STANDARDIZATION OF SEPTIC TANKS FOR BANGLADESH

A Project Report

by

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ABSTRACT

The septic tank system of sewage disposal is widely used in the towns and cities of Bangladesh. However, in the absence of any unified code of practice, numerous models and types of septic tanks are in use, all of which can neither serve the purpose effectively nor are desirable from the economic point of view for a country like Bangladesh.

This study attempts to examine the scope and extent of standardization of septic tank systems for Bangladesh. Recent literature on the subject has been reviewed; information and data on the functional and design aspects of septic tanks has been presented and analyzed.

Design details of septic tanks currently used in Bangladesh by various government and private organizations have been presented. Their defects and weaknesses have been identified.

Finally an attempt has been made to propose standardized versions of septic tank systems suitable for the local conditions of Bangladesh.

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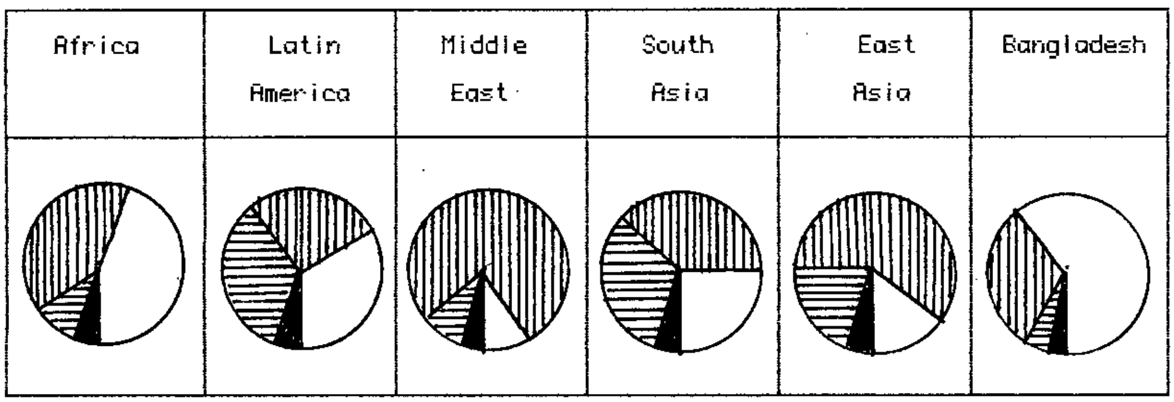
CHAPTER 1

INTRODUCTION

1.1 General

For a city having piped water supply, a water-carried sewerage system discharging into a sewage treatment plant can satisfy all the requirements of safe and nuisance-free wastewater disposal. However, as shown in Figure 1.1, only a small proportion of the urban population in developing countries are served by sewers. The number of people without sewers is increasing because population growth is exceeding the provision of new sewer connections.



Sectors of circles proportional to urban population

Legend:
- sewer system with treatment
- sewer system with no treatment
- household systems, e.g., septic tanks
- no sanitation

Figure 1.1: Urban Sanitation in Developing Countries (Based on Gabriel 1981 and Rahman 1989)

In areas with no municipal sewerage system, the household system, i.e., septic tanks, is the most common method of providing water-carried sanitation. A well-designed septic tank with an effective effluent disposal system has all the advantages of a sewerage system.

1.2 Rationale

Standardization is the process of specifying a body of guidelines based on knowledge gained from research and long-term experience, the main aim of which is to simplify and codify design, construction or application leading to an adequate and optimum solution which is ultimately beneficial to the user and general public. Our knowledge on septic tank systems has expanded substantially in response to rapidly evolving research on it.

Since the processes within a septic tank are fairly accurately known, there apparently is no justification behind constructing different types of septic tanks for a small country like Bangladesh. Standardization of septic tanks can lead to simplification of the manufacture of its various components. There will also be a reduction in the possibility of defects in the system.

It thus seems justified to have standardized versions of septic tank systems, with only minor modifications as and where necessary.

1.3 Objectives

The objectives of this paper are as follows:

- Review of the septic tank method of waste disposal as adopted in various countries, including Bangladesh
- Study of the design of septic tanks currently produced by different government and private organizations in Bangladesh, and finally,

- Development of standardized versions of septic tanks which are technically sound, economical, and suitable for conditions prevailing in Bangladesh.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Description

A septic tank is a watertight chamber, usually located just below the ground level, that receives both excreta and flush water from toilets. Sometimes other household wastewaters, or sullage, are drained in also.

The main functions of the tank are:

a. to separate solids from the liquid,

b to store the solids,

c. to provide digestion of organic matter, and

d. to discharge the partially clarified liquid for further treatment and disposal. This partially clarified liquid can be disposed off through soil absorption systems, soil mounds, evaporation beds, or anaerobic upflow filters, depending upon the site and other conditions.

The essential components of a septic tank are shown in Figure 2.1.

2.2 Processes Within The Tank

The processes occuring within the septic tank are complex and interrelated. However, the primary processes can be identified as follows:

a. Separation of suspended solids - This process results in the formation of three distinct layers: (i) a sludge layer at the bottom; (ii) a floating scum layer at the top; (iii) and a relatively clear liquor zone in the middle. This phase is basically a coagulation process followed by sedimentation or flotation, depending on particle size and density.

b. Digestion of sludge and scum - Organic matter in the sludge and scum is anaerobically digested, which is ultimately converted to carbon dioxide and methane. This reaction is represented by the following simplified equation:

$$C_xH_yO_zN + H_2O \longrightarrow CH_4 + CO_2 + NH_3$$

(organic matter) (methane)

Gas formation in the sludge layer causes flotation of sludge flocs which resettle after gas release at the surface. Densification of the sludge layer occurs due to accumulation of overburden.

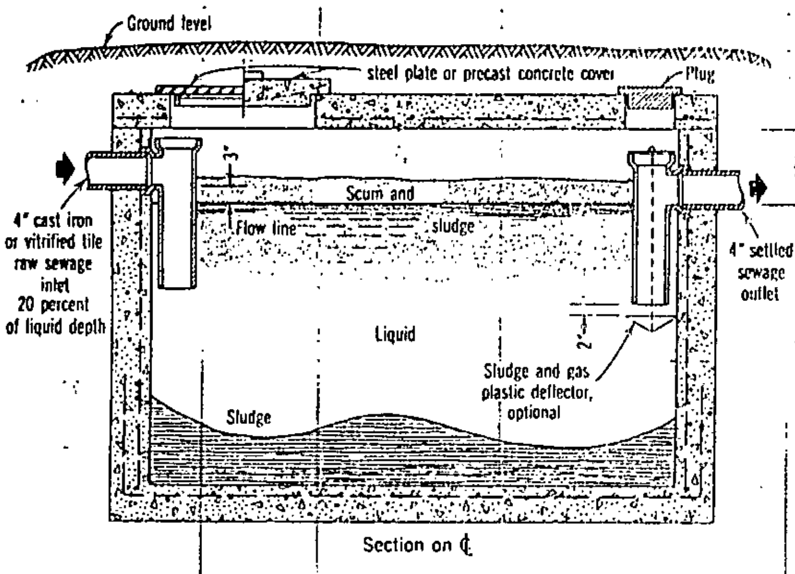


Figure 2.1: The Conventional Septic Tank

c. Stabilization of the liquid - During retention in the tank, organic matter in the clarified liquid are stabilized by anaerobic bacteria.

d. Reduction of microorganisms - Some microorganisms are separated out in the sedimentation process. Some die off naturally in the adverse environment in the tank. Thus, there is an overall reduction in the number of microorganisms. However, a large number of them can be present in the effluent, sludge and scum and can cause health hazards if people come in direct contact.

2.3 Performance

The TSS (total suspended solids) in sewage entering a septic tank ranges from 150 to 300 mg/l. A part of the settleable solids settle out and float in the scum layer. The remaining are carried out with the septic tank effluent. Table 2.1 gives typical effluent concentrations and percent removed.

As can be seen, the effluent is generally high in BOD, organic nitrogen, phosphorus and coliform.

Factors which affect septic tank performance are:

a. hydraulic retention time,

b. ambient temperature,

c. nature of influent wastewater,

d. organic content of sewage,

e. microbial population, and

f. construction details of the tank.

removal of settleable solids and soluble organic matter by anaerobic decomposition to as high a degree as possible.

To accomplish this, the septic tank must provide the following:

a. a liquid volume sufficient for 24 hour liquor retention at maximum sludge and scum accumulation,

b. proper placement of inlet and outlet devices and adequate storage of sludge and scum to prevent their discharge into the effluent,

c. provision to permit escape of gases produced in the tank. Since the digestion process is anaerobic, no direct ventillation is, however, necessary.

2.5 Capacity of Septic Tank

2.5.1 General Requirements

The septic tank should provide space for the following:

a. liquor,

b. sludge,

c. scum, and

d. freeboard (or space to accommodate gases).

The volume for liquor depends on the hydraulic retention time. This retention time should not be less than 24 hours. The volume for sludge and scum depends on the frequency of cleaning which depends on the rate of sludge and scum accumulation, which in turn depends on:

a. hydraulic retention time,

b. ambient temperature,

c. volume of wastewater,

d. anal cleansing material used.

To make matters more complicated, all the various factors are interrelated.

2.5.2 Theoretical Approach

2.5.2.1 General Equation

The capacity of a septic tank can be calculated by the following general equation:

$$V = G + PQT + PSFD$$

where,

V = total volume of the septic tank

G = freeboard or volume for gas accumulation

P = number of users contributing to the tank

Q = per capita sewage (wastewater) flowrate to the tank

T = minimum hydraulic retention time

S = per capita rate of sludge (and scum) accumulation

F = factor related to ambient temperature and desludging interval

D = time interval between desludging operations.

Commonly adopted units are:

V in liters or gallons

G in liters or gallons

P in capita

Q in liters per capita per day (lpcd) or gallons per capita per day (gpcd)

T in days

S in liters per capita per annum (lpca) or gallons per capita per annum (gpca)

F is dimensionless

D in years.

The Indian Code of Practice is based on a general equation of the above form.

According to the British Code of Practice CP 302, the general equation has the form:

$$V = 2000 + 180.P \text{ in liters}$$

The general equation is a summation of three components:

a. freeboard or gas volume

b. liquor volume

c. sludge and scum volume.

2.5.2.2 Calculation Of Liquor Volume

The component of liquor volume in a septic tank is given by PQT, where the notations are defined in Section 2.5.2.1. The average wastewater flow Q can be determined by measuring sewage flows for a given period, but this is often not practicable. In the absence of specific data in this regard, the following values of Q are generally satisfactorily assumed:[Rajput 1982]

a. 120 lpcd (27 gpcd) if all fittings (i.e., WC, bath, sinks, etc) are connected to the water supply and septic tank.

b. 50 lpcd (11 gpcd) if water is available only at a compound tap and all wastewater goes to the septic tank.

c. 40 lpcd (9 gpcd) if wastewater only from the WC goes to the septic tank.

d. 20 lpcd (5 gpcd) if water is obtained from a nearby standpipe.

e. 5 lpcd (1 gpcd) if water is obtained from a public standpipe or well, and only minimum water is used to clean the WC.

Account should be taken of the possibility of improvement of the water supply situation in the near future.

The minimum retention time T in the septic tank is generally taken as 1 day. Most authorities recommend that the septic tank size should be based on a 3 day retention time at start-up, which is equivalent to a 1 day retention time just prior to desludging. However, minimum retention times as low as 12 hours and as high as 3 days are also used.

2.5.2.3 Calculation Of Sludge And Scum Volume

The component of sludge and scum storage in a septic tank is given by PSFD, where the notations are defined in Section 2.5.2.1.

In the Indian Code of Practice, the sludge accumulation rate S is taken as 77 lpca (17 gpca). The rate of accumulation depends on the time interval between desludging, the ambient temperature, materials used for anal cleansing, etc. Figure 2.2 shows the relationship between accumulation rate and desludging interval, as measured in America.

The time interval between desludging D is generally 5 years, but can be assumed to be 3 years if no other information is available. Table 2.2 gives rates of sludge accumulation depending on the material used for anal cleansing.

The factor F is related to the ambient temperature and desludging interval, as shown in Table 2.3.

Material Used for Anal Cleansing	W/C or Latrine Wastewater only		Household Sullage + Latrine Wastewater	
	lpca	gpca	lpca	gpca
Water, Soft paper	25	6	40	9
Leaves, Hard paper	40	9	55	12
Sand, Stone, Earth	55	12	70	15

Table 2.2: Rate of Sludge Accumulation for Various Anal Cleansing Materials [Rajput 1982]

Desludging Interval Years	Ambient Temperature		
	< 10^0 C during winter	10^0 C – 20^0 C throughout year	> 20^0 C throughout year
1	2.50	1.50	1.30
2	1.50	1.15	1.00
3	1.27	1.00	1.00
4	1.15	1.00	1.00
5	1.06	1.00	1.00
>5	1.00	1.00	1.00

Table 2.3: Values of Factor F for Given Desludging Intervals and Ambient Temperature.

2.5.2.4 Freeboard

The minimum recommended freeboard above liquid level in a septic tank is 1 foot.

2.5.2.5 Calculation Of Total Tank Volume

There are several methods for calculating the total capacity of a septic tank:

a. By summing the three component volumes in the general equation as given in Sections 2.5.2.2 to 2.5.2.4.

b. If the calculated liquor volume is less than half of the calculated sludge volume, then the minimum tank volume shall be given by 1.5 times calculated sludge volume. This ensures that the tank will be about two-thirds full when it is time for desludging.

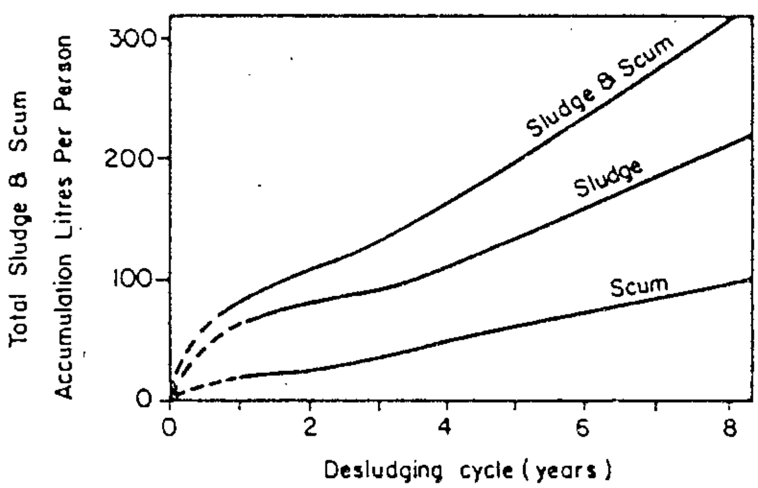


Figure 2.2: Rate of Accumulation of Sludge and Scum in Septic Tanks in the US

c. If we say that the tank will be desludged when the sludge and scum accumulation reaches two-thirds tank capacity (i.e., no fixed desludging interval), and the retention time is not less than 1 day, then the required tank capacity is given by three times daily wastewater flow. Therefore tank capacity will be given by

$$V = 3PQT$$

where,

P = number of users served

Q = average daily per capita wastewater flow

T = minimum retention time.

