THE PROTECTION OF WATER SOURCES IN DEVELOPING COUNTRIES

by

Anton Crousé

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE NATIONAL DIPLOMA IN TECHNOLOGY
(CIVIL ENGINEERING - WATER)

IN THE SCHOOL OF CIVIL ENGINEERING CAPE TECHNIKON

NOVEMBER 1986

Keywords : Water source protection; Springs; wells; Boreholes. Appropriate Technology.

Sleutelwoorde : Beskerming waterbronne; fonteine; putte; Boorgate; Toepaslike Tegnologie.

SYNOPSIS

In rural areas in Southern Africa a nearby stream or spring is a village or kraal's main water supply. The majority of these elementdry water sources are polluted. In this project the health hazard of polluted water and methods to protect water sources from pollution are discussed. The project consists of a report of fieldwork done in Southern Kwazula and compiling from the results a Technical Paper on water source protection.

SAMEVATTING

Watervoorsiening van klein gemeenskappe of 'n kraal bestaan dikwels uit 'n naby geleë stroom of fontein. Daar is gevind dat diè waterbronne meestal besoedel is. In die projek word die gevaar van besoedelde water en die beskerming van waterbronne teen besoedeling behandel. Die projek bestaan uit 'n verslag oor veldwerk in die suidelike gedeelte van Kwazulu gedoen en die samestelling van 'n Tegniese Verslag uit die resultate.

CONTENTS

INTRODUCTION

Water sources in developing countries such as our National States and other remote areas in Southern Africa consist mainly of boreholes, springs, handpumps, wells and rainwater tanks.

These sources provide drinking water for a large number of people in Southern Africa. These sources have been in use for many years and play a vital role in their social life.

The majority of the sources are polluted and therefore not suitable for drinking purposes. This resulted in diseases such as cholera and Typhoid that are transmitted by water, reaching epidemic proportions in some areas in Southern Africa. For these reasons wells, springs, etc. are not considered safe in the planning of drinking water supply systems. Water reticulation networks with standpipes are regarded as the only supply of safe drinking water.

The simplicity, low cost and effectiveness of source protection makes it a viable alternative in the short term, and in some areas a long term solution for safe drinking water.

ACKNOWLEDGEMENT

This project has been compiled and further developed owing to contributions by various individuals.

The main contribution has been made by the CSIR - National Institute for Water Research. I am grateful to Mr P.G. Williams of the Appropriate Technology division.

I further would like to mention Mr J.J. Simonis, Town Engineer and Mr A.H. Myburgh, Assistent Town Engineer of the Parow Municipality for allowing me to work on this project.

USEFUL DEFINITIONS

i) Aquifer - A water-bearing underground zone that will yield water to springs and wells.

ii) Bacteria - Single-sell microscopic organism found almost every where.

iii) Coliforms - Types of bacteria present in soil, humand and animal excreta.

iv) Impermeable - Water cannot pass through.

v) Pores - Small holes storing water and air.

vi) Protoza - Higher life form than that of bacteria.

vii) Strata - Soil layers.

viii) Topography - Features of a district.

1. APPROPRIATE TECHNOLOGY IN WATER SUPPLY

1.1 Appropriate technology

The period 1981 - 1990 has been designated as the International Drinking Water Supply and Sanitation Decade. The decade was designated by the United Nations to increase efforts to provide adequate quantity and quality of water supply.

The need for water supply is enormous in small communities in the rural areas of Southern-Africa. To supply water to small communities, factors such as, organization, administration, community involvement, environment and finance are the major constraints. One other problem is to select the suitable technology to comply with the conditions of the different small communities.

Care should be taken not to regard small community water supply systems as scaled down version of urban installations requiring less engineering skill or ingenuity.

The exact opposite may be the case. Simplicity and smallness should not be regarded as backward or second-rate, but rather as appropriate technology for the purpose. Technologies must be selected that can be integrated with the approach of community involvement which is essential in small-scale schemes.[1]

In Southern-Africa there are a number of organizations involved in technology for small rural communities, such as the government, consulting Engineers and Missionery organizations. The CSIR's National Institute for Water Research has an appropriate technology Division, they act as a catalyst in encouraging existing organizations and communities to improve their water supplies.

The NIWR's Approrpiate technology division identifies problems in water supply to communities in rural areas. If there are appropriate existing technologies to solve these problems, or to meet their needs a directed research is carried out to adapt or develop new technologies which is followed by a successful technology transfer.

Technologies such as i) Clorination of small water supply systems.

ii) Pit Latrines

iii) Slow sand filtration, etc.

1.2 Transfer of Appropriate technology

Transferring new technologies to rural communities must be done carefully and with sensitivity to the needs and cultures of the users.

There is a wide variety of appropriate water supply technologies in use in developing countries around the world. A number of international organizations are making effective contributions to transferring these technologies between countries through literature. However, these publications do not reach the rural people directly, and therefore each country needs to make relevant information widely available by means of information sheets in local languages, demonstrations or video films.

There is also a need to make engineers and government authorities aware of appropriate technology and its benefits.

Appendix A - Technical Paper On :

The protection of water sources in developing countries, is a simplified information sheet which provides details of the most suitable methods used for typical situations. This information sheet is available to interested organisations.

2. WATERSOURCE PROTECTION

2.1 Water Quality

Water quality is the relative presence of micro-organisms and the content of mineral and organic compounds in the water.

Requirements for drinking water are :

i) Free from pathogenic organisms.

ii) Contain no compounds that may have an adverse effect on human health

iii) Must be clear.

iv) Not be salty.

v) Must have a pleasant taste and smell.

Table 1 Guideline values for bacteriological quality

Organism	Unit	Guideline value	Remarks
A. Piped water supplies			
A.1 Treated water entering the distribution system			
faecal coliforms	number/100ml	0	turbidity<1 NTU:for disfection with chlorine, pH preferably <8.0, free chlorine residual 0,2-0,5 mg/litre following 30 minutes (minimum) contact
A.2 Untreated water entering the distribution system			
faecal coliforms	number/100ml	0	
coliform organisms	number/100ml	0	in 98% samples examined throughout the year-in the case of large supplies when sufficient samples are examined.
coliform organisms	number/100ml	3	in an occasional sample, but not in consecutive samples
A.3 Water in the distribution system			
faecal coliforms	number/100ml	0	
coliform organisms	number/100ml	0	in 95% of samples examined throughout the year - in the case of large supplies when sufficient samples are examined.
coliform organisms	number/100ml	3	in an occasional sample but not in consecutive
B. Unpiped water supplies			
faecal coliforms	number/100ml	0	
coliform organisms	number/100ml	10	should not occur repeatedly, if occurrence is frequent and if sanity protection cannot be improved an alternative source must be found if possible.
C. Bottled drinking water			
faecal coliforms	number/100ml	0	source should be free from faecal contamination
coliform organisms	number/100ml	0	
D. Emergency water supplies			
faecal coliforms	number/100ml	0	advise public to boil water in case of failure to meet guideline values.
coliform organisms	number/100ml	0	

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The most important criteria of drinking water is the bacteriological content. It is not practical to test water for all organisms that it might possibly contain. The water is tested for a specific type of bacteria which originates in large numbers from human and animal excreta and whose presence in the water is indicative of faecal contamination, and thus detrimental to human health. Faecal bacteria are members of a much larger group of bacteria called the coliforms. Coliform bacteria can be found in soil. Faecal contamination is indicated by coliform, known as Escherichia-coli (E-coli). Faecal coliforms in water increases the possibility of the presence of pathogenic bacteria and viruses in the water.

In the table below one can see the difference between the E-coli counts of the protected water sources and the unprotected sources.

Table 2 Summary of faecal coliform analyses of water samples taken during fieldwork in Kwazulu.

Location	Water source	Faecal coliform results/100 mℓ
Vukuzakhe	Protected spring	
	(i) Sample from tap	2
	(ii) Sample from bucket filled from tap	40
Tongaat	Covered rainwater tank at cemetry	1
Lloyds higher primary school	Uncovered rainwater tank filled by mobile tanker	11
Nkobongo	Covered rainwater tank in village	Nil
Driefontein	Concrete pipe sunk into bed of small stream	>500
Mvundlweni	Protected spring. Sample from tap	Nil
Kwashishi	Protected spring. Sample from tap	Nil
Mbubu	Water hole in stream bed	>100
Mbubu	Unprotected spring which is unused and in uninhabited area	Nil

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Bacteriologically polluted water can cause 20 to 30 infectious diseases. There are four ways that these diseases can spread :

i) Through water supplies (By drinking the water) - water borne diseases.

ii) Lack of water for personal hygiene - Water washed diseases

iii) Infections through animals living in the water - Water based diseases.

iv) Infection spread by water insects - Water related insects.

Tabel 3 Infective diseases in relation to water supplies

Category	Examples	Relevant water improvements
I Water-borne infections		
(a) Classical	Typhoid, cholera	Microbiological sterility
(b) Non-classsical	Infective hepatitis	Microbiological improvement
II Water-washed infections		
(a) Skin and eyes	Scabies incliema	Greater volume available
(b) Diarrhoeal diseases	Bacillary dysentery	Greater volume avaiable
III Water-based infections		
(a) Penetrating skin	Schistosomasis	Protection of user
(b) Ingested	Guinea warm	Protection of source
IV Infections with water-related insect vectors		
(a) Biting near water	Sleeping sickness	Water piped from source
(b) Breeding in water	Yellow fever	Water piped to site of use
V Infection primarily of defective sanitation	Hookworm	Sanitary faecal disposed

2.2 Protection of the watersource

Boreholes, springs, handpumps, wells and rainwatertanks are the five most commonly found watersources in rural areas in South Africa and our neighbouring states.

Most of these watersources obtain water from the water table below ground level.

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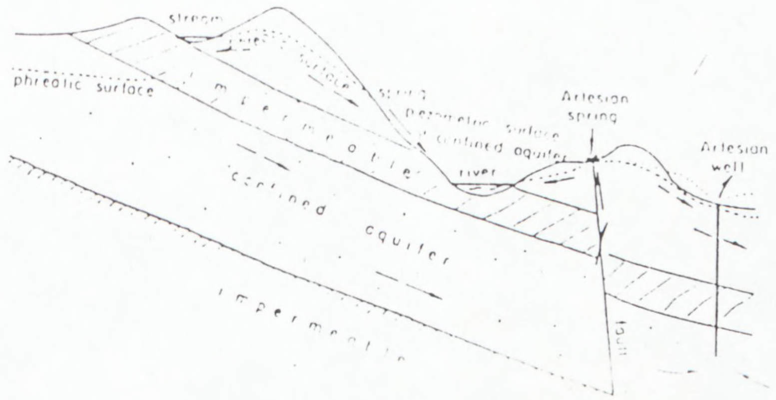

Fig. 39 Modes of occurrence of groundwater[2]

Water that flows in an aquifer is normally of good quality due to the percolating and filtering effect of the soil strata. Pollution of underground water is caused by pit latrines, refuse dumps and agricultural lands that have been treated with fertilizer.

Pollution of underground water has its origin on the surface. In rural communities the pollution of water sources are mainly caused by the animal and human activities in the area immediately surrounding the source. The polluted water on the ground surface then finds its way to the water table. This could be seen from the results obtained from samples taken during fieldwork done in Kwazulu - see Appendix B.

36. Mbongintwine - This water source is a spring at the bottom of a road cutting.

Pathogens rely on the flow of the aquifer to be transported. Protoza, which is a higher form of life than bacteria and viruses died of first in underground conditions. Bacteria and viruses can live longer and it has been found that bacteria may travel some distances below ground when transported by water.

12. Driefontein - Concrete pipe sunk in bed of small stream. Water is clear, but has more than 500 faecal coliforms/100 mℓ . This is the water source for the village.

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2.2.1 Protection of Boreholes and Handpumps

(a) Means of contamination

Boreholes and handpumps can be contaminated by surface water (which are considered as polluted). The surface water seeps down the casing to the water table and is pumped to the surface for drinking purposes and other uses.

Other sources of contamination could be nearby pit latrines or refuse dumps.

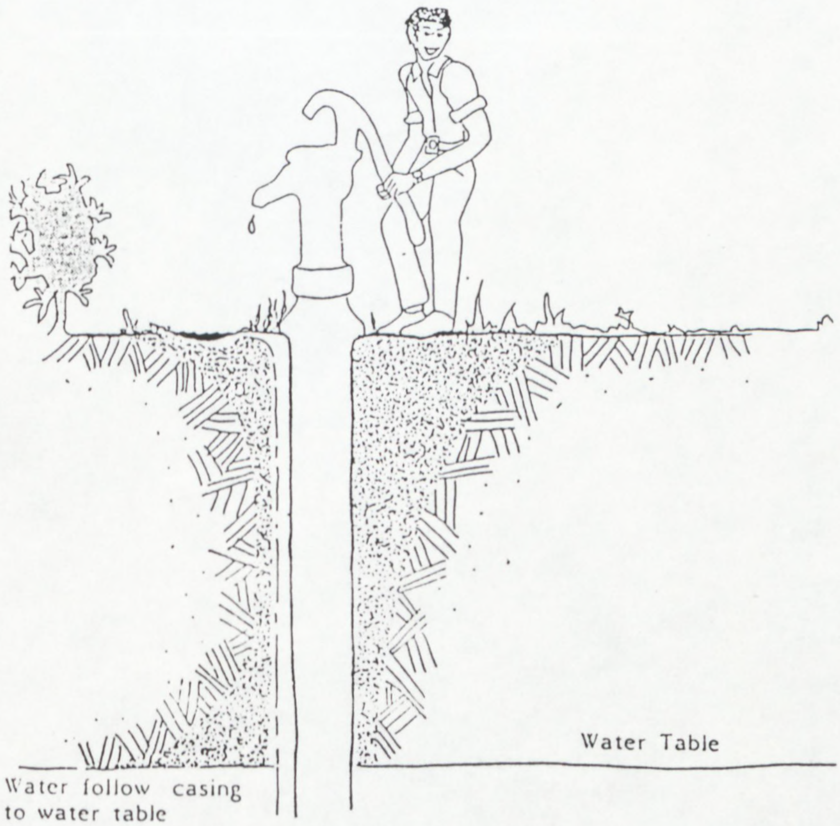

Fig. 2 : Pollution of boreholes

(b) Means of protection

Boreholes and handpumps can be protected from surface water by:

i) Site selection - By selecting a proper borehole site, it can eliminate or reduce the risk of contamination. The borehole should be uphill or at least 15 metres from a pit latrine or refuse dump.[4]

ii) Grouting - By grouting the space between the casing of a borehole and the surrounding soil it acts as a seal and prevents the ingress of surface water.

