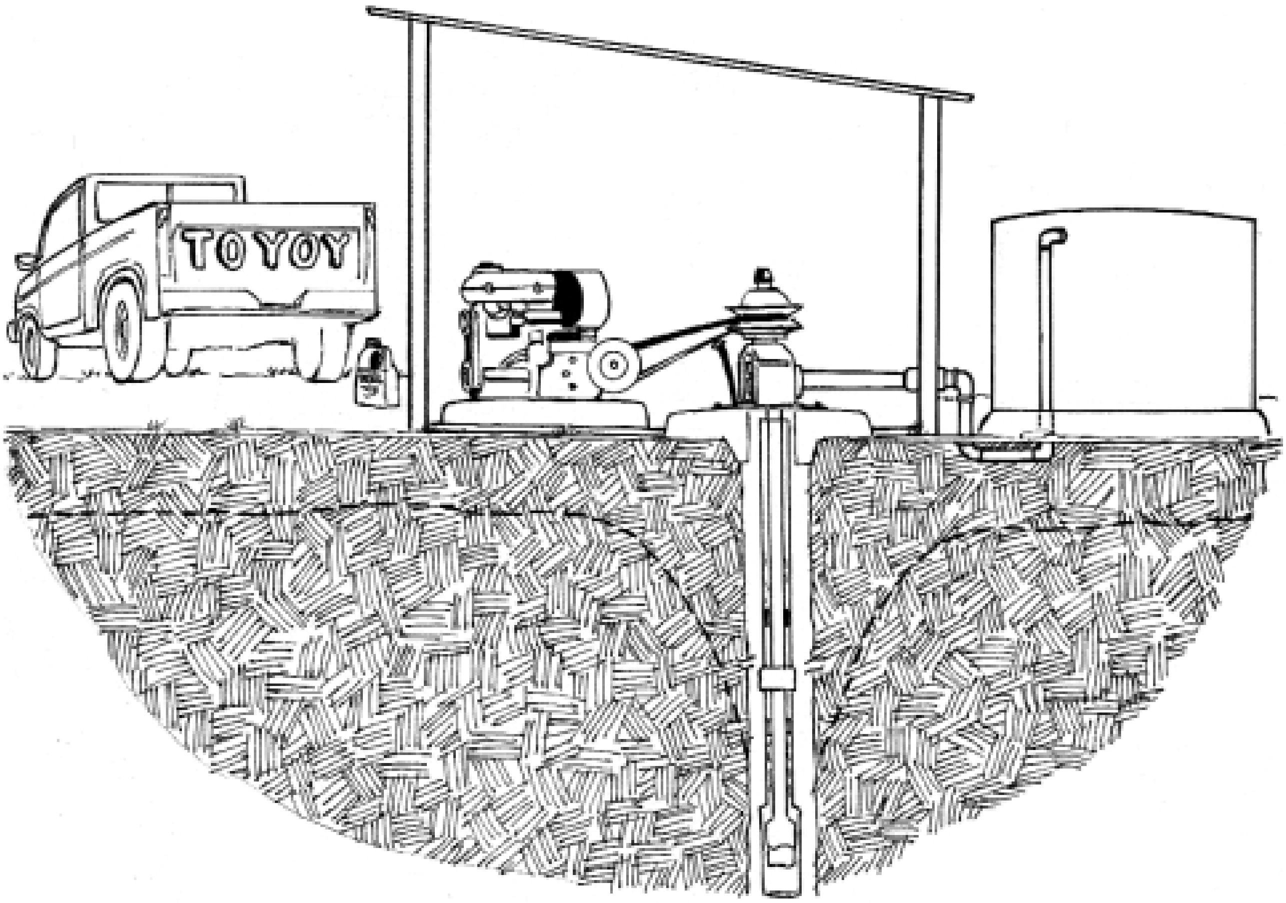
Introductory Guide to Appropriate Solutions for Water and Sanitation



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NORWEGIAN AGENCY FOR DEVELOPMENT COOPERATION

TOOLKIT for WATER SERVICES: Number 7.2

This guideline is for use by municipalities and their service providers as an introduction to the range of appropriate solutions available for water supply and sanitation, and where and how these are suited to different situations.

Introductory Guide to Appropriate Solutions for Water and Sanitation

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Foreword

Toolkit for Water Services

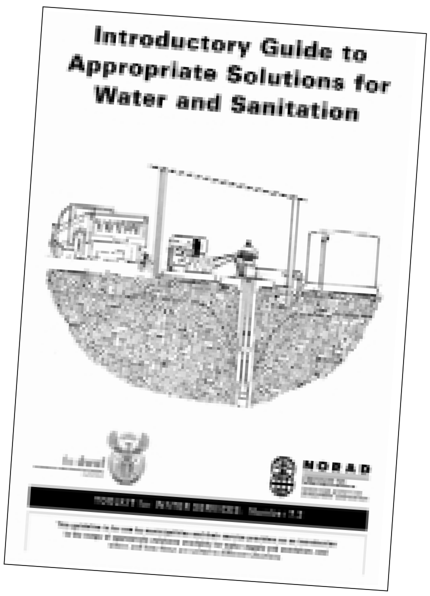
Groundwater has historically been given limited attention, and has not been perceived as an important water resource, in South Africa. This is reflected in general statistics showing that only 13 % of the nation's total water supply originate from groundwater. However, because of the highly distributed nature of the water demand in rural and informal peri-urban settlements, regional schemes are, in most instances, not economically feasible. And because of generally increasing water scarcity and decreasing available river and spring flows during low flow and drought periods, as well as wide-spread problems of surface water pollution in rural areas, groundwater will be the most feasible option for a large part of the new water demand. Already it is estimated that over sixty percent of community water supply is from groundwater, making it a strategically important resource.

The NORAD-Assisted Programme for the Sustainable Development of Groundwater Sources under the Community Water and Sanitation Programme in South Africa was managed by the Department of Water Affairs and Forestry (DWAF) between 2000 and 2004. The Programme undertook a series of inter-related projects aimed at enhancing capacity of water services authorities and DWAF to promote and implement sustainable rural water supply schemes based on groundwater resources and appropriate technologies.

Page 2 has a full list of the Programme outputs. The formats for these range from documents to software programmes and an internet portal, to reference sites where communities have implemented appropriate technologies. For more information on the "package" of Programme outputs contact your nearest DWAF Regional Office or Head Office in Pretoria.

It is our sincere hope that this Programme will contribute to the body of work that exists to enable more appropriate use and management of groundwater in South Africa.

Introductory Guide to Appropriate Solutions for Water and Sanitation is Number 7.2 in the Toolkit for Water Services. This guideline is for use by municipalities and their service providers as an introduction to the range of appropriate solutions available for water supply and sanitation, and where and how these are suited to different situations.



Toolkit for Water Services

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Acronyms

CMA	Catchment Management Agency
CWSS	Community Water Supply and Sanitation
DWAF	Department of Water Affairs and Forestry
O&M	Operation and Maintenance
SSA	Support Services Agent
WRM	Water Resource Management
WSA	Water Services Authority
WSDP	Water Services Development Plan
WSP	Water Services Provider

Introduction to the Guide

The need for appropriate solutions

South Africa is one of the 30 most water scarce countries on the planet. In line with our need to use our nation's limited water resources to achieve a better life for all, Cabinet approved South Africa's first National Water Resource Strategy in September 2004. This is in accordance with the requirements of the National Water Policy (1997) and the National Water Act (1998). To ensure that the Strategy is achieved it is essential that appropriate solutions are implemented for sustainable services.

Every water or sanitation scheme has a unique set characteristics relating to:

- water resources
- water demand
- location in relation to support services
- acceptability to users
- affordability
- institutional arrangements

Each scheme, therefore, requires a solution appropriate to these characteristics. This will ensure that water services are operated "effectively and efficiently, to be financially viable, and to honour the services delivery agreement" (Strategic Framework for Water Services, 2003). Remote communities, low income settlements and water scarce areas of the country present the greatest challenges in finding appropriate solutions – and they are often very different from solutions implemented in high income, urban settlements.

Why this Guide?

The Department of Water Affairs and Forestry (DWAF) has developed this Guide to assist water services authorities in making sound decisions. It is intended to give readers an introduction to the range of appropriate solutions available, and to provide information on where and how different technologies (solutions) will be suited to different situations. For more detailed information, see the reference documentation starting on page 95.

How to use the Guide

Sections 1 – 3 contain stand-alone information on a range of appropriate technical solutions with respect to:

- Water supply technologies,
- Sources of power for pumps, and
- Sanitation technologies.

Each technology is covered in broad terms, and information under each technology includes:

- What the technology is and how it works
- Requirements
- Institutional support
- Capital needs
- Operation and maintenance
- Advantages and disadvantages of the technology
- Experience as regards practical implementation

Section 4 focuses on solutions for the control of water supply and payment options, and is dealt with differently from sections 1-3. It is divided into two sub-sections:

- Communal standpipes
- Individual household connections

Information under the sub-sections is explored in terms of technologies for the control of water supply and loss, and the various payment options available.

Section 5 provides additional information in the form of a description of the various pumps available, and water treatment options at household and municipal level.

Section 6 provides additional references to books, journals and articles for in-depth further reading for each solution.

Using the Guide to support use of the *Decision Making Framework*

The ***Decision Making Framework for Municipalities*** (Number 7.3 in the Toolkit for Water Services) is a stand-alone flowchart (available in poster and A4 formats). It is for use by municipalities in making decisions for water supply and sanitation. This Guide can be used as a reference when using the ***Decision Making Framework***, and where an explanation of the different solutions mentioned in the Framework is required.

1 WATER SUPPLY TECHNOLOGIES

INTRODUCTION

WATER SUPPLY TECHNOLOGIES - GROUNDWATER

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Hand Dug Wells

Tube Wells

Spring Protection

Abstraction from a Sand Dam

Artificial Recharge

WATER SUPPLY TECHNOLOGIES - OTHER

Rainwater Harvesting

Cloud / Mist Harvesting

Greywater Recycling

Introduction

The focus of this section is on access to the water resource / source. These sources are divided into:

- Underground water resources / sources;
- Atmospheric water resources / sources; and
- Recycling of the water resource / source.

Underground water resources / sources

These comprise of both groundwater and springs. Groundwater systems include both aquifers that are unconfined, shallow, and relatively accessible, and aquifers that require considerable effort and subsequent management to extract water. Whether shallow or deep systems dominate, and whether porous or fractured aquifer systems are present, yield depends on the geological, geomorphological, and past climate regimes of an area. Springs may arise due to both shallow and relatively deep subsurface flow systems.

It is critical that these underground water supplies are recharged. Recharge occurs naturally through the infiltration of water into the soil and underlying strata, or by artificial recharge. Artificial recharge is a method of replenishing groundwater resources by increasing the rate of infiltration by ponding on the surface, or by injecting water down boreholes.

Atmospheric water resources / sources

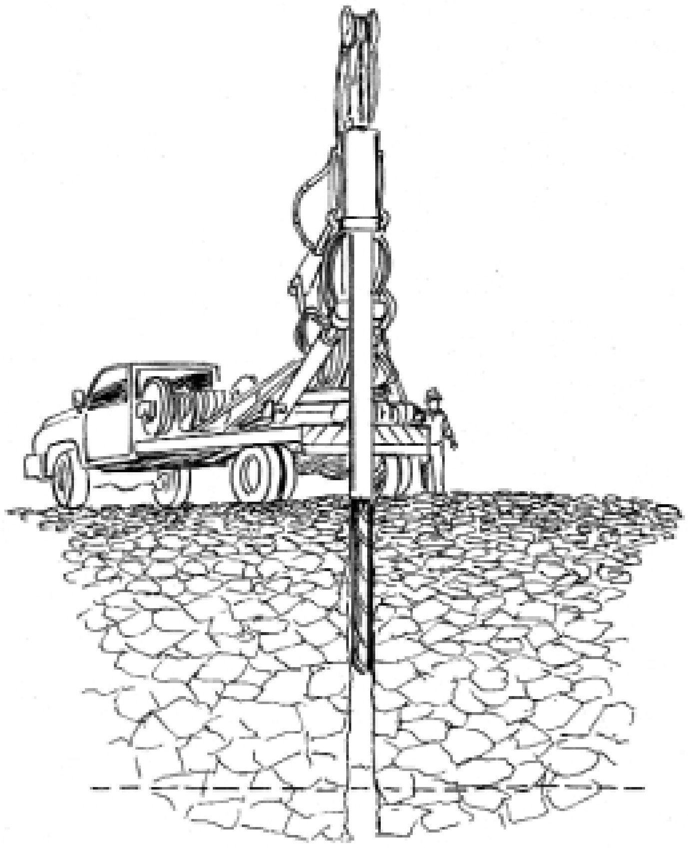
Atmospheric water resources are obtained through the 'harvesting' of both rainwater and cloud / mist. Rainwater harvesting involves the interception and storage of rain before water is lost to runoff and infiltration processes. Cloud / mist harvesting involves the interception of mist or fog with a fabric mesh or sheet and the collection of water droplets into a storage tank. The additional water gathered in this manner is generally small. It supplements other surface or groundwater sources.

Household management of rainwater occurs when collection is from roofs, whilst municipal management occurs when rainwater is harvested from larger surfaces, such as rock faces.

Recycling of Greywater

Greywater refers to household wastewater. This includes water used for personal hygiene, washing of clothes, and washing dishes. Instead of disposing of this water in a sewer system or septic tank, it can be recycled and used for garden irrigation.

Boreholes



What is a borehole and how does it work?

In South Africa the definition of boreholes has evolved to mean a small diameter drilled hole using a drilling rig. Boreholes are too small in diameter for a person to enter for either the construction or the maintenance of the hole. Borehole diameters range from 101 millimetres to 318 millimetres (4 inches to 12,5 inches). The standard drilling method is rotary percussion drilling in hard rock. In soft sediments the standard method is mud rotary drilling. The type of construction method used will depend on the expected ground conditions and the availability of equipment, power sources, and skills. The water is brought to the surface by a pump or a small diameter bucket or bailer.

Borehole requirements

The depth of the borehole should accommodate seasonal or annual fluctuations in water levels so as to avoid the borehole going dry when the water table is low. A hydrogeological survey to determine the appropriate siting of the borehole is recommended. The optimum diameter of the borehole must be determined taking into account the anticipated yield, the demand, and the extraction method used.

Water quality

Water quality depends on the inherent properties of the groundwater when extracted, threats of contamination during the extraction process, and threats of contamination from the surrounding environment. However, it is important to remember that groundwater is still generally better quality than untreated surface water. Further, there is less of a chance of contamination from boreholes than from hand dug wells. A sanitary seal should prevent contaminants from entering down the side of the borehole casing.

Insitutional support

Consultation with qualified and experienced professionals is required to determine the position of the site and for drilling, testing, and pumping yield recommendations.

Capital requirements

Costs are associated with:

- Drilling / auguring equipment;
- Casings;
- Screens; and
- A sanitary seal.

Operation and maintenance

If the borehole yield decreases over time, boreholes may need to be remediated. Clogging may be improved by cleaning out the borehole using a weak acid solution under high pressure. Abstraction from the borehole and water levels must be regularly measured to avoid over abstraction and the borehole running dry.

Advantages of boreholes

Advantages of boreholes include:

- Boreholes are the only means of extracting water in hard rock environments;
- They are more efficient per metre than hand dug wells, as less material needs to be removed;
- They can be constructed within short timeframes ; and
- The water source is generally reliable, as they can extend deeply, to reach reliable aquifers.

Limitations of boreholes

Limitations of boreholes include:

- The borehole offers limited storage capacity for low yielding aquifers;
- Problems with clogging of screens and scouring of sand from behind the screen may be encountered
- If the raw water has a high iron or manganese content the abstraction screens will clog, greatly reducing the yield
- Uncased boreholes are liable to collapse in highly weathered formation;
- Expert advice must be sought to establish when casing is necessary or not;
- Down-hole equipment must be used for down hole maintenance; and
- Borehole drilling costs are higher than hand excavation.

Practical experience

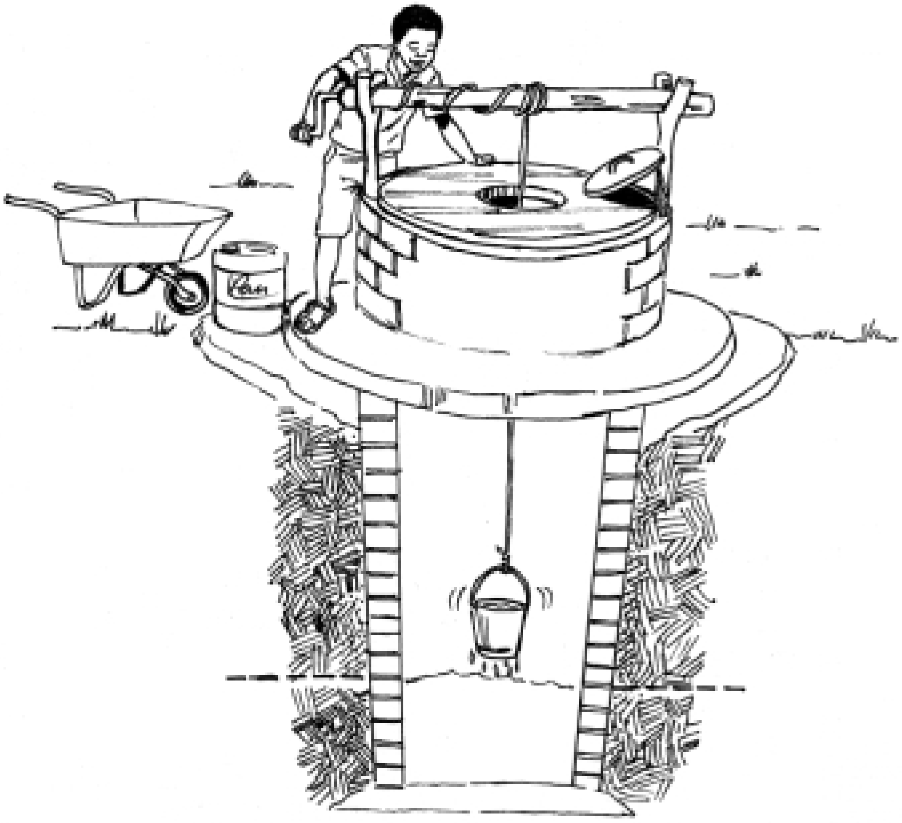
Boreholes are common across South Africa.

Key references:

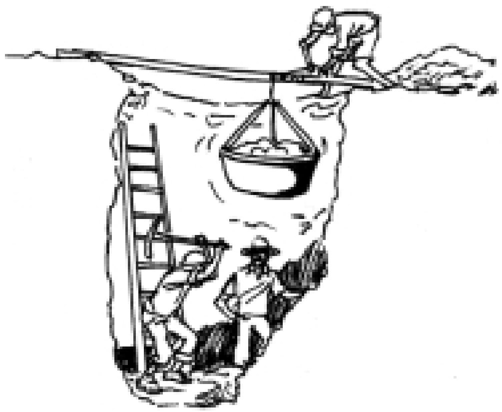
- Ball, Peter, 2001, *Drilled Wells*, Series of manuals on drinking water supply, volume 6, SKAT.
- Waterlines, 1995, *Technical Brief No.43: Simple drilling methods*, Vol.13, No.3, January.
- Department of Water Affairs and Forestry (1997). *Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme*. First edition.
- NORAD Project 3 and DWAF, *Standard Descriptions for Boreholes*.

Useful contacts include:

- Department of Water Affair and Forestry
- Groundwater Division of the Geological Society of South Africa
- Borehole Water Association of Southern Africa
- South African Drilling Association
- Groundwater Association of KwaZulu-Natal



What is a hand dug well and how does it work?



This is a large diameter well dug by hand. The diameter must be greater than 0.8 metres. To enable two people to dig the well it should be 1.2 metres or more. The diameter, depth of the well, and lining used (if required), can vary depending on the conditions at the site. A lining prevents collapse of the sides of the well, and can also protect the well from surface water entering and causing contamination.

