FINAL REPORT

on

The development, evaluation and field trials of a small scale, multi-stage, modular filtration system for the treatment of rural water supplies

RURAL WATER TREATMENT PACKAGE PLANT
Research Project R3760

A collaborative project between

University of Surrey
CEPIS/PAHO/WHO
Ministry of Health, Peru

Submitted by :

Barry Lloyd, Mauricio Pardón, David Wheeler

DelAgua
c/o CEPIS/PAHO/WHO
Casilla Postal 4337
Lima 100
Peru

The Robens Institute
UNIVERSITY OF SURREY
Guildford
Surrey GU2 5XH
England

Sponsored by the Overseas Development Administration of the Government of the United Kingdom,
ODA, Eland House, Stag Place, London SW1

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BJL/MP/DW July 1986

SECTION I. INTRODUCTION, SUMMARY AND CONCLUSIONS

a INTRODUCTION

The principal objective of the project was to develop **small scale treatment technology for the provision of safe drinking water from contaminated, turbid surface water sources.**

The progress of the project has been described in five reports submitted to the Overseas Development Administration These reports were dated February 1983 (1), December 1983 (2), May 1984 (3), March 1985 (4) and July 1986 (11) See References page 41

The **first report** (1) described the **performance of prototype protected slow sand filter (PSSF) units.** Design criteria for populations of up to 1,000 persons based on a per capita consumption of 50 litres/day were evolved Techniques of sand washing, sand grading and cleaning of sub-sand prefilters were developed and evaluated The value of filter fabrics in PSSF was established.

The **second report** (2) included **specifications for packaged PSSF units** developed at the University of Surrey. The design and production of treatment tanks, flow control devices, abstraction and prefiltration packages, underdrainage and distribution networks were described. Reviews of comparable technologies were included, and detailed analysis of scientific data relating to operational efficiency was presented. The value of effective prefiltration, fabric protection and flow control was further demonstrated. But significant questions were raised concerning the application and efficiency of sub-sand abstraction as a pretreatment for PSSF. The potential of horizontal and vertical prefiltration using gravel was noted and therefore included in the final specifications for the field trials

The **third report** (3) was submitted from Peru. Details of field surveys to **identify target communities** were presented. These details were related to the existing problems of rural water supply and treatment in Peru and to the administrative structures within which the demonstration programme was to run. Six target communities were identified in the sierra and coastal regions The full proposal, including options, was provided for one community as a case study (San Vicente de Azpitia, Mala Valley) Briefer descriptions of site surveys, community details and plant designs were presented for San Buenaventura, Cullhuay, Carhua, Minay and Nuevo San José

The **fourth report** (4) was principally concerned with **gravel prefiltration**, because by this time the efficient operation of PSSF units had been substantially proven - both in the UK and Peru. Design criteria for vertical and horizontal gravel filtration based on research in the UK and in Peru were presented. The main criteria were the number of units in series, depth (or length) of filter medium, size of filter medium, and velocity. This report also contained the second Peruvian field report (December 1984) which provided details of **design and construction for the first 3-stage in-series vertical gravel prefilter to be built for use in conjunction with PSSF.**

The **fifth report** (11), which was funded under a separate ODA scheme, described a pilot rehabilitation project of a treatment system in the highlands of Peru. The main feature was the **construction of a 3-stage horizontal flow gravel prefilter** in advance of conventional slow sand filters. Complementary works involved the reconstruction of the raw water intake, the rehabilitation of the slow sand filters and the installation of terminal disinfection. Continuing work involves the rehabilitation of other systems, the evaluation of performance of the systems and the training of operators.

This **final report** summarises the main conclusions (Section I) and the research components of the study (Section II); the installations which were successfully undertaken in the coastal, sierra and selva (jungle) regions of Peru (Section III); and the evaluation of operational efficiency, costs and overall acceptability of the installations (Section IV).
The appendices represent draft manuals for the replication of the technologies developed under Research Scheme R3760. They are:

Appendix I Design and Selection Manual
II Installation Manual: PSSF
III Operation and Maintenance Manual: PSSF
IV Construction Guide: Gravel Prefilter
V Operation and Maintenance Manual: Gravel Prefilter

1b SUMMARY & CONCLUSIONS

1) Prefiltration with gravel in advance of protected slow sand filtration is essential for small treatment plants where source waters are subjected to high or fluctuating turbidity loadings. This combination of unit treatment processes is an excellent means of removing suspended solids and attenuating faecal indicator micro-organisms and viral agents of waterborne disease.

2) The hypothesis that two stages of sand filtration (by sub-sand abstraction and slow sand filtration) could provide a reliable supply of safe drinking water from contaminated surface sources was tested and shown to be invalid. It was demonstrated that sub-sand abstraction could not be adequately controlled and therefore vertical and horizontal triple stage gravel prefilters were designed, evaluated and substituted as the first stage of treatment. Thus the concept of double sand filtration has been superseded.

3) Gravel prefilters are now being incorporated into a major programme of rehabilitation of small treatment plants which previously comprised non-functional sedimenters and slow sand filters.

4) Even the effective combination of prefilters and slow sand filters cannot produce coliform-free water when grossly contaminated raw water sources are used. Terminal disinfection is necessary under most circumstances and the development of pot and drip chlorinator systems for both surface and groundwater sources requires serious applied research and urgent attention. The great majority of pot chlorinators do not work.

5) It was demonstrated that the effective long term operation and maintenance of rural water treatment systems, and the replication of treatment designs depends on the development of effective infrastructures at the community, area and regional levels. The operation and maintenance of the protected slow sand filter is described in Appendix III and that of the prefilter in Appendix V.The filtration technology was effective only when supported by community participation, operator training and programmes of supervision, sanitary inspection, and water quality monitoring by public health authorities.

6) The research project has given rise to a Peruvian national programme of water quality surveillance and improvement which was initiated in 1984 and has become a bilateral aid programme supported by ODA.

7) The research and development project has led to a series of major initiatives in water treatment and testing in Latin America which are collaborative with:

The World Health Organization
The Pan American Health Organization (CEPIS)
Ministry of Health, Peru
Ministry of Health and National Water Authority, Nicaragua
International Reference Centre for Wastes Disposal,Switzerland.

8) The PSSF packaged system won a UK national award for pollution abatement technology in 1984.

9) Azpitia, a village which received protected slow sand filtration and gravel prefiltration system won a Peruvian national award for community development in 1985.

SECTION II. SUMMARY OF RLSEARCH COMPONENTS

The three principal areas of research relate to·

a) **Protected slow sand filtration (PSSF);**
b) **Prefiltration;**
c) **Microbiology.**

The efficiency of PSSF has been described in the first two reports (1, 2) and in two publications (6, 7). The second of these publications provides an overview of all UK research in PSSF and copies are available from the Robens Institute, University of Surrey, England.

The efficiency of two types of prefiltration: sub-sand abstraction and coarse medium roughing filtration has been extensively studied. This work is described in all four reports (1, 2, 3, 4) and two additional publications (8, 9). The second of these publications was commissioned by the German Agency for technical cooperation (GTZ) and copies in Spanish are available from CEPIS, Lima, Peru.

The studies of microbiological inactivation by PSSF are summarised in section IV and in a supplementary report (10).

a. PROTECTED SLOW SAND FILTRATION (PSSF)

1. Multiple layers of filter fabric placed above the surface of a slow sand filter significantly improve physical efficiency.

2. Filter fabrics provide an excellent environment for the growth and proliferation of beneficial micro-organisms and aid the biological performance of slow sand filtration.

3 Small scale PSSF provides a filtrate of consistantly improved physico-chemical and microbiological quality at least equal to that expected of full scale conventional filters.

4. Constant flow controllers placed downstream of PSSF units perform reliably and effectively, maintaining effluent velocity ± 10 per cent for the entire filtration run length and substantially reducing maintenance commitments.

5 PSSF may be successfully packaged using a combination of standard synthetic and non-synthetic components.

b. PREFILTRATION

1. Sub-sand abstraction is not appropriate as a prefiltration step where the required volume of water exceeds 25 m^3 per day unless multiple units and diligent semi-skilled labour are available.

2. Coarse medium gravel prefiltration is ideally suited to precede protected slow sand filtration PSSF and can provide substantial improvements in both the physical and microbiological quality of raw waters.

3. The most important parameters which influence prefiltration are :

   Raw water quality;
   Filtration velocity;
   Particle size of medium;
   Filtration depth (or length);
   Number and type of filtration units : Vertical or Horizontal.

4. The construction and operation of gravel prefilters is simple and appropriate for typical conditions in less developed countries.

5. The questions which remain are :

   The inter-relationship of diverse factors affecting efficiency;
   The optimum mechanism for cleaning and/or washing media;
   The effect of time on efficiency;
   The effect of high levels of colloidal material on efficiency;
   The comparative efficiency of vertical and horizontal gravel filtration.

c MICROBIOLOGY

1 All available literature, and the results of the experimental programme suggest that enteric viruses are attenuated by conventional slow sand filtration and by PSSF at least as efficiently as the faecal bacterial indicators.

2. Biologically active synthetic filter fabrics provide valuable reductions in the density of both faecal indicator bacteria and viral indicators prior to slow sand filtration.

3. Bacteriophage (bacterial viruses) can successfully index the range of bacterial indicator attenuation in PSSF.

4. Sand taken from depth in a functional slow sand filter appears no more efficient in the removal of faecal indicator bacteria and viral indicators than sterile, clean, and even acid-washed sand.

5. Filter fabric with an associated active biological community provides reductions in simian rotavirus densities comparable with sand and schmutzdecke from conventional and protected slow sand filters. These reductions are substantially higher than those observed with sterile substrates.

6 The importance of biological mechanisms for the attenuation of bacterial and viral indicators and rotavirus has been confirmed.

SECTION III

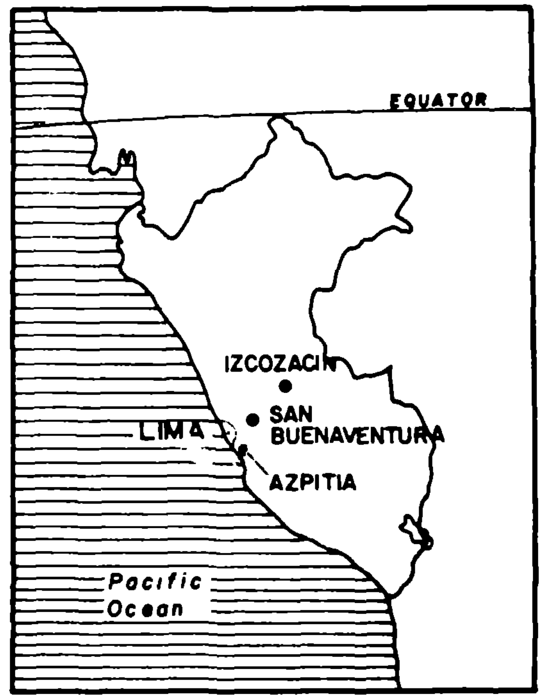
INSTALLATIONS OF THE RURAL WATER TREATMENT PACKAGE PLANT IN PERU

Water treatment systems were introduced into all three geographical zones of Peru coastal, highland (sierra) and jungle (selva) The number of packaged slow sand filtration systems introduced in each case was four, two and three respectively A summary of the communities which received installations is provided in Table 1

Communities were selected after exhaustive survey work in several Departments in Peru. In every community surveyed there were several possible options for the rehabilitation of existing facilities or the construction of new treatment systems However, only in those communities where the packaged system was considered the most appropriate option was it installed Even in those communities eventually selected, other options were available and the discussion of these options and the eventual choice was an integral and vital part of the communities' participation in the project. A summary of design options discussed with each selected community is presented in Table 2

The component parts of each installation are described in Table 3 and in Figures 2, 3 and 4

Timescales necessary for the planning and supervision of water treatment interventions are necessarily long Extensive surveys, community contact, discussions and the due decision making process of the community all require time Compared with these processes, the time required for actual installation of a plant can be very small - particularly if no new construction is necessary Table 4 describes the activities connected with the Peruvian installations and relates them to the time required for their execution



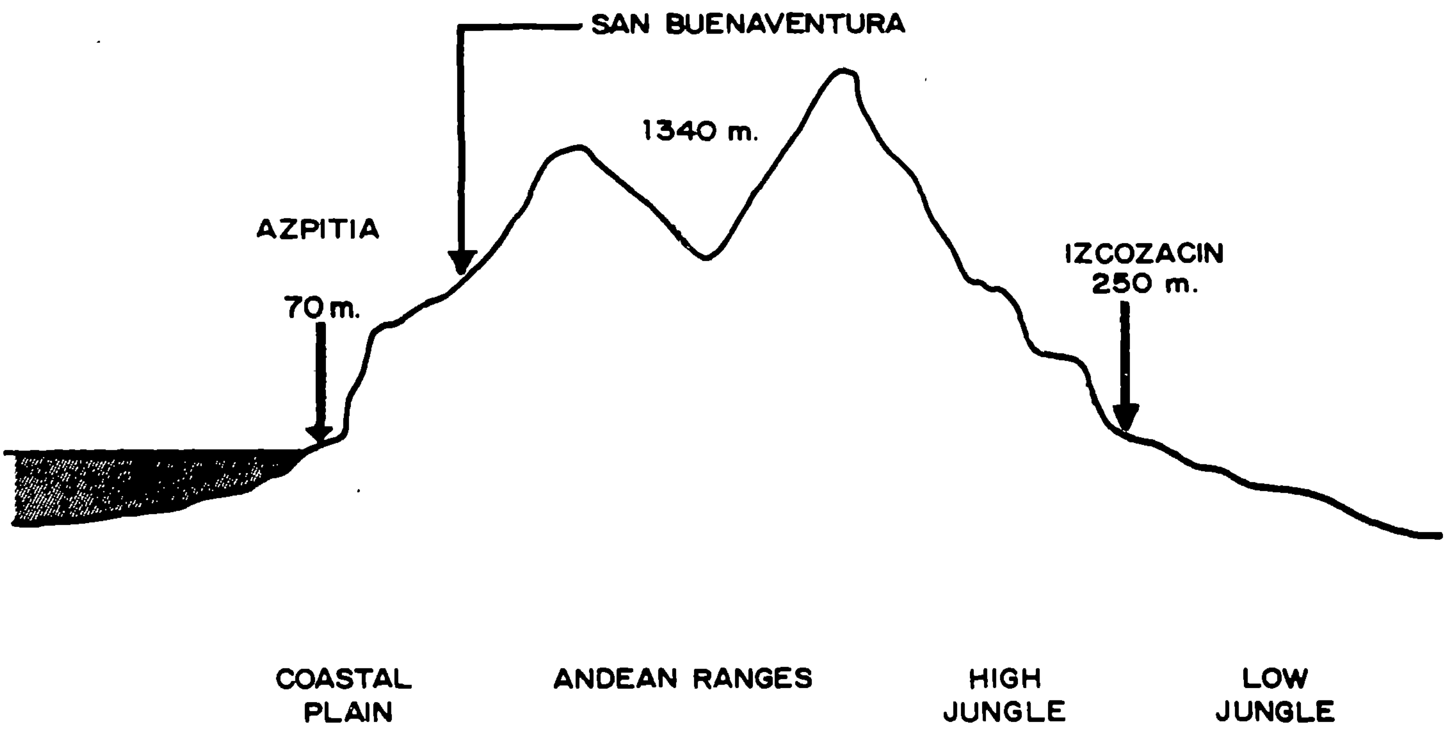


Figure 1 Geographical distribution of installations in Peru

Table 1 Details of communities which received packaged water treatment systems

Name of community	San Buenaventura	San Vicente de Azpitia	Iscozacin
Zone	Sierra	Costa	Selva
District	San Buenaventura	Santa Cruz de Flores	Huancabamba
Province	Canta	Canete	Oxapampa
Department	Lima	Lima	Cerro de Pasco
Type of community	Hillside, agricultural	Coastal agricultural	Jungle, workcamp
Access	Earth road	Earth road	Air or river
Number of inhabitants	400	600	250 plus
Language	Spanish and Quechua	Spanish	Spanish
Authority	Ltnt Governor	Ltnt Mayor	Project Chief
Institutions	Primary school Church Council	Primary school Church Health post Council	Pichis Palcazu development project
Activities	Production of potatoes, maize, yuca	Production of grapes, apples, pears, cotton, bananas, wine	Various development

Table 2 Design options for three communities ultimately selected for PSSF demonstration programme

Community	Design options	Final selection
San Buenaventura	1) Rehabilitataion of existing filters to include new drainage, sand, inlet and outlet structures, and re-rendering of masonry.	
	2) Introduction of packaged PSSF systems x two.	***
San Vicente de Azpitia	1) Sink well in river basin, pump 70 m head continuously.	
	2) Divert irrigation water, construct abstraction, prefiltration, distribution, storage and introduce packaged PSSF systems x four.	***
Izcozacin	1) Sink well, pump by hand.	
	2) Rapid filtration and disinfection.	
	3) Introduction of packaged PSSF systems x three.	***

Table 3 Components of three PSSF installations and costs of materials. Incidental costs, labour and supervision are not included in this analysis.

Community	Components	Cost (USD)
San Buenaventura	Conduction line	135
	2 x PSSF units etc	950
San Vicente de Azpitia	Abstraction	120
	Prefilter	565
	4 x PSSF units etc	2510
	Conduction & distribution	4450
	Storage & stand posts	3230
Izcozacin	3 x PSSF units etc	1860

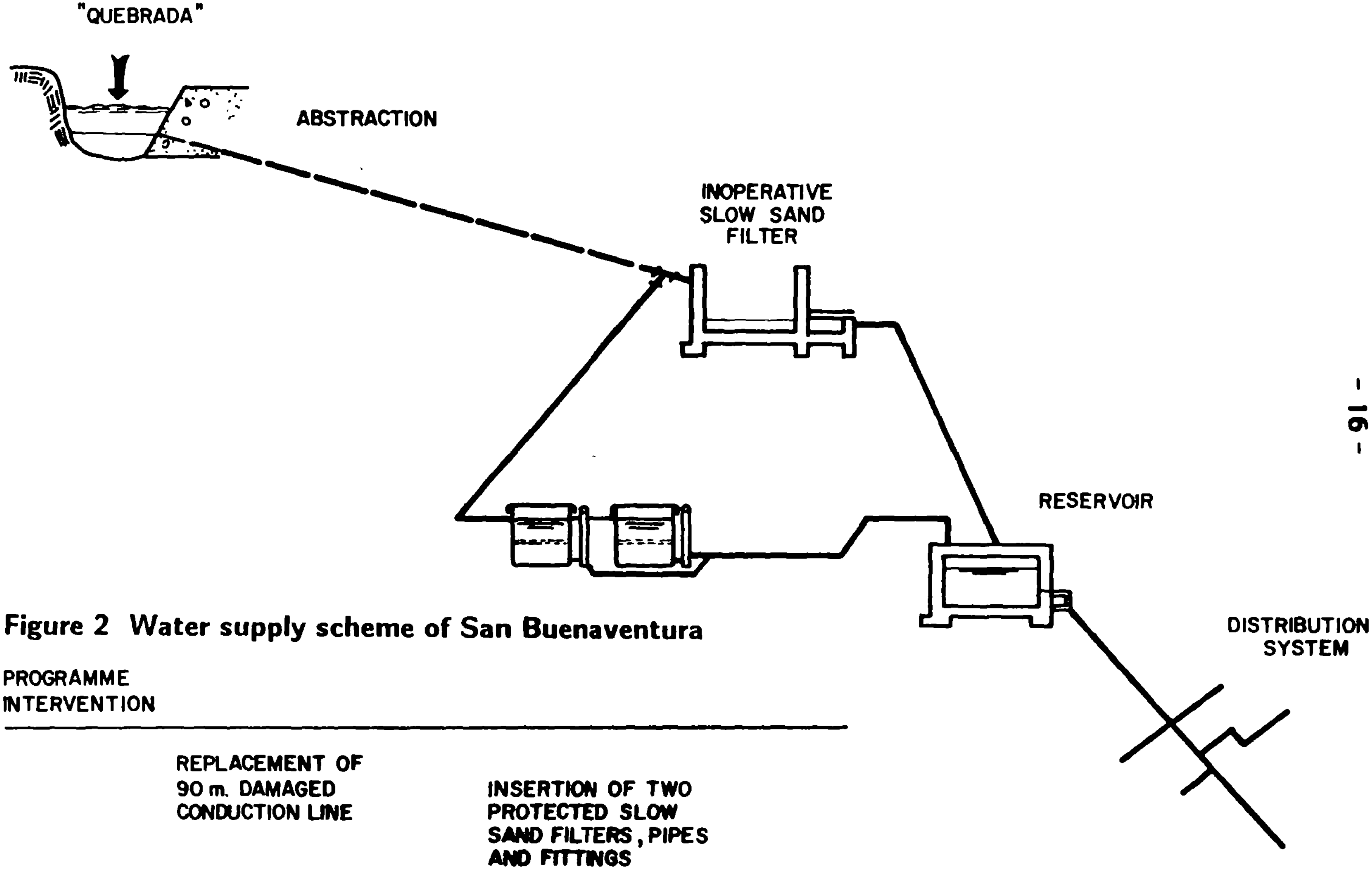


Figure 2 Water supply scheme of San Buenaventura

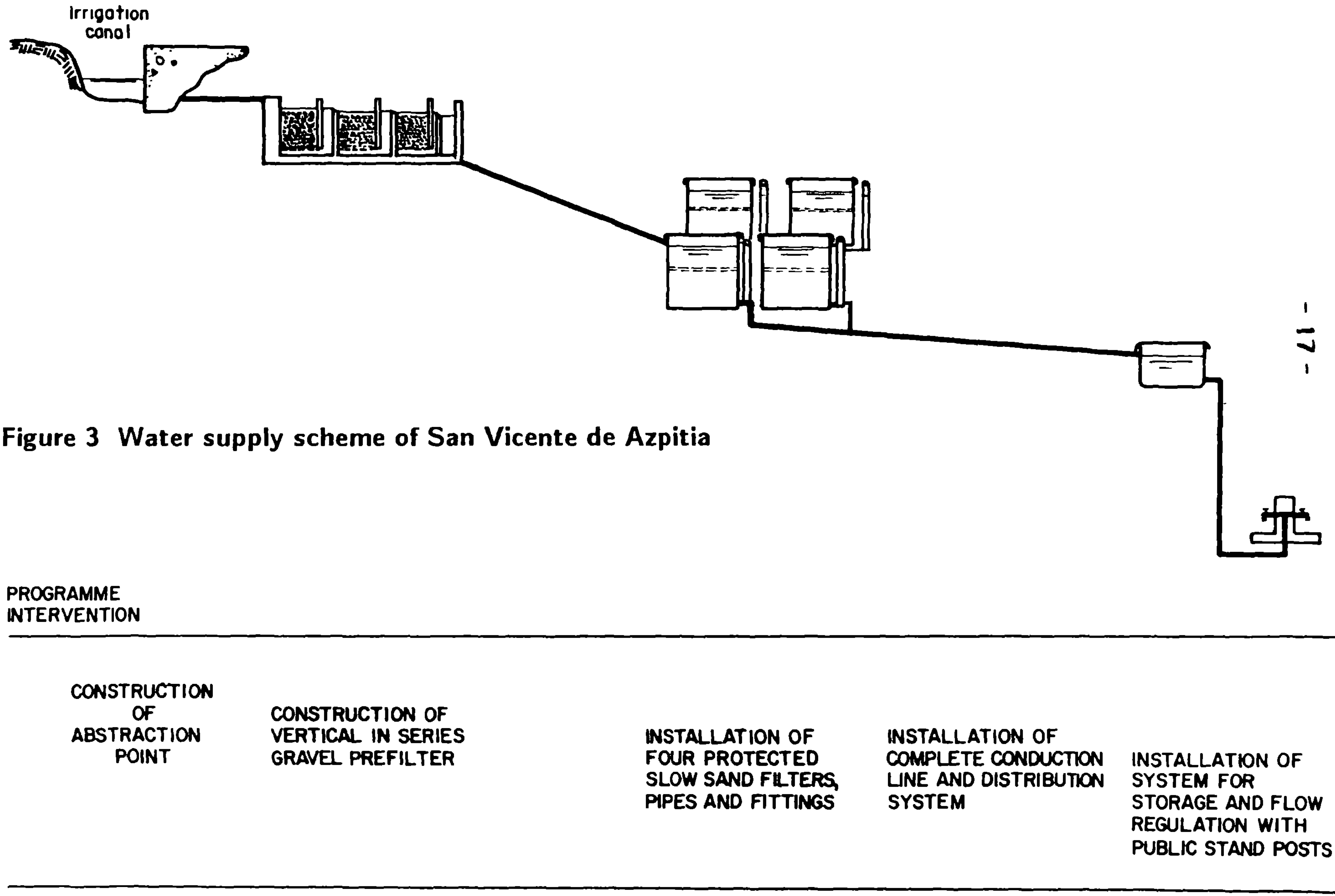


Figure 3 Water supply scheme of San Vicente de Azpitia

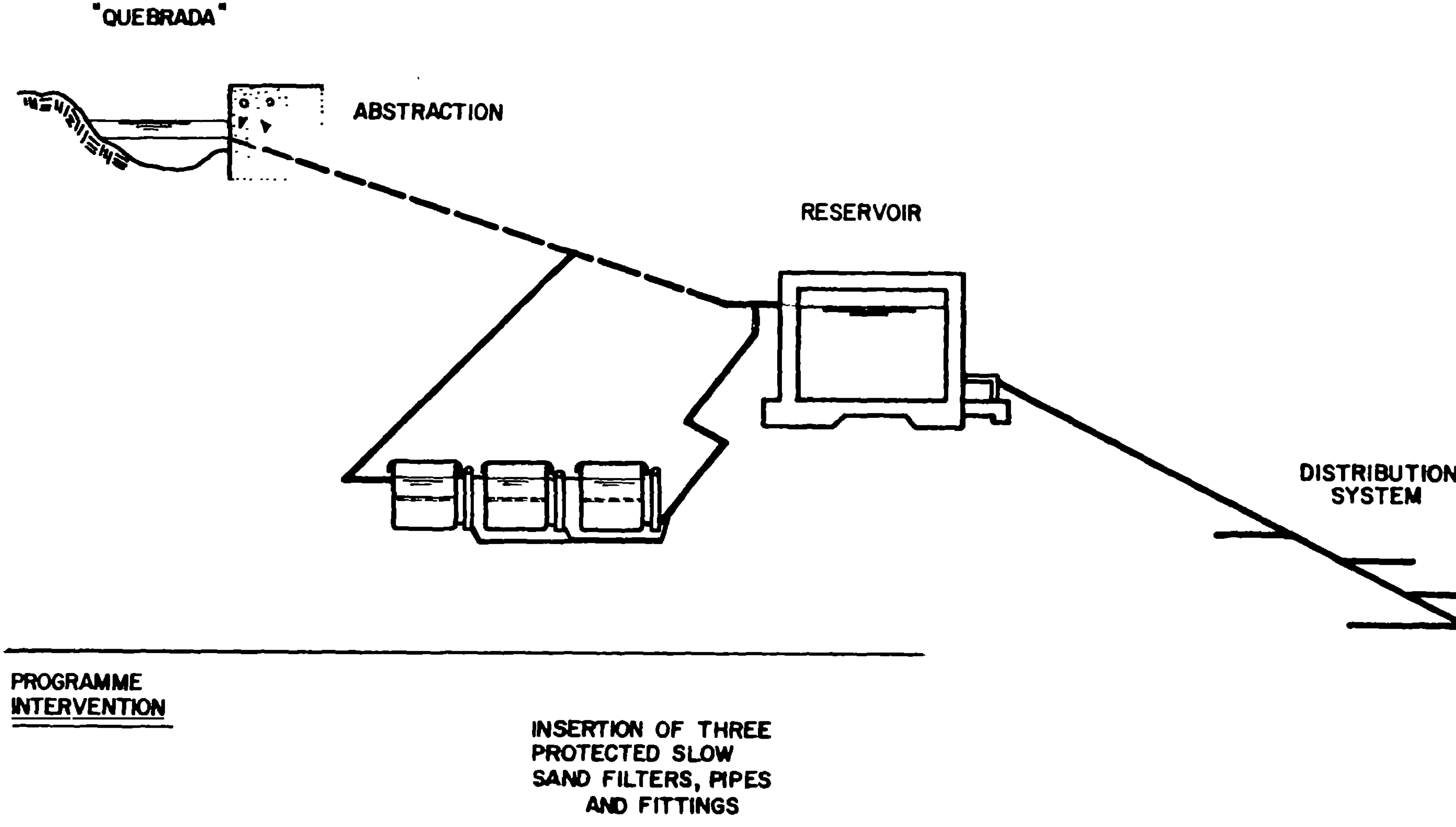


Figure 4 Water supply scheme of Izcozacin

Table 4 Programme activities and timescale for installation of PSSF package plants in Peru.

Programme activity	Timescale 1983	1984	1985	1986
General survey				
San Buenaventura				
Preliminary contact and community planning				
Installation and commissioning				
Operation and evaluation				
San Vicente de Azpitia				
Preliminary contact and community planning				
Construction, installation and commissioning				
Operation and evaluation				
Izcozacin				
Preliminary contact and community planning				
Installation and commissioning				
Operation and evaluation				

SECTION IV

EVALUATION OF WATER TREATMENT SYSTEMS

TECHNICAL APPRAISAL OF PSSF IN THE UK

The performance of the protected slow sand filtration unit in the UK during three years of evaluation has been described (1, 2, 4, 6, 7) However, for ease of reference, some key performance data are provided here.

Figure 5 shows the PSSF unit.

Figure 6 illustrates the extension of filter run length due to the exclusion of suspended solids by filter fabrics

Figure 7 shows the accumulation of head loss and silt penetration with depth in the PSSF unit

Figure 8 illustrates the enhanced colonisation by ciliated protozoa of filter fabrics compared with sand.

