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SERVICES FOR SHELTER

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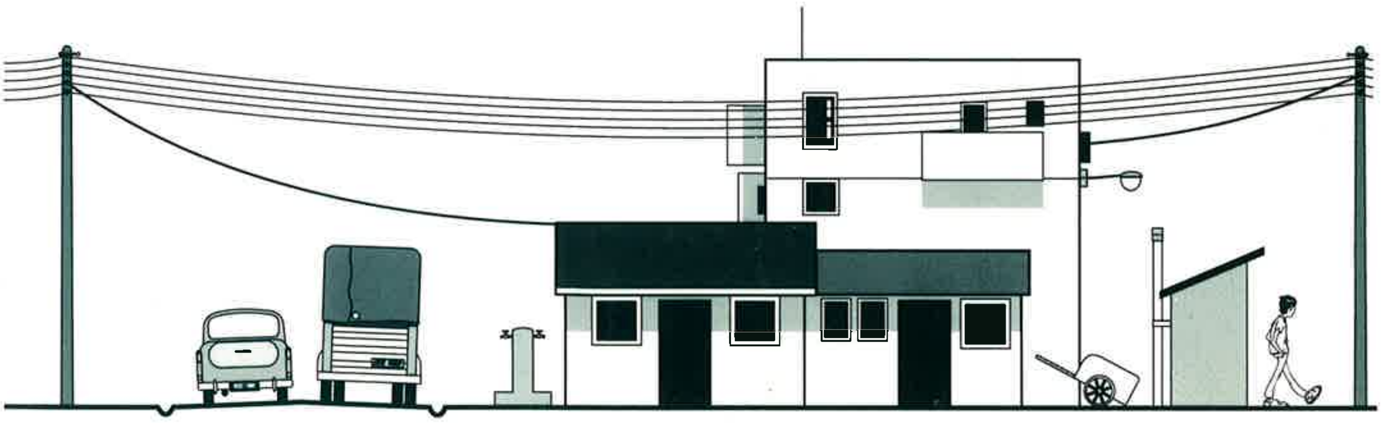

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Foreword

This book is written for engineers, planners and architects who are involved with the provision of new or upgraded housing for the urban poor in the developing world. Whilst the book is about the provision of physical infrastructure, or services, for housing, it is not intended to be an engineering design manual. The book presents and analyses a strategy for planning, implementation, operation and maintenance of services within the context of the people whom they are serving and their shelter. The emphasis is on a support-approach to service provision.

Physical infrastructure improvement is an essential component of housing, yet its planning and design are rarely properly integrated with the other physical and social planning components of the housing process. This books aims to share with those professionals responsible for housing provision and community development the problems and constraints which face the infrastructure engineers. It aims to help the engineers understand that technology alone is not sufficient for long-term sustainability and that the objectives of infrastructure provision are more important than arbitrary adherence to Standards and Codes which may not be appropriate for low-income housing. It aims to assist all the professionals in their task of enabling low-income householders to achieve affordable sustainable housing.

A strategy for service provision which places the emphasis on participation of householders and communities is presented in Chapter 1. The more detailed material in Chapters 2 to 9 which covers the technical options for infrastructure is set within the context of this approach; particular attention is paid to aspects of maintenance and cost recovery. Chapter 10 describes mechanisms by which community involvement in services provision might be achieved.

Both authors work in the Water, Engineering and Development Centre (WEDC) based in the Civil Engineering Department at Loughborough University of Technology, UK. Much of the material presented in this book was developed as a result of the authors' experiences working on Technical Co-operation programmes related to urban housing and urban management in Sri Lanka, India and Nepal, funded by the UK Overseas Development Administration.

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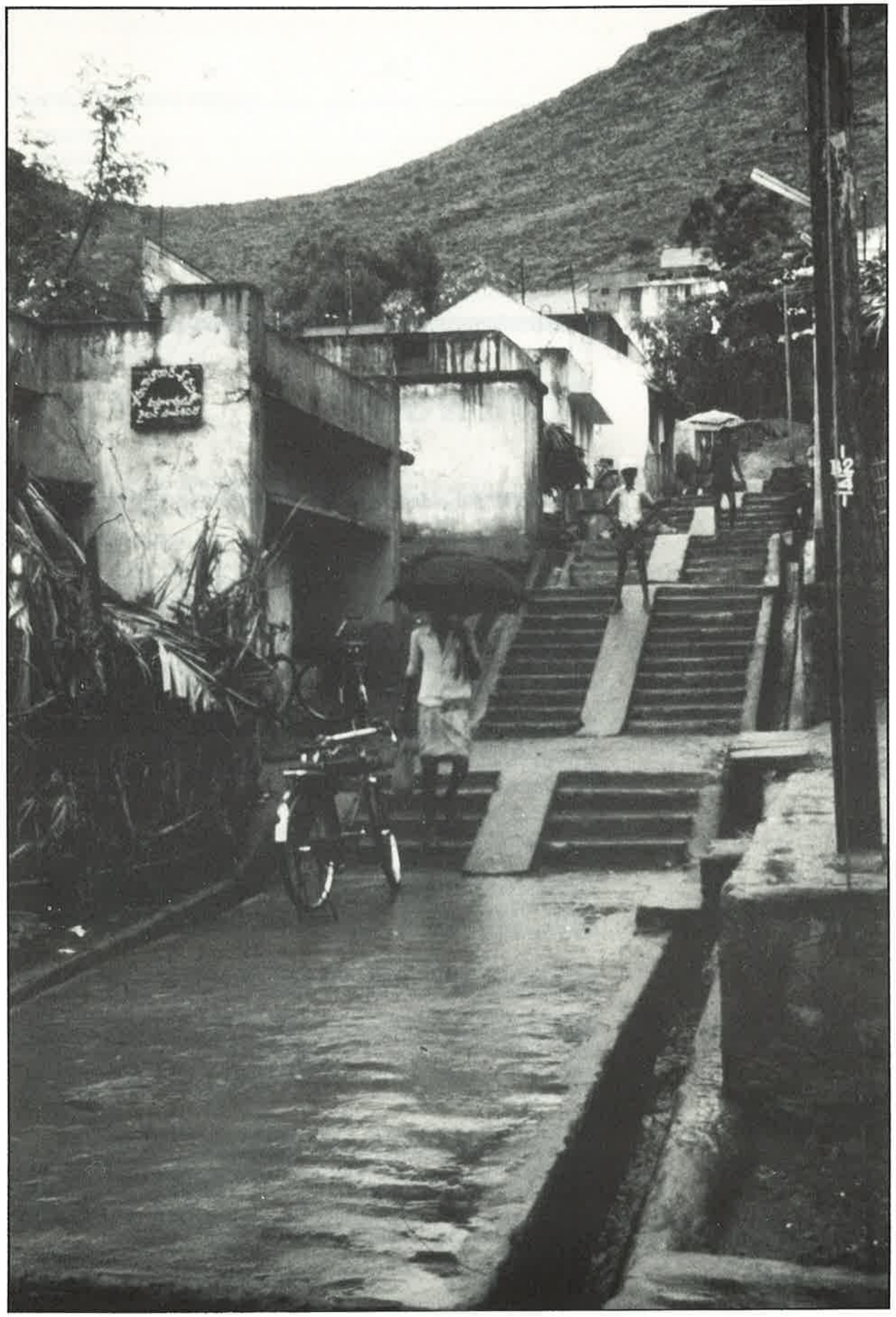


Above: Access to a hillside site

People, shelter and services 1

Introduction

The dramatic growth in the population of urban areas in many less developed countries has not been matched by the provision of adequate shelter. Increasing numbers of people are seeking some form of shelter on informal, unimproved housing settlements which lack basic social and physical amenities. These settlements are often on marginal land which may be expensive to develop; common locations include steep hillsides and low-lying areas prone to frequent flooding.

The desperate physical characteristics of many such unimproved housing sites bear testament to the lack of physical infrastructure: waterlogged ground thick in mud due to poor drainage; ill-defined access ways and unpaved roads; long queues to obtain water from a single public tap or an expensive water vendor; open spaces covered with human excrement because there are no sanitary facilities; heaps of rotting garbage which remain uncollected. It is clear that provision of physical infrastructure or services is essential to the improvement of shelter.

Nevertheless, the inhabitants of these areas have somehow succeeded in creating homes with basic versions of the necessary services. Often using considerable improvisation, the people have demonstrated their ability to manage their environment. It must be noted that adequate infrastructure is only one of many unsatisfied needs of low-income communities (United Nations Centre for Human Settlements, 1984); people will undertake improvements to the limit of what they perceive to be satisfactory given their limited resources and their own priorities of how those resources are best deployed.

It is desirable to improve services for low-income communities to a certain minimum level; firstly to improve environmental health, reducing morbidity and mortality rates, especially amongst children, and secondly for long term economic growth. There is tremendous pressure to provide affordable housing for many millions of people; the challenge is to integrate the provision of appropriate physical infrastructure with shelter to ensure that the housing of today does not become the slums of tomorrow.

Seven principal infrastructure sectors are described in the chapters which follow:

Ground preparation to provide the foundation for the construction of shelter, including the protection of low-lying land from inundation by flood waters and the prevention of soil erosion and movement on steep hillsides.

Drainage to permit both stormwater and household wastewater to drain away without creating stagnant pools;

Access and roads to define a site layout with clear boundaries for housing plots, access routes, rights of way and emergency vehicle access.

Water supply to provide clean water in adequate quantities to cope with basic needs.

Sanitation to remove and dispose safely of human wastes; this is an essential component of environmental health.

Solid waste management to ensure that refuse which is generated on the site is collected and disposed of.

Power supply for cooking, lighting or to run other electrical appliances.

Urban growth, shelter and services

Shelter needs

The rapid expansion of cities in developing countries has been influenced by many different factors. A significant element appears to be that the poorest and landless can survive in urban areas more easily than in rural areas. Recent statistics suggest that in the Low-Income Countries 22% of the population now live in the urban areas and in the Lower Middle-Income countries 36% live in the cities. Cities and urban areas are growing by an average of 4% per annum in the Low-Income countries and 3.7% per annum in the Lower Middle-Income countries (World Bank, 1989). This rapid increase implies a doubling in size of many cities within twenty years; during the International Drinking Water Supply and Sanitation Decade, 1981-1990, population increases of 50% were common in urban areas.

The sheer scale of the problems to be faced in the provision of urban shelter is daunting. Estimates in 1987 indicated that approximately 430 million urban people lacked adequate shelter; this is likely to increase to 2700 million by the year 2007, which would require about 400 million new dwellings over the twenty-year period.

Often, between one-third and one-half of the residents of a city live in slums or shanties on squatter settlements. 'Slum' is the term used to describe old dwellings (but occasionally of recent construction) which through overcrowding, neglect and breakdown of supporting services have deteriorated to an insanitary, unsafe condition. 'Squatter settlements' are sites, often close to areas of employment, to which householders have no legal title. Due to the resultant lack of security, temporary structures known by many different terms, for example shanties, are erected. They are usually made from the cheapest materials available.

Service needs

The scale of the housing problem also reflects the scale of the physical infrastructure problem, because housing needs the support of adequate services for the people. Just as there has been much debate as to what actually comprises 'adequate shelter', there is equal scope for argument regarding the interpretation of the requirements of 'adequate services'.

Two different options for servicing are shown in Table 1.1. Option 1 represents the 'conventional' standard of infrastructure, based on what is provided in high-income countries; option 2 provides a lower level of service. The different technologies are all fully described in the chapters which follow.

Whilst the high service level of option 1 caters fully for the needs of public health, status, and convenience, it is costly to provide. Infrastructure costs for low-income housing schemes in India, the Far East and Southern Africa have been analysed by Franceys and Cotton (1990). The total annual cost per household (TACH) which includes capital, operation, maintenance and replacement costs of both servicing options is shown in Figure 1.1.

The cost differential is of major importance, and is significant even for the smallest plot size investigated of 30 square metres. The cost of infrastructure is very high in relation to the income levels of slum dwellers, as the following calculation illustrates.

The poorest 40% of the population to be housed have an annual income of less than US $700 per year; whilst the level of affordability is widely debated, a reasonable estimate is for 20% of income to be spent on housing and services; this comes to US $140 per year. Assuming a total annual cost per household of US $100 for housing (based on a plot size of 30 square metres at a minimum building cost of US $30 per square metre, amortised at 5% over 20 years), this leaves approximately US $40 per household for supporting physical infrastructure, that is: water; sanitation; drainage; roads and access; power; solid waste removal.

Even allowing for fluctuations in costs and income between different countries there is clearly a serious affordability gap. Whilst it can be argued that the poorest people should not have to pay the full economic cost of the services from which they benefit, the size of the affordability gap is so great that even significant cross-subsidies cannot solve the problem. Globally, the affordability gap amounts annually to about US $62 billion. Income distribution figures indicate that the poorest 80% in low-income countries earn only US $1200 per year; the differential between the poorest 40% on US $700 and the poorest 80% on US $1200 is not sufficient to provide a tax base for the redistribution which would be necessary.

Table 1.1: Infrastructure options

Service	Option 1	Option 2
Access width	5 metres	2.5 metres
Storm drains	Lined	Road-as-drain
Sanitation	Sewerage	Improved pit latrine
Water supply	House connection	Public standpost
Sullage disposal	Sewerage	Lined sullage drain
Roads	Sealed surface	Paved surface
Power	Overhead lines	Overhead lines

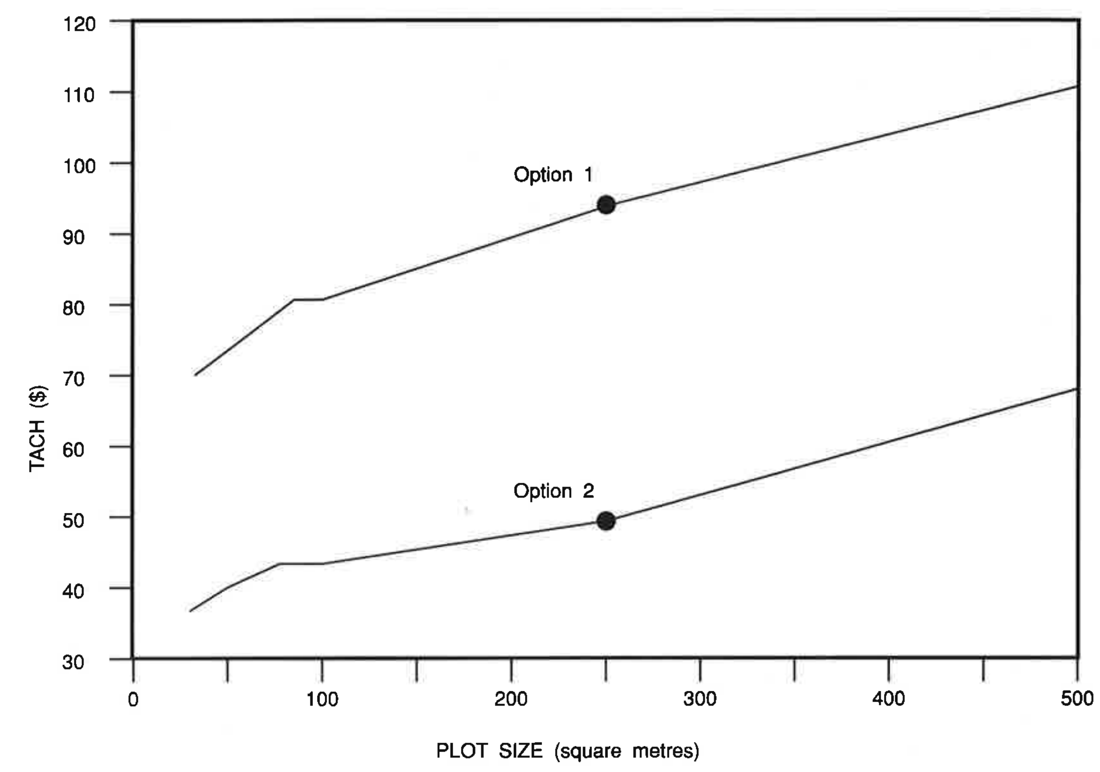


Figure 1.1: Servicing costs for options 1 and 2 (Table 1.1), based on data from India

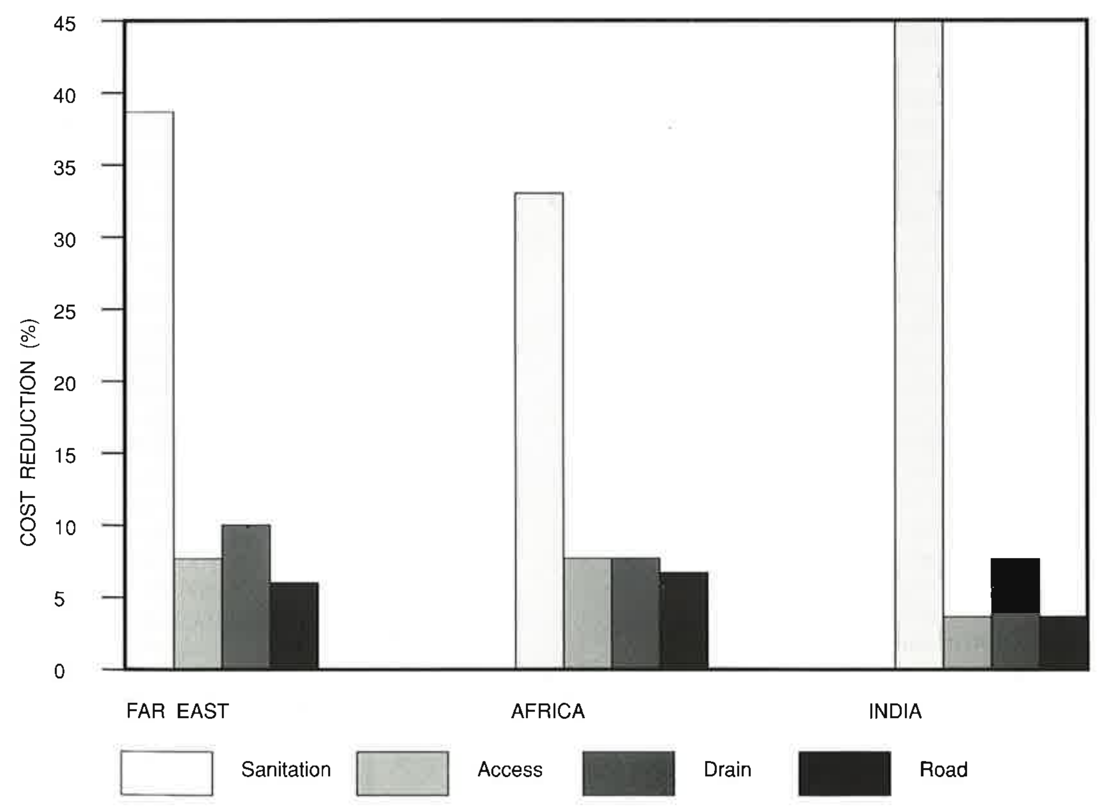


Figure 1.2: Potential cost reduction in various service sectors

Conventional high standards of service often incur high recurrent costs for operation and maintenance which are beyond the means of the majority of local authorities and householders to bear. Thus the infrastructure which has been so expensively provided quickly falls into disrepair and disuse.

It is clear that the blinkered view of 'adequate services' being synonymous with conventional standards of infrastructure requires radical rethinking in order to encourage sustainable levels of service. An important area for consideration is the use of lower cost, more appropriate technologies. There has been a tendency in many low-income housing schemes, especially of the 'sites and services' type, to ignore the wide range of service options which are actually available and to use 'conventional' service levels which are unnecessarily expensive.

In general, it is a gross over-simplification to regard infrastructure cost merely as a function of 'service length' in relation to site layout; the wide range of options within each sector have significantly different capital and maintenance costs in their own right. It can be seen from Figure 1.1 that savings of 40%-60% can be achieved by using more appropriate lower levels of service (option 2).

Figure 1.2 shows the potential infrastructure cost savings by sector for 30 square metre plots. It is clear that the choice of sanitation technology has the greatest potential to reduce costs through the use of on-plot latrines; Significant but lesser savings have been identified through:

- limiting the access width within the cluster or street;
- using the road-as-drain option for stormwater drainage;
- cheaper road construction such as profiled earth or gravel or local paving stone; this will lead to concomitant reductions in drainage cost.

Technology choice alone cannot provide a complete solution to the problem; novel methods of implementation and management of services also need to be developed. In recent years, radical new approaches to shelter provision have been developed; these are described in the following section, because they may help to indicate a way forward regarding services provision.

Sustainable shelter and services

Shelter: The support approach

Attempts to provide housing through government projects, for example blocks of multi-storey flats, have proved neither effective nor sustainable; it is estimated that such housing cannot be afforded by over half the population of most urban areas (World Bank, 1974). It is also increasingly clear that governments cannot afford to continue to subsidise what had previously been considered 'low-cost' housing.

Planners and housing experts now consider that the 'support approach' to shelter is most likely to provide a solution which is both economic and sustainable (Wakely, 1988). With this approach, the construction work for new dwellings or improvements to existing structures is largely under the control of the individual household concerned. Thus the housing agency increasingly withdraws from its conventional role of direct construction. Its new role is likely to involve facilitating security of tenure and providing social, financial and technical support for the individual householders and the community.

The movement towards the support approach to housing is gathering momentum as cost savings and community development benefits become apparent. In Zambia it was found that a new house built by its owners cost one-fifth of the cheapest government housing; in El Salvador the cost was approximately halved (Keare and Parris, 1982) as also it was in Sri Lanka. The cost to the Government of Sri Lanka reduced by 75%, as it was found that granting tenure and a loan of half the construction cost was sufficient to release savings from the extended family of the low-income households.

The savings on construction do not always come about because of significant labour input from the householder; it has been noted that the opportunity cost of labour is surprisingly high (World Bank, 1974). However, the individual control of a householder over a mason or builder working directly for him is such that there is minimal wastage and most importantly, the substantial overheads and profits of the large contractors are omitted (Cotton and Franceys, 1988).

Whilst there are several modes of shelter improvement, it is appropriate for the purposes of this book to consider programmes under two main headings, namely sites and services and settlement upgrading.

In a sites and services project, land which has not previously been used for housing, or a site which has been cleared of shanties, is prepared. This involves blocking out the site with regular plot sizes, roads and access ways; services are laid on to the site before householders move on to commence house construction. In some programmes the services provision has included the construction of 'wet cores' where a toilet block is built (usually connected to a sewerage system), complete with a bathroom and/or kitchen with water supply. It is anticipated that the superstructure of the house is subsequently constructed around the 'wet core'.

In settlement upgrading, an existing slum or shanty is gradually improved whilst the residents remain in their homes. Water supply, sanitation and drainage are often the starting point of improvement. In addition, the size and shape of some housing plots may be altered, roads widened and paths surfaced; with security of tenure given, householders re-build their houses.

Services: The support approach

Householder participation in shelter provision can achieve affordable housing over which the householder has control. There is no reason why the householder participation principle cannot be applied to physical infrastructure in order to obtain similar benefits; that is, to enable the people to get the services they actually want and can sustain. Involving people in the provision of infrastructure requires a flexible approach with the conventional 'provider agencies' of central and local government becoming 'facilitator agencies'.

Community participation in technology such as rural water supply and sanitation is now widely promoted. However, most professionals have tended to believe that urban infrastructure is too complicated to permit the involvement of the beneficiaries in planning, implementation, operation and maintenance.

The consequence of this is the specification by the professionals of conventional standards of service such as those previously described which are too high and do not reflect the needs and priorities of the beneficiary community (Bahl and Lin, 1987). It has already been suggested that such service levels are too expensive, unsustainable and unreplicable on the scale required. It also appears to be an over-provision of services when compared with the standard of housing that can be achieved in a self- build programme. Infrastructure is frequently constructed by commercial contractors who have little connection with the area and charge an excessive mark-up over and above realistic costs and profit margins.

Lowering infrastructure standards is unlikely to be a straightforward task. Shankland Cox (1977) rightly comment that it is often difficult to batter down long-standing commitments to out- moded standards in order to carry through cost-reducing innovations. Van der Linden (1986) also comments that "the struggle for low standards appears to be a hard one." Almost invariably the local authorities insistence on high standards is a problem in sites and services projects.

As an illustration of this difficulty, one survey of infrastructure standards reported that 83.5% of the population of one particular area "used pit latrines or had no toilets at all" (Laquian, 1983). It is remarkable that the survey quoted by Laquian equates pit latrines with a complete lack of sanitation; it is clear that there is considerable confusion between the objectives of infrastructure and the means.

However, the poor, like the rich, are good at evaluating and ordering their own needs and priorities (Tym, 1984). To formulate designs and financing proposals without consulting them is now seen to be courting failure. What is required are "rigorously applied minimum standards" which avoid the all too common situation where the facilitating agency places a higher value on infrastructure than do households (Van der Linden, 1986).

It is now believed that individual householders and groups of householders forming a small cluster or community can take significant responsibility for their own infrastructure provision. This responsibility should include:

- involvement in planning and choice of technology;
- determining the rate at which improvements are made;
- organising and managing skilled artisans and sub- contractors to implement the works as and when the community thinks appropriate.

It is important to emphasise that 'involvement' means a lot more than providing unpaid labour; it should assign to the beneficiaries a central role in decision-making.

Who pays for services ?

It is a commonly held view that "the government" in some shape or form should be the provider of services, notwithstanding the fact that conventional standards of service are generally unaffordable in low-income countries. A much wider range of options for financing needs to be explored, involving central government, local government, communities themselves, and individual householders. The future success of improving the lot of the urban poor is likely to depend strongly on developing new and more flexible approaches because it is unlikely that "the government" is going to come up with all of the answers. The inertia from which central and local government agencies frequently suffer suggests that communities and individual householders may be the key actors in improving their own conditions.

Changing approaches to the provision and financing of physical infrastructure are suggested by a number of organizations. It was believed that off-site and on-site infrastructure could not be successfully organised by the individual as " they are a public good" (Tym, 1984). However, the Organisation for Economic Cooperation and Development 1987) is now suggesting that a new trend affecting the organisation and financing of public services is the reconsideration of the definition of public and private goods in the field of services provision.

"Strong pressures linked to slow rates of economic growth and the objective of limiting taxation to stimulate private sector activity, along with consequent limitations on public revenues, have led governments to take a close look at their roles and responsibilities in the national economy. They have sought innovative approaches which do not assume all urban service provision should be entirely in the hands of the public sector or financed entirely by tax revenue".

The report goes on to argue that the ability to finance infrastructure and service improvements other than through general revenues may work in favour of a more sustainable budgetary position for urban administrations. Cost recovery techniques including user charges, fees, licenses, rentals or special assessments are becoming increasingly important for cities.

There is clearly a multitude of ways in which services can be funded and different approaches are needed to match the local situation. Nevertheless full involvement of communities and individual householders is an essential component for success. This feature is incorporated in the approach to the delivery of services which is described in the following section. This particular approach allows for the capital cost of basic infrastructure to be paid for by the sponsoring agency (for example, a national housing authority or a local urban development authority) but for all operation and maintenance costs and any additional capital costs to be paid for by the householders.

This approach is not presented as "The Solution" to the problems; obviously many other approaches and mechanisms are possible. What is important is to demonstrate that the previously narrow views about service provision need to be and can be broadened to incorporate new ideas and options. The further development of new ideas is essential if the burgeoning problems of urban services and shelter are to be successfully tackled.

Delivery of services

Objectives and means

The affordability gap between the cost of conventional service standards and income levels of the urban poor is so large that the objectives and requirements of physical infrastructure need to be reconsidered. Specific sector objectives are discussed in the relevant technical chapters. However, in general terms, these objectives can be thought of as an attempt, primarily through the built environment, to obtain the following benefits:

- public health;
- safety;
- social well-being;
- general convenience and status.

The means of achieving these objectives is through the provision of physical infrastructure; however, confusion arises if, for example, the provision of a sewerage system is regarded as an objective in its own right. This is misleading; the objective is to achieve public health benefits through satisfactory disposal of human wastes, and there are ways of achieving this other than by installation of mains sewerage.

A further problem is that whilst health benefits are often used to justify investments, there is little quantitative evidence to suggest "what benefit" accrues from "what investment". This creates serious difficulties because the level of service provision needs to be questioned in view of the unacceptable cost of conventional service standards which may give high but unaffordable benefits. The problem becomes one of identifying incremental benefits accruing from incremental investment.

In reality, many slum dwellers exist in an environment which totally lacks drainage, sanitation, suitable access, solid waste removal, and power supply; there may only be access to small quantities of grossly polluted water. In effect, this corresponds to a 'zero baseline' service level. Any improvement in service is therefore likely to result in some benefit to the inhabitants. This suggests an alternative approach whereby the level of service is increased in an incremental fashion to give incremental benefits in health, safety, social well-being and convenience over a period of time, and to move away from the view that conventional service standards are an objective in their own right.

Primary level of service

The primary level of service is defined as that which produces the first and lowest stage of improvement above the zero baseline of physical infrastructure to satisfy basic needs in each sector. It is a starting point in the achievement of objectives which are commensurate with the standard of housing. Appropriate primary level services are suggested in Table 1.2.

Primary level service is not designed to meet the desires of householders or politicians for high service standards which are above the level of sustainability. It aims to provide buildable land with positive drainage which is marked-out for plots and access ways; a communal water point; supervised temporary communal latrines; and solid waste removal. These services are basically 'communal' in nature; for example, stormwater drainage external to the housing plot cannot be undertaken as an improvement by an 'individual' because a drainage system must be planned and designed in its entirety if it is to be effective.

Slum upgrading projects may already possess primary level services with the possible exceptions of adequate rights of way and drainage. The provision of primary level service is an appropriate infrastructure objective in order for householders to take up residence on a new site and begin to construct their housing.

The need to replicate projects on a large scale has led to the belief that householders will have to pay the cost of their housing and the support infrastructure. The United Nations Centre for Human Settlements (1984) goes so far as to say that "basic infrastructure projects should aim at full cost-recovery". The extent to which this is a practical proposition at all levels is questionable. Sites and services projects which achieve full cost recovery may in fact be housing middle-income rather than low-income groups; many of the urban poor may simply not be able to afford to pay for total cost recovery, and the question which must be faced is whether the poorest people should be left wallowing with 'zero' infrastructure as a matter of principle.

It is suggested that primary level service should normally be provided without cost to the householders

Table 1.2: Options for infrastructure development

	PRIMARY Promoted and funded (capital only) by agency		INTERMEDIATE Promoted and funded and maintained by household and community charges with loans from agency	ULTIMATE Promoted and funded and maintained by local taxation through municipality
			Limit of agency enabling	
	OBJECTIVE	**MEANS**		
GROUND PREPARATION	Building land free of inundation or erosion	Engineered, contoured fill or cut	Landscaping of semi-private & semi-public land	Landscaping of public land
DRAINAGE	Safe disposal of sullage; rapid disposal of storm water	Soakage pits Lined drains from water points Earth storm drains	Lined sullage drains Lined road drains All drains lined	Open drains covered in cluster or piped drains
ROADS	Pedestrian and vehicle access to all houses at slow speeds	Profiled and compacted earth roads	Profiled & compacted gravel roads Water bound macadam roads Bituminous surfacing	Bituminous macadam
WATER	Potable water within reasonable distance	Water point per 200 people for 20 litres pc	Water point per cluster Yard connections Metered house connections	Metered household connections In-line water storage Solar water heating
SANITATION	Safe disposal of excreta	Temporary communal latrines with restricted entrance	Household improved pit latrines Household off-set pour flush latrines Communal septic tanks Reduced cost sewerage Communal latrines and bathing, restricted entrance	Conventional sewerage
SOLID WASTE	Adequate removal and disposal of solid waste	Communal bin within 100 metres	Increased number of communal bins Street corner collection	Kerbside or household collection
POWER	Economic power consumption; Future power line installation	Allowance for improved cooking stoves; Clearance maintained between plot boundaries and access routes for O/H lines	Security street lighting One amp semi-conductor fuses Full street lighting Five amp semi-conductor fuses	Household energy meters
COMMUNITY STRUCTURES	Acknowledged meeting place	Designated site with temporary shelter	Secure offices on designated site Secure meeting hall and offices	Social, educational and medical buildings
	principally for health benefits and for social necessities		*principally for convenience benefits*	

excepting reasonable land charges and possibly a water use charge.

Incremental upgrading

Improvements to and upgrading of services beyond the primary level should be the responsibility of the householders and the immediate community, with respect to planning, implementation and payment for the improvements. It is vitally important that the detailed design of the primary level infrastructure is carried out with a view to these subsequent improvements. For example, provision of adequate access widths for future improvements is particularly important. The whole issue of how the choice of a particular facility in one infrastructure sector affects the other sectors is highly complex and such 'Interactions' are dealt with in Chapter 9.

The facilitator agency or municipality may assist through the provision of long-term loans to both individual householders and to community organisations to enable service levels to be upgraded. Additional help can be provided through technical advice and demonstration units. However, the site dwellers should demonstrate their commitment to these improvements by being prepared to pay not just the user charges but also the capital cost. Otherwise the investment is likely to be wasted as maintenance is not carried out and systems fall gradually into disrepair.

Incremental upgrading gives householders and site communities the opportunity to upgrade their physical infrastructure at their own pace, as and when they believe they can afford it. This upgrading is rarely constant and systematic; rather it tends to be haphazard and unpredictable. Expensive options such as mains electricity supply are likely to be desired and paid for before less costly improvements such as drain lining which bring the aesthetic benefits desired by donors and planners.

Some upgrading may be started immediately. For example, whilst temporary communal latrines theoretically solve the problem of excreta disposal, many authorities rightly encourage the construction of on-plot pit latrines in parallel with house construction.

Budgeting for such incremental improvement is also difficult. Fashions change, even in physical infrastructure and on occasions the demand for loans for upgrading may be high and at other times there may be no demand at all. One way to overcome this problem is to set up a revolving fund specifically for infrastructure improvement. If the fund is over-subscribed then applicants have to wait until sufficient monies have been repaid. This can also act as an incentive for others to repay regularly.

A system of loans for upgrading and charges for operation and maintenance costs is only as effective as its enforcement. If the people learn that no action will be taken against defaulters, whether out of political considerations or simply from mismanagement, then the programme will fail. If the people want the improvements, particularly if they relate to status and convenience, it is reasonable to expect them to be paid for. If they are not paid for, then it is likely that the full benefits will not be realised anyway and therefore the investment could have been more productively used elsewhere.

Evaluation findings from past projects suggest that planners have been tempted to build too many components into their schemes, "seeking to internalise all important externalities at once" (Keare and Parris, 1982). The approach described here aims to hand over responsibility for timing and progress to the community itself.

The effect of incremental upgrading on financial cost has been investigated by Franceys and Cotton (1988) using a case study from Sri Lanka. A summary of the findings is given in Table 1.3; a considerable saving in overall discounted costs of 53% can be achieved with an even more valuable saving to the sponsoring agency of 77%.

Table 1.3: Effect of incremental upgrading on servicing cost, expressed as discounted cash flow in US $

	Mode 1	Mode 2	Mode 3
Household loan repayment or utility charges	106	252	28
Agency non-recoverable costs (capital, operation and maintenance)	809	186	192
Total	915	438	220

Mode 1: existing approach of high level of service provision by an agency.

Mode 2: proposed incremental option approach with community take-up of loans. (This example assumes individual toilet and leaching pit with staged introduction of other services above primary level over a fifteen-year period.

Mode 3: Proposed incremental options approach but without any loans being taken up to upgrade the service levels.

Each discounted cash flow is the sum of the capital, operation and maintenance costs for drainage, roads, water supply, sanitation, power supply and solid waste removal. The discounting period is 15 years using a discount rate of 10%.

Ultimate level

Ultimate level service provision simply marks that point at which the facilitator agency ends its particular support. There is no restriction on householders continuing to improve their facilities as their resources allow. In Table 1.2 it is suggested that the ultimate level of what might be considered as conventional infrastructure should be promoted and funded and maintained only as local taxation and the institutional capacity of the local municipality allows.

There is a physical restriction to infrastructure expansion in that plot sizes on low-income sites are likely to be smaller than on higher-income sites. This is one means of screening out householders with above average incomes who might prefer to use their wealth on larger plots, not associating so closely with the 'poor'. However, planning studies suggest that a range of incomes on a site is desirable to enhance employment opportunities.

The retention of housing sites which do not have the full range of facilities (above primary level) could be considered to be beneficial in the long term as they can act as the 'bottom rung' of a ladder of housing conditions. As people's wealth and status vary there are therefore options available in the housing market for moving up and down the ladder.

Householder and community involvement

In general, householders are motivated most strongly to provide and improve services for their own families. In the early years, all available finance is likely to go into the house construction and it is unlikely that householders will have surplus monies to invest in improved services. However, with a system of loans, payable in phases over a realistic time span it is possible to give householders control of the improvement of their services. With the disbursement of future funds dependent upon satisfactory repayment of existing loans, an incentive can be provided to encourage repayment.

Communal services which cannot be individualised such as roads and drainage need to come under the responsibility of a 'cluster committee', or 'community development committee', that is, an identifiable group of householders. For trunk services a site management committee is required to organise not only construction but also operation and maintenance, collecting rates as well as disbursing small maintenance contracts.

These ideals of community participation work most effectively where there are owner occupiers on site, that is, people who own the house on land to which they hold rights. Tenants within the household may aid the construction and loan repayment process with their regular rents which can be a significant aid to development. On new sites and services schemes the householders are clearly identified when the plots are allocated. However, on upgrading schemes there are likely to be absentee landlords with tenants occupying a significant proportion of houses. The tenants may be cajoled into helping to keep the site relatively clean but they are not likely to want to invest their time and efforts in improving their landlords' property through the provision of additional infrastructure, whether it be on-plot or off-plot.

In these situations the incentives of loans and grants may have to be complemented with regulations and bye-laws. Such rules can require a landlord to be occupying site housing before any disbursements are made for that plot though this is difficult to enforce long term; alternatively they can require the landlord to invest in basic facilities such as on-plot sanitation within a specified period.

Site management committees, community development committees and cluster committees all become important intermediaries between the local authority, any facilitator agency and individual householders. Great care is required to ensure that such committees are representative of householders, particularly where there are female-headed households or where there is a significant income variation on site.

Briscoe and de Ferranti (1988) consider that there are five conditions necessary for success in community-based projects:

- the communities must be involved in all stages of the project, not simply as unpaid labour;
- the roles and responsibilities of community and government agency must be clearly defined at the outset and both parties must be prepared to fulfil their obligations;
- the facilitator agency must act as a supporter of the community, not as the owner or manager of the programme;
- the contact between the community and the facilitator agency should be through staff whose primary skills are in organising and motivating communities rather than in technical matters;
- government agencies need to fulfil their limited but vital tasks of motivation, facilitation, training and technical assistance.

Affordability and willingness to pay

The approach to the provision of physical infrastructure described in previous sections assumes that the capital costs for primary level service are not recovered from the householders. The reason for this exemption is the understanding that the poorest in a community should not have to bear the development costs of the most unsuitable land.

There remains the operation and maintenance cost of primary level water supply and sanitation to be paid for by the users as well as any additional services. It is therefore necessary in the planning of these services to ensure that they are affordable by the low-income groups. Affordability has often been looked at as a simple percentage of income, commonly in the area of 20% for housing in general which is presumed to include the cost of services. Planners in the water sector have used figures of 3% of household income for water supply and 3% for sanitation. More detailed studies suggest that for the poorest a total of 1% to 2% is available to be spent on water and sanitation in total. However, it has been found that where water has to be purchased from water vendors because there is no alternative supply, people may be paying up to 56% of their income at certain times of the year, that is up to 120 times the amount paid by those with a household connection (Cairncross and Kinnear, 1988).

Affordability therefore must be linked with 'willingness to pay' which depends not only upon income levels but also upon the perceived benefits to be gained from the service, the characteristics of any existing service and the level of service being purchased. For example recent surveys in Zimbabwe show that people are prepared to pay 2.3 times as much for yard connections as they are for standposts (Briscoe and de Ferranti, 1988).

Willingness to pay for any one service depends upon the priority given to that sector. For example in Indonesia, electricity is considered a higher priority than a water connection and users are unwilling to pay more per month for water than they pay for electricity (Briscoe and de Ferranti, 1988). Priorities between services and willingness to pay for different levels of service are impossible to determine in advance by top-down planning. It is for this reason that the model proposed in Table 1.2 gives considerable freedom to householders and their community to make their own decisions in their own time.

This approach aims to demystify the planning process and the technology involved so that householders can purchase elements of infrastructure in a similar manner to purchasing any other product from the local market place:

- they can see what they are getting for the agreed price;
- they can be advised as to the running costs of any particular item;
- they have complete ownership of the goods and recognise their responsibility to care for and maintain them, because if this care and maintenance is not done by the owner there is clearly nobody else who should be doing the work.

Institutional support

The improvement of infrastructure on low-income housing sites is frequently hampered by the large number of central and local government agencies likely to be involved (Marsden, 1988); there are considerable institutional weaknesses to be overcome in order to implement successful schemes which involve community participation on a wide scale.

Because of the nature of urban development which covers so many different departmental responsibilities there will always be difficulties in integrating roles. McGarry (1982) suggests that it is difficult enough to combine water supply and sanitation let alone other engineering disciplines as well. The problems of interdepartmental conflicts and jealousies, inadequate financial resources, low management capabilities and underpaid staff all lead to a housing environment which is below potential.

The role of specialised agencies such as housing authorities or low-income housing units can be vital in overcoming inter-departmental delays. They are also most important in building up a reservoir of trained and experienced staff who understand the particular needs of low-income housing projects. However, this expertise has to be channelled through existing structures rather than bypassing them. It may appear quicker to go outside the bureaucratic procedures in order to achieve progress on site, but in the long run the existing departments and authorities will be responsible for operation, maintenance and renewal. They must therefore be a part of all that is planned and implemented, so that when the sites become fully operational there does not have to be a complete change of approach or at worst a complete failure in the supporting institutions.

'Actors' and 'participants'

The success of any project ultimately depends upon all the actors and participants working effectively together. Angel (1981) suggests that six groups of participants may be identified in any shelter and infrastructure scheme:

- "housers", primarily concerned with actual shelter;
- "community development workers" interested in community organisation and empowerment;
- "engineers" aiming to improve infrastructure and environmental health;
- "politicians" who need to be seen to be doing something for their voters;
- "international funders" who want to be seen to be helping the poor efficiently;
- "the people" who want to improve their quality of life and are pleased to get anything they can out of a project.

Angel goes on to explain that no one "expert" could be considered to be fitting into one category exclusively. However, the engineers have tended to be far too remote from the planning, conceptual design, implementation and from the beneficiaries themselves. They have often been in the situation of being given a completed layout by the "housers" with the expectation that they fill in the services according to normal standards. This inevitably leads to the use of conventional contracts and contractors constructing works to standards which require cost subsidies and which no members of the community can afford to maintain.

It is essential that the work of engineers, planners, architects and community development workers is fully integrated; the success of innovative approaches to shelter and services provision necessitates attitudinal changes amongst the professionals.

Conclusion

The provision of services for shelter has to be viewed from a new perspective. Traditional high-cost, high-technology solutions for many low-income communities are not sustainable; an alternative approach is needed which harnesses the multiplicity of resources which households and communities possess.

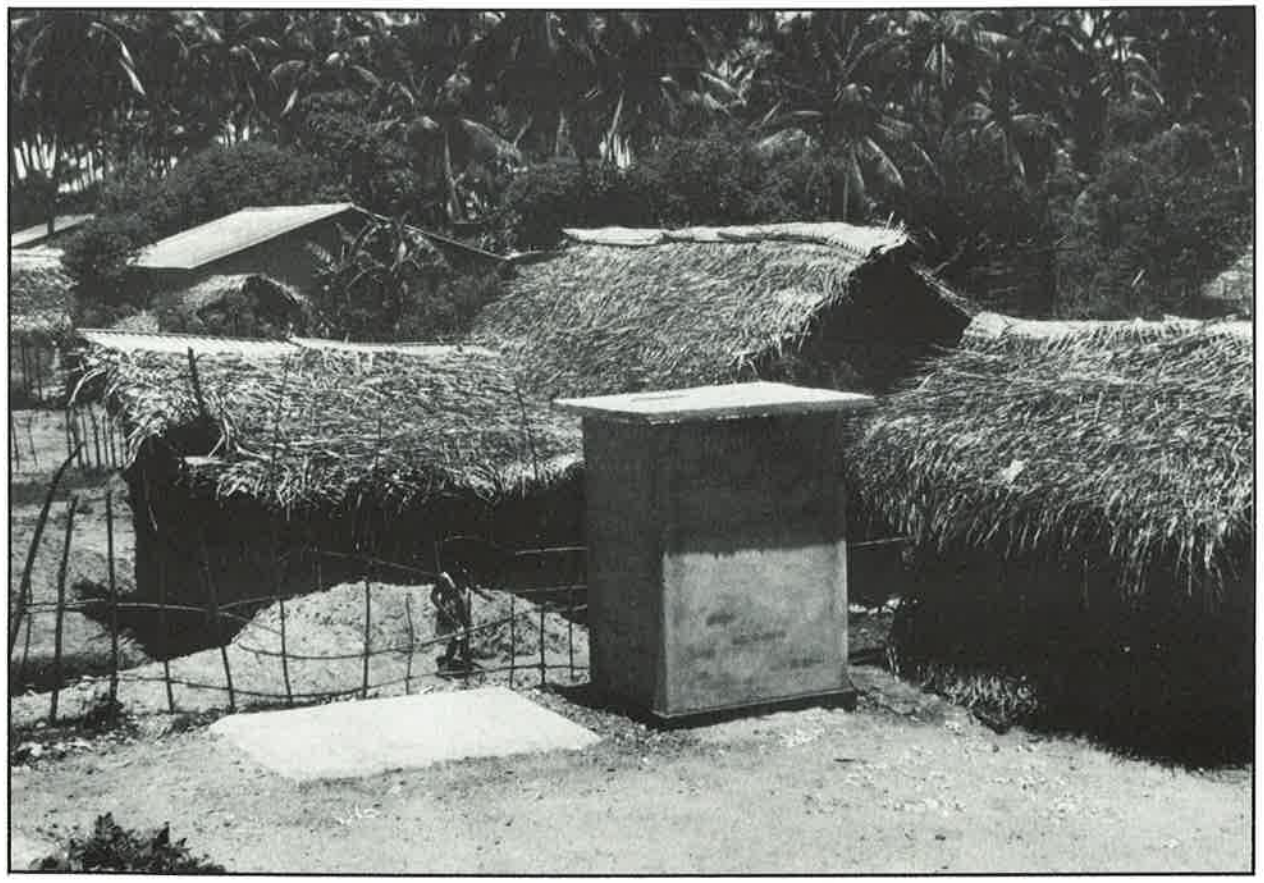
Primary level infrastructure meets the basic requirements of environmental health and safety, with the capital costs funded by the implementing agency. Careful design of the primary level infrastructure enables the level of service to be upgraded over a period of time. It is the householders and the community who should decide what the future service levels will be; this is the only way to reflect the priority which households and communities give to the greater benefits which result from improved service levels. The capital costs of such improvements should be paid for by the benficiaries, although a facilitator agency would usually be expected to provide loans to finance the improvements.

Such an approach gives freedom to householders and communities to make their own decisions in their own time which reflect their priorities. This cannot be achieved by 'top-down' planning which necessarily involves professionals making value judgements on behalf of the beneficiaries. Full involvement of the people at all stages should engender a sense of ownership of the services with greater likelihood of satisfactory maintenance.

Below: Householders inhabit temporary shacks along the roadside whilst constructing brick dwellings immediately behind

Above: Engineers and planners must work together! A concrete road is pointless if its access is restricted in this way

Below: The householder builds his latrine with aid of a loan before commencing house construction



Ground preparation 2

Objectives

Many sites available for urban resettlement are on marginal land; squatters frequently inhabit such sites which private or commercial developers do not think it worthwhile to use. An exception to this is where government land is released for low-income housing having been previously reserved for other purposes. Because there are no other sites available at an affordable price or within acceptable travelling distances, the apparently unsatisfactory land has to be improved to provide locations for low-income urban housing schemes.

Typical examples of marginal land are:

- low lying and marshy ground, close to major land drainage such as rivers, streams and canals where the water table is high and the risk of flooding is also high;
- steep slopes with problems of excavating building plots, erosion due to poor drainage and danger of landslides.

The main requirements for developing such land for low-income housing are:

- to provide a suitable foundation for low-rise buildings;
- to facilitate stormwater and sullage drainage without danger of erosion or ponding;
- to limit inundation by water from surrounding areas;
- to prevent the danger of ground movement.

To upgrade marginal land to the desired standard, the options open to existing communities and to any facilitating agency appear to be expensive and time consuming. There are rarely any simple, cheap, 'appropriate' or intermediate alternatives for ground preparation.

For people on low incomes with limited resources, the ground has to be adequate before prospective householders can be expected to build upon it. Where householders are investing much their wealth in their future homes it is not acceptable to have the land settle significantly after housing construction or for it to be flooded at frequent intervals.

In particular, where householders are involved in participative building programmes, often designing and building their own homes, great care must be taken to ensure that the resultant housing is not likely to suffer from inadequate site preparation.

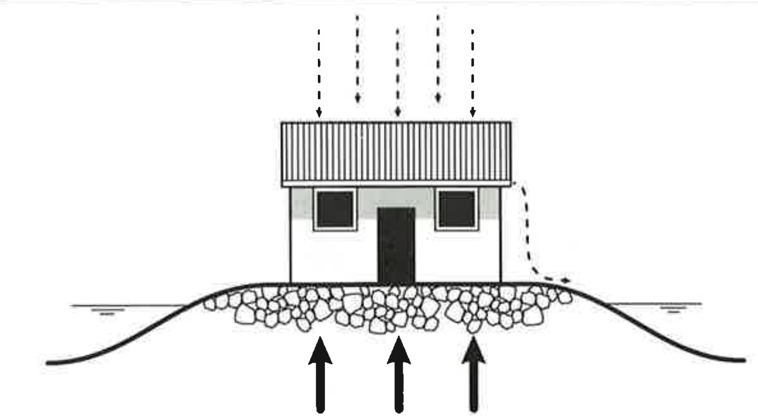


Figure 2.1: Housing needs for foundations and water disposal

Preparation of low-lying land

There are three main options to be considered for ground preparation of low-lying land: drainage; protection; and filling. In extreme situations it may not be possible to prepare the land adequately and the only option is for the dwellings to be built upon stilts over water with inter-linking bridges between houses. The major difficulty with such an approach is to provide safe sanitation.

Drainage

Wherever possible, marshy or water-logged areas are drained. Should the local water table be perched, it may be possible to breach the impermeable soil barrier to allow the surplus water to drain away by gravity through a suitable ditch or canal (Figure 2.2). However, this is only feasible in a limited number of cases.

Where gravity drainage is not possible, an alternative is to construct land drains across the site leading to a sump or depression in one corner. The water that collects is then pumped to the nearest suitable river, canal or drain (Figure 2.3). This method, although common in certain parts of the world, requires expensive high capacity pumps to deal with very large stormwater flows and a constant guaranteed power source with considerable operations and maintenance back-up. It is unlikely to be suitable for low-income housing except where there is clear commitment by a local authority or, very rarely, a community.

Protection

Protection of an exposed site is possible using a bund or dike. An embankment is constructed around the proposed housing area to a finished level which corresponds to a defined probability of flood waters over-topping the embankment. Stormwater and sullage is disposed of via pipes leading to a pumping station or passing directly through the bund, discharging into a canal or drain through flap valves (Figure 2.4). Construction costs are normally less than general filling of a site, but the method depends upon the reliability of the flap valves. Leaking valves may cause the site drains to surcharge, that is to fill up and overflow.

If the sullage is collected in open drains, the valves must open under minimal head to discharge the waste water. To be light and flexible enough to open under these conditions makes the valves susceptible to failure under high external heads. It is common to find such valves jammed open with waste material that causes the site drainage system to surcharge and flood. Thorough and regular maintenance is required to ensure that the flaps prevent flood water backing up into the site.

Where the valves do work, there is always a danger of over-topping of the embankment under extreme conditions. This might lead to failure of the bund such as occurs when an earth dam is over-topped. The subsequent flood of water would lead to significant damage to housing.

An alternative method of protection is to provide storm ponds for temporary storage of flood water. Rather than overloading a drainage system and perhaps causing flooding downstream, the excess water is diverted to holding ponds and is then released slowly once the peak flows have subsided. Whilst of great value in peripheral housing areas, the land requirements are considerable and the system is not appropriate for densely populated urban housing sites.

Construction of floodwalls, channel improvements or bypasses on nearby watercourses are also recommended to reduce inundation (Caminos and Goethert, 1976). Straightening or widening channels can increase the velocity of a river flow and lower the water levels, which reduces the likelihood of subsequent flooding. Bypasses can divert flood water away from or around a site.

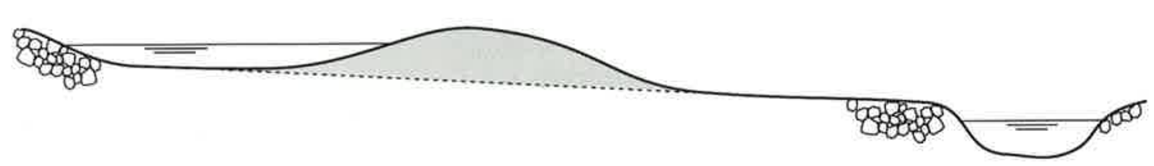


Figure 2.2: Draining water-logged areas

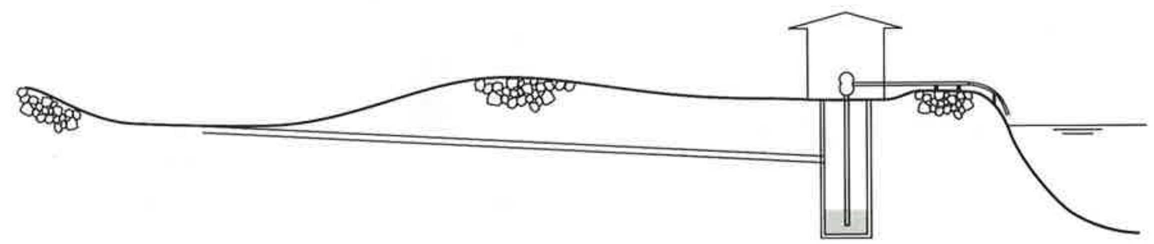


Figure 2.3: Pumping storm and wastewater from a housing site

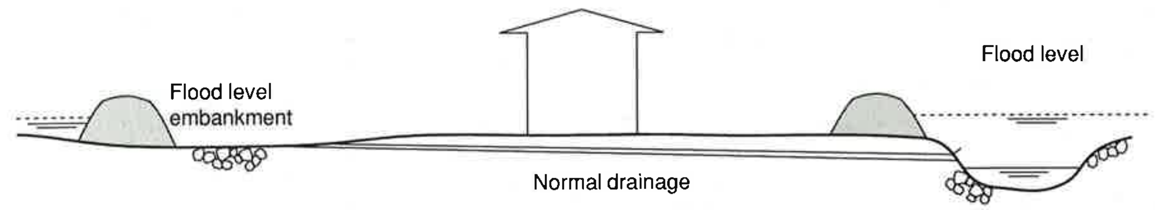


Figure 2.4: Embankment protection to a housing site

Fill

In most situations the cost of imported fill material is relatively high. However, it is likely that in many cases the only feasible option for long-term ground improvement is to bring in good quality material from outside the site to raise it to an acceptable level.

In certain circumstances, fill costs can be minimised by accepting substantial flooding on the site; the houses are protected by constructing high foundation walls to raise the floor above an acceptable flood level (Figure 2.5). This may be particularly appropriate on sites where the existing ground is good and firm, but are prone to frequent flooding; such conditions can arise close to sea lagoons. Road levels are raised so that they are similar to floor levels to permit access even when the site is flooded. However, this approach is only economical where plot sizes are significantly larger than house areas; otherwise it is cheaper to fill the entire site.

An alternative technique is to divide the land into strips and give householders a larger land allocation than normal. This allows people to excavate one part of their plot to obtain the fill required to build up the area where they want to construct their house (Figure 2.6). The excavated area should connect with excavations on adjoining plots to create a drainage channel with access to the nearest watercourse.

However, on most sites the ground is prepared by filling the whole site with good quality imported fill, levelled and compacted to suitable contours with an interval allowed for the fill to settle before construction commences. It is common to find that sites are filled to a common level to provide a flat surface for building on. This practice is not recommended as it leads to ponding of stormwater and inadequate disposal of sullage. A minimum gradient or crossfall of 0.33 per cent should be established in all areas of the site.

Preparation of sites on medium to steep slopes

Low-income housing increasingly comprises a medium to high density layout of small dwellings that can be built individually. This creates particular problems on slopes where the need is for low-cost solutions that do not require extra construction work. There are general elements of ground

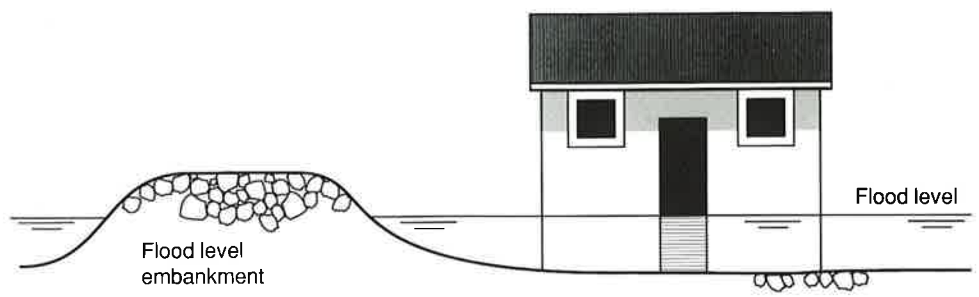
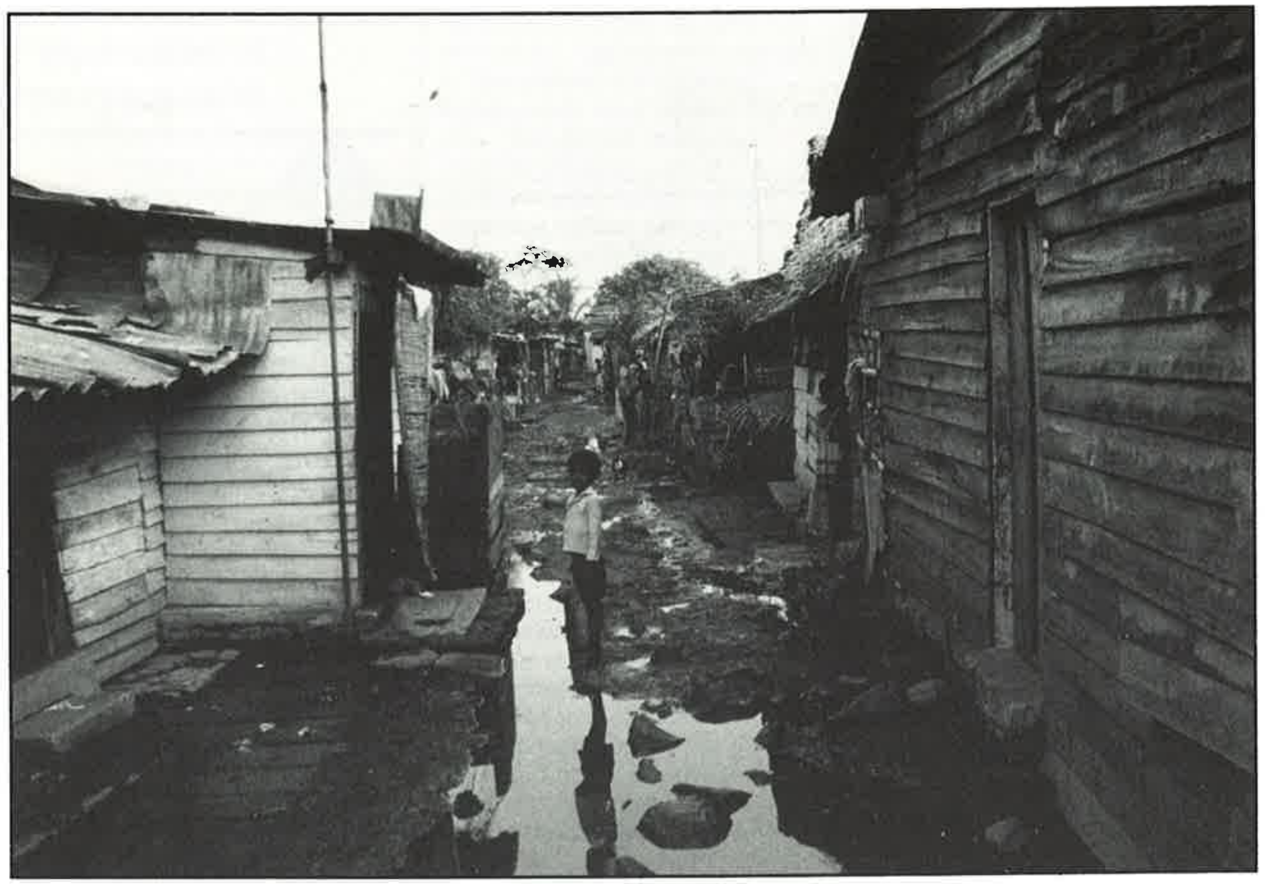


Figure 2.5: Raising a house above flood level



Above: The need for ground preparation demonstrated on an upgrading site

Below: Filling a site with community management - but without adequate compaction

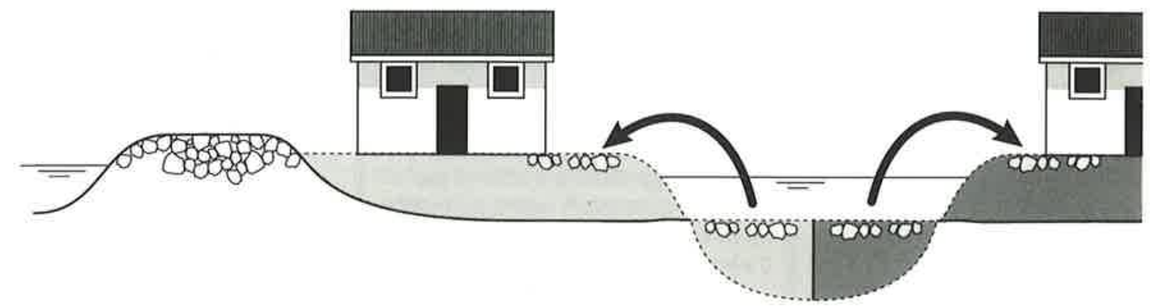


Figure 2.6: On-plot excavation and fill

preparation to be considered that enhance slope stability. Simpson and Purdy (1987) describe the use of slope alterations, control of surface water, limiting of ground water, terracing, hard surfacing and vegetation cover.

