of service and cleaned.

The slow sand-filter does not act by a simple straining process. It works by a combination of straining and bacteriological action of which the latter is the more important. The mode of operation is complex. There is no doubt that the purification of the water takes place not only at the surface of the bed but for some distance below. Dr. A. Van de Vloed distinguishes three zones of purification in the bed. 1st, the surface coating, 2nd the autotrophic zone existing a few millimeters below and 3rd the heterotrophic zone which extends some 30 cm into the bed.

1st stage = acts as an extremely fine-meshed strainer

2nd stage = decomposes plankton and the filtrate becomes oxidised by chemical reaction

3rd stage = bacteriological filtration

In order to guarantee a good bacteriological filtration, attention should be paid to achieving:

- favourable conditions for bacteriological reproduction and digestion
- slow filter velocity
- raw water quality (pre-treated by sedimentation only, no chemical additives like chlorine etc.)
- Minimal charge (steady flow) ca. 5 - 10% of the max. charge, in order to keep the temperature on the filter steady and to avoid the growing of seaweed.

4-6.3.2 Hydraulic system

From the hydraulic point of view a slow sand-filter and sedimentation basin form an inseparable unit. Our main aim is to increase the service time of a filter as much as possible. First, we treat the raw water by sedimentation and secondly, we regulate the filter charge in such a way that no unnecessary water is filtered. Flow into the sedimentation basin should be determined as exactly as possible by water requirements. This can be done by choosing different sizes of inlet pipes, or better, by constructing a distribution chamber with a weir (measuring weir).
An adjustment of the inlet by throttle valves is not advisable; it may cause blockages due to leaves etc. in the raw water.

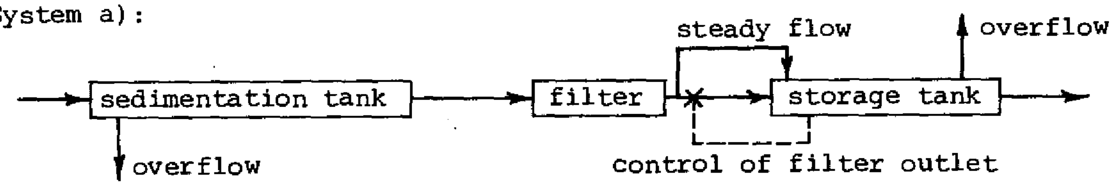
There are two ways to control the filter:

a) In controlling the filter outlet: this can easily be done by installation of a ball valve in the storage tank. A reduction tee fitted immediately before the ball valve guarantees a minimum filter charge (steady flow = 5 - 10% of the nominal charge). A continuous circulation through the storage tank is ensured if the storage tank overflow is installed at the opposite end of the tank to the inlet.

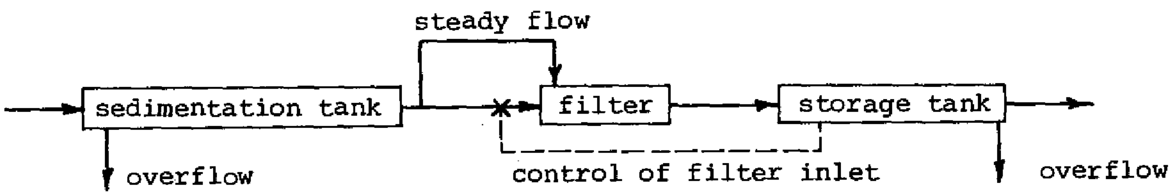
b) In controlling the sedimentation tank outlet: this can be done with a similar installation as the one above. This solution has the advantage of no extra water being retained in the filters. Therefore, the growth of the algae is reduced and the service time of the filter increases.

In Case a) and b) the excess water overflows in the sedimentation tank.

System a):



System b)



4-6.3.3 Size and number of filters

The size of the filterl bed can easily be calculated with the following equation:

$$S = \frac{Q}{V}$$

S = surface m2
Q = quantity of water per h or per day, m3/h or m3/day
V = velocity below 7.25 m3/m2/day or 0.3 m/h

The ratio of length to width should be between 1 and 4.

