THE GOVERNMENT OF PERU

TECHNICAL DIVISION OF ENVIRONMENTAL SANITATION
of the MINISTRY OF HEALTH

A Pilot Project Report
Concerning Horizontal Roughing Filtration

THE REHABILITATION OF THE WATER TREATMENT SYSTEM

OF THE RURAL COMMUNITY OF COCHARCAS

HUANCAYO/JUNIN

PERU

**July
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**DELAGUA LTD
PUBLIC HEALTH CONSULTANTS
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(Under assignment by the Overseas Development Administration
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TERMS OF REFERENCE

The Terms of Reference have remained unchanged since the preceding Phase 2 report.

I have the honour to refer to the Note of the Ministry of Foreign Affairs of 8th August 1985 concerning the "Regional Training Programme for Water Quality Surveillance and Water Treatment" and to propose that, having regard to the Agreement between the Government of the Republic of Peru and the Government of the United Kingdom of Great Britain and Northern Ireland (hereinafter referred to as the Government of the United Kingdom) on Technical Cooperation signed at Lima on 1 June 1966, the Peruvian and British Governments will cooperate in providing assistance for carrying out this project. The terms and conditions of the Agreement which will apply to this project are as follows:

Organizations Involved

a) Peru. The agency which will coordinate the project will be the Technical Division for Environmental Sanitation (hereinafter referred to as DITESA), acting on Behalf of the Ministry of Health, with support from the Health Areas of Huancayo, Tarma, Jauja, Huancavelica, Selva Central y Cerro de Pasco, and with coooperation from the Pan-American Center for Sanitary Engineering and Environmental Sciences (hereinafter referred to as CEPIS).

b) United Kingdom. The project, which will be for three years in the first instance and may be extended by mutual agreement between our two Governments, will be carried out with the direct participation of water supply scientists and public health experts from "DelAgua" and such other British organizations as the British Overseas Development Administration acting on Behalf of the Government of the United Kingdom may wish to make available.

Project Objectives

The objectives of the project will be:

a) To equip the Health Area laboratories in Huancayo, Tarma, Jauja, Huancavelica, Selva Central and Cerro de Pasco, with essential water testing equipment and supplies.

b) To train sanitary technicians and laboratory technicians in these Health Areas in appropriate methods of water analysis and sanitary inspection, as well as in equipment maintenance.

c) To expand, and where necessary, initiate routine water surveillance and inspection to cover the majority of water supplies.

d) To encourage the development of drinking water quality control laboratories at the level of the areas.

e) To establish a Procedures Manual and Standards for the use of sanitary and surveillance data in order to promote corrective maintenance of water treatment and supply systems.

f) To extend the existing collaborative rural water treatment project in order to assist in the rehabilitation, construction, operation and maintenance programmes of the Health Areas.

Project Implementation

The proposed phasing of the 3 year project is as follows:

Phase 1: Preliminary training and orientation of persone! by means of a pre-plan training course in the Hospital Area of the Huancayo Health "Region" followed by data gathering.

Phase 2: Evaluation of Phase 1. Planning full "regional" pilot course and extension of surveillance throughout the health areas of Huancayo, Tarma, Jauja, Huancavelica, Selva Central and Cerro de Pasco, which includes La Merced, Oxapamapa and Satipo.

Phase 3: Equipping of laboratories and implemention of diagnosis and surveillance for water supply schemes.

Phase 4: Providing funds and time remain available, the expansion of training and surveillance to other Health Areas.

British Input

The Government of the United Kingdom will provide the following:

a) Staff: A team of consultants from DelAgua Ltd., consisting of:
   i) Principal water scientist (28 man months)
   ii) Field sanitary engineer (24 man months)
   iii)Senior water/Public health scientist (24 man months)
   Secretarial support in Peru (Partially in the United Kingdom for helping in the purchase of equipment).

b) Staff expenses: Stipends, air fares and local costs of the scientific and associated United Kingdom staff and their families.

c) Scientific equipment.
   i) The cost of laboratory equipment and field equipment up to a total associated cost limit of £55,000.
   ii) Didactic training materials up to a maximum cost of £10,000.
   iii)Field costs for transport of DelAgua instructors, surveillance teams, and associated implementation costs up to a maximum total of £43,000.

Peruvian Input

The Government of Peru will provide the following:

a) Staff: The following counterpart staff will be allocated to the programme on a part time basis:
   i) Senior Engineer from DITESA, to act as Manager and Coordinator.
   ii) Representatives of the Health Areas of Huancayo, Tarma, Jauja, Huancavelica, Selva Central and Cerro de Pasco.
   iii) Directors of the Health Areas of Huancayo, Tarma, Jauja, Huancavelica, Selva Central and Cerro de Pasco.
   iv) Heads of laboratories and technical staff from DITESA and the Health Areas of Huancayo, Tarma, Jauja, Huancavelica, Selva Central and Cerro de Pasco.

Additional staff will be allocated to the programme on a full time basis:
   i) General Coordinator and Coordinators of the Health Areas.
   ii)Sanitary technicians in each Health Area.

b) Secretarial support staff and stipends of Health Areas staff

c) Support in transport operational costs in all Health Areas.

d) Laboratory and office facilioties in all Health Areas.

e) Salaries of local staff (for training courses and programme implementation)

CEPIS/Lima will continue to provide the following:

a) Back-up laboratory support and advisory services, including data analysis.

b) General office base for the Overseas Development Administration staff.

c) Additional training support, including printing of manuals and other didactic materials.

Joint Coordination

Both Governments will appoint co-managers for the programme from their staffs, who will coordinate their activities with DITESA.

If the arrangements set out above are acceptable to the Government of the Republic of Peru, I have the honour to suggest that this Note and your reply to that effect will place on record the understanding of the Government of the United Kingdom in this matter which will come into operation on the date of your reply.

I avail myself of this opportunity to renew to Your Excellency the assurances of my highest consideration.

J W R Shakespeare
Her Britannic Majesty's Ambassador

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ACKNOWLEDGEMENTS

The present work was carried out by DelAgua Consultants within the ODA/British Government Technical Cooperation Programme "Regional Training Programme for Water Quality Surveillance and Water Treatment".

The pilot rehabilitation project was assisted by the Swiss International Reference Centre for Wastes Disposal (IRCWD) within their horizontal prefiltration demonstration project. The design of the Horizontal Roughing Filter was reviewed by M. Wegelin (IRCWD) and the construction stage of the unit was executed by DelAgua in collaboration with CARE-Peru. Two builders from CARE were hired and the supervision was shared between M. Campos (CARE) and DelAgua.

Preliminary training of the Junta Administrativa of Cocharcas was carried out in collaboration with J. Sanchez (CESPAC-Lima) with the support of sanitary technicians of the Rural Sanitation Division of the Ministry of Health (DISAR) - Huancayo. The complementary works involved the installation of a raw water abstraction unit, V-notch weir and the repair and rehabilitation of 2 slow sand filters; these were supervised by DelAgua with the direct involvement of personnel of DISAR.

The work would not have been possible without the participation of the community of Cocharcas and their well-organised authorities and leaders.

ABSTRACT SUMMARY

1. The problems of rural water treatment plants in the central highlands and high jungle of Peru are critically analysed in the context of an established regional water quality surveillance and improvement programme. Existing plants rely on sedimentation and slow sand filtration. The plants are neither adequately designed to cope with raw water turbidity and microbiological contamination nor are they correctly operated.

2. A pilot rehabilitation project including operator training was proposed for the water treatment supply scheme of the community of Cocharcas (Huancayo). The design capacity was 103 m^3/day (for a population of 1076).

3. The main feature of the rehabilitation project was a prototype 3-stage horizontal gravel prefilter designed for the removal of turbidity and suspended solids and for the protection of the slow sand filtration process. Detailed design considerations are included.

4. Complementary works involved the reconstruction of the raw water intake (abstraction), the rehabilitation of the slow sand filters. The scheme requires the development of terminal disinfection which is an ongoing project at Cocharcas.

5. The planning and construction stage of the project lasted from September 1985 to May 1986; the system is now operative and a complete evaluation of the performance of the plant and its operation and maintenance will be carried out during the next 12 months.

1. INTRODUCTION

During the development of the Peruvian/British technical cooperation Programme for Water Quality Surveillance and Water Treatment which was initiated in September 1985 in the Central Highlands and High Jungle of Peru, a clear pattern of common problems of water supply systems has emerged. This has led to the formulation of pilot projects for rehabilitation, preventive maintenance and training of community workers.

For a better understanding of the subsequent discussion it is helpful to state how responsibilities for rural water supply are structured in Peru. A water supply scheme which is constructed under the joint auspices of the "Plan Nacional de Agua Potable Rural" (PNAPR) of the Ministry of Health and the community, remains the property of the Ministry of Health. Thus the responsibility for supervising preservation is retained by the Ministry whilst an elected "Junta Administrativa del Agua Potable" (JAAP) is responsible for the operation, maintenance and administration of the system.

In this report, the problem of water treatment plants for rural supplies will be addressed. A preliminary survey carried out on 18 rural water treatment schemes (the Nation Plan reports the existence of a total of 28 rural water treatment plants in the Health Region of Huancayo) showed major common deficiencies. They can be grouped into two main categories:

a) inadequate operation, maintenance and administration; and,
b) bad designs and /or faulty construction.

A summary of the findings of this preliminary survey is presented in Table I.

Table 1

Survey of the State of Rural Water Treatment Systems in the Central Highlands and High Jungle of Peru, 1985

Component	No. Sites surveyed	No. of systems presenting major deficiencies and operating problems No.	%
Abstraction	18	16	89
Sedimentation	18	11	61
Slow sand filters	16	16	100
Disinfection	18	18	100

Note: The Ministry of Health reports the existence of a total of 28 rural treatment systems in the Region.

Source: Lloyd et al., (1986.)"Developing Regional Water Surveillance in Health Region XIII - Peru." DelAgua; Phase One Report.

Common faults in water treatment schemes and their consequences

a. General

i) The raw water quality in the rainy season exceeds the capacity of the treatment processes traditionally used in rural water supplies thus rendering them inoperative with slow sand filters (SSF) subject to frequent blockage or by-passing.

ii) Lack of adequate training of the caretakers results in mismanagement of treatment systems that require simple but continuous attention.

iii) Lack of adequate supervision and support of the local administrators by national authorities results in deterioration of the systems.

b. Abstraction point

i) All water treatment processes are designed to work at a fixed rate of flow of water. All the designs of the national plan rely on flow control at the abstraction point, with a well designed concrete structure but with a 90^0 V notch weir, which is totally inadequate to measure flows of less than 0.8 l/sec (70 m^3/day), a range of flow common to communities of less than 1200 inhabitants (50 litres per person per day). In 16 out of the 18 plants visited the weir was not installed at all.

ii) In the majority of cases the source of water is an irrigation canal, which supports the agricultural and thus the economic activities of the community. The abstraction of a proportion of the water from the aqueduct is often seen as a threat or at least in competition with crop production, although the volumes of water required for water supply are nearly always insignificant compared to those required for agriculture.

