S.S.F.
Research and Demonstration Project on Slow Sand Filtration

DESIGN AND CONSTRUCTION OF SLOW SAND FILTERS

**Report of a National Workshop
held in New Delhi, India
January 19-21 1987**

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE (C.S.I.R.) NAGPUR, INDIA

INTERNATIONAL REFERENCE CENTRE FOR COMMUNITY WATER SUPPLY AND SANITATION, THE HAGUE, THE NETHERLANDS

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PREFACE

To provide safe water and effective sanitation for all important efforts must continue in which Governments and recipient communities will have to collaborate closely to achieve this cherished goal. Innovative strategies will be required to develop and implement programmes that are technologically appropriate, socially relevant and affordable. But that is not enough; long proven concepts and technologies will have to be re-examined and further improved to ensure their appropriateness.

Water purification by slow sand filtration is such a concept, and has been successfully practised for over 150 years. It has however, met with problems, often due to inappropriate design, inadequate operation and maintenance, and premature clogging due to excessive raw water turbidity. In some cases this has even led to abandonment of this technology, but fortunately in recent years a new approach was adopted. Extensive research has been carried out in the context of the International Research and Demonstration Project on Slow Sand Filtration sponsored by the Department of Research and Development of the Netherlands Ministry of Foreign Affairs.

This project was initiated by institutions in Colombia, India, Jamaica, Kenya, Sudan and Thailand in collaboration with the International Reference Centre for Community Water Supply and Sanitation (IRC).
The positive results of this project clearly show that slow sand filtration is a simple and reliable treatment method. Often it will be the only reliable and effective method to provide safe drinking water from surface sources in developing countries. These encouraging results have been confirmed by research carried out or sponsored by other organizations including IRCWD in Dübendorf, Switzerland, the University of Dar es Salaam in Tanzania and the Environmental Protection Agency in the USA.

The project has also resulted in improved and more cost effective designs, and therefore it was considered relevant to establish a workshop jointly with National Environmental Engineering Research Institute (NEERI), and with help of experienced design engineers to review and possibly improve SSF designs currently in use in India.

This report presents the results of this workshop. It was prepared by Mr. V. Varadarajan in close collaboration with Mr. A. Raman, and Mr. R. Paramasivam from NEERI and Mr. J.T. Visscher from IRC.

Grateful mention is made of the very active and relevant contributions from the participants and the important support received from CPHEEO, CSIR and NEERI. A special thanks goes to the secretariate for organizing this successful meeting.

It is hoped that this report will stimulate design engineers ro reflect upon their designs and to offer them a change to improve upon them and make them more cost effective and hence offering more communities the possibility to obtain a good water supply system.

INTRODUCTION

Slow Sand Filtration (SSF) can be used to advantage as a method of treatment of surface water for rural water supplies and even for municipal water supplies. Under suitable conditions SSF will often prove to be not only the cheapest but also the most efficient and reliable method of surface water treatment in developing countries.

The design and construction of slow sand filters is relatively simple. The filters can be constructed with locally available material by local craftsmen. With some training, the operation and maintenance can be taken care of by members of the local community. The cost of operation and maintenance of the system will be low.

In order to promote the application of SSF in developing countries, the International Reference Centre for Community Water Supply and Sanitation (IRC), The Netherlands initiated an integrated research and demonstration project on slow sand filtration (SSF Project) in collaboration with national institutes in five countries viz India, Thailand, Sudan, Kenya and Ghana. In India, the collaborating institute has been the National Environmental Engineering Research Institute (NEERI), Nagpur under the Council of Scientific and Industrial Research. The SSF Project has been developed in three phases. In Phase I, extensive applied research was carried out by the national institutes in the countries mentioned earlier on important parameters having bearing on the functional efficiency and cost of SSF. Based on the findings, rational design guidelines were formulated for the SSF system to meet the situations in developing countries.

Under Phase II of the project, demonstration plants were constructed to demonstrate the efficiency of the method under field conditions. In India, four plants were constructed in rural communities, one each in the states of Haryana, Tamil Nadu, Andhra Pradesh and Maharashtra. Community education and participation programmes were run concurrently with the demonstration project to sustain the commitment of the community towards the water supply and ensure its long lasting operation. The demonstration plants were evaluated for their performance over a period of 1-2 years and their appropriateness and relevance for rural water supplies established.

Under Phase III of the SSF project, the earlier findings are being widely disseminated through publications and national and international seminars/workshops organised in the participating countries.

As a part of the promotional activities, IRC in collaboration with NEERI organised a workshop on SSF design and construction at New Delhi from 19-21 January, 1987. The workshop was attended by senior water supply design engineers from the states of Andhra Pradesh, Karnataka, Haryana, Sikkim, Manipur, Kerala, Madhya Pradesh and Maharashtra and also representatives of NEERI, IRC, UNICEF and DANIDA (see Appendix I for list of participants). The workshop had the following general objectives.

- To critically study and review the design and construction practices of slow sand filtration schemes currently followed by different states in India;
- To suggest possible improvements, and
- To develop new design approaches suited to Indian conditions.

The programme followed for the workshop is given in Appendix II. The workshop was inaugurated on 19th January, 1987 by Mr. V. Venugopalan, Adviser, Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, Government of India, New Delhi. Mr. V. Venugopolan stressed the importance of simple, cheap, and at the same time efficient technologies for community water supply which would be readily understood and accepted by the community. He pointed out that one such technology is slow sand filtration and hoped that the workshop would lead to some worthwhile improvements in the current practices in the country in regard to SSF design and construction. The IRC representative explained the background of the SSF Project and the purpose of the workshop.

In the first technical session of the workshop, technical presentations were made by Scientists of NEERI and by the Programme Officer of IRC on: the basics of the SSF process, the design of various filter components and recent developments and experience on SSF in other countries such as Columbia, Thailand, Great Britain, etc. The session was followed by a study tour to two SSF plants in the state of Haryana, one at Rohtak and the other at Jhakoda village. A summary of the technical presentations and report on the field visits are given in Chapter 2.

The second day's session was devoted to a crtical review of the design and construction practices being followed for slow sand filters in India. Three groups of participants were formed for this purpose (Appendix III). Designs and detailed drawings for five typical SSF plants received from some of the states in the country were reviewed in this session. The groups examined the designs and drawings in detail and formulated critical comments on them with suggestions for improvements.

The group findings were presented on the final day of the workshop for general discussion. Some of the points stressed in the presentations were:

- the need for continuous 24-hour operation of filters;
- need for back-filling drained filters before recommissioning;
- non-desirability of stand-by provision;
- economy achievable by use of local sand and other local materials;
- design should facilitate easy of operation.

The presentations generated lively discussions and frank exchange of views between the participants. The summary of the review carried out on current design practices is given in Chapter 3.

In the concluding session of the workshop, important aspects of the design and construction of SSF, particularly in rural water supply, were discussed. Based on these discussions, recommendations and annotated design criteria have been formulated in Chapter 1. It is hoped that these recommendations will be usful to water supply engineers not only in India but also in other developing countries.

The concluding session of the workshop was addressed by Prof. P. Khanna, Director, NEERI and Mr. K.N. Johry, Council for Scientific and Industrial Research CSIR, New Delhi who spoke on the new areas for research in community water supply and the need for furthering international collaboration in this field.

CHAPTER 1

RECOMMENDATIONS

Based on the technical presentations, the review of current design practices and the discussions that took place during the workshop, the following recommendations are formulated for the design, construction and operation of slow sand filter schemes.

1.1 Suitability of slow sand filtration

1.1.1 Slow sand filtration can be applied as a single step treatment when raw water turbidity does not exceed 30 NTU except occasionally for a few days. When higher turbidities are encountered, suitable pre-treatment should be provided.

1.2 Plant location and lay-out

1.2.1 Wherever possible, SSF plants should be so located that the raw water can be gravitated to the filters.

1.2.2 The location of the plant and its ruling levels should be fixed taking into account:
- flood level: Filter should not be subject to flooding.
- ground water table: Filter box foundations should be well above low ground water table and preferably also above high water table. In case this is not possible special attention is required to ensure water tightness of the filter box.
- nature of subsoil: Excavation in rock and other hard strata may be difficult and costly and should be avoided where possible.

1.2.3 Plant lay-out should be compact to facilitate operator's tasks.

1.2.4 The lay-out should permit easy future expansion.

1.3 Annotated design criteria

The workshop participants critically reviewed current design practices and recommended the adoption of the design criteria for slow sand filters presented in Table 1. Specific comments based on their field experience are summarized in this section. A model design incorporating the suggestions made in the workshop is presented in Appendix VI. More detailed guidelines and information is presented in IRC's Technical Paper number 24: Slow Sand Filtration for community water supply, planning, design, construction, operation and maintenance.

It should be stressed however that good design not necessarily means a good filterplant because much depends on the quality of materials used for construction, the available skills and the quality of supervision provided during construction. Too often, particularly in rural areas insufficient attention is paid to these aspects. For example, sand used to make concrete may contain clay or concrete may not be properly cured and therefore not becoming sufficiently durable.

A good design should very much facilitate adequate operation and maintenance being essential to quarantee regular supply of good quality drinking water. Involving the caretaker(s) already in the construction stage enables them to really get to know their plant. Training can already start at this stage and needs to be combined with good supervision to ensure that the investment results in an adequate and sustainable water supply.

Table 1. General design criteria for slow sand filters in rural water supply

Design criteria	Recommended value
Design period	10-15 years
Period of operation	24 h/d
Filtration rate	0.1 - 0.2 m/h
Filter bed area	maximum of 200 m^2 per unit minimum of 2 units
Depth of filter sand:	
initial	0.8 - 1.0 m
final before resanding	0.5 - 0.6 m
Specification of sand	
effective size	0.15 - 0.30 mm
uniformity coefficient	< 5, preferably below 3
Height of underdrain	
including gravel layer	0.3 - 0.5 m
Height of supernatant water	1 m

1.3.1 Design period: As there is hardly any economy of scale in the costs of SSF plants, they may be designed for a short period of 10-15 years in the first instance and expanded later on as the need arises (also see 1.2.4).

1.3.2 Filtration rate: The design rate of filtration may generally be 0.1 m/hour. However, if raw water is of comparatively good quality with turbidity less than some 5 NTU, a higher filtration rate, say 0.15 to 0.20 m/hour, can be adopted for design.

1.3.3 Mode of operation: Slow sand filters shall be designed for continuous 24 hours per day operation at constant rate. Intermittent operation, i.e., operation of the filters for only part of the day is not acceptable as it will impair bacteriological purification.

There will be no difficulty in providing continuous filtration when raw water is to be gravitated to the filters.

When raw water has to be pumped to the filters and the plant is large, continuous pumping should be provided to enable continuous, constant rate filtration.

When the raw water has to be pumped and the plant is small it may not be practicable to provide continuous pumping. In such cases often the best option is to provide high level storage of raw water before the filters to balance the intermittent pumping and the continuous constant-rate filtration. A float valve arrangement will be required on the inlet of the filters to ensure constant water level in the units. As an alternative a floating outlet weir can be provided in the raw water storage tank to ensure constant flow from the tank to the filters.

Instead of providing high level storage of raw water, declining rate filtration can be applied. When pumping is interrupted, gradually the supernatant water level in the filters will fall, and the filtration rate will decrease untill pumping is resumed. Declining rate filtration will require a larger filterbed area which is difficult to calculate precisely. Also it requires adequate control of the pump regime and hence it is not favoured.

1.3.4 Filter area: Filter area requirement (m^2) will be given by daily supply required (m^3/day) at the end of the design period divided by filtration rate (m/h) x 24-hours. No additional area is to be provided as stand-by.

1.3.5 Number of filter beds: In small plants there shall be at least two filter beds. In larger plants, the number of beds may be increased to facilitate maintenance. A rough indication of a suitable number (n) is given by the formula $n = 0.5\sqrt[3]{A}$, where A = total area of filter beds in m^2. No additional beds need to be provided as standby. When one of the beds needs to be cleaned. the rate of filtration in the other bed(s) may be increased. A temporary increase of the rate of filtration upto 0.3 $m^3/m^2/h$ does not have an adverse effect on the effluent quality.

1.3.6 Maximum filter bed area: In rural plants, the area of individual beds should be kept under 200 m^2 so as to facilitate quick cleaning of filters.

1.3.7 Filter shape and dimensions: When filter beds are of an area less than about 125 m^2 and they are to be constructed fully or almost fully below ground, circular shape may be more economical than rectangular shape. For larger installations or when small filters are fully or partly above ground, rectangular beds in a battery may be more economical.

The economical length (L) and width (B) of rectangular filters in a battery are given by the formulae:

$$L = \sqrt{2A/n+1} \qquad \text{and } B = \frac{(n+1) \times L}{2n}$$

where A = total area of filter beds (m^2), and
n = no. of filter beds in the battery.

Small filters above ground may also be constructed in ferro-cement in which case a circular shape should be adopted.

1.3.8 Height of supernatant water: It should be 1 meter minimum to allow for sufficiently long filter runs.

1.3.9 Filter media: The media may be river sand, pit sand or crushed stone. Filter sand should be relatively fine with effective size (e.s.) of 0.15 to 0.30 mm and uniformity coefficient (u.c.) preferably below 3 and not exceeding 5. Acid solubility in 1:1 hydrochloric acid should not exceed 5% after 30 minutes contact and silt content should not exceed 1% by weight.