The number of filter beds depends upon the quantity of water desired as well as on the size of each bed. Nevertheless, it must be kept in mind that the filters will have to be cleaned from time to time and therefore, at least one additional stand-by bed must be available to avoid interruption of the supply. If the two filters work together the velocity will only be 0,15 m/h.

Example:

Quantity of water = 20m3/h
Filter velocity = 0,3m/h

Surface required $= \frac{20\text{m3/h}}{0{,}3\text{m/h}} = 67\text{m2}$

a) Chosen: 2 filter beds in action plus one stand-by
Hence the dimensions are as follows:

A per filter = 67m2 : 2 = 33,5m2
chosen width = 3m
length $= \frac{33{,}5\text{m2}}{3\text{m}} = 11{,}2\text{m}$

Total filter surface (incl. stand-by) = 3 x 3.0 x 11,2 = 100,8m2

b) Chosen: 3 filter beds in action plus one stand-by
Hence the dimensions are as follows:

A per filter = 67m2 : 3 = 22,5m2
chosen width = 2,5m
length $= \frac{22{,}5\text{m2}}{2{,}5\text{m}} = 9{,}0\text{m}$

Total filter surface (incl. stand-by) = 4 x 2,5 x 9,0 = 90m2

Preference may be given to solution b) because less surface will be required. But cleaning a surface smaller than in a) will be more often required. It is up to the engineer to decide which solution is most adequate for the actual site circumstances.