The proportion of water required for domestic purposes has to be explained to the users and adequate flow control devices installed and protected or the abstraction points will invariably suffer vandalism or blockage. This leads to intermittent, inefficient, unreliable and unsafe water treatment and supply schemes.

iii) The precise location of the abstraction point in an aqueduct can minimize or maximize the level of suspended solids transported into the treatment plant thus influencing the operation and maintenance.

c. Sedimentation tanks

i) These are generally subject to shortcircuiting due to poor design including the absence of baffles and in adequate dimensions for the structures.

ii) The lack of routine cleaning further reduces efficiency.

d. Slow sand filters

i) Incorrect grades of sand in the filter beds leads to short filter runs if the sand is too fine, or inadequate quality of the effluent if the sand is too coarse.

ii) Inadequate flow control mechanisms leads to filters being operated at an intermittent or unstable rate and/or overloaded.

iii) Absence of installations for sand cleaning leading to plants eventually running out of filter media.

iv) The lack of understanding by the caretaker of how the SSF should work ends up in bad operation and ultimately by-passing of the unit.

e. Disinfection

i) A diffusion hypochlorinator is commonly recommended in the national plan. There is an urgent need to optimise the design and re-assess the point of installation of the device in order to provide an adequate continuous dose of chlorine to the supply. The original design requires a continuous flow of water whereas in every case where the device was found installed during the survey (7 of 18 systems), it was found hanging at points of the reservoir convenient for access but not located in a flow of water that guaranteed the diffusion of hypochlorous acid from the hypochlorinator. Consequently no residual chlorine was detected in any supply system.

ii) It would appear that as important as any technological problem with disinfection there is also a lack of an adequately administered disinfection programme. An appropriate infrastructure for the distribution of chlorine powder in quantity and quality to the communities is essential.

A detailed discussion of these topics can be found in reference notes (1), (2) and (3).

All the above-mentioned problems have been addressed in the Cocharcas intervention but a detailed description of horizontal roughing filtration is the main objective of this report.

2. OBJECTIVES

The objectives of the project were the following:

a. To propose and implement a full rehabilitation scheme for a typical treatment system of rural water supply in Peru.

b. To involve community participation and implement a training programme for the operation and maintenance of the scheme by the Juntas Administrativas de Agua Potable (JAAP).

c. To incorporate and evaluate the performance of horizontal prefiltration for pretreatment of water prior to slow sand filtration.

3. THE REHABILITATION PROJECT

a. Description of the Community of Cocharcas

The community of Cocharcas is located in a typical agricultural area of the high sierra of Peru in the Mantaro River Valley. Its proximity to the city of Huancayo (10 Km of paved road) guarantees a permanent market for crops grown in the community.

A summary of the characteristics of the community of Cocharcas can be found in Table 2 and its location is shown in Figure 1.

b. Description of the Water Supply Scheme

The water supply scheme of Cocharcas was constructed in 1977-1978 by the Ministry of Health/PNAPR with community participation and support from CARE. The scheme is of a typical design comprising an abstraction located on a small irrigation canal, a settler, two slow sand filters, a reservoir with no disinfection (although projected), a conduction line and a distribution system with single tap household connections. The details of the system together with the state of each stage prior to the intervention are shown in Table 3; Figure 2 presents the layout of the system.

The first contact with the community was made in mid-September of 1985. The system then worked only for 2-3 hours per day, a situation due to the fact that: i) the water source was the property of a neighbouring community, and ii) there was no flow control mechanism and thus an indiscriminate amount of water was being abstracted. This resulted in constant interference as described in the introduction under "abstraction problems". The caretaker was only concerned with filling up the reservoir and as a consequence the plant was badly overloaded and no treatment occurred. Figure 3 shows the granulometric characteristics of the 30 cm layer of sand in the SSF. The community was led to believe that the solution to the problem was to build another reservoir. In the meanwhile the people used home containers to store water drawn in the few hours that the supply was available. Gross faecal pollution of the supply occurred at the outlet valve and "clear" water chambers of the slow sand filters due to the lack of adequate drainage facilities for the filter overflow.

Table 2

General description of the community of Cocharcas

THE PLACE	
. Name of community	Cocharcas
. District	Sapallanga
. Province	Huancayo
. Department	Junin
. Altitude m.	3280
. Temperature fluctuation	0 - 25^0 C
. Average temperature	12^0 C
. Access	10 Km highway south from Huancayo
THE PEOPLE	
. No. of inhabitants (1981 census)	624
. No. of children (0 - 14 yrs)	275
. No. of houses	142
. Languages	Spanish and Quechua
. Political authority	Lieutenant Governor
. Other authority	Administration council
. Institutions/services	Primary school, Health post, Church, Council, Junta Administrativa de Agua Potable.
. Agricultural products	Potatoes, peas, yuca, camote, forrage, oats.
. Per capita income (unqualified labour)	USD 1/day
. Average family size	4 - 6

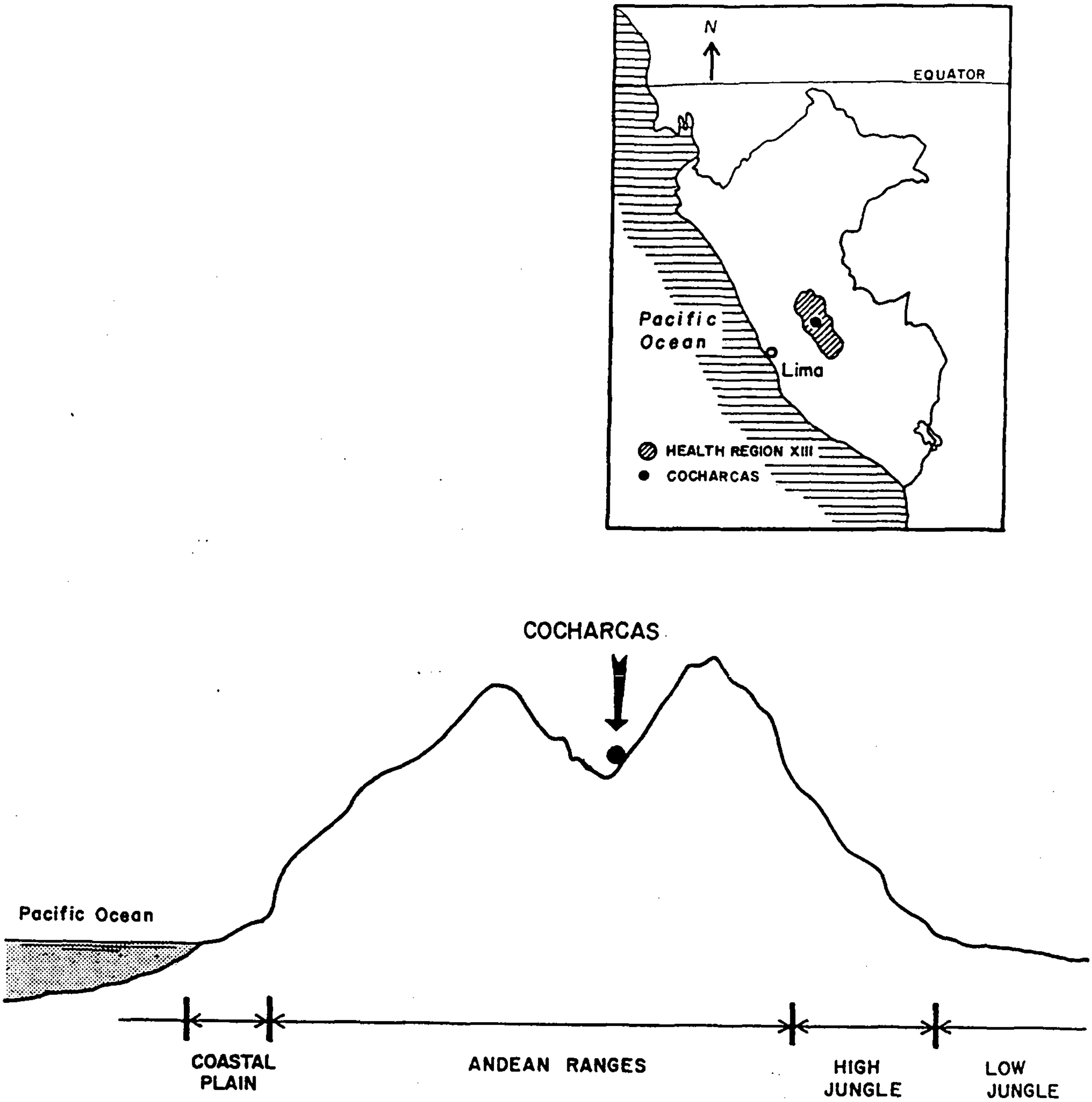


Figure 1. LOCATION OF THE COMMUNITY OF COCHARCAS

Table 3.

Main Features of the Water Supply Scheme of Cocharcas - related problems

(Design capacity Qmd = 103 m^3/d, Design population 1078 inhabitants)

Component	Description	State prior to intervention (diagnostic)
Water source	* Irrigation canal "Acequia Sapallanga" Q = 5 - 150 l/sec * Not the property of Cocharcas	. Originates from a river 4-5 Km upsteam . Heavily exposed to human and animal contamination . Seasonal increments in susp. solids loading (Nov-Mar), due to characteristics of the catchment basin
Abstraction canal	* Cement box includes - screen - outlet valve	. No dam for minimal water intake in the . No weir . No device to evacuate any excess water from the weir box . Obstructed daily by irrigation canal users
Treatment System	* 1 x settler So=0.36 $m^3/m^2/h$ Td=3.3 h * 2 x slow sand filters Vf=0.2m/ h * Material: reinforced concrete	. Load and filter velocity exceeded due to 2-3 h/day operation . No means of measuring flow of water through the SSF . No drainage system for SSF overflow and cleaning pipe line . Inadequate sand bed and underdrain material . SSF valve boxes flooded due to leakage . No disinfection practised
Storage and Balancing	* Reservoir 30 m^3 * Material: reinforced concrete	. No adequate drainage facility for reservoir overflow
Conduction Lines	* (1260) m, 2"diameter * (522) m, 4"diameter	. Sporadic air locks restrict the flow

continued overleaf...