Wells can be either protected or unprotected. With unprotected wells water is collected using a bucket, or steps can be cut into the side of the well to fetch the water directly. These wells carry a high risk of contamination. Also, children and animals can fall in.

An upgraded hand dug well is preferable. It has the following components:

- A headwall or protective collar that prevents surface water from entering the well, and children and animals from falling in;
- A well cover which is cemented onto the collar and leaves a small, central hole for lifting water using a bucket;
- A windlass which is used to raise and lower a bucket with a hook on which the bucket should be hung when not in use; and
- A drainage apron and soak-away which ensures that spilt water will drain away and not dam up around the well, causing contamination and health hazards.

The final upgrade for a hand dug well is the installation of a hand or motor driven pump at the surface. This further reduces the chances of contamination and makes the extraction of water easier.

Hand dug well requirements

The depth to which the well must be dug, the optimum diameter of the well, and the level of service must be determined. This is based upon specific hydrological conditions.

Water quality

The water quality of the well is dependant on the inherent properties of the groundwater. Further, it may be affected by contamination that can result during water extraction. Unprotected wells present the highest risk of contamination. This risk decreases as improvements are made.

Insitutional support

With the correct information local artisans can dig wells, without institutional support. Also, management of the well can be undertaken at household or community level.

Capital requirements

Costs are associated with:

- Payments to labour for the digging of the well;
- Materials for the lining;
- Building of the protective collar;
- Construction of the well cover; and
- Construction of the drainage apron.

Operation and maintenance

The well must be kept clean and in a sanitary condition. It is advisable to routinely add a small dose of household disinfectant such as Jik. Water lifting devices (whether a simple windlass and bucket or a more sophisticated pump) must be maintained and / or repaired.

Advantages of hand dug wells

Advantages of hand dug wells include:

- The risks of contamination are decreased as the well upgrades are increased;
- The large diameter means that the well can act as a form of storage; and
- This system can provide a household level of service.

Limitations of hand dug wells

Limitations of hand dug wells include:

- Children and animals can fall into unprotected wells; and
- Depending on the level of improvement made to the hand dug well, there is a risk of contamination.

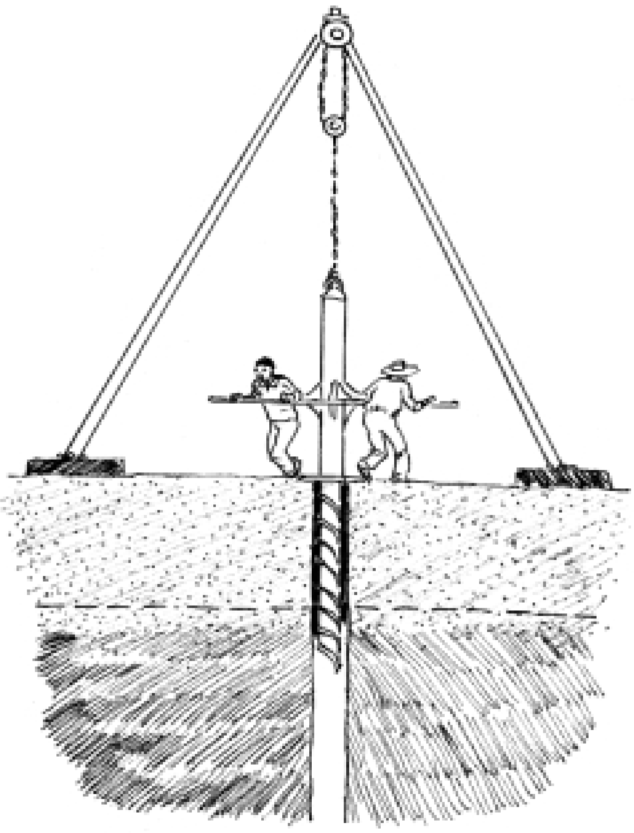
Practical experience

Hand dug wells have been used extensively in Southern Africa. The most notable example is the Zimbabwean family wells programme. In South Africa hand dug wells have been built in KwaZulu-Natal, Limpopo and the Eastern Cape.

Key references:

⊙ King, Georgina, 1996, *Development of Shallow Wells on the Zululand Coastal Plain*, DWAF, Directorate: Geohydrology, KwaZulu-Natal.

⊙ Watt, S.B. and Wood, W.E., 1979, *Hand dug wells and their construction*, Intermediate Technology Publications, London.



What is a tube well and how does it work?

In South Africa tube wells refer to small diameter holes, constructed in soft formations using a hand auger. Tube well diameters can range from 60 millimetres to 170 millimetres. The water is brought to the surface by a pump or a small diameter bucket or bailer.

Tube well requirements

The depth of tube wells should accommodate seasonal or annual fluctuations in water levels. This is to ensure that the tube well does not go dry when the water table is low. The optimum diameter of the tube well should be determined taking into account the anticipated yield, the demand, and the extraction method used. The tube well should be cased from top to bottom, and the casing should include a slotted well screen. Finally, the tube well should include a well-drained concrete slab.

Water quality

Water quality depends on the inherent properties of the groundwater. Further, it depends on possible contamination during the extraction process, from the surrounding environment. Generally, however, groundwater is purer than surface water. Tube wells have a lower risk of contamination than hand dug wells. A sanitary seal should prevent contaminants from entering the groundwater from the surface down the side of the tube well casing.

Insitutional support

Professional expertise is required for siting, testing, recommending pumping yields (if a motorised pump is installed), and monitoring construction quality. Local artisans can be trained to carry out construction and maintenance.

Capital requirements

Costs are associated with:

- Drilling / auguring equipment;
- Casings;
- Screens; and
- The sanitary seal.

Operation and maintenance

Tube wells that have become clogged may need remediation work.

Advantages of tube wells

Advantages of tube wells include:

- They are cheaper per metre than hand dug wells, as less material needs to be removed;
- They are cheaper than drilling rigs in soft formations;
- They can be constructed within short timeframes; and
- They can be sunk deeper than hand dug wells in unconsolidated sand, and may therefore provide a more reliable water supply.

Limitations of tube wells

Limitations of tube wells include:

- They offer limited storage capacity for low yielding aquifers;
- Problems with clogging of screens and scouring of sand from behind the screen may be encountered;
- If the raw water has a high iron or manganese content the abstraction screens will clog, greatly reducing the yield
- Access down the hole is not possible; and
- They can only be constructed to a limited depth as compared to boreholes.

Practical experience

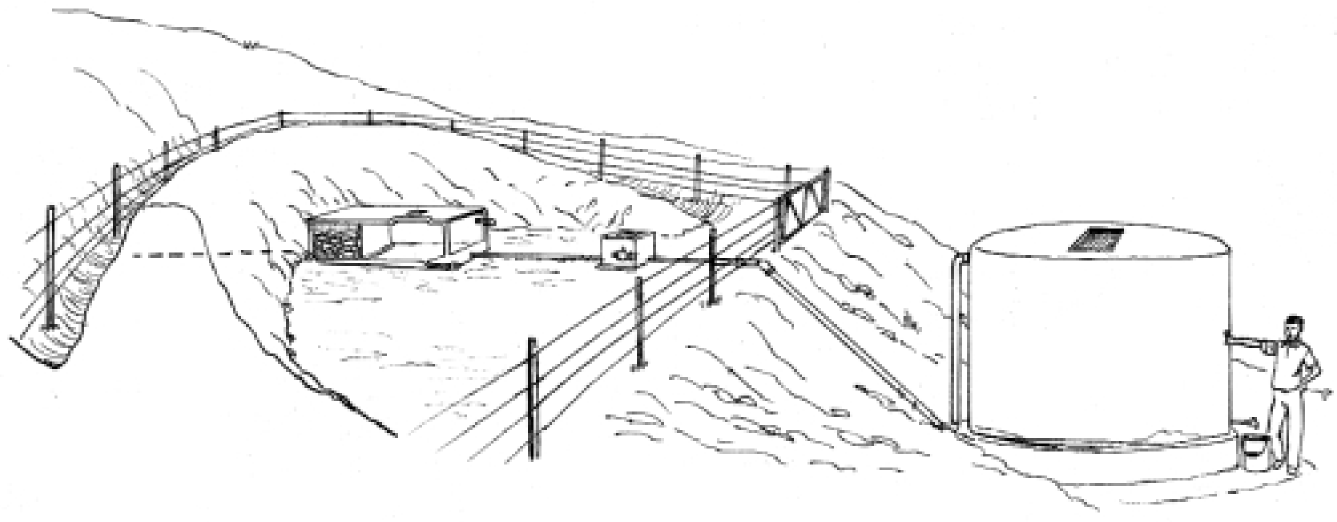
Tube wells have been constructed along the coast in Northern KwaZulu-Natal and in Zimbabwe.

Key references:

- Ball, Peter, 2001, *Drilled Wells*, Series of manuals on drinking water supply, Volume 6, SKAT.
- Still, D.A. and Nash, S. R., 2002, *The Ubombo Family Wells Programme*, Paper presented at Water Institute of Southern Africa Biennial Conference, Durban, May 2002.
- Still, DA. Nash, SR., and MacCarthy, *Hand augered wells*

Useful contacts include:

- Department of Water Affair and Forestry
- Groundwater Association of KwaZulu-Natal
- Partners in Development (for hand augured shallow wells)



What is spring protection and how does it work?

A spring occurs where groundwater is forced to the surface by an underlying impermeable layer or by artesian pressure. Spring protection refers to the modification of a spring source to capture the available water before it becomes exposed to surface contaminants.
This is done by:

- Excavating the spring until the water emerges from stable ground;
- Construction of a spring capture chamber;
- Construction of a sedimentation chamber;
- Construction of a storage reservoir to accommodate fluctuations in demand;
- Construction of diversion drains and ground stabilising structures, where required; and
- Fencing and establishing grass within the spring area.

If the spring is above the settlement, water can be piped directly from the reservoir into a reticulation. If the spring is below it can be pumped to another reservoir and then from there into a reticulation.

Spring protection requirements

Overflow should be directed back to the stream. Further, the spring should be protected against surface water contamination and erosion. At all times, water from the spring should be allowed to flow freely away from the “eye” or source of the spring, without obstruction.

The water should never dam up, as this will cause back pressure. This can lead to the groundwater finding an easier alternative route, and the spring could stop flowing. The water must flow freely under maximum flow conditions, during construction, and on the completion of construction.

Water quality

Water quality depends on the inherent properties of the groundwater when extracted, threats of contamination during the extraction process, and threats of contamination from the surrounding environment. However, it is important to remember that groundwater is still generally better quality than untreated surface water. Usually minimum or no water treatment is required. In some cases, though, the spring water source may be contaminated or have unacceptably high chemical concentrations. This requires appropriate treatment.

Insitutional support

Technical support is required to implement the scheme. Such support would include flow measurements, design of the spring protection system, an environmental impact assessment, and final construction. However, construction can be done using local skills and material. Springs can be easily managed by a local person, with minimal outside support.

Capital requirements

Costs are associated with:
- Cement;
- River sand;
- Pipes;
- Stone, concrete blocks or bricks; and
- A plastic or ferro-cement tank.

Spring protection can be carried out by a local artisan with minimal external support.

Operation and maintenance

Control of all human and animal activities around the spring is necessary. Regular maintenance of the perimeter fence (if one exists) is needed. The spring area should be kept free of litter. The growth of trees around the spring should be controlled, so as to prevent roots from damaging the spring box. Further, when required, repairs should be done to the surface water drainage system. Finally, the sedimentation chamber must be regularly scoured and cleaned.

Advantages of spring protection

Advantages of spring protection include:

- Spring protection prevents contamination of the water, making further treatment unnecessary;
- Spring protection can increase the yield obtained;
- The simplicity of the technology used for spring protection allows for labour intensive construction to be carried out by local artisans;
- The system taps base flow water, and thus has no major impact on the local water table; and
- Spring protection is generally inexpensive.

Limitations of springs

Limitations of springs include:

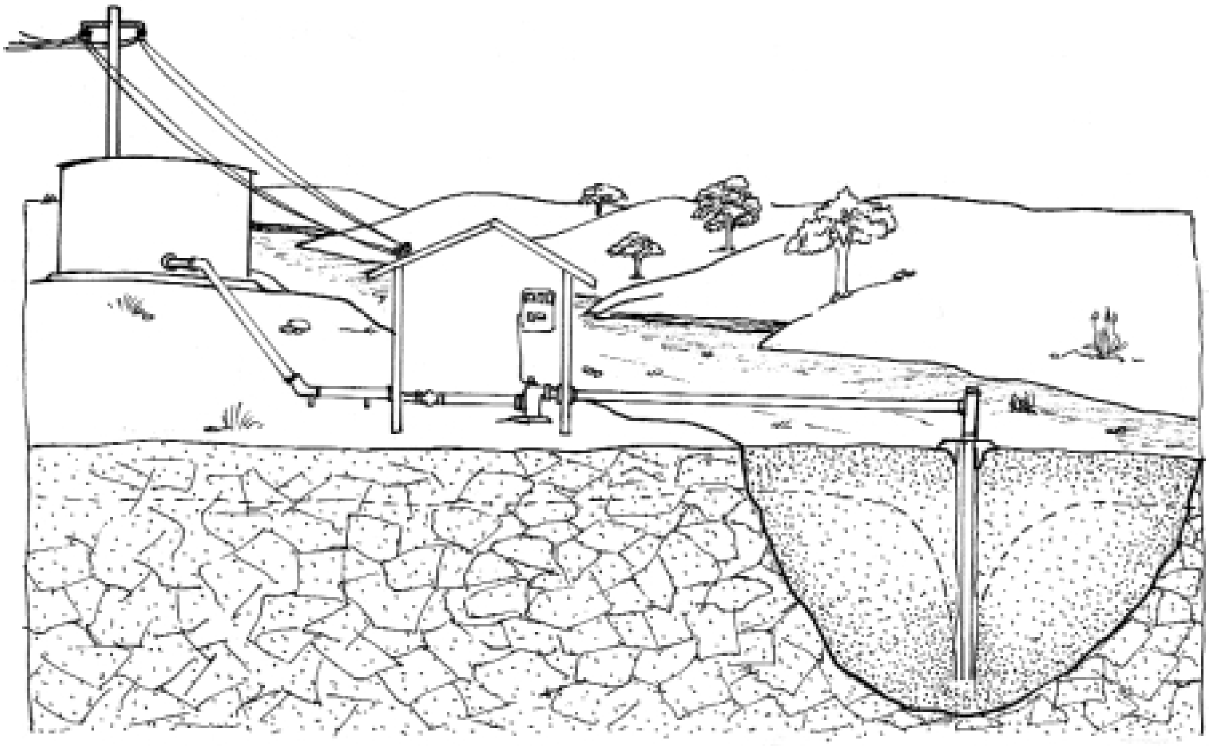
- The supply may be low, with seasonal reductions; and
- If construction is not carried out in an appropriate way, the spring can find an alternative route underground, thus bypassing the spring chamber.

Practical experience

Many towns and settlements in South Africa were established because of their close proximity to springs. A number of villages in Lesotho and the Eastern Cape are supplied with water using this technology.

Key references:

- Meuli, C. and Wehrle, K., 2001, *Spring catchment*, Volume 4 of series of manuals on drinking water supply, SKAT, Switzerland.
- Pearson, I., Weaver, J. and Ravenscroft, P., 2003, *The reliability of small spring water supply systems for community supply projects*, Water Research Commission, Report No. 859/1/03.



What is sand dam abstraction and how does it work?

Groundwater can be collected from sandy riverbeds when the river is dry, but the sand is still saturated. Sand dams can also be constructed artificially, by constructing a weir in the riverbed and allowing the area behind the weir to fill with sand. Larger sand reservoirs should be developed over time by raising the wall in stages. If the wall is raised too rapidly an accumulation of silt and clay can occur in the dam basin, affecting water quality.

Water is usually abstracted through the construction of horizontal infiltration drainpipes or galleries. The infiltration galleries are usually constructed perpendicular to the groundwater flow. The pipes have slots or perforations that allow the groundwater to enter, and screens to prevent, or minimise, the intake of sand. They can be made of concrete, stainless steel, or PVC. The pipes are placed in the riverbed, by hand, or mechanically. The water that enters the pipes is drained to a collector well, and abstracted through pumping.

Sand dam abstraction requirements

A catchment with a significant percentage of coarse sediment in the water. Access to the pipes is required for cleaning and inspection.

Water quality

The water is usually of good quality as the sand generally filters out contaminants.

Insitutional support

The level of institutional support required depends on the scale of the project. Professional expertise is necessary to determine the yield of the aquifer, and to design the system. Local labour can be used for construction.

Capital requirements

Capital requirements include the digging of trenches, the cost of pipes and screens, and the abstraction chamber.

Operation and maintenance

Flow rates should be monitored to detect any unusual increase or reduction in flow. Pipes should be cleaned after two years of operation and / or depending on the amount of sediment found. An initial assessment can help in determining how often the pipes should be cleaned.

Advantages of sand dam abstraction

Advantages of sand dam abstraction include:

- The water is generally clean since it is underground; and
- Evaporation losses are reduced.

Limitations of sand dam abstraction

Limitations of sand dam abstraction include:

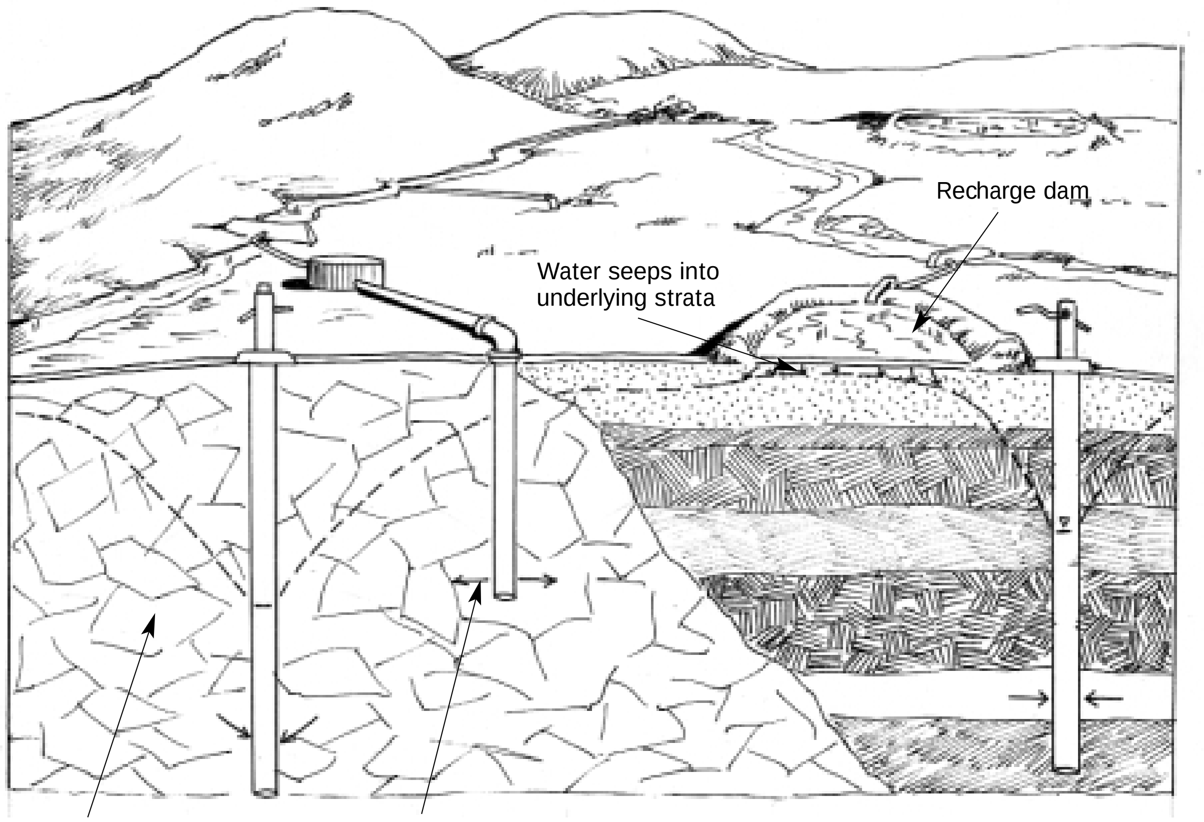
- Problems with clogging of screens and scouring of sand, from behind the screen, may be encountered; and
- If the raw water has a high iron or manganese content the abstraction screens will clog, greatly reducing the yield.