Table 5 shows the efficiency of silt removal by alternating density filter fabric combinations

Figure 9 illustrates the improvement in microbiological performance of the PSSF unit with respect to time after commissioning

Figure 10 shows the improvement in microbiological performance of the PSSF unit with respect to time after routine maintenance

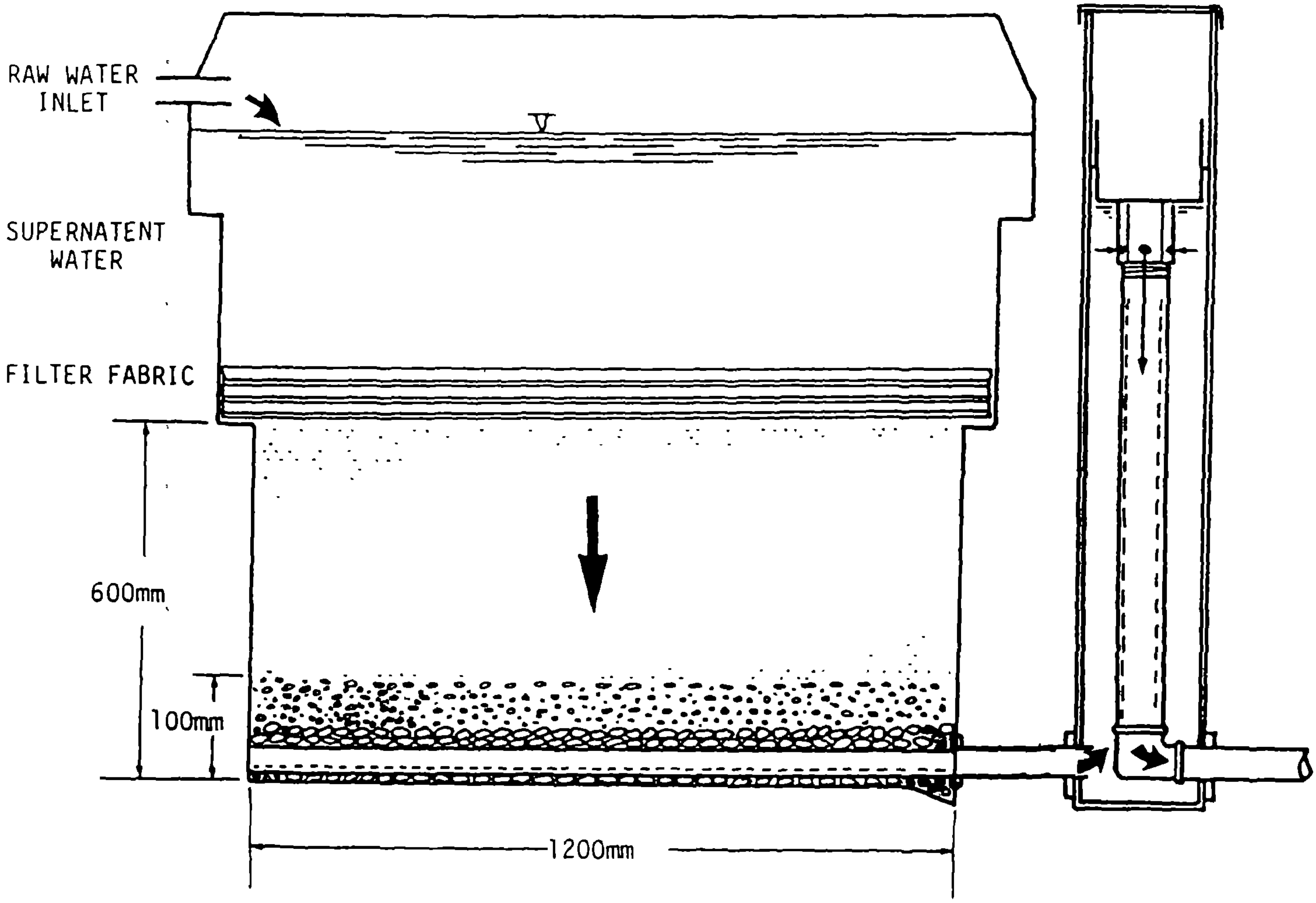


Figure 5 Dimensions and construction of PSSF package plant and flow controller

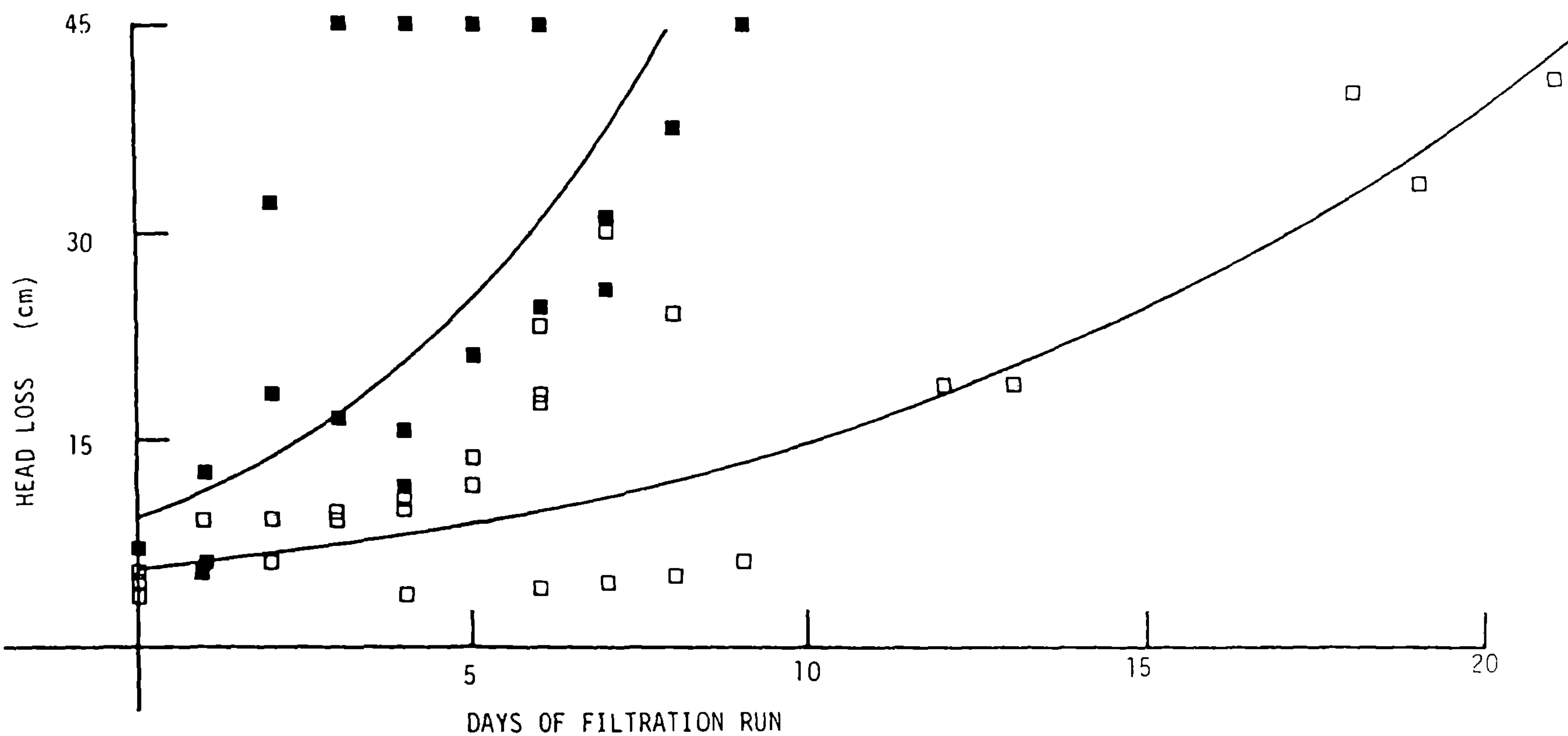


Figure 6 Difference in rate of head loss increase in protected slow sand filters □—□ compared with unprotected filters ■

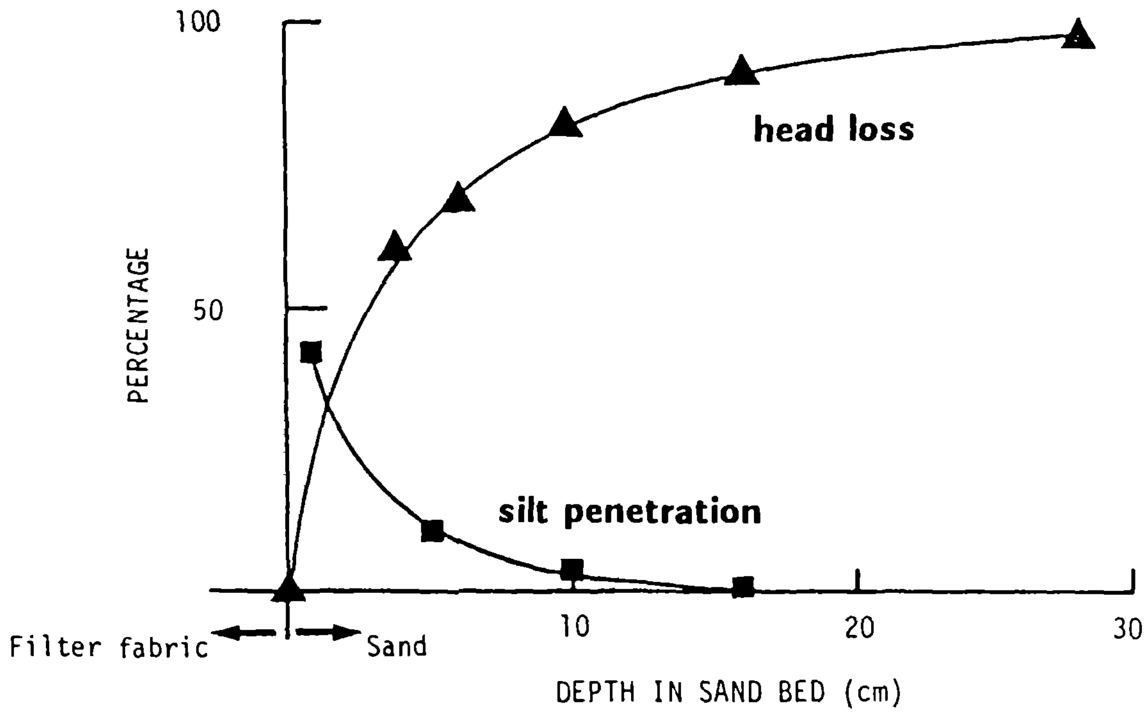


Figure 7 Accumulated head loss at various depths within the PSSF sand bed (as a percentage of total head loss) compared with silt penetration (as a volumetric percentage)

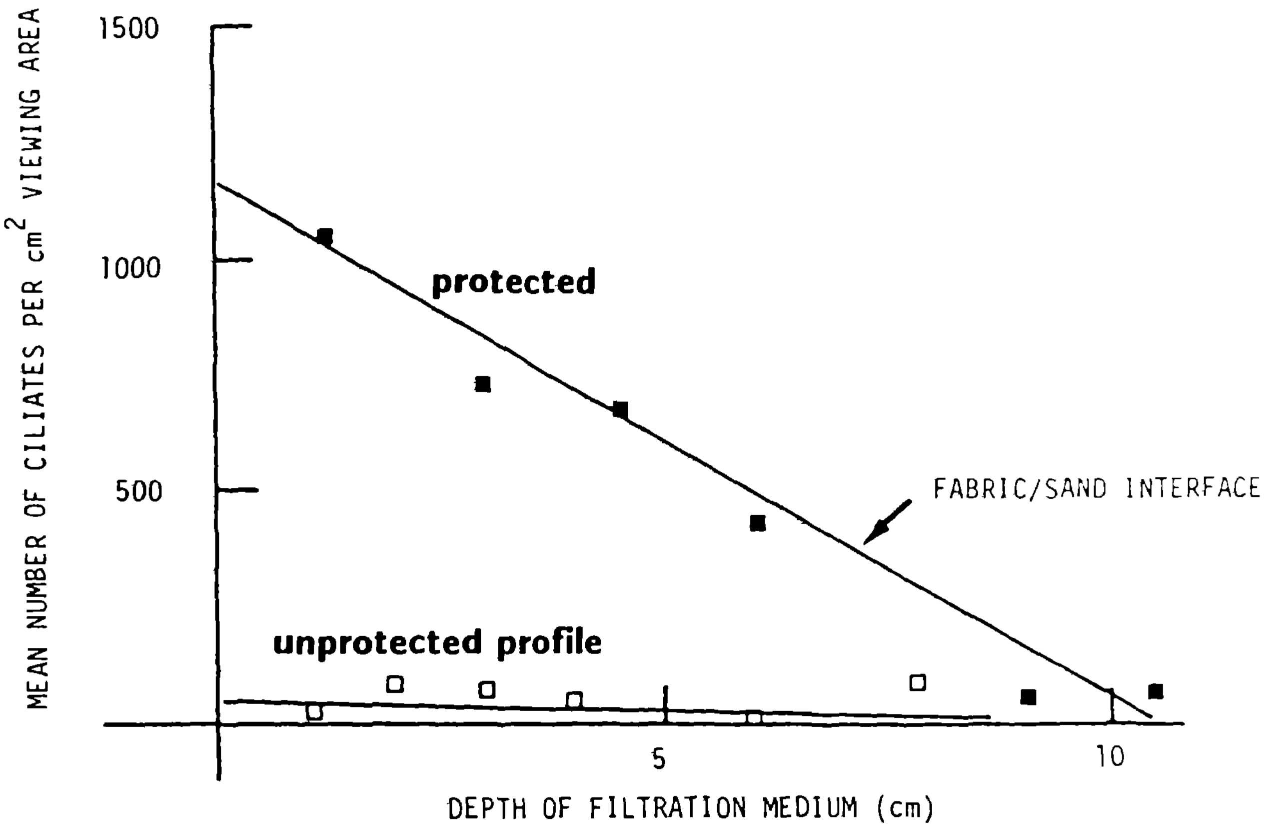
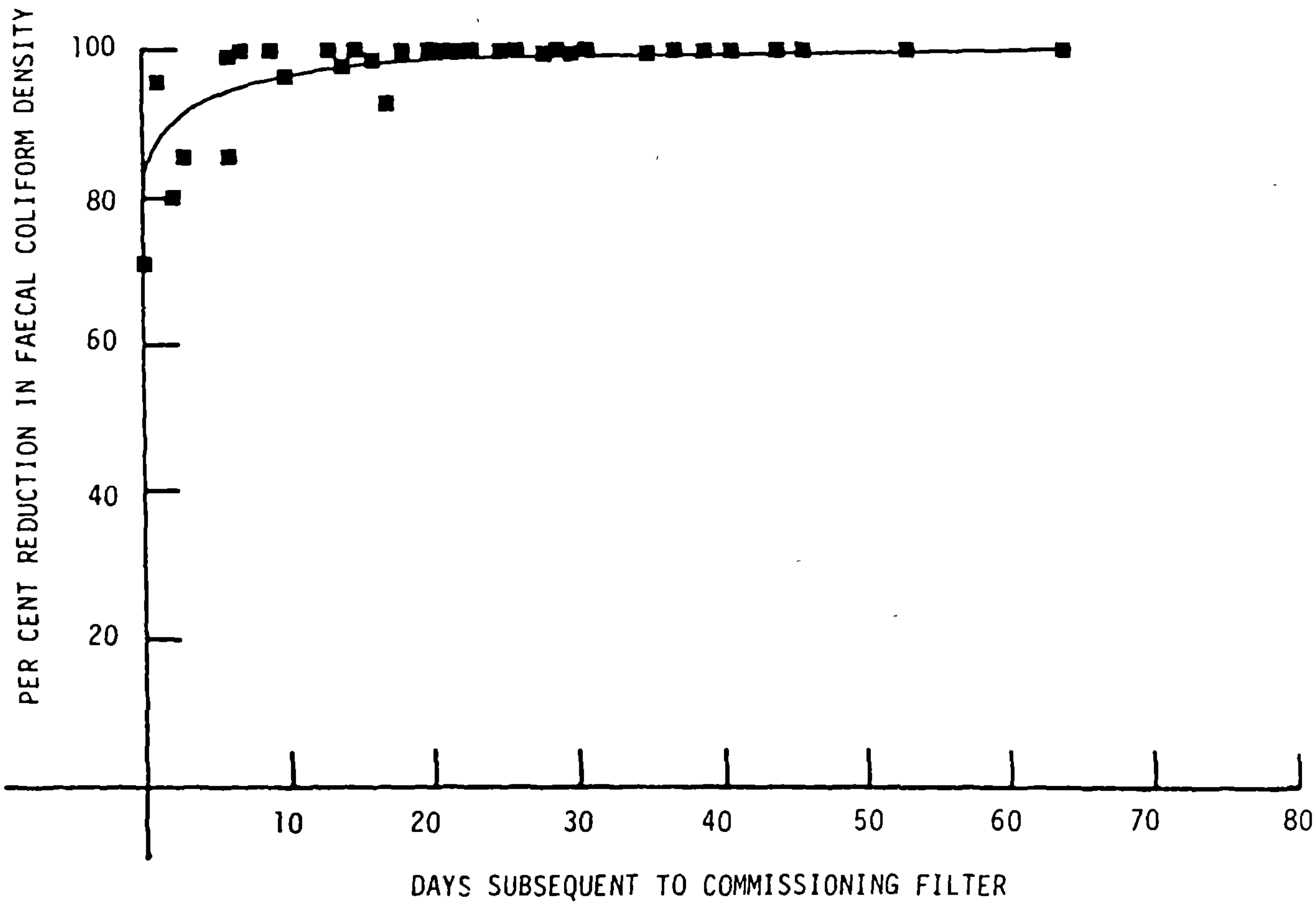


Figure 8 Vertical distribution of ciliated protozoa in sand profile protected by five filter fabrics compared with unprotected profile

Figure 9 Improvement in percentage reduction of faecal coliform densities in newly commissioned PSSF units



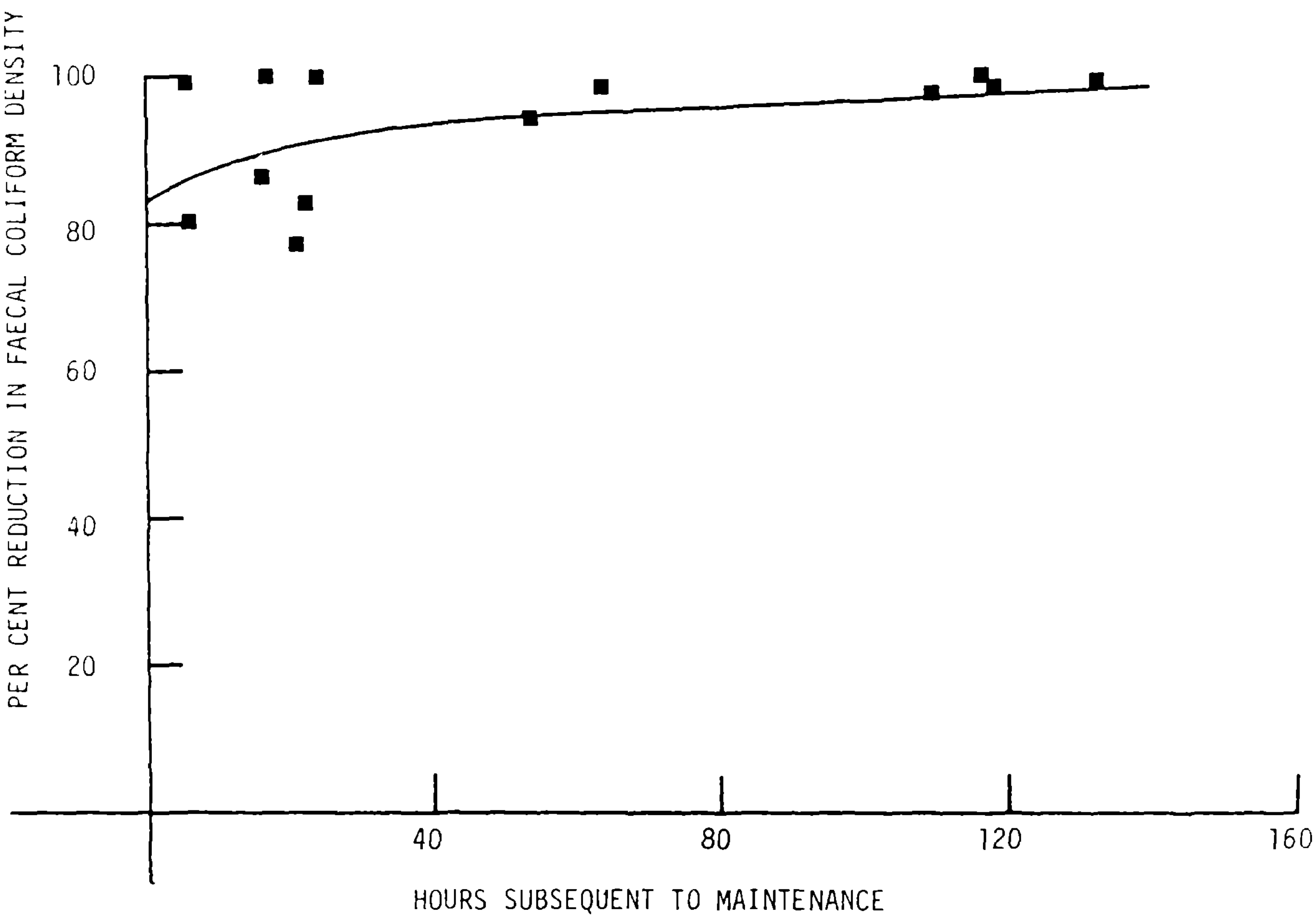


Figure 10 Recovery in efficiency of faecal coliform removal in PSSF units immediately after routine maintenance

SLOW SAND FILTER 1					SLOW SAND FILTER 2				
Layer	Layer type	Material	Silt content L/m^2	percentage of total silt penetration	Layer	Layer type	Material	Silt content L/m^2	percentage of total silt penetration
1	Top Double	Coarse	19.4	49.4	1	Top	Coarse	17 6	40 5
2	Layer	Dense	8.9	22.7	2	Triple	Coarse	2.9	6.6
					3	Layer	Coarse	1 5	3 5
3	Middle	Coarse	1.7	4.4	4	Bottom	Dense	1 1	2.0
	Double				5	Triple	Dense	0 01	0.2
4	Layer	Dense	0.9	2.3	6	Layer	Dense	0 01	0.2
5	Bottom	Coarse	0.01	0.02					
	Double								
6	Layer	Dense	0.03	0.07					
Sand	Top 5cm		8.33	21.11	Sand	Top 5cm		20.4	46.9
Total			39.27	100%				43.52	100%

Table 5 Silt penetration in a filter protected by alterning densities of filter fabric (filter 1) compared with a filter protected by a simple configuration of identical fabrics (filter 2). Silt expressed as litres per m2 of filtration area at the end of filtration run (45 cm head loss)

TECHNICAL APPRAISAL OF PSSF AND GRAVEL PREFILTRATION IN PERU

Monitoring of the performance of all three Peruvian installations described in Section III has been undertaken Preliminary information was provided in the first field report (3) and in a subsequent report devoted to gravel prefiltration (9)

The most comprehensive evaluation data has been collected for the installation in the community of San Vicente de Azpitia. Because this installation included the construction of abstraction, prefiltration, and a full distribution network in addition to the installation of protected slow sand filtration, greatest interest attaches to its performance.

The installation of five protected slow sand filters without prefiltration in San Buenaventura and Izcozacin provided confirmation of the capacity of PSSF to reduce faecal contamination by a consistent 90 - 99 per cent. In both cases this resulted in low level intermittent coliform levels in the treated water Simple terminal disinfection would readily assure compliance with World Health Organization guidelines on all occasions

The installation in San Vicente de Azpitia was evaluated extensively both in the wet season and in the dry season Results are described in Figures11, 12, 13, 14, 15, 16, 17, 18 and 19

Figure 11	demonstrates the microbiological efficiency of the Azpitia system during the first wet season to follow commissioning (1985).
Figure 12	illustrates the microbiological efficiency of the Azpitia system during an entire dry season (1985).
Figure 13	describes the microbiological efficiency of the system throughout an entire wet season (1986)
Figure 14	illustrates the improvements in turbidity provided by the system during the first wet season to follow commissioning (1985).
Figure 15	describes the improvements in turbidity during an entire wet season (1986).
Figure 16	illustrates the microbiological maturation of both principal elements in the Azpitia scheme
Figure 17	describes the physical efficiency of the three stage prefilter with respect to increasing raw water turbidity.
Figure 18	illustrates the variation in turbidity removal efficiency with respect to time of operation.
Figure 19	describes the recovery of microbiological efficiency of PSSF units following routine maintenance in Izcozacin.

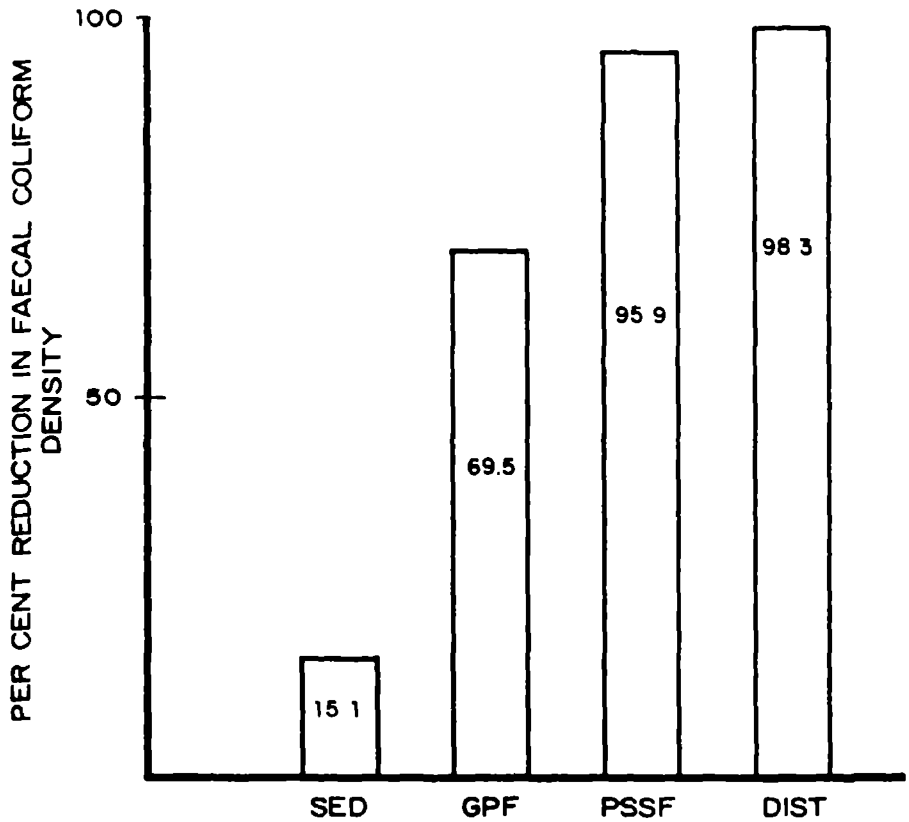


Figure 11 Cumulative improvement in microbiological water quality in the water treatment system of San Vicente de Azpitia - first wet season 12 February - 8 April 1985
SED = Sedimenter
GPF = Gravel Prefilter (Q = 0.2 m/h)
PSSF = Protected Slow Sand Filter (Q = 0.15 m/h)
DIST = Distribution System
Mean raw water quality: 1312 faecal coliforms per 100 ml (n = 21; - SD = 1653)

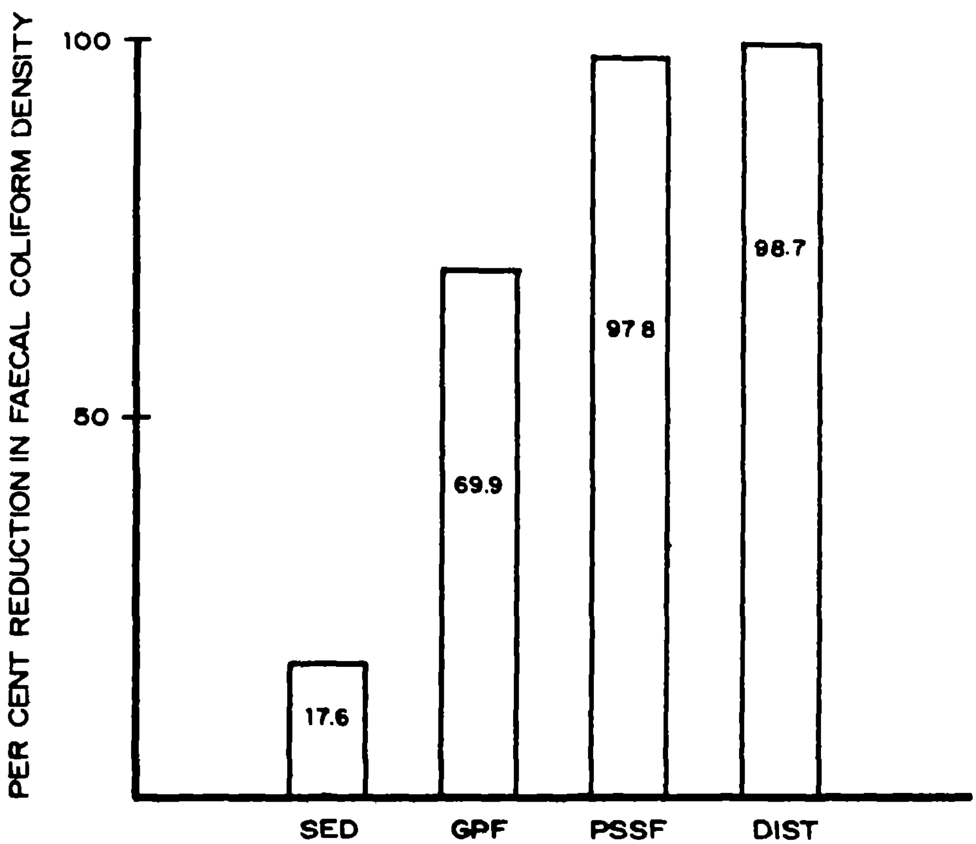


Figure 12 Cumulative improvement in microbiological water quality in the water treatment system of San Vicente de Azpitia - first dry season 9 April - 31 December 1985
SED = Sedimenter
GPF = Gravel Prefilter (Q = 0.2 m/h)
PSSF = Protected Slow Sand Filter (Q = 0.15 m/h)
DIST = Distribution System
Mean raw water quality: 330 faecal coliforms per 100 ml (n = 14; SD = 164)

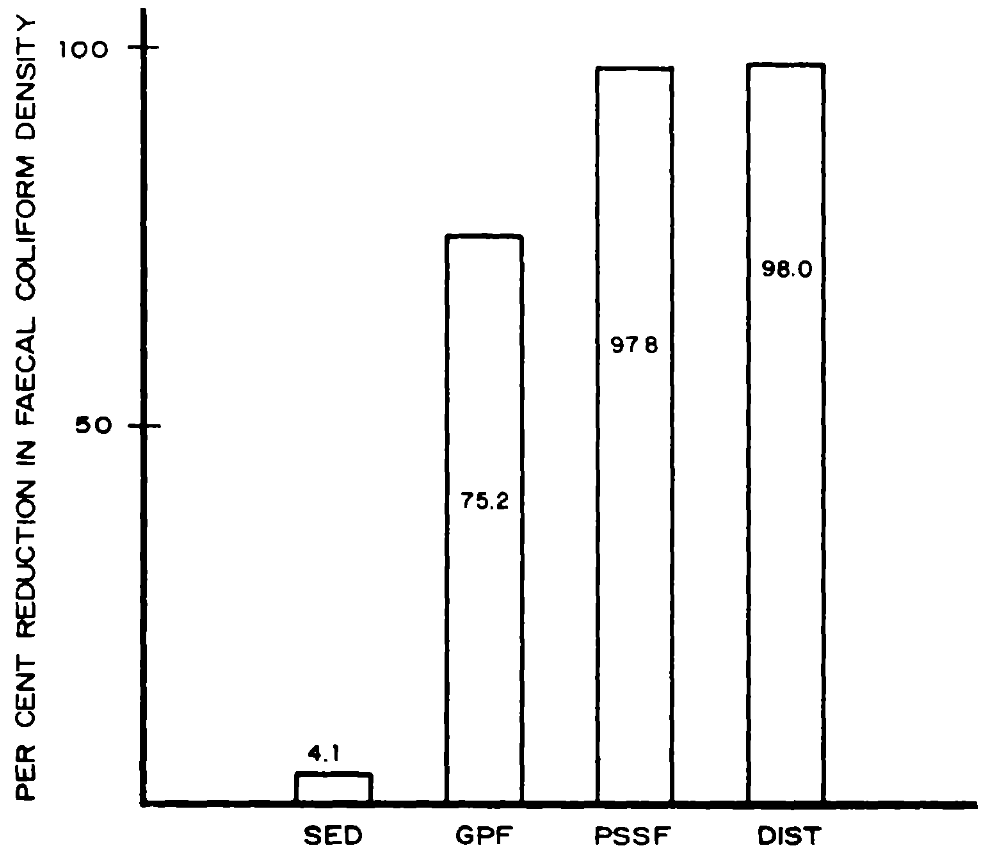


Figure 13 Cumulative improvement in microbiological water quality in the water treatment system of San Vicente de Azpitia - second wet season 1 January - 31 March 1986
SED = Sedimenter
GPF = Gravel Prefilter (Q = 0.2 m/h)
PSSF = Protected Slow Sand Filter (Q = 0.15 m/h)
DIST = Distribution System
Mean raw water quality: 728 faecal coliforms per 100 mh (n = 16; SD = 354)

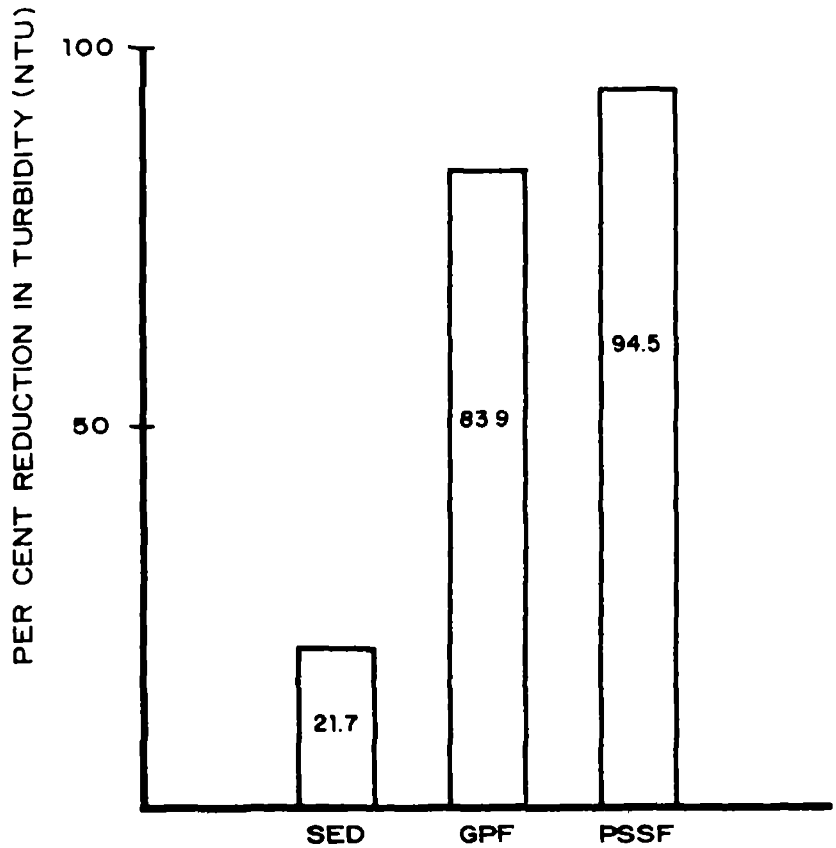


Figure 14 Cumulative improvement in physical water quality in the water treatment system of San Vicente de Azpitia - first wet season 20 January - 8 April 1985
SED = Sedimenter
GPF = Gravel Prefilter (Q = 0.2 m/h)
PSSF = Protected Slow Sand Filter (Q = 0.15 m/h)
Mean raw water quality: 217 NTU (n = 55; SD = 340)

