Chapter 10

Sanitation

10

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SCOPE

The guidelines for sanitation provision cover aspects that need to be considered when planning and implementing sanitation projects for existing residential areas and developing communities. The guidelines will also be of assistance where the Water Services Authority compiles a Water Services Development Plan (the latter forms part of the municipality's Integrated Development Plan).

The guidelines will also assist in determining and setting objectives, developing a strategy and identifying the required planning activities for implementing sanitation projects. Technical guidelines are given for use in feasibility studies and the detailed design of sanitation provision.

The guidelines form part of a planned series of management guidelines intended for use by decision makers. The series of guidelines is shown in Table 9.1 of Chapter 9: Water Supply.

INTRODUCTION

Water services (i.e. water supply and sanitation) in South Africa are controlled by the Water Services Act (Act 108 of 1997) and the National Water Act (Act 36 of 1998). The Water Services Act deals with water services provision to consumers, while the National Water Act deals with water in its natural state.

As in the case of water supply, the provision of sanitation to a community should take place in terms of the relevant Water Services Development Plan, which is required in terms of the Water Services Act. The Water Services Development Plan (which should, of course, be compiled taking cognisance of the National Sanitation Policy) defines the minimum level of sanitation as well as the desired level of sanitation for communities that must be adhered to by a Water Services Provider in its area of jurisdiction. It describes the arrangements for water services provision in an area, both present and future. Water services are also to be provided in accordance with regulations published in terms of the Water Services Act.

The provision of appropriate sanitation to a community should take place in accordance with national policy. Among the major aims set out in the National Sanitation Policy are the following:

- to improve the health and quality of life of the whole population;
- to integrate the development of a community in the provision of sanitation;
- to protect the environment; and
- to place the responsibility for household sanitation provision with the family or household.

The minimum acceptable basic level of sanitation is (Department of Water Affairs & Forestry, 2001):

- appropriate health and hygiene awareness and behaviour;
- a system for disposing of human excreta,household wastewater and refuse, which is acceptable and affordable to the users, safe, hygienic and easily accessible, and which does not have an unacceptable impact on the environment; and
- a toilet facility for each household.

The safe disposal of human excreta alone does not necessarily mean the creation of a healthy environment. Sanitation goes hand in hand with an effective health-care programme. The importance of education programmes should not be overlooked, and the Department of Health is able to assist in this (refer to the following section "Hygiene in sanitation projects").

Sanitation education is part of the National Sanitation Policy and should embrace proper health practices, such as personal hygiene, the need for all family members (including the children) to use the toilet and the necessity of keeping the toilet building clean. Education should also include the proper operation of the system, such as what may and may not be disposed of in the toilet, the amount of water to add if necessary, and what chemicals should or should not be added to the system. The user must also be made aware of what needs to be done if the system fails or what options are available when the pit or vault fills up with sludge.

Current policy is that the basic minimum facility should be a ventilated improved pit (VIP) toilet, or its equivalent. In this chapter, therefore, levels of service lower than this will not be discussed.

The use of ponds is frequently considered for dealing with wastewater in rural areas, and hence their inclusion in this document.

The five main criteria to be considered when providing a sanitation system for a community are:

- reliability;
- acceptability;
- appropriateness;
- affordability; and
- sustainability.

With these criteria in mind, designers should note the following principles from the White Paper on Basic

Household Sanitation, September 2001:

Sanitation improvement must be demand-responsive, and supported by an intensive health and hygiene programme

Household sanitation is first and foremost a household responsibility and must be demand-responsive. Households must recognise the need for adequate toilet facilities for them to make informed decisions about their sanitation options. For users to benefit maximally, they must also understand the link between their own health, good hygiene and toilet facilities.

Community participation

Communities must be fully involved in projects that relate to their health and well-being, and also in decisions relating to community facilities, such as schools and clinics. Communities must participate in decision-making about what should be done and how, contribute to the implementation of the decisions, and share in the benefits of the project or programme. In particular, they need to understand the cost implications of each particular sanitation option.

Integrated planning and development

The health, social, and environmental benefits of improved sanitation are maximised when sanitation is planned for and provided in an integrated way with water supply and other municipal services.

The focal mechanism of achieving integrated planning and development is the municipality-driven Integrated Development Planning (IDP) process (of which the Water Services Development Plan is a component).

Sanitation is about environment and health

Sanitation improvement is more than just the provision of toilets; it is a process of sustained environment and health improvement. Sanitation improvement must be accompanied by environmental, health and hygiene promotional activities.

Basic sanitation is a human right

Government has an obligation to create an enabling environment through which all South Africans can gain access to basic sanitation services.

The provision of access to sanitation services is a local government responsibility

Local government has the constitutional responsibility to provide sanitation services.

Provincial and national government bodies have a constitutional responsibility to support local government in a spirit of co-operative governance.

“Health for all” rather than “all for some”

The use of scarce public funds must be prioritised, in order to assist those who are faced with the greatest risk to health due to inadequate sanitation services.

Equitable regional allocation of development resources

The limited national resources available to support the incremental improvement of sanitation services should be equitably distributed throughout the country, according to population, level of development, and the risk to health of not supporting sanitation improvement.

Water has an economic value

The way in which sanitation services are provided must take into account the growing scarcity of good quality water in South Africa.

The “polluter pays” principle

Polluters must pay the cost of cleaning up the impact of their pollution on the environment.

Sanitation services must be financially sustainable

Sanitation services must be sustainable, in terms of both capital and recurrent costs.

Environmental integrity

The environment must be protected from the potentially negative impacts of sanitation systems.

PLANNING

The various planning stages and other information related to the planning of projects are fully described in Chapter 9 (Water supply). The planning steps and approach with respect to sanitation do not differ from those described in that chapter, and are not repeated here. The reader is thus referred to Chapter 9 for planning information.

HYGIENE IN SANITATION PROJECTS

An introductory discussion on hygiene in water and sanitation projects can be found in Chapter 9.

For people to change their cultural practices and behaviours – some of which are developed around deeply seated values – a lot of motivation is required, accompanied by marketing of the new or modified practices. For instance, when people are accustomed to defecating in the open (free of charge) it will take a lot of effort to motivate them to install toilets (at a cost), and to use those toilets, which come in as a new practice. Furthermore, the motivation for installing toilets or practising a higher level of hygiene must clearly emphasise the benefits to the individual and to the community.

The main components of a hygiene-promotion and -education strategy in a project should include the following:

- motivation and community mobilisation;
- communication and community participation;
- user education (operation and maintenance);
- skills training and knowledge transfer;
- development of messages;
- presentation of messages; and
- maintenance of good practice.

Many of these components overlap, or cut across the whole programme of implementation. For instance, motivation and community mobilisation would need to be maintained throughout the programme and after. The same goes for communication, which is required at all stages of a hygiene-promotion and -education programme. In practice there is no particular cut-off point between one component and another.

The following should be implemented during the projects' stages (see Appendix A) to ensure that water supply and sanitation projects have a positive impact on the quality of life and level of hygiene in communities:

- *Development and structuring of a strategic plan for the implementation of hygiene promotion and education in water and sanitation projects*: This strategic plan should fit in and dovetail with national and provincial strategies for health and hygiene in South Africa, and should include advocacy, training and capacity-building, implementation, monitoring and evaluation.

- *Liaison with other programmes/projects active in the health and hygiene field*: Other initiatives regarding hygiene (PHAST, etc) should be identified and coordinated to prevent duplication, and to optimally address the needs of government and the communities. A number of other activities and programmes in schools, clinics, hospitals and the media (TV, radio, newspapers, magazines), should be identified and coordinated for a broader impact of hygiene promotion and education.

- *Informing and training local government structures, environmental health officers (EHOs), non-governmental organisations (NGOs), community-based organisations and consultants*: A programme should be developed to inform and train all local, regional and national institutions and structures involved in water supply and sanitation, health and hygiene promotion and education.

- *Monitoring and evaluating the implementation of hygiene in water and sanitation projects*: A body or organisation should be established and tasked to monitor the quality and standard of hygiene promotion and education. The results of hygiene promotion and education should be evaluated against key health indicators set up at the start of a project.

- *Disseminating information regarding hygiene in water and sanitation projects*: The process and results of hygiene promotion and education in a project should be disseminated in articles, conference papers, reports, seminars and workshops with other researchers in the field of health and hygiene.

TECHNICAL INFORMATION

Before a sanitation system is selected, the available options should be examined. This section describes the various systems and factors that could influence the selection. Detailed design information is not included in this chapter. Instead, reference is made to various publications in which all the required information may be found. Some general background information on the different sanitation technologies is, however, included.

Only sanitation systems commonly used or accepted in South Africa are described.

Categories of sanitation systems

There are two ways to handle human waste. It can either be treated on site before disposal, or removed from the site and treated elsewhere. In either case, the waste may be mixed with water or it may not. On this basis the following four groups may be distinguished:

Group 1: No water added – requiring conveyance.

Group 2: No water added – no conveyance.

Group 3: Water added – requiring conveyance.

Group 4: Water added – no conveyance.

Table 10.1: Categories of sanitation systems

	REQUIRING CONVEYANCE (off-site treatment)	NO CONVEYANCE REQUIRED (treatment, or partial treatment, on site; accumulated sludge also requires periodic removal)
NO WATER ADDED	GROUP 1 Chemical toilet (temporary use only).	GROUP 2 Ventilated improved pit toilet. Ventilated improved double-pit toilet. Ventilated vault toilet. Urine-diversion toilet.
WATER ADDED	GROUP 3 Full waterborne sanitation. Flushing toilet with conservancy tank. Shallow sewers.	GROUP 4 Flushing toilet with septic tank and subsurface soil absorption field. Low-flow on-site sanitation systems (LOFLOs): Aqua-privy toilet.

Table 10.1 illustrates the sanitation systems associated with each of the above groups. Note that some of the systems fall somewhere between the four categories as, for example, where solids are retained on each property and liquids are conveyed from site, or where water may be added, but only in small quantities. Since increasing the number of categories would complicate the table unnecessarily, these systems have been included in the categories that best describe the treatment of the waste. The operating costs of systems in which waste is conveyed and treated elsewhere can be so high that these systems may in the long term be the most expensive of all. The capital and installation costs of any conveyance network using large quantities of clean water to convey small quantities of waste are very high, and a possibly inappropriately high level of training and expertise is also required to construct and maintain such systems.

Developers should consider all the sanitation alternatives available before deciding on the most appropriate solution for the community in question. A solution that may be appropriate in one community may be a total failure in another because of cost, customs and religious beliefs, or other factors. A solution must also not be seen as correct purely because developers and authorities have traditionally implemented it.

Description of sanitation systems

The main types of sanitation systems are described below. The list is not complete and many commercial manufacturers provide systems that may be a variant of one or more.

The advantages and disadvantages of each system will depend on its particular application. What may be a disadvantage in one situation may in fact be an advantage in another. Thus the advantages and disadvantages listed after each description should be seen not as absolutes, but merely as aids to selecting the right sanitation system for a particular application.

Group 1: No water added – requiring conveyance

(for treatment at a central treatment works)

<u>Chemical toilets (not a preferred option)</u>
A chemical toilet stores excreta in a holding tank that contains a chemical mixture to prevent odours caused by bacterial action. The contents of the holding tank must be emptied periodically and conveyed to a sewage works for treatment and disposal. Some units have a flushing mechanism using some of the liquid in the holding tank to rinse the bowl after use. The chemical mixture usually contains a powerful perfume as well as a blue dye. Chemical toilets can range in size from the very small portable units used by campers to the larger units supplied with a hut. The system can provide an instant solution and is particularly useful for sports events, construction sites or other temporary applications where the users are accustomed to the level of service provided by a waterborne sanitation system. The system can also be used where emergency sanitation for refugees is required, in which case it can give the planners the necessary breathing space to decide on the best permanent solution. It should not be considered as a permanent sanitation option.

Factors to consider before choosing this option are the following:

- Chemical toilets have relatively high capital and maintenance costs.
- It is necessary to add the correct quantity of chemicals to the holding tank.

- Periodic emptying of the holding tank is essential; this requires vacuum tankers, so access should be possible at all times.
- The system only disposes of human excreta and cannot be used to dispose of other liquid waste.
- The units can be installed very quickly and easily.
- They can be moved from site to site.
- They require no water connection and require very little water for operation.
- They are hygienic and free from flies and odour, provided that they are operated and maintained correctly.
- The chemicals could have a negative effect on the performance of wastewater treatment works.

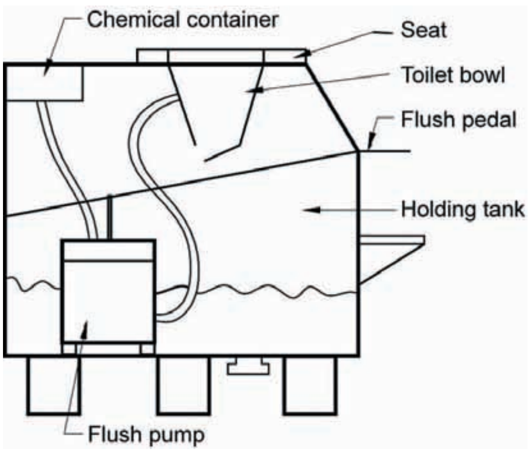

Figure 10.1: Chemical toilet unit

Group 2: No water added – no conveyance

(treatment or partial treatment on site before disposal)

<u>Ventilated improved pit (VIP) toilet</u>

The VIP toilet is a pit toilet with an external ventilation pipe. It is both hygienic and relatively inexpensive, provided that it is properly designed, constructed, used and maintained. Detailed information on VIP design is available in the publication *Building VIPs* by Bester and Austin (1997), which is obtainable from the Department of Water Affairs & Forestry, Pretoria. Information on different soil conditions, as they affect the building of VIP toilets, is also included. A SABS Code of Practice for the construction of VIPs is currently under preparation by the SABS. There are also variations of VIP toilets available – the Archloo, Phungalutho, Sanplat, etc. Those mentioned have been used with success and are firmly established in the industry.