The major threat to housing on steep slopes is water, whether on the surface or in the ground. If the water flow can be controlled or modified, the slope is likely to be more stable and therefore the housing will be more secure and longer-lasting.

Developments up the slope have to be considered as well as changes down the slope. Both can modify patterns of water flow; loss of vegetation on the upslope leads to higher stormwater flows that can damage housing below; major works on the downslope can restrict the escape of ground water leading to saturated ground which is more likely to slip.

Hard surfacing can reduce the amount of water entering the ground as can appropriate vegetation cover. Rubble filled land drains collect and safely discharge surface water as well as draining the soil layer. Stepped buttress drains (Figure 2.7) provide a safe route by which the water can escape down the slope (Simpson and Purdy, 1987).

Extra masonry

On slight slopes of up to 5 per cent cross-contour drains should be provided which preferably are lined to prevent erosion. No other allowance has to be made for special ground preparation. The effects of the slope are catered for in the dwellings by the use of extra masonry on the downslope side of the buildings (Figure 2.8). The additional building cost is not substantial. Allowance might be made in any loan packages for house construction to take account of any such increases in cost.

Cut and fill

For medium slopes between 5 per cent and 12.5 per cent, cut and fill is the usual option. Ground is excavated and then banked on the downslope to form a level platform for house construction. There is a danger of differential settlement between the cut platform and the fill. This may be reduced by careful preparation of the downslope, requiring removal of the top soil and on occasion benching of the downslope before the fill is placed. The purpose of this work is to reduce the possibility of a slip plane developing between the original ground surface and the fill.

The final slope of the fill is limited to approximately 30 per cent for wet clays and 50 per cent for granular soils. Gupta (1986) suggests that cut slopes in ordinary soil are stable at slopes of 100 per cent for cuts of up to 10 metres. For ordinary soil with dense rooting or soft shales the limit is approximately 200 per cent. However, such slopes are only stable at these angles for a few

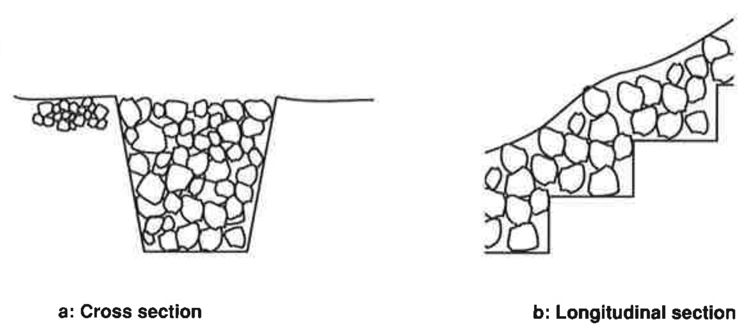
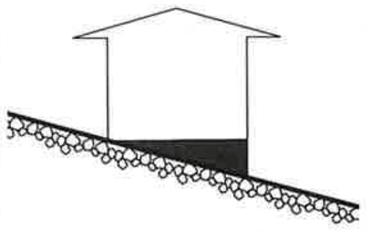
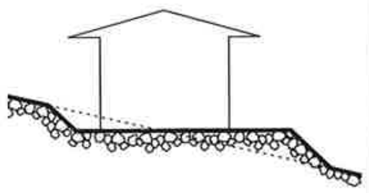


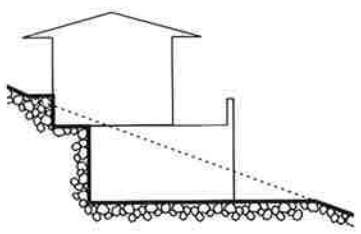
Figure 2.7: Stepped buttress drains



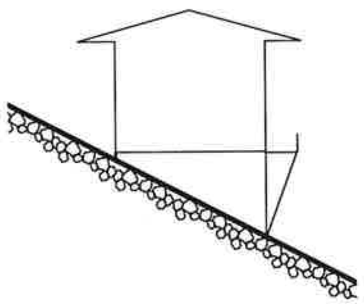
a) Extra masonry



b) Cut and fill



c) Amended section



d) Stilts

Figure 2.8: Building alternatives on slopes

years before the effect of weathering begins to reduce them to the natural angle of repose. To retain these slopes in the long term some form of ground protection or retaining wall is required. Retaining walls are expensive because of the need for deep, secure foundations and drainage blankets behind the wall to ensure that there is no build up of water pressure; if possible, their use should be avoided.

These limitations lead to an increased land-take per plot to accommodate the slopes. The amount of land taken up in this way is proportional to the width of the housing unit; longer and narrower designs of houses are therefore preferred.

Amended section

Steep slopes between 12.5 per cent and 25 per cent have potential problems of soil creep where the ground surface edges slowly downwards over many years; there are also dangers of mud slides. Except where the natural soils are particularly stable when excavated, a modified form of cut and fill is recommended. An amended section or stepped-storey dwelling is built in two or more stories with the upslope ground floor wall forming a blank retaining wall. This retaining wall in the house has to be waterproofed to prevent ingress of groundwater. With low cost building materials, waterproofing is not easily achieved.

Stilts

On very steep slopes between 25 per cent and 50 per cent there is an increased danger of soil instability. Slopes of 50 per cent are at the critical limit for naturally occurring slopes. Ground preparation is limited to provision of access ways with suitable drainage along the contours. Housing is accommodated by lightweight structures supported on stilts or posts.

Operation and maintenance

Operation and maintenance needs are necessarily limited in ground preparation. Long-term viability of the land for housing is influenced by the exposure to flooding, high water tables or erosion by water. Because of this, the section on operation and maintenance of drains in Chapter 3 is of particular relevance.

Vegetative cover around a site should be conserved to limit ground erosion; for example, turfing in Kuala Lumpur was found to reduce erosion by 50 per cent. Ground cover limits the nuisance from dust in dry seasons. Vegetation also serves to maximise cooling effects in the micro-climate whilst the planting of trees and bushes to create wind breaks or to provide shade is to be encouraged.

Cost recovery

The cost of ground preparation may be seen as part of the cost of acquiring land. Where major works have to be carried out to prepare the land before individual house building can commence, it is unrealistic to expect this cost to be borne by the householders. The primary level service includes the provision of buildable land, free from the danger of frequent inundation or erosion. It is a form of regressive taxation, penalising the poorest, to make low-income householders pay the cost of preparing unsuitable land.

Landscaping and the promotion and preservation of vegetative cover will normally be the responsibility of the site and cluster communities. Particular items such as tree planting around the community centre may be assisted by the facilitating agency but should be paid for and under the control of the community.

Detailed design factors

Filling of low-lying land

The recommended approach is to consider drainage as the starting point from which the ground contours can subsequently be established; this provides a sound method for ensuring that the different elements of site preparation are compatible. Therefore it is advised that this section is read in conjunction with Chapter 3.

The ground levels on site can be determined by considering the following factors.

- The need to prevent inundation by water that originates off the site, for example flooding from a nearby watercourse such as a river or canal. This implies that the site must be filled to a certain 'base level' which might reasonably correspond to the once in five year flood level in the watercourse. Where on-site sanitation is used it may be necessary to reduce this flooding frequency to once in seven or ten years. Estimation of acceptable frequency of flooding is necessarily arbitrary and subjective. However unacceptable any flooding might be to the future residents, increased levels of protection are likely to render low-income sites uneconomic.
- The need to remove stormwater from the site; this requires positive drainage which results from contouring the site appropriately to minimum gradients of about 0.33 per cent.
- The need to remove sullage water by lined open channels from all houses by ensuring a minimum gradient of 0.7 per cent on these drains.
- The requirement that building foundations should be constructed above normal ground water level. This gives a minimum depth of 500 mm of ground between the lowest point on the site where houses are to be built and the normal water table.

Determination of ground levels

The site base level (that is, the minimum ground level on the site before contouring) is the higher of either the once in five year flood level or 500 mm above normal ground water level as shown in Figure 2.9.

Each site will have one or more outfall drains (that is a drain which conveys the water that has been collected on the site to a discharge point in the watercourse). The length of a drain to the outfall point is very important.

The minimum gradient of lined drains that carry sullage should be 0.7 per cent to ensure adequate drainage of low flows. If the drains are to carry only stormwater, the minimum gradient should be 0.33 per cent. From the viewpoint of construction, operation and maintenance the maximum and minimum depths of open sullage drains should be fixed according to practical construction, operation and maintenance considerations. A recommended minimum depth is 75 mm, representing the depth of one brick (for where drains are constructed from brick) or 'half' a 150 mm pipe (Figure 2.10). A maximum depth is more arbitrary, taken here as 500 mm for safety and ease of cleaning.

Having fixed the site base level, the outfall invert level of the drainage network is fixed at 500 mm (i.e. the suggested maximum drain depth) below that ground level. From this point, the highest point on the site can be determined by working back up the longest drainage line at a

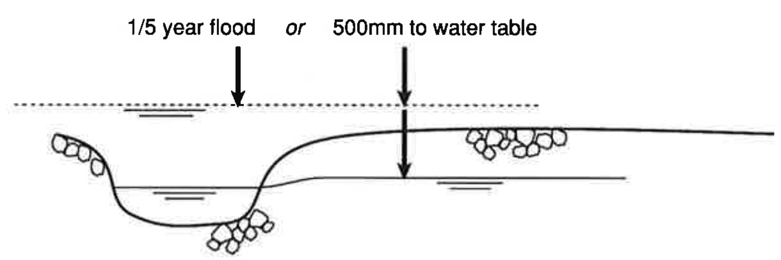


Figure 2.9: Base level for site filling

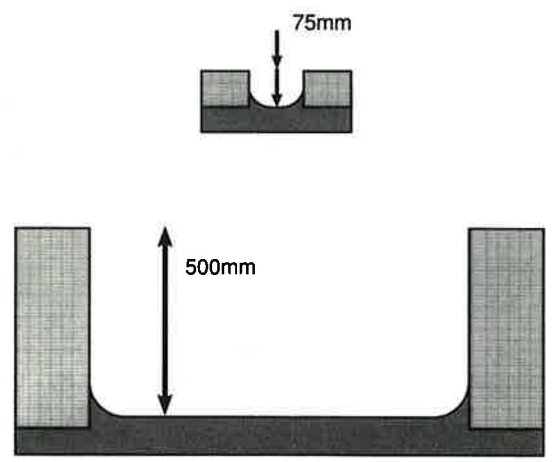


Figure 2.10: Site drain sizes for brick construction

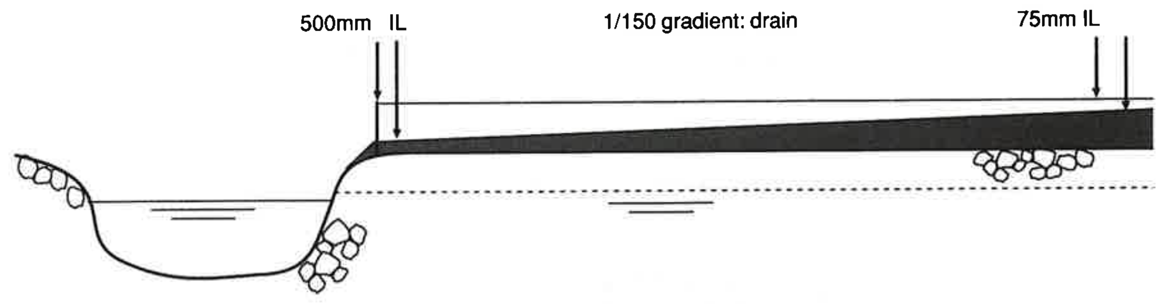


Figure 2.11: Determining site levels

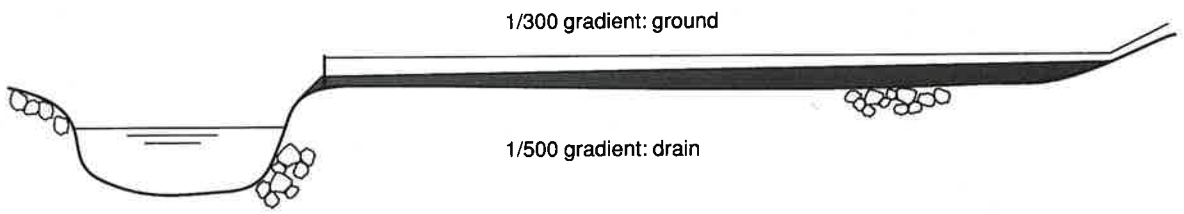


Figure 2.12: Minimum gradients on small sites

gradient of 0.7 per cent (combined stormwater and sullage drains) or 0.33 per cent (stormwater-only drains). At the highest point, the ground level will then be 75 mm (i.e. the recommended minimum drain depth) above the drain invert level (Figure 2.11).

The ground levels and falls across the site are then fixed by the calculated high point and low point. Because of the importance of the length of the longest drainage run in determining levels, it is important to consider how to minimise the distance of the furthest house to the drainage outfall point.

On a small site where the maximum drainage run is 60 m or less, the above criteria would lead to the creation of a flat site at a height of the base level. However, to prevent ponding of water around the houses it is important to create positive drainage across the land surface. Any increase in ground level can appreciably add to the costs of site development. A minimum site gradient of 0.33 per cent (Figure 2.12) is therefore recommended, this being the minimum that is practicable to construct given the problems of site supervision and control.

There is no conflict in having different slopes for the drains and the ground profile; the result is that the drains increase in depth in the direction of the outfall. This is significantly cheaper than accommodating the drains by increasing the ground slope to 0.7 per cent with the attendant increase in fill volume.

However, if the resultant site gradient is steeper than 0.36 per cent the cost of ground preparation is likely to be unacceptable; in this case, the option of bringing the outfall into the watercourse closer to the site should be considered. This can be done by excavating a small canal about 2 metres wide and 1.5 metres deep (Figure 2.13). In such a situation the canal is not acting strictly as an outfall drain; it is sufficiently large to provide temporary storage capacity for the discharged drainage water and flow occurs in the direction towards the watercourse as the hydraulic head increases at the point of discharge from the site into the canal.

Whilst this solution overcomes the problems of stormwater drainage, it causes additional difficulties if the surface drains are used for sullage

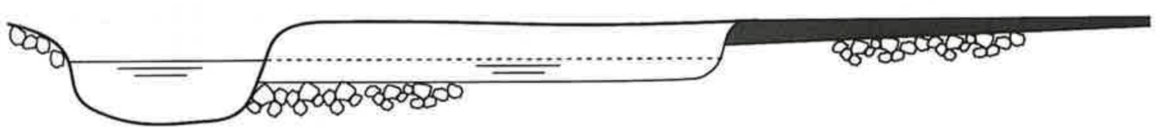


Figure 2.13: Small canals for site drainage

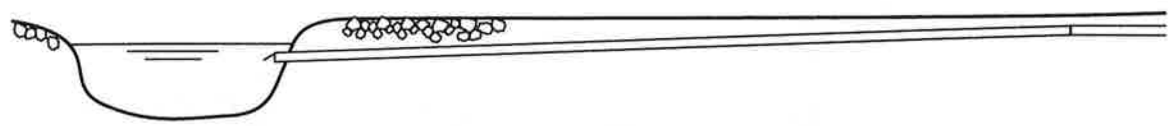


Figure 2.14: Drainage discharge below normal water level

disposal. During periods of no rainfall, the drains discharge only sullage into the canal, which results in a deterioration in water quality. Where the nearest watercourse is some distance from the site and a subsidiary canal is not feasible, an alternative option is to construct the outfall drain as a buried pipeline. The high point on the site is determined by a gradient of 0.33 per cent above the base level (previously fixed according to flood levels). On a large site, the invert level of the outfall at the watercourse may be below mean water level (Figure 2.14). This requires either a flap valve at the discharge point to prevent backing up, or allowing the outfall drain to be partially submerged for much of the time.

There are practical difficulties relating to the condition of the banks and bed of the water course at the discharge point and the degree of silting that occurs. To cope with the maximum stormwater flow, the hydraulic design of the outfall has to be executed with care; it must be ensured that the site does not flood due to the stormwater backing-up in order to create sufficient head to discharge under submerged conditions.

A summary of the recommended design procedure is as follows:

- determine site base level from the once in five year flood level or 500 mm above normal ground water level, whichever is higher;
- fix the depth of the lined drain at the outfall; the recommended depth to the invert is 500 mm;
- from the outfall invert level, work back along the maximum drainage run at an increasing gradient of 0.7 per cent;
- determine the ground level at highest point of the site by adding the minimum drain depth (the recommended value is 75 mm) on to the drain invert level at the most distant point along the drainage run;
- check that the difference in ground levels between the high point and the base level at the outfall gives a site gradient of not less than 0.33 per cent. (Where a site gradient of 0.33 per cent rising from the base level intersects with the existing ground level before reaching the boundary of the site it is acceptable to have two different grades across the site);
- if the resultant ground slopes are too steep, consider the alternative options of small canals or buried pipeline outfall drains.

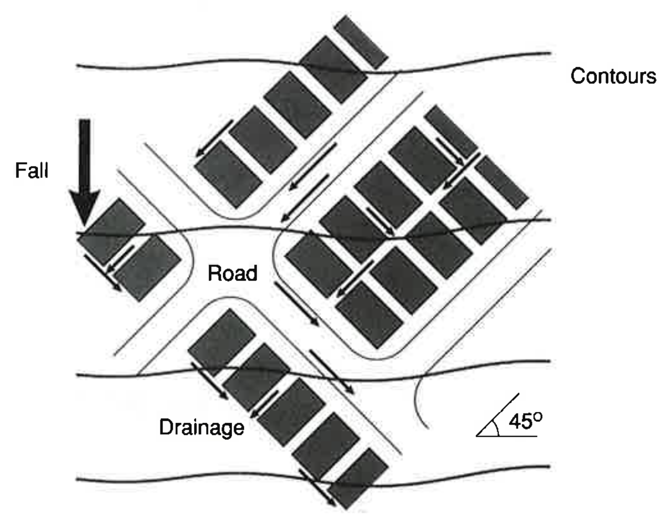


Figure 2.15: Building orientation to gradient

Determining site contours

The crossfall of the ground should be in the region of 0.33-0.37 per cent to achieve positive drainage whilst minimising the cost of importing fill material. One way of using this crossfall is for the road and building grid to be laid out at an angle of 45° to the maximum gradient, that is at 45° to the contour lines (Figure 2.15). This ensures positive drainage along both sides of any building (for removal of storm and sullage water) and there is automatically a fall on constant depth lateral drains as well as the main drains.

On a site that is initially flat and roughly square in layout, the minimum land fill is obtained by creating a central high point with four separate drainage areas, each falling to one edge (Figure 2.16). If there is an outfall on one side only, it is normally cheaper to construct drainage canals around the site rather than to fill the land to be suitable for a single outfall.

The drainage system of a linear site alongside an existing watercourse can discharge at several points. Positive drainage can be ensured by arranging the site layout at 45° to

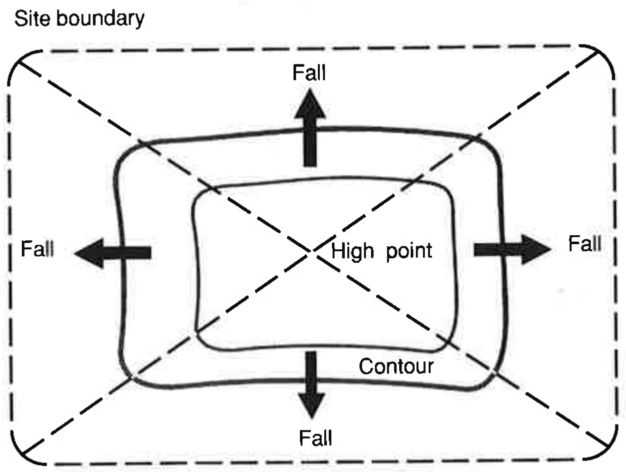


Figure 2.16: Minimizing fill for positive drainage

the canal, which nevertheless takes some ingenuity. The alternative is for there to be longitudinal rises and falls along the length of the site. The extra fill required to do this is substantial and it might be cheaper to construct the drains as pipelines to cope with the difficulty of increased drain depths.

Each site has its own specific problems governed by its shape, the natural ground contours and the proximity of suitable watercourses into which the site drainage system can discharge. There is no general solution applicable to all sites to overcome the problems of contouring; the only way to find the optimum solution is by trying out a range of alternatives using some of the methods outlined above.

Sites on medium to steep slopes

Over extremely long periods natural slopes tend to find their equilibrium. By a combination of very slow and more occasionally very rapid earth movements the ground profile for a particular sequence of soils and underlying rocks attains a stable angle of repose.

Where a slope has reached equilibrium, the first task of the engineer and planner is to ensure that any construction works carried out, whether affecting loading or water movement, do not jeopardise that stability. The second task is to ensure that excavations for cut and fill, considering both the newly excavated bank and the deposited excavated material, are also stable in the long term.

Where a slope has not reached a generally stable condition there is always the likelihood of movement at unpredictable intervals; different types of movement are described below. In situations where householders have already built housing on unstable hillsides it is unrealistic to expect to be able to prevent ground movement. However, it is possible to prevent the results of the housing development accelerating ground movement that might otherwise have catastrophic effects.

Stability of slopes

Slippage occurs on slopes where the shear stress between layers is greater than the shear strength. The increase in shear stress, described by Simpson and Purdy (1987), can be caused by:

- an increase in slope because of earthworks;
- buildings upslope causing additional loading;
- changes in drainage patterns caused by earthworks resulting in increased soil weight;
- subsidence or swelling of shrinkable soils;
- slip paths created by ineffective drainage

Various types of mass soil movement described in Institution of Civil Engineers (1976) are summarised below.

Creep; soil creep is the slow movement of the soil layer down the slope at a rate of between 10 mm and 1000 mm per year. The rate of movement is affected by diurnal temperature variations and seasonal rainfall. Trial trenches normally reveal evidence of the movement declining with depth whereas surface symptoms include surface cracking, variations in gradient and angular movement of trees or structures.

Mudflows; descriptions of mudflows are divided into mudslides with slow mass movement of not more than 10 metres per day on slopes greater than 10 per cent, and mudspates where there is rapid movement higher than 1 metre per second of material with a high water/soil ratio on slopes as low as 1 per cent. The flows usually are caused by old landslides, resting on well developed shear surfaces being artificially re-mobilised.

Rotational and translational slides; major slides are dependent upon the geological structure of the slope. In general, unstable slopes susceptible to these types of slides are less likely to be used for housing, even by illegal squatters as the signs of past failures are normally evident. Rotational slides occur where soft, weathered or over-consolidated clays are over-loaded such that a circular or planar movement can take place. Compound slides describe the effect of non-cohesive soils overlying soft stratum or clays and silts overlying firm ground. Translational slides occur where a weak layer exists parallel to the surface of the slope.

Table 2.1 Approximate angle of repose

Clay	wet	30 %
	dry	50 %
	well drained	100%
Sandy clay	wet	35 %
	dry	70 %
Compact earth	wet	100%
	dry	70 %
Sand	wet	50 %
	dry	65 %
Sandy gravel	dry	70 %
Gravel	wet	50 %
	dry	85 %

Slope stabilisation

There are two main methods of stabilising existing slopes:

- adjustment of the loading on the slope by the transference of ground load from the top of the slope to the toe; in effect, this is artificially carrying out what a slip would do naturally;
- drainage; Institution of Civil Engineers (1976) comments that it is often stated that water causes lubrication of slip surfaces but this is secondary; the principal action of water is the reduction of effective stresses across the slip surface, leading to reduced shear strength.

Effective drainage is essential to reduce the risk of slides. Sullage water, waste water and stormwater must all be disposed of in a way that does not lead to erosion of the surface. Shallow groundwater may be controlled by land drains as described earlier.

Stability of soils in excavation

Excavation is normally required on medium to steep slopes to form platforms for housing or benching for access routes. Most soils stand at a steep angle immediately after excavation has exposed the new face. It is tempting for low-income communities to assume that the face is therefore stable. However, weathering begins with the change in seasons and the exposed face gradually begins to fall to its natural angle of repose unless otherwise supported. The decision has to be taken whether to use an increased land-take in order to excavate to the angle of repose immediately, or to build expensive retaining walls.

The excavated material used to build the downslope also has to be deposited at the natural angle of repose suitable for loose material unless it too is to be supported by a retaining wall. Whether it is supported or not, there is a danger of this deposited material settling over time. Foundations for the housing should not span from the natural material of the bench on to the deposited material.

Natural repose of groundworks

The natural angle of repose of various soils to be used for determining stability of excavations and excavated materials is shown in Table 2.1

Breast walls

A breast wall or face wall is used to protect a newly exposed face to prevent its gradual collapse due to weathering. Using the natural strength of the undisturbed soils means that a thinner section may used than is possible for a retaining wall (Figure 2.17). Khanna (1990) recommends a thickness equal to one-fifth of the height for slopes of 200 per cent to 400 per cent. Alternatively a ferro-cement covering of layers of chicken wire and cement mortar may prevent weathering.

Retaining walls

A retaining wall resists the thrust of the fill material supported behind it; this thrust is trying to overturn the wall as well as causing it to slide horizontally.

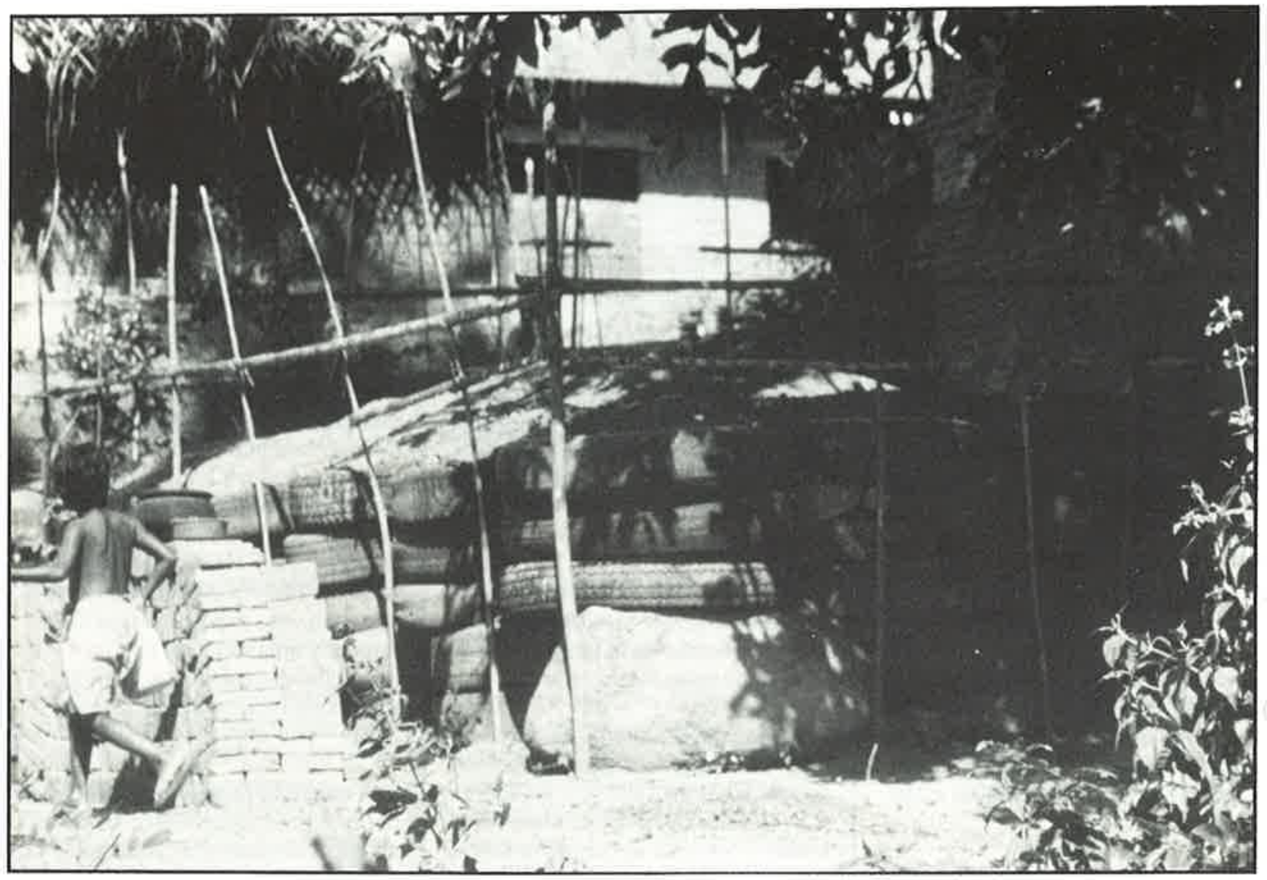
There are two main types of retaining wall: gravity and reinforced cantilever. Gravity walls are most likely to be used on low-income housing sites where dry rubble, masonry or brick can be adequately constructed by skilled masons (Figure 2.18). Reinforced cantilever walls in reinforced concrete or steel piles are very expensive and are normally only required for specialised applications such as protecting other services (Figure 2.19).

The height to breadth-at-base ratio of dry rubble walls should be taken as approximately 2.5 (Khanna, 1990) whereas for stone or brick in cement mortar a value of 3.0 may be used along with a suitably widened foundation. Counterforts or buttresses may be used to give extra support to a retaining wall, thus allowing the thickness of the main wall to be reduced between supports.

Failure of retaining walls is normally due to unequal settlement of foundations on long walls, excess of toe pressure, or lack of drainage.

Drainage and weep holes

If water is retained behind a wall, considerable increase in thrust results; the combined pressures of the soil and water can easily lead to failure. It is therefore necessary to ensure that any water in the soil can drain away. The normal practice is to build weep holes through the retaining wall to allow the small quantities of water to escape. Weep holes are normally set at 2 to 3 metre centres with a drainage blanket of rubble, gravel or coarse sands forming a permeable layer between the wall and the retained soils.



Above: Old tyres strengthening an embankment on a slope

Below: A site prepared without adequate gradient or drainage

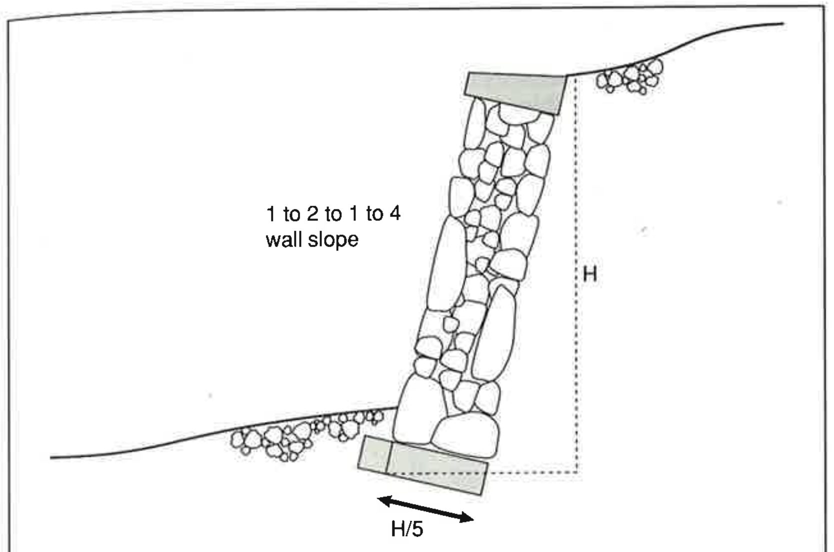


Figure 2.17: Breast retaining wall

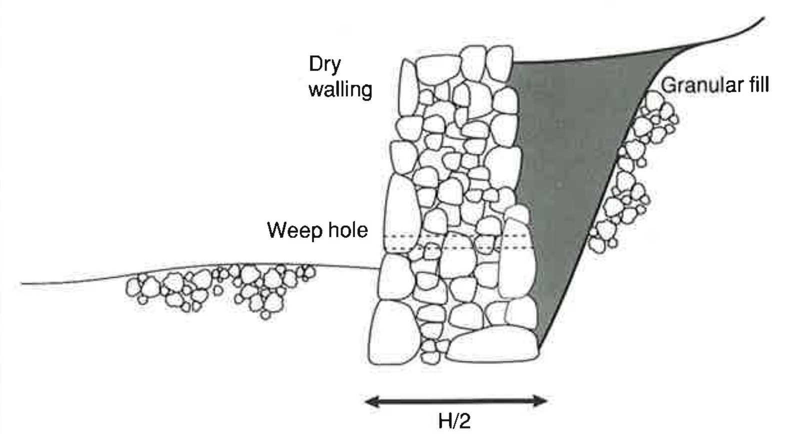


Figure 2.18: Retaining wall

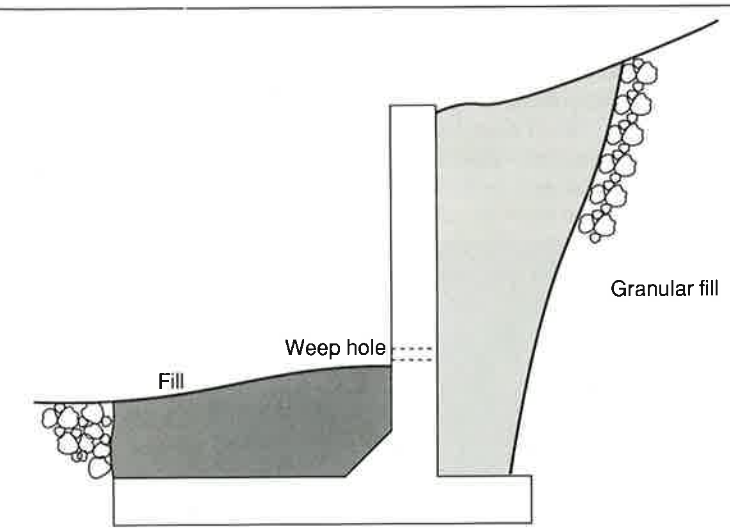


Figure 2.19: Reinforced concrete retaining wall

House walls

In special circumstances, the actual wall of the house may act as a retaining wall. The wall need not be as thick as a conventional retaining wall as the thrust of the ground is transmitted through the perpendicular walls of the house which act similarly to buttresses. This type of construction requires that the buried or partially buried upslope wall is waterproofed (an expensive requirement) and of sufficient strength to span between the perpendicular walls. A more sophisticated drainage blanket is required to direct any build up of ground water around the edges of the structure; obviously, weep holes are not acceptable in this case.

It is difficult to envisage this form of house construction being widely used in low-income housing schemes, particularly where the houses are individually built by the prospective householders. In general, householders are not as imaginative as architects and are deeply suspicious of new forms of housing.

Housing layout

The requirements described above for slope stability and the stability of excavations have important implications regarding the housing layout if cut and fill operations are to be minimised. Buildings should be constructed with their major axis parallel to the contour lines; thus the longest face of the building is parallel to the access route; this is contrary to normal practice. The result of reorienting houses in this way leads to increased service runs per plot served. Two-storey houses must therefore be considered as a means of minimising both land-take and servicing costs.

The design of buildings must take into account the possibility of stronger winds than is normal on flatter sites. There is also the chance of rain being driven up the slope by strong winds and entering the dwelling through ventilation openings normally protected by the eaves.

Implementation of ground preparation

Site survey

The site is surveyed on a regular grid pattern to obtain as many accurate levels as possible. The accuracy of the calculations of the required volume of fill, and hence the site preparation cost, depends upon the quality of the survey data. Particular attention should be paid to low spots; levels are required even though the area may be marshy or under water. On a steep site the slope and the degree of variability of the slope are of primary interest.

An outline soil survey is also carried out to determine the depth of existing top soil, to identify the underlying soils and to locate approximate groundwater levels. Soil samples can be obtained either by excavating open trial pits or by augering.

Soil identification is useful for predicting the behaviour of the ground with regard to possible slope instability and settlement when it is loaded by foundations, roads or overburden. The most significant characteristic is particle size distribution; moisture content becomes particularly significant in clays, which have a very small particle size.

Soils are made up principally of different combinations of sand, silt and clay; the proportions of each in any particular soil are normally determined by a sieve analysis, carried out in a materials testing laboratory. However, the loads likely to be exerted on a soil by single-storey construction on a low-income housing site rarely justify the time and expense of a full test. A simple jar test where a representative sample of the soil is placed in a jar with water and a little salt is acceptable (Figure 2.20). The jar is closed, shaken and then allowed to stand so that the contents settle. The heavier grains of sand fall to the bottom immediately, followed by the silt, and over a longer period the brown particles representative of the clays. When the water clears it is possible to determine the rough proportions of the sand (0.06 mm to 2 mm), silt (0.002 mm to 0.6 mm) and clay (less than 0.002 mm).

The significance of the results is related to the load-bearing characteristics of the different soils. Sandy soils are almost incompressible when compact; clayey soils have the capability to change volume slowly over a period as their moisture content changes. This makes them susceptible to slow settlement over a long period which can lead to cracking of buildings.

The ideal soils for fill material are ones where the proportion of clays and silts is not greater than approximately 70 per cent. The coarse material gives excellent stability and the clay material acts as a binder. The stability of different materials tends to be dependent upon the granular material, whether sandy or with stones and pebbles.

Site filling

However effectively the fill material is compacted, there is still likely to be settlement over a period of time. This is particularly true on a site where there has been marshy ground, because the underlying material settles under the weight of the fill besides settlement of the fill itself.

There are different methods for estimating probable settlement, all of which include different degrees of uncertainty. As a rough guide it is suggested that an allowance for settlement of 7.5 per cent of the filled depth should be taken for fill that has been rolled at a suitable moisture content. This rises to 15 per cent and possibly even higher for poor quality fill that has not been adequately compacted. Up to 50 per cent of this settlement normally takes place in the first year after compaction, 75 per cent will have occurred after two years and 90 per cent within three years.

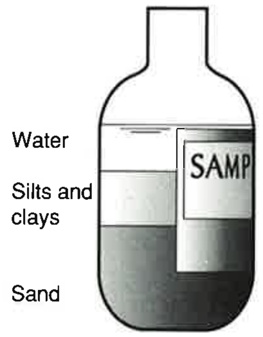


Figure 2.20: Sampling soil

Differential settlement is the major cause of cracking and failure in buildings. If the fill is of a uniform depth, even though it settles there is unlikely to be any significant damage to individual small houses. However, allowance must be made for this ground movement in determining finished ground levels.

The ground levels and contours are fixed according to flood levels and drainage gradients. Therefore it is vital that these ground levels are achieved after the two-to-three year settlement process is complete. Filling to the finished levels without allowing for future settlement leads to an increased probability of flooding and inadequate gradients on drainage channels (Figure 2.21).

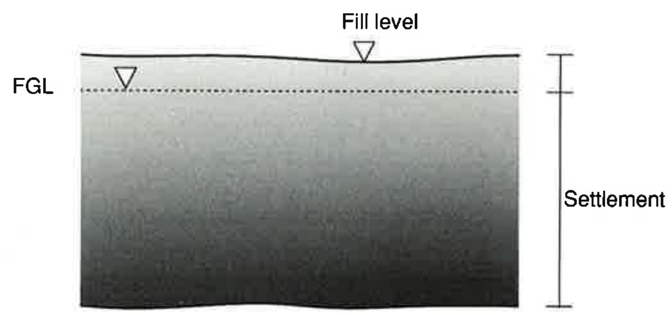


Figure 2.21: Fill level compared with finished ground

On completion of the design, construction commences by stripping off any vegetation and topsoil, normally to a depth of approximately 300 mm. This is necessary to reduce the amount of settlement caused by decomposing vegetation. Where possible, the whole site should be stripped back to the underlying ground; it might then be necessary to resurvey the site to obtain accurate estimates of the volume of fill required.

The site is then filled and compacted in layers no thicker than 200 mm, to a depth 7.5 per cent greater than the designed fill depth. Compaction is more effective if the moisture content is controlled to between 8 per cent and 16 per cent; the higher figure refers to fill that has a greater proportion of clay and the lower figure to sandy soils. Watering of the fill or compaction after rain showers has the potential to double effective compaction compared with using no water at all.

At least six passes of a five tonne sheepsfoot roller are required to compact each 200 mm layer. The result of rolling layers that are thicker than 200 mm is that the top 200 mm of the material is compacted but the remaining fill is uncompacted and settles gradually over time. Other rollers may be used with the number of passes increased or decreased according to the weight of roller available. The more modern double axle vibrating rollers are believed to be most effective in compacting soils and other materials, but such equipment may not be available.

It is advisable to install a permanent datum point on firm ground away from the fill; this can be used to check the amount of settlement taking place. Ideally, the site should then be left for a least six months to settle; after this time, problem areas of severe settlement are identified which can then be surcharged. The finished ground contours are then laid out and the site is left for another three months before resurveying and placement of the final layers of fill.

This sequence assumes that there can be at least a twelve-month wait after filling the site before people move on to commence house construction. It is possible to short cut the time involved by any of the following options, but it should be stressed that these alternatives are more expensive and there is really no adequate substitute for leaving the site to settle.

Alternatives to waiting for settlement are listed below.

- Completely strip the site of all vegetation, roots and peaty material over and above the 300 mm specified earlier and then fill; in some cases this may triple the cost of site preparation.
- Install sand drains and filters within the fill material to enhance drainage of the clay material and hence speed up the rate of settlement. This requires a layer of permeable material such as sand to be laid across the site with vertical sand drains at suitable intervals.
- Surcharge the whole site with at least 1 metre of extra fill. The extra weight speeds up consolidation but the surcharged material will have to be expensively excavated and moved away before construction can begin.
- Provide raft or piled foundations for each building so that the effects of severe settlement are limited. It is assumed that this would have to be funded and supervised by the initiating agency rather than being added to the householder's cost of building.
- Allow people to move onto site on completion of initial ground preparation and hope that the estimates of settlement are approximately correct and that any subsequent damage to buildings will not be too obvious.

There are certain circumstances where prospective householders can become involved in ground preparation. However, because of the costs involved, it may normally be assumed to be the responsibility of the initiating agency to create a properly compacted and contoured site. The community can then participate by building their new homes and creating their own infrastructure.

Sites on steep slopes

There are greater possibilities for householder involvement in ground preparation on steep slopes. Because there is no need to import fill at high cost, people can excavate a cut and fill bench on their plot without assistance.

However, there should be an engineering input to advise on the maximum slopes that are likely to be stable without retaining walls on any particular site. It is also advisable to prepare the engineered cut and fill access routes before house construction commences. These routes must then be monitored regularly to ensure that the work of householders does not threaten the integrity of the road.

Where retaining walls are required, engineering expertise should be made available to householders to ensure that the investment in walling is not wasted.

Buildings on filled ground

Ground which has recently been filled and compacted continues to consolidate and settle over a period of time. Increased care must therefore be taken with the foundations of any structures built upon it, even with small houses built by their occupants.

Foundations

Footings should be dug to depths of between 350 mm and 400 mm. As the finished ground level has to be at least 500 mm above the normal maximum groundwater level, the recommended depth of footing ensures that the base of the foundations is above the groundwater level. This is important because the allowable bearing capacity of the ground has to be approximately halved where the footing is supported by saturated soils (Figure 2.22).

As the foundations are dug deeper, so the acceptable bearing pressure increases by an amount that is at least equivalent to the weight of soil displaced. Deeper footings are less likely to be troubled by ground movements caused by seasonal swelling and shrinking of clay. However, care must be taken to ensure that the footings do not penetrate the water table.

To minimise the load on the ground, the size of the footing should be such that it spreads wider than the width of wall it supports. Site advisors or inspectors should check the stability of the footings, particularly if the householder plans to build a two storey building. The bearing pressure exerted by the building on the ground can be determined from:

$$\text{Bearing Pressure} = \frac{\text{Total Load per metre run}}{\text{Width of footing}}$$

where: Total Load = Weight of wall + upper floor + roof + live load

Recommended loadings are given in Table 2.2

The calculated bearing pressure must be less than the estimated bearing capacity of the soil, taking into account a factor of safety. The values given in Table 2.3 include conservative factors of safety between 2 and 3; this is necessary because of the considerable variability in individual soils. These values should be halved if the footings are within the groundwater table.

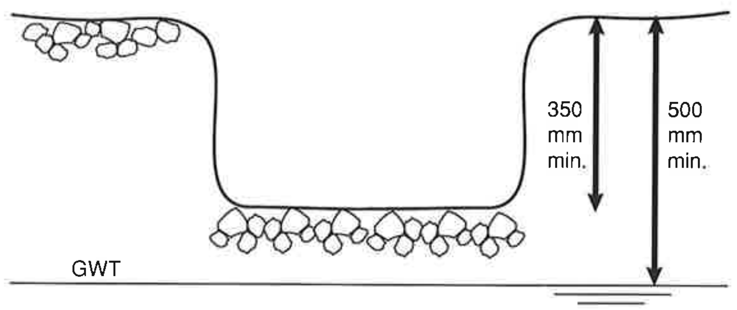


Figure 2.22: Foundations and water table

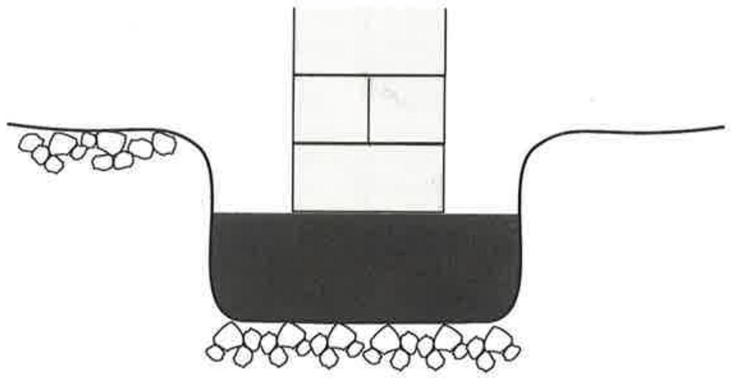


Figure 2.23: Concrete foundations

Table 2.2 Weight of walls and recommended loadings

Brickwork	4	kN/m² 225 mm thick wall
Stone masonry	10	kN/m² 400 mm thick wall
Concrete block	3	kN/m² 150 mm thick wall
Roof trusses & purlins & rafters	0.25	kN/m²
Tiles	0.60	kN/m²
Wood upper floor	0.25	kN/m²
Upper floor live load	2	kN/m²

Table 2.3 Recommended bearing capacities

Soft clay and silt	50	kN/m²
Firm clay	150	kN/m²
Sands and clay	200	kN/m²
Well graded sands	300	kN/m²
Gravels and sands	300	kN/m²
Made or filled ground	50	kN/m²

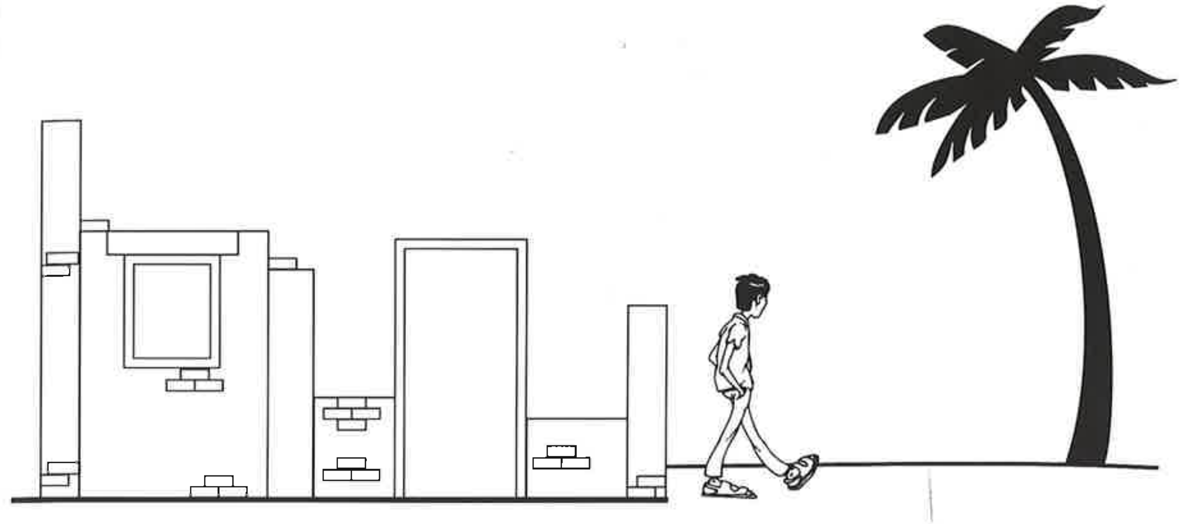


Figure 2.25: Slow construction allows the ground to adjust to the new load

Concrete footings that are at least 150 mm deep are most suitable; they should be laid as quickly as possible after the excavation of the foundation. Settlement of the footings can be minimised if the builder consolidates the base of the trench by ramming the soil with a wooden tamper. A concrete mix of 1:4:8 (cement: sand: aggregate) is perfectly acceptable even though the normal standard in some countries is 1:3:6. Where householders are trying to save money, a mix as weak as 1:8:16 is still more effective than an incorrectly jointed brick footing.

Brickwork can be used where skilled masons are on hand to guarantee adequate bonding of the foundations, thus allowing the load of the wall to spread out at approximately 45 degrees. For a 225 mm brick wall, the lower brick courses should spread out to a width of at least 500 mm (Figure 2.24). Householders should be encouraged to build slightly wider than this to ensure an effective footing 500 mm wide.

Similarly, stone masonry can be laid to spread the load. However, the site advisors should ensure that the stones are properly embedded in cement mortar, in the same way as if they were building a wall above ground. The method of filling a trench with stones and then trying to flush the mortar in from the surface is not recommended. The stones at the base will not be surrounded in mortar and the point loads created by the angles of the rock lead to increased settlement.

Slow construction of the building produces much better ultimate results as compared with fast erection (Figure 2.25). Building slowly allows the ground to accept the imposed load gradually and adjust to it before the crack-sensitive parts of the building are constructed.

Reinforcing foundations

In poor ground or newly filled ground it is usual to reinforce the concrete footings with 8 mm or 10 mm reinforcing steel at 200 mm centres, top and bottom. This criterion means that six bars are required in a 500 mm wide footing (Figure 2.26). Such reinforcement is expensive and for low-cost self-built housing may not be possible. It is therefore even more important to ensure that unreinforced footings are constructed correctly.

Alternatively, a reinforced concrete ring beam at lintel level ties the building together and prevents any movement of the walls and excessive cracking (Figure 2.27).

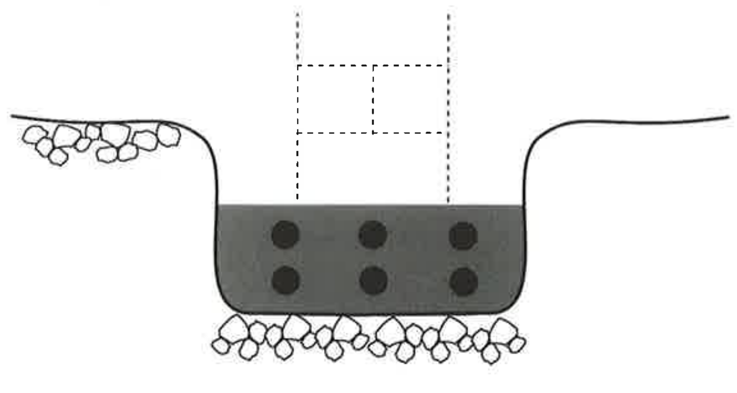


Figure 2.26: Reinforced concrete foundations

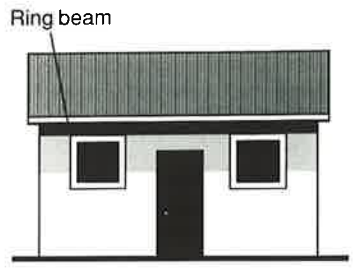


Figure 2.27: Ring beam at lintel level

Use of reinforcing steel at this level is even more beneficial than in the footings.

Cellular or articulated construction

Where it is difficult to minimise settlement by conventional engineering techniques, householders should be advised to design their buildings in such a way that the effects of the settlement are minimised.

The house design of larger single-storey buildings can allow individual rooms to move and settle as independent cells. The use of rooms separated by verandah areas with low walls and screening or by access corridors allows each part of the house to settle at its own rate; roofs are normally flexible enough to accommodate this movement.

Floor to ceiling windows and doors can also be used to reduce the likelihood of unsightly cracking. However, to use this technique requires a good understanding of how the structure behaves. Every part of a structure built in this way must be part of a corner section, either with internal or external walls, to ensure structural stability.

Earthquakes

To minimise the effects of earthquakes, buildings should be simple symmetrical structures, square or rectangular in plan, without any additions or extensions. There should be roughly equal openings on opposite walls with a minimum of 500mm between door or window openings and any corner or wall junction in the structure. In areas of minor seismic activity a ring beam at lintel level is preferred. In areas of greater seismic activity there should be vertical reinforcement at corners and wall intersections (Daldy 1972).

It is possible that the shaking effect of an earthquake may liquefy any unconsolidated fill, causing a loss of natural strength particularly where the soils are saturated. Although the mechanism is not well understood, it might cause the failure of any structures built upon the fill. In a recent earthquake this liquefaction effect caused buildings to settle by over one metre into the ground.

Buildings on steep slopes

The use of extra courses of masonry or brickwork on the down slope side of the building is the simplest form of building on moderate to steep slopes which avoids major excavations. Simpson and Purdy (1987) describe other forms of building suitable for steep slopes. Narrow buildings which are normally at least two storeys high to compensate for the smaller 'footprint' at ground level are one example (Figure 2.28). They require reinforcement at lintel level to tie the structure together to cope with the potential slow movement of soil creep.

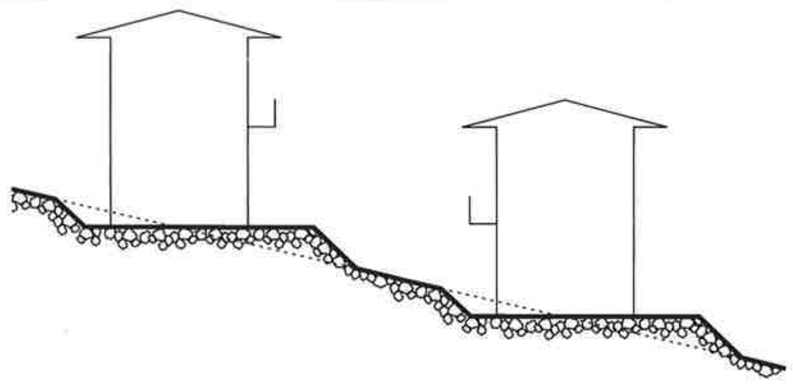


Figure 2.28: Narrow buildings for slopes

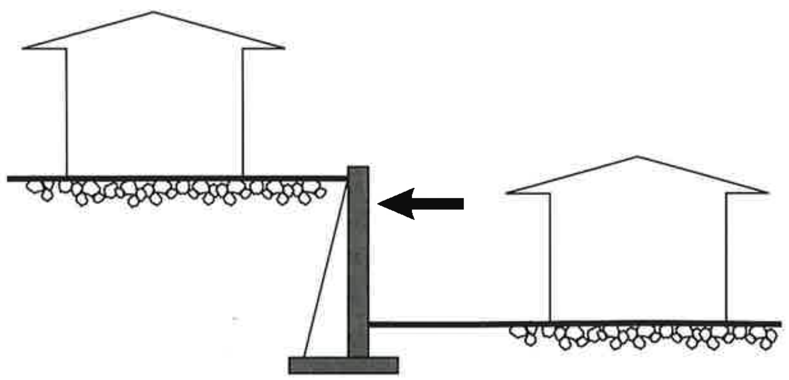


Figure 2.29: Retaining walls for steeper slopes

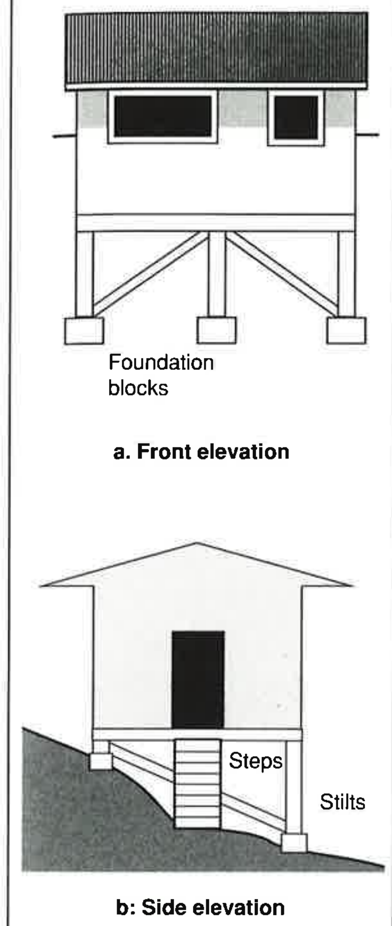


Figure 2.30: Housing on stilts

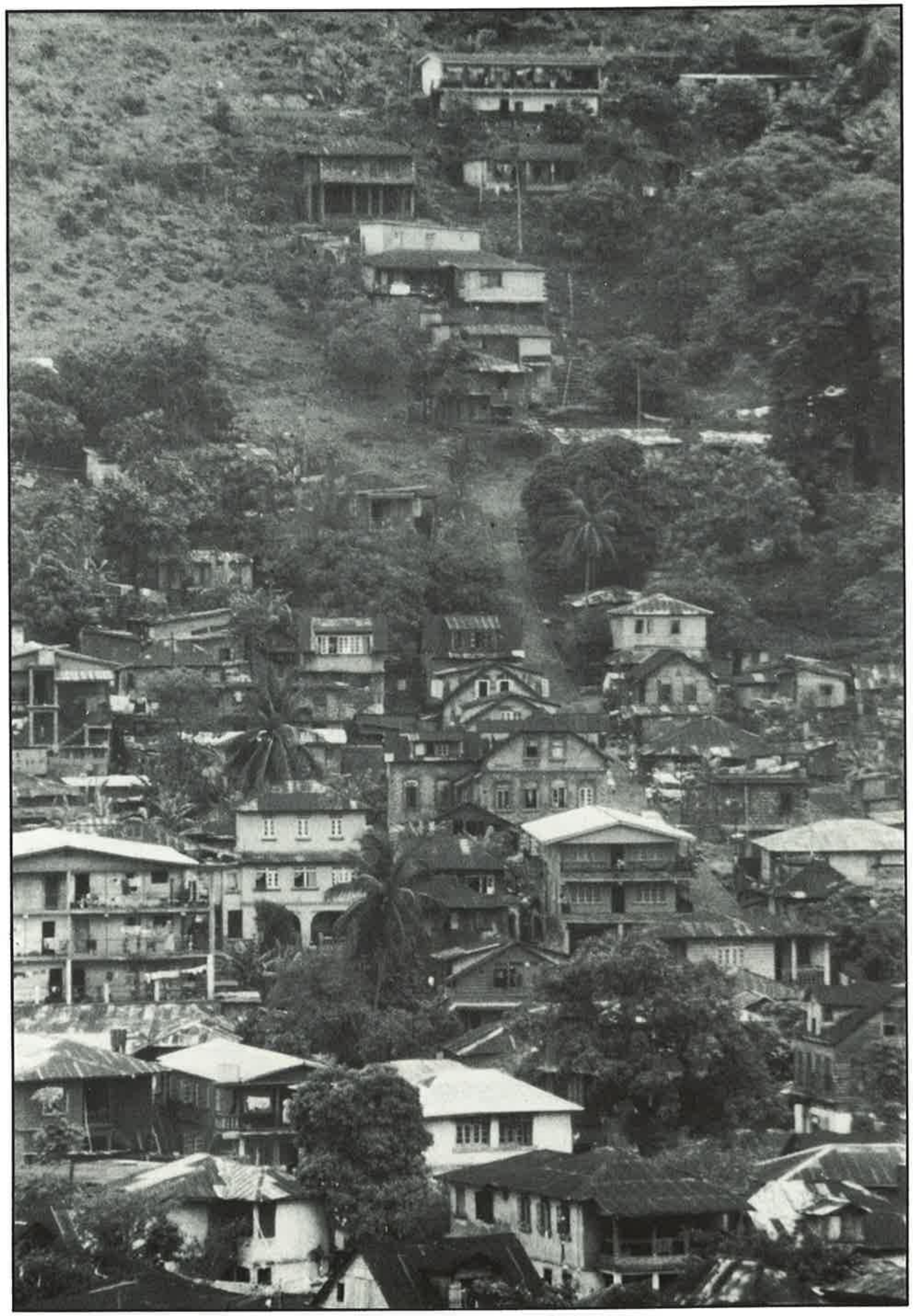
Table 2.4 Classification of slopes

	0.33%	1/300	0.2°	minimum for surface drainage
Slight	1%	1/100	0.6°	**'Extra masonry'**
	5%	1/20	3°	
Medium	10%	1/104	6°	**'Cut and fill'**
	12.5%	1/8	7°	
Steep	20%	1/5	11°	soil creep danger **'Amended section'** **'Retaining walls'**
	25%	1/4	14°	mud slides danger
Very steep	50%	1/2	27°	soil stability problems **'Stilts'**

Where cut and fill terracing has been used to create buildable land, the foundations of the building should not rest on the filled ground (Gupta, 1986) except where special engineered precautions have been taken (Figure 2.29). Any variations in loading should ensure that greater weight is on the inner side of the cut to reduce possibilities of slipping.

Split level, cascade, or stepped-storey buildings are generally too expensive for low-income housing. The design of split level buildings requires a comprehensive understanding of soil mechanics and retaining walls, whilst cascades which join together several dwellings have to be built by a contractor.

One option for low-income housing is to use stilts; a timber framed structure rests upon the hillside at the back wall and is supported on stilts at the front (Figure 2.30). Care is required to ensure that the stilts are suitably braced to resist shear forces and that they are tied in to foundations to resist any possible uplift from very strong winds.



Above: Buildings on a steep slope

Drainage 3

Objectives

The principal function of drainage on urban low-income housing sites is to remove unwanted water from the site as rapidly as possible in order to minimise potential public health hazards and the deterioration of other infrastructure. The requirements are for:

- drainage of sullage, that is, household wastewater which has been used for washing, cooking or cleaning purposes, but which does not contain excreta;
- drainage of stormwater, that is, water which runs off the buildings and land as a result of rainfall.

