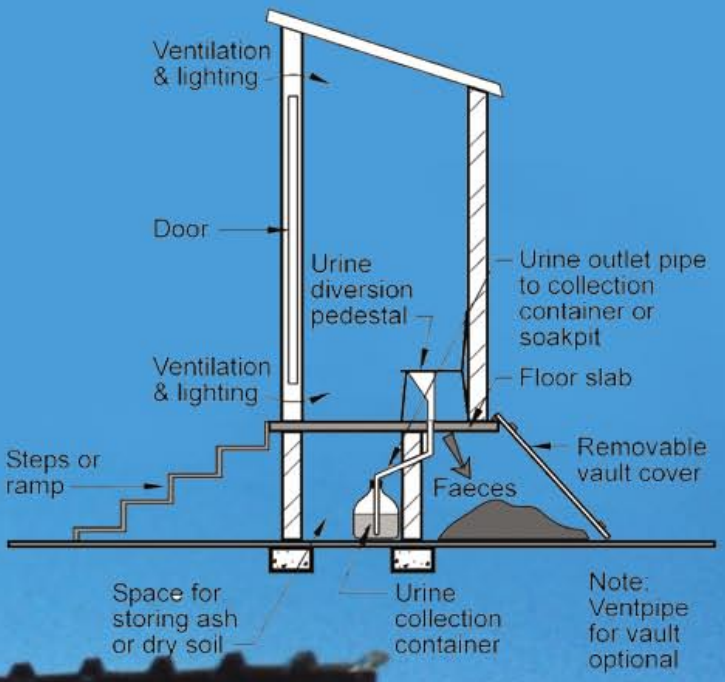
Guidelines for the Design, Operation and Maintenance of Urine-Diversion Sanitation Systems

Volume 4

LM Austin



TT 275/06
Water Research Commission

GUIDELINES FOR THE DESIGN, OPERATION AND MAINTENANCE OF URINE-DIVERSION SANITATION SYSTEMS

Volume 4

Report to the

WATER RESEARCH COMMISSION

by

LM Austin

CSIR Built Environment

WRC TT 275/06

JULY 2006

Obtainable from:

Water Research Commission
Private Bag X03
Gezina
0031

The publication of this report emanates from a project entitled: Strategy for the furherance of knowledge and good practice of ecological sanitation (ecosan) technology in South Africa
(Project No 1439)

ISBN 1-77005-456-1
ISBN Set No 1-00775-452-9

Printed in the Republic of South Africa

EXECUTIVE SUMMARY

BACKGROUND

This report forms part of the output of Water Research Commission project number K5/1439 entitled "Strategy for the furtherance of knowledge and good practice of ecological sanitation (ecosan) technology in South Africa". The aims of this research project were as follows:

- To establish the current "state of the art" in ecological sanitation (ecosan).

- To determine:

  (a) the nature of processes taking place in the vault of a urine-diversion (UD) toilet; and
  (b) the relevant pathogen destruction parameters in order to increase understanding of the health aspects of UD toilet operation and maintenance (O&M), as well as safety criteria for use of the processed excreta.

- To explore appropriate practices for faeces collection and disposal, in order to facilitate the abovementioned safe O&M of the toilets.

- To produce a report describing the research conducted for the project, with conclusions and recommendations for improving the future implementation of UD sanitation projects.

REPORT STRUCTURE

The literature review of this study was published by the Water Research Commission as Report no. TT246/05. The other outputs emanating from this study are presented in four separate volumes.

The four volumes are:

- Volume 1: 1439/1/06 – Pathogen destruction in UD sanitation systems

- Volume 2: 1439/2/06 - Use and acceptance of UD sanitation systems in South Africa

- Volume 3: 1439/3/06 - Use of human excreta from UD toilets in food gardens: Agronomic and health aspects.

- Volume 4: TT275/06 - Guidelines for the design, operation and maintenance of UD sanitation systems (this volume).

SUMMARY OF THIS VOLUME

This volume is presented in two chapters:

Chapter 1: Introduction

The background and content of the whole project is described, in order that this volume can be put into context.

Chapter 2: Guidelines for the design, operation and maintenance of urine-diversion sanitation systems

The concept of urine-diversion is briefly introduced. This is followed by guidelines for constructing a UD toilet, with sections on building materials and methods for the superstructure, faeces vault, urine pipes, ventilation and fly control, and upgrading of VIP and bucket toilets. A number of illustrations accompany the text, including pictures of both good and bad practice.

Operation and maintenance aspects are covered in detail, with sections on dehydration, odour and fly control, cleaning the pedestal, disposal of anal cleansing material, urine collection and disposal, clearing blockages in the urine pipes, and faeces management.

Some suggestions for further reading are also included.

ACKNOWLEDGEMENTS

The project team acknowledges with thanks the following persons and organisations for their contributions to the project:

- The Water Research Commission for funding the project.

- Members of the Reference Committee for their valuable advice and support:

Mr J N Bhagwan	Water Research Commission (chairman)
Mr B Pfaff	eThekwini Water and Sanitation
Dr N P Mjoli	Hlathi Development Services cc
Mr R D Holden	Department of Science and Technology
Mr D A Still	Partners in Development cc
Mr D Gadd	Rand Water
Prof C A Buckley	University of KwaZulu-Natal
Mr I Pearson	WATSUP Development cc
Dr K C Wall	CSIR
Mr F G Tsibani	Department of Water Affairs and Forestry

- Mr M C Bolton for the architectural drawings in this volume.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

This report forms part of the output of Water Research Commission project number K5/1439 entitled “Strategy for the furtherance of knowledge and good practice of ecological sanitation (ecosan) technology in South Africa”. The aims of this research project were as follows:

- To establish the current “state of the art” in ecological sanitation (ecosan).
- To determine:
  (a) the nature of processes taking place in the vault of a urine-diversion (UD) toilet; and
  (b) the relevant pathogen destruction parameters in order to increase understanding of the health aspects of UD toilet operation and maintenance (O&M), as well as safety criteria for use of the processed excreta.
- To explore appropriate practices for faeces collection and disposal, in order to facilitate the abovementioned safe O&M of the toilets.
- To produce a report describing the research conducted for the project, with conclusions and recommendations for improving the future implementation of UD sanitation projects.

1.2 REPORT STRUCTURE

The literature review of this study was published by the Water Research Commission as Report no. TT246/05. The other outputs emanating from this study are presented in four separate volumes.

The four volumes are:

- Volume 1: 1439/1/06 – Pathogen destruction in UD sanitation systems
- Volume 2: 1439/2/06 - Use and acceptance of UD sanitation systems in South Africa
- Volume 3: 1439/3/06 - Use of human excreta from UD toilets in food gardens: Agronomic and health aspects.
- Volume 4: TT275/06 - Guidelines for the design, operation and maintenance of UD sanitation systems (this volume).