It is possible to construct the entire toilet from local materials, although it is more usual to use commercial products for the vent pipe and the pedestal. Several toilet superstructures are also commercially available. When the pit is full, the superstructure, pedestal, vent pipe and slab are normally moved to a freshly dug pit and the old pit is covered with soil. The VIP toilet can be made more permanent by lining the pit with open-jointed brickwork or other porous lining. The pit can then be emptied when required, using a suitable vacuum tanker, without the danger of the sides of the pit collapsing. Water (sullage) poured into the pit may increase the fill-up rate (depending on soil conditions) and should be avoided; this sanitation technology is therefore not recommended where a water supply is available on the site itself.

Factors to consider before choosing this option:

- If the stand is small there may be insufficient space to allow continual relocation of the toilet; therefore arrangements should exist for emptying the toilet.
- Unlined pit walls may collapse.
- The excreta are visible to the user.
- The system may be unable to drain all the liquid waste if large quantities of wastewater are poured into the pit.
- The cost of the toilet is relatively low; it provides one of the cheapest forms of sanitation while maintaining acceptable health standards.
- The toilet can be constructed by the recipients, even if they are unskilled, as very little training is required.
- Locally available materials can be used.
- If required, the components can be manufactured commercially and erected on a large number of plots within a short space of time.
- The system is hygienic, provided that it is used and maintained correctly.
- The system can be used in high-density areas only if a pit-emptying service exists.

- The system can be upgraded at a later stage to increase user convenience (e.g. to a urine-diversion toilet).
- The system cannot ordinarily be installed inside a house.
- The quantity of water supplied to the site should be limited.
- If a pit-emptying service exists, proper access to the pit should be provided.

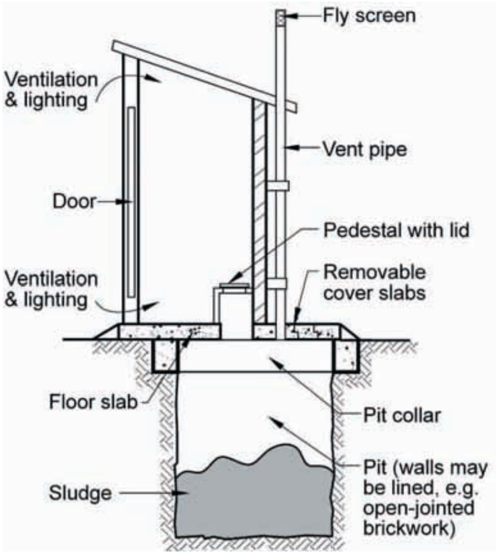

Figure 10.2: VIP toilet

Ventilated improved double-pit (VIDP) toilet

The VIDP toilet, also known as the twin-pit composting toilet, was developed mainly for use in urban areas where, because of limited space on the smaller plots, it may be impossible to relocate the toilet every time the pit becomes full. The VIDP is a relatively low-cost and simple but permanent sanitation solution for high-density areas. Two lined shallow pits, designed to be emptied, are excavated side by side and are straddled by a single permanent superstructure. The pits are used alternately: when the first pit is full it is closed and the prefabricated pedestal is placed over the second pit. After a period of at least one year the closed pit can be emptied, either manually (if this is culturally acceptable) or mechanically, and then it becomes available for re-use when the other pit is full. Each pit should be sized to last a family two to three years before filling up. It is important that the dividing wall between the pits be sealed, to prevent liquids seeping from the pit currently in use into the closed pit, thus contaminating it. The VIDP toilet can be built partially above the ground in areas where there is a high water table, but the distance between the pit floor and the highest water table should be at least 1 m.

Detailed information on VIDP design is also available in the publication *Building VIPs* by Bester and Austin (1997), obtainable from the Department of Water Affairs & Forestry, Pretoria.

Factors to consider before choosing this option are similar to those for the VIP, but include the following:

- Some training is required to ensure that the pit lining is properly constructed.
- The contents of the used pit may be safely used as compost after a period of about two years in the closed pit.
- The user may not be prepared to empty the pit, even though the contents have composted.
- The superstructure can be a permanent installation.
- The system can be regarded as a permanent sanitation solution.
- The system can be used in high-density areas.
- The system can be used in areas with hard ground, where digging a deep pit is impractical.

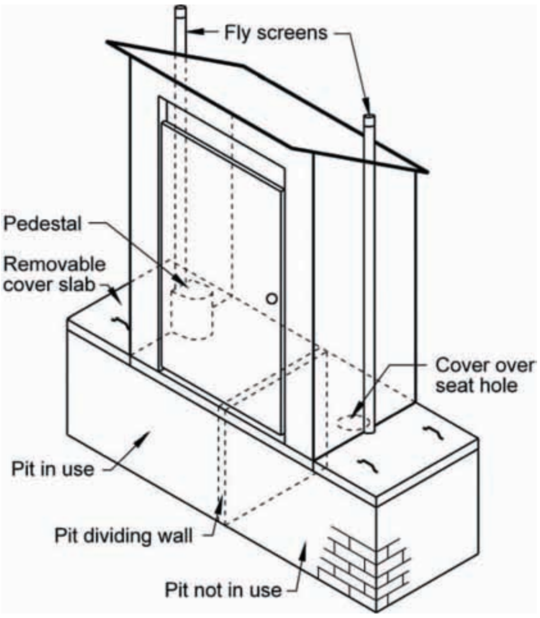

Figure 10.3: VIDP toilet

Ventilated vault (VV) toilets

The VV toilet is basically a VIP toilet with a watertight pit that prevents seepage. It can be regarded as a low-cost, permanent sanitation solution, especially in areas with a high groundwater table or a poor capacity for soil infiltration, or where the consequences of possible groundwater pollution are unacceptable.

The amount of wastewater disposed of into the vault should be limited to avoid the need for frequent emptying, so it is advisable not to use this type of sanitation technology where a water supply is available on site. Should an individual water connection be provided to each stand at a later date, as part of an upgrading scheme for the residential area, then the vault can be utilised as a solids-retention tank (digester) and liquids can be drained from the site using a settled-sewage system, also called a solids-free sewer system (see the section on "settled-sewage systems" under Group 3). Ventilation, odour and insect control operate on the same basis as the VIP toilet.

Factors to consider before choosing this option are similar to those of the VIP, but include the following:

- It is necessary to make use of a vacuum-tanker service for periodic emptying of the vaults.
- Builder training and special materials are required if a completely waterproof vault is required.
- The system can be used in areas with a high water table if the vault is properly constructed.
- The system can be used in areas where pollution of the groundwater is likely if a VIP toilet system is used.
- The system can be used in high-density areas.
- This system provides very good opportunities for upgrading since the vault can be used as a solids-retention tank when upgrading to solids-free sewers.

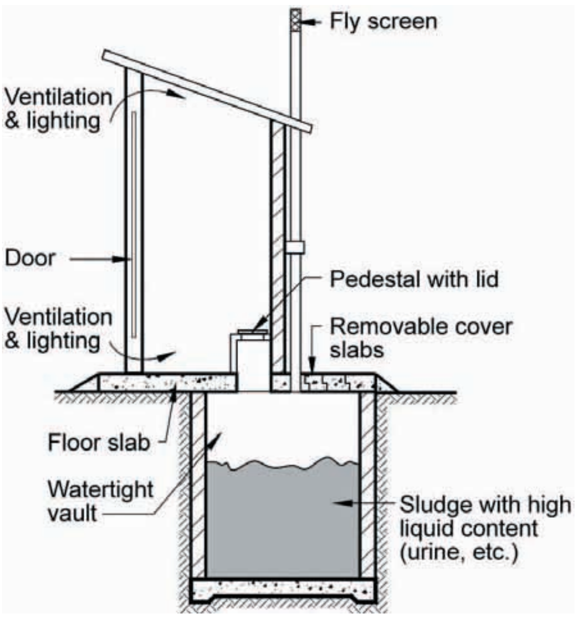

Figure 10.4: Ventilated vault toilet

- The cost of emptying equipment and the operation of a vacuum-tanker service could be excessive (see also the section on vacuum tankers).

<u>Urine-diversion (UD) toilet</u>

The urine-diversion toilet, also known as the "dry-box", is a superior type of dry toilet that circumvents the problems sometimes encountered with the implementation of VIP toilets, namely unfavourable geotechnical or hydrological conditions, high-density settlements with small erven, etc. The main advantage is that a pit is not required, so the toilet may be installed inside the house, if desired by the owner. Urine is diverted at source by a specially designed pedestal and, owing to the relatively small volumes involved, may simply be led into a shallow soakpit. Alternatively, urine can be easily collected in a container and re-used for agricultural fertiliser, as it is rich in plant nutrients such as nitrogen, phosphorus and potassium. Faeces are deposited in a shallow vault and covered with a sprinkling of ash or dry soil, which absorbs most of the moisture. They are further subjected to a dehydration process inside the vault, which hastens pathogen die-off. Depending on the temperature and degree of desiccation attained in the vault, the faeces may be safe to handle after a period of six to eighteen months, and can then be easily removed from the vault and either disposed of or re-used as soil conditioner, depending on individual preferences.

Other favourable aspects of this type of toilet are an absence of odours or flies (if it is properly used), a relatively low capital cost that may, depending on the specific circumstances, be even less than a VIP toilet, and a negligible operating cost. There are also environmental advantages, due to the fact that no pit is required.

Detailed guidelines on the implementation of this technology are contained in the publication *Urine-diversion ecological sanitation systems in South Africa* by Austin and Duncker (CSIR, 2002).

Factors to consider before choosing this option:

- The technology is well suited to dense urban settlements and places where environmental conditions do not favour other types of sanitation.
- Use of the toilet requires an adherence to certain operational requirements, and a proper commitment from owners is required. Good user education is therefore especially important.
- Building materials similar to those for a VIP toilet may be used, and the toilets can be

constructed by relatively unskilled persons. Components can also be manufactured commercially.

- The system is hygienic, provided that it is used and maintained correctly. Safe re-use of the urine and faeces is also facilitated.
- The system can be installed inside a house, if desired.
- There may be reluctance on the part of the user to empty the vault, even though the contents are innocuous.
- The system can be regarded as a permanent sanitation solution that will never need upgrading.

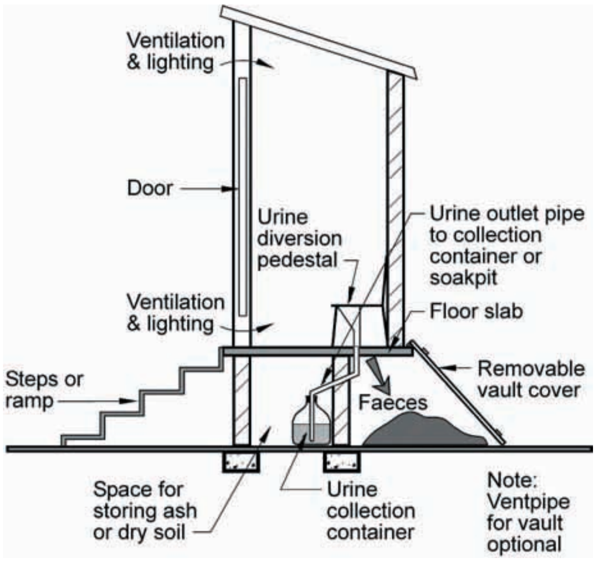

Figure 10.5: Urine-diversion toilet

Group 3: Water added – requiring conveyance
(treatment at a central works)

Full waterborne sanitation

This is an expensive option and requires ongoing maintenance of the toilet installation, the sewer reticulation and the treatment works, and the recipient community should be informed accordingly. The system requires a water supply connection to each property. The water is used to flush the excreta from the toilet pan and into the sewer, as well as to maintain a water seal in the pan. The excreta are conveyed by the water, in underground pipes, to a treatment works that may be a considerable distance from the source. The treatment works must be able to handle the high volume of liquid required to convey the excreta. The quantity of water required (usually 6-10 litres per flush) can be reduced by using low-flush pans designed to flush efficiently with as little as three litres. Research has indicated that the operation of the sewer system is not adversely affected by low-volume flush toilets. Flush volumes of 8-9 litres are normally used, however. In an area where water is costly or scarce, it may be counter-productive to purify water only to pollute it by conveying excreta to a treatment and disposal facility.

Factors to consider before choosing this option are the following:

- The system is expensive to install, operate and maintain.
- The system can be designed and installed only by trained professionals.
- The treatment works must be operated and maintained properly if pollution of waterways is to be avoided.
- The system requires large amounts of water to operate effectively and reliably.
- The system is hygienic and free of flies and odours, provided that it is properly operated and maintained.
- A high level of user convenience is obtained.
- The system should be regarded as a permanent sanitation system.
- The toilet can be placed indoors.
- This system can be used in high-density areas.
- An adequate, uninterrupted supply of water must be available.