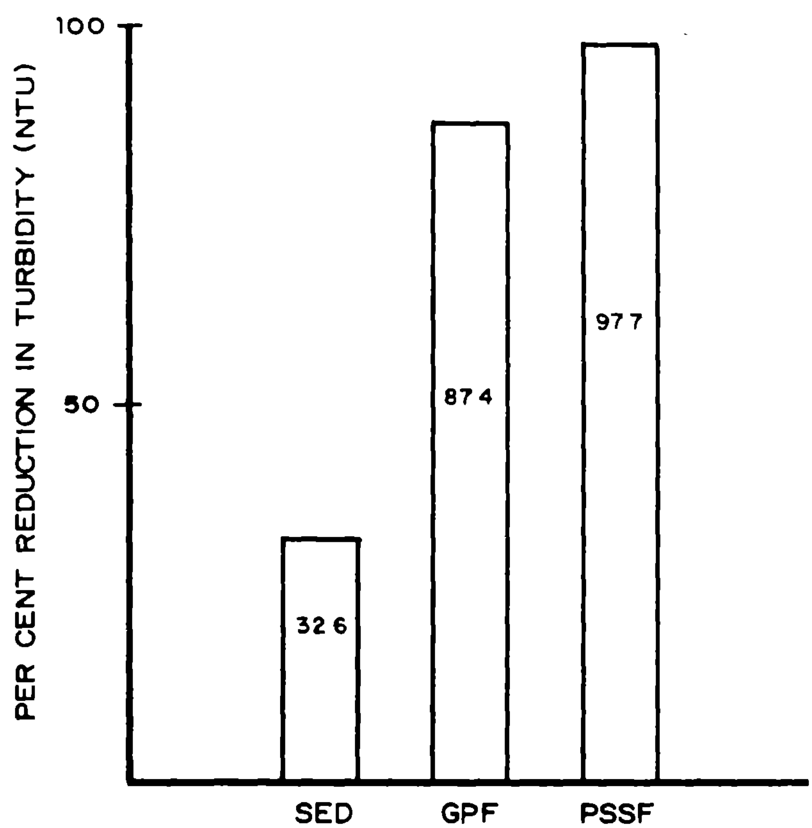


Figure 15 Cumulative improvement in physical water quality in the water treatment system of San Vicente de Azpitia - second wet season 1 January - 31 March 1986

SED = Sedimenter
GPF = Gravel prefilter (Q = 0.2 m/h)
PSSF = Protected Slow Sand Filter (Q = 0.15 m/h)
Mean raw water quality: 178 NTU (n = 56; SD = 250)

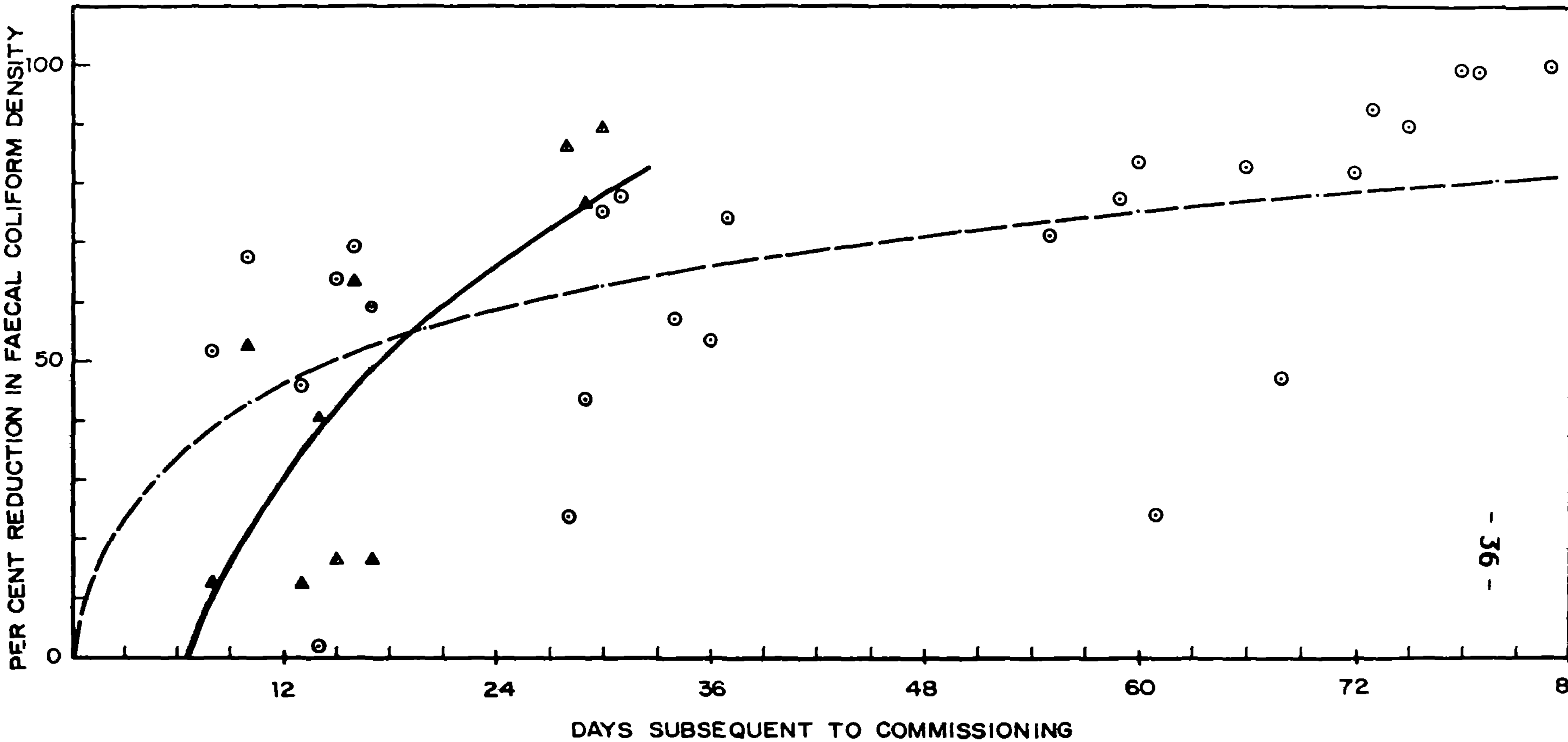


Figure 16 Microbiological maturation of Gravel Prefilter (— — ⊙) and PSSF unit (—▲—) after commissioning in San Vicente de Azpitia

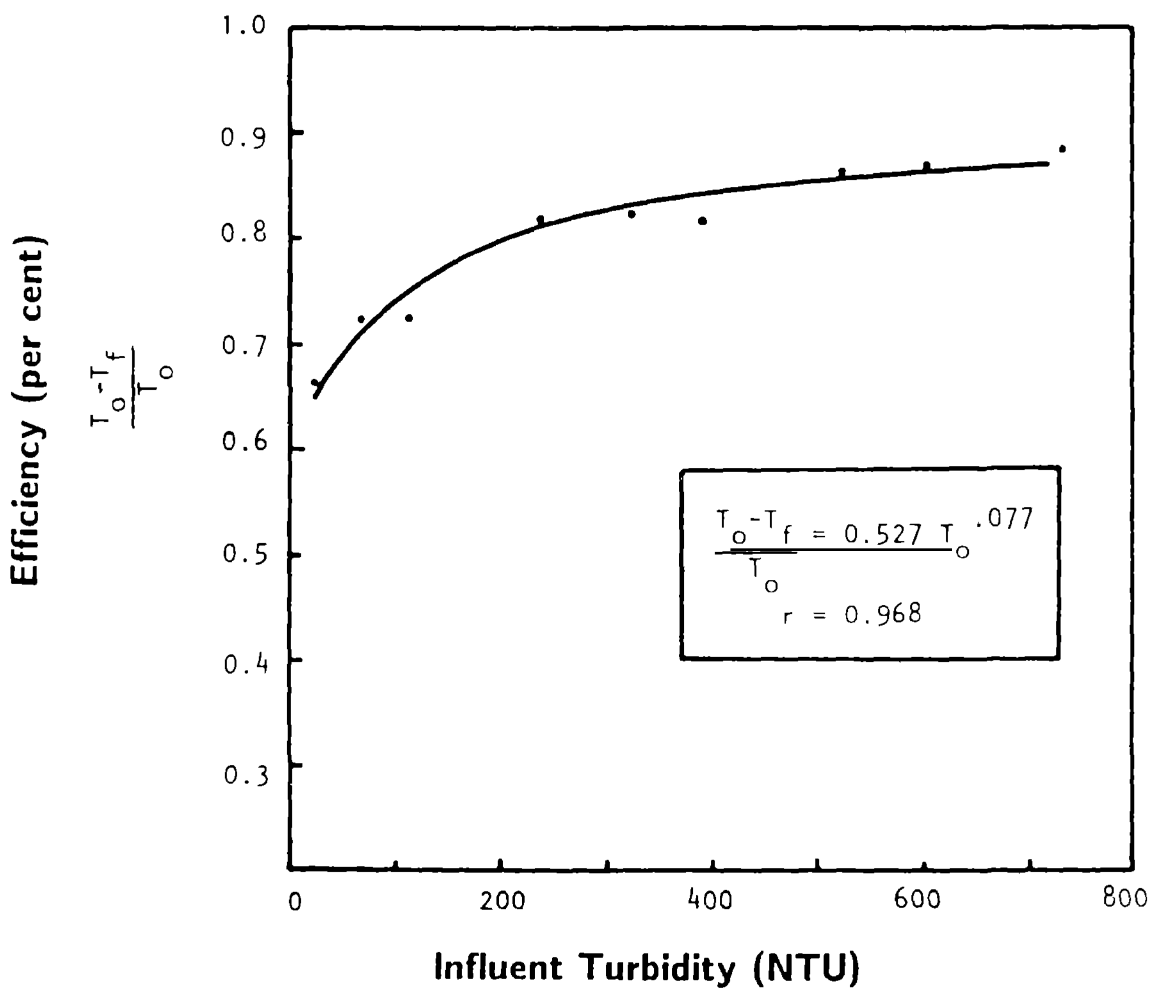


Figure 17 Physical efficiency of the three stage Gravel Prefilter of San Vicente de Azpitia with respect to raw water turbidity

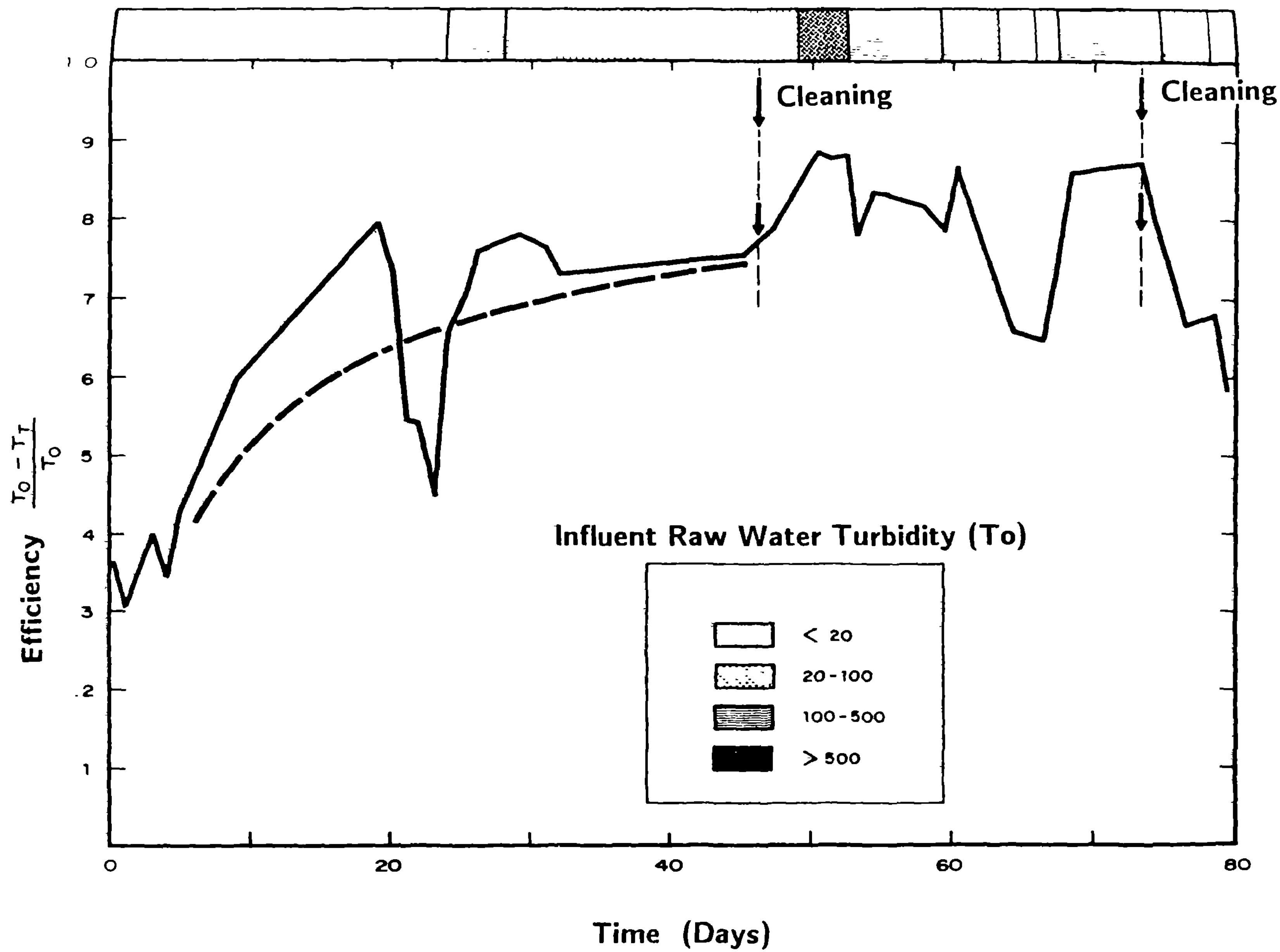


Figure 18 Variation in efficiency of turbidity removal with respect to time of operation for the Gravel Prefilter of San Vicente de Azpitia

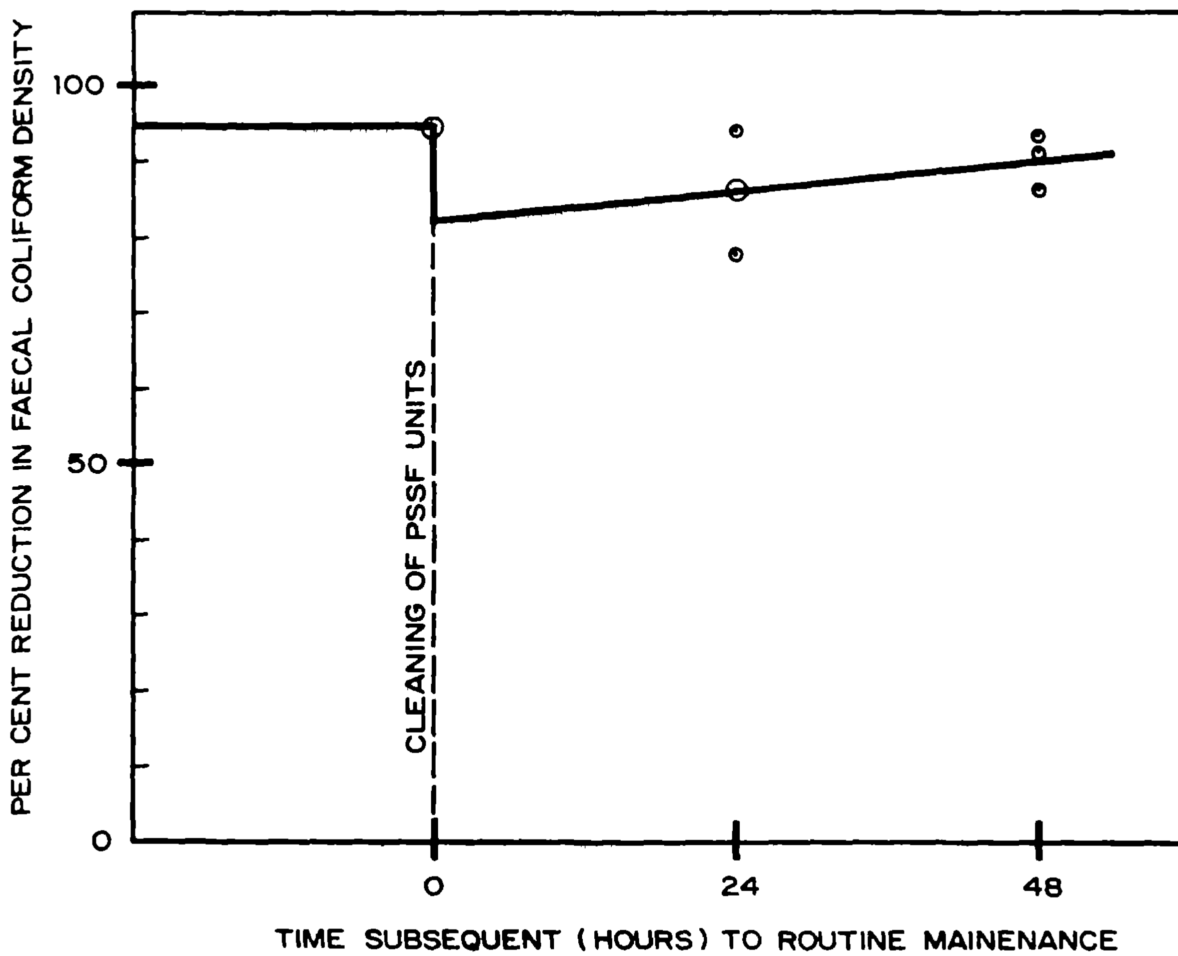


Figure 19 Recovery in efficiency of microbial removal following routine maintenance of PSSF units in Izcozacin (Q = 0.30 m/h)

It is worthwhile to note that where community organisation was strong and supervision diligent, for example in San Vicente de Azpitia, no problems were experienced in the operation and maintenance of what was a totally new drinking water supply system Even in the wet seasons where influent turbidities averaged 217 NTU (1985) and 178 NTU (1986) (ranges 6 - 5,400 NTU and 17 - 1,000 NTU respectively), slow sand filter cleaning was not required more than once during the three month periods When the prefilter and sand filter had been established for nearly a year, the wet season resulted in a mean drinking water turbidity of only 4 1 NTU These observations provide absolute confirmation of the efficacy of the PSSF designs and the principle of gravel prefiltration

However, some important details which also emerged are

1 Slow sand filter maturation was substantially retarded in the Azpitia installation (compare figures 9 and 12) This was probably due to a combination of depleted dissolved oxygen levels (caused by the biological maturation of the gravel prefilter and the relatively high water temperatures) and the fact that the system was commissioned well into a wet season when fine silt was likely to smother and inhibit the growth of the beneficial microfauna and flora

2 In each installation, drinking water quality did not consistently match the World Health Organization guideline of zero faecal coliforms per 100 ml throughout the year Many authorities would therefore recommend the addition of marginal terminal disinfection as a further treatment to assure compliance with the standard on all occasions

3 Where community organisation was weak, for example at San Buenaventura, and water quality surveillance and sanitary inspection by local health authorities absent, lapses in operation and maintenance practice occurred Even with substantial community involvement in planning and installation and detailed training of local operatives, the treatment plant at San Buenaventura was not maintained properly after 12 and 24 months following commissioning Simple corrective measures were applied, but there is clearly no substitute for regular inspection and water quality monitoring by public health or sanitary technicians if standards are to be maintained in this type of small community water supply A summary of performance indicators for the three communities is provided in Table 6

TABLE 6. PERFORMANCE INDICATORS OF INSTALLATIONS IN SAN VICENTE DE AZPITIA (SVdA), SAN BUENAVENTURA (SB), AND IZCOZACIN (IZ).

Indicator		Time Elapsed after commissioning of plant (months)			
		1.5	6	12	24
Sanitary Inspection Acceptable *	SVdA	yes	yes	yes	
	SB	yes	yes	yes	yes
	IZ	yes			
Technical Performance Acceptable **	SVdA	yes	yes	yes	
	SB	yes	yes	no +	no +
	IZ	yes			
Operation and Maintenance Acceptable ***	SVdA	yes	yes	yes	
	SB	yes	yes	no +	no +
	IZ	yes			

* Plant in good repair
** Microbiological and physico-chemical criteria acceptable
*** Flow rates, cleaning schedules etc. maintained.
\+ Simple corrective action taken

REFERENCES

1 Wheeler, D , Pardon, M , and Lloyd, B J , 1983. Progress Report. Rural water treatment package plant. University of Surrey, Guildford, UK.

2 Wheeler, D., Symonds, C N , Lloyd, B J and Pardon, M., 1983 Progress Report (Phase II) Rural water treatment package plant. University of Surrey, Guildford, UK

3 Lloyd, B.J , Pardon, M. and Wheeler, D , 1984. Preliminary Field Report. Rural water treatment package plant University of Surrey, Guildford, UK

4. Wheeler, D., Pardon, M., Lloyd, B J. and Symonds, C.N., 1985. Aspects of prefiltration concerned with the application of small scale slow sand filtration in rural communities University of Surrey, Guildford, UK.

5 Lloyd, B J , 1982. Rural water treatment package plant Collaborative project grant application with CEPIS and Ministry of Health, Peru. University of Surrey, Guildford, UK.

6 Pardon, M., Wheeler, D , and Lloyd, B.J, 1983 Process aids for slow sand filtration. Waterlines, 2(2), 24-28.

7 Wheeler, D., Skilton, H , Pardon, M., and Lloyd, B , 1986 The enhancement of slow rate sand filters by the incorporation of synthetic fabrics. J. Am Water Works Assoc. In press.

8 Visscher, J.T., 1986. Prefiltration for slow sand filtration Chapters on Vertical gravel filtration (Pardon, M.) and Sub-sand filtration (Wheeler, D and Lloyd, B.J). IRC, The Hague, Netherlands. In press.

9 Perez, J.M , Pardon, M , Lavado, I. and de Mayo, C.V., 1985. Informe preliminar de la investigacion sobre prefiltros de grava. CEPIS, Lima.

10 Wheeler, D., 1986. An investigation of strategies for the reduction of enteric viral disease in less developed countries with reference to small commmunity water supplies Report University of Surrey, Guildford, UK

11 DelAgua, 1986 The rehabilitation of the water treatment system of the rural community of Cocharcas. A pilot project report for the Technical Division of Environmental Sanitation, Ministry of Health, The Government of Peru, CEPIS/PAHO/WHO, Lima.

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APPENDICES

RURAL WATER TREATMENT PACKAGE PLANT (R 3760)

FINAL REPORT FOR THE UK OVERSEAS DEVELOPMENT ADMINISTRATION

B J LLOYD
M PARDON
D WHEELER

APPENDIX I

DESIGN AND SELECTION MANUAL

PSSF PACKAGE PLANT AND PREFILTRATION SYSTEM

DelAgua, P.O. Box 92, Guildford, GU2 5TQ, England

DESIGN AND SELECTION

PROTECTED SLOW SAND FILTRATION PACKAGE PLANT AND PREFILTRATION SYSTEM

CONTENTS

1. INTRODUCTION

This design and selection manual refers to protected slow sand filtration units which may be constructed from lightweight materials and transported for local installation in small rural communities The materials recommended here will be available in many less developed countries, but a list of UK suppliers is also provided for those who are unable to identify local suppliers of identical or equivalent components

It is STRONGLY RECOMMENDED that consideration be given first to conventional construction of treatment plants - particularly where community size exceeds 1,000 persons The best sources of information concerning the planning, design and construction of plants using conventional materials ie concrete, ferrocement, and masonry are

International Reference Centre for Community Water Supply and Sanitation, 1980 Slow sand filtration for community water supply in developing countries Bulletin Series No 16 IRC, The Hague, Netherlands

Paramasivam, R et al, 1986 Slow sand filtration for community water supply Planning, design, construction, operation and maintenance Draft 19860301. IRC, The Hague, Netherlands

Perez, J M and de Vargas, L C, undated Guia para diseno de plantas de filtracion lenta para el medio rural DTIAPA No. C-3, CEPIS, Lima, Peru.

Thanh, N C, 1978 Functional design of water supply for rural communities. AIT, Bangkok, Thailand.

Thanh, N C and Hettiaratchi, J P A, 1982 Surface water filtration for rural areas - guidelines for design, construction, operation and maintenance. ENSIC, Bangkok, Thailand

van Dijk, J C and Oomen, J H C M, 1978. Slow sand filtration for community water supply in developing countries. IRC Technical Paper Series No 11 IRC, The Hague, Netherlands

Wegelin, M, 1986 Horizontal flow roughing filtration A design, construction and operation manual (draft) IRCWD, Dubendorf, Switzerland

Where conventional construction is considered too slow, inconvenient or inappropriate, the checklist overleaf should be applied. But if a packaged system of water treatment is eventually selected, there are still a number of other considerations which must not be omitted:

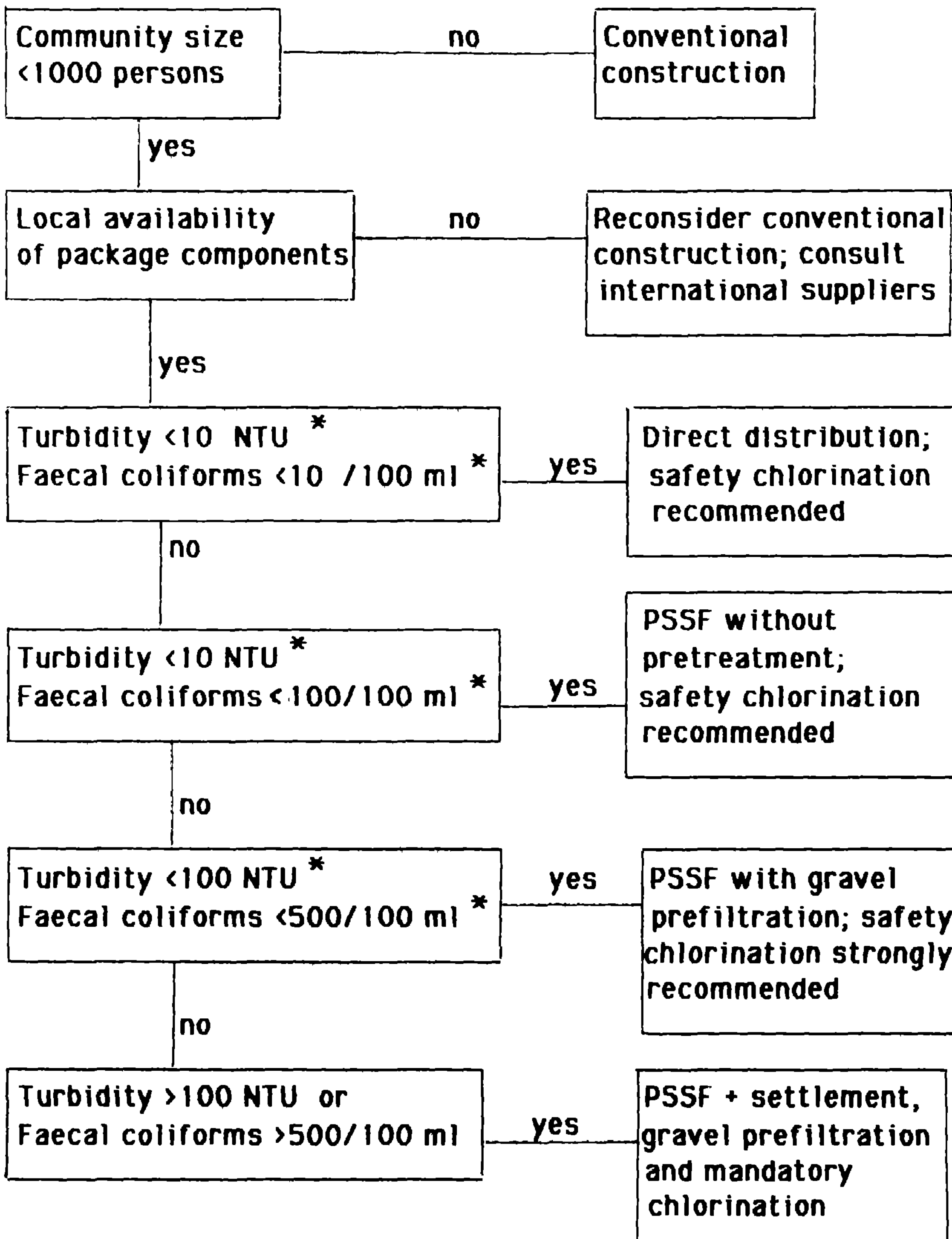
1 No rural water supply can be successfully executed without careful planning and co-ordination with the recipient community

2 Effective community organisation and awareness of the benefits of an improved water supply are vital pre-requisites for participation in installation, the collection of tariffs, and delegation of resources for operation and maintenance.

3 Although some construction may be avoided by selecting a packaged treatment system, substantial extra works may be required for introducing abstraction, storage, prefiltration, disinfection and distribution.

4 To maintain momentum on operation and maintenance practice, there is no alternative to careful training of operatives and regular follow-up visits by public health technicians for the purpose of sanitary inspection and water quality surveillance.