1.3 PROJECT OUTPUT

Volume 1: Pathogen destruction in UD sanitation systems

This section of the report covers the following study objectives:

- Determination of the environmental factors affecting the survival of excreted pathogens in dehydrated faeces and how application of NaOH, ash and pasteurisation reduces the numbers of pathogens in these faeces;

- Determination of the biocidal effect of urine in relation to storage temperature and pH.

- Determination of the minimum vault storage time for faecal material commensurate with safety for handling. In essence, this research was aimed at determining pathogen die-off rates under different conditions of faecal storage. Parameters investigated included storage time, effect of various lid materials on vault temperature, effect of ventilation, and effect of various bulking agents.

Volume 2: Use and acceptance of UD sanitation systems in South Africa

The terms of reference for this section of the project were to assess the knowledge, attitudes and practices of people using UD toilets in various parts of the country. The results of this research are intended to provide information to assist implementation of the technology in all areas of the country. Surveys were carried out in four provinces, namely Eastern Cape, Northern Cape, North West and KwaZulu-Natal.

Volume 3: Use of human excreta from UD toilets in food gardens: Agronomic and health aspects (this volume)

Due to the emphasis on use of human excreta from ecosan toilets in many countries, there is a fair amount of international literature on the subject of increased crop yields resulting from this practice. Prior to this project, however, no work had been done in South Africa on the subject and the intention of this part of the research was to go some way in addressing the matter. An important motivational issue was the need to find ways of reducing poverty and improving family nutrition in South Africa, particularly among the poor.

Field and glasshouse investigations were conducted into the use of dehydrated faecal material from UD toilets for growing of spinach and cabbage. This was followed by trials using human urine on cabbage, spinach, maize and tomato.

As a logical extension to this work there was a need to establish the safety, from a health point of view, of using faecal material originating from UD toilets as a soil amendment for crop growing purposes. Pathogens can be recycled to humans if improper agricultural practices are implemented. The same faecal material used for the field investigation described above was used as a soil amendment in the cultivation of spinach and carrots. Detailed microbiological tests were conducted on this material as well as on the in situ soil before sowing and after harvesting, on the irrigation water, and on the harvested crops.

Volume 4: Guidelines for the design, operation and maintenance of UD sanitation systems

A large store of knowledge has been gathered on UD sanitation systems in South Africa, not only during the course of this particular project but also since the technology was first implemented in the country in 1997. Much has been learned from overseas experience as well. The guidelines contained in this volume are based on best practices that have been observed and documented, as well as the conclusions and recommendations contained in the various sections of the research report.

Additional project output: Some alternative models for the management of faeces from UD toilets

Initially, this part of the project was to include the establishment, on a pilot basis, of a business opportunity to provide a faecal collection concern in a community with urine-diversion toilets. For various reasons it was not possible to establish such a business at the time. The WRC Research Manager instead requested the project team to conduct a theoretical desktop study on the potential for entrepreneurial business development for faeces collection from UD toilet systems. It was decided to disseminate the findings of this study in the form of a journal paper or article.

Two scenarios were considered:

- The use of an independent agent to collect faeces from UD toilets, transport to a collection station or directly to a disposal area within 10 km of the target community for the permissible disposal by the relevant local authority.

- The use of an independent agent to collect faeces from UD toilets, transport this product to a designated site (eco-station) within 10 km of the target community for the manufacture of compost and sale of this compost to the local authority.

CHAPTER 2

GUIDELINES FOR THE DESIGN, OPERATION AND MAINTENANCE OF URINE-DIVERSION SANITATION SYSTEMS

2.1 INTRODUCTION

Urine-diversion (UD) toilets have been used successfully for many years in a number of developing countries, e.g. Vietnam, China, Mexico, El Salvador, Ecuador, Guatemala and Ethiopia, and recently also in Zimbabwe and South Africa. The technology is not restricted to developing countries, however; some highly developed countries, such as Sweden for example, have incorporated these sanitation systems into various housing estates in both single and multi-storey houses and apartment blocks. The most important difference between UD and composting toilets is the moisture content in the faeces receptacle. Urine is diverted at source by a specially designed pedestal and is not mixed with the faeces. A pit is not necessary as the entire structure may be constructed above ground; alternatively, only a shallow excavation (maximum 500mm) may be required. The toilet may even be inside the dwelling. Material such as ash, dry soil or sawdust is sprinkled over the faeces after using the toilet. These agents absorb the moisture and also control odours and flies. The dry conditions facilitate rapid desiccation of the faeces. The desiccated faeces make a good soil conditioner, while urine is an excellent source of fertiliser, being rich in nitrogen, phosphorus and potassium.

A schematic representation of a UD toilet is given in Figure 2.1, while Figure 2.2 depicts a typical UD pedestal. Figure 2.3 shows some examples of easy to build toilet structures.

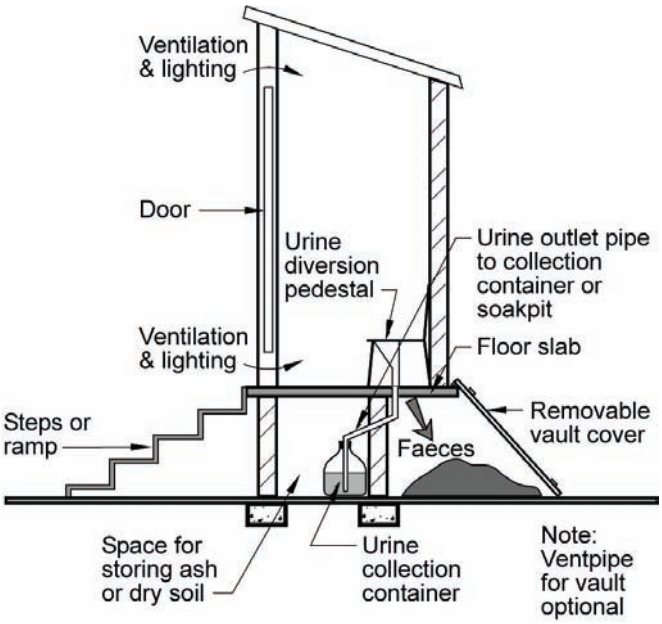


Figure 2.1
Schematic representation of a UD toilet.

Figure 2.2
Typical UD pedestal.