Practical experience

They are used widely in Namibia and a smaller number in South Africa and Zimbabwe.

Key references:

- Clanahan, M.J., 1997, *Sand Abstraction Systems*, Proceedings of the 23rd WEDC Conference (Durban), Loughborough University.
- Hussey, S.W., 1997, *Small-scale "Sand Abstraction" Systems*, Proceedings of the 23rd WEDC Conference (Durban), Loughborough University.
- Hussey, S.W., 1999, *Acceptability/utilisation of sand-abstraction water supplies*, 25th WEDC Conference, Ethiopia.
- Wipplinger, O., 1958, *The storage of water in sand*, South West Africa Administration, Water Affairs Branch
- Burger, SW. and Beaumont, RD., 1970 *Sand Storage dams for water conservation*. Proceedings of the Water year 1970 Convention, Pretoria



What is artificial recharge and how does it work?

Artificial recharge is used to increase the yield of groundwater, by increasing the rate of infiltration, or by direct replenishment. Surface water is either led to infiltration basins where it is allowed to stand and seep into the ground; or water is fed directly down a borehole into the aquifer. (This is after the water has been filtered, to ensure the removal of sediment.)

Artificial recharge requirements

Requirements include that the aquifer must be unconfined and extensive enough to provide storage. When using infiltration basins, the surface soils must be permeable enough to ensure a good rate of infiltration.

Water quality

Artificial groundwater recharge can improve groundwater quality if the groundwater has a high percentage of dissolved solids in it, and the surface water has a lower concentration. However, the quality of the recharge water should be monitored to prevent the injection of contaminants into the aquifer system.

Insitutional support

Professional expertise is needed for the planning of an artificial recharge scheme, including the determination of a suitable site, and the design of run-off conservation mechanisms. Further, a professional geochemical investigation to assess clogging potential and water treatment needs, may be required. This is if the groundwater, or the recharge water, does not meet drinking water standards.

Capital requirements

Costs are associated with:

- Water treatment ranging from basic filtration to complex systems;
- The drilling of injection boreholes; and
- The building of infiltration basins.

Operation and maintenance

Operation and maintenance includes:

- Periodic scraping of the bottom of infiltration basins;
- Monitoring and managing the recharge water quality;
- Monitoring the efficiency of injection wells to detect clogging; and
- Restoring the efficiency of injection wells with backflushing or other methods.

Advantages of artificial recharge

Advantages of artificial recharge include:

- It allows for the maximising of natural underground storage capacity until water is needed i.e. in times of drought; and
- It allows for the optimal use of water that may otherwise have been lost to evaporation.

Limitations of artificial recharge

Limitations of artificial recharge include:

- Artificial recharge schemes need to be designed according to the local, geological, water quality, and institutional conditions in place, otherwise their efficiency will decrease;
- Recharge water may introduce contaminants into the groundwater;
- High evaporation rates, and the presence of clay lenses, can make infiltration basins less effective; and
- Clogging of the injection well system, due to mechanical, physical, chemical, and biological processes, can be a severe limitation to the success of the system.

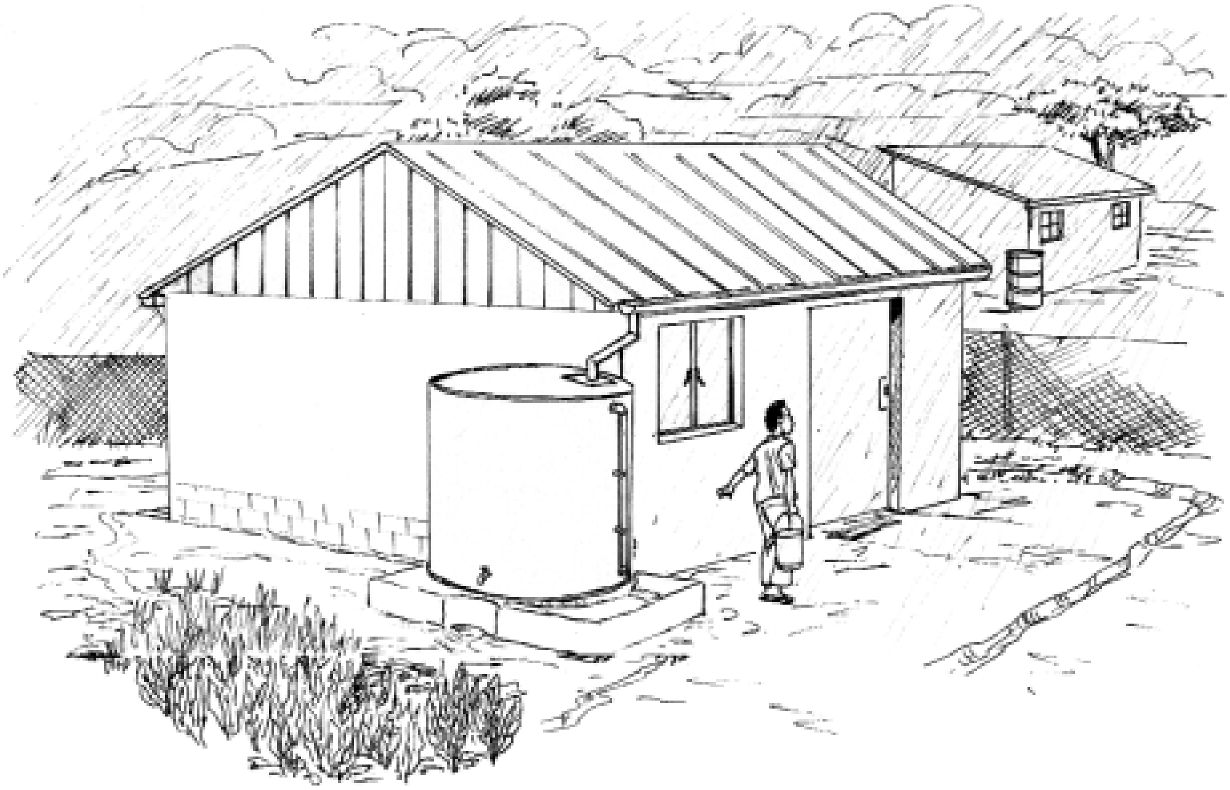
Practical experience

Artificial recharge schemes exist throughout the world. Earth dams are found on farms across South Africa, and in some cases these act as a means of artificial recharge. Operational artificial recharge sites have been established in Atlantis, Windhoek, Polokwane, Omdel (supplying Henties Bay, Swakopmund, and Walvis Bay), Karkams (in Namaqualand), and Calvinia.

Key references:

- Murray, E.C., 2004, *Artificial groundwater recharge, Wise water management for towns and cities*. WRC report no. TT219/03.
- Murray, E.C. and Tredoux, G., 1998, *Artificial Recharge, A technology for sustainable water resource development*, WRC Report no. 842/1/98.
- Murray, E.C. and Tredoux, G., 2002, *Pilot artificial recharge schemes: Testing sustainable water resource development in fractured aquifers*, WRC Report no. 967/1/02.

Rainwater Harvesting



What is a rainwater harvesting and how does it work?

Rainwater is collected from impermeable surfaces, and led to storage tanks. These surfaces include roofs and specially prepared ground and rock.

- Rainwater collected from roofs is channelled, via gutters and pipes, into storage tanks.
- Rainwater gathered from the ground is collected from sloping surfaces which are either compacted or covered with tiles, concrete, asphalt, or plastic sheeting. Water is directed to a storage tank.
- Rock surface rainwater is collected from rocks that have been cleared of vegetation and soil. Loose rocks and any fissures or fractures are sealed. The water is prevented from running off the rock face by a low wall, which leads to a low point. The water is then led through a filter and then conveyed to large storage tanks, or a storage dam.

Rainwater harvesting requirements

The material selected should be easy to clean, and should not pollute the water being collected. Examples of appropriate material include corrugated iron (with no lead-based paint), tiles (with no lead flashing), plastic, concrete, and asphalt.

With rainwater harvesting from the roof, a good guttering and down pipe system must be constructed from PVC, fibre cement, aluminium, or impermeable grade shade cloth.

With ground or rock face rainwater harvesting, a collection system is required along a low edge, often a low wall, which must slope to a low point. From here the water is piped to a storage tank. With ground and rock face rainwater harvesting, a simple filter helps to remove dust, droppings etc.

A storage tank should be designed and constructed taking into account the material available, and the size of the tank required. The size of the tank depends on rainfall patterns and the water demand. In South Africa storage of up to nine months might be necessary. This water is often used in conjunction with lower quality ground and surface water sources, the rainwater being used for potable uses whilst the other sources are used for washing, bathing etc.

Water quality

Rainwater harvested from catchments, other than the roof, is not recommended for drinking purposes, unless the water is treated first. However, this water can be used for washing, and watering of plants and animal watering.

Rainwater quality from roofs can be improved by the inclusion of a coarse screen between the guttering and the delivery pipe. Further improvements can include a fine screen between the delivery pipe and the tank, a lid on the tank, a first flush system that sends the initial run off to waste, and the use of suitable roofing material. Water quality can be poor in areas experiencing significant air pollution. However, this is usually not a threat in rural areas.

Insitutional support

The householder can undertake installation of a roof rainwater harvesting system, with no outside advice or assistance. A ground or rock face rainwater harvesting system might require external support due to the scale of the construction. Both systems can be constructed using local materials and artisans.

Capital requirements

Costs are associated with:

- The roof, cleared rock face, or prepared ground surface;
- The guttering system, downpipes, or collection wall;
- Filters; and
- Storage tanks.

Operation and maintenance

If it has not rained for a long time, the roof must be cleaned before rainwater is collected. Another option is to wait for the first rains, but to divert this run-off. The tank, gutters, pipes, and screens must all be inspected and cleaned on a regular basis.

Advantages of rainwater harvesting

Advantages of rainwater harvesting include:

- The technology is easily and simply applied;
- Water is collected at household level so there is ownership of the system ;
- Water is provided at the point where it is needed (i.e. near the house);
- The quality of the water is easily maintained;
- Soil erosion and flooding around the house is reduced;
- Gutters and storage tanks can be constructed from locally available material; and
- The groundwater is less likely to be over exploited if it is used in conjunction with rainwater harvesting.

Limitations of rainwater harvesting

Limitations of rainwater harvesting include:

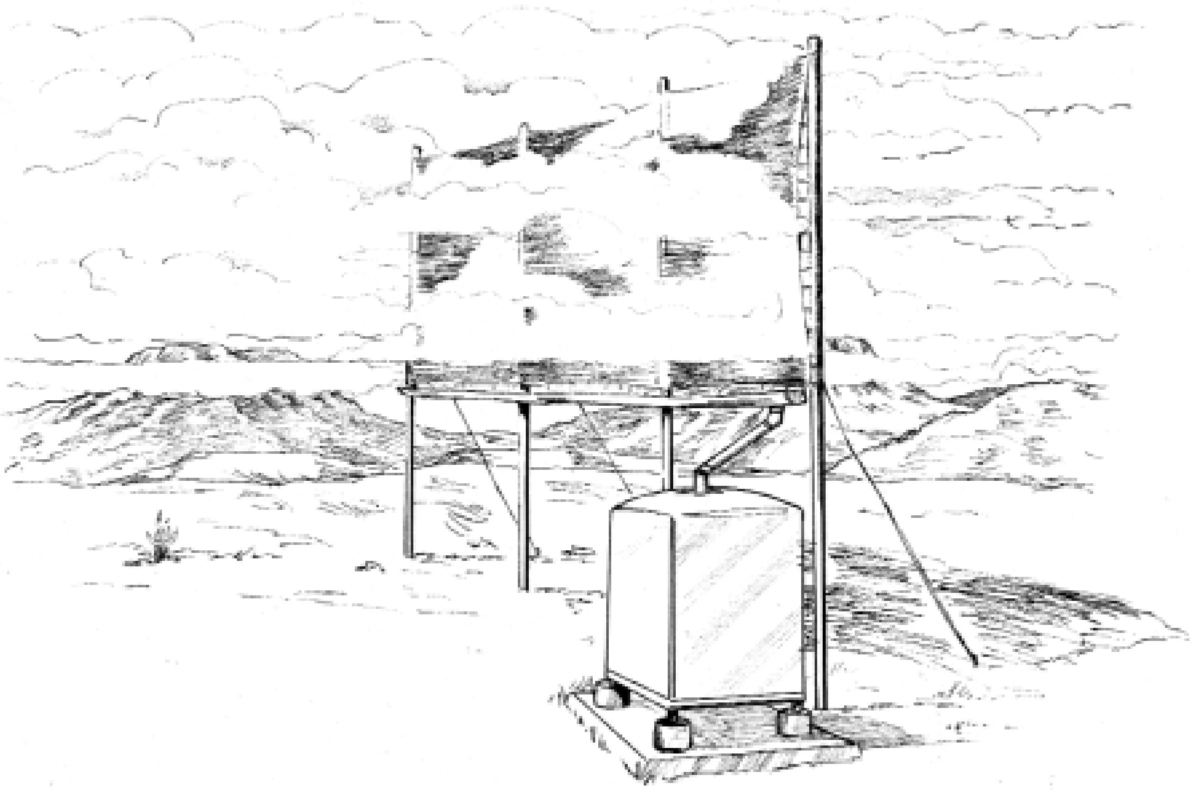
- Rain is an unpredictable and irregular source of water;
- Large storage tanks may be required in areas where the dry season is long; and
- It is difficult to attach guttering systems to circular or thatched roofs, these require flexible guttering like impermeable shade cloth.

Practical experience

Rainwater harvesting has been used for water supply for thousands of years. It is still used extensively all over the world, even in highly developed countries. It has been used extensively in South Africa, particularly where groundwater is poor and surface water is not perennial.

Key references:

- Gould, John, 1999, *Rainwater Harvesting Information Resources Booklet for Southern Africa*
- Houston, P., 2001, *A synthesis of rainwater harvesting models: The development of an appropriate Southern African model*, Partners in Development prepared on behalf of The Mvula Trust.
- Houston, P. and Still, D., 2001, *An overview of rainwater harvesting in South Africa*, Prepared by Partners in Development on behalf of The Mvula Trust and the Department of Water Affairs and Forestry.
- Houston, P. and Still, D., *Rain Water Harvesting, A neglected rural water supply option*, Partners in Development.



What is cloud or mist harvesting and how does it work?

In cloud or mist harvesting water droplets are intercepted and collected in a system comprising of vertical rectangular panels of nylon mesh or shade cloth, supported on either side by wooden posts, and held up with steel cables. This structure is then placed perpendicular to the direction of the prevailing wind. The water droplets in the cloud or mist precipitate onto the mesh, fall into gutters at the bottom of the panel, and are then led under gravity to a storage tank. Storage must be provided for several days to cater for times when there is minimal or no cloud or mist. This system is suitable for cloud or mist-prone areas such as hills or mountains, and on coastlines with a cold current offshore.
The collectors are easy to construct and only require wind energy. A number of systems may be required to provide an adequate supply for a particular settlement.

Cloud or mist harvesting requirements

Cloud / mist must occur frequently throughout the year. It should have a high moisture content and be accompanied by a wind to ensure that the moisture is blown through the collecting screens.

Water quality

The water is usually potable but may contain some dust and be salty in areas close to the coast.

Insitutional support

Professional assistance is needed to determine the suitability of a site for cloud / mist collection, the determination of the projected yield, as well as the construction of fog nets and their proper positioning.

Capital requirements

Costs are associated with:

- Shade cloth / nylon mesh;
- Wooden poles;
- Steel cables;
- Bolts, nuts, washers and clamps;
- Rope;
- Pipes; and
- Storage tanks.

Operation and maintenance

General quality checks to the fog collector system should include checking the cable tensions, cable fasteners, and horizontal net tensions. Further, maintenance, repair and / or replacement of the nets are required. Dust should be washed out of the gutter at regular intervals. Regular maintenance of pipes and storage tanks is also necessary.

Advantages of cloud or mist harvesting

Advantages of cloud or mist harvesting include:

- The structures can be constructed with locally available materials;
- The collectors can often be erected in close proximity to the user;
- The amount of water collected can be varied according to the number and size of the collectors;
- The source is generally sustainable over many years;
- Water may be collected from fog during dry periods, and even through drought periods; and
- If users participate in the installation of the system, additional training for maintenance will not be necessary.

Limitations of cloud or mist harvesting

Limitations of cloud or mist harvesting include:

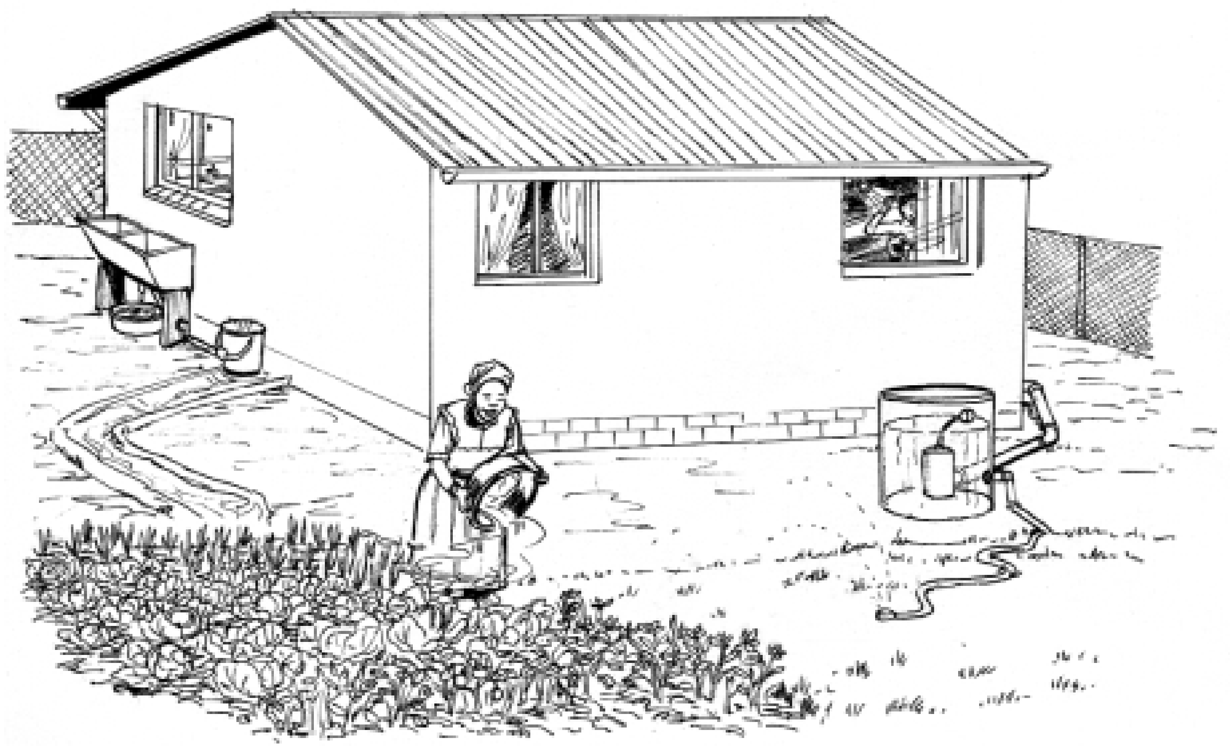
- Fog formation is often irregular in nature and this system is highly sensitive to climatic changes;
- If the users are not located near the harvesting point, the installation of mechanisms to pipe the water in areas of high topographical relief may be costly; and
- Only small quantities of water are produced.

Practical experience

Pilot projects have been conducted in South Africa and Namibia. In South Africa, these have been conducted along the West Coast, in high altitude areas in the Limpopo Province, and in the Eastern Cape.