2. CHECKLIST+ FOR THE APPLICATION OF PSSF FOR SMALL COMMUNITY WATER SUPPLIES



+ Based on an idea from IRC (3)

* on 80 per cent of sampling occasions

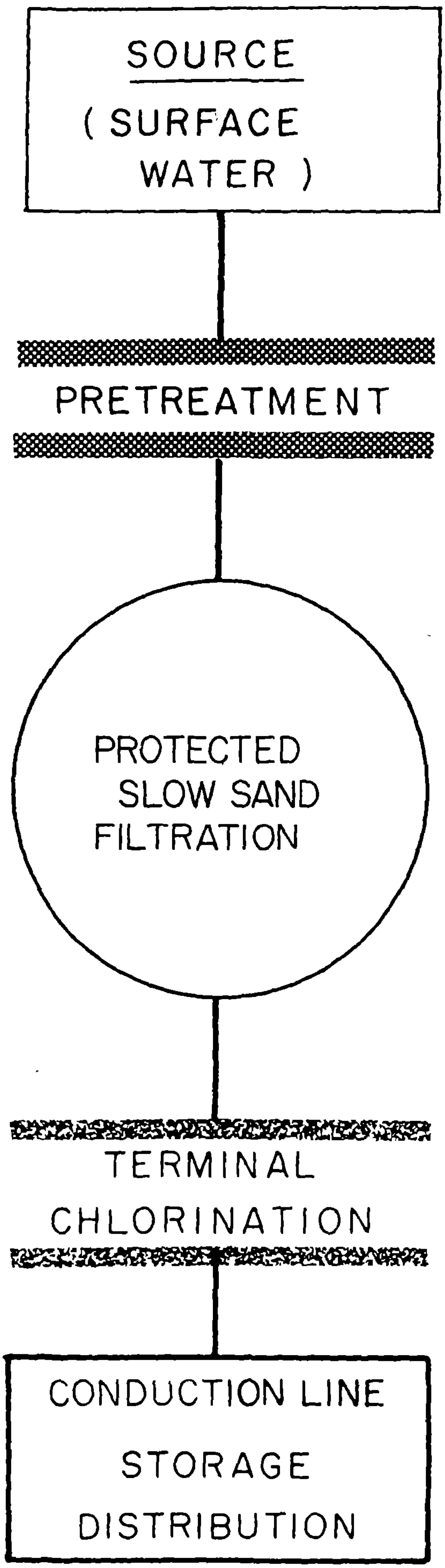


Figure A1 General lay-out

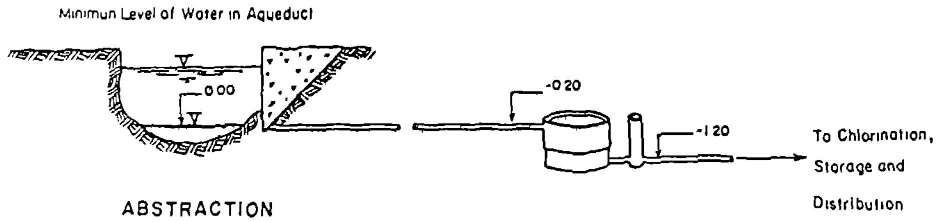


Figure A2 Where turbidity is less than 10 NTU

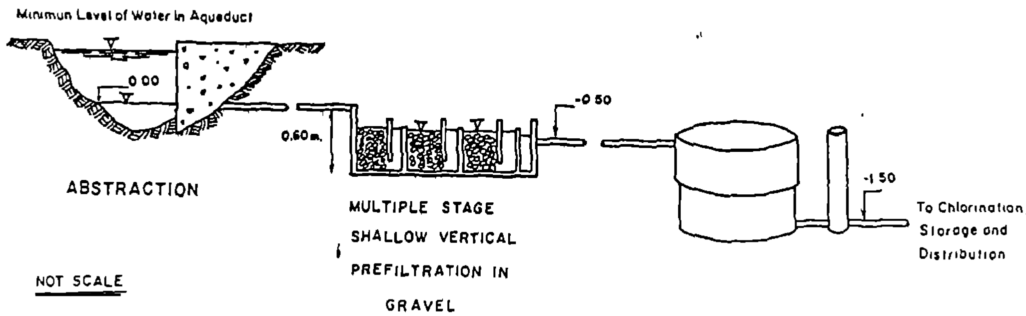


Figure A3 Where turbidity is less than 100 NTU

NOT SCALE

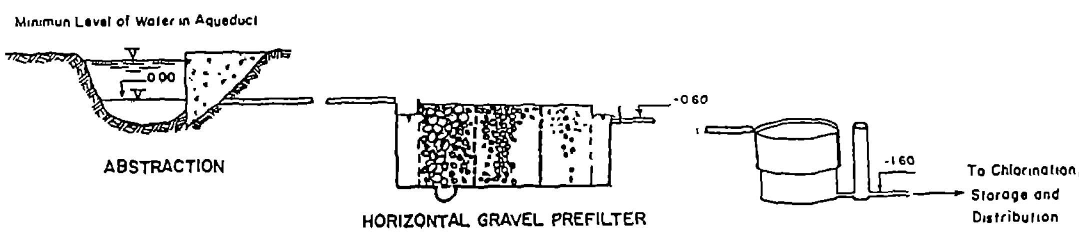


Figure A4 Where turbidity is less than 100 NTU

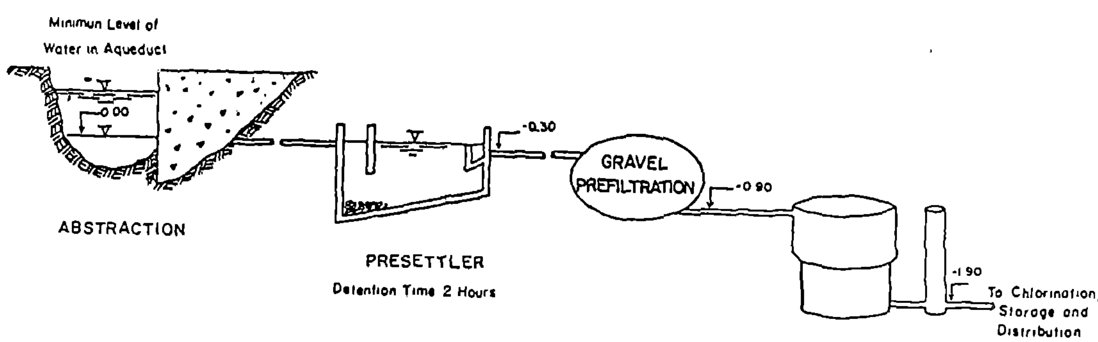


Figure A5 Where turbidity is more than 100 NTU

NOT SCALE

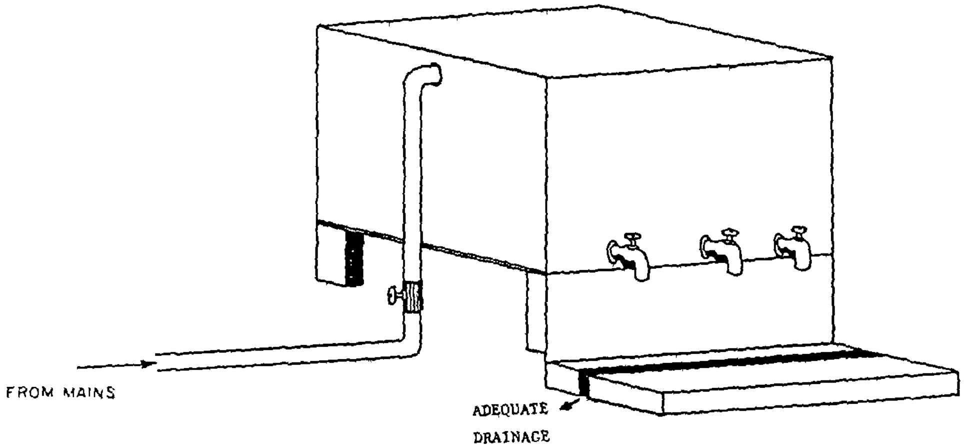


Figure A6 A public water point with storage

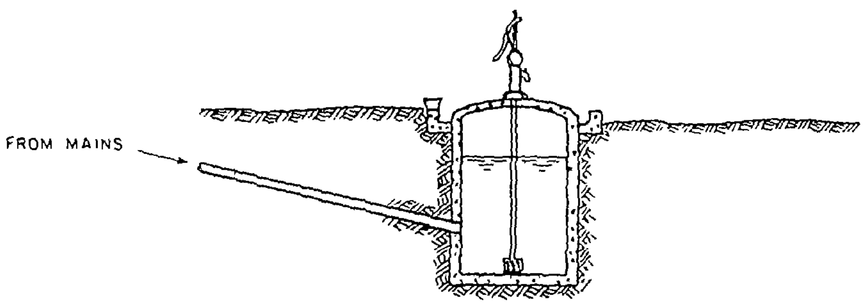


Figure A7 A public water point, storage and silo (for systems with little available head)

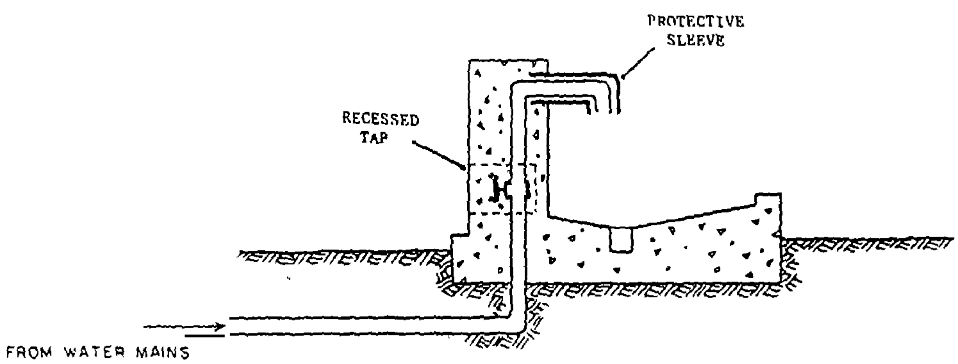


Figure A8 A public standpost

3 DESIGN CRITERIA FOR PSSF

3.1 a. To maintain continuity of water supply during routine maintenance it is essential that a minimum of two filters are installed whatever the size of community. However, the size of community and the per capita consumption of water per day will determine the area of filters required for efficient treatment

To calculate the required filtration area for PSSF, use the relationship below .

$$A = \frac{PCS \times Vol\ PCPD}{Vel \times 2.4 \times 10^4}$$

where : A = Filtration Area Required
PCS = Projected Community Size
Vol PCPD = Litres Per Capita Per Day
Vel = Filtration Velocity (m/h)

3.1.6 For practical purposes, it is unlikely that prefabricated units will be cost effective where filtration area exceeds 6-10 m^2. By using tanks of 2.0 m^2 and a flow rate of 0.3 m/h, a community of 1000 could be supplied by a system of 4 PSSF units providing 50 litres per capita per day. If the same volume of water, but a lower flow rate is preferred (eg to reduce the frequency of cleaning), conventional construction would be more appropriate. The upper limit of feasibility for packaged systems is shown by a broken line in both tables overleaf (---).

Projected community size in 15 years	Filtration velocity (m/h)		
	0.1	0.2	0.3
200	4.2	2.1	1.4
500	10.4	5.2	3.5
1000	20.8	10.4	7.0

Filtration area required for community sizes 200-1000, allowing for a per capita consumption of 50 litres per day.

Another example:

Projected community size in 15 years	Filtration velocity (m/h)		
	0.1	0.2	0.3
200	2.5	1.3	0.9
500	6.3	3.1	2.1
1000	12.5	6.3	4.2

Filtration area required for community sizes 200-1000, allowing for a per capita consumption of 30 litres per day.

RURAL WATER TREATMENT PACKAGE PLANT (R3760)

FINAL REPORT FOR THE UK OVERSEAS DEVELOPMENT ADMINISTRATION

B J LLOYD
M PARDON
D WHEELER

APPENDIX II

INSTALLATION MANUAL

PROTECTED SLOW SAND FILTRATION PACKAGE PLANT

DelAgua, P.O. Box 92, Guildford, GU2 5TQ, England

INSTALLATION

PROTECTED SLOW SAND FILTRATION PACKAGE PLANT

CONTENTS

1. LIST OF COMPONENTS AND REQUIREMENTS

Component number	Component type	Description	Materials	Amount required per PSSF unit
1	FIL	Filter tank	1	1
2	FIL	Filter tank lid	1	1
3	FIL	Filter fabrics (coarse)	2	3
4	FIL	Filter fabrics (dense)	2	3
5	FIL	Fabric mesh	2	1
6	UND	Cross piece	3	1
7	UND	a) Perforated pipe, 1.1/4" or	3	3m
		b) Pipe, class C, 1.1/4"	3	3m
8	UND	Plain cap, 1.1/4"	3	3
9	UND	Plain bush, 1.1/4"	3	1
10	UND	Nipple with extended thread, 1.1/4"	3	0.2m
11	UND	Backnut, 1.1/4"	3	2
12	UND	3mm soft washer	4	4
13	CFD	Ball float, 5"	5	1
14*	CFD	Threaded socket, 2"	3	1
15	CFD	Pipe, class C, 2"	3	0.6m
16	CFD	Pipe, class C, 1.1/2"	3	0.6m
17**	CFD	Pipe, class E, 2"	3	0.2m
18	CFD	Tank connector, 1.1/4"	3	1
19	CFD	Plain elbow, 1.1/2"	3	1
20***	CFD	Concave spacer, 1.1/2"	3/6	2
21***	CFD	Convex spacer, 1.1/2"	3/6	2
22	CFD	3mm soft washer	4	4
23	CFD	Threaded nipple, 1.1/2"	3	1
24****	CFD	Threaded reducing bush, 1.1/2" x 1.1/4"	3	2
25	CFD	Drainage pipe, 6"	3	1.2m
26	CFD	Cap for drainage pipe, 6"	3	2
27	CFD	Tank connector, 3/4"	3	1
28	CFD	Threaded cap & seal, 3/4"	3	1

29	GEN	Three way T valve, 1.1/2"	3/6	1
30	GEN	Y piece connector	3/6	1
31	GEN	Jubilee clip	7	10
32	GEN	Flexible hose	4	10m
33	GEN	a) Inlet valve, 1.1/2" with hose unions, or	3/8	1
		b) Ball valve, 1.1/2"	8	1
34	GEN	Outlet valve, 1.1/2 with hose unions	3/8	1
35	GEN	Tank connector with hose fitting, 1.1/2"	3/6	2
36	GEN	Tank connector, threaded fitting, 1.1/2"	3	2
37	GEN	Threaded cap and seal, 1.1/2"	3	2

KEY

FIL = Filter unit component
UND = Underdrainage component
CFD = Constant flow device component
GEN = General component

* = Modification required for CFD float collar
** = Modifications required for float collar and telescopic seal
*** = Fabrication required
**** = Modification required for CFD outlet hose connection

MATERIALS

1 Medium density polyethylene (black) or equivalent eg GRP
2 Polypropylene, nylon or equivalent
3 UPVC
4 Approved synthetic for contact with drinking water
5 Polyethylene
6 Nylon
7 Alloy
8 Brass

IMPORTANT

When ordering any fittings recommended for PSSF always state that materials must be suitable and approved for intimate and long term contact with drinking water.

Tools requrired for installation

38 Adjustable spanner(s) 5 - 45 mm
39 Medium screwdriver
40 Knife
41 Hacksaw
42 Holesaw set 1.1/2" - 2.1/2"
43 Drill
Solvent cement (100 g) and PTFE tape (10 m)

Tools for fabricating and modifying certain components

44 Files and rasps (or lathe)
45 Stock and die set to include provision for 1.1/4", 1.1/2" and 2" threads
46 Assorted sandpaper

IMPORTANT

To build a complete PSSF system from the components list may require access to workshop facilities. For a typical system comprising abstraction, prefiltration, protected slow sand filtration, storage, distribution and public standposts it would be normal to allow 60 - 70 per cent of costs for water conduction. In this case the costs of protected slow sand filtration using imported materials may be as much as 20 per cent of total costs and 25 per cent of materials costs.

2. CONFIGURATION

2.1 MINIMUM CONFIGURATION : TWO PSSF UNITS

Inlet through A

Connection through B

Common overflow through C

Filtered water outlet D

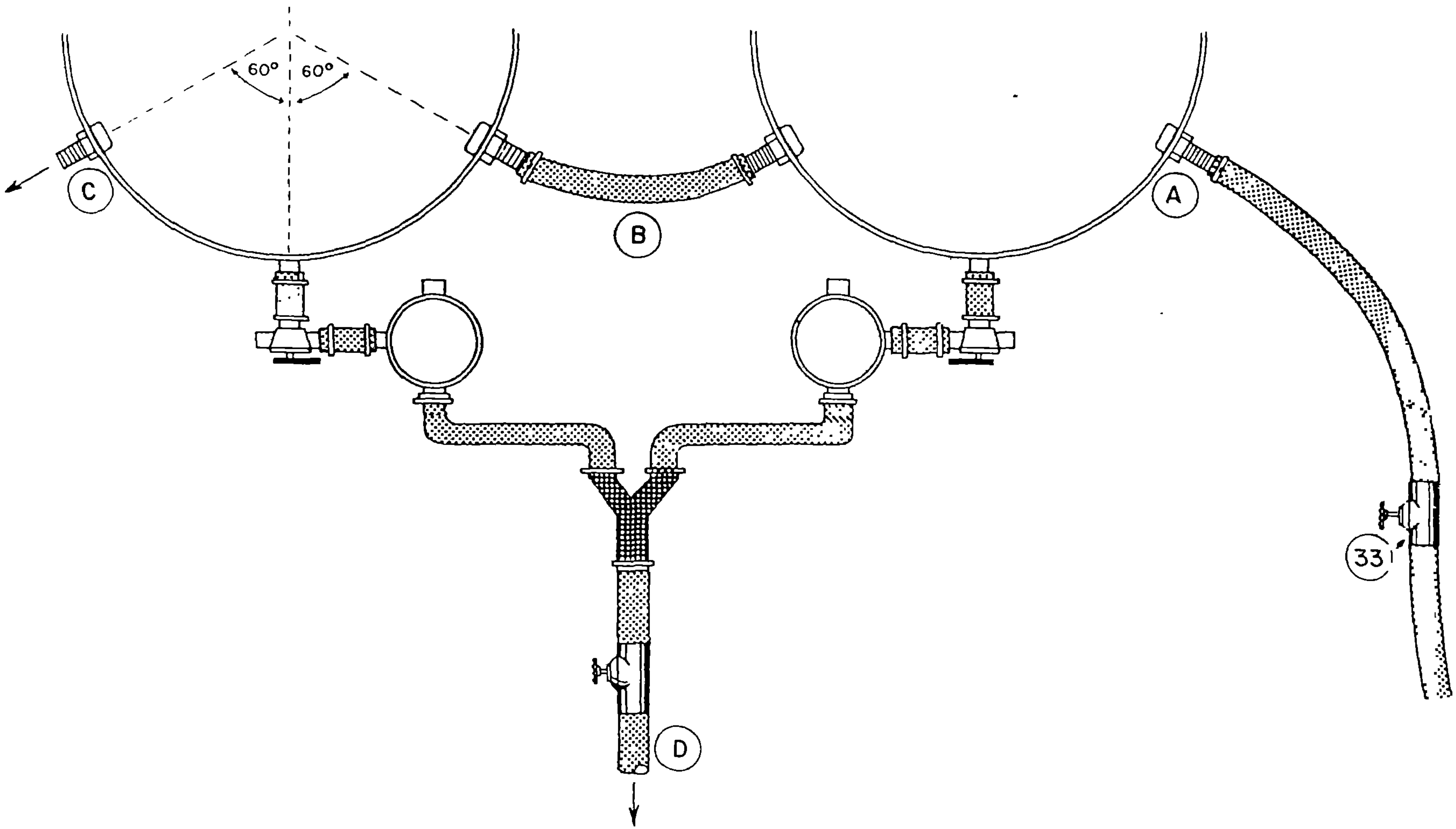


Figure A9 Minimum configuration - PSSF

2.2 THREE PSSF UNITS

Inlet through A

Connections through B

Overflow through C

Filtered water outlet D

Site of possible extra filter E

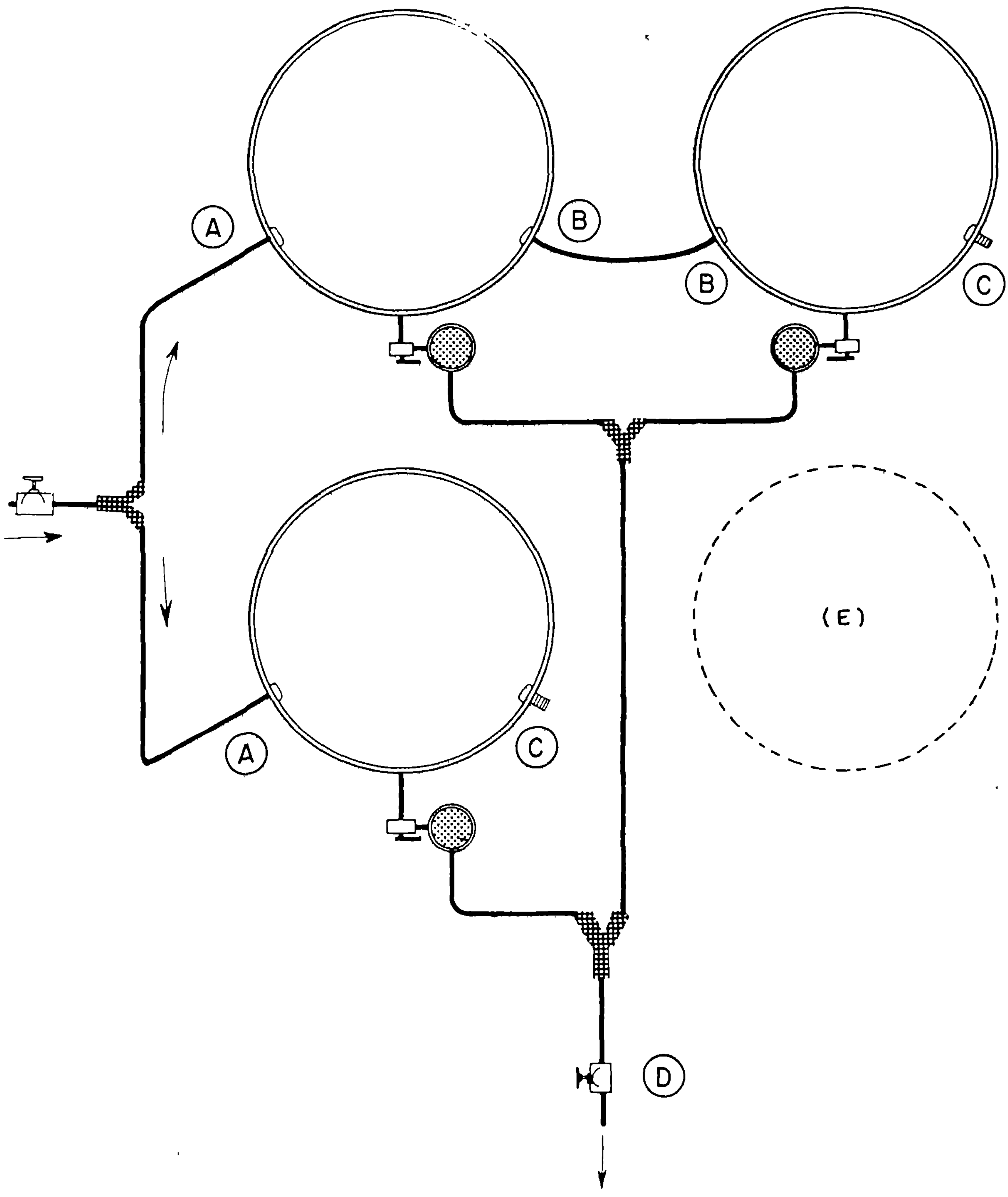


Figure A10 Three PSSF units

2.3 FOUR PSSF UNITS

Inlets through A

Connections through B

Common overflows through C

Filtered water outlet D

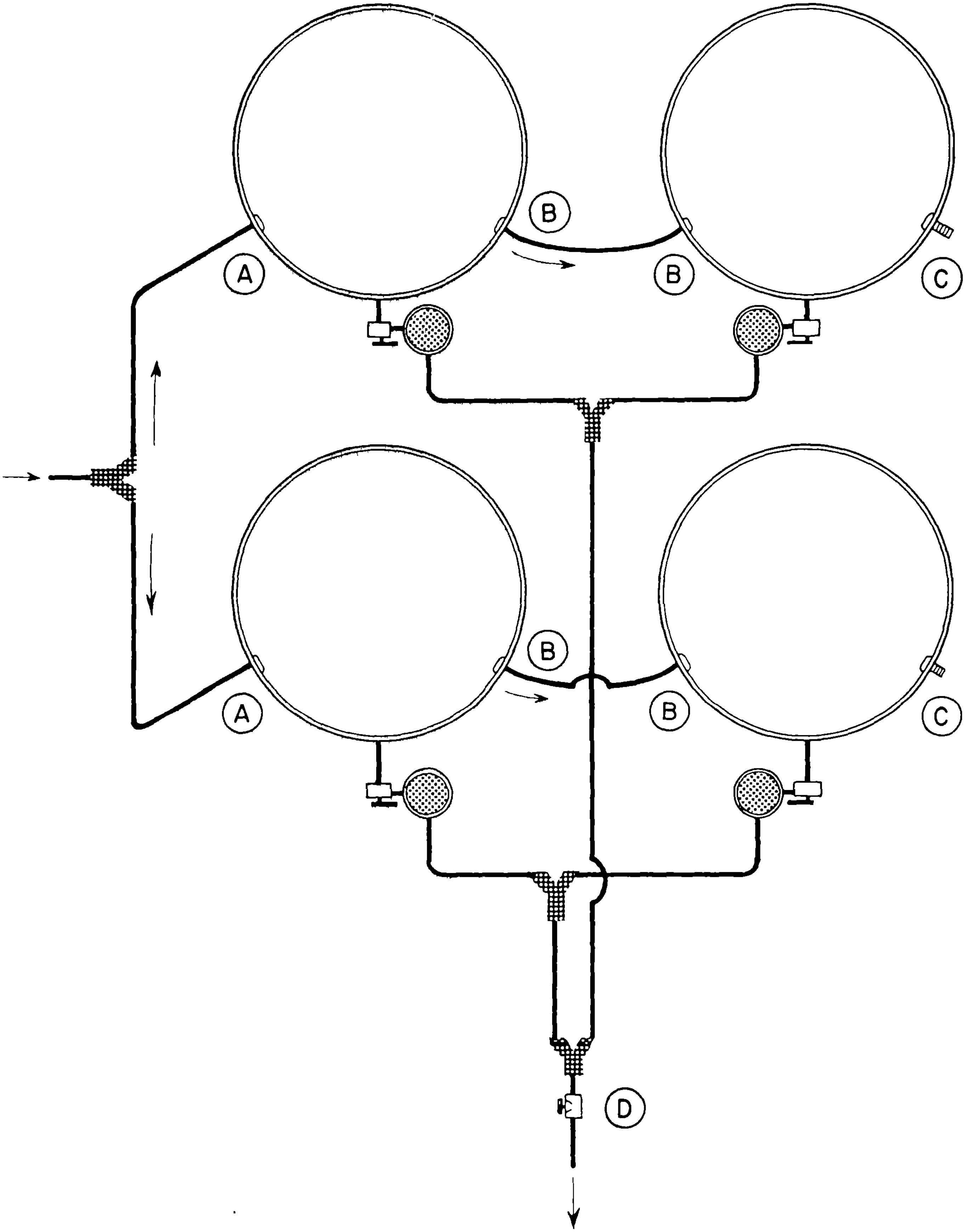


Figure A11 Four PSSF units

3. ASSEMBLY

3.1 Filter Tanks

3.1.a. The filter tanks (1) should be carefully selected. They should be made of materials suitable for intimate contact with water and they should incorporate a ridge to support the filter fabric layers. Assuming such tanks are available and that they are of the requisite dimensions (1.0 - 2.0 m^2 cross sectional area and height of at least 1.2 m), they will require four types of orifice to be cut.

A) Inlet

B) Overflow / Interconnection

C) Backwash overflows (side drains)

D) Underdrainage

3.1.6 Appropriately sized hole saws and a drill (preferably electric) should be used for cutting through polyethylene tanks. For other materials, a drill and rasp may be more appropriate. If in doubt, contact the tank manufacturer. DO NOT cut any holes until the final orientation of the tanks has been determined.

3.1.c. It is advisable to install PSSF units on a concrete plinth with a very slight slope to prevent the ponding of water. An overflow waste channel should be constructed.

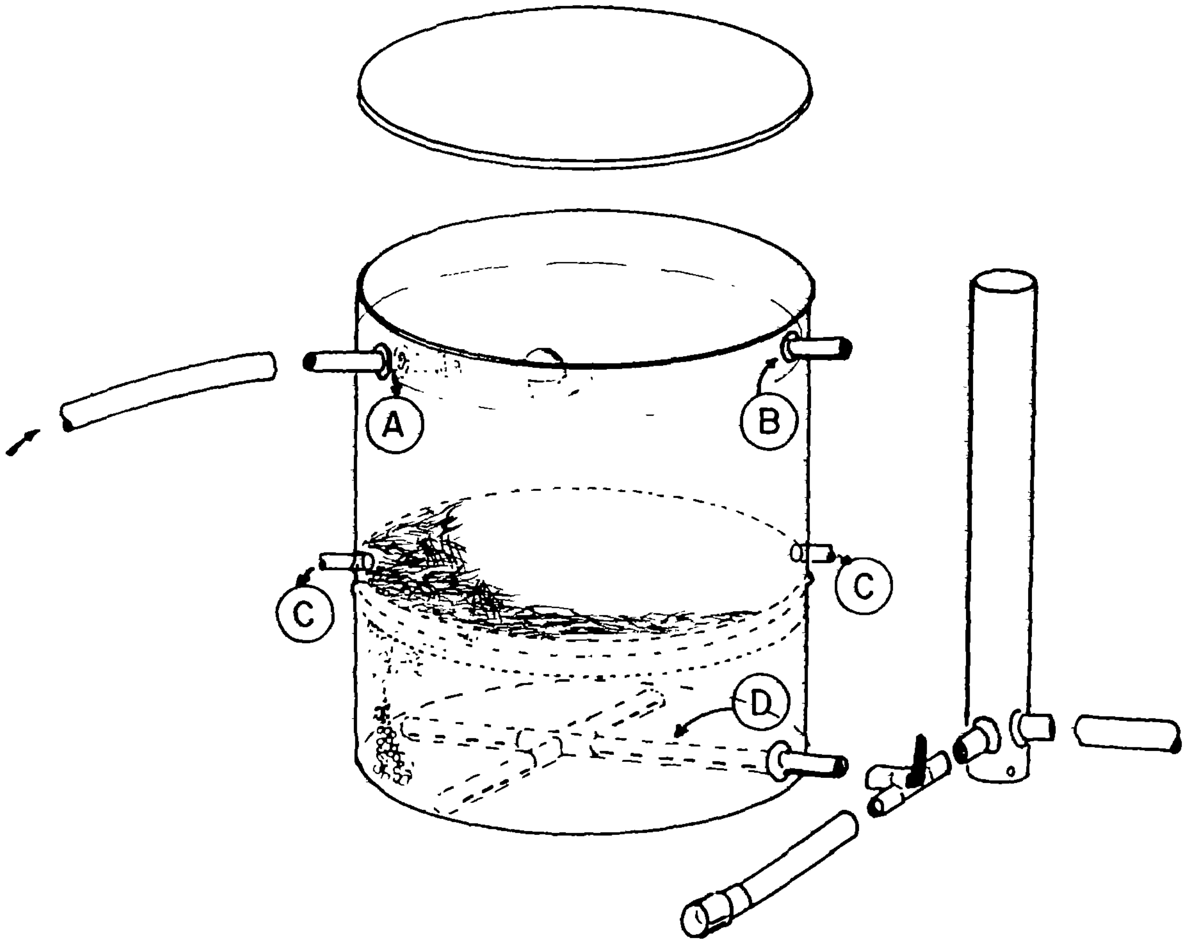


Figure A12 Ports required for PSSF units

3.2 UNDERDRAINAGE

3.2.a. The objective of the underdrainage system is to ensure a uniform and free flow of water through the filter. If perforated or slotted drainage pipe (7) is not available, holes may be drilled in standard UPVC pressure pipe. Select a thickwalled pipe which will remain strong when it has been drilled. Drill 6 mm holes at intervals of 50 mm at an angle of 30 degrees below the horizontal.

3.2.b. An underdrainage 'cross' should be constructed which fits tightly into the base of the filter. The three ends of the cross not leading to the outlet should be capped. Components should not be cemented until all lengths and configurations have been verified. Cut four lengths of perforated pipe (7) and insert them into the cross piece (6). Place caps (8) on three ends of the cross and ensure that the cross fits tight in the filter base.

3.2.c. The arm of the cross leading to the outlet should be cut to allow the bush (9) and threaded nipple (10) to be inserted through the outlet orifice. Ensure that there is sufficient thread on the inside of the orifice to install a backnut (11) and washer(s) and sufficient thread on the outside of the orifice to install a backnut and washer(s) and leave a further 50 mm of thread beyond the backnut for the attachment of hose.

3.2.d. When the underdrainage configuration is verified as satisfactory, and a perfect seal can be made at the orifice, the caps (8) may be cemented onto the blank ends of the perforated pipe. Ensuring that all drainage holes are oriented downwards, cement the perforated pipe sections into the cross piece (6).

3.2.e. Arrange the bush (9), nipple (10) and internal backnut (11) and washer(s) (12) in position, and cement the under drainage cross to the outlet assembly. Leave the cemented components for at least one hour before tightening the underdrainage cross in place. Use one or two washers on both sides of the tank to ensure a perfect seal at the outlet orifice. Do not overtighten backnuts.

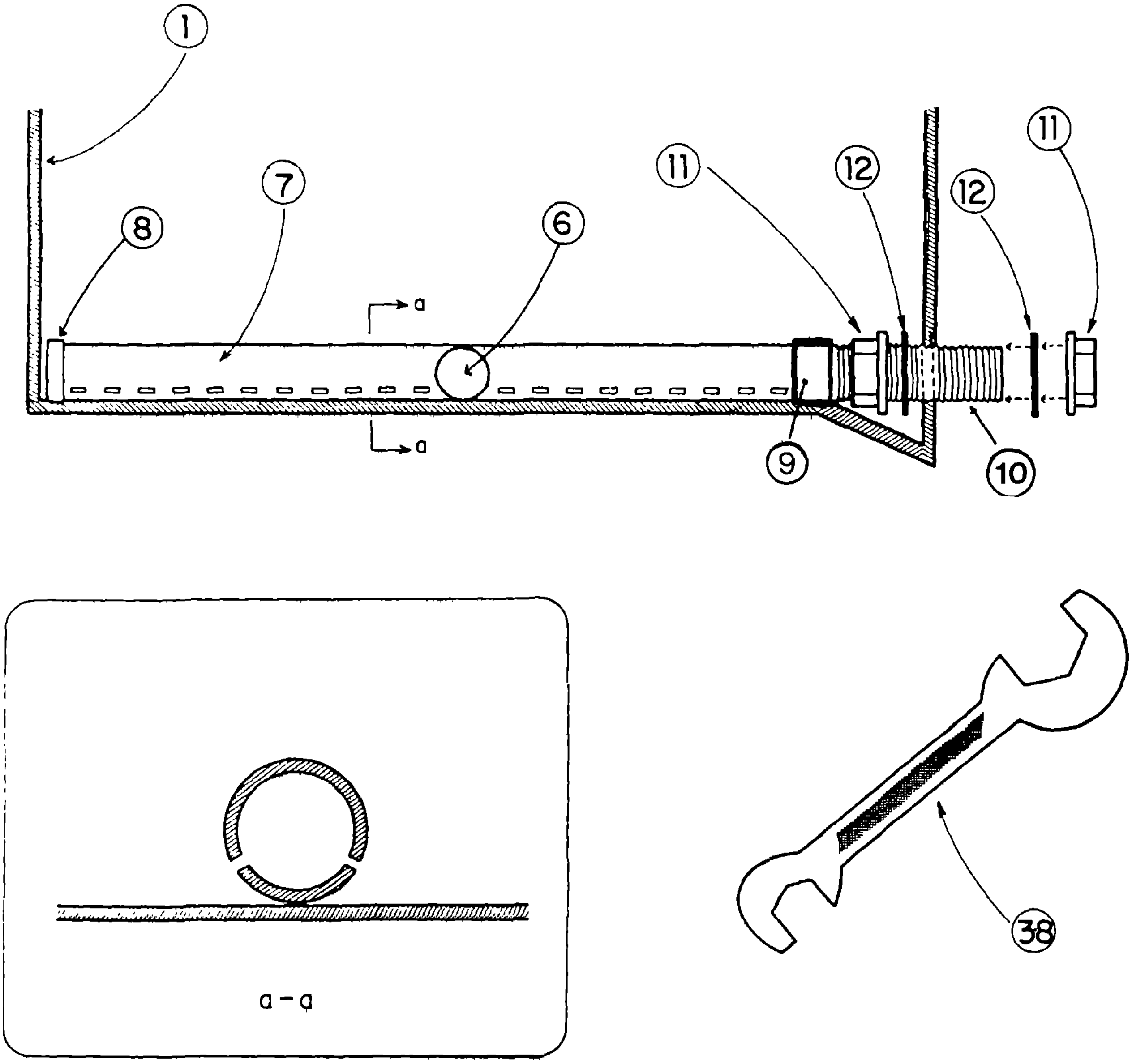


Figure A13 Underdrainage assembly

3.3 TANK CONNECTORS

3.3.a. Two types of tank connector are recommended for inlets and overflows to the PSSF unit. The first ends in a hose fitting (35). If a ball valve is not used to control the flow into the tank(s), this type can be used both for the inlet (A) and top overflow (B) or interconnection to an adjacent tank. The second ends in a screw thread (36) to enable a screw cap and seal to be fitted (37). This type is preferred for the backwash overflow ports or side drains (C).