(Photograph: CSIR)

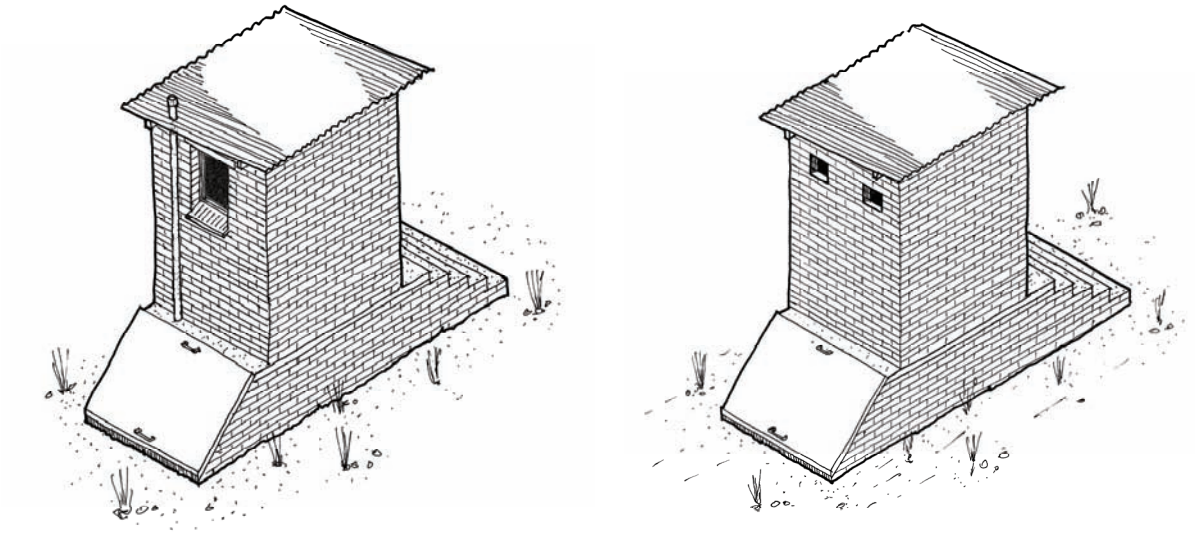


Figure 2.3: Typical examples of simple, easy to build UD toilet structures. As an alternative to conventionally built brick structures, some commercially available toilets are built with thin prefabricated concrete panels that are assembled on site
(Drawings: MC Bolton).

2.2 CONSTRUCTING A UD TOILET

2.2.1 Introduction

UD toilets require careful operation, but are inherently simple systems. For successful implementation, this feature should be maximised as far as possible, particularly in low-income communities. As proper operation and maintenance of the toilets are crucial factors in the success of any sanitation scheme, particular attention should be paid during the planning and design process to making these tasks as easy as possible. This will help to ensure sustainability.

UD toilets can be based on either the single vault or double vault principle. Many thousands of both types are found in South Africa and the world, and the decision on which type to implement in a particular project should be based on detail discussions between the implementing agent and the intended users.

UD sanitation systems have been developed and adapted over many years, and valuable lessons have been learned in the process. These guidelines are intended to illustrate what is generally regarded as “good practice”, incorporating the knowledge and experience acquired during evolvement of the technology. The guidelines should therefore not be regarded as the last word on the subject and the construction details shown here should be seen as suggestions, not mandatory requirements. The main criteria are that the basic principles governing UD sanitation, and good building practices, should be adhered to.

2.2.2 Building materials and methods

(a) Superstructure

Any suitable building materials may be used, as long as they meet the criteria of strength, durability and weather resistance, and have good thermal (i.e. poor heat-conducting) properties. Note that the latter requirement implies that galvanised corrugated iron should not be used for the walls. Most importantly, a toilet should be comfortable to use. User comfort will be enhanced by reducing heat gain in the superstructure.

In contrast to ventilated improved pit (VIP) toilets, which need to be partially darkened inside to assist fly control, UD toilets may be light and airy, as fly control is achieved by other means (covering faeces with ash, soil, etc). This enhances the attractiveness of the toilets. Provision should also be made for adequate ventilation of the superstructure.

Suitable roofing materials are galvanised corrugated iron, ferrocement, tiles, shingles, thatch or precast concrete. The main criteria are that the roof should be waterproof and adequately fastened to the walls of the superstructure. Ferrocement and precast concrete roofs have the advantage of not requiring timber beams or wire fixings, as they may simply be mortared in position. They are also the most durable and are not likely to require maintenance.

Figures 2.4 (a) to (e) show suggested dimensions for UD toilets that are built as separate rooms or structures. If retrofitting a new toilet into an existing dwelling or adding one to a new dwelling is being considered (Figure 2.7), the illustrations will also be useful in determining the feasibility and scope of the project. Dimensions have largely been determined by operation and maintenance requirements. Note that only basic, and not detailed, dimensions are shown, as different materials will require different thicknesses for the various elements, as well as different building techniques, etc.

(b) Faeces vault

A faecal material accumulation factor of 70 litres per person per year is recommended for design purposes. This allows for the addition of covering material (ash, soil, etc) and soft toilet paper. If other types of anal cleansing material are used this will result in a substantial increase in the accumulation factor.

A minimum storage period of twelve months before use in the garden is recommended for faecal material. In the case of a single vault toilet, depending on the number of users and the size limitation of the vault, it may be necessary to remove the material from the vault periodically and store it in a sack or other suitable holder for a further time so that a total period of twelve months elapses from the last addition to the pile until the material is used or disposed of.

For a double vault system, each vault should allow for twelve months use in order for the resting period to be the same length of time before the material is removed from the vault.

It is essential to make provision for adequate stormwater drainage around the vault. Consequently, the floor should be a minimum of 75 mm (one brick height) above the natural ground. In addition, the ground should slope away from the access door of

the vault; however, if this is not possible, then a shallow ditch should be excavated around the vault to facilitate the diversion of stormwater away from the structure.

It is important for toilet owners to have easy access to the vault for emptying purposes (see Figure 2.5). Lids should be made of lightweight material (e.g. thin ferrocement sections or galvanized sheet iron (GSI)) and should not be grouted in place. They should, however, fit snugly in order to prevent flies and vermin from gaining entry, and to keep rainwater out (see Figure 2.4(b)). Figures 2.10 and 2.11 show some examples of poor practice that should be avoided. It is also preferable for the floor of the vault to be as close to ground level as possible. Where there is a slope to the natural ground this should be utilised to orient the toilet structure in such a way that the entrance to the toilet is on the higher side while the vault is on the lower side. In this way it is possible to minimise the number of steps at the entrance while ensuring that the vault is sunk into the ground to the minimum extent possible (Figures 2.6 and 2.8). Should it be necessary for the floor of the vault to be below ground level, a short ramp should be provided on the inside to facilitate the removal of faecal material by raking (Figures 2.4(c) and 2.5).