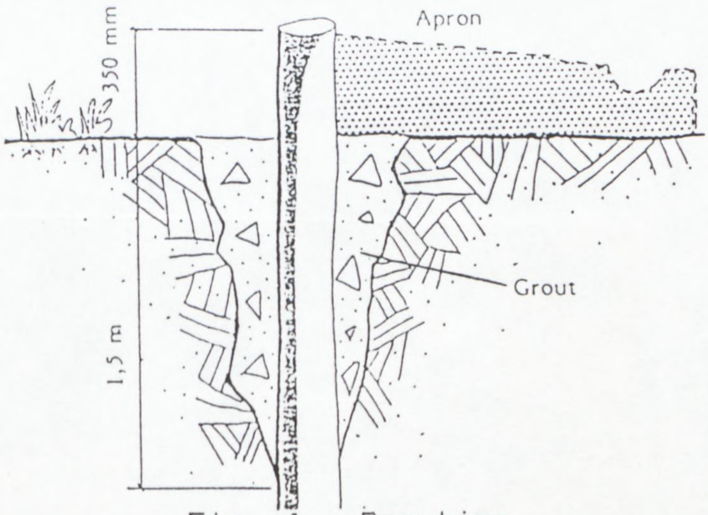

Fig. 4 : Grouting

iii) Construction of an Apron - In most cases it is the water that is pumped from a borehole that in turn contaminates the source. The purpose of an apron is to drain spilled water from the containers away from the borehole. The apron also provides a clean and dry working area as well as a level platform for water containers

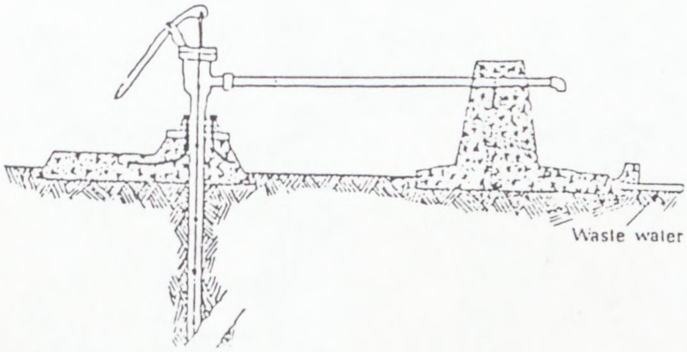

Fig. 13 : Off-set pump

iv) Off-set pumps - By making use of the off-set system a site can be selected more carefully. The off-set system has the advantage that the activities of the water collectors and the operation of the borehole are separated and therefore, reduces the risk of contamination.⁸

39. Adams Mission - Single handled mono pump. Note inadequate drainage around the pump. Water from this borehole turns yellow-brown when stored. Sample tested at NIWR and found to contain 3 000 µg/ℓ iron and 600 µg/ℓ manganese.

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33. <u>Eziko</u> - Borehole with two-handled mono pump.
This handle was very difficult to turn.

2.2.2 Protection of springs

(a) Means of contamination

Rainwater that infiltrates the soil to the underlying strata is called ground water. The quantity of the ground water thus stored depends on the porosity of the sub-surface strata. The water-bearing strata, called aquifers consist of materials such as sand, gravel or more consolidated material such as sandstone.

The water in the pores of an aquifer is subject to gravitational forces and so tends to flow downwards. The water in the aquifers usually moves slowly towards the nearest free water surface such as a lake or river, or the sea. If there is an impermeable layer underlying an aquifer and this layer outcrops on the surface, then the ground water will appear on the surface in a seepage zone or as a spring. When a ground water aquifer is overlain by an impermeable layer, water will rise to the surface if there is an opening in the impermeable layer. This is called an artesian spring.

20. Mbubu - Unprotected spring. Water is collected in the pools of the small stream flowing from the spring. More than 100 faecal coliforms/100 mℓ .

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21. Mbubu - Unprotected spring in uninhabitated area. This spring is to be protected and the water piped to a nearby village. Nil faecal coliforms/ 100 m ℓ .

22. Mbubu - Close up view of the eye of the spring.

The quality of spring water is generally good, and free from pathogenic organisms. The contamination of springs are due to the animal and human activities around a spring. Contamination occurs by dirty containers and hands coming in contacted with the water in the source, people bathe nearby or in the spring, animals make use of the source for drinking water etc.

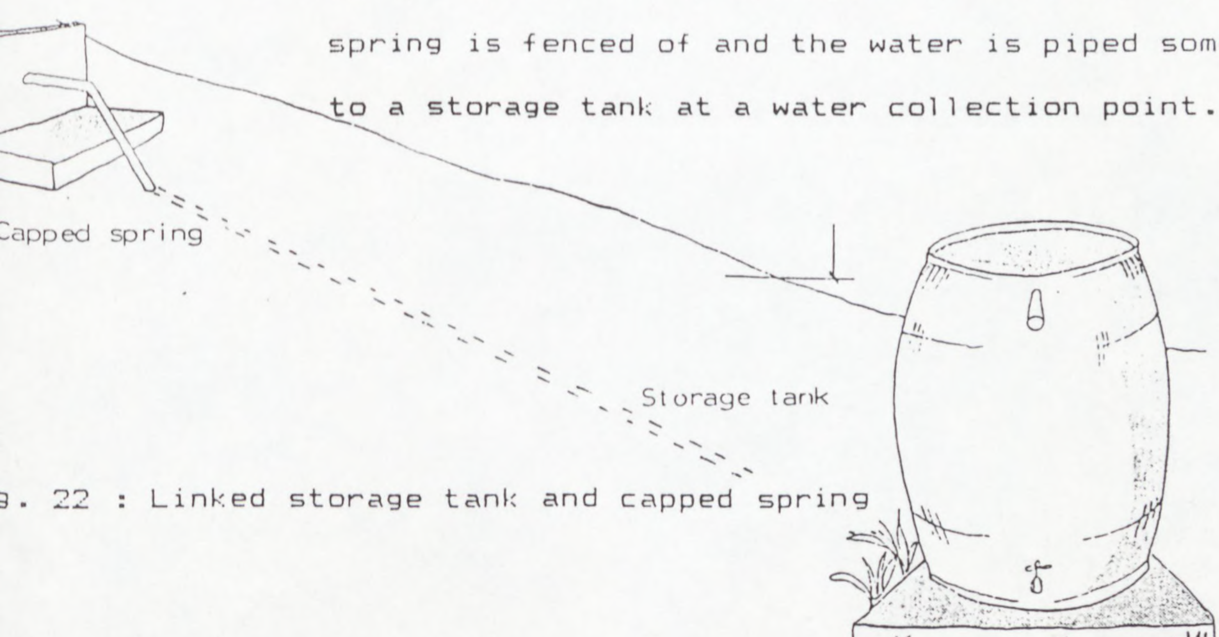
37. Collecting water from the spring.

(b) Means of protection

The main factors for the protection of watersources are to prevent the ingress of surface water into the water source and to protect the spring from human and animal activities.

17. Kwashishi - Protected spring with storage tank and two taps.

A spring is protected from surface water by a retaining wall; spring box or a seepage collection system. The spring is fenced of and the water is piped some distance to a storage tank at a water collection point.



g. 22 : Linked storage tank and capped spring

Protecting gravity springs is difficult. Such a spring is best protected by building a retaining wall structure.[1] The retaining wall will act as a dam below groundlevel and with a proper apron or by piping the water to a storage tank it will protect the water source from contamination. In the summary of faecal coliform analyses of water samples, Appendix B, it can be seen that the faecal coliforms in the Mvundleveni and Kwashishi protected springs are nil per 100ml.

Artesian depression springs are similar to gravity springs but their yield is greater and less fluctuating, as the water is forced out under pressure. A spring box is used to cap an artesian spring. It consists of a collection box; cover; overflow and outlet. The spring is connected to a storage tank.[4]

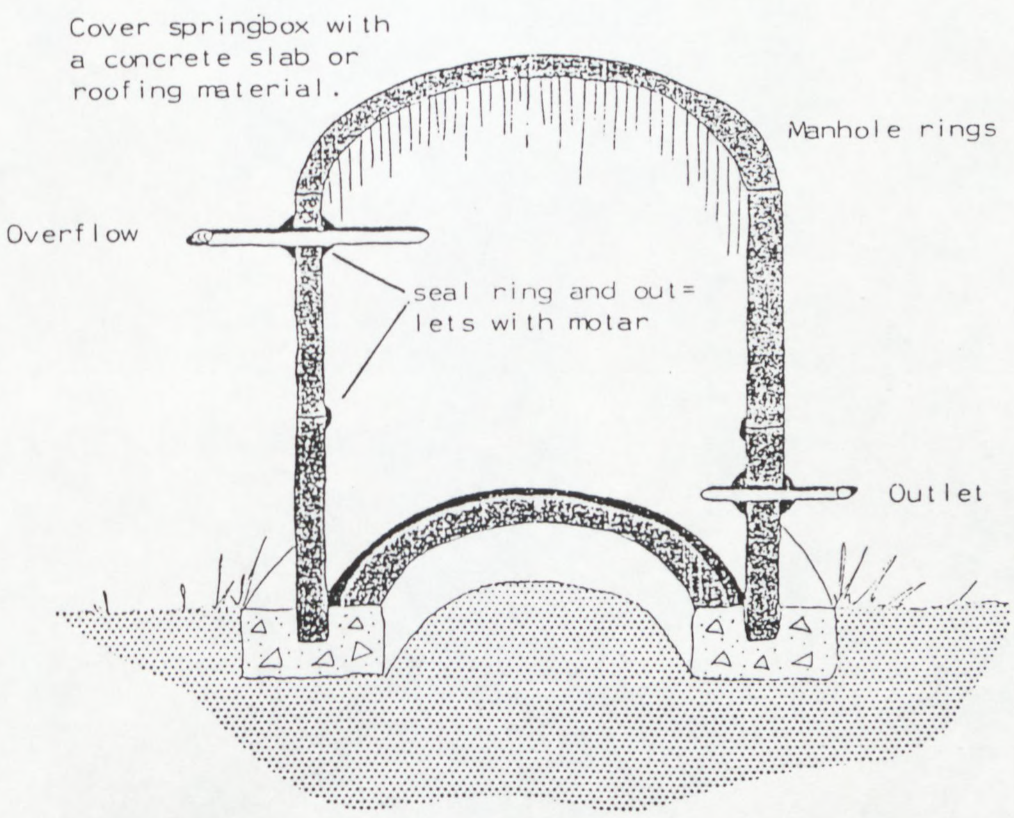


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Fig. 24 : Precast concrete pipe spring box

2.2.3 Protection of Wells

(a) Means of contamination

Hand dug wells are still in use in developing countries. Wells are normally highly polluted due to improper protection such as improper drainage, poor well lining and the contamination of the bucket and rope, if this system is used.

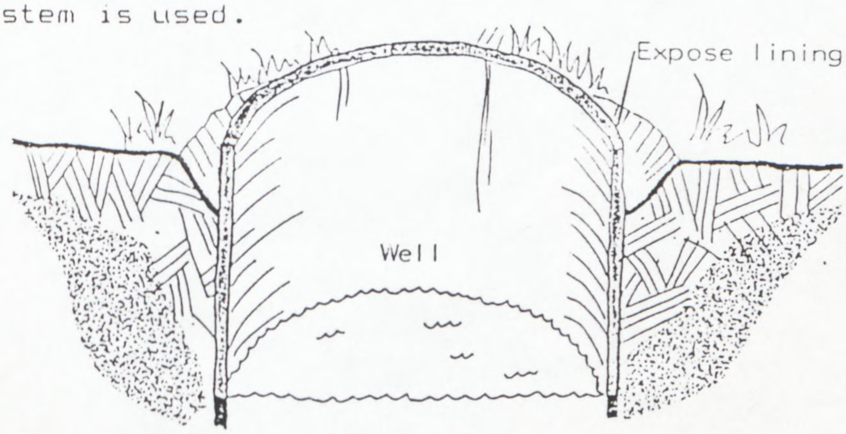


Fig. 27 : Expose lining

(b) Means of protection

By constructing a proper apron and a water seal it will protect a spring from surface water. To effectively protect a hand dug well, it may be covered with a concrete cover.

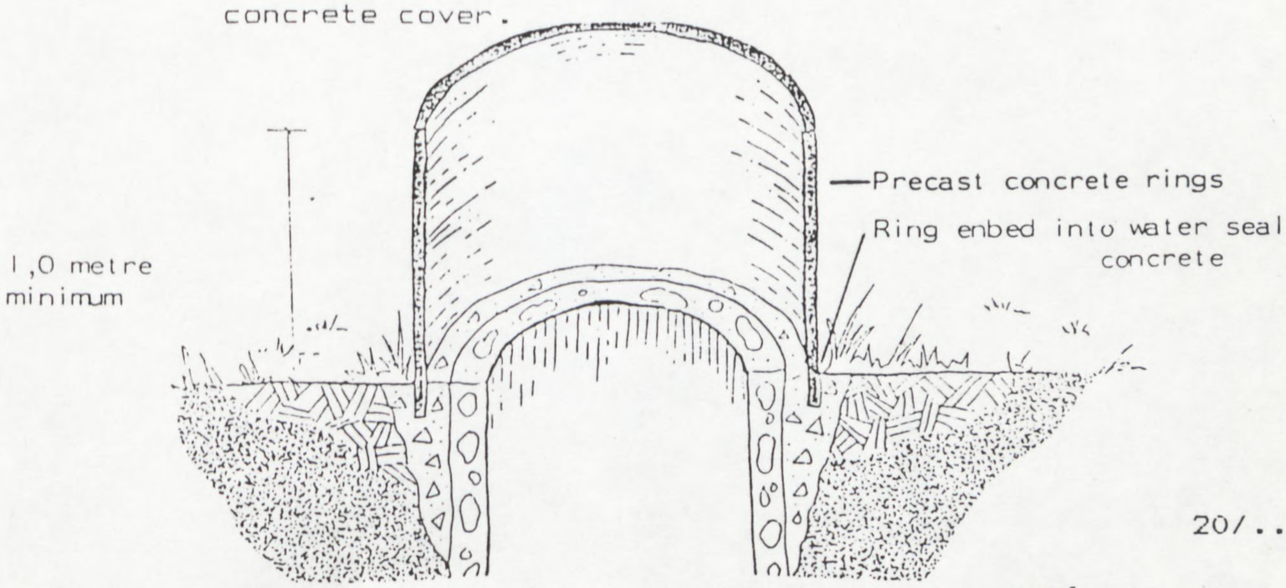


Fig. 29 : Concrete ring into water seal

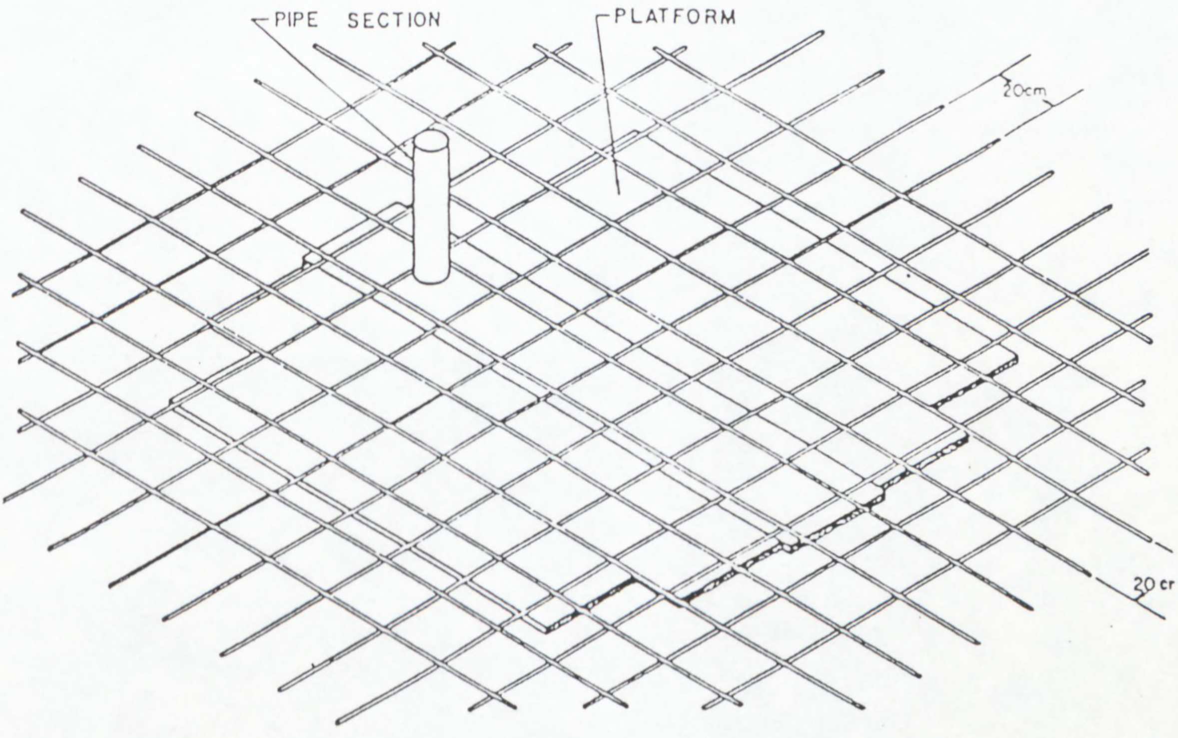


Fig. 33 : Reinforcement for Dug Wells

6. Tongaat - Rainwater tank,
1 faecal coliform/100 mℓ .

2.2.4 Protection of rainwater collection system

(a) Means of contamination

The runoff from a roof after the first rainfall, accumulates dust, bird droppings and dirt and is referred to as the foul flush. In order to protect the rainwater collection system, the flush must be diverted before reaching the storage tank.