Volumes given by b and c above should be multiplied by 1.2 to 1.3 to account for freeboard.

2.5.3 Empirical Approach

There are numerous formulae, codes, standards for determining the volume of septic tanks. The basis for calculation are also various, such as:

a. number of bedrooms per dwelling,

b. number of contributing users,

c. average daily wastewater flow, etc.

2.5.3.1 Capacity Based On Number Of Bedrooms

The required minimum capacities of septic tanks based on the number of bedrooms, are shown in Table 2.4.

2.5.3.2 Capacity Based On Number Of Persons Served

The required minimum capacities of septic tanks based on the number of persons served are given in Table 2.5. As a matter of fact there is a great variation in the capacities of septic tanks as suggested by different codes and standards. Figure 2.3 shows the relationships between tank capacity and number of users according to some widely used standards.

2.5.3.3 Capacity Based On Dwellings In Various Countries

The septic tank standards for single houses used in different European countries is shown in Table 2.6.

Number of Bedrooms	Tank Capacity		Equivalent Capacity per Bedroom	
	gallon	liter	gallon	liter
1 - 2	625	2840	315	1420
3	750	3410	250	1140
4	915	4160	230	1040
5	1085	4920	215	980
6	1250	5670	210	940

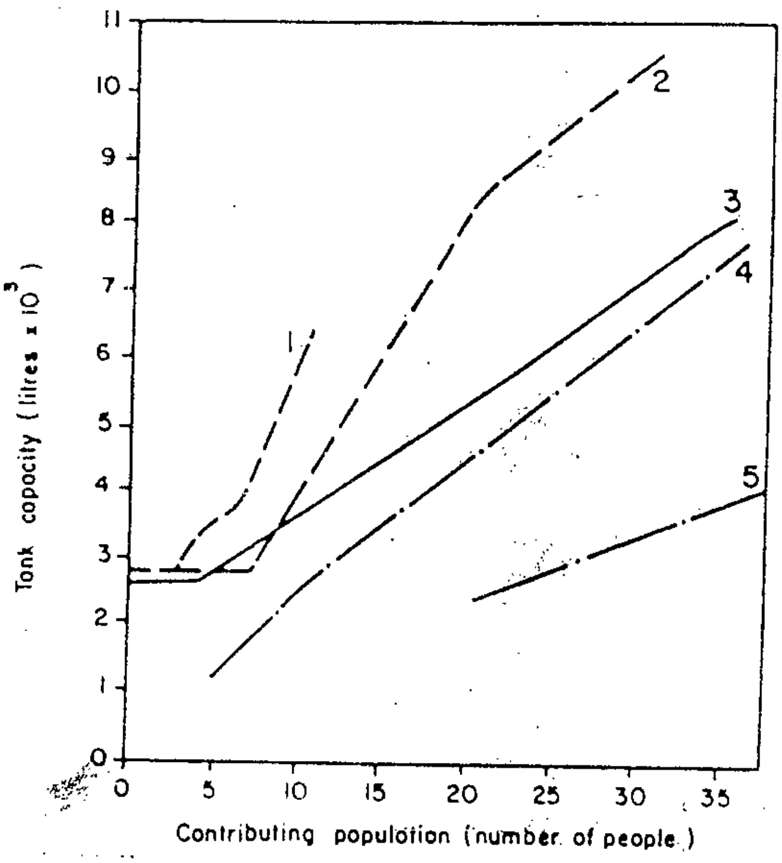
Table 2.4: Required Capacities of Septic Tanks Based On Number Of Bedrooms [Salvato 1982]

Number of Persons	Tank Capacity		Equivalent Capacity per Person	
	gallon	liter	gallon	liter
1	110	500	110	500
4	415	1890	105	470
6	500	2270	83	370
8	625	2840	78	350
10	750	3410	75	340
12	915	4160	75	340
14	1085	4920	78	350
16	1250	5680	78	350

Table 2.5: Required Capacities of Septic Tanks Based On Number Of Persons Served [Salvato 1982]

Country	Tank Capacity		Compartments	Retention Time
	gallon	liter		days
USA	420	1900	2	2 - 3
UK	540	2460	1 - 2	2 - 4
France	500	2270	1 - 3	5 - 10
Switzerland	730	3330	3	3 - 4
Germany	540	2460	3	5 - 10
Belgium	275	1250	2	2
Greece	525	2380	2	-
Finland	225	1050	1 - 2	1 - 2

Table 2.6: Septic Tank Standards for Single Houses in Various European Countries [Rajput 1982]



Legend:
1 - US Manual of Septic Tank Practice, private houses
2 - US Manual of Septic Tank Practice, institutions
3 - British Standard CP 302
4 - Indian Standard, cleaning interval 2 yr (IS. 2470)
5 - Indian Standard, cleaning interval 6 mo (IS. 2470)

Figure 2.3: Minimum Septic Tank Capacities According to Different Standards

2.5.4 Minimum Dimensions

In case of very small tanks, the size is often determined by other considerations. For example, the width of the tank cannot be less than 2 ft (60 cm) in order to allow a man to work inside during construction and maintenance.

2.6 Shape And Proportions

The shape of a septic tank is an important parameter in its proper functioning. The shape of the tank influences:

a. the velocity of wastewater flow through the tank

b. depth of sludge accumulation ,

c. presence or absence of dead or stagnant pockets of liquid

d. surge storage capacity.

For a given tank volume, if the depth is too great, then the plan dimensions will be small. There will be every possibility of short circuiting between the inlet and outlet. This will result in a shortening of the effective tank volume, hence the retention time. Low surface area also implies high overflow rate (which is defined as the wastewater flow rate per unit surface area). This is detrimental to sedimentation efficiency and solids removal will be low.

Conversely, if the tank is too shallow, the depth for sludge storage will be low causing undue reduction of effective cross-section. However, a larger surface area is desirable to lower overflow rate thereby improving sedimentation performance.

Wastewater flowing into the tank is not uniform or continuous, but comes in surges. These surges disturb the whole liquid system in the tank. It has been established that for a sedimentation process, quiescent conditions are required. In the septic tank, disturbance due to surges can be reduced by increasing the surface area. Longer inlet flow pipes are also helpful. The longer effective retention time thus provided aids in the re-separation of sludge and scum which are mixed by turbulence caused by influent surges.

It has been experimentally established that tanks with low length/width (L/W) ratios have dead or stagnant zones which actually reduce the effective tank volume. Tanks having flow regimes approaching plug flow conditions have been shown to have less short-circuiting and provide more efficient wastewater treatment. This can be ensured by having rectangular septic tanks as against square ones. Desirable L/W ratios range between 2:1 to 5:1. The actual ratio chosen will depend on the shape and area of land available.

Tanks of cylindrical shape made of sewer pipes are also reported to be satisfactory.

The depth of septic tanks should not exceed 6 to 7 ft in order to reduce shoring costs.

2.7 Compartmentation

A single compartment septic tank having correct proportions and proper details should provide acceptable performance. But a two compartment septic tank having the same capacity has been found to provide better performance. The removal efficiencies of BOD, suspended solids, and organic colloids has been reported to be higher for a two-compartment tank than a single compartment one. This is specially true for tanks which have been designed to serve less than 100 users, and where the effluent is disposed off in soils of low to moderate permeabilities.

The hourly as well as daily wastewater flows into a septic tank can vary widely. During peak flow periods, higher solids concentration can be discharged with the effluent. Well-designed two-compartment septic tanks can diminish this effect of peak loads.

The volume of the first compartment (i.e., immediately after the inlet) should not be less than one-half of the total volume. Otherwise large flows will result, which can disrupt the sludge in the first compartment and cause it to be washed over to the second compartment.

For improved performance, the volume of the first compartment should be atleast two-thirds of total volume.

Also, to prevent disturbance to the scum layer, the partition should be taken up to 6" above the liquid level in the tank. The flow from the first compartment into the second one is achieved by horizontal slots in the partition. The slot should be located below the scum and above the sludge layer.

On the same principles, a three compartment septic tank will further improve removal efficiencies. But incremental benefit gained by the three-compartment tank has been found to be not very significant.

Sometimes hanging baffles are provided instead of partitions. But this practice leads to wash out of sludge. Therefore, hanging baffles should not be used as partitions.

2.8 Inlet And Outlet

The inlet and outlet are very important devices for the proper functioning of a septic tank.

The inlet to a septic tank should be designed to:

a. dissipate the energy of the incoming wastewater to minimize turbulence which can cause the settled sludge to remix with the liquor.

b. prevent short-circuiting.

The outlet from a septic tank should be designed to:

a. prevent to high a liquid rising velocity in the vertical legs of the outlet which can resuspend particles of settled sludge

b. prevent bubbles of gas in the liquid from directly entering outlet, since they carry up with them particles of sludge.

Figure 2.4 shows some examples of defective inlet and outlet design.

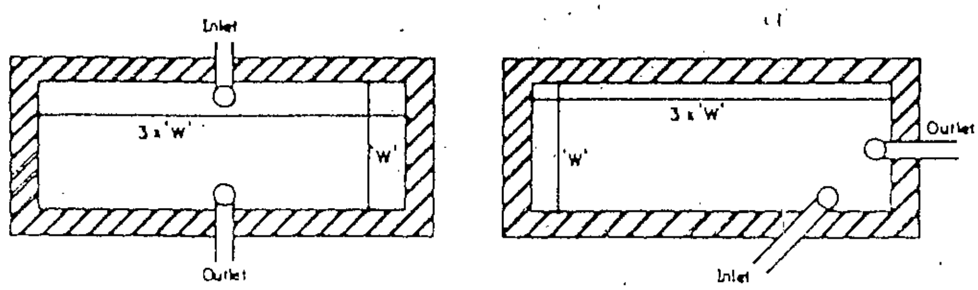
The inlet and outlet can be of sanitary tees, elbows or baffles. It is preferable to use sanitary tees to reduce turbulence at inlet.

In order to reduce action of surge flows, the pipe into the septic tank, as well as the inlet tees, should not be less than 4 inch in diameter. The top limb should rise to atleast 6 inch above the liquid level in the tank. The bottom limb should extend to atleast one-fifth the liquid depth in the tank. The last 30 ft of sewer into the septic tank should not have a gradient steeper than 1.5%.

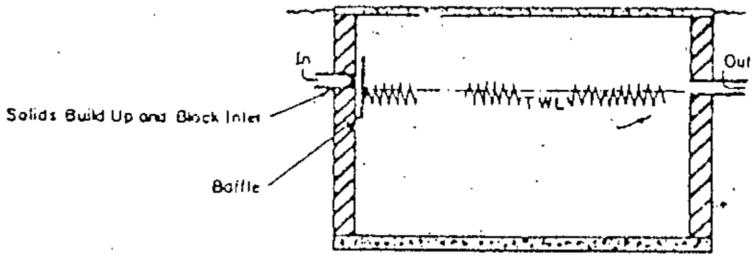
The outlet devices' ability to retain sludge and scum in the septic tank is a major factor in overall tank performance. The lower end of the vertical leg of the outlet must extend below the scum layer and be above the sludge layer, as shown in Figure 2.5. The upper end of the vertical leg is usually taken 6 inch above the liquid level and the bottom leg one-third of the liquid depth in the tank. The invert level of the outlet should not be less than 3 inch below the invert of the inlet. To prevent sludge particles from accidentally entering the outlet device, it may be desirable to install some sort of sludge deflector mechanism, as shown in Figure 2.6. However, if provisions regarding depth are properly applied, these deflectors will be of little additional advantage.

2.9 Ventillation

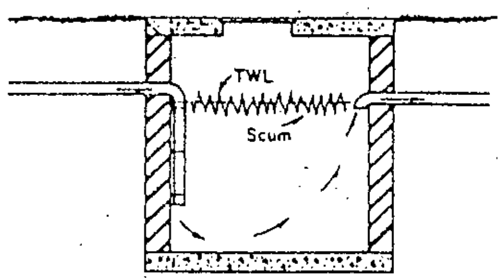
The digestion process occuring within the septic tank is primarily anaerobic in nature. Therefore, no direct ventillation to bring in atmospheric oxygen is



A and B Typical Examples of Tanks with Poorly Placed Inlets and Outlet



C : Poor Inlet and Outlet



D : Tank with Inlet too Deep

Figure 2.4: Defective Inlet and Outlet Designs

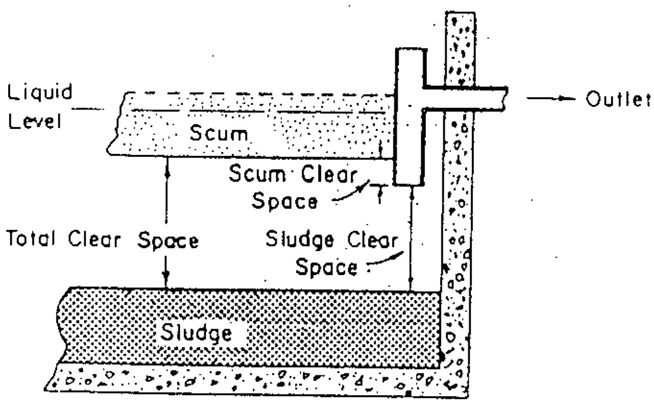


Figure 2.5: Outlet Detail

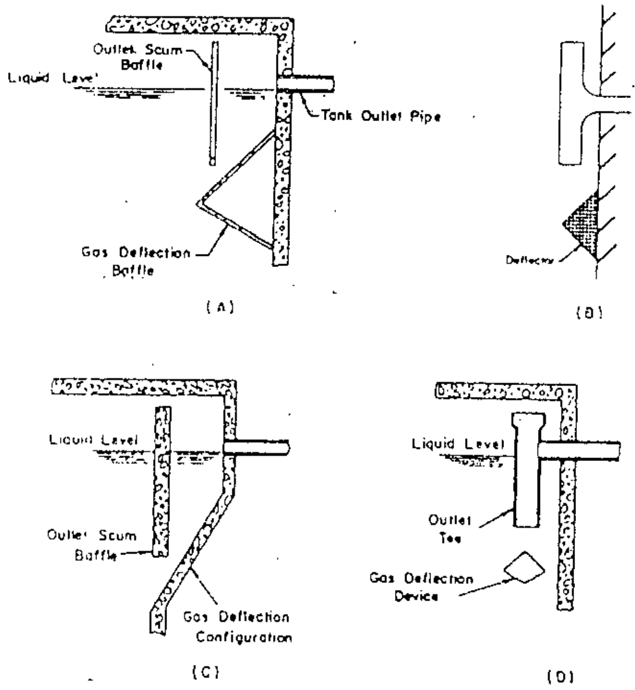


Figure 2.6: Typical Sludge and Scum Deflectors At Outlet

necessary. However, the anaerobic digestion of sludge and scum produces gases like methane, carbon dioxide and some other foul smelling gases. These gases accumulate above the liquid surface and are needed to be vented out. This can be done by providing a ventillation pipe for the septic tank itself. However, this is often unnecessary as the vent stack generally provided to buildings serves this purpose.