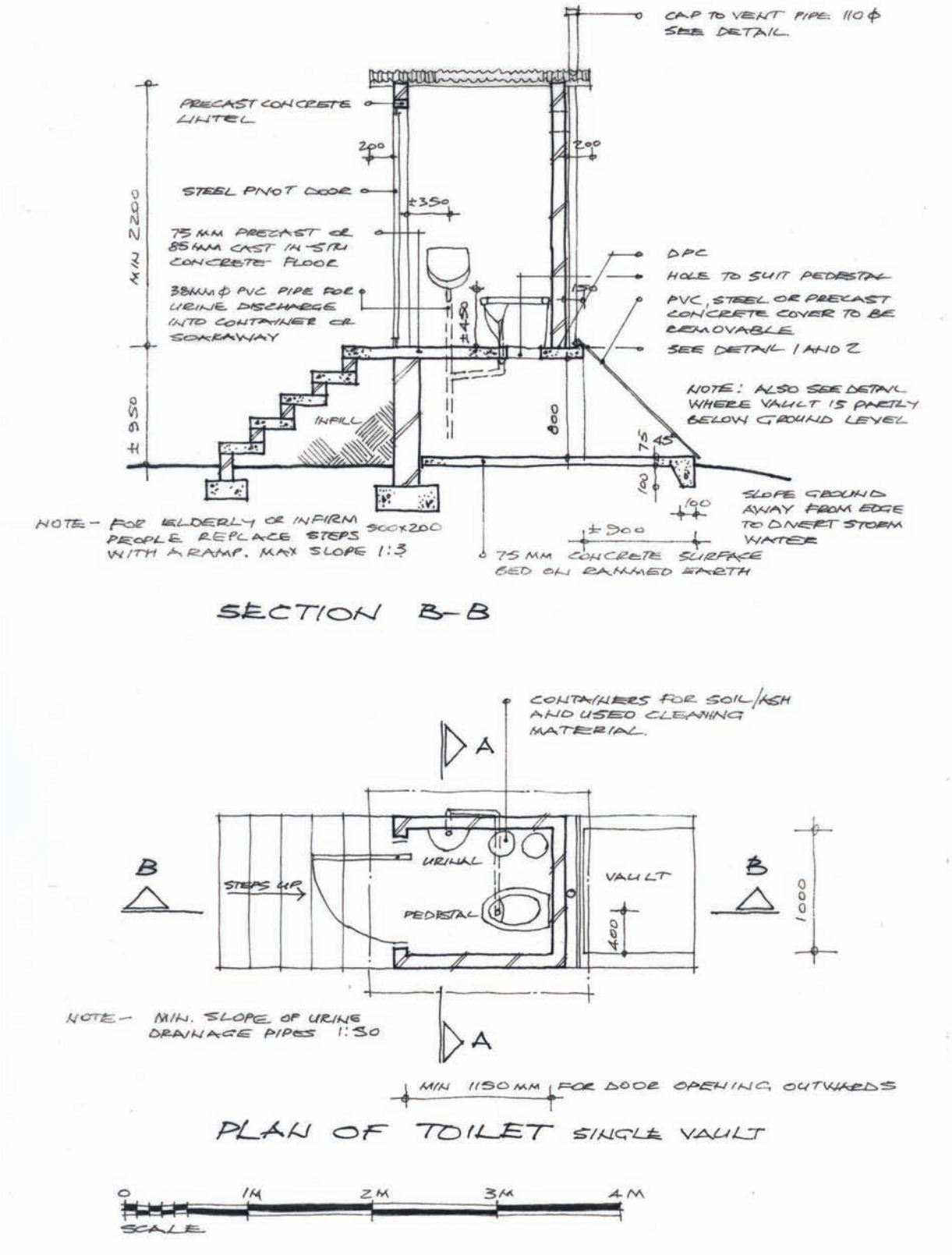


Figure 2.4(a): Details of a single vault UD toilet. The number of steps at the entrance can be reduced by constructing the floor of the vault below ground level (see Figure 2.4(c)).

(Drawing: MC Bolton)

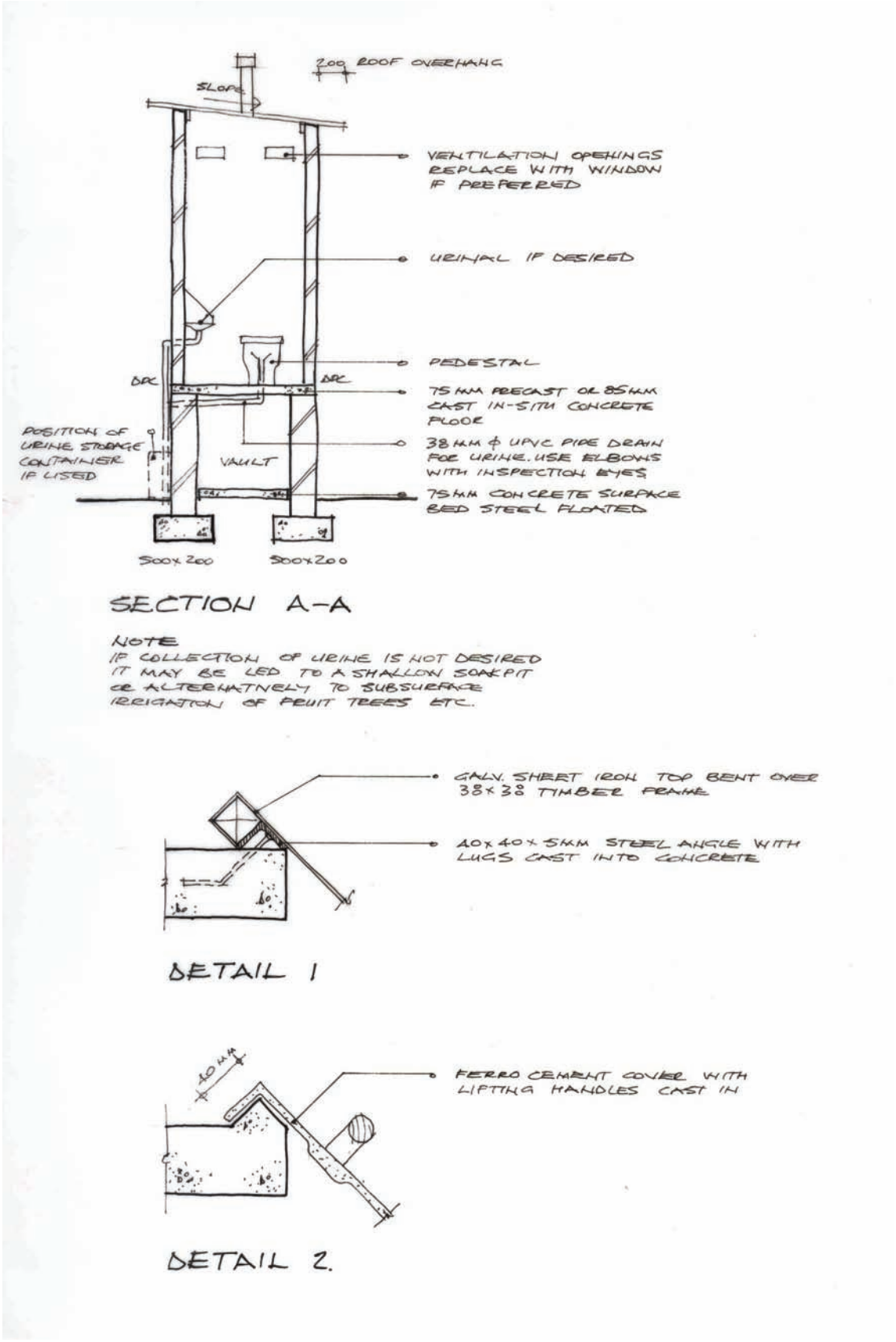


Figure 2.4(b): Details of a single vault UD toilet (continued)
(Drawing: MC Bolton)