(b) Means of protection

This method consists of a rubber pipe connection between the gutter outlet and the downpipe. This allows the downpipe to be installed in different positions. The downpipe will remain in position to drain the water away from the roof. Once the rain starts and after the flush, the downpipe is placed into the storage tank.

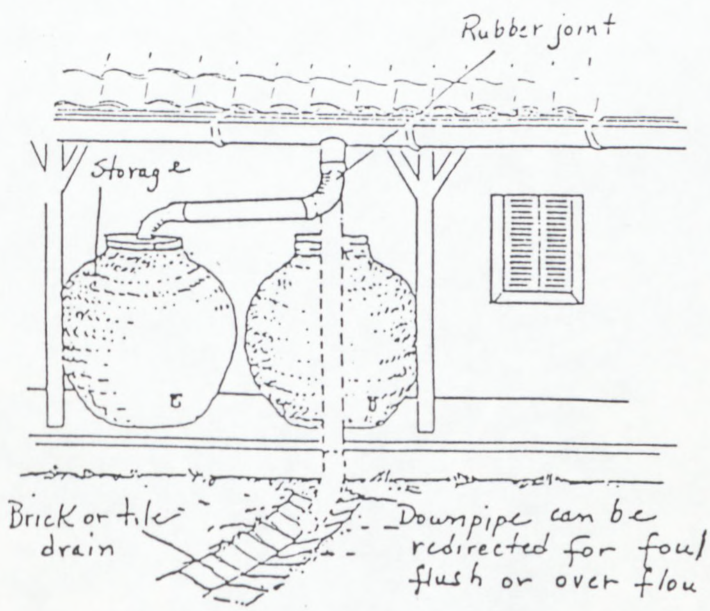
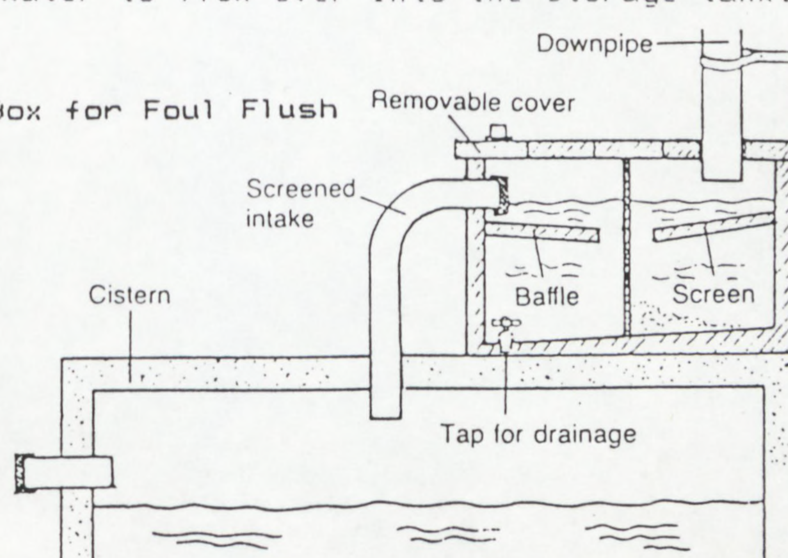


Fig. 35 : Manual Systems

Automatic foul flush systems consists mainly of a small tank on top of the storage tank. This little tank has the capacity of the flush and allows dirt to settle and clear water to flow over into the storage tank.[7]

Fig. 37 : Collection Box for Foul Flush



3. CONCLUSION AND PROPOSAL

Source protection is not often implemented at a water supply system in rural areas. Engineers and technicians are usually involved in high technology projects such as large water supply schemes and therefore simple methods of water supply are over looked. The fact that all possible water sources in Southern Africa should be utilized and also the little capital, simplicity, and effectiveness of source protection makes it a viable alternative for short term, and in some areas a long term supply of safe drinking water.

The research work on water source protection should be properly transferred to the people involved in water supply in rural areas of Southern-Africa. Therefore, as a result of my studies and fieldwork, this easy to understand technical paper (Appendix A) is compiled. It will be made available to interested organizations through the NIWR.

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APPENDIX A

TECHNICAL PAPER ON :

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CONTENTS PAGE

INTRODUCTION

Water sources in rural areas of developing countries consist mainly of

1. Boreholes
2. Springs
3. Handpumps
4. Wells
5. Rainwater collection by tanks and other means

The use of water from these water sources may be subdevided in five categories :

i) Drinking

ii) Preparation of food

iii) Cleaning and personal hygiene

iv) Garden watering

v) Stock watering

Water quality

Water quality is the determination of the micro-organisms and the content of mineral and organic compound present in the water.

Requirements for drinking water are :

i) Free from pathogenic (diseuse causing) organisms.

ii) Containing no compounds that have an adverse effect on human health.

iii) Clear (When looking through the water in a glass).

iv) Not salty.

v) Have a pleasant tast and smell.

For application by technical people the quality criteria of water has been laid down in a practical guideline. Chemical and Bacteriological quality guidelines are available in table form :

Table 1 Guideline values for bacteriological quality

Organism	Unit	Guideline value	Remarks
A. Piped water supplies			
A.1 Treated water entering the distribution system			
faecal coliforms	number/100 ml	0	turbidity < 1 NTU; for disinfection with chlorine, pH preferably < 8.0; free chlorine residual 0.2-0.5 mg/litre following 30 minutes (minimum) contact
coliform organisms	number/100 ml	0	
A.2 Untreated water entering the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 98% of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number/100 ml	3	in an occasional sample, but not in consecutive samples
A.3 Water in the distribution system			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	0	in 95% of samples examined throughout the year—in the case of large supplies when sufficient samples are examined
coliform organisms	number/100 ml	3	in an occasional sample but not in consecutive samples
B. Unpiped water supplies			
faecal coliforms	number/100 ml	0	
coliform organisms	number/100 ml	10	should not occur repeatedly; if occurrence is frequent and if sanitary protection cannot be improved an alternative source must be found if possible
C. Bottled drinking-water			
faecal coliforms	number/100 ml	0	source should be free from faecal contamination
coliform organisms	number/100 ml	0	
D. Emergency water supplies			
faecal coliforms	number/100 ml	0	advise public to boil water in case of failure to meet guideline values
coliform organisms	number/100 ml	0	

The most important criteria of drinking water quality is the bacteriological quality, i.e. the content of bacteria and viruses. It is not practical to test the water for all organisms that it might possibly contain. The water is tested for a specific type of bacteria which originates in large numbers from human and animal excreta and whose presence in the water is indicative of faecal contamination. Faecal bacteria are members of a much larger group of bacteria called the coliforms. Coliform bacteria are present in soil. Feacal contamination are indicated by coliform known as Escherichia-coli (E-coli) and faecal streptococci. Faecal coliforms in water increase the possiblity of the presence of pathogenic bacteria and viruses in the water.

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Faecal bacteria can be found in a great number of small community water supply systems. By protecting water sources the bacteriological quality of the water can be limited.

There are two methods of testing for levels of faecal coli and faecal streptococci in water i) The multiple tube method (M.P.N.) and

ii) The membrane filtration method.

Bacteriologically polluted water can cause 20 to 30 infective diseases. There are four ways that the diseases can spread :

i) Through water supplies (By drinking the water) - Water borne diseases.

ii) Lack of water for personal hygiene - Water washed diseases.

iii) Infections through animals living in the water - Water based diseases.

iv) Infection spread by water insects - Water related insect vectors.

<u>Tabel 2</u> Infective diseases in relation to water supplies

Category	Examples	Relevant water improvements
I Water-borne infections		
(a) Classical	Typhoid, cholera	Microbiological sterility
(b) Non-classical	Infective hepatitis	Microbiological improvement
II Water-washed infections		
(a) Skin and eyes	Scabies, trachoma	Greater volume available
(b) Diarrhoeal diseases	Bacillary dysentery	Greater volume available
III Water-based infections		
(a) Penetrating skin	Schistosomiasis	Protection of user
(b) Ingested	Guinea worm	Protection of source
IV Infections with water-related insect vectors		
(a) Biting near water	Sleeping sickness	Water piped from source
(b) Breeding in water	Yellow fever	Water piped to site of use
V Infections primarily of defective sanitation	Hookworm	Sanitary faecal disposal

<u>Tabel 3</u> Main infective diseases in relation to water supplies.

Category	Disease	Frequency	Severity	Chronicity	Percentage suggested reduction by water improvements
Ia	Cholera	+	+ + +		90
Ia	Typhoid	+ +	+ + +		80
Ia	Leptospirosis	+	+ +		80
Ia	Tularaemia	+	+ +		40?
Ib	Paratyphoid	+	+ +		40
Ib	Infective hepatitis	+ +	+ + +	+	10?
Ib	Some enteroviruses	+ +	+		10?
Ia, IIb	Bacillary dysentery	+ +	+ + +		50
Ia, IIb	Amoebic dysentery	+	+ +	+ +	50
Ib, IIb	Gastroenteritis	+ + +	+ + +		50
IIa	Skin sepsis and ulcers	+ + +	+	+	50
IIa	Trachoma	+ + +	+ +	+ +	60
IIa	Conjunctivitis	+ +	+	+	70
IIa	Scabies	+ +	+	+	80
IIa	Yaws	+	+ +	+	70
IIa	Leprosy	+ +	+ +	+ +	50
IIa	Tinea	+	+		50
IIa	Louse-borne fevers		+ + +		40
IIb	Diarrhoeal diseases	+ + +	+ + +		50
IIb	Ascariasis	+ + +	+	+	40
IIIa	Schistosomiasis	+ +	+ +	+ +	60
IIIb	Guinea worm	+ +	+ +	+	100
IVa	Gambian sleeping sickness	+	+ + +	+	80
IVb	Onchocerciasis	+ +	+ +	+ +	20?
IVb	Yellow fever	+	+ + +		10?

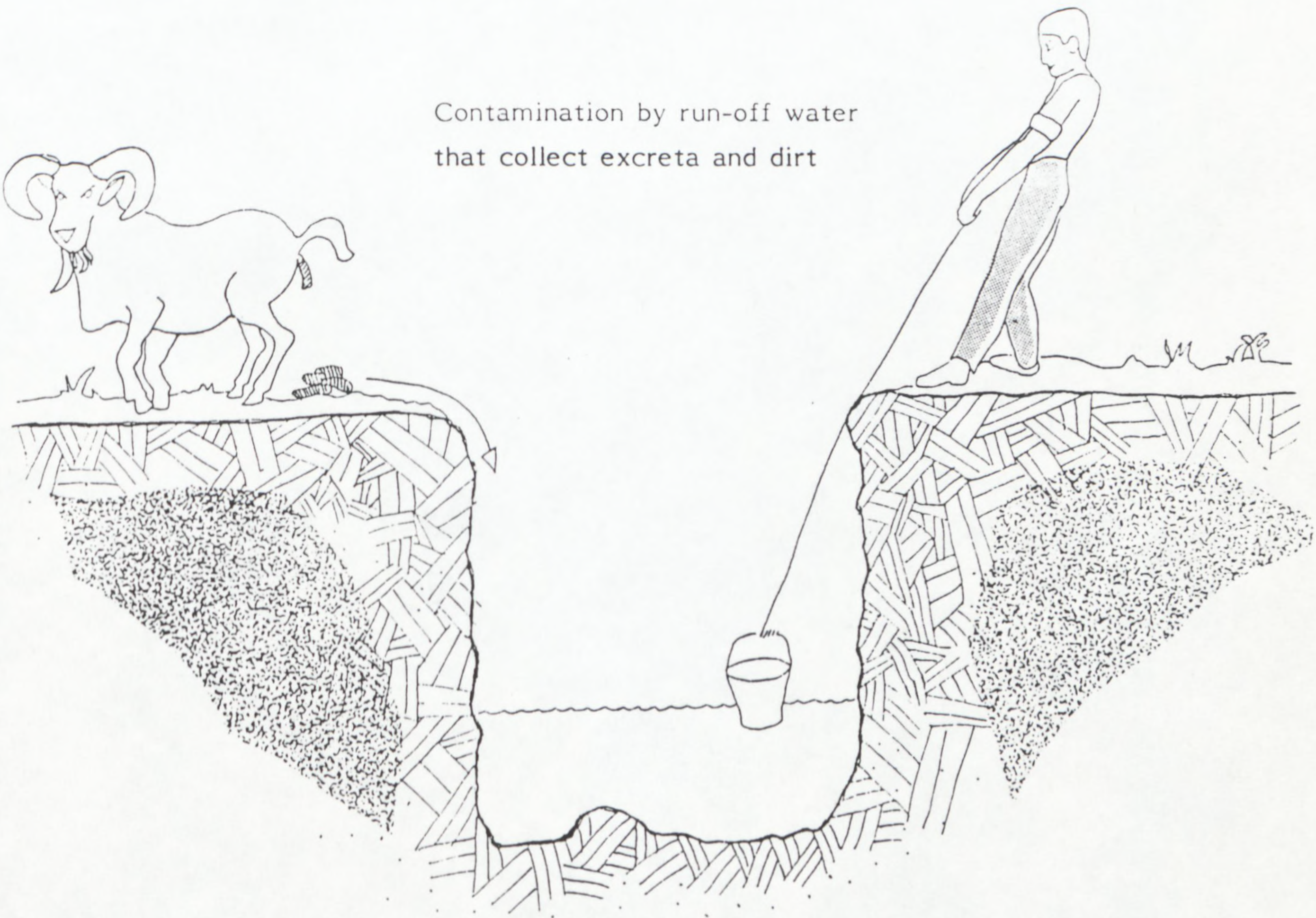

Fig. 1 : Polluted water enter water source

1. BOREHOLES AND HANDPUMPS

Boreholes can be contaminated by surface water (which are considered in this paper as polluted) that will follow the casing down to the water table and is pumped to the surface for drinking water and other uses.

Boreholes can be contaminated by seepage water from a nearby pit latrine.