Local sand should be used as filter sand wherever possible as it will cut down costs considerably. A sieve analasis is required to confirm the suitability of local sand. A first impression can be obtained in the field by testing whether most of the sample will pass through a sieve of about 1.0 mm opening and most of it will be retained on a sieve of about 0.20 mm opening with some 10% passing through. If the sand contains excess silt it should be washed before use.

The minimum depth of sand (i.e. depth before re-sanding) should be 0.5 - 0.6 m when the sand is of e.s. 0.15 - 0.30 mm. Selecting a minimum depth of 0.6 m is advisable if slow sand filtration is the only treatment and the effective grain size is in the higher range. The initial depth should be 0.8-0.9m to allow for a sufficient number of scrapings before re-sanding is needed. If it is expected that cleaning will have to be frequent because of raw water quality, the initial depth of sand may be raised to 1,0 m.

1.3.10 Underdrainage: In case of village plants, the lateral underdrains may best be formed of bricks laid on edge covered over with bricks laid flat with open joints of 5-8 mm size.

When underdrains are formed of bricks, the overlying gravel layers may be of size and thickness as specified below:

bottom layer:	18 - 33 mm size, 13 cm thick
next higher layer:	6 - 12 mm size, 6 cm thick
next higher layer:	2 - 4 mm size, 6 cm thick
top layer:	0.7 - 1 mm size, 6 cm thick.

The gravel layers may be of river bed pebbles or broken stone whichever is cheaper. If of broken stone, special sieving may be dispensed with if commercial sizes are available approximately to the specified sizes.

If underdrains are of special design such as perforated pipe laterals, drains covered by porous concrete slabs or laterals fitted with permeable capsules, the coarse gravel layers may be dispensed with, reducing gravel requirements and also the depth of filter box.

The lateral and main underdrains should be so sized that the maximum head loss in the underdrains will not exceed 25% of the head loss in the sand media with the sand being clean and the bed being at its minimum thickness after repeated scrapings. (The specification is intended to ensure that the rate of filtration is fairly uniform over the entire filter bed).

The main drain may be provided with a nominal slope of about 1/200 towards the filter drain-out end to help in cleaning out the filter box after construction. The floor of the filter box may be given a nominal slope (say 1/100) towards the main drain.

It is neither necessary nor desirable to vent the underdrains. It does not have any beneficial effect and may even result in contamination of the effluent.

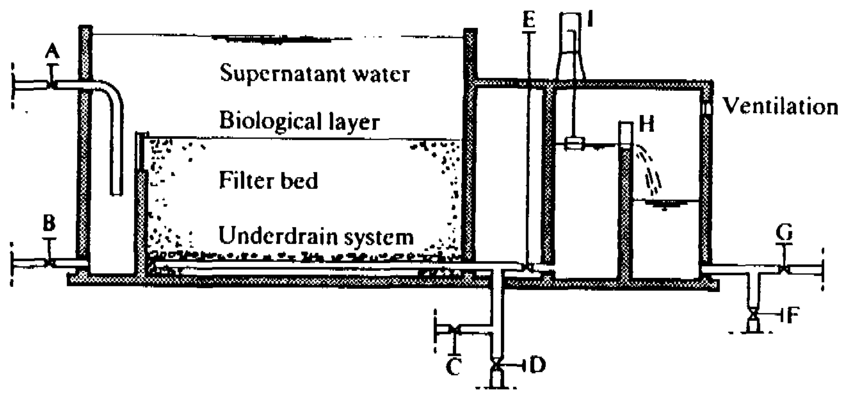
1.3.11 Filtration-rate regulation: Filtration rate may be regulated either at the inlet (Fig. 1) or at the outlet (Fig. 2). Inlet control may be used in the case of small, gravity-flow systems having filters in remote locations where daily flow regulation will be difficult. Outlet control may be adopted where it will not be difficult to provide daily flow regulation.

1.3.12 Inlet arrangements: In the case of inlet control, there should be provision for measuring and regulating the total flow to the plant and for splitting it equally between the different filter beds.

The inlet structures for individual filter beds should be designed to avoid any scouring of sand. They should incorporate provision for closure of flow and for rapid draining of supernatant water up to sand level.

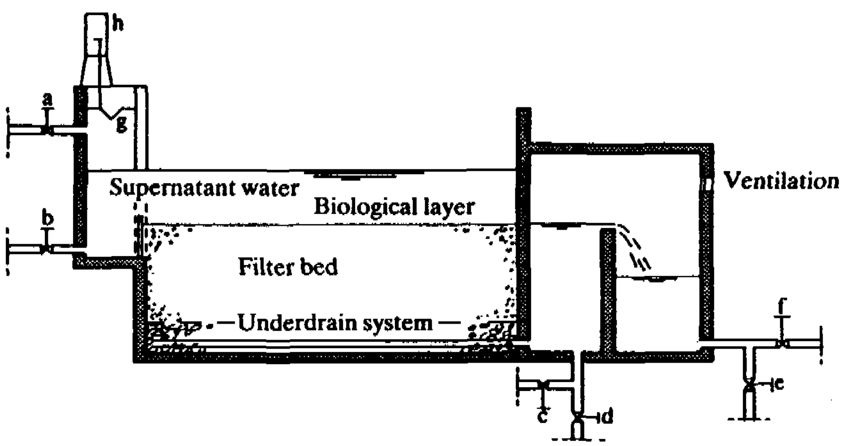
1.3.13 Outlet arrangements: The oulet arrangement for each filter bed should incorporate a filter drain-out, a means for back-filling with filtered water after cleaning by making an interconnection with the outlet pipe of the adjacent filter, a regulating valve on the filter outlet pipe, a weir with free fall having its crest fixed 3 cm above maximum level of sand to prevent 'below atmospheric pressure' in the filter, a drain pipe after the weir for filtering to waste and a valve for closing the flow to the filtered water tank during filtering to waste.

Figure 1: Basic components of an outlet controlled slow sand filter



A: raw water inlet valve
B: valve for drainage of supernatant water layer
C: valve for backfilling the filter bed with clean water
D: valve for drainage of filter bed and outlet chamber
E: valve for regulation of the filtration rate
F: valve for delivery of treated water to waste
G: valve for delivery of treated water to the clear water reservoir
H: outlet weir
I: calibrated flow indicator

Figure 2: Basic components of an inlet controlled filter



a: valve for raw water inlet and regulation of filtration rate
b: valve for drainage of supernatant water layer
c: valve for backfilling the filter bed with clean water
d: valve for drainage of filter bed and outlet chamber
e: valve for delivery of treated water to waste
f: valve for delivery of treated water to the clear water reservoir
g. inlet weir
h: calibrated flow indicator.

In the case of the 'outlet control' filter, the weir in the oulet chamber should also serve as a flow-measuring device. The measuring weir may be a V-notch for small flows and a trapezoidal weir for large flows. A float-operated rate-of-flow indicator should be provided on the upstream side of the weir. It is also desireable to provide a loss of head guage on the outlet pipe of each filter bed.

The outlet chamber should always be covered properly and also vented. Manhole covers over outlet chambers should be of overlapping type.

1.3.14 Filter box: The total height of the filter box will be 2.5 - 2.7m, inclusive of 0.2m free board. The top of filter walls should be at least 0.5m above formation ground level. An overflow arrangement should be provided in each filter box to help remove scum and prevent flooding.

1.4 Construction

1.4.1 Relevant Indian Standard Specifications should be followed for the construction of all water retaining structures.

1.4.2 Water tightness of all structures should be checked and ensured before placing gravel and sand in the filter box.

1.4.3 To prevent short-circuiting of raw water along the walls of the filters, the inside plastering of the walls may be made rough from maximum level of sand up to floor level.

1.4.4 The alternative of ferro-cement construction should be considered for circular filters as it may often be cheaper than brick or R.C.C. construction. In India, information on ferro-cement can be obtained from the Structural Engineering Research Centre, Adyar - Madras or Ghaziabad (U.P.). Information can also be obtained from the Ferro-cement Information Centre at the Asian Institute of Technology (AIT) in Bangkok, Thailand.

1.4.5 The outlet valve of the filter bed, the inter- connecting valve with the adjacent bed and the filter drain-out valve (if placed before outlet valve), should be fixed in dry sluice valve chambers to enable easy maintenance. Other valves should also preferably be installed in dry chambers rather than in wet chambers. Valves in dry pits requiring frequent operation as also valves placed in wet chambers should be provided with extension spindles and capstan heads for convenient operation.

1.5 Operation and Maintenance

1.5.1 Slow sand filters should be operated continuously 24 hours of the day as intermittent operation will impair filtered water quality. In case there is any interruption in raw water flow,the filters should not be shut down, but allowed to filter at a declining rate.

1.5.2 Generally, all the filter beds of a plant should be kept operating and no bed should be kept idle as standby as idle units will take several days after they are started to reach full efficiency.

1.5.3 Filter beds should be cleaned one at a time. When one bed is being cleaned, other beds may be overloaded to maintain total plant output. Overloading for short periods will not affect filtration efficiency.

1.5.4 Cleaning of a filter bed should be completed as quickly as possible and the bed recommissioned within 24 hours of initial shut-down but preferably quicker to limit the adverse effect on the biological flora in the filter.

1.5.5 Resanding: When the sand level in a filter has been reduced to the minimum permissible level of 0.5 - 0.6m, the filter bed should be resanded. In resanding, the "throwing over method" should be followed (see Appendix IV).

1.5.6 Filters which have been drained down below the sand level should always first be back-filled with filtered water from adjacent filters before top-filling with raw water. New filters should be back-filled with as clean water as possible before top-filling.

1.5.7 New filters and resanded filters should be run to waste until the bacteriological quality is satisfactory which may take several days. Filters which have been cleaned should be filtered to waste at least for a day.

When filtering to waste is not feasible, special care should be taken to chlorinate the filtrate before supply.

CHAPTER 2

TECHNICAL PRESENTATIONS AND FIELD VISITS

2.1 Technical Presentations

2.1.1 As an introduction to the workshop, technical presentations on various aspects of slow sand filtration were made by R. Paramasivam, A. Raman and J.T. Visscher. A summary of the technical presentations is given below.

2.1.2 Slow sand filtration is an appropriate method for purifying surface waters, especially for rural water supplies. Some of the advantageous features of the method are simplicity of design, construction and operation, high efficiency in the removal of pathogens and viruses, good reliability, low energy requirement and absence of any need for expensive chemicals. Because of its high efficiency, this method is finding increasing use in developed countries also, both as a single step treatment and as a polishing treatment after rapid gravity filtration. This method can be adopted as a single step treatment when the turbidity of raw water is generally less than 30 NTU. Where higher turbidities are encountered, suitable pretreatment would be required. For pretreatment of turbid waters, riverbed filtration, horizontal flow roughing filters (HRF), down-flow and up-flow coarse-media roughing filters and up-flow fine-media roughing filters have been tried out successfully in several places. Pilot scale testing of some of these methods is underway in Colombia and India whereas full scale tests with improved HRF plants are underway in some countries with support from IRCWD (Wegelin 1986). It should be remembered that surface water quality which may be good to start with may often deteriorate in course of time due to deforestation and agricultural and industrial development. Hence pretreatment though not initially required may often become necessary at a future date if appropriate preventive measures are not taken.

2.1.3 The purification in slow sand filters is partly due to physical phenomena such as straining, sedimentation and adsorption. But a very essential part of the purification is achieved by biological processes particularly in the filter skin which is formed as the filter run progresses. Slow sand filtration may be expected to reduce turbidity to about 1 NTU. It will also reduce natural colour by 30-40%, E.Coli by 95-100% and organic matter by 60-70%. There may be virtually complete removal of viruses, cercariae of Schistosoma, cysts and ova.

2.1.4 A cost-comparison by NEERI in 1983 indicated that in general in rural and sub-urban areas in India, slow sand filtration was more economical than rapid gravity filtration up to 8 MLD capacity. However, the comparative economy will be location-specific and each case should therefore be examined individually.

2.1.5 As there is very little economy of scale in the construction of slow sand filters, the design period can be short, say 10 to 15 years. The design filtration rate may normally be 0.1m/h and the overload rate during cleaning operations may be 0.2m/h. The minimum number of filter beds should be two. A higher number of beds will greatly increase flexibility of operation and maintenance at only slightly higher construction costs. There is clearly no need to provide any standby filters. Ripening of a stand-by filter would take far too long to be of any use. Operating the remaining filters at a higher rate whilst cleaning one unit is very efficient and does not lead to deterioration of the effluent. Filter size should not exceed 200 m^2 so that excessive time is not required for cleaning. As regards minimum size, filters have been constructed to even 0.7m diameter using steel drums.

2.1.6 The basic elements of slow sand filters are inlet arrangement, filter box with supernatant water, filter media, underdrainage system and outlet arrangement.

The inlet arrangement should be so designed as to prevent scouring of sand bed by the inflowing water. It should also incorporate arrangement for draining out the supernatant water quickly at the time of cleaning. The filter box should incorporate an overflow arrangement for removal of scum. The supernatant water depth may be 1 metre.

Filter media should be sand of effective size 0.15 to 0.30mm and the uniformity coefficient should preferably be below 3 and not greater than 5. Thickness of filter media may be 0.5 to 0.6m minimum with 0.3m extra to permit scraping of the sand surface 10 to 15 times before resanding is done.

The supporting media may be rounded gravel or borken stone depending upon local availability and cost.

Brick underdrains may often be the best for village plants because of local availability and simplicity of construction. Some special underdrains using corrugated perforated pipes, pipes fitted with permeable capsules etc are being tried out currently. The latter systems may be financially attractive as they reduce gravel requirement and result in a lower construction height.

