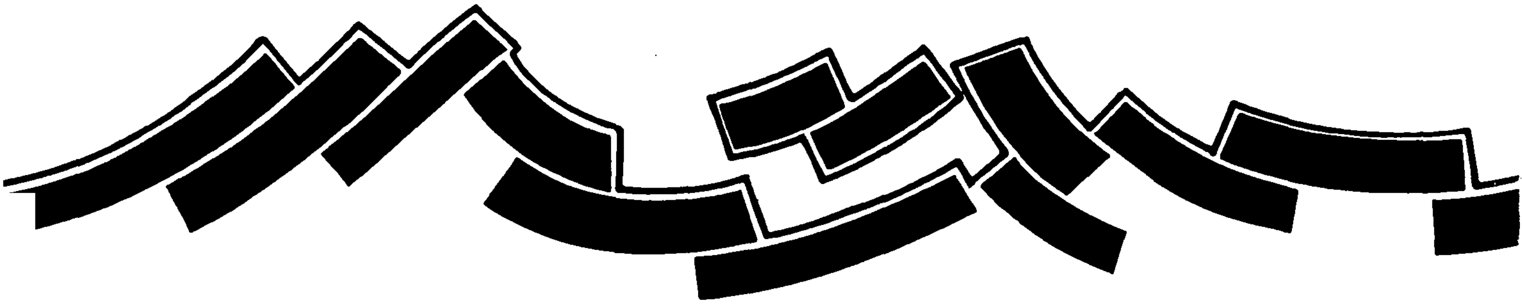
FUNCTIONAL DESIGN OF WATER SUPPLY FOR RURAL COMMUNITIES

by N.C. Thanh
Asian Institute of Technology



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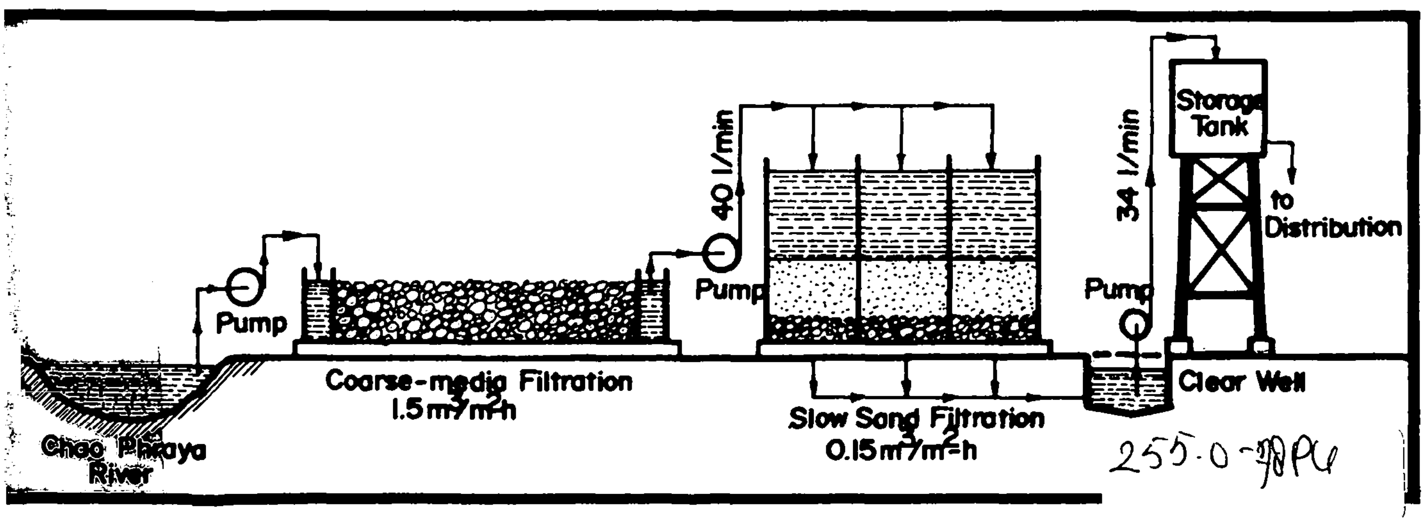

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RESEARCH AWARD REPORT

FUNCTIONAL DESIGN OF WATER SUPPLY SYSTEMS FOR RURAL COMMUNITIES IN DEVELOPING COUNTRIES

by

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I INTRODUCTION

The developing countries in Asia are extremely diverse in size and characteristics. They include some of the most populous countries in the world with very high population growth rates and poor economies. Each country has its own approach to rural water supply and sanitation and the only common factor in the past has been a general antipathy to rural conditions and needs. Nevertheless, as a result of increasing concern for the rural population, most Governments are now directing significant resources to rural development, and the area of water supply and sanitation development will undoubtedly benefit from this improvement in policy direction.

Implementation of national programmes for rural water supply and sanitation in Asian countries is often the responsibility of many government departments which often leads to serious problems in planning and coordination, affecting the effective mobilization of financial, material and human resources. In particular, the operation and maintenance of completed schemes have suffered and, as a result, there are many examples of failure.

Rural communities in most Asian countries look upon water supply as a right which the Government should provide as a free service and many Governments have accepted this attitude as reasonable. The rural population in Asia in general is much less concerned about sanitation than water supply and few Governments have attempted to develop significant rural sanitation programmes in the past. However, at the present time, in addition to the change in the attitude of Governments towards rural development, there is an increasing awareness of the importance of water supply and sanitation in improving socio-economic conditions in rural areas. The need for local participation in such schemes is now being accepted by responsible government agencies in many countries but the lack of public health education programmes is an impediment to the stimulation of interest in rural communities.

This report reviews some general characteristics of rural water supply schemes in Asian developing countries, impediments to progress as well as recommendations for a rational approach to the problem. Important aspects of rural water supply systems in Thailand will be discussed. This study was primarily initiated to consider the functional design and construction of a water treatment unit in a small village of Thailand with emphasis on the participation of the villagers during the various phases of construction and operation.

1.1 Obstacles to Progress[1/]

Numerous are the constraints which have limited past progress in improving rural water supply and sanitation. These constraints can be

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1/ THANH, N.C. and PESCOD, M.B. (1976) Application of Slow Filtration for Surface Water Treatment in Tropical Developing Countries, AIT Research Report No. 65 to the WHO International Reference Centre for Community Water Supply, Voorburg, The Hague, The Netherlands.

grouped into three categories: administrative, financial and technological. Although most countries regard financial problems as the primary constraint, it would appear that institutional problems are paramount in most countries. Technological constraints do exist but they are intimately tied to and have a bearing on the financial implications of a country's rural water supply and sanitation programme and are also closely related to institutional factors. It is evident that overlaps exist among these categories of constraints.

1.1.1 Administrative Constraints

The lack of a sufficiently high priority being given to the need for improving rural water supply and sanitation has been a principal factor limiting past achievements in this sector. In the absence of national policies for rural water supply and sanitation, only piecemeal efforts have been attempted in most Asian developing countries. A policy for rural water supply within the overall national water policy seems to be a precondition of progress in this sphere. Formulation of national plans for rural water supply, perhaps with regional ramifications, will allow decisions to be taken within a framework designed to optimize the use of finances, resources and manpower.

There has been a fragmentation of responsibility and authority in water supply and sanitation in many Asian countries. Institutional structures involving many agencies have built up and now there is a reluctance on the part of agencies responsible for the sector to give up their authority. This proliferation of agencies always gives rise to problems of coordination of efforts and is a major cause of poor selection of communities to be serviced and inappropriate system installation. It would appear sensible to reduce the number of agencies, where many government departments are involved in rural water supply and sanitation, or at least to have one of them act as the primary agency responsible for development of national policies and plans and coordination of activities of the other agencies. Normally, such an agency would need to be strengthened and have adequate manpower and resources to carry out its task.

Whatever the institutional arrangement, there is a need to ensure adequate vertical links between the policy makers and planners at the national level and the villagers at the local level. In many cases in Asia, there has been no consideration of social need, local traditions, or the mentality and skills of villagers, and certainly no involvement of villagers, in the planning and decision-making processes. In addition to the necessity of getting local beneficiaries involved in the early stages of a project, a local support structure is also essential to bring about efficient implementation and operation of schemes and the absence of this has led to the failure of many completed projects in the past. The costs of establishing and maintaining such a structure are significant but essential to the success of major rural water supply and sanitation programmes, and Governments in Asia must be prepared to commit themselves to a continuing responsibility for rural systems operation.

One of the biggest problems in administering rural water supply and sanitation programmes in many Asian countries is the acute shortage of trained manpower. Agencies responsible for rural projects are notoriously short of qualified staff and this often limits the scope of their activities, both in terms of the type of project they will undertake and the number of projects they can handle. There has been little commitment on the part of Governments to training needs in general. At the sub-professional level, there has often been no training available for maintenance personnel, plant operators and village health workers, resulting in a complete absence of information, health education and technical skills at the local level.

1.1.2 Financial Constraints

Rural water supply is relatively costly on a per caput basis because advantage cannot be taken of the economies of scale which are possible in urban systems, owing to the dispersed nature of the rural population. At the same time, the income of rural dwellers in Asian developing countries is small, making it difficult for them to pay for water supply and sanitation even when there is willingness to pay. In spite of this situation, however, it is essential that villagers be encouraged to pay the maximum amount possible for a water supply system and this should normally cover the costs of operation and maintenance. If there is to be any chance of catching up with the backlog of rural water supply service, as well as meeting future demands of population growth, every effort must be made to increase national budget allocations for this sector. Contributions from the beneficiaries will support the operation and maintenance of the completed system, when the central budget has no provision for such expenditures.

1.1.3 Technological Constraints

In all Asian countries, groundwater is the preferred source for rural water supply because it does not normally require treatment and is usually least costly but, unfortunately, it is not available in all areas. Surface waters are normally polluted, and naturally highly turbid in tropical regions, and require treatment before supply. Water distribution in rural areas of Asia is usually by means of very simple systems and public standpipes or hand pumps are more prevalent than house connections. The level of technical expertise in rural areas is very low and all parts of the supply system must be simple to operate and maintain.

Quite often in Asia, design criteria from developed countries have been adopted for rural water supply in developing countries, where the people have very different social and cultural habits. Perhaps the most basic design criterion is the quantity of water which should be supplied to a rural community. Since the cost of supply system depends very much on water consumption, this fundamental decision is one of the most important in dictating the rate at which rural communities can be served with future budget appropriations. Also, because water use is closely related to convenience of the supply, this decision should be related to the decision on form of distribution. A national policy should provide guidelines on what level of convenience, and its associated water consumption is consistent with the country's rural water supply situation. The duration of service is another factor affecting water consumption and the economics of system design. Many village water supply systems in Asian countries have been designed on the assumption of 12- or even 24-hour service but in practice have operated only 4 to 6 hours per day. A judicious choice of distribution system and duration of service would allow significant savings in costs if minimum consumption objectives are incorporated into the system design. A policy of constructing rural systems which are spartan in their provisions but reliable in service appears to be necessary in Asia if the present water supply situation is to be markedly improved in the future.

Water quality is another fundamental design criterion which affects system costs. Many developing countries in Asia have adopted the WHO International Drinking Water Standards[1/] as their criteria for rural water supply and have applied these rigidly. However, it is recognized that a much improved quality water which is convenient and acceptable to villagers is preferable to an absolutely safe water which villagers reject in favour of their traditional contaminated supply.

In general, technological constraints are not seriously inhibiting the implementation of rural water supply and sanitation programmes the way financial and administrative constraints are retarding progress. Overcoming technological problems and improving the appropriateness of the technology of rural systems could have a major effect on costs and, therefore, on the extent to which future investments would meet the needs of the rural population in Asia.

1.2 Rural Water Supply in Thailand

The 1970 census in Thailand reported a population of 36.8 million, of which 85 percent were rural. Communities of less than 5,000 people are regarded as villages and there are 50,000 such villages in the country. Rural population annual growth rate is estimated to be about 3 percent but there are signs that family planning programmes have reduced this, perhaps to 2.5 percent at the present time. It has been estimated that, in 1972, 10.6 percent of the rural population had access to safe water from piped supplies or protected wells with handpumps. This figure is expected to increase to 25 percent by 1980, in conformity with the declared global targets for the Second Development Decade of the United Nations.

Thailand has a centralized system of Government and, administratively, the country is divided into four regions: north-east, central and south. There are 72 Provinces (Changwats) which are divided into Districts (Amphers) and each of these has 8 to 10 Sub-districts (Tambols). Each sub-district comprises 5 to 10 villages (Muhbans). The district capitals and larger sub-districts have municipal bodies and other sub-districts Tambol Councils.

The National Economic and Social Development Board (NESDB) is responsible to the Prime Minister for the overall development plan of the entire country on a Five-Year Plan basis. At the national level, the responsibility for rural water supply and sanitation is shared by several agencies. The Department of Public Health Promotion in the Ministry of

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1/ WHO (1971) International Standards for Drinking Water, Third Edition, Geneva.

Public Health, the Department of Public Works in the Ministry of Interior, the Department of Mineral Resources in the Ministry of Industry and the Accelerated Rural Development Office (ARD) in the Ministry of Interior have responsibility for villages with populations between 500 and 5,000. Villages having a population of below 500 are looked after by the Department of Medical and Health Services in the Ministry of Public Health, and the Department of Local Administration in the Ministry of Interior. Added to these are the Department of Community Development in the Ministry of Interior, the Royal Irrigation Department in the Ministry of Agriculture and Cooperatives, and the Border Patrol Police Service of the Ministry of Interior, which also play minor roles in rural water supply and sanitation.

In April 1966, the Government started the "Community Water Supply Project" to be completed in five years (1966-71), which had the objective of providing safe water to the entire rural population. By the end of 1970, almost three million people had benefited from this programme, representing about 10 percent of the rural population. The Second National Plan recognized the need for increased investment in potable water supply throughout Thailand but at the end of the Plan period it was admitted that potable water schemes for smaller villages were still inadequate. Only 0.8 percent of the total outlay of the Second Plan was allocated to water supply and sanitation for rural areas, while 1.1 percent was allocated for urban water supply and sanitation. At the end of the Third National Plan (1972-1976), it was projected that about 5.3 million (15 percent) rural people would have had access to safe water, representing an additional 2.2 million people. In this Third National Plan, the share of water supply and sanitation investment for rural areas was 1 percent of the total outlay, half that allocated to urban areas. However, there has been a progressive increase in spending on rural water supply and sanitation in recent years: US$4 million in 1970, US$4.67 million in 1972 and US$6.1 million in 1974. As evidence of the Government's intentions of promoting the development of rural areas, the budget allocated to the principal Departments involved in rural water supply and sanitation in the Third Five-Year Plan was raised to 1,165 million Baht[1/], compared with 509 million Baht in the Second Five-Year Plan. Considering that the provision of about US$58 million was made in the Third Plan (1972-1976) to cover 2.2 million population of the rural community, it is estimated that an additional US$150 million will be needed to cover 25 percent of the 41.7 million population by 1980. An expenditure of US$1,000 million will be necessary in addition to the Third Plan provision to provide safe water to the entire rural population by 1980.

The present general policy of the Government is to provide tube-wells equipped with handpumps, and to construct sanitary wells fitted with handpumps. This is to be supplemented by piped water supply systems, wherever feasible. The contribution of the people to water supply schemes is significant and, in many cases, has been more than 50 percent of the capital cost, with the balance being made up by the Government. The difficulty, however, in many schemes is in maintaining public handpumps in good order. It is estimated that 50 percent of the pumps are out of order. Action is being taken by the Government to ensure better maintenance. The rural

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1/ Current exchange rate approximately 20.15 Baht = US$1.

water supply system in Thailand also faces the lack of qualified personnel for the provision of technical services. Manpower distribution in the community water supply programme in 1970 is given in Table 1.1. It can be seen that the intermediate level (sanitarians and technicians) and primary level (sanitary inspectors and operators) staffing is inadequate and has to be increased by 40 to 60 percent if the target of 25 percent coverage of the rural population with safe water by 1980 is to be achieved.

Table 1.1 Manpower Distribution in Water Supply Programme in Thailand[1/]

Categories	Number	Ratio to Total Population
High Level	124	1: 250,000
Intermediate Level	2375	1: 13,000
Primary Level	5800	1: 5,000

In Thailand, the approach towards the provision of safe water for rural communities is generally good. Thailand is, relatively, more affluent than other developing countries in South-East Asia and the people are in a better position to contribute towards water supply schemes. However, special efforts should be made for increased allocation of Government funds to achieve the target set for the future. Budget provision should be managed by the local authorities for the maintenance and operation of water supply systems. The involvement of as many as six agencies in the rural water supply programme is a major factor retarding its development. An amalgamation of several agencies would reduce the expenditure on administrative costs and ensure better use of technical and administrative manpower, supplies and equipment. A possibility worth considering is whether it might be feasible for the entire rural water supply programme to become the responsibility of one single department, covering investigation, planning, design and implementation of both piped and handpump supplies. Educational training in health and sanitation for rural people is also vitally essential in the implementation of a successful water supply programme.

1/ World Health Organization (1974), Regional Office for South-East Asia, Report on Rural Water Supply, Thailand, EH/SEARO/74.10

II DEVELOPMENT OF THE PROJECT

2.1 Background Study at the Asian Institute of Technology (AIT)

It is now well known that the main problem in using tropical surface waters as sources of water supply lies in the removal of turbidity particles consisting mainly of clay and suspended silt. Several methods have been developed to treat these turbid waters. The most common approach is the conventional rapid sand filtration process in which chemicals are used to coagulate and flocculate fine particles for further settling and rapid filtration. This complex and expensive method of water supply seems inappropriate for rural areas in developing countries. Considering the constraints to progress previously mentioned, slow-rate filtration seems to be the most suitable treatment process for surface waters. It is less complicated and, where land is not a limiting factor, usually requires less investment.

One major consideration in applying slow-rate filtration to turbid surface waters in tropical regions is that the suspended silt quickly blocks the filter. However, a slow-rate filter can be maintained in good working condition in spite of excessive turbidity (particularly inorganic turbidity) which causes rapid clogging of the filter surface, necessitating frequent cleaning. Where the raw water source contains high amounts of turbidity and algae, pre-filters (coconut fibre, pea gravel, crushed stone) can be used to remove most of the turbidity and algae before the water passes through a slow-rate filter (sand or burnt-rice-husk filter) for polishing and removal of remaining impurities. In this regard, the slow-rate filtration process developed at the Asian Institute of Technology (AIT) in Bangkok using coconut fibre and burnt-rice-husk/sand as filter media either in series or dual arrangement is found to be efficient alternatives for community water supply in tropical developing countries[1/].

Another pretreatment technique recently developed at AIT is the horizontal-flow coarse-material prefiltration[2/]. The main advantage of a horizontal-flow prefiltration is that when raw water flows through it, a combination of filtration and gravity settling takes place which invariably reduces the concentration of suspended solids. The effluent from the prefilter, being less turbid, can be further easily treated by the conventional slow sand filter.

The horizontal-flow coarse-material prefiltration system has proved to be very effective in removing turbidity of raw water. In general for

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1/ THANH, N.C. and PESCOD, M.B. (1976), Application of Slow Filtration for Surface Water Treatment in Tropical Developing Countries, AIT Research Report No. 65, to the WHO International Reference Centre for Community Water Supply, Voorburg, The Hague, The Netherlands.

2/ THANH, N.C. (1977), Horizontal-Flow Coarse-Material Prefiltration, AIT Research Report No. 70, to WHO International Reference Centre for Community Water Supply, Voorburg, The Hague, The Netherlands.

raw water turbidity ranging from 30 to 100 JTU, this system removed 60-70 percent of the total turbidity permitting a slow sand filter to remove residual turbidity and producing a good quality water.

2.2 Project Formulation

Based on the encouraging results obtained from a pilot study at AIT, the horizontal prefilter-slow sand filter system should be retained in the chain of development of low-cost technology for rural communities in developing countries. It is a simple scheme, easy to construct and operate with the greatest range of effects on water properties, and good quality water could be achieved.

The proposal to design and construct a low-cost water filtration system in Thai village was realized through part of the grant from the Research Associate Award bestowed upon the author by the Canadian International Development Research Centre (IDRC).

2.2.1 Selection of the Project Site

It has been experienced that water supply systems are better maintained and less abused if the villages to be served are carefully selected because they express a real interest in having a new or improved system. In general terms, a high sense of responsibility for the water supply system is an important condition for community involvement and should consequently be one of the criteria for selection.

The selection of the project village is a logical response to the basic objectives of the project, viz.:

- to improve the public health and socio-economic situation and thus the well-being of the villagers.
- to promote a self-generating autonomous development process, leading to self-reliance, by creating local capabilities and stimulating the use of local resources in the field of water supply and sanitation.

In this connection, several meetings were arranged in early 1977 with the Governor, Mr. Suthee Ob-oam, and Deputy Governor, Mr. Bira Boonjring, of the province (Changwat) of Pathumthani, to discuss the objectives and implementation of the project. The proposal was welcomed with great enthusiasm and permission to proceed with village selection was accorded.