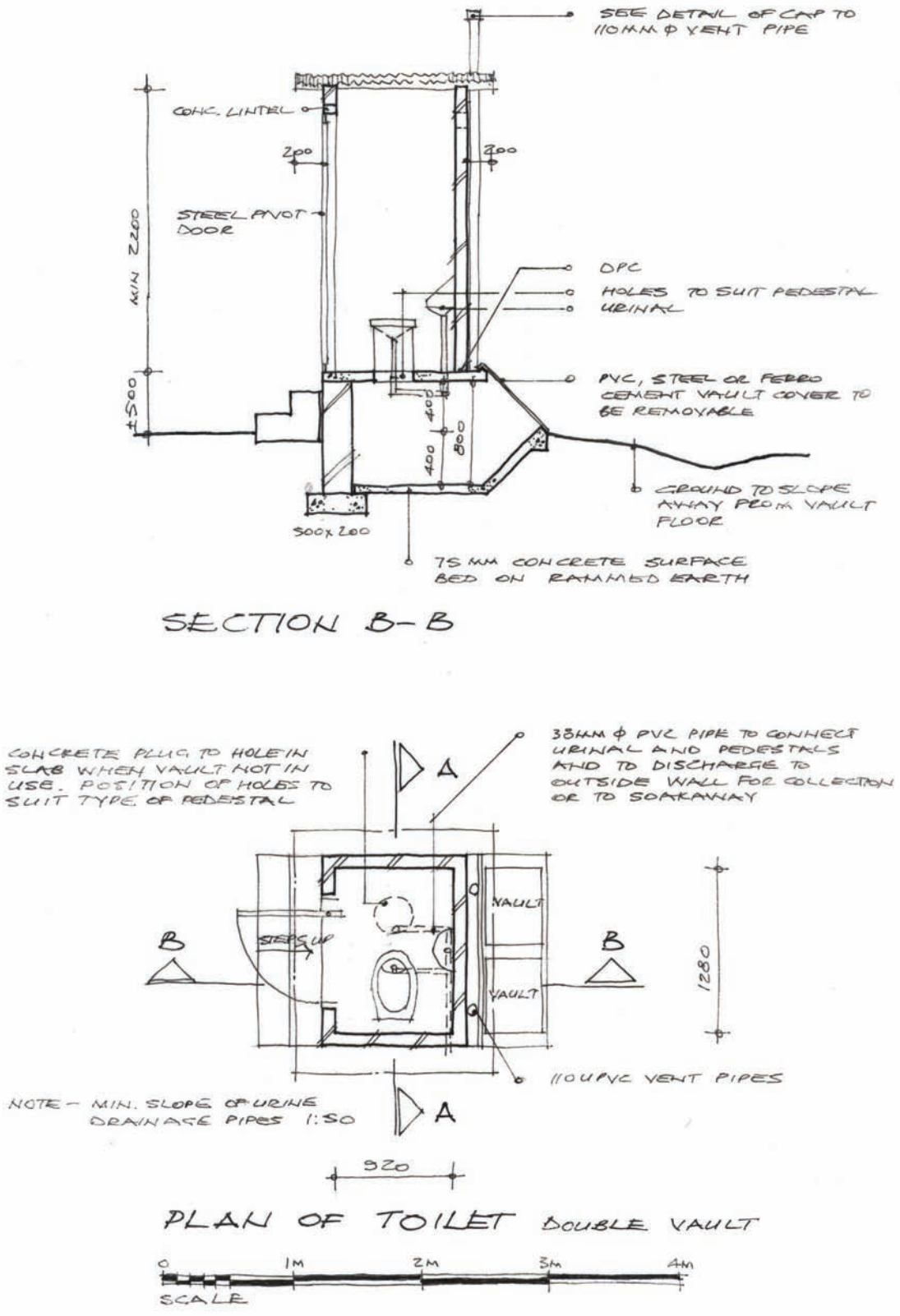


Figure 2.4(c): Details of a double vault UD toilet. Note reduction of steps by constructing the floor of the vault below ground level.
(Drawing: MC Bolton)

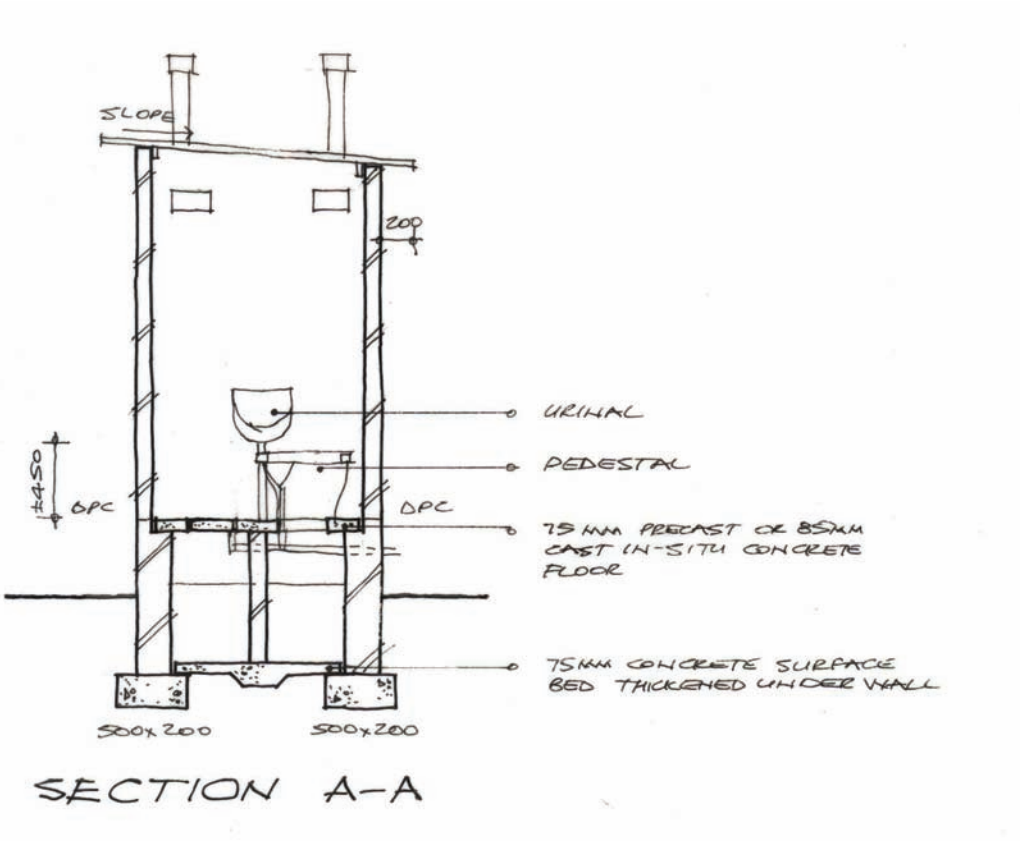


Figure 2.4(d): Details of a double vault UD toilet (continued)
(Drawing: MC Bolton)