2.10 Access

Manholes should be provided to serve as a means to inspect the septic tank and to empty the settled sludge the manholes should be airtight to prevent foul gases from escaping. Manholes should preferably be located close to the two ends of the tank and for multicompartment septic tanks, there should be atleast one manhole for each compartment.

2.11 Construction Materials

Suitable materials for constructing septic tanks are:

a. brick masonry

b. reinforced concrete

c. steel

d. plastic

e. fiberglass

f. ferrocement

Whatever material is used, the tank must be water-tight, stable and durable. From economics, ease of construction and maintenance point of view, brick masonry seems to be the most appropriate construction material.

Ferrocement should also be a suitable material, but practical performance data is lacking.

2.12 Maintenance

Septic tanks need very little maintenance. The only maintenance needed for a well-built and properly used septic tank is the periodic removal of accumulated sludge and scum. The septic tank should be inspected atleast once a year to check the accumulation of sludge and scum. The tank should be cleaned out whenever sludge depth occupies about two-thirds of the liquid depth. Failure to do so is the primary cause of septic tanks not functioning properly.

After cleaning operation, 5 to 10 liters (1 to 2 gallons) of the old sludge should be left in the tank to serve as seeding material.

2.13 Disposal Of Effluent

2.13.1 General

The partially clarified liquid which is discharged from the septic tank is highly obnoxious and contains a large number of pathogenic microorganisms and is high in BOD. This is unsuitable for direct discharge into a lake, river or on land. The effluent requires further treatment or has to be disposed off in a safe manner. Any of the following methods can be adopted:

a. subsurface soil absorption systems - (i) absorption trenches, (ii) absorption beds, (iii) absorption pits
b. sand filter system
c. mound system
d. evapotranspiration beds
e. anaerobic upflow filter
f. small bore sewerage system.

2.13.2 Subsurface Soil Absorption Systems

2.13.2.1 General Requirements

Subsurface soil absorption systems are the most popular methods for effluent disposal because of their simple design, ease of construction, low maintenance, and above all, their relatively low cost. They are suitable for sites characterized by moderate to high soil permeabilities, low ground water conditions, great depth to bedrock, gentle slope of land, and are hence appropriate for terrain of Bangladesh.

2.13.2.2 Site Selection Considerations

The potential to treat and dispose of septic tank effluent through the soil absorption systems depends on the characteristics of the area. Therefore, a systematic site evaluation should be done. This can include the measurements of soil permeability, soil depth, depth of impervious strata, degree of slope, position of water table, etc.

These systems of effluent disposal depend on the ability of the soil to accept liquid, strain out viruses and bacteria, and filter the effluent.

Soil permeability should be moderate to rapid. It depends primarily on the soil grain characteristics. It is known that clayey and silty soils have poor permeabilities. On the other hand, sandy and gravelly soils have high permeabilities.

The following tests are available for measuring soil permeability:

a. percolation test

b. crust test

c. zero-tension lysimeter test.

However, values obtained by these tests are highly variable and are of low reliability.

2.13.2.3 Ground Water Pollution Considerations

Soil absorption systems should be located such that they cannot cause contamination of wells, springs and other sources of water supply. Underground contamination can travel in any direction and for considerable distances. Therefore, effective filtration is necessary. Underground pollution usually moves in the same general direction of the slope or gradient of the water table which follows the general contour of the ground surface. For this reason, absorption systems should be located downhill from wells and springs. As a matter of fact, it is necessary to rely upon both horizontal and vertical distance for protection. Absorption systems should be located atleast 50 ft from any source of water supply. Figure 2.7 shows typical underground pollution patterns.

2.13.2.4 Absorption Trenches And Absorption Beds

Absorption trenches are shallow, level excavations 1 to 5 ft (0.3 to 1.5 m) deep and 1 to 3 ft (0.3 to 0.9 m) wide. A single line of open jointed or perforated pipe is placed on 6 inch (15 cm) of gravel. The pipe is then covered up by gravel, a semi-permeable barrier and backfill, as shown in Figure 2.8. Two or more such trenches, each upto 100 ft long, can make up an absorption field. The side walls are the principal infiltrative surface.

Absorption beds differ from trenches in that they are wider than 3 ft (0.9 m) and can contain more than one line of distribution piping, as shown in Figure 2.9. The bed bottom is the principal infiltrative surface.

Absorption trenches and beds are not suitable for conditions in Bangladesh for the following reasons:

a. Trenches and beds are excavations of relatively large areas that generally rely on the upper soil horizons to absorb the effluent through the bottom and sidewalls of the excavation. In Bangladesh, these soils are of silty or clayey nature and are of poor permeability.

b. These systems require soils which remain saturated several meters below ground level throughout the year. But the rainy season in Bangladesh lasts for months together and the problem of water-logging can be common.

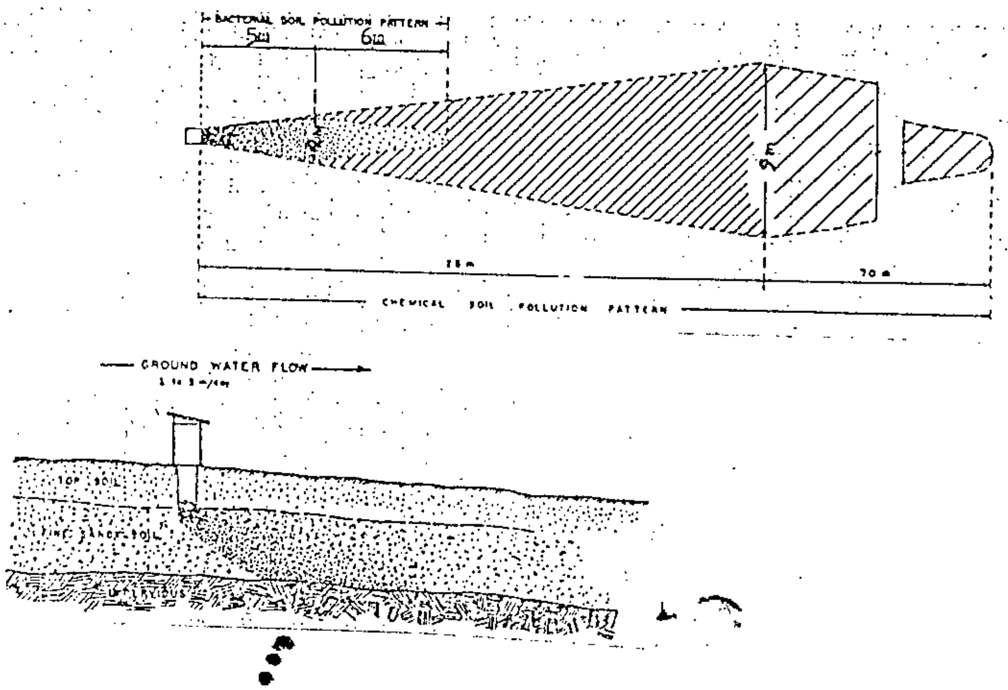


Figure 2.7: Ground Water Pollution Patterns

c. Urban land has become very highly priced. Large areas of land required for these systems implies that they can be costly to install.

2.13.2.5 Absorption Pits

Other names also used are seepage pits, soakwells, soakpits, cesspools, etc. Absorption pits are deep excavations designed primarily for lateral absorption of effluent through the bottom and sidewalls of the excavation. Covered porous-walled chambers are placed in the excavation and filled with coarse aggregate. Effluent enters the chamber where it is stored until it seeps out through the chamber wall and bottom. This is shown in Figure 2.10.

In cases where relatively impervious soils are underlaid by porous sand or fine gravel, absorption pits offer the cheapest and the best solution to effluent disposal problems.

Absorption pits can be of any diameter and depth provided they are structurally sound and are constructed without seriously modifying subsoil properties. Generally, the pits vary in diameter from 2 ft to 6 ft, and the depth can be as much as 40 ft. More than one pit can be provided, in which case a separation from wall to wall equal to atleast three times the diameter should be maintained. The size actually provided depends on the absorptive capacity of the soil and on the number of users. The absorptive capacity of soil can be estimated from percolation tests. However, in absence of such tests, values in Table 2.7 can be assumed.

The pits can be lined or unlined. The lining can be of precast concrete concrete rings, ferrocement or brick masonry. The bottom 1 ft of lined pits are filled with gravel or brick bats. Unlined pits are filled completely with gravel,

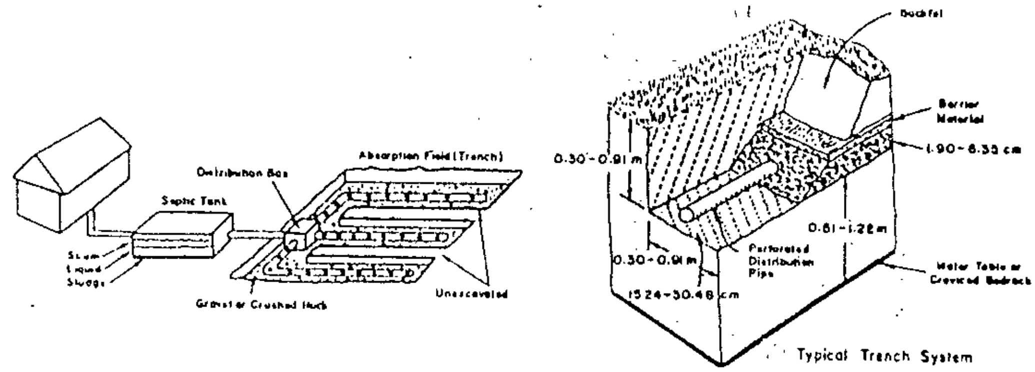


Figure 2.8: Septic Tank With Absorption Trenches

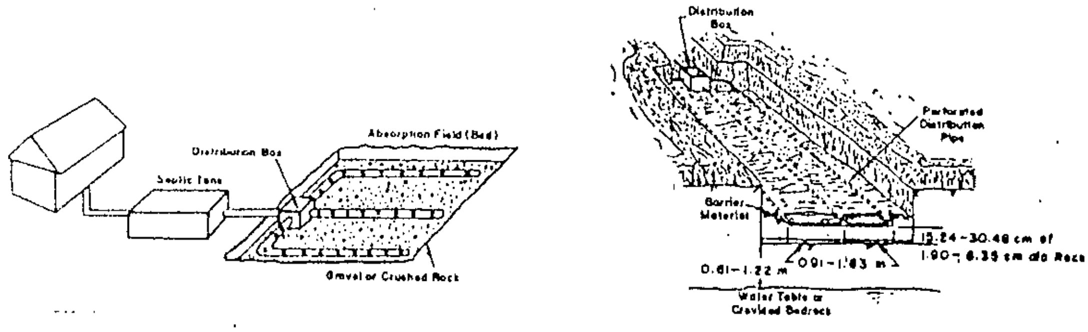
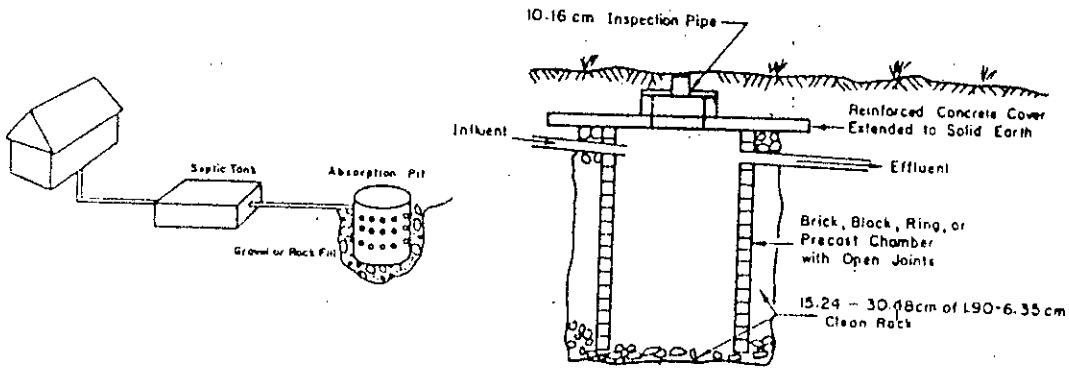


Figure 2.9: Septic Tank With Absorption Bed

Typical Bed System



Absorption Pit Cross Section

Figure 2.10: Septic Tank With Absorption Pit

brick bats and sand, preferably in the form of an inverted filter. Pits can also be partially lined.

The sand layer into which the pit is installed should not be used as a source of drinking water, e.g., by a well. This is seldom done in urban areas.

Another advantage of a well-designed and constructed absorption pit is that it requires almost no routine maintenance.

Relative Absorption	Soil Type	Effluent Loading l/m^2/d	g/ft^2/d
Rapid	Coarse sand, Gravel	140	3.0
Medium	Fine sand, Sandy loam	70	1.5
Slow	Sandy clay, Silt	30	0.6
Semi-impervious	Dense clay	20	0.4
Impervious	Rock	-	-

Table 2.7: Absorption Capacities of Soils IS-2470 [Khanna 1982]

2.13.3 Sand Filter System

Sand filters are beds of granular materials placed 2 to 3 ft deep underlain by graded gravel and collecting tile. Septic tank effluent is applied through distribution pipes at the top.

Disadvantages of this system are:

a. large land area is required

b. there may be odor problems

c. regular maintenance is required to prevent clogging.

2.13.4 Mound System

A mound system is an absorption system that is elevated above the natural soil surface in a suitable fill material. This is used in places with:

a. soils having low permeability

b. shallow permeable soils

c. permeable soils with high water table.

Disadvantages are:

a. it requires large land area

b. submersible pumps are necessary.

2.13.4 Evapotranspiration Beds

Evapotranspiration beds consist of a sand bed with an impermeable liner and effluent distribution piping. The surface of the bed is planted with vegetation. It functions by raising the effluent to the upper part of the bed by capillary action and allowing it to escape to the atmosphere by evaporation and transpiration.