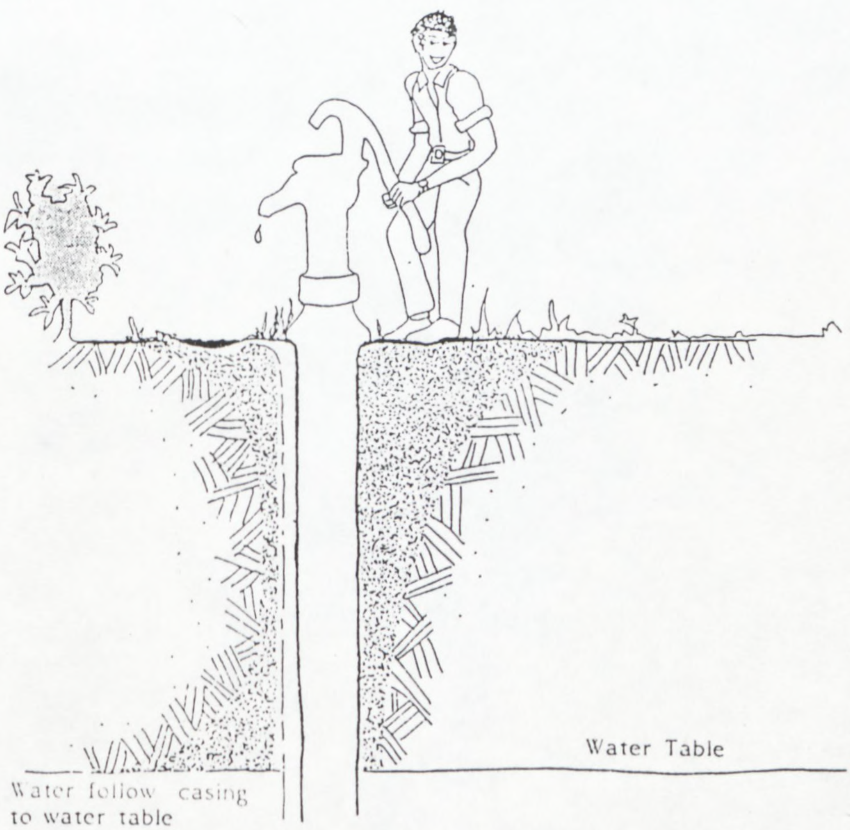

Fig. 2 : Pollution of boreholes

The protection of boreholes

1.1 Site selection

By selecting a proper borehole site it can eliminate or reduce the rish of contamination. Helpful criteria are :

i) Uphill or at least 15 meters from a pit latrine (15 meter are dependent on the underground water flow and is given as a guide only).

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ii) Reliable water sources.

iii) Acceptable water quality.

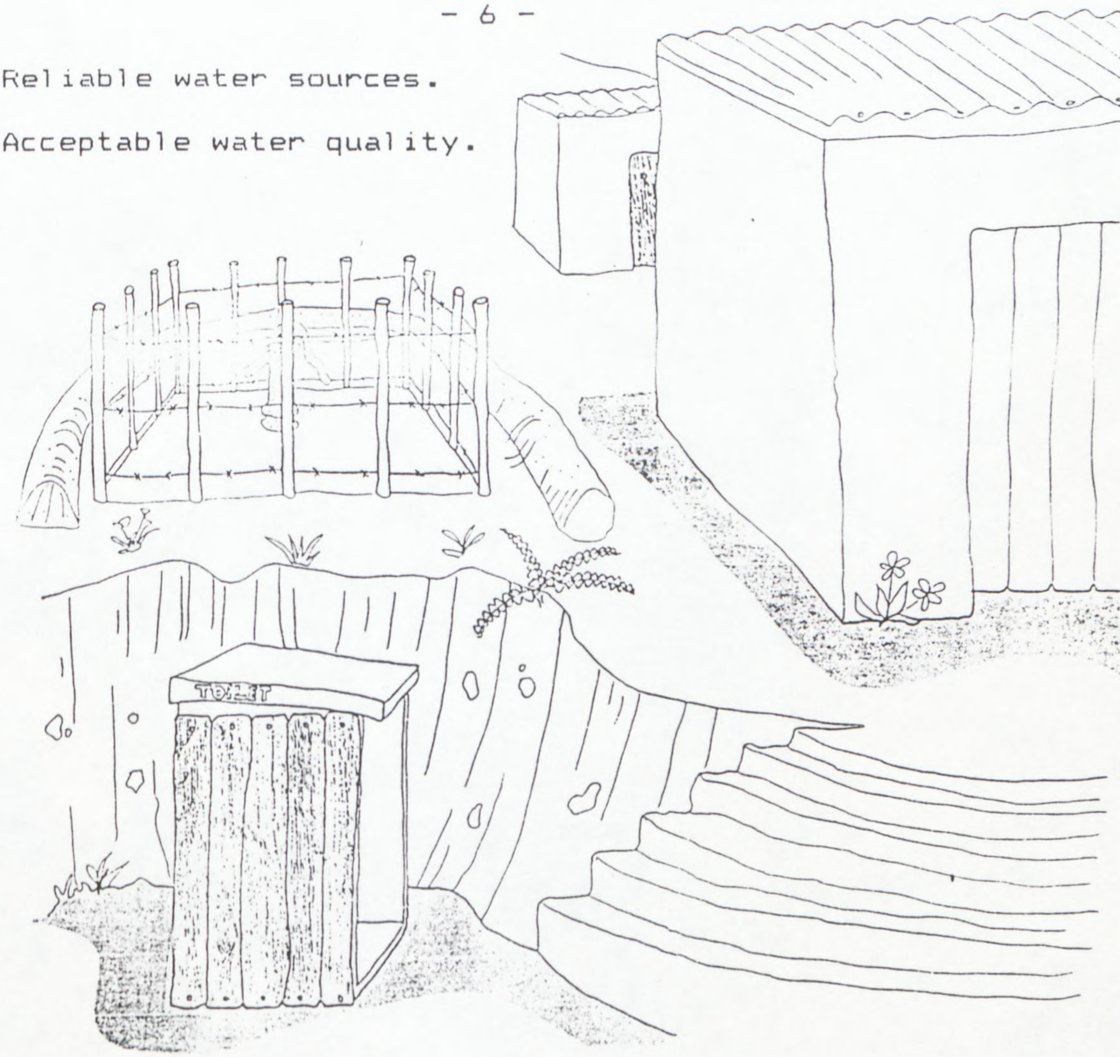

Fig. 3 : Site Selection

1.2 <u>Grouting</u>

Grouting is a process of sealing the space between the casing and the borehole to prevent the ingress of contaminated water.

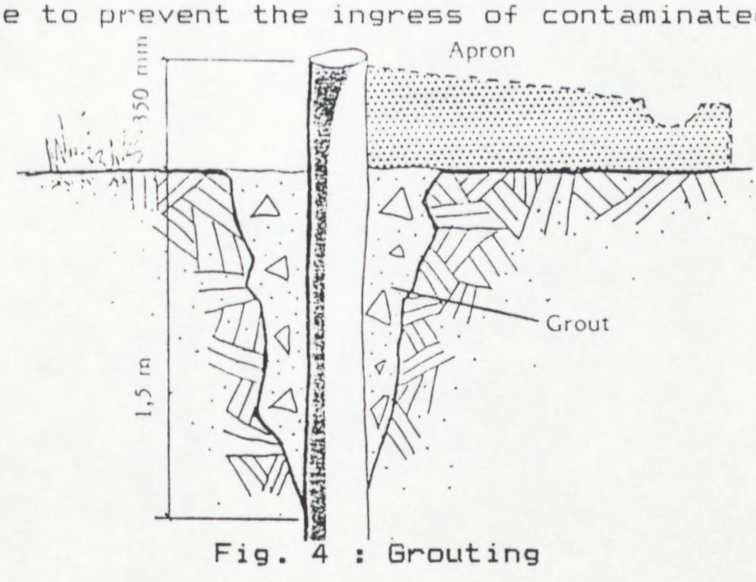

Fig. 4 : Grouting

The casing should extend 350 millimetres above the ground surface to allow for the apron, and to serve as a waterseal.

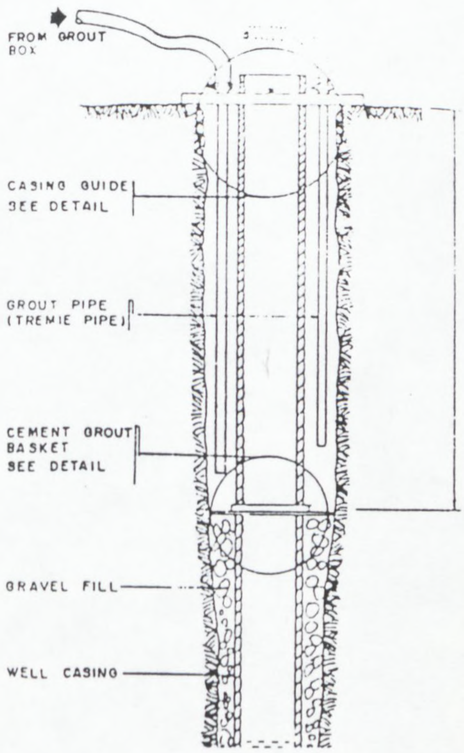

Fig. 5 : Method of grouting of shallow borehole

Grouting consists of a slurry mix of 1 kg cement and 0,5 to 0,6 litres of water.

Grouting is usually done by the drilling contractor. The cement slurry is pumped into the space between the casing and the bore-hole. Grouting starts at the bottom by pumping the cement slurry down through a pipe. The outlet of the groutpipe is submerged into the slurry and raised as the level of the slurry rises. Grouting is done continuously to prevent cracks.

1.3 Apron at the water collecting site

The purpose of the apron is to drain, spilled water, from the containers, away from the borehole. The apron also provides a

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clean and dry working area as well as a level platform for water containers.

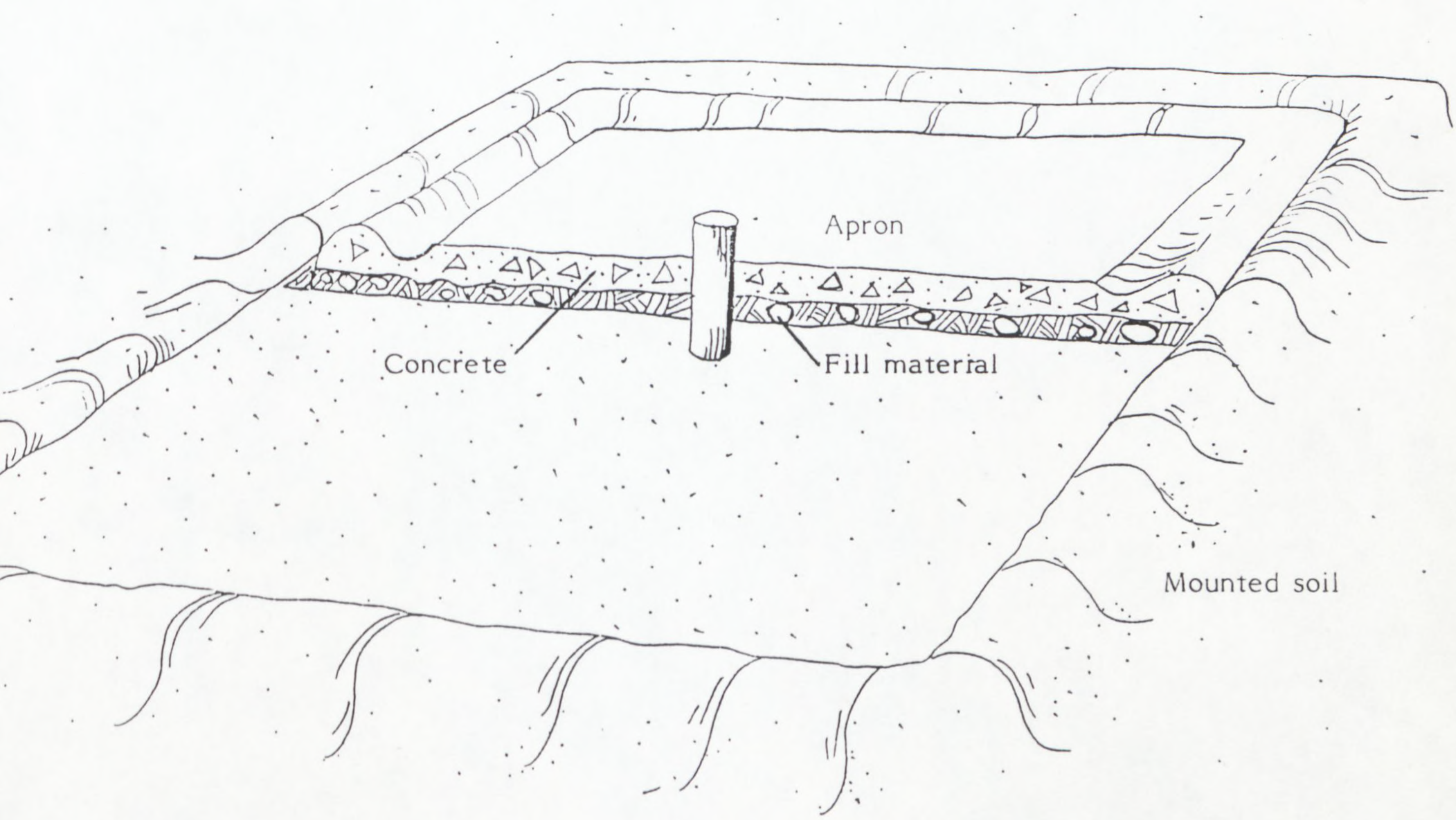

Fig. 6: Apron Construction

1.3.1 <u>Construction of the apron</u>

Remove grass and **shrubs** around the area for the apron. Prepare the floor for the apron by mounding soil around a 2 metre square block. The floor should be shaped to minimize the use of concrete and so ensure that a layer of at least 100 millimetre concrete can be cast. Wet gravel thoroughly. Pour concrete (1 bucket of cement, 2 buckets of sand and 2 buckets of stone)

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1:2:2 mix into the form. Smooth the concrete with a wooden float and form the gutter.

The size and the height of the pedestal depends on the type of containers in use.