Key references:

- Olivier, J., 2003: *Fog Harvesting: An alternative source of water on the west coast of South Africa*. Submitted, GeoJournal
- Olivier, J., 2002, *Fog-water harvesting along the West Coast of South Africa: A feasibility study*, Water SA, Vol.28, No.4, 349-360.
- Olivier, J. and van Heerden, J., 1999, *The South African fog water collection project*, Water Research Commission, Report no. 671/1/99.
- Olivier, J. and Rautenbach, C. J. de W., 2002, *Implementation of fog water collection systems in South Africa*, Atmospheric Research, 64, 227-238.
- Olivier, J. and van Heerden, J., 2003, *Implementation of an operational prototype fog water collection system*, Project implementation, Water Research Commission, Report no. 902/1/02.



What is greywater recycling and how does it work?

Greywater refers to the water used for personal hygiene, washing of clothes, and washing dishes. Instead of disposing of this water in a sewage system, if one exists, it can be recycled and used for garden irrigation. This reduces the demand for fresh water for irrigation.

Greywater recycling requirements

Pipes are required which channel the water from the bath, shower, basins and washing machine to a sump. The water is then distributed manually, or through a pump and sprinkler system, onto the garden. The garden must be of sufficient size to prevent a build up of salts, or over irrigation.

Water quality

Greywater contains chemicals from soaps and detergents as well as organic materials. It is not suitable for drinking. However, this water can be used safely for garden irrigation. Plants take up the nutrients. The amounts of pathogens in greywater are insignificant and are digested by organisms in the soil. It should be noted that in the normal kitchen environment there are significant quantities of pathogens (such as, salmonella in chicken) which are rendered harmless by cooking and washing.

Insitutional support

The installation of a sophisticated greywater recycling system in an urban area may require professional guidance, but simple systems can be built and maintained by the household.

Capital requirements

Costs are associated with:

- Filters;
- The storage chamber; and
- A submersible pump, piping; and sprinkler.

If a less sophisticated system is used, then a simple means of distributing the water manually is required.

Operation and maintenance

Regular maintenance of the filter is required. The sprinkler must be moved every couple of days, or the water must be manually distributed. Checks are important to ensure there are no blockages in the pipes, as this could lead to the pump not switching off, and thus burning out.

Advantages of greywater recycling

Advantages of greywater recycling include:

- Water that would otherwise be wasted can be used for irrigation;
- The consumption of freshwater is reduced; and
- The amount of water passing through the wet sanitation system, if there is one, is reduced.

Limitations of greywater recycling

The limitations include that greywater cannot be stored for more than 24 hours, unless it has been treated, otherwise it can turn anoxic or anaerobic.

Practical experience

Approximately 1500 household units have been installed in South Africa.

Key references:

- Holden, R., 2001, The use of dry sanitation in the urban environment, The Mvula Trust, Braamfontein.

Useful websites:

www.Water-Rhapsody.co.za
www.greywater.com
www.oasisdesign.net/greywater

2 SOURCES OF POWER FOR PUMP SYSTEMS

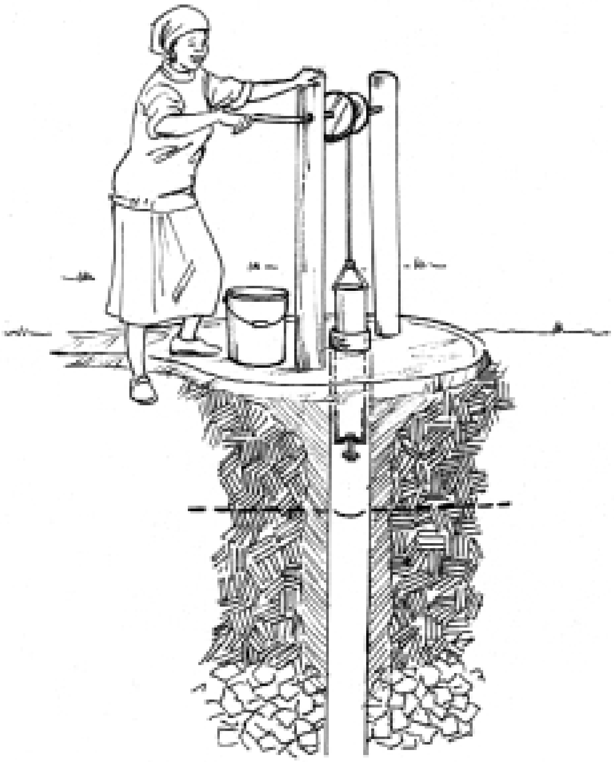
Introduction

This section covers the range of energy sources available to power pumping systems, rather than the different types of pumps.

Experience has shown that electricity from the grid is the most efficient way of powering motors. The energy is generated at a central point and brought to the site without the need for transport. However, its main drawback is that it is dependent on a functioning transmission system. In isolated areas this can be problematic. Also, with electricity, accounts are paid in arrears. In a number of situations this has led to the generation of huge bills. The responsible organisation then can not pay, and the power supply is cut, creating huge problems. Finally, electrical pumps need transmission lines to be reasonably close, to keep the capital costs down.

In contrast, diesel powered motors require fuel to be delivered to the engine. A degree of logistical planning is therefore important. But, in smaller schemes it may be easier to manage the rate of consumption of diesel than electricity. However, if the cost of supplying diesel or electrical energy is too high then alternatives such as solar, wind, and human power need to be assessed.

Hand Pumps



What is a hand pump and how does it work?

Hand pumps use human power to bring groundwater to the surface. The action of the pump handle results in a column of water being lifted to the surface. Since human effort is used to lift the water this is a major limiting factor.

Hand pump adaptations

Human-powered pumps include foot pumps where a person uses their legs, as opposed to their arms. Also, there are play pumps that look like merry-go-rounds.

Hand pump requirements

These include:

- The choice of hand pump depends on lift characteristics, pump capacity, water demand, and ease of maintenance; and
- The pump must be suited to on-site conditions i.e. be able to lift water from depth if this is required.

Insitutional support

Village level operation and maintenance (VLOM) pumps do not require outside support, if community members are trained and are given the appropriate tools. However other pump designs may require external assistance. One of the important issues here is that, since the energy source is free, there are no monthly charges. However money must be still raised for routine maintenance and possible breakages.

Capital requirements

Capital costs are associated with the purchase of the pump, installation, construction of an apron and drainage system, and fencing.

Operation and maintenance

Hand pumps can withstand irregular maintenance far better than electrical or diesel pumps. However, common aspects that require maintenance include failure of the anti-reverse system, failure of the bearings in the head, and excessive wear of gears in geared head pump units.

Generally less maintenance is required for pumps designed with the VLOM philosophy. They are designed for ease of maintenance, low capital and recurrent costs, and robustness. They are manufactured to a standard, publicly available, design and therefore the consumer is not dependant on a single manufacture or supplier.

Advantages of hand pumps

The advantages of hand pumps include the fact that they use a free energy source, namely human power.

Limitations of hand pumps

Limitations include the fact that hand pumps are not suitable to lift groundwater from depths greater than 45 metres, since human power is required to lift the column of water. However if the pump is geared it can be effective up to a depth of 90 meters, but it still require a huge effort for a minimal amount of water.

Practical experience

The number of hand pumps in operation in South Africa is estimated at between 10 000 and 15 000.

Key references:

- Arlosoroff, S., Tschannerl, G., Grey, D., Journey, W., Karp, A., Langenegger, O. and Roche, R., 1987, *Community Water Supply: The Handpump Option*., The World Bank.
- IRC (International Water and Sanitation Centre), 1988, *Handpumps, Issues and concepts in rural water supply programmes*, Technical Paper Series no. 25.
- Still, D.A. and van Niekerk, T., 2002, *Handpumps in KwaZulu-Natal*. Still the most important water supply methodology, WISA (Water Institute of Southern Africa) Biennial Conference, Durban.

What is a solar powered pump and how does it work?

A solar pump consists of an array of photovoltaic cells that convert solar radiation into electricity that drives an electric pump. Although solar pumps can pump up 200 metre heads, they are most cost-effective up to a pumping head of 50 metres.

Solar pump adaptations

Solar panels can be used in conjunction with batteries to provide capacity to store energy, and thus to ensure continuous pump use. Also, solar panels can be used in conjunction with a diesel pump, but this increases the operation and maintenance costs of the system.

Solar pump requirements

There are a number of requirements:

- The pump requires sunlight.
- A storage tank is needed for cloudy days and nights when there is no sunlight to pump water. A tank is also needed during periods when the pump is being serviced or repaired, and to balance any fluctuations in demand.
- An electric motor must be selected with care to ensure that the system can operate over a range of voltage and current levels, depending on the intensity of the sunlight. If the electric pump uses alternating current, a DC / AC converter is needed to convert direct current to AC current. (DC current is produced by the photovoltaic cells.)

Insitutional support

When problems arise with solar systems (even simple electrical faults), it is often necessary to call in a specialist from one of the major centres.

Capital requirements

Capital costs per unit of power (watt) produced are very high. Costs are associated with:

- Solar panels;
- The DC / AC converter and batteries (if required);
- The electric pump; and
- The storage tank.

Operation and maintenance

Maintenance generally involves keeping the panels free from dust and dirt and protecting them from animal and human damage.

Advantages of solar powered pumps

Advantages include:

- Solar-powered systems (like diesel systems) are generally reliable, robust, and do not require regular maintenance;
- The energy source used is free and renewable; and
- Solar energy is an attractive option for remote areas, where fuel is expensive and difficult to find, and grid electricity does not exist.

Limitations of solar powered pumps

The limitations include:

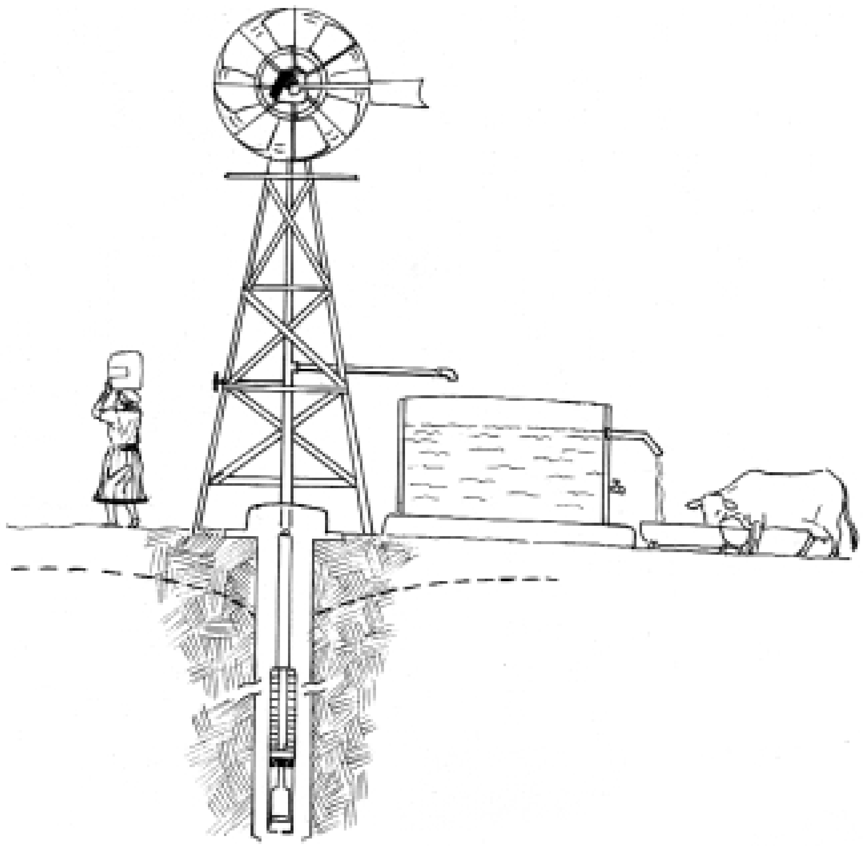
- Photovoltaic panels use advanced technology and have to be imported;
- When problems occur with solar pumps (even simple electrical faults), specialists have to be called in at great expense;
- Solar panels are prone to theft;
- Each panel can produce only a limited amount of electricity per day (for example, 250 watt hours), depending on the weather; and
- Photovoltaic systems are only cost effective where relatively low volumes of water are being pumped per day, at relatively low heads, for example up to 20 metres cubed per day to 40 metres head.

Practical experience

Solar powered pumps are used mainly on private farms and game reserves, as a substitute for diesel pumps. Rural communities, however, often face problems due to issues of theft and high costs of maintenance.

Key references:

- PV Pump Technical Information Sheet.
- Davis M, Burchers M, Dickinson B and Geerdts P, 1994, *Institutions and Financing For Effective Dissemination of PV Systems for Rural Developmen*t. Energy for Development Research Centre, Cape Town.
- Gosnell R (1991) *Demonstration and Evaluation of a Photovoltaic Powered Water Pump*. Energy for Development Research Centre, Cape Town.
- Kenna J and Gillet B, 1985, *Solar Water Pumping: A Handbook*. Intermediate Technology Development Group, London.
- Village Water Supply Section, 1994, *Solar pumping systems manual*, Ministry of Home Affairs, Government of the Kingdom of Lesotho, Maseru
- Wiseman K and Eberhard A, 1987 *A technical, economic and social analysis of alternative water pumping for underdeveloped rural areas*, Energy Research Institute, University of Cape Town.



What is a wind powered pump and how does it work?

Wind powered pumps use the energy generated by wind to lift groundwater to the surface. A rotor is mounted on top of a tower. The action of the wind turns the rotor, which through a gearbox drives a reciprocating shaft. This in turn drives the pump in the borehole.

Wind pump adaptations

The air-lift groundwater pump was developed to provide a low-cost pump for use in informal and rural settlements. This pump system can be operated with tyre pumps. It has a wind pack compressor, capable of storing wind energy as compressed air. This provides supplementary power to the pump. All the working parts of this pump are located above ground, making maintenance easy.

Wind pump requirements

The pump requires sufficient wind speeds for significant lengths of time. The wind pump must therefore be placed where there is a clear sweep of wind. Also, the borehole should provide enough water so that continuous pumping does not result in excessive drawdown. Storage for several days must be provided to cater for calm periods when there is insufficient wind speeds to pump water. Further, someone must be delegated to apply the manual brake to avoid damage during storms.

Insitutional support

The installation requires trained personnel.

Capital requirements

Capital costs vary. Costs depend on the depth of the borehole, the size of the rotor, and the height of the tower. Capital costs are associated with:

- The rotor;
- The tower;
- Transmission;
- The storm control device; and
- The reservoir.

Operation and maintenance

Operation and maintenance should include the following:

- Lubrication of the gearbox; and
- Applying the manual break during storms.

A trained community member can do routine maintenance.

Advantages of wind powered pumps

Advantages include:

- These pumps can lift water from great depths; and
- The energy source is free and renewable.

Limitations of wind powered pumps

The limitations include:

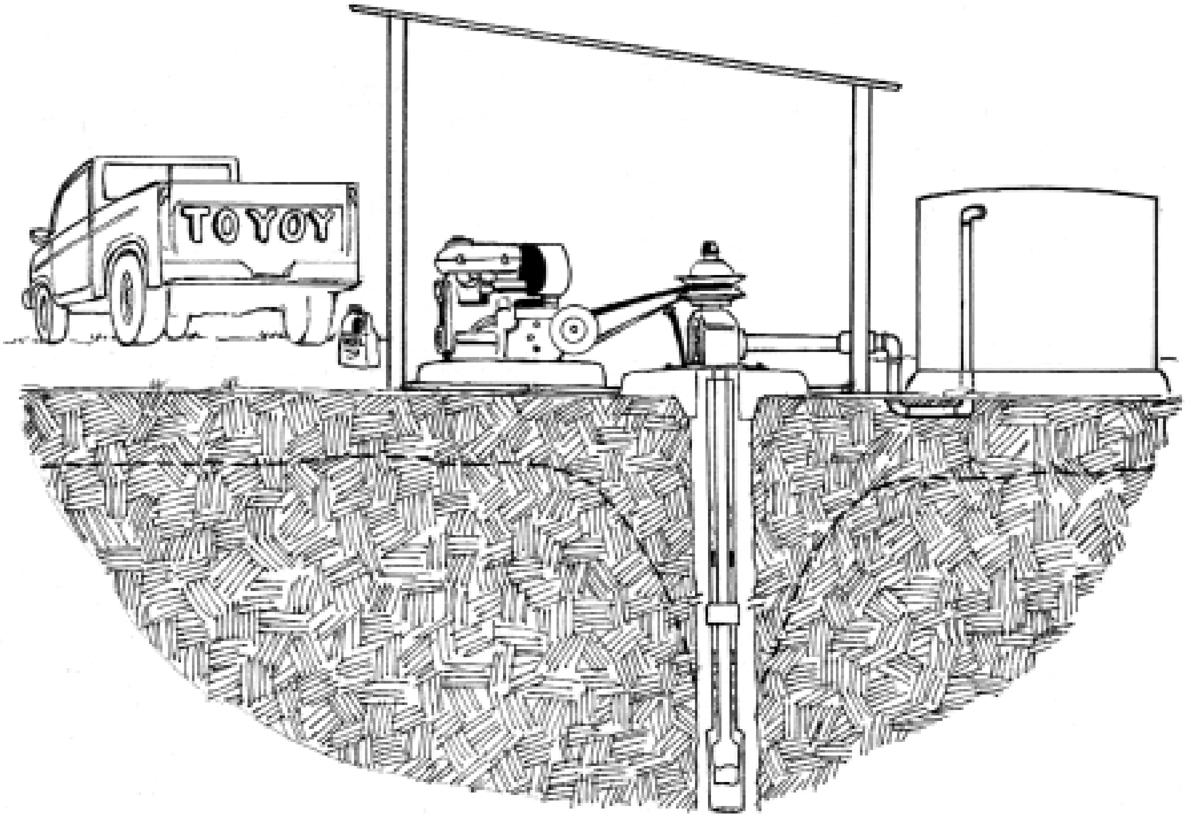
- Wind pumps have a high initial cost and require regular maintenance; and
- Breakdowns can be caused in a number of ways. These include rotor failure caused by high winds, transmission system failure caused at the wind pump head, and piston-cylinder failure caused due to the borehole running dry. (Wind pumps do not stop, unless brakes are applied.)

Practical experience

Wind powered pumps are used across the world. They are widely used by the farming community in South Africa, particularly in Umtata, KwaZulu-Natal, the Free State and the Northern Cape.

Key reference:

- Baumann, E., 2000, Series of manuals on drinking water supply, volume 7, *Water lifting*, SKAT, Switzerland.



What is a diesel powered pump and how does it work?

A diesel engine transmits power through V-belts, gearboxes, or shafts, to a pump.

Diesel pump requirements

There are a number of requirements:

- A storage tank is required for periods when the pump is not in operation, to balance fluctuations in demand;
- Fuel must be delivered on a regular basis;
- An operator is required to turn the pump off and on; and
- Trained personal must conduct maintenance checks and services.

Insitutional support

Arrangements must be made to purchase fuel, oil, and other consumables. Regular maintenance must be organised and back-up must be ensured during breakdowns.

Insitutional support

Capital costs are associated with the purchase and installation of the engine, pumphouse and reservoir.

Operation and maintenance

Engine oil and filters must be replaced regularly, usually after 250 hours of operation. Further, spare parts, fuel supplies, and regular servicing are essential. Engines should not be run at a speed exceeding 70 to 80 % of capacity as this may lead to premature wear and inefficiency. But further, engines should not be run much below this level as this leads to a build-up of excessive carbon deposits in the cylinder i.e. coking.

Advantages of diesel powered pumps

Advantages include:

- Diesel engines have a high power-to-weight ratio and can be used to drive almost any type of pump;
- There are no overhead costs during periods of non-use, unlike in the case of an electricity grid which has high basic charges; and
- Diesel is purchased upfront which means that consumers are prevented from accruing high energy bills. (In effect the diesel system is a pre-payment system.)