In selecting the most suitable village for constructing a slow sand filter, a number of villages in Pathumthani province were visited, and Jedee-Thong Village or Muhban Patana-anamai 1, district (Ampher) of Samkoke was finally selected. Mr. Thian Kaewnit is the Samkoke District Officer and Mr. Boonchoo Thongprajonk, the Head of Jedee-Thong Village. (Fig. 2.1).

N.C. Thanh and Mr. Thian Kaewnit, District Officer, finalizing the Village Selection.

From Left to Right: Mr. Thian Kaewnit, Mr. Sirisak Chenboonthai, N.C. Thanh and Dr. T.H. Venkitachalam, discussing the Project.

Fig. 2.1 Selection of Project Site

2.2.2 Jedee-Thong Village

Jedee-Thong Village is situated on the west bank of the Chao Phya river, as shown in Fig. 2.2. It covers an area of approximately 40,000 m^2 and is inhabited by 120 families of 6 persons. Villagers earn their livelihood in trading, farming or as employees in the neighbouring industries (boat building, knife and brick making, etc.). On the average, family has a monthly income of 1,000-1,500 Baht ($50-75), which is relatively higher than that of other rural communities in Thailand.

As far as water supply is concerned, households in this village have always depended on rain water in earthen jars or water direct from the Chao Phya river without any treatment. Each household has its own lavatory. The new water treatment project is another phase in the development of a water supply system as part of the total sanitary program for the village.

Jedee-Thong Village was selected for this project because it fulfilled many of the selection criteria previously mentioned, mainly the eagerness of the villagers to have a water treatment scheme and their willingness to provide mainpower and local resources for the construction of the filtration system. Land was also available; generously donated by the village "Wat" (Temple).

2.3 Scope of the Project

With the financial help of the International Development Research Centre in Ottawa, Canada, technical assistance of AIT's Environmental Engineering Division in Bangkok, Thailand and the labor of the Jedee-Thong villagers, a series-filtration system, as shown in Fig. 2.3 was designed and constructed. The system consists of a prefilter packed with coarse crushed stones to pretreat the raw river water, followed by a slow sand filter system to polish this water for human consumption by the approximately 720 village residents. Realising that rural dwellers dislike chlorinated taste, the chlorination process was not considered.

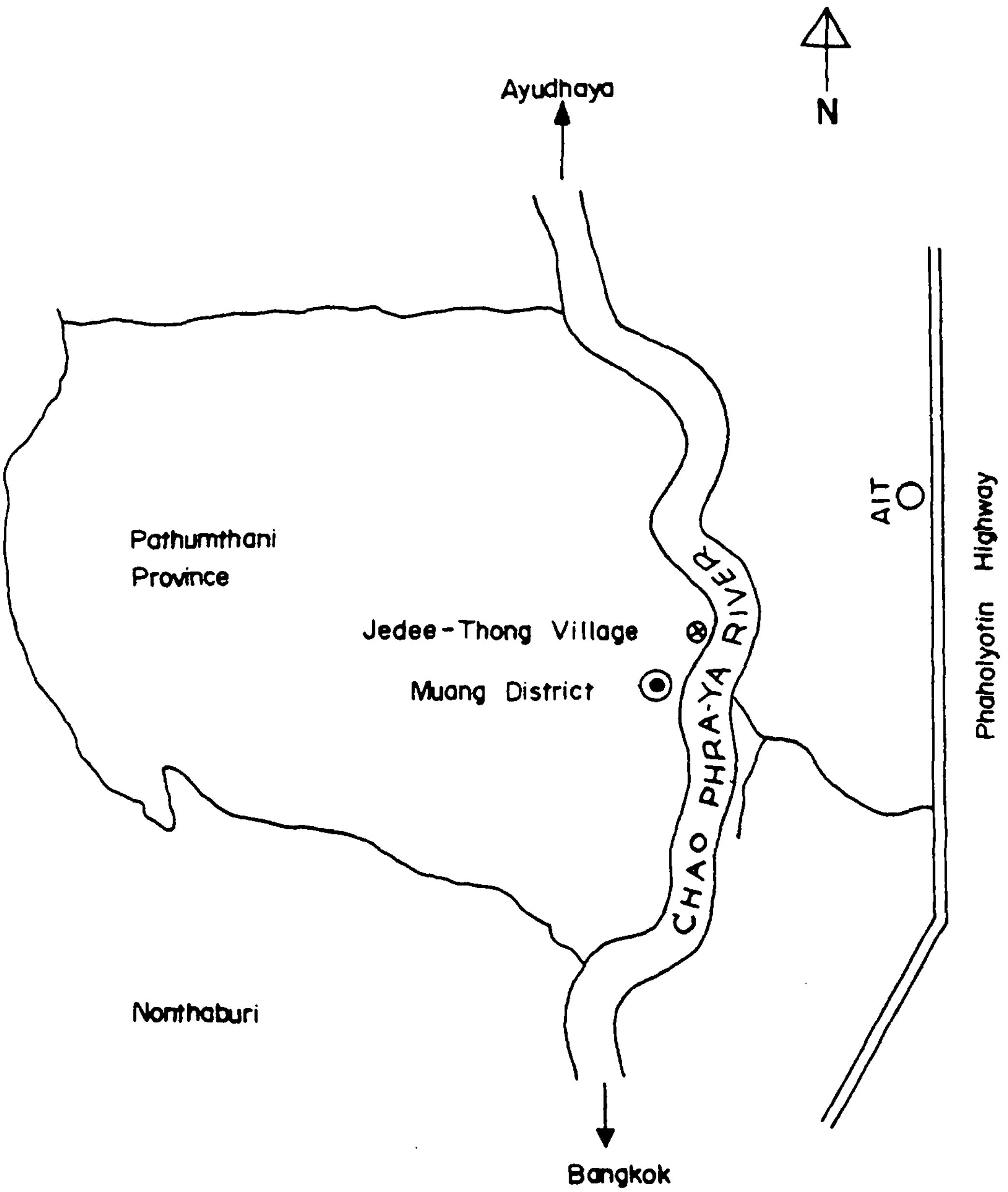

Fig. 2.2 Location of Jedee-Thong Village

Scale: 1 : 150,000

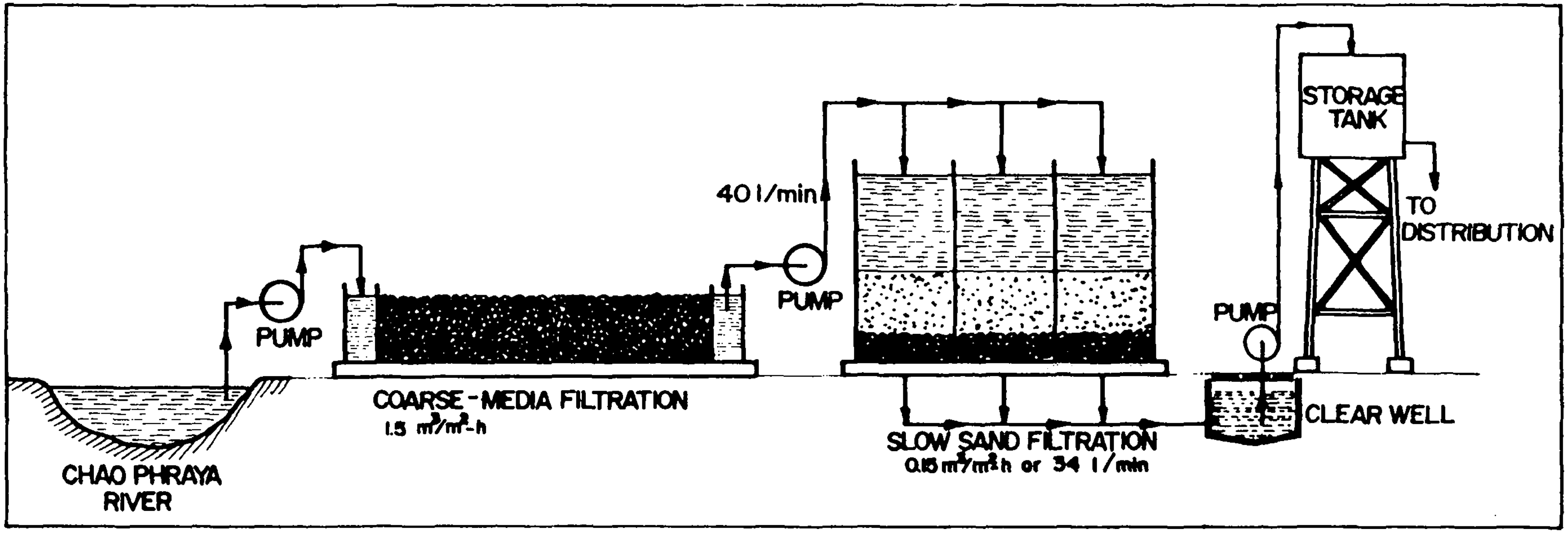

Fig. 2.3 Schematic Flow Diagram of Water Treatment System for Jedee-Thong Village, Pathumthani Province, Thailand.

III DESIGN AND CONSTRUCTION OF JEDEE-THONG VILLAGE WATER TREATMENT PLANT

3.1 General Considerations

As a precautionary measure against flooding during the rainy season, the water treatment plant site was raised up by one meter of earth above the original ground level. All construction structures were made of masonry and reinforced concrete. There was no resort to any building contractor. The Jedee-Thong Village residents contributed to the project by providing their own labor, with the technical assistance of staff from the Physical Plant of AIT. Normally, the men went about their regular work during the day and undertook heavy construction works of the plant in the evening and during week ends, whereas the women helped doing light work in the daytime. The villagers displayed a great deal of enthusiasm and willingness to improve their public health and socio-economic situation.

The water filtration system consists of one horizontal prefilter, three vertical slow sand filter units, three weir chambers, one clear well, as laid out in Fig. 3.1. There are four available elevated storage tanks which could be used for water distribution. The distribution system supplying treated water to different points in the village will be developed in the near future when funds are made available by the Provincial Government concerned.

Construction work was started in May 1977 and completed in January 1978. The following sections describe the design and construction details of different units of the treatment plant. The design of the prefilter was based on the characteristics of the slow sand filter.

3.2 Slow Sand Filter Design

In designing a slow sand filter, a number of considerations have to be made to achieve optimum performance at minimum cost. In the context of tropical surface waters characterized by high turbidity concentration, a pretreatment system to remove the gross initial turbidity is a necessary prerequisite to alleviate the burden of the slow sand filter and to prolong its run duration. The horizontal prefilter design will be discussed in the next section.

Basic design criteria of a slow sand filter concern the quantity of water to be treated, size and number of filter units (supernatant water reservoir, arrangement inside the filter box, filter bed, filter bottom and underdrainage system), and filter control system.

3.2.1 Quantity of Water to be Treated

In Thailand, the Rural Water Supply Division adopts the following criteria in the construction of any rural water system:

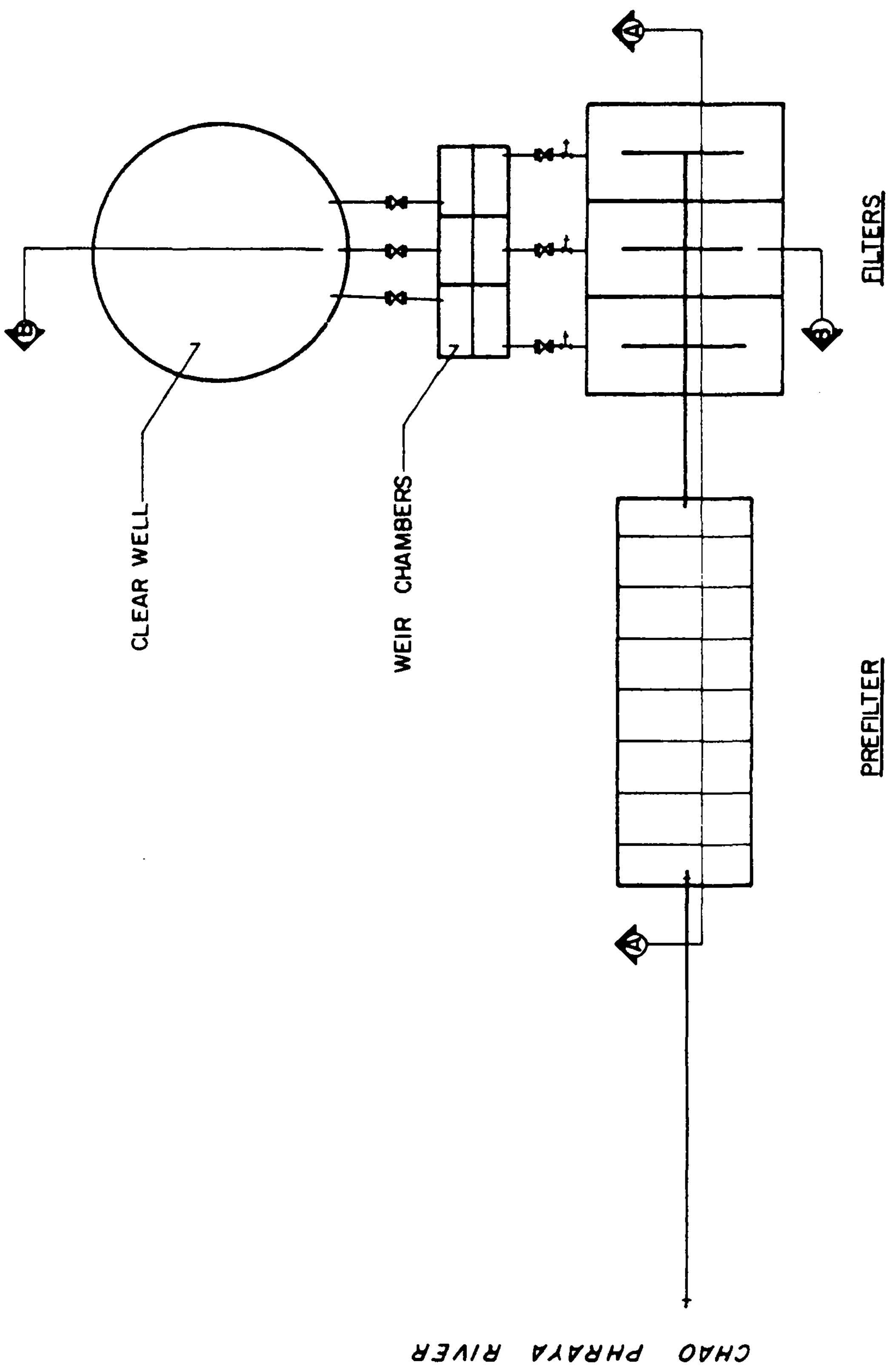

FIG. 3.1 PLAN OF WATER TREATMENT PLANT AT JEDEE - THONG

Plant life	:	10 years
Population growth	:	3 percent
Per capita consumption	:	50 litres per day (lcpd)
Maximum daily demand	:	1.5 x Average daily demand
* Peak hourly demand	:	$\frac{2.5 \text{ x Average daily demand}}{24}$

Jedee-Thong Village has an actual population of about 720. By using the growth rate of 3 percent and the design period of 10 years, the population forecasting could be computed by the following expression:

$$P = P_o (1 + r)^n$$

in which P = projected population in 10 years

P_o = present population

r = growth rate = 0.03

n = design period = 10 years

Therefore,

$$P = 720 \ (1 + 0.03)^{10}$$
$$= 720 \ (1.03)^{10} = 720 \ (1.3439)$$
$$= 967$$

Water consumption varies greatly with the extent of usage and number of users. Water usage in this village is mainly for domestic purposes, such as drinking, cooking, washing, bathing. The average daily demand (Q_d) will be,

$$Q_d = 50 \text{ lcpd x } 967 \text{ capita} = 48.350 \text{ litres/day}$$

or $Q_d = 48.350 \text{ m}^3\text{/day}$

Maximum daily demand (Q_{dm}) = 1.5 x 48.350 = 72.525 m^3/day

and Peak hourly demand (Q_{ph}) $= \frac{2.5 \times 48.350}{24} = 5.036 \text{ m}^3\text{/h}$

3.2.2 Size and Number of Filter Units

The rate of filtration rate of 0.15 m^3/m^2-h was used in the filter design. The total filter area (A) required is,

$$A = 48.350 \frac{m^3}{day} \times \frac{1}{0.15 \text{ m}^3/\text{m}^2\text{-h}} \times \frac{1 \text{ day}}{24 \text{ h}}$$

$$A = 13.43, \text{ say } 13.5 \text{ m}^2$$

It was decided to divide the total filter area into three compartments each measuring 3 x 1.5 m (= 4.5 m^2), to provide a continuous water supply and a relatively easy cleaning process.

* The factor 2.5 is adopted for this study, whereas the Rural Water Supply Division suggests 4.

3.2.3 Constituent Parts of Slow Sand Filter Box

The slow sand filter system itself is divided into three identical boxes of 3 x 1.5 x 3 m. The internal depth of each box is the sum of the following depths, starting from the top (Fig. 3.2 and 3.3)

Freeboard above supernatant water level	0.25 m
Supernatant water reservoir	1.20 m
Sand bed	1.00 m
Supporting crushed stone	0.30 m
Underdrainage	0.25 m

(a) Supernatant Water Reservoir

The reservoir serves two purposes : it provides a waiting period of some hours for the pretreated raw water, during which time sedimentation, particle agglomeration, and oxidation occur, and it provides a head of water sufficient to overcome the resistance of the filter-bed, thereby inducing downward flow through the filter (Huisman and Wood, 1974)[1/].

The water depth (1.20 m) in the reservoir is maintained constant by a 3.8 cm (1.5 in)- overflow pipe, from which excess water is fed back to the prefilter outlet. A constant depth of water reduces the dangers of disturbing the biological layer as it forms, enhancing the filter performance.

(b) Filter-Bed

The effective diameter, d_{10}, usually lies in the range 0.15 - 0.35 mm, and should be just small enough to ensure a good quality effluent and to prevent penetration of clogging matter to such a depth that it cannot be removed by surface scraping. Also, some degree of uniformity is desirable in order to ensure good regularity of pore sizes and sufficient porosity. Usually sand having a coefficient of uniformity of less than 3 is the preferred medium.

Locally available sand was selected and sieve-analyzed. From the results of sieve analysis, presented in Fig. 3.4, the medium has a coefficient of uniformity of 2.38 and an effective size of 0.25 mm, which fall reasonably well in the limits of criteria recommended. Stock sand was used to avoid the relatively heavy expense of careful grading.

The thickness of the filter-bed (1 m) was determined based on the following considerations:

(1) Immediately below the filter-skin lies the zone in which purifying bacteria abound. The thickness of this zone is usually between 0.3 - 0.4 m.

(2) Below this depth, chemical reactions take place in what may be described as the "mineral oxidation" zone, within which the organic materials liberated

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1/ Huisman, L. and Wood W.E. (1974), Slow Sand Filtration, World Health Organization, Geneva.