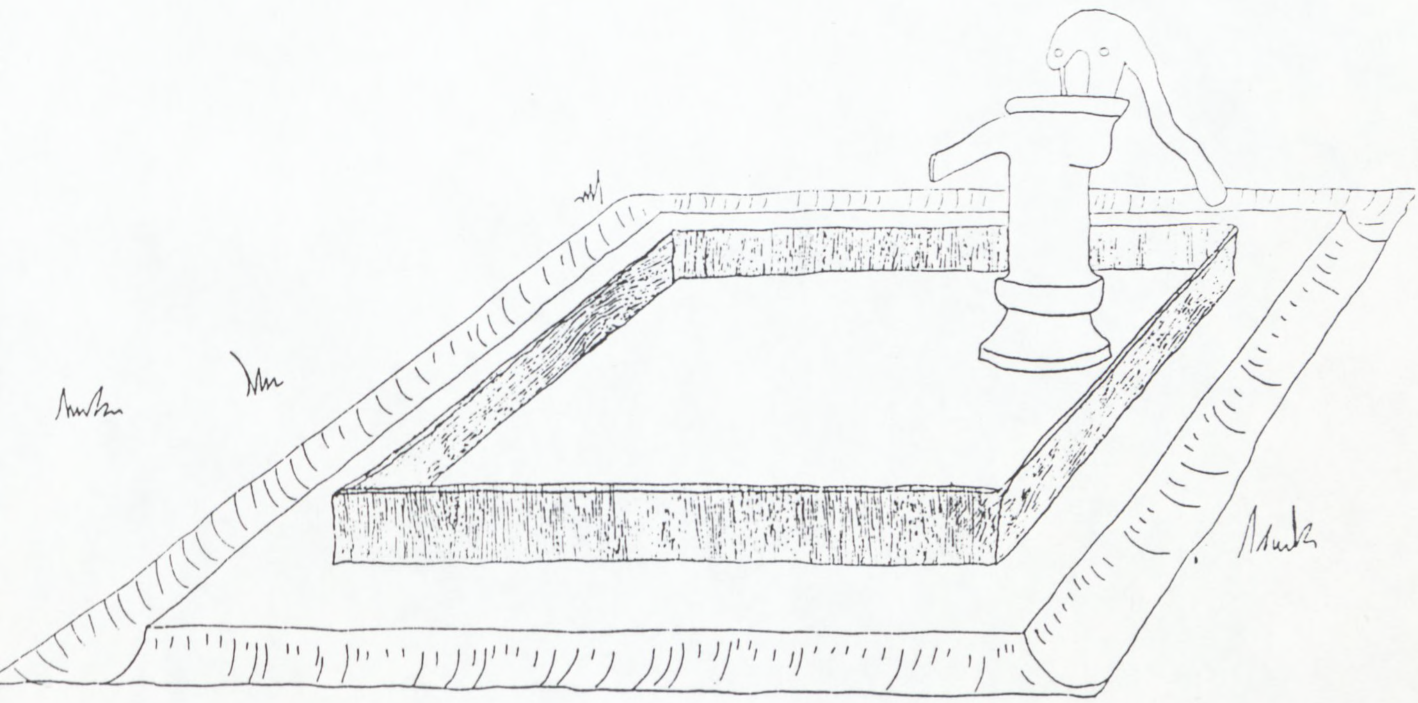

Fig. 7 : Pedestal

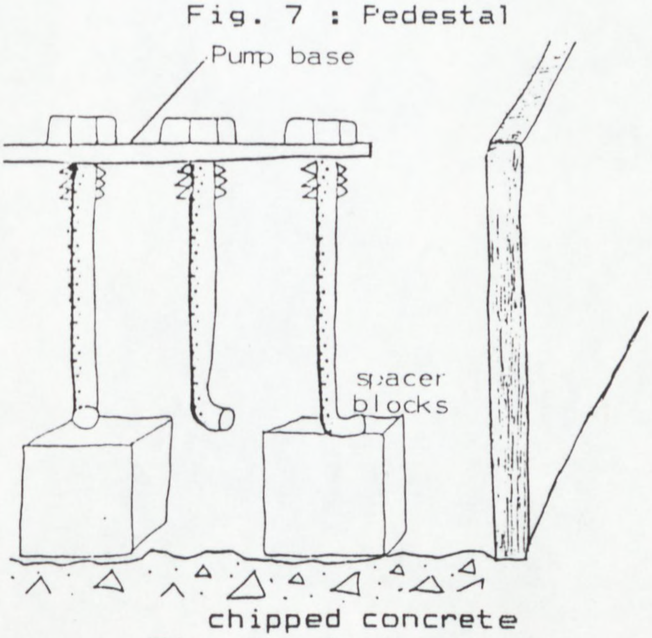

Fig. 8 : Anchor bolts

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When the apron concrete has set, chip clean and dampen the area of the pedestal on the apron to ensure a good bond. Bolt the anchor bolts to the pump base. Make sure of the pump base to set the anchor bolts in the pedestal.

Place the form, determine the height of the casing and cut it off. Place the pump base with anchor bolts inside the form, see that the pump base is plumb. Pour a 1:2:2 concrete mix into the form. (See Appendix on Concrete).

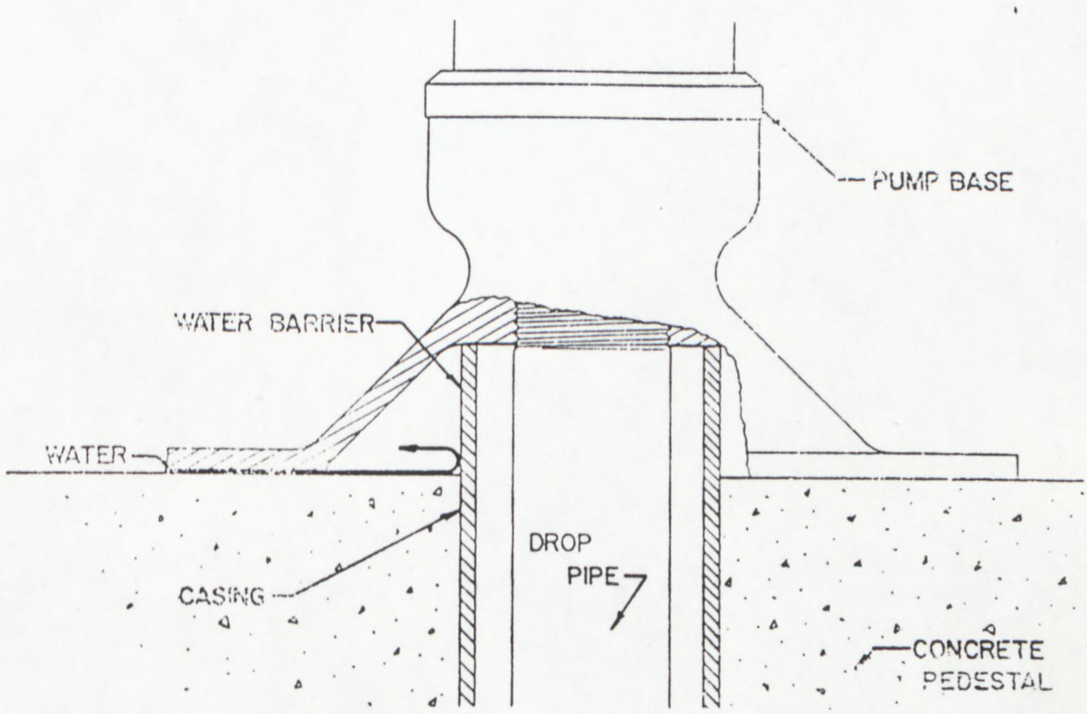

Fig. 9 : Casing as water barrier

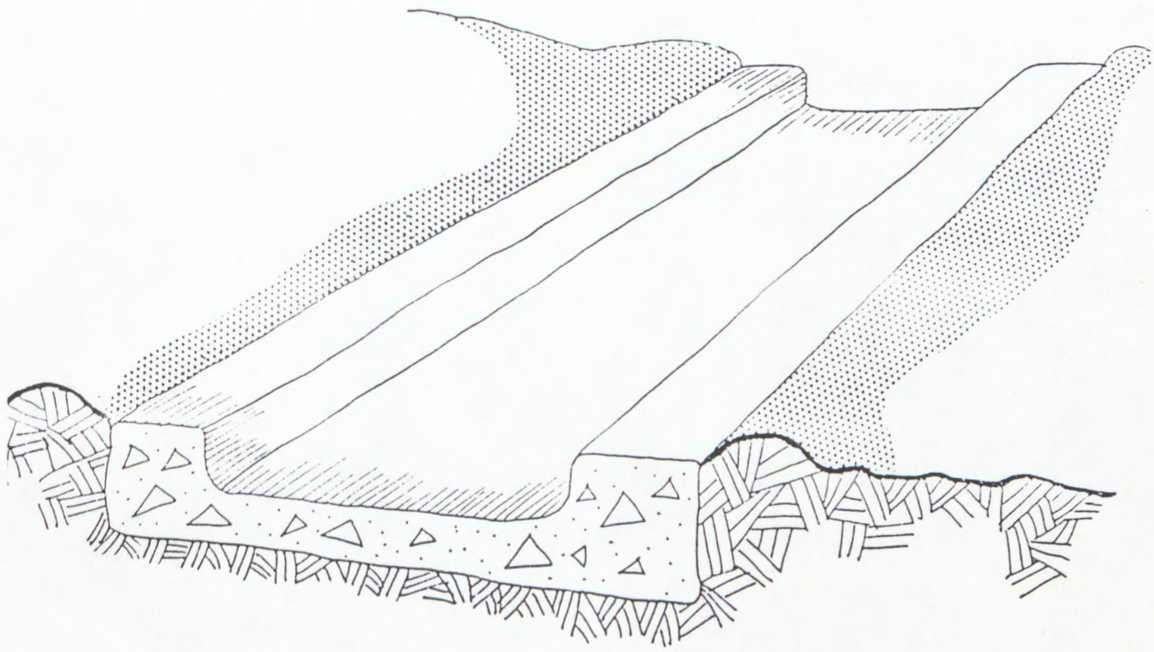

Fig. 10 : Drainage Ditch

The drain is built to remove the water from the apron gutter away to a nearby stream or soakpit.

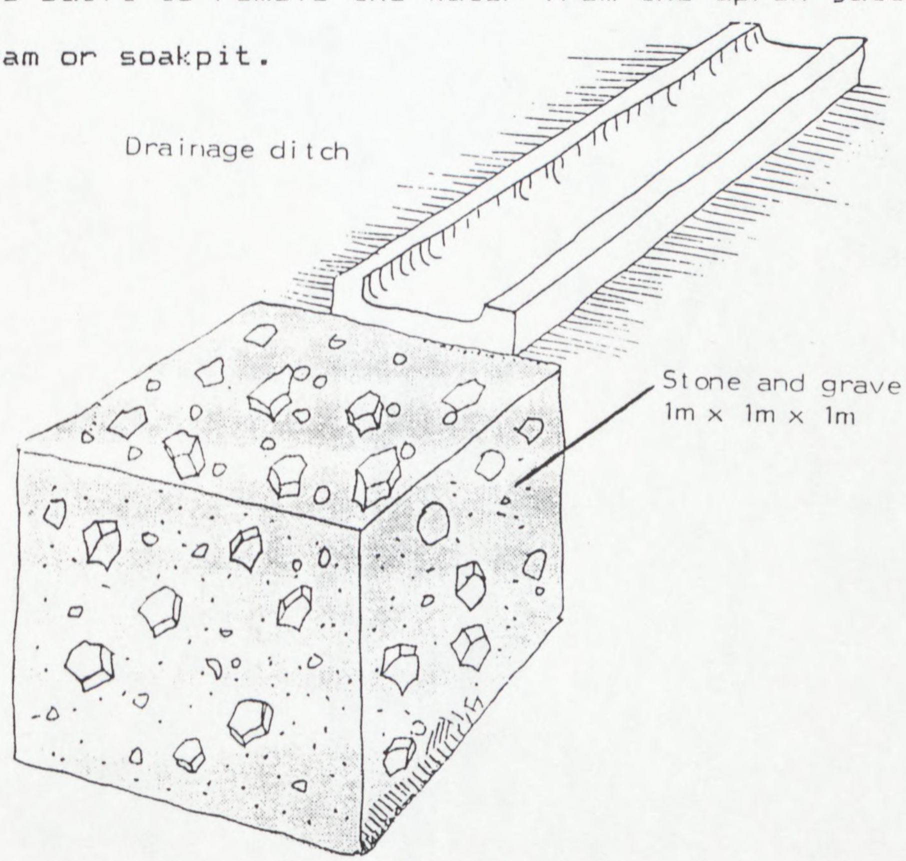

Fig. 11 : Soakpit

The soakpit consists of a hole in the ground which is filled with crushed stone. A soakpit is built to prevent water from forming a pool on the ground surface.[1]

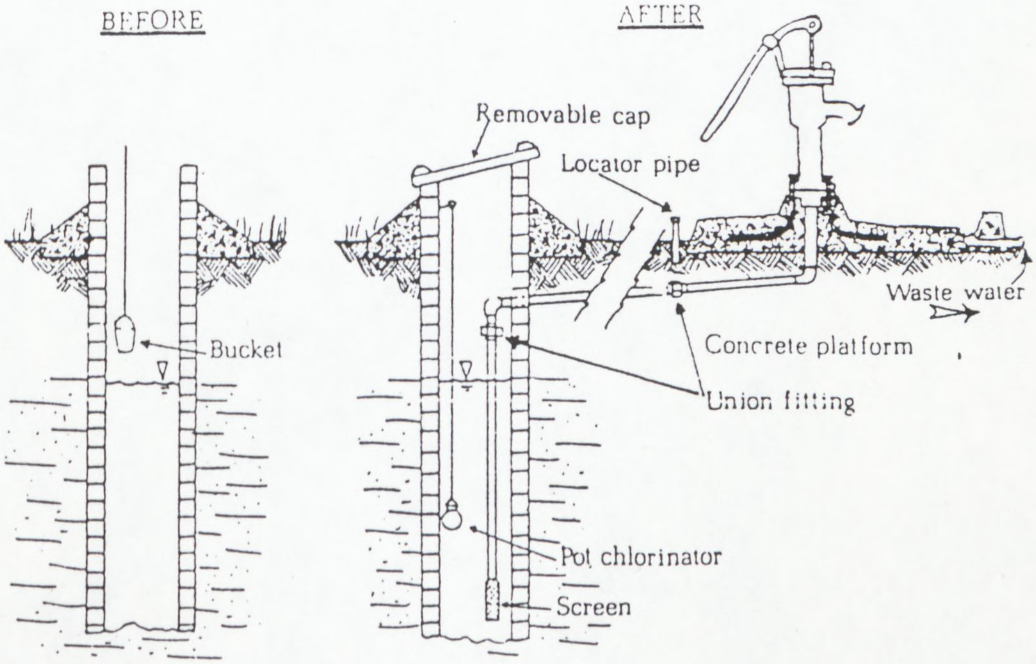

Fig. 12 : Off-set pumps

1.4 <u>Off-set pumps</u>

When the handpump is not situated directly above the borehole, but some distance away, it is called an off-set pump.

At an installation 3 metre above the watertable, a 30 metre off-set had no noticable affect on the amount of water delivered.

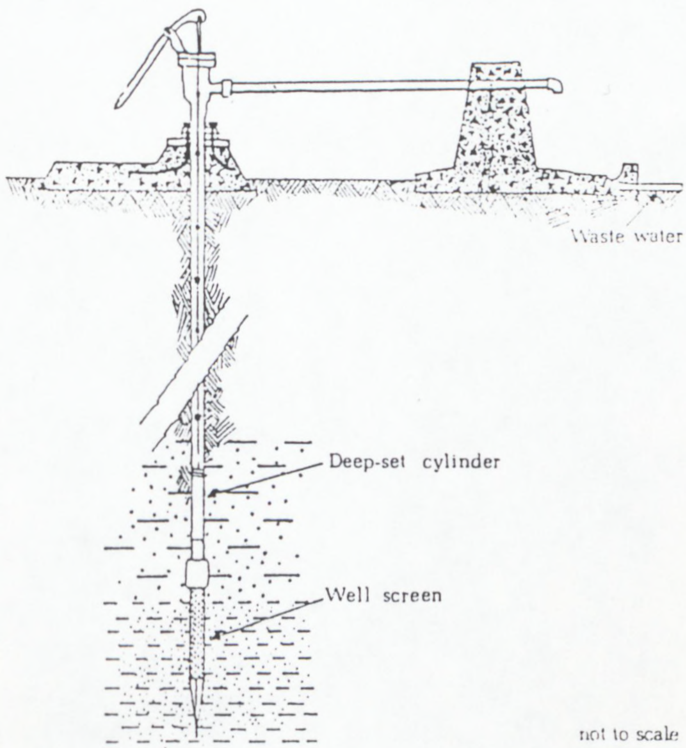

Fig. 13 : Off-set pump

This method can be used for the convenience of the local people or and more important, for source protection. Making use of the off-set system a site can be selected more carefully. The off-set system has the advantage that the activities of the water collectors and the operation of the borehole are separated and therefore should reduce the risk of contamination. There are, however, a few technical aspects such as the type of pump, the height of the collecting point (must always be at a higher level than that of the borehole site) that need the advice of an engineer [2] or experienced technician.