Limitations of diesel powered pumps

The limitations include:

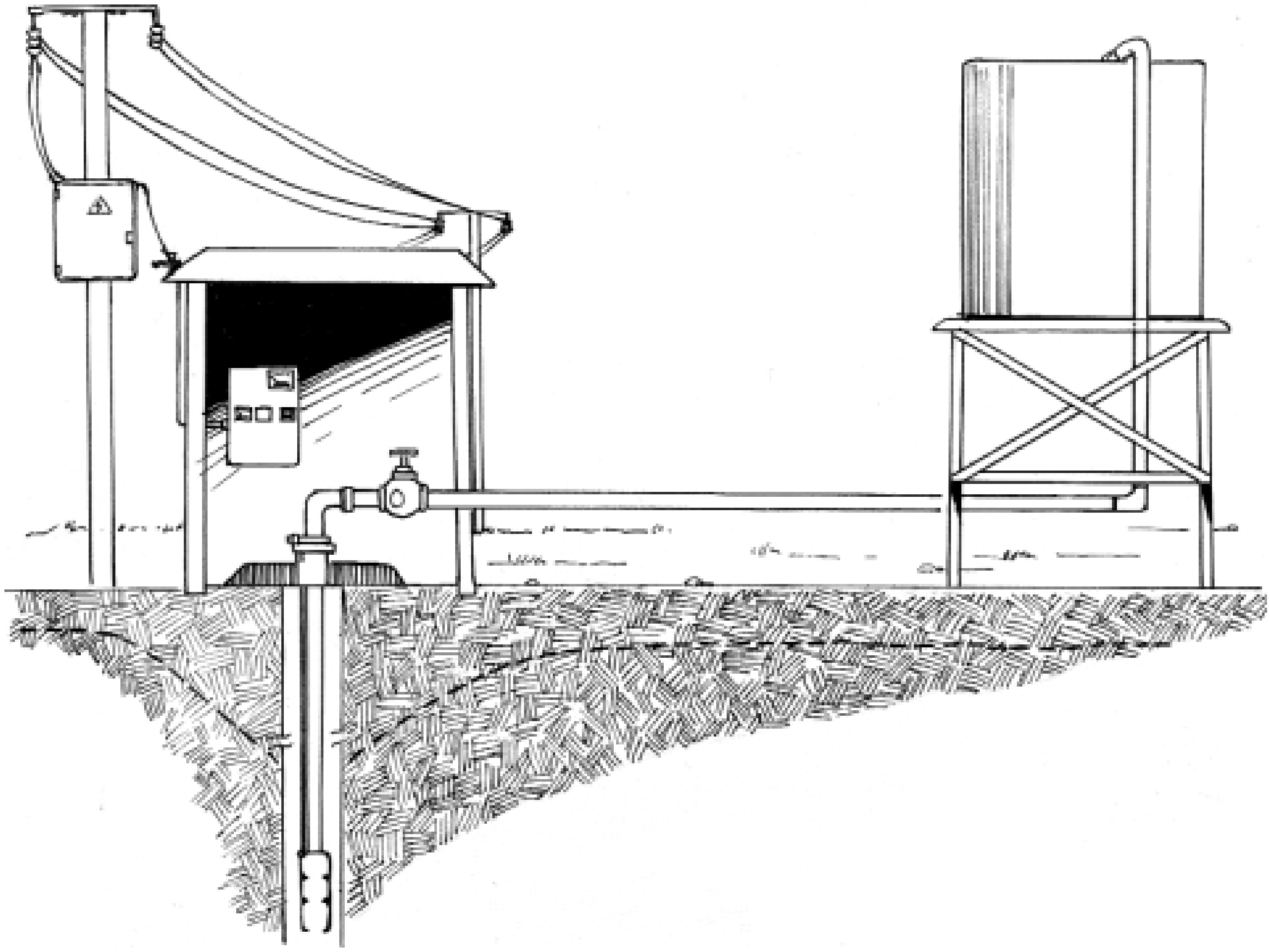
- In rural areas there are not always trained mechanics to maintain and repair diesel engines;
- Diesel engines are hard to automate, and an operator is required to switch the engine on and off; and
- The logistics of supplying diesel in rural areas can be difficult.

Practical experience

The use of diesel powered pumps is widespread in the South Africa.

Key reference:

⊙ Baumann, E., 2000, Series of manuals on drinking water supply, volume 7, *Water lifting*, SKAT, Switzerland.



What is an electric pump and how does it work?

Electricity is used to power the motor. The motor can be a separate unit attached to the pump through V-belts, gearboxes, or shafts. This type of motor is situated on the surface. Alternatively, the motor can be integrated with the pump, as in a submersible pump. The pump is then located within the water.

Electric pump requirements

The motor chosen must be of the right size for the anticipated workload. Further, a storage tank is required for periods when the pump is not in operation, and to balance fluctuations in demand.

Insitutional support

Repairs to the motor require trained personnel. Generally, specialised tasks such as rewinding need to be performed. Usually this expertise is only found in major centres. Arrangements need to be in place for the payment of electricity accounts, to prevent cut-offs and back up must be ensured during breakdowns.

Capital requirements

Capital costs include:

- The motor;
- Transmission lines; and
- Transformers

Operation and maintenance

The operation and maintenance costs of an electric engine are less than those of a diesel engine. Routine maintenance checks need to be done by trained personnel.

Advantages of electric pumps

Advantages include that electric pumps are easier to operate and do not require as much maintenance as diesel pumps. Electric pumps can be automated.

Limitations of electric pumps

Limitations include:

- Rural areas are often subject to power cuts;
- Voltage fluctuations can hamper the productivity of the pump; and
- A line fee is usually charged for connection, whether electricity is used or not.

Practical experience

Electric pumps are normally the first choice when grid electricity is available.

Key reference:

⊙ Baumann, E., 2000, Series of manuals on drinking water supply, volume 7, *Water lifting*, SKAT, Switzerland.

3 SANITATION TECHNOLOGIES

INTRODUCTION

SANITATION TECHNOLOGIES

Flush Toilet with Central Treament Works
Flush Toilet with Conservancy Tank
Flush Toilet with Septic Tank and Soakaway
Alternating Twin Pit Composting Toilet (Fossa Alterna)
Urine Diversion Dehydrating Toilet
Ventilated Improved Pit Toilet

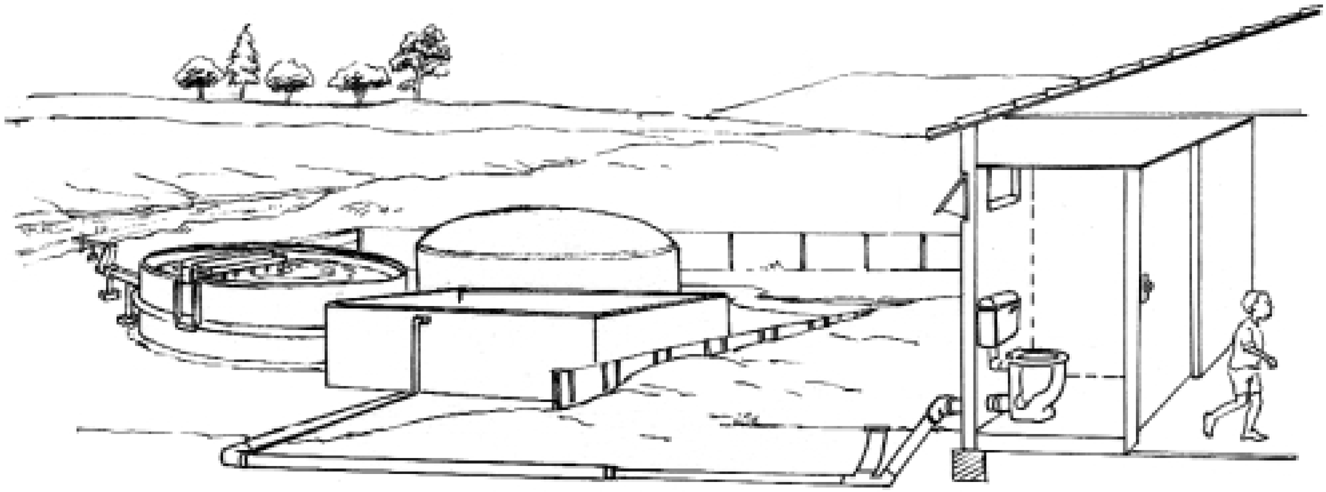
Introduction

The focus of this section is to unpack what is required for a sanitation system to function optimally. The purpose is to look at the entire sanitation cycle starting with the excreta dropping into the pedestal, and ending with the treated effluent, or solid waste, being discharged into the environment. It covers both on-site (i.e. household owned) and off-site (i.e. municipal owned) components, as well as the materials needed on-site to enable the technology to function, for example, water for waterborne sewage.

It covers the issues surrounding the structure required to house the toilet. The critical question is, "*Does the toilet need to be positioned in a separate outside building, or can it be incorporated into the house*?" This is important when comparing waterborne with on-site technologies.

Finally, this section focuses on the issue of greywater treatment. This is a topic that is often neglected as uncontrolled discharge of greywater can have serious problems, particularly in an urban environment.

Flush Toilet with Central Treatment Works



What is a central treatment works and how does it work?

Waste from the toilet and greywater is flushed into a piped system that carries the sewage to a wastewater treatment works. (Greywater, however, can be separated out and utilised at household level.) At the works, solids are separated from liquids, pathogens are destroyed, and solid waste is disposed of. The treated water is then released back into the rivers. The treatment works can vary from a simple pond system, with no operators, to a highly complex system, requiring 24-hour support.

Waterborne sewerage requirements

Waterborne sewage requires a household water connection, a sewer reticulation, and central treatment works.

Groundwater and the system

Leakages, if undetected, may infiltrate the sub-surface and result in groundwater contamination. Further, blockages and breakdowns, which result in overflowing manholes, can pollute both surface and groundwater.

Water requirements

A reliable, 24-hour piped water supply is required.

Greywater

The system can handle large quantities of greywater.

Level of comfort

The toilet can be located inside the house. A water trap prevents smells from the sewage entering the house. Also, there are no uncomfortable draughts, whilst using the toilet.

Insitutional support

Institutional support is required for the following:

- Construction of the system;
- Establishment, as well as operation and maintenance, of the treatment works;
- Municipal operation and maintenance of reticulation and bulk sewers, including replacement of missing manhole covers, detection and repair of leaks, and removal of blockages;
- The billing associated with the use of the reticulation and the treatment works; and
- Effective credit control.

Capital requirements

Capital costs include:

- An on-site piped water supply;
- A structure (This cost can be reduced if the toilet is placed inside an existing house);
- A cistern;
- A pedestal;
- On-site reticulation;
- Municipal reticulation;
- Bulk sewers; and
- Treatment works.

Operation and maintenance

The seal in the cistern will require replacement from time to time. Rodding of on-site pipes and the municipal reticulation is required to clear blockages (If tree roots penetrate the sewer this will become a regular task, unless the sewer is replaced). Pump stations and treatment works must be constantly maintained. Equipment must be replaced to ensure breakdowns do not occur, polluting the environment.

Advantages of waterborne sewerage

Advantages include:

- High levels of user comfort and convenience;
- The user does not have to handle waste, since it is flushed away for the municipality to deal with; and
- The system can easily accommodate peak usage during social events, since it is part of a larger system.

Limitations of waterborne sewerage

Limitations include:

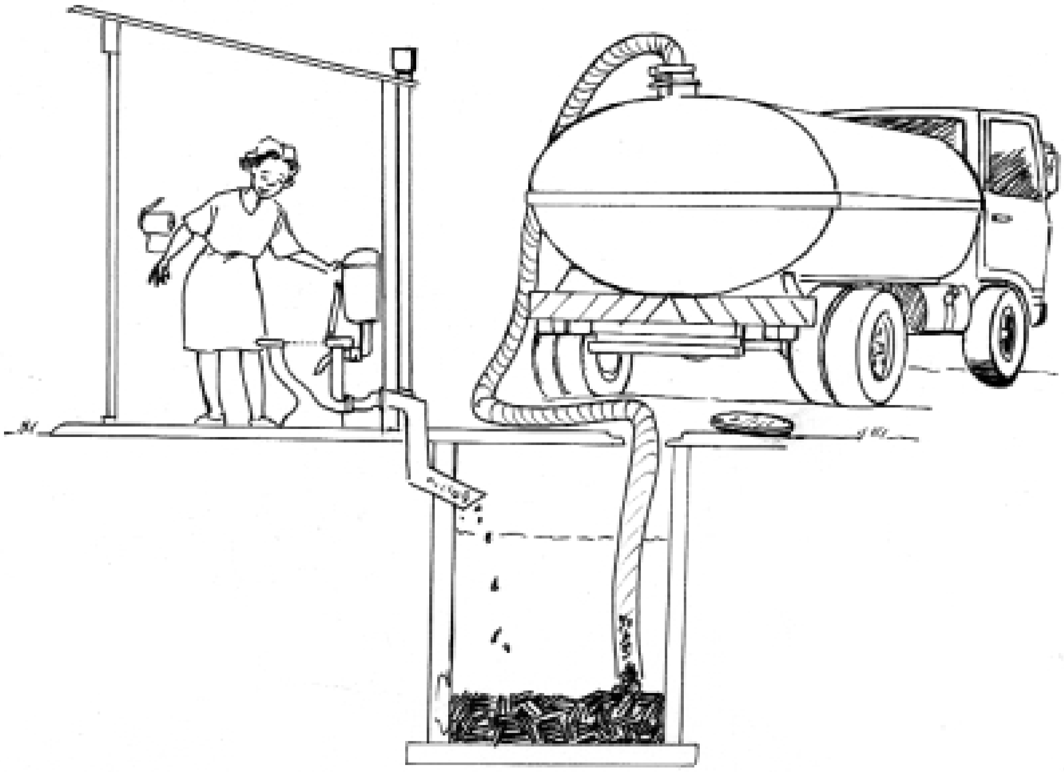
- A developed infrastructure and institutional capacity is required for construction, operation and maintenance, and for billing and credit control, of the system;
- Underground leaks are extremely difficult to detect;
- Blockages can cause large amounts of environmental pollution, unless the responsible institution has a rapid response time;
- When blockages occur on private property, and the owner fails to act, by-laws are often not framed to allow the municipality to act quickly and recover costs.
- Problems may arise if the sewage treatment works are not able to treat volumes of sewage, from the whole system, to the required standard;
- If soft toilet paper is not used blockages may occur; and
- The system can be used as a means of disposing unwanted material, such as rubbish and foetuses, causing serious blockages.

Practical experience

This sanitation option is used extensively in urban areas across the world. However, extreme environmental problems have arisen when treatment has not been provided, or the system has not been maintained.

Key references:

- DWAF Sanitation Support, 2001, *Study Report on Management of Faecal Waste from On-site Sanitation Systems in South Africa*.
- DWAF, 2002, *Sanitation for a Healthy Nation*, Sanitation Technology Options.



What is a flush toilet with a conservancy tank and how does it work?

Waste from the toilet and greywater is flushed into a watertight tank. The tank must be emptied on a regular basis (by a tanker) and the contents disposed of at a sewage treatment works. The treatment works can vary from a simple pond system, with no operators, to a highly complex system, requiring 24-hour support. The waste treatment works separate the solids from the liquids, remove pathogens, and dispose of solid waste. The treated water is then directed to a river. The tank size and the frequency of emptying depend on both the number of people using the system, and the quantity of greywater disposed of. (If greywater is separated out and utilised at household level, the frequency of emptying the tank can be significantly reduced.)

Conservancy tank requirements

A household water connection is required. The tank must be large enough to cater for the needs of the household. Further, provision must be made to empty the tank.

Groundwater and the system

If the tank leaks, and this goes undetected, waste may infiltrate the sub-surface, resulting in groundwater contamination.

Water requirements

A reliable, 24-hour piped water supply is required.

Greywater

The system can accept greywater. However, if significant quantities are disposed of, tanks will need to be emptied more frequently. This may be as often as once every week, depending on the size of the tank.

Level of comfort

The toilet can be located inside the house. A water trap prevents smells from the sewage entering the toilet. Also, this system prevents uncomfortable draughts whilst using the toilet.

Insitutional support

Institutional support is required for:

- Emptying of tanks and the transportation of sewage to the treatment works;
- Establishment, as well as operation and maintenance, of the treatment works;
- The billing associated with the use of the treatment works and the collection of the sewage by tanker; and
- Effective credit control.

Capital requirements

Capital costs include:

- The on-site piped water supply;
- The toilet structure (this cost can be reduced if the toilet is placed inside an existing house);
- The cistern;
- The pedestal;
- The tank;
- Vacuum tankers; and
- The treatment works.

Operation and maintenance

Operation and maintenance requires the following:

- The seal in the cistern requires replacement from time to time;
- Rodding of on-site pipes is necessary to clear blockages; and
- The tank must be emptied, and the contents transported to the treatment works.

Advantages of conservancy tanks

Advantages include:

- High levels of comfort and convenience; and
- The user does not have to handle waste.

Limitations of conservancy tanks

Limitations include:

- There must be access for tankers to empty the tank;
- Overflow can easily occur during peak social events; and
- The user must ensure that the municipality collects the sewage on a regular basis.

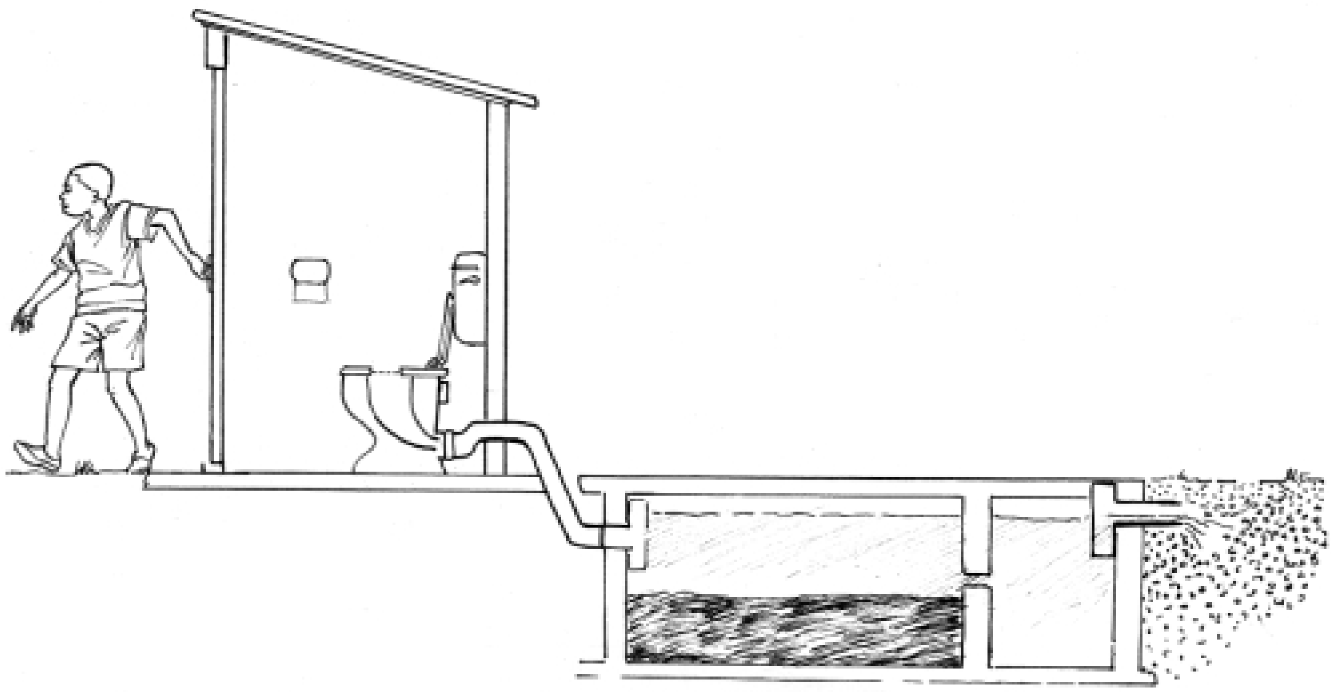
Practical experience

This toilet is used in a number of municipalities in South Africa, where septic tanks with soak-aways are not deemed appropriate.

Key references:

- DWAF Sanitation Support, 2001, *Study Report on Management of Faecal Waste from On-site Sanitation Systems in South Africa*.
- DWAF, 2002, *Sanitation for a Healthy Nation*, Sanitation Technology Options.

Flush Toilet with Septic Tank and Soakaway



What is a flush toilet with a septic tank and a soakaway and how does it work?