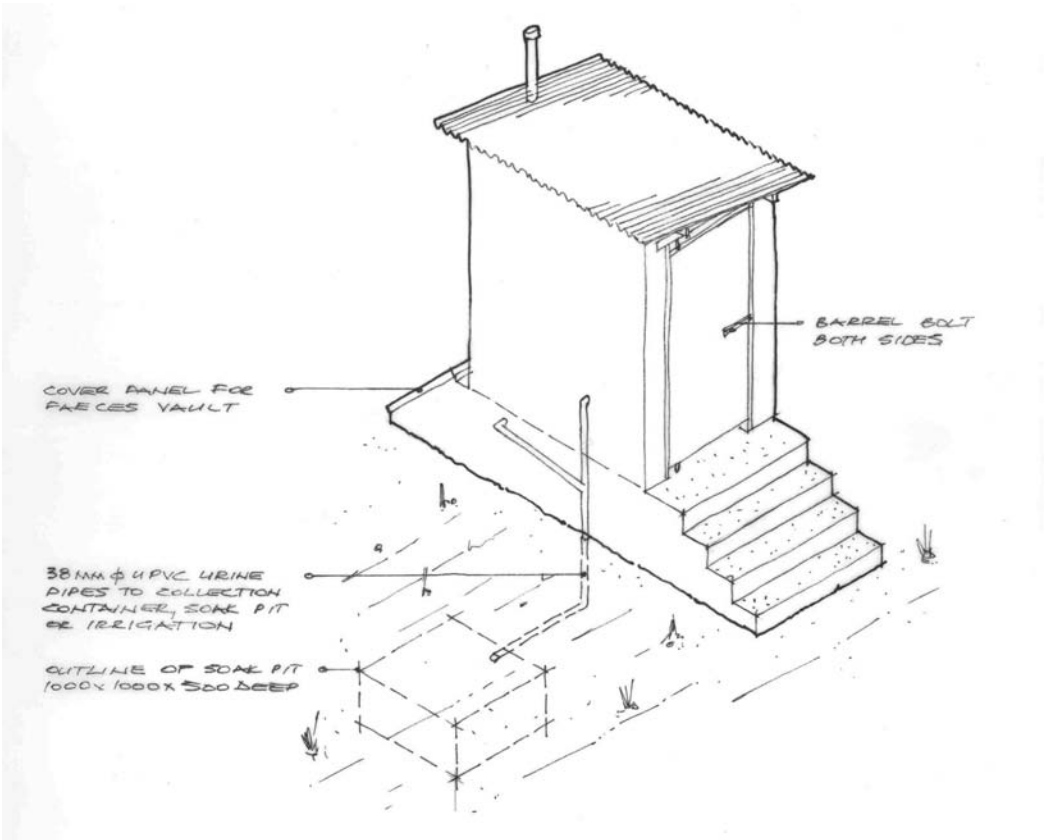


Figure 2.4(e): General layout of a UD toilet
(Drawing: MC Bolton)

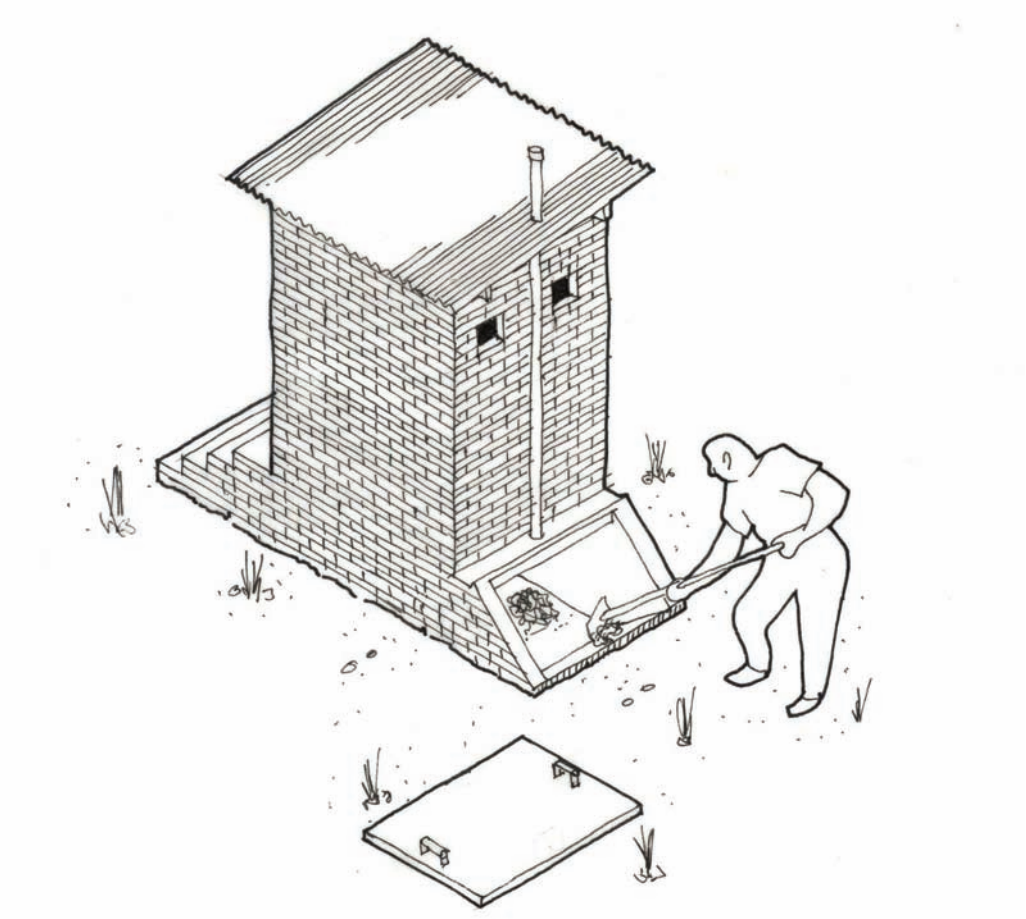


Figure 2.5: This vault is easy to empty
(Drawing: MC Bolton)