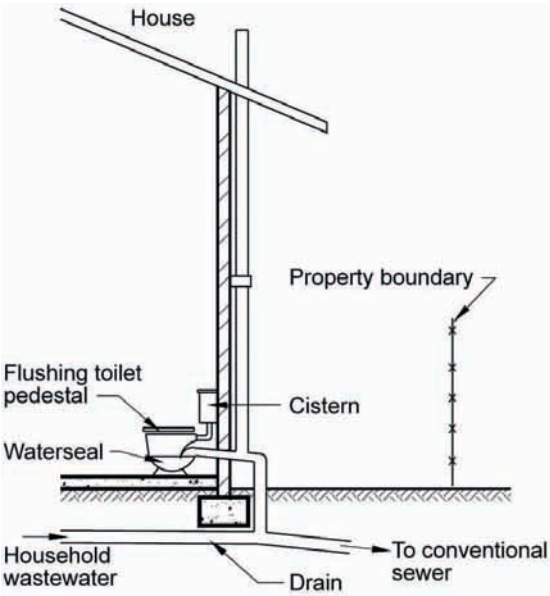

Figure 10.6: Waterborne sewerage system

Shallow sewers

The shallow sewer system is basically a conventional system where a more simple approach with respect to design and construction is followed. Basically it entails a system where gradients are flatter, pipes are smaller and laid shallower, manholes are smaller and constructed of brickwork, and house connections are simpler. Where such systems are installed, community involvement in management and maintenance issues is preferred.

Design of sewer networks:

The professional responsibility in design remains with the engineer, and guidelines should never be regarded as prescriptive. Most local authorities have their own requirements and preferences on technical detail, such as pipe slopes, manhole details, materials, and so on. These are based on their own particular experiences and new designs should therefore be discussed with the relevant controlling authority.

Designers should not assume that sewer systems will always be properly maintained, and allowance should be made for this.

The hydraulic design of the sewers should be done according to acceptable minimum and maximum velocities in the pipeline. A number of pipe manufacturers have design charts available in their product manuals and these can be used in the absence of other guidelines.

The construction of a system should be in accordance with the relevant sections of SABS 1200:1996. The depth of the sewer is normally determined by its position on site. Sewers in mid-block positions and on sidewalks can normally be laid at shallower depths. Should laying of sewer and water pipes in the same trench be considered, workmanship should be of a high standard. Appendix C gives design guidelines that should be useful.

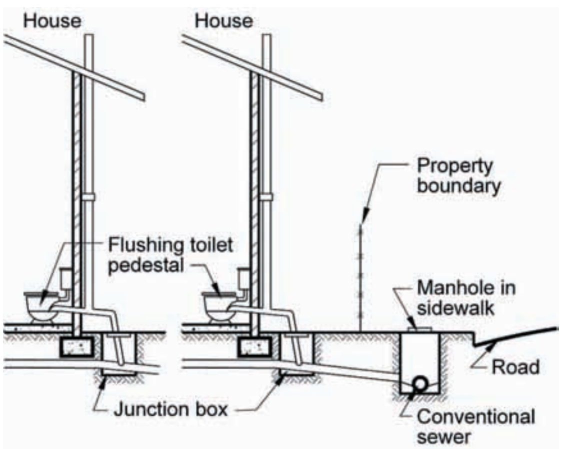

Figure 10.7: Shallow sewer system

Flushing toilet with conservancy tank

This system consists of a standard flushing toilet that drains into a storage or conservancy tank on the property; alternatively, several properties' toilets can drain into one large tank. A vacuum tanker regularly conveys the excrement to a central sewage treatment works for purification before the treated effluent is discharged into a watercourse. The appropriate volume of the conservancy tank should be calculated on the basis of the planned emptying cycle and the estimated quantity of wastes generated. Tank volumes are sometimes prescribed by the service provider.

Factors to consider before choosing this option are the following:

- The system is expensive to install, operate and maintain, although the capital cost is lower than the fully reticulated system.
- The system can be designed and installed only by trained professionals.
- A treatment works must be operated and maintained properly to avoid the pollution of waterways.
- A fleet of vacuum tankers must be maintained by the local authority.
- Regular collection is essential.
- The system is hygienic and free of odours, provided that it is properly operated and maintained.
- A high level of user convenience is obtained.
- The toilet can be placed indoors.
- The system can be used in high-density areas.

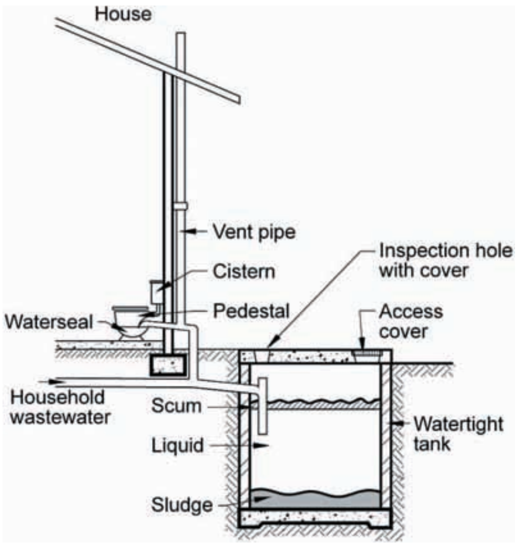

Figure 10.8: Flushing toilet with conservancy tank

- This system has good potential for upgrading since the conservancy tank can be used as a digester when upgrading to a settled-sewage system.
- An adequate, uninterrupted supply of water must be available.

Settled sewage system

In settled sewage systems, also known as solids-free systems or Septic Tank Effluent Drainage (STED), the solid portion of excreta (grit, grease and organic solids) is retained on site in an interceptor tank (septic tank), while the liquid portion of the waste is drained from the site in a small-diameter sewer. Such sewers do not carry solids, and have very few manholes. Tolerances for excavation and pipe laying may be greater than for conventional sewers, allowing lesser skilled labour to be used. Although the liquid portion of the waste must be treated in a sewage works, the biological design capacity of the works can be greatly reduced because partial treatment of the sewage will take place in the retention tank on the site. The tank will also result in a much lower peak factor in the design of both the reticulation and the treatment works. The retention tank should be inspected regularly and emptied periodically, to prevent sludge overflowing from the tank and entering the sewer. This system is an easy upgrading route from septic tanks with soakaways, conservancy tanks, and other on-site systems, as they can be connected to a settled-sewage system with very little modification. Tipping-tray pedestals and water-saving devices can also be used in settled-sewage schemes without fear of causing blockage resulting from the reduced quantity of water flowing in the sewers.

Factors to consider before choosing this option are the following:

- The system requires a fairly large capital outlay if new interceptor tanks have to be constructed (i.e. if there are no existing septic tanks which can be used).
- Care must be taken to ensure that only liquid waste enters the sewers; this may mean regular inspection of the on-site retention tanks.
- Vacuum tankers must be maintained by the local authority.
- The system is hygienic and free of flies and odours, provided that it is properly operated and maintained.
- A high level of user convenience is obtained.
- The system can be regarded as a permanent sanitation system.
- The toilet can be placed indoors.
- All household liquid waste can be disposed of via this sanitation system.
- The sewers can be installed at flatter gradients and can even be designed to flow under pressure.
- The system provides an easy and reasonably priced option when areas with on-site sanitation need to be upgraded, because of increased water consumption and higher living standards.
- The system can be used in high-density areas.
- An adequate uninterrupted supply of water must be available.
- Regular inspection of the septic tank/digester is required to prevent an overflow of sludge.

Technical information on the design of these systems may be found in the CSIR, Division of Building and Construction Technology publication *Septic tank effluent drainage systems* (1997).

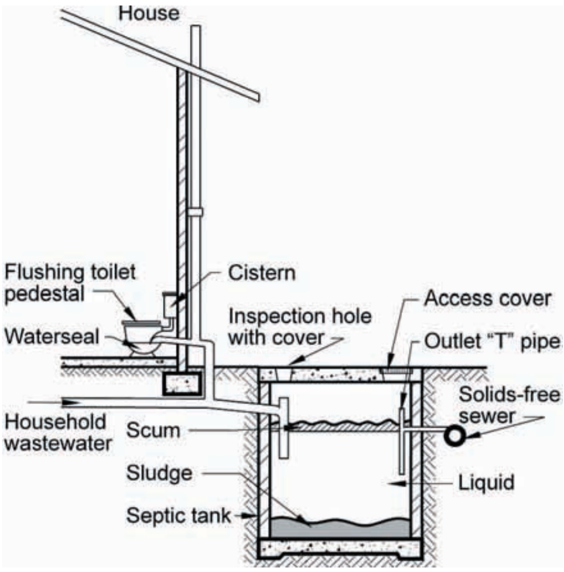

Figure 10.9: Settled sewage system

Group 4: Water added – no conveyance

(treatment or partial treatment on site before disposal)

These systems generally dispose of all or part of the effluent on site. Some systems retain only the solid portion of the waste on site and the liquids are conveyed to a suitable treatment and disposal facility.

Systems that dispose of the liquid fraction on site require a soil percolation system, and the amount of liquid that can be disposed of will depend on the system's design and the permeability of the soil.

Flushing toilet with septic tank and soakaway
Water is used to flush the waste from a conventional toilet pan into an underground septic tank, which can be placed a considerable distance from the toilet. The septic tank receives the sewage (toilet water and sullage (greywater)) and the solids digest and settle to the bottom of the tank in the same manner as in the settled-sewage system. The septic tank therefore provides for storage of sludge. The effluent from the tank can contain pathogenic organisms and must therefore be drained on the site in a subsoil drainage system. The scum and the sludge must be prevented from leaving the septic tank as they could cause permanent damage to the percolation system. It is therefore advisable to inspect the tank at intervals to ascertain the scum and sludge levels. Most tanks can be emptied by a conventional vacuum tanker. Liquid waste from the kitchen and bathroom can also be drained to the septic tank. Septic tanks should be regarded as providing a high level of service.

Factors to consider before choosing this option are the following:

- It is relatively expensive and requires a water connection on each stand.
- It requires regular inspection, and sludge removal every few years, depending on the design capacity of the septic tank.
- Percolation systems may not be suitable in areas of low soil permeability or high residential density.
- It provides a level of service virtually equivalent to waterborne sanitation.
- The system is hygienic and free of flies.
- The toilet can be inside the dwelling.
- This system has excellent potential for upgrading, since the septic tank outlet can easily be connected to a settled-sewage system at a future date.
- An adequate, uninterrupted supply of water must be available.

Designers are referred to the publication *Septic tank systems* (BOU/R9603), available from the CSIR, Division of Building and Construction Technology, for information on the design of septic tanks.

Reference to the percolation capacity of soils is made later in this chapter under the section "Evaluation of sites".

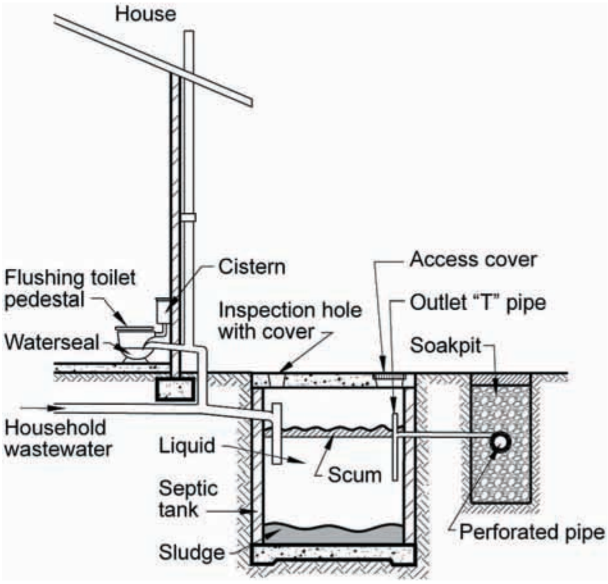

Figure 10.10: Flushing toilet with septic tank and soakaway

Low-flow on-site sanitation systems (LOFLOs)
The term LOFLOs refers to the group of on-site sanitation systems that use low volumes of water for flushing (less than 2,5 litres per flush). These systems include a pedestal, digestion capacity and soakaway component. They are:

- aqua-privies;
- pour-flush toilets* and low-flush systems*; and
- low-flow septic tanks*.

*These types are not generally found in South Africa.

Aqua-privies:

An aqua-privy is a small, single-compartment septic tank directly under or slightly offset from the pedestal. The excreta drops directly into the tank through a chute, which extends 100 mm to 150 mm below the surface of the water in the tank. This provides a water seal, which must be maintained at all times to prevent odour and keep insects away. The tank must be completely watertight; it may therefore be practical to use a prefabricated tank. The tank must be topped up from time to time with water to compensate for evaporation losses if flushing water is not available. This can be done by mounting a wash trough on the outside wall of the superstructure and draining the used water into the tank. The overflow from the tank may contain pathogenic organisms and should therefore run into a soil percolation system (it can also be connected to a settled-sewage system at a later stage).

Factors to consider before choosing this option are the following:

- The excreta are visible to the user.
- The tanks must be completely watertight.
- The user must top up the water level in the aqua-privy to compensate for evaporation losses.
- The system is hygienic, provided that it is used and maintained correctly.
- It is relatively inexpensive.
- The system can be regarded as a permanent sanitation solution.
- This system has excellent potential for upgrading, since the tanks work in the same way as a septic tank and can thus be connected directly to a settled-sewage system.
- The tanks need regular inspection, and sludge removal is required from time to time.
- An adequate, uninterrupted supply of water must be available.