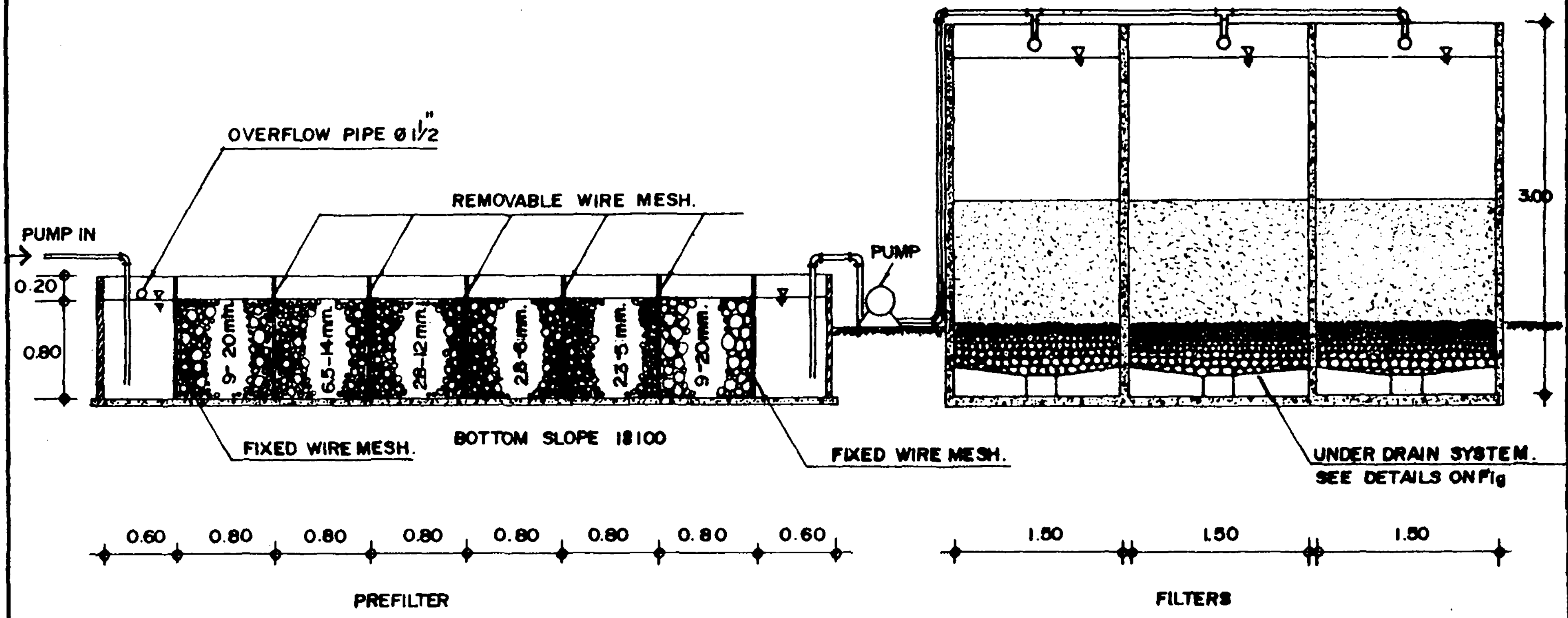

Fig. 3.2 Section A-A (from Fig. 3.1) of Horizontal Prefilter and Slow Sand Filters

Scale 1:50

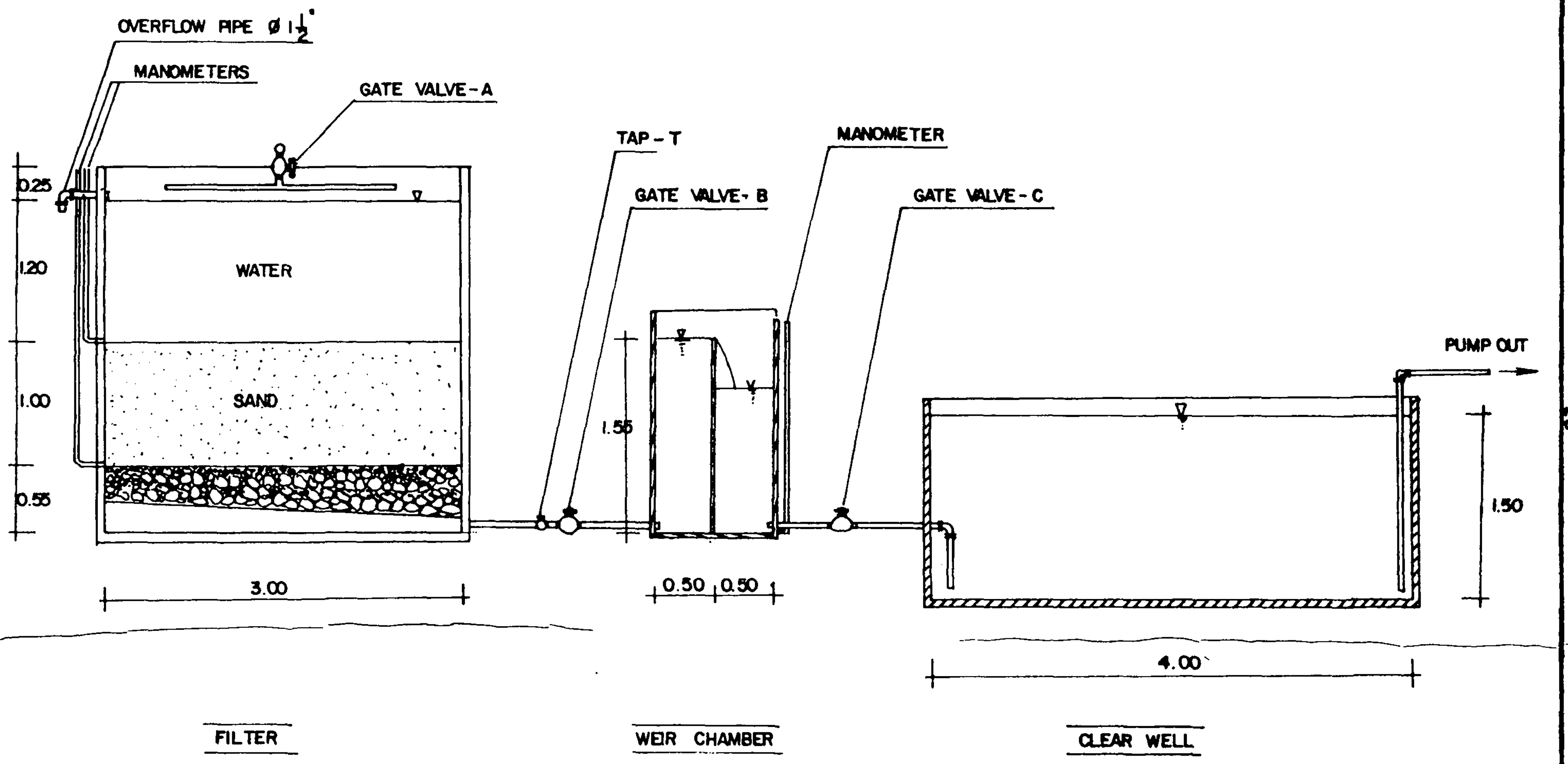

Fig. 3.3 Section B-B (from Fig. 3.1) of one Slow Sand Filter, Weir Chamber and Clear Well

Scale 1:50

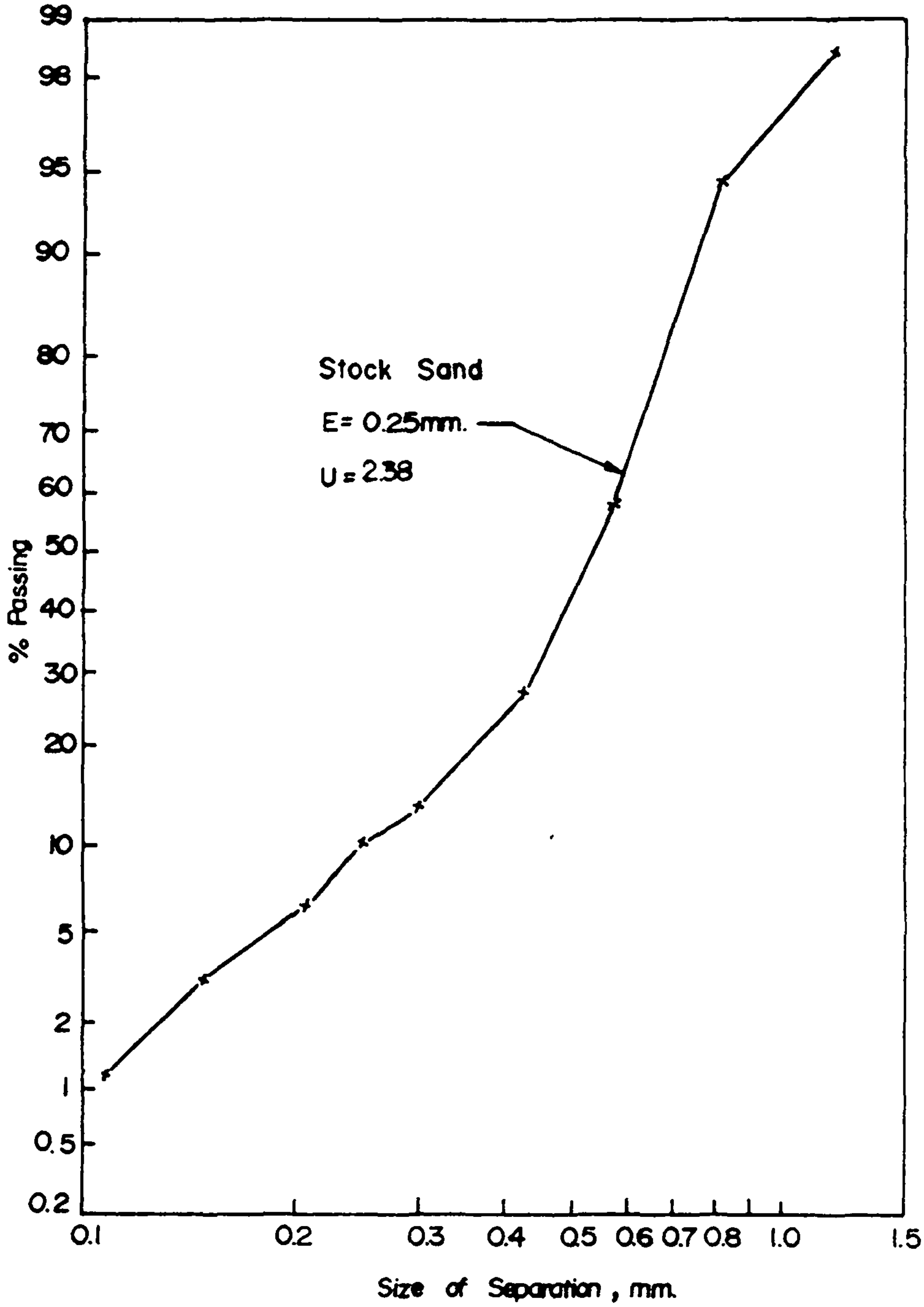

Fig. 3.4 Sieve Analysis of Sand

by the bacterial life-cycle in the upper sand layer are chemically degraded. The thickness of this zone may be between 0.4 - 0.5 m. This is to note that under no circumstances should the total sand bed depth be less than 0.7 m.

(3) A filter is cleaned by skimming off the top 1-2 cm of material. This material is not immediately replaced, and on restarting the filter the whole filtration process takes place at the same depth below the new surface, i.e., 1-2 cm lower in the same bed. Only after the filter has been operating in this way for some years will the bed surface be brought back to its former level by the addition of new material. Provision must therefore be made in the original thickness to allow for successive cleanings during this period.

It is expected that the present slow sand filter has an average run of 3 months between cleanings, some 6-8 cm will be removed each year, and an allowance of additional 0.3 m of thickness will allow for 4 years of operation before resanding becomes necessary.

(c) Underdrainage System

The underdrainage system serves the dual purpose of supporting the filter medium and of providing an unobstructed passage way for the treated water to leave the underside of the filter. The underdrain of the slow sand filter consists of a system of main and lateral drains (Fig. 3.5). The bottoms of the filters were designed with a 1:67 slope for lateral drain and 1:100 slope for main drain. Such arrangements were made using standard bricks 22 x 11 x 5 cm, with provisions of 1 cm spacings.

Between the bottom of the filters and the filter bed lay three 10 cm - layers of crushed stones with gradings of, from the top, 6-12 mm, 12-19 mm and 19-25 mm (Fig. 3.2). The crushed stones were carefully placed, the larger sized ones being packed by hand, so not to disturb the filter sand above, either leading to choking the underdrainage system or producing cavities through which the water may pass with insufficient treatment.

3.2.4 Filter Controls

The filter controls are essential parts that need careful planning in order to obtain good filter performance. Fig. 3.3 shows one of the slow sand filters on which all the various regulating devices are indicated. Basically, means must be available to:

(1) deliver pretreated water into the supernatant water reservoir. Gate value A in Fig. 3.3 controls the quantity of pretreated water influent to the filter, and the constant level of the supernatant water is maintained by an overflow pipe (Ø 3.8 cm). Excess pretreated water is returned to the prefilter outlet. The entrance of the

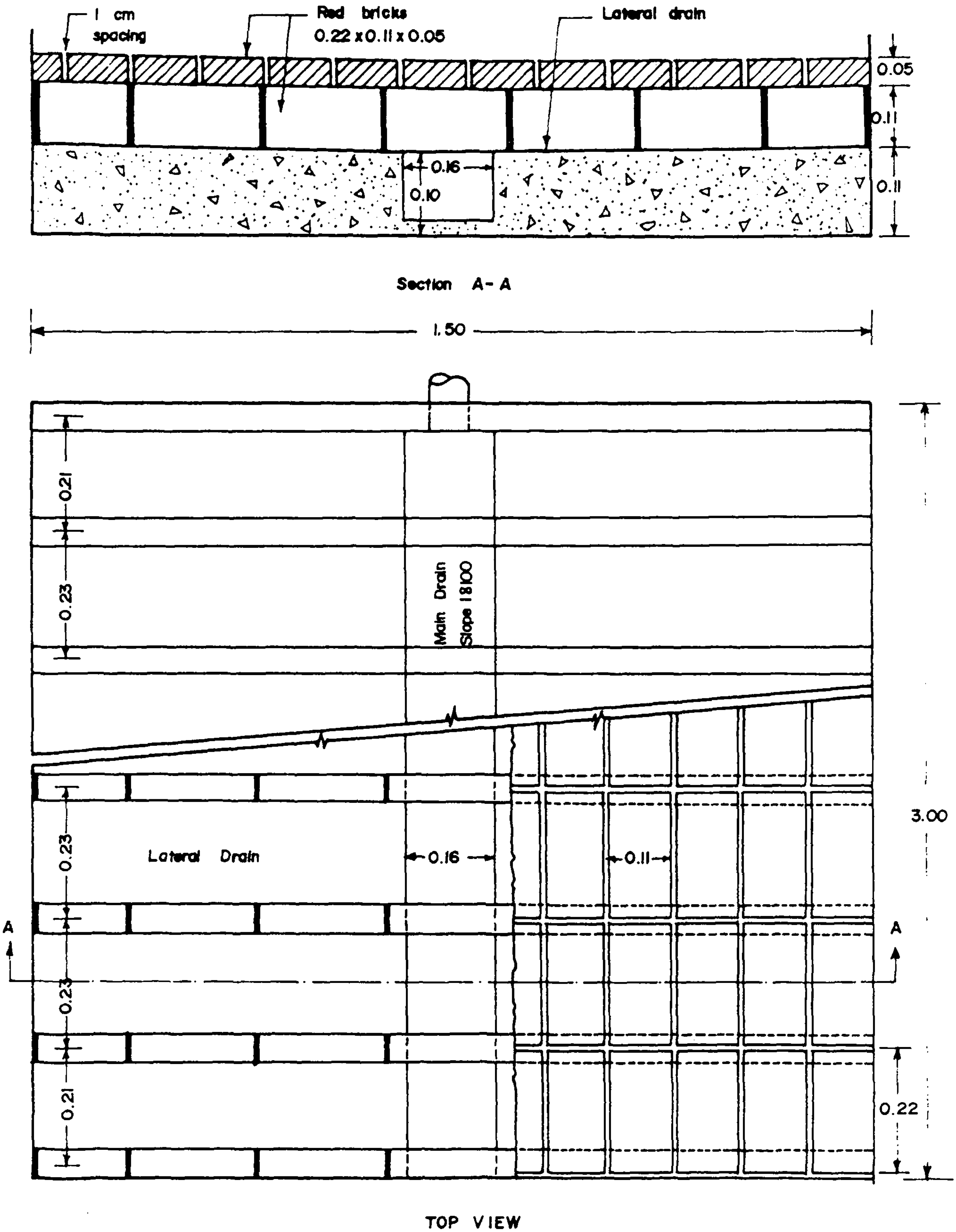

Fig. 3.5 Under Drain System for Slow Sand Filter Units

pretreated water into the supernatant water reservoir is made through a longitudinal perforated pipe so that the sand bed below is not disturbed by turbulence.

(2) drain off the supernatant water prior to filter cleaning. When a filter is due for cleaning it is necessary to remove the supernatant water so that the bed surface is exposed. Usually a separate drain and emptying trough is provided, just above the filter bed, through which the supernatant water may be discharged to waste.

This drain-off system is not provided in the present case. The filter being small, it would only take an overnight to lower the level of the supernatant water by allowing it to drain through the filter bed.

(3) lower the water level within the bed. After draining off the supernatant water it is desirable, before cleaning, to lower the level within the bed by a further 10 cm so that the biological layer (schmutzdecke) and the top layer is relatively dry and easy to handle. A tap (T in Fig. 3.3) is provided to carry this drainage to waste and also for sampling purpose.

(4) control the rate of filtration and adjust it as bed resistance increases throughout the length of the filter run. The effluent control valve is shown as gate valve B in Fig. 3.3.

(5) ensure that negative pressure cannot occur within the bed. This is carried out by a fixed weir as shown in Fig. 3.3. The purpose of the weir is threefold - to prevent negative heads developing in the bed with consequent air binding, to aerate the effluent, thus raising its oxygen content and releasing such dissolved gases as carbon dioxide, and to make the operation of the filter independent of the water-level fluctuations in the clear water reservoir.

The rate of flow in the filters is measured at the weir outlet by means of individual manometers and stopwatch.

(6) convey the filter effluent to the filtered water reservoir. Filtered water is adducted by gravity to the clear well through a 3.8 cm G.I. pipe and gate valve C (Fig. 3.3).

(7) run filtered water to waste or to the outlet side of the prefilter during the ripening period. During the ripening period of a new or recently cleaned filter it is necessary to divert the effluent to waste until the bacterial action of the bed has become established and the effluent quality satisfactory. Tap-T in Fig. 3.3 can be used for this purpose.

(8) fill the sand bed from below with filtered water after cleaning. This backfilling from the bottom is necessary to drive out air bubbles from the medium as the water

level inside the sand rises. The filtered water is obtained from the clear well or from the outlet side of another filter.

3.3 Slow Sand Filter Construction

In Thailand, the rainy season extending from June to November brings with it a high water level in Chao Phya River which floods the area about 0.5 m above the normal ground level. Before the construction works started, an area of about 20 x 10 m of the future water treatment plant was elevated with 1 m of earth. After soil settlement, manual excavation to the original ground level (1 m) was carried out for the horizontal prefilter and slow sand filter.

Fig. A1 to A6 in Appendix A give the structural details of slow sand filter construction.

3.3.1 Piling and Footing

Because the soil is of soft clay nature, a solid foundation must be provided. Corners of filter units were supported by eight footings at all, reinforced with 19 mm steel bars. Each footing measured 1.3 x 1.3 x 0.2 m and was supported by 9 wooden piles of 15 cm diameter and 6 m long. There were 72 wooden piles all together. The wooden piles were driven deep in the soil by a drive hammer attached to a rope around a pulley on top fabricated by the villagers themselves (Fig. 3.6, 3.7, 3.8 and 3.9).

3.3.2 Beams

Four transversal 0.40 x 0.45 m beams (B1 and B2 in Fig. A-2) reinforced with 19 mm top and low steel bars with stirrups of 6 mm and 9 mm diameter, respectively, rested on the footings. Also overlaid on the footings were two longitudinal 0.25 x 0.30 m beams (B3 in Fig. A-2); top and low bars were 19 mm - diameter and stirrup 6 mm - diameter steel bars (Fig. 3.10).

3.3.3 Floor Slabs

Three floor slabs (S1 in Fig. A-2), 0.15 m thick, reinforced with 12 mm top and low steel bars at a spacing of 0.25 m, completed the foundation. 15 cm - water stops were placed between the walls and floor slabs (construction joint, Fig. A-4, Fig. 3.11).

3.3.4 Filter Walls

The walls were 12 cm thick doubly reinforced with 12 mm - steel bars at a spacing of 0.25 m in both vertical and horizontal directions (Fig. A-6). The walls were supported by the beams. Fig. 3.12 shows the structural frame of filter walls.

3.3.5 Remarks on Construction of Slow Sand Filters

It took about 5 months to complete the construction of 3 filter units. In spite of the long distance between Jedee-Thong village and

Fig. 3.6 15 cm-diam. and 6m-long Piles

Fig. 3.7 Drive-Hammer System for Piling

Fig. 3.8 After Piling

Fig. 3.9 1.3 x 1.3 x 0.2 m Footings

other urban centers, it is encouraging to point out that the villagers did an excellent job with their own skills and initiative. The filters are of equal size and rectangular in shape (Fig. 3.13), with provision for the construction of additional filters adjacent to the existing ones, if and when necessary.

3.4 Design and Construction of Horizontal Coarse-Material Prefilter

The horizontal prefilter design was an adaptation of the design of a rectangular sedimentation basin, with an inlet zone, an outlet zone and a filtration/settling zone. It measured 6 m long, 2 m wide and 1 m deep. The bottom was designed with a 1:100 slope providing easy flow for the pretreated water to leave the outlet zone. The filtration/settling zone itself was divided into 6 compartments packed with graded crushed stones from coarse-fine-coarse, to a depth of 0.80 m (Fig. 3.2). The compartments were separated from each other by means of removable strong wire meshes allowing easy cleaning or changing of media.

In the order of compaction from the inlet to the outlet, the effective size (E) and the coefficient of uniformity (U) derived from the sieve analysis as shown in Fig. 3.14, are as follows:

Size range (mm)	E, mm	U
9 - 20	15	1.38
6.5 - 14	11	1.5
2.8 - 12	6.1	1.47
2.8 - 6	3.8	1.36
2.3 - 5	2.6	1.27
9 - 20	1.5	1.38

The construction of the horizontal prefilter was rather simple, compared to that of the slow sand filter units. Structural details of the horizontal coarse-material prefilter are given in Fig. B1 to B2 in Appendix B.