Disadvantages are:

a. it requires large area

b. it cannot function in rainy weather.

2.13.6 Anaerobic Upflow Filter

In an anaerobic upflow filter, the septic tank effluent enters at the bottom of a filter through a system of underdrains, and flows upward through a bed of coarse media. Since the filter is completely submerged, anaerobic conditions are created. BOD and COD removal efficiencies of upto 80% can be achieved.

Disadvantages are:

a. it is costly to install

b. frequent flushing of the filter is necessary.

2.13.7 Small Bore Sewerage System

This system consists of a network of small bore sewers which conveys the septic tank effluent of a community to a series of waste stabilization ponds having large surface area where it is aerobically digested.

High initial capital investment and recurring maintenance cost precludes its use in developing countries like Bangladesh.

CHAPTER 3

SEPTIC TANK SYSTEMS CURRENTLY USED IN BANGLADESH

The details of septic tank systems as adopted by the Public Works Department (PWD), Bangladesh Railways Department (BR), Military Engineer Services (MES), and Shaheedullah and Associates Ltd (S&A) (a leading consulting firm of the country) are presented.

3.1 Septic Tank System Of PWD

Figures 3.1 to 3.5 show details of septic tank and soakwell as adopted by the PWD.

Analysis of the design drawings reveals that tank capacity has been taken about 22 gallons (102 liters) per capita. Slots located only 18" above tank floor in the first partition means that the sludge storage capacity is very low. The tanks have to be cleaned when the sludge has accumulated to only one-third of the liquid depth. The volume of the first compartment is less than one-half of the volume of the second compartment. So large flows will result causing sludge in the first compartment to be washed over to the second compartment. The first partition is, thus, seen to cause more harm than good. The invert of the inlet and outlet are seen to be at the same level, which is not recommended.

Analysis of the soakwells reveals that the applied effluent loading varies from 1100 $l/m^2/d$ (22 $g/ft^2/d$) for the larger wells down to 120 $l/m^2/d$ (2.5 $g/ft^2/d$) for the smaller diameter wells. Soakwells serving a large number of users are, thus, clearly inadequate.

Inlets and outlets of the soakwells are at the same level. Short-circuiting may result causing septic tank effluent to discharge directly to external drains.