Separate sullage drainage is not required if sewerage is used as the system of sanitation; all sullage can be discharged into the sewers. Good stormwater drainage is critical to the general well-being of a site. Lack of adequate drainage causes rapid deterioration of road and path surfaces, restricts pedestrian and vehicular movement, results in damage to buildings and their contents, and creates generally insanitary conditions including potential sites for insect breeding.

Technical options

Sullage drainage

It is important to ensure adequate sullage drainage both from houses and communal water supply points such as standposts and handpumps; between 50 per cent and 80 per cent of the water supplied may end up as sullage. There is little quantitative data on either the quantity or the chemical and bacteriological quality of sullage; water from personal use and clothes washing may be contaminated with pathogens, but to nothing like the same extent as toilet wastes. There is likely to be a significant amount of organic matter in water which has been used for food preparation and cleaning cooking utensils.

The quantity of sullage produced varies with the quantity of water supplied and local bathing practices. The provision of individual household water connections significantly increases the volume of sullage to be disposed of. The use of large quantities of water for bathing at communal standposts or wells can create highly insanitary conditions if the drainage is inadequate.

The problems resulting from inadequate disposal of sullage tend to be indirect, rather than due to the actual quality of the wastewater itself. Pools of sullage become breeding grounds for flies; the decay of organic matter may result in unpleasant smells; a generally insanitary environment results, in which certain pathogens and worm eggs, can survive.

On-plot disposal

Sullage can be disposed of within the housing plot, either by using the sullage for garden watering, or by allowing it to percolate through the soil by means of a soakage pit as shown in Figure 3.1. The suitability of this method of disposal depends upon the quantity of sullage, the plot size, and the permeability of the ground. If the ground is very sandy and highly permeable, it may be feasible to dispose of sullage into a latrine pit. Garden watering is only appropriate if plots are large; certain plants and trees, for example the banana tree, take up large quantities of water. On-plot disposal may be feasible where water is being fetched from a public water supply point. However, it is unlikely to be appropriate when the houses have individual water connections unless the ground is very sandy, because the sullage volume will be too great.

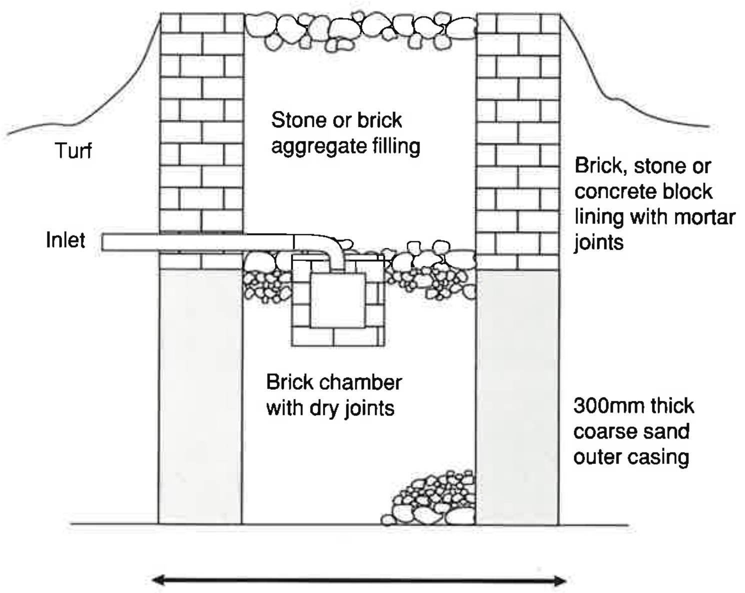


Figure 3.1: Soakage pit (after Indian Standards Institution)

Stormwater drains

Sullage can be discharged into the stormwater drains; problems may arise due to suspended matter settling out in the drain invert and careful hydraulic design is required to avoid this. Lined open channels having a compound section should be used wherever possible.

Sewerage

If a sewerage system exists, sullage should be discharged into it. This is probably the most convenient option for the householders, although it is likely to be expensive.

Storm drainage - the total system

The drainage problems of a small area or housing site cannot be solved in isolation from the town or city drainage system. There are usually three components to a complete drainage system as illustrated in Figure 3.2.

- Site drains which collect and deliver drained water to one or more points at the site boundary.
- Main drains running past the site into which the site drains discharge.
- A major watercourse, such as a river, a lake, or the sea into which the water in the main drains ultimately flows.

There are two main causes of flooding by stormwater:

- inundation from a surrounding area, for example from a river or canal which is flowing at an abnormally high level; this problem is essentially one of ground preparation and site filling as described in Chapter 2;
- inability of the drainage system to remove the required quantity of stormwater resulting from intense rainfall.

Wherever possible, drained water flows by gravity; pumping is avoided. Drainage systems are designed on the principle of defining a 'catchment area', from which drained water flows downhill to the lowest point in the catchment area, known as the 'outfall point' as shown in Figure 3.3.

A series of drains is installed in the catchment area to collect and remove the stormwater which falls on plots and access ways. The plot drainage should ensure that stormwater is led away from latrine pits or septic tanks to prevent them from flooding. In a defined catchment area, drains usually slope at a similar gradient to the ground; problems may arise if the site is flat or very steep.

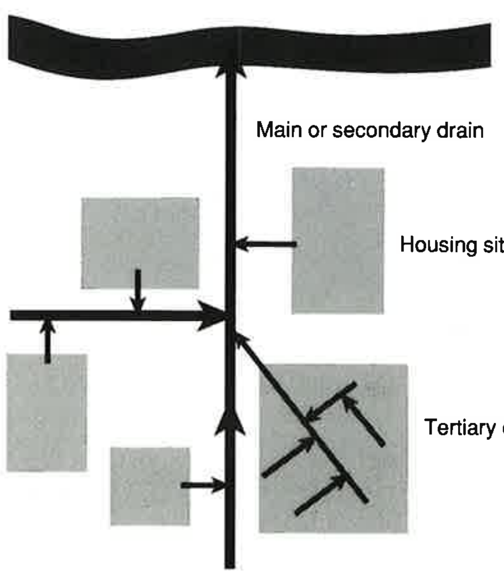


Figure 3.2: Drainage hierarchy

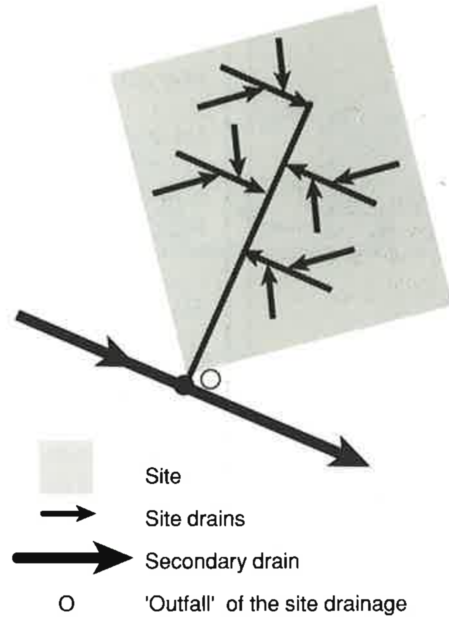


Figure 3.3: Site drainage and outfall

Figure 3.4: An unlined drain

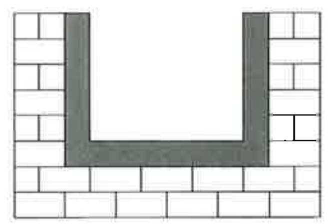


Figure 3.5: A brick lined drain with cement mortar lining

It is important to realise that the drainage problem does not end once a drainage network has been designed for the site in question. The drainage water which has been collected from the site discharges into a nearby main drain; if this main drain has insufficient capacity to cope with the additional flows, its water level rises, and water cannot escape from the site drains. Flooding occurs on the site, and the fundamental problem has not been solved. Whilst the study of large-scale main drainage problems is beyond the scope of this chapter, consideration must always be given to that part of the main drainage system which is 'downstream' of the outfall point of the site drains.

Options for stormwater drainage

There are three basic options for the provision of stormwater drains.

Open channel drainage networks

These are relatively simple to construct and maintain. The simplest open channel drain is a hand- dug, unlined ditch as shown in Figure 3.4; although there are limitations on its use, they are usually much cheaper than open channels lined with masonry or concrete as illustrated in Figure 3.5. Open channel drains take up space and pose a hazard to road users, especially if the drain is very wide or deep, or passes along a busy thoroughfare. In such cases the drains can be covered with removable slabs as shown in Figure 3.6.

If streams or ditches which carry the drainage water from other areas pass through the site, improvement of the channel section may be necessary to prevent the bed and banks from eroding during high flows.

Road-as-drain

In some densely populated settlements, paved roadways and alleys are used to carry stormwater short distances to drainage chan-nels; that is, water is deliberately allowed to flow along the paved surface and there are no channels

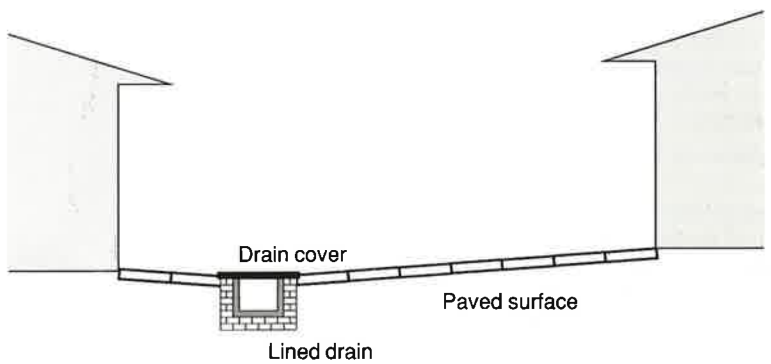


Figure 3.6: A covered drain

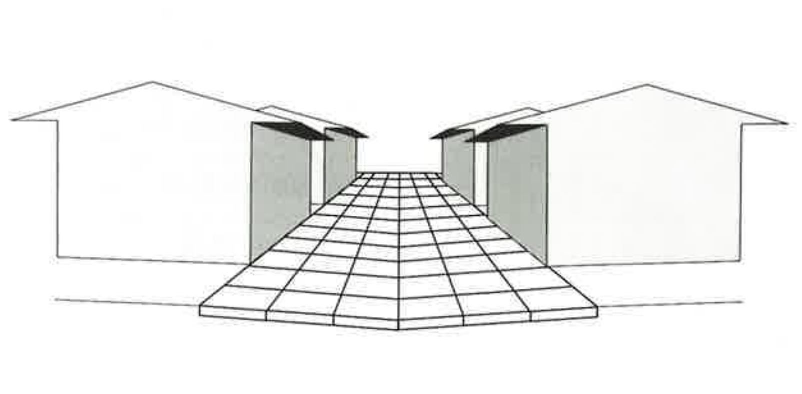


Figure 3.7: Road as drain

alongside as shown in Figure 3.7. This works where the surfaces are fully paved and well maintained; it is only applicable if adequate sullage disposal facilities exist and in general is not recommended other than for small, fully-paved areas.

Buried pipelines

Buried pipeline drainage systems have regularly spaced inlets or 'gullies' along the roadside, through which stormwater enters the drains. This option, which is commonly used in many western towns and cities, requires the roads to be constructed and surfaced to a high standard. Serious problems arise if the pipelines become blocked. The appropriate design procedures are outlined by the Transport and Road Research Laboratory (1976), and Ford (1977).

Problems with drainage

The principal problems in the design and implementation of drainage relate to the slope of the ground. Difficulties are encountered on ground which is either flat or excessively steep.

Options on flat ground

Positive drainage by gravity implies that all drains must slope downhill; on many sites this can be achieved by following natural contours. On low-lying or flat sites which are being redeveloped, ground preparation must ensure adequate contouring of the ground to permit positive drainage to occur. The available options include:

- filling and contouring;
- moving the outfall closer to the site by means of a canal;
- constructing the outfall drain as a buried pipeline.

These options are fully described in the section 'Design Factors - Filling of low-lying land' in Chapter 2 on 'Ground Preparation'.

Options on steep ground

The velocity of flow of water increases with the steepness of the slope of the channel; whilst this is beneficial from the viewpoint of rapid removal of sullage, difficulties can result when large quantities of stormwater are involved. Water gains energy as it flows downhill; this gain is balanced by energy loss due to friction, but in achieving this balance on a steep slope the water may attain a very high velocity.

On steep sites it is likely that the ground will be terraced for housing construction. Drains should follow a path parallel to the contours for short distances to help reduce the flow velocity. Where the drains run steeply downhill, a series of steps can be built as shown in Figure 3.8. This helps to dissipate some of the energy of flow, which results in a reduction of flow velocity. Detailed design of such steps or 'cascades' is described by Chow (1959).

At the outfall point, the ground slope may change suddenly from steep to flat. This creates hydraulic problems which necessitate the construction of a special hydraulic structure called a stilling basin, as shown in Figure 3.9. A significant proportion of the energy of flow is dissipated, and the water level rises, effecting a reasonably smooth transition of the flow into the receiving watercourse.

It is also important to ascertain the stability of natural streams which flow alongside steep sites and it may be necessary to line the banks and bed to prevent instability. Although this may prove expensive, the consequences of erosion during

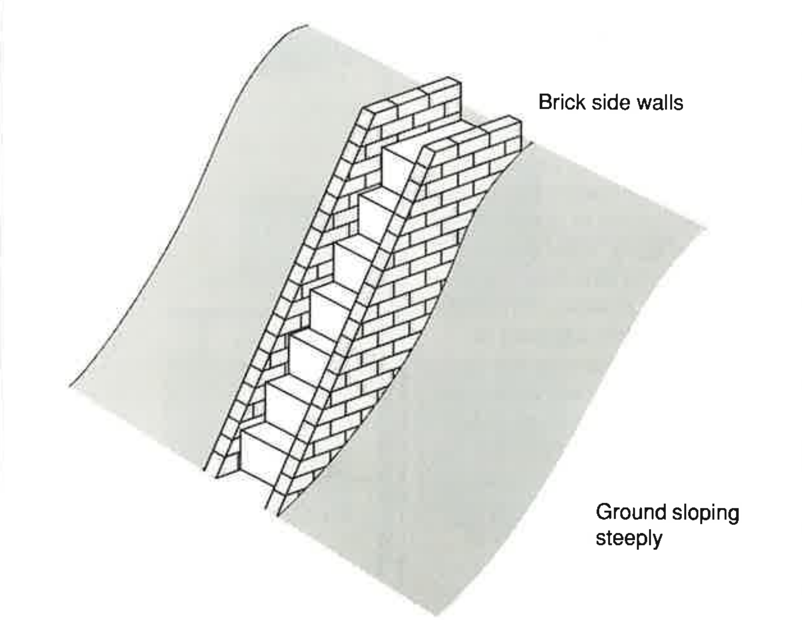


Figure 3.8: Cascade drain

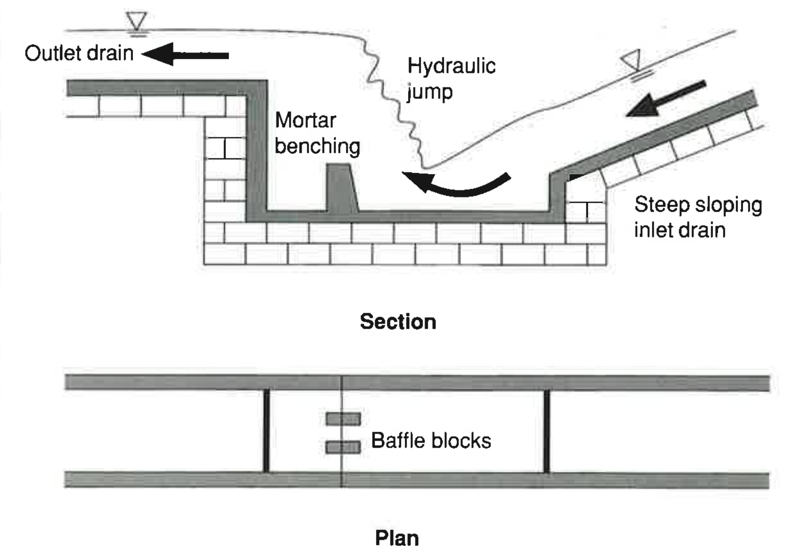


Figure 3.9: Simple stilling basin arrangement

high intensity rainfall could be disastrous if areas of the site are rendered unstable.

Drainage works on steep sloping sites may be very expensive if they are to be effective, and require careful design and construction.

Maintenance

All drainage systems are prone to blockage; silt, sand and gravel wash into and are deposited in the drains. Refuse frequently ends up in open drains if the solid waste management system is inadequate; vegetable matter from sullage may also be deposited. Such blockages result in standing pools of dirty water which are potential mosquito breeding sites; flooding may subsequently occur due to the loss of flow capacity.

Regular cleaning is probably the most essential aspect of drain maintenance; open channels are the simplest drains to clean, but care must be taken to ensure that the debris is removed to a suitable disposal point to prevent it from either being washed straight back into the drain or forming a barrier to the ingress of stormwater into the drain. In addition, periodic repairs are necessary. After major storms, erosion damage to unlined drains may require the line and level to be reset and culvert entries and exits to be repaired. The rendering and jointing of brick or masonry drains also requires inspection and repair. Cleaning covered drains presents more difficulties because the cover slabs are usually heavy and difficult to remove without causing damage. Buried pipeline drainage systems are the most difficult to unblock; unless all gully covers are maintained intact, refuse finds its way into the pipes. Unblocking is usually attempted by pushing a 'rod' along the pipe to shift the material blocking the pipe along to the next manhole. Attempts to unblock bulky refuse in this way may result in damage to the pipes.

Maintenance of the drainage system would appear to be well suited to community involvement, although its organisation may not be straightforward. It is essential that the whole system be kept unblocked, because problems manifest themselves in that part of the system which is upstream of any blockage. The community on one site in Colombo, Sri Lanka, have overcome the problem by inserting small, wire mesh screens at the upstream section of the drain which runs outside their property as illustrated in Figure 3.10. This has proved effective to date, with screens being regularly cleaned. However, it is important to note that this innovation came from within the community as a means of solving a clearly perceived problem.

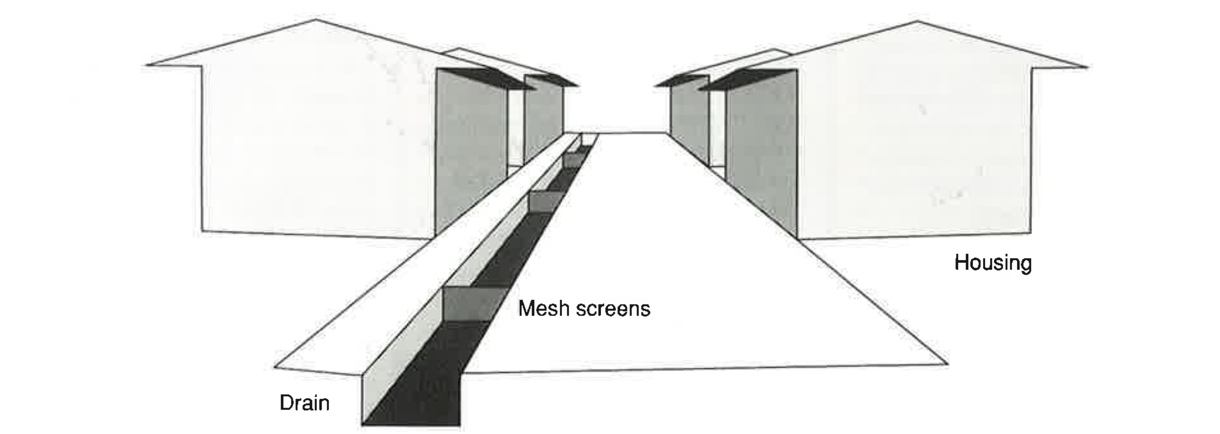


Figure 3.10: An open drain with mesh screens

Cost recovery

Drainage is a communal service from which everybody on the site benefits. At the primary level, the recovery of maintenance costs for the whole drainage system could be based on a general user charge which is levied on all those who benefit. Whilst the length of house frontage might appear to offer a way of apportioning costs, it is important to include the cost of maintaining drainage structures such as culverts and outfalls. However, the financial cost is minimal if community labour can be used for maintenance.

Improvements to the drainage system essentially consist of lining existing unlined drains which may subsequently be covered. There are many ways in which this work can be implemented and the capital costs recovered.

- The urban local authority implements the work and recovers the cost through property tax.
- The community raises the finance and engages its own contractors or labourers.
- The community contributes unskilled and skilled labour as far as is possible, and raises finance to purchase materials and skilled labour which is not locally available.

The community-based options require a high level of organisation to implement; however, many urban local authorities have neither the resources nor the ability to recover the costs for such improvements. It is not necessary for all of the drains to be improved at the same time; a group of householders in a street or housing cluster could improve their own drains independently. It is nevertheless advisable to ensure that proper technical advice is sought to ensure that such local improvements do not cause problems further downstream in those parts of the system which remain unimproved.

Detailed design factors

Sullage drainage

For design purposes it can be assumed that all of the daily sullage flow occurs during an eight hour period, which reflects typical water use patterns (Khanna, 1990). At other times the only likely sullage flow is from leaking standposts.

An on-plot soakage pit is normally adequate for household sullage disposal where the ground is highly permeable; such a pit could handle the sullage arising from a household of about six people having a per capita water supply of approximately 40 litres per day. If the ground is only slightly permeable, or is waterlogged during the wet season, soakage pits will not work.

The main problem in using the stormwater drains for sullage removal is that the quantities of sullage are extremely small when compared with the quantities of stormwater which result from intense tropical rainfall. The stormwater drains must therefore be capable of:

- satisfactorily carrying high flows resulting from intense rainfall;
- carrying very low flows of sullage at a velocity sufficiently high to prevent deposition of solids; if possible, a minimum velocity of 0.5 metres per second should be maintained.

The most common type of stormwater drain is a rectangular section open channel. Unfortunately, the hydraulic characteristics of this section give rise to very low velocities when the water flow rate is small; it is thus unsuitable for sullage disposal unless the drain is following a steep downhill gradient.

This problem can be overcome on shallower gradients by using a compound channel section which has a semi-circular invert as shown in Figure 3.11. When there is no stormwater flow, the sullage flow remains within the semi-circular portion; the upper rectangular portion is designed to have sufficient capacity to carry the required flow of stormwater. In situations where the stormwater flow is small, a 'U'-shaped drain can be used, as shown in Figure 3.12. In order to prevent low velocities, drains which carry sullage should be laid with longitudinal bed slopes in the direction of flow of no less than 1:150 (0.7 per cent) wherever possible. The semi-circular portion of a drain having an invert radius of 75 mm laid on a slope of 1:150 has a capacity of about 5.5 litres per second. Even when carrying smaller sullage flows, the flow velocity is maintained at a reasonable value.

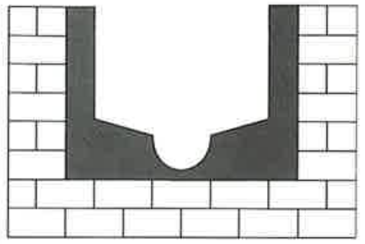


Figure 3.11: A bricked lined drain with semi-circular invert to carry sullage

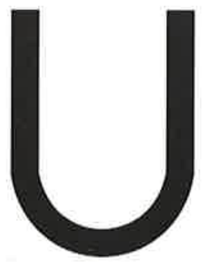


Figure 3.12: A 'U' - shaped precast concrete drain section

Stormwater drainage

The design procedure involves calculation of the quantity of stormwater or 'runoff' which is likely to result from rainfall, and the size of drains required to convey that water down the catchment to the outfall point. The stages involved are outlined below.

Stage 1: Drainage catchment

The boundaries of drainage catchments can be defined using a contoured plan of the site, given that in a gravity flow drainage system water flows downhill from a higher elevation to a lower elevation. This is illustrated in Figure 3.13.

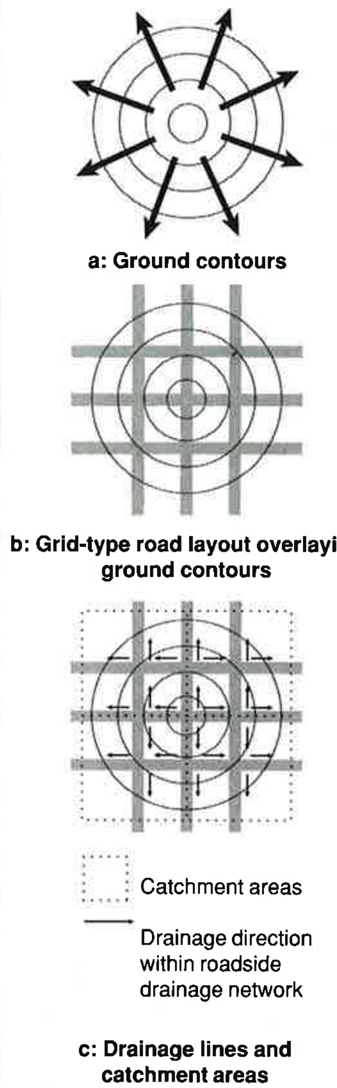


Figure 3.13: Drainage catchment

Stage 2: Calculation of runoff

The simplest way of calculating the runoff from a given catchment is by the 'rational method' which states that:

$$Q = 2.78CIA$$

where
- Q = runoff in litres per second
- C = volumetric runoff coefficient
- I = rainfall intensity of the storm in millimetres per hour
- A = impermeable area in hectares (1 hectare = 10 000 m^2)

There are a number of ways of interpreting the variables in the above formula; the most straightforward is to assume that the coefficient 'C' is 1.0 and the area 'A' comprises all impermeable areas such as roofs, roads and any surface which is likely to drain into the storm drains. Open areas which are grassed or covered in vegetation are excluded. In this case the formula reduces to

$$Q = 2.78IA$$

Stage 3: Rainfall intensity

The rainfall intensity represents a rate of rainfall, and its magnitude depends upon the storm duration (that is, the length of time for which rain is falling in a particular storm) and the return period of the rainfall intensity (that is, the number of years on average between the rainfall intensity being greater than or equal to a specified intensity). Deciding upon a suitable return period for the design storm should be based on a cost benefit analysis which quantifies the physical and social damage caused by flooding. However, no conclusive work appears to have been done which quantifies the actual costs of flooding on low-income housing sites. Thus selection of a suitable return period for the design storm is arbitrary; a return period of one year is often adopted.

Determination of a suitable value of rainfall intensity depends upon the availability of meteorological data for the exact location in question. The rainfall intensity reduces as the duration of the storm increases; examples of intensity/duration curves for a one-year return period from several locations are shown in Figure 3.14.

The rational method assumes that the storm duration which is appropriate for a particular drainage catchment equals the total time it takes for rain falling on the most distant part of the catchment to flow down to the outfall point of that catchment. This is defined as the 'time of concentration', where

Time of concentration =
Time of entry + Time of flow

The time of entry is the time taken for rain falling on the ground or a building to flow into one of the stormwater drains; it can be taken to be 3 minutes for urban housing sites. The time of flow is simply the time taken for that water to flow from its entry point into the stormwater drain to the outfall point. In order to calculate the time of flow, it is necessary to know the length of the drain and the velocity of flow in the drain, hence:

$$\text{Time of flow} = \frac{\text{Length of drain}}{\text{Velocity in drain}}$$

The length of the drain is obtained from the proposed site drainage plan; the flow velocity can be assumed to be 0.7 metres per second as a first estimate, and the time of concentration is determined.

The duration of the storm appropriate to the catchment is equal to the time of concentration; thus the appropriate rainfall intensity can be found from the rainfall intensity/duration curve for the location in question.

If there is no rainfall intensity/duration data available, a reasonable value for rainfall intensity in tropical climates is 100 millimetres per hour; this could be applied on low-income housing sites to drainage catchments which have an area less than approximately 150 hectares.

The runoff from the catchment under consideration is then calculated using the rational method formula.

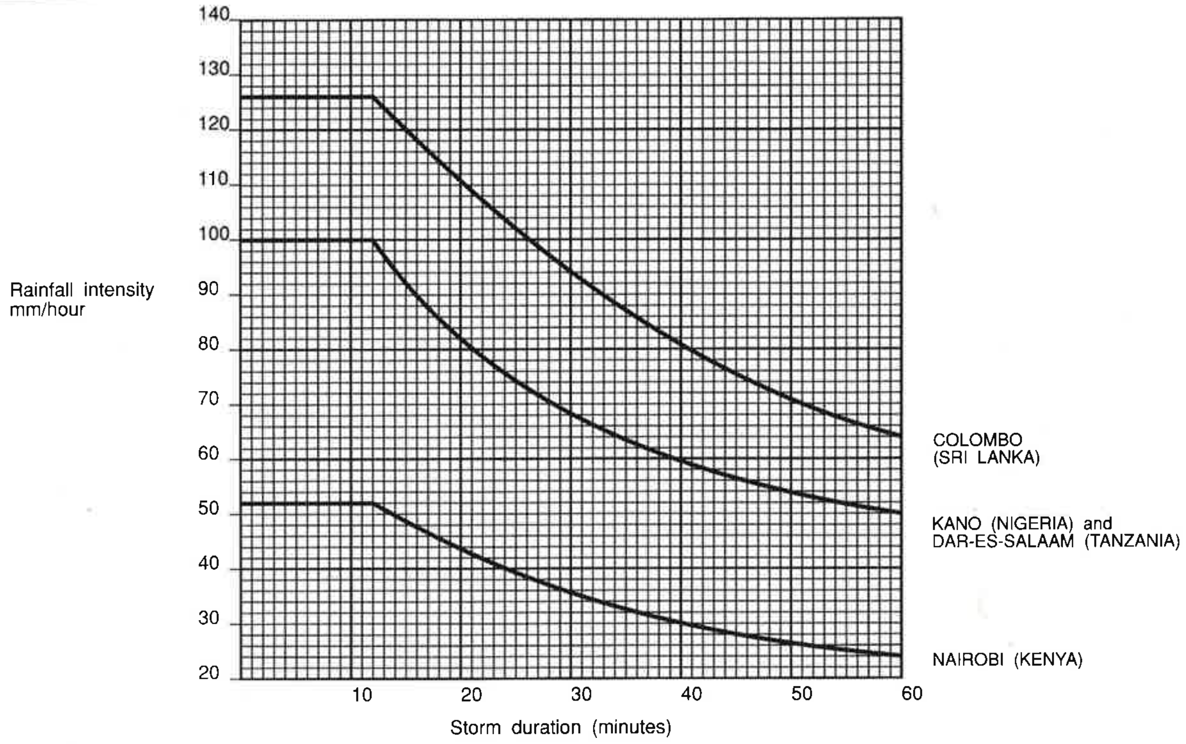


Figure 3.14: Examples of rainfall intensity for once in one year design storms at various locations

Stage 4 : Drain capacity

Having calculated the runoff at different points in the catchment, a suitable drain size must be specified which can carry the required flow. The flow velocity and capacity of an open channel are calculated from the Manning equation.

$$V = \frac{R^{0.67}S^{0.5}}{N}$$

In conjunction with the flow continuity equation, this becomes

$$Q = 1000\ \frac{AR^{0.67}S^{0.5}}{N}$$

where

- Q = capacity in litres per second
- V = velocity of flow in metres per second
- A = cross sectional area of flow in square metres
- S = longitudinal bed slope of the channel
- N = Manning's channel roughness coefficient
- R = hydraulic radius of channel in metres

where

$$R = \frac{A}{(\text{Width} + 2 \times \text{Depth})}$$

for a rectangular channel

A comprehensive list of values of Manning's coefficient is given by Chow (1959); Table 3.1 gives some typical values.

In general, the optimum shape for a rectangular cross section drain is for the width to be twice the depth; thus the capacity (Q) can be calculated for a given drain size, slope and roughness using the Manning equation. Examples of drain capacity are shown in Table 3.2 .

The drain capacity is then compared with the runoff which it is required to carry. The size of the drain is then adjusted until its capacity is at least as great as the runoff.

Having selected a drain size, recalculate the velocity of flow in this drain using the Manning formula; if it is not equal to 0.7 metres per second (that is, the value assumed in order to find the time of concentration and rainfall intensity), recalculate the time of flow based upon this recalculated value of velocity. Repeat the procedure until the velocity of flow in the drain equals that used to calculate the time of flow.

Table 3.1: Manning's roughness coefficient

Material	Manning's coefficient
Earth	0.025
Brick - unrendered	0.018
Brick - smooth rendered	0.015
Concrete - smooth finish	0.015

Table 3.2: Drain capacities in litres per second

Rectangular brick lined drain with smooth cement mortar render

Bed slope	Drain size (width x depth) in mm			
	(1000 x 500)	(750 x 375)	(500 x 250)	(250 x 125)
1:150	1080	500	170	27
1:300	760	350	120	19

Unlined earth drain with side slopes 1:2

Bed slope	Top width of drain in mm		
	1000	750	500
1:200	**	38	13
1:300	67	31	11

Unlined earth drain with side slopes 1:1

Bed slope	Top width of drain in mm		
	500	400	250
1:200	35	19	6
1:300	29	16	5

** indicates that severe erosion would be likely

Stage 5: Optimum drain sizes

It is possible to determine an exact drain size to carry the required flow. However, the method used to calculate the runoff is not exact, and is limited by the accuracy of the meteorological data available. In practice it is usual to standardise on a limited number of drain sizes in order to simplify construction; the drain selected should have the capacity to carry at least the estimated runoff.

If access widths are severely restricted, an open drain having the capacity to carry the runoff from a storm having a one-year return period may be prohibitively large. In such cases the maximum drain size which is practicable should be used; however, there will be the risk of flooding more frequently than once in one year.

At the junction of two drains, the invert level of the minor drain should be above that of the major drain which it is joining as shown in Figure 3.15. This prevents backflow of water up the minor drain. For example, consider the junction of a minor drain 300 mm deep with a major drain 400 mm deep when both are flowing full.

Step Height at junction =
Depth in major drain -
Depth in minor drain

= 400 - 300
= 100 mm

Construction of open drains

Unlined drains

The cheapest form of roadside drain is an unlined channel. The main problem with unlined drains is their lack of stability when the velocity of flow is high. The cross sectional shape, line, and level tend to be altered by the interaction of flowing water with the material forming the bed and walls of the channel.

Unlined drains can be constructed using manual labour for digging, or by using mechanical excavators. It is important that a skilled supervisor

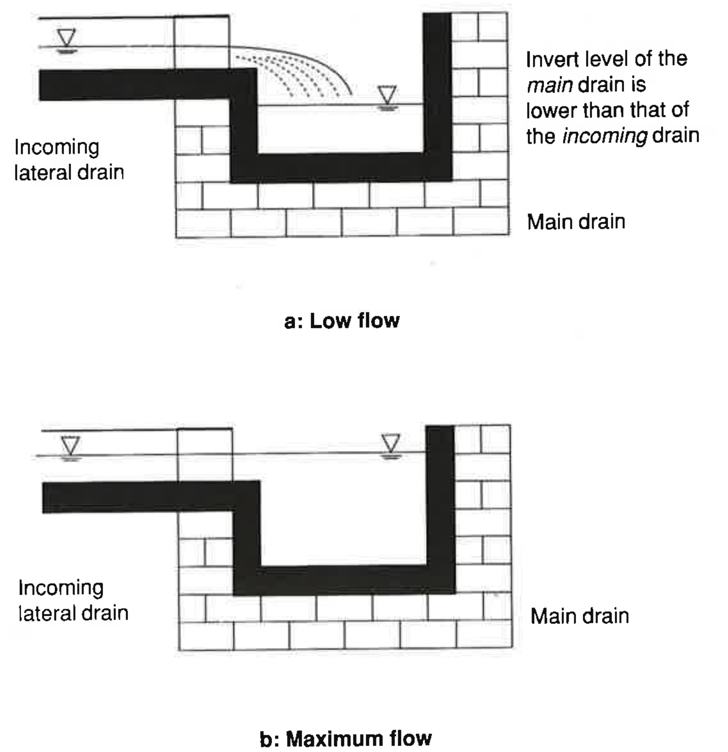


Figure 3.15: Drain invert levels

checks the longitudinal slope of the drain as digging proceeds.

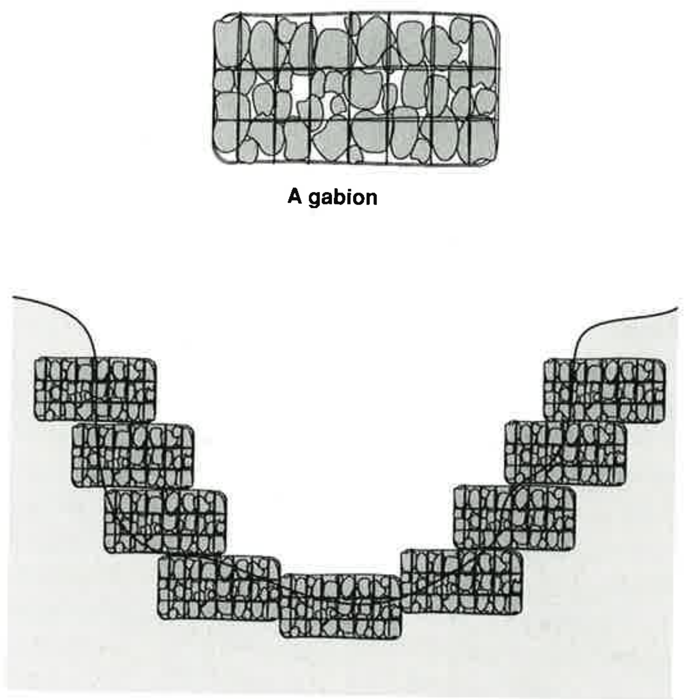
The shape and stability of an unlined drain depends upon the characteristics of the soil. With stiff, cohesive soils sidewalls may be vertical and the section resistant to high velocity flows; loose, granular material is easily eroded, and sidewalls need to be battered back so that the width at the top of the drain is greater than at the bottom. This is a disadvantage on sites where access widths are restricted, as additional space is taken up.

The following approximate guidelines can be applied to shallow drains less than 1 metre deep. Stiff, cohesive natural ground can stand vertically and resist scour by velocities up to about 0.8 metres per second. Purely granular material should have side slopes of 1 on 2, and anything in between side slopes of 1 on 1. Scouring occurs if the flow velocity exceeds 0.4 metres per second when there is any granular material present. However, if the roadway has to take vehicular traffic, vertical sided drains may be prone to collapse because of lateral traffic loads from the roadway, and the sides should be sloped.

Lined drains

Lined drains are more expensive to construct than unlined drains; for example, in Sri Lanka they are ten times more expensive. The most common lining materials are concrete, brick, and stone; the base and sides of brick or stone drains can be rendered with mortar to provide a smooth surface which has less resistance to the flow of water and limits damage to joints. Concrete drain sections can be either precast or cast in situ.

Existing unlined drains which have battered side walls can be lined to give additional stability; however, in order to reduce the land-take, vertical side walls can be constructed. If the drains are to be covered with slabs, the slabs must be sufficiently robust to resist superimposed loads, whilst remaining light enough to be removed in order to allow cleaning to be effected.



A gabion

An unstable water course lined with gabions

Figure 3.16: Gabions

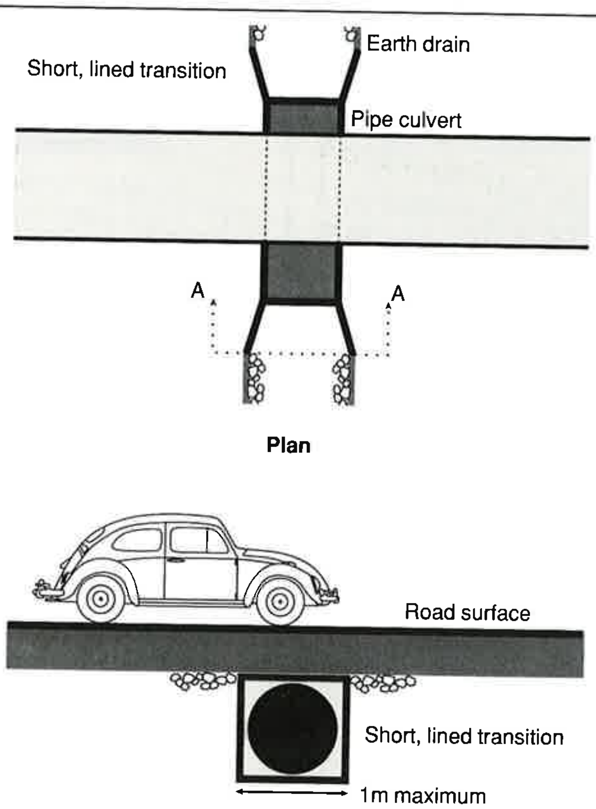
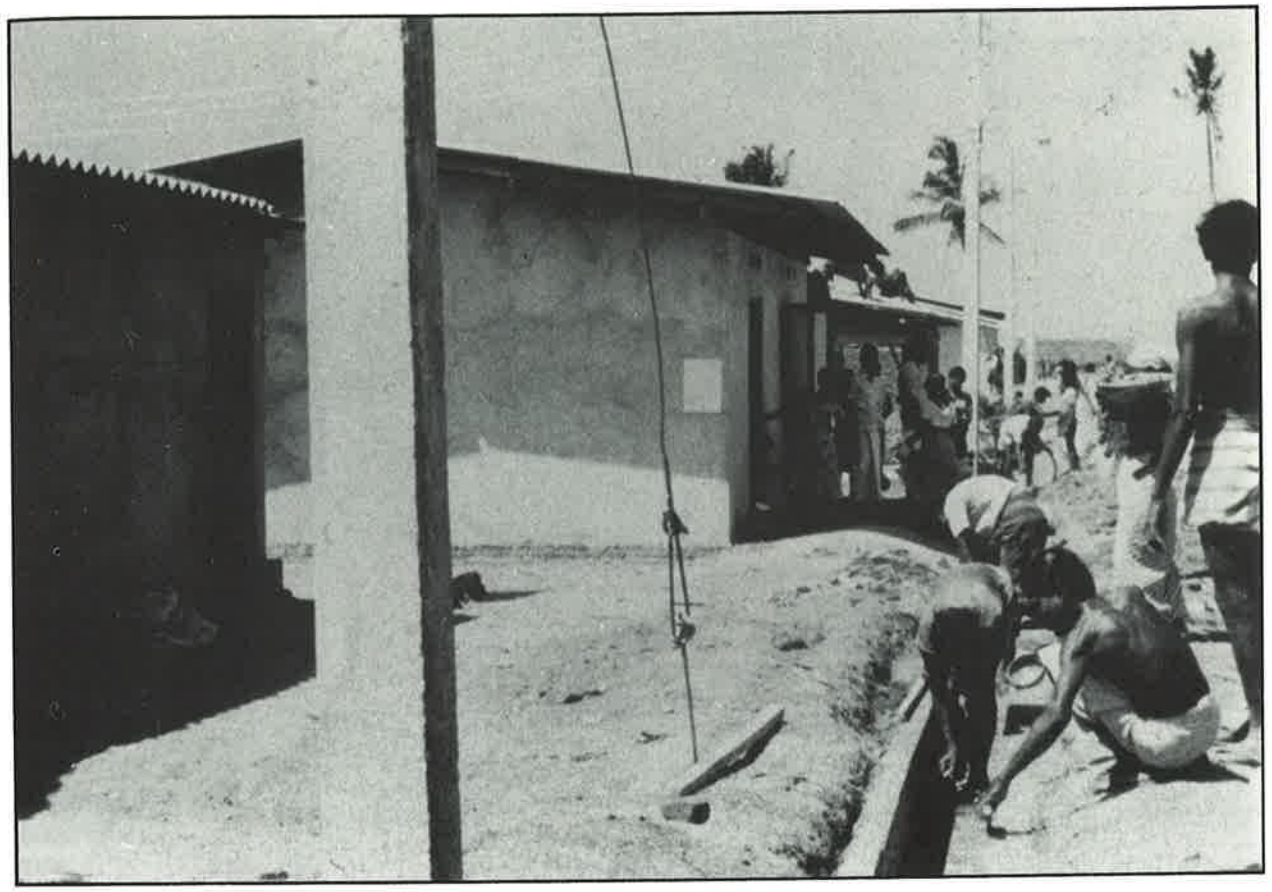


Figure 3.17: Culverts



Above: Rectangular section open channel drain under construction

Drains which carry sullage should have a semi-circular invert in order to maintain a minimum flow velocity of about 0.5 metres per second even when the discharge is small. Construction of drains with this cross section is more complex than for the simple rectangular section. Possible methods include:

- manufacture the complete section as precast concrete units;
- lay precast invert sections and construct the remainder of the section from in situ concrete, brick or stone;
- construct a rectangular section in situ from concrete, brick or masonry; then make a mortar 'benching' to give the semicircular invert. A length of plastic pipe cut longitudinally down the centre can be used as a 'former' around which the benching can be made.

Road-as-drain

In cases where storm drains do not carry sullage, a short length of fully paved open surface, such as a road or pathway, can act as the storm drain. In addition to sloping longitudinally in the direction of the nearest proper storm drain, the surface must be given a cross-slope in towards its centre to avoid flooding adjacent properties. This system should never be applied to extensive paved areas, as they are likely to become totally water-bound during heavy storms and access will be severely impeded.

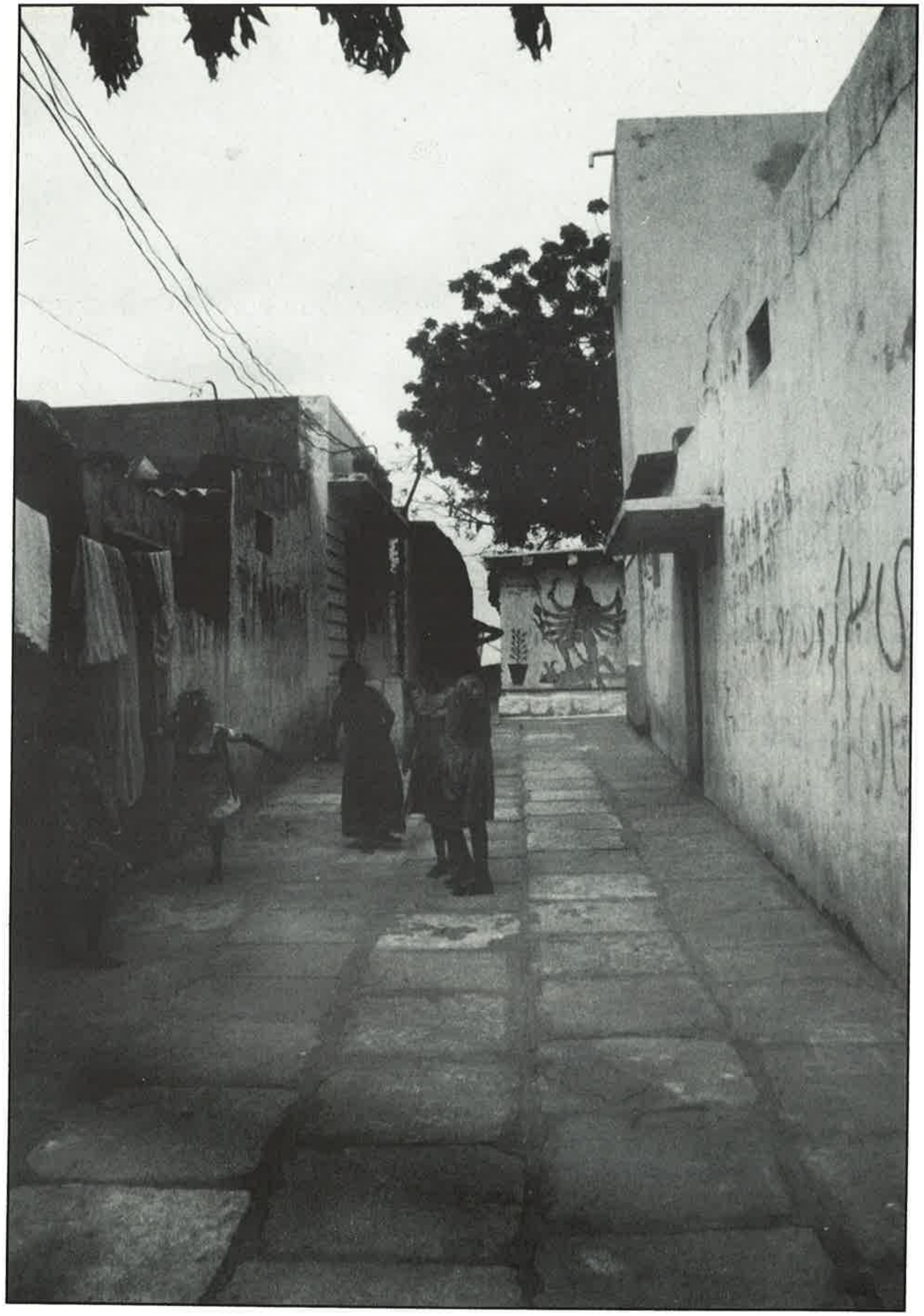
In theory this method can be applied to well-compacted gravelled surfaces, although it is not recommended since serious damage to the surface results if compaction is sub-standard. Similarly, the paved surface must be maintained to a high standard to avoid rapid deterioration.

Gabions

Should a large main drain which carries the drainage water from other areas pass through the site, consideration may have to be given to its improvement. The sides of a large main drain can be stabilised using wire baskets filled with stones, called 'gabions' as shown in Figure 3.16. Gabions can also be used on very steeply sloping drains to create a 'cascade'.

Culverts

Culverts are normally circular concrete pipes laid beneath a road, which convey drained water from one side of the road to the other as shown in Figure 3.17. A minimum cover of about 0.6 metres is necessary in order to prevent damage from traffic (Hindson, 1983). If the drains on either side of the culvert are unlined, local erosion is likely and short, lined, transition sections should be built around both the inlet and outlet to the culvert.



Above: Road-as-drain in Hyderabad, India

Access and circulation layout 4

Objectives

Access routes are required to enable the inhabitants of a site to move freely from their homes to other homes on the site and to major adjoining thoroughfares. Both pedestrian and vehicular access have to be considered. The size, spacing and layout of the paths, roads and other circulation space are normally determined by a planning agency which takes into account the site topography and generally accepted design standards for road widths.

On new sites in small towns, or on the fringes of large cities where land is not a significant constraint, there may be no difficulty in keeping to existing standards. However, one of the highest priorities of the inhabitants of low-income settlements is to live close to their place of work; the most desirable sites tend to be those close to the commercial and industrial centres rather than out on the urban fringes. Many housing schemes therefore tend to have high associated land costs. Small plot sizes in the range 30m^2 to 50m^2 (particularly in Asia) are often necessary in order both to provide enough dwellings and to minimise the cost per household.

In situations where land for housing is so scarce, the specific objectives of access need to be carefully considered. Access, roadways, public and semi-public spaces within the housing layout must be planned from first principles to minimise the land-take. This chapter focuses upon minimum standards for provision of access in order to make economical use of scarce resources. Relaxation of these standards allows for increased traffic flows and speeds in the future but does not materially affect levels of access.

Housing layout

The land-take is clearly affected by the nature of the housing layout that is adopted. The detailed layout for a particular site depends on the local conditions; however, there are two common models which provide the basis for most layout designs, namely the 'cluster' and 'linear' systems, illustrated in Figure 4.1. A major advantage of the cluster is that it creates a small community of families within the overall site community. Communal services such as standposts, solid waste bins and latrines can be provided on

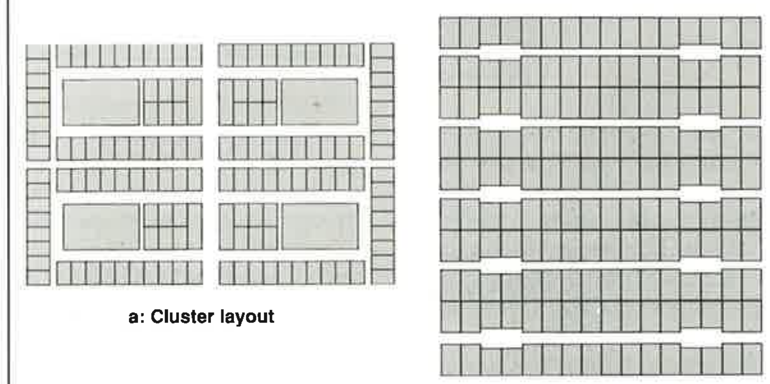


Figure 4.1: Cluster and linear layouts

a cluster basis so that they are clearly identified with a specific group of users. This in turn can help in creating a sense of 'ownership' and the likelihood of the cluster community caring and maintaining the services is increased.

The linear layout is usually simpler and cheaper to service, but small community groups are not so clearly identifiable. This can be partly overcome by constructing walls approximately 1 metre high across certain access ways to limit casual access by non-residents, as shown in Figure 4.2. These do not form a barrier in times of emergency nor do they restrict the passage of services such as pipes and drains under the wall and power lines over the wall.

In many countries within 25° latitude north or south of the equator, there can be significant benefits to householders from orienting houses approximately on an east-west axis. The subsequent reduction in solar gain leads to cooler houses that are more pleasant to live in. If there is a choice, it is advisable to have streets aligned such that with small plots, terraced houses are on an east-west axis. However, on many sites it is the requirements of drainage which are paramount to the orientation of the access ways and housing layout.

A logical design sequence is to:

- design the sullage and stormwater drainage system;
- plan the access and road layout;
- block out the housing areas.

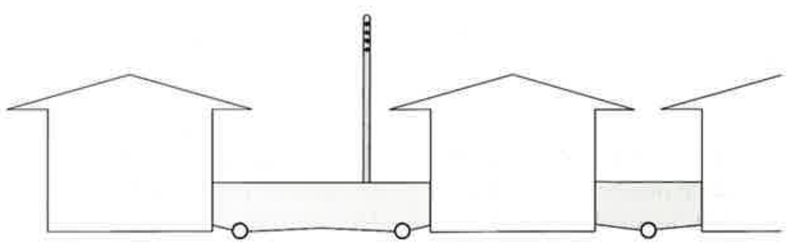


Figure 4.2: Pedestrian restrictions on linear layouts

Requirements for access

Access is considered under the requirements for people, vehicles and services.

People

Every household requires pedestrian access, suitable not only for adult householders but also routes that are safe for children and visitors. Consideration should be given to the need for access to both front and rear of the house and plot. Allowance also has to be made for people carrying goods and for bicycles, whether ridden or wheeled.

Where possible, walking distances to main trunk routes are minimised. Transit through other parts of the housing area, especially on unofficial routes or short cuts may be restricted to enhance security and community awareness within sub-sections or clusters of the housing site.

Where high vehicular traffic flows are anticipated, whether through the site or alongside a boundary, some form of pedestrian sidewalk or pavement may be necessary for safety along those busy routes only.

Vehicles

Small vehicles

In some countries, small vehicles such as scooter-based trishaws, rickshaws, single axle tractors with trailers, hand carts and animal carts play a significant role in transporting goods and people to their dwellings and to small commercial and industrial premises within the housing site.

Studies have been carried out by Rybczynski and Bhatt (1986) of informal settlements that have, by default, been self-planned by the inhabitants. The results suggest that circulation space is designed to allow push carts and auto-rickshaws direct access to most houses with small vehicle access possible at limited speeds.

Decisions concerning standards and the access that should be allowable is best taken in conjunction with residents, particularly in upgrading projects. The right of equal access for all households for all types of vehicles has to be carefully considered so as not to disadvantage any particular group of residents.

Conventional vehicles

It is often felt to be inappropriate to design low-income housing sites with full vehicular access. However, when considering the minimal extra amount of land required for vehicular access at low speeds it may be seen to be an unreasonable restriction to prevent occasional vehicular passage to any one dwelling.

Consideration of household needs for vehicular access indicates that small vehicle access for occasional personal transportation is desirable and convenient but not essential. Access for small flat-bed trucks is invaluable at the construction stage to prevent double-handling building materials. Double-handling is an expensive procedure that puts an added burden on low-income households.

Small buses and paratransit vehicles do not require access to every household but should be able to travel freely on any site distributor routes. Parking for small vehicles belonging to individual householders is not required on genuine low-income housing sites and is unlikely to be required in the future.

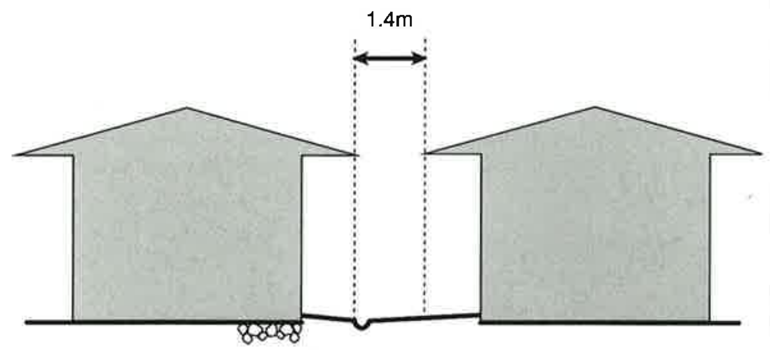


Figure 4.3: Minimum access widths

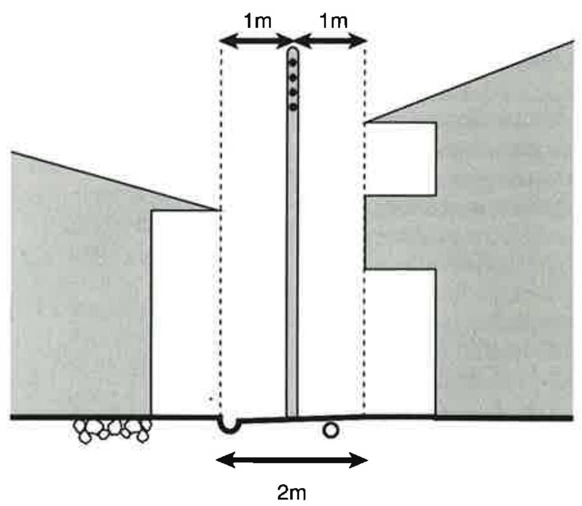


Figure 4.4: Minimum access to include overhead powerlines

Vehicles for services

Certain municipal services such as solid waste collection and latrine and septic tank emptying trucks require vehicular access; these vehicles do not normally have to reach directly to the household door. Specially designed suction tankers can generate sufficient power to evacuate pits and tanks up to 50 metres distant. Alternatively, small, highly manoeuvrable suction tankers and solid waste collection vehicles based on site dumper truck chassis have been developed for use on restricted sites.

Emergency vehicle access

Fire engines, ambulances and other rescue vehicles require access to sites. These do not normally need to reach individual households as fire engines and pumps normally carry 90 metres of hoses and patients can be carried a short distance to an ambulance. However, emergency vehicle access must be planned for and maintained; for example, it is preferable to have multiple site access routes in case of major fires or other disasters.

Pedestrian-dominated roads

The requirements discussed above lead to the design of pedestrian-dominated roads (United Nations Centre for Human Settlements, 1982) where vehicles can operate only at limited speeds. Pedestrians and human-powered vehicles are seen as having normal right of way. Motorised vehicles use the access route on limited occasions, with their speed controlled by road lengths and widths and perhaps also by speed bumps.

Services

Access routes must be designed to take into account the space required by services such as water supply pipes, sullage drainage, storm drainage, sewerage, and power lines or power cables. It is important not to limit future requirements, particularly for items such as overhead power lines, at the initial stage.

Hierarchy of access

Consideration of these objectives for access generally leads to designs for a hierarchy of access routes for any particular low-income housing site. There may be one or more site access roads leading off a suitable trunk route; a site distributor then connects all the housing clusters to the site access road. A cluster road gives access to individual households and finally, pathways may be used to interconnect clusters or to provide shorter walking distances for pedestrians.

Technical options

Access and road widths

In a programme of incremental improvement, the finished construction standard of roads and streets is likely to change over time. However, the road layout has to be fixed along with the individual plot boundaries at the initial stage of setting out. Once the rights of way have been determined it is extremely unlikely that the road widths would subsequently be changed.

Where land for low-income housing is not a significant constraint, road widths and land-take can be determined according to normal criteria for minor urban roads. A carriageway width of 5.5 metres with pavements or footpaths of 1.2 metres width on either side and suitable allowance for drainage is usually taken as the minimum standard for access roads.

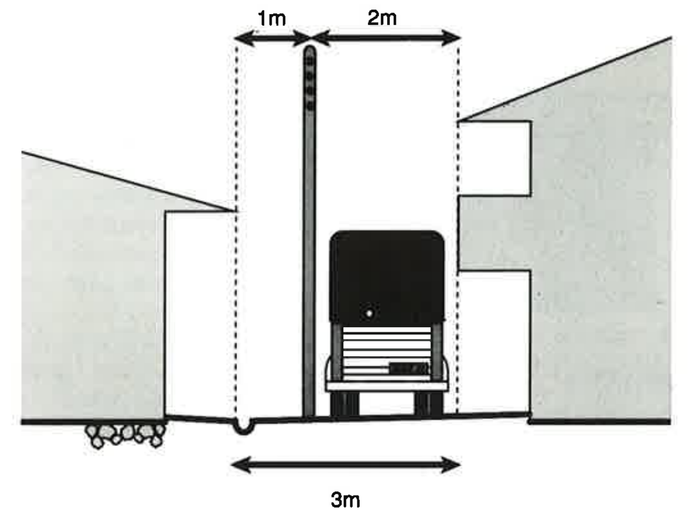


Figure 4.5: Pedestrian dominated access

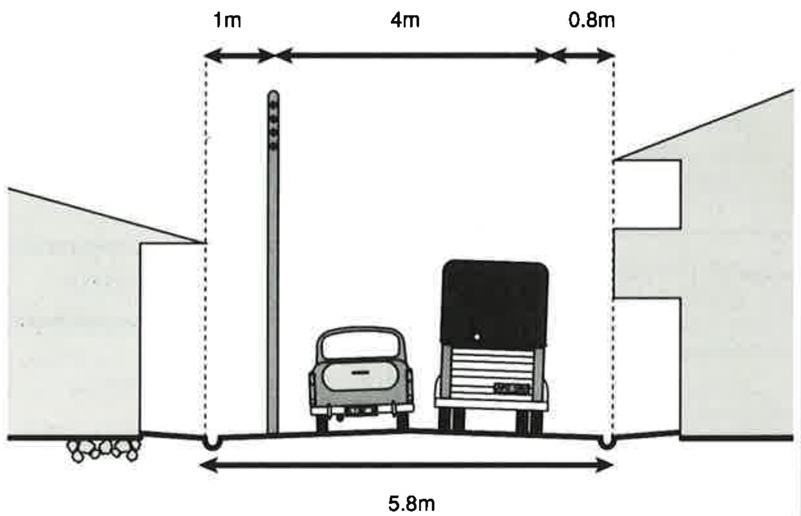


Figure 4.6: Local distributor

However, where high land costs or lack of suitable land demand a high housing density, the absolute minimum requirement is an access alley or lane for pedestrians to reach any dwelling. This could be as narrow as 1 metre (with a landtake of 1.4 m to include a drain, see Figure 4.3) although it is suggested that to allow two bicycles or two pedestrians with bags to pass, a more realistic minimum width is 1.6 metres. This necessarily precludes vehicular access but with the need to allow at least 0.4 m for a drain it allows for electricity supply by overhead lines.