Waste from the toilet, and greywater, are flushed into the septic tank. The solids are retained in the tank whilst the effluent is led to a soakaway. The time that it takes to fill the tank is dependent on the number of users. The typical filling rate is 30 litres, per user, per year. The sludge is taken to a sewage treatment works.

Septic tank requirements

The soil must provide good drainage for the soakaway to work. There should be sufficient space on the property to allow for this. Sludge gradually builds up in the tank and a tanker is required for its removal. Access for de-sludging must be provided. Also, a household water connection and an operational central sewage treatment works are required.

Groundwater and the system

Leakage in the system, if undetected, may infiltrate the sub-surface, resulting in groundwater contamination. If nitrates are not removed, they may affect the groundwater.

Water requirements

A reliable, 24-hour piped water supply is required.

Greywater

The system can accept greywater but the amount needs to be governed by the size and capacity of the soakaway.

Level of comfort

The toilet can be located inside the house. A water trap prevents smells from the sewage entering the toilet, and uncomfortable draughts whilst using the toilet.

Insitutional support

Institutional support is required for:

- Emptying of tanks and transportation to the sludge treatment works;
- The establishment, as well as operation and maintenance, of the treatment works;
- The billing associated with the use of the treatment works; and
- Effective credit control.

Capital requirements

Capital costs include:

- An on-site piped water supply;
- A structure to house the toilet (this cost can be reduced if the toilet is placed inside an existing house);
- The cistern;
- The pedestal;
- On-site reticulation;
- The septic tank;
- The soakaway;
- Vacuum tankers; and
- The treatment works.

Operation and maintenance

The soak-away needs to function effectively. No surface seepage should be evident.
The tank must be emptied and the contents transported to the treatment works.
Further, payment for use of the treatment works is required.

Advantages of septic tanks

Advantages include:
- High levels of comfort and convenience; and
- The user does not have to handle waste.

Limitations of septic tanks

Limitations include:
- There is increased susceptibility to overload during peak periods;
- Soils must be permeable so that the effluent drains away;
- Provision must be made for sludge treatment and disposal; and
- Care must be taken not to flush objects such as sanitary towels and condoms down the toilet, as these cause the tank to fill rapidly.

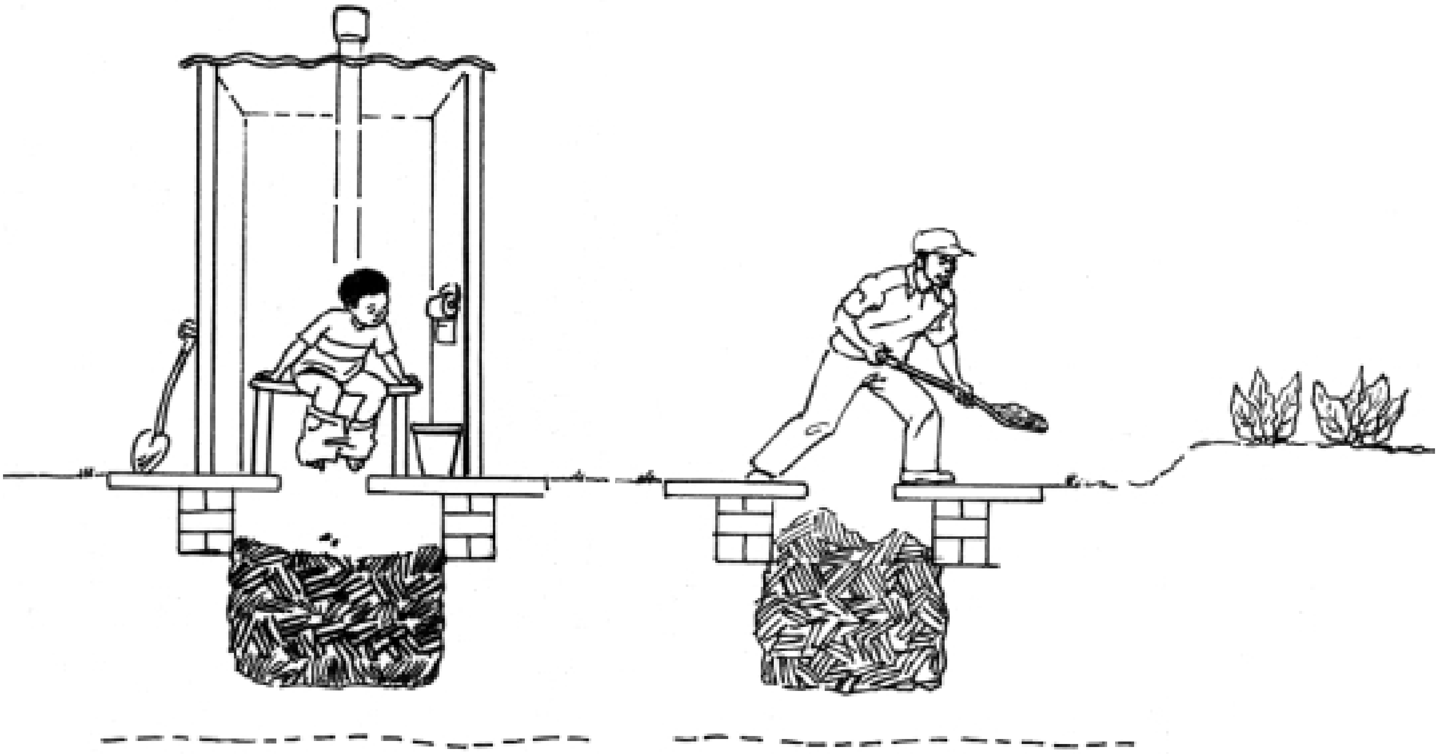
Practical experience

This sanitation option is used extensively in rural and peri-urban areas throughout South Africa. It is used in both agricultural areas and urban settlements with large plots.

Key references:

- De Villiers, D.C., 1987, *Septic Tank Systems*, BOU 98, CSIR
- DWAF Sanitation Support, 2001, *Study Report on Management of Faecal Waste from On-site Sanitation Systems in South Africa*.
- DWAF, 2002, *Sanitation for a Healthy Nation*, Sanitation Technology Options.

Alternating Twin Pit Composting Toilet (Fossa Alterna)



What is a twin pit composting toilet and how does it work?

Two shallow pits are used alternately. Solid and liquid waste drop into the pit and other matter, such as soil, vegetable matter, leaves or grass, are added at regular intervals to aid the decomposition process. When the pit is three quarters full, it is topped with a mixture of soil and leaves and is allowed to turn into compost over a period of six to twelve months. During this time, the alternative pit is used. The time taken to fill the pit depends on the number of users.

The pits are small between 0.5 and 1.0 metres deep. The humus produced can be used as a soil conditioner. A vent pipe can be fitted to assist in the control of flies and odours. The interior should be kept relatively dark. Water can be used to wash down the chute of the pedestal but the contents of the pit should not become waterlogged.

Twin pit composting toilet requirements

After each defecation, organic matter or soil should be added. Control of moisture of the waste is vital for proper operation of the system.

Groundwater and the system

The pit cannot drain if the water table is high i.e. less than one metre from the surface. In such cases alternative sanitation technologies (for example, urine diversion toilets) are recommended.

Water requirements

This toilet does not require water for effective functioning.

Greywater

This toilet cannot accept greywater. This must be disposed of in a soakaway or used for garden irrigation.

Level of comfort

The toilet cannot be placed inside the house.

Insitutional support

The household can construct the toilet without external support. Institutional support is required if the compost has to be collected and transported for use elsewhere. Otherwise the user can maintain the toilet, with no institutional support.

Capital requirements

Capital requirements are associated with:

- Building a structure;
- The pedestal; and
- Digging the pits.

The total cost depends on the materials used. Costs can be reduced if the users do all or some of the work themselves.

Operation and maintenance

The addition of organic matter, such as garden material and vegetable matter or soil will assist in the decomposition process. The top structure and the pedestal must be alternated between the pits. The humus must be excavated after six months to a year, for further use, or for the collection and transportation for use elsewhere.

Advantages of twin pit composting toilets

Advantages include:

- Waste may be used as a soil conditioner;
- The toilet can be built by the householder; and
- The two pits used occupy a small area, so the toilet is therefore suitable for areas where space is limited.

Limitations of twin pit composting toilets

Limitations include:

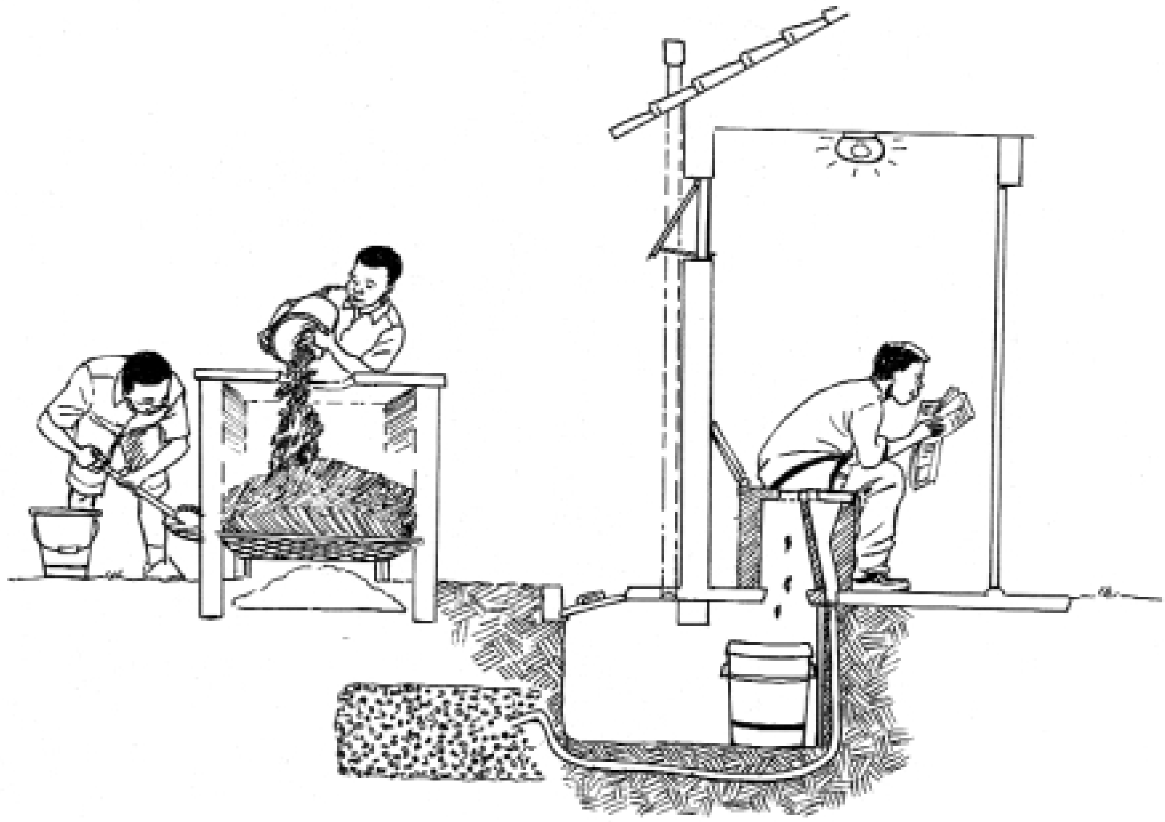
- The user must be willing to handle the compost;
- The sides of the pit may require lining if the soil is unstable;
- Sufficient soil and biodegradable organic wastes, such as garden and vegetable waste, must be on hand; and
- Land needs to be available close by where the compost can be used. If this is not available, a transport system needs to be accessible for waste removal purposes.

Practical experience

This technology has been used with success in Zimbabwe, Mozambique, Malawi and Kenya.

Reference:

⊙ Visit the following website:
http://aquamor.tripod.com



What is a urine diversion dehydrating toilet and how does it work?

A urine diversion pedestal is used to keep the urine and the faecal matter separate. The faecal matter drops into a vault below the pedestal. The vault needs to prevent groundwater or rainwater entering. After each visit to the toilet dry soil, ash or a mixture of both is added so as to control moisture content and to prevent biological breakdown. Urine is diverted at the pedestal. This may be collected and used as a fertiliser, or lead to a soakaway. No decomposition happens in the vault, therefore there is no smell, and a vent pipe is not required.

On a monthly basis, the dehydrated material is removed and composted to destroy pathogens. The material can be composted on site or bagged and taken to a central composting facility. With on-site composting, it is recommended that the user wait a year before using the compost. With a centrally run and more controlled facility this can be reduced to two months.

Urine diversion dehydrating toilet requirements

The faecal matter must be kept dry in the pit. Moisture control is vital for the proper functioning of the system. There must be sufficient space on the property for the compost to be used, or the compost must be collected.

Groundwater and the system

There is little threat of groundwater pollution. The urine is disposed of in the root zone. This means that plants can absorb the nitrates.

Water requirements

This toilet has no water requirements for effective functioning.

Greywater

This toilet cannot accept greywater. Greywater must be disposed of in a soakaway or used for garden irrigation.

Level of comfort

The toilet can be placed inside the house. Further, the closed vault without a vent pipe prevents unpleasant draughts whilst sitting on the pedestal.

Insitutional support

The household can construct and maintain the toilet, without external support. Institutional support is required if the compost has to be collected and transported for use elsewhere.

Capital requirements

Capital costs include:

- A structure (this cost can be reduced if the toilet is placed inside an existing house):
- Pedestal;
- Vault; and
- Composter.

The total cost depends on the materials used. Costs can be reduced if the users do all or some of the work themselves.

Operation and maintenance

Dehydrated faecal material must be removed to the composter, and the compost heap must be maintained. Alternatively, the dehydrated faecal material must be removed to another location for composting.

Advantages of urine diversion dehydrating toilets

Advantages include:

- The toilet can be constructed inside a house;
- The compost may be used as a soil conditioner and the urine as a fertiliser (re-usable resource);
- The system can be constructed by the user, with some guidance;
- The vault may be built above ground if hard rock or high groundwater is encountered; and
- There are no problems associated with flies or smells, as no decomposition takes place in the toilet.

Limitations of urine diversion dehydrating toilets

Limitations include:

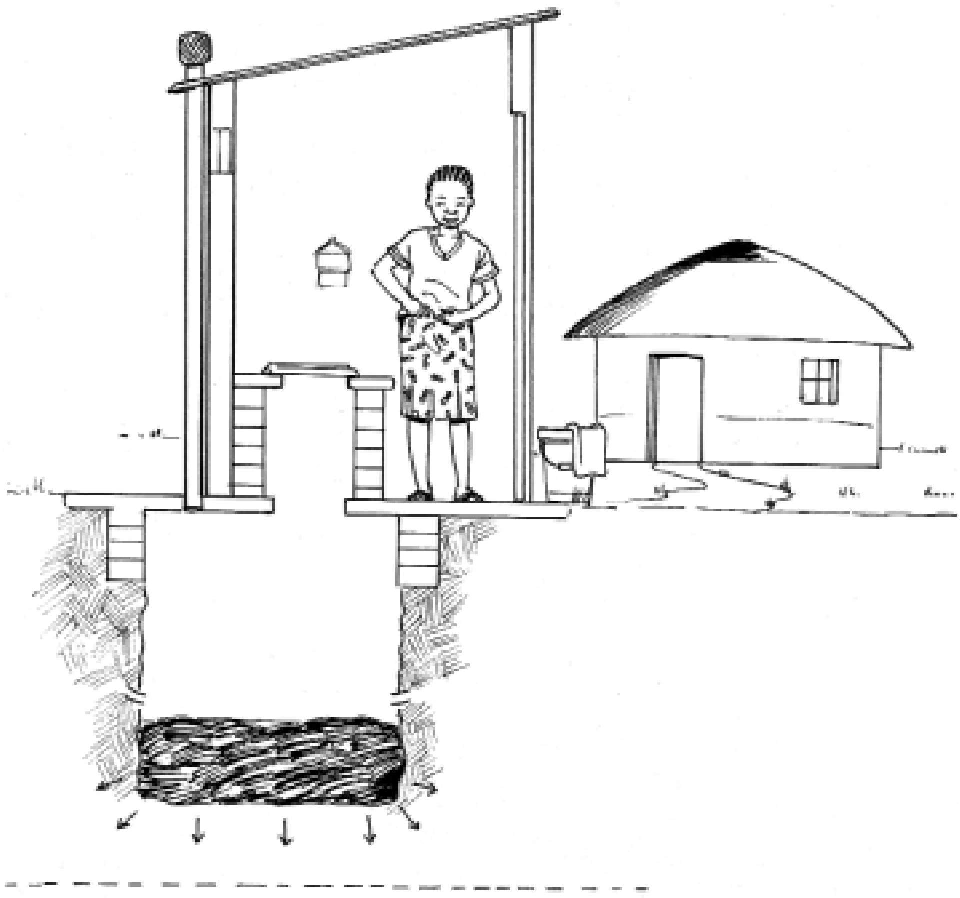
- The user must be willing to handle the dehydrated faecal matter on a regular basis; and
- The composter must be large enough to hold one year's amount of dehydrated faecal matter, soil and toilet paper. (The size depends on the number of users.)

Practical experience

This technology is extensively in the Northern Cape and is being currently being implemented in Cape Town.

Key references:

- DWAF Sanitation Support, 2001, *Study Report on Management of Faecal Waste from On-site Sanitation Systems in South Africa*.
- DWAF, 2002, *Sanitation for a Healthy Nation*, Sanitation Technology Options.



What is a ventilated improved pit toilet and how does it work?

Waste drops into a large pit where the organic material decomposes and liquids percolate into the surrounding soil. (If the pit is sealed it becomes a conservancy tank, which fills up quickly. This is not a ventilated improved pit toilet). Odours are removed and gases are vented by way of continuous airflow through the top structure, down the pedestal, and out via the vent pipe. A darkened interior is maintained so that insects entering the pit are attracted to the light at the top of the vent pipe, and are trapped by the fly screen.
The length of time taken to fill the pit depends on the number of users, as well as the size of the pit. If a large enough pit is provided (three cubic metres or more), and the system is well cared for by the householder, life spans of 30 years are not uncommon.
The breakdown of waste material in this system is through a process known as anaerobic digestion.

Ventilated improved pit toilet requirements

The pit must be protected so as to prevent ingress of stormwater. Provision must be made either for the mechanical emptying of the pit, and transportation of the sludge to the treatment works, or for the toilet to be moved when the pit is full.

Groundwater and the system

The bottom of the pit needs to be more than one metre above the water table to prevent contamination.

Water requirements

This toilet does not require water for effective functioning.

Greywater

This toilet cannot accept large amounts of greywater. Greywater must be disposed of in a soakaway or used for garden irrigation.

Level of comfort

This toilet cannot be placed inside a house. Further, the draught caused by the ventilation through the toilet to remove smells, can be unpleasant to the user in cold weather.

Insitutional support

No institutional support is required if the toilet is moved by placing it over a new pit. The old pit is then covered and its contents allowed to decompose naturally. However, institutional support is required if mechanical emptying of pits, sludge transfer, treatment and disposal, and cost recovery services are provided.

Capital requirements

Capital costs include:

- Building an outside structure;
- The pedestal;
- Digging a pit; and
- The vacuum tanker and treatment works, if mechanical emptying is envisaged

The total cost depends on the materials used. Costs can be reduced if the users do all or some of the work themselves.

Operation and maintenance

Breeding of mosquitoes in wet pits can be prevented by adding a cupful of a suitable inhibitor (such as lubricating oil or diesel), each week. When the pit is full, the toilet must either be moved to a new pit, or provision must be made to empty the pit.

Advantages of ventilated improved pit toilets

Advantages include:

- The toilet can be built by the householder; and
- All types of anal cleansing materials may be used, although some will cause the pit to fill faster than others.

Limitations of ventilated improved pit toilets

Limitations include:

- If emptying the pit is not an option, land is required for the construction of a new pit (this is not an option in dense settlements);
- If the pit is to be emptied there must be access for vehicles;
- The pit is often used as a rubbish dump, thus shortening its lifespan; and
- If the toilet is to be moved, it cannot be constructed with bricks or cement blocks.