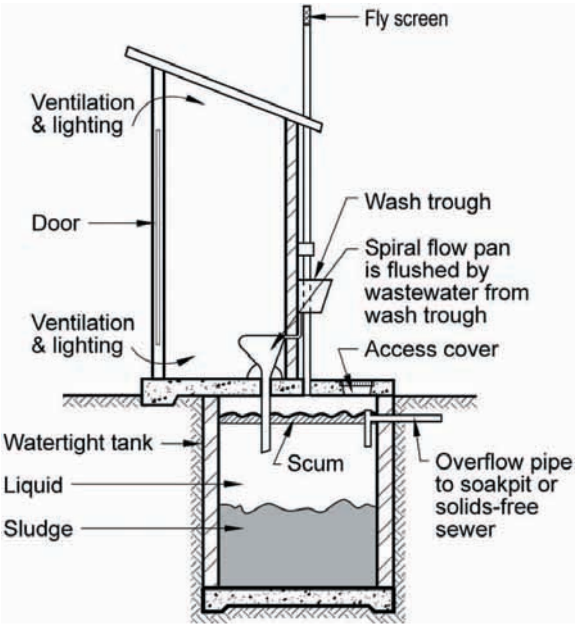

Figure10.11: Aqua-privy toilet

FACTORS AFFECTING THE CHOICE OF A SANITATION SYSTEM

General considerations

The primary reason for installing a sanitation system in a community is to assist in the maintenance of health and should be seen as only one aspect of a total health programme. The choice of a sanitation system by a community will be influenced by several factors, such as the following:

- The system should not be beyond the technological ability of the community insofar as operation and maintenance are concerned.
- The system should not be beyond the community's ability to meet the capital as well as the maintenance costs.
- The system should take into account the level of water supply provided, and possible problems with sullage (greywater) management.
- The likelihood of future upgrading should be considered, particularly the level of service of the water-supply system.
- The system should operate well despite misuse by inexperienced users.
- In a developing area the system should require as little maintenance as possible.
- The system chosen should take into account the training that can be given to the community, from an operating and maintenance point of view.
- The system should be appropriate for the soil conditions.
- The community should be involved to the fullest extent possible in the choice of an appropriate system.
- To foster a spirit of real involvement and ownership, the community should be trained to do as much as possible of the development work themselves.
- Local customs should be carefully considered.
- The local authority should have the institutional structure necessary for the operation and maintenance of the system.
- The existing housing layout, if there is one, should not make the chosen system difficult to construct, maintain or operate.

- Environmental factors should be considered: surface pollution, possible groundwater contamination, etc.

The cost of the system

Many people in developing areas are not only unable to afford sophisticated sanitation systems, but these systems may also be technically inappropriate for them. At the same time, the sanitation alternative with the lowest overall cost may also be inappropriate because of the community's cultural background or because of its unwillingness or inability to operate the system correctly.

When the costs of different systems are compared, all relevant factors should be taken into account. Examples of costs often ignored are the following:

- A pit toilet may require relocation on the site or emptying every 4-10 years, depending on its capacity.
- Sludge from septic tanks and other on-site sanitation systems may require treatment before disposal.
- Training may be required for operators and maintenance staff.
- The community may have to be trained in the use of the system for it to operate effectively.
- Regional installations such as treatment works may be required.
- Special vehicles and equipment may be required for operation or maintenance.

To keep costs to a minimum, several issues are relevant:

- Who pays what? For example, if a government institution or development agency is paying all of the capital costs, then the community will generally demand the most expensive, highest level of sanitation. If, on the other hand, the capital costs are to be recovered from the community, then its choice of sanitation system may be quite different. The lack of income to pay for maintenance could have serious financial implications as well as health risks.
- Would the community prefer lower capital costs and higher maintenance costs, or vice versa?
- Will the cost comparison between options change if all the potential benefits and costs are included?
- Are any of the costs incorrectly or dishonestly represented? For example, have capital grants or soft loans been ignored? Do certain services have hidden subsidies that produce misleading comparisons (for example, where treatment costs are paid by regional authorities)?

Where finance is limited, developers should consult the community, determine its priorities, and seek ways to achieve the improvements desired. This may take extra time but a motivated community will contribute more to successful project implementation and, perhaps more importantly, to the long-term operation and maintenance of the system selected.

Sanitation at public facilities

Sanitation facilities are required at public buildings such as schools and clinics. The large number of people using a concentrated facility can cause problems if there is inadequate on-site drainage and a lack of general maintenance, such as cleaning of the toilet and replacement of toilet paper. Most types of on-site sanitation systems can be used, provided that developers take note of the special requirements for public facilities.

Generally speaking, the system should use as little water and require as little routine maintenance as possible. Before choosing a system that requires daily maintenance for effective operation, one must ensure that maintenance tasks will in fact be performed. A rural school may not be able to afford the services of a janitor to look after routine maintenance.

The number of sanitation units required at schools is covered in the National Building Regulations (SABS 0400:1990). Because of the number of users, care should be taken to prevent pollution of the groundwater, particularly if there is a borehole supplying the school with water.

Urinals that do not require water for flushing are available from commercial sources. These can be used effectively in sanitation facilities. However, they require the weekly addition of a special oil to the trap and the application of a special deodorised cleanser to the bowl or slab. They perform satisfactorily as long as the weekly maintenance is carried out and should therefore be used only where the necessary training can be given to the cleaners and where the supply of oil and cleanser can be assured.

DISPOSAL OF SLUDGE FROM ON-SITE SANITATION SYSTEMS

All forms of on-site sanitation will result in an accumulation of sludge that, at intervals, must be removed from the pit or tank and conveyed to some treatment or disposal facility. If the pit or tank contains fresh sewage, the sludge must be treated or disposed of in a way that will not be harmful to the environment or a threat to health; if the waste matter has been allowed to decompose to the extent where there are no longer any pathogens present, the sludge can be spread on the land as compost.

Sludge can be disposed of only in accordance with the prescribed methods. See Water Research Commission (1997) *Permissable utilisation and disposal of sewage sludge.*

An effective refuse-collection system should be in operation in high-density residential areas and people should be encouraged to use it. If this is not done, the residents will probably use the toilet to dispose of tins, bottles, plastic and other forms of refuse which will result in the pits filling very rapidly. This will present problems when emptying pits with a vacuum tanker. Where regular emptying will be required, it is advisable to construct permanent pits with lined walls to prevent damage during emptying, which could lead to the collapse of the pit walls. Note, however, that pit linings should make allowance for percolation of effluent into the surrounding soil (e.g. by leaving the vertical joints of a brick lining unfilled). A regular programme for pit emptying in an area is better than responding to individual ad hoc calls for pit emptying.

Composition of pit or vault contents

In a sealed tank or vault, human excreta will usually separate into three distinct layers, namely a layer of floating scum, a liquid layer and a layer of sediment. Well-drained pits may have no distinct liquid layer, and therefore no floating scum layer. The scum layer seems to be caused by the presence of paper, oil and grease in the tank and it is also more prominent in tanks with a large number of users. It is usually possible to break up the scum layer without much effort. The water content of pits can vary between 50% and 97%, depending on the type of sanitation system, the personal habits of the users, the permeability of the soil, and the height of the groundwater table. Cognisance should be taken of the fact that different materials used for anal cleansing will have different breakdown periods. Newspaper will require more time to break down than ordinary toilet paper, and in some cases will not break down at all. This will obviously cause the pit to fill up more quickly.

Methods of emptying pits

It is possible to empty pits manually, using scoops and buckets, and to dig out the thicker sludge with spades, but this poses obvious health risks to the workers involved. The use of ventilated improved double-pit toilets overcomes this unpleasantness by allowing the excreta to decompose into a pathogen-free, humus-rich soil, after storage in the sealed pit for about two years. However, many people do not like to empty their pits manually.

The most suitable method of emptying a pit mechanically involves the use of a vacuum tanker, where a partial vacuum is created inside a tank and atmospheric pressure is used to force the pit contents along a hose and into the tank. The use of a vacuum is preferred to other pumping methods, because the contents do not come into contact with the moving parts of the pump, where they can cause damage or blockages. Various techniques can be used to convey this sludge along the pipe to the tank. Thin sludge with a low viscosity can be conveyed by immersing the nozzle below the surface of the sludge, drawing a constant flow into the tank.

Thicker, more viscous sludge requires a pneumatic conveying technique, where the particles of waste matter are entrained in an air stream. This can be achieved by holding the end of the nozzle a few centimetres above the surface of the waste and relying on the high velocity of the air to entrain particles and convey them along the pipe to the holding tank. This technique requires very high-capacity air pumps to operate effectively. Devices such as an air-bleed nozzle can be used to obtain the same effect with less operator skill and smaller air pumps. Pneumatic conveyance can also be achieved with a low-capacity air pump by using the plug-drag (or suck-and-gulp) technique. This method relies on submerging the hose inlet, allowing a vacuum pump to create a vacuum inside the tank, then drawing the hose out to allow a high-velocity air stream to convey a plug of waste into the tank. The plug-drag technique works best with a vehicle with a fairly high-capacity pump (say 10 m^3/min) and a relatively small holding tank (1,5-2 m^3).

Sludge flow properties

Sludge generally exhibits a yield stress, shear thinning behaviour and thixotropy. In effect, this means that the hardest part of the operation is to get the sludge moving. The addition of small quantities of water to the sludge can assist greatly in getting it to move by causing shearing to take place. Being thixotropic, the sludge "remembers" this and exhibits a lower shearing stress next time.

Vacuum tankers

Most vacuum tankers available today are designed for use in developed countries, where roads are good and maintenance is properly done. However, some manufacturers are realising the special conditions that exist in developing countries and are now adapting their designs or, even better, are developing completely new vehicles designed to cope with the actual conditions under which these vehicles will have to work.

The size of conventional vacuum tanker vehicles prevents their gaining easy access to toilets. They are high off the ground, which may limit the depth of pit that can be emptied, and they are so heavy when loaded that travelling over bad or non-existent roads is extremely difficult. The equipment on the vehicle is often complex and requires regular maintenance, which is seldom carried out by the unskilled people who, in most cases, will operate the vehicles. Watery sludge from conservancy tanks and septic tanks may not be a problem, but the tankers often cannot cope with the more viscous sludge found in pit toilets.

A purpose-designed pit-toilet-emptying vehicle should have the following attributes:

- a low mass;
- a low overall height;
- high manoeuvrability;
- ability to travel on extremely poor roads;
- a small-capacity holding tank with a relatively high-capacity pump, to facilitate the use of plug-drag techniques;
- the ability to transfer its load to another vehicle or trailer if there are long haul distances to the disposal site;
- both vehicle and equipment must be robust;
- little skill should be required to operate the vehicle and the equipment;
- capital and operating costs must be as low as possible, to facilitate operation by emerging contractors or entrepreneurs;
- a small pressure pump and water for washing down must be provided; and
- storage compartments must be provided for the crew's personal effects.

Disposal of sludge

Pit-toilet sludge can be disposed of by burial in trenches.

Dehydrated faecal matter from urine-diversion toilets may be safely re-used as soil conditioner, or, alternatively, disposed of by burial, if preferred. It may also be co-composted with other organic waste.

Sludge from septic tanks, aqua-privies, etc, can be disposed of only in accordance with the prescribed methods. See Water Research Commission (1997) *Permissable utilisation and disposal of sewage sludge.*

Unless the sludge has been allowed to decompose until no more pathogens are present, it may pose a threat to the environment, particularly where the emptying of pits is practised on a large scale. The design of facilities for the disposal of sludge needs careful consideration, as the area is subject to continuous wet conditions and heavy vehicle loads. The type of equipment employed in the disposal effort should be known to the designer, as discharge speed and sludge volume need to be taken into account. Cognisance should be taken of the immediate environment, as accidental discharge errors may cause serious pollution and health hazards.

Emptying facilities at treatment works need not be elaborate, and could consist of an apron on which to discharge the contents of the vehicle and a wash-down facility. The nature of the sludge can vary widely and this should be taken into account when designing the sewage works. Depending on the habits of the pit owners and the effectiveness of refuse removal in the area, there may also be a high proportion of rags, bottles and other garbage in the sludge. Generally a higher grit load will also come from developing communities. Pond systems can be very effective in treating sludge from on-site sanitation systems. If the ponds treat only sludge from pit latrines it may be necessary to add water to prevent the ponds from drying out before digestion has taken place. Sludge from on-site sanitation systems can also be treated by composting at a central works, using forced aeration.

Although it is usually still necessary to treat sludge from on-site sanitation systems, the cost of treatment is lower than for fully waterborne sanitation. This is because partial treatment has already taken place on the site through the biological decomposition of the waste in the pit or tank. In addition, the treatment works do not have to be designed to handle the large quantities of water which must be added to the waste for the sole purpose of conveying solids along a network of sewer pipes to the treatment and disposal works.

EVALUATION OF SITES

It is not possible to lay down rigid criteria for the suitability of a site for on-site sanitation, because soil and site conditions vary widely. Two basic criteria should, however, be considered – namely, whether the soil can effectively drain the liquids brought to the site and whether there is any danger of pollution of the groundwater or surface water.

Topographical evaluation

All features that can affect the functioning of the sanitation system should be noted and marked on the site plans during a visual survey of the site. The position of depressions, gullies, rock outcrops and other features should be noted and an assessment made of how they are likely to affect the functioning of the system. The type and gradient of slopes should also be noted as steep slopes can result in the surfacing of improperly treated effluent, especially during periods of high rainfall. Surface and subsurface drainage patterns, as well as obvious flood hazards, should be reported. The vegetation on the site will often reflect soil-drainage characteristics.