Table 3 (Continued)

Component	Description	State prior to intervention (diagnostic)
Distribution System	* 90 x House connection 4", 3", 2" diameter	. Single household taps . Intermittence in service leads to inadequate in house storage and poor hygiene
Protection of Facilities	* Adobe walls surround the: - water treatment plant - reservoir	. Adequate
Human Attitudes		. Well organized Junta Administrativa de Agua Potable . Awareness of the Community of Cocharcas of defects in the supply system . Operation of system delegated to a caretaker foreign to the community . The only motivation of caretaker is to fill the reservoir up every day . Belief in the community that the problem would be solved with a bigger reservoir . Willing to participate in the improvement of the system . Neighbour community owns the source irrigation canal and obstructs daily the abstraction of the system, perceived competition for the vital water resource for irrigation

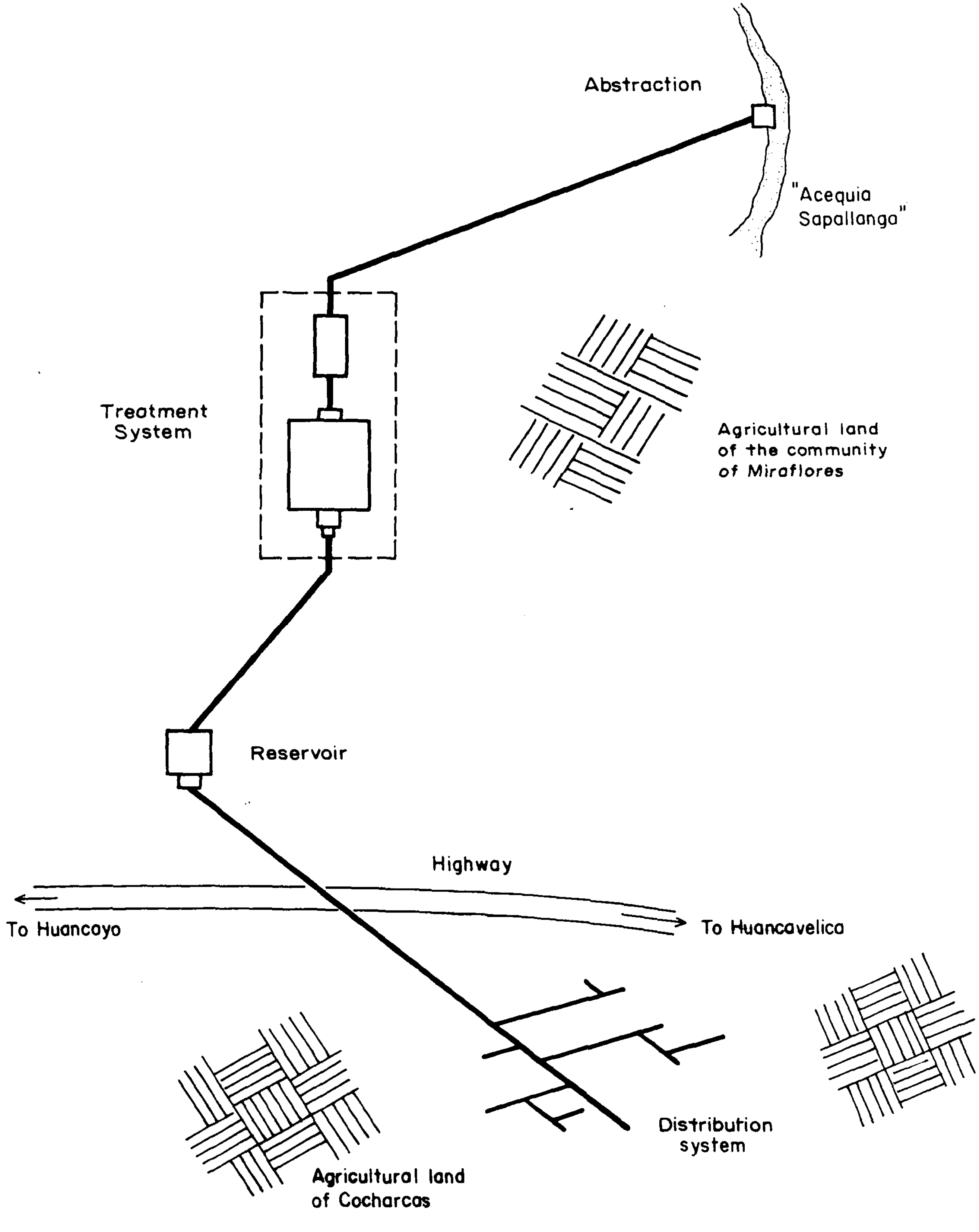
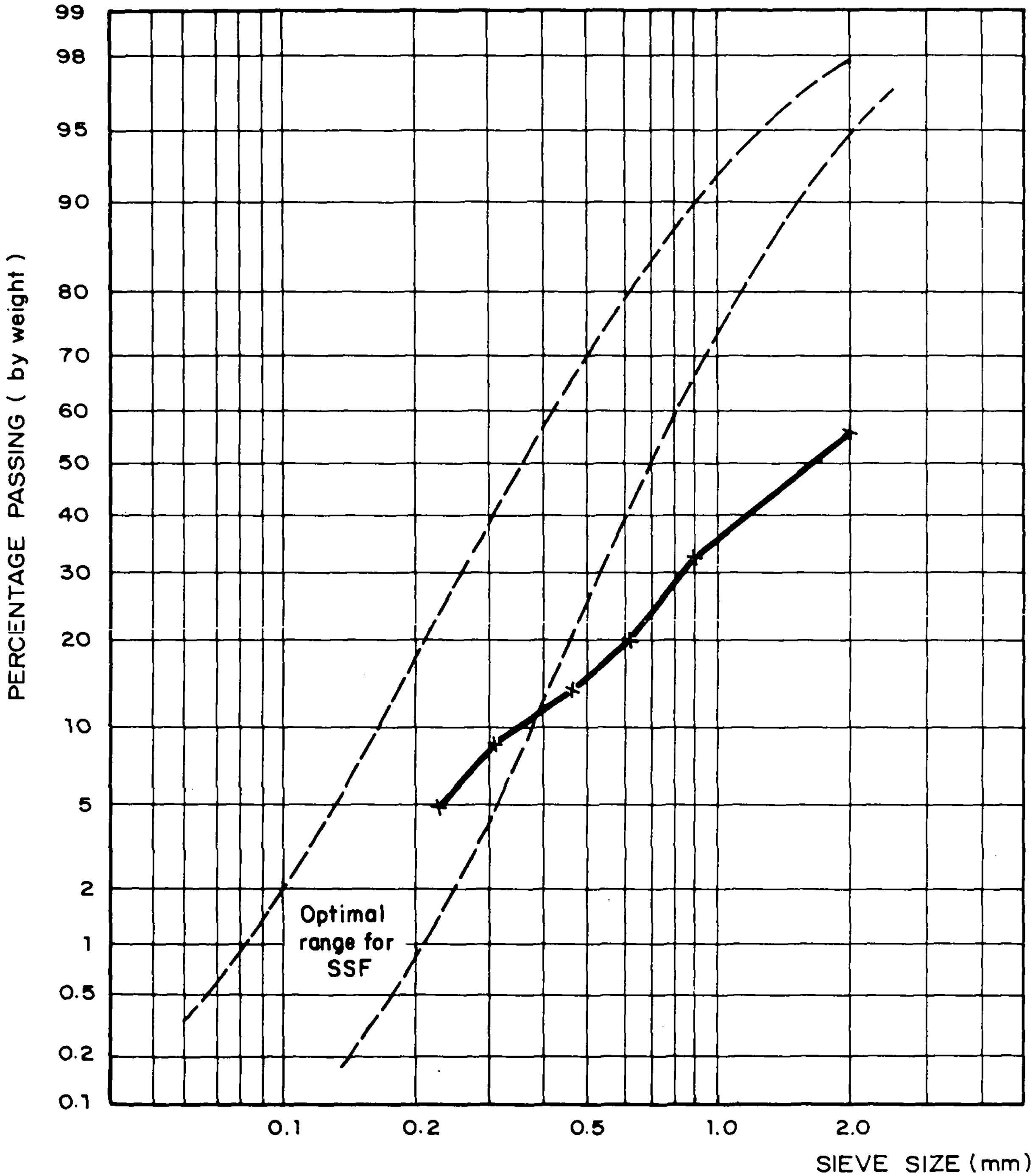


Figure 2. SCHEMATIC DRAWING OF THE WATER SUPPLY SCHEME OF COCHARCAS



EFFECTIVE SIZE = 0.32 mm

COEFFICIENT OF UNIFORMITY = 7.8

Figure 3. GRANULOMETRIC ANALYSIS OF SAND IN SSF PRIOR TO REHABILITATION OF TREATMENT PLANT IN COCHARCAS

A mixture of circumstances including faulty design, bad construction practice, disagreement over water use and inadequate operation and maintenance resulted in an insecure and intermittent service that represented a continual threat to the health of the community.

c. The Intervention Required for the Water Supply Scheme of Cocharcas.

The situation called for not only technological solutions but also participation of the various groups of people involved. Three full community meetings in two months, with DelAgua and CARE agencies, were required to organize the rehabilitation programme. A description of the components of the work proposed to the community is shown in Table 4.

d. The Design Stage

The most important technological components introduced in the rehabilitation programme were the Horizontal Prefilters. Based on the experience developed by CEPIS, DelAgua and IRCWD since 1978, a prefilter was designed. Water quality characteristics were at first assumed and afterwards verified during the rainy season (4), the resources available in the community were taken into account and the unit was designed for an expected performance. New techniques developed by DelAgua for filter cleaning were incorporated and a pilot scale horizontal filter was tested in the experimental site of the Lima "La Atarjea" water treatment plant. The design criteria used were based on these experiences.

The preliminary design of the unit was submitted to Martin Wegelin (IRCWD) for comment and amendments were adopted in the final design.

The construction techniques were recommended by Ing M. Campos (CARE) who agreed the final structural characteristics and plans of the unit for the construction stage.

The basic design parameters of the prefilter are shown in Table 4. The detailed sequence of calculations together with plans and drawings are presented in Appendices I and II. A revision of concepts in the light of the IRCWD Horizontal Roughing Filtration (HRF) Design Manual (M. Wegelin; Note 3) is presented in Appendix III.

Table 4

Description of the proposed intervention in the water supply scheme of Cocharcas

Component	Intervention required
Abstraction	. Repair of the weir box for adequate operation and install - 45° "V" notch - Adequate flow control devices
Treatment System	. Install horizontal roughing filtration . Install water evacuation scheme for overflows and cleaning mechanisms of SSF . Repair leaking valves . Incorporate disinfection
Protection of Facilities	. Cover over abstraction box . Extend surrounding wall to new treatment facility
Community	. Develop rehabilitation programme + work schedules with community . Organize teams of work . One week workshop for Juntas Administrativas de Agua Potable and community on operation, maintenance and administration of system . Contacts with neighbour communities to stop interference with the water source

Table 5

Design parameters of the horizontal roughing filter of Cocharcas

Range of turbidity load	NTU = 10 - 500	
Range of suspended solids load	mg SS/1 10 - 400	
Flow	Qmd = 103 m^3/d	
Filtration velocity	Vf = 0.60 m/h	
No. of parallel units	2	
Filtration stages	Filter length	Gravel diam.
1st stage:	3 m	1.1/2 - 1"
2nd stage:	2 m	1/2 - 1"
3rd stage:	1 m	1/4 - 1/2"
Turbidity leaving the HRF	NTU < 10	
Suspended solids leaving the HRF	mg SS/1 < 10	
Filter cleaning velocity	1.5 - 2.0 m/min	
Volume of water for filter cleaning	1.3 m^3/m^2 of filter bed	
Construction material	stone 70%, 1:5 mortar 30%	

e. The Construction Stage and Related Activities

The construction stage of the rehabilitation programme had two phases;

The first phase comprised the construction of the prefilter, the selection and installation of the gravel and the construction of the drainage canal, which lasted from December 1985 until March 1986. The second phase, after the training course for the community and caretakers in mid-March, then ran intermittently and lasted up to May. In this second phase all the complementary works were done: the refurbishing of the abstraction point and slow sand filters and other minor repairs.

To perform the first phase of the work two workers skilled in stone masonry and plumbing were hired. As a complement to them, the community provided a labour force of between 10 and 20 people per day (occasionaly 30 or more) which included women and elderly people.

The division of labour is presented in Table 6. It has to be noted that the occasional larger number of people made the work less efficient but this is an inherent feature of community participation. The involvement of people in this type of project more than offsets any apparent inefficiency. Another factor was that the construction was done throughout the rainy season, thus the hours effectively worked could be substantially lower than the figures shown in Table 6.