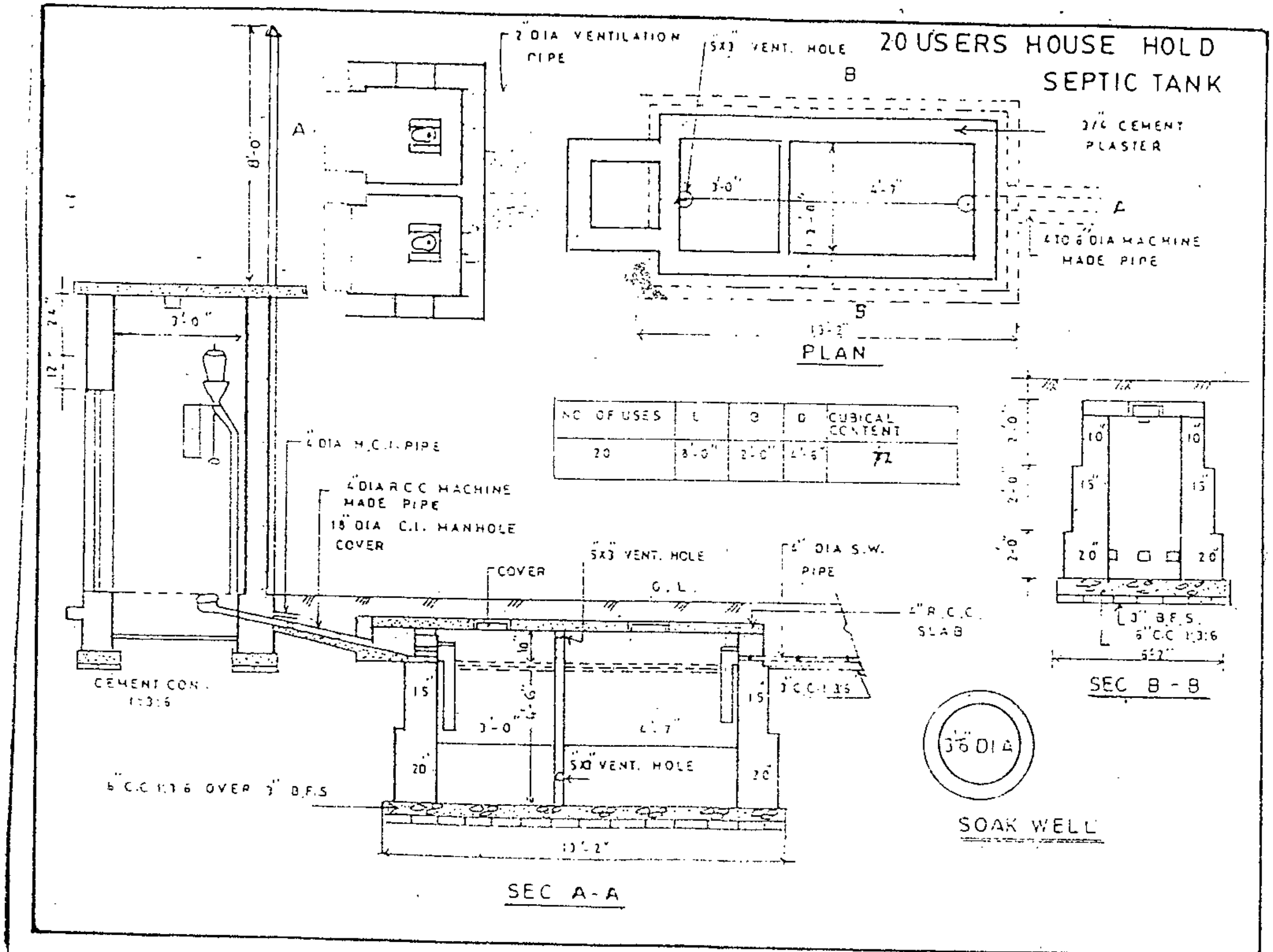


Figure 3.1: Septic Tank System of FWD

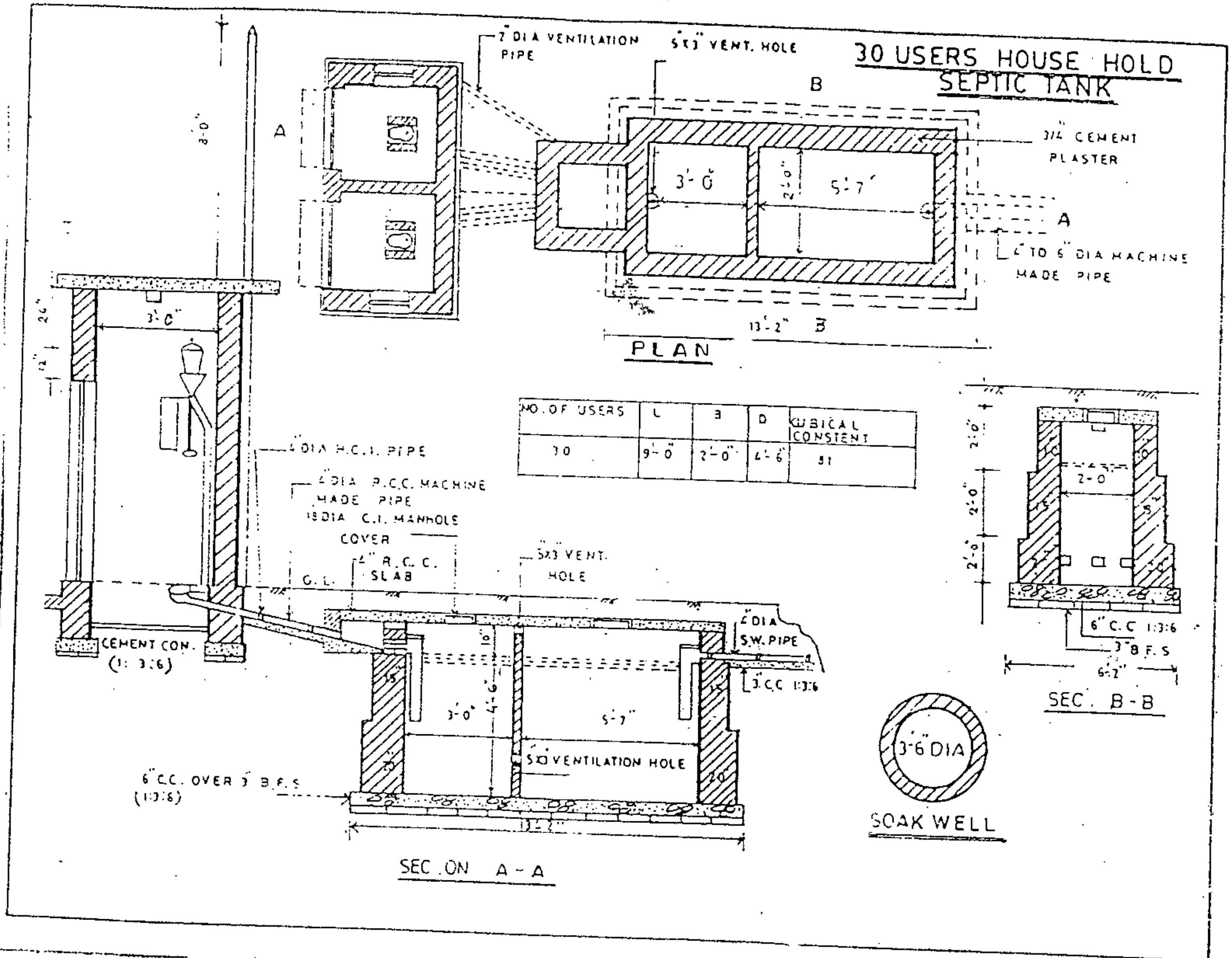


Figure 3.2. Septic Tank System of PWD

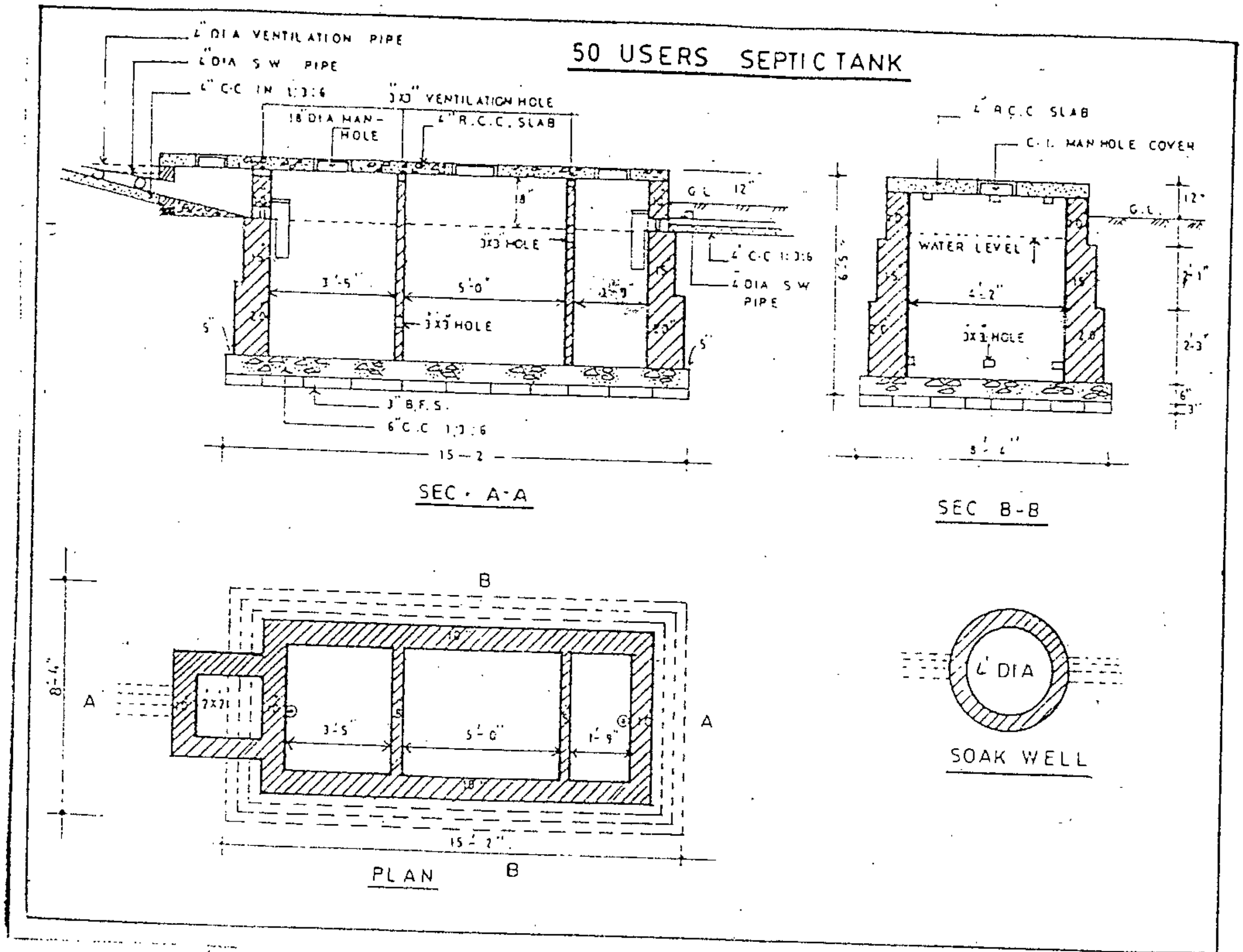


Figure 3.3: Septic Tank System of PWD

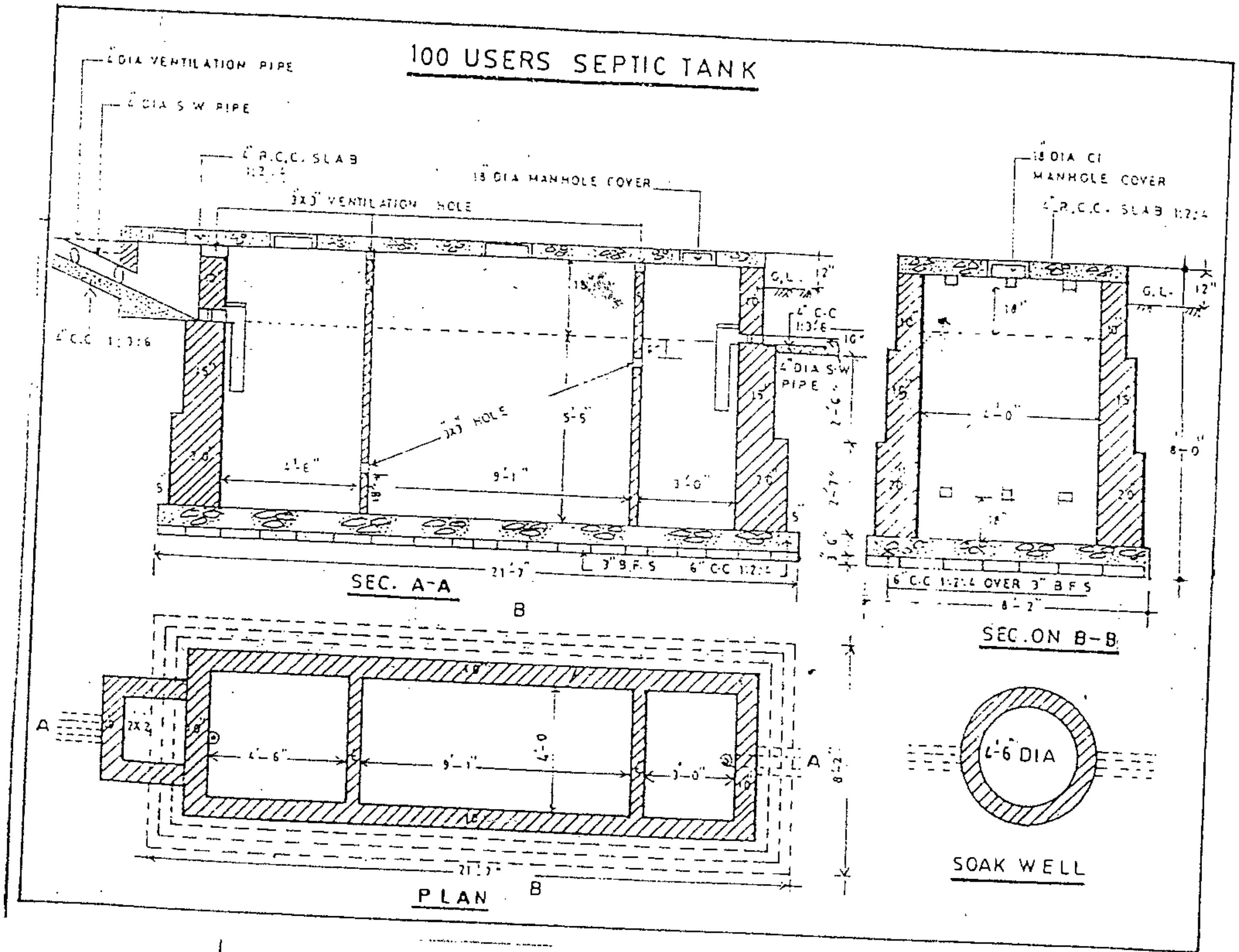


Figure 3.4: Septic Tank System of PWD

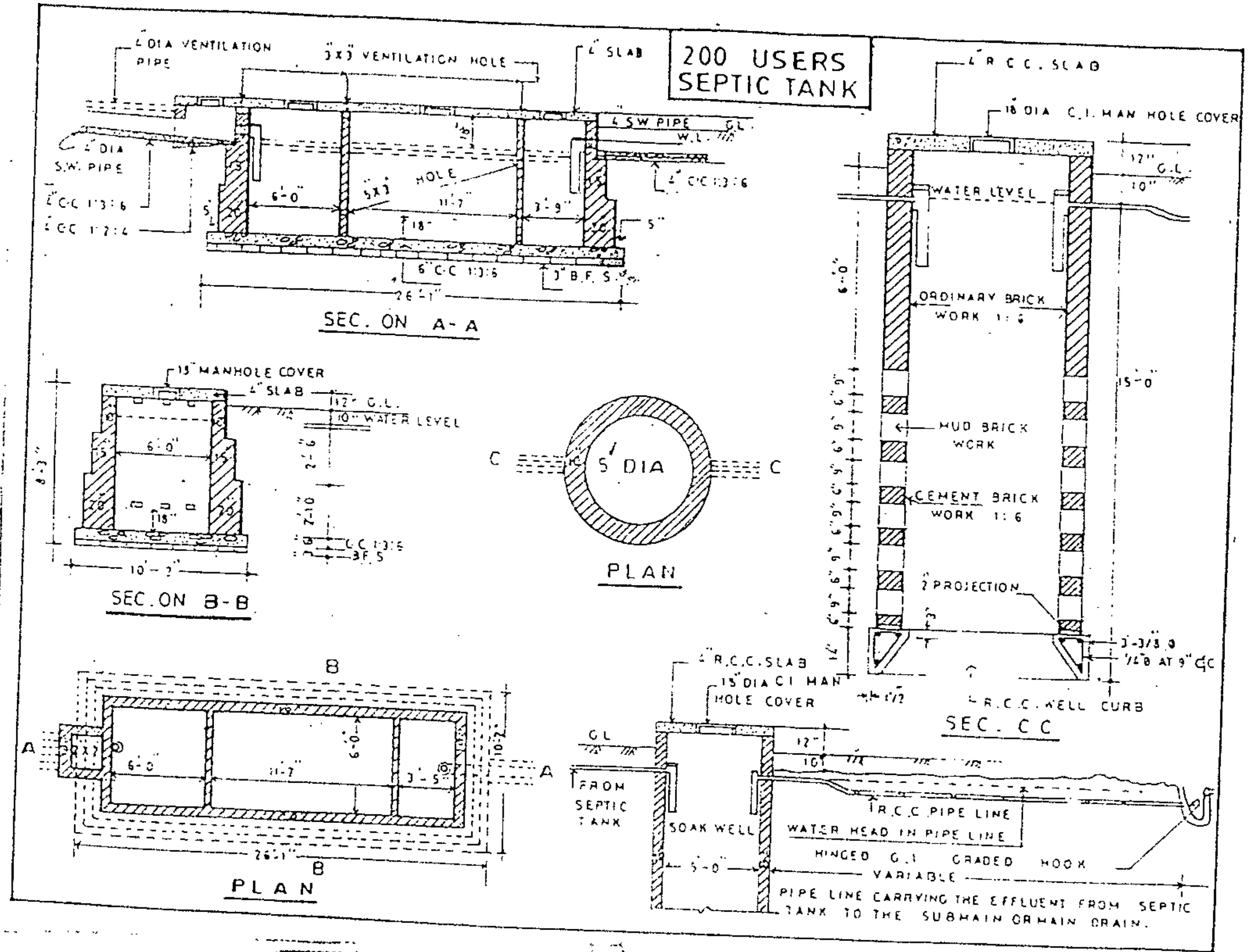


Figure 3.5: Septic Tank System of PWD

3.2 Septic Tank System Of BR Department

Figure 3.6 shows details of septic tanks used by the Bangladesh Railways department for their bungalows and quarters.

Total tank capacity of 50 gallons (225 liters) per capita has been provided which is more than adequate. The dropwall or hanging baffle near the middle serves no useful purpose, but tends to cause washout of sludge particles. The inlet is less than 4" in diameter, so that surge flows in the tank can be expected.

The soakpit is highly inefficient since closed rings extend the entire depth to the bottom of the pit.

3.3 Septic Tank System Of MES

Figures 3.7 and 3.8 show details of septic tank and absorption pit (soakage pit) used by this organization. Tank capacity has been calculated on the basis of 22 gallon (100 liter) per capita. Length/width ratios for larger tanks seem to be excessive (greater than 9:1). Actually, l/w ratios greater than 6:1 serve no useful purpose. Performance could be improved by the use of compartmentation. Baffle at the outlet of such narrow tanks is also useless.

The soakage pit is subjected to a maximum effluent loading of 10 $g/ft^2/d$ (490 $l/m^2/d$) for the larger tanks, and 1.6 $g/ft^2/d$ (80 $l/m^2/d$) for the smaller ones.

3.4 Septic Tank System of S&A

Figures 3.9 and 3.10 shows details of septic tanks and soakwells followed by Shaheedullah and Associates Ltd, a leading consulting firm of the country. The tank is designed on the basis of 40 gallon per capita of total volume. Tank width of 7'-1" is excessive. Width in excess of 6 ft requires two inlet pipes in order to reduce turbulence and stagnant zones. The ledge at outlet effectively makes the inverts of inlet and outlet at the same level which is not desirable. Liquid flow over the partition will cause scum disturbance, although location of structural struts at liquid surface will be of some advantage in this regard.

The soakwell is subjected to a maximum effluent loading of 4 $g/ft^2/d$ (200 $l/m^2/d$). The invert of outlet from the soakwell is above that of the inlet, so it is useless and might cause backup of water in the septic tank.

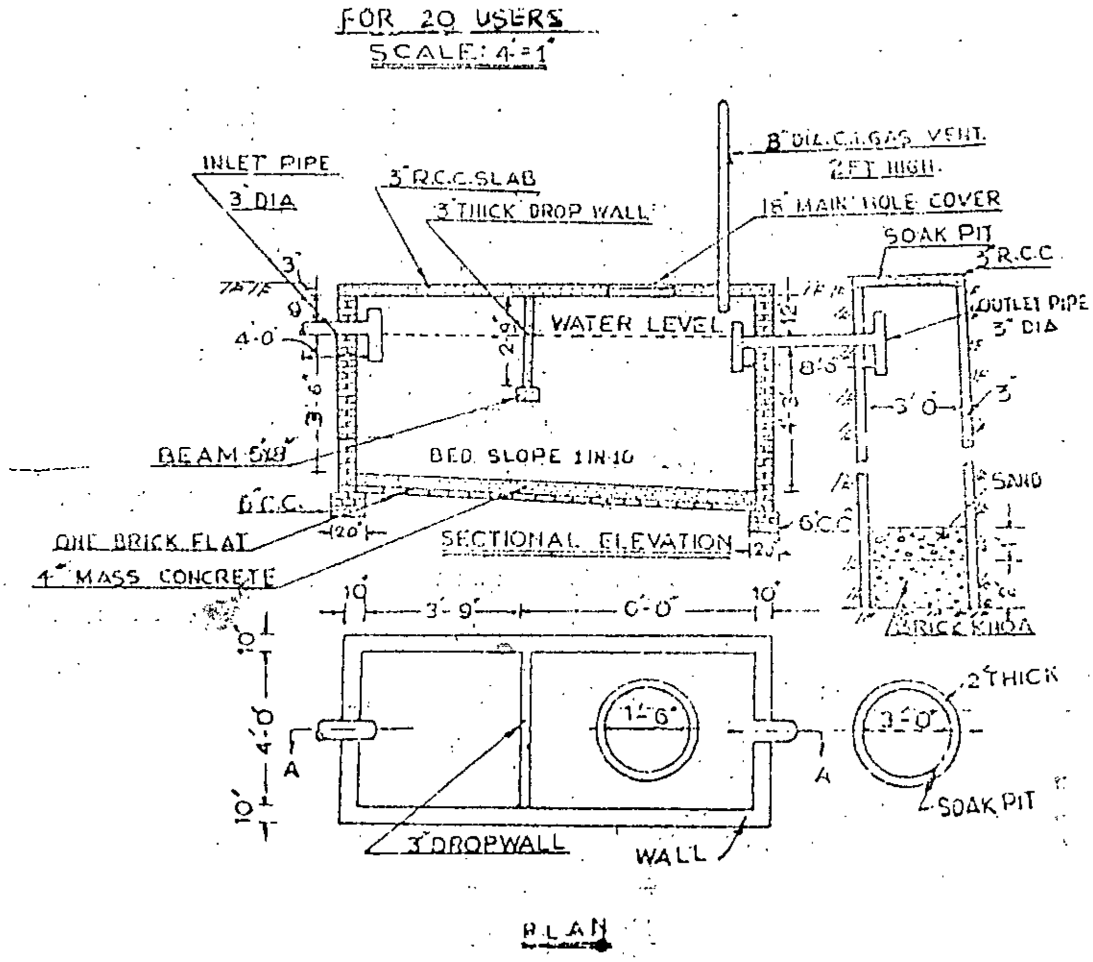
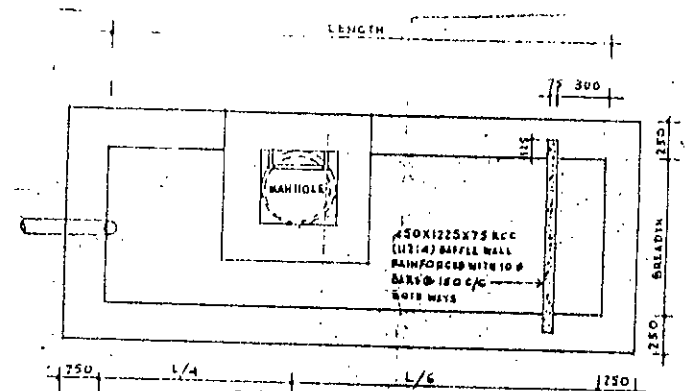
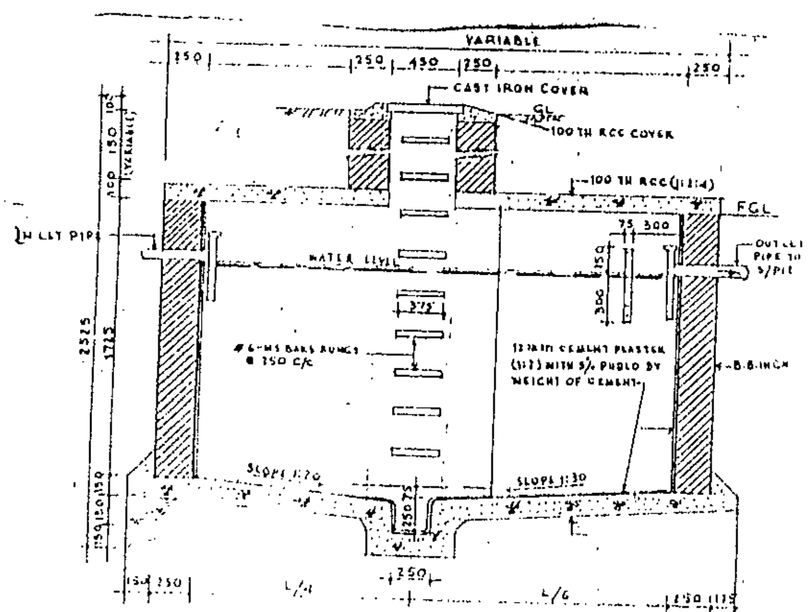