4-6.3.4 Construction details

Fig. 45 Filter bed construction

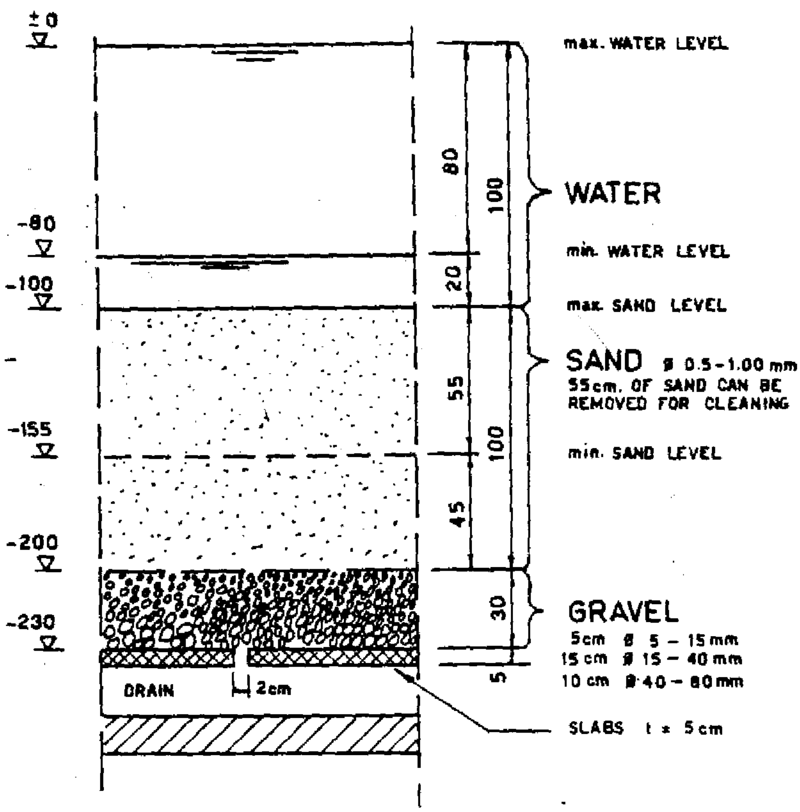


Fig. 46 Filter - long section

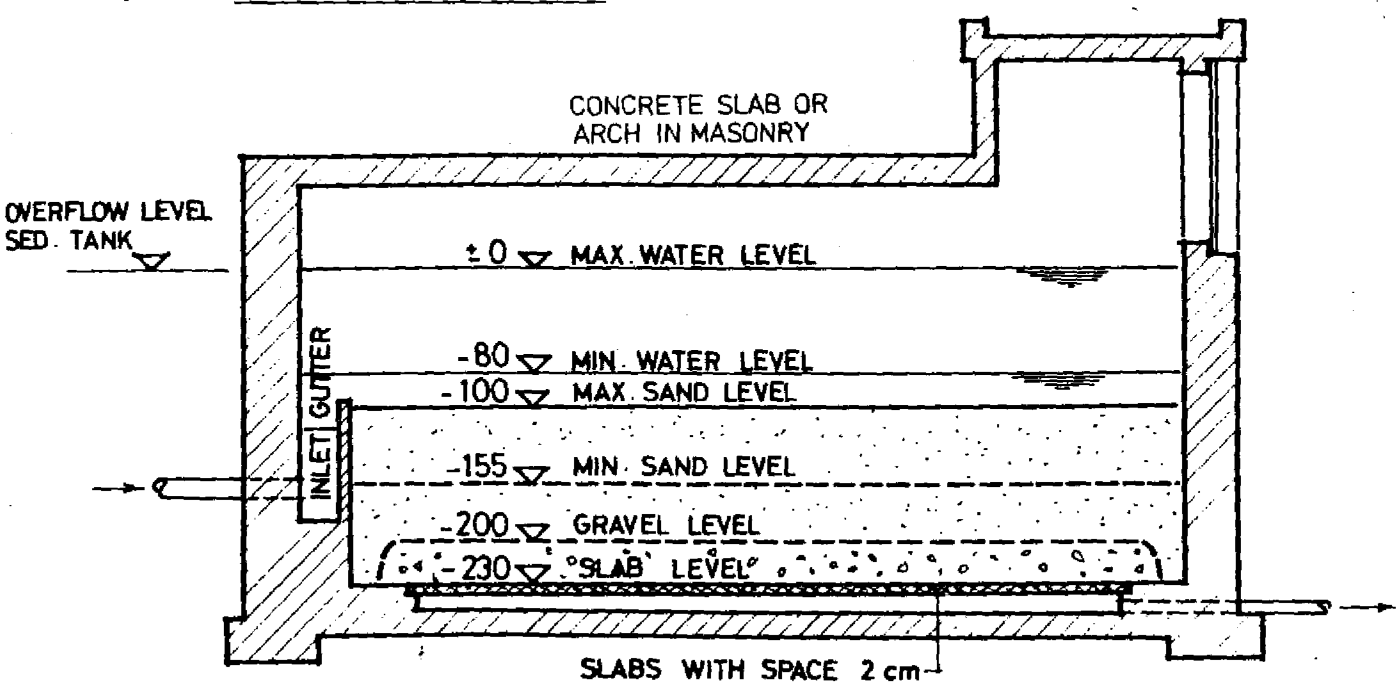