3.3.b. If a ball valve is not fitted to the inlet (A), install two tank connectors (35) with hose fittings pointing out of the filter. Ensure that a washer is on the inside of the tank and that the backnut is tightened firmly. Do not overtighten the backnut - this may distort the washers.

3.3.c. Install the two tank connectors with threaded fittings (36) in the backwash overflow ports (side drains, C). Ensure that a washer is on the inside of the tank and that the backnut is tightened firmly. Do not overtighten. Install the threaded caps and seals (37).

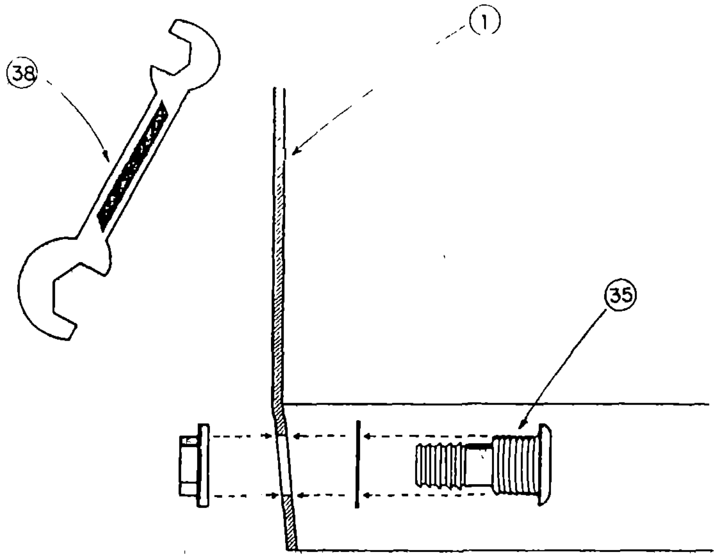


Figure A14 Tank connector with hose fitting

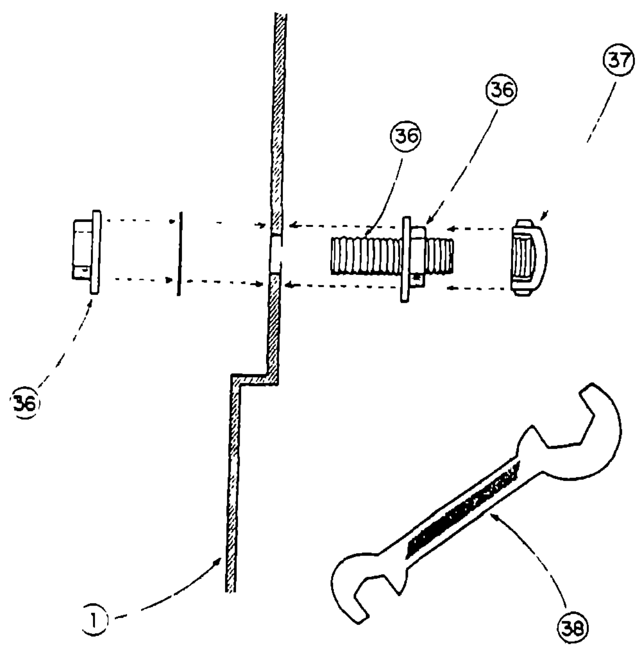


Figure A15 Tank connector with cap and seal

3.4 THREE WAY T VALVE

3.4.a. The T valve (29) allows the filter to be drained, shut off, backfilled, or operated normally by directing flow to the constant flow device.

3.4.b. Cut an adequate length of flexible hose (32). 150 or 200 mm should be sufficient.

3.4.c. Slip two jubilee clips (31) onto the hose and connect the threaded portion of the filter underdrainage outlet assembly (10) to the T valve. Secure the connections by tightening the jubilee clips firmly.

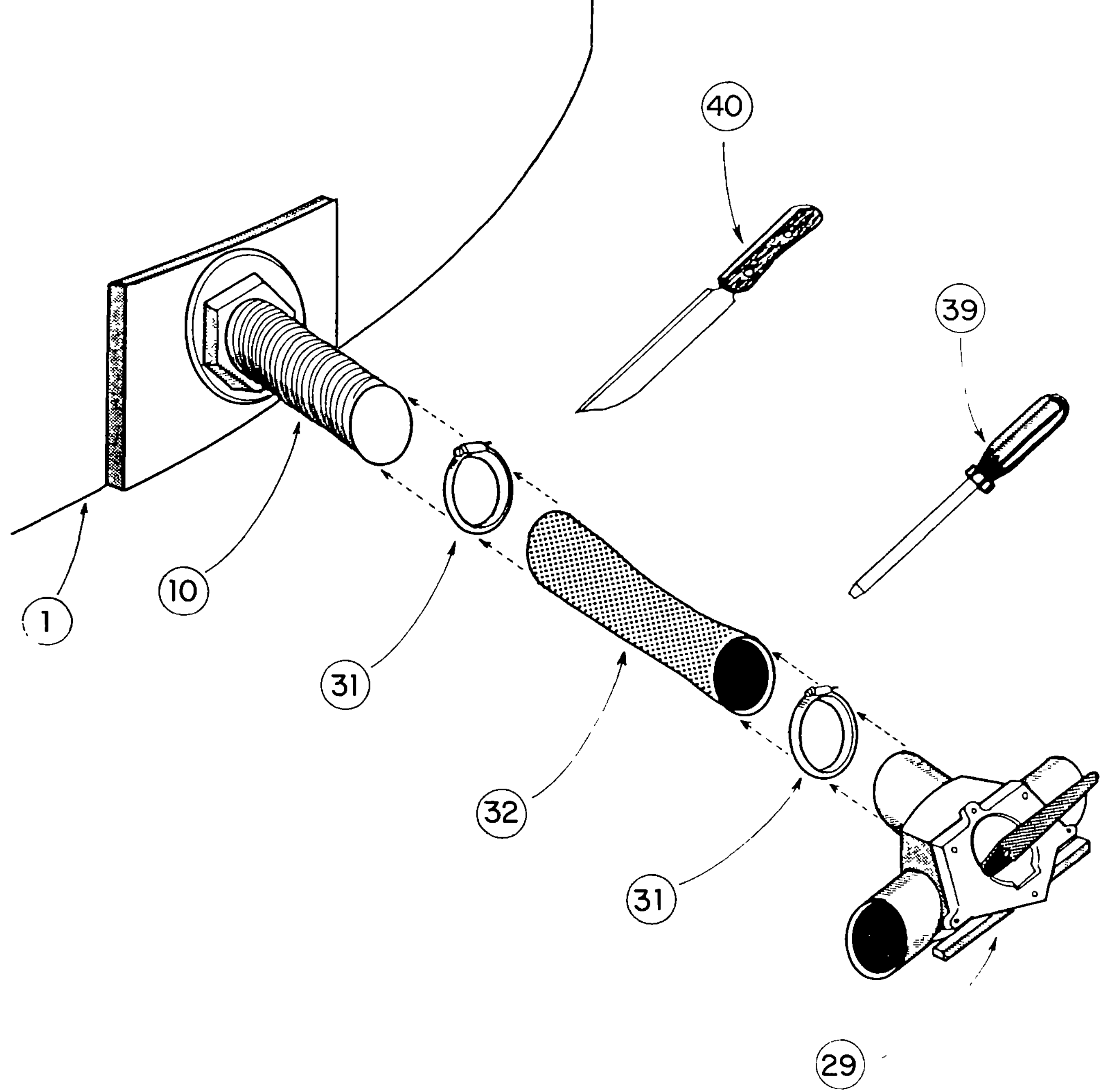


Figure A16 Outlet assembly

3.5 CONSTANT FLOW DEVICE (CFD)

3.5.a. The CFD is designed to provide a constant flow from the filter throughout filtration runs. A CFD can be constructed from standard plumbing fittings (components 13-28). However, the components need careful assembly and in some cases modification. It may be advisable to obtain the services of a competent workshop technician before trying to construct a CFD. The principle has been applied successfully for heads of water up to 1.2 m.

3.5.b. Cut an adequate length of flexible hose (32). 150 or 200 mm should be sufficient.

3.5.c. Slip two jubilee clips (31) onto the hose and connect the appropriate side of the T valve (26) to the CFD inlet (18). Secure the connections by tightening the jubilee clips firmly.

3.5.e. Assemble the 'floating weir' of the CFD by screwing the float collar (14) onto the telescopic tube (15). Do not tighten.

3.5.f. The cap for the drainage pipe (26) forms the base for the CFD. The cap must be set in concrete with the drainage pipe (26) perfectly vertical to ensure the proper functioning of the 'floating weir'.

3.5.f. Carefully slide the telescopic tube (15) onto the internal tube (16) of the CFD. Do not drop the telescopic tube into position.

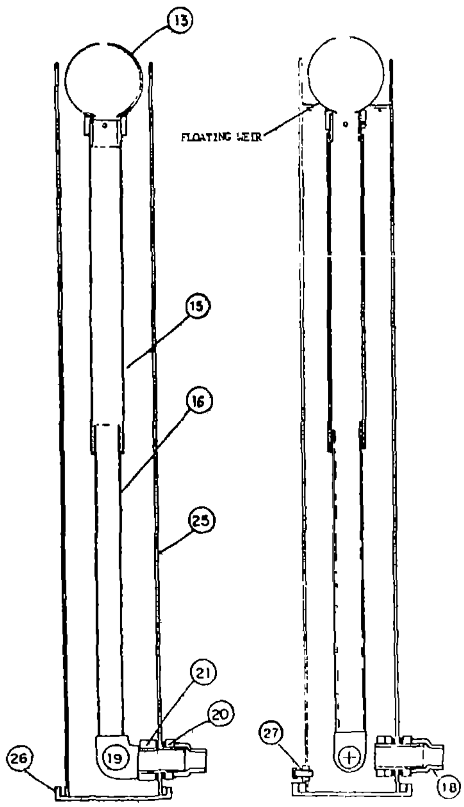


Figure A17 Constant flow device construction

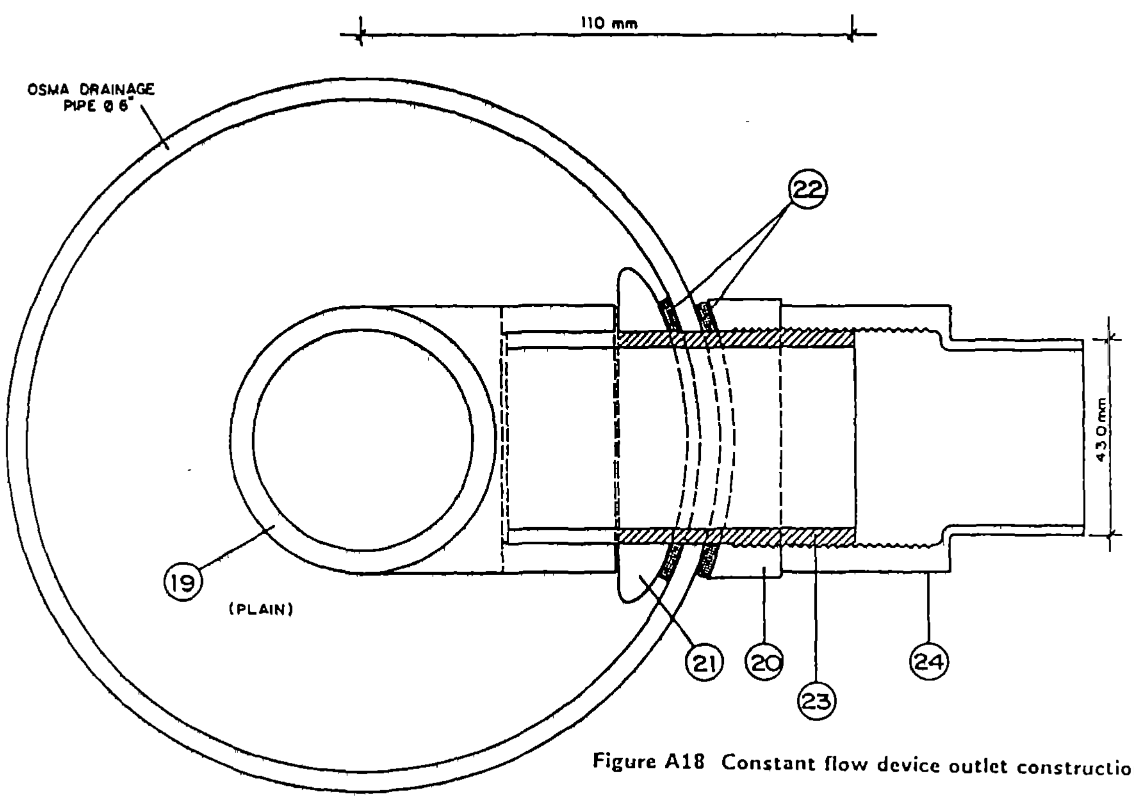


Figure A18 Constant flow device outlet construction

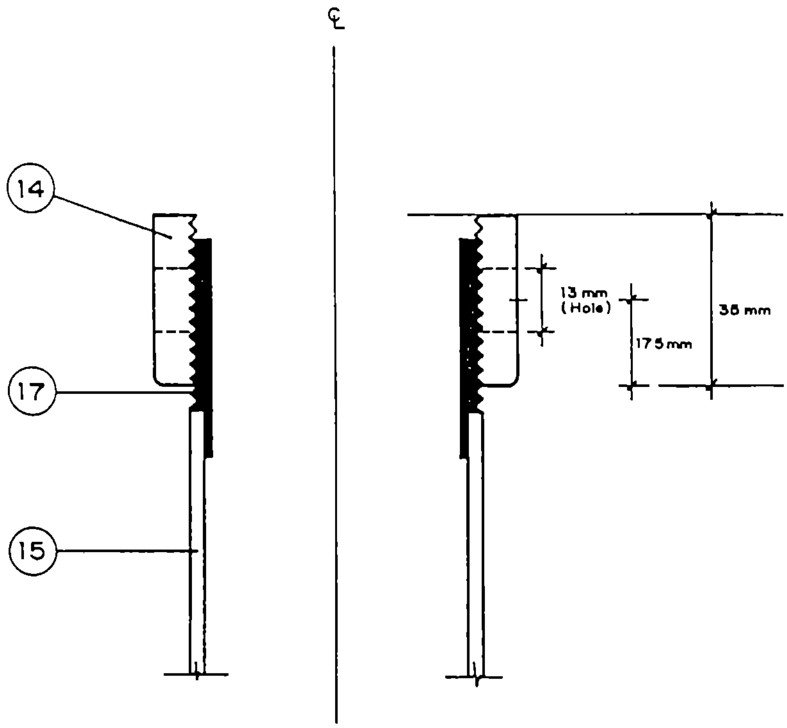
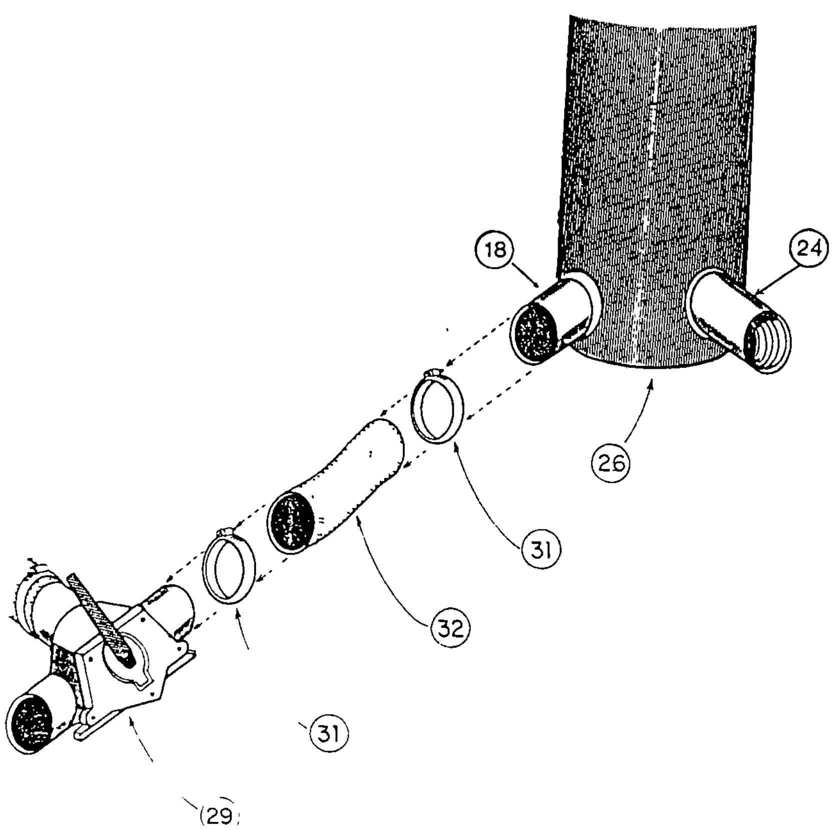


Figure A19 Constant flow device collar construction



3.6. INLET AND OVERFLOW CONNECTIONS

3.6.a. These connections allow the system to function with a single overflow and ensure that water of similar quality flows to all PSSF units simultaneously.

3.6.b. If a ball valve is not installed at the principal inlet (A), simply connect the inlet hose to the appropriate tank connector (35). Secure with a jubilee clip (31).

3.6.c. Cut an adequate length of hose to join the interconnecting outlets or overflows (B) between filters. Secure onto the tank connectors (35) with jubilee clips (31). Do not use an excessive length of hose and avoid letting the connecting tube hang in a fashion which might cause blockages or airlocks.

3.6.d. If a ball valve is not used to control flow at the principal inlet, there will be a constant overflow from the PSSF system. This should be directed away from the units and into a drainage channel leading to irrigation. This is accomplished by connecting a few metres of flexible hose to the selected overflow port (B) and directing excess water into the drainage channel. Secure the overflow hose with a jubilee clip.

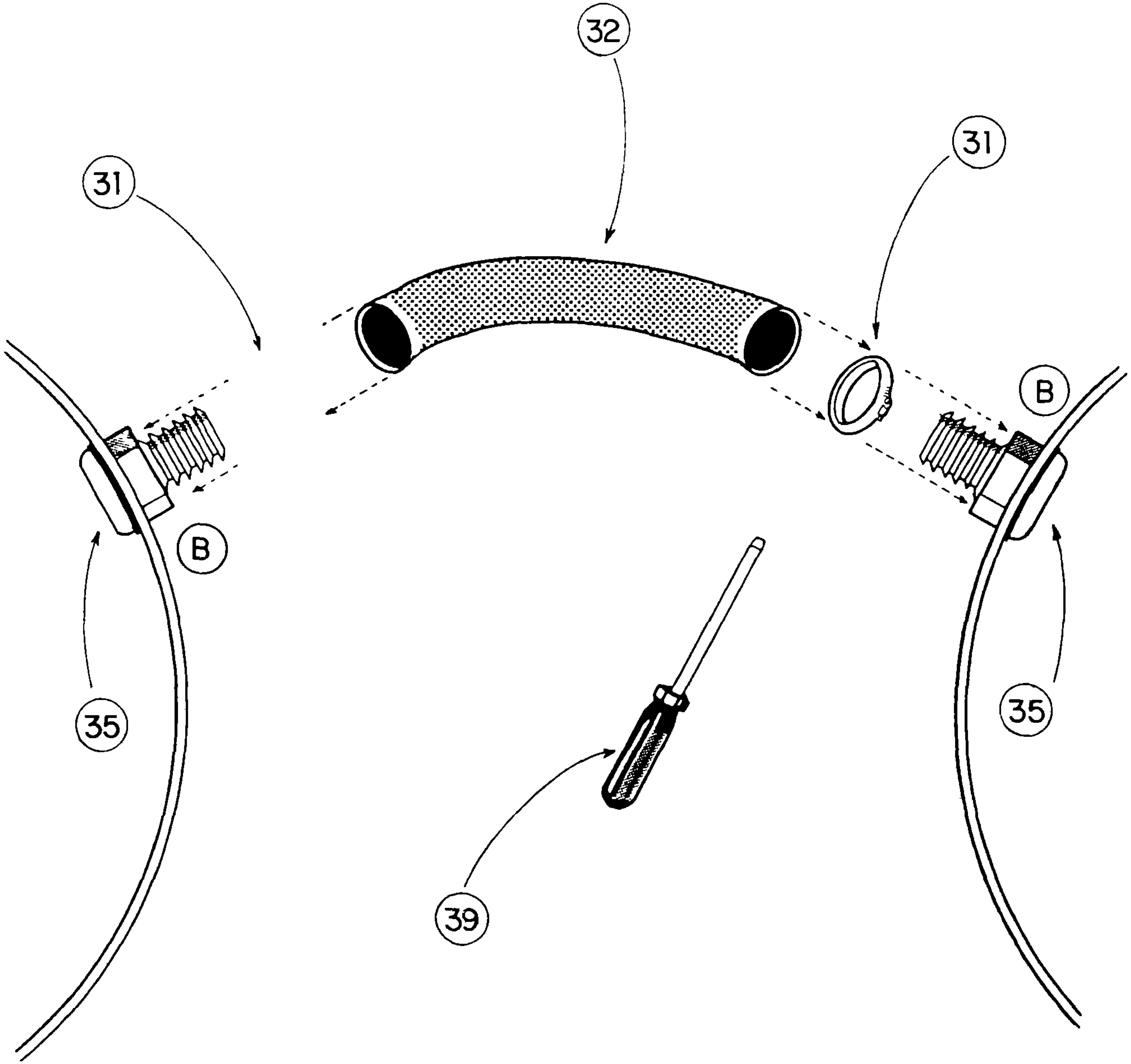


Figure A21 Inlet and overflow assembly

3.7. TREATED WATER OUTLET CONNECTIONS

3.7.a. These connections allow the system to function normally, joining the flows from several PSSF units into a common treated water outlet. They also allow the backfilling of a recently cleaned unit with filtered water from adjoining units.

3.7.b. Cut sufficient length of flexible hose (32) to connect the CFD outlets (24) from two PSSF units to a common Y piece (30). Secure with jubilee clips (31).

3.7.c. Cut a short length of hose (150 mm should be adequate) and connect the outlet from the Y piece (30) to the outlet control valve (34). Secure with jubilee clips (31).

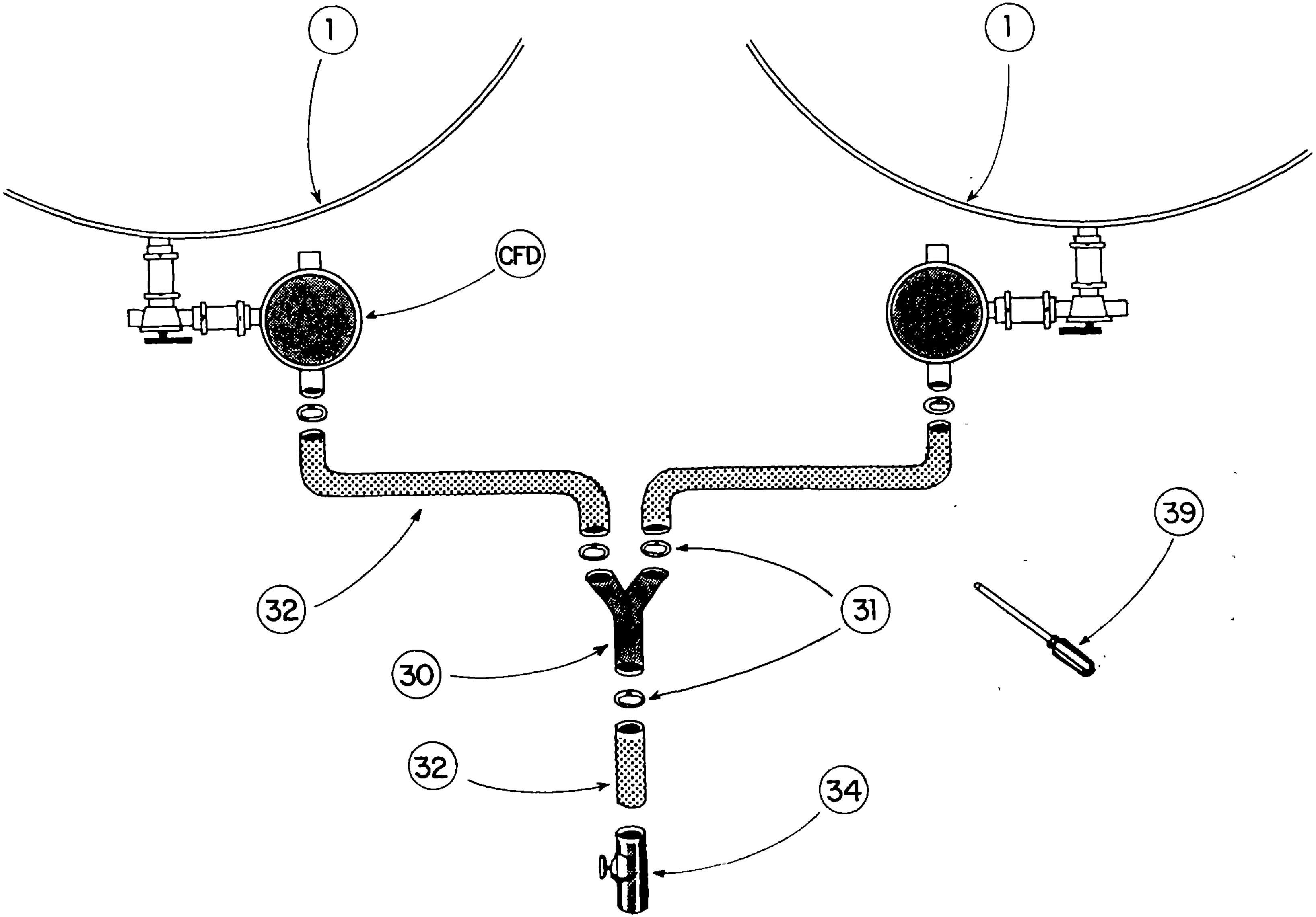


Figure A22 Common treated water outlet assembly

3.8. FILTER BED SUPPORT MEDIUM

3.8.a. It is essential to install a layer of gravel in the base of the filter to act as a support for the sand bed and to prevent blockage of the underdrainage.

3.8.b. Carefully place coarse gravel (20 - 40 mm diameter) around the underdrainage cross until it is completely covered. The overall depth of this layer should then be 50 - 60 mm.

3.8.c. Carefully spread pea gravel or shingle (6 - 10 mm diameter) over the first layer to a further depth of 60 - 80 mm. The underdrainage and sand bed support is now complete.

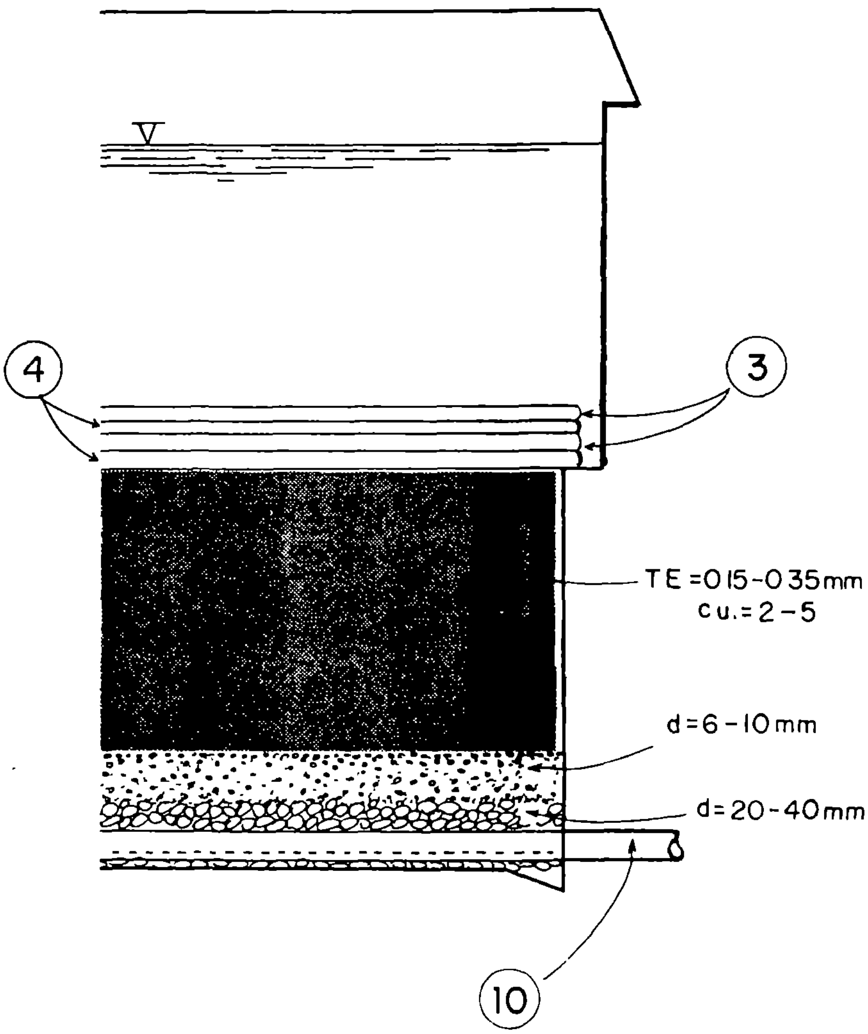


Figure A23 Filter media

TE = Ideal Effective Size
cu = Ideal Coefficient of Uniformity
d = Diameter

3.9. FILTER SAND

3.9.a. The careful installation and preparation of the sand bed is the key to effective biological treatment in the PSSF unit. It is no longer considered essential to use very carefully graded sand, but care must be observed in the selection of the medium. The sand should not be too fine - this will block too quickly. The sand should be relatively uniform and coarse - a good quality builder grade sand is often ideal. Some marine sands are perfectly acceptable after several days washing to remove salts. If there is any doubt about the suitability of a particular sand type, the grain size profile can be determined very simply using a set of grading sieves.

3.9.b. The key criteria for sand intended for slow sand filtration are that the medium should be relatively coarse (the sieve size which retains 10 per cent by weight should be between 0.15 and 0.35 mm), and it should be relatively uniform in size (the ratio of sieve size passing 60 per cent by weight to the sieve passing 10 per cent by weight should not exceed a factor of 2). These criteria are expressed as the Effective Size ($P_{10\%}$) and the Coefficient of Uniformity ($P_{60\%} \div P_{10\%}$). The procedure for defining these values depends on a granulometric size analysis by weight.

i Select a representative sand sample of at least 200 g and preferably 500 g from the sand source.

ii Dry the sample in a clean container overnight in a hot air cabinet or oven.

iii Break up the dried sample into individual particles.

iv Weigh the sample.

continued overleaf

v Clean and weigh each of a series of soil grading sieves in the size range 0.1 - 2.0 mm. A minimum of six sieves should be used. Weigh to an accuracy of ±0.1 g and record the results.

vi Assemble the sieves in a stack with the coarsest at the top and the finest at the bottom. Place the stack in a clean pre-weighed container which will catch any fine particles which pass all sieves.

vii Place the dried and separated sand sample into the top of the sieve stack and shake the stack by hand for five minutes using a vigorous circular motion. Take care not to lose any of the sample.

viii When the sample is thoroughly distributed between sieves, carefully separate the stack and re-weigh each sieve with its retained sand. Weigh to an accuracy of ±0.1 g and note the results. Also weigh the fine particles which have passed through all sieves.

ix Subtract the results of viii from the results of v to obtain the weight of sand retained by each sieve. Ensure that the total matches the original total weight of the sample.

x Express the weight retained on each sieve as a percentage of the total original weight and list the total cumulative percentage of total sand weight passing each sieve. Plot the cumulative percentages on a graph similar to that overleaf.