Figure 3.6: Septic Tank System of BR Department



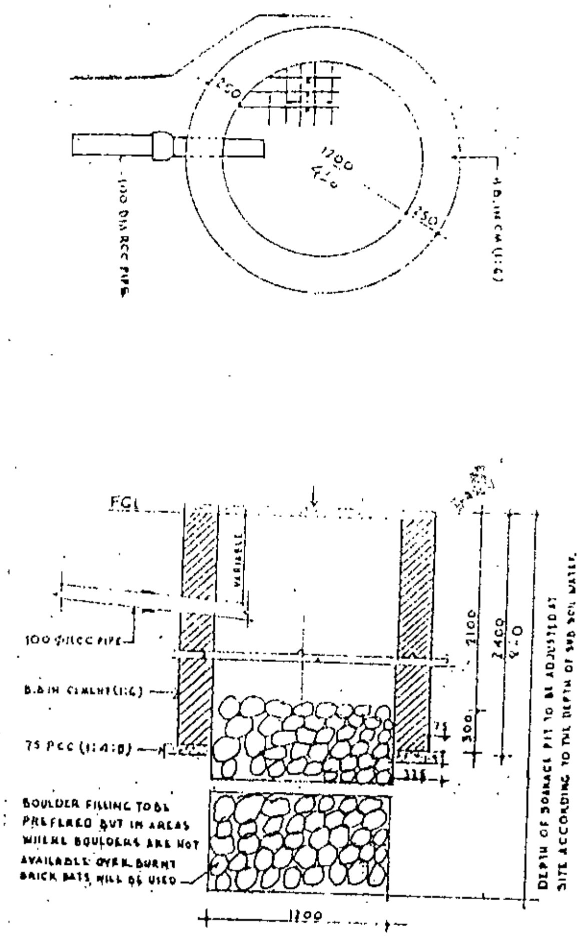
TYPICAL PLAN OF SEPTIC TANK



LONG SEC OF SEPTIC TANK

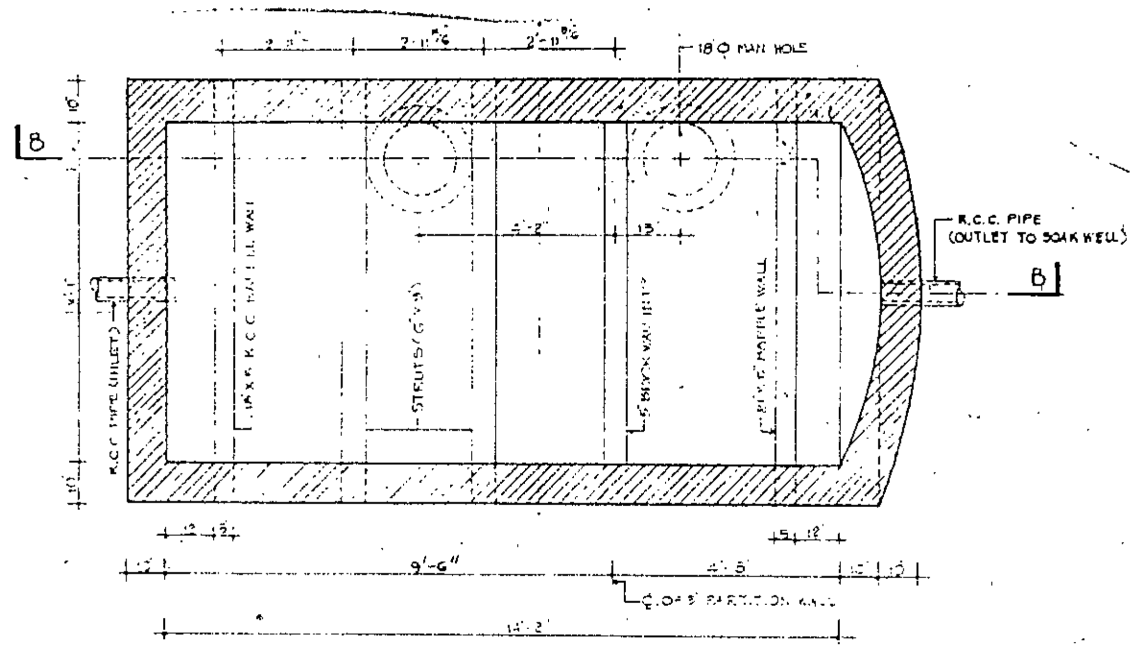
User	L	W	Liq D
25	2800	1000	1370
50	3600	1000	1370
70	5100	1000	1370
100	6600	1000	1370
150	9100	1000	1370

Figure 3.7: Septic Tank System of MES



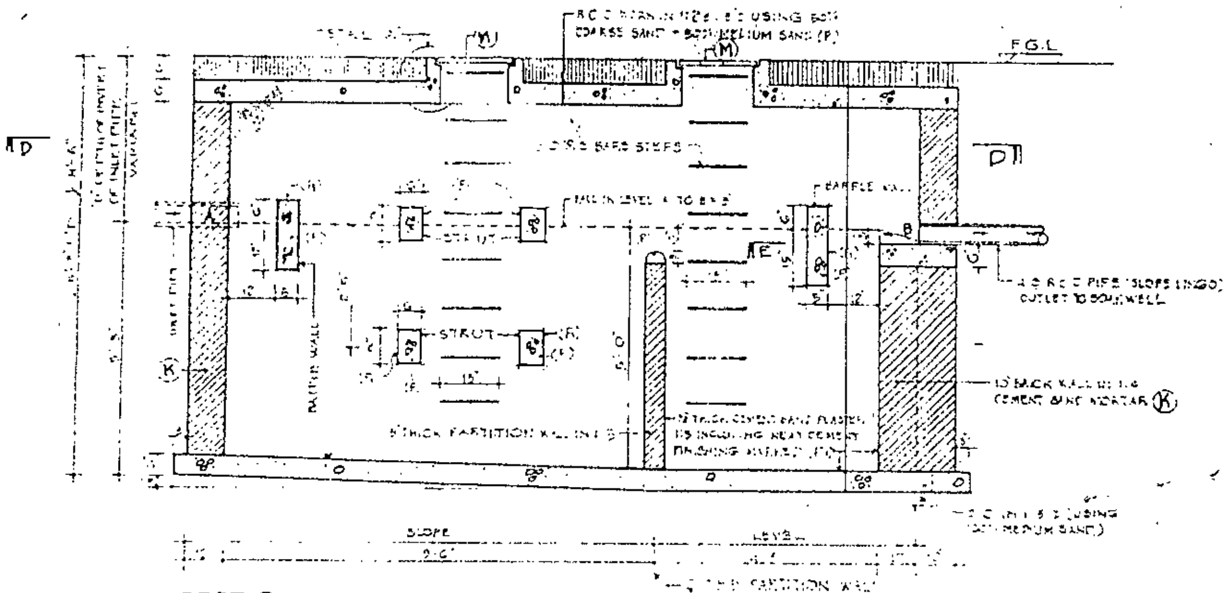
CROSS SEC OF SOAKAGE PIT

Figure 3.8: Septic Tank System of MES



SECTIONAL PLAN OF SEPTIC TANK ON D-D

SCALE :- ½"= 1'-0"



SECTION ON B-B

SCALE :- ½"= 1'-0"

Figure 3.9: Septic Tank System of S&A

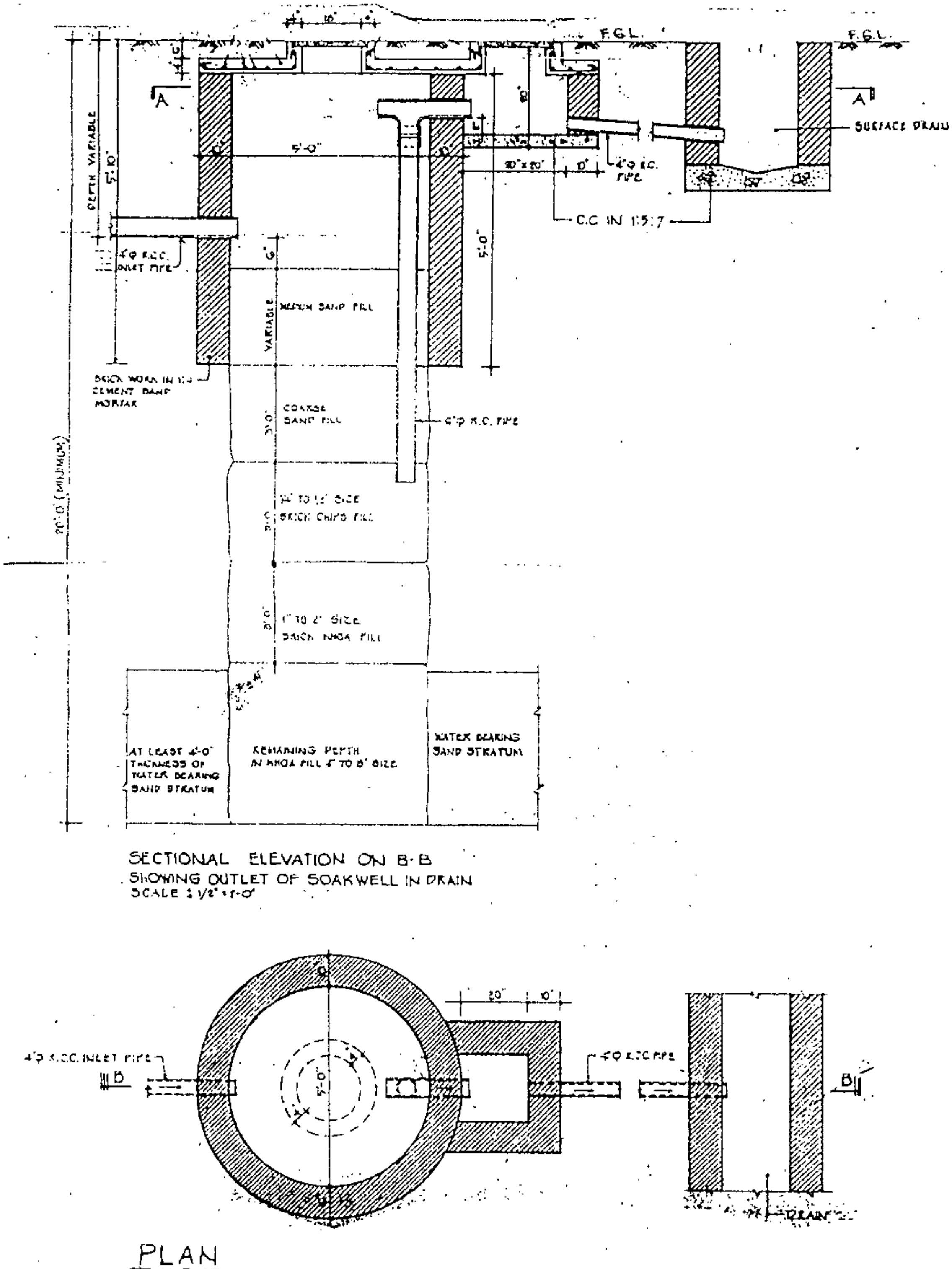


Figure 3.10: Septic Tank System of S&A

CHAPTER 4

STANDARDIZATION OF SEPTIC TANK SYSTEMS

4.1 General

The current practice in Bangladesh is to lead only W/C wastewater in to the septic tank and to allow household sullage to be discharged directly into surface drains. Sullage consists of wastewater originating in kitchen activities, washing, bathing, etc. Kitchen wastewater is generally high in BOD. From public health considerations it is unsafe to dispose of these wastewaters into open drains. Rather these should be led into the septic tank.

Table 4.1: Water Supply Data For Bangladesh. [Source: National Water Plan (NWP)]

Figures in lpcd

	Period	Rural Areas	Upazila/ Zilas	Old Dist HQs	Metropolitan Cities
NWP 1	Upto 1990	34	90	110	150
NWP 2	1990 - 2005	40	110	130	170

The volume of sullage generated is directly related to water supply. But as is evident from Table 4.1, the water supply in district towns is much less than in the cities (to the extent of 60%). Therefore, for district towns it will not be justified to lead kitchen wastewater, which is only a fraction of total wastewater, into the septic tank. For cities it will be recommended to account for kitchen wastewater in the design of septic tanks and absorption pits.

4.2 Standardization Of The Tank

Keeping in view the context of Bangladesh, the design criteria can be adopted as follows:

a. Minimum retention time just prior to desludging - 1 day (Sec. 2.5.2.2)

b. Desludging interval - 3 years (Sec. 2.5.2.3)

c. Anal cleansing material - water and soft paper

d. Minimum & maximum L/W ratio - 2:1 & 6:1 (Sec 2.6)

For district towns, wastewater contribution is 9 gpcd (40 lpcd) (Sec. 2.5.2.2) and sludge accumulation rate is 6 gpca (25 lpca). (Table 2.2)

For cities, considering kitchen wastewater also, total wastewater contribution can be taken as 15 gpcd (65 lpcd), which is approximately 37% of water supply. Sludge accumulation rate is taken as 8 gpca (35 lpca).

Therefore, total tank capacity can be calculated as follows:

	District Towns	Metro Cities
Liquor	9 gpcd X 1 d = 9 gpc	15 gpcd X 1 d = 15 gpc
Sludge	6 gpca X 1 d = 18 gpc	8 gpcd X 1 d = 24 gpc
Total	27 gpc --> 30 gpc	39 gpc --> 40 gpc

By fixing the width and depth of the tank, the length can be directly related to the number of users. Table 4.2 has been developed on the above-mentioned criteria. Essential dimensions of the proposed standardized septic tank are shown in Figure 4.1. Depth is less than 6 ft (Sec. 2.6). Two compartments have been used and the volume division ratio of 2:1 has been adopted (Sec. 2.7). The partition has been taken up 6" above liquid level to prevent scum disturbance (Sec. 2.7). Regarding the inlet and outlet, recommendations of Section 2.8 have been followed.