Fig. 47 Filter - groundplan

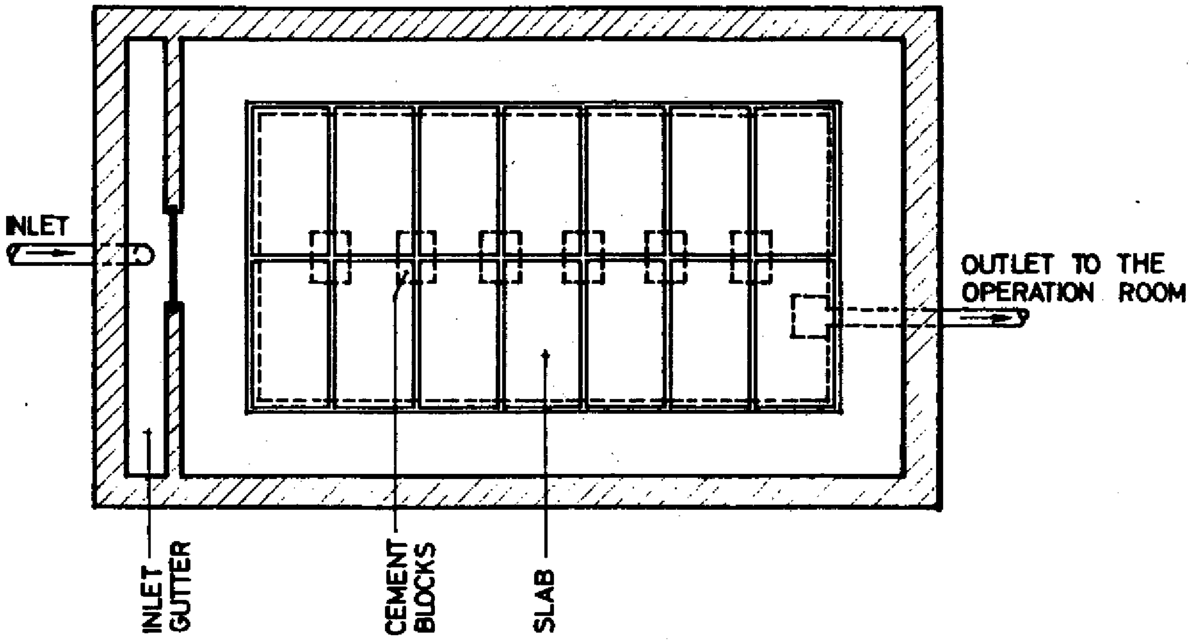


Fig. 48 Filter bottom - cross section

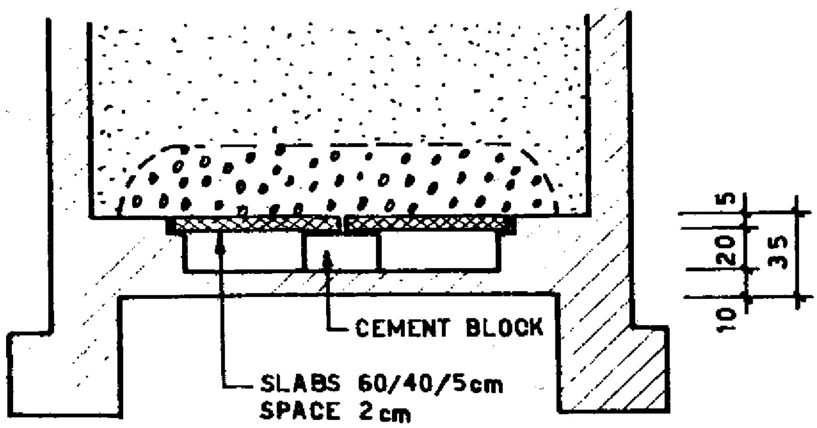
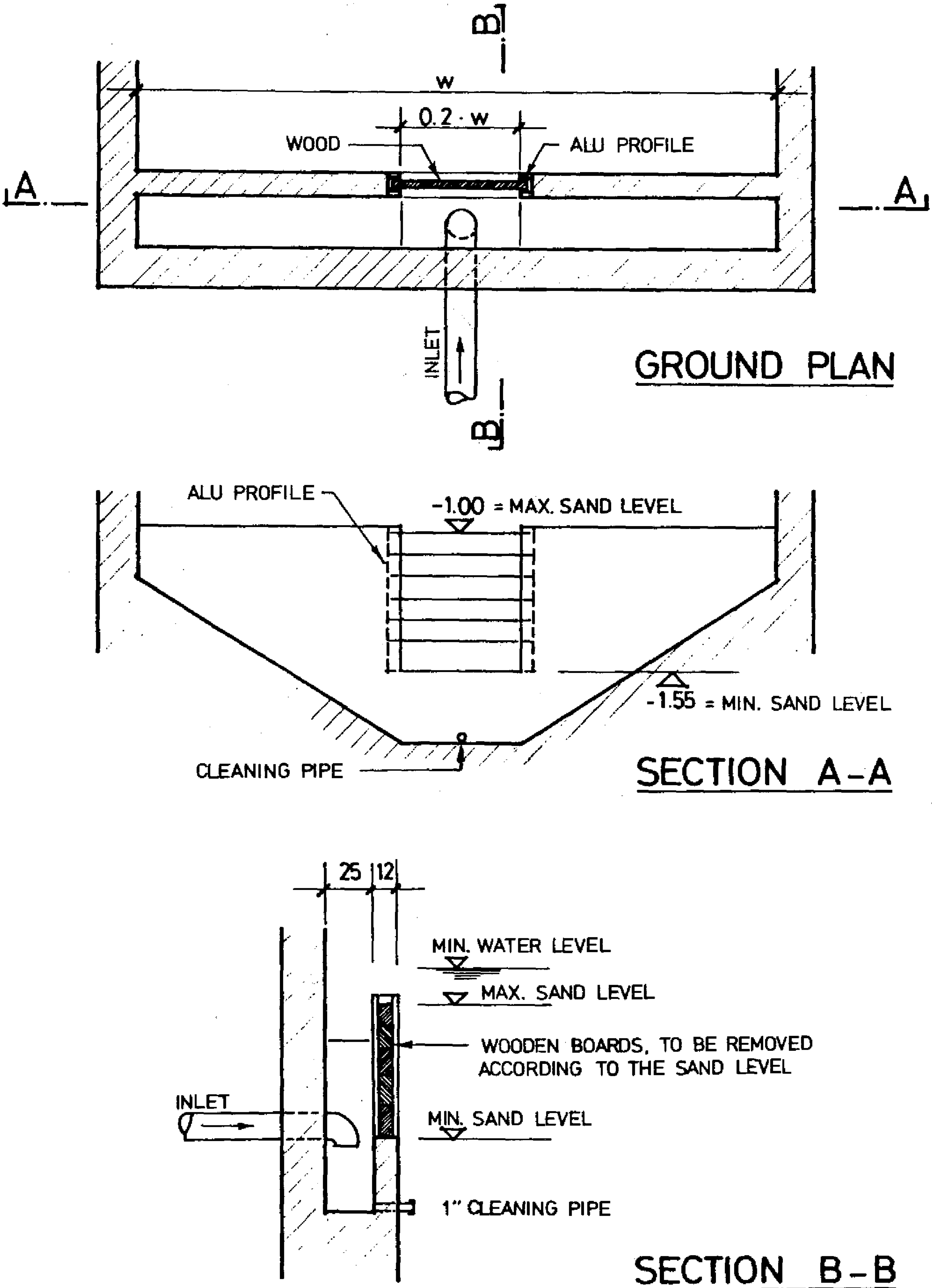