Requirements for overhead electricity power lines are detailed in Chapter 8; most important is the need for a clearance of at least one metre between the plot boundary and the power line or the power line and the edge of any road. The minimum lane width between plot lines is therefore 2 metres (Figure 4.4). Where building lines are fixed a certain distance behind plot lines there is less cause for concern over clearances to power lines. However, in high density sites with plot sizes varying between 30m^2 and 50m^2 there is a tendency to build right up to the plot boundary.

Some building guidelines allow for a set-back of 0.9 metres from the plot line for the ground storey walls but then allow roof overhangs or balconies to overhang up to the plot boundary.

An access width of 2 metres permits a storm drain to be placed along one side of the power poles and a footpath with water supply under the opposite side. Unlined storm drains require a minimum land-take of 0.4 metres with a suggested allowance of 0.8m where vehicular traffic can pass; where this requirement is additional, land can be saved by using lined drains or buried pipes.

The addition of only 1 metre to the 2 metre access lane creates a carriageway 2 metres wide. This is sufficient to allow vehicular access to all houses for small vehicles such as carts and auto rickshaws as well as slow speed access for cars and small trucks. Common vehicle widths are typically about 1.7 metres. Additional land can be saved by providing a single crossfall of 4 per cent on the access way rather than a standard camber; this means that only a single drain is required as shown in Figure 4.5. The total land-take for this recommended minimum access is therefore 3 metres. It should also be noted that this marginally increased width gives a better protection as a fire break between housing lines.

The existence of direct access to a house influences its possible future uses and may be relevant to the encouragement of income-generating activities. In addition, the cost of upgrading from a footpath width to a limited vehicle access width may not be significant when considering the needs of other services for access.

An intermediate-sized cluster road may be used which allows for two vehicles to pass each other. The passing space is obtained by allowing one vehicle to move underneath the overhead power lines between the supporting poles. If the lines are insulated or are erected at the height equivalent to lines passing over a street there should be no difficulties associated with this. However, curbing or

Table 4.1: Recommended road layouts

	Carriageway Width	Total Land Take
Site access	5.5-8 m	7.3-9.8m
Local distributor	4-5.5 m	5.8-7.3m
Intermediate	4 m	5.6 m
cluster access (with restrictions at poles)		
Cluster access	2-2.5 m	3-3.5 m
Common footpath	1.6 m	2.0 m
Individual footpath	1.0 m	1.4 m

bollards might be necessary to protect the power poles. Because of drainage requirements only 0.2 metres of land are saved resulting in a total land-take of 5.6 metres.

A site distributor road should have a carriageway width which allows two trucks or small buses to pass at reduced speeds. This implies that the width should be between a minimum of 4 metres (Figure 4.6) and a suggested maximum of 5.5 metres (the accepted standard for minor urban roads). A camber of up to 4 per cent falling towards storm drains on both sides of the road is required. One drain runs within the 1 metre clearance for overhead lines and the other requires a space of 0.8 metres giving a total land-take or right of way between 5.8 metres and 7.3 metres.

Depending upon the size of the site, the main access road is designed to accept passing vehicles at conventionally accepted speeds, which leads to a 5.5 metres carriageway having 7.5 metres land-take. If an allowance for a line of parked cars is included, this requires an 8 metres carriageway having 10 metres land-take (Figure 4.7).

Caminos and Goethert (1976) examine the ideal intervals between lines of circulation and therefore the ideal block size. It is recommended that the spacing should be small enough to facilitate pedestrian circulation whilst retaining an economic land-take and minimising maintenance costs. The suggested intervals range between 200 metres to minimise costs up to 80 metres to allow for pedestrian use.

Transit passage

It is necessary to consider the problems of care, oversight and maintenance of the semi-private land within clusters or groups of dwellings. Experience so far suggests that in an open-ended cluster nobody feels responsible for the shared courts. One proposed solution is to give only one significant access to each cluster. However, there is a danger that this might limit escape in the case of fire or other disaster close to the main entrance. At subsidiary access points, walls or barriers approximately one metre high (which can be easily climbed in an emergency) may be used to limit pedestrian movement. The alternative approaches of using wider houses or an extra house at the end of an access way to form a cul-de-sac restricts the passage of services (and emergency movement) and limits the use of ring mains and direct drainage.

The land given over to semi-private shared courts could be allocated to

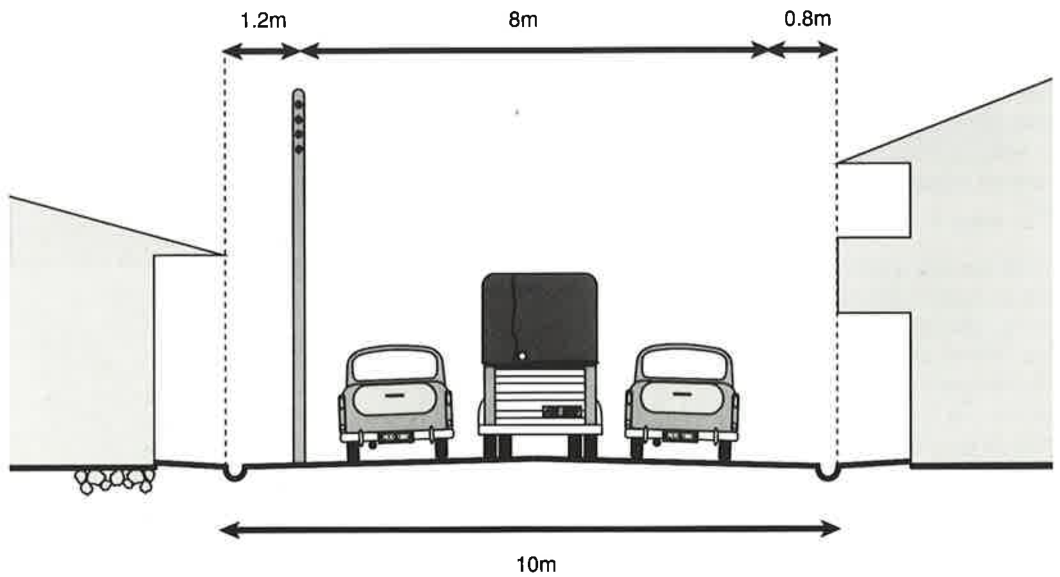


Figure 4.7: Site access with parking facility

each household in the form of a widened access in front of the house. The hope is that each householder assumes proprietorial rights over this strip on behalf of the cluster community. However, there is a danger that this area then becomes either a wider road or a private 'garden'; nevertheless, it gives the community the option of deciding how it wants to use its own space.

Vehicular parking

Although vehicle ownership is expected to be extremely limited in the short term, parking areas for visiting vehicles are needed. If there are no other obvious areas within the locality, provision such as widened site access has to be made to prevent vehicle parking in the restricted cluster streets. Any use of the restricted streets for parking blocks the access and is inconvenient for other occasional road users. It is also dangerous in times of emergency within the site, such as a house catching on fire.

Traffic speeds

The minimising of road widths to provide full access at minimum cost presumes extremely low vehicle speeds. A minimum road width of 2 or 2.5 metres in cluster access to housing implies maximum allowable vehicle speeds at walking speeds of 4 km/hr. On larger access roads of 3.5 metres width, design speeds of 20-30 km/hr are considered acceptable whereas for 5 metres wide local distributors the recommended design speed is 30-40 km/hr.

High vehicle speeds, even those obtainable on narrow roads in low-income sites, can be a significant factor in accidents, road damage and the subsequent need for maintenance. To limit vehicle movements to the design limitations, speed bumps or 'sleeping policemen' should be considered for site roads. Raised humps, 200 mm high with 3 metres long rises and falls at a maximum of 200 metres centres can reduce

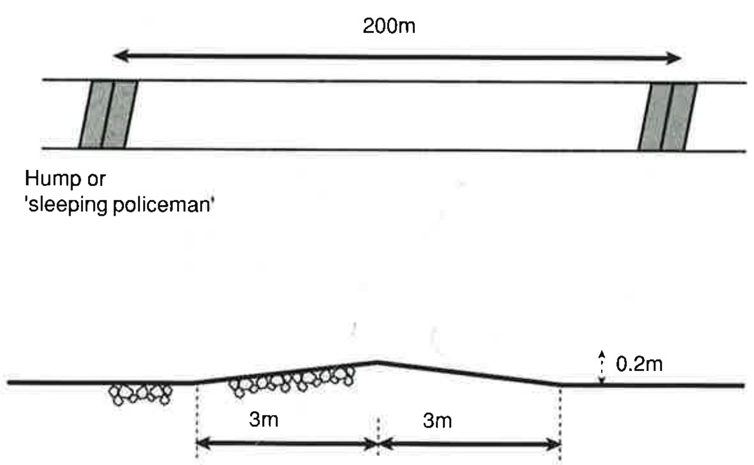


Figure 4.8: Speed restrictors

maintenance needs as well as enhance road and site safety (Figure 4.8).

These humps can be designed to lie slightly offset from the perpendicular, in which case they also serve to divert into the storm drains any stormwater flow which is developing in a longitudinal direction along the road surface. This also enhances the life and stability particularly of earth roads. (Hindson, 1983)

Gradients

It is advisable to limit road gradients wherever possible, both to minimise drainage problems and to enhance vehicle usage. Where roads have a bitumen seal, steeper gradients can be used as there is less likelihood of erosion and wheel spin.

Normal standards allow for gradients in the region of 10 per cent-12 per cent. This may be increased to 15 per cent for sealed roads but anything steeper than this should be avoided if possible even though Caminos and Goethert (1976) describe residential streets of up to 32 per cent in North America. Gradients on bends, particularly on tight hairpin bends are normally reduced to a maximum of 5 per cent.

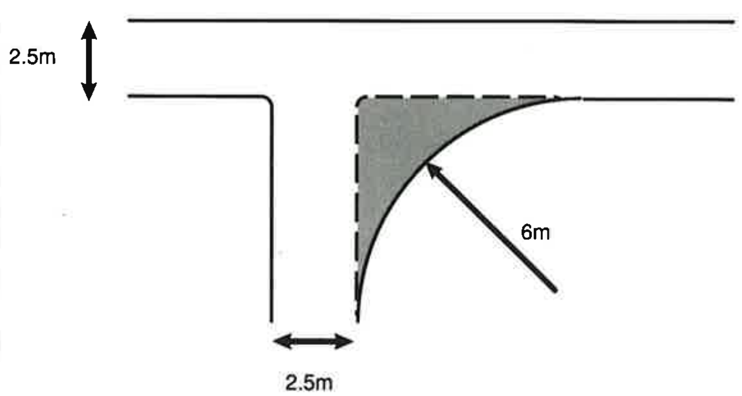


Figure 4.9: Turning circle

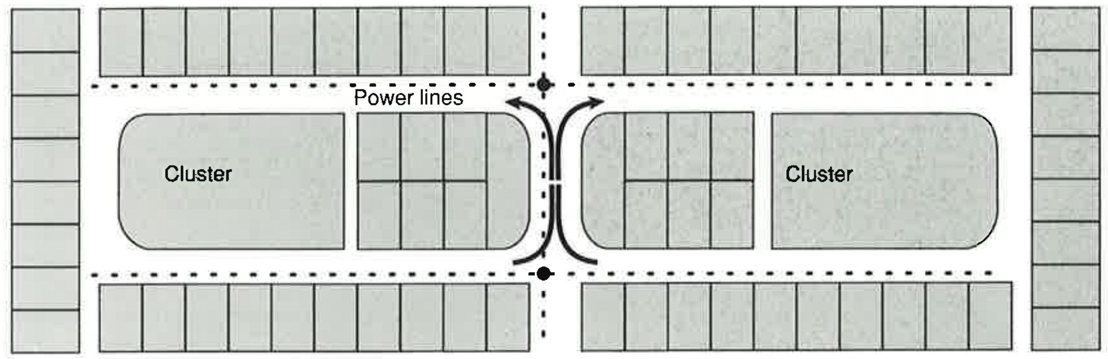


Figure 4.10: Reduced land-take turning circle

Where steeper access routes are required it is advisable to use stepped pathways between the main vehicular routes that run along the contours. Smooth paving alongside the steps allows the easy passage of bicycles along the steep short-cuts.

A minimum gradient is also advisable to ensure adequate longitudinal road drainage; 0.4 per cent is recommended for bitumen-surfaced roads and 0.7 per cent for earth roads. This latter figure ensures that adjoining earth drains run at a constant depth with suitable flow velocities.

Turning circles

Where narrow cluster streets are used to minimise the land-take, consideration must be given to the need for turning circles. A large vehicle such as a truck cannot turn directly into a 90 degree opening because of the maximum lock on the steering and the overhang of the vehicle at front and rear; land has to be set aside to enable the vehicle to turn gradually. Site measurements of a 7.5 metres long vehicle similar to the common flat bed trunks used for hauling building materials indicate that a minimum turning circle of 6 metres radius is required (Figure 4.9).

If a vehicle has to turn from a wider site access road into the narrow cluster access, because of the low expected usage of the roads, it is acceptable to assume that the vehicle can swing out onto the far side of the carriageway. Another way to minimise the land-take is to have the turning circle operating from one direction only as Figure 4.10 shows; vehicles travelling from the bottom would not be able to take the first turn into the cluster. Where the cluster is designed as a circuit, any vehicle could take the second turn using the circle space and gain access to every point.

This method has the advantage that a power pole for leading power lines into the cluster from the main road can be situated in the best location without restricting traffic movements.

Conventional design standards require that turning heads are constructed at the head of cluster access cul-de-sacs as shown in Figure 4.11. The cost of the additional land required results in

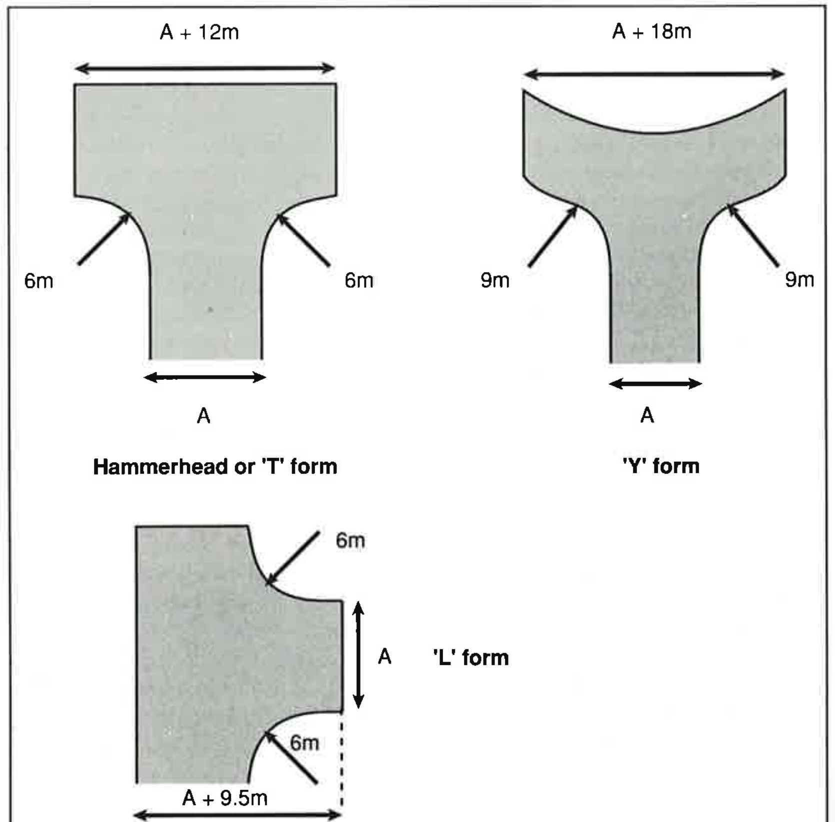


Figure 4.11: Turning heads on cul-de-sacs

Above: Low-income housing site access - what is the optimum size?

Below: An economical cluster access road

little extra benefit where vehicle usage is so limited; it is reasonable to assume that vehicles reverse out of the cul-de-sac provided that the local distributor has reduced speed access. Alternatively, a turning head may usefully incorporate an area for the standpost and solid waste collection point.

Sight lines and intersections

Sight lines are required at street junctions to prevent accidents between vehicles entering and leaving. Recommended viewing distances vary according to the relative design speeds of the intersecting roads. As a minimum, a splay on the building line of 5 metres from the edge of the road is required for slow moving urban traffic. Sometimes the communal solid waste bin and standposts are located at junctions to give the required viewing distance. Wherever sight lines would otherwise require the loss of one dwelling per intersection, as an alternative it may be permissible to introduce a speed hump at the junction to prevent fast moving vehicles joining the major road at excessive speeds.

Intersections of site distributor roads with site access roads should be spaced such that wherever possible no two intersections are opposite each other. It is preferable to have a reasonable distance between intersections on the same side of a distributor; a minimum of 30 metres is recommended (United Nations Centre for Human Settlements, 1985).

Detailed design factors

Roads and pavements

Any access route for pedestrians or vehicles requires a smooth surface, free of obstructions or holes, which is passable in wet weather or immediately after storm conditions. The particular type of surfacing used is designed to meet the normal anticipated loading from vehicles.

On low-income sites where traffic flow is likely to be limited, the method of stormwater drainage (see Chapter 3) is the most significant factor in determining the form of road construction adopted. This is the overriding requirement for a strong and long lasting road. Underneath any road, despite its surfacing, there are compacted soils which have to distribute the vehicle loads. If these soils are saturated with excess storm water or sullage, their bearing capacity is dramatically reduced which eventually leads to failure of the road surface.

On sites having slopes of over 6 per cent, erosion of unlined drains may occur if the roads and drains are laid to the natural slope of the land; widespread use of more expensive lined drains may be necessary. However, erosion can be limited if the roads can be laid so that contour lines are crossed at a gradient of about 0.66 per cent. Otherwise they should run approximately parallel to the contours, with the minimum possible length of road cutting across the contours at right angles. These cross-contour roads require lined drains which then act as collectors for the roads and drains running parallel to the contours. Where there is a risk of considerable stormwater flow across or along the road, the road surface has to be sealed. This is expensive, particularly where the traffic flow does not justify a sealed surface.

On relatively flat sites, open channel drains require a minimum slope of 0.66 per cent if the drains carry sullage and 0.33 per cent if they carry only stormwater. To avoid excessive drain depths, the road layout should minimise the length of drainage runs. If the gradient is too small, or the drains are easily blocked, the ground becomes saturated thereby reducing the load-carrying capacity of the road. As vehicles pass over the saturated area, small pot-holes enlarge into the muddy quagmires so characteristic of unimproved low-income housing areas.

Road camber

The road camber or crossfall is the perpendicular slope of the road and its magnitude determines the rate of stormwater runoff. Therefore, the camber must be maintained adequately to prevent deterioration of the surface. For an earth road a minimum camber of 4 per cent is required to prevent ponding of storm water. A bitumen sealed surface has fewer surface irregularities and is less susceptible to water damage; an allowable camber for sealed roads is approximately 2 per cent.

Where the roads are narrow, as suggested for cluster access, a single crossfall leading into a single storm drain is effective. However, where wider roads are used the surface should slope in both directions away from the centre of the road into storm drains on either side. This ensures that storm water is quickly removed before the road becomes damaged.

Pavement alternatives

Pavement and road construction encompass a variety of technical options that are well suited to an upgrading programme. Methods of construction depend upon soil conditions, climate, cost, social preferences and the suitability of labour-intensive techniques as opposed to the use of machines. The provision of a bitumen metalled road is not an objective in its own right; road design is usually related to traffic flow and there exist a range of options for road design and construction ranging from the marked right of way to the bitumen metalled road. Possible options include:

- a compacted earth road;
- stabilisation of an earth road;
- gravel surfacing on a sub-base of compacted earth or building debris;
- brick or block paving;
- concrete pavements;
- a water bound macadam surface;
- a bituminous macadam (penetration or surface dressing) road.

Many of these alternatives require different specifications from standard type plans; however, they merit detailed consideration if the levels of service are to be economic in long-term. To quote the then Prime Minister of Sri Lanka (Ministry of Highways, 1986):

"....A road should be metalled and tarred only if the conditions of climate and terrain necessitate such conversion or if the traffic volume has reached such an intensity where metalling and tarring becomes economical...."

One of the primary level options consists of a marked right of way through the site. This can be improved at an early stage, perhaps on completion of most of the house building, to a profiled earth road with earth side drains. The earth road can be upgraded by the superposition of a gravelled surface; this could be justified by traffic volume if there are regularly more than 50 vehicle (over 1000 kg weight) movements per day. Details of the economic vehicle usage of different road and pavement types are shown in Table 4.2.

It is unlikely that traffic volume in the near future justifies any further upgrading of cluster access roads. The site distributors and the main site access might ultimately require a bitumen macadam surface; however, this can only be considered when long-term responsibility for maintenance is assured. A bitumen road with potholes is far more damaging to vehicles than a poorly maintained gravel road.

Where a community decides that it wants a higher standard of surfacing than traffic flows economically allow, for example to alleviate dust nuisance or for reasons of perceived status, it should clearly be the responsibility of that community to pay for the upgrading and subsequent maintenance.

Table 4.2 Economic vehicle usage

Service Level	Road surface	Vehicle movements
Primary:	Earth	up to 50
Intermediate:	Stabilised earth gravel	up to 100
	Water bound macadam	up to 350
Ultimate:	Bituminous surface dressing	up to 1200
	Semi grouted macadam	up to 3000
	Bituminous asphalt	up to 5000

Note: In Table 4.2 vehicle movements are measured in units of 'vehicle movements per day' (vpmd) for vehicles having an equivalent weight of 1000 kg (Khanna, 1990).

Traffic flows

Road design is normally dependent upon current and future estimated traffic flows measured in vehicle movements per day (vmpd) and the composition of the traffic, that is, the number of trucks, buses, cars and light vehicles. Damage to any road surface due to a vehicle passing over it is proportional to the fourth power of axle loading. For example, a single 13 tonne axle may be equivalent to eight 8.2 tonne axles passing over the same road (Transport and Road Research Laboratory, 1988).

For design purposes, traffic flows may be converted into standard equivalent axle loadings of 8200 kg. In many countries, design guides for conventional structural design of minor roads commence at a level of approximately 150 commercial vehicles per day with equivalent standard axles of 8200kg.

This suggests that in most low-income housing sites it may be assumed that average and peak traffic flows are unlikely to be significant determining factors in road design. However, an approximate understanding of likely vehicle movements aids the selection of appropriate road surfaces. The economically viable surfaces are detailed in Table 4.2. At the very low anticipated loading of only a few commercial vehicles per day, the level of accessibility due to the route widths is of greater importance than structural strength.

Earth roads

An earth road uses existing soil along the road line mounded up to a suitable profile and compacted.

Where there is a mixture of granular material and clay material to fill the voids the resulting compacted surface forms a strong running surface. In dry weather, a fairly high proportion of clay is required to bind the surface together. However, when it rains this clay makes the surface slippery and is likely to deform and rut under traffic.

Compaction of the earth is vital to provide a lasting surface. The degree of compaction obtained is dependent upon the depth of earth layers and the moisture content of the soil. Although natural compaction of the site fill is generally sufficient, after most of the house-building is completed the roads should be re-profiled and compacted.

Besides compaction, the other most important factor determining the life of an earth road is the stormwater drainage; when wet, the bearing capacity of compacted earth falls dramatically. There is always some movement of soil into the drains after heavy rain on an earth road. It is the responsibility of a maintenance programme to clear the drains regularly and to replace the soil on the road surface.

Design details: The strength and life of an earth road depend upon the composition of the earth. Detailed tables are available (for example O'Reilly and Millard, 1969) of preferred particle size distribution, that is, the proportion of different sized particles occurring

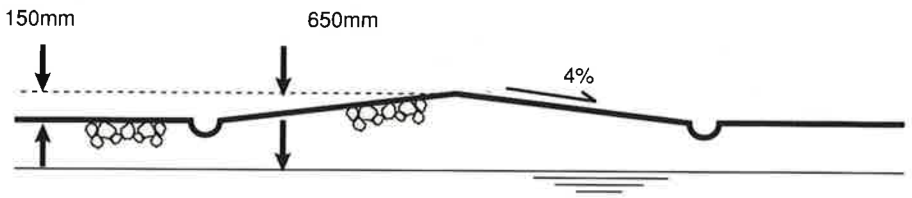


Figure 4.12: Earth road drainage and camber

within a sample of the natural earth. The requirements are fairly broad and many soils are normally adequate at the low traffic flows anticipated. General proportions of around 75 per cent sand and 25 per cent clay give suitable results; the composition can be determined approximately using the simple jar test described in Chapter 2. If a housing site has been filled with imported material, these soils are also likely to be suitable for earth roads.

To be effective, earth roads should be profiled to give a camber of not less than 4 per cent and compacted. Labour intensive methods of compaction are rarely economic or efficient; ideally, some form of double-axle vibrating roller should be used with several passes over each layer of earth. Control of the moisture content is important; it may be checked using the following 'rule of thumb' method:

"Take sufficient soil onto the palm of the hand and make a pat of soil by closing the fingers on it. When you release the fingers, if the pat crumbles then there is too little water. If you find soil clinging on to the fingers then there is too much water. However, if the soil forms a pat without crumbling or without excessive soil clinging to the fingers, then the soil is at its correct moisture content".

To preserve the strength of the road foundation, the crown, that is the highest point of the road camber, should be at least 150 millimetres above the surrounding ground level and at least 650 mm above the average groundwater level (Figure 4.12). Otherwise, there is a danger that the reduced strength of the saturated soils will lead to deformation on the surface. This requires increased maintenance if complete failure is to be avoided.

Stabilised earth roads

Stabilisation by mixing the soil with materials such as cement, lime or bitumen provides a relatively low-cost, simple means of upgrading earth roads. This stabilisation normally requires the protection of a bituminous surfacing to prevent abrasion by traffic. However, in the low-speed, low-volume traffic of housing sites, the simple addition of selected materials may meet the needs of householders for relatively dust-free, limited maintenance access routes.

Design details: Kezdi (1979) explains that stabilising soils improves the strength of the soil irrespective of weather conditions or traffic loading. Clay soils with a high bearing capacity when dry can retain that capacity when wet. Sandy soils which are cohesive because of capillary action when wet can be prevented from loosing all bearing capacity when dry. However, care must be taken as it is not desirable to have particularly high strengths because of subsequent cracking and shrinkage. The recommended proportion of cement or lime, which are the most common materials for stabilisation, therefore ranges between 3 per cent and 7 per cent by weight of the dry soil.

Cement stabilisation is more effective when carried out with machines for mixing. Lime stabilisation can be carried out by labour-intensive methods, partly because it does not set as quickly. With most soils the stabiliser requirement is about 11 kg per square metre for a 150 mm thick base.

Bitumen is most useful for stabilising sandy soils which lack cohesion due to a shortage of clay material. The recommended range is 4 per cent to 6 per cent by weight of dry sand, reducing to as little as 2 per cent if the sand is well-graded.

Gravelled roads

Where the material used in the construction of the earth road has too high a proportion of clay in it for long-term stability, the surfacing can be improved by spreading and rolling gravel material. Although 'gravel' is normally taken to be small stones and sand, in the context of road gravelling it refers to any material that is brought in from a distance to improve the surface of the road. This form of surfacing can substantially increase the carrying capacity of an earth road.

Design details: Where the existing soils are unsuitable or where traffic has increased significantly, a layer of gravel between 100 mm and 200 mm thick is laid and compacted on top of the profiled earth. The gravel material having a maximum particle size of 25 mm may be graded as 15 per cent in the 25 mm to 20 mm range, 75 per cent in the 20 mm to 6 mm range with 10 per cent fines below 6 mm to provide the binding material to hold the surface together. For example, the Sri Lankan Ministry of Highways (1986) recommends a soil with plasticity index of between 4 and 9 for the climatically wet zones and between 6 and 20 for the climatically dry zones.

Compaction of the gravel surfacing requires an 8 to 10 tonne smooth-wheeled roller (or equivalent) taking between 6 and 8 passes for a 150 mm thick layer. The rolling is carried out by commencing from the edge of the road and then moving in towards the crown.

Water bound macadam

Water bound macadam is the term given to stone surfacing that has been laid using water as a lubricant to help the stone or road metal lock together to produce a dense material. Although water bound macadam roads are now rarely used, where stone which is suitable for road metal is freely available, the community might choose this option before investing in the ultimate level of bituminous macadam.

Design details: With a good existing sub-grade or earth foundation, a base course of road metal can be laid. Where mechanically crushed rock is not widely available, a more traditional method known as pitching or soling can be employed. The technique is to produce a tightly keyed coarse aggregate by hand-placing large stones of about 100 millimetre size onto the sub-base or formation. This is followed by two layers of 50 millimetre stone, normally topped with a layer of 20 millimetre aggregate. To be economic, this method depends upon low labour costs.

The metal is compacted by rolling, with water applied to act as a lubricant to help the road metal lock together and produce a dense material.

It can be difficult to compact the road metal satisfactorily and inadequate compaction may result in voids through which rain water can enter. The sub-base may be softened and then work its way up between the larger stones, possibly causing failure. Therefore if the surface is not being treated with bitumen immediately, it is advisable to prepare the sub-base with a layer of rock dust or other fine granular material.

It is estimated that this surfacing gives a five year life for up to 100 vehicle movements per day. Annual maintenance costs are approximately 5 per cent of original capital cost and renewing the surface after five years costs about 50 per cent of the original cost (Khanna, 1990).

Brick paving

Fired bricks may be laid on edge on a bed of sand, tightly packed together. This method is particularly popular on the Indian sub-continent in areas where suitable road metals are scarce.

Alternatively, dense concrete blocks, similar in size to bricks, but with chamfered edges, are now widely used for paving. They are particularly useful in areas where a bituminous surface might be damaged by engine oil dripping from stationary vehicles. These are laid in a similar fashion to the fired bricks and tend to have a longer life, although the capital cost is greater.

There is clearly scope for using paving materials that are readily available locally. Quarried stone slabs or flags provide a good surface that drains well and is easy to maintain. They are prone to crack under heavy loads and are not normally suitable for access ways which carry anything other than pedestrians and light vehicles.

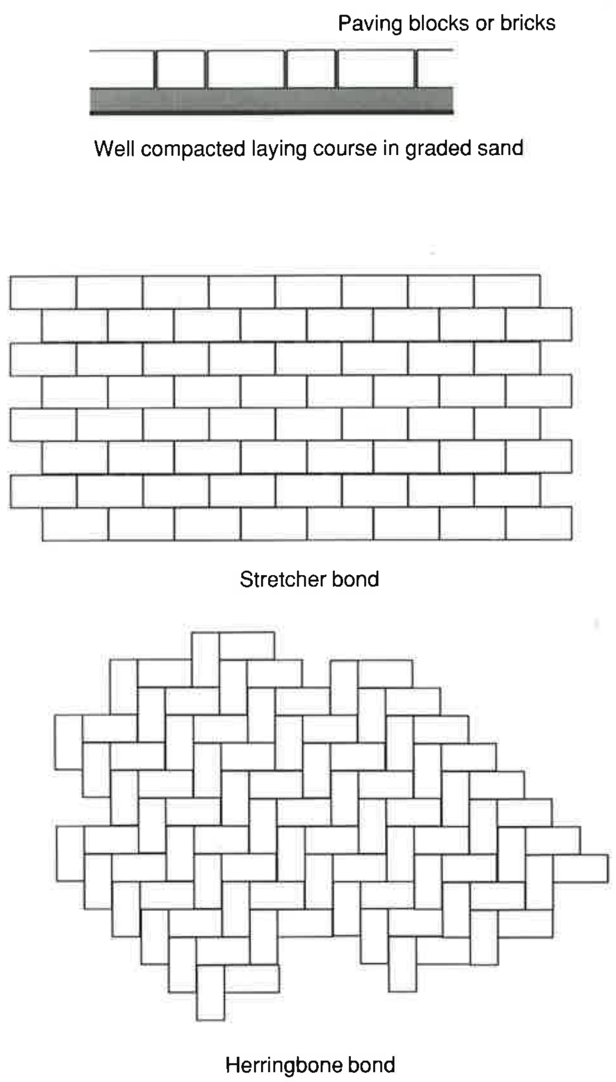


Figure 4.13: Brick or block paving

Design details: Well-fired bricks without 'frogs' (the depression in one surface to aid bonding in a wall) are laid on a 25 - 50 mm coarse sand cushion, or in heavily trafficked areas on 50 mm - 75 mm rammed ballast or cement mortar. The bricks are normally laid on edge with their length perpendicular to the road line. Alternate rows of bricks should have their joints staggered to ensure that there are no through joints. The edging bricks, laid at right angles to the main surface, must be secured by kerb or concrete. If this edge restraint is lost the road surface in that area will gradually migrate towards that weak point, eventually leading to failure. At crossings where it is not possible to lay bricks perpendicular to vehicle movement a herring-bone arrangement is used (Figure 4.13).

Bricks can also be laid with cement mortar joints or joints filled with bitumen before dusting with fine sand. Where a tamping plate is available, a higher strength can be achieved with good quality bricks by vibrating fine sand into the joints, forming an interlock between bricks and sand.

The principal advantages of brick pavements over rigid concrete are firstly, the possibility for easy replacement and maintenance and secondly, neither curing time nor joints and sealing compounds are required.

Concrete blocks are laid in a similar fashion, although not on edge.

Concrete paving

Rigid concrete pavements are often used for pedestrian routes. They tend to be more expensive initially but have a lower maintenance cost than bituminous surfacing. Their inherent structural strength means that there is less likelihood of damage to the edges of the surfacing in comparison with flexible bitumen. Concrete is unlikely to be used for vehicular routes unless there is a significant cost advantage in using locally produced cement rather than imported bitumen.

Concreting uses local skills which are already present in the building industry. However, great attention has to be given to quality control on site as incorrectly cured concrete rapidly disintegrates. One alternative for small areas is to use factory-made concrete slabs for paving.

Design details: Successful concrete paving or roads depend upon the suitability of the base foundation and the construction quality. For the unreinforced Grade 20 (1:2:4) concrete likely to be used it is important that the underlying ground has even bearing capacity. Any soft areas can lead to a bridging effect which under a heavy load may lead to cracking and subsequent failure of the concrete pavement. At the road edge it is necessary to ensure that the foundation material extends by a minimum of 300 mm to ensure that the concrete remains supported.

Because of thermal contraction and expansion it is necessary to include joints in concrete slabs. The Indian Roads Congress (IRC 15, in Khanna, 1990) recommends contraction joints at 4.5 metres spacing and full expansion joints every 100 to 150 metres. These joints require special care to avoid problems due to unsuitable material filling the joints and rendering them useless. Joints may cause an uneven surface that can result in impact loading from vehicles and possible damage to the slab from repeated high shock loads.

Concrete paving can be cast directly onto thoroughly compacted gravels having a suitable bearing capacity. The recommended thickness of the concrete is 100 mm to 130 mm. However, a base of water-bound macadam or cement-stabilised material is required for weaker soils or for areas of higher loading. Because of the interaction between the concrete and stone base a 75 mm thick slab is considered adequate for light traffic intensity (Khanna, 1990). This may be contrasted with a minimum slab thickness of 150 mm (160 mm for unreinforced) recommended by the Department of Transport for cul-de-sacs and minor residential roads in Europe. Their recommended joint spacings are 5 m for contraction and 40 m for expansion joints in slabs less than 200 mm thick.

Bituminous macadam

There are many different forms of bituminous surfacings with different combinations of bitumen types, sizes of road metal and thicknesses of layers. For low-income housing sites the most obvious choices are:

- to construct a penetration bituminous macadam mat by pouring bitumen onto road metal which has already been laid;
- to lay on the compacted gravel a surface dressing comprising one or more thin layers of bitumen with single sized stone chippings rolled in.

Pre-mix bituminous materials where aggregates and binders are heated and mixed together are not normally used on sites with limited traffic. Medium textured macadams that derive their stability from the interlocking of the aggregates and dense asphalts with closely graded mixtures of fine and coarse aggregates are expensive to prepare and require increased site supervision and quality control to be effective.

Design details: For penetration macadam, the surface of 40 mm to 50 mm sized road stone is prepared by semi-grouting the compacted road metal to approximately 50 mm depth. Bitumen of suitable viscosity at the correct temperature is poured onto the road metal such that the bitumen penetrates only the top half of the stone layer. This method uses about 400 kg of bitumen per 100 square metres. Full grouting, where the binder penetrates to the bottom of the stone layer, is not recommended. It is unnecessarily wasteful and there is the danger of surplus bitumen rising to the surface and creating a slippery traffic surface that is difficult to treat.

The bitumen used is generally an emulsion, a viscous cut-back emulsion, a tar or a straight run bitumen. At the time of spraying, the binder must be fluid enough to penetrate the voids and coat the aggregate. But it should not be so

Above: Bitumen surfaced cluster access clearly defined by drains

Below: Stone paving on a cluster access

fluid that it runs through the metal to the formation, failing to fill up or grout the top layer. Two applications of bitumen or hot tar are normally required, the second being blinded with river sand to form a hard waterproof wearing surface.

The surface dressing technique requires compacted or stabilised gravels to be primed with a cut-back bitumen, that is one of low viscosity, at a rate of about 0.5-1.0 litres per square metre. This binds together the top 5 mm layer of earth so that the tack coat or binder applied at a rate of 0.9-1.5 litres per square metre can bond the 13 mm road metal to the earth base. The road metal is rolled onto the tack coat at a rate of 13 kg per square metre. In general it is best to use the most viscous binder that can be sprayed uniformly with the equipment available (Transport and Road Research Laboratory, 1977).

Depending upon requirements, a seal coat may then be applied; for example, this might comprise 7 mm stones rolled and compacted at a rate of 10 kg per square metre. The best combinations of soils, road metal and sizing and types of bitumen are normally determined according to local conditions.

A bituminous surface is estimated to have a fifteen year life with up to 3000 vehicle movements per day using the road. Annual maintenance costs are assumed to be 2 per cent of capital cost with a new seal coat required after five years costing 25 per cent and renewal of the road after fifteen years costing about 85 per cent of the original capital cost (Khanna, 1990).

Operation and maintenance

The small volume of traffic on low-income housing sites is unlikely in itself to cause significant problems; protection from the effects of stormwater therefore becomes the most important task for maintenance work.

The camber or crossfall on the road or path surface has to be maintained in order to shed rain as it falls. If the water forms a pool on the surface, the next vehicle to pass deforms the road further in that area. The lower bearing pressure of the saturated ground leads to the formation of a pothole, which grows and eventually leads to failure of the road. If the camber is regularly maintained, the long-term needs for repair can be minimised. Once the water has reached the storm drains it is important that it can flow away rapidly to prevent flooding; details of drain maintenance are given in Chapter 3.

The most effective means of ensuring adequate maintenance of both roads and drains is to employ 'lengthmen' who are given responsibility for particular lengths of roads and associated drainage. They systematically work along their length, cleaning drains and filling potholes. Such a system is more effective than sending in a maintenance team from a centralised authority depot only when the problem has become serious enough for it to be reported.

A lengthman can also reduce dust nuisance from earth or gravel roads by keeping the surface level and compacted and by ensuring that speeds are kept to appropriate levels by maintaining speed bumps.

The need for re-surfacing is drastically reduced by good maintenance. With earth roads, re-surfacing is carried out relatively easily by bringing in new loads of gravel to replace losses due to stormwater or dust erosion. On gravelled roads, the amount of material lost is approximately 20-30 millimetres thickness per year per 100 vehicles using the road per day (Transport and Road Research Laboratory, 1988).

Bitumen roads can easily be patched and at infrequent intervals may be given a new surface dressing of bitumen coating with aggregate rolled in. However, where the road has been allowed to deteriorate into large pot-holes, more extensive and expensive re-building is required.

Cost recovery

Following the model described in the first chapter, the primary requirement for profiled earth roads with adequate drainage is met by the initiating agency; maintenance by lengthmen can be organised by the cluster and site communities.

Upgrading of pavement surfacing for convenience benefits is the responsibility of the cluster or site community unless local taxes are being paid at a rate where the municipal authorities may reasonably be expected to take over this responsibility.

Above: What width of access is required down the back of housing?

Water supply 5

Objectives

The principal objective is to provide a reliable supply of water in sufficient quantity and of adequate quality which is readily accessible to the consumers. Many urban dwellers resort to obtaining water from ponds, streams, canals or ditches which are likely to be severely polluted. Their only access to water of reasonable quality may involve queuing at distant standposts or purchasing at inflated prices from water vendors or the houses of private individuals.

However, it is difficult to define exactly what constitutes an appropriate level of service to achieve the stated objectives. Whilst the principal benefits are improvements to health and reduction in time spent collecting water, there has been a mistaken tendency to regard the high level of service which most developed Western countries enjoy as an objective in its own right (Cairncross and Kinnear, 1988).

A complex relationship exists between the environmental conditions in which people live, their awareness of basic hygiene practices, and their health. Water is but one component; given the general squalor in which many low income people live, a single measure such as improving only the quality of water supplied would have little measurable effect on health. The inter-relationships between water supply, sanitation, health, and environmental conditions are described in detail by Cairncross and Feacham (1983).

Water quantity

The quantity of water to which people have access is perhaps the most significant factor. People need water principally for drinking, cooking, bathing, and laundry. The bodily requirement for an adult is normally less than 8 litres per day; it is difficult to quantify the other uses such as bathing and laundry because they are a function of the amount of water which is actually available. Religious and cultural practices also affect the amount of water used for bathing.

The presence of many common illnesses such as diarrhoeas, dysenteries, enteric fevers, infectious skin and eye diseases, and certain louse-borne infections can be reduced by improvements in personal and domestic hygiene.

The availability of sufficient quantity of water for bathing, cleaning and laundry is thus of great importance, whereas the quality of this water is not especially important.

Accessibility and reliability

Water can be supplied either to communal public supply points or directly to individual households. The location and number of public supply points provided is an important factor in water supply planning. The vast majority of low-income people are unlikely to have a water supply, be it a tap or a well, on their property; their access to water is through a system of public supply points.

The water resources and distribution systems of many towns and cities are inadequate to meet the required demand. One result of this is water rationing, which the authorities achieve by limiting the time for which water is supplied into different parts of the distribution system; some areas may only receive one hour's supply daily. Wells and boreholes may dry up frequently in the dry season as the level of the local water table falls. The result is that long queues form at public standposts and people have to walk further to obtain water from those supply points which are still functioning.

In such a situation, all options should be explored; it may be feasible to provide sufficient number of standposts to permit people to collect water for drinking and cooking purposes, whilst using improved wells for bathing and laundry. Storage of water in the home helps to ensure some continuity of supply.

Water quality

Water which is collected from public supply points, such as standposts or wells, is frequently contaminated during collection and storage in the household, because of a lack of understanding of basic hygiene. Such contamination can occur even if the water issuing from the standpost is uncontaminated,

Inefficient water treatment plants, coupled with problems of intermittent supply and leakage in distribution systems, gives rise to bacterial contamination in many piped water supplies. Whilst the provision of bacteriologically pure water is a desirable long-term goal, it is not a prerequisite for improving existing supplies. For example, there would be little point in shutting off public standposts because the water suffered low-level bacterial contamination, if people were then driven to use a filthy stream or canal.

Technical options

Sources of water

Unprotected sources

Unprotected surface water sources such as ponds, streams, ditches or canals which are seriously polluted are difficult to improve and should be abandoned at all costs. Groundwater from shallow wells or springs can be improved and protected from pollution.

Off-site sources

The source of mains water supply for a town or city may be either:

- surface water, that is water abstracted directly from streams, rivers and lakes, *or*
- groundwater, that is water which is abstracted from beneath the ground using wells, or from protected springs.

In some cases a combination of surface and groundwater sources may be used. The water is usually treated to be of potable quality, and is distributed via a network of pipes known as the 'distribution system'. Water for low-income housing developments is commonly taken from the mains and distributed locally around the site through a system of smaller pipes to public standposts, or to individual house connections.

On-site groundwater

If there exists groundwater of good quality on the site, the resource can be fully developed provided that on-plot pit latrines are not used for sanitation. In many situations it is cheaper to develop an off-site groundwater source and pipe the water into the site than it is to develop on-site groundwater and have to provide sewerage as the form of sanitation.

Unprotected shallow wells and springs are prone to pollution by dirty water, mud, and excreta which result from human and animal activity around the water source. Details of spring protection are described by Cairncross and Feacham (1978); an improved shallow well is illustrated in Figure 5.1.

One of the best means of protecting and abstracting groundwater is to drill a borehole and cap it with a handpump to raise the water. Handpumps can be used at public supply points and for individual household supplies. If the water table is only one or two metres below ground level, the groundwater is likely to be contaminated by seepage from open drains, sewers, and pit latrines. In such situations a piped water supply from an off-site source is necessary which, at the very least, provides sufficient water for drinking and cooking purposes. In general, groundwater is safer from pollution when the aquifer is deep and confined.

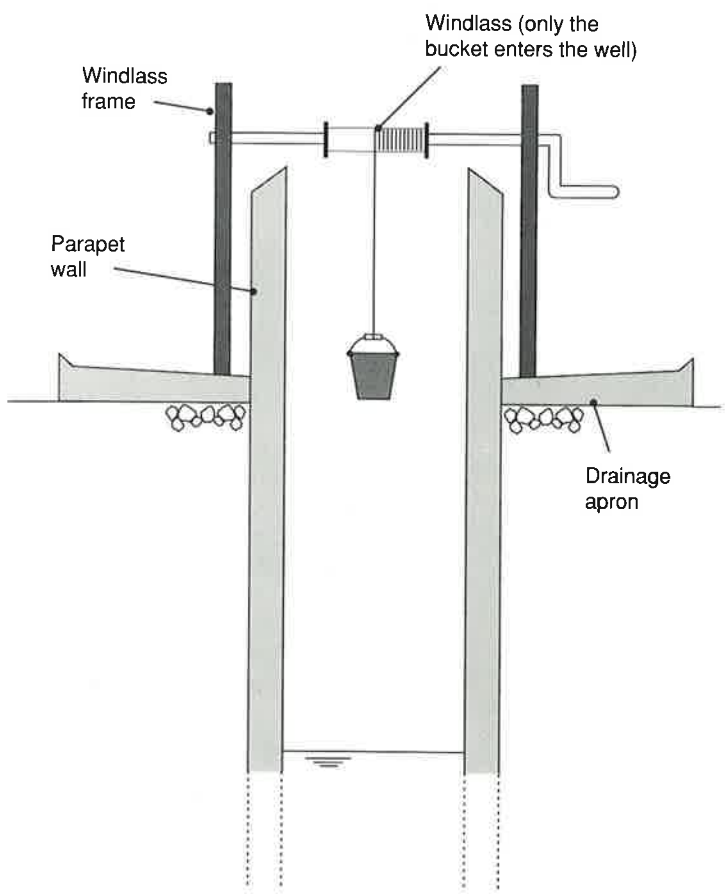


Figure 5.1: An improved well

Rainwater

The direct collection and use of rainwater is widely practised at an informal level by householders. A tile or sheet roof acts as the 'catchment', the rain is collected in gutters and led into storage vessels as shown in Figure 5.2. It is unlikely that all the household demand can be met because of the limited area of the roof catchment and the need for considerable storage capacity to store water through prolonged dry periods. Nevertheless, in areas where the water supply is inadequate, rainwater is a useful resource which can meet at least part of the water demand at certain times of the year.

The quality of the water depends principally on the cleanliness of the roof and gutters, although atmospheric pollutants can be absorbed into rain in urban areas. Whilst the cost of informal collection without modifying the roof or gutters is low, it is expensive to provide storage to cope with long dry periods (Cotton, 1986). Public sector intervention with a large programme is unlikely to be appropriate; communities should be made aware of the potential use of rainwater and provided with advice on how to improve their collection system.

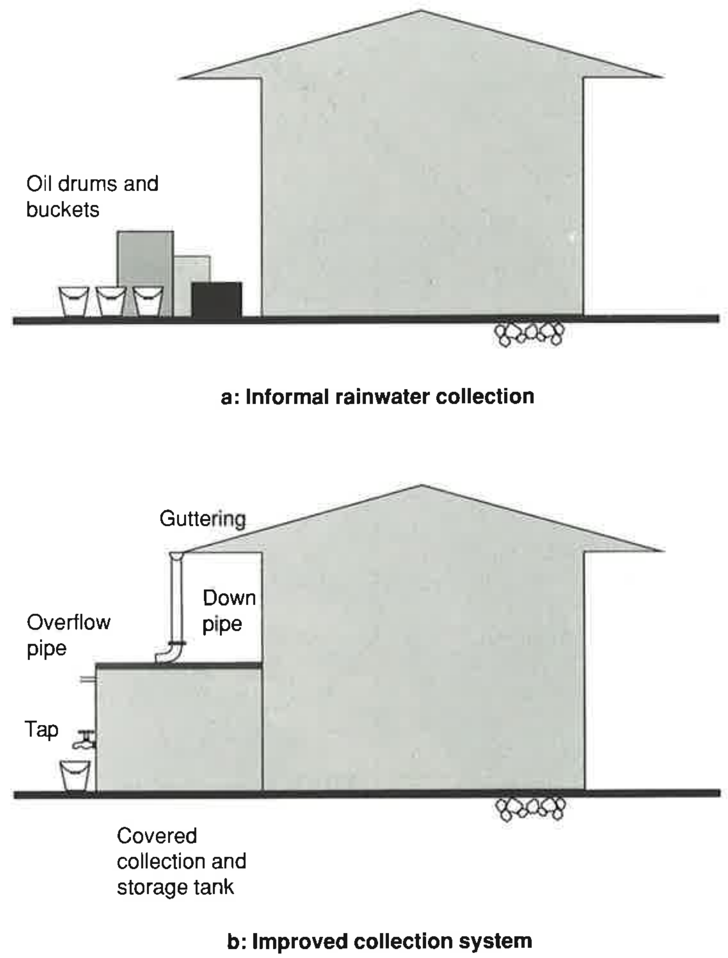


Figure 5.2: Household rainwater collection

Water distribution

There are three options for the distribution of water which reflect different levels of service provision.

Communal supply points

Water is provided at a limited number of public supply points to which individuals walk to collect their water. Bathing and washing of clothes may be done at the supply point; water is carried back to the house and stored in vessels or a small tank until required. Household storage of water is a means used by many people to overcome the problems of an erratic water supply; the volume stored depends upon the size of container which can be afforded and upon the reliability and accessibility of the supplied water.

For piped water supplies, public taps are provided on standposts as shown in Figure 5.3; if groundwater is used, communal wells or handpumps are provided. It has been observed that in some communities householders connect in turn their own hosepipes to the public standpost (Bradley and Ponniah, 1988). This is an effective way of conveying water to the house, but may result in relatively high water use, which has implications on cost recovery as discussed later.

Individual house supply

Each individual house has either its own private tap connected to the site distribution system, or its own open well or handpump if groundwater is used. Most households store water either in purpose-built elevated tanks, or in smaller vessels, both for convenience and in order to maintain the availability of water if the mains

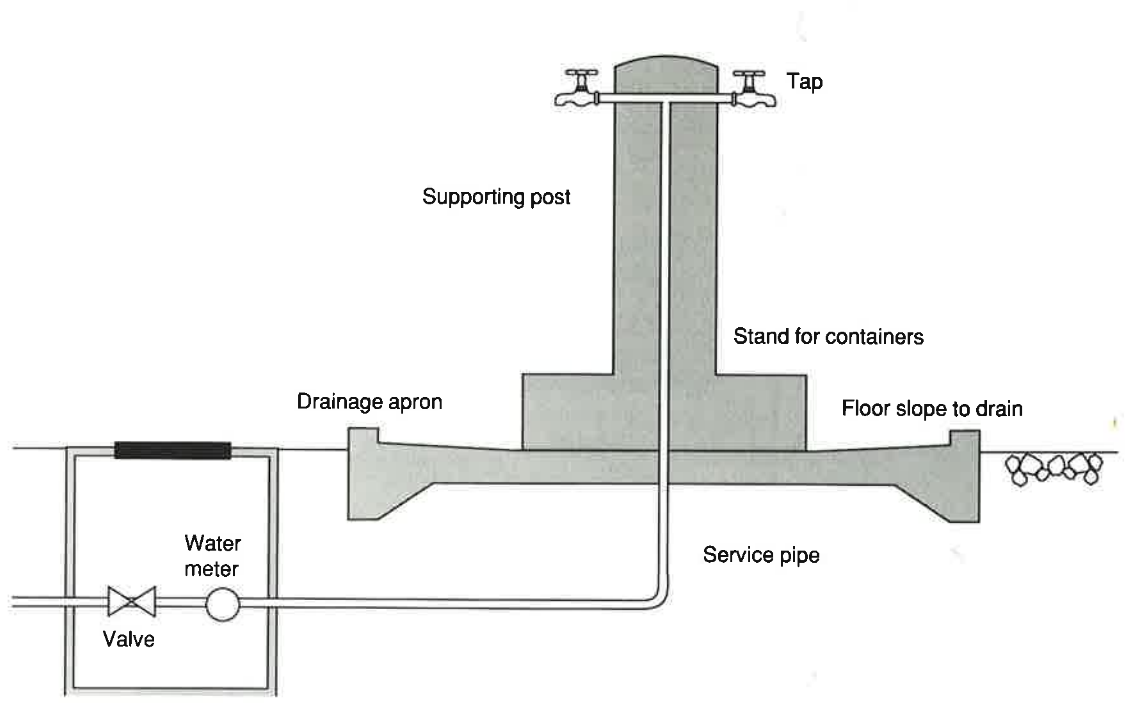


Figure 5.3: Standpost

supply is unreliable. The mains water connection may discharge via a level-controlled float valve into the storage tank.

Water vendors

Many people in urban areas obtain water from commercial vendors who deliver water to individual houses. This practice normally exists where the formal water supply is inadequate; water vendors are thus satisfying a need for which low-income people are prepared to pay a high price, as reported by Water and Sanitation for Health (1988) and Cairncross and Kinnear (1988). This form of water vending is almost exclusively a private sector activity; whilst it is not anticipated that there would be major interventions by the public sector, it is important to realise that water vendors are performing a valuable service in low income areas. Given that it may take some years to construct a standpost distribution system, water vending should be recognised as one method of supplying the demand in the interim.

Legalising water vending where necessary is a relatively simple and helpful action for the authorities to take in many situations. One drawback of water vending activities is the potential for monopoly which would drive up prices; however, a study by Water and Sanitation for Health (1988) reports that whilst the cost charged to the consumer is high, the profit margins of vendors are quite low. It appears more likely that those with private water supplies or taps who sell water to the vendors are guilty of excessive profiteering.

Levels of service

The planning of a water supply system depends upon the nature of the primary level of service and the stage at which the primary level is upgraded to provide a higher service level.

It is common for engineers to design water supply systems to provide sufficient capacity to satisfy demand for a long time into the future, perhaps upwards of thirty years. However, work by Yepes (1982) suggests that in purely economic terms such long design lives are inefficient; the 'design horizon' should be much shorter, perhaps only ten to fifteen years, depending upon the prevailing discount rate and possible economy of scale factors. The implication is that the provision of capacity at the outset of a scheme which remains unused for a considerable proportion of the design life is not justifiable economically.

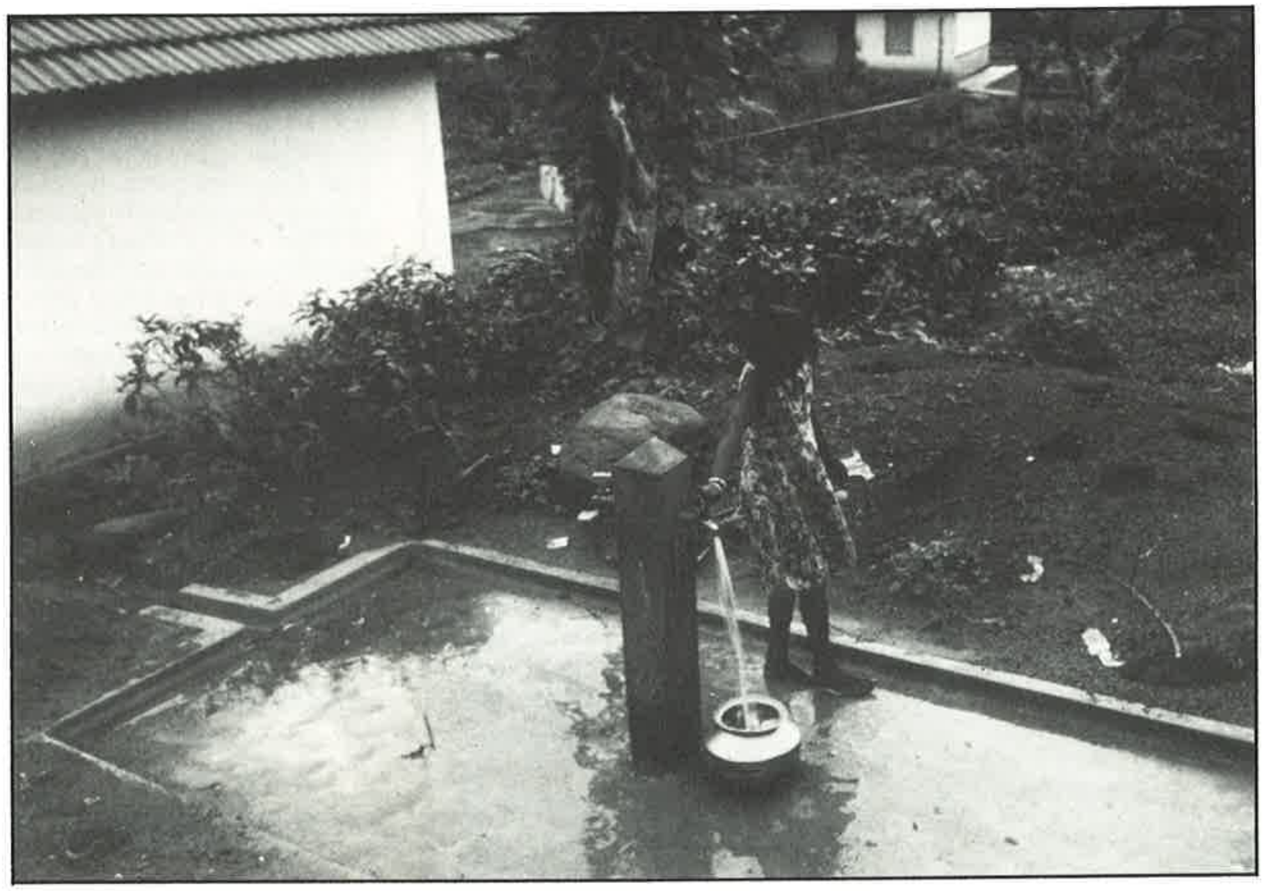
The primary level service normally consists of public standposts or wells; if groundwater is the source of water supply, householders can upgrade by constructing their own well as and when they wish. However, if there is a piped water supply, the ability to upgrade to a house connection depends upon whether the capacity of the site distribution network is sufficient to cope with the increased water demand. This poses the problem of whether to build additional capacity into the system from the outset.

Two possibilities for the primary level design capacity of the site distribution network are:

- a system which is capable of supplying only the demand from public standposts;
- a system which is large enough to satisfy the ultimate water demand when all houses have individual connections.

Above: A queue forms at a standpost when the supply is intermittent

Below: A double-tap standpost with a large drainage apron to permit bathing



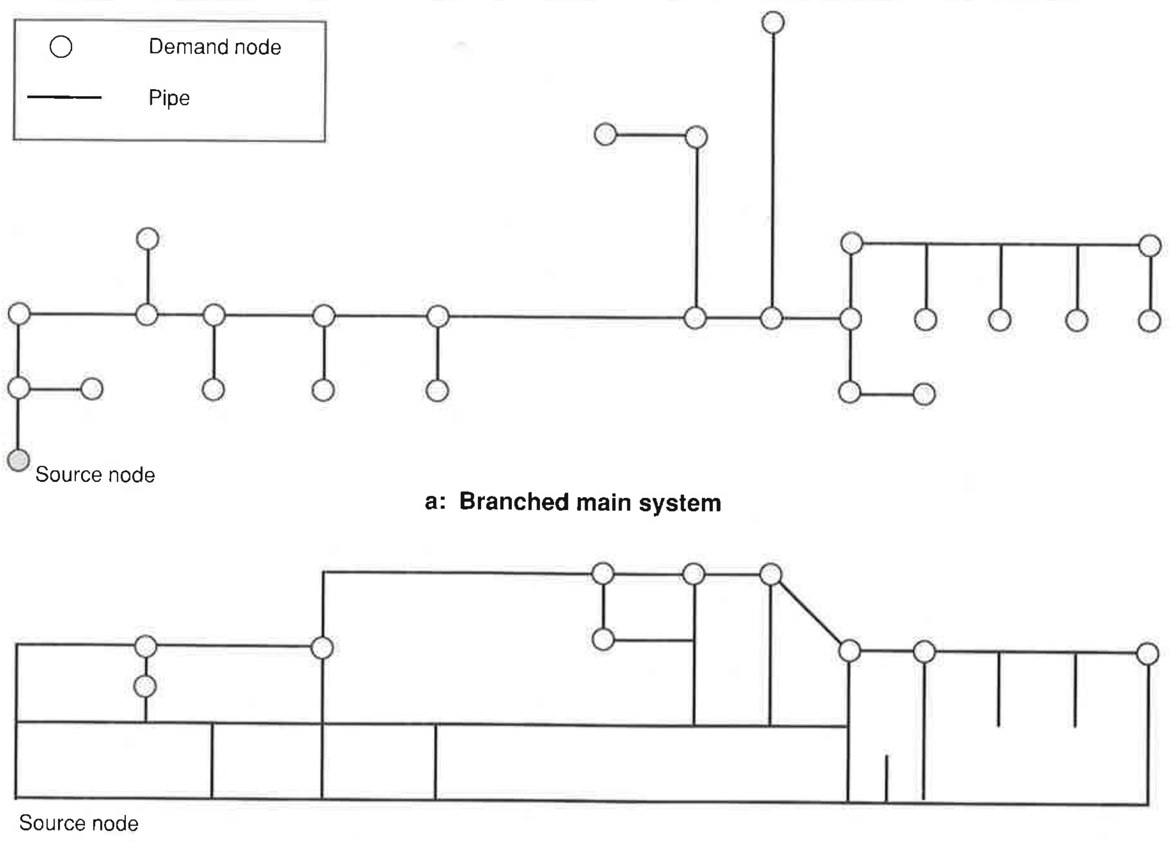
The cost differences between these alternative site distribution systems may be considerable. A standpost supply can frequently be served by a simple 'branched' pipeline network, whereas the high service level usually requires a 'ring main' system. Examples of both types of network are illustrated in Figure 5.4. Bahl and Lin (1987) suggest that high levels of service are not a strong priority in many communities, contrary to the beliefs of many planners and engineers. If this is the case, only a limited number of individual connections might be expected over a long period; initial investment in a ring main which satisfies the ultimate demand is wasted.