As in the case of slow sand filters consolidation of the base was done with broken bricks. Settlement and levelling out of the base were manually undertaken by a rectangular wooden block. The concrete floor slab was 20 cm thick reinforced with 12 mm - diameter steel bars in two directions at a spacing of 25 cm. The walls were made of bricks, 20 cm thick, arranged in two rows and coated with fine mortar. Fig. 3.15 to 3.18 shows different stages of the prefilter construction.

3.5 Design and Construction of Weir Chambers

There are three weir chambers for three filters. Each weir chamber measured 1 x 1 x 2 m and the width was divided into 2 compartments of 0.5 m^2 (= 0.5 x 1 m), with the purpose of preventing negative head loss in filter beds and raising dissolved oxygen content in the treated water by aeration (Fig. 3.3).

Details of design and construction of weir chambers are given in Fig. C1 and C2 in Appendix C. The concrete floor slab was 20 cm thick reinforced with 12 mm - diameter steel bars with spacings of 25 cm.

Fig. 3.10 Longitudinal and Transversal Beams

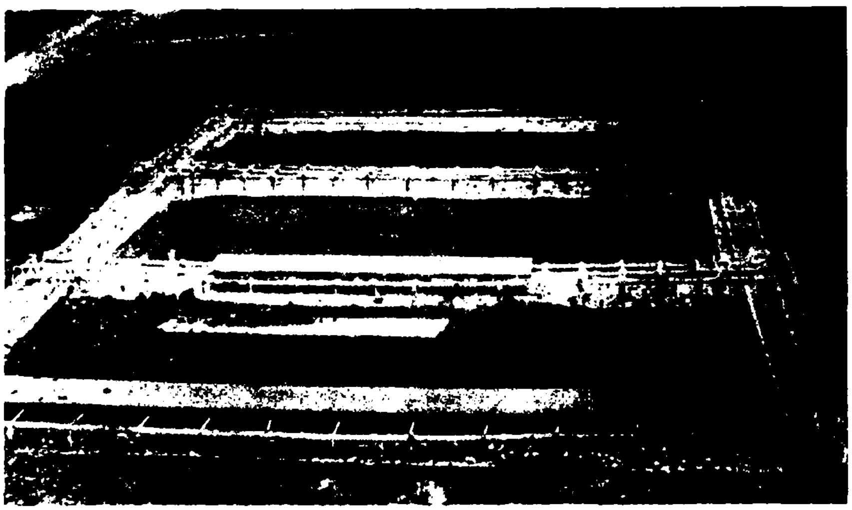

Fig. 3.11 Preparatory Works for Floor Slabs Installation

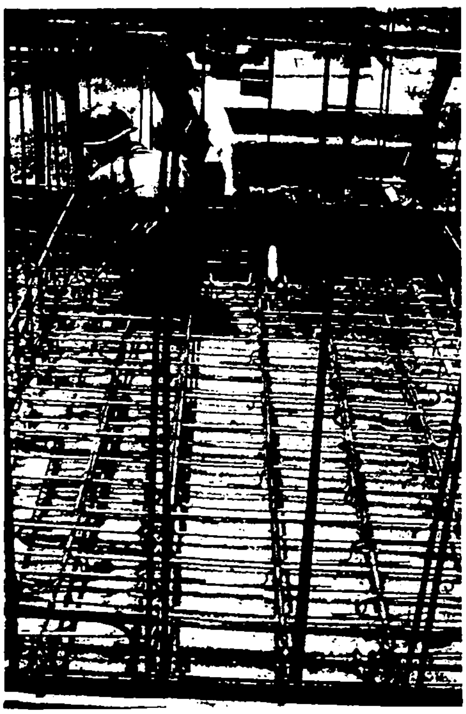

Fig. 3.12 Structural Frame of Filter Walls

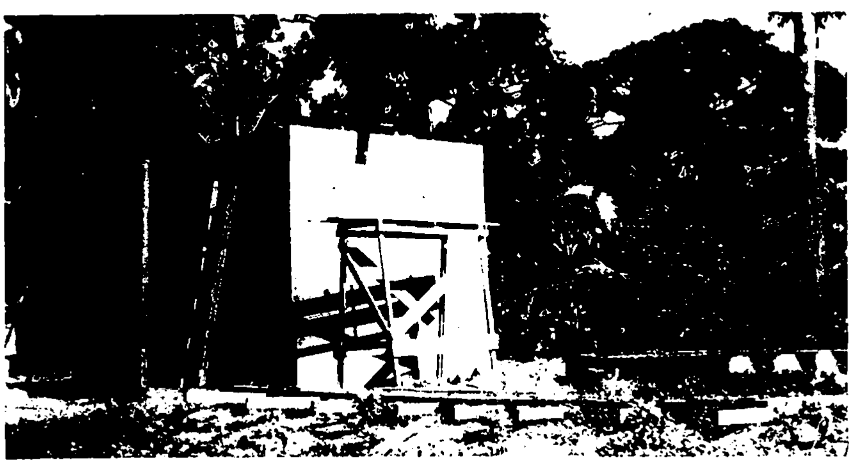

Fig. 3.13 Final Shape of 3 Adjacent Filter Units

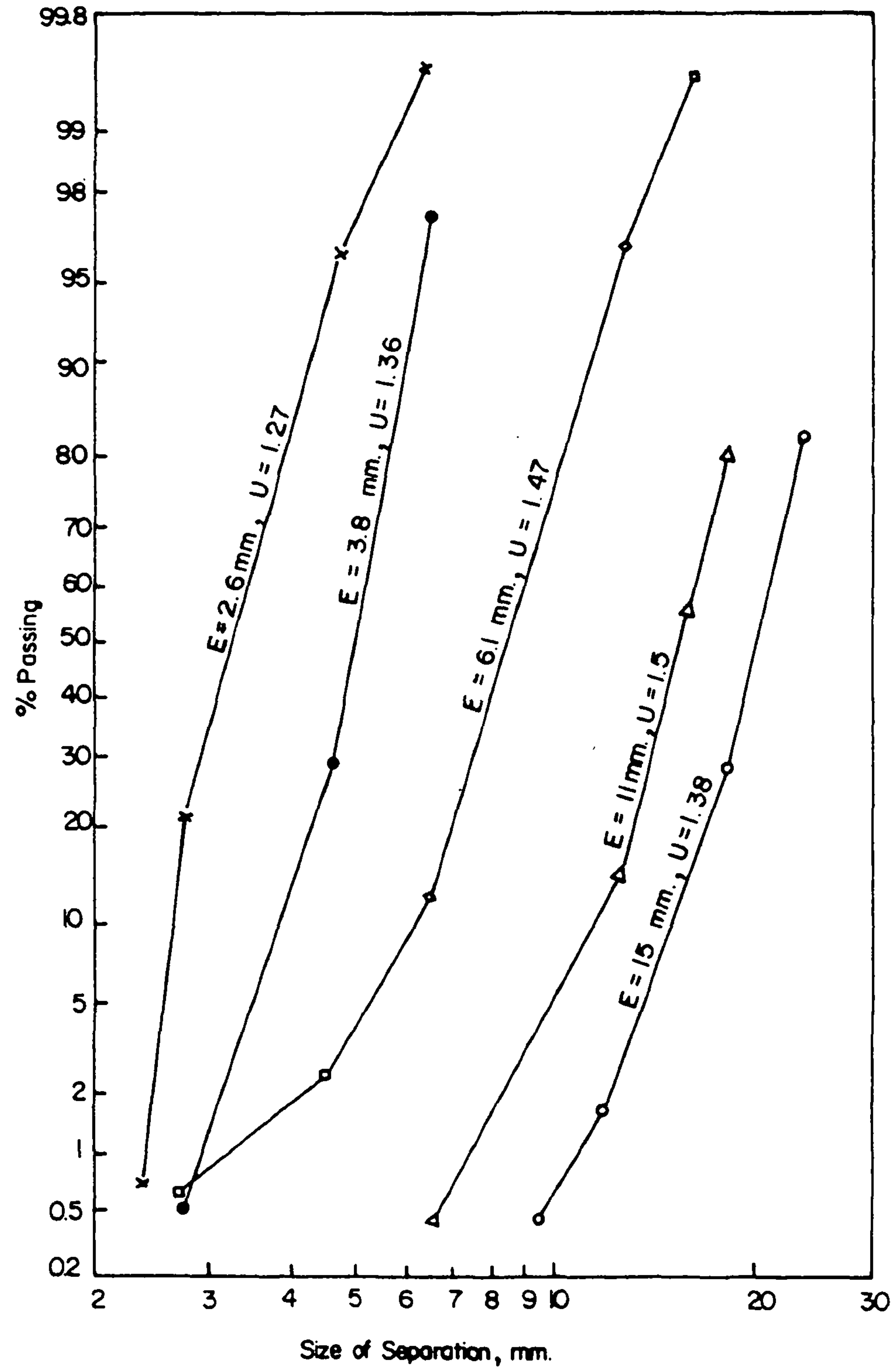

Fig. 3.14 Sieve Analysis of Crushed Stone

Fig. 3.15 Base Settlement of the Prefilter

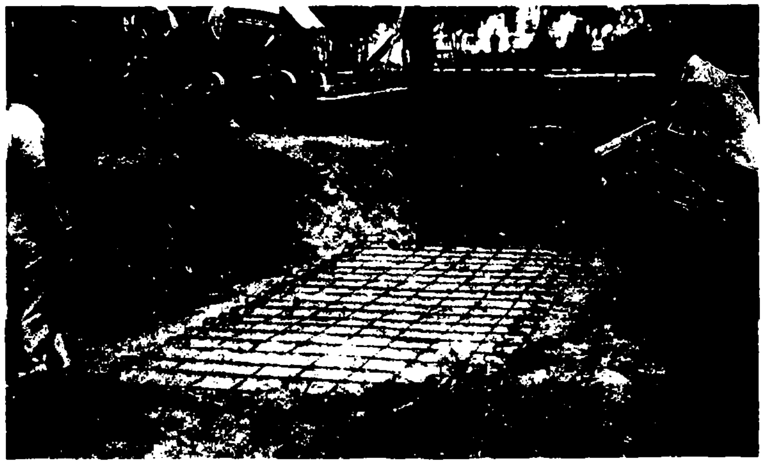

Fig. 3.16 Steel Bar Reinforcement of Prefilter Base

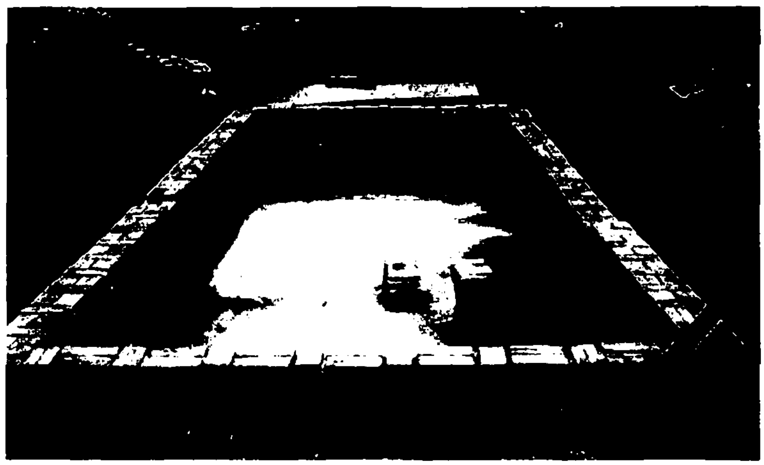

Fig. 3.17 Prefilter During Construction

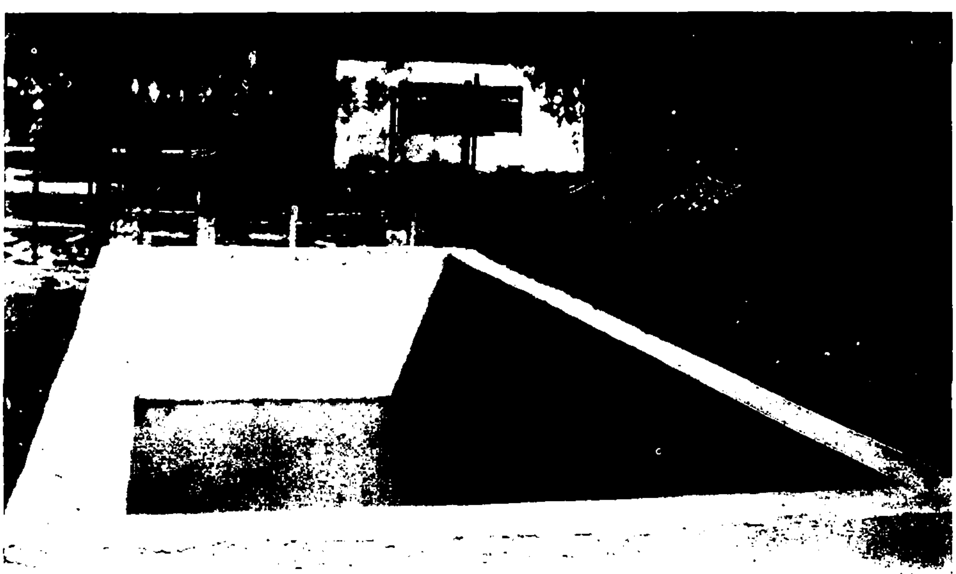

Fig. 3.18 Final form of Prefilter

The walls were made of bricks arranged in two rows and covered with mortar. The partition walls of different compartments were reinforced with various sizes of steel bars (Fig. C2 in Appendix C). Fig. 3.19 shows the weir chambers under construction.

3.6 Design and Construction of Clear Well

The clear well was designed with a view to accommodating half of the daily capacity of the filters. It measured 2 m high and 4 m in diameter (Fig. C1 in Appendix C). The wall was made of bricks arranged in two rows reinforced with steel bars of 6 mm and 9 mm in diameter, as detailed in Fig. C1 in Appendix C. The concrete floor slab was 20 cm thick reinforced with steel bars of 9 mm diameter with spacings of 20 cm. Fig. 3.20 and 3.21 show the clear well under construction and its covering structure, respectively.

3.7 Covering of Water Treatment Plant

The prefilter slow sand filters weir chambers and clear well were all roofed with removable frames covered with galvanized iron sheets, and having small sections which can be easily lifted for inspection. Covering of these parts is necessary for two main reasons:

(1) to prevent algal growth in water, by excluding sunlight.

(2) to avoid deterioration of raw water and treated water quality through windborne contamination, rain, bird droppings, flies or mosquitoes.

Fig. 3.22 shows the covering of different parts of the water treatment plant.

3.8 Water Tower

Near the temple where the water treatment plant was constructed is an existing water tower 10 m high which stores river water for domestic uses of the temple. The water tower consists of 4 G.I. tanks measuring 1.2 x 1.2 x 1.2 m, providing a total capacity of 6,912 l. It is surmounted on a reinforced concrete structure, with possibility of future expansion to respond to a greater water demand. Fig. 3.23 shows the existing water tower.

3.9 Distribution System

At the present time, the water distribution system is only part of the whole water supply scheme which has not yet been installed in Jedee-Thong Village due to lack of funds. Piped-treated water is being used by the priests of the temple, but the villagers have to come to the treatment plant to fetch water. Funds are now being collected, part of it from the villagers themselves, but the major contribution will come from the new fiscal year budget of the local government.

Jedee-Thong Village is elongated on a distance of 420 m along the west bank of Chao Phya River. A concrete footpath and small wooden bridges form the communication ways in the village. The following

Fig. 3.19 Weir Chambers under Construction

Fig. 3.20 Clear Well under Construction

Fig. 3.21 Covering Frame of Clear Well

Fig. 3.22 Covering of Water Treatment Plant

is the proposed design of the water distribution system.

Length of 5.08 cm (2 in) PVC pipe	= 420 m (1,378 ft)
Spacing of public taps	= 48 m
Number of public taps	$= \frac{420}{48} = 9$ taps
Peak hourly demand	= 5.036 m^3/h
	= 90 l/min or 1.5 l/sec

So, each tap will take about 10 l/min.

Recommended pipe = 2 in or 50 mm PVC pipe

From the chart for rigid PVC pipe (Fig. 3.24) and using 50 mm pipe, the 1.5 litres per second vertical line is crossed by the 50 mm sloping line at a friction loss reading of 9 meters per 1,000 metres. So in the 420 m of pipeline the pressure head loss due to friction will 3.78 m, say 4 m.

The existing elevated tank of 10 m head of water is high enough to pass a reasonable flow through the taps. The installation of standpipes will be arranged as shown in Fig. 3.25. The height of these public taps will be 1 m above ground level to avoid risk of contamination during flooding period.

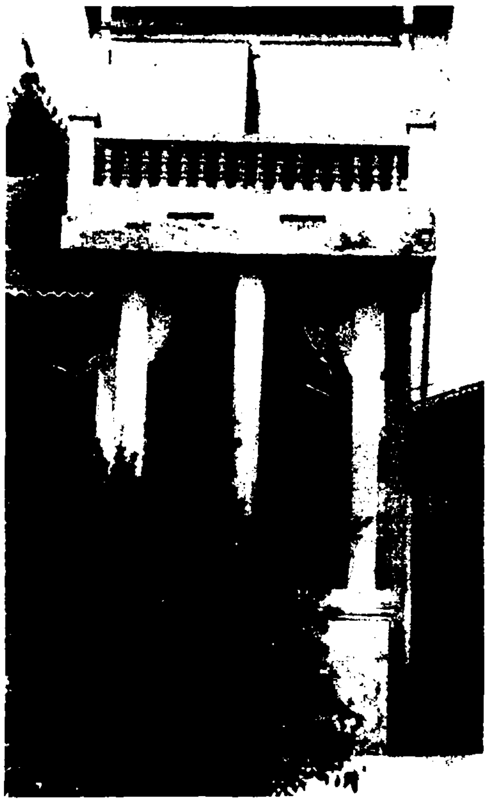

Fig. 3.23 Existing Water Tower

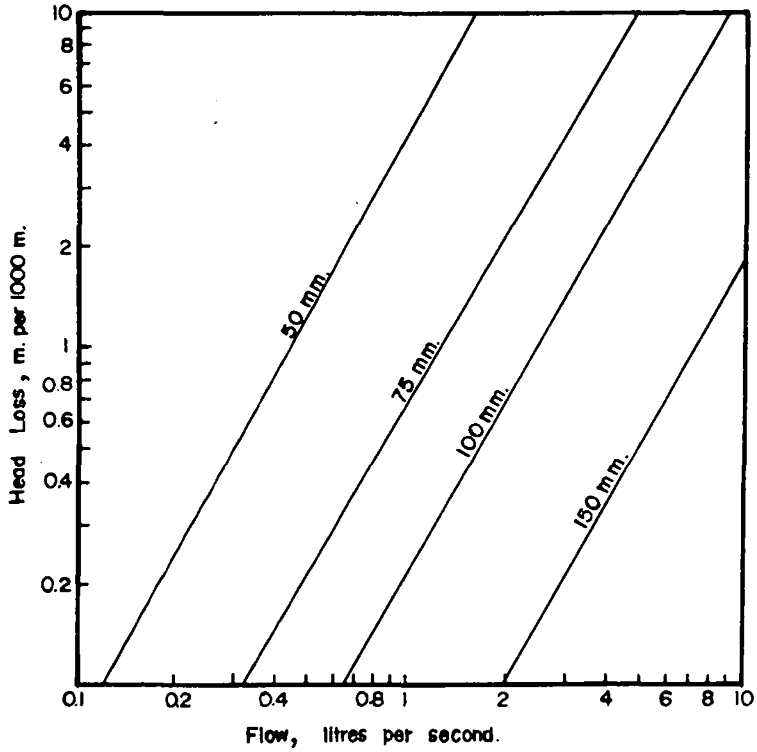

Fig. 3.24 Head Loss in Pipelines
(Rigid P.V.C. Class C)

(Source: Mann, H.T. and Williamson, D., 1973, Waste Treatment & Sanitation, Intermediate Technology Development Group Ltd., London).