After 40 days of work it was clear that permanent supervision by the community authorities had to be established. Representatives of the local administrative committee, the political authorities and the Concejo de Administracion assumed this responsibility and established work teams on which the "supervisors" exerted a moral pressure and some direction of the activities.

Table 6

Division of labour in the rehabilitation programme of Cocharcas
(days)

Activity	Labour		Supervision	
	Unqualified	Qualified	Eng level	Tech level
Construction of the horizontal roughing filter (a)	*	-	16	-
- Preliminary works and excavation	200	2		
- Construction of the HRF, includes selection of building material	550	113		
- Drainage canal, excavation and construction	250	30		
Selection and installation of gravel for the HRF (b)	600	-	4	1
Selection and installation of sand for SSF (b)	430	-	2	3
Complementary works	-	5	3	10
Totals	2,030	150	25	14

(a) The total amount of unqualified labour in the construction of HRF is accurate but the division subsequently shown is only approximate.

(b) Gross errors in these values are possible given the nature of the activity.

N.B. The estimates quoted do not include time spent in planning and designing the system.

Construction details: (a critical appraisal may be found in the section on recommendations)

- The whole prefilter structure was constructed of stone masonry work; 70% washed rounded stones and 30% 1:5 cement-sand mortar.

- The internal filter walls were plastered to make the filters water-tight.

- The prefilter's dividing walls were constructed with mortar and stones, reinforced with 1/8" diameter steel. The holes, through which water was to flow from one stage to the next, represented 20% of the surface area and were formed from 2" diameter drainage pipe.

- The drainage canal (55 metre long and 0.25 m^2 cross sectional area) was also constructed of stone masonry work. The previous lack of a drainage system for the SSF overflow required the construction of a 1.2 - 1.5 m deep buried canal with a domed roof.

Selection of gravel and sand:

Gravel was transported 3 Km by lorry from a river bank to the HRF site where it was graded with sieves as shown in Figure 4. This required 10 days work per cubic metre of selected and installed gravel. It is interesting to note that in previous projects where labour was hired the relation was an average of 4.7 work days/m^3.

The sand for slow sand filters was similarly transported from the same river bank site and graded at the treatment plant for the SSF. The final granulometric characteristics for the reconditioned sand bed are shown in Figure 5.

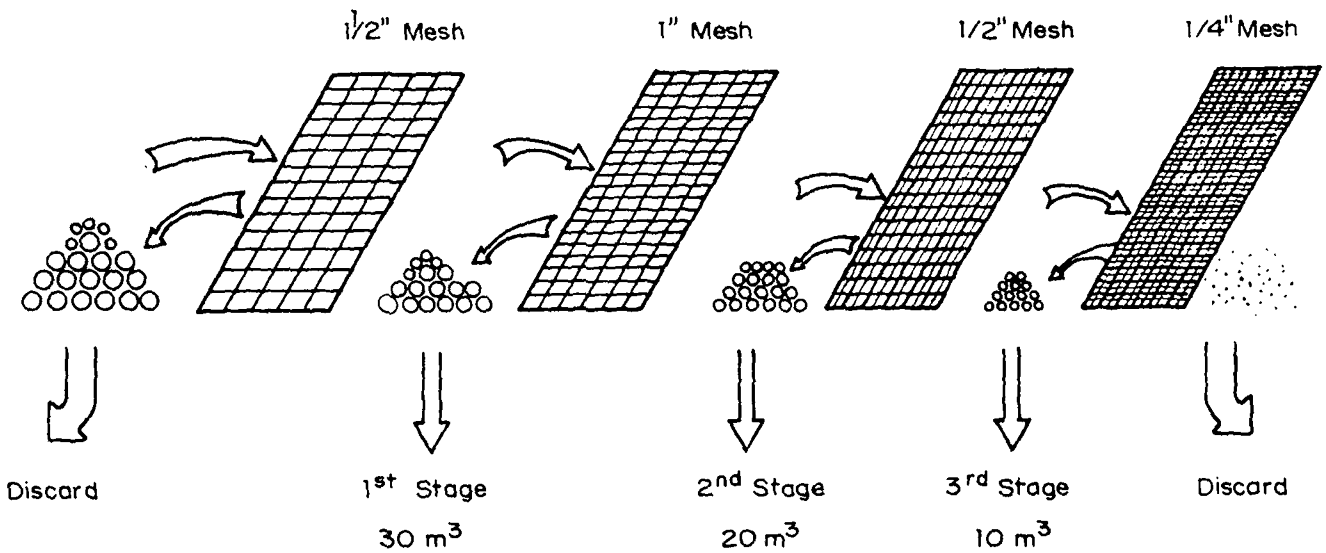
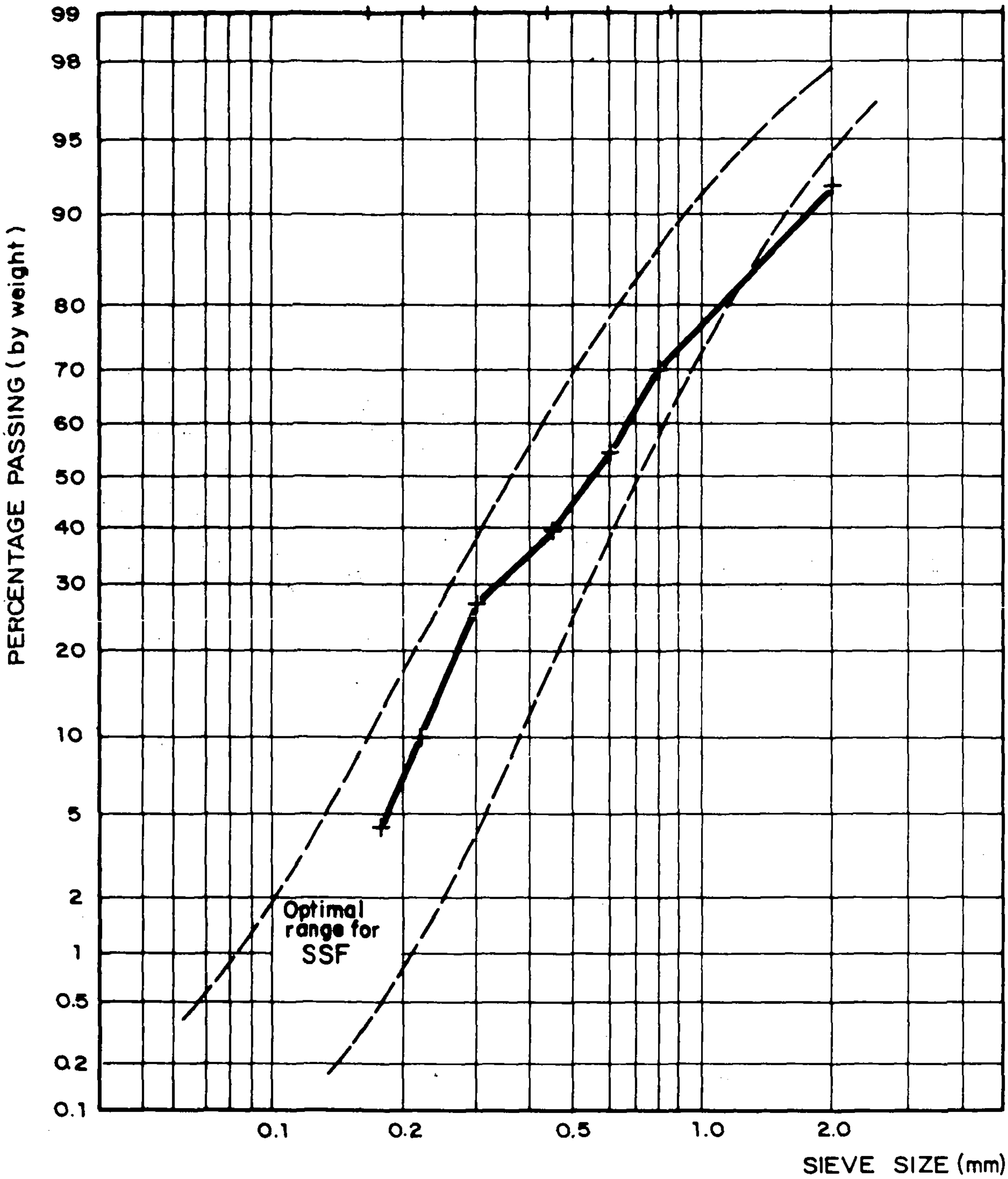


Figure 4. SELECTION OF GRAVEL FOR THE HRF OF COCHARCAS



EFFECTIVE SIZE = 0.21 mm.
COEFFICIENT OF UNIFORMITY = 3.1

Figure 5. GRANULOMETRIC ANALYSIS OF THE SAND USED IN THE REHABILITATION OF THE SLOW SAND FILTER OF COCHARCAS

f. Analysis of Costs

1. The general structure of costs of the rehabilitation project is shown in Table 7. (detailed costings are presented in Appendix E.).

2. The major cost component of this rural water treatment scheme is the Horizontal Roughing Filter (75%), vital for the protection of the slow sand filtration unit. The slow sand filter treatment system did not present deterioration of its concrete structure so the complementary works were primarily the repair of the slow sand filter underdrainage and valves and the refurbishing of sand and gravel beds and of the abstraction point.

3. Note that the labour of the community is not costed into the analysis. The factor of inefficiency described in e. would only produce misleading values. Qualified labour of (albaniles) and per diems of technical staff of the Ministry of Health are the only values considered.

4. As a consequence of 3. the cost of supplying gravel is not considered (apart from hire of lorries) in the analysis. Wegelin (8) reports typical costs of gravel of 20% of the total works and a previous project in Peru the relation was 12% of the total cost (9).

5. The total cost of materials for the HRF was of USD 1,725. The design capacity of the structure is 103 m^3/day; producing a relation of 16.7 USD/m^3/day capacity (contrast Wegelin Note 8).

g. Evaluation

By the time the scheme was ready to operate the rainy season had prematurely faded, delaying to the next year the evaluation of the performance of the HRF.

A protocol for the evaluation of the complete treatment scheme is presented in Table 8; the activities of this evaluation programme commenced in early June and will last a complete year. It is already clear that disinfection will be necessary and hypochlorination technology is under investigation.

Table 7

Rehabilitation project of Cocharcas - Resume of costs (USD)

Component	Materials	Labour (1)	Total
1. Construction of the horizontal roughing filter structure	1,725	885	2,610
2. Construction of the HRF drainage canal	85	230	315
3. Complementary works	240	40	280
4. Operating costs and general supervision	125 (2)	150	275
TOTALS	2,175	1,305	3,480

(1) Only qualified labour considered.
(2) Mainly fuel costs.

Table 8
Proposed scheme of evaluation of the water supply system of Cocharcas

Record / Parameter		Frequency	
Field Monitoring			
Flow rate HRF + SSF		3 / week	
Filter resistance HRF		1 / week	
Filter resistance SSF		3 / week	
Efficiency of filter cleaning procedure		2 / rainy season	
Chlorine consumption in the plant		1 / week	
Bacteriological and Chemical Parameters		rainy season	dry season
Turbidity:	of raw water	2 / week	1 / month
	of effluent of HRF	1 / day	-
	of effluent of SSF	1 / day	1 / week
Faecal Coliforms:	of raw water	1 / week	1 / month
	of effluents of HRF + SSF	2 / week	1 / mon
Chlorine Residual:	Distribution system	2 / week	2 / week
pH Conductivity Total hardness Alkalinity Ca^{2+} Mg^{2+} Suspended solids	of raw water	1 / season	1 / season

N.B. The evaluation will run over a complete hydrological cycle.