In principle, the site water distribution system should be designed to cope only with the primary service level of public standposts. If it is necessary to expand the network in the future, the additional capital costs could be recovered from the beneficiaries. However, it is difficult to generalise for all situations. The capital cost of the system is primarily dependent upon service length, rather than pipe diameter. The plan shape of the site and the housing layout determine the length of pipeline required and therefore exert a strong influence on the cost of the system. For certain sites it may be possible to provide a ring main at the outset for relatively little extra cost; this should be done as it avoids having to plan and implement further work, with the attendant disruption due to additional construction work at a later date.

Public water supply points

Options for the number and location of standposts (for piped water supply) and handpumps (for on-site groundwater supply) need to be carefully assessed. It must be ensured that there are sufficient supply points to enable users to obtain the assumed per capita demand, and to select the location so that people do not have to walk unreasonably long distances. It is important to consult the community during the planning stage and take into account their opinions regarding suitable locations for public water supply points.

If the piped water supply to public standposts is intermittent, it must be made possible for people to obtain sufficient water for their needs. If there are no alternative sources of water, such as shallow wells, which could be used for washing and bathing water, additional standposts may be necessary. Standard recommendations for the number of users per standpost (World Health Organisation, 1979) are based on continuous water supply and are clearly inadequate if the supply is intermittent.



a: Branched main system

b: Ring main system

Figure 5.4: Distribution systems

Conversely, provision of too many standposts can prove expensive and wasteful especially if taps are regularly broken. There is clearly a balance to be struck between providing access to sufficient quantity of water to realise health benefits whilst trying to minimise the cost of the supplies.

Maintenance

The most common problems requiring maintenance are:

- broken or leaking taps;
- fractured or leaking pipes;
- broken or faulty handpumps;
- faulty valves, meters, and fittings.

The quality of materials used and the standard of construction are important factors governing the useful life of the system. Poor quality pipes, fittings and valves will leak; plastic pipe which is not laid according to specification is prone to fracture damage.

Broken taps on public standposts are a major problem because of the wastage of water which results; the cost of the water wasted far outweighs the cost of the simple repair. Even the most robust taps can be vandalised or accidentally damaged during continuous use. Leakage in house connections is less of a problem; if the supply is metered, there is a strong incentive for the leak to be repaired. Illegal house connections installed using unskilled labour often result in serious leakage, in addition to defrauding the water utility of revenue.

The urban local authority is usually responsible for maintenance once the site has been fully adopted. Unfortunately, many authorities are able neither to react sufficiently quickly to small problems such as broken taps, nor to carry out routine inspections of the pipelines and fittings to detect leaks.

Whilst major repairs such as relaying sections of fractured pipe require skilled labour and supervision, there is scope for the community to be involved in simpler tasks such as replacement of broken taps, the repair of handpumps, and reporting more serious problems to the local authority (Arlosoroff et al, 1989; Glennie, 1983). The existence of a sense of community ownership may well be the only effective way through which abuse and vandalism can be prevented. Illegal house connections and perpetual breakage of public taps are serious detriments which no local authority can realistically deal with. If the community feel that the system is theirs right from the initial planning stages, their involvement in sustaining the service is more likely. Having to pay for the water used may also limit damage to the facilities.

In addition to the cost of supplying water, the annual maintenance cost of a site distribution system is believed to be approximately 5% of the initial capital cost.

Cost recovery

It is expensive to abstract, treat and distribute water; the recovery of these costs is essential for a sustainable water supply service. Whilst direct capital cost recovery from the community of the primary level service is not envisaged, it is reasonable that the operation and maintenance costs should be found.

If on-site groundwater is used, apart from the maintenance of communal handpumps, most other costs , such as construction and maintenance of individual supplies, are incurred directly by the users.

The capital cost of the provision of additional standposts is small compared with the benefits to be gained from the increased availability of water to consumers. However, the operating cost of providing the water throughout the lifetime of the standposts is significant; frequent breakage of taps and fittings gives rise to high operating costs due to the large amount of water which runs to waste. The efficiency of the public water supply service depends greatly upon the involvement and cooperation of the community.

The most appropriate method of charging the consumer for water is by metering consumption and charging according to usage. The 'block pricing' tariff structure is popular, in which the rate charged varies with consumption as illustrated in Table 5.1. The initial water consumption supplying basic needs is charged at a low rate; the rate charged increases as water consumption increases. Block pricing can be used to discourage excessive water consumption, as many households try to avoid moving into a higher tariff range.

Where supplies are not metered, a flat rate charge can be levied.

However, where there is no safe water supply, even the poorest people may be prepared to pay. Studies on water vending reported by Water and Sanitation for Health (1988) and Cairncross and Kinnear (1988) give an interesting insight

Table 5.1 Tariff structure for Francistown, Botswana (1989)

Scale	Consumption (cubic metre)	Tariff (Thebe per cubic metre)
1	0-15 (and water sold through standpipes for domestic use)	40
2	16-40	165
3	>40	190

into the value some low-income dwellers place on access to water of reasonable quality. In the shanty towns of the city of Tegucigalpa in Honduras in the dry season the cost of water sold by vendors is US $8.5 per cubic metre, compared with the official government price of US $0.25. Water consumption is 17 litres per person per day, which represents an expenditure of 12% of household income on water. The capital and recurrent costs of a piped distribution system would be fully recovered with tariffs considerably lower than the rate paid to the vendors. It would appear that massive cost subsidies are not a prerequisite of water supply schemes.

In general, consumers may be unwilling to pay the economic cost of water even though it could be afforded; politicians have been known to pledge water supplies as part of their manifesto, which may result in tariffs which do not reflect the economic cost of production of water.

Cost recovery through water metering can be applied more readily to individual house connections than to public standpost supplies. However, adoption of the incremental approach to services provision means that low-income communities will continue to be served by public standposts for many years, and the recovery of operation and maintenance costs must be attempted. Some methods of recovering these costs include:

- The sale of water using water vendors appointed and paid by the urban local authority. This requires a high level of efficiency on the part of the authority.

- The use of 'coin in the slot' standposts; this also requires a high level of authority involvement.

- The levy of a flat rate charge included in the property tax. This assumes that the community is fully integrated into the urban system of tax collection; however, this may take years to achieve. Even then, many low-income households may be below the threshold for property tax.

- The sale of water through community-organised vendors; this occurs in Accra, Ghana.

- The community collects a flat rate charge from the users; if possible, site water meters could be used to estimate the charge.

The additional capital costs of upgrading the distribution system to a higher level of service in the future should be recovered directly from the beneficiaries.

The cost of water supplied to small industrial and commercial premises can be recovered by direct metering and charging at an appropriate tariff; in some cases this may include a charge for removal and disposal of wastewater.

Detailed design factors

The detailed design of a water supply system requires:

- prediction of present and future water demand;
- estimation of the number of public supply points;
- design of the distribution system for piped supplies;
- public supply point design;
- knowledge of the construction materials available.

Water demand

Prediction of present and future water demands is necessary to enable distribution systems to be designed and to ensure that local groundwater resources are not over exploited. The assessment of safe groundwater yield is described by Raghunath (1983).

Population prediction

Accurate forecasting of the future population is notoriously difficult. Whilst there may be national growth rate statistics available, there is no guarantee that they reflect trends in a particular low-income urban community where growth may be spasmodic. Discussions with those who have regular contact with the communities, including non-governmental organisations, may prove useful. Nevertheless, if there is no specific information, the national growth rates may have to be used.

Population predictions are usually based on compounding a percentage annual growth rate:

$$P_N = P_O (1 + i/100)^N$$

where:

P_N is the population in year N
P_O is the initial population at the start of year 1
i is the annual percentage population growth rate

Domestic water demand

The total daily quantity of water which each person requires for drinking, cooking, washing and bathing, is called the 'per capita demand' and is measured in units of litres per person per day (abbreviated to lpd).

Primary level per capita demand for public supply points is not easy to predict. Most water undertakings have found it difficult to meter and collect revenue from public standposts; metered records of consumption are thus not available, and consumption is not restricted by tariff charges. However, access to water is limited by the number of users and the distance from the household to the supply point, both of which restrict the demand.

It is believed that the per capita demand for users of public supply points is in the range 15 to 50 lpd (World Health Organisation, 1979). For piped supplies to public standposts, the reliability of the supply is an important factor. If the supply is continuous all of the demand could be met from standposts; if it is intermittent, then it must be decided what proportion is to be supplied from standposts, and how much must be obtained from other sources.

Table 5.2: Commercial and institutional water demand

Institution	Per capita water demand (lpd)
Offices	45
Clinic	100
School	45

Future water demand predictions are likely to involve supplies to individual houses and can be estimated with reasonable confidence from information on existing metered consumption. In general, the per capita demand for those with house connections is of the order of 100-150 lpd.

The total domestic demand is obtained by multiplying the per capita demand by the population served.

Commercial and institutional demand

The development of large low-income communities using the 'sites and services' approach may involve the provision of small industries and commerce for employment generation. In addition, schools, health clinics and offices may be provided. Commercial demand can only be estimated reliably from metered records of consumption; some estimates for institutional water demands recommended by Khanna (1990) are shown in Table 5.2.

Fire-fighting demand

Where there are piped water supplies, it is normally assumed that provision should be made for water for fire-fighting purposes. However, on low-income housing sites this may be unrealistic and unjustifiable in terms of economic cost benefit analysis. The fire-fighting services of many towns and cities are woefully inadequate and the chances of a fire-fighting vehicle arriving in time to extinguish a fire may be considered remote. Nevertheless, matters may well improve within the design life of the water supply system. Assessment of fire risk is very difficult; the major fire hazards occur in industrial workshops and commercial premises and in houses which are constructed using large amounts of wood and thatch.

A reasonable allowance is for all buildings to be within about 300 metres of a fire hydrant. The distribution system should be capable of conveying a discharge of 15 litres per second to the hydrant, where the residual pressure head should be 4 metres; this assumes that the fire tender itself pumps the water up to sufficient pressure (Khanna 1990).

Peak water demand

In order to design a piped distribution system, the maximum likely flow must be estimated. The total daily water demand is the sum of the domestic, commercial and institutional demands. Provision for fire demand should not be included in the total; it is assumed that all of the water entering the site distribution system could be diverted for fire-fighting purposes. Such assumptions are necessary in order to prevent escalation of costs.

The total water demand is not spread evenly over 24 hours of the day, and 'peaks' occur. The magnitude of the peak water demand depends upon the relative number of house connections and standposts and the extent to which houses, commercial and industrial premises have their own water storage facilities.

Water storage is a simple means by which a continuous water demand can be satisfied from an intermittent or variable supply. For example, if a piped water supply to a house tap only functions for one hour each day, either the household must carry out in that one hour all of the daily functions which require water, or they must fill up a storage tank whilst the water flows. The latter course enables them to draw water out of the tank as and when they require it; thus they have a continuous supply even when the tap is not flowing. If the per capita demand is 100 lpd, a storage tank of at least 600 litres capacity would be needed to cater for a household of six people; this would require the tap to deliver a flow of at least 600 litres per hour each day.

Large tanks known as 'service reservoirs' are usually incorporated into the trunk mains to cater for variable water demand throughout the day. The inflow is constant, but the outflow is variable depending upon the demand; typically these reservoirs fill up during the night when the demand is very low, and empty during the day under peak demand.

People who rely on standposts have to queue for their water and at peak times all standposts are in continuous use. The capacity of the distribution system for a standpost supply can therefore be calculated if the number of standposts and the quantity of water discharging from each standpost are known.

The peak demand (in litres per second) for individual house connections is usually expressed as the product of the 'peak factor' and the average daily demand. The value of the peak factor depends upon the magnitude and distribution of the population served, but is commonly assigned a value between 1.5 and 3.0 for large populations (Fair, Geyer and Okun, 1966).

It should be noted that on small sites the fire demand (if it is to be considered) is likely to be greater than the peak demand.

Supply point design

Many different designs of public standposts are described by the World Health Organisation (1979).

Details on handpump selection and installation are presented by Arlosoroff et al. (1989) and the IRC (1988).

At public water supply points, considerable quantities of wastewater result from spillage and leakage; the standpost or handpump must be properly drained as shown in Figure 5.3 to prevent insanitary conditions from developing. The design should be carried out with the aid of the community; their customs and habits in respect of water collection and use must be accommodated. For example, if people wish to bathe at the standpost, then a large paved and drained apron should be provided to enable them to do so.

Standposts

In order to estimate the number of standposts required, it is necessary to know the flow rate of water in litres per hour delivered by the tap. This depends upon both the size and type of the tap and the available head, that is, the water pressure in the distribution pipe immediately upstream of the tap. The flow rates delivered by the most common types of tap for different values of available head are shown in Figure 5.6. A reasonable first estimate is to assume a minimum available head of 5 metres at the standpost; a standard three-quarter inch tap delivers about 1000 litres per hour (lph) at this pressure.

The following example illustrates how to estimate the number of people who can be served by a single three-quarter inch tap which delivers 1000 lph. It is necessary to know the times of the day during which people desire to draw water; this example assumes that most water is used during two periods each lasting three hours, that is, the daily water demand should be satisfied in six hours. Assuming a per capita demand of 40 lpd the maximum number of people to be supplied by a single tap is:

No. of people = (6 x 1000)/40 = 150

If the average household size is five people, then approximately 30 households could be served by this tap. If each standpost has two taps on it, one standpost would be required for 300 people or 60 households. More than one tap should be provided at each standpost as the additional cost is negligible compared with the benefits from reducing the queuing time. The World Health Organisation (1979) recommends that there should not be more than 250 people served by 'several taps' on a single standpost.

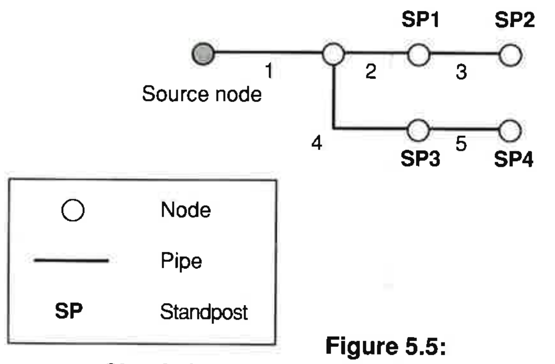


Figure 5.5:
Simple branched system for primary level service

In less densely populated communities, the distance from the household to the standpost is likely to limit water use. All houses should be within 200 metres of a standpost (World Health Organisation, 1979). However, if plot sizes are very large and the housing density is correspondingly low, a standpost system may be grossly inefficient; the '200 metres' guideline might mean one standpost to every few houses. To avoid gross wastage of water, it might be cheaper to provide house connections and meter the water consumption.

Handpumps

The guidelines for the number of handpumps required are based on estimates of both the time taken to pump up the water from the borehole, and (as with standposts) a maximum distance from any household to a handpump.

The quantity of water which can be delivered by a handpump in a given time depends upon the depth of the water table and the design and efficiency of the handpump. Comprehensive data on the performance and reliability of over forty makes of handpumps are given by Arlosoroff et al. (1989). As an approximate guideline, for per capita demand in the range 15 to 50 lpd, one handpump should serve about 150 people. If a proportion of the demand is to be obtained from other sources, the ratio can be altered accordingly. All houses should be within 200 metres of a handpump.

Pipeline design

As water flows along a pipeline, it loses energy due to friction between the flowing water and the pipe walls. This energy loss manifests itself as a drop in pressure, known as headloss, along the pipe. Pipeline design involves the relationship between the headloss, diameter, and flow rate along the pipe. The background is fully described by Twort et al. (1985). The following example illustrates the design of the simple branched system illustrated in Figure 5.5 for primary level service.

Assume that the distribution system supplies a total of four standposts each of which has two taps, with each tap delivering 1000 lph. The pipe material is uPVC and it is assumed that the available head at the start of the system is 10 metres and that there are no changes in ground elevation. 'Nodes' are

Above: An undrained standpost creates appallingly insanitary conditions

Below: Water is wasted from an unmaintained standpost which has been broken off and removed

Table 5.3: Pipeline calculations

1 Pipe	2 Pipe length (m)	3 Taps supplied	4 Flow rate (lph)	5 Diam. (mm)	6 Head loss (m per m)	7 Actual headloss (m)
1	250	8	8000	64	0.009	2.25
2	300	4	4000	51	0.008	2.40
3	200	2	2000	38	0.010	2.00
4	200	4	4000	51	0.008	1.60
5	250	2	2000	38	0.010	2.50

points at which either two or more pipes join, or there is a water demand.

Stage 1: Calculate the discharge which must be delivered by each of the pipelines 1 to 5; for example, pipe 2 must carry sufficient flow for two standposts, that is four taps requiring a total flow of 4000 lph. Insert values in column 4 of Table 5.3.

Stage 2: The relationship between headloss (expressed as hydraulic gradient), discharge and standard pipe diameters for uPVC pipe is shown in Figure 5.7. In order to minimise headloss in the system, a hydraulic gradient of 0.01 metres per metre length of pipe is assumed. For each pipe, use Figure 5.7 to locate the intersection of the vertical line of hydraulic gradient equal to 0.01 metres per metre with the horizontal line corresponding to the discharge in the pipe. Locate the pipe diameter line which is nearest to the intersection point and enter the value in column 5 of Table 5.3.

Table 5.4: Node pressures

Node no.	Head (metres)
1	10.00
2	7.75
SP1	5.35
SP2	3.35
SP3	6.15
SP4	3.65

Stage 3: The actual headloss in each pipe is calculated by multiplying the pipe length by the hydraulic gradient in metres per metre. Note that in stage 2 it is necessary to select the nearest available pipe size for that particular flow, in which case the hydraulic gradient is not exactly 0.01 metres per metre. In this case read off the actual hydraulic gradient in metres per metre from Figure 5.7, insert the value in column 6 of Table 5.3 and use it to find the actual headloss (column 7, Table 5.3).

Stage 4: The available head at each node can now be calculated simply by starting from the initial available head of 10 metres and subtracting the headloss along each of the pipes; Table 5.4 shows the available head at each of the nodes.

Note that the available head at each standpost is different; it was assumed that the discharge from each standpost was 1000 lph, but clearly the actual discharge will vary (see Figure 5.6), being greater than this value at standposts SP1 and SP3, and less at SP2 and SP4. If it is decided that the actual discharge and therefore the available head is too small, the pipe diameters must be increased and the headloss calculations repeated. In general, the flow to any branch or standpost can be restricted (but not increased) by installing valves which can be adjusted until the correct flow is obtained.

The design of branched systems is relatively straightforward, whilst ring mains are much more complicated. Design programs are available which run on microcomputers of the 'Personal Computer' (PC) type; the programs produced by the United Nations Development Programme (1987) are strongly recommended because they are ideal for the small distribution systems encountered on many low-income housing schemes. The programs are easy to use, and dispel the myth that such programs need to be operated by software specialists. The software is available free of charge (at the time of writing) to potential users from less developed countries.

Materials of construction

The most common pipe material used in small distribution systems is 'plastic', in particular unplasticised polyvinyl chloride (uPVC) and polyethylene (PE). These materials are classed as flexible in that they deflect under loading, and transfer part of the loads exerted on the top of the pipe into the trench in which the pipe is buried. In order to withstand traffic loads it is important that the trench is prepared according to specification. This is particularly relevant if the community is to be involved in construction of the distribution system. Asbestos cement pipes are also widely used. A thorough discussion of pipe materials, jointing methods, pipe fittings, and valves is presented in Chapter 8 of the Institution of Water Engineers and Scientists Manual (1984).

Consideration must be given at the design stage to the availability of materials including pipe sizes and fittings. The use of a large number of different sizes may complicate materials supply and construction. Unfortunately, the pipe fittings of different manufacturers are not necessarily interchangeable, even though the nominal size may appear the same.

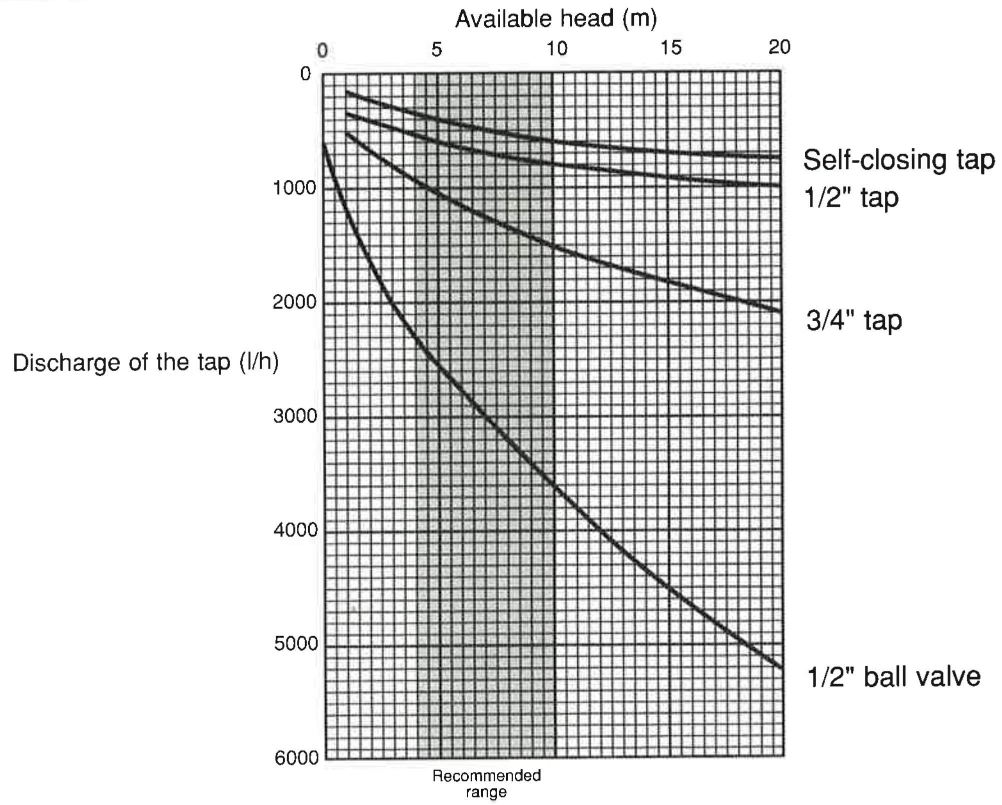


Figure 5.6: Discharge rates from standpost taps

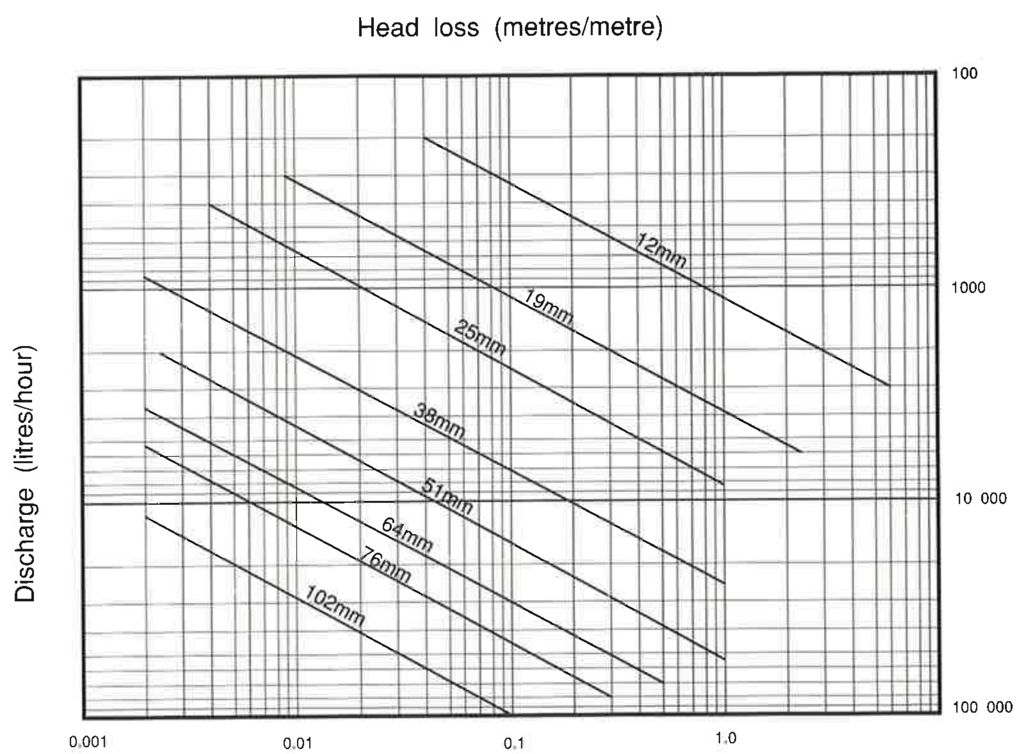
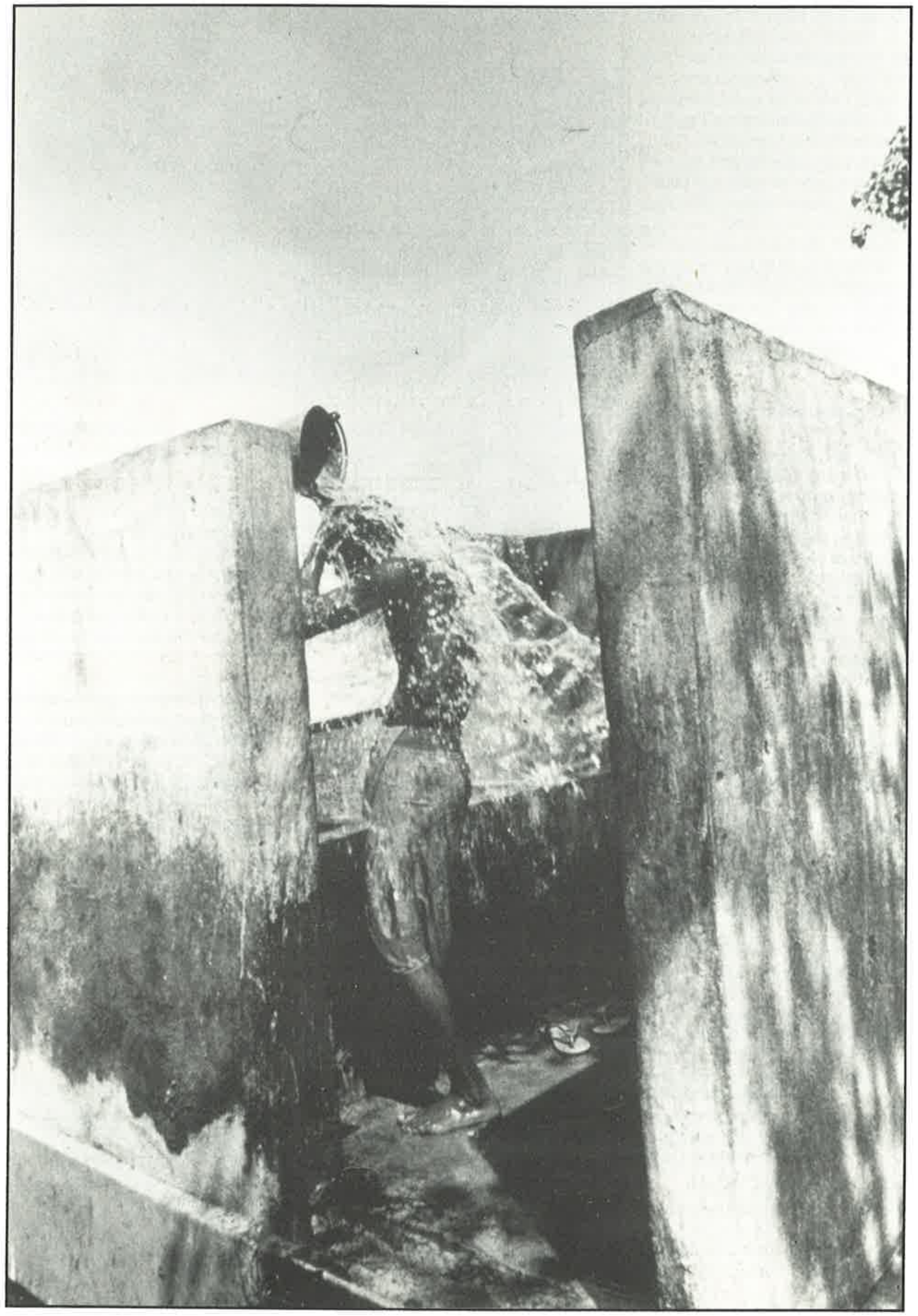


Figure 5.7: Headloss in uPVC pipes



Above: This community wanted a bathing area which afforded some privacy

Sanitation 6

Objectives

In the context of this book, sanitation is concerned with the safe disposal of human excreta; good sanitation is aesthetically desirable, and has important health implications. Many common diseases such as diarrhoeas, dysenteries and enteric fevers can be transmitted through contact with the excreta of an infected person; the important faecal-oral route of disease transmission is illustrated in Figure 6.1. The provision of latrines or toilets is thus an important measure in the prevention of excreta-related diseases, in particular through the breaking of the faecal-oral transmission mechanism. A detailed classification of these diseases and their interactions with water supply and environmental conditions is given by Cairncross and Feacham (1983).

Technical options

There are many options for excreta disposal; the following classification is useful from the viewpoint of urban low-income housing.

'On-plot' sanitation systems in which safe disposal of excreta takes place on or near the housing plot; pit latrines and septic tanks fall into this category.

'Off-plot' sanitation systems in which excreta are collected from individual houses and carried away from the plot to be disposed of; sewerage and vault and cartage fall into this category.

Communal latrines which are shared by a number of households; excreta removal and disposal may be either 'on-plot' near the communal latrine, or 'off-plot'.

The selection of the most appropriate sanitation system is influenced by technical, cultural, financial, and institutional factors; the following points are of fundamental technical importance.

- The quantity of water available for use in the sanitation system. Water requirements of different systems vary from zero to 80 litres per person per day; hence the level of service for water supply is important.

- The material used for anal cleansing after defecation; this depends upon the cultural and religious practices of the society, and materials used include water, paper, leaves, sand, and stones.

Figure 6.2 presents a simplified guide to the selection of an appropriate sanitation system based on the options described below.

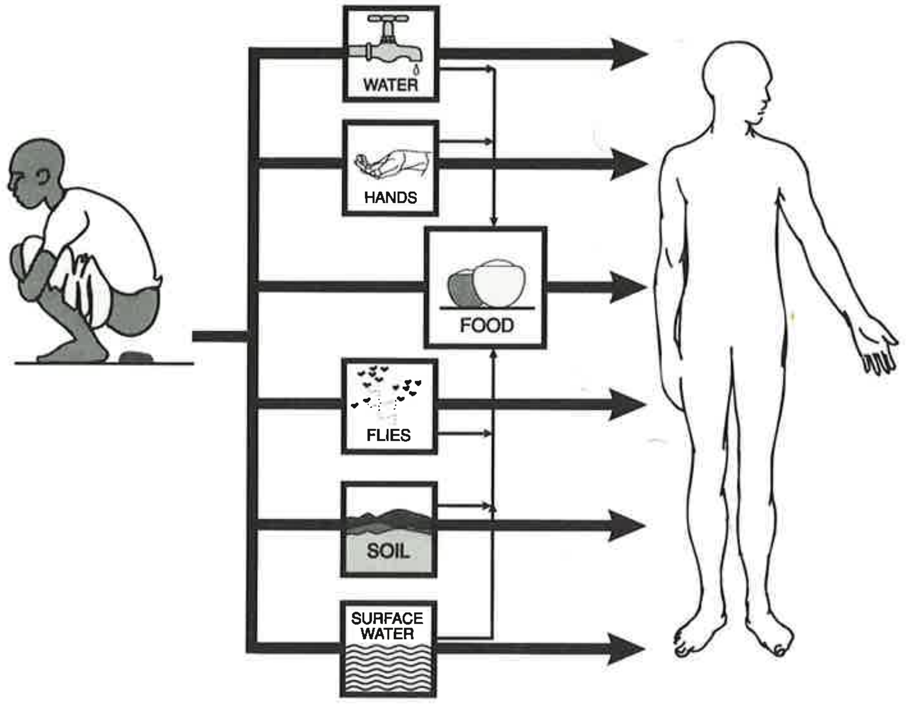
On-plot systems

The two most common types of on-plot sanitation are firstly pit latrines and secondly septic tanks; both require land to be set aside on or nearby the plot. The housing density, site layout, and the layout of individual house plots in respect of building lines and plot boundaries must be carefully considered when planning on-plot excreta disposal systems.

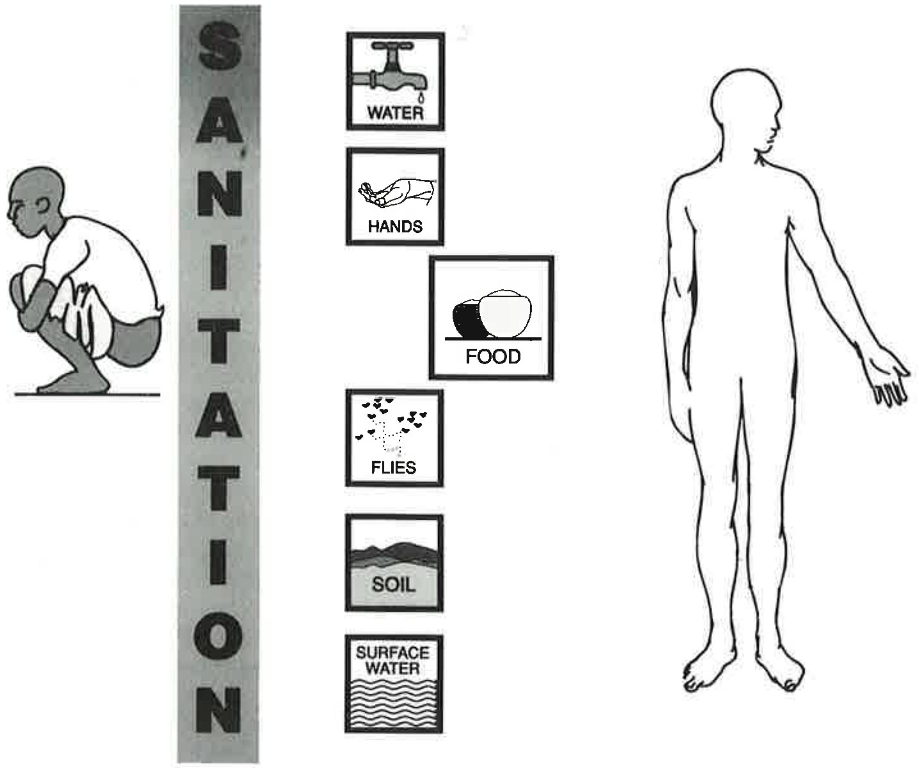
Pit latrines

The term 'pit latrine' is used here to cover a wide range of different designs whose mode of operation is basically the same, and includes 'sealed lid latrines', 'ventilated improved pit latrines' and 'pour flush latrines'.

The principle of all types of pit latrine is that excreta and anal cleansing materials are deposited in

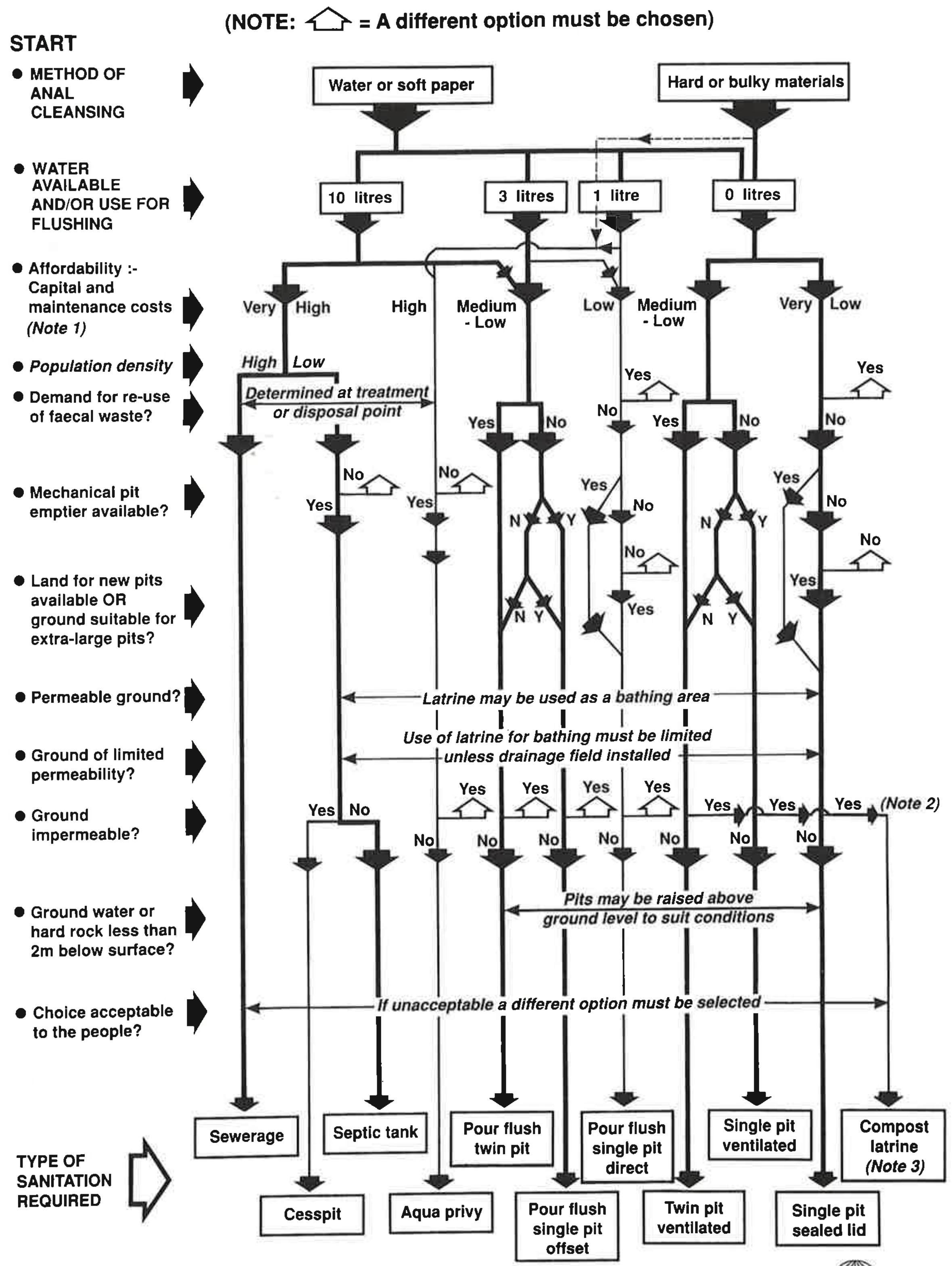


a: Faecal-oral transmission route of disease



b: The 'sanitation barrier' to faecal-oral transmission of disease

Figure 6.1: The importance of sanitation



Note 1: Not all possibilities are illustrated as it is assumed that water availability is related to affordability

Note 2: Use extra large pits or consider composting

Note 3: Also dependent on willingness to collect urine separately, demand for compost, availability of ash or vegetable matter etc.

Figure 6.2: A guide to sanitation selection

(Franceys, 1991a)

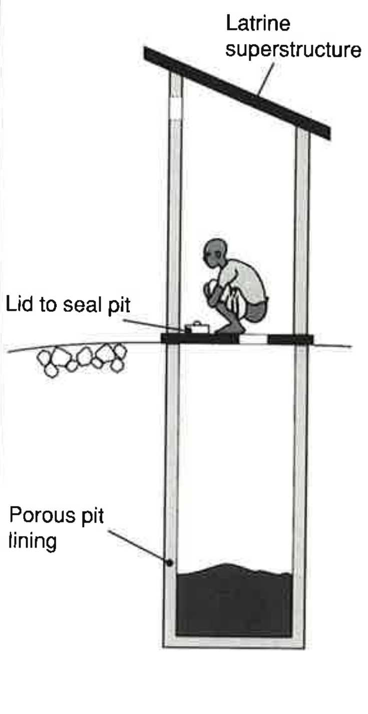


Figure 6.3: A simple improved pit latrine

a hole in the ground. In its simplest form, as illustrated in Figure 6.3, the pit latrine consists of a superstructure which affords privacy to the user; a hole (or seat) set into a slab which covers the pit; and a pit beneath the slab into which excreta are deposited.

Pit latrines are not used in conjunction with conventional flush toilets (see 'septic tanks'); therefore only a relatively small volume of water enters the pit. The pit itself is not sealed, and liquid is allowed to seep from the pit into the surrounding ground. Whilst in the pit, excreta undergoes complex biological and chemical reactions which result in its eventual decomposition into humus-like solids, water, and gases. Water seeps away through the sides of the pit, and gases escape to the atmosphere, leaving a solid residue in the pit. The important point is that during the decomposition process, disease-causing organisms (pathogens) are killed; the decomposition proceeds slowly with time, and only after one year can the decomposed excreta be handled without undue risk of contamination.

The latrine slab serves both as a support and as a seal. It has to support the weight of a person using the latrine and possibly the weight of the latrine superstructure, depending on the design. It is also required to seal the pit, with the exception of the squat hole and the vent hole (if required).

A pit latrine normally requires a piece of land not less than 1.5 metres square in order to accommodate the pit and superstructure. The latrine must be accessible in order that the pit can be emptied when full. A latrine at the rear of a house should be accessible either from the rear of the plot boundary, or from the front via an access way to the side of the building.

There are two major problems with simple 'unimproved' pit latrines; they often smell, and produce vast numbers of flies. Female flies are attracted by odours emanating from the pit and enter via the hole in the slab to lay their eggs in the faeces.

Improvements have been devised which help to reduce these nuisances.

Sealed pit latrines

Brandberg (1985) describes the development in Mozambique of an improved low-cost latrine. The principal improvements are achieved by using a relatively cheap unreinforced dome-shaped concrete slab and a tight-fitting lid of high quality concrete which fits into the hole in the latrine slab, as shown in Figure 6.4.

It is reported that the lid has been successful in controlling the movement of flies in and out of the pit and in reducing odour problems. A permanent superstructure is not necessary because the interior of the latrine does not have to be dark, unlike the VIP latrine described below. This reduces the cost considerably, as the latrine can thus be constructed in a fenced-off corner of the plot. An additional benefit is that the tight-fitting lid

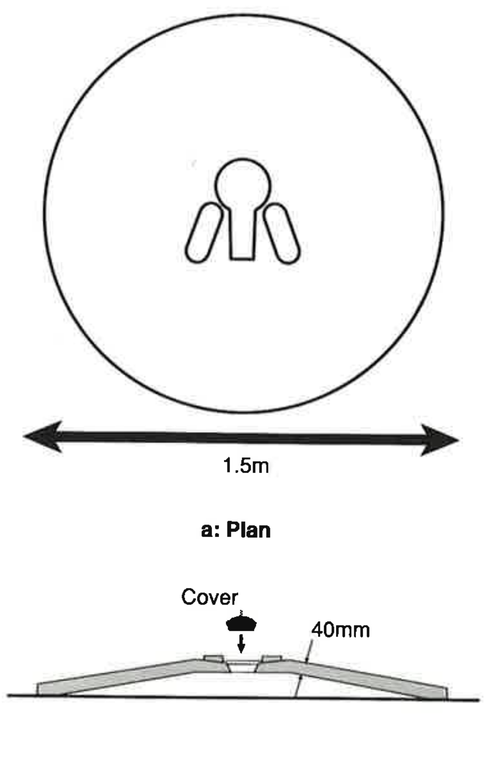
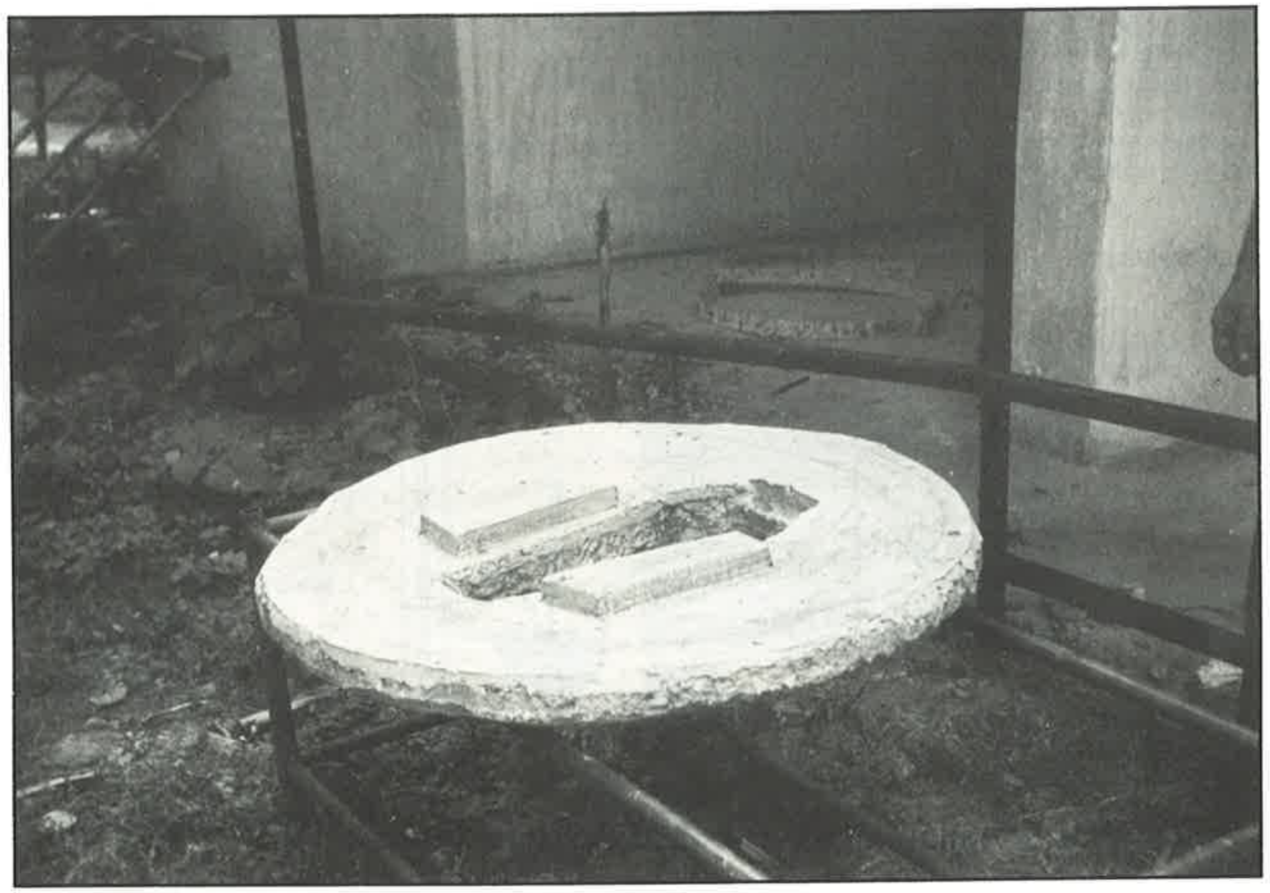


Figure 6.4: Unreinforced domed slab

Above: Raising the cover of a latrine pit located at the front of a house (See Figure 6.9)

Below: Local production of latrine slabs for sale to householders



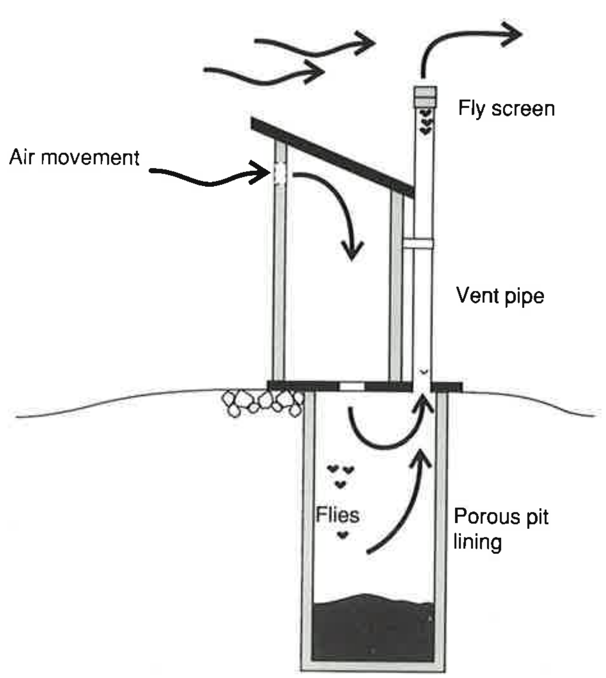


Figure 6.5: Ventilated improved pit latrine (VIP)

prevents cockroaches from emerging from the pit. The operational success of this latrine depends upon keeping the tight-fitting lid in place at all times when the latrine is not in use. This type of latrine does not require water for its operation and there are no restrictions on the type of anal cleansing material which can be used.

Ventilated improved pit latrines (VIPs)

The pit is ventilated by means of a vertical pipe; the action of wind blowing over the top of the vent pipe creates a 'chimney effect' whereby an updraught of air flows up the pipe. Air is draw down through the hole in the cover slab and circulates in the pit; unpleasant odours pass up the pipe rather than out of the hole in the cover slab into the superstructure, as illustrated in Figure 6.5.

Flies are attracted to the top of the vent pipe, but the presence of a fly screen made out of fine gauge mesh prevents many flies from entering. Some fly breeding is inevitable; newly emerged flies tend to head towards light, but their exit is blocked by the screen, and they eventually die and fall into the pit. The interior of the latrine needs to be darkened, which requires the latrine to have a permanent superstructure with a roof. Experiments in Zimbabwe by Morgan (1977) have demonstrated dramatic reductions in fly populations in a latrine as a result of providing ventilation. However, Cairncross and Feacham (1983) observe that the vent pipe is not necessarily effective against mosquitoes which breed in flooded pits.

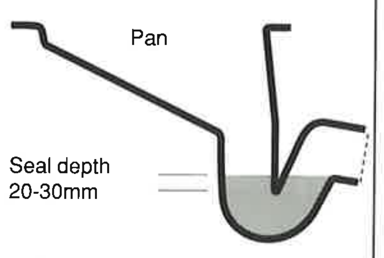


Figure 6.6: A water-sealed bowl for a pour flush latrine

The VIP latrine does not require water for its operation and there are no restrictions on the type of anal cleansing which can be used.

Pour flush pit latrines

In regions where water is used for anal cleansing, as opposed to solid material such as paper, leaves, stones or sand, it is possible to adapt the simple pit latrine by inserting a bowl into the hole in the pit cover slab as shown in Figure 6.7. When filled with water, this bowl forms an effective seal which isolates the pit from the user; this is a most effective way of eliminating smells and fly nuisance.

The bowl is designed so that it requires only a small volume of water to flush excreta into the pit, as shown in Figure 6.6. Depending upon the detailed design, 1 - 6 litres of water are required for each flush, which is much less than the 10 - 20 litres for conventional cistern flush toilets.

The pour flush latrine has great flexibility in its application. For example, the pit can be constructed to one side and connected to the slab by a short length of sewer pipe; this is known as an 'offset' pour flush latrine, which is illustrated in Figure 6.8. Pour flush latrines are particularly useful in densely populated urban areas where access for pit emptying is restricted. Unlike the VIP which requires the superstructure and pit to be at the same location, with the pour flush latrine it is possible to locate the actual toilet in one part of the house whilst having the pit elsewhere. On one urban low-income housing site in Colombo, Sri Lanka, the latrine is at the rear of the house, but the actual pit is at the front between the building line and the plot boundary, as shown in Figure 6.9. Such an arrangement offers greater flexibility when planning the site layout and access.

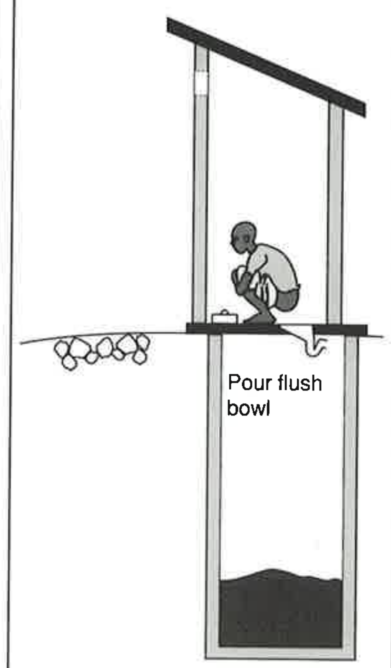


Figure 6.7: A simple pour flush latrine

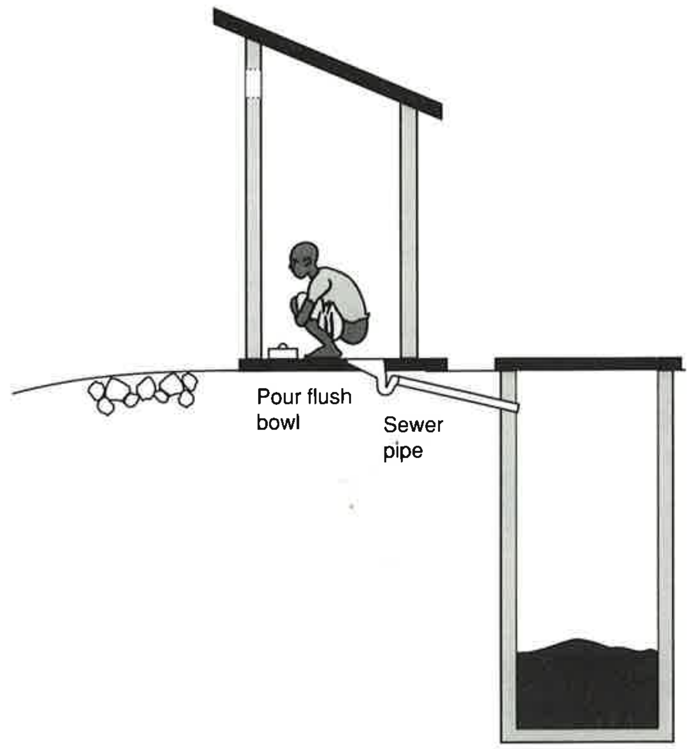


Figure 6.8: Offset pour flush latrine

Problems caused by ground conditions

Digging a pit is difficult when the ground is either extremely hard or extremely soft. Excavation in rocky conditions is expensive, and it is not normally feasible to dig deep pits. If the ground is totally impermeable, for example black cotton soil or hard rock, and there is no infiltration, another sanitation option must be selected.

Conversely with soft ground, such as running sand or alluvium, the excavation needs supporting and the sides of the pit must be lined down to the bottom as shown in Figures 6.10 and 6.11.

Problems caused by high water table

Excavation is also made difficult by the presence of a high water table. The pit should be excavated in the dry season when the water table is at its lowest; in most situations it is not practical to dig more than about 1 metre below the water table.

The mere presence of water in the pit does not inhibit the functioning of the digestion process; the data in Table 6.1 shows that excreta decomposition is most effective in just these conditions. However, there are potential problems if pour flush latrines are used where the

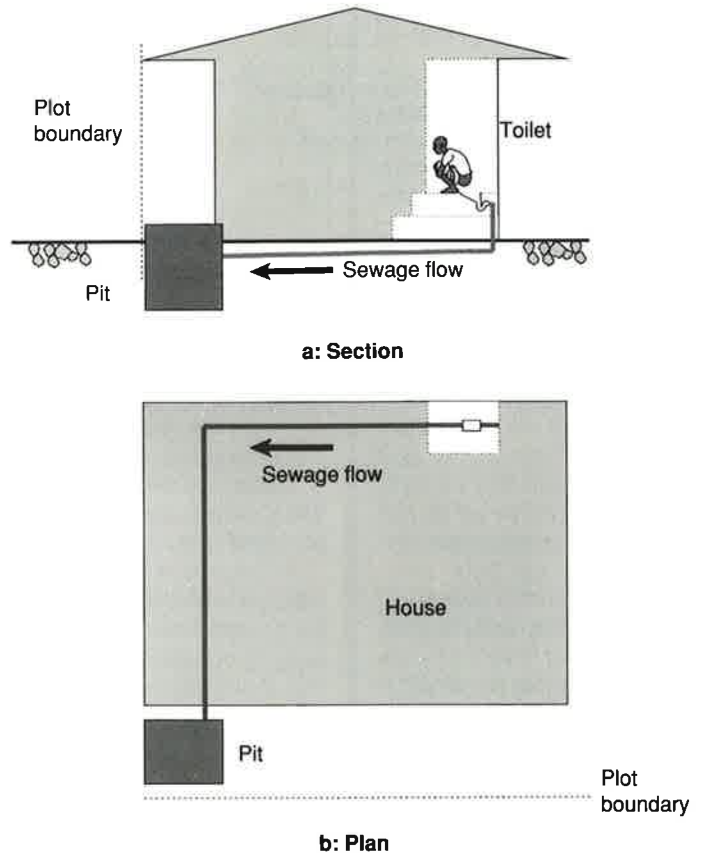


Figure 6.9: Latrine arrangement observed in Colombo, Sri Lanka

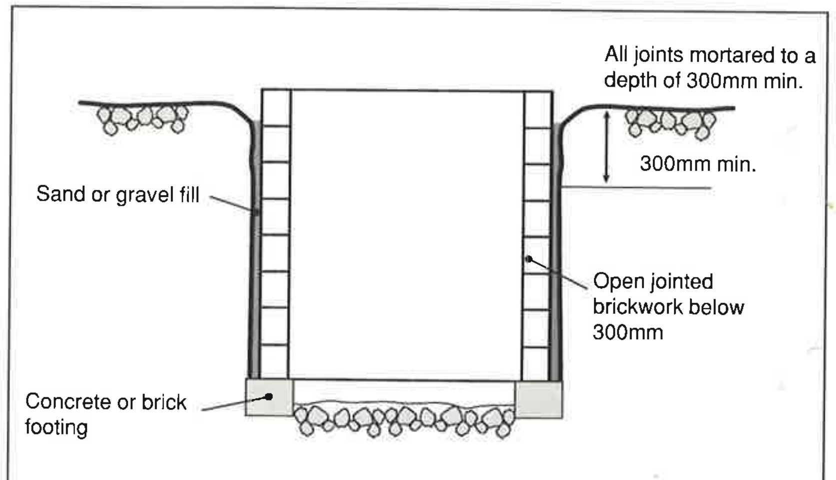


Figure 6.10: Brick lining for a pit in soft ground

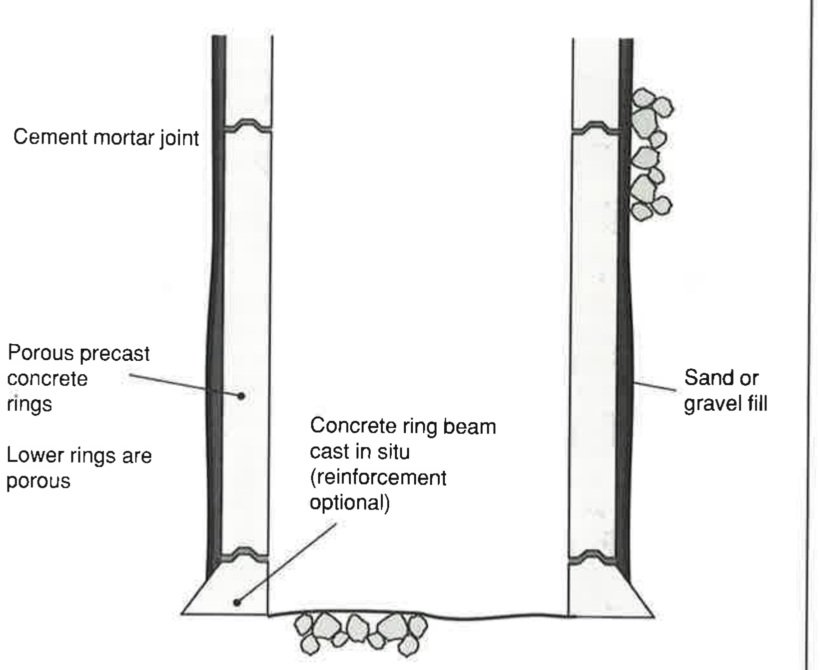


Figure 6.11: Pit lined with pre-cast concrete rings

water table is high or the soil is relatively impermeable, and the housing density is high. Poor percolation may result in the ground near the pit becoming water logged.

For example, if each of six people in a household use 6 litres of water per day for flushing the latrine, the percolation rate through the ground surrounding the pit should be at least 36 litres per day. If this is not achievable, another sanitation option must be selected.

The groundwater pollution problem

If the pit penetrates or is close to the groundwater table, water seeping out of the pit is bacterially and chemically contaminated and the surrounding groundwater may become polluted. This is particularly serious if shallow wells are located near to pit latrines. The extent of the pollution depends upon the soil conditions; the most dangerous case occurs in fissured rock, as the groundwater may travel rapidly through the fissures, transporting the pollution a considerable distance from the latrine. The travel of bacterial pollution through sandy soils is limited to a few metres (Nath and Chatterjee, 1984); however, chemical pollution of groundwater by nitrates has proved to be a serious problem in one case in Botswana (Lewis et al., 1980).