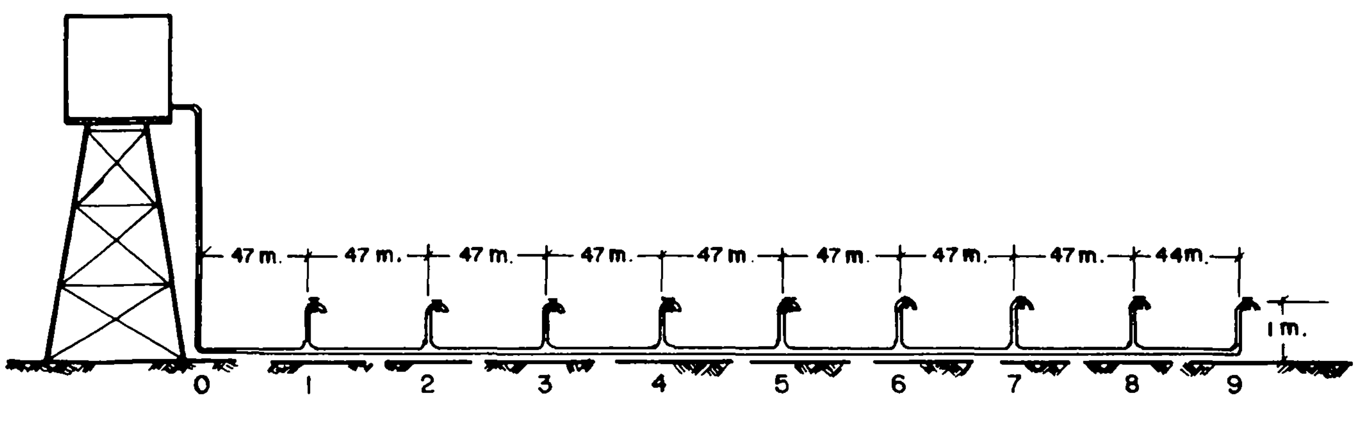

Fig. 3.25 Arrangement of Stand Pipes.

IV OPERATION AND MAINTENANCE

As a water treatment process slow sand filtration is noted for its high simplicity of operation. With some care and routine of operation, there will be little that can go wrong.

The operation of a slow sand filter is determined by the filtration rate, which is controlled at the effluent outlet. Raw water is drawn from the Chao Phya River by means of a 1-hp centrifugal pump to the inlet of the horizontal prefilter, over a distance of about 40 m through a 4.5 cm G.I. pipe readily available at the moment of construction. Flow rate in the prefilter is maintained at about 40 l/min or 1.5 m^3/m^2h (gate valve A in Fig. 3.3) to satisfy the total demand of three slow sand filters maintained at a flow rate of 0.15 m^3/m^2h or 34 l/min. A 3.8 cm G.I. pipe is used as overflow conduit at the prefilter inlet zone to return excess water to the river.

The effluent from the prefilter is admitted by a 0.5 hp centrifugal pump to three slow sand filters through a 2.54 cm PVC pipe. A constant level of supernatant water is maintained by a 3.8 cm G.I. overflow pipe. Excess supernatant water is returned to the prefilter outlet. Constant flow rate of 0.15 m^3/m^2h is maintained in each filter by gate valve B along the 3.81 cm outlet pipe of the filters (Fig. 3.3). Head loss is recorded by manometers.

Filtered water flowed to the weir chambers and from there to the clear well, by gravity through 3.81 cm G.I. pipes. Filtration rates of slow sand filters are controlled by closing gate valve C and allowing the filtered water to flow up in the manometer of the weir chamber and recording the time with a stop-watch. Knowing the cross sectional area of the weir, the flow rate can be calculated, as follows:

Surface area of each filter	= 4.5 m^2
Flow rate	= 0.15 m^3/m^2h
Flow = 4.5 x 0.15	= 0.675 m^3/h
Cross sectional area of each weir chamber	= 0.5 m^2

Let y be the increasing water level (in cm) in the manometer in one minute, then

$$0.5 \text{ m} \times y \frac{\text{cm}}{\text{min}} = 0.675 \frac{\text{m}^3}{\text{h}} \times \frac{1}{60} \frac{\text{h}}{\text{min}}$$

$$\therefore y = 2.25 \text{ cm/min}$$

Therefore the rate of 2.25 cm/min or 9 cm/4 min in the weir chamber corresponds to the flow rate of 0.15 m^3/m^2h in slow sand filters.

As already mentioned, it is very important to maintain the filtration rate constant because its determines the operation of slow sand filter. In order to render the task of unskilled operator easy and simple, a routine operation must be provided, as illustrated in Fig. 4.1.

For example, if y_1 = 17 cm at t_1 = 0, y_2 should be 19.25 cm at t_2 = 1 min, corresponding to an increase of 2.25 cm/min in the manometer or filtration rate of 0.15 m^3/m^2h in the filters. If y_2 is less or more than 19.25 cm, gate valve B should be adjusted accordingly (flow slightly increased and decreased, respectively, until the filtration rate of 0.15 m^3/m^2h is met.

From the clear well, treated water is elevated to the water tower by a 1.5 hp centrifugal pump through 2.54 cm pipe over a distance of about 28 m for distribution.

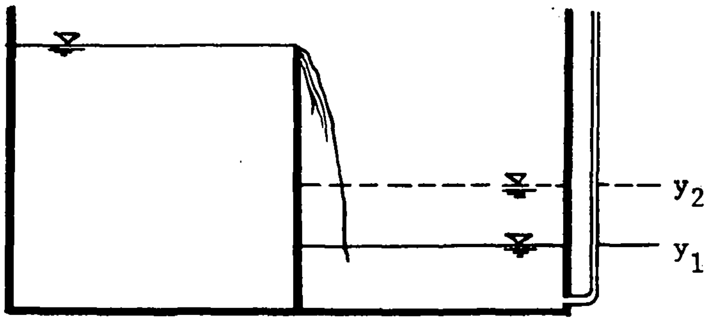

Fig. 4.1 Control of Filtration Rate at the Filter Outlet

4.1 Preparation of Prefilter Medium

The prefilter medium was washed by dipping and shaking bamboo basketfuls of crushed stones in earthen jars containing river water to remove earth and dirt attached to the stones. This washing operation is illustrated in Fig. 4.2. Washed crushed stones were then packed in successive layers in the prefilter as already described. (Fig. 4.3).

4.2 Initial Commissioning of Filters

Sand medium was first placed in the clear well and washed with river water pumped by a fire engine. Before sanding the filters, clean water from a nearly town was transported by truck to the site and pumped into the filters. Sand was then gradually admitted into the filters, tap-T and gate valve B (Fig. 3.3) being closed. This operation was initiated to prevent air bubbles in the sand bed. Water above the sand bed was then siphoned out of the filter. This mode of operation was repeated 2-3 times until the supernatant water was clean, and the filter was then put into operation, when first constructed.

4.3 Filter Cleaning

No filter cleaning has taken place since the filters were put into operation. However, the filter bed must be cleaned when the bed resistance has increased to such an extent that the regulating valve is fully open (gate valve C in Fig. 3.3), or the head loss has reached its maximum, which can be regularly checked.

To clean a filter bed, the raw water inlet valve must be closed (gate valve A in Fig. 3.3), allowing the filter to continue to discharge

Fig. 4.2 Washing of Prefilter Medium

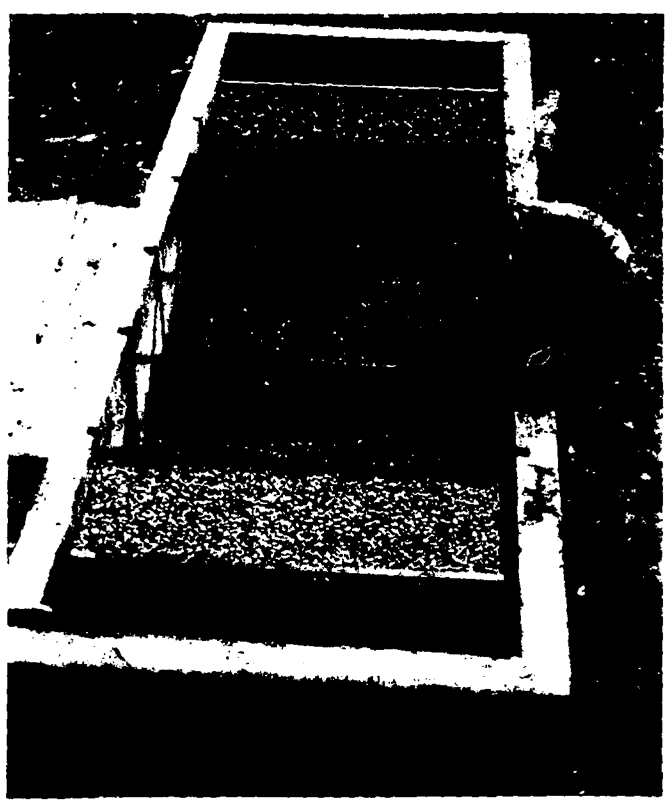

Fig. 4.3 Placing of Crushed Stones in Prefilter

to the clear water well as long as possible (overnight). When the water above the bed has fallen until the level of the weir outlet, the effluent delivery to the clear water well is closed (gate valve C in Fig. 3.3), and the supernatant water is drained off through tap-T until it is some 10 cm below the bed surface. As soon as the biological layer (schmutzdecke) is dry enough to handle, cleaning should start. Manual cleaning consists of skimming off the top 1-2 cm of material.

During cleaning operations, precautions should be taken to minimize the chances of pollution of the filter-bed surface by the labourers themselves. Such measures as the provision of boots that can be disinfected in a tray of bleaching solution may be wise, hygienic personal behaviour should be rigidly imposed, and no labourer with symptoms that might be attributable to waterborne or parasitic disease should be permitted to come into direct or indirect contact with the filter medium.

After cleaning, filter water is introduced from the bottom of the filter to drive out air bubbles from the medium as the water level inside the sand rises. The filtered water is obtained from the clear well or from the outlet side of the adjacent filters.

4.4 Supervision

The management of the water treatment plant is in the hands of the district officer who commissions the head of the village to supervise its operation. An operator has been trained and is now sufficiently acquainted with the routine running of the plant to be able to ensure that it is being carried out efficiently.

The AIT's Environmental Engineering Division is conducting a regular record of the performance of the plant, the quality of raw and treated water (turbidity, colour, total bacterial count, *E. coli*). It is hoped that, when the whole scheme of water supply is completed with the installation of the distribution system, Jedee-Thong village will be equipped with a strong programme of health education and sanitation so it could be a model for other rural communities to follow.

V COST ESTIMATION

5.1 Capital Costs

Capital costs incurred represent the actual costs of the materials used for the construction of the prefilter, slow sand filters, weir chambers and clear well. The costs of land and water tower are excluded in the calculation of the capital costs, as they are provided by the temple. The expenses involved in the payment of one mason and two labourers are included in the estimation of capital costs. Table E1 gives the breakdown of construction material costs.

Material costs	=	88,716 Baht[1/]
1 Mason for 7 months, ฿800/month x 7	=	5,600
2 Labourers, 7 months, ฿500/month x 7 x 2	=	7,000
Total Construction Cost	=	฿101,316
	=	$\frac{101,316}{967}$ = ฿105/person or ฿630/family of 6

The installation of the water distribution system is estimated to be ฿25,000. If it is included in the calculation of the capital costs, the total capital cost will be ฿126,316.

Allowing for 10 percent contingency,

Total Capital Cost	=	฿138,948 (US$6,947)
	=	฿143.70/person
	=	฿862/family of 6 persons

5.2 Operating Costs

The water supply system in Jedee-Thong Village has been designed on the assumption of 24 h service but in practice operates only 6 to 8 hours per day. Let us calculate the operating cost for 8 h operation per day. The main operating costs in this case are electricity charges and wages for 2 operators.

Assume that the 0.5 and 1 hp pumps run 8 h per day and the 1.5 hp pump 3 h per day.

Electricity Costs

1 hp pump = 746 watts = 0.746 kw

0.5 hp pump = 373 watts = 0.373 kw

1.5 hp pump = 1119 watts = 1.119 kw

1/ Current exchange rate approximately 20 Baht (฿) = US$1.-

0.5 hp and 1 hp pumps operating 8 h per day and 1.5 hp pump, 3 h per day. The total electricity consumption will be:

1.119 kw x 8 h/day + 1.119 kw x 3 h/day = 12.309 kw/day

12.309 kw/day x 30 days = 369.27 kw/month

The Metropolitan Electricity Authority (Bangkok) monthly charging rate is as follows:

First 5 units	=	5.00	฿/unit
Next 10 units	=	0.70	฿/unit
Next 45 units	=	0.90	฿/unit
Next 340 units	=	0.95	฿/unit

∴ Electricity cost for
369.27 kw/month = 5.00 + (0.70 x 10) + (0.90 x 45) + (0.95 x 309.27)

= 5.00 + 7.00 + 40.5 + 293.8

= ฿346.31/month

Salary of 2 operators (฿500 x 2) = ฿1,000/month

Pump maintenance cost = ฿200/month

Total Operating Cost = ฿1,546.31/month

= ฿1.60/cap. month

= ฿9.60/family month

In other words, 1 m^3 of water costs approximately 1.06 Baht or US¢5, which is quite reasonable as far as rural water supply is concerned.

VI PERFORMANCE OF JEDEE-THONG WATER TREATMENT PLANT

The project was started in March 1977 with visits of prospective villages, meetings and project discussion with provincial government officials. The selection of Jedee-Thong Village was made in May 1977. Redressment up of the site land, excavation and piling works were completed in July 1977, followed by reinforced concrete and masonery works. The construction of the treatment plant was completed in January 1978, including covering of different units, piping and pumps installation. The water treatment plant was put into operation on January 26, 1978 without any difficulty. The system controls worked properly, and samples were collected and analyzed starting from January 31, 1978. The quality characteristics (turbidity, total coliforms) of raw water, pretreated water and final treated water were determined at 2-4 days intervals, as well as head loss development in filters. Dissolved oxygen was also monitored regularly.

This report covers the results extending from January 31 to March 23, 1978. Detailed data are tabulated in Tables F1 to F3 in Appendix F and relevant results presented in the following sections. The plant was still in good working condition at the moment of preparing this report, and continuous monitoring of water quality is being conducted by AIT's Environmental Engineering Division.

6.1 Raw Water Quality

Raw water source is the Chao Phya River. Being upstream, this portion of river has relatively good water quality free from industrial pollution. The only danger is fecal contamination originating from human settlements located along the banks of the river. Table 6.1 gives some characteristics of the raw water. Removal of turbidity and coliform organisms is the main concern of this water treatment plant.

6.2 Turbidity Removal

Fig. 6.1(a) shows the variations of turbidity in the raw water, prefilter effluent and final treatment water. Raw water turbidity varied between 18 and 32 JTU during 51 days of continuous operation, while the mean value of turbidity in the effluent of the prefilter was about 12 JTU, indicating 50 percent removal efficiency. The turbidity of treated water was quite good and remained in the range of 1 to 5 JTU after the "ripening period" (about 20 days after the starting of operation). The overall efficiency turbidity removal by the prefilter slow sand filter system was about 92 percent.

6.3 Coliform Organisms

Fig. 6.1(d) reports count results of total coliforms in raw water and effluents from the prefilter and slow sand filters. The most probable number (MPN) of raw water total coliform varied from 2,300 to 10,000 per 100 ml of sample, attaining accidentally 46,000 in a few occasions. The effluent from the horizontal prefilter had a coliform count which varied from 430 to 2,400 MPN per 100 ml. The fluctuation of coliform organisms in the prefilter seems to be independent of the coliform organisms content in raw water. In general, the horizontal prefilter accounts for 80 percent removal of coliform organisms while the slow sand filters accomplish 16 - 19.99 percent removal of the remaining coliform organisms resulting in an overall removal of 96 - 99.99 percent. It is interesting to point out that the ripening period which took place about 3 weeks after the starting operation, brought about the highest removal of turbidity and coliform organisms, ensuring safe treated water for drinking purpose.

Table 6.1 Characteristics of Raw Water

Parameter	Concentration
pH	7.2
Temperature	25 - 28^{o}C
Turbidity	20 - 32 JTU (during dry season)
Colour	20 units (Hach)
COD	20 mg/l
BOD	3.1 mg/l
DO	3 mg/l
Alkalinity	84 mg/l
Total hardness	98 mg/l
Total solids	202 mg/l
Suspended solids	36 mg/l
Coliforms	2,300 - 10,000 MPN/100 ml (sometimes 40,000 MPN/100 ml)

6.4 Dissolved Oxygen

The dissolved oxygen content in raw water and effluents from different filters was determined after 38 days of continuous operation. Fig. 6.1(c) shows the variations of DO concentration at different sampling points. DO concentration in the prefilter effluent and clear chamber effluent were always higher than that of raw water. The increase of DO concentration in the prefilter effluent was due to aeration of recirculated water. Cascading slow sand filter effluent over the weir chamber increased considerably the DO concentration of treated water in the clear well.

6.5 Head Loss

Head loss development is an important criterion in filtration since it announces the conclusion of filter runs. Fig. 6.1(b) records the head loss build-up across the three slow sand filters. In all cases, head loss development was rapid at the beginning of filtration run and became very slow, at the average rate 0.6 cm/day once the ripening period had been reached. If extrapolation is permitted for a total head loss of 1 m, filter runs of 5 months could be achieved. With proper maintenance and careful supervision, this achievement in longer filter runs is very encouraging for the wider implementation of slow sand filtration coupled with prefiltration in rural areas of developing countries.

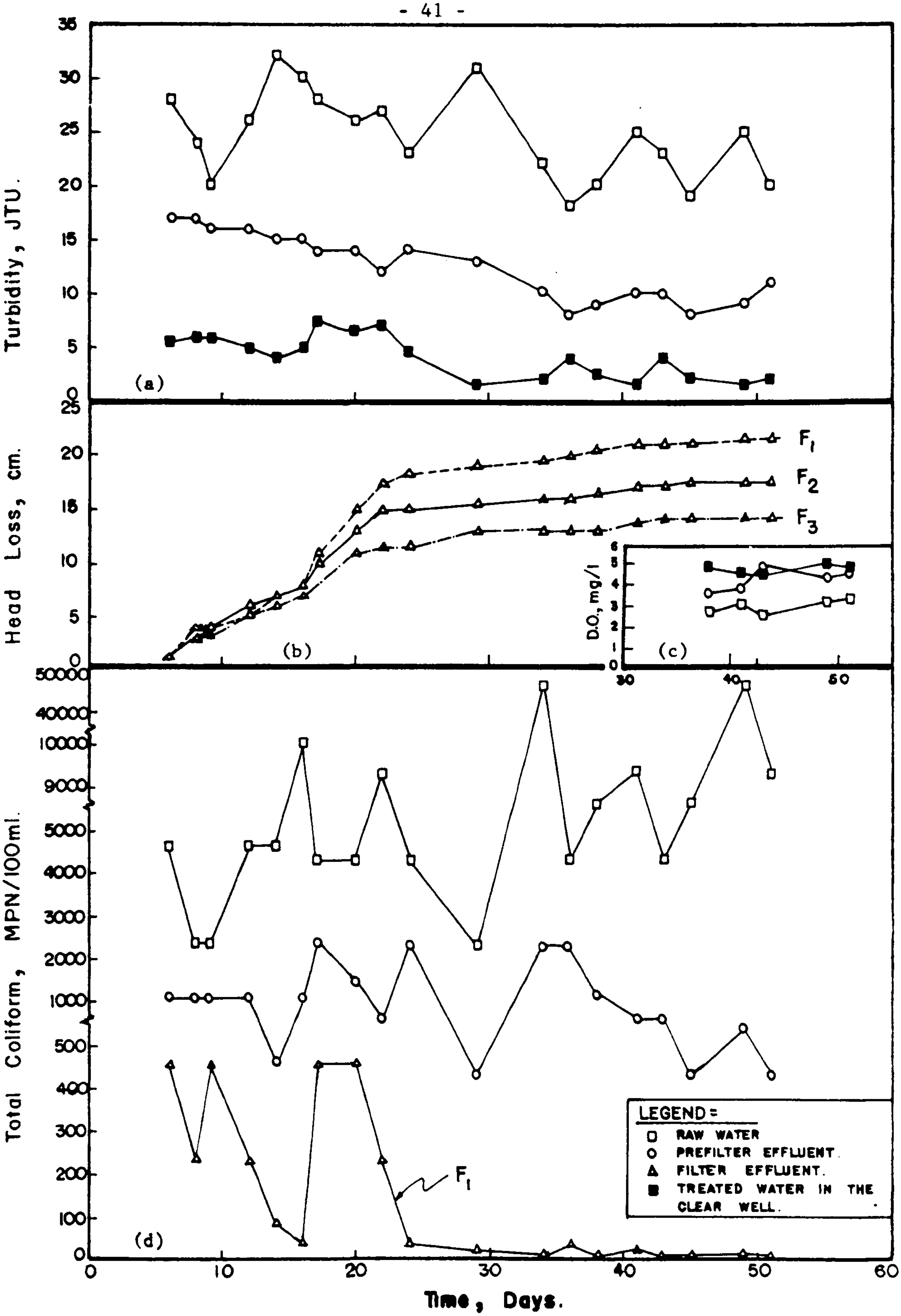

Fig.6.1 Turbidity, Dissolved Oxygen and Coliform Organisms of Raw Water, Effluents from Different Filters and Clear Well and Head Loss in the Filters F_1, F_2, F_3

VII CONCLUSION

In recent years, there seems to be an increasing concern of Governments in developing countries to provide water supply and sanitation systems for the rural population in these countries. Rural communities will undoubtedly benefit from this change in policy direction. On the other hand, rural populations should be aware of the importance of water supply and sanitation in improving their socio-economic conditions. Local participation in such schemes and public health education programmes, are the main factors which can ensure the successful implementation of such projects. Sustained efforts of operation and maintenance of completed schemes are necessary to achieve a high degree of efficiency.