4. RECOMMENDATIONS

General

. Rehabilitation projects have to be carefully programmed to promote integration with community activities.

. Rehabilitation projects should not be executed during the rainy seasons because
- work is intermittent
- selection of sand and gravel is extremely inefficient under rainy conditions (high tides in river banks, impossibility of sieving sand etc.)

. Implementation of HRF in rehabilitation programme requires advance planning to procure raw water quality information of preceding rainy seasons for design purposes.

Construction details

. Dividing walls of HRF should in the future be made of prefabricated bricks of the type shown in Fig. 7. The use of pipe for apertures in the walls demands a lot of patient and careful work.

. Fast opening gates of the type shown in Figure 8. have proven an excellent solution for the gate dimensions required for efficient filter cleaning. Ordinary gate valves of the necessary cross sectional area required (500 mm diameter) can cost up to 5 times more and the operation would never be as satisfactory because of the time that the full opening would take.

The gate is opened in two sequences. First, untightening the screw of a lock bar [(A) in Fig. 8] and swinging it laterally. Second, lifting the handle bar [(B) in Fig. 8] which will completely release the lock bar. The head of water in the filter will then violently open the gate and instantaneously produce a high velocity in the filter bed which will dislodge the sediments and achieve efficient cleaning. The double pivot in the hinges is used to secure a perfect water tightness between the plate and the frame of the gate.

. When working with stone masonry it is practical to raise the whole structure progressively instead of building wall by wall. The availability of sufficient wood for shuttering is advisable to secure a continuous work schedule.

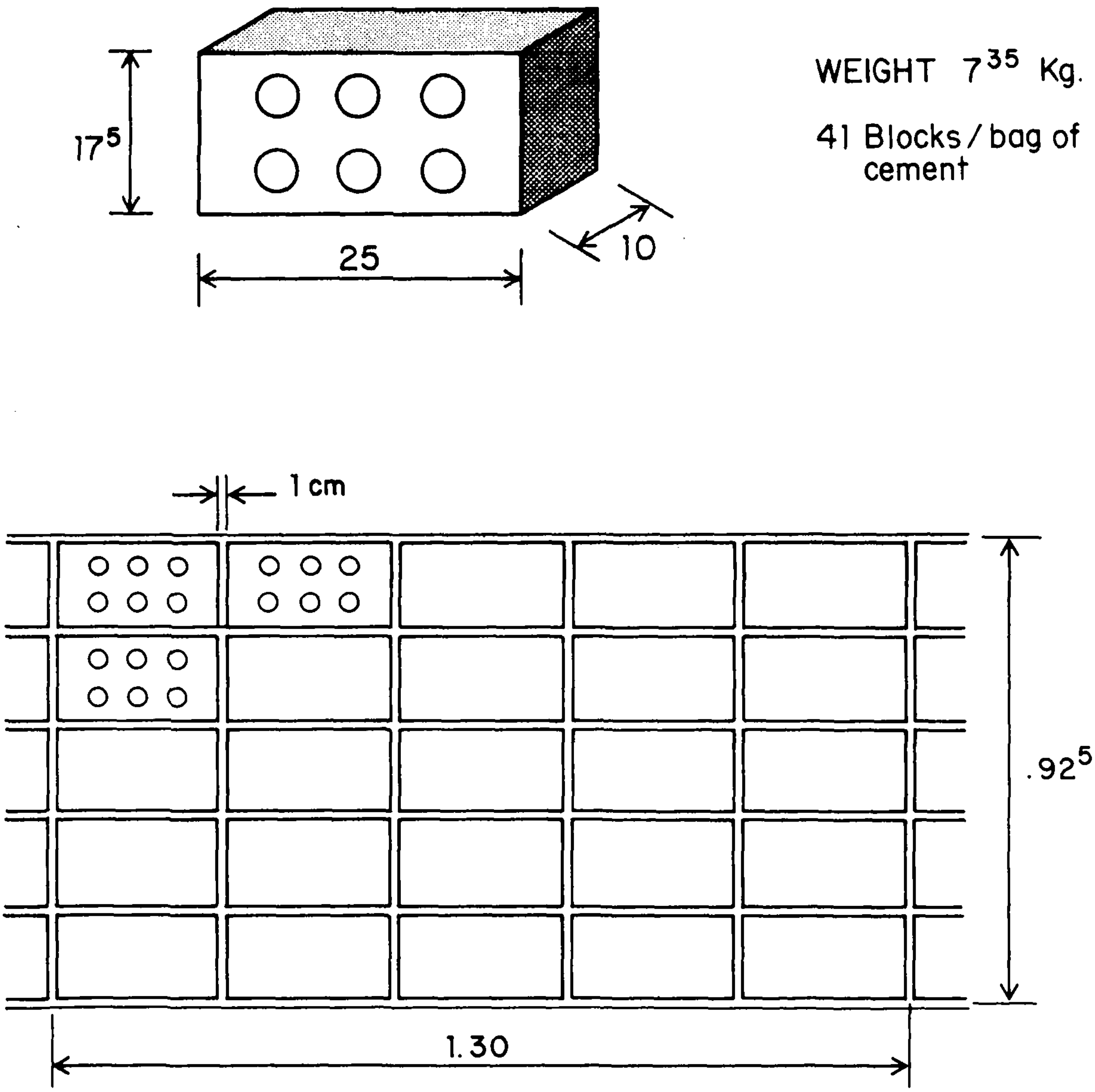


Figure 6. BLOCKS RECOMMENDED FOR SEPARATING THE WALLS OF HORIZONTAL ROUGHING FILTERS (After M. Campos)

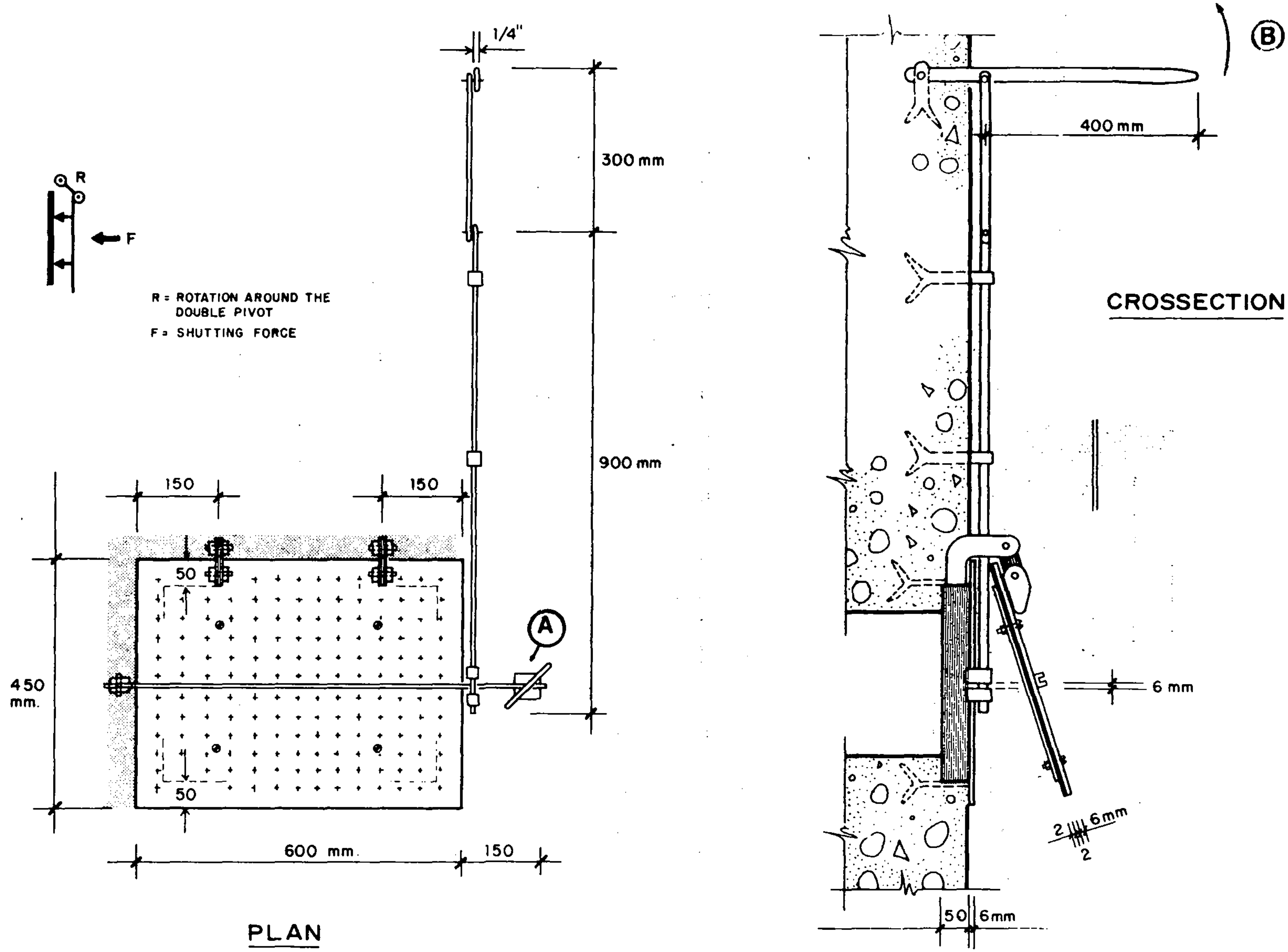


Figure 7. FAST OPENING GATES OF THE HORIZONTAL ROUGHING FILTER OF CUCHARCAS

5. FUTURE ACTIONS

- A second rehabilitation programme with emphasis in HRF construction for a high jungle rural community is now at the planning stage. Different raw water characteristics will provide more evidence of the efficiency of the units under different operating conditions.

- Evaluation is required of the efficiency of the criteria developed for hydraulic cleaning. The information required will be provided following next rainy season (November 1986-March 1987).

Reference Notes

(1) Lloyd et al.(1986) DelAgua Phase 1 Report. Developing Regional Water Surveillance in Health Region XIII-Peru pp. 23-26.

(2) Canepa, L. (1982) Filtros de Arena en Acueductos Rurales. Informe Final Investigacion No. 3, Lima CEPIS pp. 5-9.

(3) Wegelin, M. (1986) Horizontal Flow Roughing Filtration. A design, construction and operation manual. DRAFT. Switzerland. IRCWD. pp 83-84.

(4) The preliminary design was calculated on the basis of an assumed value of influent presettled water containing 750 NTU. During the construction stage (rainy season), the raw water never exceeded 500 NTU.

(5) Note (3) p. 70 Characteristics of the kaolin suspension used for the experimental work with a uniform particle size of 2um tends to give rather conservative values of efficiency.

(6) Perez et al. (1985) Informe preliminar de la investigacion sobre prefiltros de grava. CEPIS, Lima. Anexo 4.