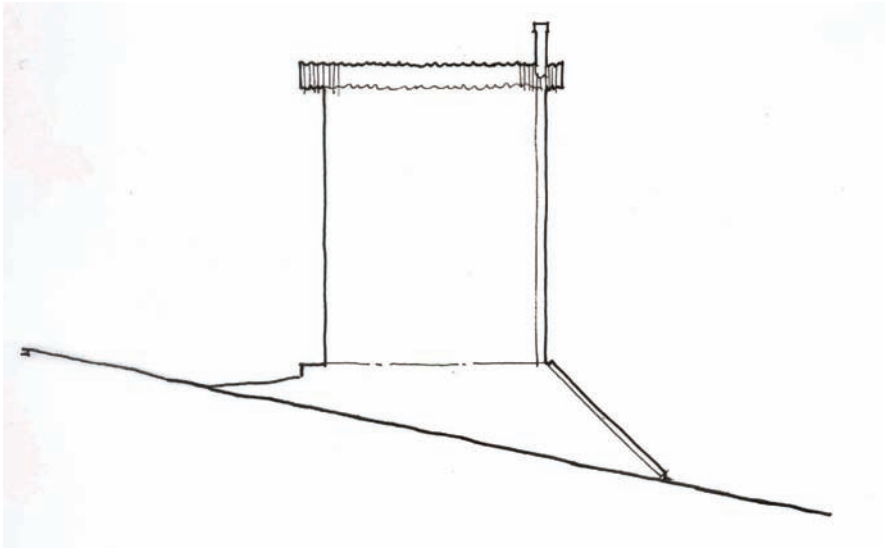


Figure 2.6: Using the natural ground slope to minimise steps at the entrance and depth of vault below ground level
(Drawing: MC Bolton)

(a)

(b)

Figure 2.7: Double vault UD toilet being added onto a house.
(a) Exterior view; (b) interior view
(Photographs: R. Holden)

Figure 2.8: Using the natural ground slope to minimise steps at the entrance and depth of vault below ground level
(Photographs: F. Stevens, eThekwini Water and Sanitation).

Figure 2.9: Well-fitting vault lids at a school toilet block
(Photograph: CSIR)

Figure 2.10: Examples of poor practice 1: It is extremely difficult to gain access to these vaults for emptying purposes
(Photographs: CSIR)

Figure 2.11: Examples of poor practice 2: These vaults are not sealed against ingress of flies, rodents, snakes, rainwater, etc
(Photographs: CSIR).

(c) Urine pipes

Urine drainage pipes should preferably be not less than 38mm diameter and slopes should be at least 2% (1:50) in order to prevent struvite build-up caused by standing urine, which can eventually block the pipes. This minimum size reduces the likelihood of blockages occurring through accumulation of hair, etc. Standard 38mm diameter waste pipes with elbow inspection caps should be used, which enables blockages to be cleared easily. Metal pipes should be avoided, as fresh urine is corrosive.

(d) Ventilation and fly control

UD toilets function on a different principle to VIP toilets, and their operating requirements are therefore not the same. Whereas VIP toilets require specific arrangements to be made for fly control as well as ventilation of the pit and superstructure, UD toilets are much less of a problem. Pit toilets produce odour due to mixing of faeces and urine, which causes the pit contents to be wet, or at least damp, more or less permanently. In a well-operated UD toilet, however, the faeces are covered with ash, dry soil or other moisture absorbing agent, urine is diverted and moisture kept out of the vault as far as possible. The faeces therefore dehydrate to some extent (this also depends on ambient temperature), flies are not attracted, and odours are virtually, and often completely, eliminated (efficiency of odour elimination depends to a large extent on proper use of the toilet). Therefore a different approach to building the toilet can be adopted.

As discussed above, the inside of the superstructure should be light and airy, not partially darkened as for a VIP toilet. In a well-operated UD toilet the faeces are covered with ash or soil; therefore they do not produce odours, so flies are not attracted. Proper windows may thus be provided, if desired. Should this be too expensive, or not preferred, then sufficient small openings should be left in the walls to provide for light and ventilation.

A ventpipe may be provided, if desired, in order to encourage ventilation of the vault. Although flies should not normally be a problem, a flyscreen should be fitted to the top of the ventpipe, and both the pipe and screen should be made of corrosion-resistant materials. Ventpipes should be 100 mm in diameter and extend to at least 500mm above the highest point of the roof. If possible, the ventpipe should be painted black and positioned to make maximum use of sunlight, although this is not a critical requirement. Ventilation occurs mostly due to movement of air across the top of the ventpipe, which induces suction in the system. It is only on windless days that thermal convection caused by sunlight will be responsible for air movement in the pipe. Note that provision should be made to prevent rainwater entering the ventpipe, and thus the faeces vault, as shown in Figure 2.12.

The ventpipe should be rigidly fixed to the superstructure with galvanised wire ties, and the hole through the cover slab well sealed.

Practical experience in hot and temperate climates has shown that, as long as the toilet is operated correctly (see section 2.3 “Operation and maintenance aspects”) there will be no odours or flies. Under these conditions, a ventpipe is not strictly necessary and may be dispensed with. Its use is encouraged, however, as good operation of the toilet cannot be guaranteed.

(e) Upgrading VIP and bucket toilets

From the drawings in Figure 2.4 it can be seen that pit and bucket toilets can be upgraded to UD toilets at minimal cost. All that is required is that the old pedestal be removed and replaced with a new UD type according to the user’s preference (plastic, concrete, etc) a urinal added, and urine drainage pipes fitted.