The outlet arrangement should have an overflow weir with its sill above maximum sand level so as to avoid "below atmospheric pressure" and also to prevent accidental draining of the filter. There should be an arrangement for measuring the rate of flow and a valve for regulating the rate. The outlet arrangements should incorporate pipings for backfilling, draining down the filter and filtering to waste.

2.1.7 The filtration rate may be controlled either at the outlet or at the inlet. The first method is more common and consists of keeping the water over the sand always at MWL and throttling the outlet valve initially and reducing the throttling as the loss of head in the sand increases. In the inlet control method, the inflow to each filter bed is maintained constant over a weir and the outlet valve is kept fully open. Initially, the water level over the sand will be low, but the level will automatically rise as the days progress and the top of the filter bed gets more and more clogged. The inlet control method requires less day-to-day attention, but there is some danger that aquatic weeds may develop on the sand because of the low depth of the water prevailing initially.

2.1.8 Ferro-cement offers an attractive material for the construction of small filters. The filter boxes can be constructed either completely of ferro-cement or the walls may be of brick with ferro-cement lining inside. Lined earthen basins also have been employed instead of concrete and masonry filters.

2.1.9 Filters should be operated continuously. Intermittent operation should be avoided as this will result in unacceptable deterioration of the effluent. When newly commissioned, the filtrate should be run to waste until the filters have ripened and filtered water has reached satisfactory bacteriological quality. Filtering to waste (for one or two days) is also desirable after periodical scraping. Only when post chlorination is applied is filtering to waste not required. Before letting in raw water from the top (top-filling) into filters which have been drained down for scraping or resanding, they should be "back-filled" with filtered water from adjacent beds up to the crest level of the outlet weir.

2.1.10 People's participation is essential for the success of any community water supply. The participation has to be continuous, at the stage of planning, during implementation and, later on, during operation and maintenance. Slow sand filter systems lend themselves very well for community understanding and participation because of the essential simplicity of the technology. Therefore, community participation should be fully enlisted in slow sand filtration projects. Hygiene education should also form part of the project so as to stimulate use by all and maximise health benefits of the water supply.

2.2 Field Visits

2.2.1 The technical presentations were followed by a field visit to two slow sand filter plants located in Rohtak district in Haryana State. The visit was arranged by Mr. J.C. Yadav, Superintending Engineer, Public Health Engineering Branch - PWD, Rohtak.

2.2.2 The first visit was to the SSF plant at Jakhoda village. The plant is new and has been only partly commissioned. It serves a group of five villages with a total design population of 19,000 and water supply demand of 0.86 mld. The raw water is obtained from a branch of the Western Jamuna Canal. A raw water storage tank of 28 days' capacity has been provided to meet periodical closure of the canal. From the storage tank the water is pumped to the filters. The rate of filtration has been fixed at 0.1m/hr. Four (4) circular filters of 12.5m diameter have been proposed but only two have been constructed as yet. The filters have plain pipe inlets with a cushioning slab below. Supernatant drain-outs are provided at a fixed level at the top of sand. As float valve chambers have been proposed (yet to be provided) on the inlet lines, no overflow has been provided. The sand depth is kept as 0.68m. Filtration rate is regulated with the outlet valve, the flow being measured over a V-notch. Provision has been made for filter drainage but not for "filtering-to-waste" or for "back-filling". Ventilating shafts embedded in the filter walls have been provided for the underdrainage which enhances a risk of contamination of the treated water. Acute power shortage is a major problem in the operation of the plant.

2.2.3 The second visit was to an SSF plant serving Rohtak city (population: 180,000). The plant was constructed in 1931 and is still in operation, meeting about 10% of the present needs of the town, the balance being met by rapid gravity filter plants. The raw water is drawn from a branch of the Western Jamuna Canal through a raw water storage tank of 28 days' capacity. From the storage tank, the water is pumped to a rectangular sedimentation tank (manually cleaned) with provision for addition of alum when required. From the settling tank, the water is gravitated to a battery of 8 rectangular filters each of size 19.8m x 13.7m. Rate of filtration is 0.1m/h with 24 hour operation. Each filter bed has been provided with a float valve chamber from which the filter is fed. The floats are not operative now. The filter beds are similar to the filters described for Jakhoda in regard to inlet, ventilating shafts for underdrains, sand depth, outlet arrangements, etc. As at Jakhoda, provision is made for draining the filters; but, there is no provision made for rapid drain-out of supernatant water, filtering-to-waste or back-filling drained filters. During periodical cleaning, the water is drained through the sand to about 0.8m depth below V-notch sill and then scraped. The draining takes 3-4 days and the scraping about 1 day. Scraped sand is stored without washing and cleaning is done only at the time of resanding. It is reported that after prolonged storage the sand does not get properly cleaned. Hence resanding is nowadays being done with fresh sand.

2.2.4 The visits to the two SSF plants served to orient the workshop participants to the review of typical designs for SSF plants that they were to take up in the next session. The visits were particularly useful because some of the design features of these plants were based on traditional design practices which are not concurrent to latest ideas and research findings. The open discussions following the field visits very much served the purpose of exchange of knowledge and experience which will ultimately lead to improved design and better understanding.

CHAPTER 3

REVIEW OF CURRENT DESIGN PRACTICES

3.1 In Technical Session 2 of the Workshop, the participants undertook a critical review of the design and construction practices generally being adopted for slow sand filters in India. This chapter presents a resume of the reviews.

3.2 Five typical designs for SSF plants received from Andhra Pradesh, Haryana, Himachal Pradesh and the Punjab were taken up for review. Brief details of the plants are given below:

Case A: This is a large plant (9 mld) serving a number of villages having a total design population of about 178,000. The source of supply is a summer storage tank fed by an irrigation canal. The daily supply proposed is about 9mld. Six rectangular filters each of size 50m x 20m have been proposed. Sixteen hours of raw water pumping has been adopted with declining rate filtration for remaining 8h.

Case B: This is a small plant having two circulal filters of 7.7m diameter. The plant has been designed for a daily output of 0.22mld with 24 hour constant rate operation.

Case C: This is a medium-sized plant having two rectangular beds of size 14m x 10m. The daily supply is 0.76mld with continuous filter operation.

Case D: This is a small plant having two circular filters of 8.53m diameter with provision for adding one more unit in the future. The population to be served is about 5500 and the filter output will be about 0.26mld. The source of water is an irrigation canal with storage tank. An increased depth of supernatant water has been proposed for the filter, reportedly to avoid the need for high level storage.

Case E: This is a medium-sized plant having two rectangular filters, each of size 26.5m x 18.0m. The filter output is 2.30mld assuming 24 hour, constant-rate operation.

3.3 Three groups of participants were formed to review these designs (see Appendix III for group composition). Group 1 examined cases A and B, Group II examined cases B and C, and Group III examined cases D and E. The review was focussed towards two main aspects: (i) the changes required in design and construction practices to facilitate effective functioning of the plants, and (ii) the improvements that could be carried out in case the plants have already been constructed. The findings of the 3 groups were presented for general discussion in the concluding session of the workshop. A brief report on each case based on the group findings and the subsequent general discussions is presented in Appendix V.

3.4 Major Findings

It emerged from the discussions that many of the design and construction features requiring improvements were common to most of the five cases reviewed. These and other major findings of the review are summarized below:

3.4.1 In all the designs reviewed, the filtration rate has been adopted as 0.1m/h. While this rate was considered generally acceptable, it was felt that when the raw water is drawn from storage tanks of long detention as in some of the cases reviewed, the water quality may imporve to such an extent that higher rates of filtration can be adopted. However, the possibility of algae growth in the storage tanks should also be assessed. If storage will reduce the turbidity to less than some 5 NTU, a filtration rate up to 0.15m/h can be adopted if there are only two filter beds. When there are more than 2 filter beds, the rate may even be

0.2m/h. The idea is that the rate of filtration should not exceed 0.3m/h (up to which filtered water quality may not be affected) when one filter is being cleaned and the entire flow is being filtered through the remaining filters.

3.4.2 In one of the designs, intermittent pumping of raw water with declining rate filtration has been proposed. In another case, presumably there is intermittent pumping and an increased depth of supernatant water has been provided as a substitute for high level storage to permit 24 hour operation of filters. In the other three cases, 24-hours operation of filters has been assumed but no mention is made of how raw water will be fed to the filters all the 24 hours. It was agreed that filters should be operated continuously for 24 hours to avoid deterioration in bacteriological quality of the filtrate. Also, the rate of filtration should be held constant at design rate all the 24 hours so as to minimize the filter area required.

There will be no difficulty in operating the filters continuously at constant rate when the raw water can be gravitated to the filters. In the case of large plants, when the raw water has to be pumped and there is electric supply only for part of the day, standby power and staff for three shifts should be provided to enable 24 hour operation of the filters. In the case of small plants where the raw water has to be pumped, provision of stand-by power and employment of staff for three shifts may not be practicable. In such cases, high level storage tanks may be provided before the filters to balance intermittent pumping of raw water and continuous feed to the filters. The storage tank capacity required will depend on the pumping schedule. A float valve will have to be provided on the feeder pipe from the high level storage tank to the filters to maintain constant water level in the filters, though water level in the storage tank will be fluctuating. Increasing the depth of supernatant water often will be a costly subsititute for high level storage.

Declining rate filtration in which filters are not closed when pumps are shut down but are allowed to filter at declining rate, will no doubt avoid deterioration in water quality arising from intermittent filter operation. However, under this mode, it will be difficult to calculate the filter output correctly; also, the area requirements will be higher than for 24-hours constant rate operation. Hence, declining rate filtration is a less suitable design alternative even for small plants.

3.4.3 In two of the designs reviewed, extra area or an extra bed has been provided for the filters as stand-by, presumably to take care of the situation when a bed is being cleaned. It was felt that stand-by provision is unnecessary since when a filter is under cleaning the remaining unit(s) can be overloaded without affecting the filtrate quality. Further, keeping a filter bed dry as a stand-by is not a desirable practice as such a bed would take several days after being put into operation to ripen and produce filtered water of satisfactory quality.

3.4.4 In the three cases of large/medium filters reveiwed, the number of filter beds proposed was felt to be insufficient to provide the required flexibility of operation (See 1.3.5 for formula for optimum number of filter units). The number of filter beds would also depend on the size of bed which can be cleaned speedily enough. Generally, a filter bed should be cleaned and put back into operation within 24 hours, so that useful biological life in the sand does not die out resulting in a long ripening period after the filter is restarted. From this consideration, filter bed area for village SSF plants should not exceed 200 m^2. However, in the case of large plants, it may be possible to employ additional labour and clean much larger areas in the time specified.

3.4.5 Two of the designs provided for circular filters. There was disucssion about when circular filters could be adopted. They may be more economical than rectangular beds in the case of small plants, especially when the filters are fully or almost fully below GL as the filter walls will then have to be designed only for hoop compression. Generally, the economical limit for circular filters was considered to be about 12.5m in diameter.

In the case of rectangular filters, the length to width ratio should be fixed to give minimum length of walls so as to economize on cost (See 1.3.7).

3.4.6 As cost of filter sand forms a major part of the cost of slow sand filters, adequate effort should be taken to locate the cheapest possible source for it. In this context, local sand sources should be investigated for their suitability.

Sand of proper specification may be difficult to obtain in certain areas. It was felt that in such cases, crushed stone could be used. Media of this type being angular, may increase the initial head loss in the filter to some extent; but as initial head loss will be only a fraction of the final head loss, the filter run may not be reduced appreciably.

3.4.7 In four out of the five designs, the supporting gravel media were not graded properly. The purpose of the gravel layer is to prevent the sand entering and choking the laterals. Each layer should be so sized that the interstices in it are smaller than the gravel in the upper layer. The gravel size in the lowest layer should not be less than twice the diameter of the openings in the laterals.

It was agreed that broken stones could be used instead of river-bed gravel, if cheaper. The normal size specifications for gravel media may be slightly relaxed if required to enable use of commercially available sizes of broken stone which will avoid the cost of special sieving.

3.4.8 In some of the designs, slopes are indicated for lateral and main underdrains, the need for which invited discussions. No slope is required for the drains from hydraulic considerations as the flow in them would be under pressure. However, a slope of the main drain towards the filter drain-out and a slope of the filter floor towards the main drain will be useful in cleaning out the filter boxes before filling them with media. The slope may be nominal, say, 1/200 for the main drain and 1/100 for the filter floor.

3.4.9 In one of the designs, permeable capsules have been specified for underdrains. Permeable capsules and other patented types of underdrains may help to reduce gravel requirements; but availability, design suitability and cost should be duly considered before their adoption. Generally it was felt that in village SSF plants, the lateral drains should be of brick work as then only local materials and local skills would be required for construction.

3.4.10 During the review of the designs, the procedure for sizing lateral and main underdrains was discussed. The components should be so sized that the maximum head loss in the underdrainage system is less than 25% of the head loss in the sand which will ensure uniform filtration rate over the entire filter area (See Seelye, E.E., Data Book for Civil Engineering Design, P 6-33, McGraw Hill & Co., 1958).

Head loss in 1m of filter sand of different e.s. at a filtration rate of 0.1m/h and temperature of 50 degrees F will be as follows:

ES (mm)	Head loss (m)
0.20	0.085
0.25	0.051
0.30	0.034

At filtration rates other than 0.1m/h, head loss given above should be multiplied by the factor: proposed filtration rate divided by 0.1. At temperature other than 50 degrees F, head loss at 50 degrees F is to be multiplied by 60/(F+10).