General guidelines are difficult to give because of the dependence on the specific ground conditions; pit latrines should always be downhill from a well and as far away as possible. Areas of high housing density have potentially high densities of pit latrines and there is a real danger of wells and pits being too close together. There is clearly an important interaction between the water supply and sanitation sectors (see Chapter 9), and great care must be taken at the planning stage.

Double pit latrines

The problems associated with ground conditions, high water table and groundwater pollution described above usually lead to the pit being very shallow. Unfortunately this means that the pit fills rapidly, and regular emptying is required. Pit emptying can present a major health hazard; whilst excreta at the bottom of the pit is completely digested, the upper layer of the pit contents contains fresh excreta.

This difficulty can be overcome by using the double pit system in which both pits are shallow, but not less than 1.2 metres deep as illustrated in Figure 6.12; additional capacity can be obtained by increasing the plan area or raising the pit as described below, but this increases the cost. The capacity of each pit should be sufficient to ensure at least one year's use. The first pit is used until it is full, and the second pit is then put into use. When the second pit is full, the first can be emptied safely because the contents will have been digesting for at least one year.

Pour flush latrines with double pits have been used on a large scale in urban areas on the Indian subcontinent. Pathak (1981) reports their successful use in slum areas

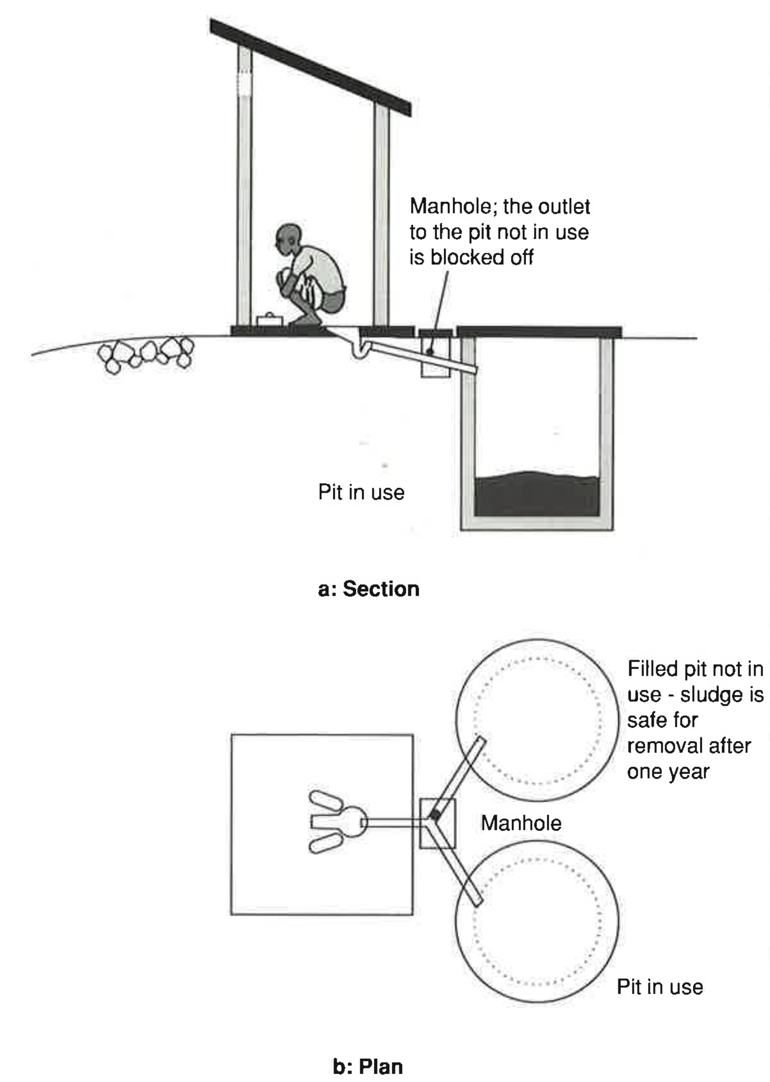


Figure 6.12: A pour flush double pit latrine

of high housing density which incorporate multi-storey buildings; if no land was available on the plot, the pits were located beneath the access way.

The double pit system can also be operated with VIP latrines as shown in Figure 6.13.

Raised pit latrines

In low lying areas which are prone to flooding, the whole latrine may need to be raised above existing ground level to avoid water completely filling the pit and bringing partly digested excreta up through the slab. Raising the pit provides a means both of increasing the capacity of the pit when excavation is difficult, thereby prolonging its useful life, and of overcoming difficulties with a high water table or groundwater pollution. Both VIPs and pour flush latrines can be raised; the raised portion of the pit above ground level should be lined and rendered so that it is impermeable, preventing the seepage of foul liquid out of the pit, as shown in Figure 6.14.

Septic tanks

A septic tank comprises a sealed tank having both an inlet and an outlet into which excreta are flushed from a conventional cistern flush toilet using typically between 10 and 20 litres of water for each flush. The tank is usually connected to the toilet by a sewer pipe, and partially treated effluent flows out of the tank, as shown in Figure 6.15. This marks an important difference from the pit latrine, in which any water entering the pit leaves by percolation into the surrounding ground. Septic tanks may receive either toilet wastes alone, or both toilet wastes and sullage from sinks, showers and baths.

The volume of water entering a septic tank is large compared with the volume entering a pit latrine, and it is assumed that each house has an individual water connection and cistern flush toilet. The septic tank acts as a settlement unit in which solids settle out by gravity; the solids undergo a process of anaerobic decomposition which results in the production of water, gases, sludge, and a layer of floating scum.

It is important to appreciate that the effluent which flows out of the septic tank constitutes a potential health hazard, and must be adequately disposed of. The residence time of the liquid in the tank is typically 1 to 3 days and many pathogens survive for longer than this.

The main problems usually arise from inadequate disposal of the tank effluent, which should not be allowed to run directly into the surface water drainage system. A common disposal method is by absorption into the ground using a soakage pit or trench. A large area of land is normally required because even when the ground is permeable, septic tank effluent only infiltrates very slowly. The land required for the soakaway is greater than for the septic tank and this limits the plot size and housing density for which septic tanks are a feasible option.

Given the problems of effluent disposal, it is normally better to allow only toilet wastes to be treated in the septic tank in order to reduce the volume of water to be handled by the soakaway.

Septic tanks may be used to provide primary treatment on a sewered site, or at communal latrines; the principal problem

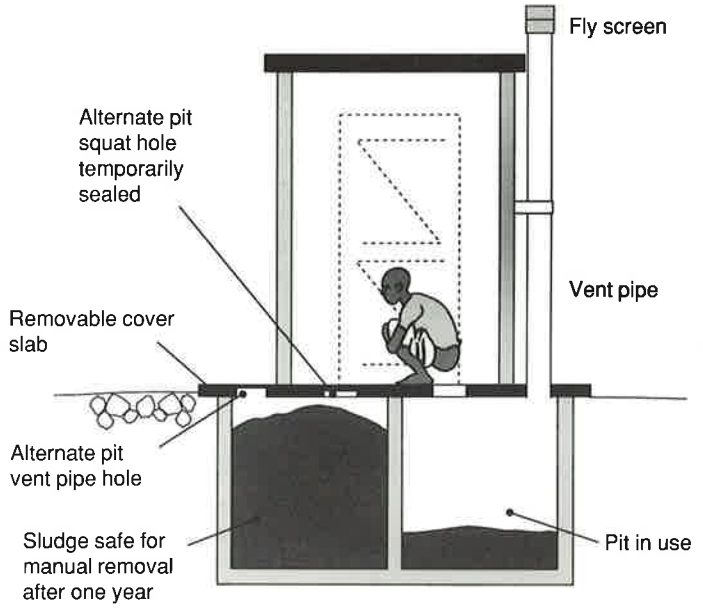


Figure 6.13: A double pit ventilated improved latrine

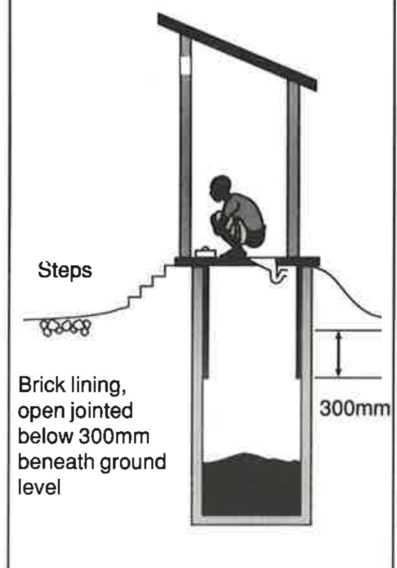


Figure 6.14: Raised pour flush latrine

remains how to dispose safely of the tank effluent, because there is unlikely to be sufficient space for a soakaway in congested urban areas which have a high housing density.

Off-site systems

Sewerage

Water borne sewerage provides a means of removal of both excreta and sullage, which together are referred to as 'sewage'. It is very convenient from the users' point of view, and is widely used in many Western towns and cities. The sewerage system comprises a network of buried pipes or sewers into which the sewage is discharged; examples of layouts are shown in Figure 6.16. A large volume of water is required to carry the sewage solids along the sewers and to prevent their deposition. Only water or soft paper should be used for anal cleansing; sewers may block if bulky hard material is used. The sewers should deliver the sewage to a sewage treatment facility where suitable treatment processes render it safe for disposal into a river or the sea. It is important to note that the sewerage system itself is simply a means of removing excreta from one place and transferring it to another; it does not safely dispose of or treat the excreta.

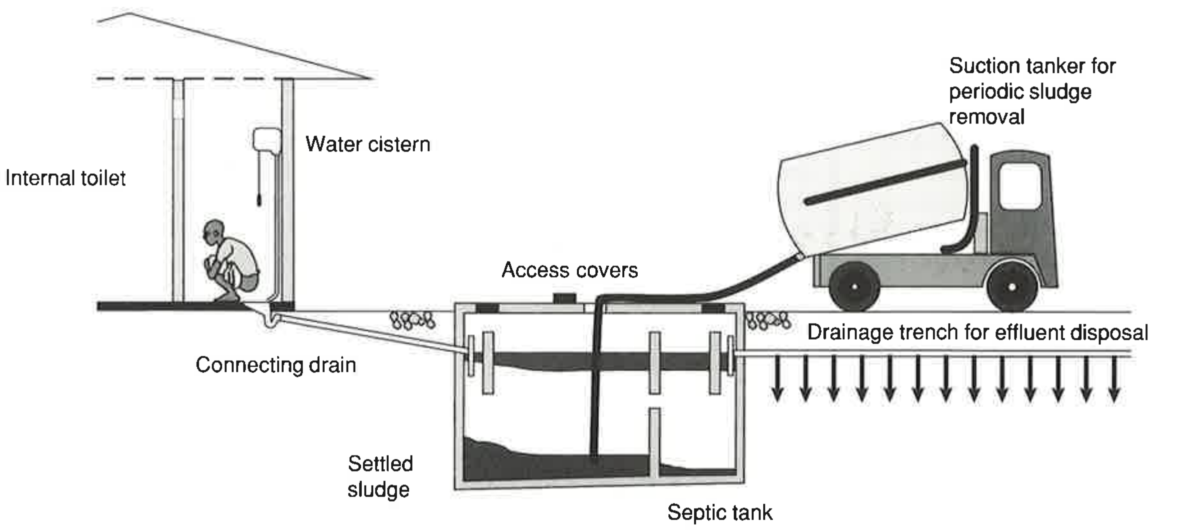


Figure 6.15: Septic tank and drainfield

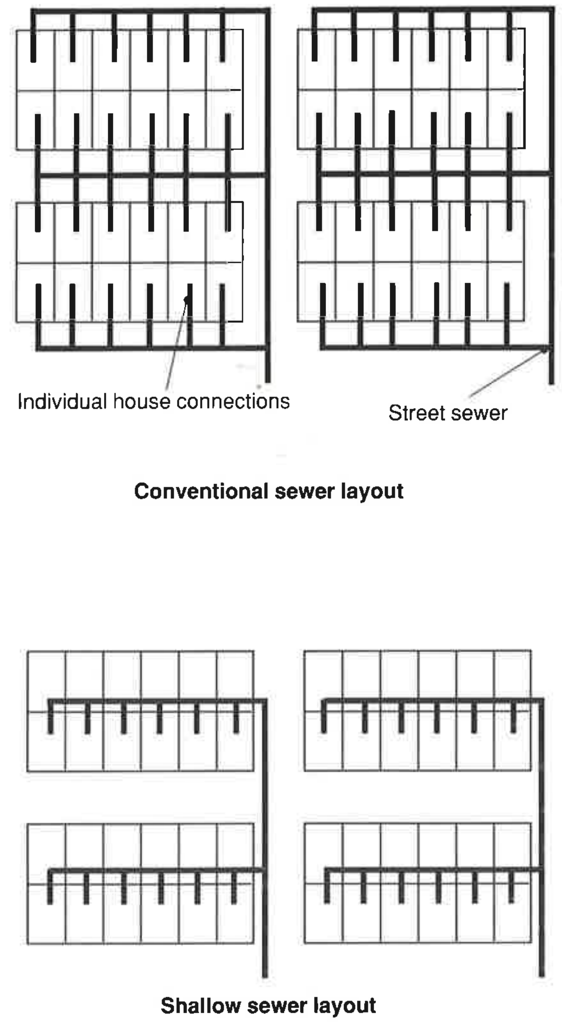


Figure 6.16: Schematic layout of conventional and shallow sewer systems

If sewers are to be provided on low-income housing sites, they should discharge into an existing town or city main sewer which runs close to the site boundary. If land is cheaply available on the site, it may be feasible to provide a small sewage treatment facility such as waste stabilisation ponds; Mara (1976) describes the processes and gives basic design details.

In some situations a large communal septic tank can been used to provide primary treatment for the sewage; however, the size of tank required may be prohibitively expensive and there remain the problems both of septic tank maintenance and safe disposal of the septic tank effluent. Sewers should never discharge untreated sewage directly into nearby water courses; apart from contravening the public health orders in many countries, it is self-defeating in terms of the objectives of sanitation.

Sewage flows down sewers by gravity; on flat sites this can cause problems because the sewers must be buried progressively deeper below ground in order to maintain their downward slope. On large sites this may result in the need for an expensive pumping station to pump the sewage back up to a higher level.

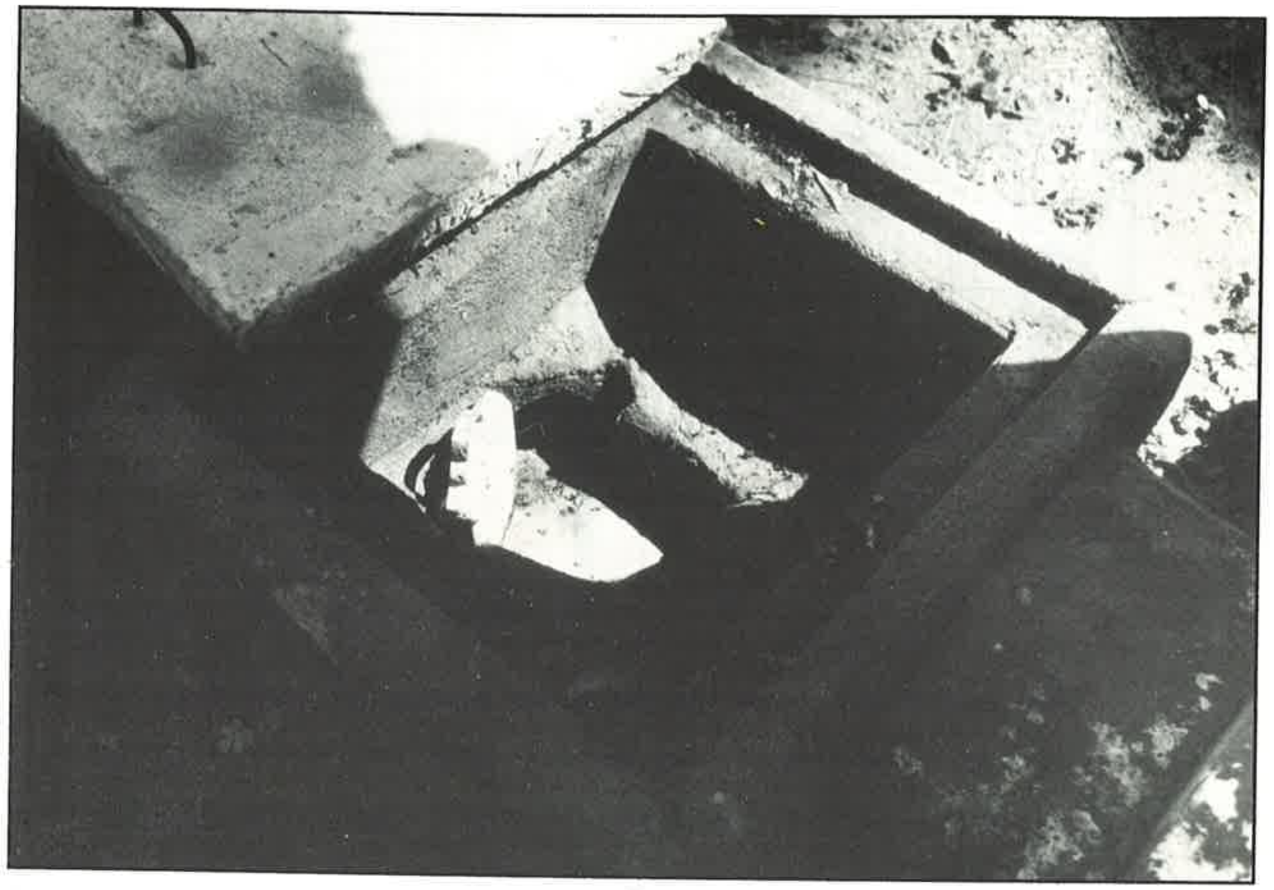
Bradley (1983) compared the use of septic tanks and sewerage in Sabah, East Malaysia; if a septic tank and soakaway were provided for the disposal of toilet wastes only, with sullage being discharged into the surface water drains, it was found that the alternative option of sewerage was only cost effective where the population density exceeded about 350 persons per hectare.

It is theoretically possible to upgrade offset pour flush pit latrines by connecting them into a sewerage system (Kalbermatten et al., 1980). This might occur as the level of water supply service improves, and the household installs conventional flush toilets and requires to dispose of large volumes of sullage. The pit traps out the gross solids, implying that the sewers can be of smaller diameter and be laid to shallower gradients, because the velocity of flow need not be so high. Regular emptying of the pits is essential, otherwise the sewers will block . Such a system has apparent cost advantages, but there is little data on its operation over long periods of time.

Vault and cartage

This system, which is used in the Far East, consists of a low volume water flushed toilet (usually of the pour flush variety) which discharges into a sealed tank or vault in which the waste is stored for a few weeks. It is then emptied by a vacuum suction tanker and taken away for suitable disposal. This system overcomes the problem of frequent emptying experienced with bucket latrines. The capacity of the vault should include an allowance for additional storage of up to 50% to cope with irregularities in the emptying service.

The system is expensive to operate and requires a highly efficient urban local authority to organise regular vault emptying. However, providing that sufficient access is available for the tankers, this method is flexible in that it can be adapted to changes in site layout which may result from slum upgrading programmes.



Above: The manhole arrangement for a double pit latrine showing the blocked off entry to the left pit (as viewed)

Below: An unrepaired sewer causes the collapse of the roadway

Communal latrines

A communal latrine consists of a number of latrine cubicles which are connected either to an on-plot disposal system such as a septic tank or large leaching pit, or to an off-plot disposal system such as sewerage or vault and cartage. Communal bathing facilities and standposts may also be provided.

The detailed design and layout of communal latrines must give careful attention to local customs and practices, for example, the segregation of sexes, or adults and children. In general, one toilet cubicle should be provided for every 25 people served.

Communal latrines frequently suffer from lack of regular cleaning and basic maintenance; they can rapidly become dirty and unpleasant, which understandably makes them unpopular with users. In addition, there is a lack of privacy for the users who may have to walk a considerable distance from their homes. Communal latrines are likely to be satisfactory if there is a strong sense of community responsibility or an attendant who controls access and looks after the general cleanliness; users may be required to pay an entry charge. There are examples in China, Ghana, and with the Sulabh latrines in India, where excellent operation and maintenance prevail. However, without this level of support, communal latrines are unlikely to be successful.

Whilst the provision of temporary communal latrines theoretically satisfies the primary level service requirements, many authorities encourage immediate upgrading through the construction of individual household latrines in parallel with house construction. Everything should be done to encourage this practice as there are sound public health reasons for facilitating the provision of individual latrines as soon as possible.

Despite the drawbacks of communal latrines, there are likely to remain certain situations in slum upgrading where they offer the only practical option, at least in the short term, of providing some form of excreta disposal.

Operation and maintenance

The classification of sanitation systems into 'on-plot', 'off-plot' and 'communal' distinguishes important differences in the responsibility for operation and maintenance.

Off-plot systems, of which sewerage is the most important, require the existence of an efficient agency to undertake all maintenance activities. These include general cleaning, removal of blockages, flushing out, repair and replacement of damaged sewers and appurtenances, and management of the wastewater treatment plant. Whilst there are isolated cases of community involvement in the implementation of neighbourhood sewerage schemes (United Nations Centre for Human Settlements, 1986), in most cases an agency must shoulder the responsibility.

The agency concerned is likely to be an urban local authority, as national-level institutions are rarely charged with maintenance responsibilities even if they undertake the design and construction works. The maintaining agency must be identified and its ability to undertake maintenance must be established before implementation of a sewerage scheme. This is especially important if the agency has no experience in the operation and maintenance of sewerage. The ability of many urban local authorities in less developed countries to carry out these functions is severely limited by lack of resources and means to recover costs incurred.

On-plot systems, including all types of household pit latrines and septic tanks, have the great advantage that operation and maintenance are the responsibility of the individual householder. Other than general cleaning and effecting minor repairs, pit latrines require little maintenance. Shallow pits and septic tanks require emptying every few years, depending upon their capacity; larger pits last for many years without attention. It is important to establish how pits are to be emptied when the time comes. In most cases this involves manually digging out the pit contents; suction tankers have been developed for pit emptying (Building Research Establishment, 1982), but are only likely to be effective when the pit contains a wet sludge. The design of vehicles which are smaller, cheaper and thus more appropriate for densely populated urban housing sites than conventional suction tankers is described by Coffey (1988).

The double pit system has an operating cycle involving the alternate use of the two pits; this facilitates pit emptying whilst ensuring that sufficient time elapses for pathogens in the excreta to die. Emptying a single pit can be more complicated; possible solutions to avoid handling fresh excreta when emptying full single pits are:

- move or reconstruct the superstructure and slab on to another pit dug next to the existing one;
- if the pit is an offset pour flush, a second pit can be dug alongside the first, and the pour flush bowl connected into this new pit.

Problems arise with communal latrines when there is no clear responsibility for cleaning or effecting minor repairs to doors and squatting slabs. There is the danger that many users will revert to defecation in the open in preference to using dirty communal latrines. The popular Sulabh public toilets and wash places pioneered in India (Pathak, 1981) have attendants who collect a small entrance charge, dispense soap and are responsible for maintaining cleanliness. If the latrines are connected to a septic tank, regular emptying by the maintaining authority is essential.

Cost recovery

The responsibility for the financing and construction of on-plot sanitation can rest entirely with the individual householders, who may either choose to do the work themselves or pay others to do it for them. In contrast, off-plot technology such as sewerage requires an implementing agency to be responsible for financing and construction. Sewerage can account for a high proportion of infrastructure costs and Laquian (1983) states that in most basic housing projects supported by the World Bank, sanitation in the form of sewerage accounted for 40-50% of total site infrastructure costs.

Recovery of the full capital, operation and maintenance costs by the agency is difficult. Attempts to make people pay through charging for a service connection from the street sewer to the house may result in very few connections to the sewers. Each household also needs to pay a user-charge which could either be included within the water charges, or be paid indirectly through general property tax. Many low-income communities are considered to be below the thresholds for property tax; in other cases the tax collected is so small that it does not cover the operation and maintenance costs.

There is little prospect of recovering capital, operation, or maintenance costs for communal latrines, although there are isolated examples which have been successful, such as the Sulabh public toilets and wash-places in India.

Capital cost recovery of a lower cost, more affordable, technology such as individual household pit latrines, is more likely. There are programmes in which householders have been required to construct an approved type of latrine as part of a general loan package for improved housing. Although in practice loans for sanitation are likely to be subsidised, some degree of capital cost recovery is achievable.

The cost implications to a central implementing agency of the choice between on-plot or off-plot technology are therefore considerable. On-plot technologies appear to offer much greater possibilities for the recovery of capital, operation and maintenance costs, whilst at the same time requiring minimal involvement of the agency.

Detailed design factors

Pit latrines

The rate of accumulation of solids in latrine pits in litres per person per year (l/py) depends upon the conditions in the pit. Approximate values are shown in Table 6.1.

These values are conservative and some measurements in wet pits suggest that the values could be halved (Adhya, 1986).

The approximate time taken to fill a pit can be estimated using the data in Table 6.1. For example, consider a pit latrine having a pit which is 1 metre square in plan and 3 metres deep. It is used by a family of 6, and water is used for anal cleansing; the pit does not penetrate the groundwater table.

Pit volume = Plan area x useable depth

= [1.0 x 1.0] x [3 - 0.5] = 2.5 m^3
= 2500 litres

The useable depth can be taken to be 0.5 metres less than the total pit depth.

V = PNA where
V = Available pit volume
P = Number of users
A = Sludge accumulation rate
N = Number of years between emptying

2500 = 6 x N x 60

N = 6.9 years

Thus the latrine can be used for about seven years before the pit needs to be emptied. In general, the pit should be dug as deep as is practicable in a given situation in order to minimise the frequency of pit emptying.

The diameter (for circular pits), or length of side (for rectangular pits), is normally about 1 metre. Circular pits are more stable because of the natural arching effect of the ground around the hole where there are no sharp corners to concentrate the stresses; however, people often find that rectangular holes are easier to dig.

In most cases, the walls of the pit require lining in order to support the excavation, unless the soil is self-supporting. The top 300 mm to 500 mm of the pit should always be lined and sealed to support the slab and, where necessary, the superstructure.

Shallow pits up to 1.5 metres deep can almost always be excavated to their full depth and lined from the bottom up. The method of excavation of deep pits depends upon the stability of the soil during

Table 6.1 Solids accumulation rates in pit latrines

Excreta under water in pit; degradable anal cleansing materials used, e.g. water, soft paper	40 l/py
Excreta under water in pit; non-degradable anal cleansing materials used, e.g. stones, heavy paper	60 l/py
Excreta in dry conditions in pit; degradable anal cleansing materials used	60 l/py
Excreta in dry conditions in pit; non-degradable anal cleansing materials used	90 l/py

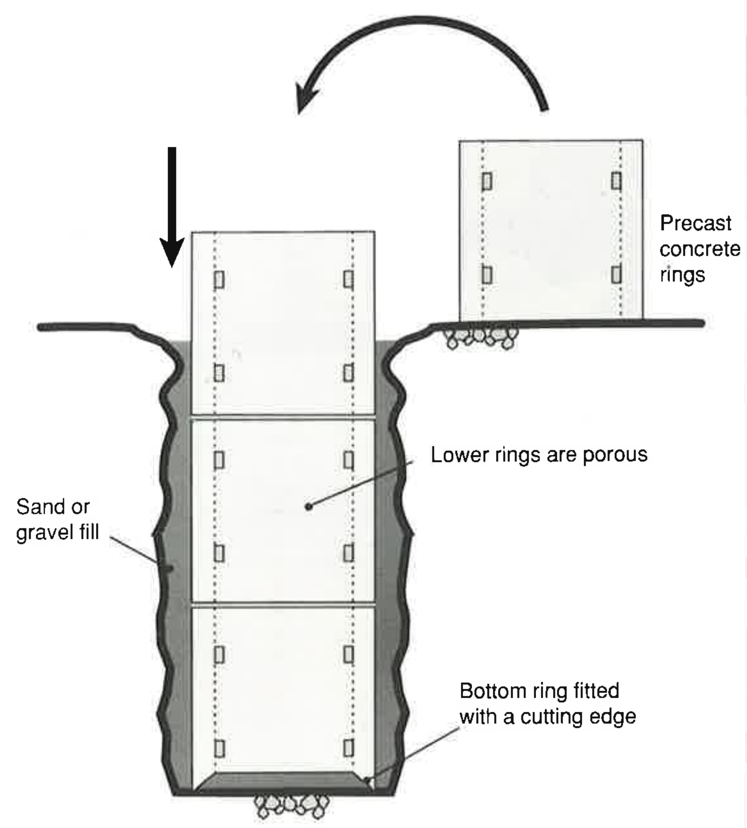


Figure 6.17: Caisson method of pit lining

excavation; in soils that are not self-supporting, the pit lining must be constructed as the pit is dug. If the ground is very loose, 'caissoning' can be used. The pit lining is prefabricated above ground and placed in a starter excavation; soil is dug out from below and the lining sinks as the hole is dug, as illustrated in Figure 6.17. Any space around the outside of the pit lining should be backfilled with compacted earth taken from the pit, or, where available, with sand and gravel.

Pit linings can be constructed from:

- pre-cast rings of concrete or fired clay;
- brickwork, blockwork or stone;
- concrete which is cast in situ;
- ferrocement;

In order to permit liquid to seep out of the pit into the surrounding ground, the pit lining must be porous. With brickwork, blockwork or local stone linings, a proportion of the vertical joints are left unmortared. If the ground is strong, a more open 'honeycomb' technique can be used. Concrete, ferrocement and fired clay ring linings are made porous by creating 25mm to 50mm diameter holes through the lining.

Although the latrine slab can be made of local material such as treated timber, steel-reinforced concrete is probably used most widely. However, domed slabs as shown in Figure 6.4 can be constructed from unreinforced concrete, which is cheaper (International Development Research Centre, 1983). The weight of cement-based slabs is an important consideration if they have to be moved; for example, a 65mm thick circular concrete slab, 1500 mm in diameter, weighs approximately 275 kg. The slab normally overlaps the supporting pit lining or foundation by a minimum of 100mm on all sides to ensure that the load is equally transferred. It is possible to minimise the span of the slab by corbelling the brickwork lining as shown in Figure 6.18.

The latrine floor should be impervious and slope gently to facilitate cleaning and prevent the

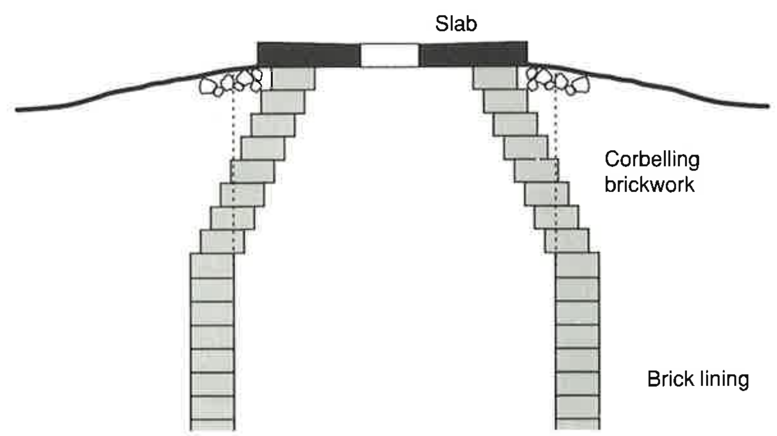


Figure 6.18: Minimizing the span of the slab

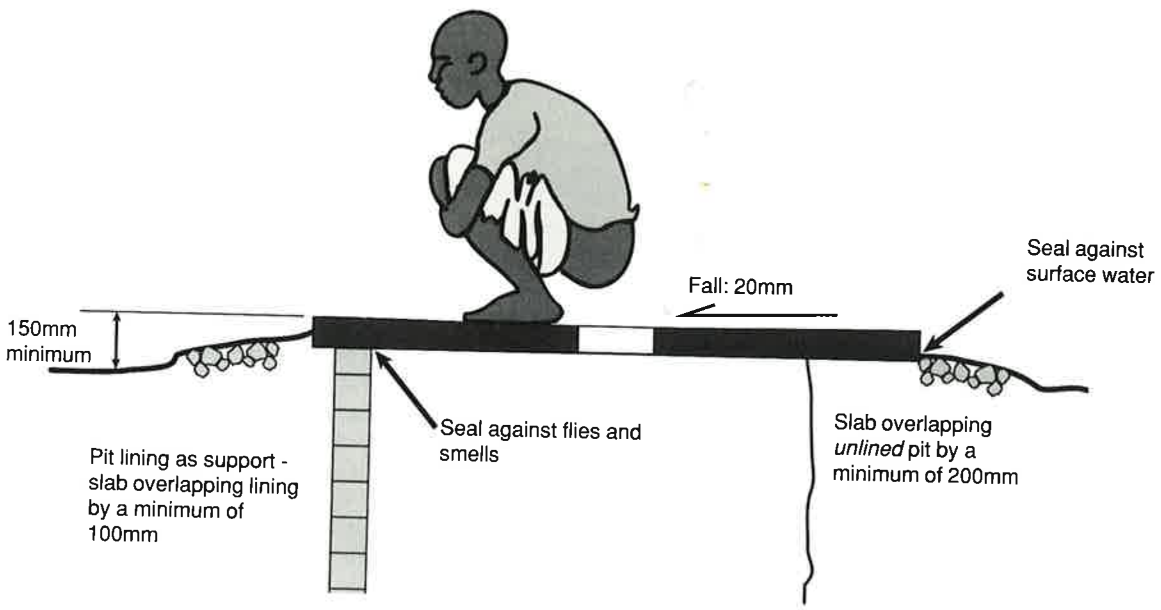


Figure 6.19: Requirements of slabs

ponding of surplus wash water, as shown in Figure 6.19. The slope is normally from the outer edge towards the squat hole; a fall of 20 mm between the edge and the centre of a slab up to 1500 mm across is sufficient. Where seats rather than squat holes are used, the floor slopes away from the seat.

In VIP latrines, the effectiveness of the ventilation depends primarily upon the wind speed blowing across the top of the pipe. Wind speeds increase with elevation above ground level; the higher the pipe extends, the better the ventilation will be. The vent pipe should be at least 150 mm in diameter and extend to a minimum of 500 mm above the highest part of the roof. Ideally, the pipe should extend as high as is practical especially when the housing density is high, because the vent pipe tends to be shielded by neighbouring buildings thus reducing the effectiveness of the ventilation.

Where possible, the vent pipe should be located on the 'sunny side' of the building, because the temperature of the air in the pipe is raised; the warmer air rises, aiding the upward draught in the pipe. A fly screen having a mesh size of 1.2 mm - 1.5 mm must be placed over the top of the vent pipe, as shown in Figure 6.20. It should be fabricated from material such as stainless steel or PVC-coated glass fibre or steel which will not deteriorate significantly on account of temperature, sunlight, or the corrosive gases which come up the vent pipe.

With the pour flush latrine, the sewer pipe connecting the slab to the pit should have a fall of not less than 1 in 80.

Septic tanks

Many countries have Codes of Practice which govern the detailed design and construction of septic tanks; the following general procedure is a summary of that given by Pickford (1980).

The first stage in septic tank design involves estimating the capacity required to retain the incoming sewage for at least 24 hours, and allowing additional capacity for the accumulation of sludge and scum.

Capacity for 24 hours sewage retention = PQ litres

where
P = number of people served by the tank;

Q = sewage flow per person. This depends upon whether sullage enters the tank in addition to toilet wastes.

Figure 6.20: Fly screen on a vent pipe

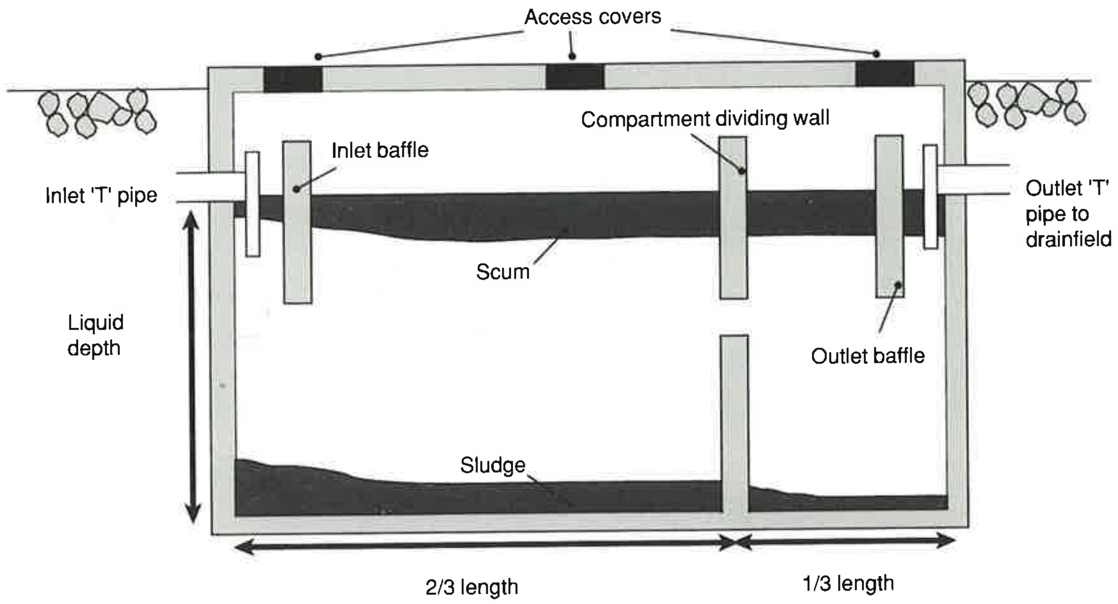


Figure 6.21: Septic tank arrangement

Capacity for sludge and scum accumulation = PNS

where N = number of years between desludging (usually between 2 and 5 years);

S = 25 litres per person per year for toilet waste only, or 40 litres per person per year for sullage and toilet waste.

The minimum tank capacity is the sum of the capacities for liquid retention and sludge and scum accumulation. A typical arrangement is shown in Figure 6.21.

The size of soakage pit or trench required in permeable ground can be estimated by assuming an infiltration rate in the range 10 - 30 litres per day through each square metre of sidewall.

Sewerage

The detailed design of sewerage systems is described by Fair, Geyer and Okun (1966). This involves the calculation of:

- the maximum sewage flow which must be carried;
- the diameter of the sewer pipes and the gradients to which they are laid.
- the design and location of manholes and other appurtenances;
- specification of materials and construction method.

The toilet, kitchen and bathing areas should be connected to the sewer. On low-income sites it is neither appropriate nor likely that houses have large-volume cistern flush toilets; the maximum sewage flow is more likely to occur as a result of the house tap discharging rather than the toilet flushing.

Sewers of less than 100 mm diameter should not be used because they are prone to blockage and are difficult to clean and unblock. Conventional Western design practice requires that the sewer slope is steep enough to maintain a velocity of not less than about 0.7 metres per second.

Tables for the hydraulic design of sewers are presented by Hydraulics Research (1983).

Some researchers feel that the 'minimum velocity' criteria is unnecessarily conservative (Wakelin and Uujamhan, 1979) and it is reported that gradients of 1 in 167 which result in lower velocities of about 0.5 metres per second have been successfully installed at Orangi, near Karachi in Pakistan (United Nations Centre for Human Settlements, 1986). It is recommended that the minimum gradient for sewers at the head of the sewerage system where the smallest flows occur (including the connection from the house to the street sewer) is 1 in 167.

Table 6.2 indicates the hydraulic capacity of sewers of various diameters laid to different gradients. It is difficult to relate this capacity to the number of households connected to a sewer of a given size which is laid to a particular gradient because of the uncertainty in estimating household sewage flows. Nevertheless, this has been attempted based on the probability

Table 6.2: Sewer capacity and connection data

Upper figure: capacity in litres per second
Lower figure: approximate number of house connections

Gradient 1 in: / %	400 0.25	300 0.33	200 0.50	167 0.60	100 1.00	50 2.00
Diameter (mm)						
100				5 70	6 100	9 170
150			12 250	14 300	18 450	25 700
200	19 500	22 600	27 750	29 850	38 1250	54 2050
250	34 1050	39 1300	48 1750	53 2000	69 2900	97 4600

Hydraulic capacity is calculated assuming a roughness height of 0.6 millimetres

of a given number of households having simultaneously discharging taps, causing the peak sewage flow. The principles underlying the method are described in detail by the Institute of Plumbing (1988); an approximate estimate of the number of connections which can be made is also shown in Table 6.2.

If the sullage contains large quantities of solid material, for example vegetable matter from food preparation, it is advisable to install a small 'catchpit' where the sullage enters the building sewer to trap out the solids.

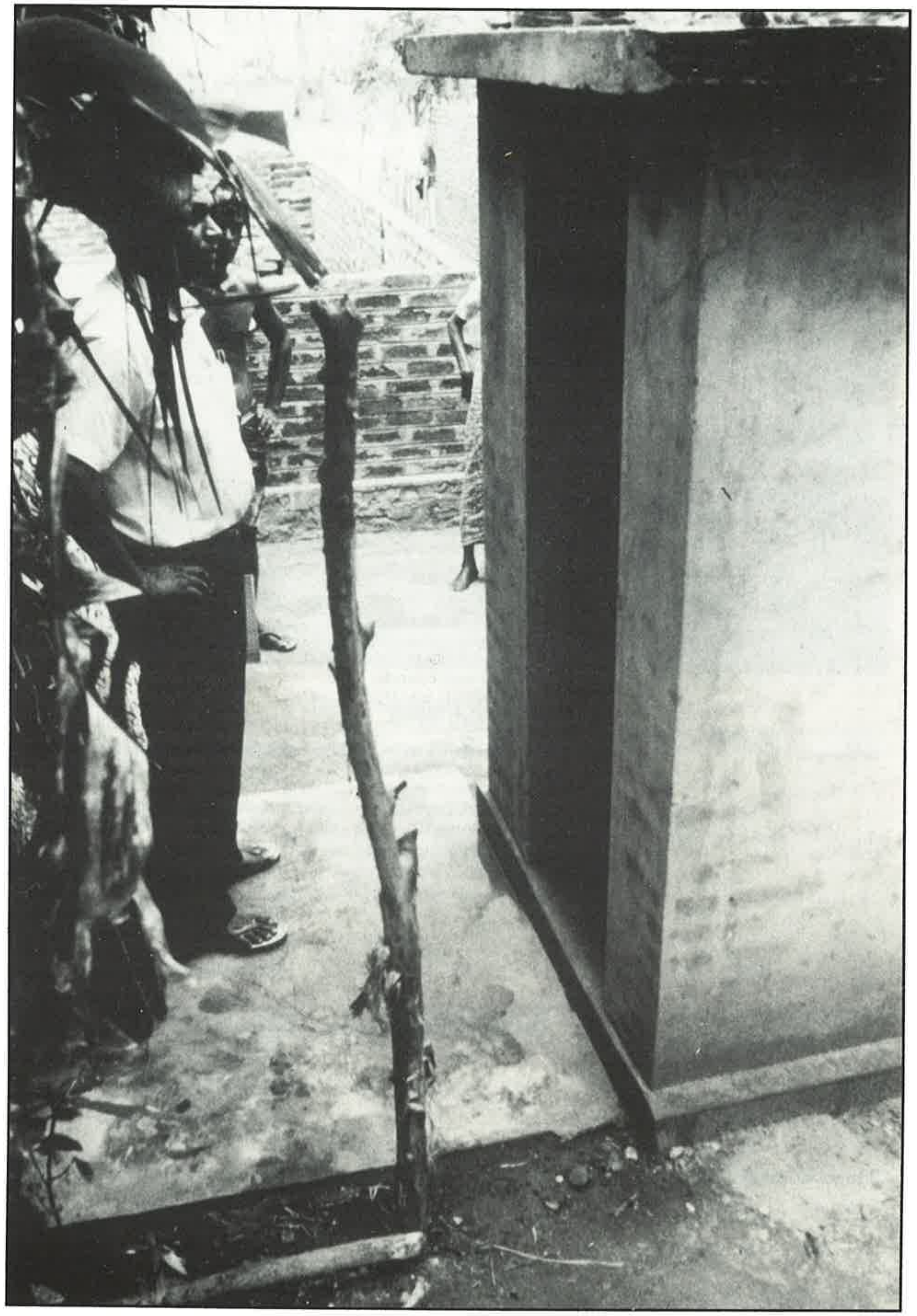
A significant element in the capital cost of sewerage is excavation of the trench into which the sewer pipes are laid. This can be reduced if sewer lines are laid to the minimum possible gradient and are run beneath 'pedestrian only' access ways, which avoids damage due to traffic loading. Sewers must either be buried to a depth of about 1 metre or protected by a concrete collar if they are to be subject to vehicular loading.

There is undoubtedly scope for attempting to reduce the costs of sewerage below that which would result from the stringent application of conventionally accepted western design practice. Reed and Vines (1990) report the preliminary results of field evaluations of "reduced cost sewerage" using a variety of layouts such as those shown in Figure 6.16.

Summary of sanitation options

The requirements, advantages and disadvantages of the systems appropriate for urban low-income housing are summarised below.

	ADVANTAGES	DISADVANTAGES
Sealed pit latrines	● Cheap ● Do not require water ● Do not require permanent superstructure ● Small land requirement on plot ● Control of flies & cockroaches providing that a tight fitting lid is placed over the hole in the slab	
Ventilated improved pit latrines	● Cheap ● Do not require water ● Control of flies ● Less smell in latrine ● Small land requirement on plot	● Extra cost of vent pipe and superstructure
Pour flush latrines	● Cheap ● Absence of smell in latrine ● Control of flies ● Contents of pit not visible ● Excellent from the user's point of view	● Only suitable if water is used for anal cleansing ● Extra cost of pour flush bowl ● Requires reliable water supply
Septic tanks	● Users have convenience of a conventional cistern flush toilet ● Problems with effluent disposal ● Large land requirement for effluent disposal; unsuitable for high-density housing	● High cost ● Reliable and ample water supply from house connection
Sewerage	● User convenience; no concern what happens after toilet is flushed ● Means of sullage disposal ● Usable with very high density housing	● High construction & maintenance cost ● Efficient institutional organisation needed for construction, operation and maintenance ● High level of water supply service required (minimum about 70 litres per person per day) ● Only suitable if water or soft material is used for anal cleansing ● Adequate sewage treatment process is required before discharging to a water course
Vault and cartage	● Satisfactory for users if the collection service is reliable	● High construction & operation cost ● Highly efficient central organisation required to maintain regular collection service ● Serious health hazards if collection is inefficient Adequate sewage disposal facilities required
Communal latrines	May be the only option in highly congested sites with poor water supply	Lack of responsibility for funding and carrying out maintenance service If maintenance is bad, latrines will not be used Inconvenient and undesirable for the user unless access is controlled



Above: An offset pour flush pit latrine

Solid waste management 7

Objectives

Solid waste, or refuse, is generated by many human activities. The principal source of solid waste relevant to low-income urban communities comprises kitchen waste from food preparation and a wide variety of materials for which no further use can be found. Community centres, schools, shops, and small industries also generate solid wastes.

The objectives of the solid waste management system are the satisfactory storage, collection, and disposal of these solid wastes and the cleaning of streets and other public places. This is an essential component of both public health and the aesthetic quality of the environment in which people live. Heaps of putrefying waste provide a breeding medium for flies, and a home for rats. If stagnant pools of water are created, there may be a mosquito problem.

Solid waste management differs from all other components of physical infrastructure on low-income housing sites in that it depends upon an efficient operational system being established from the very outset. Other services, such as roads or drainage, can operate adequately for a considerable period of time after construction with practically no input on the maintenance side until something actually goes wrong. Thus solid waste management is principally concerned with operation rather than design and construction.

All too frequently solid waste management receives scant attention at the planning stage, yet it may consume between 20% and 40% of municipal revenues (Cointreau 1982); in India, it employs between 3 and 6 people per 1000 population (Nath et al, 1983). Street cleaning comprises a significant proportion of the solid waste management budget.

It is rarely possible to dispose of solid wastes within the boundaries of a low-income housing settlement; the wastes must be collected and transported away from the site, usually to a municipal disposal area on the fringes of the town or city. Disposal methods, which are described by Flintoff (1984), Holmes (1984) and Cointreau (1982), are outside the scope of this chapter, which deals principally with storage and collection of solid wastes.

Scavenging of solid wastes is common in many countries; small communal bins, waste transfer stations and waste disposal sites all attract scavengers. This should not always be viewed as a "problem" because the poorest families substitute waste materials for purchased goods, which can lead to important savings for them. At the lowest level of scavenging from communal bins and small transfer stations, women and children predominate as scavengers (Furedy, 1991). The benefits to the solid waste management system are clear; the less waste there is to collect and transport, the cheaper the system should be. However, scavenging frequently creates problems due to waste being scattered on the ground and not returned to the container, which may increase the costs of street sweeping and general cleaning.

Technical options

Components of solid waste management systems

The solid waste management system appropriate for an urban low-income housing site should consider the following factors:

- Storage of waste in household or communal containers.
- Method of collection of the waste from the storage containers.
- Frequency of collection of the waste.
- Transfer of waste from smaller containers to larger ones.

The quantity and characteristics of the solid waste which is generated are important in determining the frequency of collection and the type of vehicles used. The relative costs and availability of labour and equipment determines the most economic system for a given situation.

There are a range of options for operating waste collection and removal, some of which provide opportunities for community involvement. However, it is important to remember that it is rarely possible to design a complete solid waste management system in isolation from the current practices of the urban local authority, with whom there must be an interface at some stage.

Solid waste characteristics

In order to estimate storage requirements and collection frequencies it is important to consider the characteristics of solid waste. Waste can be characterised by the mass generated in kilograms per person per day (kg/pd), its density in kilograms per cubic metre (kg m^{-3}), and an analysis of the different materials contained within. Unfortunately it is not possible to generalise about the composition of solid wastes, which vary widely with income level, location, and environmental conditions. Flintoff (1984) quotes the following range in characteristics:

Generation rate:	0.25 - 1.0 kg/pd
Density:	100 - 600 kg m^{-3}
Putrescible matter: (which decomposes)	20 - 75 % by weight

The volume generated, which is important in planning the local storage and collection on the site, could be anywhere between 0.4 and 10 litres per person per day (l/pd) and vary from being largely inert, to containing a high proportion of vegetable matter which rapidly decomposes in hot and humid conditions.

Table 7.1: Solid waste generation in low-income communities

	Generation rate		Density
	kg/pd	l/pd	kg m^{-3}
Orangi, Karachi Pakistan (Sinnatamby 1986)	0.17	1	170
Shiraz, Iran (Coad 1984)	0.25	1	260

In low-income communities much material is salvaged either for sale or reuse; the same material would be thrown away by richer people. As income levels rise, the mass of waste produced increases and its density decreases, leading to marked increases in the volume. Some data are available on the overall characteristics of solid wastes generated in towns and cities (Cointreau 1982, Holmes 1984, Tariq and Hyat,1981). Holmes (1984) quotes values in the range 1.0 to 2.4 lpd for various developing countries. There is little data which relates specifically to clearly defined low-income communities other than that shown in Table 7.1.

The waste generation rate should be ascertained from the urban local authority; in the absence of any data, it is reasonable to assume 1 lpd.

Refuse storage

Household storage

Ideally, household waste should be stored in a sturdy container of sufficient capacity which is easy to empty and clean, and has a well-fitting lid. Galvanised steel and plastic bins can satisfy these criteria; however, they are not affordable in most low-income communities, and such containers would be used for more pressing needs such as water or food storage. Many houses use small containers for which no other use can be found, or accumulate a small pile of waste outside the house which is eventually to be carried to a communal container in a basket.

Better quality waste containers suitable for house-to-house, roadside, or street corner collection, may only be appropriate either when the household income level has risen, or when the level of collection service is highly efficient and householders are willing to invest in order to benefit from the service.

Communal storage

The use of communal storage containers to which householders carry their waste is widespread and seems likely to remain a common option for low-income communities. A frequent problem is the provision of too few containers of insufficient

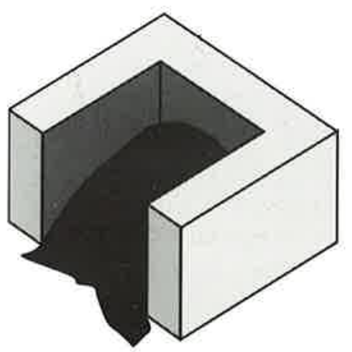


Figure 7.1: A small enclosure

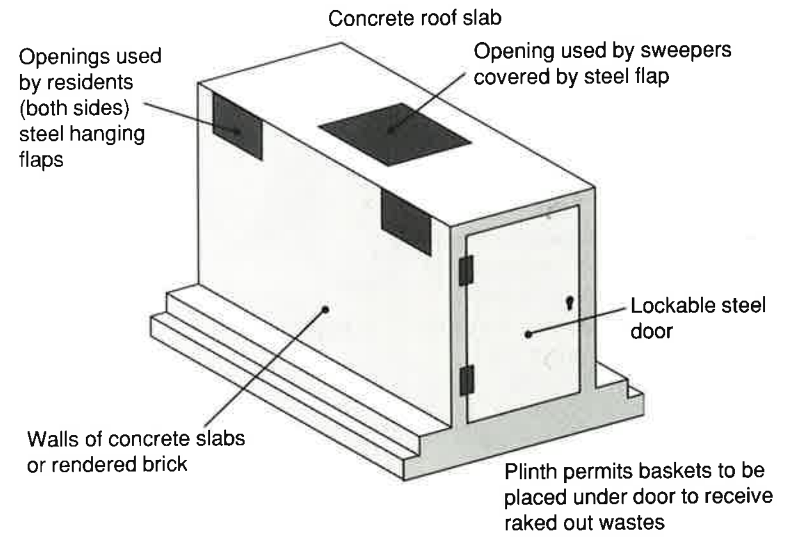


Figure 7.2: Communal solid waste bin (after Flintoff, 1984)

capacity which are inappropriately located. Containers are usually open, giving access to rats, flies, animals and scavengers which is undesirable for both hygienic and aesthetic reasons. It is unlikely that many householders will want a communal container outside their house, and location of the containers must be done in conjunction with the residents. This is a particular problem on densely populated sites; in some cases householders are prepared to walk longer distances to a larger communal storage point which is on the fringe of the site, and slightly away from the houses.

Enclosures constructed from concrete, masonry or timber are commonly used for communal storage; whilst there is no theoretical limit on the size of enclosure, capacity is typically in the range 1 to 10 cubic metres. The waste is screened off by walls, and there is at least one opening to enable waste to be deposited and to permit emptying, as shown in Figure 7.1. Enclosures are usually located along the side of a road; the capacity required is determined by considering maximum walking distances, the population served, and the frequency of emptying. Problems with this type of storage include:

- the full capacity of the enclosure is rarely utilised because people throw their waste just inside the entrance forming small heaps which overflow on to the street;
- removing wastes from the enclosure is unpleasant and unhygienic;
- scavenging animals and flies have unlimited access;
- a large enclosure may be used for defecation and urination.

Fixed storage bins differ from enclosures in having no direct entrance; the walls are normally less than 1.5 metres high so that waste can be dropped directly inside. There is an opening covered by a flap in one of the walls to enable wastes to be raked out.

Concrete pipe sections placed upright along the roadside are sometimes used as communal waste containers. A pipe of one metre diameter standing one metre high provides about 700 litres storage capacity; their low capacity indicates that they are better suited to areas of low population density. Concrete pipes are almost indestructible and are unlikely to be stolen; however, pipe sections are difficult to empty completely and it is hard work digging out the waste. As such containers are open, waste may be spread about by animals and scavengers.

200-litre oil drums can be used providing that there is a plentiful supply to replace those which become damaged. The low capacity means that more than one drum should be provided at each point; they are easily overturned by scavengers and may be stolen if residents perceive alternative more effective uses for them. Small portable steel or plastic bins with fitting lids provide hygienic storage if the collection frequency is high; however, they are expensive and are likely to be stolen as their resale value is significant.

The use of portable containers or 'skips' which when full can be hoisted on to a standard vehicle and replaced by an identical empty container is another option for communal storage. This method usually depends upon the local authority possessing the equipment, but in some cities the existence of private skip operators may offer an alternative solution for the community.

Unfortunately, none of the above means of communal storage is satisfactory for a low-income community. Whilst the ideal communal container does not appear to exist, Flintoff (1984) proposes a concrete container of capacity 2 cubic metres with steel doors and flaps, as illustrated in Figure 7.2. It resolves many of the problems of hygiene, restricting access and ease of emptying. Whilst it would appear to be expensive compared with other containers, in relative terms when compared with the high costs of other infrastructure it is perhaps a reasonably realistic proposition.

The capacity of a communal container should be:

$C = NRI$ where:

- C = Capacity (litres)
- N = Number of users
- R = Refuse generation rate (l/pd)
- I = Emptying interval (days)

The number of users is determined through consultations with the community; in general, a reasonable maximum walking distance is 100 metres. Flintoff

(1984) recommends the use of a container of twice the capacity of that calculated to allow for irregularities in the collection service.

Collection systems

An important feature of storage and collection systems for solid wastes is the varying degree of participation required from the householders. There are four basic options.

Communal storage

Communal storage containers can be positioned at a number of strategic locations; this requires maximum effort on behalf of the householder, who is required to carry the solid waste from the house to the communal storage container, which may entail walking considerable distances.

Street corner collection

A collection vehicle halts at predetermined places and householders carry their solid waste to the vehicle.

Roadside collection

The householder leaves the household storage container by the side of the road at an appointed time and it is emptied by waste collection workers.

House collection

The workers collect the waste container from within the boundaries of the plot; this involves the minimum effort on the part of the householder.

Collection vehicles

Solid waste management involves the transfer of waste from one location to another; careful consideration must be given to the vehicles which are employed. Access widths, and the type of waste storage in use are relevant to the vehicle design. However, in steep or inaccessible areas waste may be manually carried to a transfer station in baskets or shoulder panniers connected by a bar.

Handcarts

The simplest handcart consists of an open box on wheels with a capacity of 200 to 500 litres, as shown in Figure 7.3. Such handcarts are widely used in street sweeping and general cleaning, and can be used for transferring waste from communal containers; they are suitable for areas having a high population density. However, loading and unloading can be messy as it frequently involves emptying the contents out of the cart on to the ground when transferring the waste. Frame handcarts which carry portable storage bins as shown in Figure 7.4 are an improvement; for a one-man operated cart, bins should not weigh more than about 25 kg when full, otherwise two people may be needed to lift and empty them. Strong and efficient handcarts comprising a tubular steel frame and rubber-tyred wheels have been designed, but are probably too expensive to be afforded by low-income communities.

Tricycles

The use of either pedal or motorised tricycles to power a frame carrying portable containers speeds up the transfer operation and increases the radius of collection; they are appropriate in areas of low population density. Whilst bicycles are sometimes used to carry small containers on the front and back,

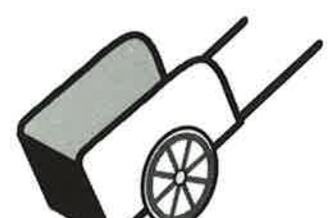


Figure 7.3: A simple handcart

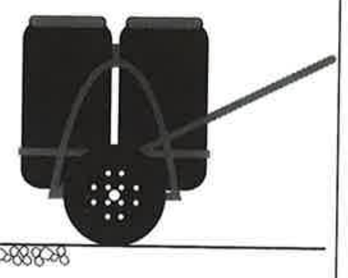


Figure 7.4: A handcart for portable bins

there is obviously a limit on the size of container which can be carried safely.

Animal carts

Animals may be saddled with baskets and used for waste collection in areas where access or the terrain is especially difficult, as illustrated in Figure 7.5. Carts drawn by bullocks, horses or donkeys can pull much larger loads over longer

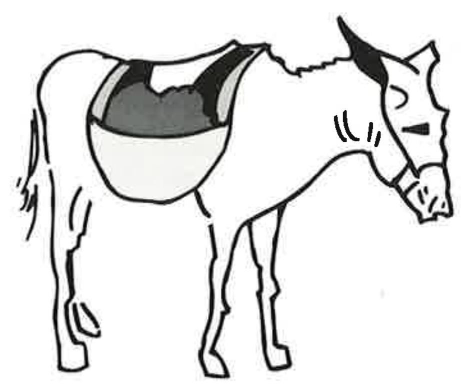


Figure 7.5: Animal transport

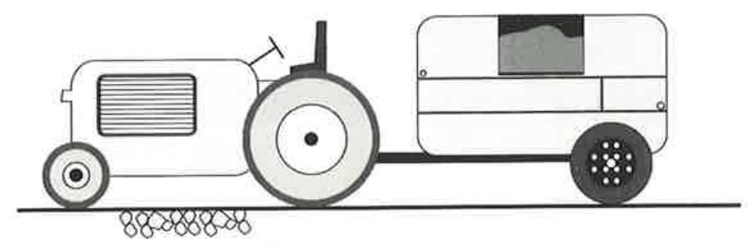


Figure 7.6: Conventional tractor-trailer unit

distances than tricycle systems, although they are very slow. In many cities this does not present too much of a problem as traffic congestion prevents rapid transit by any sort of vehicle. Cointreau (1982) observes that animal carts are quiet and do not consume fossil fuels.

Tractor-trailer units

Tractor-trailer units are much quicker than animal carts. For on-site transfer of waste, the small single-axle "mini" tractor units common in south-east Asia can carry between 1000 and 3000 litres depending upon the trailer design. Conventional tractors as illustrated in Figure 7.6 can carry larger payloads.

Large vehicles

There exists a wide range of vehicles for the longer range transfer of waste to the final disposal site, details of which are given by Flintoff (1984), and Holmes (1984). Coffey (1989) describes recent work on the design of vehicles appropriate for restricted access situations and describes the pitfalls of choosing inappropriate Western-designed vehicles for use in less developed countries. Careful choice of small container handling vehicles can result in operating costs four times less than those for conventional western compactor vehicles. Whilst this is a problem to be faced by the urban local authority, it is important to ensure that the design of communal containers and transfer stations enables the local authority to adopt the most efficient solution.