Fig. 49 Inlet gutter details



4-6.4 OTHER FILTER TYPES

4-6.4.1 Rapid gravity filter

Rapid gravity-filters owe their name to the fact that the rate of flow through them is about twenty times faster than through the slow sand-filter (144 m3/m2/day for tropical areas only). Rapid filters work on other principles than those of a slow sand-filter. There is no "Schmutz-decke" film acting as a strainer on their surface; the sand bed is cleaned regularly by forcing air and water upwards through the bed and discharging the dirty wash water to waste; also the incoming water must be chemically treated. The rapid gravity filter acts more as a "strainer in depth" than the slow sand-filter but the process of water purification is not entirely one of straining. As with the slow sand-filter, certain complex biological and chemical changes are induced in the water as it passes through the bed and these - as far as is known - are believed to be the chief mode of action of the filter.

Rapid gravity-filters generally require too much maintenance and supervision to be adopted in rural areas.

Nevertheless a rapid gravity filter has been introduced in a treatment station as an experiment. The reasons are the following:
It has been experienced in slow sand filters that they are blocked after one to two weeks in rainy season because streams carry a lot of suspended matter which cannot be settled out by the common plain sedimentation. Due to this blockage filters need to be cleaned continuously and the biological purification is disturbed. After cleaning, it takes several days to build up the biological process again. In order to avoid this continuous disturbance on the operation of slow sand filters a rapid gravity filter has been preinstalled. It is expected that this rapid gravity filter (v=60m3/day) will work as a strainer to the suspended matters which have passed the sedimentation tank. While this rapid gravity filter will require continuous cleaning the slow sand filters are expected to work for months without blockage.