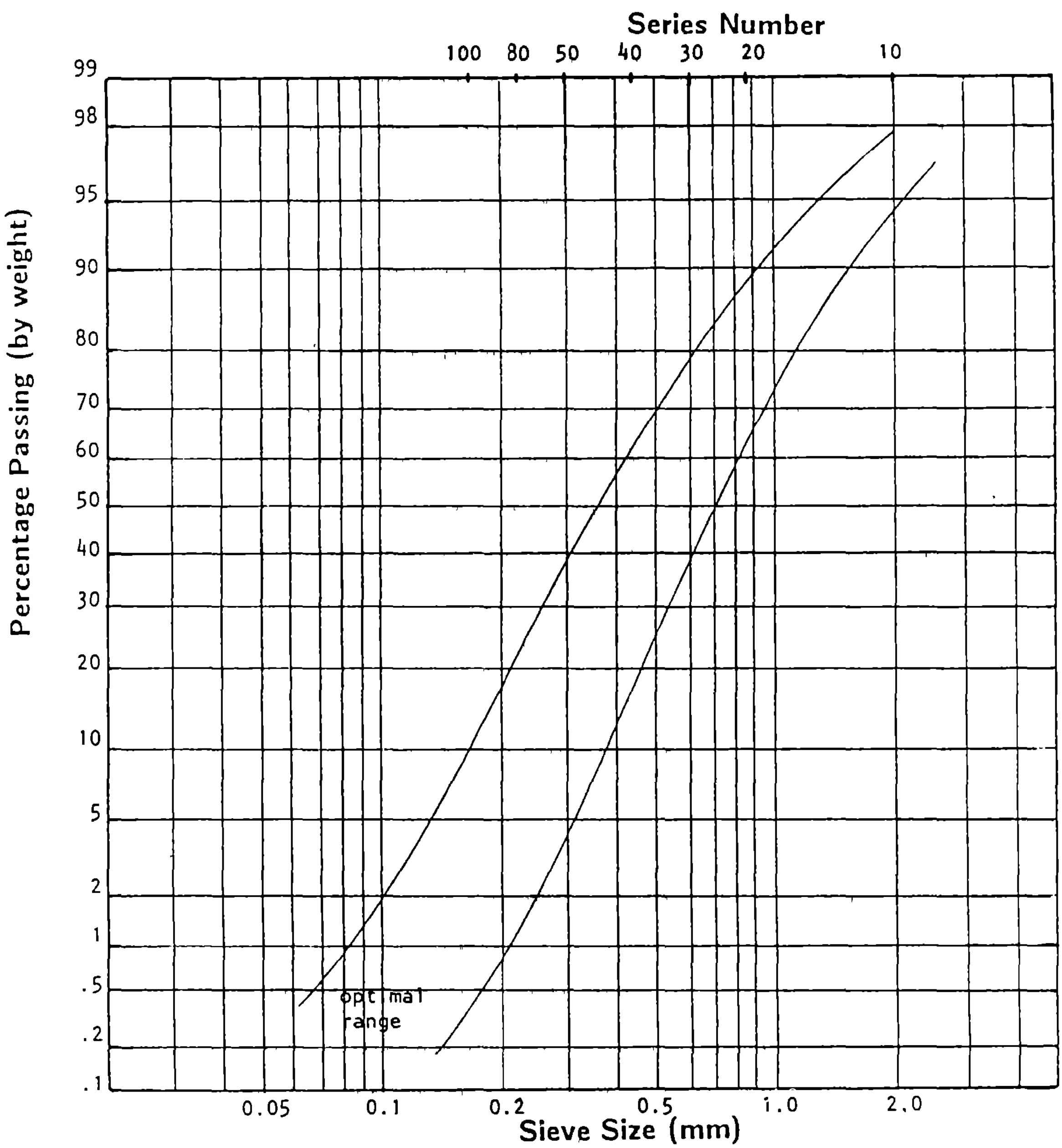
3.9.c. Introduce the best quality sand available into the filter to a level 50 mm above the filter fabric support ridge.

3.9.d. Refer to the operation and maintenance manual for details of cleaning the sand in situ. It may be noted that following washing the sand should have a silt content of less than 3% by volume in the 5 minute settling test.

Figure A24 Sand analysis for PSSF units

District.......................... Sample by.......Date........

Source .... Analysed by.....Date........



Sand Particle Analysis: $P_{10\%}$.....mm $P_{60\%}$.....mm C.U.=$P_{60\%}/P_{10\%}$ ....

Silt Contents (5 min. test) ....%

Observations ....

....

....

Range	Effective Size, mm P 10%	Coefficient of Uniformity C.U.
Desirable	.15-.35	<2
Maximum	.10-.45	<3

3.10. FILTER FABRIC

3.10..a. Filter fabrics provide protection for the sand bed, extending filter run lengths and improving biological efficiency.

3.10.b. After the sand bed has been thoroughly cleaned, it should be remixed with a spade. Then, three layers of coarse fabric (3) and three layers of more dense fabric (4) should be installed in alternating layers. A dense layer should be next to the sand bed and a coarse layer should be at the top of the fabric pile.

3.10.c. Fabrics should be anchored in place with a suitable frame of non-degradable mesh (5).

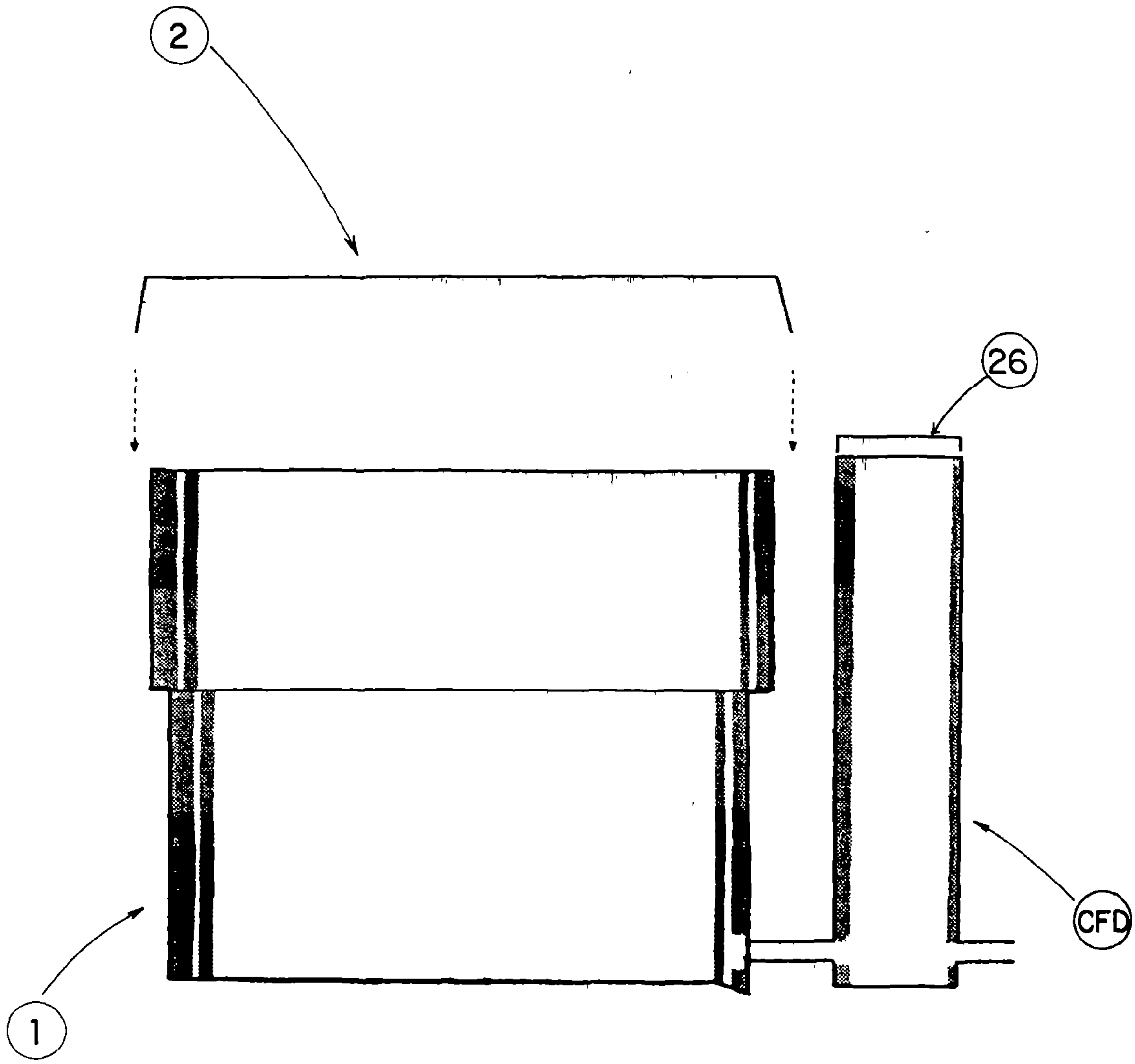


Figure A25 Lids for PSSF unit and flow controller

3.11 LIDS

3.11.a. Lids for the PSSF unit (2) and constant flow device (26) prevent the ingress of contaminants. By excluding light, they also prevent the proliferation of undesirable algal species in the water.

3.11.b. Lids should be installed as soon as possible after initial commissioning of the PSSF unit. Make sure that lids cannot be displaced by children, animals, or adverse weather conditions.

3.12 SECURITY

Always build a strong wall or fence around a PSSF installation. The protection should be at least 2 m high to prevent interference by children or animals. The entrance or gate to the installation should be kept locked at all times, and the keys lodged with at least two responsible persons.

4. LIST OF SUPPLIERS

1. Suppliers of complete PSSF systems
   Potapak Ltd., Longacre, London, UK.

2. Suppliers of all UPVC fittings, plumbing parts, etc.
   Capper Plastics Ltd., Horsham, Sussex, UK.

3. Suppliers of nylon components (29, 30, 35)
   Munster Simms Ltd., Belfast, N.I.

4. Suppliers of MDPE tanks (1)
   WCB Roto Mouldings Ltd., Stalybridge, Lancs, UK.

5. Suppliers of filter fabric (3, 4)
   Earlys of Witney Ltd., Witney, Oxon, UK.

6. Suppliers of flexible hose (32)
   Griflex Creators Ltd., Woking, Surrey, UK.

7. Components possibly requiring raw material for fabrication
   5, 20, 21.

8. Suppliers of general laboratory equipment
   ELE International Ltd., Hemel Hempstead, UK.

For further details of suppliers etc please contact DelAgua

RURAL WATER TREATMENT PACKAGE PLANT (R3760)

FINAL REPORT FOR THE UK OVERSEAS DEVELOPMENT ADMINISTRATION

B J LLOYD
M PARDON
D WHEELER

APPENDIX III

OPERATION AND MAINTENANCE MANUAL
PROTECTED SLOW SAND FILTRATION PACKAGE PLANT

DelAgua, P O Box 92, Guildford, GU2 5TQ, England

OPERATION AND MAINTENANCE

PROTECTED SLOW SAND FILTRATION PACKAGE PLANT

CONTENTS

1. GENERAL POINTS

1.1.a. Slow sand filtration is largely a biological process. For maximum efficiency, low, constant flow rates (0.1 to 0.3 m/h) and uninterrupted continuity of operation ie filter runs of at least four weeks, are essential. Short filter runs caused by premature blockage render the process inefficient.

1.1.b. It is assumed that the operator has an understanding of the basic process and has a packaged protected slow sand filtration plant with at least two PSSF units comprising all of the components listed in the installation manual.

1.2 OPERATIONAL FEATURES OF THE CONSTANT FLOW DEVICE (CFD)

1.2.a. The constant flow device has been designed to perform the following functions:

i) regulate flow;
ii) avoid the need for flow measurement;
iii) avoid the need for daily adjustment of flows to compensate for filter blockage;
iv) notify the operator of daily head loss increases in order to plan maintenance;
v) maintain a minimum overflow level to avoid accidental drainage of the filter with consequent damage to active biological mechanisms;
vi) allow for interconnection of PSSF units to enable backfilling with treated water;
vii) aerate the water leaving the PSSF unit.

The position of the assembly at the beginning of a filtration run is illustrated. As the filter run progresses and the sand bed blocks, the float will descend to the position shown . The time taken to reach this position is dependent on raw water quality and filtration velocity. For a well operated filter, a normal run should last at least 4 - 16 weeks. Shorter runs indicate the need for more pretreatment.

1.2.b. A close inspection of the float design shows a constant head of water (h) over the outlet orifices in the telescopic tube (15). Thus the flow of water through these orifices should always remain the same (± 10 per cent allowing for a small amount of leakage at the telescopic seal).

BEGINNING AND END OF FILTER RUN

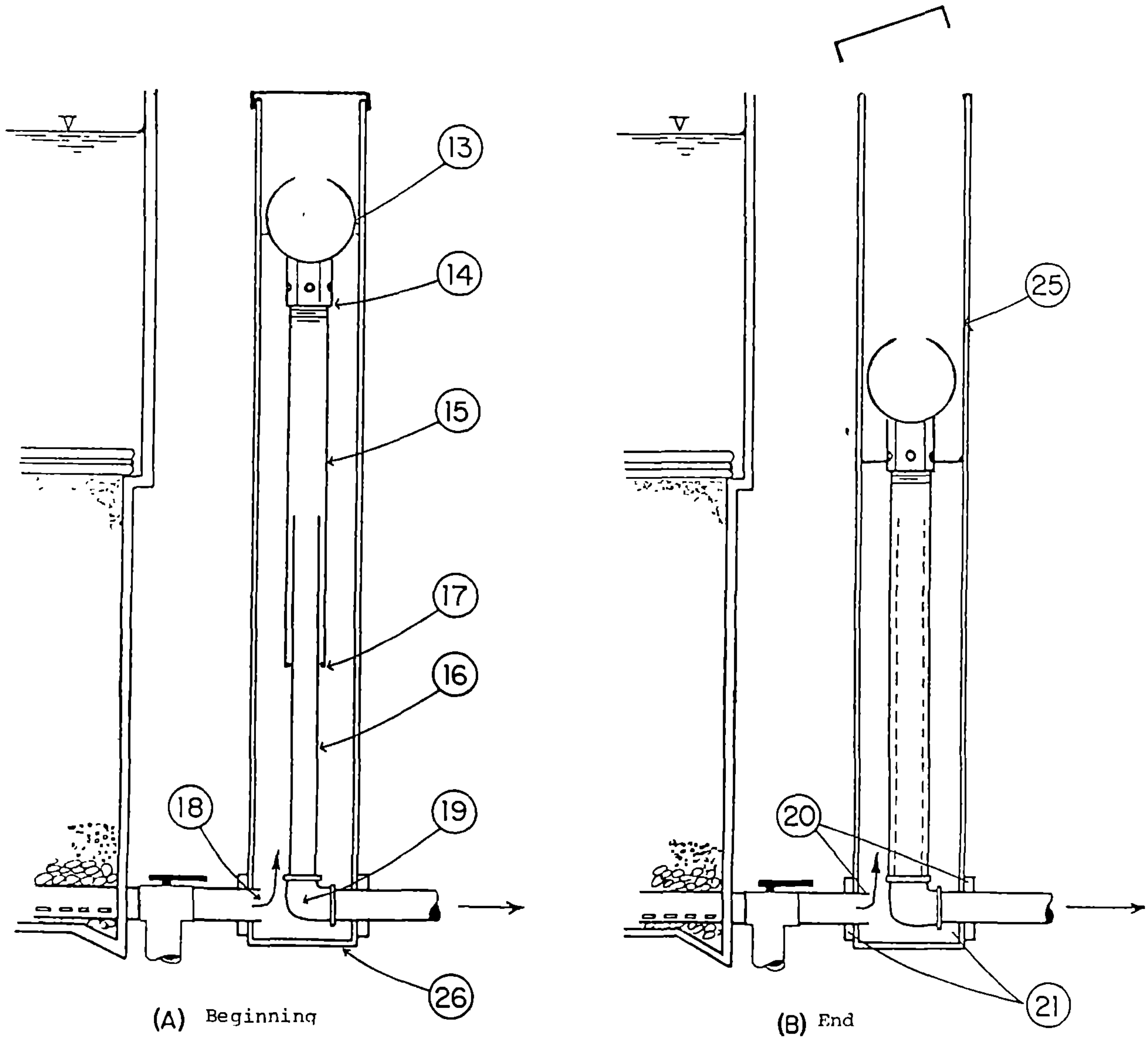


Figure A26 Constant flow device operation

1.2.c. Filtration velocity is calibrated by altering the aperture of the orifices in the telescopic tube and floating weir. This is effected by turning the collar around the tube. The amount of water leaving the constant flow device can be measured using a graduated cylinder and stop watch. Given that the internal cross sectional area of the filter is known, the filtration velocity can be calculated using the following relationship.

$$V = \frac{\text{Volume of Water (litres)}}{\text{Time Recorded (secs)}} \times \frac{3.6}{\text{Filtration Area (m}^2\text{)}}$$

where V = Filtration velocity (m/h)

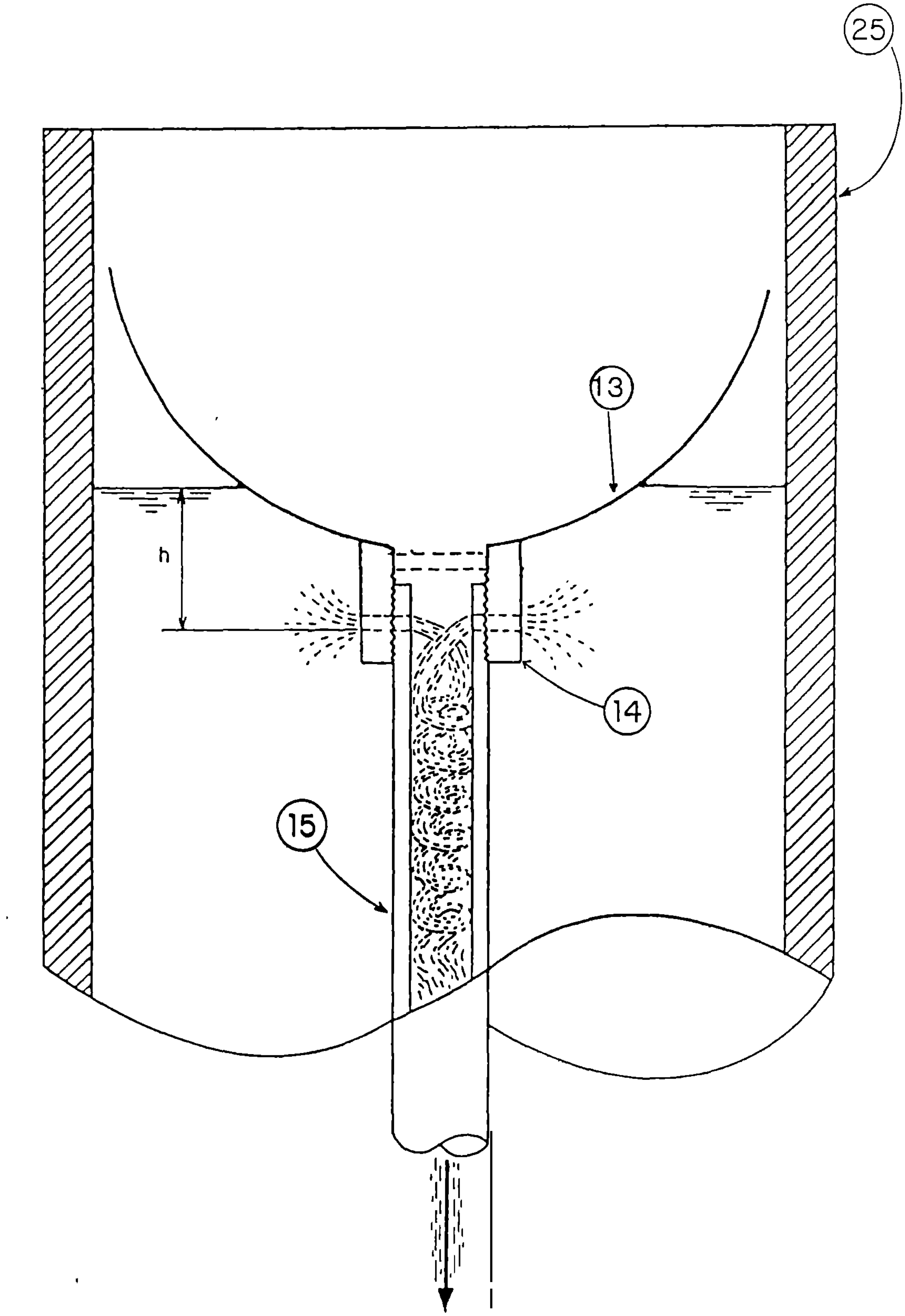


Figure A27 Telescopic float operation

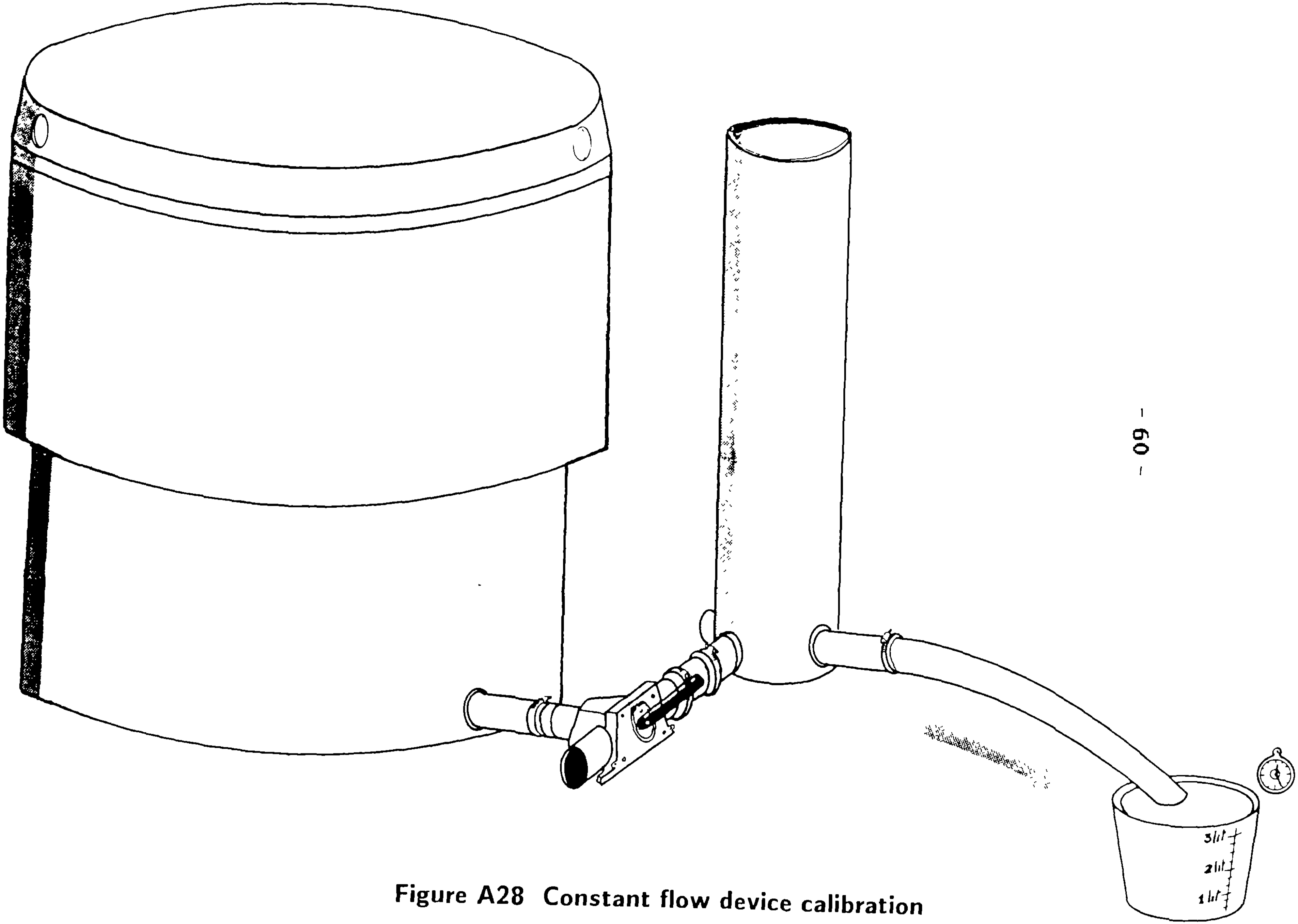


Figure A28 Constant flow device calibration

1.3. OPERATION OF THREE WAY (T) VALVE

The T valve has three positions:

Position A - Valve closed

Position B - Flow to CFD (normal operation)

Position C - Drainage or backfilling

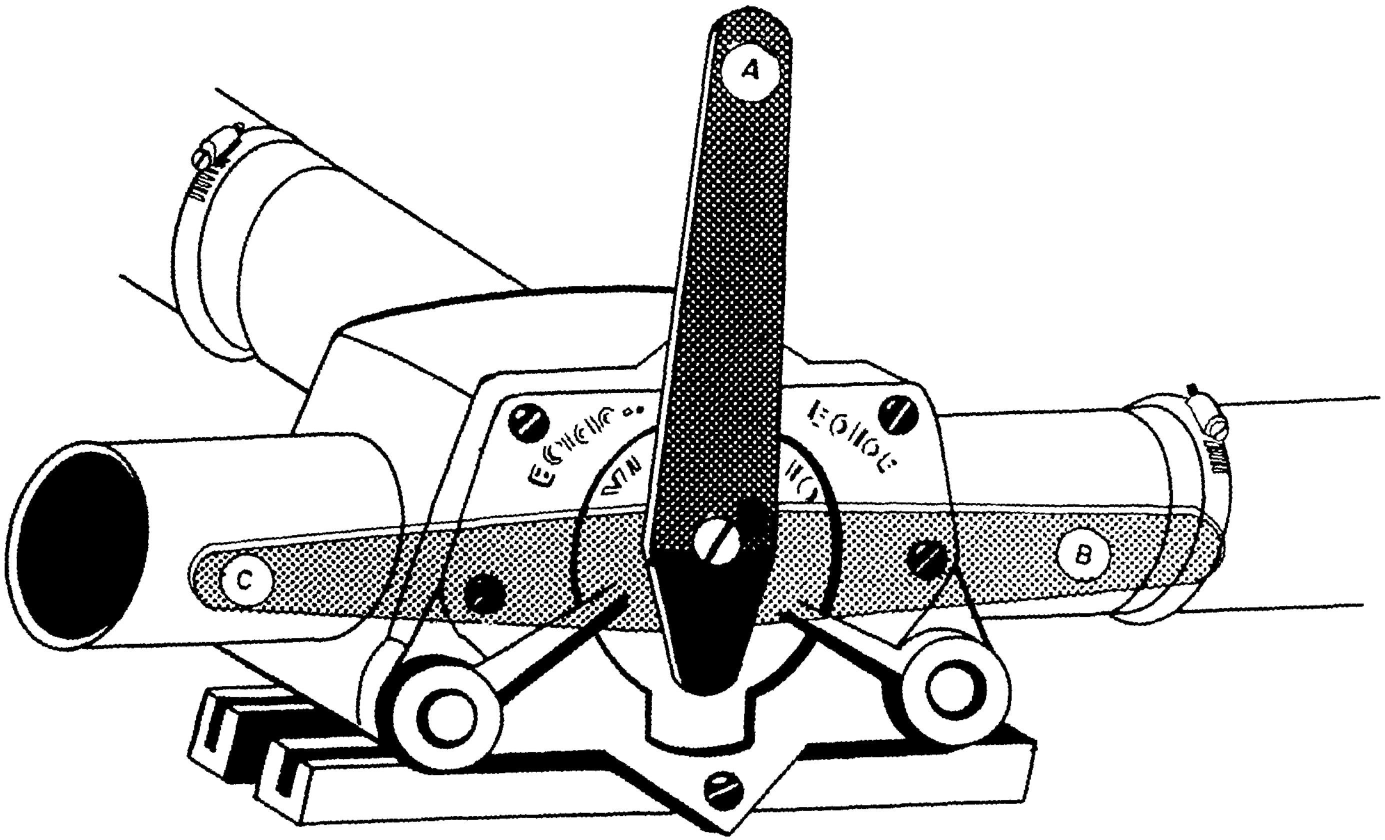


Figure A29 Three way valve operation

2. COMMISSIONING THE FILTER

2.1.a. In many cases, sand selected for the filter will contain silt or other undesirable material. However, it is possible to clean the sand after placing it in the filter by means of a simple backwashing technique.

2.1.b. Once the sand has been placed on the supporting gravel bed to a level 50 mm above the desired sand bed depth, connect the raw water hose (A) as indicated. Open the drainage ports (21) to allow the backwash water to waste. The process should aim to 'fluidise' the bed so that a stick or shovel thrust into the sand experiences no resistance. Several metres of head may be necessary to achieve such vigorous backwashing. Continue backwashing until the effluent emerging from the drainage ports is observed to be clean.

2.1.c. If raw water turbidity is very high, it may be preferable to consider alternative means of washing the sand.

2.1.d. Any fine material remaining on the sand bed surface after backwashing should be removed using a small spade or trowel.

2.1.e. The final sand level should be at least 50 cm above the gravel support level and should be convex with respect to the filter fabric support ridge.

2.1.f. Install the layers of filter fabric on top of the convex sand bed and replace the side drainage plugs.

2.1.g. Slowly backfill the filter to a level at least 100 to 150 mm above the top fabric layer. Ensure that no air is trapped between sand and fabrics or between fabric layers.

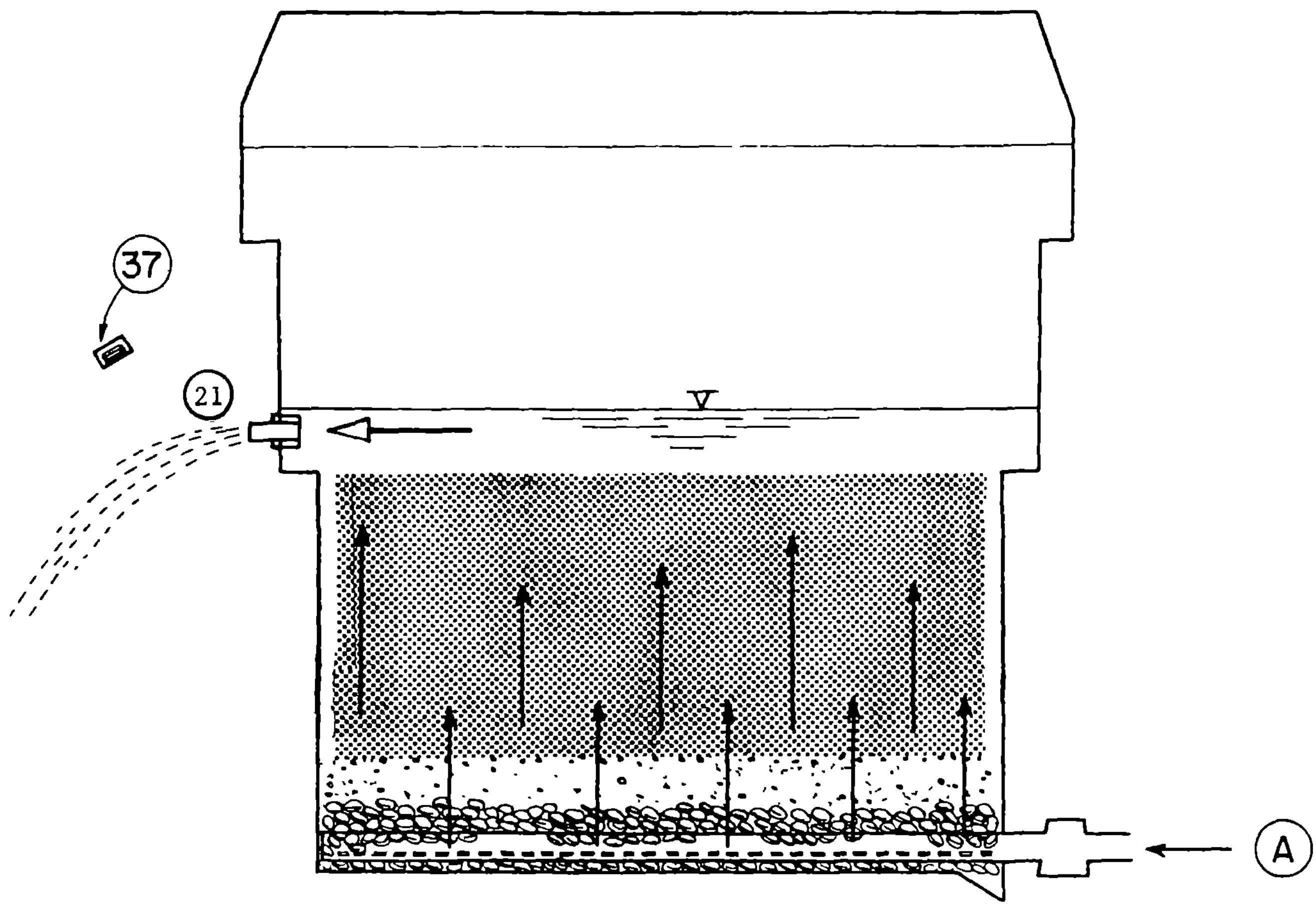


Figure A30 Vigorous backwashing of PSSF unit

2.1.h. Slowly fill the tank by top charging. Take care not to cause splashing which might disturb the sand and fabrics or introduce air bubbles into the filtration media.

2.1.j. Press down the filter fabrics in their support to release any trapped air. Make sure the fabrics are well secured and will not float. Take care to ensure that the flow into the filter is unrestricted - particularly if a ball valve is fitted. If the supernatent head above the filter is maintained by an overflow make sure that the overflow is sufficient to maintain flow through the filter.

2.1.k. Partially open the T valve half way to position B. Do not open this valve fully until the CFD is 80 per cent full. High velocities may result in sand penetration of the gravel underdrainage and 'packing' of the sand bed.

2.1.l. Ensure that the telescopic tube and floating weir move freely in the CFD.

2.1.m. Calibrate the flow (see Section 1.2.c.), to <u>not more than 0.3 m/h.</u>*

2.1.n. Place the lid in position. Water treatment has now commenced.

N.B. It is advisable to commence a filter run at 0.1 m/h and increase to 0.3 m/h over a number of days.

IMPORTANT

It may take several days or several weeks for the PSSF unit to attain maximum efficiency. Factors which will retard maturation of the biological properties of the filter are:

1. Low dissolved oxygen levels in the raw or influent water. This can be caused by prefilters or high water temperatures.