Collection frequency

Up to 70% of solid wastes in low-income areas consist of material which decomposes; there is a high proportion of vegetable matter (Holmes, 1984). Decomposition of the waste proceeds more rapidly in hot and humid climates than in temperate regions. After two days, offensive odours are produced and infestation by flies and rats may occur. Regular collection is essential; Flintoff (1984) recommends collection three times a week from communal storage containers, twice a week from individual dwellings with storage containers outside the house, and daily collection from houses with storage containers inside the house.

Short-range transfer

Any of the four methods described in the section on 'collection systems' may require the waste from the site to be deposited in a larger container or vehicle at a transfer station; waste is subsequently taken relatively rapidly either to the disposal area or to a larger transfer station for a long-haul journey to the disposal site. If the community has responsibility for the day-to-day operation of the waste collection on the site, a transfer station is necessary nearby. If the urban local authority is fully responsible for all aspects of solid waste management, the need for a transfer station depends upon the type of vehicles used for collecting waste from the site. A local transfer station is needed if the vehicles have a short operating range due to limited capacity and low speed.

Short-range transfer stations can be either single- or split-level.

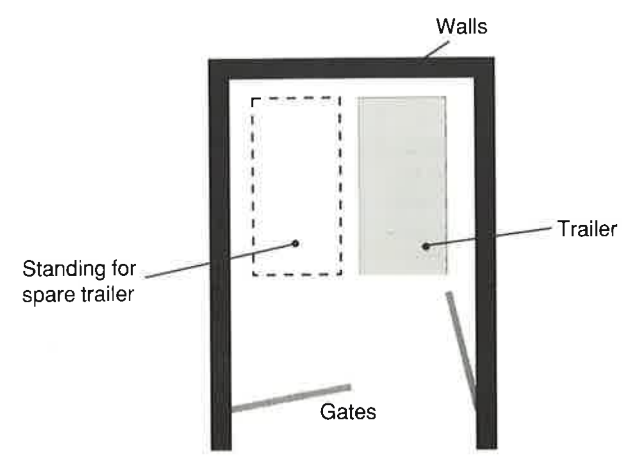


Figure 7.7: Plan of a simple single-level transfer station

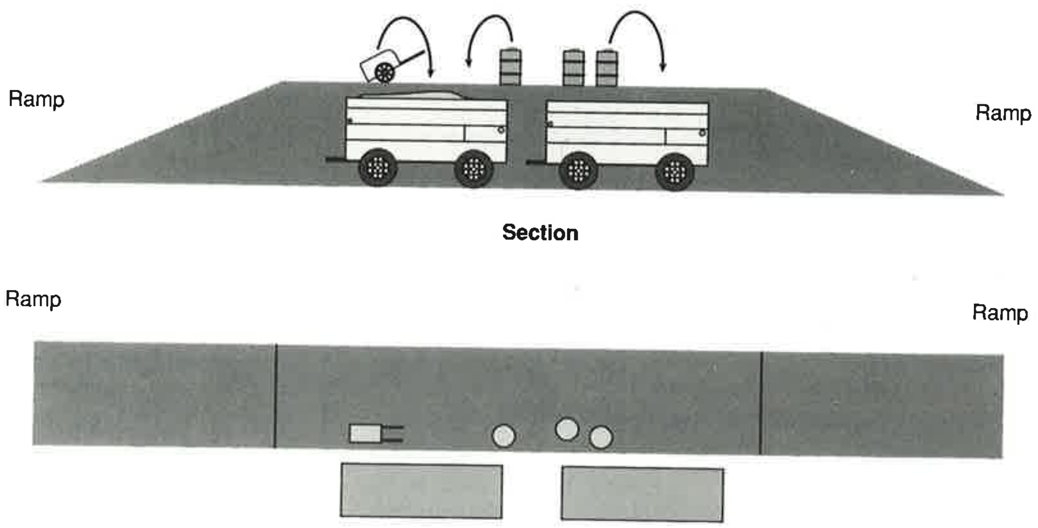


Figure 7.8: A simple split-level transfer station

The simplest form of single-level transfer station is an open space with sufficient room for small containers to be manually emptied into larger ones, as shown in Figure 7.7. Typically the waste may arrive in handcarts or on cycle-carts and be transferred to a trailer. It is important to ensure that there are sufficient trailers available throughout the day in order to avoid inefficient 'double handling' of waste by dumping it out of one container on to the floor and subsequently loading it up into a trailer. Split-level transfer stations comprise a ramp leading up to an elevated platform, from which the waste is deposited into trailers as illustrated in Figure 7.8. Full trailers can be exchanged for empty ones in such a way as to optimise the use of towing vehicles. Regular cleaning of transfer stations is needed and it is useful if a water tap is provided to enable the surfaces to be washed down.

Transfer stations are likely to attract scavengers; whilst this can be an effective way of recycling waste materials it is important to prevent the waste being scattered about indiscriminately. Ideally, a transfer station should be manned to exercise some control over scavenging and to oversee waste transfer from handcarts or portable bins into trailers.

Irrespective of the method adopted for operational management on the site, the transfer station is the interface between the site operation and the urban local authority or its agents. It is thus essential that the possible modes of operation on the site are considered in conjunction with those of the urban local authority, especially in the design of the transfer station.

Street cleaning

An efficient street cleaning system is an essential component of solid waste management; problems arise due to:

- waste dumped by householders in the street or drains;
- waste blown around from communal storage bins;
- sand and silt on paved roads and in open drains;
- leaves and vegetation;
- animal dung, especially where bullocks and goats roam freely.

Street cleaning is a major item of expenditure for many urban local authorities and may account for up to 30-50% of the budget for urban solid waste management (Flintoff, 1984); the World Health Organisation (1975) states that the Indian city of Bangalore employed 3000 sweepers for 1500 km of roads.

The work can be achieved with simple equipment, as shown in Figure 7.9:

- long-handled brooms having stiff bristles for paved surfaces and soft bristles for unpaved surfaces;
- flat-front shovels;
- two flat boards for picking up and transferring waste (especially leaves) are sometimes used;
- handcarts.

Densely populated areas need more frequent cleaning, and markets should be swept at least daily.

Operation

Operation is the key to the success of solid waste management; there are two principal options which could be adopted.

- The urban local authority is responsible for all aspects of waste collection and street cleaning.
- The community is responsible for part or all of the activities on the site, and for transporting solid waste to a transfer station; labour can be used from within the community or hired from outside. Subsequent transfer of waste is the responsibility of the urban local authority or its contractors.

There is much scope for community involvement in solid waste management; indeed, if the local urban authority is grossly inefficient, this may be the only practical solution for waste collection and street cleaning on low-income sites. A system which could be operated by the community is described below.

At the outset, the most appropriate system is likely to be the use of communal storage containers of the 'enclosure' type. The collection system can be labour intensive, using unskilled labourers with handcarts to transport the waste to a transfer station. A team comprising two labourers plus one handcart, broom, and shovel is responsible for emptying the communal containers, and general street cleaning in a particular neighbourhood. In general, communal containers should be emptied three times per week in residential areas, and daily in market areas. The range of each team and the number of teams required is a function of the population density and site layout.

Each team empties the handcarts at a transfer station; it is then the responsibility of the urban local authority to remove the waste from the transfer station. Such a system requires the minimum of equipment, but is very slow. It could be improved by using animal drawn or motorised carts, or "mini" tractors and trailers.

Solid waste management may create serious difficulties on low-income housing sites. All too often the urban local authority is deemed responsible, but is unable to carry out its duties effectively; at the same time the community does not see itself as being responsible. Whilst the models described above are theoretically workable, undertaking the day-to-day operation of solid waste management is by no means simple, and requires a high degree of motivation and cohesion on behalf of a community.

Cost recovery

The capital costs of upgrading the solid waste management service are principally borne by the urban local authority as it improves its stock of vehicles; the householders' investment is in an approved solid waste container. However, the day-to-day operation costs of collection must be found.

The urban local authority can recoup these costs through its general rates or property taxes. If the community is responsible for the management, either householders contribute their labour, or labourers are hired by the community and paid for by a contribution from each householder. Loans could be given to purchase the simple tools required, or animal carts or mini tractor-trailer units could be hired.

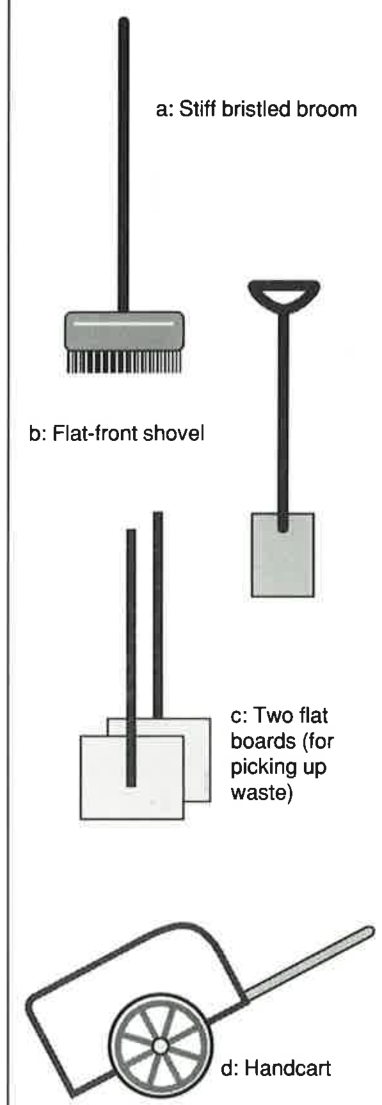


Figure 7.9: Simple equipment for street cleaning

Above: Solid waste spills out and blocks the drains due to incorrect siting of the enclosure and infrequent emptying

Below: Local solid waste collection and street cleaning using a simple handcart

Power supply 8

Objectives

All communities need power at an affordable price. Within low-income housing schemes this need is most often expressed as a desire for street lighting and household electricity connections. However, the household demand for power is extremely limited and rarely justifies investment in a conventional electricity distribution system. The primary requirement is normally power for cooking. Where this is perceived as women's responsibility and where traditional methods appear to men to be satisfactory, this demand is often wrongly disregarded by planners and infrastructure engineers.

Besides cooking, power is needed for lighting within individual households as well as for street lighting to improve security. Radios, televisions, fans and other household appliances increasingly necessitate some form of electricity supply. Power may also be required for heating water for washing purposes although in hot, tropical areas this is less of a priority.

Figure 8.1: Improved charcoal stove

Technical options

There are various means of supplying these needs that do not necessarily require the provision of conventional electricity distribution.

Cooking is still primarily powered by fuelwood, charcoal, and in certain parts of the world, animal dung. Improved efficiency in the use of these valuable resources, particularly in large cities where fuelwood is rapidly increasing in cost will enhance conservation and bring significant savings to the household. This may be achieved by the use of improved stoves such as those shown in Figure 8.1. Stoves may be freestanding, as in the Kenyan model, or may be built into the kitchen with a permanent chimney installed for maximum efficiency as in the Sri Lanka model (Figure 8.2).

To overcome the bias against such technology, models and demonstration units should be prepared as part of low-income housing schemes.

If available, kerosene and bottled gas are more efficient for cooking but require investment in small stoves and deposits on gas bottles which are often beyond the reach of the poorest people.

Where hot water is required, passive solar water heaters are the most economical choice in the long term. Designs vary, but the basic system uses some form of collector tank with water-ways, usually pipes or panels with fins which are painted black, underneath a glass cover to retain the sun's rays. This is connected to a hot water tank at a slightly higher elevation so that the natural circulation of hot water rising always keeps the tank at the highest temperature. The panel is

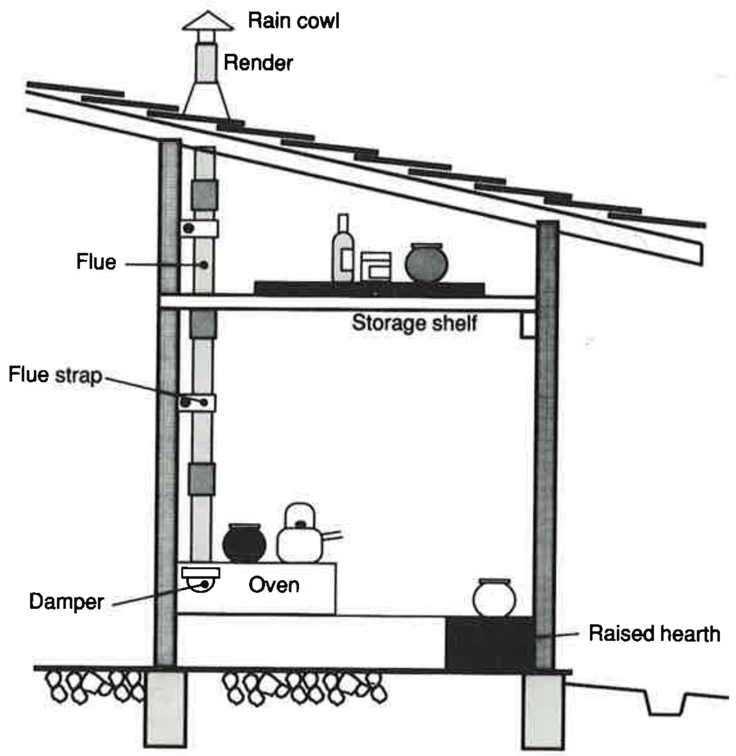


Figure 8.2: Improved kitchen oven with chimney

most efficient when positioned facing the equator, tilted at an angle similar to the latitude of the location to maximise the possible solar gain. However, the high capital costs make these systems unaffordable unless special loans with long pay back periods can be arranged.

For the much smaller power requirements of lighting and small appliances, kerosene and batteries can be used but are expensive and inefficient compared with mains electricity. For example, in Sri Lanka it is estimated that the use of kerosene for lighting costs ten times the equivalent price of using mains electricity. Similarly, the cost of powering a radio with ordinary dry batteries is fifty times the cost of using a mains supply (Development Planning Unit and Water Engineering and Development Centre, 1988). The World Bank (Plas, 1988) has found that the most common form of household lighting where electricity is available is a 60 watt tungsten-filament incandescent lamp; this gives equivalent light output of 60 candles, 18 kerosene wick lamps or 1.8 pressure lamps.

Electricity supply

Conventional mains electricity supply is normally the cheapest source of energy when considering the price paid by the consumer for a unit of power. The difficulty for the electricity supply agency is that a conventional distribution system is unlikely to be economic at the levels of demand that are normally attained on low-income housing sites. This demand is typically in the region of 1 kilowatt hour per household per day and is unlikely to increase significantly in the short term.

The demand for electricity supply is likely to be high on the list of priorities of the householders providing that the agency pays for the capital costs. A supply is often considered by politicians and many others to be an integral part of slum and shanty upgrading. However, cost benefit analysis where the life cycle costs of a system are compared with the social and economic benefits cannot justify this standard of provision of power. In most circumstances it is therefore unreasonable to consider a mains electricity supply as a basic need which has to be supplied regardless of measurable benefits.

Because of the high cost of installing a conventional distribution system with individual household energy meters there are some alternative means of electricity supply which may be investigated.

Street lighting

Residents want street lighting both to give increased security for householders and their homes and as a symbol of progress and development. Conventional street lighting requires a considerable investment in poles, stays and fittings which may account for about 50 per cent of the cost of a full household power installation. Where standard street lighting is uneconomic, it is the practice in some countries to allow temporary power lines on temporary poles for special occasions. This approach can be used to provide security lighting whilst householders build their own homes. However, if a project uses a temporary system it is unlikely that the householders will allow this to be withdrawn after the initial stages of construction are completed.

One solution is to use a limited number of photovoltaic street lamps. These comprise isolated poles with reduced power street lamps attached, unconnected to any mains supply (Figure 8.4). The power comes from the photovoltaic panel which converts the sun's energy, falling onto an array of special silicon discs, into electricity. This electricity is collected and stored during the daytime in appropriate sized batteries fixed to the top of the pole. The batteries release their energy at night when the street light automatically switches itself on.

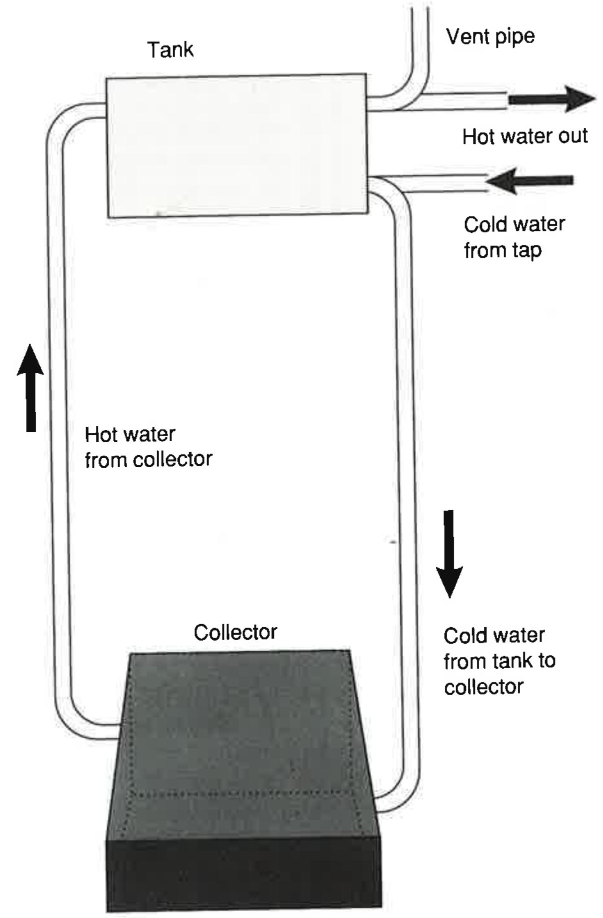


Figure 8.3: Solar water heater

At present these systems are expensive, costing US $1,600 for a single 35 Watt sodium lamp complete with pole, panels and battery (Derrick et al, 1989). It should also be noted that these systems do not fit smoothly into a future upgrading programme as they are not compatible with a conventional mains supply.

Individual electricity supply

In a similar manner, individual households can use photovoltaic panels to generate electricity for a 12 volt system within the home. The panels are expensive and cost US $6 per peak watt supplied. It is anticipated that the cost will fall to approximately US $2 per peak watt by the mid 1990s. The minimum present needs of a single household are a photovoltaic panel and charge controller costing US $250 with a 12 volt storage battery costing US $50. This is connected to simple low voltage wiring to supply 12 volt fluorescent lights and is also suitable for a radio and a television (Figure 8.5).

The total investment per household is similar to the capital costs of a conventional electricity distribution system - which the householder would not normally pay for directly. However, it may be worthwhile for an individual householder to make this investment when there is no alternative power supply.

A less expensive system dispenses with the solar panel, which is the most costly item, but retains the wet battery of the type used in trucks or large cars and the 12 volt wiring system. The battery is then recharged as necessary at a community centre or by a trader who has mains electricity and a battery charger. The householder pays an appropriate fee for the small amount of power consumed in recharging the battery.

Batteries have to be sized and cared for correctly if the desired benefits are to be obtained. Normally designed for an ambient temperature of 25 degrees, in higher temperatures they are likely to have a shorter life. There is a need for careful maintenance and topping up only with distilled water. Undersized batteries are likely to be discharged more fully each evening which may reduce life from twenty years to four years as compared with a battery run down by just 10 per cent each day (Foley, 1989).

Electricity produced by small petrol-driven generators is usually much cheaper than that generated by photovoltaic panels; a generator may be purchased by a household, a group of households or a trader operating within the site. Capital costs range downwards from US $0.70 per watt to which must be added fuel costs of about 0.6 litres per hour besides spare parts and maintenance.

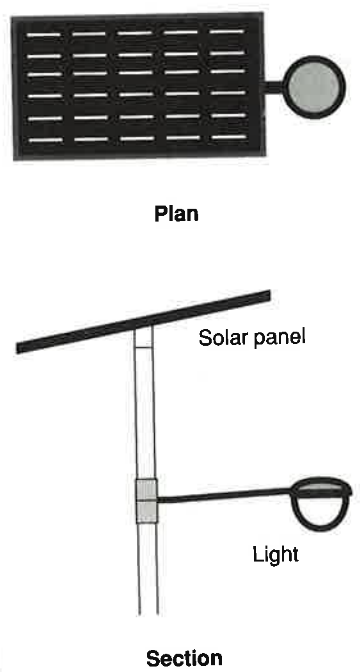


Figure 8.4: Photovoltaic lighting system

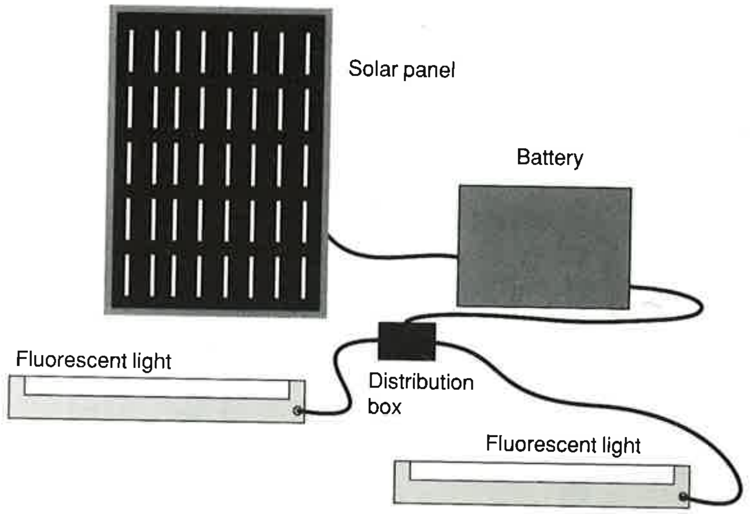


Figure 8.5: Household photovoltaic lighting system

Mains electricity supply

The cost of conventional power supply is influenced by the proximity of the housing site to existing three-phase power supply lines. Where extensions to the primary distributor system are required along with new transformers and ancillary equipment the cost to the developer can rise significantly.

The choice of a particular system of power supply is also determined by the tariff structure of the power supply agency. Some agencies try to recover the full cost of a household connection by requiring a single connection fee to be paid, representing the total cost. Other agencies allow this connection cost to be paid off over a longer period as part of the metered user charge. With the cost of the electricity meter, a total cost connection fee normally puts a mains electricity supply out of reach of the poorest households.

Fixed current supply

As an alternative to an expensive energy meter to monitor electricity use, it is possible to use circuit breakers which allow a fixed current to be taken (Kirke and Williams 1978). A suitable tariff system is devised such that householders pay a fixed, known amount each month for the estimated amount of electric power that it is possible to draw. Such a system enables the electricity supply agency to save costs not only on connection but also on meter reading and tariff collection.

One disadvantage of using circuit breakers is that they have to be accessible. When excess load is applied and the breaker switches the current off, it is necessary to be able to re-set the breaker by hand. This accessibility can make it easier for householders to bypass the circuit breaker with their own wiring and therefore draw more power without having to pay.

Recent advances in semiconductors have led to the development of 'everlasting fuses' which are automatic current limiting devices, rated at 1, 2 or 5 Amps. Using positive temperature coefficient thermistors or high density polyethylene carbon 'multi-fuses' these everlasting fuses allow the automatic limiting of the current to a fixed amount. If a larger load is connected, for example an electric cooker or extra fans, the limiter disconnects the supply automatically until the load is reduced below the rated amount; the supply is then automatically reconnected. The fuses can be safely mounted in a protective box at the top of a distribution pole, where the supply line connects to the distributor, out of reach of most users. As the demand for power increases from any particular household and their ability to pay similarly increases, larger everlasting fuses may be installed, for example, uprating from a 1 Amp fuse to 2 Amps.

Because of this need for future upgrading, there are unlikely to be any significant savings on the cables or lines required. One analysis suggests that site wiring costs for a system rated at 5 Amp supply to each household is only 8 per cent higher than one rated for 1 Amp (Development Planning Unit and Water Engineering and Development Centre, 1988). It is unlikely that this saving is worthwhile where it significantly limits possible individual household upgrading. However, considerable costs may have to be incurred to permit householders to upgrade to a 5 Amp supply at some undetermined time in the future. If it is necessary to upgrade the supply network to the site and to provide a three-phase distribution system then it is reasonable to allow a maximum of only a 2 amp connection to each house.

Where an electricity supply agency is unwilling to adjust its tariffs to meet the special needs of low-income housing sites it is possible to use a Community Development Committee or Resident's Association as the main purchaser of power. They take responsibility for a three-phase supply with an appropriate energy meter and then sell on the power to their members through the fixed current devices. Each member then pays the same fixed proportion of the monthly or quarterly costs dependent upon the rating of their everlasting fuse.

Larger users of power, whether commercial, industrial, medical or educational, continue to have individual power meters under this method.

Distribution system

Fixed current systems and conventional energy meter connections require power lines to be distributed throughout the housing area in an efficient manner. Even where it is anticipated that a conventional power supply system is not affordable soon, the planning of access ways and housing layout must consider the needs for future power line installation.

Primary distribution

To generate electricity economically, power is normally taken from three coils, each surrounding one third of the rotating magnet in the generator. Power from each coil is known as a phase and to balance the load on the generator, the electrical load on each phase has to be roughly equalized. This is done most effectively by transmitting power in the three-phase form to a district sub-station from where the loads to individual consumers can be estimated and balanced. The incoming line to any locality is usually described as a three-phase primary feeder comprising three overhead phase lines and in some systems a neutral or return wire. Medium voltage distribution networks operate at between 15kV and 11kV, reducing to 6.5kV in some countries (Foley, 1989).

Transformers

Because of the nature of electrical conductors and the losses of power incurred in transmitting energy, the most effective means of transporting electricity is at high voltage. To distribute the power to the users, the voltage is gradually stepped down by transformers at grid sub-stations and district sub-stations.

The need for a sub-station or transformer specifically for the area served depends upon the size of the housing site. Depending upon the extent of anticipated future power demand and the high cost of land on inner city or marginal sites, transformers up to 200 kVA (kiloVoltAmps) may be mounted on poles to minimise the land-take (Figure 8.6).

The transformer is normally situated either at the centre of the site or at the entrance in order to limit the low-voltage lines to a maximum length of 200 metres. A typical sub-station requires a plot size of 5.5 square metres to house a 1.2 square metres concrete base pad for the transformer. An access width of 3 metres is then required from a main road.

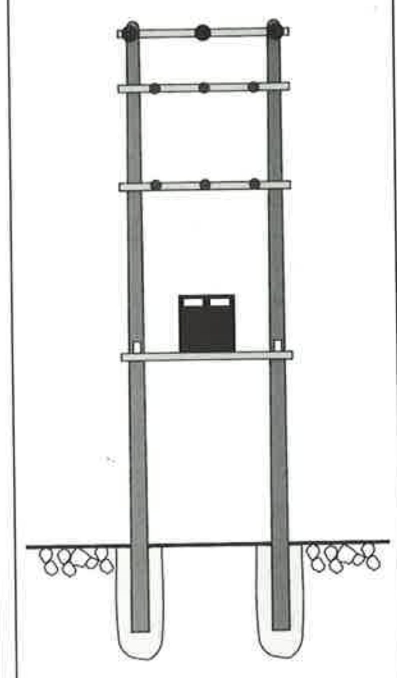


Figure 8.6: Pole-mounted transformer

Secondary distribution

With a distribution transformer at the local sub-station, secondary distribution of power at 380V - 415V three phase or at 220V - 240V single-phase is taken from the primary distributor. Alternative low voltage distribution networks operate at 110V. The lower voltage system has been recommended on safety grounds; however, it leads to increased conductor size and higher costs without significantly improving consumer safety (Electricity Council, 1973).

The low-voltage secondary distributor usually comprises three power lines representing one line for each phase plus an earth line. (In some systems there may also be a line for the street lights, Figure 8.7.) It is from this distributor that the individual service connections to each household are taken. With a three-phase supply, approximately the same number of tappings are taken off each phase to balance the load in an area. Because of the limited anticipated power demand on low-income sites it is possible to use single-phase spurs into cluster access ways serving up to 50 households.

There are various possible arrangements for distributors as illustrated in Figure 8.8 (Taylor and Boal 1966). The radial circuit is cheapest but gives no alternative supply in case of faults and the subsequent need for repair. There is also the danger that consumers at the end of the line are more likely to suffer voltage variations as the load on the distributor varies. However, the cost of providing some form of ring or interconnected system on low-voltage systems is uneconomic (Prior et al., 1973) and Lakervi and Holmes (1989) confirm that present practice is for radial operation to predominate.

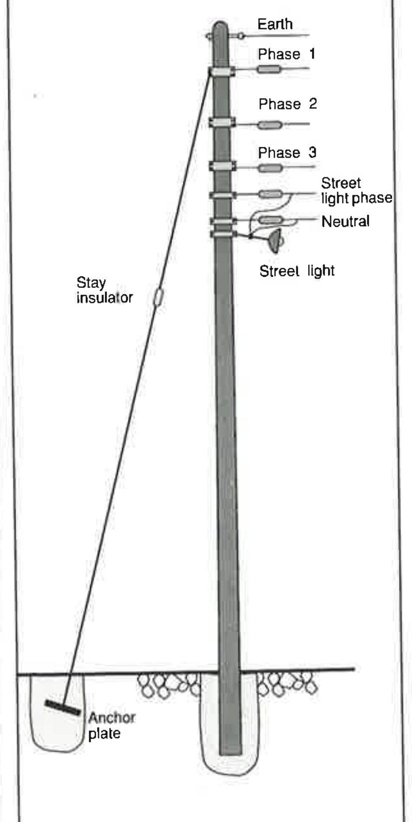


Figure 8.7: Example of a local electricity distribution system

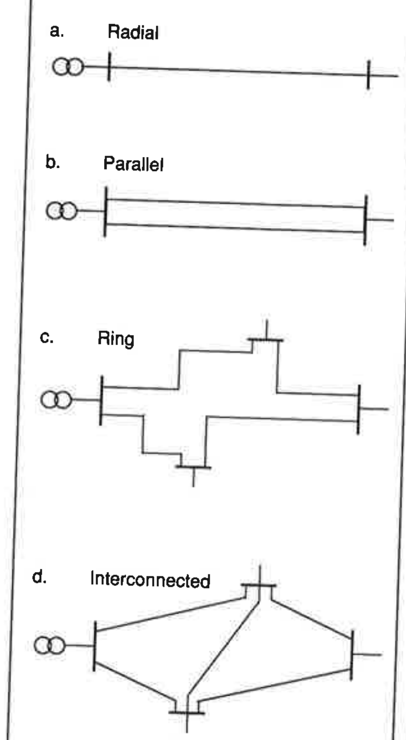


Figure 8.8: Alternative arrangements for distributors

From a knowledge of the maximum power demand, load-flow calculations are made to ensure that the current in the various branches of the network does not exceed a safe working limit. Voltage and voltage drop calculations are also undertaken to ensure that the voltage at the consumer's terminals remains within acceptable limits.

The conductor size of the secondary distributor normally has to be determined from the restrictions on maximum allowable voltage drop rather than on current rating. The accepted limits for voltage drop are normally taken to be in the range of plus or minus 5 per cent or 6 per cent. However, the limits are fixed at these levels so that sophisticated electrical or electronic equipment is not damaged by excessive fluctuation in the power supply. In low-income housing the most sensitive equipment is likely to be a television. Kirke and Williams (1978) comment that modern televisions can operate safely with variations in voltage of plus or minus 10 per cent. As the conductor size may be dependent upon voltage drop, increasing the limits will enable smaller and cheaper conductors to be used in the cluster spurs.

Line and cable systems

Power may be distributed by overhead lines or by underground cables. Overhead lines may be bare or insulated and either suspended between power poles or attached to the faces of buildings. Conventional secondary distribution lines of 120/220V have been costed at $5,000 to $8,000 per km with the lines and poles in a typical system representing 80-90 per cent of the total cost (Foley, 1989).

The choice of system depends greatly upon local practice and the relative costs of lines and cables. In India underground cables cost up to twice as much as overhead lines (Girdhar et al, 1977) whereas an analysis from the USA (Fink and Beaty, 1978) showed that underground systems were 40 per cent more expensive. Cotton and Barber (1970) report that 11kV underground cables were three times as costly as overhead lines whereas 400V cables were twice as expensive, whereas more recently Lakervi and Holmes (1989) suggest a one to five ratio (line/cable) in built up areas for medium and low voltage networks. However, Saulez (1967) comparing systems for a site network in Uganda found that the costs of each were similar.

Underground cables, whilst generally more expensive, have a longer life and are less likely to suffer from the type of faults associated with overhead lines, such as from storms, lightning and birds. However, any faults that develop are more difficult to locate and repair. Overhead lines require regular maintenance by skilled linesmen to inspect for defects, wear and illegal tappings whilst cables need no maintenance under normal operation.

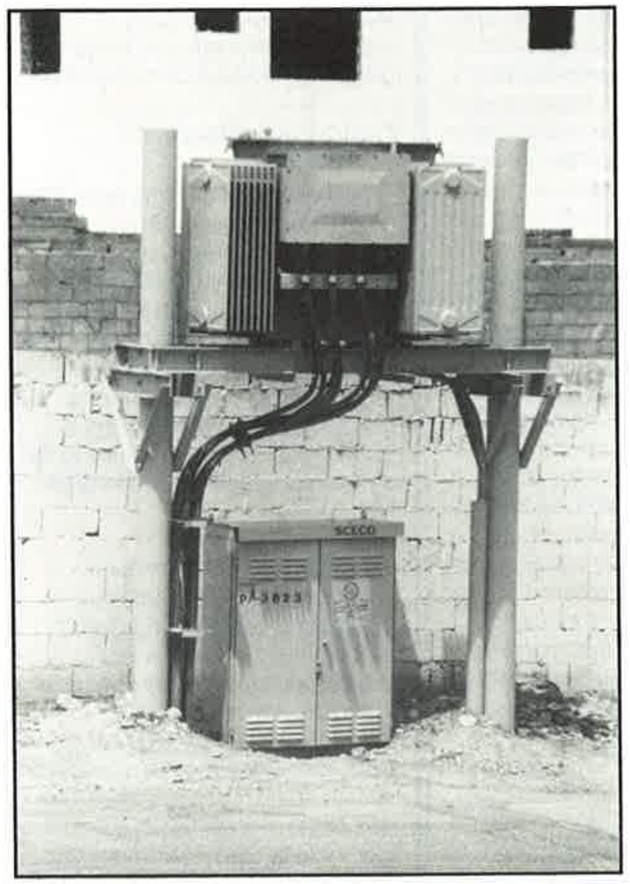
Girdhar et al (1977) suggest that if current carrying capacity is the important factor then an overhead line is preferable. However, if voltage drop is more important underground cables are favoured, particularly at low power factors. Combinations of lines and cables may be used on a single site; for example the primary distributor could be underground but single phase spurs into individual clusters might be overhead to simplify household connections.

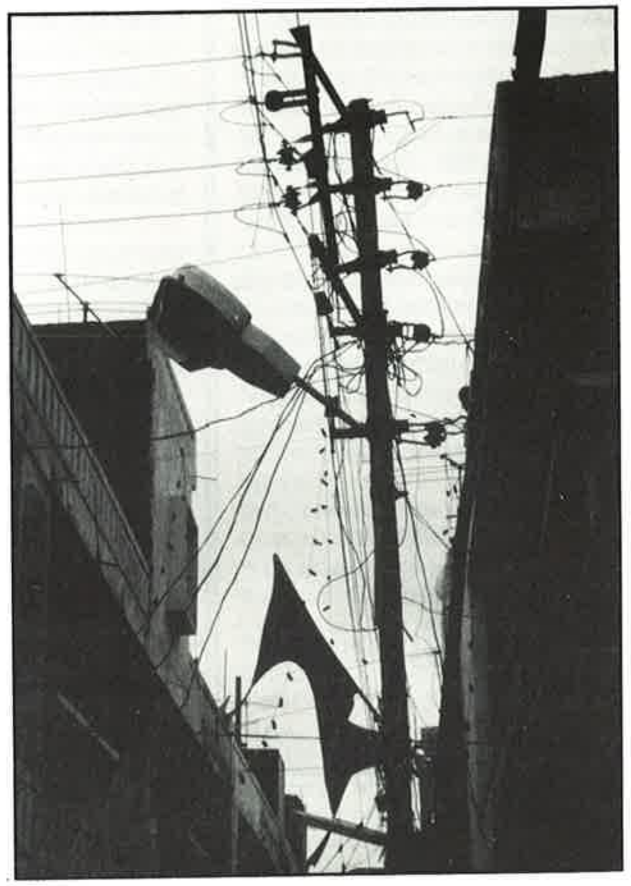
Insulated overhead lines are more costly than bare lines but cheaper than cables; these have the advantages of fewer faults and less likelihood of illegal connections.

The use of insulated lines along building frontages is recommended in the study by Kirke and Williams (1978) for Assiut and Alexandria. This method permitted savings of 62 per cent on supply and distribution costs and reduced connection costs by 83 per cent. However, on low income housing sites where householders are being encouraged to build or upgrade their housing it is more difficult to coordinate installation when the houses have not all been built to similar standards. In slum and shanty upgrading projects where narrow and winding streets often preclude overhead lines because of lack of necessary clearance, cables fixed to walls are a suitable option. However, underground cables may be preferred because of the difficulties with continual building or upgrading.

Operation and maintenance

Maintenance of the power supply system is more straightforward than many other services because of the general understanding that electricity is a service that has to be paid for. It is therefore usually much easier to collect tariffs and to disconnect consumers who do not pay their bills. If the tariff structures are adequate, it is reasonable to assume that the electricity supply agency will carry out the regular maintenance required.





Above: Left: Power transformer for a housing site Right: Overhead power lines and street lighting

Below: Telephone lines as well as power lines on a low-income housing site

Because of the safety aspects it is not possible to envisage any form of community involvement other than the possible replacement of street lighting bulbs or tubes. However, as part of the community management of a housing site, any faults or likely dangers should be reported to the supply agency. The site management committee should also be prepared to discourage and report illegal connections. Access for repairs should be maintained and a watch kept on any building activities that are likely to reduce the necessary clearances.

Where a site committee has installed and taken responsibility for their own power meter, onward distribution to households may be undertaken by a suitably qualified electrician under the control of the committee.

Cost recovery

Individual items such as improved stoves, water heaters, low-voltage battery systems or generators are purchased by householders as and when they are needed and can be afforded. The provision of demonstration systems and loans will enable these items to be purchased earlier than would otherwise be the case.

Conventional electrical supply is extremely expensive. A project plan for the city of Galle, Sri Lanka estimated that the cost of household power supply was equivalent to 40 per cent of the costs of building the actual house (Development Planning Unit and Water Engineering and Development Centre, 1988). Seventy per cent of the cost related to the extension of the 11 kV medium voltage primary feeder to the site.

It is unreasonable to expect to recover these off-site costs directly from low-income households, other than by including the development costs as an addition to the city-wide tariffs. However, the site development costs, whether by conventional design or to a current limited design, should be borne by the community directly benefiting. Considering electricity supply as primarily providing convenience benefits rather than a basic need, the community should make its own decision when it can afford to invest in household electricity.

Loans can be made available to the community for the secondary distribution network and to the householder for the cost of the individual connection and the house wiring. Besides paying back these loans, householders are responsible for paying for the power consumed, based upon meter readings or according to the fixed current connection with a block tariff.

To prevent the accumulation of large electricity bills on metered supplies 'coin in the slot' or 'token' meters have been used where the electricity has to be paid for in advance. Such meters are more expensive than ordinary meters and have to be emptied periodically, leading to higher electricity tariffs. Advances in semi-conductor technology are leading to the development of magnetic and optical 'smart' cards that have the potential to increase the utility's control over power use whilst reducing the consumer's tariff and liability to accumulate debts (Hoffman et al., 1989).

Detailed design factors

Power demand

In designing a distribution system, the electrical engineer considers an estimate of the potential load, the likely growth in that load and a utilisation or diversity factor. A design horizon of just five years is recommended for load growth (Electricity Council, 1975) with an ultimate load of 500 watts per household for low-income housing sites. Caminos and Goethert (1976) suggest a demand of 1.5 kW per dwelling with a diversity factor of 2. Kirke and Williams (1978) recommend an 'after diversity maximum demand' of 1 kW per household; this has been used in Mexico. The higher figure of 1 kW should be used with low-income groups in middle-income countries.

Conductor materials

Traditionally, copper has been the most common material for conductors. However, aluminium is now more popular, to such an extent that in some countries it is now rare for copper (because of its high cost) to be used for new developments. An aluminium conductor, although requiring a greater cross section relative to the current carried, leads to a cheaper line.

The main types of aluminium conductor are 'ACSR', aluminium conductor, steel reinforced, 'AAC', all aluminium conductor and 'AAAC', aluminium alloy conductor. The corrosion resistance of aluminium is due to the natural oxide film which forms on pure metal and alloy conductors. There is no corrosion providing that the oxide film is not broken; lines should be greased with a material suited to high temperatures (Stockley, undated).

Insulators form only a small proportion of overall line costs in a distribution scheme. However, reliability of supply depends on the ability of insulators to withstand varying atmospheric and electrical conditions applied to them. Glass and porcelain are the preferred materials.

Overhead line supports

Low-voltage distributor lines may be supported on a variety of poles spaced up to 50 metres apart. These supporting poles may be made of wood, tubular steel, reinforced concrete or lattice steel. Where available and where termite or other insect attack is controllable, timber is to be preferred as a supporting material. Timber poles are relatively cheap, light in weight and can be easily installed. The poles require regular inspection, particularly as they may rot below ground level, and have an estimated life of between 20 and 25 years. Timber supports are limited to maximum line voltages of 11kV.

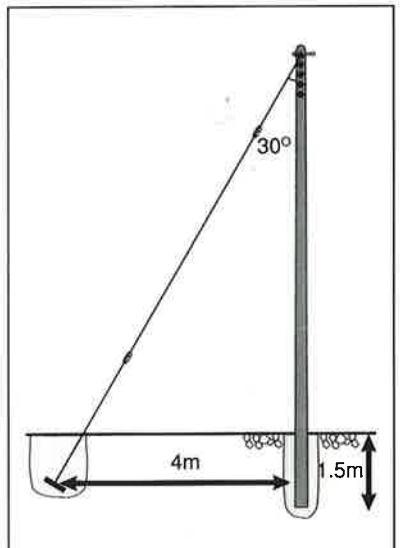


Figure 8.9: Guys for power poles

Reinforced concrete poles are more costly but can be manufactured locally; these generally require no maintenance and have a very long life. Transportation and erection are more difficult than with wooden poles due to the increased weight. This can be reduced with better quality manufacture by casting vertical slots into the poles, which can also ease climbing for installation, house connections and maintenance. Steel poles, whether tubular or of a lattice design, are normally restricted to higher voltages than are likely to be found on housing sites.

Supporting poles are normally in the range of 7.6 metres to 9 metres long and are embedded with one sixth of their length in the ground, that is, 1.2 metres to 1.5 metres. In certain conditions such as poor, unconsolidated ground the poles require a concrete collar between 200 mm and 300 mm thick to give added stability. This collar need not rise more than 150 mm above ground level except where particular protection from vehicular traffic is required. A simple method to cast any above-ground protective collar is to use an old 200 litre oil drum as a permanent former for the concrete.

Pole stays or guys are needed to prevent the poles leaning over because of the unequal pull of the power lines that arises where there is:

- a bend in the overhead line;
- a single-sided spur or connection reaching into side streets;
- the termination of a line.

The planner must be aware of the land requirements, particularly on high-density housing sites. The preferred inclination of a guy is 30 degrees to the vertical; for a pole of normal height, the guy meets the ground approximately 3 metres from the base of the pole. The guy is buried about 1.5 metres deep at a similar angle, requiring a total land availability of 4 metres from the base of the pole (Figure 8.9). In particularly tight situations this can be reduced to 2 metres, but this requires excellent ground conditions, otherwise the pole quickly begins to lean. Where the guy line would apparently have to be installed in the middle of a road, a single pole brace or concrete strut is used on the inside of the bend, at an angle of 30 degrees to the vertical.

Overhead lines which run between the poles sag in the centre of the span. In general at this point, the lowest lines must not be lower than 5.5 metres to 5.8 metres when crossing any street or 4.6 metres to 5.2 metres when running alongside the street (Figure 8.10). A minimum height of 4.6 metres above pedestrian areas is normally acceptable. However, this may reduce to 4 metres where the overhead lines are insulated. If there are local Codes of Practice, appropriate values should be obtained directly from them.

Sag depends upon the distance between the pole supports, the installed tension of the conductor, the weight of the conductor, an allowance for wind loading on the conductor and the average ambient temperature. To ensure adequate clearance in mid-span, the sag 'S' can be calculated from the formula

$$S = \frac{wL^2}{8T}$$

where 'w' is the weight per unit length, 'L' is the length between pole supports and 'T' is the line tension, as Figure 8.11 shows.

The lines should normally be at least 1 metre (some codes specify 1.2 metres, Figure 8.12) horizontally away from any structure and 2.5 metres above any building. This vertical restriction should take into account the possibility of

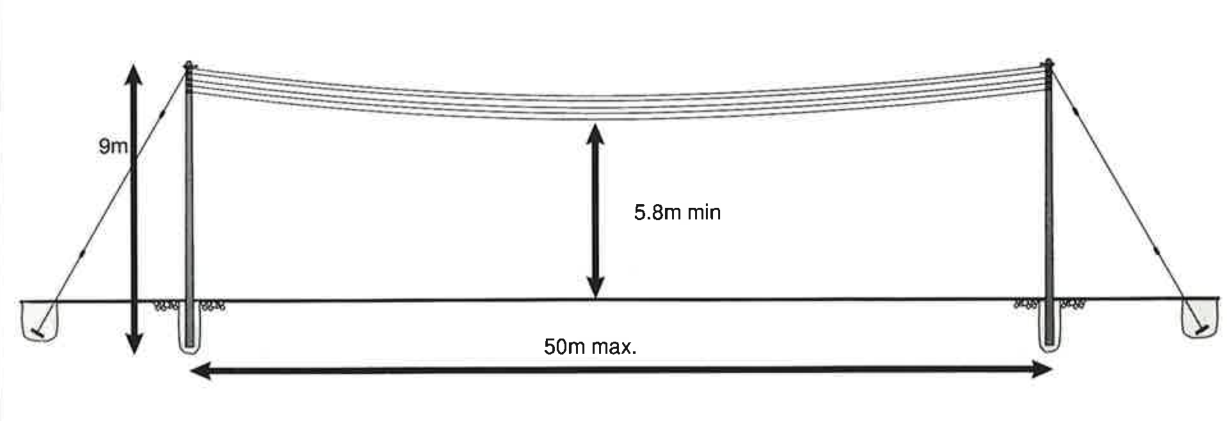


Figure 8.10: Power poles, spacing and clearance

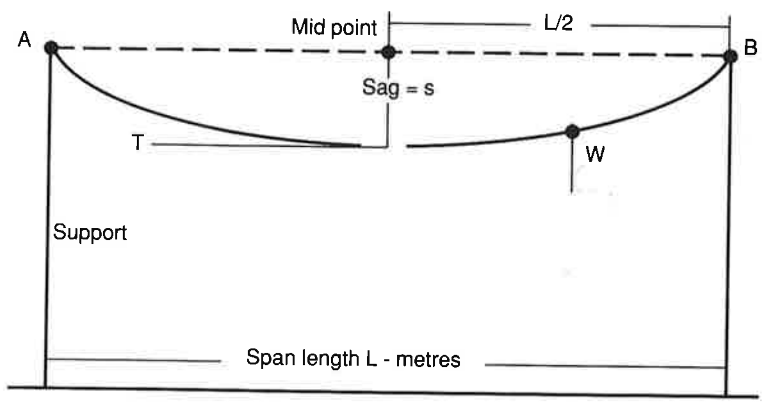


Figure 8.11: Determining sag in power lines

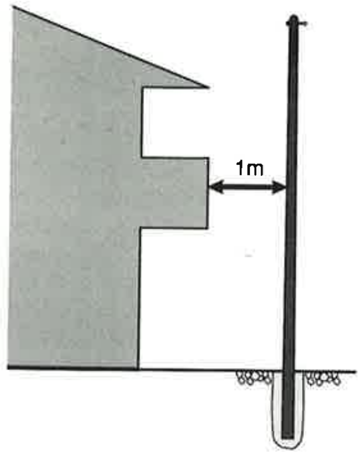


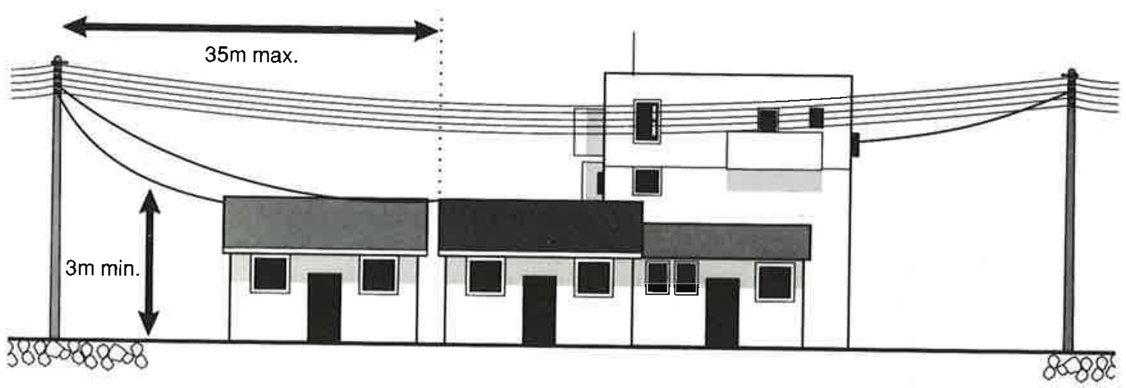
Figure 8.12: Clearance between power lines and buildings

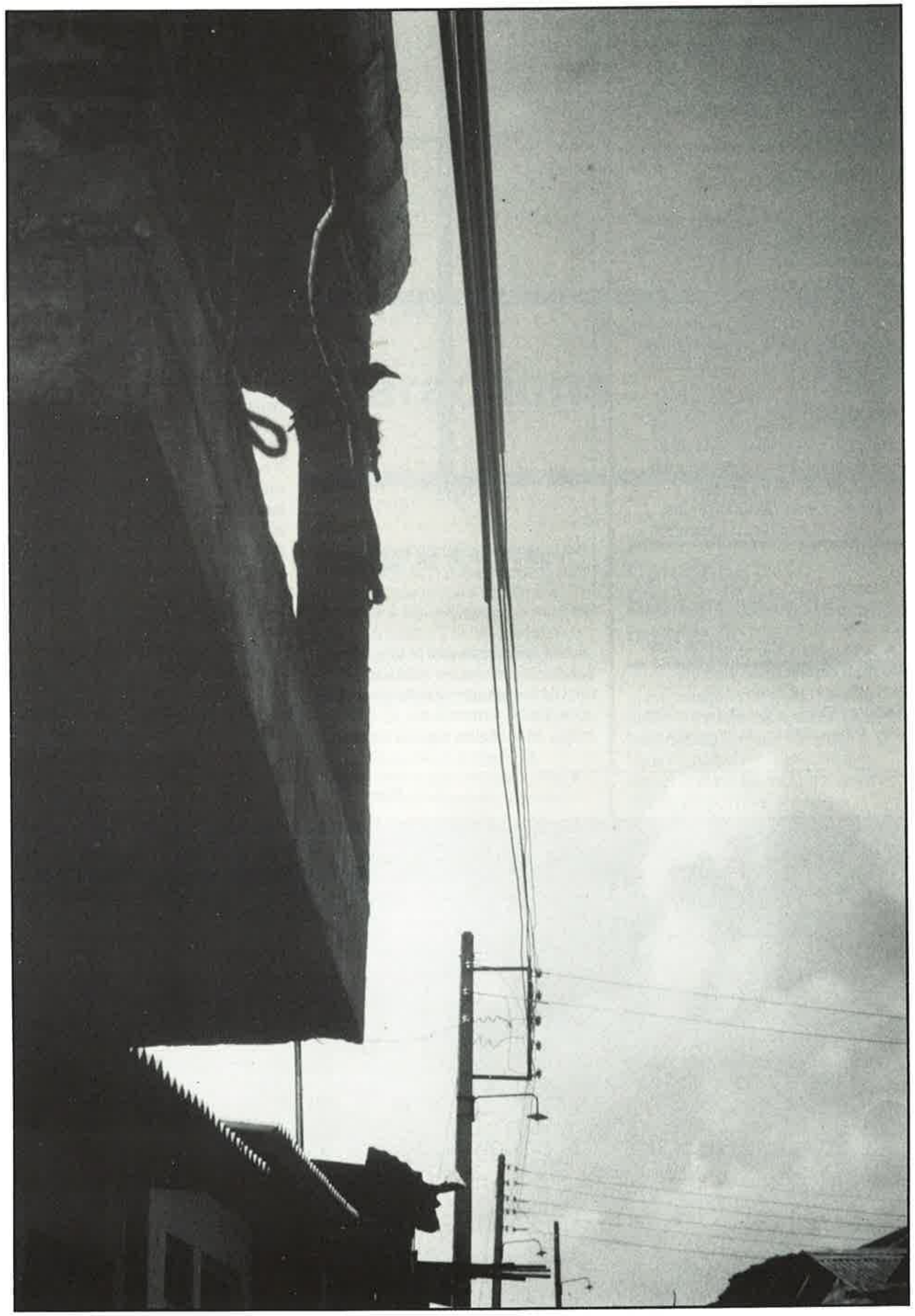
householders adding extra stories to their houses in the future. The purpose of this restriction is to ensure a space around every line so that people standing on a roof or balcony cannot reach out and accidentally touch a live line. Normally there is a similar requirement for a 1 metre to 1.2 metres clearance between the line and the road edge to prevent swaying power lines in strong winds coming close to high sided vehicles. However, it is unlikely that such vehicles would be used in low-income areas.

Where space is extremely limited, extension brackets may be used to support overhead lines up to 750 mm offset from the centre line of the posts.

Service main connections or service drop wires to individual households are attached to the overhead lines at the pole supports. The recommended maximum length of a connection is between 25 metres and 35 metres (Figure 8.13) and the spacing of the poles may have to be designed to take this into account. Some systems use vertical insulated poles across the overhead lines at midspan to minimise service connection lengths; these are not normally recommended. A service drop should never be lower than 3 metres (some codes require a minimum of 4.8 metres) above ground, even at the point of connection to a single-storey house. If necessary an extension pole must be used to carry the service drop above the roof line. Connections which cross any street have to meet the earlier criterion of a clearance of 5.5 metres.

Although the electricity supply agency is normally responsible for design, installation and maintenance of the power lines, it is important for planners and infrastructure engineers to understand these restrictions at the planning stage. To meet these criteria it may be necessary to revise the width of access ways to households to ensure that overhead lines can be used satisfactorily. Care must be taken to ensure that road widths and particularly the





Above: Problems of community housing design clashing with the safety needs of utilities siting of turning circles are designed with power requirements in mind. Otherwise, householders in the future may become liable to pay considerably increased charges to pay for the extra cost of installing underground cables.

Street lighting

Where overhead lines are installed it is simple to erect lights on the same poles. Khanna (1990) recommends a ratio of 8:1 for the horizontal spacing of street lights to their vertical mounting height above ground. With lights on power poles at 50 metres intervals, a minimum height of 6.25 metres above the ground is required (Figure 8.14). Street lights on poles are erected below the power lines and below the additional line required for the lighting circuit. More detailed information may be found in the Institution of Lighting Engineers (1990).

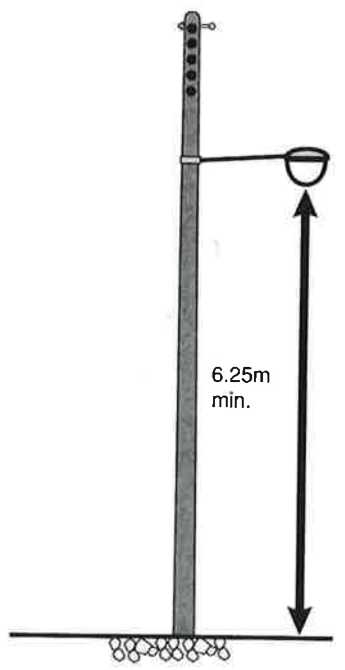


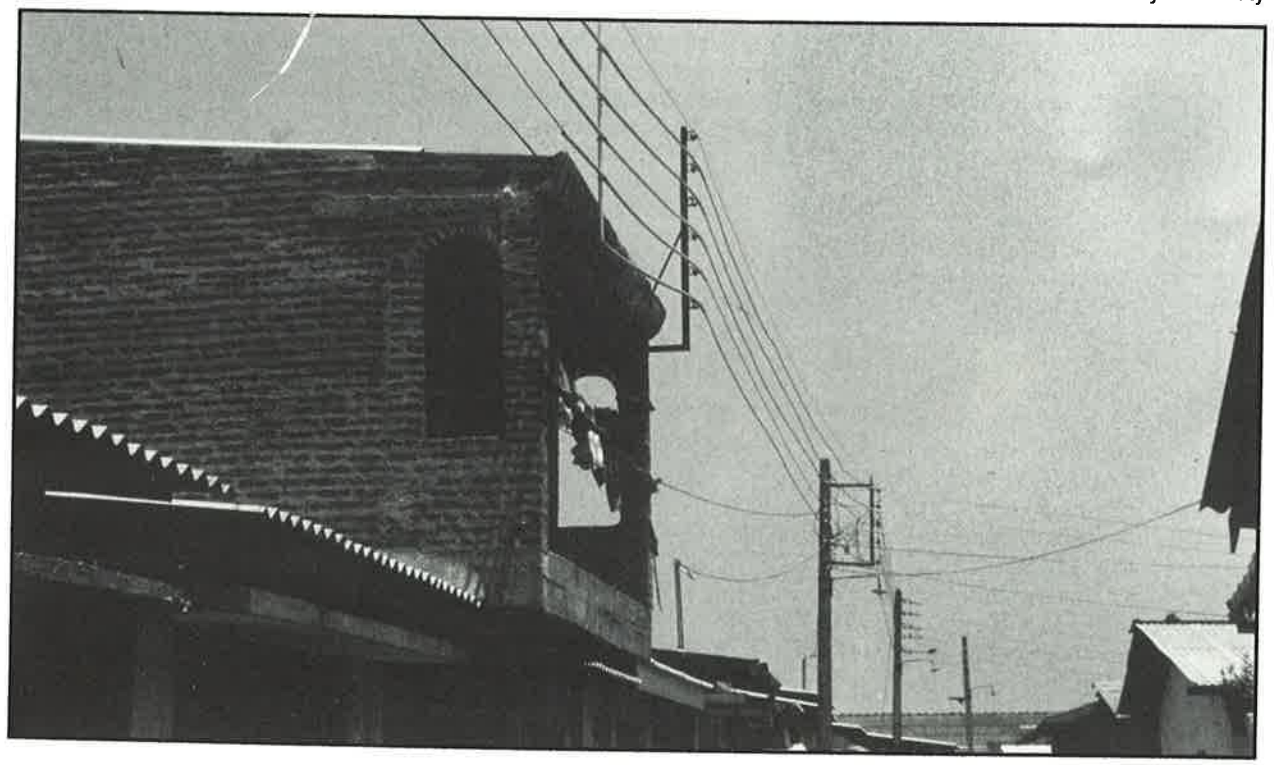
Figure 8.14: Street lighting

On low-income sites with 6.4 metres high poles above ground level it is possible that this 8:1 requirement cannot be met. The street lighting will then appear to be discrete patches of light rather than a constant illumination of the access way. Where lighting is primarily for security purposes and not specifically to reduce accidents on heavily trafficked roads this may be acceptable. Alternatively, as a first stage, street lights may be installed only at road junctions for road safety.

Conventional household incandescent bulbs or fluorescent tubes may be used as street lamps. Although these systems have the advantage of being relatively cheap and readily available, this may also tempt their removal for household purposes. Running costs are also important, as measured by the light output relative to the power consumed and the life of the lamp. For example, higher capital cost lamps such as low pressure sodium can produce up to ten times the equivalent light of an ordinary bulb for each watt of electrical energy consumed whilst also lasting up to six times longer (O'Flaherty, 1986).

It is wasteful to allow the light to radiate in all directions from the lamp and reflectors are required to concentrate the light onto the access route. Cut-off type reflectors allow a main beam of light up to 70 degrees from the vertical with no horizontal light emitted. Although providing more light onto a road, a closer spacing of the lights is required. The semi-cut-off allows for partially restricted light radiated between 70 degrees and 90 degrees from the vertical.

Below: Power lines lifted clear of balcony for safety



Interactions 9

Objectives

The seven principal infrastructure sectors are:

- **ground preparation**
- **drainage**
- **access and roads**
- **water supply**
- **sanitation**
- **power supply**
- **solid waste management**

Within each of these sectors, a range of technical options has been described. Many of these options have important but conflicting implications regarding site layout, plot size, and availability of open space within the plot boundary, all of which will affect housing density on the site. In addition, the choice of a specific technology in one sector may both influence and constrain the use of certain technologies in other sectors. In order to avoid conflicts in planning and design it is therefore necessary to define all of the likely effects which a given technical option will have. These factors which either influence housing density or lead to inter-sectoral effects and constraints are defined as *interactions*.

An important consequence of these interactions is that the planning and design of site infrastructure, site layout and the use of space must be fully integrated. It is the objective of this chapter to identify interactions in a way which will assist the overall physical planning process.

There are a large number of interactions and it is useful to classify them; two categories have been defined. However, it is not possible to demarcate all interactions precisely into these two categories and there is necessarily something of a 'grey area' in between. In general, interactions can be considered as follows:

Category 1 interactions which pertain to housing density through effects or constraints related to access, site layout, or the availability of space on the housing plot.

Category 2 interactions identify issues which arise from the way in which the choice of a particular technology in one sector influences and constrains the use of available technologies in the other sectors.

Category 1: Housing density interactions

In this category, consideration is given to those factors which relate both directly and indirectly to housing density. Clearly the site layout is of particular importance in this respect. There are some interactions which place restrictions on the orientation of the site layout, whilst in other cases, the site layout affects both the design and the cost of infrastructure.

Many of the technical options available for infrastructure have minimum access requirements for both construction and maintenance of the services provided. If the site infrastructure is to be upgraded over a period of time, it is vital that the access provided does not in any way restrict the future development of the site. This will affect the overall housing density which can be achieved.