Progress in improving rural water supply and sanitation is closely associated with three important areas: administrative, financial and technological. The proliferation of agencies often leads to problems of coordination and this is a major cause for the poor selection of communities to be serviced and the installation of inappropriate systems. It would appear sensible to reduce the number of agencies, where many government departments are involved in water supply and sanitation, or at least to have one of them act as the primary agency responsible for development of national policies and plans, and the coordination of activities of the other agencies. It is essential that villagers be encouraged to pay the maximum amount possible for water supply services and this should normally cover operation and maintenance costs. The level of technical expertise in rural areas is very low and all parts of the supply system must be simple to operate and maintain.

Jedee-Thong village, situated on the west bank of Chao Phya River, was selected for this project. Criteria selection were based on the eagerness of the villagers to have a water treatment plant, their willingness to provide manpower for its construction and the strong support of local government.

The water treatment plant at Jedee-Thong Village is an application of a successful study carried out at the Asian Institute of Technology. The system consists of an horizontal coarse-material prefilter to pretreat the raw river water, followed by a slow sand filter to polish this water for human consumption by approximately 720 village residents.

Village residents contributed to the project by providing their own labor with technical assistance from the Asian Institute of Technology. Construction works were started in May 1977 and completed in January 1978. The water distribution system is only part of the total water supply and distribution scheme which has not been completely installed in Jedee-Thong Village due to lack of funds. Treated water is being used by the nearly temple, and the villagers have to come to the treatment plant to fetch water. Standpipes will eventually be installed along the footpath of the village with funds drawn from the local government budget and contributions from the village residents themselves.

The water treatment plant was put into operation on January 26, 1978. The horizontal prefilter did a very good job accounting for 50 percent removal efficiency, raw water turbidity being 18 - 32 JTU and pretreated water about 12 JTU. Slow sand filters performed perfectly and, after 3 weeks of "ripening", gave an excellent water quality, readily available for human consumption. Head loss development was very slow, indicating that filter runs of 5 months could be expected.

This water supply system is simple to operate and maintain. With sustained efforts of routine running of the plant by a well trained operator, high performance efficiency will be ensured. It is hoped that Jedee-Thong Village with this new water supply system will eventually lead to a strong programme of health education and sanitation so that it will become a model village for other rural communities to follow.

POSTCRIPT

INAUGURATION OF JEDEE-THONG WATER TREATMENT PLANT

After 81 days of operation of the treatment plant, the villagers of Jedee-Thong organized an inauguration ceremony held on Tuesday, 18th April, 1978. The occasion was graced by the presence of the Governor and the Deputy Governor of Pathumthani Province, President Robert B. Banks of the Asian Institute of Technology and Mrs. Banks, Mr. Paul Stinton of IDRC, Ottawa, Canada and Mrs. Dale Whiteside of the Canadian Embassy in Bangkok. Many members of faculty, staff and students of AIT, and hundreds of villagers participated in the ceremony, making the atmosphere colourful and gay.

It was a beautiful blue-sky day and according to Thai calendar, an auspicious day as it coincided with the period of the "Songkran" festival. In April, when rivers and canals are low, the fields are parched and the rain water stored in large earthenware jars for drinking often run dry, comes the Songkran festival. Astrologically it marks the entrance of the sun into the sign of the Ram (Aries). It is, in fact, the Hindu New Year, but for Thais it is a celebration of the rains and fertility to come. Much of its meaning also amounts to sympathetic magic involving water, and the sexual symbolism that is thought to bring about rain and fertility[1/].

For Jedee-Thong residents, the inauguration ceremony was an occasion for solemn thanksgiving and joyous merry-making. It began early in the morning with the offering of alms to Buddhist monks in order that the community may gain merit. Guests arrived in the afternoon, and the official opening ceremony took place in the courtyard of the Jedee-Thong temple, near the water treatment plant. The Governor of Pathumthani Province expressed his appreciation for the work achieved and recognized the honour bestowed upon Jedee-Thong Village which was selected to have a water treatment plant. In his speech, President Banks reiterated the primary role of AIT to train young men and women of diverse Asian nationalities to lead in development processes at work within Asia especially where technological innovation and construction are involved, aimed at improving the quality of life in Asia. In recognition of the cooperation and hard work of the Jedee-Thong Villagers, the filter plant was dedicated to them, and the water treatment unit was turned over to the local Government with the understanding that the technical supervision of the plant will be assumed by AIT's Environmental Engineering Division for the time being.

The ceremony was characterised by a taste test of treated water by many of the guests. The next day's survey revealed no incidence of intestinal discomfort among any of the drinkers!

The ceremony ended up with the ritual water-pouring ceremony : a little water being poured over the distinguished guests' hands in a sign

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1/ Extract from A Portrait of Thailand, by Monkol Chang and Tom Chuawiwat of respect and appreciation. The occasion was crowned with singing and the dancing of the "Ramwong", a traditional Thai dance for community celebrations. And finally, a reception sponsored by the village featuring "Summer Iced Rice".

The atmosphere of the ceremony reflected the warm hospitality of the villagers, their pride for having contributed to the project and their happiness in having good quality water.

Overview of the Water Treatment Plant.
(L—R) Storage Tank, Weir, and Filter Units

Dr N.C. Thanh presenting the blueprint plans of the plant to Mr Suthee Ob-Oam, Governor of Pathumthani Province. Mr Thian Kaewnit, Samkok District Officer is at left.

AIT President Dr Robert B. Banks unveiling the commemorative sign for the water treatment plant at Jedee-Thong Village.

Villagers at work.

The graceful movements of the traditional Thai "ram-wong" dance expresses the festive joy of Jedee-Thong villagers after the opening ceremony.

Safe drinking water at last !

ACKNOWLEDGEMENTS

It is impossible to mention everyone who has helped me on this project. My note of thanks extends to all who assisted me in one way or another to the successful completion of this project.

For their constant encouragement, my deepest gratitude is conveyed to : Professor Robert B. Banks, President of the Asian Institute of Technology; my colleagues in AIT's Environmental Engineering Division especially Mrs. Samorn Muttamara, Dr. B.N. Lohani and Dr. Chongrak Polprasert; Dr. T.H. Venkitachalam, who assisted me in the early stages of this project; to my good and helpful student, Mr. Sirisak Chenboonthai, who was instrumental in the design and construction of this water treatment plant; to all members of AIT's Environmental Engineering, who contributed in one way or another to this project. My appreciation also to Mrs. Emilie Ketudat and Mrs. Wiyada Tasakorn for their assistance during the inauguration ceremony.

I am also indebted to the Governor of Pathumthani Province, Mr. Suthee Ob-oam and the Deputy Governor, Mr. Bira Boonjing for their sustained cooperation; to Mr. Thian Kaewnit, Samkoke District Officer, for his assistance in selecting the project site and during various phases of the plant construction; to Mr. Boonchoo Thongprajonk, Head of Jedee-Thong Village, and to the villagers themselves who demonstrated a high sense of responsibility and community involvement. This filtration system is dedicated to them.

The cooperation of my good friend, Mr. Soo-Jin Lee in taking some of the photographs and in editing this manuscript is gratefully recorded. My heartfelt thanks to Mrs. Ratana Siengsukon for typing and arranging this report.

I wish to acknowledge and thank the International Development Research Centre, Ottawa, Canada, which sponsored my research; Mrs. Louise Rohonzy, IDRC Senior Program Officer who has always lent a helpful hand when necessary; and the Asian Institute of Technology which hosted me during my award tenure. And last, but by no means least, my affection for my wife Marie for her unstinting understanding and patient support throughout the project.

APPENDIX A

STRUCTURAL DETAILS OF SLOW SAND FILTER CONSTRUCTION

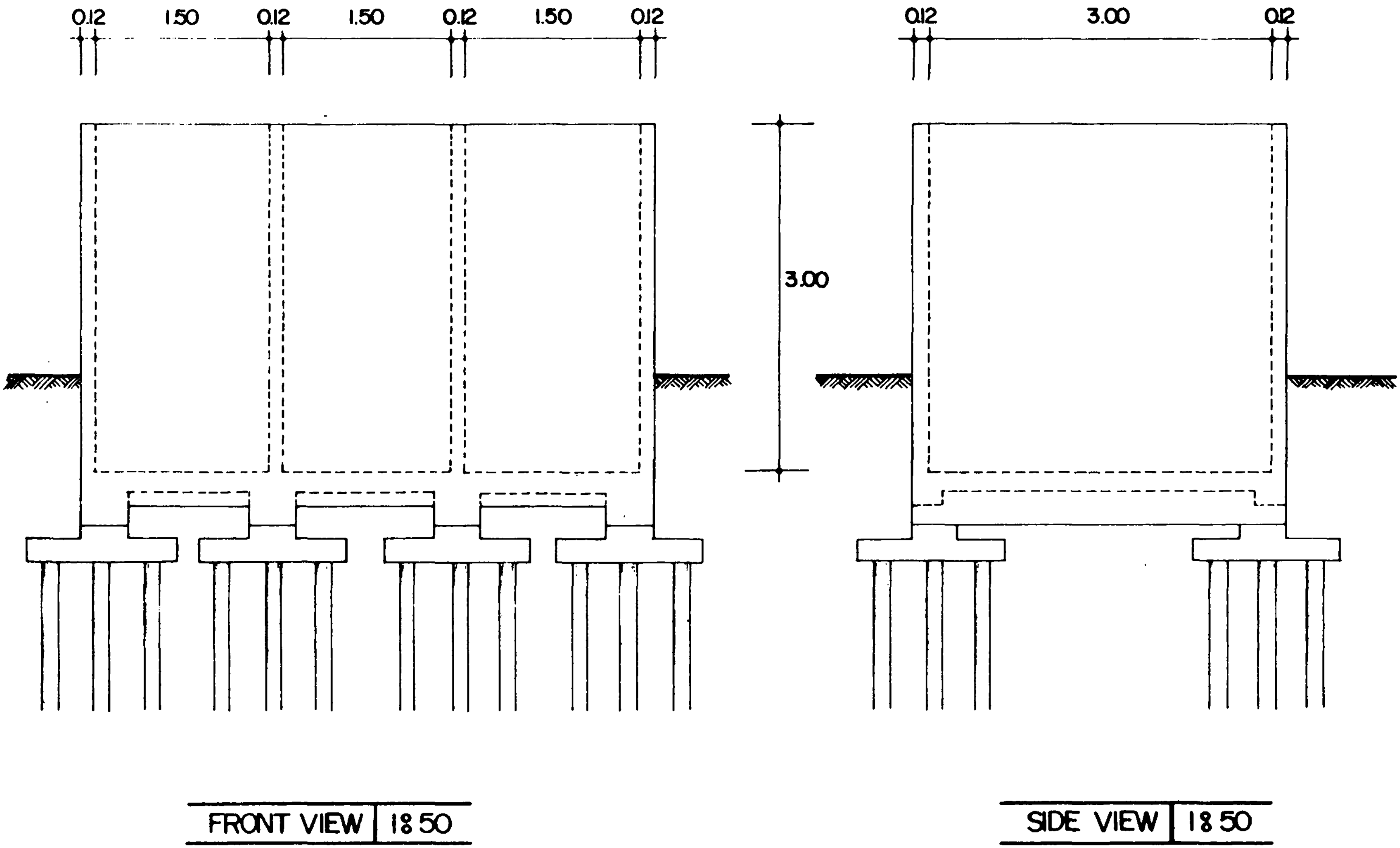


Fig. A-1 Filter Units and Foundation

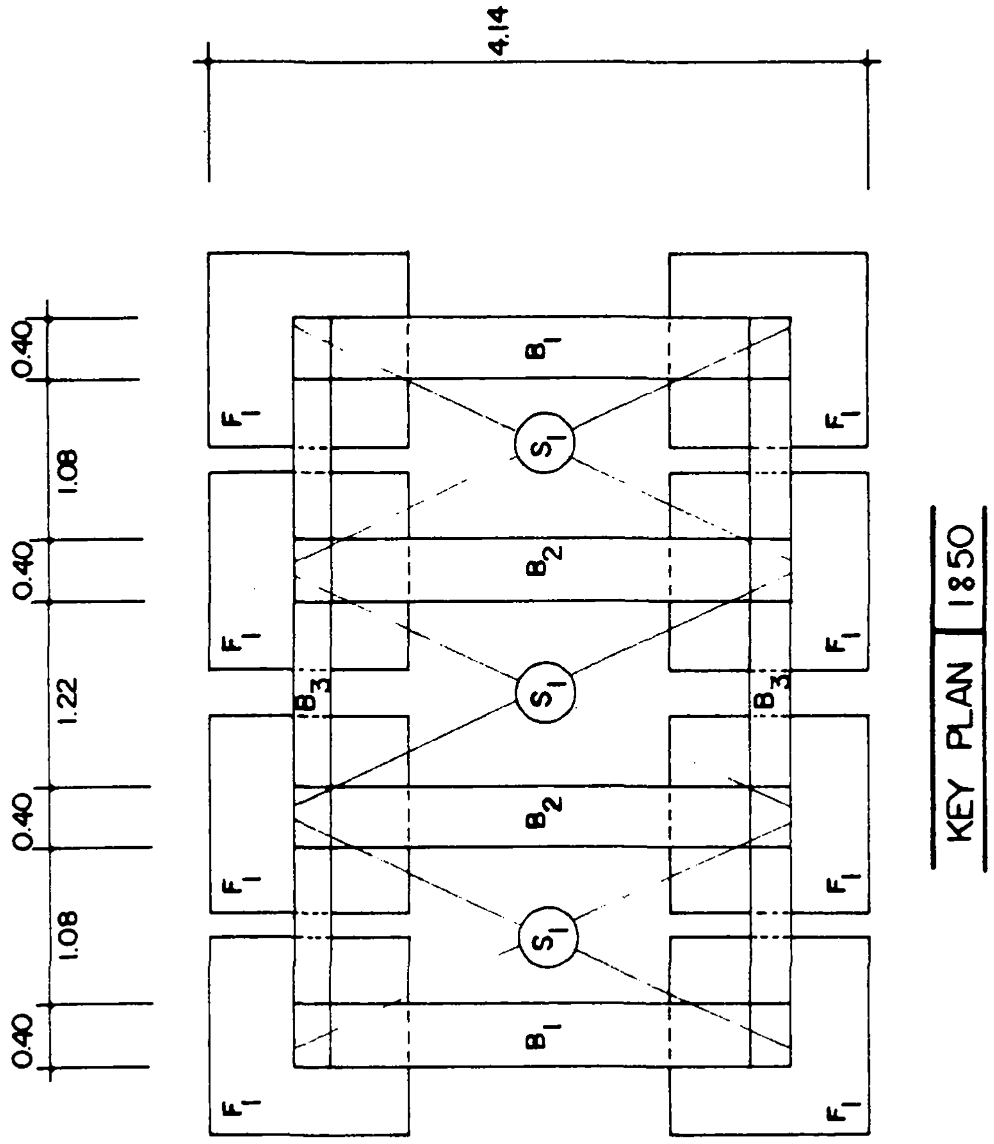


Fig. A-2 Footings, Slabs and Beams

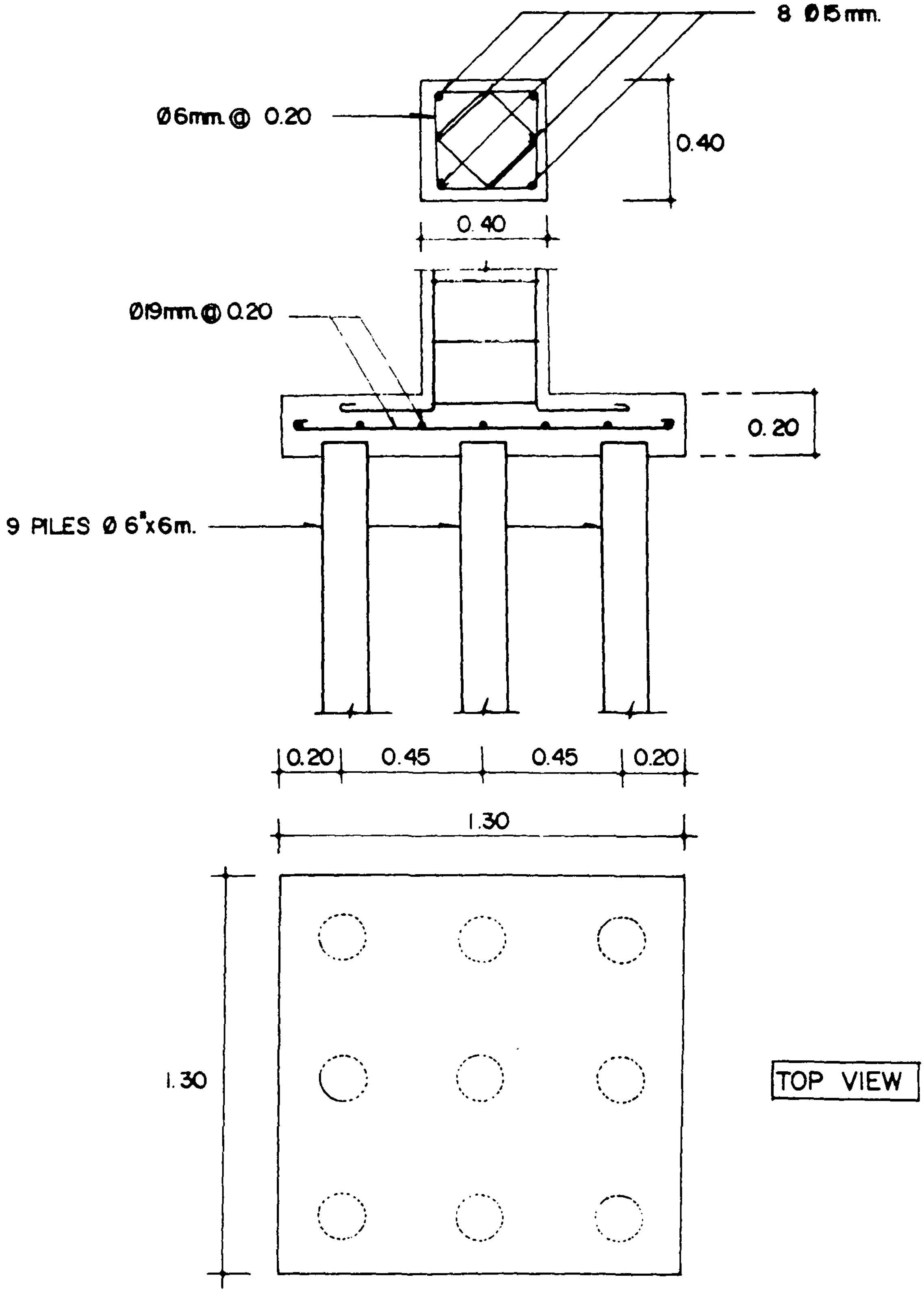
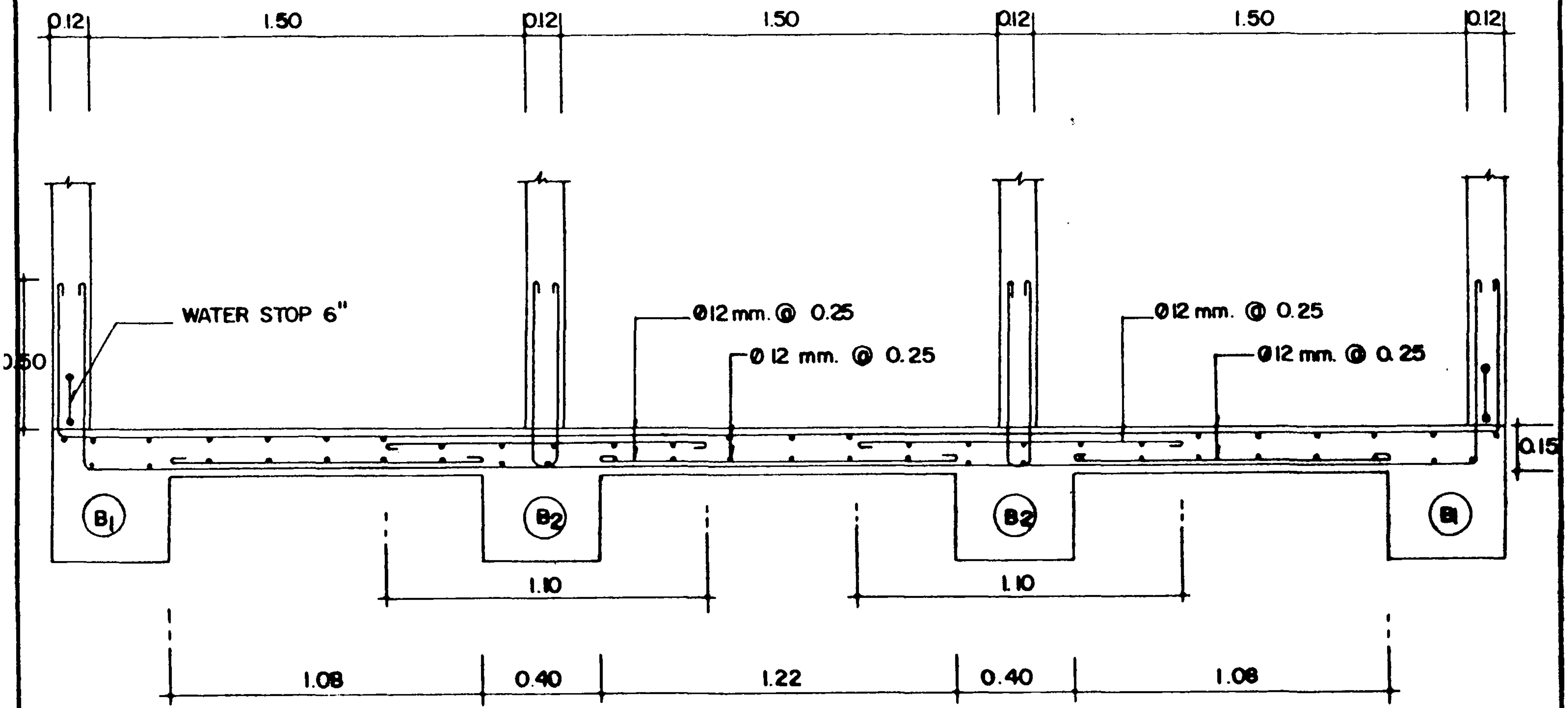