Soil profiles

Sampling holes should be excavated to a depth of at least one metre below the bottom of proposed pit toilets or soakaways. Soil properties (such as texture, structure and type) should be determined. The presence of bedrock, gravel, groundwater or a layer with poor permeability should be noted. Soil mottling indicates the presence of a high seasonal groundwater table, which can affect soil percolation.

Percolation capacity of the site

If the soil is unable to drain liquid waste effectively, swampy, unsanitary conditions can result. This can occur in areas with very shallow water tables or with poor permeability, or where a shallow, restrictive layer such as bedrock occurs. On-site sanitation can be used in low-permeability soils, but the system must be carefully selected in relation to the quantity of water supplied to the site. If the efficient functioning of a soil-percolation system is in doubt, it is advisable to create an inspection point where the level of the water in the subsoil drain can be monitored, so that adequate warning of failure is obtained to allow the local authority to plan for an alternative solution to liquid drainage problems before a crisis develops. This will be effective only if the recipient community fully understands the need for regular inspection of the drain, as well as the consequences of failure. On-site sanitation can be used in areas with poor percolation, but it may be necessary to retain all the liquids on the site in a sealed vault and provide a regular emptying service, or to drain the site with settled sewage systems.

The percolation test is designed to quantify the movement of liquids in the soil at a specific time of the year. Percolation rates usually change as the soil's moisture content changes, and it is best to conduct the test in the rainy season. The percolation test should be regarded only as an indication of the suitability of the soil for a specific sanitation system. The following procedures should be complied with:

Calculation of number of test holes

The number of test holes needed is determined by the size of the settlement and the variability of the soil conditions. Usually test holes should be spaced uniformly throughout the area, at the rate of five to ten holes per hectare, if soil conditions are fairly homogeneous.

Percolation test

The test procedure to be followed is described in SABS 0400.

POLLUTION CAUSED BY SANITATION

When there is a high density of people living in an area, both the surface water and groundwater can be expected to become polluted to some degree, irrespective of the type of sanitation system used in the area. Some basic precautions will minimise the risk of serious pollution.

Surface pollution

The surfacing of partially treated effluent can create a direct health risk, and can cause pollution of surface waters. This type of pollution should and can usually be avoided. It is most likely to occur in areas where the groundwater table is very high or in areas with steep slopes where a shallow, permeable layer of topsoil covers an impermeable subsoil. In areas where cut-and-fill techniques are used to provide platforms for house construction, sanitation units and soakaways should be carefully sited to minimise the possibility of surface pollution. Sanitation units and soakaways should also be sited in such a way that rainwater ingress cannot occur, as this could cause flooding, with resultant surface pollution.

Poor maintenance of reticulation systems, pumping stations and sewage-purification works can cause serious pollution with associated health risks, especially in remote areas close to streams and rivers.

Groundwater pollution

Groundwater can be contaminated by a sanitation system; therefore the risk should be assessed or the groundwater periodically monitored, particularly where this water is intended for human consumption. The guidelines made available in the publication *A protocol to manage the potential of groundwater contamination from on-site sanitation* by the Directorate of Geohydrology of the Department of Water Affairs & Forestry (1997), should be observed. The soil around the pit toilet or subsurface drain provides a natural purification zone, and tests carried out both in South Africa and other parts of Africa indicate that on-site sanitation does not pose a serious threat, provided the water is not intended for human consumption. Generally, the susceptibility of a water source to pollution decreases quite sharply with increasing distance and depth from the source of pollution, except in areas with fissured rock, limestone, very coarse soil or other highly permeable soils.

Soakaways attached to on-site sanitation systems should, wherever possible, be located downstream of drinking water supplies. The following could be used as a guide for the location of a soakaway:

- 7,5 m from the drinking-water source if the highest seasonal water table is more than 5 m below the bottom surface of the pit or soakaway;
- 15 m from the water source if the highest seasonal water table is 1-5 m below the bottom surface of the pit or soakaway;
- 30 m from the water source if the highest seasonal water table is less than 1 m below the bottom of the pit or soakaway; and
- there is no safe distance from a source of drinking water in areas that have fissured rock, limestone or very coarse soil.

These distances are given as a guide only. Permeability of the soil is not the only factor. Geology, topography, the presence of trees, groundwater flow direction, etc, also influence the position of the borehole (Xu and Braune 1995).

SULLAGE (GREYWATER) DISPOSAL

General

On-site excreta-disposal technologies require that separate provision be made for the disposal of sullage. Sullage, also referred to as greywater, is defined as all domestic wastewater other than toilet water. This refers to wastewater from baths, sinks, laundry and kitchen waste. Although this “greywater” is supposed not to contain harmful excreted pathogens, it often does: washing babies’ nappies, for example, automatically contaminates the water. Sullage, however, contains considerably fewer pathogenic micro-organisms and has a lower nitrate content than raw sewage. It also has a more soluble and biodegradable organic content.

Sullage is produced not only on private residential stands but also at communal washing places and taxi stands, and provision should therefore be made for its disposal.

Volumes

The per capita volume of sullage generated depends on the water consumption. The water consumption is to a large extent dependent on the level of water supply and the type of on-site sanitation the contributor enjoys. It is not difficult to find local figures of generation and one should try to obtain these, even if it requires actual measurement in the field. Typical figures are given in Table 10.2.

Health aspects

Mosquito breeding can take place where ponds are created by casual tipping of sullage, and conditions favourable for the development of parasitic worms could also be created in this way. Infection can also occur in constant muddy conditions. In order to reduce potential health hazards, it is of the utmost importance to choose the right option for sullage disposal. See also Figure 6.31, Chapter 6.

Disposal

The type of disposal system chosen by the designer will depend on various factors such as the availability of land, the volume of sullage generated per day, the risk of groundwater pollution, the availability of open drains, the possibilities of ponding and the permeability of the soil. Where water is available on the site, a disposal facility should definitely be considered.

Disposal systems

Sullage can be used to effect flushing of certain systems.

Casual tipping

Casual tipping in the yard can be tolerated, provided the soil has good permeability and is not continually moist. Where casual tipping takes place under other conditions it may result in ponding and/or muddy conditions, with adverse health effects as mentioned above. Good soil drainage and a low population density can accommodate this practice.

Garden watering

This practice can also be tolerated, provided plants and vegetables that are watered in this manner are not eaten raw, for disease transmission may occur.

Table 10.2: Sullage generation

AVAILABLE WATER SUPPLY AND SANITATION	SULLAGE GENERATION – LITRES PER CAPITA PER DAY
Standpipes, water vendors. Pit toilets.	20 - 30
On-site single-tap supply (yard connection). Pit toilets.	30 - 60

Soakaways

A soakaway is probably the safest and most convenient way of disposing of sullage, as long as soil conditions permit this. The design of the soakaway can be done according to the guidelines given in SABS 0400. Designers should be aware that groundwater pollution is still a possibility, though to a much lesser extent. Where simple maintenance tasks are able to be carried out, the use of grease traps should be considered.

Piped systems

The disposal of sullage in piped systems is hardly ever an economical solution, although it may be a viable option when dealing with communal washing points generating large amounts of sullage. Solids-free sewer systems are ideal for this purpose.

Sullage treatment

The fairly high BOD_5 value of sullage (typically 100 mg/ℓ) makes it unsuitable for discharging into rivers and streams. If treatment is required, single facultative ponds could be used.

TOILET PEDESTALS AND SQUATTING PLATES

Various types of toilet pedestals and squatting plates can be used with on-site sanitation systems. Members of some cultures are used to squatting for defecation, and cases of constipation have been recorded when they change to a sitting position. Some cultures also require water for anal cleansing.

The simplest form of appliance is a plain seat or pedestal, or a squatting plate. The hole should be approximately 250 mm in diameter for adults, and have a cover to restrict the access of flies and other insects to the pit. It is good practice to provide a second seat with a hole size of approximately 150 mm for young children, so that they need not fear falling into the pit. The plain seat found in a VIP toilet normally has similar dimensions.

Pedestals with water seals can be used in conjunction with most sanitation systems. Various methods can be employed to effect a water seal in a toilet system. They significantly increase user convenience by eliminating odour and screening the contents of the pit. Some water seal appliances require a piped water supply. These are not recommended for on-site sanitation systems, unless the extra water can be disposed of on the site (see the section on sullage disposal). Most water seal appliances can operate efficiently on a tank filled by a bucket of household wastewater.

A conventional toilet bowl is an example of a water seal pedestal, but it can require between 6 and 12 litres per flush. Special pans or bowls, so-called low-volume flush pans, have been developed that require only three litres per flush. These low-volume flush toilets do not have any negative effects on the self-cleaning capacity of waterborne sewerage systems. Various tipping-tray designs are also available, with flush requirements varying from 0,75 to 2 litres, depending on the design. These appliances have a shallow pan or tray that holds the water necessary for the seal. After use the tray is cleared by tipping it, allowing the waste matter to fall into the pit below. Thus the water is used solely for maintaining the seal, not for clearing the pan.

Pour-flush bowls can also be used to maintain a water seal. These pans are flushed by hand, using a bucket, and generally require about two litres per flush. The biggest disadvantage of this appliance is that the effectiveness of the flush depends on the human element – which varies greatly – and there is no control over the amount of water used per flush.

The pedestal of an aqua-privy does not have its own water seal. The water seal is effected by directing the pipe straight into the digester. No water is needed for flushing, but the level of liquid in the tank must be maintained.

DESIGN OF VIP TOILETS

Detailed design information can be obtained from the publication *Building VIPs* by Bester and Austin. A VIP Code of Practice is currently also under preparation by the SABS.

TOILET FACILITIES FOR PHYSICALLY DISABLED PERSONS

Some introductory remarks on water and sanitation facilities for disabled persons can be found under the section "Public or communal water-supply terminals" in Chapter 9.

Toilet aids help to preserve the dignity and independence of disabled persons. Outdoor toilets should be situated on smooth, even pathways, and ramps should be provided in lieu of steps. Ramps should be not less than 1100 mm wide, with a slope not exceeding 1:12. The appropriate layout and dimensions of a toilet room suitable for wheelchair users are shown in Figure 10.12. If there is enough space for a person using a wheelchair, then there should be enough space for ambulant people using crutches or technical aids. Taps or washbasins, if fitted, should also be in an accessible position and at an appropriate height for use from a wheelchair. Reference should be made to Part S of SABS 0400-1990 for further design information.

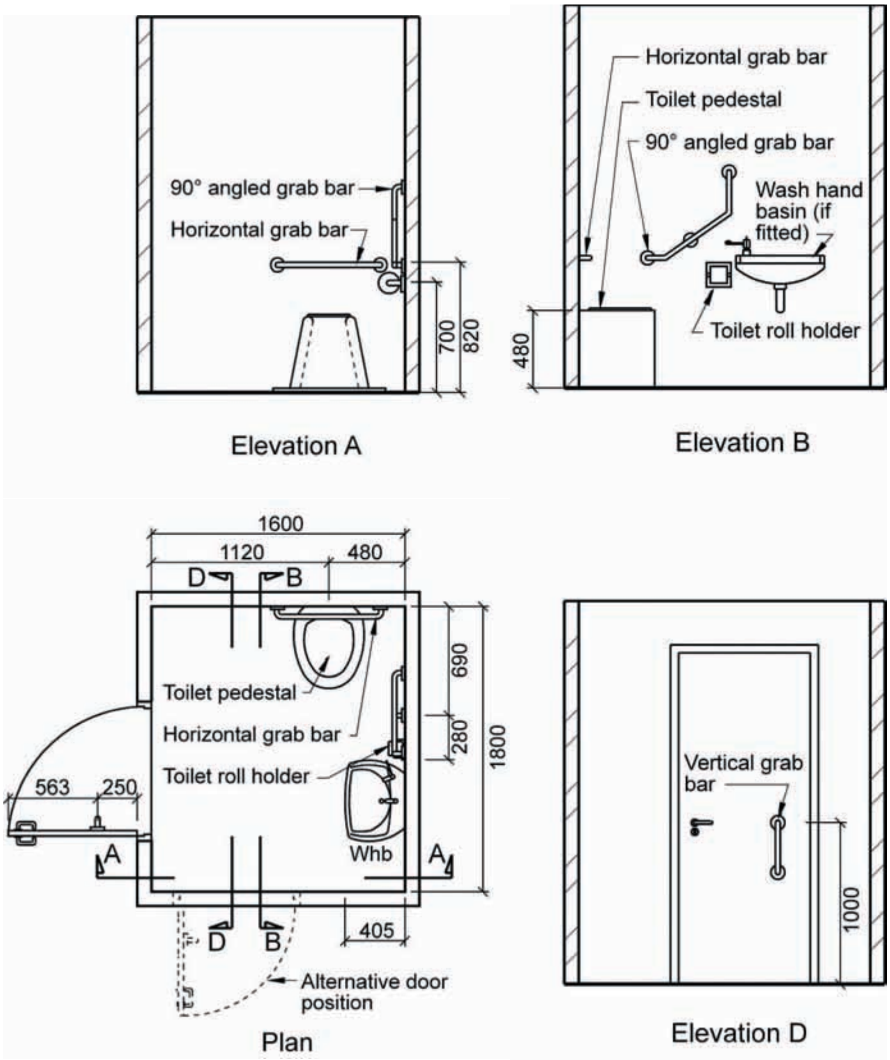

Figure 10.12: Minimum dimensions of a toilet room for physically disabled persons

TRAINING OF MAINTENANCE WORKERS

The training of local people as maintenance workers should be seen as an integral part of capacity-building within the community. Training should not take place merely because it is a fundamental principle or policy of the day.