2. SPRINGS

Springs are one of the oldest and most common water sources in developing countries. The prevention of springs from being contaminated by surface water, animal and human activities are generally referred to as springcapping or spring protection.

Springcapping is often used bacause of -

(i) Low initial cost

(ii) Simplicity of construction and minimal maintenance required

(iii) The spring is selected by the local people before capping and is therefore acceptable to the local community

(iv) Making use of local participation for construction and administration.[3]

There are a few criteria to evaluate before capping of a spring is considered.

(i) Is the flow adequate and reliable during summer and winter?

(ii) Is the water safe to drink?

(iii) Topography - Adequate slope for drainage and protection from flooding and erosion.[4]

The type of spring protection structure and method of construction, depends on the type of spring.

Responsible persons must be appointed to manage and maintain the spring. Maintenance such as cleaning of the spring box, repairing of fencing and minor repair work must be done on a continuous basis.

A government official or a person from the local authority responsible for water sources in the area should visit springs regularily to chech for undermining of the foundation, poor flow and any irregularities. Malfunctioning springs must be repaired or closed.

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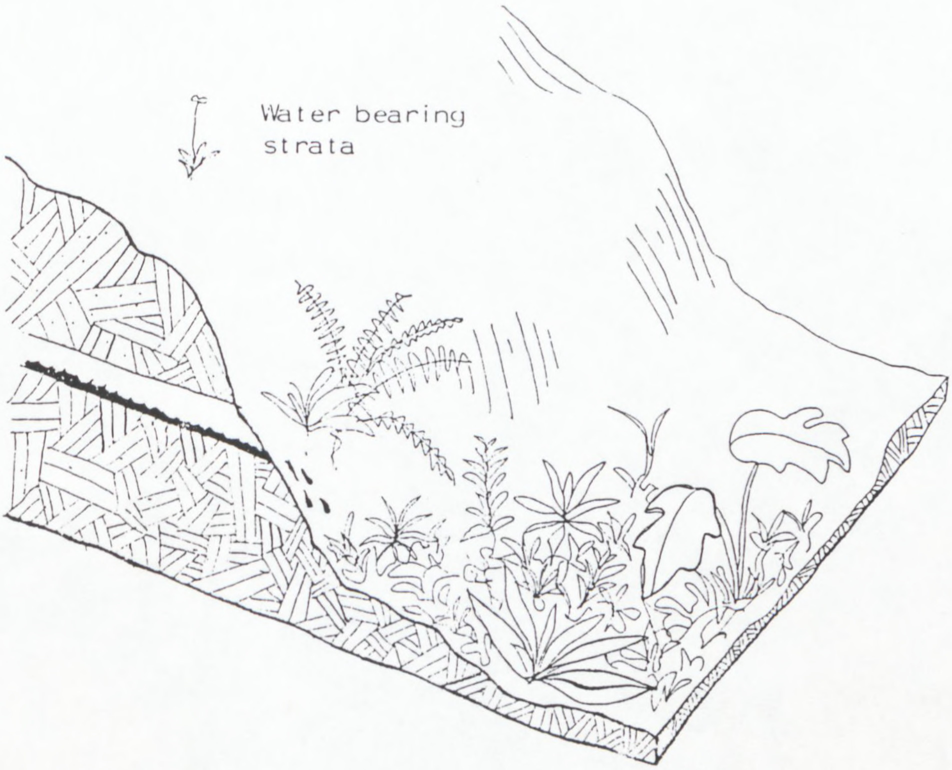

Fig. 14 : Gravity Spring

A gravity spring situated on a slope as in Fig. 14 is protected by a retaining wall structure.

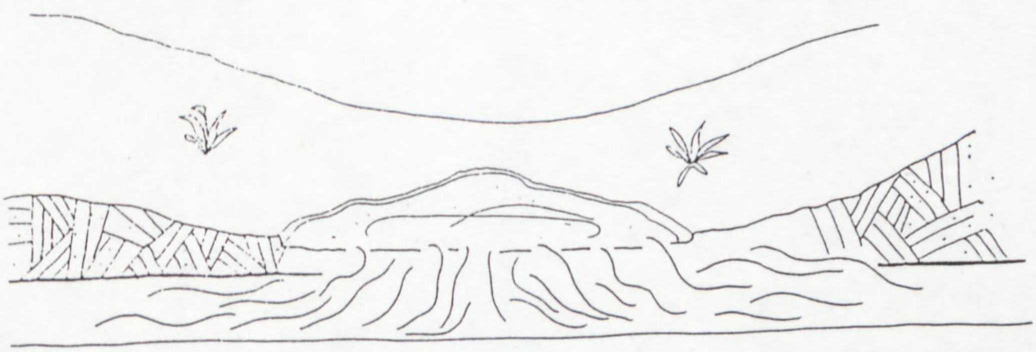

Fig. 15 : Artesian Spring

An artesian spring as in Fig. 15 is protected by a spring box.

Fig. 16 : Small Springs

Some springs consist of a number of small openings in the ground. The method of protecting these springs is complicated and is referred to as a seepage collection system.[5]

Once a type of spring improvement is selected the layout and the site preparation commences. Care should be taken to find the exact position of the spring (the eye of the spring). Clean the area of bushes and shrubs. The position of the structure can be marked with wooden stakes and excavation can commence.

2.1 Gravity spring protection

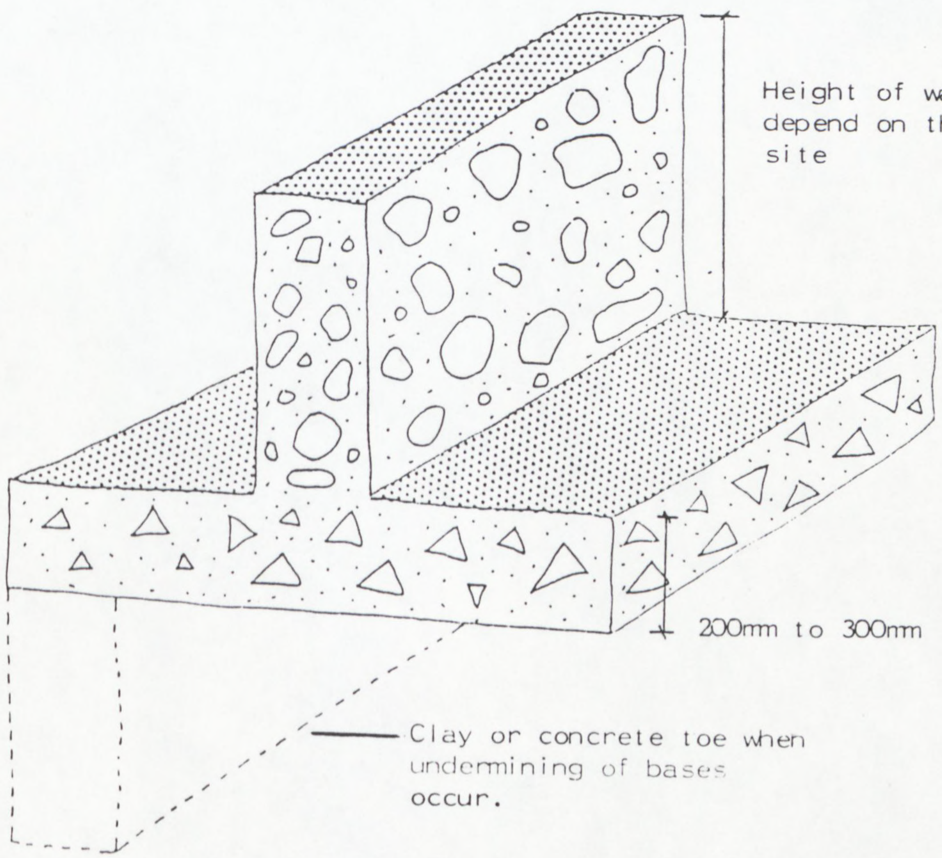

Fig. 17 : Retaining wall

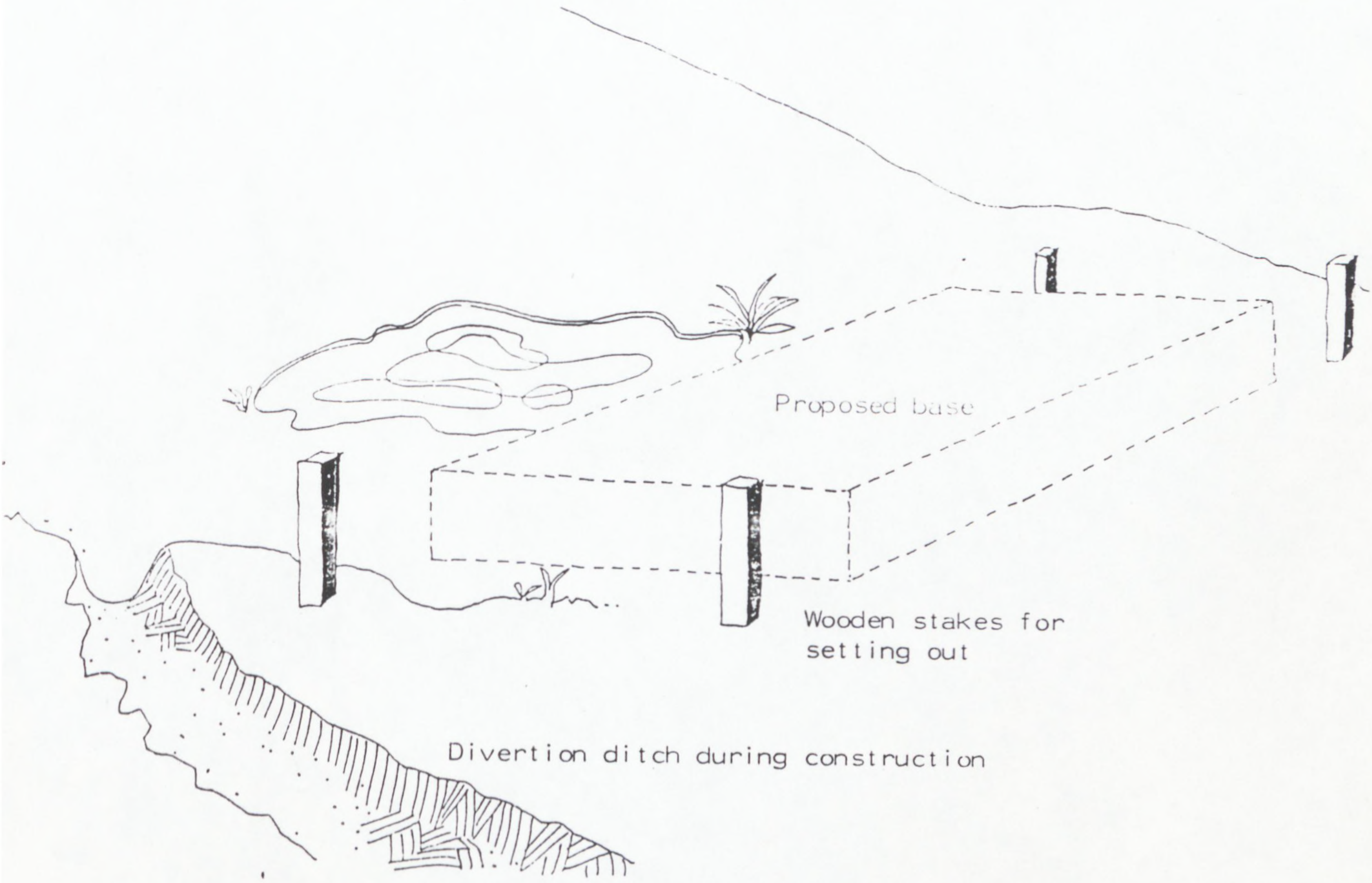

Fig 18 : Retaining wall base

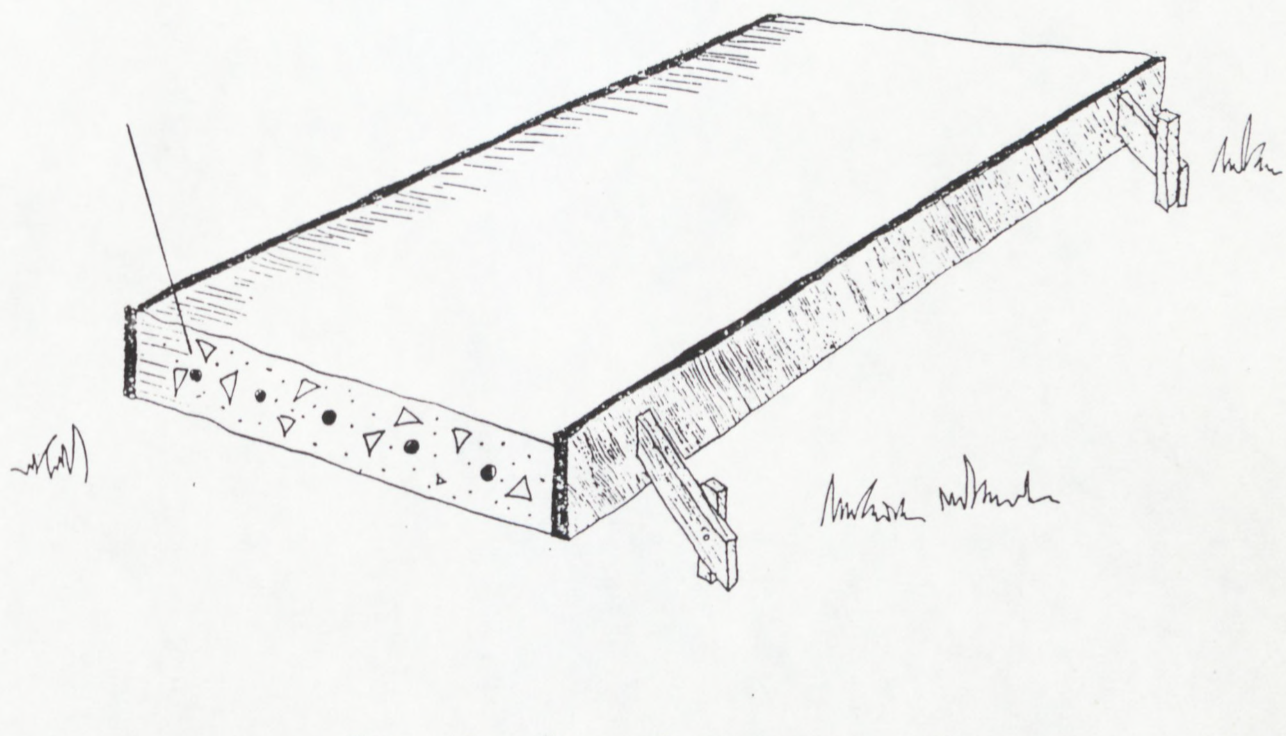

Fig. 19 : Base of retaining wall

The base can be constructed with a 1:3:3 mix concrete. (See appendix on concrete). The retaining wall is constructed with mortar and stone. The use of formwork will ease construction.