Fig. A-3 Footing F_1 1:20



SLAB (S1) | 1:20

Fig. A-4 Details of Slab Construction

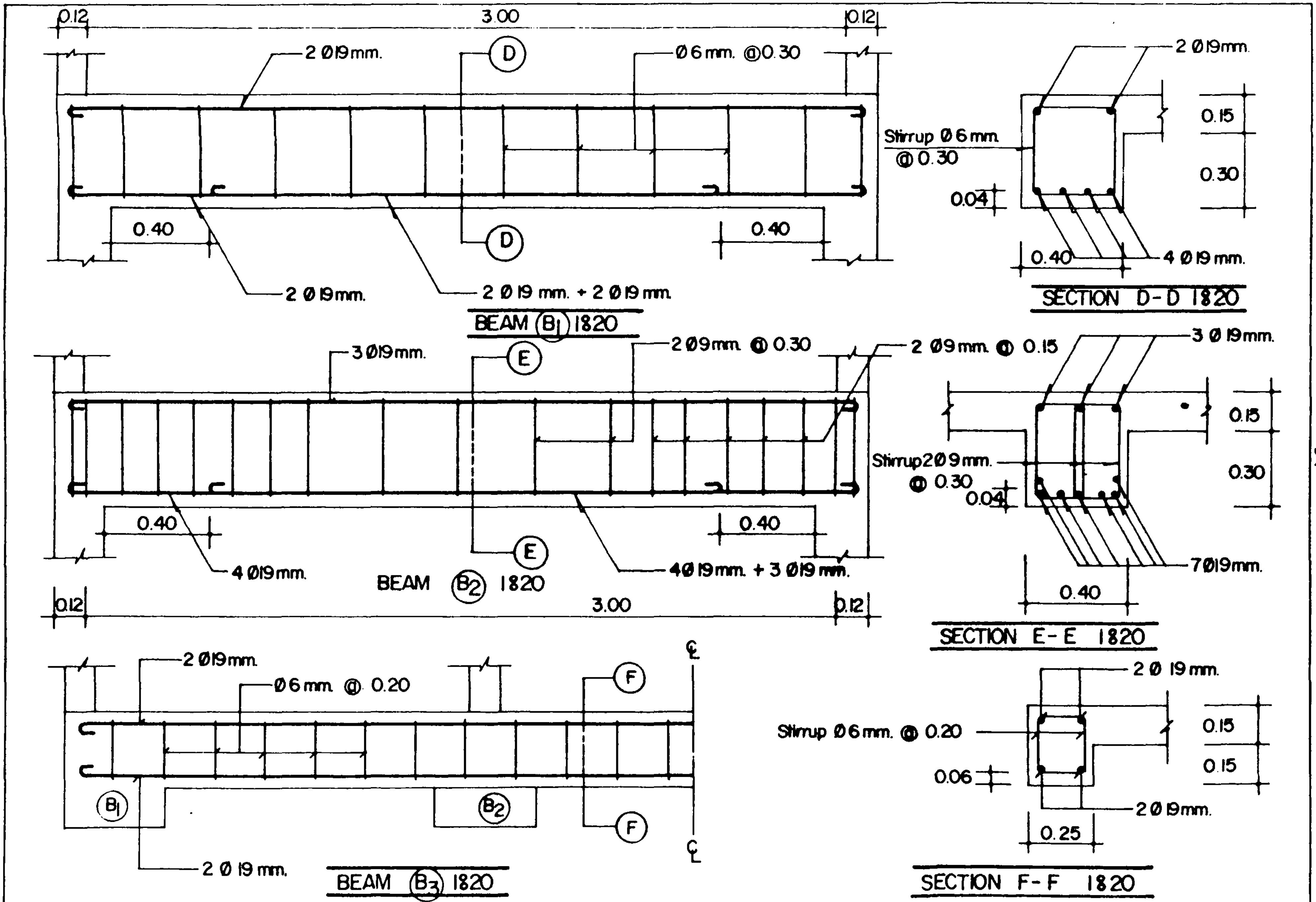
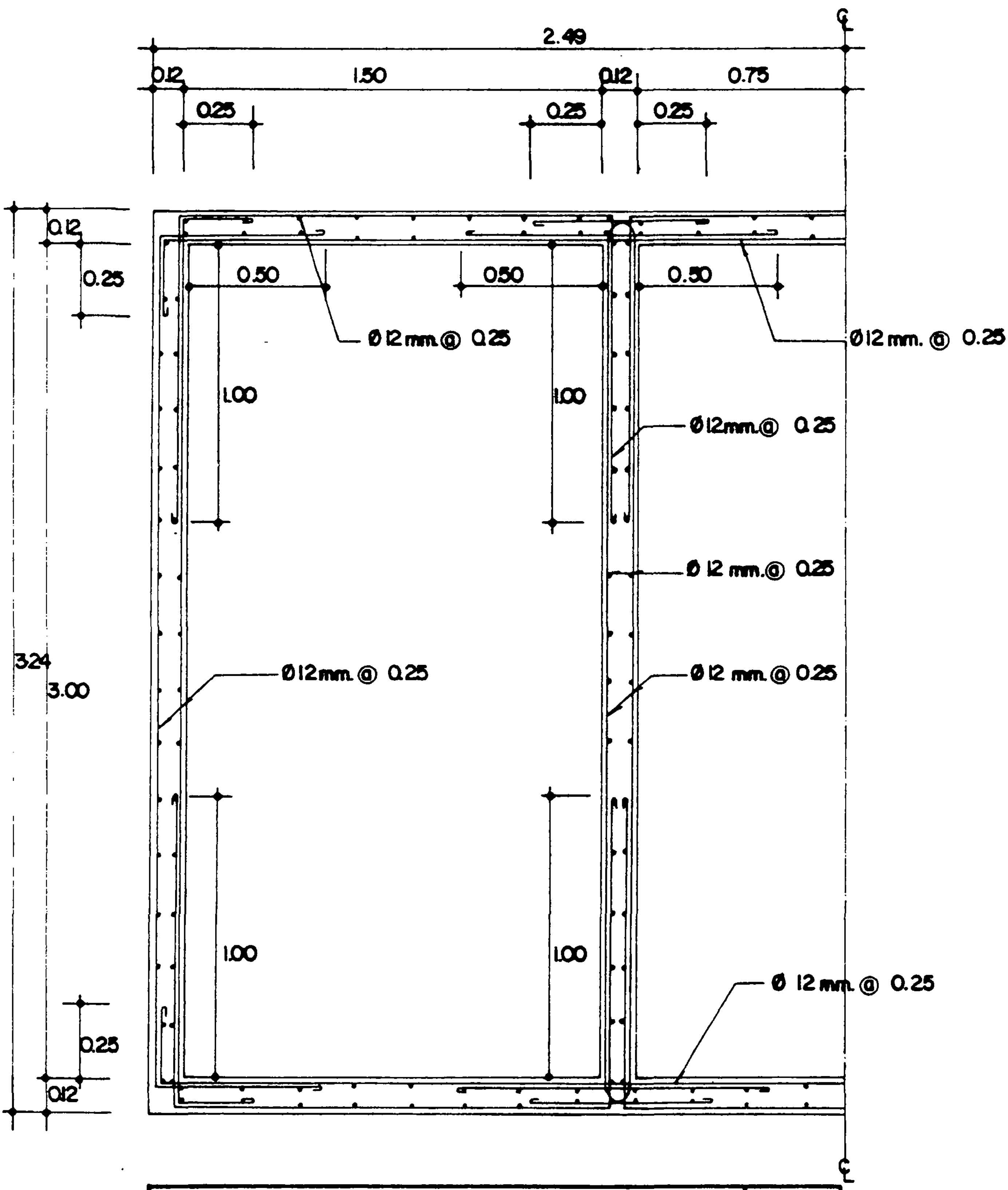