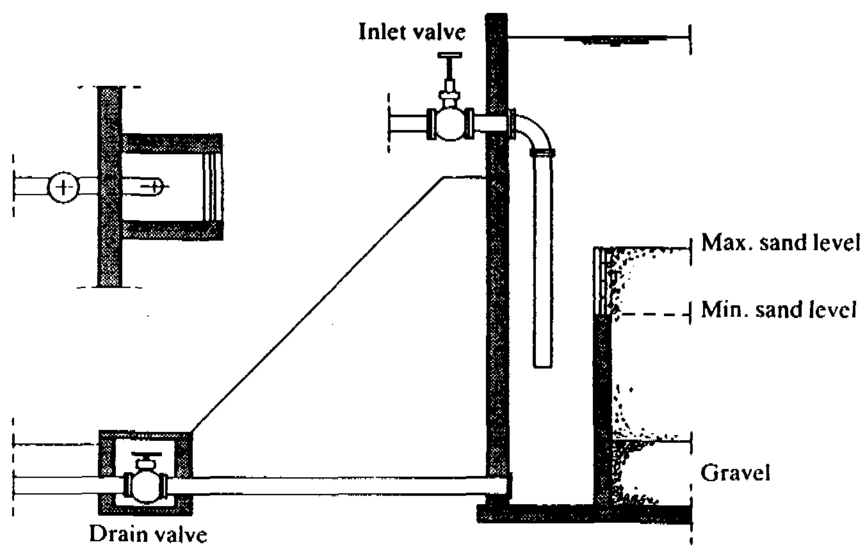
Head loss in sand should be calculated for the condition when sand depth is at its lowest i.e. just before resanding. Head loss in gravel may be neglected. Losses in drainage system should include velocity head.

3.4.11 In four of the designs reviewed ventilating shafts have been provided, embedded in the filter walls and connected to the lateral underdrains. Ventilating shafts cannot prevent air binding in the sand when filters are charged from the top (which should not be done anyway) and when filters are charged from the bottom upwards there will be no air-binding. Ventilating shafts are therefore not required, and may in fact be harmful,permitting entry of dust and insects.

3.4.12 In four of the designs reviewed, the inlet arrangements were found likely to cause scouring of sand with consequent short-circuiting of raw water and deterioration in filtered water quality. Experience with inlets of the type reviewed has been that scouring may expose even the gravel layers, especially when back-filling is not practised before top-filling. It was felt by the participants that the need cannot be over-emphasized for designing inlet structures to avoid scouring of sand and disturbance of the schmutzdecke.

Three of the designs did not provide for fast drainage of the supernatant water. In another design, the supernatant scour-out provided was not adjustable to suit the fall in sand level with repeated scrapings. Draining the supernatant water through the sand is a slow process and will prolong the down-time of the filters during periodical cleaning. Therefore, it is important to provide an adjustable supernatant scour-out in each filter bed which may conveniently be incorporated in the inlet structure itself. A possible design which does effectively prevent scouring, and can be adjusted to the sand level, is shown in Figure 3 and allows for rapid drainage of the supernatant water level.

Figure 3: Inlet Structure



3.4.13 In none of the designs reviewed has any interconnection been provided between adjacent filters to enable back-filling after cleaning/resanding which is an important requirement for preventing air-binding of the sand and also scouring of the sand when raw water is let in. No provision is also made for filtering the water to waste during ripening period. In one case the V-notch provided was found to be insufficient for the discharge involved. In some other cases, V-notches were found to be liable to submergence. While designing outlet structures it should be ensured that weirs are of adequate size and provide free fall. The outlet structures should have flow indicating devices (float operated) and air vents. It may be desirable to have a head loss indicator also in the outlet structure.

3.4.14 It was observed in some of the designs that excessive freeboard had been provided which could be reduced to 0.20m. However, the top of the filter walls should be at least 0.5m above surrounding formation level to prevent entry of surface water and to avoid accidents.

3.4.15 In some of the designs, wet pit installation has been indicated for some of the filter valves. The participants felt that such installation will lead to problems when the gland packings have to be replaced and other repairs have to be attended to. It is essential that the main outlet valve of each filter bed and the valves on branches from the outlet pipe preceding the main outlet valve (e.g. drain-out valve and interconnecting valve) are installed in dry pits as otherwise the filter would have to be drained down completely for their repairs/maintenance. Preferably, other valves also should be installed in dry pits.

Valves which require frequent operation, e.g., the main outlet valve, should be provided with extension spindles and capstan heads for convenient operation even when they are installed in dry pits. Similar provision should also be made for valves installed in wet pits even if they require only infrequent operation. Valves in dry pits requiring infrequent operation may be provided with handwheels to be operated after entry into the pit.

3.5 A model design with drawings for a rectangular filter plant incorporating the various suggestions made during the workshop is presented in Appendix VI.

3.6 The question whether filter beds should be resanded immediately after each cleaning or whether resanding should be done only after several scrapings was discussed in the workshop. The former method will no doubt require 20-25cm less of sand and also lesser depth of filter box to an equal extent. However, it has the serious disadvantage that only the top 0.05m of filter media gets cleaned each time and the sand below this layer remains in place indefinitely causing persistent and cumulative fouling. Hence, the second alternative should be adopted.

APPENDICES

I List of Participants
II Programme of Workshop
III Composition of Review Group
IV Throwing over Method of Re-sanding
V Case studies
VI Model Design for a small Rectangular SSF Plant

I LIST OF PARTICIPANTS

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ROHTAK (Haryana)

II WORKSHOP PROGRAMME

19th January 1987

09.00 hrs	:	Registration
09.30 hrs	:	Inauguration
10.30 hrs	:	Basics of SSF Process - R. Paramasivam
11.10 hrs	:	Functions & Design of different SSF Components - A. Raman
11.50 hrs	:	Recent Developments & Experiences in other countries - J.T. Visscher
13.30 hrs	:	Introduction to Field Visits - J.C. Yadav
Afternoon	:	Field Visit to SSF Plants

20th January 1987

09.30 hrs	:	Formation of Working Groups
09.45 hrs	:	Presentation of SSF Designs for Review
11.15 hrs	:	Review of SSF Designs
14.00 hrs	:	Review of SSF Designs (contd.)
15.30 hrs	:	Consolidation of Working Group Findings

21st January 1987

09.30 hrs	:	Presentation of Group Findings and Discussions
11.15 hrs	:	Discussions (contd.)
14.00 hrs	:	Plenary Discussions & Conclusion

III COMPOSITION OF REVIEW GROUPS

I	II	III
1. Mr. Anil Kumar Kerala Water Authority Trivandrum	1. Mr. R.A. Altekar MERI Nashik (Maharashtra)	1. Mr. A. Binod Kumar PHED, Manipur Imphal.
2. Mr.S.S.N. Murthy PR, NRKP Machilipatnam (AP)	2. Mr. Lalit Kumar PHED Haryana	2. Dr. Luong UNICEF New Delhi
3. Mr. S.R. Sarkar Royal Danish Embassy New Delhi	3. Mr. I.Prabhakar R. Panchayat Raj Hyderabad (AP)	3. Mr.G.Rama Naidu Panchayat Raj Hyderabad (AP)
4. Mr. G.R. Sharma Govt. of Sikkim Gangtok	4. Mr. C. Ramanna PHE Circle Belgaum (Karnataka)	4. Mr. A.V.M. Rao PHED, Guna (MP)
5. Mr. Gouro Singh PHED, Manipur Imphal.	5. Mr.Th.Kumar Singh PHED, Manipur Imphal.	5. Mrs. Sudha Devi Kerala Water Authority Trivandrum.

Secretariat

1. Miss. N.S. Joshi
2. Mr. V.A. Mhaisalkar
3. Mr. R. Paramasivam
4. Mr. A. Raman
5. Mr. J.T. Visscher

IV THROWING OVER METHOD OF RESANDING

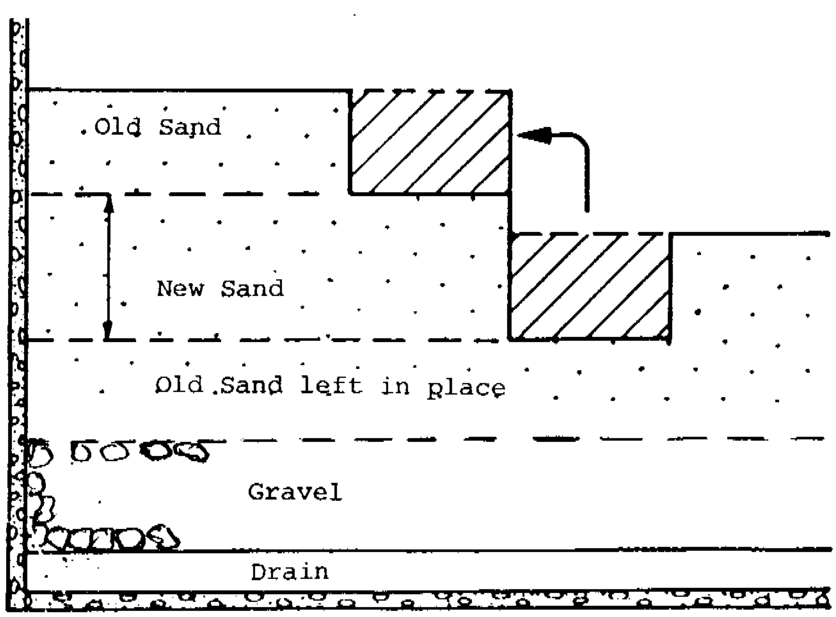
When, after repeated scrapings, the sand depth in a filter bed has fallen to its minimum design level (0.5 - 0.6 m above gravel) resanding has to be done and the sand depth restored to its design level (0.8 - 1.0 m).

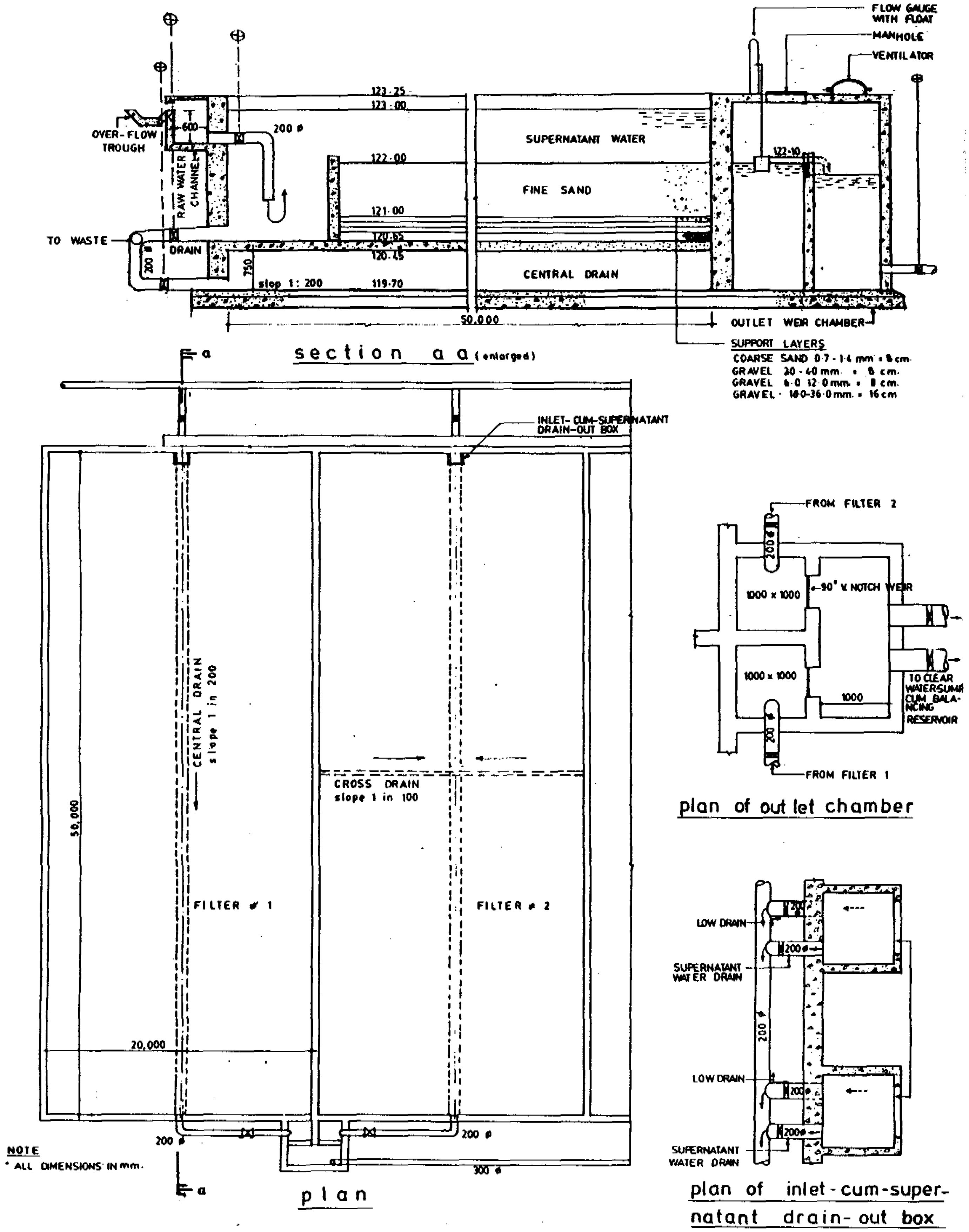
If, in resanding, new sand is placed directly over the old sand left in the bed there would be cumulative fouling of the latter as some of the raw water impurities and products of biological growth do penetrate to these layers also. Cumulative fouling is indicted by progressive increase in initial head loss (head loss imediately after filter scraping) and will lead to shorter and shorter filter runs.