Practical experience

This sanitation option is widely used internationally, as well as in rural and peri-urban areas across South Africa.

Key references:

- Bester, J.W. and Austin, L.M., 2000, *Design, construction, operation and maintenance of VIP in South Africa*. WRC Report no. 709/1/00
- DWAF Sanitation Support, 2001, *Study Report on Management of Faecal Waste from On-site Sanitation Systems in South Africa*.
- DWAF, 2002, *Sanitation for a Healthy Nation*, Sanitation Technology Options.

4 TECHNOLOGIES FOR THE CONTROL OF WATER SUPPLY AND PAYMENT OPTIONS

INTRODUCTION

COMMUNAL STANDPIPES

Normal Tap

Push Button Tap

Mechanical Pre-Payment Dispensing Meter

Electrical Pre-Payment Dispensing Meter

Payment systems for communal standpipes

INDIVIDUAL HOUSEHOLDS

Electrical Pre-Paid Dispensing Meter

Trickle Feed System

Ethekwini (Durban) Tank System

Arrear Billed Mechanical Meters

Payment systems for individual households

Introduction

This section covers the range of technologies available to control water supplies, and to collect the tariff from the household.

Control of water losses is as important as cost recovery, particularly in areas with communal standpipes, or controlled delivery systems. Poor management can result in losses higher than consumption.

In terms of payment options, consideration must be given to where the householder can make payment, collect coupons, or recharge pre-paid meter cards. Travel costs can greatly add to the overall cost of the service. For example, in the major urban areas payment can be made by direct debit, through checkouts at major supermarkets, post offices etc. The consumer only pays the transaction charge. No extra travel or time costs are incurred. However, this is not the case in rural areas. Travel and time costs for the payment of bills and collection of pensions are considerable. Travel costs must be properly calculated as ultimately this has a major impact on what is an appropriate and sustainable institutional set-up.

Communal Standpipes

Communal standpipes are placed along roads and in public places. Householders bring their containers to the standpipe. They fill them and carry them home. Research has shown that the biggest limitation to consumption is the physical act of carrying water to the house. As a result only between 100 and 125 litres are utilised, per household, per day.

To dispense water to the consumer, a communal standpipe can be fitted with the following technologies:

- A normal tap that the householder can open or close. There is no limitation to the amount of water released.
- A push button tap that releases a set amount of water e.g. push button taps in Durban that release exactly 25 litres of water.
- A mechanical pre-payment dispensing metre. A token is inserted, which allows for the release of a set amount of water, from a holding tank in the meter.
- A tap with an electrical pre-payment dispensing meter. A coupon is inserted. The water flows until the credits are exhausted, or the tap is closed. This technology dispenses the exact amount of water required.

The advantages and disadvantages of the different technologies are discussed below.

Normal Tap

There is no control over how much a consumer can use. The potential for water wastage is high. Community members need to bear the responsibility of ensuring that taps are turned off correctly. Some communities deal with the issue of water wastage, by locking their standpipes, and only opening them at certain times of the day.

However, the consumption of water is generally low if water wastage is dealt with effectively. Normal tap technology is cheap. It is easy to install and easy to maintain. Outside intervention may be required for installation of standpipes but the community can manage on-going operation and maintenance.

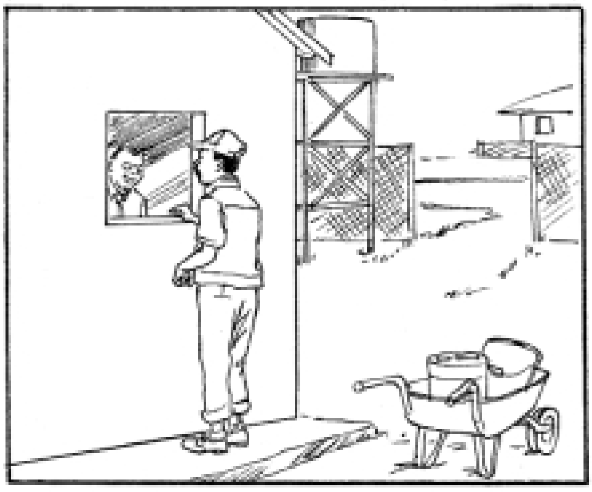
Push Button Tap

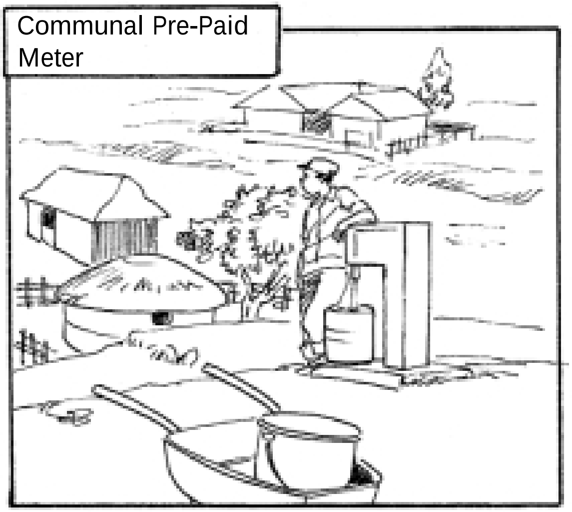
There is some control over how much a consumer can use. The potential for water wastage is lower with this option, only a set amount of water is released. If people do not have the correct size container water may be wasted, but research has shown that this is less than if taps are left open. The technology is cheap, easy to install, and easy to maintain. Outside intervention may be required for installation of standpipes. However, the community can manage on-going operation and maintenance.

Mechanical Pre-Payment Dispensing Meter

This meter controls the amount of water that a consumer can use. The tokens must either be purchased, or if a free basic water policy is in place, given to the consumer. If people do not have the correct size container water may be wasted but research has shown that this is less than if taps are left open.

The mechanical units are more expensive than electronic dispensers, but their operation and maintenance is not as complex. This allows community members to play a key role. However, some outside assistance is required.





Electrical Pre-Payment Dispensing Meter

This meter controls the amount of water that a consumer can use. The credits on the coupons must either be purchased, or if the free basic water policy is in place, given to the consumer.

The electrical dispensers are cheaper to install than the mechanical ones, however their operation and maintenance is more complex. In the capital cost, allowance must be made for the equipment to recharge coupons with credit. It is difficult for community members to get involved. These meters are more suitable for urban and peri-urban areas. Specialist assistance is needed for operation and maintenance.

Payment systems for communal standpipes

A number of payment systems are available to recover the tariff from the consumer:

No payments are collected

One option is not to charge community members for water usage on standpipes. If water consumption is kept low, through the carrying of water to the household, then most households will use less than the free basic water amount of 6000 litres of water, per household, per month. This saves costs on collecting money, and on the installation of pre-payment meters. However, problems may arise with water loss, unless control mechanisms are in place.

A flat rate is collected

The flat rate system works along the following lines:

- A fixed amount is charged per household;
- Accounts need to be sent out regularly (monthly or quarterly);
- A payment point must be established and payments reconciled against accounts; and
- Credit control must be enforced.

The benefits of this system are that it is easy to administer and that there are no overheads for meter reading. However, there are also limitations. The system can be viewed as unfair because users who live in close proximity to the tap usually use more water, and yet they pay the same amount. Problems may arise with water loss, unless control mechanisms are in place.

Water kiosks / Vendor system

This system relies on a water vendor to sell water from their own metered connection to consumers. The system either uses:

- Coupons where a coupon worth a set amount, is bought from the municipality and given to the vendor to get the water. The vendor then takes the coupons to the municipality where they are checked against the meter readings.
- The community members pay the vendor and the vendor pays the municipality on the basis of water readings. The vendors are paid either on a commission basis or a set wage by the municipality; or
- The vendor charges whatever mark up they want on the water bought from the municipality.

One of the key requirements of this system is that the number of people buying from the kiosk must be high enough for the vendor to make a living without making the water too expensive. This is usually only possible in more densely populated urban areas.

Pre-payment system

Pre-payment systems include both electrical and mechanical meters. Payments are made upfront. No costly bills are generated in arrears. The limitations come from the costs of implementing the technology and operating and maintaining the system. The free basic water policy is facilitated through allocating a number of free credits or tokens to householders.

Key references:

- DWAF, 1997, *Implementing Prepayment Water Metering Systems*, Department of Water Affairs and Forestry
- Hazelton, D. and Kondlo, S., 1998, *Cost recovery for water schemes to developing urban communities: A comparison of different approaches in the Umgeni Water planning area*. WRC No. 521/1/98.

Individual Households

A number of technologies can be utilised to serve communities at household level. They include the following:

- An electrical pre-paid dispensing meter;
- A trickle feed system;
- The Ethekwini (Durban) tank system; and
- Arrear billed mechanical meters.

The advantages and disadvantages of the different technologies are unpacked below.

Electrical Pre-Paid Dispensing Meter

This system uses coupons. The householder takes these to a central point where they purchase credits which are loaded onto the coupon. Water consumption is then controlled in terms of the number of credits purchased. The coupon is placed in the slot and water runs until the credits on the coupon are exhausted. This system is relatively expensive to install. Further, outside assistance is required for operation and maintenance.

The advantage of this system is that the credits can be sold through any retail point and the consumer is immediately aware of their expenditure. The disadvantage is that purchases, by the consumer, might not be on a regular basis making it difficult to introduce rising block tariffs. Another disadvantage is that if the meters fail, they fail in the closed position, cutting off the householder's water supply. It is therefore critical that a repair team is on constant standby to replace meters.

Electrical pre-paid dispensing meters are used extensively. However, there have been a number of problems with maintenance, especially in rural areas.

Trickle Feed System

This is a low-pressure system that delivers water constantly at a very low flow to a household storage tank. The tanks have a small box fitted onto the inlet, with a float valve controlling flow into the box. The box has a very small hole towards the bottom, through which water constantly trickles into the larger tank. The flow is constant and is determined by the size of the hole in the inner tank, and by the height of the water above the hole which is constant under normal conditions. The larger the hole in the inner tank, the greater the flow (or trickle) into the main tank. It is thus possible to regulate the maximum daily flow, by choosing an appropriate size of trickle flow orifice. The size of the hole is set by the water services provider, according to a monthly flat rate, and the specific daily amount of water delivered.

There are a number of advantages:

- The buffer storage capacity means that the system as a whole has a lower peak demand, and short-term lapses in supply do not affect the household;
- The lower peak demand means that smaller pipes can be used;
- Some storage is provided at the household level and therefore bulk storage can be reduced;
- Water losses or taps left running are noted quickly by a temporary shortage of water; and
- The system promotes greater awareness of water use, as only a set amount is available each day.

There are also a number of limitations:

- Households are limited to a maximum daily amount that cannot be changed;
- It is not possible to put a pressure hose on the outlet to wash a car or water the garden;
- The temperature of the water in the tank rises on warm days, especially if it positioned in the sun; and
- Leaks in the reticulation are difficult to detect using traditional methods, such as the low night flow method.

Successful pilot trickle feed schemes have been implemented in Limpopo and KwaZulu-Natal. The technology has been implemented internationally in New Zealand and South America.

Ethekwini (Durban) Tank System

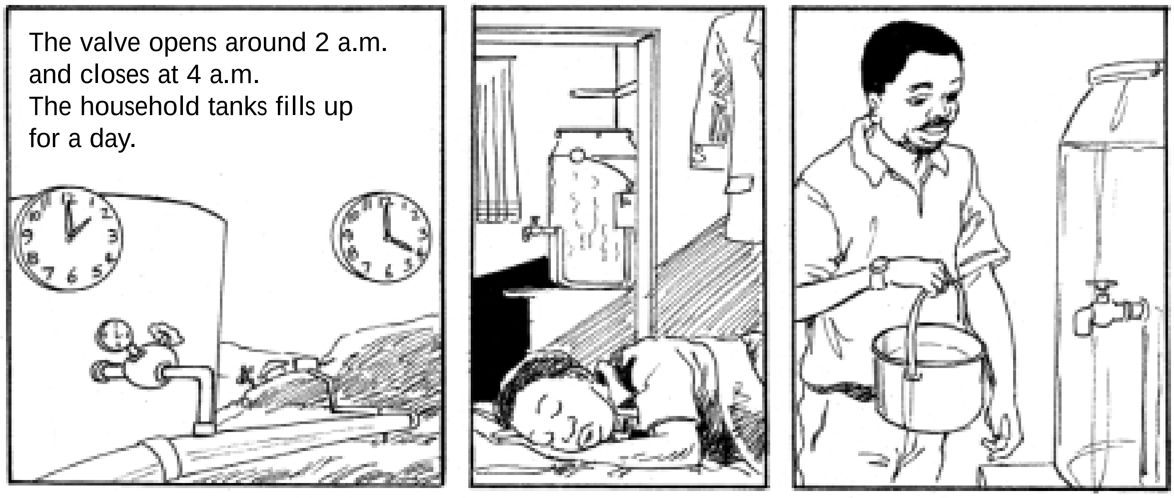
This system is similar to the trickle feed system but there are also some important differences. The Durban Tank system comprises of a 200 litre tank installed in every household. A maximum of 200 litres is delivered every day. When the tank is full a float valve closes off the inlet. If the tank is not empty before filling commences, then less than 200 litres will be delivered. To minimise abuse of the system, (including householders bypassing tanks, making illegal connections etc.), and to minimise reticulation losses, the reticulation is only charged during the early morning for a two-hour period. The valve is activated electronically so that no manpower is required for the normal operation of the system.

The system requires a small diameter reticulation (since peak demand is reduced); reticulation with individual household connections; and the installation of a household storage tank. The unit is installed on a small platform to allow space for the placing of containers underneath.

Support is required to operate and maintain the supply system. The tank must be checked periodically to ensure the float valve has not been removed.

The advantages and disadvantages of this system are very similar to the trickle feed system. The only difference is that this system is better adapted to prevent potential abuse.

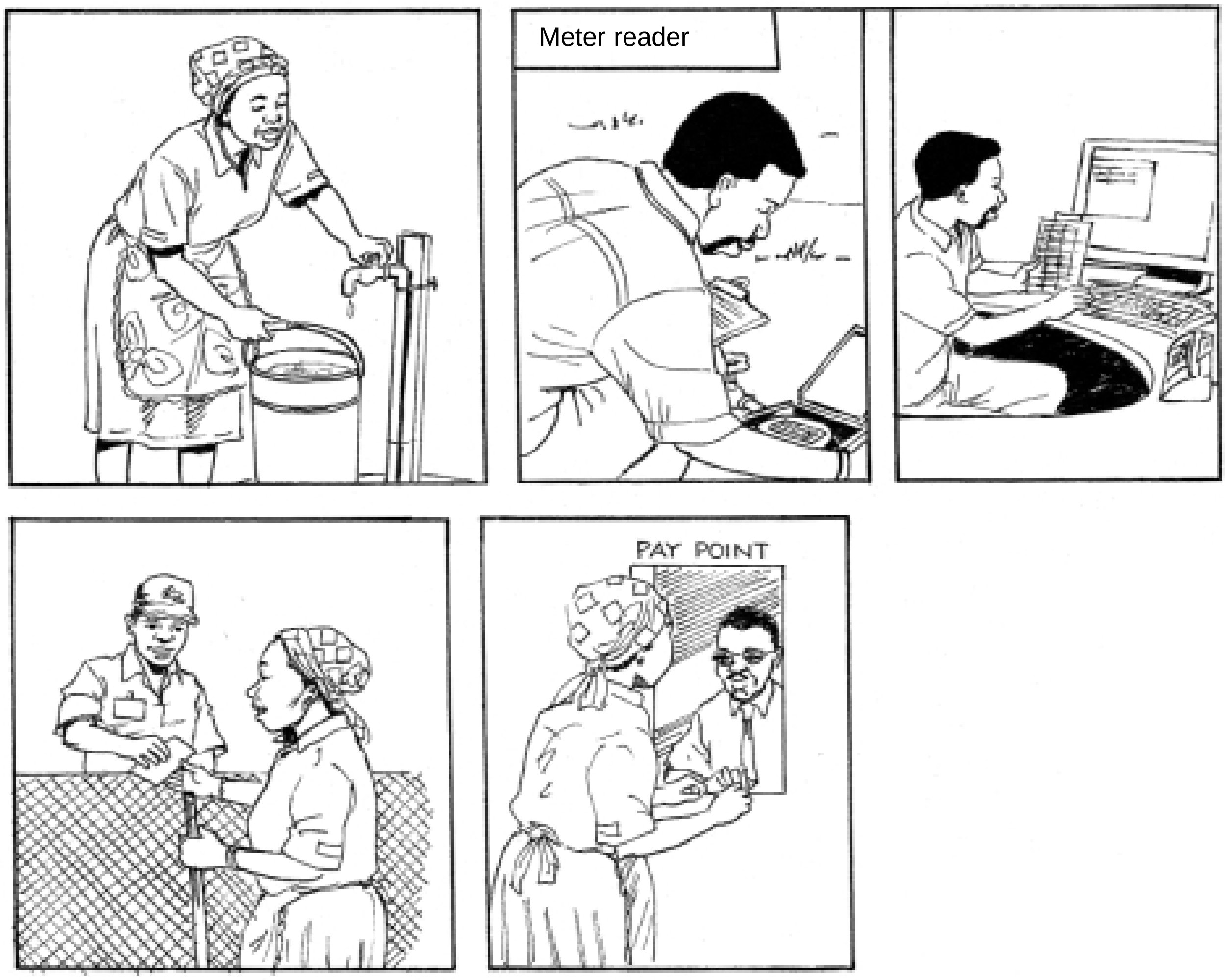
Ethekwini (Durban) has piloted this technology extensively. The municipality has made many modifications to ensure an optimum service. It is currently supplying 30 000 households.



Arrear Billed Mechanical Meters

In this system each household has a water connection with a meter. The water authority or municipality is responsible for the reading of meters at regular intervals, and for billing the user. The advantages include that a rising block tariff can be instituted.
The disadvantages include that if a leak occurs very high charges can be incurred, before the householder realises what is happening.

This method is used extensively in most urban areas of South Africa where there are house connections.



Payment systems for individual households

A number of payment systems are available to recover the tariff from the consumer.

No payments are collected

Ethekwini Metro has implemented the free basic water policy in conjunction with its tank system. The tank system provides 200 litres of water per household per day. This works out to approximately 6 000 litres per household per month. Ethekwini Metro supplies this water to households free of charge.

No meter reading, accounts, or credit control sections are required by the water services authority or water services provider. Meters are installed only for loss control purposes.

Although the costs of implementing the system are high, the operation and maintenance costs are low. Since no payment is required, the system is easy to manage.

A flat rate is collected

The Ethekwini (Durban) Tank system and other trickle feed systems allow for the charging of flat rates. This significantly simplifies the billing system. No meter readings are required.

Payment is collected up front

If a pre-payment system is implemented credits must be purchased up front. The benefit of this system is that large accounts cannot be generated unknown to the consumer. However, problems may arise from expensive capital and operation and maintenance costs. No meter readings are required.

Payment is collected in arrears

The meters are read by the water authority on a regular basis (normally once a month or every quarter). The consumer is then billed according to the amount of water used. Bills are delivered to the consumer, and the consumer must pay the municipality. This method of billing can be adapted in a number of ways. These include:

- An invoice can be delivered by the meter reader, saving on the cost of postage;
- An invoice can be delivered and the money collected by the meter reader; and
- A self-billing payment system can be implemented at a centralised point. (Spot auditing and a penalty system for incorrect readings may be necessary here.)

Costs are associated with reading and maintaining the meters, and administering the billing, collection of revenues, and credit control.

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5 BACKGROUND INFORMATION

DESCRIPTIONS OF PUMPS

WATER TREATMENT

Household Level Treatment

Municipal Level Treatment

Descriptions of Pumps

Any pumping system requires two basic components: the pump driver and the pump. The pump is the device that lifts the water, and the driver is the source of energy. The very simplest pumping system is a person (the pump driver) lowering and raising a bucket on a rope (the pump) in and out of a well.

The following **pump drivers** are found in practice:

Petrol engines: Usually used for small portable pumps (for example, pumps for food gardens, fire fighting, and water tankers).