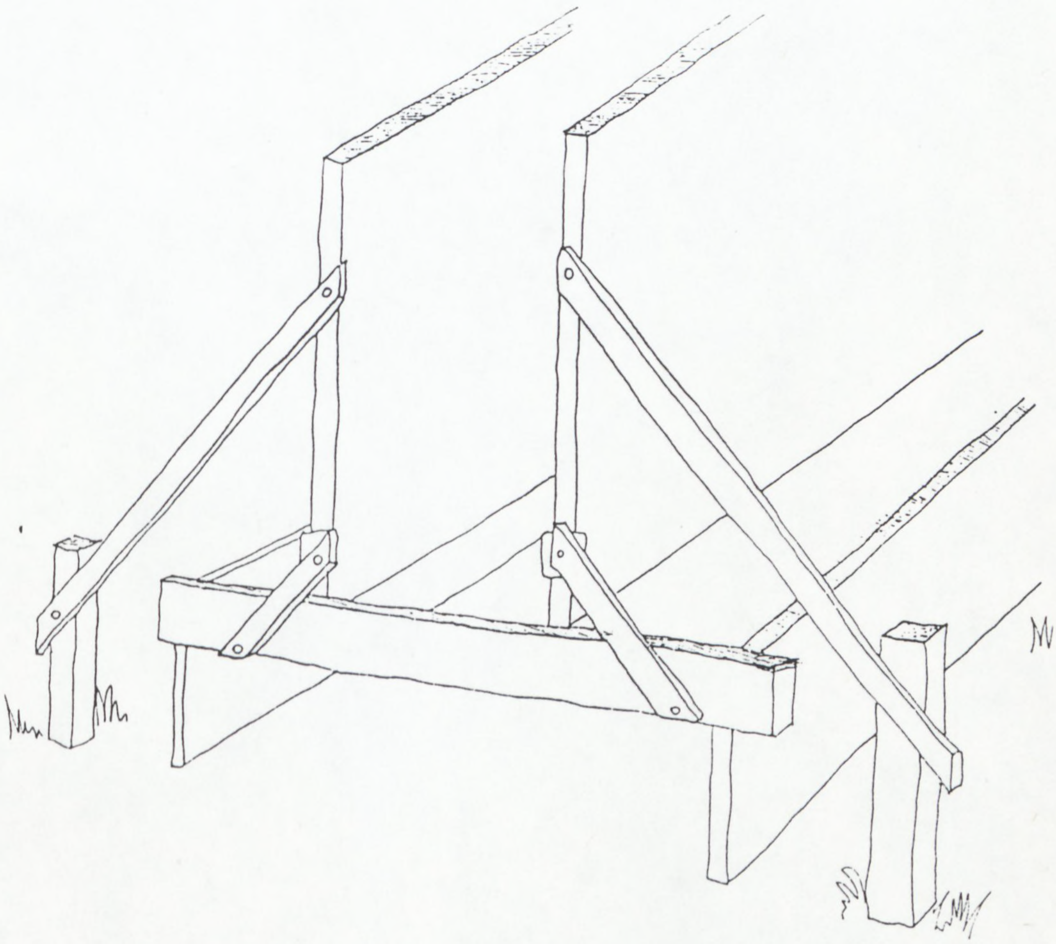

Fig. 20 : Formwork of base and wall

Fill behind the wall with stone and rock to within 200 metre from the top of the wall. Place a layer of 150 metre clay on top of the rock. Complete filling with soil and place topsoil.

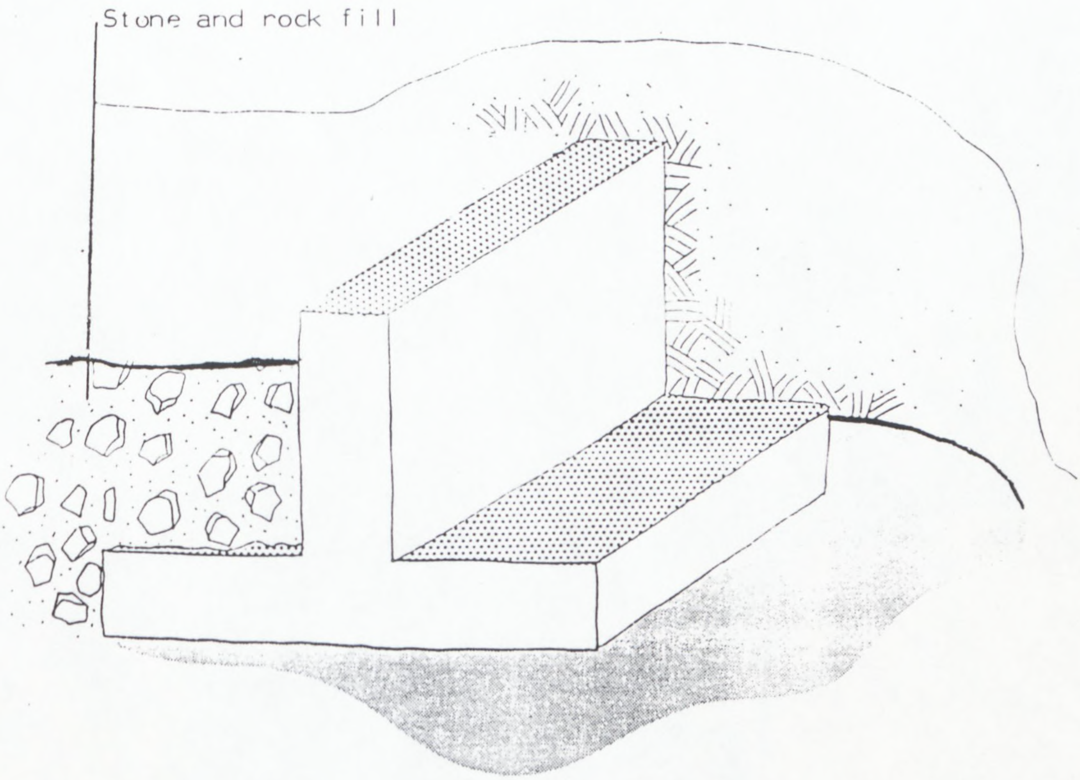

Fig. 21 : Fill behing wall

The construction of the apron and drainage ditch is similar to that of the handpump. The retaining wall structure can be built in the form of a V or curved, depending on the site.

The water collection point and the spring can be separated for the convenience of the people. This increases the protection of the spring because human and animal activities are then separated from the water source.

Care should be taken that the overflow of the storage tank at the water collecting point is at a lower level than that of the overflow of the spring. If not, the pressure in the system may cause the water at the spring to folow a different flow path and cause the system to fall completely.

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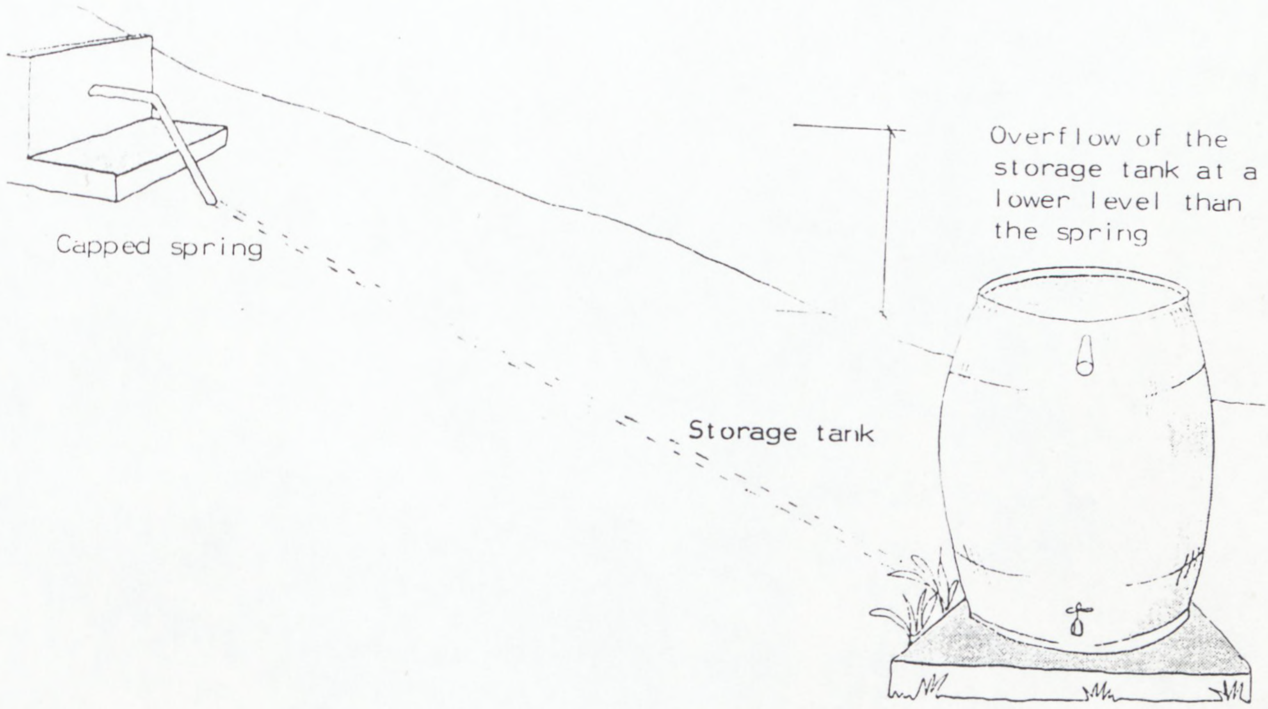

Fig. 22 : Linked storage tank and capped spring

When a storage tank is used a proper apron and drainage ditch must be provided around the tank.

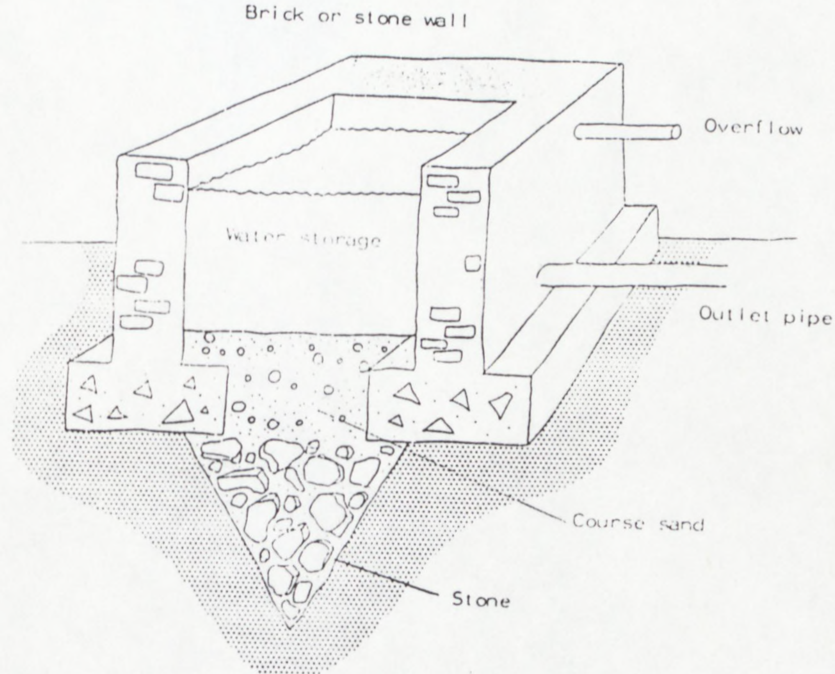

Fig. 23 : Spring box

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This type of structure is used on an artesian spring. The water enters from the bottom or side of the structure. A spring box consists of a collection box; cover; overflow and outlet. The spring box is constructed of concrete. When precast concrete pipes or manhole rings are available they can be used instead for ease of construction. The spring box is then connected to a storage tank.[5]

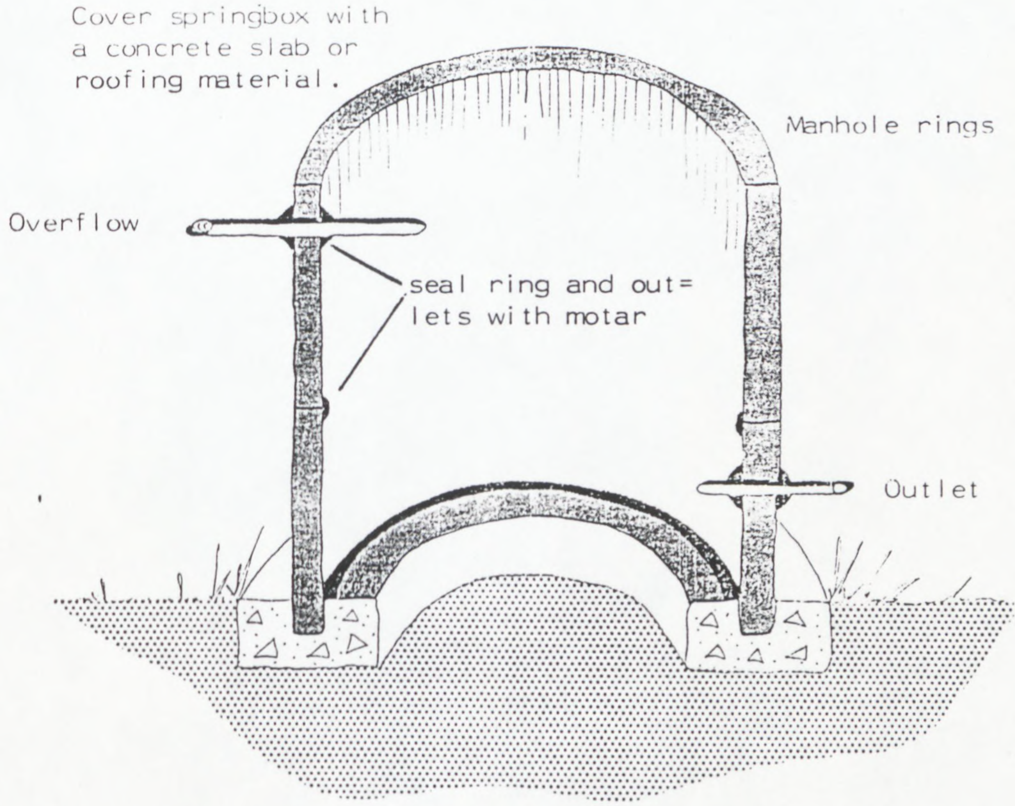


Fig. 24 : Precast concrete pipe spring box

2.3 Seepage collection system

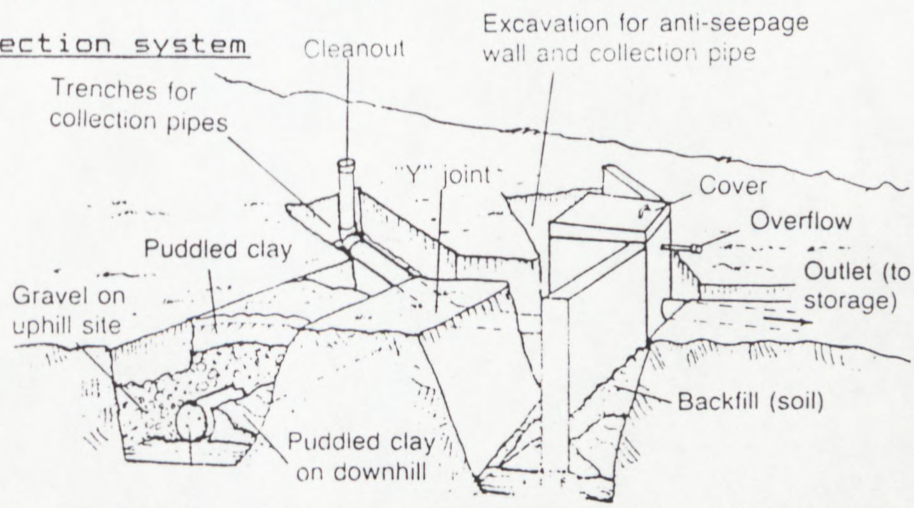
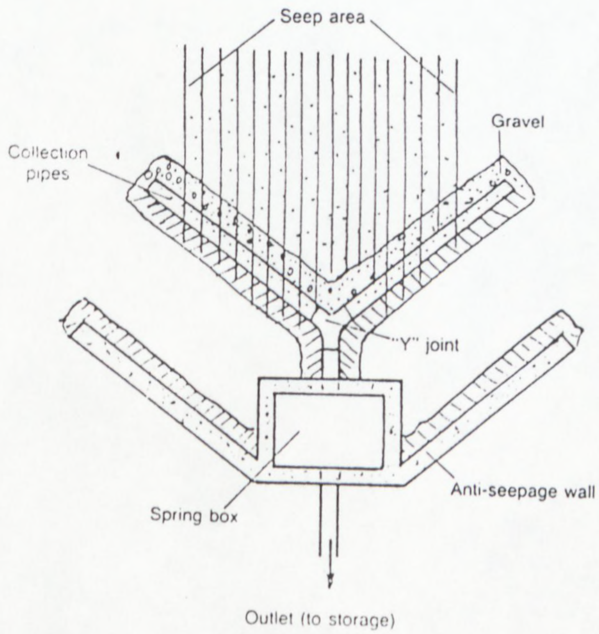


Fig. 25 : Basic Design Feature of a Seep Collection System

As previously mentioned this type of system is used when there are a number of small springs to be combined into one system. This system consists of a water collecting drainage pipe; a storage box as in the spring box system and an anto-seepage wall. The anti-seepage wall causes a build up of water and causes the water to flow towards the collecting pipe.