(7) See reference in Note (3) pp 40-41.

$$Trun = 10'000 \times \frac{L}{(Ti-To) \times Vf}$$

Trun = (h) time interval between two cleanings
L = (m) filter length of first filter fraction
Ti-To = (TU) Turbidity units at inlet/outlet
Vf = (m/h) filtration rate

(8) See reference in Note (3) p 46.

(9) Construction of a vertical in series gravel prefilter for the community of Azpitia-Peru
Capacity 35 m3/d

Total cost of the structure	US$ 1035
Cost of selection of gravel (labour)	US$ 120

APPENDICES

APPENDIX A

Design Criteria and Calculations for the Horizontal Roughing Filter of Cocharcas

1. Community: Cocharcas
   District: Sapallanga
   Province: Huancayo
   Department: Junin

2. Parameters of the existing project

   i. Ministry of Health - Project No.: 5-117A
   Date: February 1977

   ii. Design parameters:
   Population: 1,078 p.
   Water consumption: 80 lppd.
   Service level: house connections

Consumption	L/s	m3/D
Q	0.998	86
Qdmax=1.2 Q	1.198	103
Qhmax= 4 Q	3.992	343

   iii Existing water supply system: 1) Abstraction - flow control structure, 2) settling, 3) slow sand filtration (2 units), 4) storage, 5) conduction-distribution, 6) house connection.

3. Design Parameters for the HRF's

i. Flow: Qmd = 103 m3/D

ii Water Quality entering the HRF (post sedimentation)
Turbidity 10 - 500 NTU
Suspended solids: 10 - 400 mg SS/L

iii. Water Quality leaving the HRF
Turbidity < 10 NTU
Suspended solids < 5 mg SS/L

iv Number of Parallel HRF units: 2

v Prefiltration velocity: 0.60 m/h

vi Filter cleaning process:

- flush water velocity: 1.5-2.0 m/min
- ratio, m3 of wash-water per m2 filter bed: 1.30 m3/m2.

4. The filter media

Parameter	Dimension
1) Unit (u) flow $Q_u = Q/n = 4.30/2$	$Q_u = 2.15$ m/h
2) Filter area of each HRF unit $A = \frac{Qu}{Vf} = \frac{2.15}{0.60} = 3.58$	$A_u = 3.60$ m
3) Dimensions: i height h = 1.0 m ii width b = 3.60 m iii length	

stage	gravel size (in)	length (m)
1st	1 1/2" - 1"	3.0
2nd	1" - 1/2"	2.0
3rd	1/2" - 1/4"	1.0

5. Methodology used in the calculation of the initial efficiency and overall length of the HRF.

Required length of a prefilter:

$$L = \frac{-\ln(T / T_o)}{\lambda}$$

L = length of the prefilter, m
T = effluent turbidity, NTU
To = influent turbidity, NTU
λ = impediment module

Experimental values of λ (after Perez (*))

Vf (m/h)	Gravel diam (mm) 10 - 20	20 - 30
0.10	1.00-1.40	0.70-0.90
0.20	0.70-1.00	0.60-0.80
0.40	0.60-0.90	0.40-0.70
0.80	0.50-0.80	0.30-0.60

Case study:

Stage	Nominal Gravel Diameter (in)	λ (approx)	L m	To (NTU)	T (NTU)
1st	1"	0.50	3.0	500	110
2nd	1/2"	0.775	2.0	110	23
3rd	1/4"	0.90	1.0	23	9

6. Flow control: distribution chamber with two 45o "V" notch weirs
For a unit flow of 2.15 m3/h = 0.6 lps
Head over weir h = 6.5 cm

(*) Perez, J. & Canepa, L. Guia para el diseno de plantas de filtracion lenta para medio rural. CEPIS-DTIAPA, Lima, 1984.

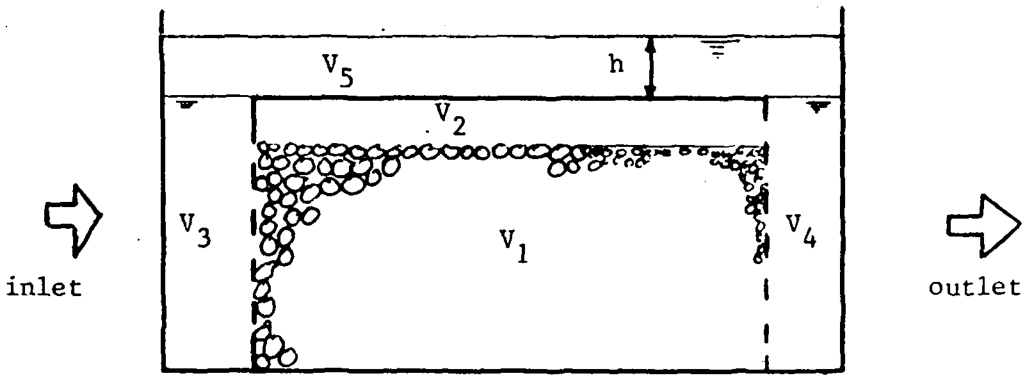
7. Filter cleaning mechanism

Parameters: Cleaning velocity in the filter (V_c) = 1.5-2.0 m/min
Ratio of volume of water available (R) = 1.3m^3/m^2
to surface area of the filter

Problems: a) Calculate the required volume of water
b) Calculate the cross-sectional area of the drainage gate

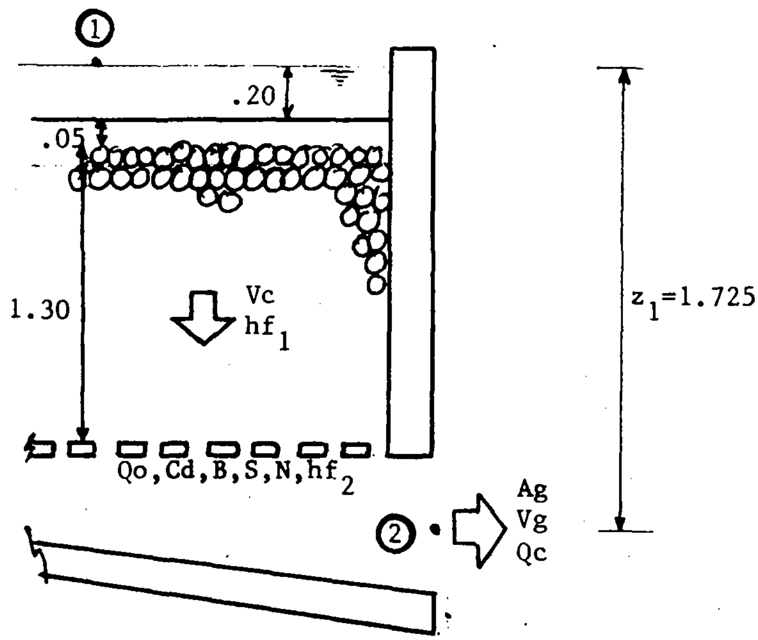
Solution:

a) Required volume of water in the structure (V_w)



V_1 = Volume of water in gravel bed; assume 35% porosity, m^3
V_2 = Supernatant volume of water up to dividing wall level, m^3
V_3 = Volume of water in inlet chamber, m^3
V_4=Volume of water in outlet chamber,m3
V_5=Supernatant vol. of water on top of the whole structure,m3
h =Height of level of water over the dividing wall of the two HRF units,m
A_i=Surface area of each filter unit,m2

c: Calculation of the crossectional area of the drainage gate



Vc = cleaning velocity, m/min
Ag = crossectional area of the drainage gate, m2
Qc = flow of water for cleaning, m3/s
Vg = velocity of water in the drainage gate, m/s
W = width of the filter basin, m
L =length of the filter basin, m
Qo = unit flow through the spacement between each slab ,m3/s
B = Spacement between slabs, m
S = width of underdrainage canal, m
N = No of spacements of slabs in the underdrainage canal,m
Cd = contraction coefficient, 0.65
H = height of gravel bed, m
hf = head loss during cleaning, m
hf_1= headloss in the gravel bed, m
hf_2= headloss in the slabs, m

Calculations

V1	=	0.35(3.60x6.00x1.30)	=	9.80
V2	=	3.60x6.00x0.05	=	1.10
V3	=	3.60x0.80x1.40	=	4.00
V4	=	3.60x0.60x1.40	=	3.00
V5	=	7.20(6.00+0.40+0.80)x h	=	(51.80)h
Vw	=	V1+V2+V3+V4+V5	=	17.90+(51.80)h
Ai	=	3.60x6.00	=	21.60

By definition R = Vw/Ai = 1.30

h [(1.30x21.60)-17.90] / 51.80 = 0.20

With the dimension of h (0.20 m), the required volume of water for cleaning is defined.

NB All dimensions have been simplified and wall thicknesses are not considered.

Calculations

$Qc = (Vc \times W \times L) / 60 \quad = \quad 0.63$

Applying Bernoulli and simplifying between points 1 and 2

$z1 = (V_2^2 / 2g) + hf$ ....(1)

$hf = hf_1 + hf_2$ ....(2)

$hf_1 = (Vc \times H) / 3 \quad = \quad 0.76$ ....(3)

$Qo = Qc / N = 0.0175$

$hf_2 = [Qo/(Cd \times B \times S)]^2 / 2g \quad = \quad 0.24$ ....(4)

(3) + (4) in (2)

$hf_1 = 0.76 + 0.24 = 1.00$ ....(5)

(5) in (1)

$V_2 = V_g = [(z_1 - hf) \times 2g]^{1/2} \quad \doteq \quad 3.77$

$Ag = Qc / Vg = 0.17$

Crossectional area of drainage gate must be approximately 1700 cm2

Dimensions : 350 x 500 mm

Note: an adequate opening mechanism is required given the dimensions of the gate.