4-6.4.2 Pressure filter

Pressure filters are identical in bed construction and mode of action to open rapid gravity-filters, except that they are contained in a steel pressure vessel.

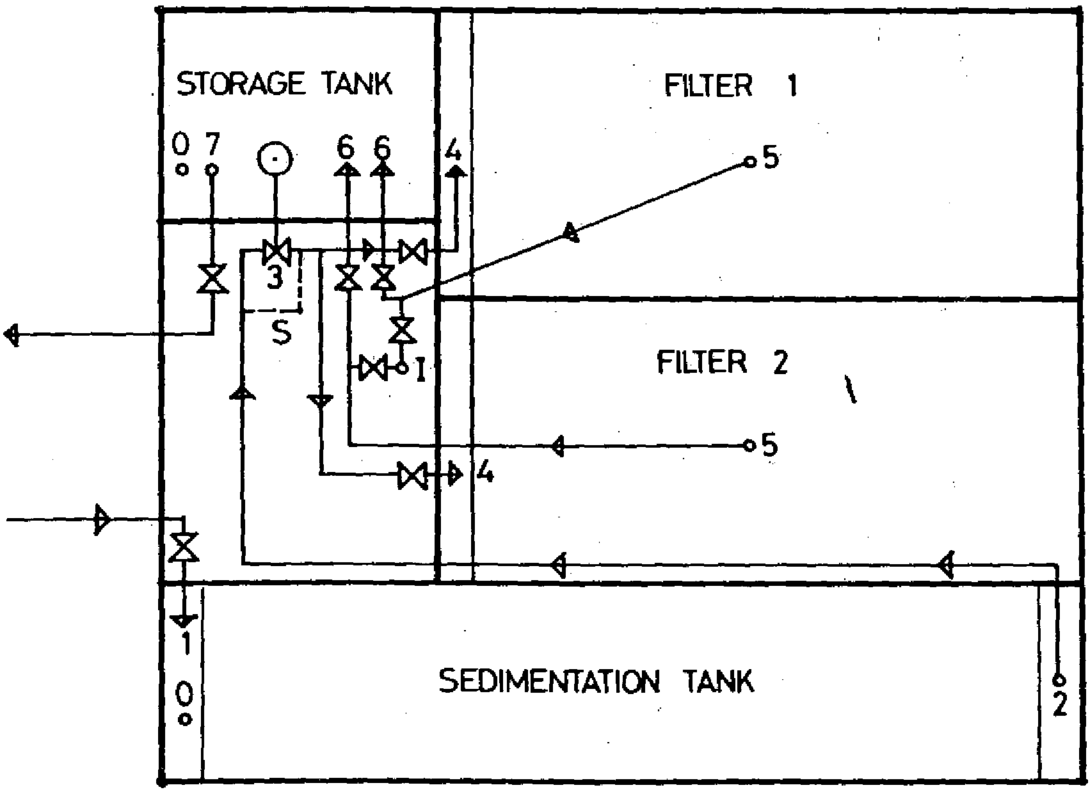
The advantage of pressure filters is that the pressure of water in the mains (not above 75 m pressure) is not lost when the filter process takes place, as is the case with an open rapid gravity plant (friction loss 1 m to 3 m).

4-6.5 TREATMENT STATION: LAY-OUT

Lay out for one sedimentation tank, two sand filters and one storage tank (collection basin).