2. Cold water temperatures.

3. High levels of fine silt smothering the top portions of the filter bed.

4. Toxic chemicals in the influent water.

During the period of maturation, microbiological testing should be conducted on a daily basis. The filter should not be brought into service until levels of faecal coliforms in the treated water fall to less than 1 per 100 ml on 95% of sampling occasions. This may necessitate terminal disinfection in many cases. The filter can be considered mature when reductions in faecal coliform levels are consistently greater than 95 per cent.

For information concerning water quality testing, contact :

DelAgua, P O Box 92, Guildford GU2 5TQ, England.

3 ROUTINE MAINTENANCE

3.1.a. Routine maintenance must be undertaken when the float in the CFD reaches the lower position in Section 1.2.a. Always ensure that filters do not block simultaneously so that they can be maintained separately. A constant supply of water can only be maintained if a minimum of one PSSF unit is in operation at all times.

3.1.b. Remove the PSSF unit lid and place it to one side with the top downmost on clean ground next to the filters.

3.1.c. Close the inlet valve to the filter and close the T valve (position A).

3.1.d. Remove the side drain plugs (37) and drain the supernatent to waste.

3.1.e. Move the T valve to position C and continue draining the filter until the fabrics are exposed and the supernatent is level with the sand bed surface.

3.1.f. Close the T valve.

3.1.g. Remove the fabrics and place them on the lid of the PSSF unit for safe keeping. The upper two layers of fabric should be cleaned, but the lower layers should be left as undisturbed and moist as possible in order to keep their biological populations intact.

3.1.h. Wash the upper fabric layers in clean running water or with a jet of pumped clean water from a hose. Place them on top of the undisturbed fabrics to keep them moist.

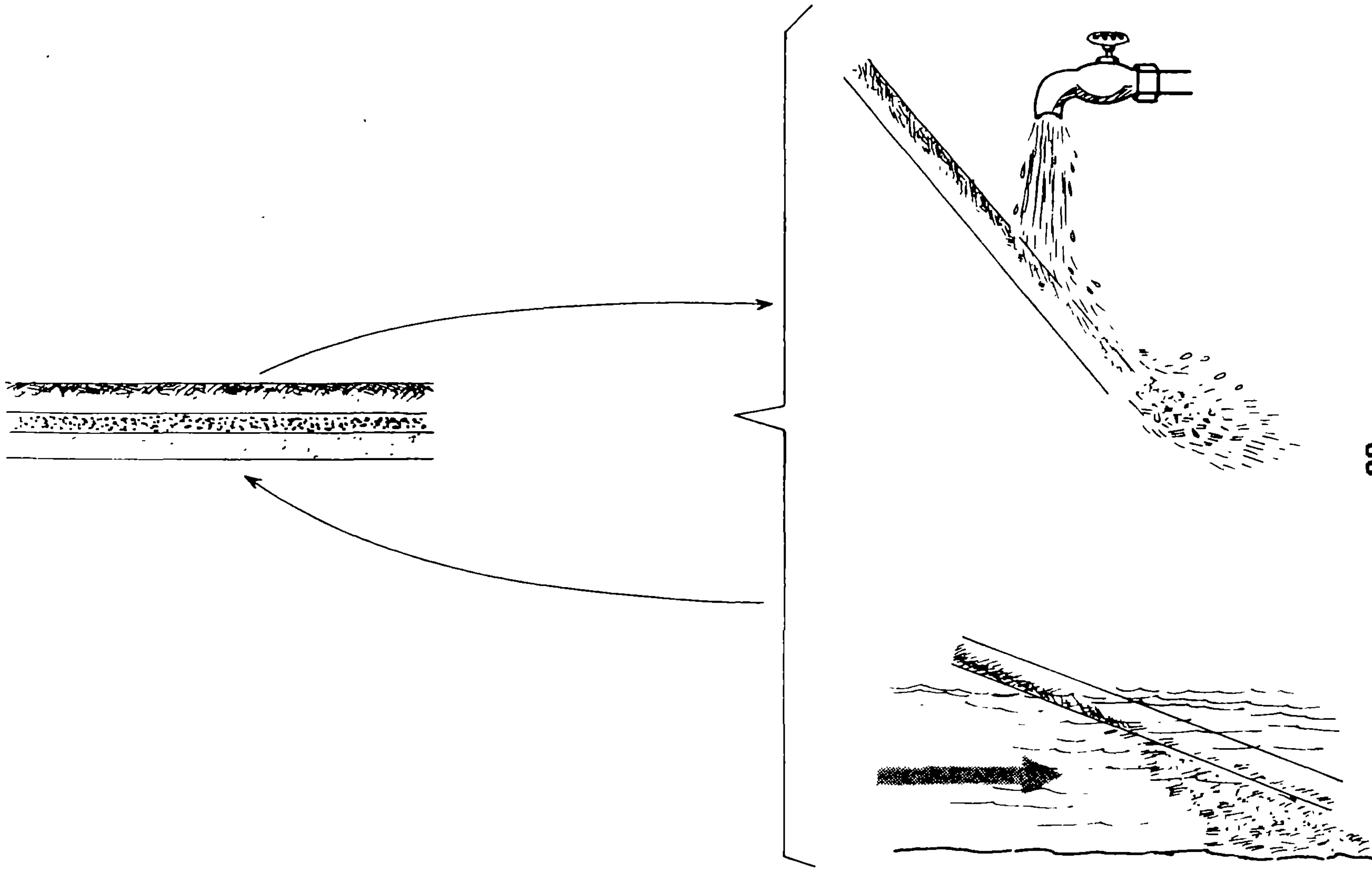


Figure A31 Cleaning filter fabrics

3.1.j. If it is evident that the silt has penetrated the fabrics to cause blockage and cementing of the sand bed itself, remove the top 20 - 40 mm of the sand and place it in a suitable container for washing and rinsing. When the sand has been thoroughly cleaned, replace it immediately back into the filter. In this way filter medium will not be lost or discarded.

3.1.k. Replace the previously upper, cleaned fabrics on the sand bed, and place the undisturbed layers above them. This process is of significant benefit in maintaining the continuity of biological efficiency.

3.1.l. Backfill the filter using treated water. This is achieved by closing the outlet valve to the entire system (34), removing the telescopic float from the filter being backfilled, and opening all T valves to position B.

3.1.m. Leaving the side drains open, allow the first 10 - 15 minutes of backfill water which emerges above the fabrics to run to waste. This should remove any samll amounts of scum.

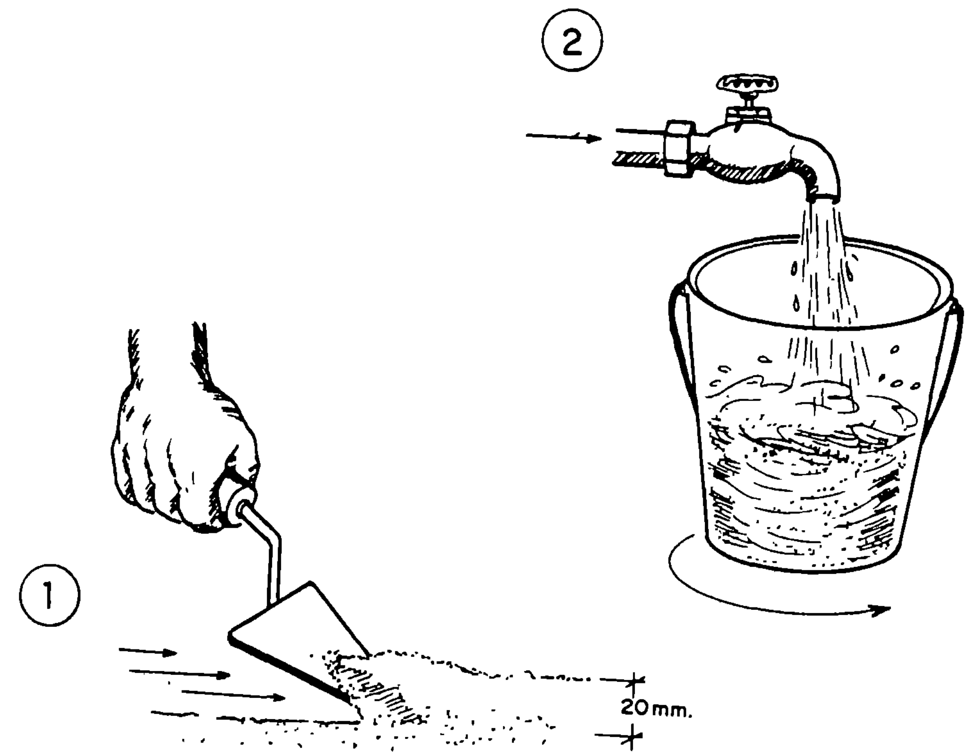


Figure A32 Skimming and washing sand

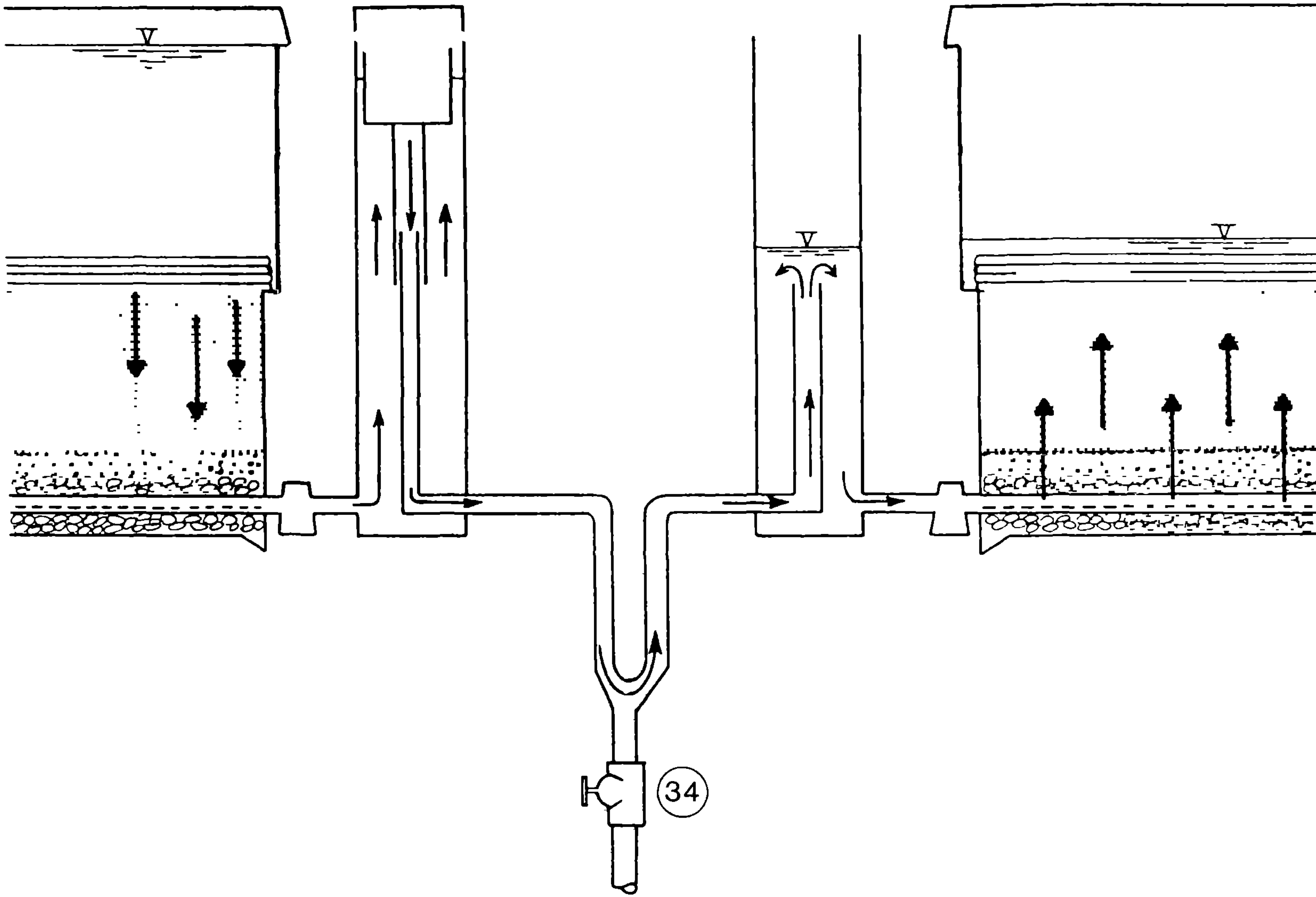


Figure A33 Backfilling with treated water

RURAL WATER TREATMENT PACKAGE PLANT (R3760)

FINAL REPORT FOR THE UK OVERSEAS DEVELOPMENT ADMINISTRATION

B J LLOYD
M PARDON
D WHEELER

APPENDIX IV

CONSTRUCTION GUIDE

GRAVEL PREFILTRATION

DelAgua, P O Box 92, Guildford, GU2 5TQ, England

CONSTRUCTION GUIDE - GRAVEL PREFILTRATION

CONTENTS

1. LIST OF COMPONENTS AND REQUIREMENTS

Component Number	Description	Material	Amount Needed for Unit of $35m^3$/day
1	45^0 V notch weir (0.4 x 0.4 m plate)	1	1
2	Inlet overflow plate (1.0 x 0.2 m)	1	1
3	Integral presettler	2	1
4	Presettler baffle screen	1	1
5	Baffle guides	3	2
6	Three stage prefilter	2/4	1
7	Reinforced concrete slabs	4/5	36
8	Reinforcement wire 3/8"	5	18 m
9	Pipe, class C, 1.1/4"	6	8 m
10	Plain elbow, 1.1/4"	6	3
11	Valve with unions, 1.1/4"	6/7	2
12	Hinged gate (0.25x0.25m)	1/8/9	4
13	Fine mesh (0.5-1.0mm)	10	0.1 m^2
14	Bolts, fastenings, etc.	7	-
15	Inlet channel	2	1
16	Outlet channel	2	1
17	Waste channel	2	1

Materials

1	Galvanized iron
2	Masonry
3	Aluminium
4	Concrete
5	Iron
6	UPVC
7	Brass
8	Steel
9	Soft synthetic rubber
10	Bronze

Quantities required for unit of 35 m^3/day

Basement concrete	6.2 m^3
Reinforced concrete for columns	0.12 m^3
Masonry bricks	50 m^2
Mortar for rendering etc.	80 m^2
40 mm stones	1.0 m^3
20 - 40 mm gravel	5.5 m^3
10 - 20 mm gravel	3.6 m^3
6 - 10 mm gravel	3.6 m^3

Other requirements for unit of 35 m^3/day

Skilled labour for construction etc.	60 days
Unskilled labour for excavation etc.	120 days
Direct supervision (excluding design, planning, etc.)	30 days
System for grading gravel filtration media	

IMPORTANT

The figures quoted above are typical but approximate. Allowance should be made for local variations. For a typical system comprising abstraction, prefiltration, protected slow sand filtration, storage, distribution and public standposts it would be normal to allow 60 - 70 per cent of costs for water distribution and conduction. In this case the costs of gravel filtration construction are unlikely to exceed 10 per cent of total costs and 7.5 per cent of materials costs.

2. CONFIGURATION

2.1.a. The three stage in-series vertical gravel prefilter will normally be installed between the abstraction point or a sedimenter and the protected slow sand filtration units.

2.1.b. There is little head loss through the gravel prefilter, but care needs to be exercised in siting the gravel filter with respect to the sand filtration units and the distribution network to ensure that water will flow through the system. An example of how configurations can be planned taking head losses into account is illustrated. The hydraulics of conduction lines and distribution networks need to be calculated carefully.

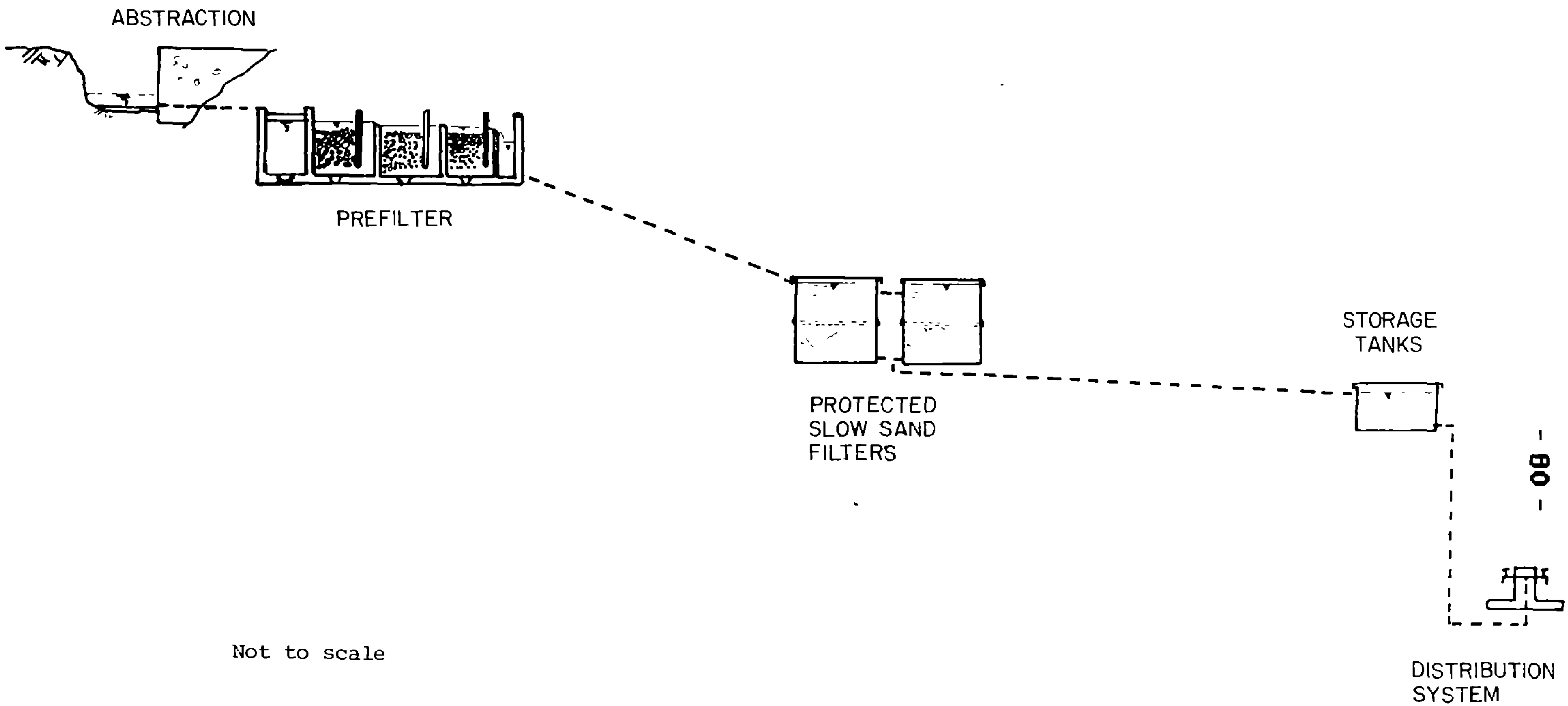


Figure A34 Orientation of gravel prefilter

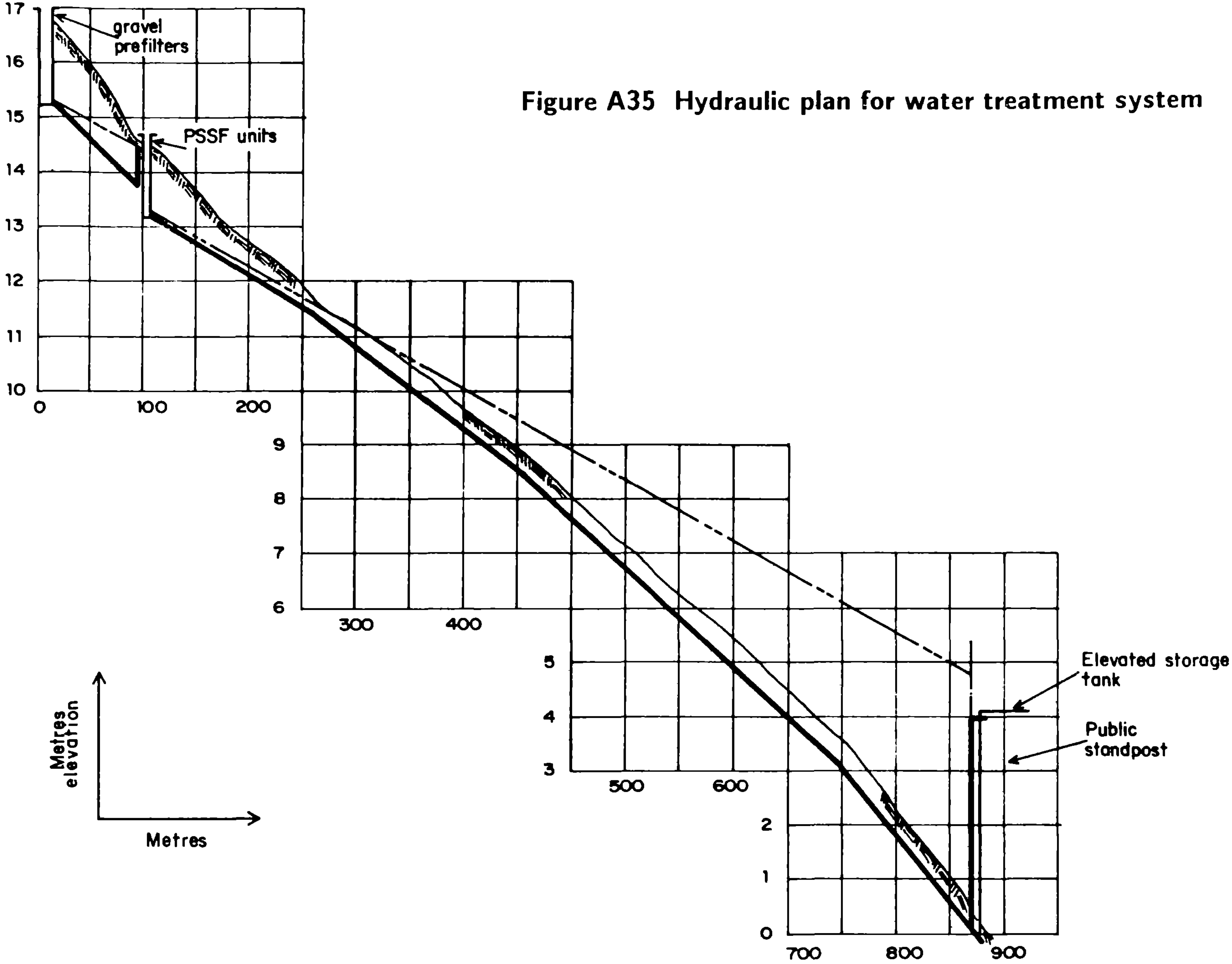


Figure A35 Hydraulic plan for water treatment system

3. CONSTRUCTION

3.1 LABOUR

3.1.a. Whenever contemplating conventional construction of a gravel filter, a qualified engineer should be consulted. Advice should be sought on the following points:

site selection
hydraulic design
materials

3.1.b. Skilled labour will need to be engaged for the purpose of iron-work, reinforced cement fabrication and masonry. These skills may need to be secured outside the recipient community. Unskilled labour should be recruited within the local community in consultation with the recognised community organisation.

3.2 INSTALLATION

3.2.a. A plan view of the three stage gravel prefilter is shown together with two sectional views.

3.2.b. The outside walls of the prefilter should be well supported. This is easily achieved by locating the base of the filter well below ground. Thus the first stage of construction is likely to be the excavation of a suitable area for installation of the prefilter. Hydraulic considerations may also play a role in deciding the depth of excavation.

3.2.c. The base of the filter should be laid level. Inlet and outlet structures, and reinforced concrete pillars are installed to ensure the strongest possible framework for masonry works. The filter should be constructed using the criteria and designs of this manual together with the recommendations of Wegelin, 1986 (see Appendix I).

3.2.d. Before proceeding to the construction of underdrainage and commissioning the filter, the structure should be checked for watertightness and physical integrity. When the structure is finished and cured, fill it with water, note the level and leave for a suitable period. Any lowering of levels greater than that expected by normal evaporation should be investigated.

3.2.e. Install fine mesh protective screens over the final outlet pipe and any other exposed orifice which might suffer accidental blockage eg the bypass inlet.

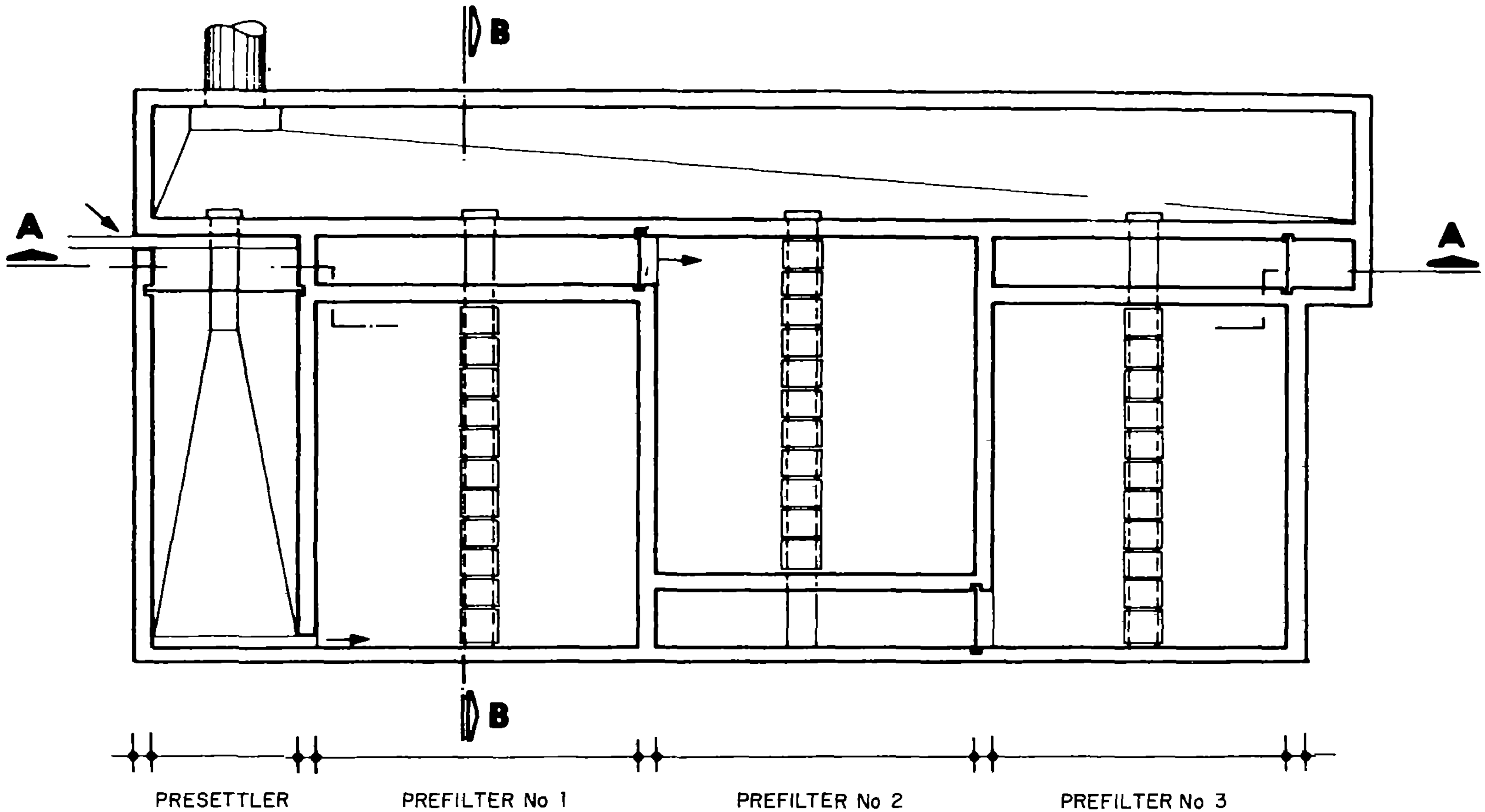
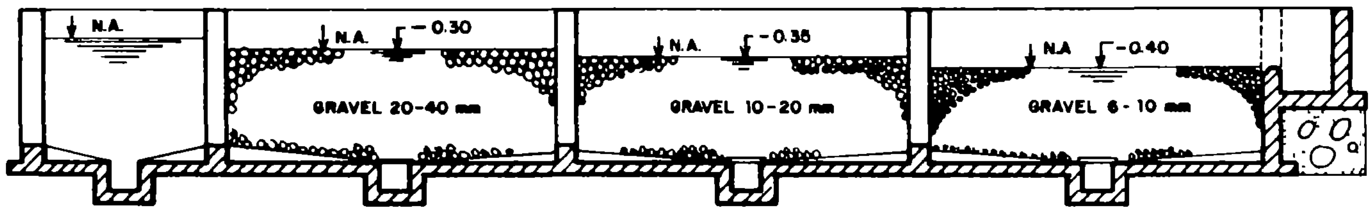
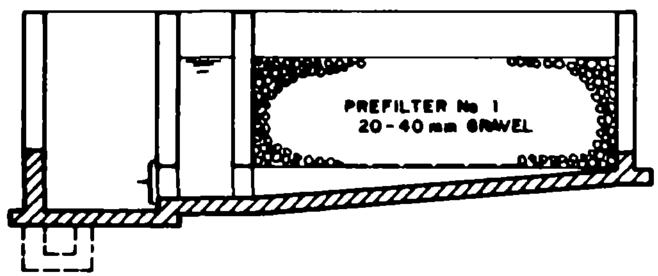


Figure A36 Plan View Vertical-in-Series Gravel Prefilter



SECTION A-A



SECTION B-B

Figure A37 Sectional Views Vertical-in-Series Gravel Prefilter

RURAL WATER TREATMENT PACKAGE PLANT (R3760)

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B J LLOYD
M PARDON
D WHEELER

APPENDIX V

OPERATION AND MAINTENANCE MANUAL GRAVEL PREFILTRATION

DelAgua, P O Box 92, Guildford, GU2 5TQ, England

OPERATION AND MAINTENANCE MANUAL

GRAVEL PREFILTRATION

Contents

1. GENERAL POINTS

1.1 INLET FLOW CONTROL

1.1.a. The flow through the gravel prefilter is maintained constant at the inlet to the unit by means of a narrow V notch weir and overflow. Within reason, variations of flow in the inlet channel (I) are accommodated by the overflow plate (P) with very little change in depth of water in the channel. The flow through the narrow 45^0 weir is determined by the height of water against the V notch.

1.1.b By raising the level of the overflow plate (P), the level of water in the channel (I) rises and the flow through the V notch weir increases.

1.1.c. Constant flows to the gravel filter unit may be calibrated using the relationship illustrated.