APPENDIX B

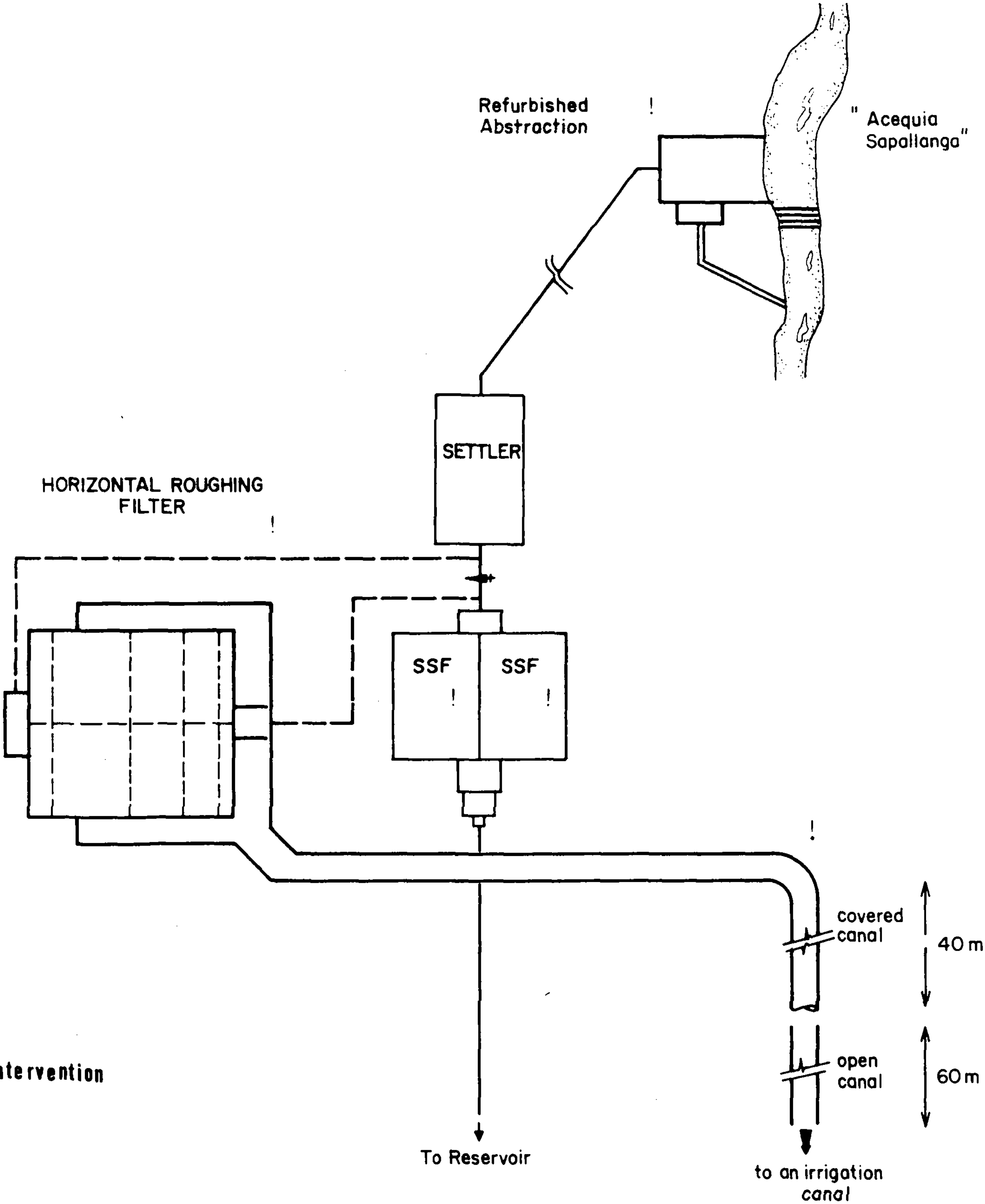
Plans and Drawings

B.1 Schematic drawing of the rehabilitated water treatment plant of Cocharcas

B.2 Horizontal Roughing Filter of the community of Cocharcas- Plan View

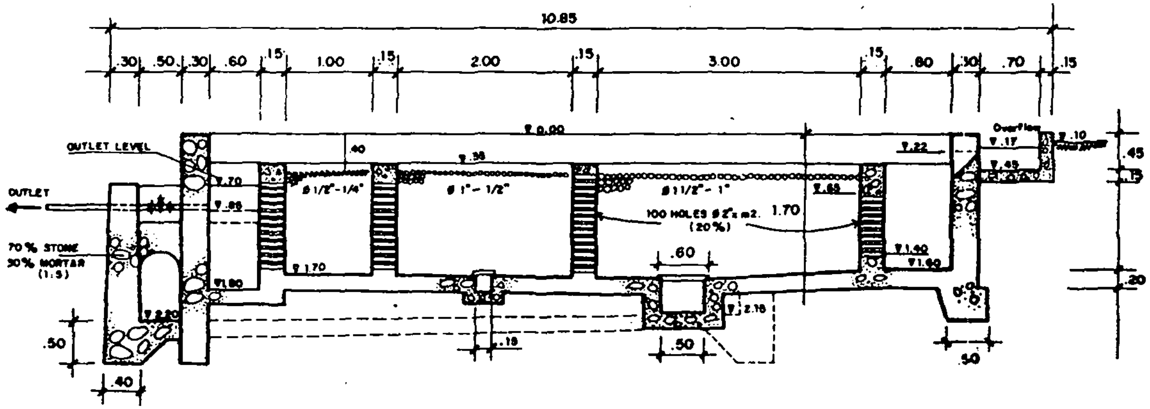
B.3 Horizontal Roughing Filter of the community of Cocharcas- Elevation

B.4 Rehabilitated abstraction point of Cocharcas

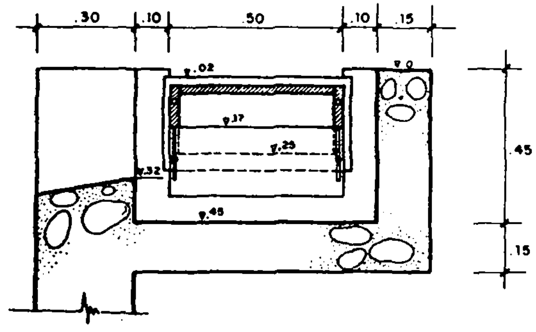


intervention

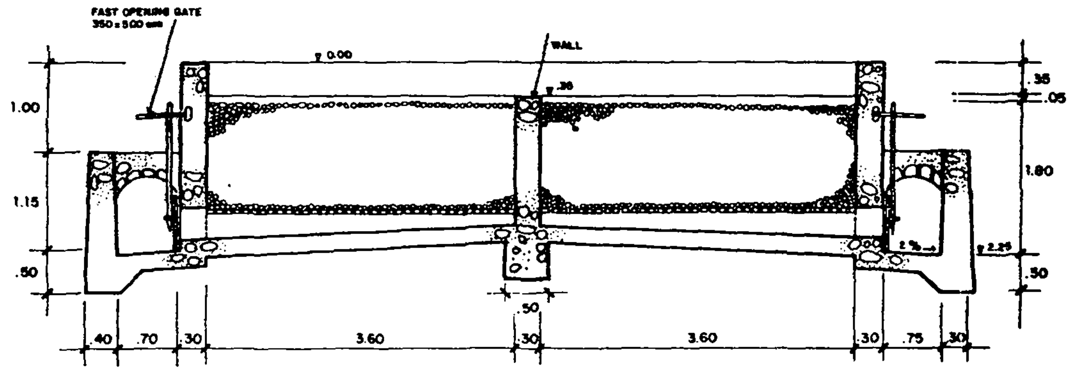
Figure B.1. SCHEMATIC DRAWING OF THE REHABILITATED WATER TREATMENT PLANT OF COCHARCAS