Cumulative fouling can be avoided by adopting the "throwing over": process of resanding. In this process, the bottom layer of sand is moved to one side, new sand is placed to make up the level and the old sand is then put back on top of the new sand. "Throwing over" ensures that the bottom sand layer is also subjected to scraping in due course. It also ensures the presence of biologically active sand at the top after resanding which will help in quick re-ripening of the filter.

"Throwing over" is carried out in strips. Excavation is carried out on each strip in turn, making sure that it is not dug as to disturb the gravel layers below. The removed material from first strip is stacked to one side in a long ridge; the excavated trench is filled with new sand and the adjacent strip is excavated, throwing the removed material from the second trench to cover the new sand in the first. When the whole of the bed has been resanded, the material in the ridge from the first trench is used to cover the new sand in the last strip.

Fig. 1 Throwing-over Method of Resanding
(Ref. 'Slow Sand Filtration by Huisman & Wood, WHO Geneva, 1974).





Case study A: Large SSF plant in reinforced concrete (8909 m^3/d)

V CASE STUDIES

V.A. Case Study A - LARGE SSF PLANT IN REINFORCED CONCRETE

This is a case of a large SSF Plant serving a group of villages and having rectangular filter beds.

A.1 Design of Plant

The following design has been adopted for the plant.

Design period	: 15 years
Design population	: 178,183
Design daily demand	: 178,183 x 0.05 = 8909 m^3
Period of pumping	: 16 hours per day.

Note: A 16 hour period of operation of raw water pumps has been adopted which brings down the staff needs to 2 shifts. The filters operate for remaining part of the day under declining rate.

Raw water source is a storage tank which draws water from an irrigation canal.

Design filtration rate : 0.1 m/hr

Filter area required : $\frac{8909}{(0.1 \times 16) + 0.5} = 4242\ m^2$

Note: During 8 consecutive hours of declining rate filtration, the output is assumed as 0.5 m^3/m^2.

Adopted size of each filter unit is 50m x 20m. Six filters have been suggested with a total area of 6000 m^2.

Design of filter box:

Free board	0.20 m
Depth of supernatant water	1.00 m
Depth of sand	1.00 m, e.s. : 0.2 to 0.3 U.C. : 2 to 3
Depth of Gravel bed	0.40 m Top layers: 8 cm thick coarse sand (0.7 to 1.4 mm size). 2nd layer: 8 cm thick fine gravel (2 to 4 mm size). 3rd layer: 8 cm thick gravel (6 to 12 mm size). Bottom layer: 16 cm thick gravel (18 to 36 mm size).

Laterals:
40 laterals each of 10 m length and 80 mm (internal diameter) (slope 1 in 100) have been planned thus bringing the area served by each lateral to 25 m^2. Permeable capsules are inserted in laterals on every 60 cm.

Manifold:
A manifold of 1 m x 0.75 m (slope 1 in 200) has been proposed, the cross sectional area required being:

$$\frac{\text{filter area}}{1500} = \frac{1000}{1500} = 0.667 \text{ m}^2.$$

A.2 Review of design

A.2.1 The turbidity of raw water is likely to be low because of long term storage thus it may be possible to increase the filtration rate (say to 0.15 $m^3/m^2/h$) provided there is no danger of excessive algae growth in the storage tank.

A.2.2 While working out filter area, it has been assumed that during the entire 16 h of pumping, the filter will give a constant rate output of 0.1 $m^3/m^2/h$. However, at the commencement of pumping, the water level in the filter will be below MWL and it may take some hours before water level reaches MWL and filtration rate reaches 0.1 $m^3/m^2/h$. Further, it is not certain how much water the filter will deliver during the 8 h declining period as the yield will depend on the state of clogging of the sand. Hence, it will be difficult to calculate the filter area requirements precisely. Declining rate filtration may also necessitate regulation of the pumping rate once the filter MWL is reached to avoid overflow and wastage of raw water.

In view of the design uncertainty involved and careful operational attention required for declining rate filtration, it may be better that the plant is designed for 24 h operation, providing three shifts of raw water pumping. This will reduce area requirements to 3712 m^2 effecting considerable savings.

A.2.3 There is no need to provide 25% standby area for the filters.

A.2.4 A bed of 50m x 20 m (1000 m^2) area as proposed is too big for quick cleaning. Adopting 24 hr operation and 0.1 m/h filter rate a total area of 3712 m^2 would be required which can best be divided over $0.5\sqrt[3]{3712} = 8$ units. The area of each bed will then be 470 m^2, which may be permitted as the plant is large and there should be no difficulty in employing extra labour during cleaning.

A.2.5 Sand media: If sand is relatively fine (e.s.: 0.20 to 0.25 mm) the initial sand depth may be reduced to 0.8 m. If sand is relatively coarse (e.s.: 0.25 - 0.30 mm) depth may be fixed at 0.9 m.

A.2.6 Gravel media: Since permeable capsules are proposed, the last layer of gravel can be dispensed with. Choice between gravel and broken stone may be based on relative costs.

A.2.7 Depth of filter box may be reduced to 0.20 m free board + 1.00 m supernatant water + 0.80 m sand + 0.24 m gravel or 2.25 m total in case pipe laterals with permeable capsules are used.

A.2.8 Laterals and Manifold:
Assume sand has e.s. of 0.2 mm, sand depth just before resanding is 0.5 m and temperature is 90° F. Head loss in sand is then
$0.5 \times \frac{60}{100} \times 0.085 = 2600 \times 10^{-5}$m (see 1.3.10 and 3.4.10).

Laterals will have discharge at end = 2.5 m^3/h and velocity = 0.138 m/s. Head loss in laterals (10 m length) = 97 x 20^{-5}m velocity head + 133 x 10^{-5} frictional loss (allowing for increasing flow along length) = 230 x 10^{-5}m.

Manifold is 50 m long with discharge at end = 100 m^3/h, velocity = 0.037 m/s. Head loss in manifold = 7 x 10^{-5} velocity head + 14 x 10^{-5}m frictional loss (allowing for increasing flow along length) = 21 x 10^{-5}m.

Total head loss in laterals and manifold = 251 x 10^{-5}m. This is less than 10% of the head loss in sand indicating oversize. The size of the manifold may be reduced. Try 0.5 m x 0.5 m size, V = 0.111 m/s. Head loss in reduced size = 63 x 10^{-5}m velocity head + 212 x 10^{-5}m frictional loss. Total loss in laterals + manifold = 505 x 10^{-5}m. This is less than 25% of head loss in sand and therefore permissible. During cleaning of one unit rate in the others will only slightly increase due to large number of units, thus indeed the smaller size could be adopted.

A.3 Review of drawings:

A.3.1 Plan: The slope shown for main drain is not towards the filter drain-out and will not therefore be useful. There is no interconnection between adjacent filters for back-filling. There is also no arrangement for filtering-to-waste.

A.3.2 Longitudial section: Instead of a common overflow connected to inlet channel, each filter bed should be provided its own overflow to help in removal of floating scum. The sill of the filter outlet weir should be raised to 0.03 m above top of sand. The level of the draw-off piping from the filter outletbox to clear water tank may be raised which will reduce depth of excavation for the piping.

A.3.3 Sectional plan of outlet chamber: Connecting pipe with valve may be provided in the dividing wall between the 2 upstream compartments to permit "back-filling". A 90° V-notch with 0.10 m head as proposed will be inadequate to discharge the likely peak output of a filter bed, viz, 150 m^3/h. The weir should be changed from V-notch to trapezoidal type.

The downstream side of the outlet box should be divided into two compartments and each compartment should be provided with a drain pipe to permit "filtering-to-waste". Only one outlet to clear water sump is necessary as shown in main plan.

A.4 Possible improvement in case plant is already constructed:

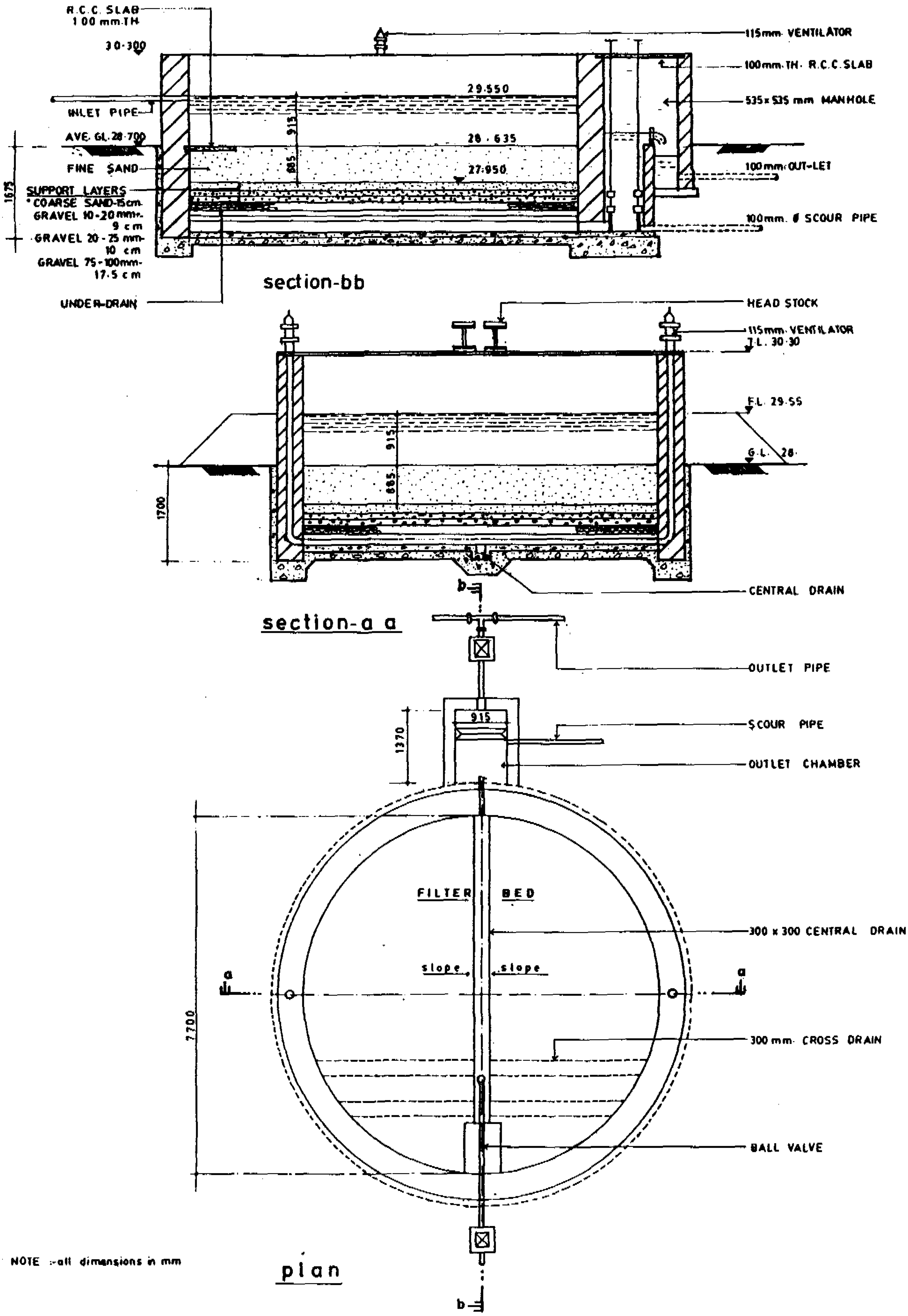
A.4.1 Overflows may be provided for each filter bed.

A.4.2 Top of sand (max) may be lowered to a level 3-5 cm below sill of outlet weir.

A.4.3 Valved interconnection may be provided between upstream compartments of outlet chambers.

A.4.4 Downstream side of each outlet chamber may be subdivided into two and each compartment provided with a drain-out and a draw off.

A.4.5 V-notches in outlet chambers may be replaced by trapezoidal weirs.



Case study B: Circular SSF plant (224 m^3/d)

V.B. Case Study B - CIRCULAR SSF PLANT

This is a case of a small filter plant having 2 circular filters each of 7.7 m dia.

B.1 Design of plant

The following design criteria have been followed for the plant:

Rate of filtration	:	0.1 m/h
Period of design	:	15 years
Minimum number of filter beds	:	2
Maximum area of one bed	:	250 - 400 m^2
Filter media	:	Sand 84 cm, bazri (grit) 18 cm,gravel 18 cm.
Sand specification	:	e.s. 0.2 to 0.3 mm; UC 2-3
Supernatant water	:	0.9 m.

B.2 Review of design

B.2.1 The filtration rate should be fixed taking into account the raw water quality. If quality permits, filtration rate may be fixed as 0.15 m/h and filter area reduced. At 0.1 m/h, the plant output would be 224 m^3/d assuming constant rate, 24-hours operation.

B.2.2 If raw water has to be pumped, the pumping may have to be restricted to two shifts because of the small size of plant.

In such case, high level storage should be provided to enable 24-hours operation of filters. Float valves which are required with high level storage have already been provided (see drawings).