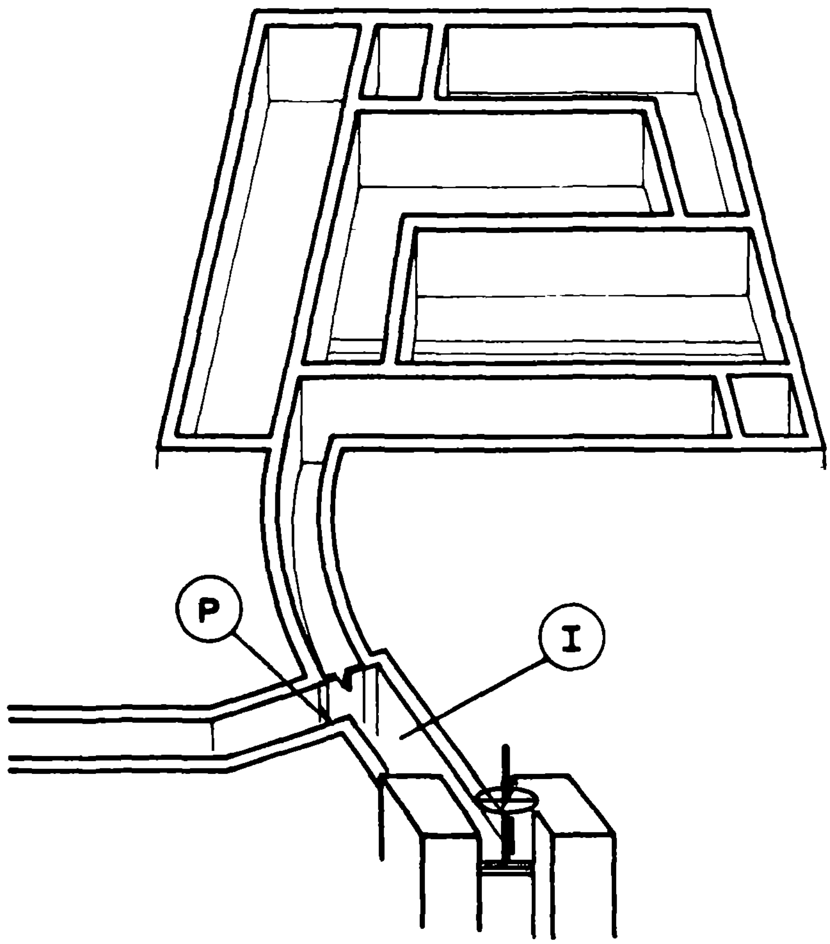

Figure A38 Inlet channel arrangement

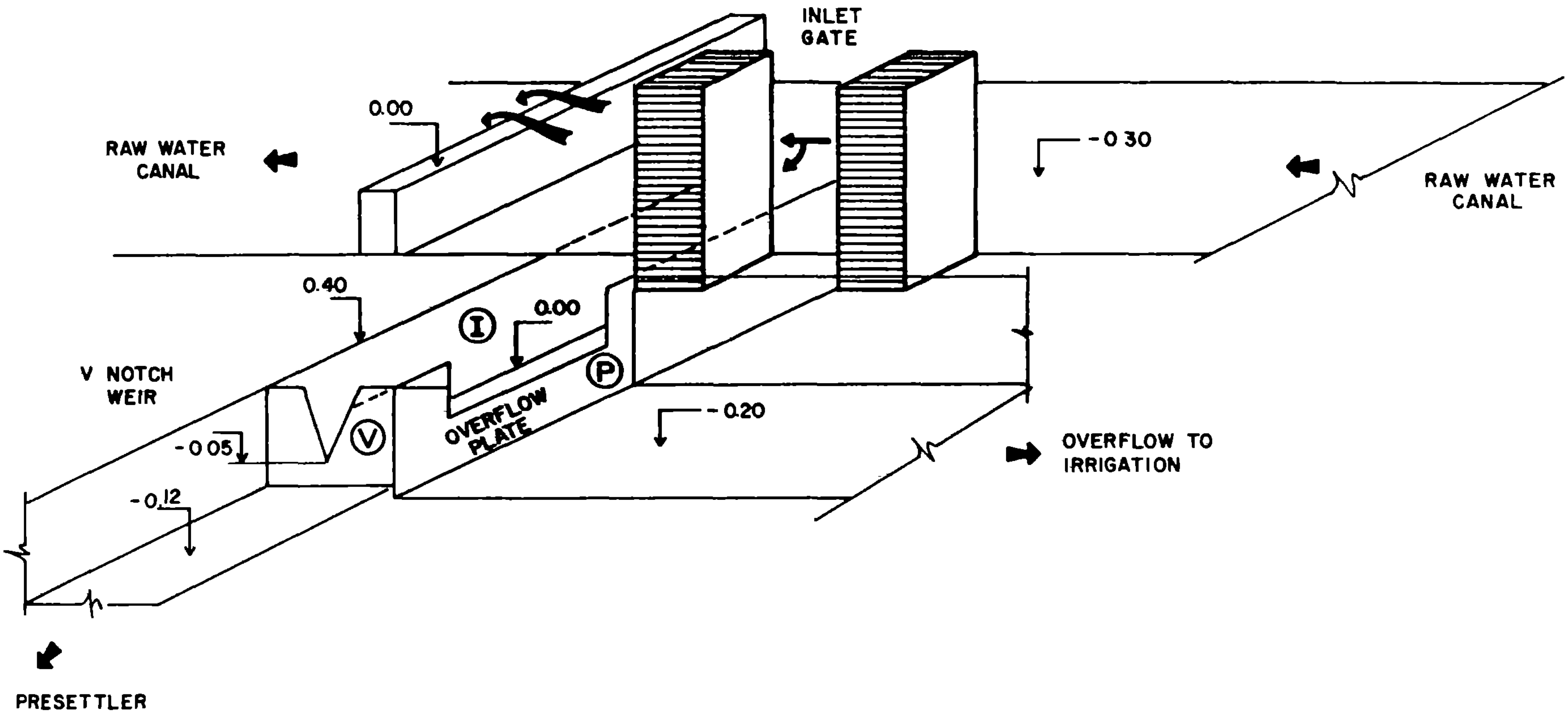

Figure A39 Inlet flow control

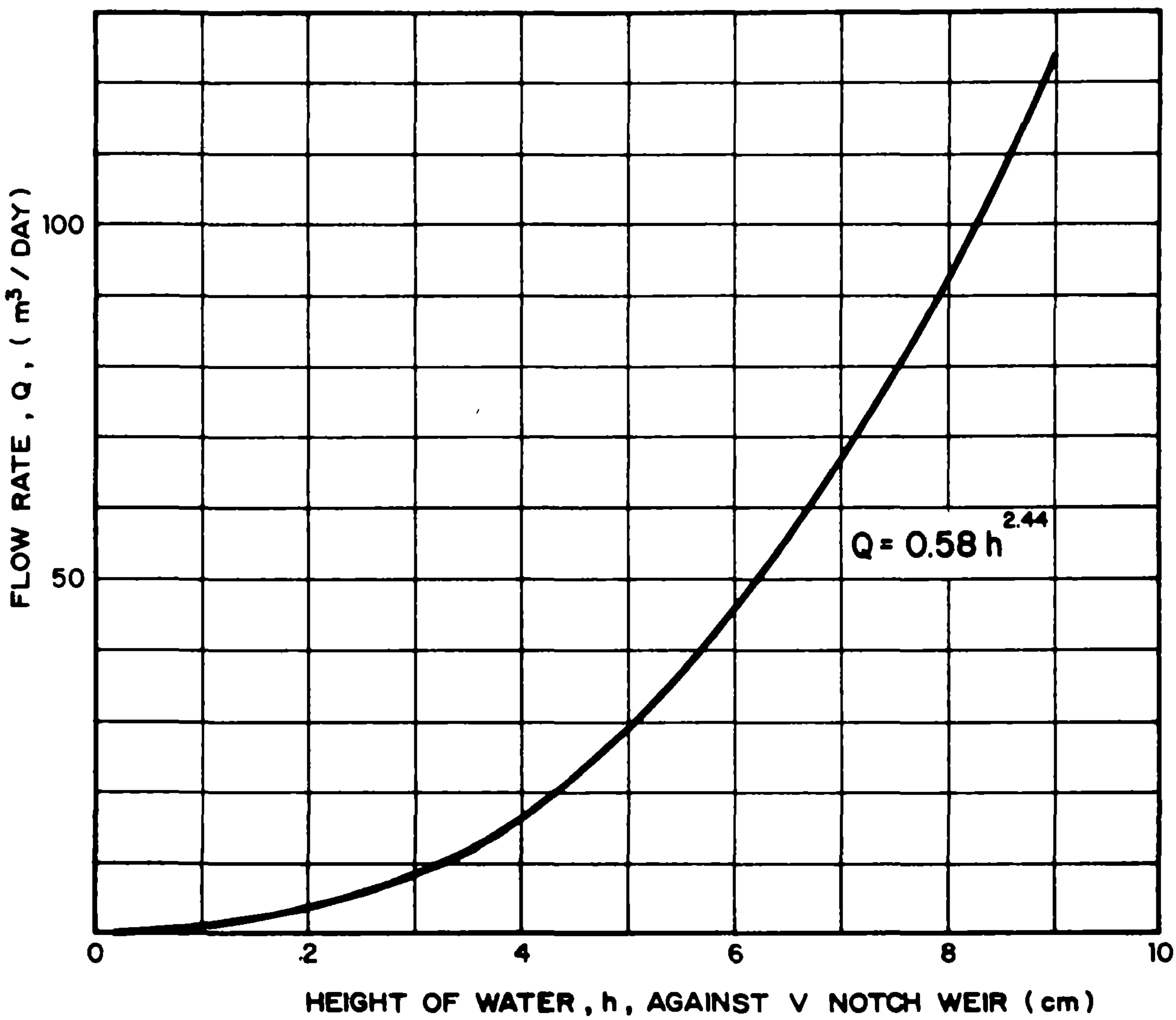

Figure A40 Calibration of 45 ° V notch weir for constant flow control

1.2 INTEGRAL PRESETTLER

1.2.a. The sedimentation section (5) of the prefiltration unit has a baffle (B) which helps ensure a nominal retention time of two hours. During this period the largest suspended solids and aggregates will settle to the bottom of the tank.

1.2.b. The presettler also has a drainage channel (D) and a gate (G) which allows the section to be drained and desludged on a periodic basis.

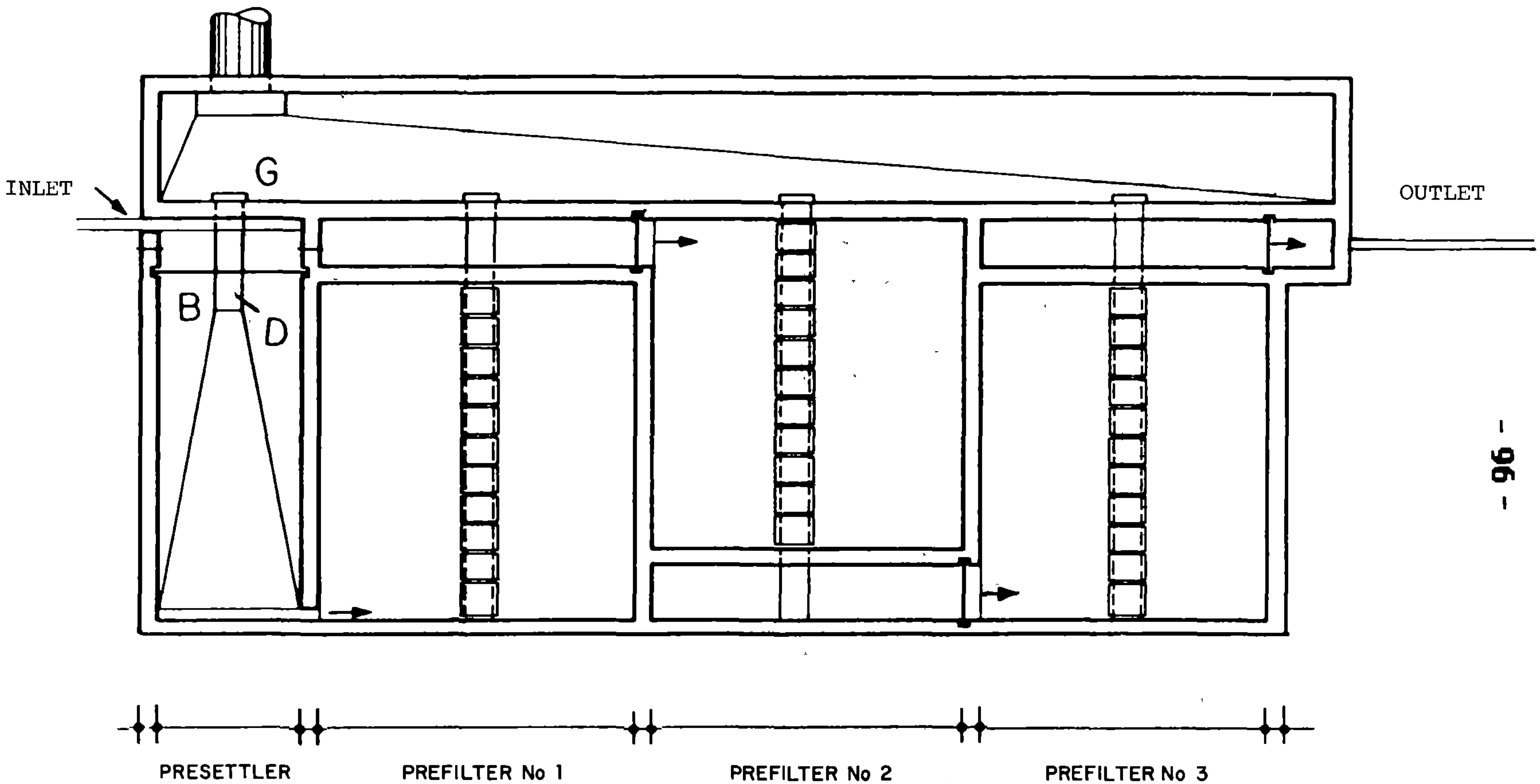

Figure A36 Plan View – Gravel prefilter

1.3 FILTRATION CHAMBERS

1.3.a. All three gravel filtration chambers have an overflow weir (W) which allows the effluent from the previous unit to flow into the filtration chamber. Water flows vertically down through the media.

1.3.b. Underdrainage collection channels (U) collect filtered water into narrow chambers (C) from where water passes to the overflow weirs. The final overflow weir leads to the collection pipe which takes prefiltered water to subsequent parts of the water treatment plant.

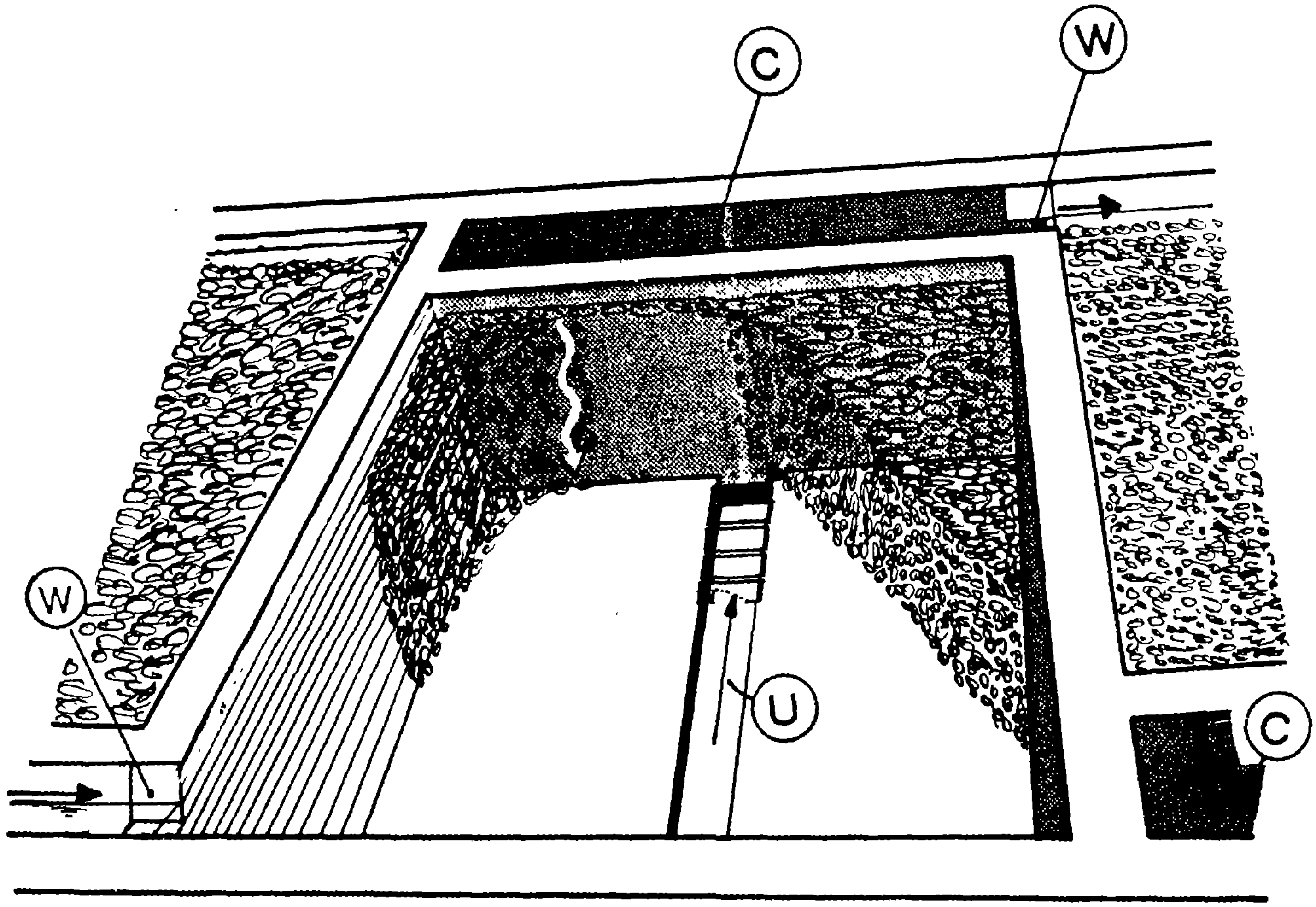

Figure A41 Gravel prefilter chamber

1.4 DRAINAGE GATES AND CHANNELS

1.4.a. Drainage gates (G) are fast opening wide outlets for all sections of the prefilter, including the integral presettler. They allow the rapid draining down of water to effect cleaning. The drain-down velocity should be between 1.5 and 2.0 m/min, and water should be substantially voided in under 60 seconds for each section.

1.4.b. The gates have a soft synthetic rubber seal (R) and a clasp mechanism (M) which together ensure a tight seal between the plates and the gate frame (F).

1.4.c. The drainage channel (C) allows large volumes of water to be removed from the units in a short space of time. It is vital therefore that the waste outlet (O) be wide (at least 12") and unobstructed. It is normal for the waste outlet to flow to irrigation.

1.5 OUTLET AND BYPASS VALVES

1.5.a. The outlet arrangement and valve do not regulate flow through the filter. They simply permit the collection and onward transmission of prefiltered water.

1.5.b. Closing the outlet valve has the effect of flooding the unit to a height of approximately 200 mm above the gravel level. This is only useful during routine or special maintenance.

1.5.c. The bypass valve connects the presettler inlet direct to the outlet chamber of the third prefilter section. It is used to bypass the filters during special maintenance. It should not be used during routine maintenance and in any case only when raw water turbidities are lower than 10 NTU.

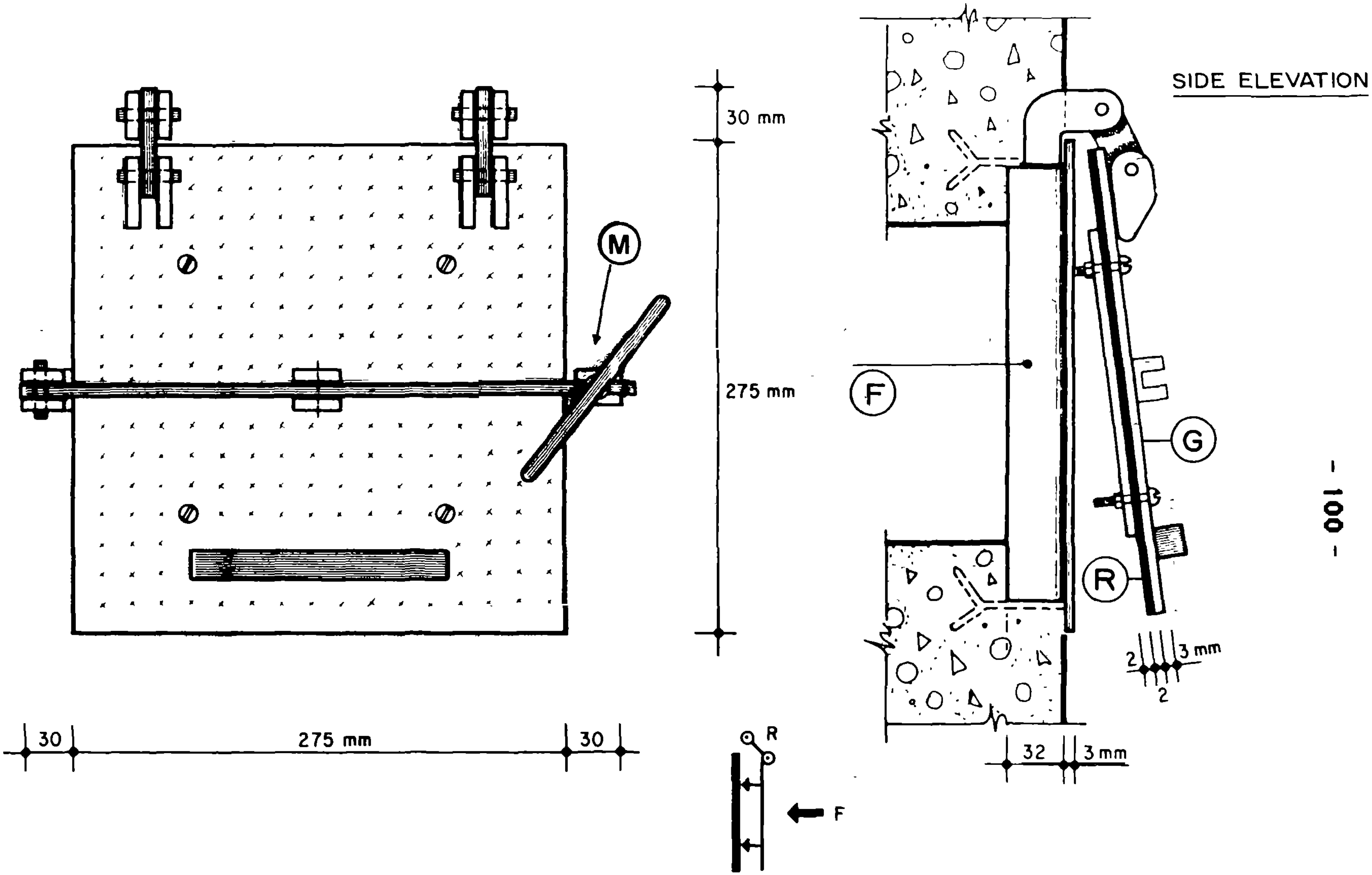

Figure A42 Drainage gate detail

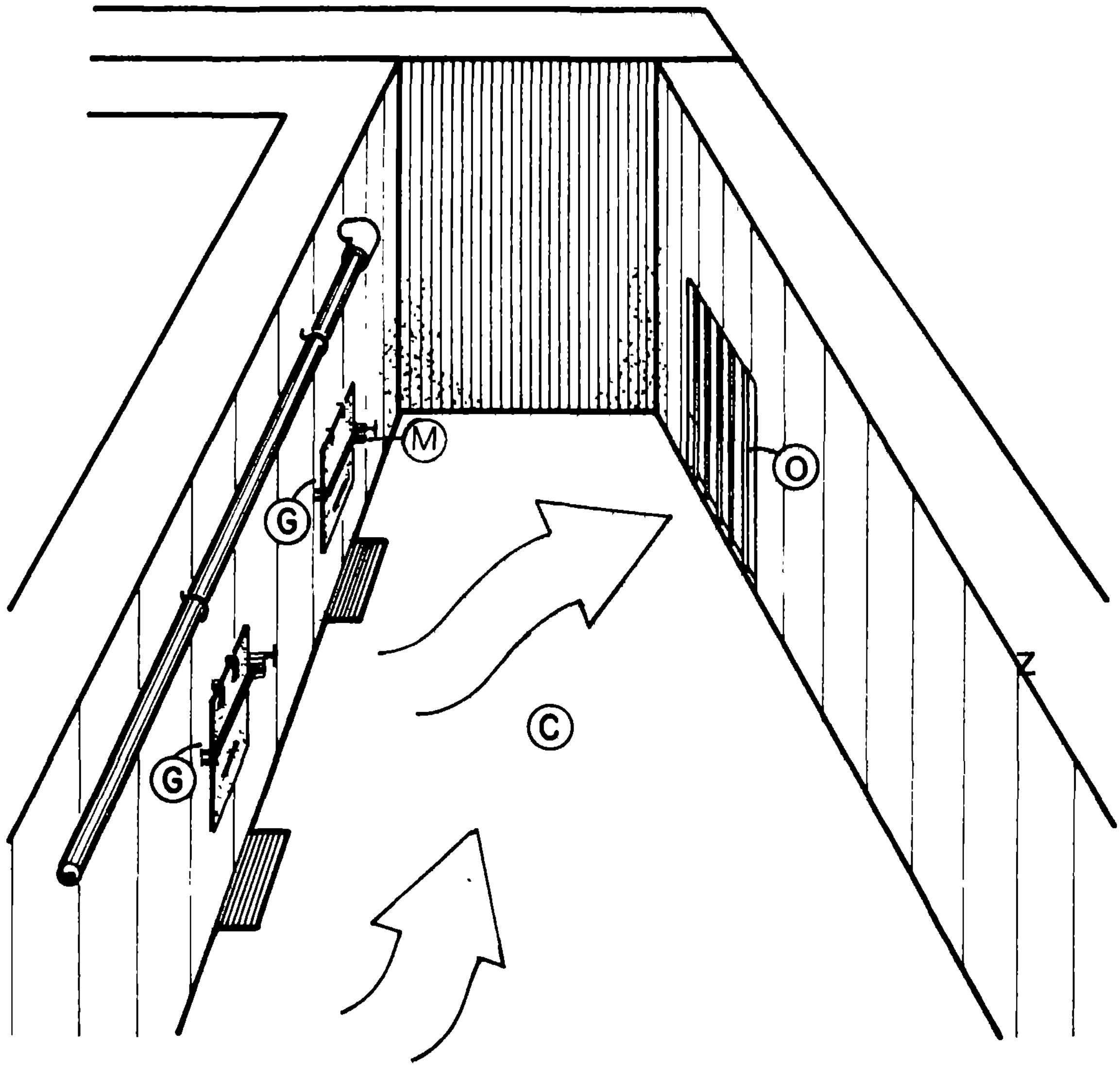

Figure A43 Drainage channel detail

2. COMMISSIONING

2.1.a. Ideally commissioning should occur in periods of low raw water turbidity.

2.1.b. Underdrainage slabs are arranged in such a fashion that 25 mm gaps remain above the channel.

2.1.c. Clean gravel is graded on site using screens of appropriate mesh size and dimensions. Required quantities are indicated in the construction manual.

2.1.d. The largest stones (50 - 150 mm diameter) are arranged in a single layer around the channel and underdrainage slabs to prevent support medium or filtration media falling into the apertures between slabs.

2.1.e. Support medium (40 mm diameter gravel) is placed carefully into each filtration chamber to a depth of 100 mm above the level of the drainage slabs. This is equivalent to filling the entire sloped section at the base of each filtration chamber.

2.1.f. Clean 20 - 40 mm diameter gravel is then added to the first filter, 10 - 20 mm gravel to the second and 6 - 10 mm gravel to the third to a depth of approximately 650 mm. This is equivalent to 100 mm above the outlet overflow weir for each filter chamber. It is important that this level is adequate to prevent the formation of a supernatent water above the filtration medium. Having placed the media in the prefiltration unit, the gravel must be washed.

2.1.g. Close the drainage gates and outlet valve. Raise the inlet overflow plate to its maximum height to ensure the fastest possible filling of the entire unit. The unit should be filled to 200 mm above the gravel media so that all chambers are flooded and water begins to overflow into the drainage channel.

2.1.h. Keeping pressure against the first filter drainage gate (G) eg with the foot, release the clasp mechanism (M). Step smartly away from the gate, allowing it to open quickly and rapidly drain the unit. Repeat for the other filter drainage gates.

2.1.i. When all water has drained from the units, close all outlet gates and refill the prefiltration plant to the maximum flood level. Repeat the rapid draining procedure to give the media a second wash.

2.1.j. Close all valves. Adjust the height of the overflow plate to provide the desired height (h) and flow (Q) in cubic metres per day at the V notch weir. Fill the filtration chambers slowly.

2.1.k. When water is observed flowing over the final filter chamber overflow weir, the outlet valve may be opened. It is advisable to run the filter to waste for 24 hours, after which it may be assumed that the system is in steady state.

3. ROUTINE MAINTENANCE

3.1.a. Always ensure that the moving parts of the drainage gates are greased to keep them free from corrosion or seizure.

3.1.b. Always remove debris from the channels and surface of the gravel filter media.

3.1.c. During periods of high influent turbidity the prefilter should be cleaned on a periodic basis. Experience will dictate the frequency of such cleaning. If turbidity removal declines to consistently below 80 per cent and if the effluent is consistently higher than 20 NTU, cleaning may be necessary.

3.1.d. Undertake steps 2.1.g. - 2.1.k.

3.1.e. When water is observed flowing over the final filter chamber overflow weir, the outlet valve may be opened.

4. SPECIAL MAINTENANCE

4.1.a. After several years service, it is possible that routine cleaning of the filtration media may not be sufficient to adequately re-establish efficiency. This may occur if large volumes of silt and other suspended solids have sedimented deep into the gravel bed causing either partial blockage or cascading release of material during filtration. In this case more extensive cleaning of the filter media is required.

4.1.b. Close all valves and drain all chambers of the unit with the exception of the presettler. Using shovels, transfer half of the filtration medium in the first prefilter into the presettler. Do this as vigorously as possible to dislodge the maximum amount of silt. Wash the 20 - 40 mm gravel in the presettler by rapid draining down of the chamber.

4.1.c. Remove the cleaned gravel from the presettler using shovels. Place to one side of the prefiltration unit on a strong, clean plastic sheet. Refill the presettler with raw water. Place the remainder of the 20 - 40 mm gravel from the first prefilter in the presettler in the same fashion as the first portion. But DO NOT remove the filter medium support in the base of the prefilter.

4.1.d. Fill the first prefilter with water to a depth of 250 mm above the support medium. Using a shovel, turn over the support medium taking care not to disturb the large stones around the drainage slabs. When the maximum amount of silt has been dislodged, drain the chamber to wash the support medium. Refill the chamber with water to the maximum depth.

4.1.e. Transfer all of the 10 - 20 mm gravel from the second prefilter chamber into the first prefilter. Do this as vigorously as possible to dislodge the maximum amount of silt. DO NOT remove the underdrainage or support medium in the base of the second prefilter. Wash the 10 - 20 mm gravel in the first prefilter chamber.

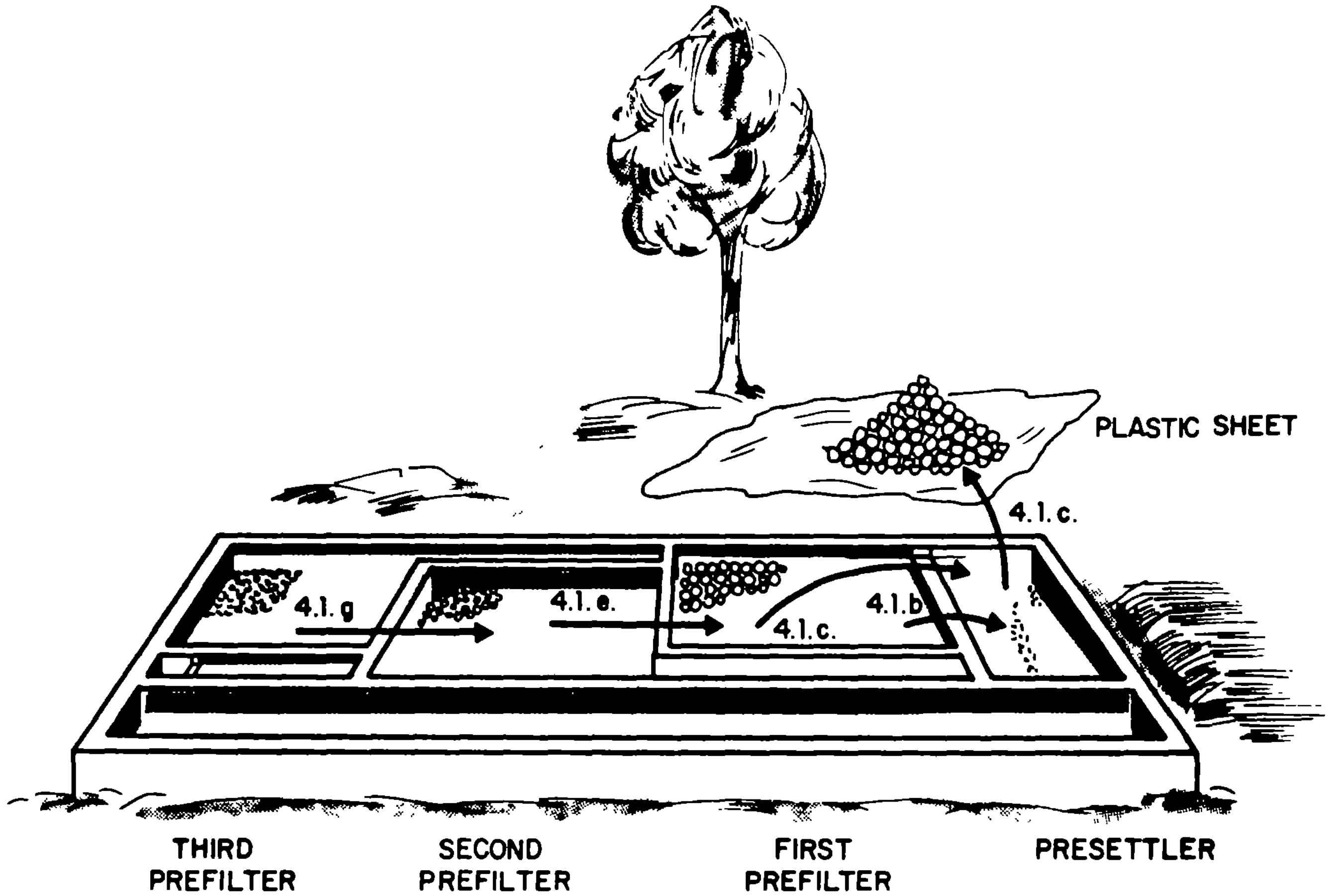

Figure A44 Gravel prefilter - Special maintenance

4.1.f. Repeat step 4.1.d. for the support medium in the second prefilter.

4.1.g. Repeat step 4.1.e. for the filtration medium in the third prefilter (6 - 10 mm gravel). Wash in the second chamber.

4.1.h. Repeat step 4.1.d. for the support medium in the third prefilter.

4.1.j. Drain all chambers.

4.1.k. Transfer media into the correct chambers taking care not to disturb support media and underdrainage systems. Where necessary, remove the last portion of filtration medium by hand. This is equivalent to step 2.1.f.

4.1.l. Repeat steps 2.1.g. - 2.1.l.