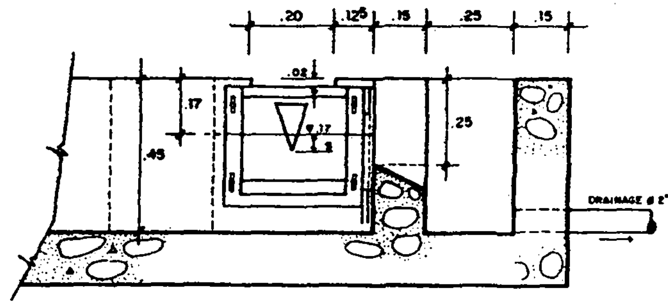
CORTE A-A



a - a



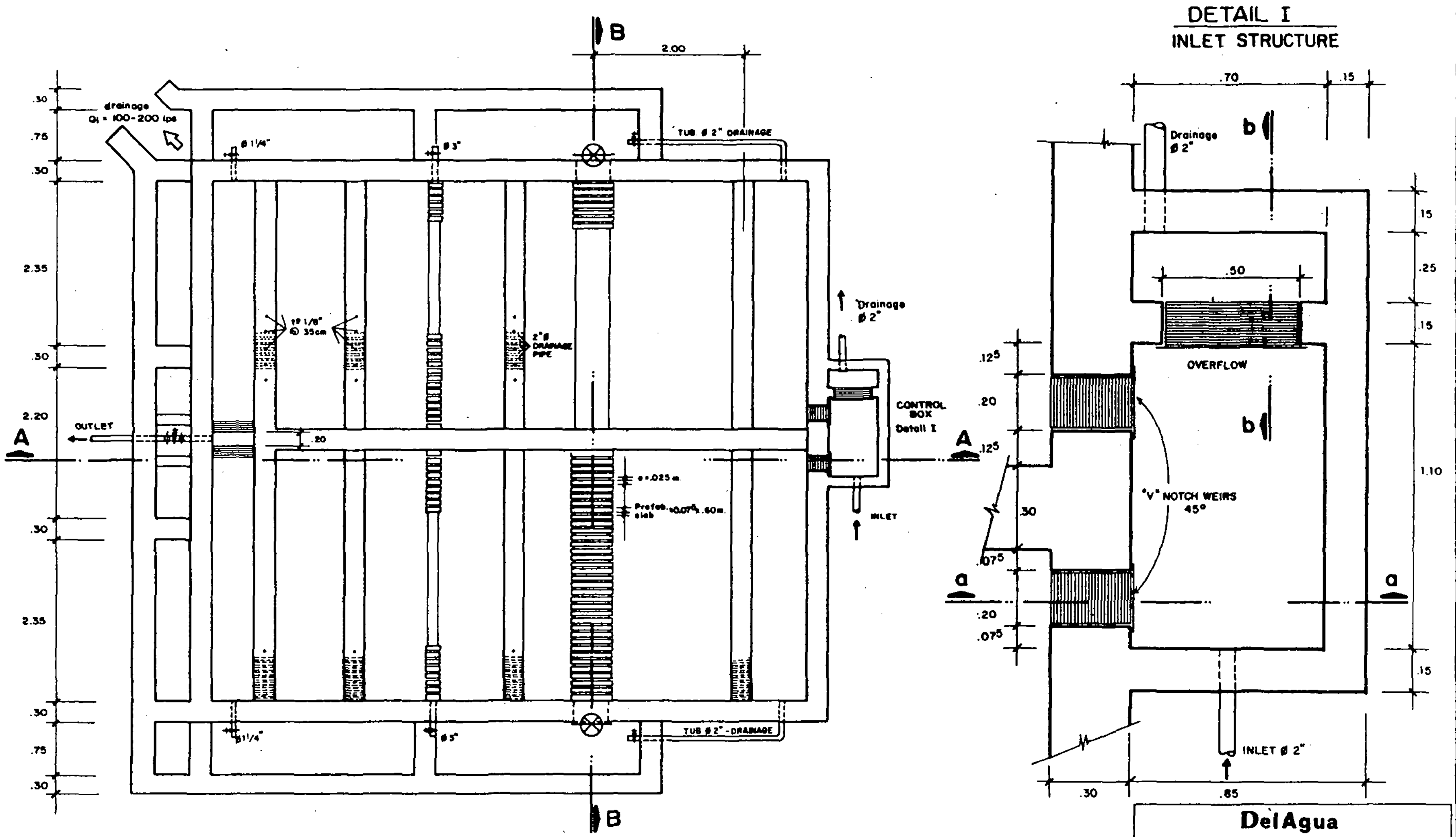
CORTE B-B



b - b

HORIZONTAL ROUGHING FILTER OF THE COMMUNITY OF COCHARCAS

DelAgua



HORIZONTAL ROUGHING FILTER OF THE COMMUNITY OF COCHARCAS

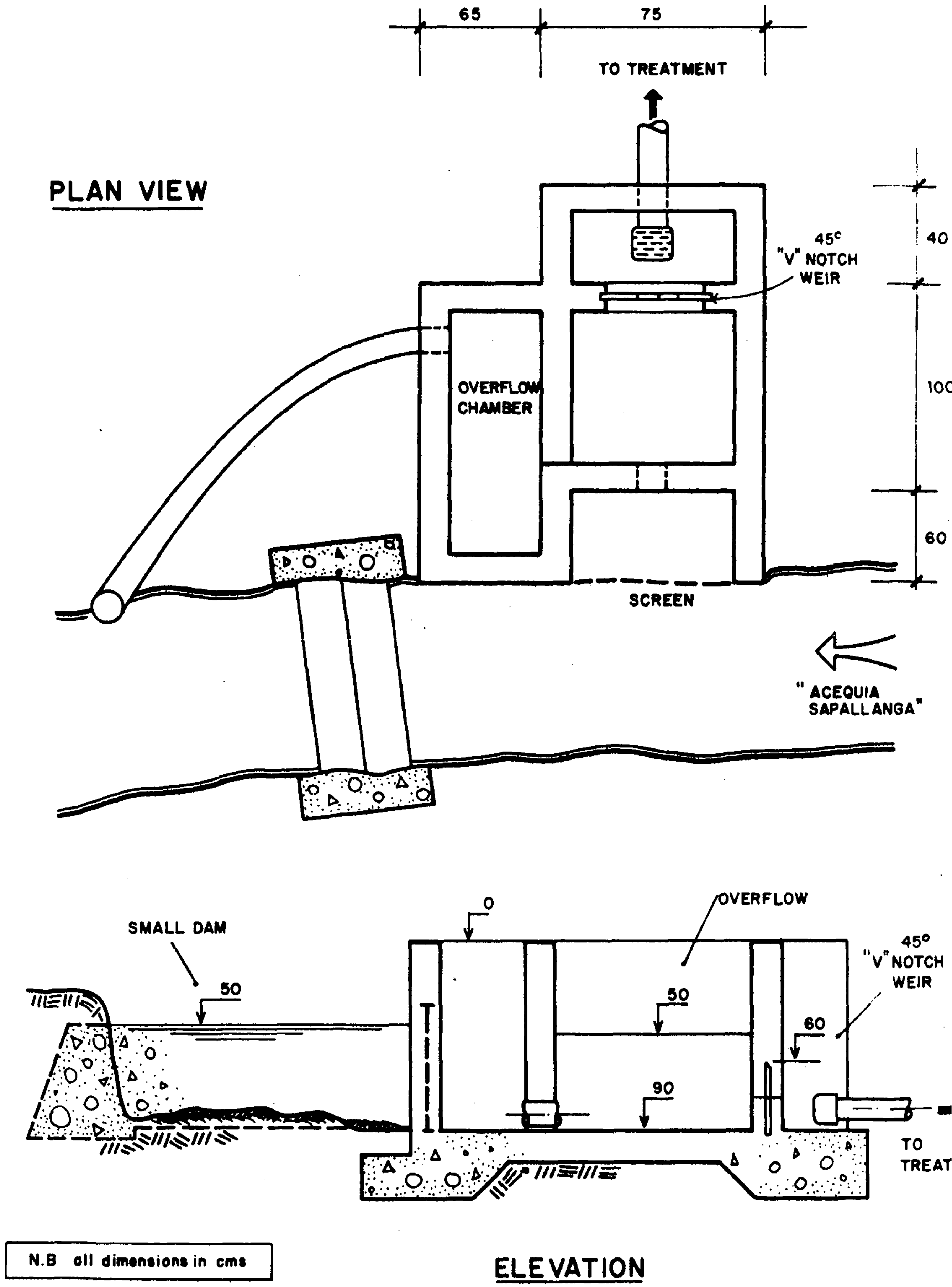


Figure B.4. REHABILITATED ABSTRACTION POINT OF COCHARCAS

APPENDIX C

REVISION OF DESIGNS AND CONCEPTS

After the Horizontal Roughing Filter of Cocharcas had been designed, and with the rehabilitation programme well on its way the Draft Design construction and Operation Manual for Horizontal Flow Roughing Filtration [ref. of note (3)] was kindly forwarded to the project in Peru, although preliminary concepts from it had already been received via personal correspondence with M. Wegelin.

In the light of the in-depth analysis of HRF that the manual presents we have considered it valuable to revise the design concepts used in the HRF of Cocharcas and present the discussion within this report.

1. Experimental work with natural suspensions of solids (fast flowing rivers) supports the order of magnitude of the λ values presented with the design criteria in Appendix I. This is consistent with the discussion of Wegelin (5). The second design for high jungle, where turbidity is likely to be due to more stable , smaller suspended particles, will be calculated on the basis of the criteria proposed by Wegelin (reference of Note (3)).

2. The criteria presented in the Design Manual for frequency of hydraulic cleaning (7) will be adopted for the evaluation stage.

3. The Design Manual states the requirement for cleaning velocities of the order of 60-90 m/h and proposes a mechanism. Two observations:

   i) If there is accumulation of solids in the bottom of the unit, the first seconds of the drainage sequence are the most important ones given the velocities achieved. The simultaneous opening of several drainage points as suggested in the Manual could prove inefficient and inconvenient. The calculation method for a single gate is shown in Appendix I.

   ii) During the evaluation of a prototype vertical gravel prefilter in Peru, it was demonstrated that the drainage velocity of water from the gravel bed alone is not enough. Additional water had to drain through the gravel beds in order to achieve an improved efficiency & consistent removal of solids. Experimental data is presented in the following table.

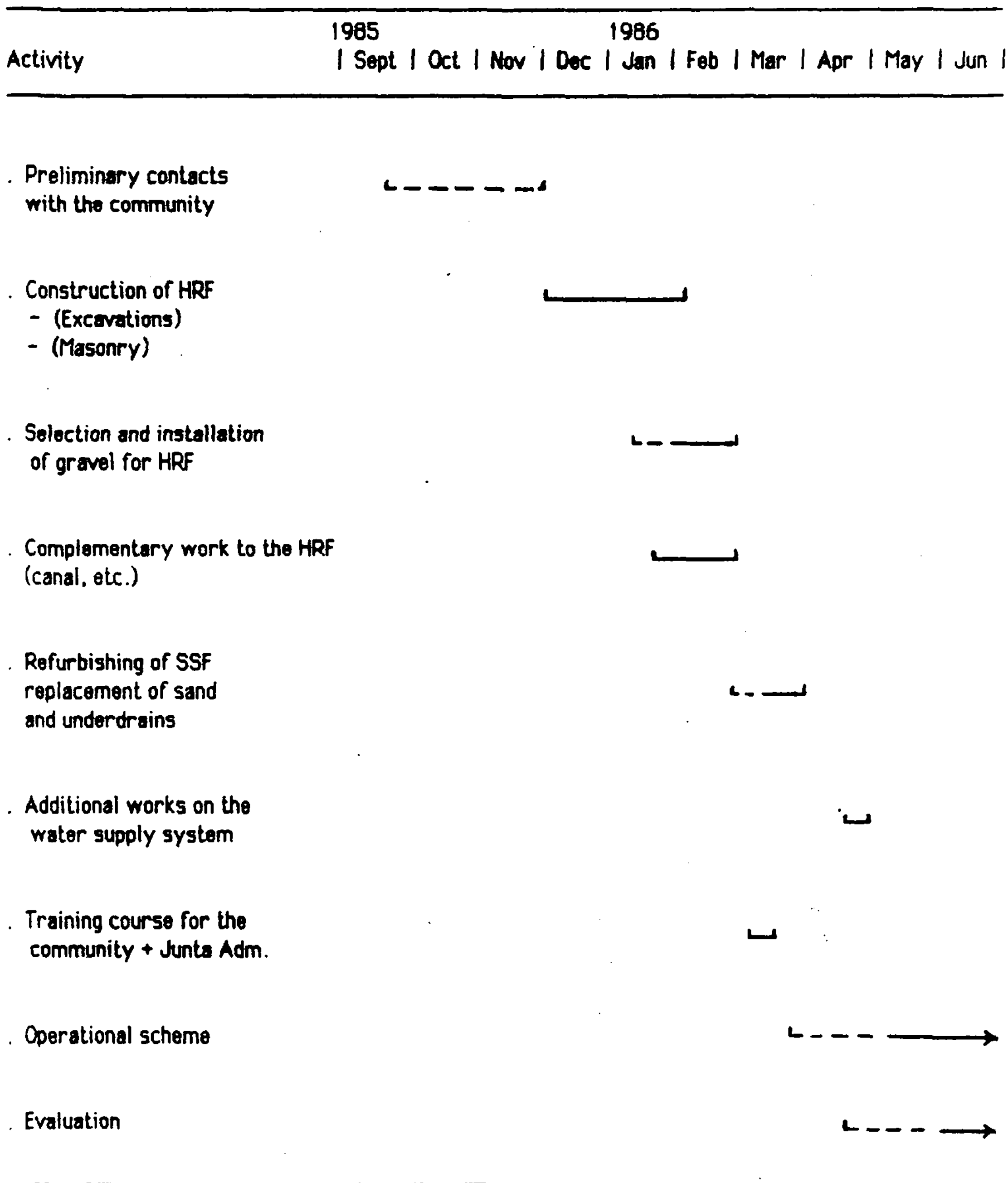
Practical and Experimental experience with cleaning gravel prefilters

Evaluation conducted in	Conditions of cleaning	Efficiency of cleaning (% solids removed)
Vertical in series pre-filter of Azpitia	Vc = 0.9 - 1.8 m/min	7% - 21%
Experimental test rig	Vc = 1.5 - 2.0 m/min Vol of water = 1.1-1.5 m3 water / m3 bed	62% - 72%

We therefore recommend a total volume of 1.3 m^3 water per sq.m. of filter for an adequate regeneration of the unit. From here the recommendation to increase the available cleaning water by allowing the supernatant water of all the structure to drain into the filter to be cleaned was developed. The calculations are presented in Appendix I.

Appendix D

Chronogram of Activities
for the rehabilitation programme for the community of Cocharcas



Appendix E1

Rehabilitation project of Cocharcas - Costs of materials (USD)

Component	Quantity	Cost	Total
1. Horizontal Roughing Filter Structure			
a) Cement	276 bg	690	
b) Reinforcing steel rods 0 1/8"	50 kg	35	
c) Pipe - PVC pressure 0 2"	35 m	70	
- PVC drainage 0 2"	480 m	165	
d) Fast opening gates, crossectional area 500 x 350 mm	2 u	220	
e) 45^0 "V" notch weirs and overflow plates	3 pz	15	
f) Galv. iron nipples	7 pz	80	
g) Fittings (G.I and PVC)	global	55	
h) Gate valves 0 2"	3 u		
0 3"	2 u		
0 1.1/4"	1 u	365	
i) Various	global	30	1725
2. HRF drainage canal			
a) Cement	34 bgs	85	85
3. Complementary works			
a) Cement	10 bgs	25	
b) Reinforcing steel 0 3/8"	5 r	10	
c) Accesories 45o "V" notch weir	1 pz	5	
d) Various	global	10	50
4. Sieves for selection of sand and gravel	global	190	190
	TOTAL		2,050

Appendix E-2

Rehabilitation programme of Cocharcas - Cost of qualified labour US$

Component	Man days	Cost
1. Construction of the horizontal roughing filter structure	115	885
2. Construction of the HRF drainage canal	30	230
3. Complementary works	5	40
4. General supervision (technician level)	global	150
TOTAL	US$	1,305