B.2.3 The sand depth of 84 cm is to consist of fine sand (e.s.: 0.2-0.3) for 0.685 m depth and coarse sand for 0.155 m depth vide drawings. The sand media should be one uniform layer of 0.8 m depth if sand has e.s. of 0.2 mm and 0.9 m depth if sand has e.s. of 0.3 mm.

B.2.4 The gravel media is 10-20 mm size 9 cm thick, 20-25 mm size 10 cm thick and 75-100 mm size 17.5 cm thick vide drawings. The grading is not satisfactory and may be chnaged to standard specifications (see 1:3:10) so as to support filter sand properly.

If cheaper, broken stone may be used in place of gravel. If broken stone is to be used, size specifications may be somewhat relaxed to permit use of commercial sizes which will avoid cost of special sieving. For example, use 20-40 mm commercial size for lowest layer instead of 18-33 mm size.

B.2.5 For sand media, local sources should be investigated.

B.2.6 Supernatant water depth may be increased to 1.0 m.

B.3 Review of drawings

B.3.1 Plan: The inlet arrangements are unsatisfactory. A standard inlet chamber may be provided, incorporating supernatant scour which has not been provided now. Also an overflow should be provided in the filter box. The outlet chamber should, in addition to the scour provided, incorporate the following:

- an interconnection with the adjacent filter for backfilling, which should be made before the regulating valve;
- a drain-out after the weir (for filtering to waste).

B.3.2 Section aa: The ventilating pipe embedded in the filter walls should be deleted. Provision should be made for preventing short-circuiting along filter walls by providing a cut-off skirt or by roughening the inside finish of the walls. The free-board provided (0.75 m) is excessive.

B.3.3 Section bb: It may be cheaper to provide loose-jointed bricks over the lateral drains than RCC slabs which may be required only over main drain. The outlet structure should incorporate the folowing changes in addition to those mentioned under 'plan':

- a screened ventilator opening
- a flow indicating device.

The construction specifications for the filters should follow relevant Indian Standards for water retainng structures.

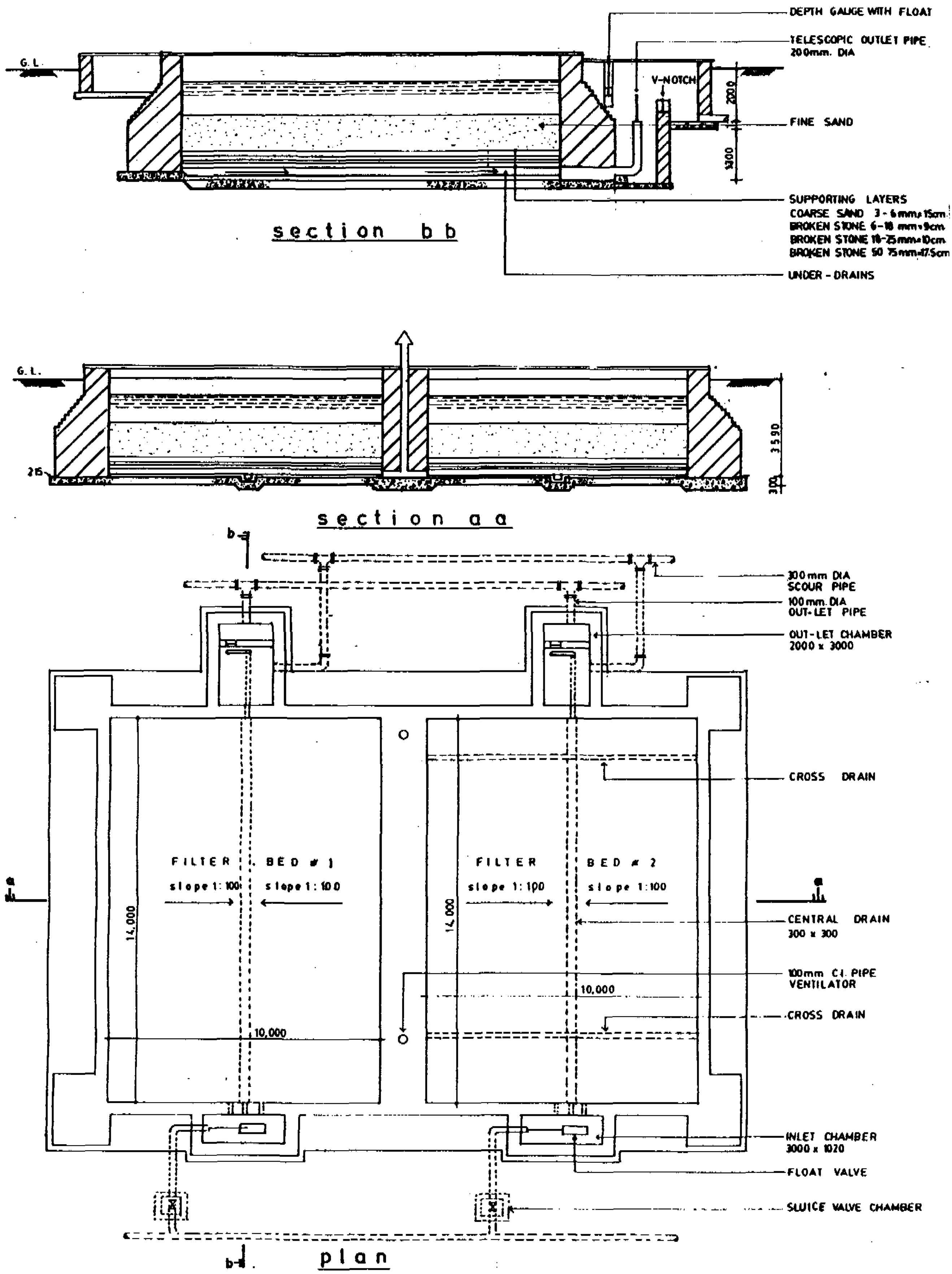
B.4 Suggested improvements if plant is already constructed

B.4.1 High level storage for raw water to be provided to ensure 24 h operation of filters. Overflow to be provided. Inlet structure to be changed to standard type.

B.4.2 Ventilating shafts in filter walls to be sealed to prevent ingress of dust and insects. Inside walls to be roughened from top of sand upto top of gravel, when re-sanding is taken up.

B.4.3 Fine sand depth to be increased to 0.8 m and supernatant water depth to 1.0 m making use of excess free board now provided.

B.4.4 Outlet to be modified providing air vent, flow indicator, interconnecting pipe and "filter-to-waste" drain. V-notch sill to be raised to suit raised sand level.



Case study C: Medium size rectangular SSF plant (763 m^3/d)

V.C Case Study C - MEDIUM SIZE RECTANGULAR SSF PLANT

This is a case of medium size plant having rectangular filter beds.

C.1 Design of plant

The following design details have been furnished for the plant:

Daily demand	:	763 m^3
Design rate of filtration	:	0.11 m/hour
Area of filter required	:	280 m^2
No. of filter beds provided	:	2
Size of each filter bed	:	14 m x 10 m

C.2 Review of design

C.2.1 The prefered no. of filter beds should be $0.5\sqrt[3]{280}$ or 3. Area of each bed will be 93 m^2.

C.2.2 The economical l-b dimensions for 3 beds will be l = 12 m and b = 8 m (see 1.3.7).

C.2.3 It is presumed that flow of water to the filters is by gravity and there will be no problem in running the filter for 24 hours continuously.

C.3 Review of drawings

C.3.1 Plan: For the area of 93 m^2 per bed now suggested, circular filters might have been cheaper, especially since filters are proposed below ground. The inlet chamber is not satisfactory. It should be modified as per standard design (see Annex 6) to avoid scour of sand. There should be provision for draining out supernatant water. The filter boxes should be provided with overflows. The ventilator pipes shown in side walls should be avoided. The adequacy of size of cross and main drains should be checked up. In the outlet structure, no provision is made for filtering-to-waste after V-notch. No valves are also indicated. No provision is made for back-filling.

C.3.2 Section aa: The filter is shown below GL. It is presumed that topography prevents raising the filter so that MWL may be at GL which will avoid need for excessive free board. The supernatant water depth as scaled out is 1.4 m. This could be reduced to 1,0 m. The upper limit of e.s. for filter sand should be reduced to 0.35 mm. If e.s. is about 0.35 mm sand bed thickness should be 0.9 m. If nearer to 0.2 mm, the thickness provided is sufficient. The supporting gravel media may be revised as per recommended standards (see 1.3.10).

C.3.3 Section bb: The cross drain size (25 mm) appears to be too small. The main drain size has not been furnished. The sizes should satisfy the criterion that head loss in underdrainage be less than 25% of head loss in sand. The outlet is of the telescopic type. With this arrangement, it will be possible to adjust the filtration rate more precisely than with gate valves. However, the telescopic pipe should be on a tee. The tee end should be provided with sluice valve for purposes of draining the filter and back filling. The filtered water draw-off should be kept sufficiently below the sill of the V-notch to ensure free fall. The outlet box should be vented to the atmosphere.

C.4 Improvements possible in case plant is already constructed

C.4.1 A new inlet chamber may be provided inside the filter box as it will prevent sand scour. It will have to be explored whether a hose-type of supernatant scour-out can be constructed in the inlet chamber at this stage.

C.4.2 The filter box may be provided with overflow for removal of scum.

C.4.3 The inside faces of the filter walls may be roughened up when the filter bed is taken up for resanding.

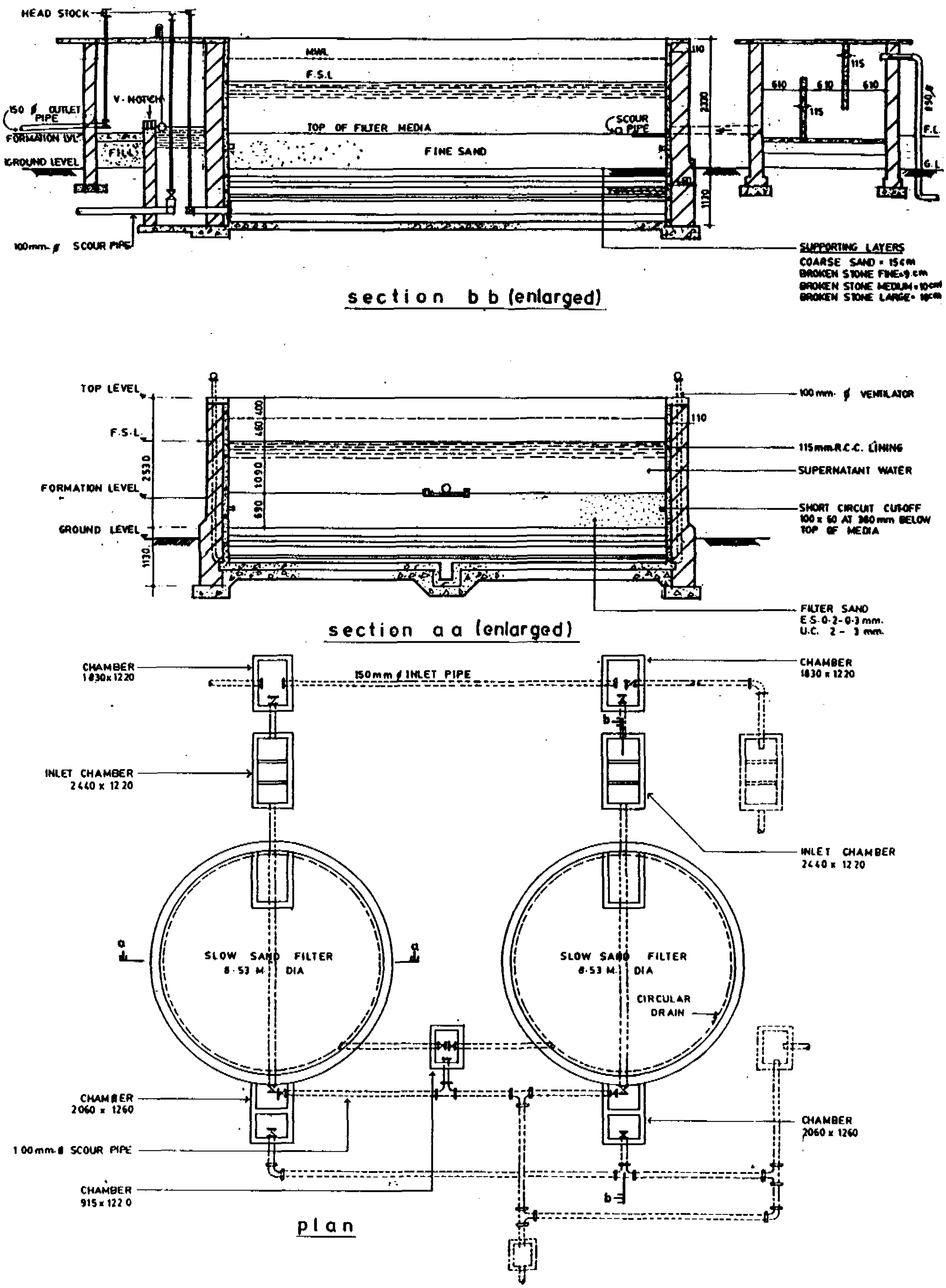
C.4.4 The ventilating shafts provided should be plugged.

C.4.5 Interconnecting pipe may be provided between outlet chambers of adjacent filters at lowest possible level to enable back-filling.

C.4.6 A drain-out may be provided after the V-notch in the outlet structure for "filtering-to-waste".