Members of the community should be trained to install and operate a system, or to act as advisers to others who would like to install their own system. This can be achieved by establishing a “sanitation centre” where the community can purchase a variety of appliances and other necessary materials. The manager of this centre can be trained to become the local sanitation expert and can advise the population on maintenance requirements when necessary.

When assessing training needs, one must expect that some of the people trained will move to other areas where greater employment opportunities are available.

The degree of training and the amount of institutional support required will increase with the level of complexity of the sanitation system. On-site sanitation has the advantage that the greater part of the system belongs to the users. Sewer systems, on the other hand, have long lengths of underground piping and manholes, as well as pumping installations, which are the property of the local authority and must be regularly maintained by properly trained people in order for the system to work properly.

UPGRADING OF SANITATION FACILITIES

Possible upgrading routes should be considered when the initial choice of a system is made, particularly if an appreciable increase in the water supply is expected at some time in the future. However, it is unlikely that all the residents of a township will be able to afford upgraded services at the same time, which will be necessary if one is upgrading to full waterborne sanitation.

Most forms of pit toilet can be greatly improved by providing a water seal between the user and the excreta. This effectively stops odours and flies from exiting the pit via the toilet pedestal, and removes children's fears of falling into the pit. A water seal can be provided by a tipping-tray, a pour-flush or a low-flush toilet bowl. Designers should ensure that the quantity of water used with every cleaning operation does not increase the water content of the pit to a point where it can no longer be drained by the soil.

When the water supply is increased to the point at which the soil can no longer absorb it naturally (usually when an individual water connection is provided to each stand), it will be necessary to make special arrangements to remove the wastewater from each site in order to maintain healthy living conditions.

This is a major step in the upgrading process and will require additional financial input from the residents. The most economical solution may be a settled-sewage system, as this would be far easier to install in an existing settlement than a conventional sewer system.

If the developer is reasonably confident that the area's water supply will be upgraded within a few years, it may be advantageous to install septic tanks at the time of the original development. If this is done, then the settled-sewage system can be connected directly to the outlet from these systems and the soakaway can be bypassed and left inactive on the site.

Some possible upgrading routes are described in Appendix B.

OFF-SITE WASTEWATER TREATMENT

Off-site wastewater treatment is considered a specialised subject and, except for some general comments on pond systems and package purification units, falls outside the scope of this document. Where the introduction of a treatment works is considered, specialist consultants should be involved. The quality of effluent emanating from a wastewater treatment works is prescribed by legislation and has to meet licensing requirements. Water Services Providers should be licensed in terms of the National Water Act.

Pond systems

Although pond systems are regarded as treatment plants, the effluent does not normally meet acceptable effluent standards. Pond effluents have therefore to be irrigated. A pond system is regarded as a wastewater treatment works and its owner should also obtain a licence from the Department of Water Affairs & Forestry.

Pond systems are usually used in remote or developing areas, normally where land is available and relatively cheap. Skilled operators are not required and, depending on the circumstances, electricity need not be a requirement. Stabilisation (or oxidation) ponds are cheaper to build than conventional sewage purification works.

Although pond systems are regarded as being comparatively less sophisticated than other purification systems, they nevertheless require proper planning, application, design, construction and maintenance. Ponds do not need daily attendance, but should never be allowed to fall into disrepair.

The Water Institute of South Africa (WISA) has made available a design manual based on South African experience. This manual can be used as a guide to the design of pond systems.

Stabilisation or oxidation ponds are classified according to the nature of the biological activity taking place, as follows:

- facultative-aerobic ponds (where aerobic and facultative conditions exist) – facultative organisms use dissolved oxygen when it is available, but convert to anaerobic processes in its absence; and
- anaerobic-aerobic ponds (where the primary ponds are completely anaerobic and the secondary ponds are mainly aerobic).

The following important aspects should be considered regarding siting and land requirements:

- the cost of the land;
- the minimum distance between pond systems and the nearest habitation;
- the direction of the prevailing winds – ponds should, as far as possible, be downwind of town limits;
- possible groundwater pollution;
- geotechnical conditions that will influence costs;
- the land required for irrigation purposes, which is an integral part of the pond system; and
- the topography of the site, which can influence costs.

Irrigation of crops may take place only as prescribed in the publication *Permissable utilisation and disposal of sewage sludge* by the Water Research Commission 1997.

Package purification units

The use of package purification units is dependent on factors similar to those mentioned above, but the operational costs involved when opting for package purification plants should be carefully considered. It is not a preferred option.

APPENDIX A

INFORMATION REQUIRED FOR THE PLANNING AND DESIGN OF SANITATION PROJECTS

This appendix gives information regarding data that should be collected for the proper planning, design and implementation of a sanitation project. Note that the definition of sanitation in the White Paper on Basic Household Sanitation of 2001 is the following:

> "Sanitation refers to the principles and practices relating to the collection, removal or disposal of human excreta, household wastewater and refuse as they impact upon people and the environment. Good sanitation includes appropriate health and hygiene awareness and behaviour, and acceptable, affordable and sustainable sanitation services.
>
> The minimum acceptable basic level of sanitation is:
>
> (a) appropriate health and hygiene awareness and behaviour;
>
> (b) a system for disposing of human excreta, household wastewater and refuse, which is acceptable and affordable to the users, safe, hygienic and easily accessible and which does not have an unacceptable impact on the environment; and
>
> (c) a toilet facility for each household."

COMMUNITY MANAGEMENT APPROACH

Research done and projects launched in culturally different communities require an openness and adaptability to the issues that are important to the community. A growing awareness of the failures of conventional development approaches in meeting the needs of people with few resources has led to the exploration of alternative methodologies for investigating resource-management issues, and planning, implementing and evaluating development initiatives. There is a wide range of approaches with strong conceptual and methodological similarities. These include:

- Participatory rural appraisal (PRA);
- Participatory learning methods (PALM);
- Rapid rural appraisal (RRA);
- Rapid assessment procedures (RAP);
- Participatory action research (PAR);
- Rapid rural systems analysis (RRSA);
- The demand responsive approach (DRA);
- The SARAR approach;

and many others. The themes common to all of these approaches are:

- the full participation of people in the processes;
- the concept of learning about their needs and opportunities; and
- the action required to address them.

The experience gained in the past decade in particular has pointed to the need for three key elements to be successful both in water-supply and in sanitation projects, namely:

- involvement of the community in all aspects of the projects;
- the use of appropriate technology; and
- the need for institution-building and -training activities in conjunction with the project.

Community development, however, does not take place in a vacuum; it is always situated in a concrete social, economic and political context. Therefore, it is of the utmost importance that a multi-disciplinary team be involved in community development. Because development is development for the people, the people should remain central to the process. To ensure this, it is inevitable that social engineering should precede any development project, and run parallel with it until completion of the project.

Over the past few years, holistic development has become a vital aspect of sustainable development. It is recognised worldwide that projects that take human factors into consideration are more likely to be successful than those that do not. It is therefore of the utmost importance for development agencies to collaborate closely with communities at inception and through all stages of infrastructural development.

As distinct from community participation, community management means that beneficiaries of infrastructural services have the responsibility for, and authority and control over the development of such services.

Although the spin-offs of this approach are obvious, they are not easy to achieve within a short space of time. It should also be noted that the mere participation of communities in the project is not a solution, but a necessary forerunner of successful community projects. It is imperative that participation should be coupled with capacity-building efforts through training.

The application of scientific research methods (such as fact-finding and community surveys) is recommended in the initial stages of community development. These methods can be adapted in research forums that promote community participation, and which will create opportunities for interaction between the developer and the identification of needs by community members themselves. Examples include community surveys, social reconnaissance and action research. This emphasises a systems approach and inter-disciplinary teamwork, continued involvement of the community members in all decisions and activities, development as a learning process (including the need for training), and continued monitoring and evaluation activities.

Seven phases have been identified in the participatory strategy for integrated rural development.

Phase 1

This phase consists of an initial reconnaissance of the community among which the project is going to be implemented by the social scientist or community worker. Existing documentary sources about the community are studied and field visits, mini-surveys and interviews with key people, etc, are undertaken. The main aim is to identify initial goals and to commit the development committee, which must include representatives (male and female) from the community, to these goals.

Phase 2

The second phase is the identification of priorities by means of field studies and research. The planner/developer performs specific investigations in order to identify areas of priority or problems. Community members and other agents are trained in problem identification and analysis. Insight is also gained in the functioning of the system and its problems.

Phase 3

The third phase consists of the formulation of possible solutions for the identified problems. The social scientist or community worker gives direction, but community members are involved fully in exercises of discovering solutions. Continued involvement and participation of the community members should be ensured.

Phase 4

In the fourth phase feasibility studies are performed. It is important that objectives be compatible with each other.

Phase 5

This phase is the implementation of the project. The implementation implies various political and planning activities, such as official approval of the project, planning and design, formal project descriptions, communication with the authorities, liaison and linkage with other institutional agencies, financial support, physical input and specific services.

Phase 6

This phase consists of planning the completion, termination, or continuation of the project. Community members should be trained in the operation and maintenance of the system, and supported in their efforts for a period of time to ensure sustainability.

Phase 7

The seventh phase refers to project evaluation. Formal project evaluation, preferably by an external agent, is supported by internal evaluation procedures as an ongoing activity in the development process. Monitoring and auditing form part of the evaluation activities. The main function of evaluation is to identify weaknesses in a project, in order to avoid similar problems and facilitate sound planning in future projects.

HUMAN-RELATED DATA

The following data are necessary to ensure sustainability.

Socio-cultural data

Religious and tribal customs, as well as cultural factors affecting the choice of technology (for example, traditional materials and practices for cleansing and ablution), include:

- the general level of literacy and education, especially hygiene education;
- important watersource-related activities (such as laundry, bathing and animal watering); and
- community attitudes to the recycling and handling of decomposed human waste.

Community preferences

After considering costs, note preferences of the community regarding the following:

- the type of sanitation service;

- the position of the toilet (for example, should it be inside or outside the house? If outside, should the toilet door face the house? How far should the toilet be from the house?);
- the appearance of the toilet building and pedestal (colour, form, etc);
- the size of the toilet;
- the seats or squatting plates; and
- the permanency of the superstructure.

Economic and social conditions

These include:

- present living conditions, types of housing (including condition, layout and building materials used) and occupancy rates;
- population numbers according to income levels (present and projected), and the age and sex distribution of the community ethnic groups, and settlement patterns in the project area;
- land-use and land-tenure patterns;
- locally available skills (managerial and technical); and
- major occupations, approximate distribution, unemployment and under-employment.

Health and hygiene conditions

These include:

- location of toilet/defecation sites;
- toilet maintenance (structure and cleanliness);
- disposal of children's faeces;
- hand-washing and use of cleansing materials;
- sweeping of floors and yard;
- household refuse disposal;
- drainage of surrounding area;
- incidence and prevalence of water- and faeces-related diseases;
- treatment of diseases; and
- access to doctors/clinics/hospitals.

Institutional framework

These include:

- The identification and description (responsibility, effectiveness and weaknesses) of all institutions and organisations, both governmental and non-governmental, that are providing the following services in the project area:
  - water and sanitation;
  - education and training;
  - health and hygiene;
  - housing;
  - building material supplies; and
  - transport.
- Identification of all other major local organisations (social and political), the type and number of members they have and the influence they could have on the project.

Environmental and technical aspects

Important factors to consider are:

- the position of the site in relation to existing settlements;
- existing supplementary services (type, availability, reliability, accessibility, cost, etc) such as water supply, roads, energy sources and sanitation schemes;
- environmental problems such as sullage removal, stormwater drainage, refuse removal, transport routes;
- site conditions such as topography, geology (soil stability, rockiness, permeability, etc);
- groundwater data, such as availability, quality and use;
- prevailing climatic conditions such as rainfall, temperature and wind;
- type and quantity of local building materials that may be suitable;
- existing building centres supplying building materials and equipment (type of materials and equipment, availability, quality and cost); and
- the need for, and existence of, appropriate building regulations and by-laws.

INFORMATION REQUIRED FOR POST-PROJECT EVALUATION

To evaluate the success and sustainability of a sanitation project, it is necessary to correlate environmental conditions in the project area with the health profile of the community concerned after the scheme has been in operation for some time (especially projects where the upgrading of existing services is planned). To be able to do this, additional information should be collected – for example the following:

- A concise description of the community's living conditions in general, and their existing sanitation and water supply facilities in particular.
- How long have the people been living in the area and for what period have the existing sanitation facilities been in use?
- With regard to the community's perception of the present situation and sanitary practices, and their interest in or susceptibility to change:
    - Do they regard the present water supply as satisfactory, in quantity and quality?
    - What arrangements are there for refuse removal – do they regard them as satisfactory?
    - What facilities exist for personal hygiene – where do they bathe or wash themselves?
    - Are they aware of any advisory service on health and hygiene, and do they make use of it?
    - What amount of money do they spend on

      doctors, clinics, medicines and other health-related aspects?
    - Do they regard the present sanitation facilities as adequate?
- Identify all major health problems in the community:
    - List all diseases recorded in the area that can be related to water supply and sanitation.
    - Obtain figures on present morbidity and mortality rates.
    - Identify possible disease-contributing factors, such as possible contamination of drinking water.
    - What was the actual total cost of the project?

APPENDIX B

UPGRADING OF EXISTING SANITATION SYSTEMS

BASIC UPGRADING ALTERNATIVES

Alternative 1 – Aesthetic upgrading

The options in this category can be implemented by individual stand-owners, as the necessary financial resources become available. These are limited to the superstructure and the pedestal. An example would be where a functional superstructure is replaced with a more permanent or more aesthetic structure, such as one built from bricks and mortar. The property owner can decide on factors such as the size of the superstructure and whether the door should open inward or outward. The door and roof materials of the original superstructure could be re-used.