Fig. A-5 Details of Beam Construction



WALL REINFORCEMENT (TOP VIEW)	1:20

Fig. A-6

APPENDIX B

STRUCTURAL DETAILS OF THE HORIZONTAL COARSE-MATERIAL PREFILTER

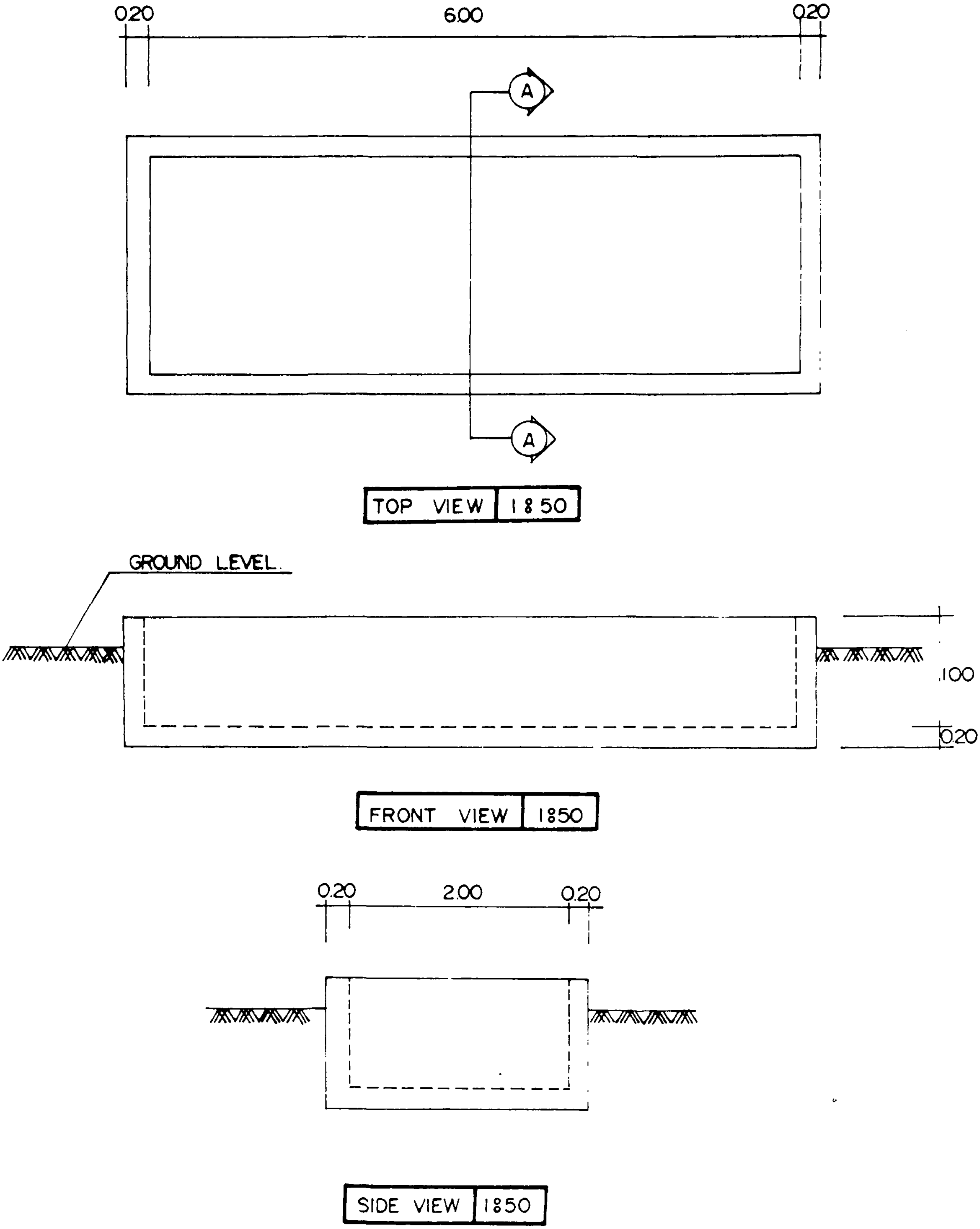


Fig. B-1 Horizontal Prefilter

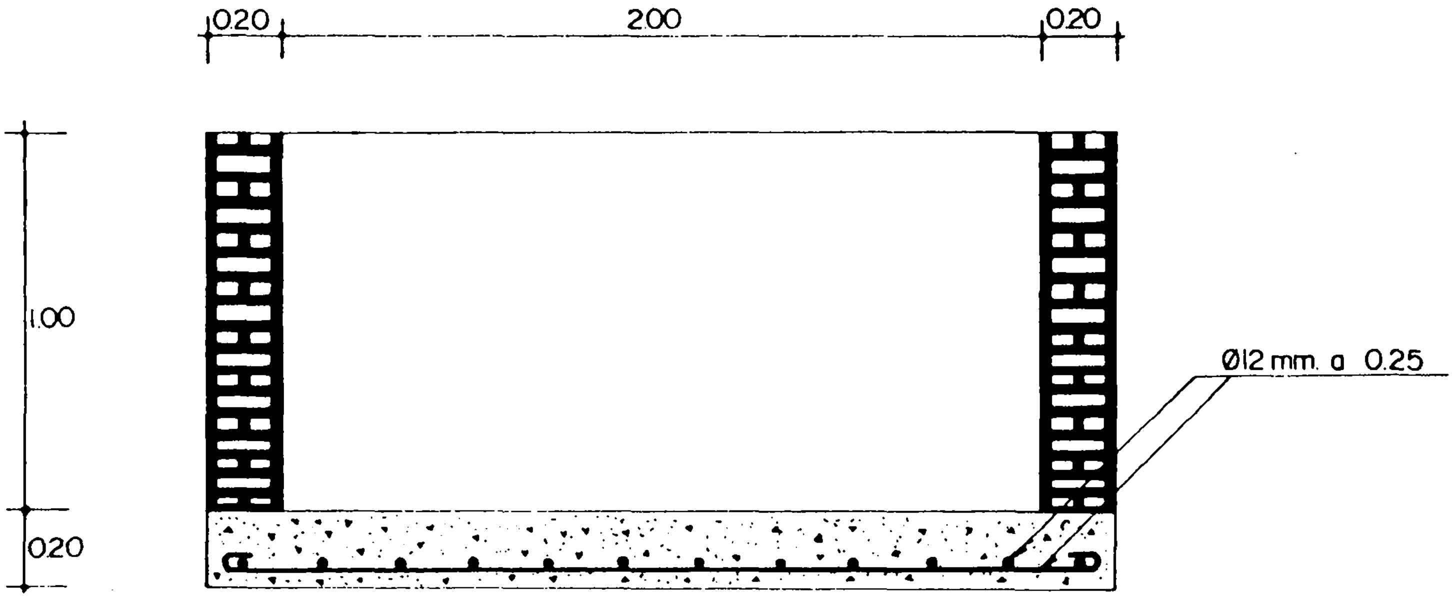


Fig. B-2 Section A-A (Fig. B-1) of the Prefilter

APPENDIX C

CONSTRUCTION DETAILS OF WEIR CHAMBERS

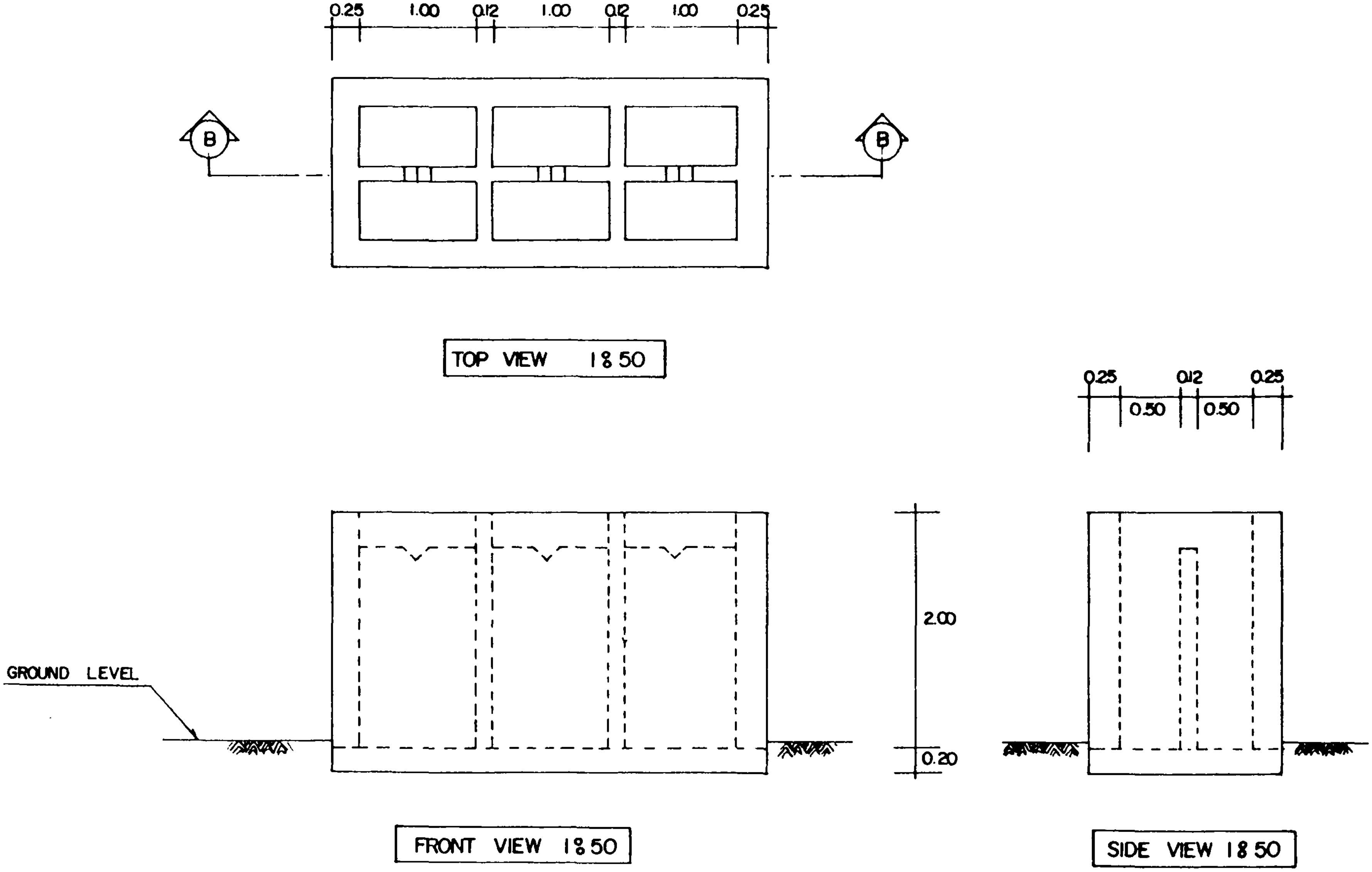


Fig. C-1 Weir Chambers

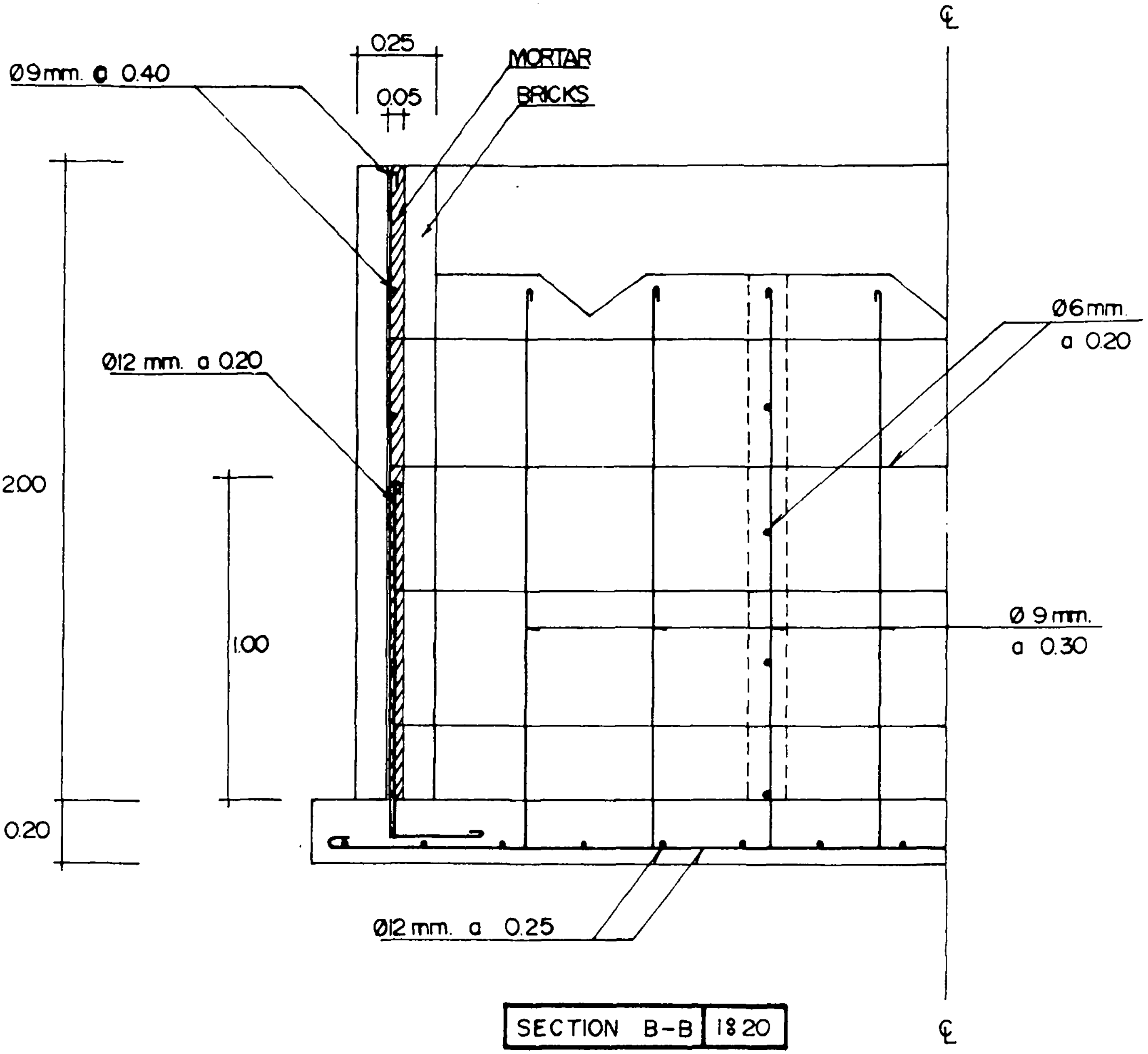
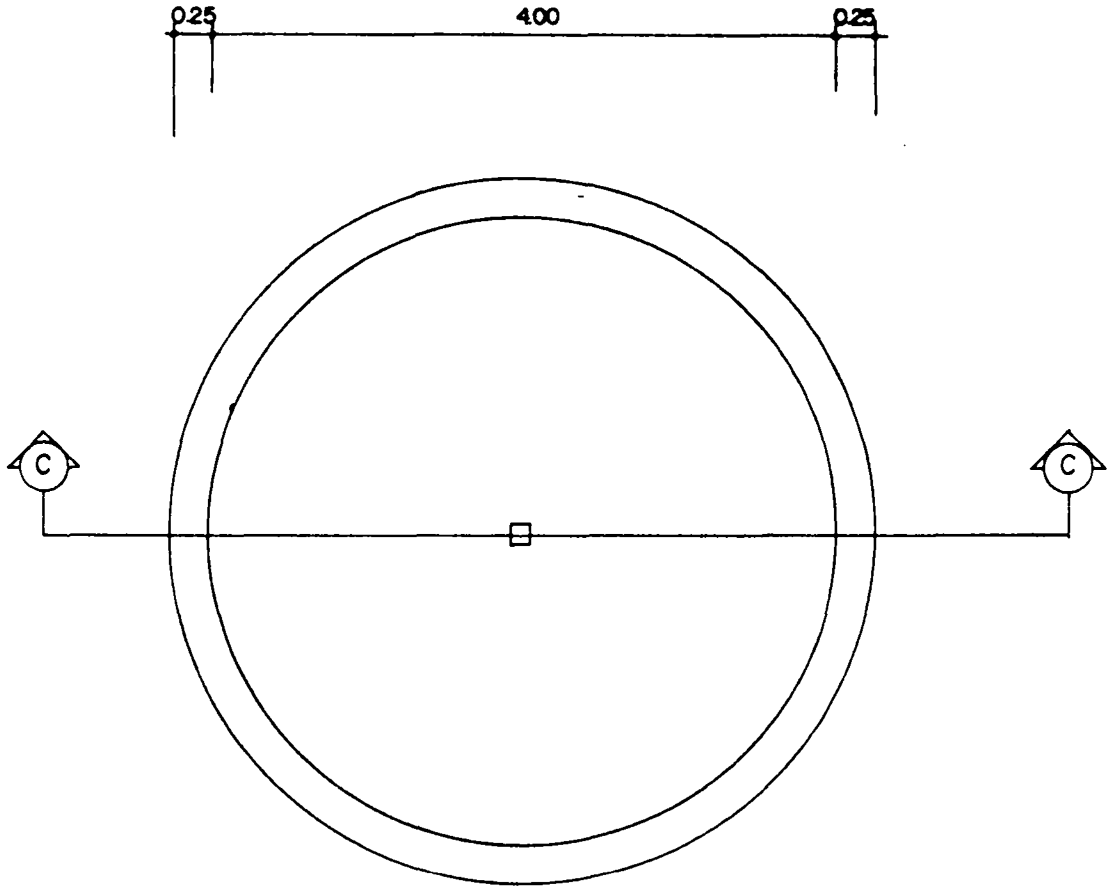


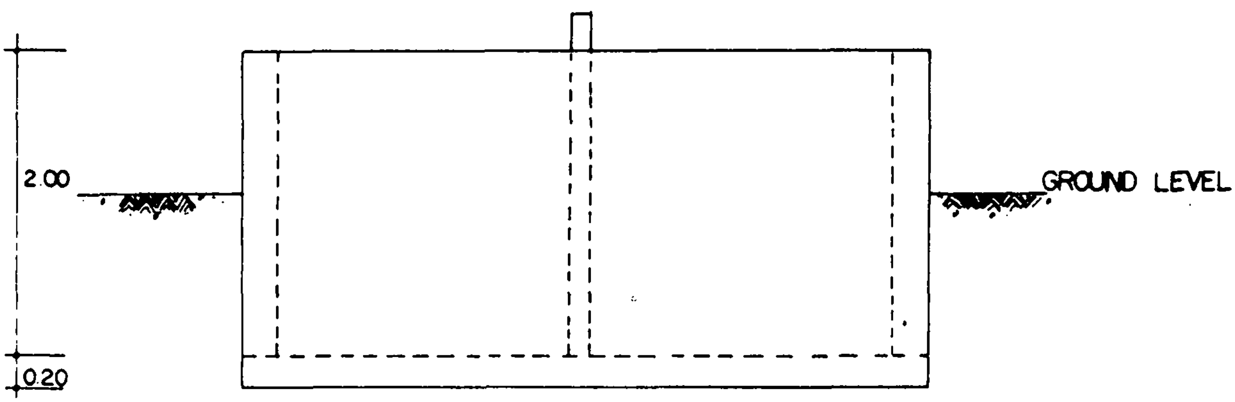
Fig. C-2 Section B-B (from Fig. C-1) of Weir Chamber (1:20)

APPENDIX D

CONSTRUCTION DETAILS OF CLEAR WELL



TOP VIEW 1:50



SIDE VIEW 1:50

Fig. D-1 Clear Well

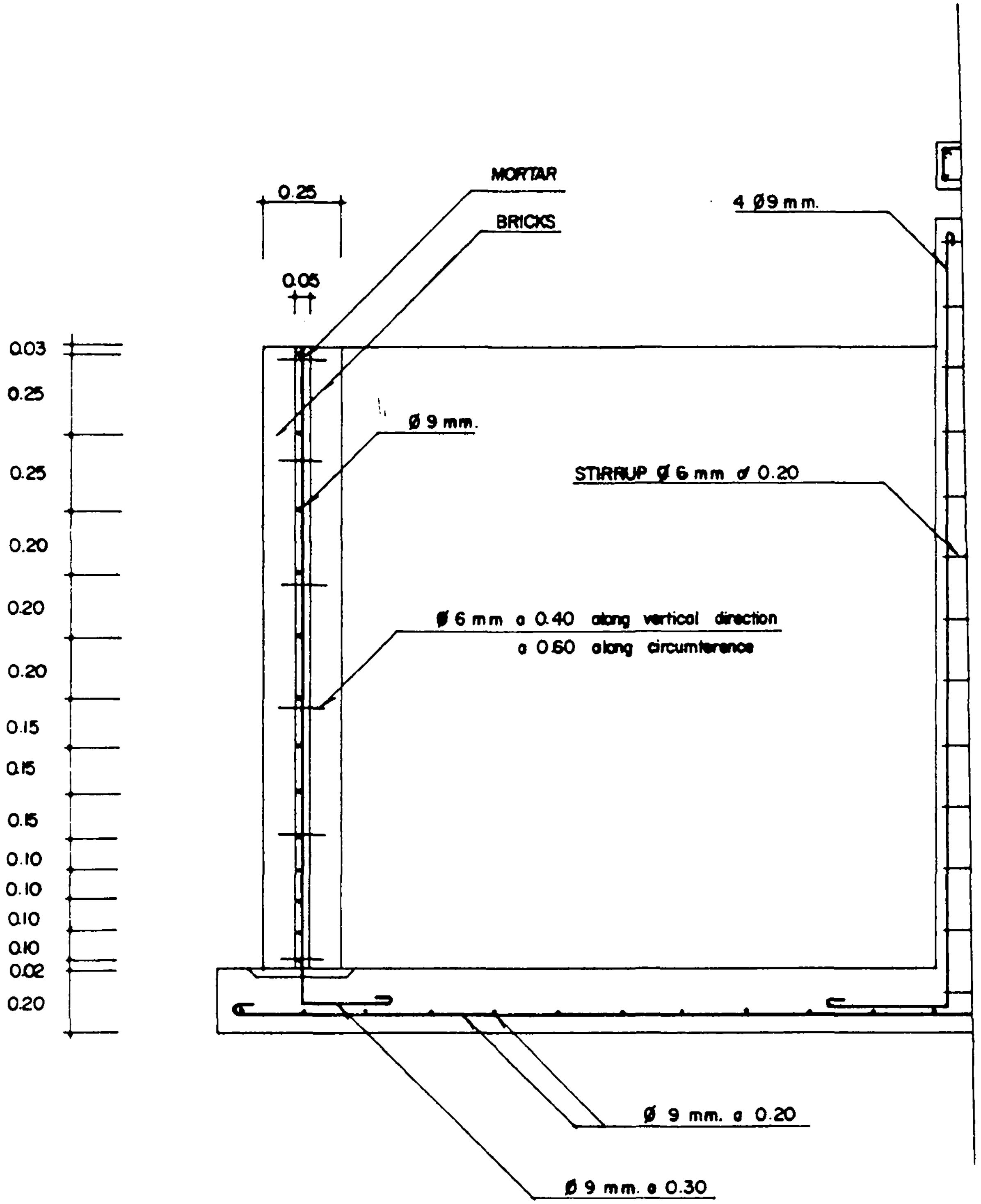


Fig. D-2 Section C-C (from Fig. C-1) of Clear Well (1:20)

APPENDIX E

COSTS OF CONSTRUCTION MATERIALS

Table E1 - Costs of Construction Materials (1977)

Material	Unit Price, Baht 1/	Quantity	Cost, Baht 1/
Wooden piles 16 cm x 6 m	75	72 piles	5,400
Cement			
Tiger brand	32	272 sacks	8,704
Elephant brand	40	17 sacks	680
Sand	$100/m^3$	$78\ m^3$	7,800
Crushed stone	$130/m^3$	$51\ m^3$	6,630
Steel bar			
∅ 6 mm	16/10 m	444 m	710
∅ 9 mm	34/10 m	310 m	1,054
∅ 12 mm	53/10 m	2,380 m	12,614
∅ 15 mm	105/10 m	80 m	840
∅ 19 mm	160/10 m	300 m	4,800
Brick			
16 x 5 x 3 cm	0.09	29,000 pieces	2,610
22 x 11 x 5 cm	3	900	2,700
Concrete block 10 cm			
(ready made)	3	120	360
Water stop (15 cm)	100/m	17 m	1,700
Timber (Yang)			
1" x 8" x 6 m		52	4,052
1" x 8" x 3 m		12	
1½" x 3" x 6 m	48	27	1,296
Timber (Yang)			
1½" x 3" x 4 m	32	4	128
1½" x 3" x 3.5 m	28	12	336
1½" x 3 " x 3 m	24	6	144
1½" x 3" x 2.5 m	20	10	200
1½" x 3" x 2 m	16	51	816

1/ Current exchange rate approximately 20 Baht = US$1.-

Table E1 (Cont'd)

Material	Unit Price, Baht 1/	Quantity	Cost, Baht 1/
Timber (Kabark)			
1" x 8" x 6.5 m	94	4	376
1" x 8" x 6.5 m		10	4,339
1" x 8" x 6 m		10	
1" x 8" x 2.5 m		10	
Used Timber			
1" x 6", 1" x 8", 1" x 10"		120	1,410
Plywood 4 mm x 4'	85	8	680
Lime	7	28 sacks	196
Galvanized Sheet			
8'	56	10	560
6'	25	30	750
4'	20	30	600
Wire	12	16 kg	192
Nail			
4"	10	5 kg	50
3"	10	13 kg	130
2½"	10	4 kg	40
1"	20	4 kg	80
G.I. pipe Ø 1" and Ø $\frac{3}{4}$"	-	-	2,100
Galvanized tee 1½ x 1½ x $\frac{3}{4}$"	18	3	54
Tap Ø $\frac{3}{4}$"	45	3	135
Foot valve Ø 1"	75	3	225
Gate valve			
Ø 1½"	150	6	900
Ø 1"	100	4	400
Pipe PVC			
Ø 1½"	25	16 m	400
Ø 1"	14.50	28 m	406
Bend PVC			
90^{o} x 1½"	13	7	91
90^{o} x 1"	10	8	80

Table E1 (Cont'd)

Materials	Unit Price, Baht 1/	Quantity	Cost, Baht 1/
Coupling PVC			
1½"	12	1	12
1"	6	1	6
Tee PVC			
1½" x 1½" x 1½"	15	2	30
1" x 1" x 1"	6	5	30
Pumps			
1.5 hp	3,870	1	3,870
1 hp	2,500	1	2,500
0.5 hp	1,900	1	1,900
Crushed stone for prefilter			
1/8" x 3/16"	20	20 bags	400
3/16" - 1/4"	20	10 bags	200
1/4" - 3/8"	20	10 bags	200
3/8" - 1/2"	20	10 bags	200
1/2" - 3/4"	20	20 bags	400

Total = ฿ 88,716.-

APPENDIX F

EXPERIMENTAL RESULTS

Table F1 - Turbidity of Raw Water and Effluents from Different Filters

Run Duration Day	Date	Turbidity, JTU			% Removal		
		R.W.	P.F.	C.W.	P.F. VS R.W.	C.W. VS P.F.	Overall C.W. R.W.
6	31/1/78	28	17	5.5	39.3	67.6	82.1
8	2/2/78	24	17	6	29.2	64.7	75
9	3/2/78	20	16	5.8	20	63.75	71
12	6/2/78	26	16	5.2	38.5	67.5	80
14	8/2/78	32	15	4	53.1	73.3	87.5
16	10/2/78	30	15	5	50	66.7	83.3
17	17/2/78	28	14	7.5	50	46.4	73.2
20	20/2/78	26	14	6.5	46.2	53.6	75
22	22/2/78	27	12	7.1	55.6	40.8	73.7
24	24/2/78	23	14	4.4	39.1	68.6	80.9
29	1/3/78	31	13	1.6	58.1	87.7	94.8
34	6/3/78	22	10	2	54.5	80	90.9
36	8/3/78	18	8	3.8	55.6	52.5	78.9
38	10/3/78	20	9	2.5	55	72.2	87.5
41	13/3/78	25	10	1.3	60	87	94.8
43	15/3/78	23	10	4	56.5	60	82.6
46	17/3/78	19	8	1.8	57.9	77.5	90.5
49	21/3/78	25	9	1.5	64	83.3	94
51	23/3/78	20	11	2.2	45	80	89
Average		24.6	12.5	4.1	48.82	68.06	83.4

<u>Legend</u> :

R.W. = Raw Water

P.R. = Effluent from the prefilter

C.W. = Treated water in the clear well

Table F2 - Total Coliform of Raw Water and Effluents from Different Filters

Run Duration, Days	Date	Total Coliform (MPN/100 ml)					% Removal			
		R.W.	P.F.	F_1	F_2	F_3	P.F. VS R.W.	F_1 VS R.W.	F_2 VS R.W.	F_3 VS R.W.
6	31/1/78	4,600	1,100	460	240	460	76	90	94.8	76
8	2/2/78	2,400	1,100	240	93	460	54.2	90	96.13	80.8
9	3/2/78	2,400	1,100	460	460	460	54.2	80.0	80.8	80.8
12	6/2/78	4,600	1,100	240	460	240	76	94.8	90	94.8
14	8/2/78	4,600	460	93	93	150	90	97.98	97.98	96.74
16	10/2/78	11,000	1,100	43	43	150	90	99.61	99.61	98.63
17	17/2/78	4,300	2,400	460	1,100	460	44.2	89.3	74.42	89.3
20	20/2/78	4,300	1,500	460	460	240	65.1	89.3	89.3	94.42
22	22/2/78	9,300	930	240	150	93	90	97.42	98.39	99
24	24/2/78	4,300	2,400	43	93	150	44.2	99.0	97.84	96.51
29	1/3/78	2,300	430	23	9	93	81.3	99.0	99.61	95.96
34	6/3/78	46,000	2,400	9	15	75	94.8	99.98	99.96	99.83
36	8/3/78	4,300	2,400	43	93	43	44.2	99.0	97.84	99.0
38	10/3/78	7,500	1,200	9	21	23	84	99.88	99.72	99.69
41	13/3/78	9,300	930	23	23	75	90	99.75	99.75	99.19
43	15/3/78	4,300	930	7	9	15	78.4	99.83	99.79	99.65
45	17/3/78	7,500	430	9	11	11	94.3	99.88	99.85	99.85
49	21/3/78	46,000	750	14	7	15	98.4	99.97	99.98	99.97
51	23/3/78	9,300	430	7	9	11	95.4	99.92	99.9	99.88
Average		9,910	1,215	151	178	169	76	99.07	95.56	94.74

<u>Legend</u> : F_1, F_2, F_3 = Treated Water from the Filters, 1, 2 and 3 respectively

Table F3 - Head Loss in the Filters F_1, F_2, F_3 and Dissolved Oxygen of Raw Water, Effluents from Prefilter and the Clear Well

Run Duration, Days	Date	Head Loss, CM			Dissolved Oxygen, mg/1		
		F_1	F_2	F_3	R.W.	P.F.	C.W.
6	31/1/78	1	1	1			
8	2/2/78	3	4	3			
9	3/2/78	4	4	3.4			
12	6/2/78	6	5.2	5			
14	8/2/78	7	7	6			
16	10/2/78	8	8	7			
17	17/2/78	10	11	10			
20	20/2/78	13	15	11			
22	22/2/78	15	17.5	11.5			
24	24/2/78	15	18.5	11.5			
29	1/3/78	15.4	19.2	13			
34	6/3/78	15.8	19.5	13			
36	8/3/78	16	20.2	13			
38	10/3/78	16.5	20.5	13.2	2.8	3.5	4.8
41	13/3/78	16.8	20.8	13.7	3.1	3.8	4.6
43	15/3/78	17	21	14	2.6	4.8	4.6
45	17/3/78	17.3	21	14	-	-	-
49	21/3/78	17.3	21.3	14	3.1	4.3	5
51	23/3/78	17.5	21.3	14	3.3	4.5	4.8

<u>Legend</u> :

R.W. = Raw Water

P.F. = Prefilter Effluent

C.W. = Treated Water in the Clear Well