C.4.7 The downstream side of the V-notch chamber may be reconstructed with lowered level to avoid drowning of the V-notch provided the clear water reservoir level permits.

C.4.8 The outlet chamber may be provided with an air vent.



Case study D: Circular SSF plant (224 m^3/d)

V.D. Case Study D - CIRCULAR SSF PLANT

This is a case of a small plant serving two villages and having two circular filter beds of 8.53 m dia with provision for adding another filter later.

D.1 Design of plant

The following design has been furnished for the plant:

Design period	:	15 years
Design population	:	5534
Per capita supply	:	45 litres/day
Daily demand	:	249 m^3
Source of water	:	Irrigation canal with storage tank of 27 days' capacity to take care of closure period of canal
Storage tank size	:	48m x 38m x 1.67m, 2 nos.
Design rate of filtration	:	0.1 m/hr.
Period of operation	:	24 hours
Area required	:	249 : (24 x 0.1) = 104 m^2
Add about 25% extra. Total	=	130 m^2
Provide 3 nos. circular filter beds of area	=	$\frac{130}{3} = 43.3\ m^2$

Required diameter of each filter is 7.6 m.
An additional height of 0.46 metre has been provided to eliminate need for high level tank.

D.2 Review and design

D.2.1 Though mode of operation is stated as 24-h constant rate, there is some doubt whether raw water pumping will be for all 24 hours or for shorter period as there is a mention that 0.46 m extra depth is provided in place of high level storage. Anyway, for a small plant of the size involved here, 24-h pumping may not be worthwhile and 16-h pumping may be better. With discontinuous pumping (16-h), extra depth as proposed will not enable continuous operation of filters (at constant rate) and a separate high level storage tank (8-h capacity) becomes essential. The high level storage tank should have its LWL more or less at GL and, for this, the filters which are now located with FSL 2.3 m above ground level will have to be lowered. The supply from the high level tank should be taken to the different filters through a common constant head chamber equipped with float valve.

D.2.2 If substantial improvement is expected in raw water turbidity and bacteriological quality in the 27-days storage tank, a higher rate of filtration (upto 0.15 $m^3/h/m^2$) could be adopted. However, the possibility of algae growth in the storage tank should also be considered.

D.2.3 Some additional area is provided probably to cater for declining rate filtration. Again it should be stressed that provision of stand-by capacity is not required and should be discouraged.

D.3 Review of drawings

D.3.1 Plan: For the filter beds, separate raw water receiving chambers are shown for each filter box, presumably to break the pumping. These chambers can be avoided and raw water can be let directly into the filters if proper inlet structures are provided in the filter beds.

The inlet arrangements inside the filter are not shown in detail. The inlet may be of standard design (see Appendix 6) to avoid scour of sand. The supernatant scour-out is not satisfactory as it is at a fixed level and not ajustable with the sand level which will fall with repeated scrapings. An adjustable scour-out may be incorporated in the inlet structure. An overflow should be provided in the filter wall to enable scum removal and prevent flooding.

In the outlet structure, no interconnecting pipe is shown for "back-filling" of filter. No drain out is also provided after the V-notch for "filtering-to-waste". A standard outlet structure may be provided (see Appendix 6). The crossconnection shown between the filter outlet header and the filter drainout-cum-supernatant scour-out header should be avoided.

D.3.2 Section aa & bb: The free-board can be reduced from 0.40 m to 0.20 m. Instead of providing the 0.46 m extra depth, higher level raw water storage in a separate tank might be more economical.

Depth of the fine sand should be increased from 0.69 m to 0.9 m if e.s. is about 0.30 mm and to 0.8 m if e.s. is about 0.20 mm.

The supporting media may be of standard specifications (see 1.3.10). The total thickness of supporting media can be reduced to 31 cm.

With various changes as now suggested total depth of filter box could be reduced from 3.285 m to 2.575 m.

The outlet weir may not be able to provide free fall as down-stream floor level and final outlet pipe are fixed too high.

The ventilating shafts shown in the filter walls are not required and may lead to contamination of treated water.

Construction details should follow Indian Standard specifications for water retaining structures.

The skirt slab provided in the filter wall for preventing short-circuit will be difficult to construct. Instead, the finish of the wall (inside) may be kept rough.

D.4. Improvements possible in case plant is already constructed

D.4.1 In case only 16-h pumping is possible, the filter outlet should be left open at end of pumping and filtration should be allowed to continue at declining rate. The filter output will be: pumping rate x 16 h provided no overflow occurs during pumping.

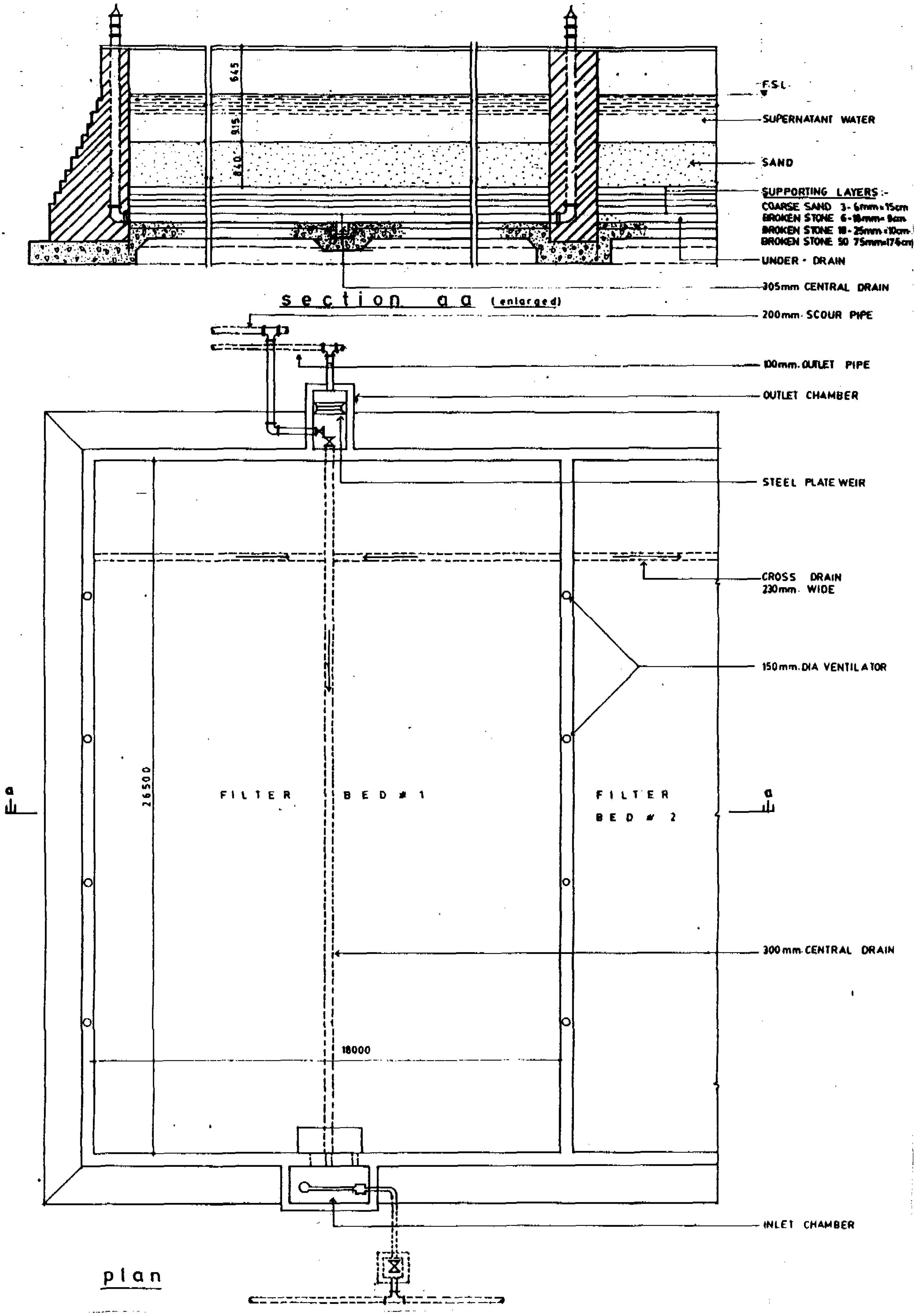
D.4.2 Proper inlet structures may be constructed in the filter beds. It may be difficult at this stage to incorporate supernatant drain-outs in them. Hence, adjustable lips need not be provided in the inlet structures.

D.4.3 The depth of fine sand may be increased to 0.8 m - 0.9 m depending on the e.s. of sand. The inlet structure should be designed to suit the new sand level. The present supernatant scour-out level should also be raised.

D.4.4 An overflow may be provided at 0.2 m depth below top of filter wall. The filter will operate with supernatent water depth of 1.34 m which may help to increase filter run to some extent.

D.4.5 In the outlet chamber, the weir sill may be raised to suit new sand level. This will incidentally help to have freefall over the weir. Filter drain out may be used also as interconnection for back-filling by providing a valve on the common pipeline to drainage. The connection from supernatant scour-pipe to filter drain pipe should be removed and separate drainage should be provided for the former. Drain-out with valve should be provided downstream of weir to enable filtering to waste.

D.4.6 The ventilating shafts should be closed.



Case study E: Medium size rectangular SSF plant

V.E. Case Study E - MEDIUM SIZE RECTANGULAR SSF PLANT

This is a case of a medium size plant having rectangular filter beds.

E.1 Design criteria

E.1.1 The general design criteria for the plant have been reported as follows:

Rate of filtration	:	0.1 m/h
Period of design	:	15 years
Minimum no. of beds	:	2
Maximum area of bed	:	250 - 400 m^2
Filter bed	:	Fine sand 68.5 cm thick (e.s.: 0.20 - 0.30 mm, uc= <3.0). Coarse sand: 15.5 cm thick. Total 84 cm thick.
Support media	:	Bazri (grit) 18 cm, gravel 18 cm.
Supernatant water	:	0.90 m

E.1.2 The filter size as per plan is 26.5 m x 18.0 m. In the absence of any data, it may be assumed for purposes of review that there would be 2 beds with total area of 954 m^2. Total plant output will be 2300 m^3/d assuming 24-hours constant rate operation.

E.2 Review of design

E.2.1 The area of 477 m^2 for a bed is excessive. Area should be restricted to 200 m^2. For a total area of 954 m^2 two beds are inadeqaute. The no. may be increased to $0.5\sqrt[3]{A}$ or 5. Each filter bed will be of 191 m^2 area.

E.2.2 With five beds, the economical dimensions for each bed will be 17.8 m x 10.7 m (see 2.3.7).

E.2.3 Fine sand depth should be increased from 0.685 m to 0.8 m-0.9 m depending on sand size.

E.2.4 The supporting gravel media should be of standard sizes and standard thickness (see 1.3.10).

E.2.5 Supernatant water depth should preferably be 1.0 m.

E.3 Review of drawings

E.3.1 Plan: The drawings received indicate filter sizes approximating to the suggestions made in the review, viz, 17.8 m x 10.7 m and not 26.5 m x 18.0 m as per design. The float valve in the inlet chamber may be essential only if there is a high level storage tank. No provision is made for supernatant scour-out. The inlet platform inside the filter box can not prevent scour of sand. There is no overflow arrangement for scum removal. The ventilators shown in the side walls should be avoided. In the outlet structure, there is no interconnection with adjacent filters for "back-filling". There is no provision of drainout after V-notch for "filtering-to-waste". The outlet chamber should have filtration rate indicator and should be vented.

E.3.2 Section aa: The adequacy of the sizes provided for the lateral and central drains should be checked to ensure that head loss in underdrainage (excluding gravel) is less than 25% of that in sand when it is at minimum depth.

The filter media should be as suggested in para 2.3 and 2.4. The supernatant water depth should be as suggested in 2.5. The free board may be reduced to 0.20 m subject to the condition that top of wall is 0.5 m above formation level.

E.3.3 Construction specifications: The inside walls of the filter should be rendered rough to prevent short circuiting.

E.4 Improvements possible in case plant is already constructed

E.4.1 The thickness of fine sand may be increased to 0.8 - 0.9 m. The supernatant water depth may be increased to 1.0 m. However, the wall thickness should first be checked for structural safety against the increased depth of water.

E.4.2 A new inlet chamber which will prevent sand scour should be provided inside the filter. A supernatant scour-out of a hose pipe design may be possible to facilitate operation and maintenance.

E.4.3 An overflow may be provided in the filter box.

E.4.4 The ventilating shafts should be plugged.

E.4.5 Interconnecting pipe may be provided between outlet chambers of adjacent filters at lowest possible level.

E.4.6 A drain-out may be provided after the V-notch for filtering-to-waste.

E.4.7 If the filter walls are smooth plastered, they should be roughened up when resanding is taken up next.

E.4.8 The outlet chamber may be provided with a flow rate indicator and air vent.

VI MODEL DESIGN FOR A SMALL RECTANGULAR SSF PLANT

The SSF Plant is to serve a village with an anticipated population of 3000 after 15 years and 4500 after 30 years. Rate of water supply will be 45 lpcd. The raw water will be gravitated from a hill stream. The turbidity is in the range 5-30 NTU. The subsoil is hard rock below 1.2 m. depth.

1. Design Criteria

1.1 As turbidity will often exceed 5 NTU, design filtration rate is restricted to 0.1 m/h.

1.2 Adopt 24-h, constant rate operation. As filters are to be fed by gravity, there is no need for high level storage tank. Filter output rate will be 2.4 m^3/day/m^2 filter area.