Alternative 2 – Introduction of a water seal

This will effectively remove odours emanating from the pit and will ensure that the user cannot see the excreta. This will also reduce the fear, particularly among children, of falling into the pit. A water seal can be introduced by installing a tipping tray, a pour-flush pan or a low-flush pan. The difference between the three types of water seal lies mainly in the quantity of water required, and thus their suitability would also depend on the ability of the soil to drain the additional quantity of water supplied to the site. This type of upgrading can be undertaken by the individual owner whenever funds are available. Depending on what type of water-seal appliance is used, it may or may not be necessary to provide an individual water connection to each stand.

Alternative 3 – Removal of liquids from the site

When individual water connections are provided to each stand, the situation will often arise where the soil can no longer adequately drain the additional water. This makes the removal of water necessary to maintain health standards. Liquids can be removed from the site by means of sewers (either a full waterborne sanitation system or a settled sewage system), or they may be retained on site in a conservancy tank and then removed periodically by a vacuum-tanker service. The installation of a sewer system will be a costly step in the upgrading process, and will require each resident to contribute to the construction costs, or some form of outside subsidy will need to be found. The ability of the local authority to manage and maintain these sanitation systems must be assessed when considering the introduction of the system. Generally, the sewers would need to be laid in the entire township at the same time. Upgrading should be undertaken only when the community can afford to pay for the higher level of service. Practically, this means that upgrading in Group 1 and 2 can be implemented at any time by individual property owners, independently of neighbours. On the other hand, upgrading in Group 3 will require both the greatest financial outlay from the property owners and implementation of the entire development at the same time. Note that, in the case of a settled sewage system, the sewers will need to be laid to neighbourhoods at the same time, but individual owners need not all connect to the system simultaneously, since it is not necessary to maintain cleansing velocities in sewers that convey only the liquid portion of the wastes. Thus, property owners could connect to the system when they have the financial means to construct the necessary solids-retention tank. Note that some on-site sanitation systems, for example septic tanks, can be used as solids-retention tanks and therefore can be connected to the settled-sewage system with only minor alterations.

UPGRADING ROUTES FOR THE VARIOUS SANITATION SYSTEMS

There are many possible upgrading routes that could be taken and the following should be seen as an indication of the various possibilities for the systems as defined in Table 10.1, which categorises sanitation systems.

Group 1

Upgrading chemical toilets

The use of chemical toilets would probably be a temporary solution in a developing community. Upgrading to a more permanent system would therefore take the form of total replacement with any one of the other sanitation systems. The chemical toilet would be removed from the site as a unit; thus there would not be any re-use of materials.

Group 2

Upgrading unventilated pit toilets

The first and most important step in upgrading would be to install a vent pipe to convert the toilet into a ventilated improved pit (VIP) toilet. This upgrading should be undertaken at the earliest possible opportunity. After the addition of a vent pipe, further upgrading would follow the same route as a VIP toilet.

Upgrading ventilated improved pit (VIP) toilets

The VIP toilet provides several opportunities for upgrading. A major improvement can be obtained by introducing a water seal between the user and the excreta, thus providing a level of convenience that is more acceptable to users.

It may thus be necessary to consider Alternative 3 upgrading (removal of liquids from the site) only if problems arise with the drainage of excessive quantities of water, which situation can be expected when individual water connections are provided to each site. Since the pit of a VIP toilet is not watertight, it will probably be necessary to construct a new tank on the site for solids retention if upgrading to a settled-sewage system is required. The pit of the VIP toilet will then become redundant. Thus, if at the outset the final stage of the upgrading route is known to be a conservancy-tank or settled-sewage system, it is preferable to begin with a sealed-tank system (such as a vault toilet, aqua-privy or on-site digester), to avoid constructing a new tank when the upgrading takes place.

The installation of a urine-diversion pedestal will make a significant difference to a VIP toilet. The contents of the existing pit should be covered with a layer of earth, and the structure may thereafter be operated as a normal urine-diversion toilet, where urine is diverted to a soakpit or collection container and faeces are covered with ash or dry soil.

Upgrading ventilated vault (VV) toilets

This system is a variation of the VIP toilet, with the important distinction that it has a waterproof pit or vault. The comments on upgrading in Alternatives 1 and 2, for VIP toilets, also apply to this system. Upgrading to Alternative 3 will be different from that of the VIP toilet because the VV toilet has a lined, waterproof vault that can be used. The option of upgrading to a conservancy tank is not mentioned because the ventilated vault toilet is a type of conservancy tank. Because the VV toilet already has a waterproof tank, this system is ideal for upgrading to a settled sewage system and it is therefore highly unlikely that this system would be upgraded to a fully waterborne sewer system.

Upgrading ventilated improved double pit (VIDP) toilets

This system is basically a variation of the VIP toilet, so the comments for the VIP also apply to the VIDP toilet.

Group 3

Upgrading full waterborne sanitation

No upgrading of this system is necessary, but the stand owner can implement aesthetic improvements to the pedestal and superstructure.

Upgrading conservancy tank systems

A conservancy tank provides an ideal opportunity for upgrading to a settled sewage system, since the tank can be used to retain solids on the site.

Upgrading the settled sewage system

No upgrading of this system is necessary, but the stand owner can implement aesthetic improvements to the superstructure.

Group 4

Upgrading septic tank systems

A septic tank also provides an ideal opportunity for upgrading to a reticulated system, since the outlet from the septic tank can be connected to a settled sewage system without any further alterations being necessary. Solids would be retained on the site and digested in the septic tank.

Upgrading aqua-privies

The aqua-privy has a rough water seal, but this can be greatly improved by removing the pedestal and chute and replacing them with a device such as a tipping-tray, pour-flush or low-flush pan. An aqua- privy also provides an ideal opportunity for upgrading to a settled sewage system, since the outlet from the aqua-privy can be connected into the reticulation system without any further alterations. Solids would then be retained on the site and digested in the aqua-privy tank.

APPENDIX C

DESIGN GUIDELINES FOR WATERBORNE SANITATION SYSTEMS

SCOPE

These guidelines are applicable to the design and construction of sewerage reticulation for undeveloped residential areas, where the future houses are to be provided with full waterborne sanitation. They do not apply to on-site drainage, and do not cover any form of on-site disposal such as septic tanks and soil-percolation systems. They also do not apply to settled sewage systems.

Certain basic guidelines applicable to non-gravity systems (i.e. pump stations and rising mains) are included, but detailed design criteria for these systems are not included, as they are regarded as bulk services.

Except in cases where illustrations are provided, the reader is referred to various figures in the relevant sections of SABS 1200.

DESIGN CRITERIA

Design flows

Flow-rate units

The unit of flow rate used in these guidelines is litres per second (ℓ/s).

Depth of flow and infiltration

Sewers should be designed to flow full at the peak design flow. An allowance of 15 per cent for stormwater infiltration and other contingencies should be incorporated in the design figures used for single-family dwelling units.

Average daily flow (A)

The average daily flow per single-family dwelling unit is given in Table C.1.

General residential

For erven zoned as “general residential”, including blocks of flats and hotels, an average daily flow of 600 litres per day for every 100 m^2 of erf size should be used.

Notes:

(i) The above figure is based on a dwelling unit with a floor area of 100 m^2 and a floor space ratio (FSR) of 0,6. If a FSR other than 0,6 is prescribed, the flow figure above should be adjusted accordingly.

(ii) Maximum density allowable under the scheme is the overriding factor.

Church sites

A church site should be treated as a “special residential” erf.

Schools and business sites

The discharge from day schools and business sites need not be taken into account, since these are relatively minor flows that do not peak at the same time as the main residential flow.

Peak design flows

In these guidelines the following factors apply to single-family dwelling units:

Peak Factor (PF) = 2,5

Percentage allowed for extraneous flow = 15 %

To calculate the unit design flow rate:

Average daily flow (ℓ/du/d) = A

$$\text{Average daily flow rate } (\ell/s) = \frac{A}{24 \times 60 \times 60} = \frac{A}{86\,400}$$

Table C.1: Average daily flows per single-family dwelling unit (du)

INCOME GROUP	LOWER	MIDDLE	HIGHER
Litres per dwelling unit per day	500	750	1 000
Based on average total persons per dwelling unit	7	6	5

Peak flow rate = Average daily flow rate x peak factor

$$\frac{A \times 2{,}5}{86\ 400} = B$$

Design flow rate = Peak flow rate + % of peak flow rate for extraneous flows

$$B \times 1{,}15 = \frac{A \times 2{,}5 \times 1{,}15}{86\ 400}$$
$$= 0{,}000\ 033\ A$$
$$= C$$

Thus, for a population up to 1 500,

$$C = \frac{A\ (\ell/s/du)}{30\ 000}$$

Thus, from Table C.1:

C = 0,0167 ℓ/s/du for lower income group
= 0,0250 ℓ/s/du for middle income group
= 0,0333 ℓ/s/du for higher income group

If unit design flows are, instead, obtained from actual flow-gauging of adjacent settlements of similar nature, these unit design flows should not exceed those given above.

Attenuation

To take advantage of the attenuation of peak flows in gravity sewer systems as the contributor area and population increases, design peak factors may be reduced in accordance with the graph in Figure C.1 for sizing any sewer receiving the flow from a population greater than 1 500. If actual local attenuation factors are available, however, these should be used instead.

Hydraulic design

Flow formulae

The following flow formulae are acceptable for the calculation of velocity and discharge in sewers:

Manning	(n = 0,012)
Crimp and Bruges	(n = 0,012)
Colebrook-White	(Ks = 0,600)
Kutter	(n = 0,012)

Any formula can be used as long as it produces values approximately the same as the equivalent Colebrook-White formula using Ks = 0,6.

Minimum size of sewers

The minimum diameter of pipe in sewer reticulation should be 100 mm.

Limiting gradients

Sewers may follow the general slope of the ground, provided that a minimum full-bore velocity of 0,7 m/s is maintained.

Table C.2 shows the minimum grades required to achieve this minimum full-bore velocity for various pipe sizes up to 300 mm in diameter.

If flatter grades and lower velocities than those in

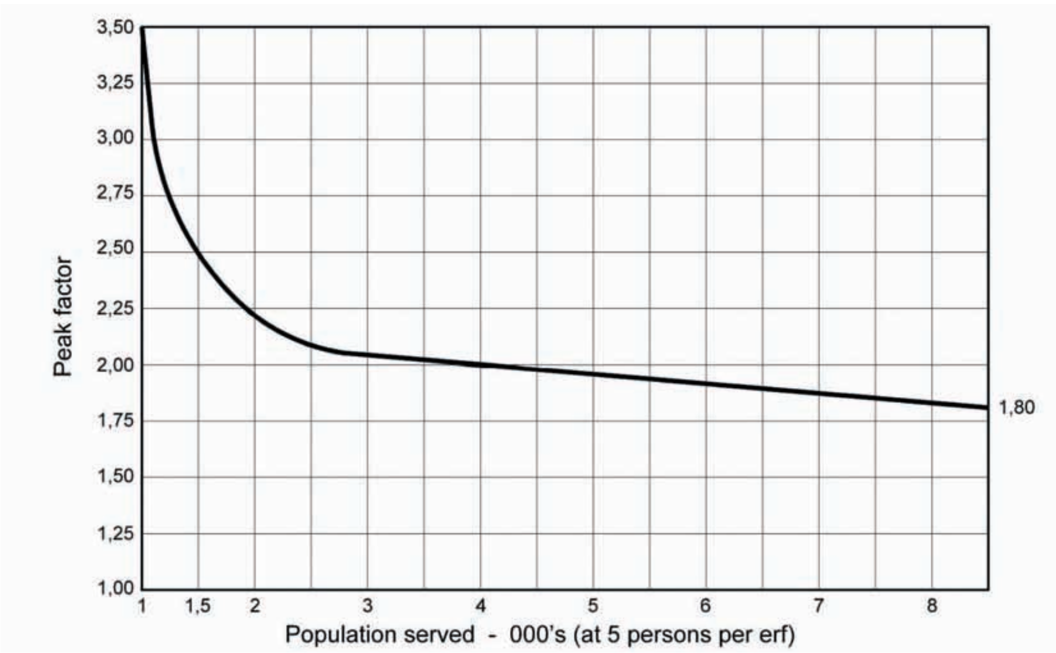

Figure C.1: Attenuation of peak flows

Table C.2: Minimum sewer gradients

SEWER DIAMETER (MM)	MINIMUM GRADIENTS
100	1 : 120
150	1 : 200
200	1 : 300
225	1 : 350
250	1 : 400
300	1 : 500

Table C.2 are contemplated, it is essential that a detailed cost-benefit study be carried out. This should take into account the cost of the regular systematic maintenance and silt/sand removal that will be required when flatter grades and lower velocities are used, instead of the additional first cost required to maintain the above minimum grades and full-bore velocity of 0,7 m/s.

Non-gravity systems

Rising mains
Velocities:
The minimum velocity of flow in a rising main should be 0,7 m/s.

The maximum velocity of flow in a rising main should be 2,5 m/s.

Minimum diameter:
The minimum diameter of a rising main should be 100 mm, except where a macerator system is used, in which case the diameter can be reduced to 75 mm.

Gradient:
Wherever practicable, rising mains should be graded so as to avoid the use of air and scour valves.