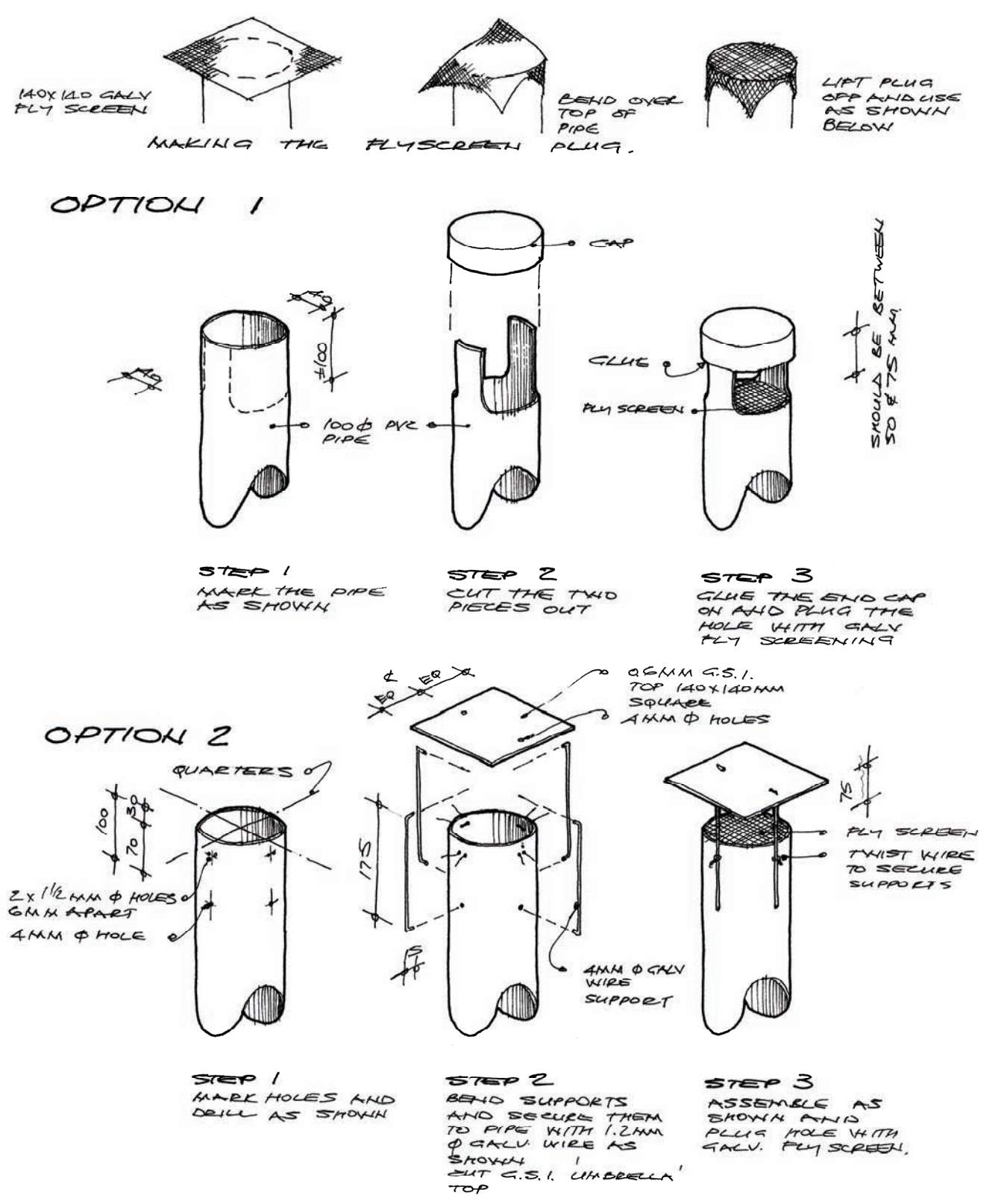


Figure 2.12: "Umbrella" for ventpipe
(Drawing: MC Bolton)

2.3 OPERATION AND MAINTENANCE ASPECTS

2.3.1 General

UD toilets require a higher level of commitment from users than do other forms of dry sanitation, such as VIP toilets. The reason is that they are more sensitive to, and consequently less tolerant of, abuse. In many of the poorer and under-serviced communities in South Africa, pit toilets are often used as rubbish depositories as well. The use of anal cleansing materials other than tissue paper, such as rags, plastic bags, newsprint, maize cobs, etc, is also common, and these objects then end up in the pits. Furthermore, wastewater may occasionally be poured into the pits. If one considers the nature of a UD toilet, it becomes obvious that abuse of this nature can only lead to failure of the system.

2.3.2 Dehydration, odour and fly control

The key operational factor for a successful UD toilet is minimal moisture. A supply of ash, dry soil, or other absorbent material, should always be available in a suitable container, and this should be sprinkled over the faeces after defecation. A cupful (approximately 200ml) should normally be sufficient, but users will quickly learn how much is required for their individual needs. This material will absorb the inherent moisture in the faeces, thus aiding the dehydration process. Flies and odours are also controlled in this manner. Furthermore, ash, particularly wood ash, has a relatively high pH (approximately 10), which is useful in reducing pathogenic organisms in the faeces.

2.3.3 Cleaning the pedestal

As with any toilet, cleanliness is essential for good hygiene. If the inside of the pedestal or squat plate becomes soiled, it may be cleaned with a damp toilet brush or cloth, as small amounts of water that enter the vault in this case will evaporate quickly. If disinfectant is used, care should be taken that only small amounts come into contact with the faecal material. The urine bowl, however, should be periodically rinsed with a little disinfectant diluted in water. Only a small quantity of water (about 200 ml or a cupful) is required for this operation.

2.3.4 Disposal of anal cleansing material

Various methods are used for the disposal of anal cleansing material. It is usually recommended that this material not be put into the vault, as the lack of moisture prevents its breakdown. A special container should be kept next to the toilet for storing used cleansing material, which may then be periodically disposed of by burning or burial. Alternatively, where a well-operated solid waste removal service exists, the used materials can simply be enclosed in a suitable bag and disposed of in the rubbish container.

Where faecal material is used in the garden or co-composted with other organic material, the toilet paper can be deposited into the vault, as the paper decomposes when wetted afterwards. It should be noted that only soft tissue paper can be used in this case, and the quantity may need to be restricted, depending on the size of garden and extent of use.

In hot and dry climates, where faeces dehydrate rapidly, all cleaning paper may be deposited in the vaults and periodically burned – paper as well as dehydrated faeces.

Where use of the faecal products is not desired, this is a relatively easy way to dispose of the contents of the vault.

2.3.5 Urine collection and disposal

Where it is intended to use urine for fertilising crops, it should be collected in a sealed container. If the container is not sealed, nitrogen is lost in the form of ammonia and the urine thus loses some of its fertilising value.

It is generally recommended that the urine be diluted at least three to five times before use, in order to avoid over-application of fertiliser to the crop. The soil should be loosened before addition of the mixture, and the urine worked in quickly, in order to minimise nitrogen loss.

For persons who do not wish to handle or use the urine, it may be led into a shallow soakpit adjacent to the toilet. The volumes produced by the average family are small and, except for very clayey soils, will not present a disposal problem.

2.3.6 Clearing blockages in the urine pipes

Occasional blockages of the urine pipes may occur due to precipitation of struvite forming on hairs or fibres. These may be cleared with conventional caustic soda drain cleaner.

2.3.7 Faeces management

Proper management of the excreted faeces is crucial for sustainable operation of a UD toilet. Various factors play a role in the dehydration process, and thus also in the reduction or elimination of pathogenic organisms. Because part of the management procedure consists of handling the faecal material, health and safety aspects are important.

The faecal material needs to be collected in a way that facilitates storage and easy removal from the vault. In a single vault toilet it can be collected and stored in either of two ways - in a suitable container or in a heap on the floor of the vault. For the former method, two separate containers are required. When the first container is full, it is moved to one side and the second one moved into place beneath the pedestal. By the time the second container is full (usually a few months, depending on the size of container and number of users) all the material in the first one should be sufficiently dehydrated to resemble a crumbly type of soil with a slight musty, not unpleasant, odour. It should then be removed from the container and stored in a sack for a further period, as there may still be vast numbers of viable pathogens present. A minimum total storage period of twelve months, from the time when the container is full to eventual use in the garden, is recommended.

The second method of collection and storage, in a heap on the floor of the vault, involves a little extra attention. When the heap reaches a certain size, it should be raked to the side of the vault where it can dehydrate for a further period, until the space is needed to store more material. Further storage in a sack for a total storage period of twelve months is also recommended in this case.

With a double vault toilet the two sides are used alternately, thus allowing faecal material to be stored in a full vault for at least twelve months before it needs to be removed.

Even if a community is not particularly inclined towards use of the desiccated faeces, experience in the field has shown that their disposal does not pose a problem, as they may simply be buried.

2.4 FURTHER READING

CSIR (2002). *Urine-diversion ecological sanitation systems in South Africa*. Boutek report no. BOU/E0201. CSIR, Pretoria.

WRC (2005). *Ecological sanitation – literature review*. Report no. TT 246/05. Water Research Commission, Pretoria.


1770054561