2. Design of Plant

2.1 Initial water demand = 135,000 lpd
Ultimate demand = 202,500 lpd
Filter area, initial = 135/2.4 = 56 m^2
Filter area, final = 202.5/2.4 = 84 m^2
No. of filters required = $0.5\sqrt[3]{84}$ = 2.25 or say 3
Area of each bed = 28 m^2
Provide 2 beds in first instance and add third bed later on.

2.2 Filter box will be kept above GL for most of its height to avoid exacavation in hard rock. Rectangular beds (of RCC) will be adopted as circular shape may have no special advantage when construction is mostly above GL.

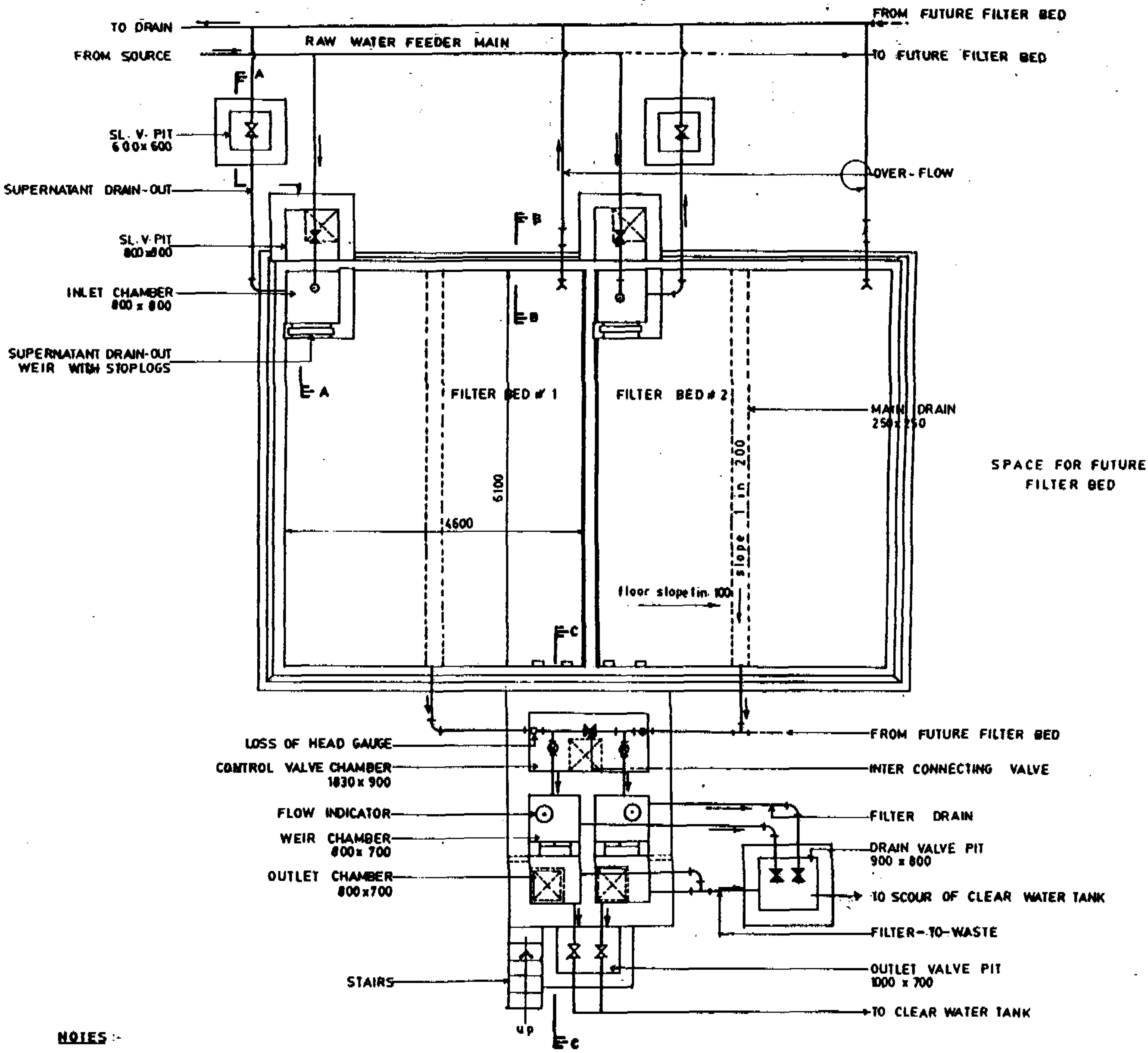
2.3 Only immediate requirements are considered for determining economical l and b values for filter beds.
Economical length of bed = $\sqrt{2 \times 56/(2+1)}$ = 6.1 m
Breadth will be = 56 : (2 x 6.1) = 4.6 m
Provide 2 filters of size 6.1 m x 4.6 m in first instance.

2.4 For future expansion add a third bed of same size for which space needs to be reserved.

2.5 Supernatant water depth will be 1.0 m. Filter sand will be of e.s. 0.25 mm and UC 3. Adopt 0.6 m minimum depth of sand in view of comparative coarseness of sand. Provide 0.4 m depth extra for periodical scraping. Total depth of sand will be 1.0 m.

2.6 Gravel media will be as indicated in 1.3.10. Total thickness: 31 cm.

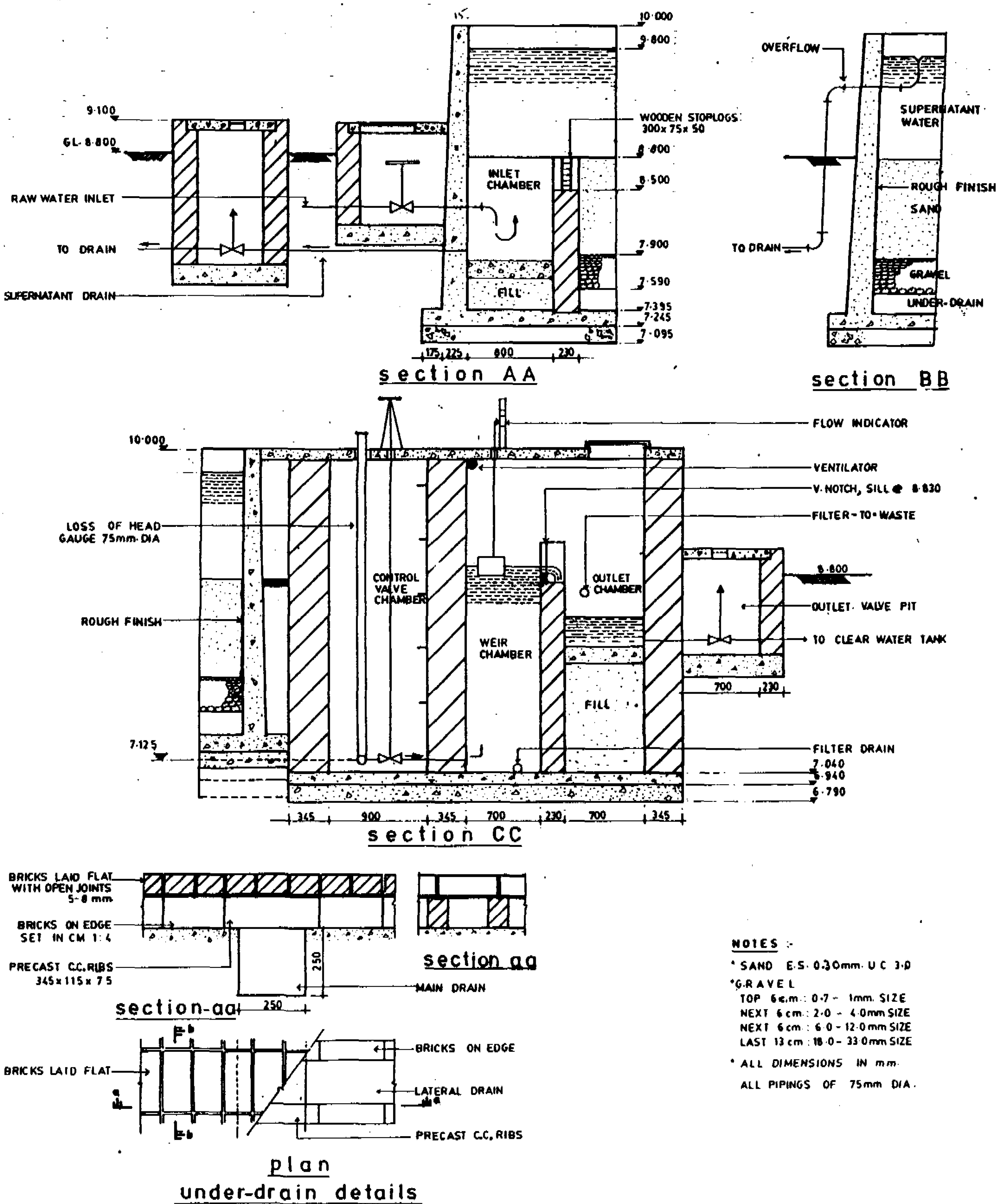
2.7 Rate of flow to plant (ultimate): 202,500/(24 x 60 x 60) = 2.35 lps.
Adopt 75 mm ID pipe with v = 0.53 m/s.
Peak flow to each filter = 2.35 x 2/3 = 1.57 lps.
Adopt 75 mm size itself with v = 0.35 m/s.
Adopt 75 mm size for all other pipings of plant.



NOTES :-

- ALL PIPINGS 75 mm DIA.
- ALL DIMENSIONS IN mm
- SLUICE VALVE WITH EXTENSION ROD AND KEY.
- SLUICE VALVE WITH HAND WHEEL.
- SLUICE VALVE WITH EXTENDED SPINDLE & CAPSTAN HEAD
- MANHOLE COVER 500 x 500
- MANHOLE COVER OVERLAPPING TYPE 500 x 500
- SECTIONAL DETAILS SHOWN IN FIG-2

Model design of outlet-controlled SSF; lay-out and piping



Model design details inlet and outlet boxes

2.8 Laterals will be formed of brick (size: 23 cm x 22.5 cm x 7.5 cm) laid on edge, set at bottom in cement mortar 1:4, covered with bricks laid flat with loose joint. Lateral waterway will be about 16 cm x 12 cm (depth assumed allows for bottom mortar joint thickness also).

Cross sectional area (A)	= 0.16 x 0.12 = 0.0192 m^2
Wetted perimeter (P)	= 2(0.16 + 0.12) = 0.56 m
Hydraulic dia	= 4A/P = 4 x 0.0192/0.56 = 0.14 m
Area served by lateral	= 2.3 x 0.235 = 0.54 m^2
Discharge at end of lateral	= 0.54 x 0.1 m^3/h or 1.5 x $10^{-5} m^3/s$
Velocity at end of lateral	= 7.8 x 10^{-4}m/s

Head loss in lateral = velocity head + frictional losses

= $v^2/2g$ + 1/3 (for linear increase of velocity) x f (friction factor in Colebrook formula say 0.04) x $v^2/2g$ (where g has a value of 9.81 m/s^2) x 1/hy.dia

= 0.03 x 10^{-6} + 0.002 x 10^{-6}m.

Manifold drain may be of size 25 cm x 25 cm in concrete.

Cross sectional area (A)	= 0.0625 m^2
Wetter perimeter (P)	= 0.25 x 4 m
Hydraulic dia	= 4A/P = 0.25 m
Discharge at end	= 28 x 0.1 = 2.8 m^3/h
Velocity at end	= 12.4 x 10^{-3} m/s
Head loss	= velocity head + frictional head = 7.8 x 10^{-6} + 0.4 x 10^{-6} m

Total head loss in laterals and manifold = 8.2 x 10^{-6} m say. This should be less than 25% of head loses in sand.
Head loss in 0.6 m of sand of e.s.: 0.27 mm at temperature of 90°F = 0.04 x 0.6 x (60/10+90) = 14.4 x 10^{-3}m see 3.4.10).
Thus head loss in laterals and main drain will be only a fraction of head loss in sand and uniformity of filtration over whole of filter bed is assured.

2.9 Side depth of filter box will be 0.2 m free board + 1.0 m supernatant water + 0.9 m sand + 0.31 m gravel + 0.075 m lateral drain cover + 0.12 m lateral drain depth = 2.65 m say.

2.10 Peak flow over outlet weir of each filter will be 5.6 m^3/h or 1.57 lps.
Head required over 90° V-notch = 6.5 cm. At normal flow (0.79 lps) head required = 4.8 cm.

Alternatively, for more sensitive measurement of head, adopt sharp-crested (cd=0.61) free fall orifice of dia 4 cm (area = 12.6 cm^2). Head required for peak discharge will be 21.6 cm. Head required for normal discharge will be 5.4 cm (head will be from centre of orifice to water surface).

3. Construction notes

3.1 Inlet chamber is proposed at one corner of filter bed to simplify lay-out of lateral drains. Proposed location will not affect functioning of filter.

3.2 Inside walls of filter box will be finished rough over height of sand bed.

3.3 Excavated earth will be banked around the filter box.

3.4 For reducing cost, only valves requiring daily operation and placed in deep pit viz. the filter outlet valves will be provided with extension spindles and capstan heads for operation. Other valves which require only periodical operation will be placed in dry valve pits and provided with hand wheels and operation will be by entering into the valve pit. Manhole covers should be large to enable easy entry and light to enable easy opening.

Outlet chamber may be kept independent of filter box to avoid clash of foundations.