Fig. 50 Hydraulic system - ground plan

According to system b) in chapter 4-6.3.2

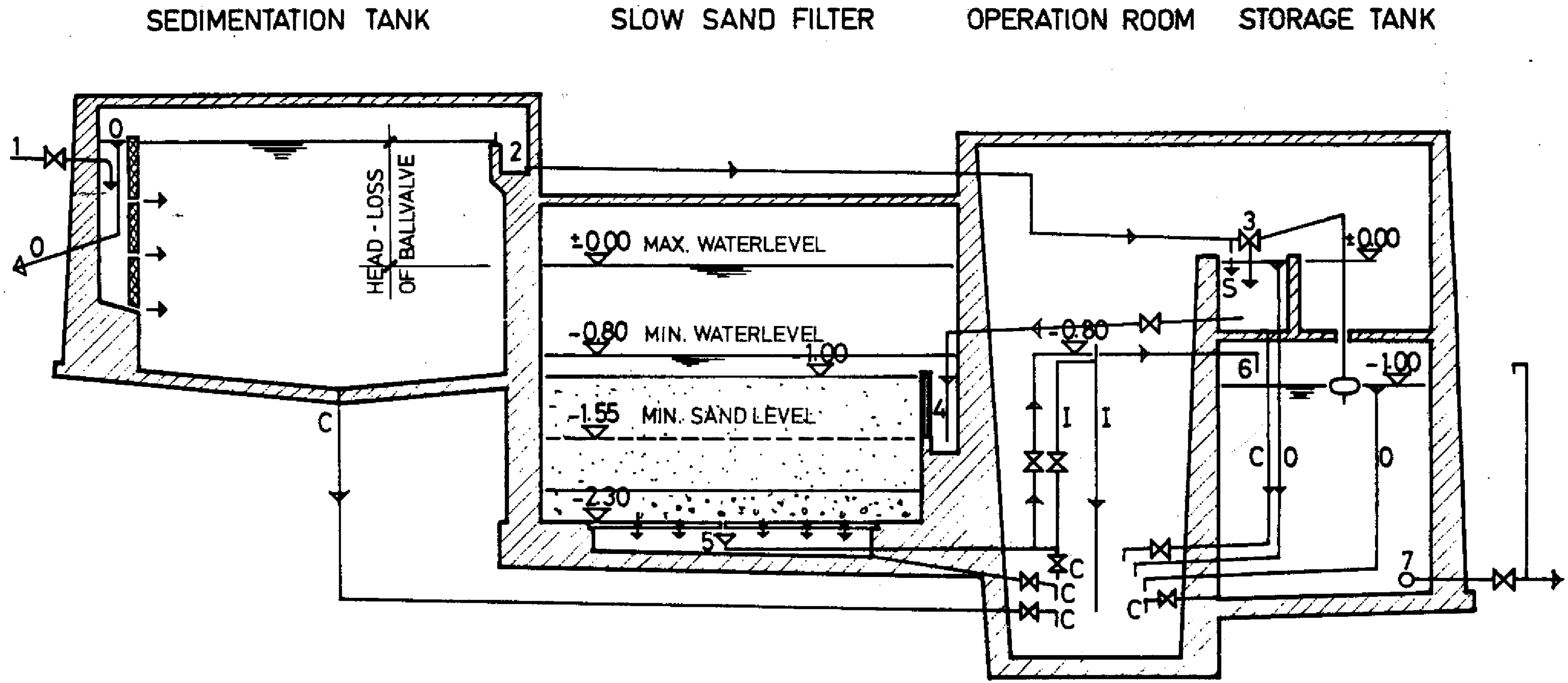


(the cleaning pipes are not shown)

1 inlet to sedimentation tank
2 outlet of sedimentation tank
3 ball valve (depending on storage tank water level)
4 inlet to slow sand filters
5 outlet of slow sand filters
6 inlet to storage tank (collection basin)
7 outlet of storage tank (supply to consumer)

0 overflow ⋈ = *valve*
I idle pipe ∘ = *outlet*
S steady flow → = *inlet*

See section in Fig. 51



1 *inlet sedimentation tank*
2 *outlet sedimentation tank*
3 *ball valve*
4 *inlet slow sand filter*
5 *outlet slow sand filter*
6 *inlet storage tank*
7 *outlet storage tank*

0 *overflow*
I *idle pipe*
S *steady flow*
C *cleaning pipe*

⋈ *valve*

(Ground plan see Fig. 50)

Fig. 51 ***Hydraulic system - section***