Table 4.2: Dimensions of Standardized Septic Tanks

No. of Users P	Liquid Depth D	Width W	Length L ft Dist. Towns	Metro. Cities
10 - 20	3'-6"	2'-6"	0.55 P	0.66.P
20 - 30	3'-6"	3'-6"	0.40 P	0.52.P
30 - 50	4'-0"	4'-0"	0.30 P	0.40.P
50 - 100	4'-6"	4'-6"	0.20 P	0.26.P
100 - 200	5'-3"	5'-3"	0.14 P	0.18.P

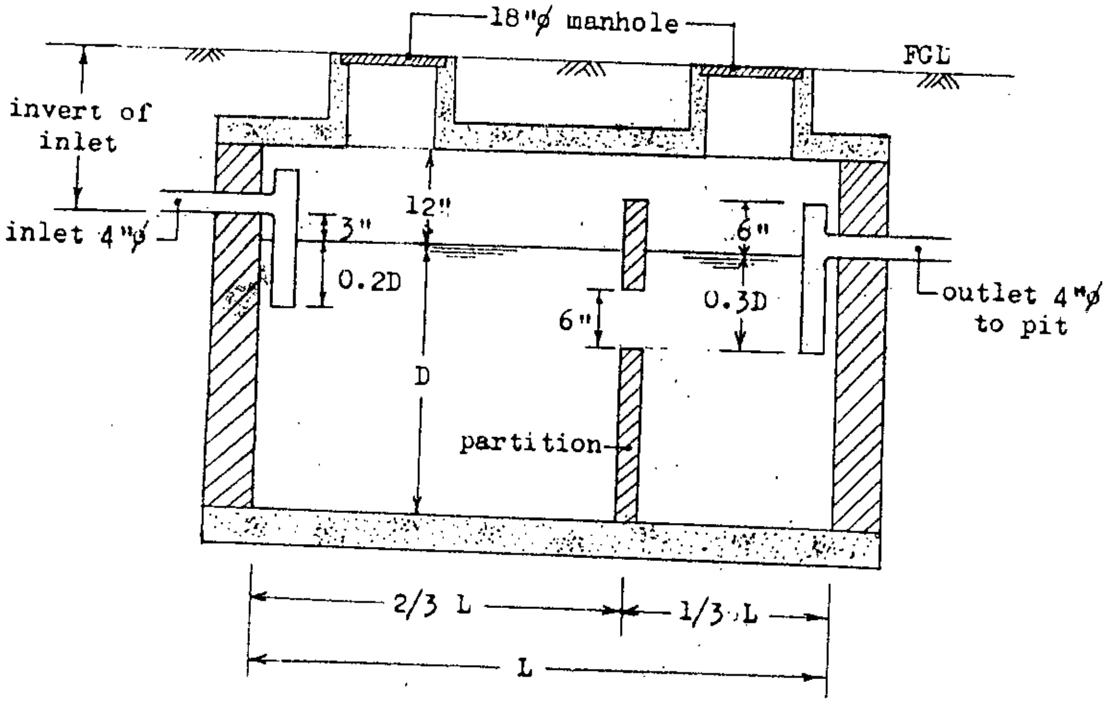


Figure 4.1: Details of Standardized Septic Tank

4.3 Standardization Of The Absorption Pit

Figures 4.2 to 4.7 show borelogs of different districts of the country. One basic feature is seen to be common - the upper layers of soil are underlaid by deep layers of saturated fine sand. Depending on the location, this is situated from 11 to 23 ft below ground level. The absorption pit is, hence, the most suitable method for septic tank effluent disposal for Bangladesh.(Sec. 2.13.2.5). Taking maximum effluent loading rate of 3.0 gallon/ft^2/d for a medium relative absorption of the soil (Table 2.7), the required depth and diameter of absorption pits can be calculated, as given in Table 4.3. Figure 4.8 shows the details of the proposed standardized absorption pit.

Table 4.3: Dimensions of Standardized Absorption Pits

Number of Users	Dist. Towns		Metro Cities	
	Diameter	No. of Well	Diameter	No. of Well
20	3'-0"	1	3'-0"	1
30	3'-0"	1	3'-6"	1
50	3'-6"	1	5'-0"	1
100	5'-6"	1	5'-0"	2
200	5'-6"	2	6'-0"	2

Note: Depth of all pits 20 ft minimum

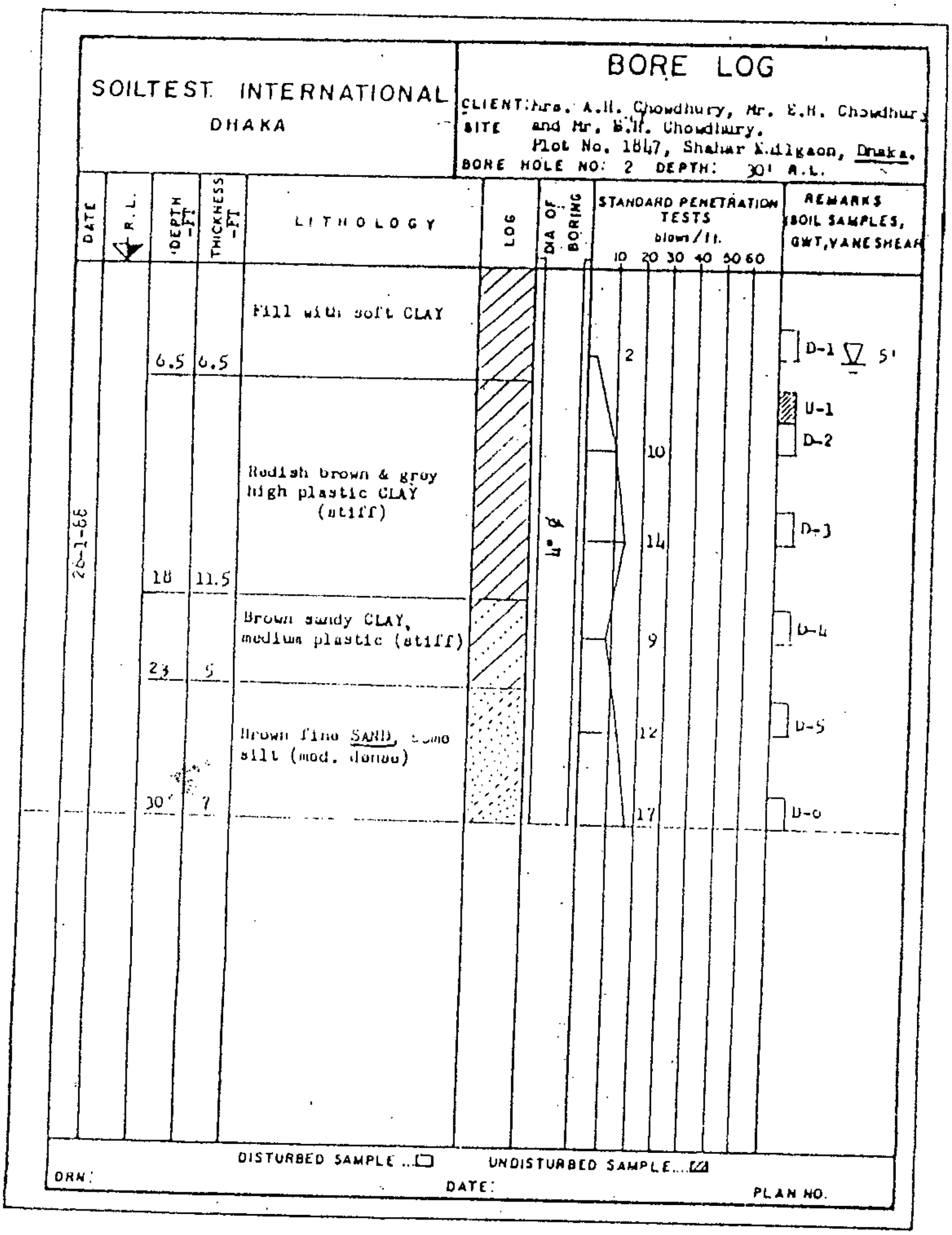


Figure 4.2: Soil Bore Log, Dhaka

M/S UNIQUE BORING AND ENGINEERING 7, Mymensing Road, Shamsuzzoha market Dhaka.	SOURCE: SHAHEEDULLAH AND ASSOCIATES LTD. SITE: COMILLA HOLE NO.: 1

DATE	DEPTH M	THICK M	STRATA ENCOUNTERED	LOG OF BORE	DIA OF BORE	NO. OF BLOWS PER FOOT	☐ DISTURBED ☒ UNDISTURBED
	0.00 – 6.50	6.50	Grey soft to medium stiff silt, traces clay and fine sand.			5, 4, 7, 8, 9	G.W.T. — .30 m; 1.50, 1.95, 2.50, 2.95
	6.50 – 8.00	1.50	Blackish medium dense sandy silt.			10	
	8.00 – 10.00	2.00	Greyish medium dense fine sand, traces silt.			14, 18, 18	