Stilling chambers:
Stilling chambers should be provided at the heads of all rising mains, and should be so designed that the liquid level always remains above the soffit level of the rising main where it enters the chamber. Stilling chambers should preferably be ventilated.

Sumps for pump stations
Emergency storage:
A minimum emergency storage capacity representing a capacity equivalent to four hours flow at the average flow rate should be provided, over and above the capacity available in the sump at normal top-water level (i.e. the level at which the duty pump cuts in). This provision applies only to pump stations serving not more than 250 dwelling units. For pump stations serving larger numbers of dwelling units, the sump capacity should be subject to special consideration in consultation with the local authority concerned. Emergency storage may be provided inside or outside the pump station.

Sizing:
In all pump stations, sumps should be sized and pump operating controls placed so as to restrict pump starts to a maximum of six per hour.

Flooding:
Care should be taken in the design of pump stations in order to avoid flooding of the dry well and/or electrical installations by stormwater or infiltration.

Screens:
Adequate protection, where necessary, in the form of screens or metal baskets, should be provided at the inlets to pump stations for the protection of the pumping equipment.

Pumps
Standby:
All pump stations should be provided with at least one standby pump of a capacity at least equal to the capacity of the largest duty pump. The standby pump should come into operation automatically if a duty pump or its driving motor fails due to mechanical failure.

Safety precautions
Safety precautions in accordance with the relevant legislation should be incorporated into the design of all pump stations and, in particular:

- all sumps and dry wells should be adequately ventilated;
- handrails should be provided to all landings and staircases and to the sides of open sumps and dry wells;
- skid-proof surfaces should be provided to all floors and steps; and
- the layout of the pumps, pipework and equipment should allow easy access to individual items of equipment without obstruction by pipework.

Physical design

Minimum depth and cover

Except under circumstances discussed in the following paragraph, the following are the recommended minimum values of cover to the outside of the pipe barrel for sewers other than connecting sewers:

- in servitudes 600 mm
- in sidewalks 1,4 m below final kerb level
- in road carriageways 1,4 m below final constructed road level

Lesser depths of cover may be permitted, subject to integrated design of all services including trunk services allowed for in development plans, provided that, where the depth of cover in roads or sidewalks is less than 600 mm, or in servitudes less than 300 mm, the pipe should be protected from damage by:

- The placement of cast-in-situ or precast concrete slab(s) over the pipe, isolated from the pipe crown by a soil cushion of 100 mm minimum thickness. The protecting slab(s) should be wide enough and designed so as to prevent excessive superimposed loads being transferred directly to the pipes (see Figure C.2); or

225 mm diameter. Standard rigid pipes are laid on either Class D or Class C beds, as depicted in Drawing LB-1 of SABS 1200 LB, while flexible pipes (plastic or pitch fibre) are laid according to Drawing LB-2 of SABS 1200 LB.

Structural design of the pipe/bedding should be checked where trenches are:

- located under roads;
- deeper than 3 metres; and
- other than those classified as “narrow” (i.e. where overall trench width is greater than nominal pipe diameter d + 450 mm for pipes up to 300 mm diameter).

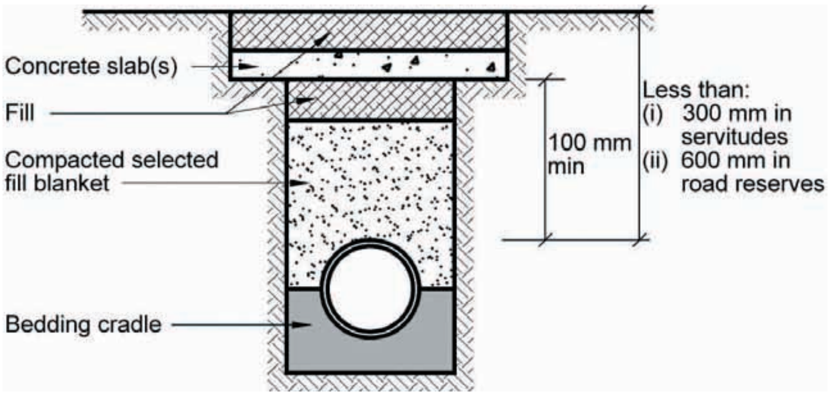

Figure C.2: Protection of pipes at reduced depths of cover (e.g. Class B bedding)

- The use of structurally stronger pipes able to withstand superimposed loads at the depth concerned; or
- The placement of additional earth filling over the existing ground level in isolated cases where this is possible.

Except in very special circumstances, the encasement of pipes in concrete is not recommended. Where encasement is unavoidable, it should be made discontinuous at pipe joints, so as to maintain joint flexibility (see Figure LD-6 of SABS 1200 LD).

Trenching, bedding and backfilling

The trenching, bedding and backfilling for all sewers should be in accordance with the requirements of SABS 1200 LB and the supporting Specifications.

Under normal ground conditions, structural design considerations for pipe strength and increased bedding factors do not come into play for sewers up to

Where grades steeper than 1 in 10 are required, 15 MPa concrete anchor blocks should be provided that are at least 300 mm wide and embedded into the sides and bottom of the trench for at least 150 mm, as shown on Drawing LD-1 of SABS 1200 LD.

Curved alignment

A straight alignment between manholes should normally be used, but curvilinear, horizontal or vertical alignment may be used where the economic circumstances warrant it, subject to the following limitations:

- the minimum radius of curvature is 30 m;
- curvilinear alignment may be used only when approved flexible joints or pipes are used;
- in the construction of a steep drop, bend fittings may be used at the top and bottom of the steep short length of pipe, thus providing a curved alignment between the flat and steep gradients.

Siting

Sewers should be sited so that they provide the most economical design, taking the topography into account (i.e. in road reserves, servitudes, parks, open spaces, etc). When the sewer is to be located in a trench by itself, the minimum clear width to be allocated to it in the road reserve should be 1,5 m.

Manholes

Location and spacing
Manholes should be placed at all junctions and, except in the case of curved alignment and at the top of shallow drops, at all changes of grade and/or direction.

The maximum distance between manholes on either straight or curved alignment should be:

- 150 m where the local authority concerned has power rodding machines and other equipment capable of cleaning the longer lengths between manholes;
- 100 m where the local authority concerned has only hand-operated rodding equipment.

Note:
The economics of acquiring power cleaning equipment in order to permit a greater manhole spacing should be demonstrated to local authorities.

Where manholes have to be constructed within any area that would be inundated by a flood of 50-years recurrence interval, they should, wherever practicable, be raised so that the covers are above this flood level.

Sizes
The minimum internal dimensions of manhole chambers and shafts should be as shown in Table C.3. The minimum height from the soffit of the main through pipe to the soffit of the manhole chamber roof slab, before any reduction in size is permitted, should be 2 m.

Benching
An area of benching should be provided in each manhole so that a man can stand easily, comfortably, and without danger to himself, on such benching while working in the manhole.

Table C.3: Minimum internal dimensions of manhole chambers and shafts

SHAPE	CHAMBER	SHAFT
Circular	1 000 mm	750 mm
Rectangular	910 mm	610 mm

Manhole benching should have a grade not steeper than 1 in 5 nor flatter than 1 in 25, and should be battered back equally from each side of the manhole channels such that the opening at the level of the pipe soffits has a width of 1,2 d, where d is the nominal pipe diameter.

Design
All manholes, including the connection between manhole and sewer, should be designed in accordance with the requirements of SABS 1200 LD and, where manholes are of cast-in-situ concrete, chambers, slabs and shafts should be structurally designed to have a strength equivalent to a brick or precast concrete manhole.

For manholes located in road reserves, spacer rings or a few courses of brickwork should be allowed for between the manhole roof slab and the cover frame, in order to facilitate minor adjustments in the level of the manhole cover. Adjustable manhole frames may also be used.

Steep drops
Steep drops should be avoided wherever possible, but where this is unavoidable (e.g. to connect two sewers at different levels), use should be made of a steep, short length of pipe connected to the higher sewer by one or more 1/16 bends and to a manhole on the lower sewer also by one or more 1/16 bends, as shown in Figure C.3.

Sewer connections

Size and siting
Each erf, excepting those listed below, should be provided with a 100 mm (minimum) diameter connecting sewer, terminating with a suitable watertight stopper on the boundary of the erf or the boundary of the sewer servitude, whichever is applicable. The connecting sewer should be located deep enough to drain the full area of the erf portion on which building construction is permitted.

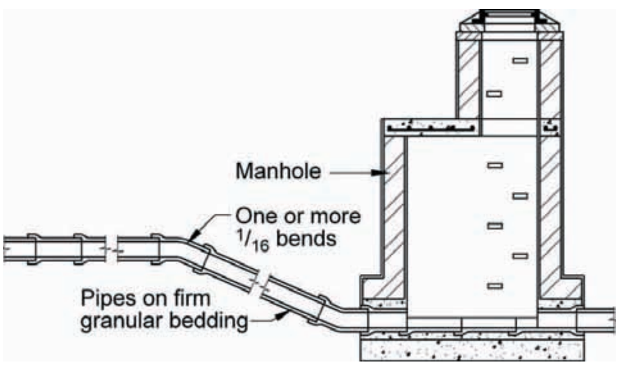

Figure C3: Steep drops in sewers

Exceptions

- In special residential areas, where an erf extends for a distance of more than 50 m from the boundary to which the connecting sewer is laid, provision need only be made to drain the area of the erf within 50 m of this boundary.
- School sites should be given special consideration with regard to the position, diameter and depth of the connection(s) provided.
- Where detailed development proposals are submitted for subdivided erven as group schemes, one connecting sewer may be provided to serve such group of erven.

Note:
Where erven have to be connected to a sewer on the opposite side of a street, consideration should be given to the economics of providing 100 mm diameter sewer branches across the road to serve the connecting sewers from two or more erven.

The sewer connection should be provided at the lowest suitable point on the erf. On street boundaries the connection should be located either at a distance of 1,15 m or at a distance of 5 m or more from a common boundary with an adjacent erf, unless a local authority has already an accepted standard location.

Depth and cover
Except under the circumstances described in the following paragraph, recommended minimum values of cover to the outside of the pipe barrel for connecting sewers are:

- in servitudes 600 mm
- in road reserves 1 000 mm

Where lesser depths of cover are permitted, this should be subject to the same conditions discussed previously in this appendix, and the same protection should be provided.

When designing the invert depth of the main sewer in order to ensure that all the erven can drain to it, the fall required from ground level at the head of the house drain to the invert of the main sewer at the point where the connecting sewer joins the main sewer should be taken as the sum of the following components:

- 450 mm to allow for a minimum cover, at the head of the house drain, of 300 mm, plus 150 mm for the diameter and thickness of the house drain;
- the fall required to accommodate the length of the house drain and the connecting sewer, assuming a minimum grade of 1 in 60 and taking into account the configuration of the erf and the probable route and location of the house drains; and
- the diameter of the main sewer (see Figure LD-7 of SABS 1200LD).

Note:
In the case of very flat terrain, and where the house drains may be laid as an integral part of the engineering services, flatter minimum grades than 1 in 60 for the house drains may be considered. This relaxation could also be applied to isolated erven difficult to connect, or the ground in such erven could be filled to provide minimum cover to the drains.

Junction with main sewer
A plain 45° junction should be used at the point where the connecting sewer joins the main sewer. Saddles should not be permitted during initial construction.

Type details
Details of the connecting sewer should be in accordance with one of the types shown in Figures LD-7 and LD-8 of SABS 1200LD.

Invert levels

The invert levels indicated at a manhole location should be the levels projected at the theoretical centre of the manhole by the invert grade lines of the pipes entering and leaving such manhole. In cases where branch lines with smaller diameters enter a manhole, the soffit levels of these branch lines should match those of the main branch line. However, in areas where pipes are laid to minimum grades, this practice may need to be relaxed.

The slope of the manhole channel should be as required to join the invert levels of the pipes entering and leaving the manhole, without allowing any additional fall through the manhole chamber.

MATERIALS

Pipes and joints

Pipes suitable for the conveyance of sewage, under the particular working and installation conditions to which they will be subjected, should be in accordance with Sections 3.1 and 3.2 of SABS 1200 LD.

All joints for rigid pipes should be of a flexible type, and rigid joints should only be used where the pipes themselves are flexible.

Manholes

All materials used for manholes should be in accordance with Section 3.5 of SABS 1200 LD.

Pumping installations

In general, all materials should be durable and suitable for use under the conditions of varying degrees of corrosion to which they will be exposed.

Pipework

The relevant requirements for materials given in SABS 1200 L and 1200 LK should apply if a rising main forms part of the sewerage system.

Concrete

Structural reinforced concrete and plain concrete below ground level and/or in contact with sewage should be designed and constructed in accordance with SABS 1200 G or 1200 GA, whichever is applicable.

Structural steelwork

All exposed steelwork should be adequately protected against corrosion with a suitable approved paint system, and should otherwise be designed and constructed in accordance with SABS 1200 H or 1200 HA, whichever is applicable.

Electrical installations

All electrical installations should comply with the Factories Act and with the relevant local authority electricity supply by-laws/regulations.

Other materials

Other materials used should comply with the requirements of SABS 1200 LD where relevant.

GLOSSARY

BOD_5: The oxygen used for bacterial oxidation of organic pollutants or ammonia, determined under standard conditions of incubation at 20° C over 5 days.

Sullage: Wastewater emanating from baths, kitchen sinks, laundries and showers (toilet water is excluded).

Thermophilic bacteria: A kind of bacteria functioning best at a certain temperature range.

Thixotropic: Refers to the property of becoming temporarily liquid when disturbed and returning to its original state when stationary.

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