Diesel engines: Used for larger pumping installations where no grid electricity is available. Diesel engines are more economical to run and last longer than petrol engines.

Electric motors: Favoured for practically all static pumping installations where grid power is available. Electric motors are easily automated, which is a key advantage.

Wind/solar: Solar or wind power can be economically used to drive small pumps for low volume and low head pumping requirements. This is generally implemented in areas where there is no electrical grid. For larger pumping requirements, solar or wind power is expensive. Solar power for instance is only economical for pumping requirements of approximately 20 kilolitres per day to a 40 meter head. Wind can be harnessed via windmills (direct) or wind generators (indirect). Solar energy is harnessed through solar panels.

Animal: Animals such as cattle or donkeys can be used to power pumps. Such installations use a gearbox with a high ratio, so that for every time the animal walks around the well, the pump turns many more times. This is suitable for high-volume low-head pumps, for example pumping water out of a river to irrigate an adjacent field.

People: Hand pumps and foot pumps are reliant on people to drive them.

The most common drivers are electric motors. These can be run off three-phase power at 420 volts, or single- phase power at 210 volts. Three-phase motors are more economical for medium and large pumping installations (typically with less than one kilowatt power requirement). Virtually all electric motors suited for pumping, use alternating current (AC).

Electric motors have to be controlled by a set of electrical controls and switches. These include safety devices that are needed to protect the pump and motor from damage. These typically protect the pump and motor from fault conditions such as:

- Pumping without water;
- Pumping against a closed valve causing over-pressurisation;
- Overload caused by conditions such as a blocked inlet, a blocked outlet, a jammed pump, or by bearing failure in the pump or motor; and
- Faults with the electrical supply such as phase failure, phase rotation and voltage out of range.

Surge arrestors and other forms of lightning protection are also required to provide some protection against lightning damage. However, if lightning strikes the pump house directly, no amount of protection will save the installation.

Some electric motors are enclosed in waterproof housings with sealed shafts, to enable them to operate under water. Such pumps are termed submersible, and are used, for example, in the smaller borehole pumping installations (typically less than 5 kilowatt applications).

There are two main classes of **pumps**:

Centrifugal pumps: A centrifugal pump consists of one or more impellors (similar to a boat propeller), each of which rotates within its own housing. When there is only one impellor, the pump is called a single-stage pump. When there are several impellors, the pump is called a multi-stage pump. With higher pumping heads, more stages are added and the power requirement increases.

Any centrifugal pump has a maximum pressure rating (with a given motor and drive setup), and cannot lift water above that pressure level. If there is a problem with the pipeline that causes the pump to operate beyond its maximum rating, the water will not move through the pump and the pump will overheat.

Positive displacement pumps (which include reciprocating and rotary pumps):

Reciprocating pumps: The typical example of a reciprocating positive displacement pump is a windmill or handpump which works by the raising and lowering of a set of rods, which in turn operate a piston in a cylinder near the bottom of a well. With each upstroke of the piston, water is drawn into the cylinder from the well. With each downstroke of the piston, water is pushed from the cylinder up a riser pipe out of the well. A pair of opposed valves at the bottom and the top of the cylinder are basic to the operation of such a pump. Maintenance typically consists of keeping these valves and the piston seals in working order.

Rotary pumps: The typical example of a rotary pump is a progressive cavity pump (e.g. the Mono pump). This kind of pump uses the rotation of a screw-shaped element (the rotor) within a similarly shaped housing (called the stator) in order to lift water. Unlike a centrifugal pump, a rotary progressive cavity pump is not self-limiting in terms of how much pressure it can produce, and therefore it is more versatile. However, if the pump operates against a closed valve or if the pipeline is blocked, the pump will keep on raising the pressure until either the pump or the pipeline is seriously damaged. To prevent such damage an adequately sized pressure relief device must be incorporated into

Notes on terms used to describe pumps and pumping operations

Head: The term *head* is used to mean the number of metres by which the water must be lifted. The *static head* is the vertical distance between the level from which the water must be lifted to where it will be used, or stored. The *dynamic head* is the extra lift that is required to overcome friction in the pumping line.

Curves: Figures or graphs are used to show how much water a given pump can lift per second (or hour), at different pumping heads and rotational speeds (known as *the head capacity curves*). Other curves show how much power is required for different pump duties (*the power demand curves*), what the pump efficiency is at those duties (*the efficiency curves*), and from what level a pump can suck the water below its inlet without damaging itself (the Net Positive Suction Head curve, or *NPSH curve*). These various figures are known as the *pump curves*.

Depending on the design of the pump and the materials from which it is made, a pump may only be able to pump clean water, or it may be able to handle muddy water or sewage. Some pumps can even work with water containing gravel and small stones. The latter types of pumps are heavier and more expensive relative to a clean-water pump, for which lighter, cheaper components are acceptable. Thus the type of water to be pumped must be specified when a pump is selected.

Some pumps use mechanical seals that do not need frequent maintenance, but are more expensive. Others use gland packing, which is cheap but requires more frequent attention and technical understanding. Note that it is normal to see a slow dripping of water between the pump shaft and the gland packing. If there is no dripping, the shaft will not be adequately lubricated and will damage the pump set up.

Types of Hand Pumps

There are a number of different types of hand pumps.

Rotor / Stator Positive Displacement Systems

These are the most common hand pump installations in South Africa. The pumps used are MONO T5 and T7, Orbit and Cemo pumps. The discharge rates are lower than with direct drive systems, and the energy and power required to lift water are greater. Considerable power is required to lift 25 litres of water from depths of 80 to 90 metres. This can make the system difficult to operate for children and for older members of the community.

Reciprocating (Wheel) Pumps

About 40 years ago, the climax pump was the most commonly used, but this is no longer the case. The large wheel and long handle provide good leverage so that large quantities of water can be pumped easily. The height of the system can sometimes make it difficult for children to operate. It can operate efficiently with heads up to 100 metres. The pump requires a maintenance team for installation, services and repairs.

Bucket Pumps

The Zimbabwe 'Bucket Pump', developed by the Blair Institute in Zimbabwe is a simple, inexpensive technology suited to a tube well or borehole. A windlass (cylinder around which a rope is wound to lift the bucket) is mounted to the cover slab of the tube well. A cylindrical bucket is lowered down a casing in the well. The bottom of the bucket has a valve that opens on contact with the water, as the bucket is lowered. It closes when the bucket is pulled up, keeping the water inside. A well cap and the fact that the bucket is stored in the casing, reduce the risk of contamination. A reduction in the retention time of water in the well casing ensures that any contamination that pollutes the well is rapidly removed. However, this system does not provide a high level of service.

Rope and Washer Pumps

The rope-and-washer pump is not commonly known in South Africa, but is used extensively in South America. The pump consists of a single loop of chain or rope running over a winding wheel. Small rubber or plastic washers of approximately 20 millimetres in diameter are attached to the chain at approximately one-metre intervals. On the upward journey, the chain passes through a pipe. The washers form a seal with the pipe, and water is lifted. The head of the pump should be sealed to prevent contaminants entering the well from the surface, and it is advisable that the rope and washers are enclosed at all times. This pump is inexpensive and relatively easy to construct, however it can only be used for relatively low lifts of less than 30 metres.

Afridev

This is the most common VLOM pump in South Africa. It functions effectively for lifts of less than 45 metres. It is less suitable for deep wells. The long lever makes it easy to operate, even for children. The PVC column is resistant to corrosive waters, but the solvent welded joints make it difficult to re-install the column properly after repair. Alternative jointing systems are being considered.

Vergnet

Only a few of these pumps have been installed in South Africa but they are widely used in Francophone Africa. This is a foot-operated pump that is easy to install and repair. It is not manufactured in South Africa, the pump and all its parts have to be imported from France, making it costly.

Household Level Treatment

Boiling of Water

The boiling of water can destroy most micro-organisms in the water to make it safe for drinking. The water should be boiled for at least 10 minutes.

Disinfection

Household bleach can disinfect water if the water does not contain too much soil or organic matter and with the proper dosage. Five millilitres (one teaspoon) of bleach should be added per 25 litres of water. The water then needs to be left to stand away from sunlight for at least two hours. Disinfection is effective, as long as the water is not heavily polluted. HTH granules and pills can also be used to disinfect water in larger quantities.

Filtration

Filters available for household use range from expensive membrane filters to cheaper filters that can be constructed by the householder. The filtration method may not remove all micro-organisms, so disinfection might be required after filtration to ensure safe drinking water.

Solar Disinfection (SODIS)

Solar disinfection is the disinfection of water using the sun's rays. SODIS can be used to treat small quantities of water at household level. Water should be placed in plastic bottles and exposed to sunlight. On bright days or when there is up to 50 % cloud cover, the water should be exposed for 5 hours. On cloudy days, the water should be exposed for two consecutive days. The disinfection process can be speeded up by adding oxygen to the water. This can be done by shaking the bottle vigorously both before exposure, and every hour during exposure. The temperature of the water is raised through exposure to sunlight, which increases the effectiveness of this method.

Settlement

Suspended solids can be removed from the water by allowing the water to stand until the solid particles settle at the bottom of the container. Clearer water can then be taken from the top of the container, or the water can be carefully transferred to another container and the procedure repeated before the water is used.

Municipal Level Treatment

Municipal water supplies are treated to change the attributes of the water source in order to make the water more acceptable for use.

These attributes include:

- The clarity or turbidity of the water
- The colour of the water
- The taste / odour of the water
- The hardness of the water
- The chemical content of the water
- The bacterial content of the water.

A treatment works normally has a series of unit processes. Each unit process may contribute towards the removal of more than one substance. Some substances may require more than one unit process for their removal. A complete treatment process consists of a cost-effective combination of unit processes that will provide water of an acceptable quality.

Table 1: Municipal water supply treatment

Attribute	Explanation	Treatment method
Clarity / Turbidity	Water may contain suspended or very fine dispersed particles such as silt or plant residues that cause it to be murky.	Suspended particles are removed by filtration. Fine, dispersed particles, also called colloids, pass through a normal filter. They are normally coagulated / flocculated to form larger particles (flocs) before the filter.
Colour	The colour of water can arise naturally or can be caused by pollution. Natural colour such as that found in the brown waters of the Cape is caused by plant residues and is harmless. Small amounts of iron and mangenese that occur naturally can also cause colour. Colour arising from industrial pollution may spell danger.	Natural colour can be removed by coagulation / flocculation followed by filtration. Similarly colour resulting from pollution can be removed, but careful monitoring and expert advice is needed. Iron and manganese may need aeration prior to coagulation.
Taste / Odour	Taste is affected by dissolved gases, chemicalsand residues from plant and other materials.	Aeration can be used to eliminate dissolved gases. The removal of excess salts requires advanced treatment procedures such as those discussed under desalination. Organic substances can be removed by coagulation / flocculation and filtration with absorbtion on activated carbon for really persistent substances.
Hardness	Dissolved calcium and magnesium salts in the water cause hardness. Hardness increases the amount of soap needed to give lather and results in deposits in geysers and kettles.	Softening processes should be used such as adding sodium carbonate or using ion exchangers.
Changing the Chemical Content	As discussed under colour, taste/odour and hardness, water can dissolve most substances. The natural inorganic salts, when seen as a group, are normally referred to as the TDS of the water. High concentrations of these salts make the water brakish, and are removed through desalination. Pollution arising from human activities such as mining, industry and agriculture may give rise to certain harmful chemicals in the water that need to be removed. Arsenic, fluoride and nitrates are naturally occurring substances that may require removal when present in high concentrations.	Desalination processes such a reverse osmosis, electrodialysis, distillation and ion exchanges, as discussed below, are suitable for removing TDS. The removal of specific toxic substances arising from natural causes or pollution needs special advice.
Reducing the Bacterial Content of Water	Most surface waters and some ground-water contain bacteria, some of which may be harmful to human health.	Bacteria are removed by the disinfection processes that are discussed below.

Treatment processes include:

Chemical Stabilisation

Chemical stabilisation is achieved through the addition of chemicals such as lime or carbon dioxide. This is used to protect pipelines and fixtures from chemical scale (hard deposits on the inside of pipes, kettles etc.) and corrosion.

Coagulation/Flocculation

Coagulation can be used to improve the chemical quality of water. Further, it can be used to treat micro-organisms and water with a high turbidity (high TDS). The coagulant causes the fine particles to form larger particles (flocs) which then settle to the bottom of the tank and can be removed.

Defluoridation

Fluoride can be removed from water using activated alumina or bone char and ion exchange. A high intake of fluoride can cause tooth staining and hardening of the bones making them brittle.

Desalination

Desalination reduces the level of dissolved solids in water. This is important in areas where borehole waters have a high salinity (brackish water) and where the possibility of finding other affordable sources of water is low. The processes that can be used for desalination include ion exchange, electrodialysis, reverse osmosis, distillation and chemical precipitation.

Distillation

Energy is applied to the brackish water (high total dissolved solids) to form water vapour (leaving dissolved salts behind) and the vapour is condensed to form pure water with low total dissolved solids. Solar energy can be used to produce water vapour and this process is known as solar distillation or solar still.

Electrodialysis

Electrodialysis uses membrane technology, but the driving force in this case is electrical potential. Water passes through electrically charged membrane pairs. Dissolved solids are then removed from the water. This process can be used to treat water with high concentrations of TDS, chloride, potassium, sodium and sulphate.

Filtration

Water is passed through a filter to improve quality. Simple, inexpensive systems can reduce turbidity. More sophisticated systems can also remove some contaminants. The filtration method may not remove all micro-organisms, so disinfection is required after filtration to ensure that the water is safe for drinking.

Ion Exchange

Ion exchange is achieved using an ion exchange resin. The undesirable cat-ions or anions in the water are exchanged for ions found within the resin as the water passes through it. The resins have a limited capacity to exchange ions and, when this is exhausted, the resin must be regenerated using a brine solution. The ion exchange process can be used to soften hard water, for desalination (reduction of TDS), and for the chemical treatment of water i.e. for the removal of fluoride, nitrate, iron etc. The ion exchange process can also be used at a household level. This however can be very expensive.

Mixed Oxidant Gases Generated On Site for Disinfection (MOGGOD)

The MOGGOD process uses normal table salt to manufacture a chlorine equivalent. An electric current is passed through the salt. The chlorine that results is then used to disinfect the water supply.

Nitrate Removal

Nitrate can be removed from water using ion exchange, reverse osmosis and biological reduction (denitrification). The presence of high levels of nitrate in water can be of risk to babies.

Ozone Treatment

Ozone is produced on site by passing a current of dry filtered air between two electrodes subjected to an alternating voltage. The ozone acts as a disinfectant and an oxidant that reduces the contents of iron, manganese and lead. It can also eliminate taste and odour problems.

Reverse Osmosis

Fresher water can be produced by forcing water with a high content of total dissolved solids, under pressure, through a special membrane. The dissolved solids are rejected by the membrane and they stay behind, while pure water goes through the membrane. Reverse osmosis can be used for the treatment of water with high concentrations of nitrate / nitrite, potassium, sodium, sulphate, chloride, fluoride and TDS.

Sedimentation

Sedimentation is a process where water is allowed to stand for a period of time. Suspended solids settle at the bottom of the container through gravity.

Treatment of Encrustation / Biofouling of Boreholes

If borehole water is tinted brown and smells of rotten eggs it is an indication that it has been infected by either metal encrustation or bacteria, or both. Treatment can begin by using mechanical tools to clean easy-to-reach places. This can be followed by chemical treatment that uses acids to dissolve precipitations. The well should then be cleaned out by jetting, airlifting or bailing, followed by the addition of a disinfectant such as chlorine.

UV Treatment

An Ultra-Violet (UV) light is used to disinfect water. UV lamps can be placed in water pipes, ensuring that the water passing through these pipes receive a fixed average dose. Lamps can also be mounted above shallow tanks through which the water is passed.

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- ⊙ Department of Water Affairs and Forestry have published the South African Water Quality Guidelines (1996) for both Fresh and Coastal Marine Waters. See www.dwaf.gov.za or go to your nearest regional DWAF office.

- ⊙ The following five volumes on Water Quality are available from the Water Research Commission:
  - Quality of Domestic Water Supplies
  - Volume 1: Assessment Guide WRC no. TT 101/98
  - Volume 2: Sampling Guide WRC no. TT 117/99
  - Volume 3: Analysis Guide WRC no. TT 129/00
  - Volume 4: Treatment Guide WRC no. TT181/02
  - Volume 5: Management Guide WRC no. TT 162/01

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Glossary and definitions

Aquifer
Defined by the National Water Act (1998) as a geological formation which has structures or textures that hold water or permit appreciable water movement through them.

Ambient groundwater quality
Background water quality. It reflects the groundwater quality of the area at a specific time.

Borehole
Defined by the National Water Act (1998) as a well, excavation or any artificially constructed or improved underground cavity which can be used for the purpose of:

(a) Intercepting, collecting or storing water in or removing water from an aquifer;
(b) Observing and collecting data and information on water in an aquifer; or
(c) Recharging an aquifer.

Catchment Management Agency (CMA)
CMAs are responsible for regional water resource management (National Water Act, 1998).

Determinands
Variables such as ions, pH and temperature to be included in a water quality assessment.

Dip meter
The instrument used to measure the depth to the water level in a borehole.

Groundwater
Water held within a saturated soil, rock-medium, fractures or other cavities within the ground (SANS, 2002).

Groundwater level
The depth to the water level in a borehole or well from the ground.

Groundwater management
Groundwater management for Community Water Supply involves taking responsibility for protecting groundwater from contamination and ensuring its sustainable use.
The main responsibilities are:

(a) Data collection, capture and analysis, and recommendations for operational or behavioural changes based on the data analyses. Operational changes may be, for example, to reduce the abstraction rate. Behavioural changes may include, for example, the restriction of groundwater polluting activities or increasing the monitoring frequency.
(b) Making operational or behavioral changes based on the data analyses.

Groundwater monitoring
Groundwater monitoring forms part of the groundwater management function. Specifically, it includes data collection and capture. Boreholes need to be properly equipped in order to make monitoring possible. A description of all the necessary tools for groundwater monitoring is described in the ***Toolkit for Water Services***.

Groundwater monitoring tools
Tools used in monitoring groundwater, like a water level meter, a flow-meter, a logbook and computer software.

Observation or monitoring borehole
A borehole used to measure changes in groundwater levels (often in response to a nearby pumping borehole), and / or to monitor changes in water quality (either through the collection of water samples or by means of a "down-the-hole" electronic sensor).

Piezometer tube
A tube (manometer), usually a plastic pipe having a diameter of 15 to 25 millimetres, which is inserted into a borehole with the pump, so that groundwater levels can be measured using a dip meter or electronic sensor.

Water board
Defined by the Water Services Act (1997), as "an organ of state established or regarded as having been established in terms of this Act to perform, as its primary activity, a public function"; and the Act further states that the primary activity of a water board is to "provide water services to other water services institutions within its service area".

Water pollution
Defined by the National Water Act (1998) as the direct or indirect alteration of the physical, chemical or biological properties of a water resource so as to make it:

(a) Less fit for any beneficial purpose for which it may reasonably be expected to be used;

or (b) Harmful or potentially harmful:

i) to the welfare, health or safety of human beings;
ii) to any aquatic or non-aquatic organisms;
iii) to the resource quality; or
iv) to property.

Water services
Defined in the Water Services Act (1997) as covering both water supply and sanitation.

Water Services Authority (WSA)
Municipality responsible for ensuring access to water services (Water Services Act, 1997).

Water services institution
These include Water Services Authorities, Water Services Providers, water boards and water services intermediaries (Water Services Act, 1997).

Water services intermediary
An institution or individual who provides water to consumers but whose primary function is not water services provision. For example, a farmer who provides water to staff as part of a contract of employment, is a water services intermediary (Water Services Act, 1997).

Water Services Provider (WSP)
Any institution that is appointed by a Water Services Authority to provide water services to consumers or to another water services institution (Water Services Act, 1997).

Water table
The surface of a groundwater body at which the water pressure equals atmospheric pressure, i.e. the uppermost level of the groundwater body beneath the land surface.

Water User Association (WUA)
An association of water users, for example, farmers who share a common water resource.