Managing Partner

Figure 4.3: Soil Bore Log, Comilla

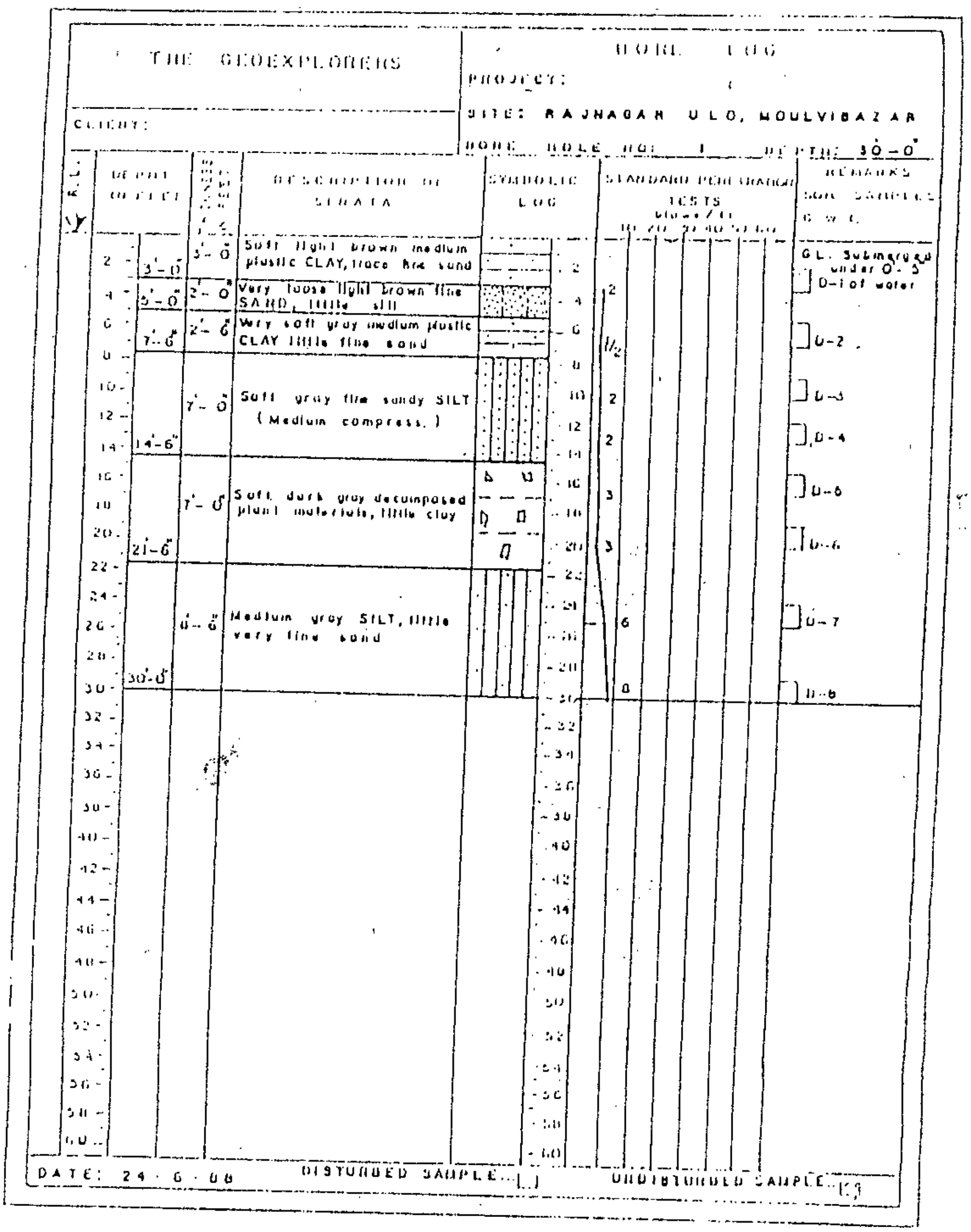


Figure 4.4: Soil Bore Log, Moulvibazar

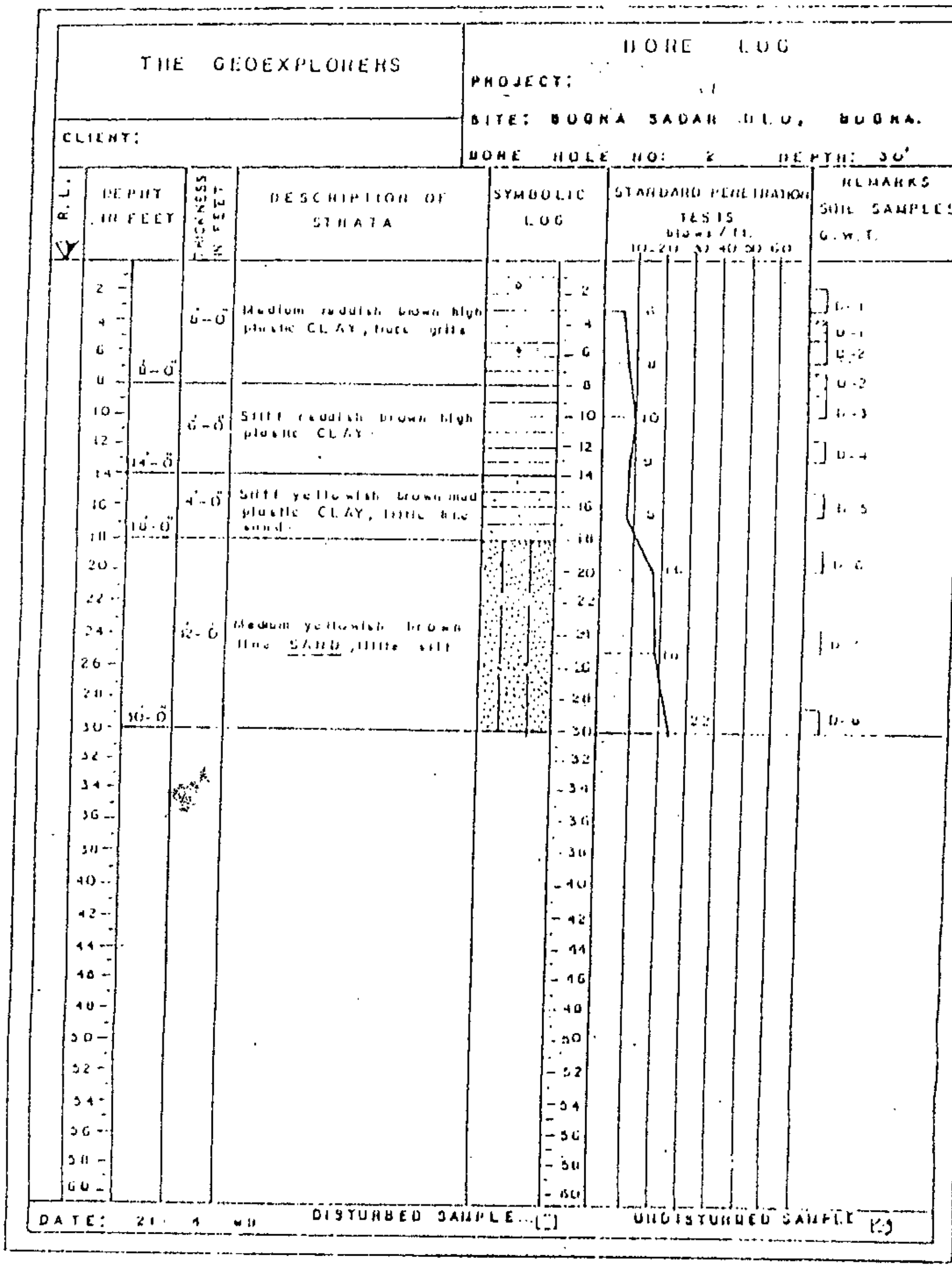


Figure 4.5: Soil Bore Log, Bogra

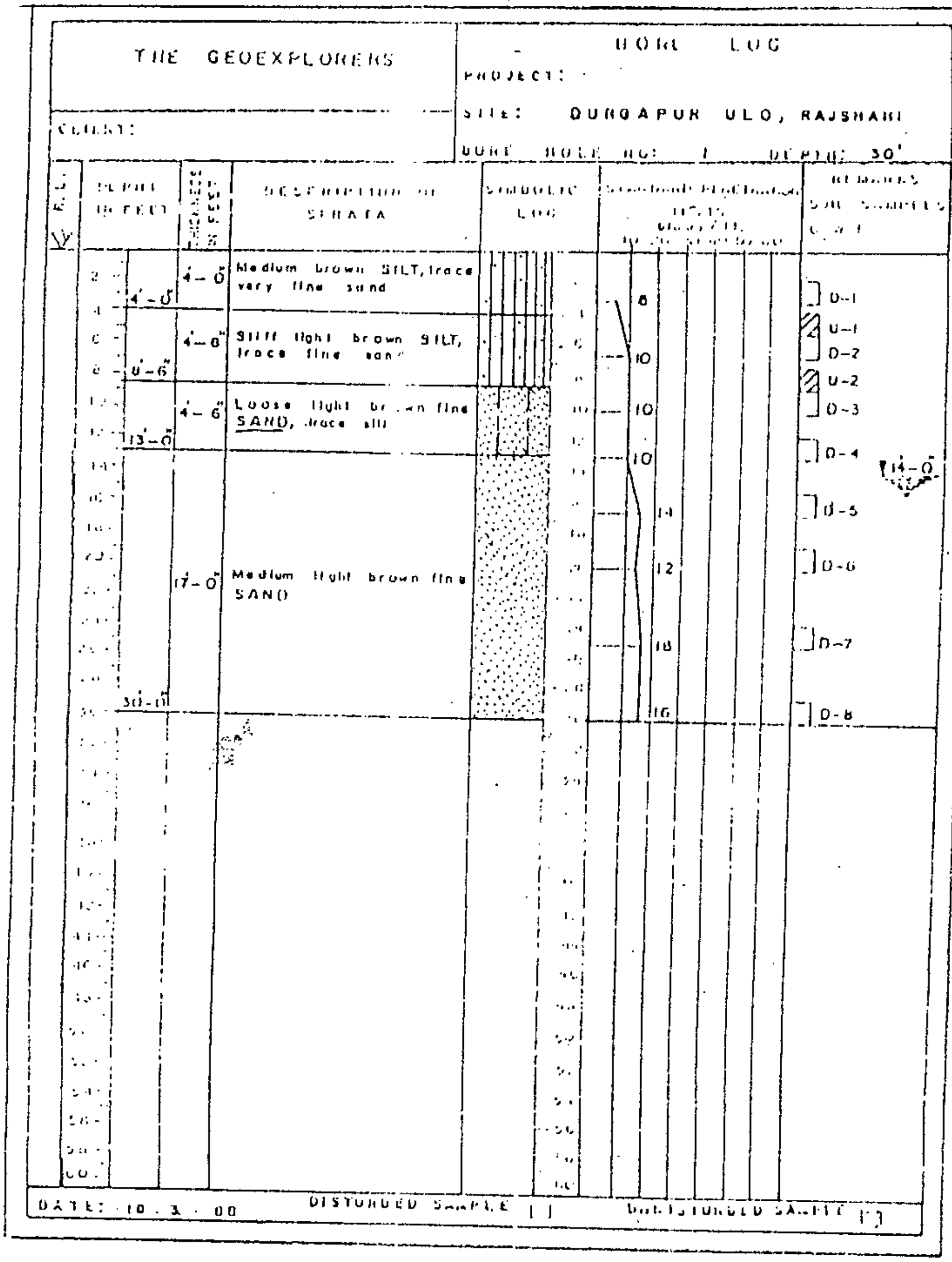


Figure 4.6 Soil Bore Log, Rajshahi

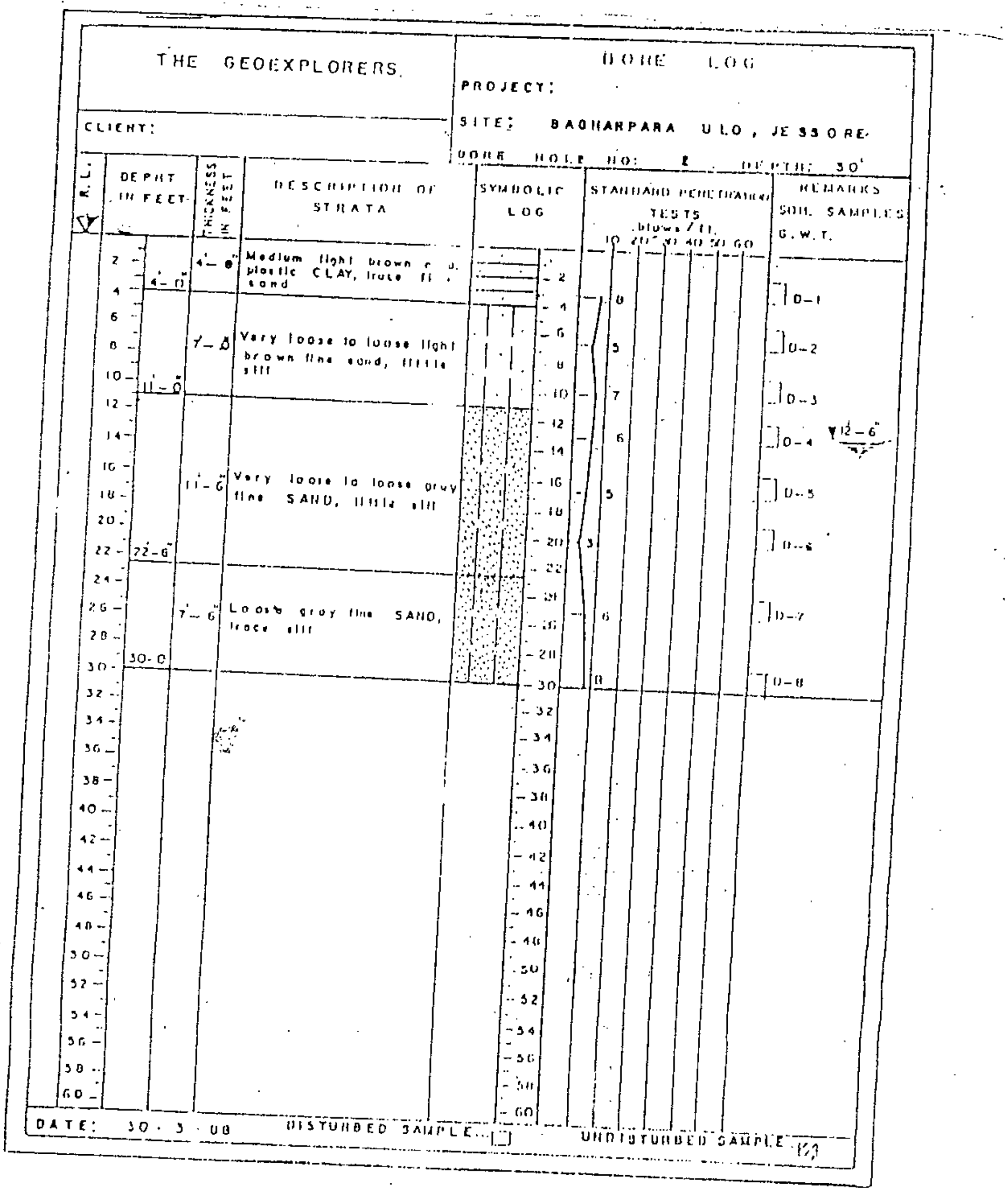


Figure 4.7: Soil Bore Log, Jessore

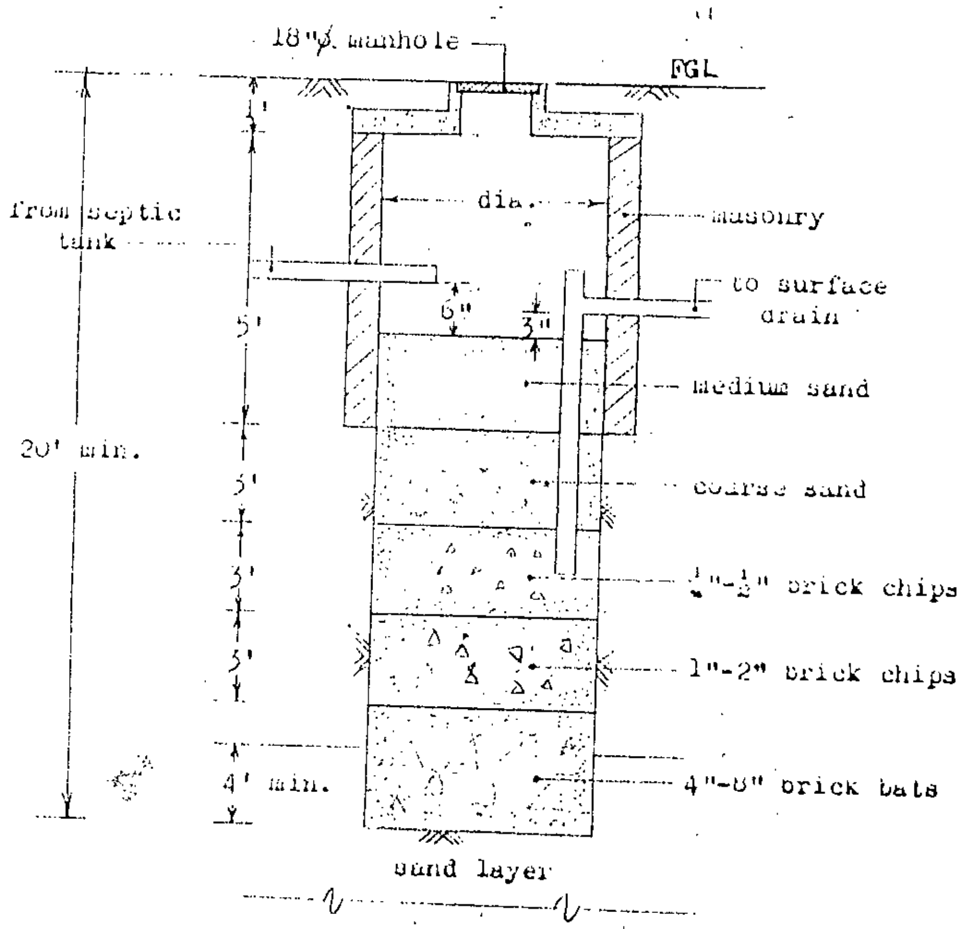


Figure 4.8: Details of Standardized Absorption Pit

4.4 Septic Tank and Absorption Pits Serving Institutions

It is to be noted that provisions for dimensioning septic tanks and absorption pits as stated in Sections 4.2 and 4.3 are applicable for residential buildings. For institutions, e.g., factories, schools, commercial buildings, etc, total effective septic tank volume can be based on 10 gal per capita contribution. Dimensioning details of Tables 4.2 and 4.3 can be used for institutions based on the following Table 4.4.

Table 4.4: Equivalence Table For Number of Users in Institutions and Residences [Based on Aziz 1972]

Septic Tank		Absorption Pit	
No. of Users Institutions	Equivalent No. of City Users Residences	No. of Users Institutions	Equivalent No. of City Users Residences
10 - 50	10 - 20	50	20
50 - 80	20 - 30	80	30
80 - 140	30 - 50	140	50
140 - 270	50 - 100	270	100
270 - 550	100 - 200	550	200

4.5 Structural Design of Septic Tank

The traditional septic tank in Bangladesh is built of plain concrete floor, brick masonry walls and reinforced concrete top slab. Construction costs can be economized by proper design of the components. Forces on the various components depend on the size and shape of the tank, depth, location, soil characteristics, etc. Design of the top and bottom slabs are fairly simple. Material requirements of the walls can be minimized by providing stepped wall thickness, or buttresses, or collar beam with struts. This can be the subject of another research paper.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

a. Review of literature by various authors on septic tank systems reveals that the basic processes occuring within the septic tank are quite clearly understood. Much research has been conducted on septic systems in foreign countries and a large volume of information is available. However, no research has been carried out in Bangladesh.

b. Analysis of the septic tanks currently installed by various government and private organizations in different parts of Bangladesh shows that some are inadequate, whereas others are being over-designed. There is no consistency in design. Dimensions and details are being adopted which only serve to show lack of sound knowledge.

c. Standardized versions of septic tanks and absorption pits have been proposed. Dimensions and details have been based on research and performance data, with special relevance to conditions prevailing in Bangladesh.

d. With adoption of the proposed standardization all over the country, the following benefits are to be expected:

i. Since dimensions and proportions are being standardized, the design, and hence, the material requirements can be minimized.

ii. The components can be mass produced, leading to further economy.

iii. The cause of any malfunction or failure can be easily identified and rectification will be quicker.

5.2 Recommendations for Research

a. This paper has concentrated on the dimensional aspects of septic tank systems. The structural design also needs to be standardized. Research can be carried out on the most durable and economical structural design of septic tanks.

b. After desludging of the septic tank, the extracted sludge is presently being dumped into surface drains or on garbage disposal lands. Research on improved sludge disposal methods should be done.

c. Environmental considerations are currently receiving importance in Bangladesh. The environmental impacts of chemicals released with septic tank effluents need to be studied so that the fragile ecological balance is not damaged.

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