There are some technical options relating to on-plot services which require space to be set aside on the housing plot. The specific requirements of these servicing options will affect the housing density.

Ground preparation

On steeply sloping sites the need for cut-and-fill operations and the extent to which retaining walls are used determines the availability of land for housing, thereby affecting the maximum achievable housing density.

Drainage

The need for flood protection and good drainage determines the feasible site layout options. On sites which are to be filled in order to raise the existing ground levels to ensure positive drainage, an optimum solution exists for placing the fill and creating contours and gradients in relation to the drainage outfall points which minimises these ground preparation costs. The resulting filling plan defines drainage catchment areas which govern the direction in which the drained water flows. On sites which do not require ground preparation, the natural contours define drainage catchments.

The drainage catchment areas, whether man-made or natural, determine the lines and levels of the drainage network. Those sites which are either drained by pumping or protected from inundation by a bund also have drainage lines which are determined by the location of drainage outfall points. Given that the majority of site drains run alongside access ways, this constrains the orientation and nature of the site layout.

On sites situated on steeply sloping ground, drainage catchments and thus the line and level of the drains are affected by both cut-and-fill operations and the site topography, which limits available options for site layout.

Housing density and plot size influence the quantity of storm runoff resulting from rainfall in a complex way. The volume of runoff is larger for high density housing where plots have little open ground attached to them. This leads to high stormwater flows during intense rainfall with the need for correspondingly large drains. A further complication is that drain width affects the land-take and thereby influences the maximum achievable housing density; lined drains with vertical side walls take up less land than earth drains which require sloping side walls.

If soakage pits are to be used for sullage disposal, land must be set aside on the housing plot.

Access

The movement of vehicles and pedestrians around the site is determined by the access provided. Access restrictions enable particular objectives in site layout to be achieved. For example, small neighbourhood groups can be encouraged to develop within housing clusters, which can be identified by limiting vehicular circulation and thoroughfares in a particular area. This has important implications for the maintenance of communal services.

Water supply

Site layout determines the length and cost of the water distribution system for piped supplies, which is of particular relevance if ring mains are to be installed. Housing density affects the walking distance to communal water supply points; as the density reduces, it becomes necessary to provide more supply points for a given total population. The likely proximity of a well to pit latrines or septic tank soakaways is dependent upon housing density.

The location of communal water supply points needs to be designated; the site layout should aim to identify a particular group of users with each water supply point.

Sanitation

All of the technical options for sanitation have minimum access requirements for routine maintenance and the emptying of pits or tanks. There should be vehicular access for the large conventional vacuum suction tankers within 50 metres of a latrine tank or pit. Vehicles based on smaller chassis are currently under development for use in areas where access is restricted. Access for such vehicles up to the plot boundary should be provided.

If emptying is to be done manually, then direct access to the pit or tank is required without the need to go through the interior of the dwelling. There should be at least pedestrian access to pits and tanks located to the rear of the house.

Maintenance of sewerage systems often involves working from manholes to remove blockages in the sewers. It is thus important that all manholes have pedestrian access and be within 100 metres of a road of sufficient width to allow access for a maintenance vehicle of similar size to a conventional vacuum tanker which carries sewer jetting equipment.

Adequate space should be set aside on the housing plot when on-plot sanitation is envisaged. With pit latrines, only a small area is needed; however, septic tanks which incorporate drainage fields require considerable areas of ground in order to be effective.

If communal latrines and bathing areas are proposed, specific locations with adequate space should be designated. As far as possible the site layout should identify a group of users with each communal facility in order to engender a sense of ownership and responsibility.

Site layout influences both the cost and performance of a sewerage system because it determines the length of sewer run and the gradient to which the sewers can be laid. Operational problems may arise if the gradients used are less than those recommended in order to limit the depth to which the sewer needs to be buried on long sewer runs.

In areas of high housing density the ventilation mechanism in VIP latrines is less effective due to the sheltering effects of adjacent buildings and taller vent pipes may be necessary to achieve good ventilation.

Solid waste

Access widths govern the type of refuse collection system which is possible throughout the site. Kerbside or house-to-house collection requires access by the collection vehicle to the boundary of each plot; a transfer station requires full local distributor road access.

Space must be designated for communal solid waste bins and transfer stations. The exact location is often a sensitive issue due to the nuisance from smells, flies and rodents and the community should be consulted on their location. The site layout affects journey times for solid waste collection, thus limiting the operating range of collection vehicles and crews.

The operation of general street cleansing and tidying on a neighbourhood basis can be encouraged through the site layout identifying groups of households with particular areas.

Housing density affects walking distances to communal refuse containers; as housing density reduces for a given population, correspondingly more containers are required.

Power supply

The length and cost of power lines and street lighting are determined by site layout and housing density. It may also be necessary to provide space for a transformer or sub-station. Local regulations governing the minimum permitted horizontal and vertical clearances from building lines affect the land- take and influence the maximum housing density which can be obtained. The land-take can be reduced through the use of wall-mounted cables or underground cables.

Sufficient space must be provided to permit the transport and erection of power poles and street lights.

Category 2: Technology interactions

This category of interactions concerns the way in which the choice of a specific technology in one sector may both influence and constrain the use of certain technologies in other sectors. The implications are far-reaching, encompassing issues of:

- public health;
- technical feasibility and compatibility;
- detailed design;
- construction;
- operation and maintenance;
- cost.

Within this category, the interactions are listed on a sector-by-sector basis. For example, the sub section 'Solid waste' within the section 'Water supply' gives details of the ways in which solid waste management affects or is affected by the water supply system in respect of the issues listed above.

Ground preparation and conditions

Drainage
The contours and gradients of filled ground are determined by the minimum recommended gradients for drains carrying sullage or stormwater. This leads to an optimum plan for placing the fill; the importance of this in relation to site layout has already been discussed.

Soakpits for sullage disposal are unlikely to work if the groundwater table is permanently high.

On steep slopes, the velocity of flow is likely to be too high to permit the use of unlined drains. It may also be necessary to incorporate 'cascades' and stilling basin structures into the system, all of which increase the cost. Care must be taken to avoid locating soakage pits for sullage disposal in places where the ground may be rendered unstable through saturation.

Roads and pavements
Roads are particularly susceptible to settlement both when the groundwater table is high and when there is a relatively high risk of flooding, as may be the case in low lying areas; more frequent reinstatement of the road may be required. If the site is protected from inundation by a bund, special care must be taken in the design, construction and maintenance of the road where it crosses the bund.

Access for certain types of vehicle is limited by the maximum gradient; pedestrian access ways require steps when the gradient is steep .

Sanitation
The presence of a high groundwater table reduces the ability of the ground to absorb water; septic tanks with soakpits or soakaway trenches are unlikely to be effective. The construction of pits, tanks and sewerage systems is made more difficult and results in higher costs.

Sewers which are laid to steep slopes may experience hydraulic instability. To avoid this, sewers can be laid to shallower gradients and incorporate special structures such as drop manholes and stilling chambers. This increases the complexity and cost.

Care must be taken to avoid locating latrine pits, septic tanks and soakaways in places where the ground may be rendered locally unstable through saturation.

Solid waste
Steep gradients on roads restrict vehicle movements and may deny access to certain types of collection vehicle. The weight of refuse which can be transported per journey is reduced by steep gradients.

Power supply
There may be problems with the stability of power poles on filled sites or where the ground is weak.

Drainage

Roads and pavements
Lined or covered drains should not be used with earth roads because the road surface is prone to erosion

and its level may fall below that of the sidewalls of the drain. This prevents stormwater from draining off the road surface which leads to rapid deterioration in the condition of the road.

Buried pipeline drains require a metalled road surface to prevent damage to the pipes.

Culverts are necessary where drainage lines cross access ways.

Water supply
The wastewater from all communal water supply points (handpumps or standposts) should flow into a lined drain. Wherever possible a communal water supply point should be placed at the head of each drainage line which carries sullage in order to keep the drain flushed out. Houses having individual water connections must also have adequate provision for sullage drainage into either an on-plot soakage pit, or a lined open drain, or a sewerage system.

Sanitation
If water is collected from public supply points, the household volume of sullage is likely to be small; providing that the ground is highly permeable, the sullage could be disposed of via the latrine pit. However, stormwater drainage on housing plots should lead water away from latrine pits and tanks to avoid flooding the pit and temporarily rendering it inoperable.

Septic tank effluent should not be permitted to enter surface water drains because it contains high numbers of pathogens and constitutes a serious public health risk.

Solid waste
Open channel drainage systems are prone to blockage by refuse; communal solid waste bins should be located to minimise the likelihood of refuse entering the drains. Covered drains and sewers are less prone to blockage; however, when refuse does get into these systems, it is more difficult to clear the blockages.

When rain falls on open heaps of refuse in containers or transfer stations, it seeps through and absorbs substances including certain chemicals and bacteria. The water which drains out of the refuse, which is called the leachate, is likely to be highly contaminated, and constitutes a public health risk.

Power supply
If unlined drains are in use, care must be taken to ensure that erosion around the foundations of the power poles does not occur.

Roads and Pavements

Sanitation
Roads under which sewers are laid should be surfaced with road metal to prevent damage to the pipes and erosion of the road surface, which leaves sewer manholes exposed above the surrounding road level. It is advantageous to run sewers along the backs of plots, assuming that there is no vehicular access.

Water supply

Sanitation
Groundwater which is close to the surface is highly susceptible to pollution from the liquid seeping out of pit latrines and from soakaways disposing of septic tank effluent. This constitutes a potential public health risk; either the water source or the sanitation system should be modified to ensure that water of an appropriate standard can be provided.

Both septic tanks and sewerage require a high level of water supply service and should not normally be used unless individual household water connections are available.

Solid waste
A water supply point should be located at solid waste transfer stations to provide water for cleansing of all areas which hold refuse. Regular washing down helps to reduce both unpleasant odours and the nuisance from flies and rodents.

Power supply
If it is necessary for water to be pumped up to high levels in order to distribute it by gravity around the site, the power requirements for the pumping must be determined to enable a suitable power supply to be installed.

Sanitation

Solid waste
Serious maintenance problems can arise if solid waste enters a sewerage system; this is likely to occur if manhole covers are either broken or removed without being replaced.

Power supply
It is possible to generate power for lighting from biogas, which is produced by digesting the excreta produced at communal latrines. This has been successfully done at a number of Sulabh communal latrines and washing places in India.

Involvement and implementation 10

Objectives

Physical infrastructure complements housing to meet the basic needs of people for safe, serviced dwellings; these services must be affordable and sustainable. It is apparent from many parts of the world that services of too high a standard are often used; urban local authorities are then frequently unable to maintain these services. The users are unable to take over responsibility for maintaining their environment because the technology used is above the level that would normally be chosen by the people. It is perceived to be 'owned' by the implementing agency or the 'government'.

Urban local authorities often have inadequate financial resources because of limited political commitment to enforce local taxation at a viable level. They become reliant upon subventions from state or national governments that tend to vary according to the economic climate. Such financial uncertainty necessarily leads to inefficient management which is felt most strongly by the poorest and weakest in the community.

This chapter considers different approaches to the implementation, operation and maintenance of physical infrastructure on low-income housing sites. The objectives of these approaches are to limit dependence upon urban local authorities and agencies whilst maximising the involvement of householders and the community.

The model used in discussing the different possible approaches is described in detail in Chapter 1. This considers a Primary Level of services that represents a minimum level of services required to obtain health benefits, that is the minimum infrastructure which is required before housing can be developed. Recurrent costs would be charged to householders, but capital costs would not be recovered. Above this level may be envisaged an Intermediate stage where householders and community groupings who want to upgrade their facilities, usually for convenience benefits, can borrow investment funds from an enabling agency, such as a housing authority. Finally there is an Ultimate level with conventional standards of service provided by the municipality, funded by tariffs and local taxation.

Beyond the confines of the housing site there have to be fully engineered trunk services provided by the municipality and paid for by taxation or tariffs.

Resources for infrastructure provision

The resources available for low-income housing may come from householders and tenants, both as individual household units or as a community. Although their low income can only generate modest amounts to invest in housing and their savings may be small, the extended family often has extra resources that can be used. Similarly the rent that tenants pay is frequently used in the early stages of housing development to upgrade housing and services.

The community as a whole may have resources of leadership and commitment which will enable communal services to be implemented to the benefit of all. Urban local authorities and other external agencies such as housing authorities may have funds for capital works as well as technical advice.

Revised approach to infrastructure provision

Given these resources, the approach of any institution involved in providing services for low-income housing schemes should be to:

- maximise householder participation and responsibility;
- maximise community participation and responsibility;
- minimise agency responsibility, especially for maintenance.

This may be done primarily by promoting technologies that can be built and managed by individual householders. Where some form of communal technology is required, wherever possible it should be at a level that the community themselves can build, operate and maintain. Trunk services such as water or power should be supplied in such a way that householders can pay directly for these services as they are consumed.

Community participation and social acceptance

In many countries, a more participative approach to house-building has given the people the housing facilities they want at a price they can afford with significant cost savings to the housing authority (Cotton and Franceys, 1988).

This participative approach may also be developed to enable householders to be involved actively in the provision of their own infrastructure. As described above, the main reasons for including consumers in services provision is the inability of existing authorities and agencies to cope with the dramatic increase in the demand for services from low-income households.

This weakness results from a significant shortage of finance to pay for capital works and the subsequent requirements for the operation and maintenance. There is also a lack of managerial skills necessary to take on the increased work-load created by low-income housing development. This is normally caused by poor motivation within the authority because of the reduced potential for personal advancement, both financial and technical.

Urgent attention is needed to involve local authority officers in the process of development. However, the lack of finance can be circumvented to some extent by reducing capital costs through careful mobilisation of the community and by giving the people significant responsibilities for the operation and maintenance of their facilities.

The savings do not necessarily come only from a significant reduction in the labour costs, but also from the removal of the profit and overhead charges of the contractors and sub-contractors. In one example these were in the region of 350 per cent; it was estimated that over a fifteen year period with incremental improvement of services by participative methods the initiating agency had the potential to make savings of over 75 per cent on discounted service costs per plot (excluding ground preparation). This approach still allowed the community to pay those of its members who contributed their labour at normal rates of pay (Cotton and Franceys, 1988). In another country site sewerage built by the community was found to cost only one-sixth of the amount charged by contractors.

The cost savings resulting from involving the community are not the only reasons for following this approach. The increased sense of ownership of a scheme which results from the people making decisions leads to improved facilities that are more likely to be maintained.

There are different forms of community participation which can be considered for infrastructure provision ranging from involvement in surveys, consultation and design through to community management, construction and maintenance of the facilities.

Planning infrastructure provision

Government responsibilities

The overall responsibility of the government for planning may lead to a sector plan which should attempt to describe the present infrastructure situation for low-income housing, the declared objectives and the resources required to meet those objectives.

For each identified housing site, the existing service levels for ground preparation, drainage, access, sanitation, water supply, power supply and solid waste disposal are assessed. The primary level service targets are then set. These targets are not simply physical standards to be achieved, for example 40 litres of clean water per person per day, but also should indicate what percentage of the target population should be receiving these benefits by what date.

The resources required to meet these targets by upgrading existing service levels are then determined. Available resources from the householders, the community as a whole, the local authorities, government agencies and donors are then compared with the required resources.

Any discrepancies between available and required resources, whether manpower, materials or finance, are investigated to identify solutions to remove these constraints. Finally, priorities for investment and project implementation are set with regard to geographical areas, income groups and levels of infrastructure. Special requirements such as special training for staff involved in community infrastructure provision should be included.

Programme

Although this chapter is addressed at specific infrastructure projects it is recognised that these projects form only a part of wider housing

programmes. And the housing programmes themselves may be seen to be a part of the development process by which individuals, households and institutions gain more effective control over their environment.

It is usual for projects within housing programmes that have a significant participative element to follow a certain pattern. In general they start slowly and, where successful, gradually gather momentum as trust between the various partners builds up. Householders gain confidence and appreciate that they can improve their environment and infrastructure.

Rondinelli (1983) describes an Experimental stage, a Pilot stage, a Demonstration stage and a Replication stage. Glennie (1983) explains the process as a Demonstration phase, a Consolidation phase, and an Expansion phase. The demonstration phase is a practical test of the feasibility of the recommended technical options in a particular socio-economic setting. This is followed by a consolidation period, primarily to organise the institutional aspects of the project; these include the mechanisms by which people receive technical advice, the paperwork needed to take out loans for upgrading, and the bureaucracy required to ensure that community contracts are satisfactorily completed. At the end of the consolidation phase there may be some independent check on the work carried out, usually known as appraisal, with final governmental approval to continue. Only when all this is completed can the specific project (or component of a programme) progress on to the mobilisation or expansion phase when most the works are expected to be implemented.

The time-scale of this sequence depends upon the extent to which similar projects have been or are being carried out in the country or within the locality. It may also vary according to the size of the population to be served, its receptivity to development ideas and the financial resources available. However, it is usual to find such a sequence taking years rather than months. This may have a significant effect on the type of donor funding that can be used, as donors normally have a far shorter time-scale within which to achieve visible physical progress than is appropriate for community projects.

Demonstration phase

Following the sectoral planning exercise and the commitment of funds for the commencement of infrastructure provision, it is normally necessary to have a demonstration or pilot phase with three main objectives:

- to experiment with techniques and materials that are effective at minimum costs;
- to demonstrate the resulting approaches to community, government and donors;
- to begin to stimulate demand for appropriate infrastructure from individual householders and communities.

Experimental period

Within the demonstration phase an experimental period may be required. This is to allow field staff to prove that the proposed combination of materials and techniques works effectively at an affordable level within a particular socio-cultural background and geographical area. The initiators need to prove the technical details to their satisfaction before promoting the idea to others. For the target households on low incomes the recommended systems have to be correct as they cannot afford to invest their limited resources in somebody else's experiments.

The time of experimentation also acts as an opportunity for informal training of project staff. Those involved in trying out the various alternatives learn the advantages and disadvantages of many different techniques. This enables them subsequently to explain in more convincing detail and from first hand experience why certain options are being recommended to the prospective users.

Only where there are already affordable designs, well recognised and accepted by the prospective users, may the experimental phase be omitted. As the project staff gain confidence in the technologies they are investigating, the experimentation period merges into a demonstration time when all interested parties can see the types of proposed facilities and make recommendations and decisions.

This enables the promoters to ensure that the selected technology is socially and culturally acceptable to the people. In particular, community representatives from identified low-income housing sites are given the opportunity to see and discuss the proposals. Results of the surveys (described below) which the respondents may not always have understood are checked against the physical reality of demonstration units.

Government officials from sponsoring ministries, related departments and local authorities are encouraged to participate in discussions about the demonstrated systems. Particularly where officials believe that only conventional standards are acceptable it is vital to show that alternative approaches are affordable and sustainable whilst giving the desired quality. Where non governmental organisations are involved it is important that government departments have the opportunity to comment and criticise before significant progress is made.

The experimental phase may produce several designs or combinations of upgradeable technologies that appear to be suitable for a particular project area. Variety of design can be encouraged where it enables householders of differing income levels to participate. The selection of appropriate infrastructure options should be the responsibility of the people who will ultimately use and sustain them. The demonstration phase may therefore be considered as a shop window where potential consumers can see what is on offer at a particular price and begin to determine what version they require. Although most of the 'selling' will take place during the mobilisation phase, it is important, even at an early stage, to begin to stimulate demand.

Individual services

For low-income communities, it is recommended that any experiments or demonstrations should concentrate wherever possible on individual or household services. It is advantageous when attempting to transfer responsibility to householders to give as much control as possible to the smallest feasible unit. Methods of involving larger communal groups are discussed later.

If it is assumed that in most cases the only on-going responsibility of the urban local authority is for trunk services such as power and water mains, it is implicit that the services need to be controllable by the householder. For example, in the sanitation sector, individual pit latrines that rely upon 'private' vacuum tankers for emptying are preferred to sewerage which requires urban local authority involvement in maintenance.

Water which is paid for directly according to usage is preferable to a general water rate. Alternatively, water kiosks, or a community member collecting payment and supervising a lockable tap, or coin-in-the-slot standposts give a direct linkage between payment given and service received. Community water distribution systems drawing upon a single community-managed water meter are showing potential in Sri Lanka.

Power supply, using the 'everlasting fuses' described in the chapter on power, enables people to pay for what they receive at an affordable level. Alternative systems by which some form of community organisation has a conventional power meter and sells on electricity to the members through restricting 'everlasting fuses' is also a possibility. Systems with external lockable fuse boxes where the householder pays a small fee which buys the right to have a low-current fuse inserted in the box for a limited period are also under consideration. Such ideas are similar to the long established methods of paying for telecommunications through coin boxes and more recently through 'telephone cards'.

It is more difficult to give individual control over drains and roads and it is here that the community has to play an important role as an intermediary between the urban local authority and the householder.

Partnership

In most infrastructure projects, engineering professionals assume that design and selection are too complicated for householders to be involved in. However, responsibility for construction, operation and maintenance must be transferred to the community at the earliest opportunity unless the project is to be completely managed by contractor and maintained by the urban local authority without any community involvement.

Experience has shown that the most successful projects involve a partnership between the people who will use the scheme and a 'facilitator' agency. The temptation is for the agency to take too strong a lead role and to attempt to move the project along too quickly. Whilst working without community involvement may appear to enhance progress in the short term, in the long term it will work to the detriment of the project.

Consolidation phase

At the community level, the distinction between the demonstration phase and the consolidation phase may appear indistinct. However, there comes a point where the basic technologies have been proved to be feasible and the project as a whole is generally acceptable. Before widespread implementation can begin a period of consolidation is required, primarily to organise the institutional aspects of the project.

Proving work on technical details continues so that the community can see that the demonstration elements are still important and cared for. However, the primary thrust is to obtain governmental and donor acceptance of the proposed techniques and to determine the technical, financial, material and administrative support that the agency has to provide to enable householders to build their own infrastructure. Training of community personnel and technicians, identification of community leaders, involvement of health, educational and other sectoral staff, confirmation of necessary adjustments to bye-laws and regulations, testing of promotional materials and general administrative support all have to be considered.

Following on from the demonstration phase and initial contacts with community leaders, the initiating agency and other institutions have to recognise that householders and communities are unlikely to come to simple, clear-cut decisions. Unless the community is unusually homogeneous it is probable that people will want a range of solutions for infrastructure at varying costs.

The subsequent flexibility required to meet the differing expectations of different householders and different communities makes the work of any supporting agency more difficult. The assistance proffered has to consider the various income levels, social characteristics, desires and expectations of the varying groups. The professional skill of the agency is used to focus on and support those aspects of the programme that are crucial to its success. These may be technical, financial, institutional, social, operational or promotional, but the agency is advised not to be diverted into trying to enforce one set solution.

Financial support

The financial responsibility for primary level infrastructure should rest with the government so that the most basic needs of the low-income community are met. In upgrading schemes it is imperative that householders are involved in decision making regarding such improvements to infrastructure. Improvements beyond the primary level, through the intermediate level to the ultimate level of service, should be the financial responsibility of householders and the community. However, they will be unable to do this without support.

In the context of small industries it has been noted that availability of finance is only part of the problem (Harper, 1976). Often of equal or greater significance is the ability of people to manage the finances they have. Therefore projects may well have to consider giving simple advice on money planning or budgeting as part of the 'enabling' process.

Loans from the urban local authority or the promoting agency would normally be made available for upgrading of services. These loans may be given directly to householders for individual services or to recognised groups of householders for communal services such as drain or road upgrading.

Loans should be restricted to those with limited income and should not exceed their ability to pay back the loan within a reasonable period. Working through the household's financial commitments with a financial development officer may therefore be a reasonable pre-condition to the granting of a loan. Clearly presented and simple repayment tables detailing the loan taken, the interest rate (particularly where the concept of interest is not well understood), the payback period and the amount of monthly repayments must be given to every person who takes out a loan.

Loans given out of a specific revolving fund for services improvement may encourage repayment. In this way, granting further loans, either to the individual householder or to the wider community, is dependent upon regular repayments. People come to appreciate that they are not simply taking from the government or project in not repaying but are also taking from their neighbours.

Where possible, any financial assistance should be seen as part of a wider local government responsibility for care and maintenance of services. Where local taxes are paid at a rate adequate to operate and maintain infrastructure there may be no need to consider supplementary loans for services.

However, in the more normal situation prevailing in low-income communities there is the possibility of considering a two-tier system of fiscal and financial support:

level 1; the urban local authority is responsible for the provision and management of trunk services;

level 2; at community level the municipality is responsible for the provision of primary level services only. The basic premises upon which this approach is based are:

- that it is the obligation of the local authority to provide basic urban services, including land;
- that a local authority should recover its costs;
- that the method of cost recovery is through local taxes and charges for services;
- that the local taxes and charges should reflect the quality and quantity of services made available.

The Development Planning Unit and the Water Engineering and Development Centre (1988) suggest that local authority taxes comprise two components, a Primary Rate and a Development Rate.

The Primary Rate is derived from the average cost of providing primary level infrastructure throughout the area of its jurisdiction. This cost may be discounted over, for example, a twenty year period. Those areas that have already developed above primary level will help bring down average costs; if from the beginning proposed development areas are also considered then future expansion after that can be carried out using surpluses generated from the older parts of the local authority area.

The Development Rate is derived from a consideration of the general level of development as well as the particular on-site developments in much the same way that property rates are serviced in many countries. Naturally, the more attractive, well developed areas will have a higher rate than the undeveloped, low-income housing areas, some of which are likely to have a zero rating value. The rate will be dependent upon both the quality of service provided and the quantity consumed.

Technical support

Ideally, any low-income housing site would be able to call upon a single designated Technical Development Officer. She or he would have the breadth of training and experience to advise and assist with the solution of any technical difficulties encountered in the provision of infrastructure. They would have all the necessary information and documentation on options, costs of options to individuals and to the community, availability and cost of loans, specimen plans and technical design. Where specific individuals are not available to fill this role, the number of different technical experts relating to the community should be kept to the absolute minimum.

Standard designs are prepared, both in model form as well as in the more conventional forms of drawings and plans. These can be given to householders and community leaders for discussion and consideration as to which are most appropriate for any particular situation.

Material support

Material support consists of making available for purchase any necessary components. Where possible, this does not mean that the authority sets up in business to make and sell the required items. Rather it enables local traders, businessmen or cooperatives to make the units to the required quality at an acceptable price.

The local authority ensures that there is no profiteering at the expense of low-income people but should try to avoid the temptation of doing the job themselves.

Administrative support

During the consolidation phase the initiating agency determines the extent of the support that is required to enable householders to develop their own infrastructure without creating dependency. Whatever support approach is taken to suit local conditions, standardised procedures must be fixed during the consolidation phase. These procedures must be determined before widespread promotion within the community; this avoids the confusion that would be caused by changing the promised level of support during the project. Agency staff are then trained in these procedures to enable them to give clear and coherent explanations and answers to householders.

Any necessary office-based administrative procedures required to support the field staff are developed during this period on the understanding that they are there to assist and enable rather than to restrict or limit. Where possible, 'One-stop offices' are developed so that householders or members of community development committees can sort out all their problems at one urban local authority centre. This is more satisfactory than having to waste valuable time queuing in various offices in different buildings. Offices must be easily accessible from a housing site, not requiring expensive and time-consuming bus journeys to reach them.

Building codes and bye-laws of relevance to the programme are examined and where necessary are adjusted to meet the new conditions. In general, it is important to recognise that no regulation should be made that cannot be enforced and that no law can be enforced without the cooperation of most of the persons concerned.

Training support

During the consolidation phase, technical and community development staff who were not involved in the demonstration phase are taught the results and techniques practised earlier. In addition, related sectoral staff are also introduced to the programme. The extent of their training is dependent upon their proposed role within the programme, but at the least they need to be fully informed what is being expected of the householders.

Similarly, teachers in local educational establishments are introduced to the programme and ideally are provided with suitable educational material to use with their students. Artisans not directly responsible to the authority, but who may become involved as small contractors, are trained in specialised techniques that may have been developed during the experimentation. Training programmes for householders are prepared and tested for later use during the implementation phase.

Any leaflets, plans, posters or other explanatory or promotional materials are pre-tested during the consolidation phase to ensure that the message being received by the householders is the same as that intended by the promoters.

Appraisal and approval

Within the conventional Project Cycle (Baum, 1982) it is normal to have an appraisal stage. Then advisers not directly involved in the project (usually representatives of the funding institution or ministry) have the opportunity to consider whether the proposals are likely to be successful. This should therefore come after the demonstration phase when different and perhaps new ideas have been tried out, tested and costed, but before the large-scale dissemination or widening of the programme.

Appraisal should consider all aspects of a project and it is useful to consider the following aspects:

- sociology, culture, health and environment;
- technology;
- economic benefits;
- finance and institutional capability.

Sociology and culture, health and environment

The appraisal should consider whether the proposals are likely to be acceptable to the target population regarding their beliefs, habits and preferences as well as concerning their long-term development. For example, does people's participation in this project improve their ability to undertake further improvements on their own?

It is also necessary to check that it is not only the privileged who benefit from the project. The disadvantaged such as the disabled, the elderly and ethnic minorities should also be receiving assistance.

A frequently stated objective of upgrading infrastructure for low-income communities is to improve health. Proposals should be carefully scrutinised to see if the level of investment is likely to produce corresponding health benefits, particularly amongst the vulnerable age groups such as the very young and the elderly.

Disposal of wastes must be given careful examination to ensure that the effects are beneficial; problems in the target area should not simply be transferred to a nearby area.

Technology

The technology will have been chosen because it appears to meet the particular needs of the people; these technologies should be sustainable in the long term.

The following points are relevant:

- Are spare parts available and obtainable?
- Is fuel or power affordable to keep any mechanical systems functioning?
- Is any particular training required to understand the new techniques?
- Can the technology be managed at household and community level?

Above: Services for shelter must be right for the people, not just for the engineers

Below: A community centre, part provided by the agency, to be completed as the community desires

Economic benefits and finance

The term 'appraisal' is often used loosely to mean 'economic appraisal'. This technique aims to determine whether the economic benefits over the lifetime of the project are likely to outweigh the economic costs. Economic costs represent the total resource cost of any improvements to the nation as a whole. That is what the country has to pay in real terms for the use of labour, materials, health, changes to the environment and foreign exchange. It also represents the value of any benefits that could have been obtained if the resources had been used in an alternative project.

Economic costing aims to give an objective, quantifiable cost to all the elements that go to make up a facility, enabling fair comparisons to be made between competing technologies. It is important for planners and project staff to have considered all the alternatives in order to recommend the most economic systems for promotion. This then gives best value for money invested in the primary level and allows householders to make the final decisions for upgrading in terms of financial affordability and convenience.

It is often difficult to quantify the benefits to be obtained from providing primary level or upgraded services. Where there is a choice in technology available to achieve similar objectives, the benefits obtained may be presumed equal for the sake of simplicity. Economic comparison of the alternatives may then be restricted to a 'least cost analysis' which focuses solely upon the economic costs of improving infrastructure.

Each alternative must be considered according to consistent criteria. Non-monetary contributions by householders, for example digging latrine pits, are quantified. Similarly, imported fittings such as foreign made self-closing taps for example, are recorded at their true costs to the national economy, taking into account 'real' exchange rates.

In economic terms there is a cost involved in using money for one purpose, such as sanitation, as opposed to using it for an alternative purpose such as business expansion schemes. This cost of using money is known as the opportunity cost of capital which may be defined as the return on an investment in the best alternative use. This cost influences the choice between alternatives regarding the balance between initial capital investment costs and recurrent operation and maintenance costs. For example, some technologies are expensive to build but cheap to run whilst others cost very little to construct but have to be maintained or replaced at regular intervals. This effect is known as the 'time value of money'. Economic analysis gives a fair comparison between such alternatives. Detailed information on economic analysis and methods of determining 'real' values for items is given in United Nations Industrial Development Organization (1986).

Financial costs, which are what a householder or agency has to pay out in cash for any infrastructural facility, must be checked against the expected revenue. Both within the urban local authority and within any facilitating agency the probable flow of cash must be determined, not just at the start of the project but over many years. When considering whether a particular project or item of infrastructure is affordable by the target community, it is vitally important to appreciate the difference between 'ability to pay' and 'willingness to pay'.

The 'ability to pay' of the community is normally ascertained according to a generally accepted percentage of average household income. However the 'willingness to pay' criterion is often of more importance as it relates to the actual service levels that households are willing to support. An investigation of willingness to pay often shows that consumers are prepared to pay a substantially higher proportion of their income for services that have significant convenience benefits.

Institutional capability

The approach to services provision recommended in this chapter assumes that the urban local authorities are weak; nevertheless, any project should also aim to strengthen these local institutions, which may require training and resources. A solution often used in the interests of rapid progress is to set up a specialised unit to look after low-income housing and services which bypasses the local authority. This may mean that more is accomplished initially but leads to subsequent problems of operation and maintenance when the project is finally handed over to the municipality officers who have no understanding of the special unit's approach.

As a general principle therefore, all low-income housing infrastructure development should be done through the municipal authority, albeit with the assistance of special project officers who have had the relevant training and experience.

Questions to be considered by appraisers of the institutional aspects of a proposed project include:

- Do these proposals strengthen or bypass the local municipal authority?
- Are the municipal officers capable and motivated?
- Do the professional staff understand the needs of low-income communities?
- Is extra training required for the technical /administrative financial staff?

Governmental approval

As far as possible, the agency finalises the recommended designs and seeks the widest possible governmental acceptance for the programme. This approval is sought not only from the institution or authority that is directly responsible for servicing low-income housing sites but from all interested ministries, councils and committees.

Householder and community approval

Approval is also sought for the recommended designs from householders in the demonstration areas. Wider approval of the target population may be judged by the degree to which ideas of incremental improvement are taken up in the expansion phase.

Mobilisation or expansion phase

The mobilisation or expansion phase aims to encourage and enable each low-income community within the target area to achieve at least the primary level of infrastructure within a certain period. With the preparatory demonstration phase completed, the preferred options can be promoted with confidence, in the knowledge that they are technically feasible, socially acceptable and financially affordable. Even though it is the agency's responsibility to upgrade existing shanties to primary level, the community must agree what is proposed and how it is to be carried out.

This period of expansion may be considered in terms of promotion, surveys, hand over and construction. Promotion consists of selling the idea to individual householders and communities that they need to improve their physical infrastructure and have the capability to do so. At the point where people make their decision, it might be considered that a hand over of responsibility and decision-making has taken place from the initiating authority to the community. The construction phase therefore may be considered as directly under the control of the community (excepting new sites and services schemes on new sites). However there remains the need for a significant degree of support from the authority.

Promotion

The mobilisation phase is a time of mass communication. It is an opportunity to share information and lessons learnt from the preceding stages with the people who are the target group for the programme. There are many different methods of communication ranging from television and radio through posters and leaflets to individual visits by community and technical development officers.

The continued use of the demonstration sites serves as a powerful showcase for what can be achieved. When allied to information regarding costs of different types of development and possible grants and loans, householders and communities can make their own, reasoned decisions about what they want, can afford and are willing to pay for.

Demand for improved housing is usually clearly expressed; demand for improved services may be expressed in more general terms of a desire for improved convenience and enhanced cleanliness. This desire may be harnessed by taking a 'supermarket' approach to individual services whereby people see what they want in a demonstration area and choose according to their own priorities and wealth.

However, if outside intervention to infrastructure improvements is partly justified in terms of improvements to health and well-being rather than direct economic returns or householder convenience, the promotion period must include a health education programme.

There are many different approaches to assisting householders to construct and improve their infrastructure facilities. For each project the correct mixture of motivation, assistance and legislation is determined to produce the desired results. If the people do not want to improve their infra-structure above the primary level, it simply reflects their priorities and should not be seen as a project failure.

Householder and community responsibilities

To make the broader decisions of relevance not just to householders but also to the immediate community, a new tier of management is usually required at the community level. This might be called a Community Development Committee (CDC). The CDC represents the community in all dealings with the municipal authority and is responsible for the day-to-day management of services within the community. It would be the responsible decision-making body within the community for all aspects of infrastructure provision. It would also supervise the implementation of communal works, formulate and enforce community building and planning guidelines, and ascertain and implement the community's wishes regarding the level and quality of provision of urban services.

Besides physical infrastructure it can be assumed that the CDC also becomes involved with the establishment and organisation of community activities such as creches, preschools and adult literacy classes as well as assisting in identifying and establishing income/employment generating activities. Where a community 'thrift society' exists to help householders save regularly, the CDC liaises and assists the thrift society in its work. Where no thrift society exists the CDC might consider helping to set one up for the benefit of the householders and to act as the banker for the CDC.

The CDC acts as the executive organ of a voluntary association of members of a community. Where possible, the community should be self-defined and would ideally consist of between 50 and 150 households. It is helpful if the physical extent of the CDC area is easily identified by fixed physical features, for example roads, railway lines, drainage channels or streams. The CDC is normally elected to represent and manage the affairs of the community and is registered with the urban local authority.

Any CDC requires a constitution and regulations to help the members in carrying out their agreed functions. An example of a CDC constitution is shown on the right.

This type of constitution provides a framework for relationships between householders and the municipal authorities. It is in effect adding an informal layer of government that is totally under the control of a particular segment of the wider community and therefore should be more responsive its needs.

However, this insistence on community involvement in order to ensure the long-term success and sustainability of infrastructure often leads to difficulties within the authority. For example, the time-scales over which CDCs operate rarely fit in conveniently with an authority's schedule. The CDCs may react extremely quickly with rapid mobilisation of their members and demand loans and materials and advice far faster than the authority is geared up to supplying. On the other hand the community may be very slow in its approach, taking far longer than was budgeted for; the authority is then left with budgeted funds unspent at the end of the accounting period.

This unpredictability is characteristic of community projects. Allowance has somehow to be built into the authority's operating procedures to cope with it. Even though this may be difficult and time-consuming it is preferable to bypassing the authority with special project teams.

Individual/specific site survey - rapid appraisal

To design appropriate infrastructure to complement low-income housing, information is required about the socio-economic conditions of the proposed beneficiaries as well as the technical limitations of the site.

The objective of the professional is to provide services that the people want and that they can afford to use and maintain. To do this, the professional must understand what is desired, that is the priorities which the people place on their different needs.

An outline constitution could include:

Generally accepted name, location and address of recognised office or office-holder of the CDC.

The general objective of the CDC, for example: To promote through community mobilisation and community action the physical, mental and social well-being of the general membership, based upon self-reliance and community participation in the community building effort.

The specific objectives of the CDC, for example:

1. To identify community needs and priorities for physical improvement, provision of common amenities and social development.

2. To create awareness, organise and activate community participation in planning and implementation of CDC area programmes, designed to cater for identified community needs according to priorities.

3. To sponsor, assist, supervise and maintain all technical services and physical infrastructure made available to the CDC area through participative programmes and local authority provision.

4. To encourage and help the general membership to undertake building or improvement of houses, with financial and technical assistance from the housing authority.

5. To achieve the above objectives, the CDC may organise Thrift Societies.

6. To maintain close relations and rapport in coordinating work among Community Development Officers, Technical Development Officers, Primary Health Care Workers, other Government officers and staff of recognised Non Governmental Organisations and to help them in all programmes under the urban basic services strategy.

7. To promote social cohesion and mutual understanding among varying ethnic, religious, social and economic groupings resident in the CDC area, through social and cultural activities.

8. To identify the needy and vulnerable child groups such as early school leavers and drop-outs and provide learning opportunities through non-formal education activities.

9. To encourage the women members to undertake economic pursuits such as income generating and self-employment activities to enhance earning capacity.

10. To take such other measures as are necessary for the upliftment of the community.

Membership: The membership of the Community Development Committee comprises all residents of the CDC area who are over 18 years of age.

Office bearers: The office bearers of the CDC shall consist of the following:
- The Chairman
- The Vice-Chairman
- The Secretary
- The Treasurer
- Four other members of the CDC elected as Executive Committee Members

Management Executive Committee:
The affairs of the CDC shall be managed by the Executive Committee comprising all elected office bearers and the four other elected members. Objective seven of the constitution will be recognised in determining suitable nominees at elections.
All posts are honorary.

The quorum for the Executive Committee shall be one half of the total number of the Committee. The Executive Committee shall be subject to the direction, authority and control of the general meeting of the CDC.

Under that control it may:
1. Interpret the constitution and determine any matter on which the constitution makes no special provision.
2. Take all necessary steps to fulfil the objectives of the CDC and the decisions of the Annual General Meeting of the CDC or Special General Meeting and act and function in the name of the CDC.
3. Deal with any matter not provided in the constitution in the furtherance of the objectives of the CDC.

Subscription: There will be an annual subscription payable by members of the CDC.
Funds: The funds of the CDC will be deposited in a recognised Bank in the name of the CDC with withdrawals authorised by signature of two of Chairman, Secretary or Treasurer.

Duties and functions: The Chairman shall preside over meetings or in his absence the Vice-Chairman.

The Secretary shall: Summon all meetings and shall keep in a minute book a record of meetings of the Executive Committee and the CDC.. Prepare the Agenda and give reasonable notice to all members. Attend to all correspondence arising out of the business of the Council under the direction and control of the Executive Committee. Present to the Annual General Meeting the Annual Report and the audited statement of accounts. Compile a record of official visitors to the CDC and the purpose of their visits.

Annual General Meeting: Shall be held once a year with at least two weeks notice given and the Agenda distributed to all members. The quorum for the AGM shall be 30 per cent of members.

On all matters not provided for in this constitution, the decision of the Executive Committee is final.

It has been said that "surveys show what outsiders need to find out about what insiders already know" (Werner and Bower, 1983). As the purpose of the survey is to ensure good design for the people it makes sense to involve the people right from the beginning so that they can go on to help in the actual design and planning.

Socio-economic survey

A survey does not have to be taken by using an official-looking questionnaire as this may not bring out the real information that is needed. This is particularly the case where 'closed' questions are used, that is questions with set choices and 'yes' or 'no' answers. These may be quick and easy to analyse but they are not so likely to elucidate the information that is required to produce a good design. A better approach is to begin to get to know people in their homes. Information learned through friendly casual visits is often more accurate and useful. It is advisable to find out what problems people feel are most important or which difficulties they want to solve as a priority. The person who is responsible for the survey should ask primarily for the information that makes sense to them and not simply because they were told to ask for it. It is important that both the questioner and the people understand why the information is needed.

Wherever possible local people are to be involved in gathering the information as this can be a significant step in involving them in the planning. The more people can take part and the earlier they can become involved, the more likely they are to share the information that can ultimately lead to an appropriate design. (Werner and Bower, 1983)

From the point of view of the infrastructure engineer, it is not necessary to do a full socio-economic survey for every site in an area. It is unlikely that conditions will change significantly with regard to desirability and affordability of services for low-income housing within a municipality. However, it is recommended that engineers make a personal rapid appraisal of socio-economic conditions in at least one representative site in each district so that they are then able to assess more accurately the data the planners present.

The following are key social questions, adapted from McPherson (1985).

- Is there an identifiable community living on or near the site or a target community who are willing to move to the proposed site?
- Is there an existing community organisation to take responsibility on behalf of the householders?
- How interested in the proposed facilities are the potential users?
- Are the users willing and able to pay part of the costs?
- Are the people willing to contribute materials or labour?
- Do the potential users possess any skills that could be used in the project?
- Is the proposed technology acceptable to the users?

Technical survey

Although the engineer does not need to be involved in every socio-cultural survey it is vital that the person responsible for the design work makes their own technical survey. Check-lists such as the one shown or in the sample report card are simply 'prompts' to remind the professional engineer to consider all the important factors. Check-lists are no substitute for the trained eye but they do help to train the eye and mind of the engineer.

In all surveys it is necessary to think why the information is needed, so that the important points which might otherwise be missed are observed. It is particularly important to consider the conditions and existing services around the site as such factors will often have a major influence on the range of technical options that are feasible.

Following the engineer's survey, a detailed topographical survey will normally have to be carried out. The engineer will be able to decide upon the grid sizing for levelling and the significant features to be noted as a result of his own survey.

Technical Check-list

GROUND CONDITIONS

- Flood levels river/canal
  rain
  frequency
  duration
- Soil profile and soil classifications
- Ground permeability
- Water table
- Prevailing wind
- North point

EXISTING STRUCTURES

- Housing units permanent/semi- permanent
- Shops
- Commercial buildings
- Community buildings
- Roads or paths
  Estimate of usage
- Bridges and culverts
- Power supply & pylons
- Street lighting

TOPOGRAPHY

- Approximate contours
- Significant spot levels
- Required levelling grid
- Natural drainage
- Presence of surface water
- Trees and dense vegetation

EXISTING SERVICES

Water supply
- Mains pipes
- Standposts
- House connections
- Handpumps
- Wells

Sanitation
- Toilet blocks
- Bathing facilities
- Individual toilets
- Existing practices

Hand over

With the technological experimentation completed, the Community Development Committee formed, the specific site survey carried out, the Community and Technical Development Officers are able to make strong recommendations regarding the development of the particular site. However the CDC and individual householders will also have strong opinions. It now becomes the role of the professional staff to present the feasible options whilst allowing the CDC and the householders to make their own decisions.

The municipal authority may be expected to lead in the decision-making regarding primary level infrastructure on a new sites and services scheme where there are no existing householders. However, for slum and shanty upgrading and for incremental improvement above primary level, the decision-making and subsequent management of the implementation should be handed over to the CDC and the individual householders.

Implementing infrastructure provision

Construction phase

After all the preparation, the desired works are completed during the construction phase. Wherever possible, the aim is to leave control with the people who are living on the site. It is generally recognised that this type of approach for construction takes longer to complete; it is also extremely difficult to programme both regarding cash flow and completion dates.

However, the objective remains to provide services that are sustainable in the long term without significant external support. Therefore it is advantageous to wait a little longer for completion of works that will last rather than push ahead to completion of services which will fall into disrepair within a short period.

Figure 10.1 shows the typical 'S' curve representing progress both in terms of completion on an individual site and also the number of schemes implemented. On an individual site, progress is slow to begin with until the larger community is convinced that things are going to change for the better; only then do they begin to commit themselves. As completion approaches, progress slows again as most of the apparent benefits are realised and people begin to find other priorities in their lives. Disbursements of loans and grants and other forms of assistance must be carefully timed to make it worthwhile to complete the planned works.

Considering progress on a number of sites in an area, at first only a limited number will be interested in such a programme and those are the sites where it is advisable to commence any demonstration phase. After the ideas catch on, it is to be expected that the majority of sites will then accept the help on offer and make progress in their own site improvements. There will then be a small number of sites where, for a variety of reasons, there will be no apparent response at all. The temptation project organisers then face is to change the framework of operations and make special allowances to give these inactive sites extra incentives. This temptation should be avoided wherever possible unless further investigation into these sites reveals particular disadvantaged groups who had not been identified in the initial surveys.

Implementing agents

Construction may be carried out by individual householders or by groups of householders through the Community Development Committee. Alternatively, smaller groups of householders may form themselves into a cooperative which takes on the work. Private contractors, sub-contractors or direct labour from the municipal authority can also be considered. Where possible, priority is given to householders and community groupings to carry out any work.

Forms of contract

Forms of contract, particularly with a householder or community grouping, need to be simple, clear and straightforward. They should be as short as possible but should state exactly what is expected of the 'contractor' and the level of assistance the contractor can expect from the facilitating agency.

All payments due under any contract should be clearly staged and linked to achievable, understandable targets. It is likely that some payments (whether grants or loans) will be paid on commencement of work in order to facilitate purchase of tools and materials. However, it may be advisable to expect some level of site preparation, which does not require a cash investment, as evidence of the commitment to carry out the works before disbursement of any money.

Further phased payments should be matched wherever possible with clearly defined progress points in the work as well as with actual payments. Community contracts for communal works such as roads or drainage may usefully include some small element of 'profit', only realisable at the end of the work, to reward the community initiative in taking on the work and to encourage them to take on further works. The level of this 'profit' might usefully be linked with the rate of progress on the work to encourage early completion.

Site supervision

Particularly where unskilled householders and community groups are implementing projects, quality control must be maintained by adequate site supervision. The municipal authority needs skilled Technical Development Officers who are not only capable of making decisions regarding technical matters but are also in sympathy with the development ideals of a participative programme. This latter requirement is most important so that they are able to be an encouragement to the community workers as well as acting in a supervisory capacity.

Technical Development Officers need to have confidence in their understanding of the objectives of a programme so that they can decide when any technical discrepancy is significant and when it is merely a cosmetic nuisance.

Operation and maintenance

Household responsibilities

The responsibility for operation and maintenance of individual household services rests with the householders. However, they may still need support in understanding the services and their implications; for example, advice on the satisfactory operation of pit latrines including emptying and to prevent inconvenience or nuisance to neighbours.

Community responsibilities

The community as a whole will need to have a desire to keep their area in good condition. In particular, with regard to earth roads and drains, unless there is a desire amongst the residents to have an attractive and clean environment then no one will be interested in paying their share of a lengthman's wages.

One method used to encourage a spirit of pride in the environment is to use competitions. On a city-wide basis, a 'best kept cluster' competition, or a 'best kept site' is one way to encourage people to care for their particular locality. This should be made easier by the understanding that 'the government' are not going to come along and do it for them. So often it is possible to pass the responsibility on. It is assumed that the people who should be doing the work will come soon and therefore there is no point in anybody else doing anything about it. When there is no alternative, there is a greater incentive for the community itself to do the work.

Local authority responsibilities

The local authority still has responsibilities for trunk services and if it is to expect people to pay the necessary tariffs or fees then these services must be delivered on time to the required quantity and quality.

With a reduction in their responsibilities for individual areas and sites, their limited managerial and technical skills may be more fully utilised in keeping trunk services functioning. However, some form of technical inspection, such as public health officers, building advisers, and 'services officers' will normally be required to ensure that the objectives (rather than any particular standards) are being met by all the participating householders and supporting agencies.

Private contractor opportunities

Contractors who are offering services, whether for latrine emptying or road upgrading will require a framework within which to work. It is in the nature of private enterprise to try to maximise profits to such an extent that quality of service begins to decline. Some form of objective monitoring as outlined above is necessary. There may be a conflict of interest where the local municipal authority is itself acting as a contractor. A suitable operating framework will be required to ensure that the authority's monitoring staff are free to criticise the standards of the contracting staff.

In the long term it is possible that the council or local authority will have the expertise and strength to take over or adopt services within the low-income housing areas. This has to be dependent upon a suitable arrangement for local taxation. Householders still pay for their services, but out of convenience, pay for them through the council as their agent. However, this does not necessarily mean that the direct labour employed by the council should be increased to meet the higher work load. The council may still decide that it is more efficient to employ a contractor or many small contractors in order to carry out the work.

Evaluation

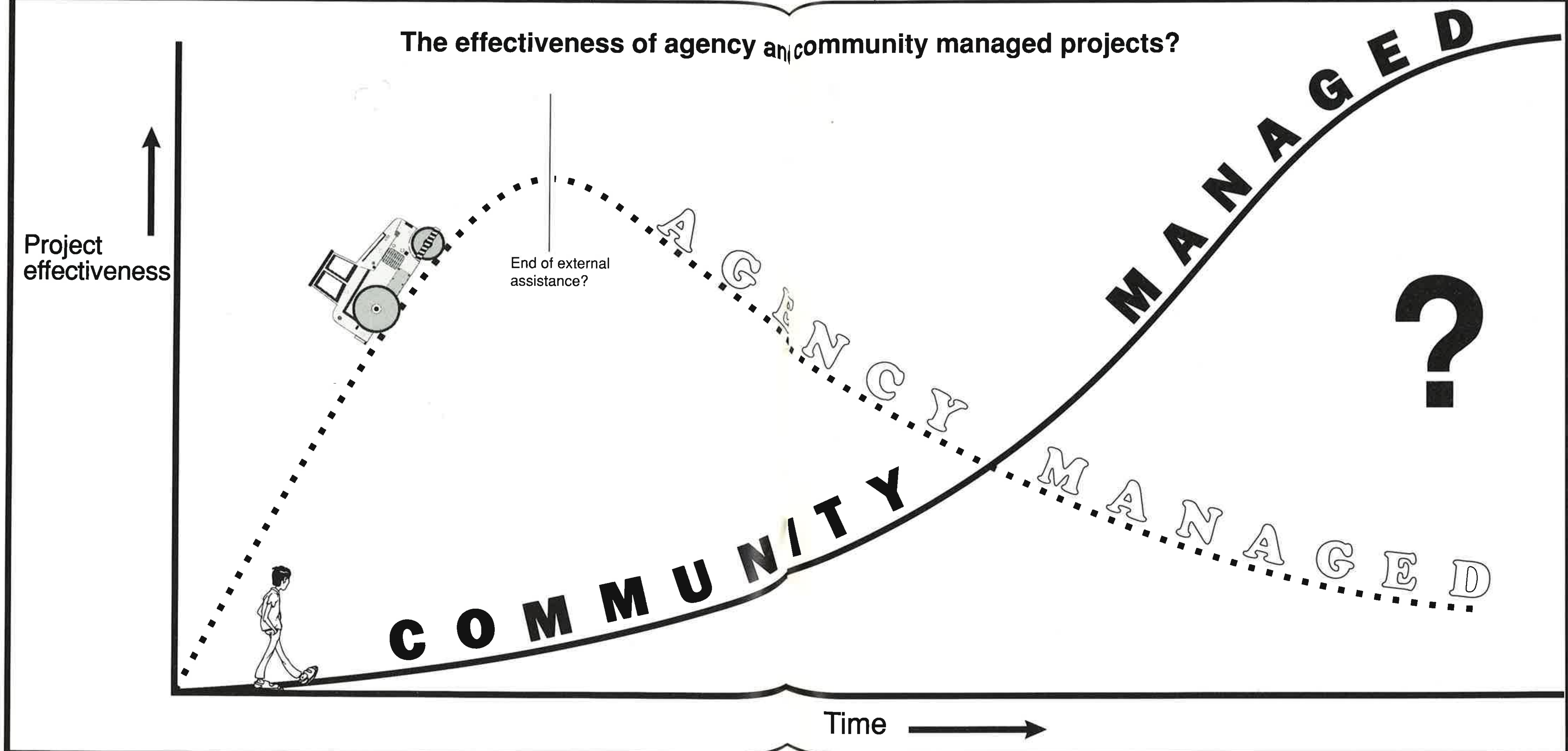
The planning, construction and implementation of any scheme does not finish the apparently successful start of the operation and maintenance phase. All schemes should undergo some form of evaluation to check whether they have achieved the declared objectives.

Evaluation is only of relevance to the community where the participants are prepared to correct any mistakes identified, particularly those of a technical nature which may lead to difficulties with operation and maintenance in later years. Evaluation is of importance to the implementing agencies as it helps staff to have a better understanding of what has been effective and why it is successful. At the same time it pinpoints any failures which should be avoided in future projects.

In the sense that evaluation is an on-going management tool to ensure effective use of resources, it is sometimes considered necessary to engage in constant evaluation of all stages of a programme. Monitoring of this kind should be carried out routinely by the management of any authority or implementing agency. However, the evaluation carried out at the end of a project must be done by a person or team who may be familiar with the project but should not have been too closely associated with the planning and implementation. This is to avoid the natural tendency to make allowances for short-comings and weaknesses in any scheme with which personnel have been involved.

Although the principal evaluator will necessarily be a professional involved in services provision, it is important to see that the majority of any evaluation 'team' should consist of representatives of the householders themselves who will have an intimate understanding of the project.

COMMUNITY Felt need for improved water supply and sanitation Exposure to health education	Response to questions by health workers and agency/government staff about health, wealth, water and sanitation. Discussions regarding experiments into affordable means of improving water and sanitation	Training of community members to assist with the programme. Training of local artisans and contractors	Publicity about the programme Visits by community representatives to working systems Drawings and models and cost forecasts made available to all Systems for financial assistance established COMMUNITY/HOUSEHOLD DECISION TO PARTICIPATE	Use and care of facilities	Comments about further improvements and upgrading



IMPLEMENTING AGENCY/GOVERNMENT **Demonstration:** Assignment of responsibilities; encouragement of health educaton; stimulation of demand; technical and social surveys; planning with communities and households; local testing of practical aspects of systems; establishing confidence of government and potential donors; training of field staff.	**Consolidation:** Integration with other government programmes (health, education, agriculture etc.); standardization of technical details; bulk ordering of materials with long delivery dates; establishment of revolving fund facilities; training of community development staff	**Expansion:** Mass promotion in the target communities; continued health education; use of mass media for information and selling; demonstration units as water and sanitation supermarket with financial, material and technical assistance where required; waiting for communities to respond; advice on responsibility of community and households for care and maintenance.		
FUNDING AGENCY/ GOVERNMENT Sector plan identification | Pre-feasibility	Feasibility, appraisal and approval, detailed design	Implementation	Operation and maintenance	Evaluation

Figure 10.1: The different roles of participants in community water supply and sanitation programmes (Franceys, 1991b)

Methods of evaluation

Because of the pressures on project budgets and professional staff time, with political pressure always to move on to new work, the evaluation has to be at a level which gives the required information at minimum cost. Occasionally it may be considered to be of interest to carry out a number of evaluations over a period of years subsequent to the project completion. Such evaluations will tend to be more for academic interest in planning future schemes rather than for any direct help for the community involved.

The World Health Organisation has developed a Minimum Evaluation Procedure (MEP) for water supply and sanitation projects (WHO, 1983) which may reasonably be modified to meet the wider needs of all services provision. Evaluation is defined as "a systematic way of learning from experience and using the lessons learned both to improve the planning of future projects and also to take corrective action to improve the functioning, utilisation and impact of existing projects."

The MEP firstly considers how effectively the facilities are working or functioning. It then goes on to investigate how well the services are being used and maintained by the people. Finally it considers the impact on the community according to the declared objectives, the reasoning being that until any problems with functioning and utilisation have been identified and corrected there is no point in measuring impact.

Evaluation, to be useful, needs to be based upon factual data as well as taking into account the users subjective views. For example such data could include:

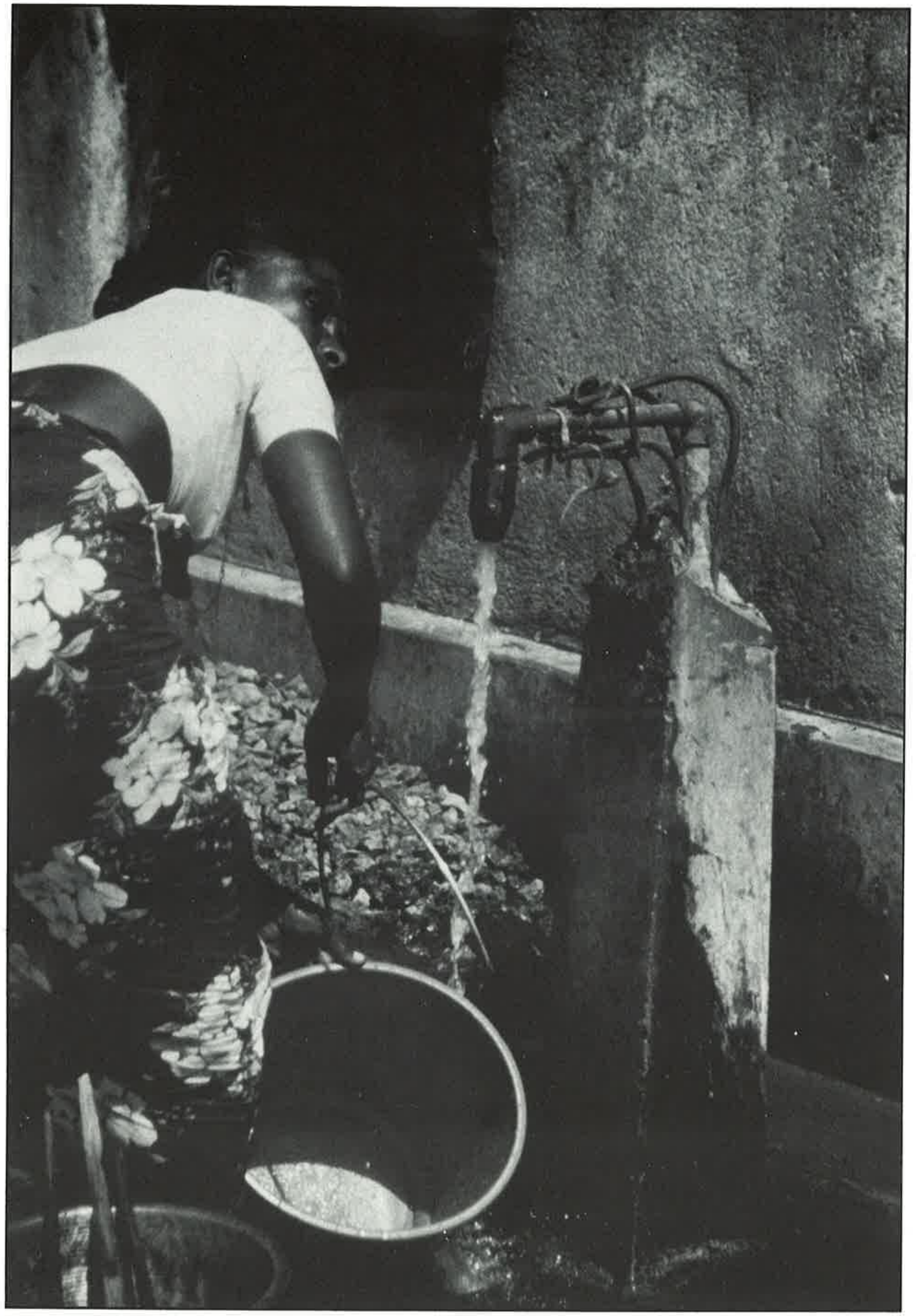
- the percentage of households on a particular site with adequate sanitation;
- the percentage of planned drain length that has actually been completed;
- the number of houses with power supply;
- the proportion of roads open for emergency access;
- the number of sullage drain blockages per 100 metres.

Evaluation of economic benefits and health impact is only worthwhile when the factors hindering functioning and utilisation have been overcome. Such studies tend to be expensive and normally require specially trained personnel such as economists and epidemiologists.

The ultimate evaluation is where householders by their own choice have invested a significant amount of time and money in the implementation of their own physical infrastructure and demonstrate their satisfaction by their own continued willingness to use, operate and maintain these services.

Above: $20,000 for a flat in a multi -storey block or $1,000 for a serviced house when it has been upgraded?

Above: Finding out what householders want



Above: The tap is still working but maintenance is required

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