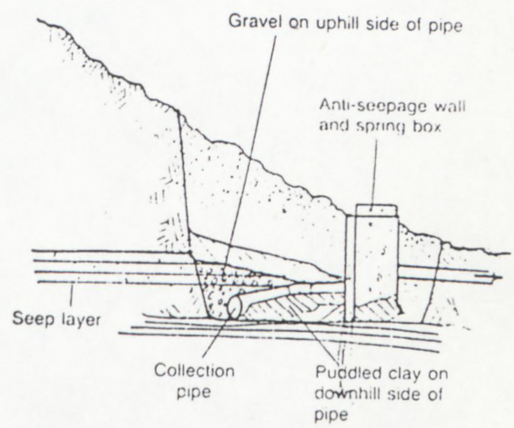


Fig. 26 : Seepage Collection System

The system is linked to the storage tank.

3. WELLS

Hand dug wells are still in use in developing coutries. Wells are normally highly polluted due to improper protecting such as improper drainage; poor well lining and the bucket and rope, if this system is used.

3.1 Apron Construction

Clear the site of debris and ensure that the well lining is clearly visible.

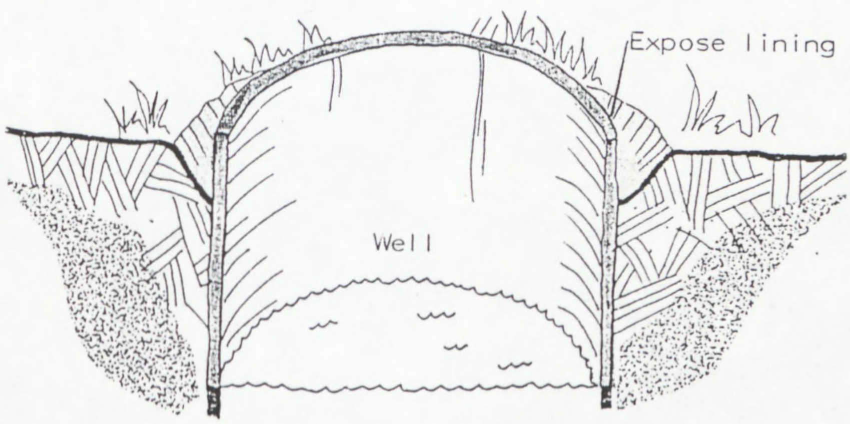


Fig. 27 : Expose lining

Ensure that there is a proper water seal around the well lining. If not, excavate a narrow trench around the well lining, a minimum of 1,5 metre deep. Fill the trench with concrete. This will act as a water seal for surface water. In newly constructed wells the water seal should be 3 to 4 metres deep.

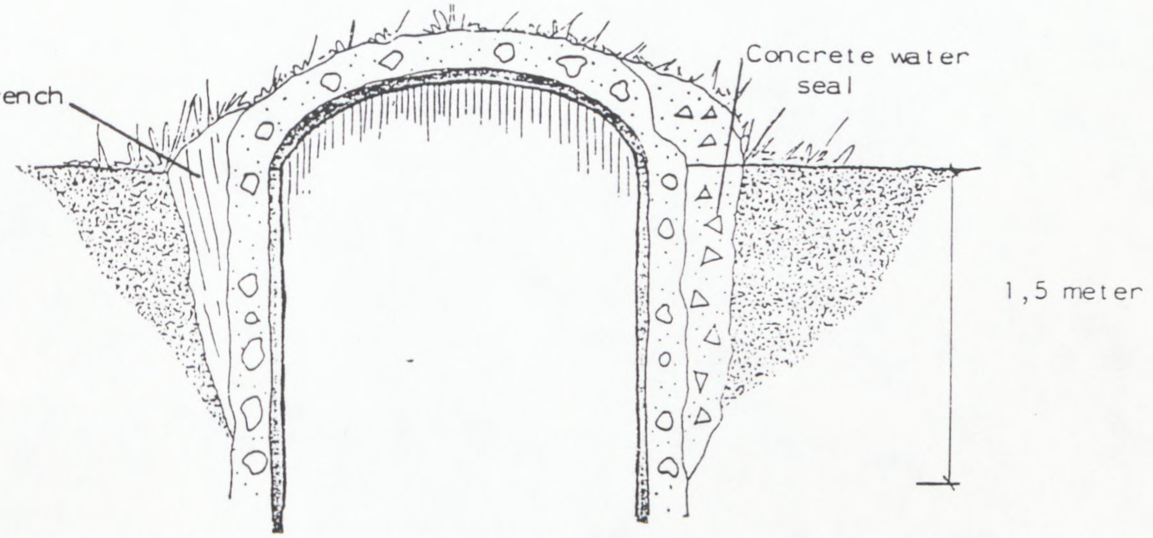


Fig. 28 : Water seal

Whilst the concrete of the water seal is still damp, place the first precast concrete ring or pipe onto it.

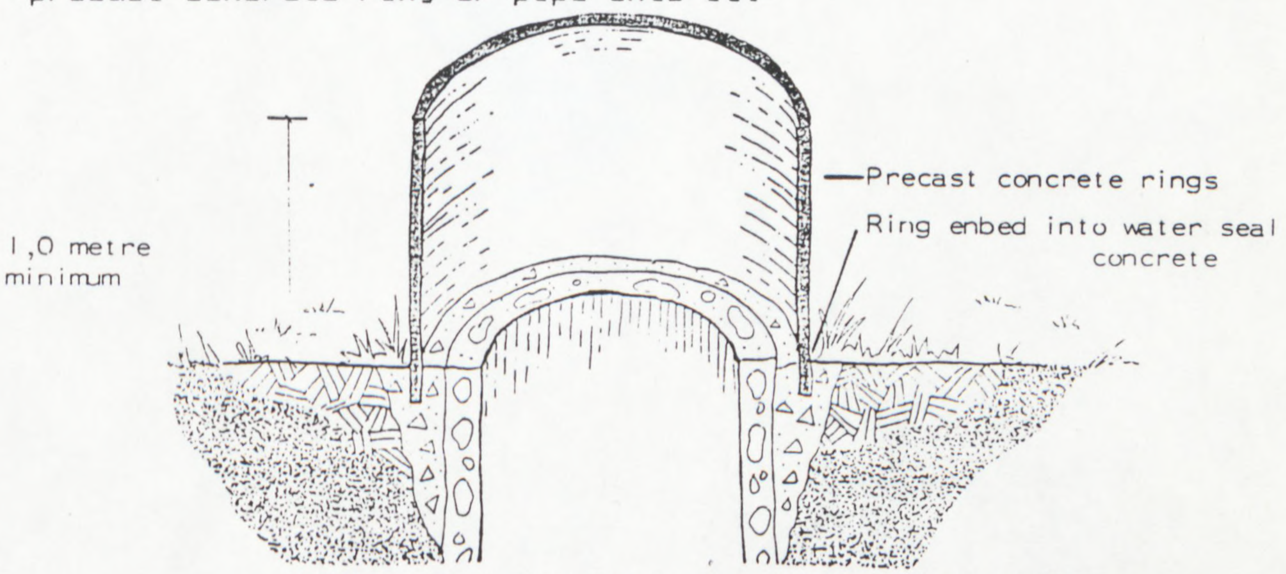


Fig. 29 : Concrete ring into water seal

Clear a circular area around the well extending 2 metres from the well. Shape the ground to slope away from the well, this will be the floor on which the concrete for the apron is to be poured.

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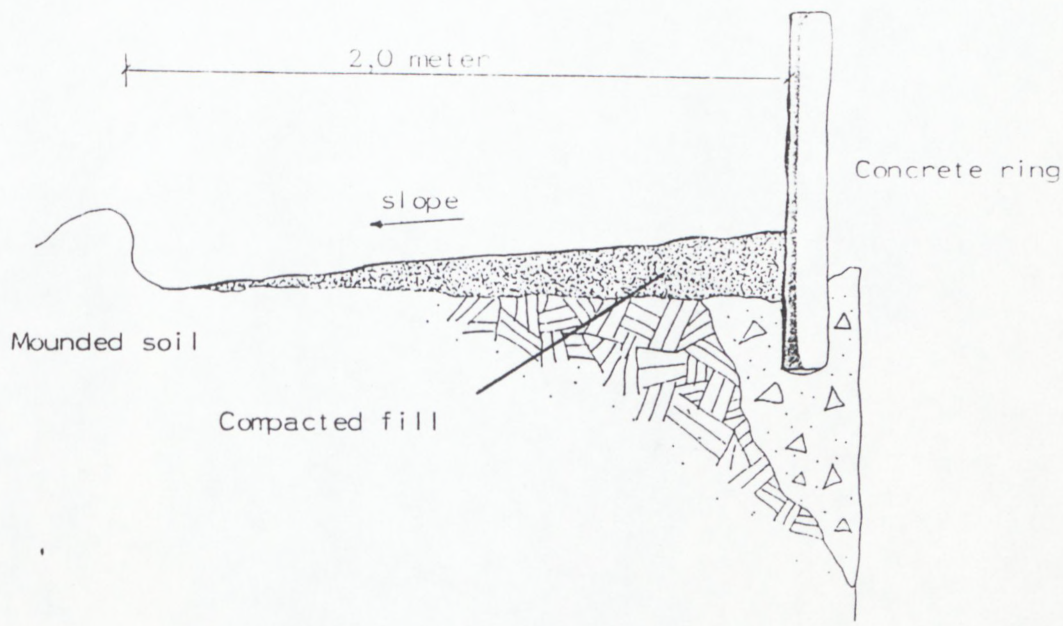

Fig. 30 : Apron

Dampen soil and compact firmly before pouring concrete.

Pour a 150 millimetre thick layer of concrete. The concrete must be workable - not too much water. Smooth the surface with a wooden float and form gutter around the apron.

Dig a shallow trench to a soak away and line the trench with concrete.

3.2 Reconstruction of wells

To effectively protect a hand dug well, it may be covered with a concrete cover.

If the excisting well diameter is not too big, place a wooden platform over the opening. Locate a hole for the pump at the deepest end of the well. The pump cylinder must fit through the hole in the cover. Place a 0,5 metre pipe length over the hole, this will act as a guide and a waterseal.

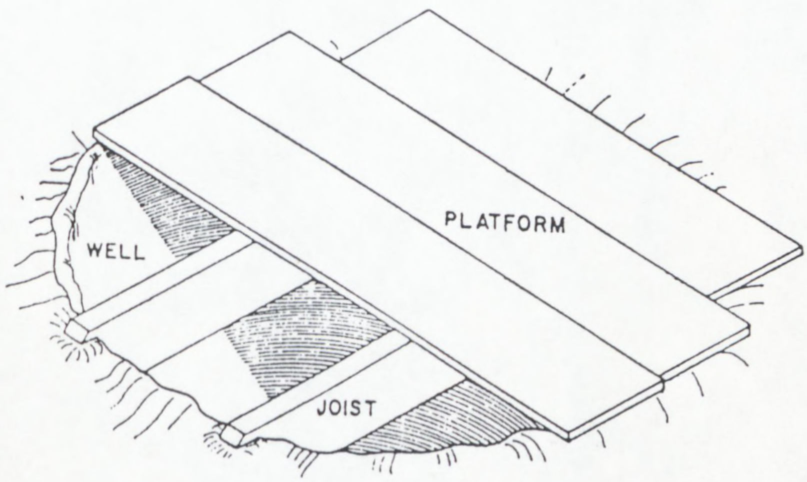

Fig. 31 : Platform Construction for Dug Wells

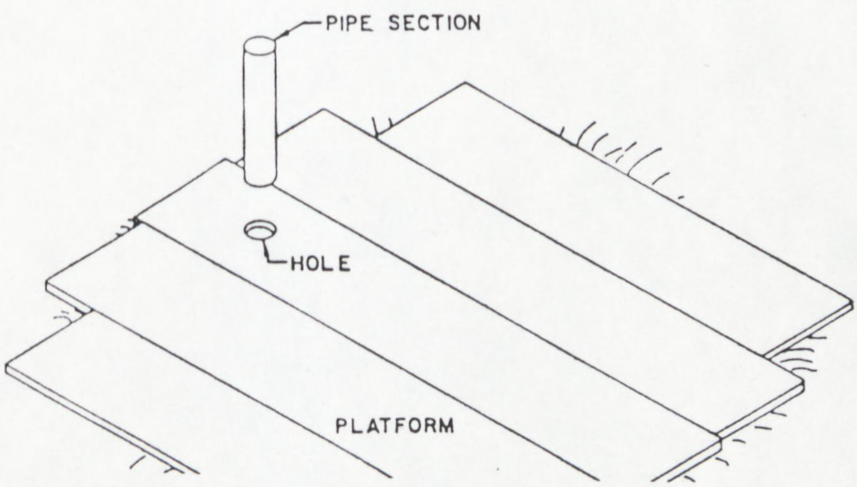

Fig. 32 : Locating Pipe Section

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Place reinforcing mesh on the wooden platform. Make use of spacer blocks so tha the reinforcing mesh is not placed directly on the wooden platform. The reinforcing mesh should be covered by at least 40 mm of concrete to prevent corrosion. The thickness of the concrete apron should be at least 100mm.

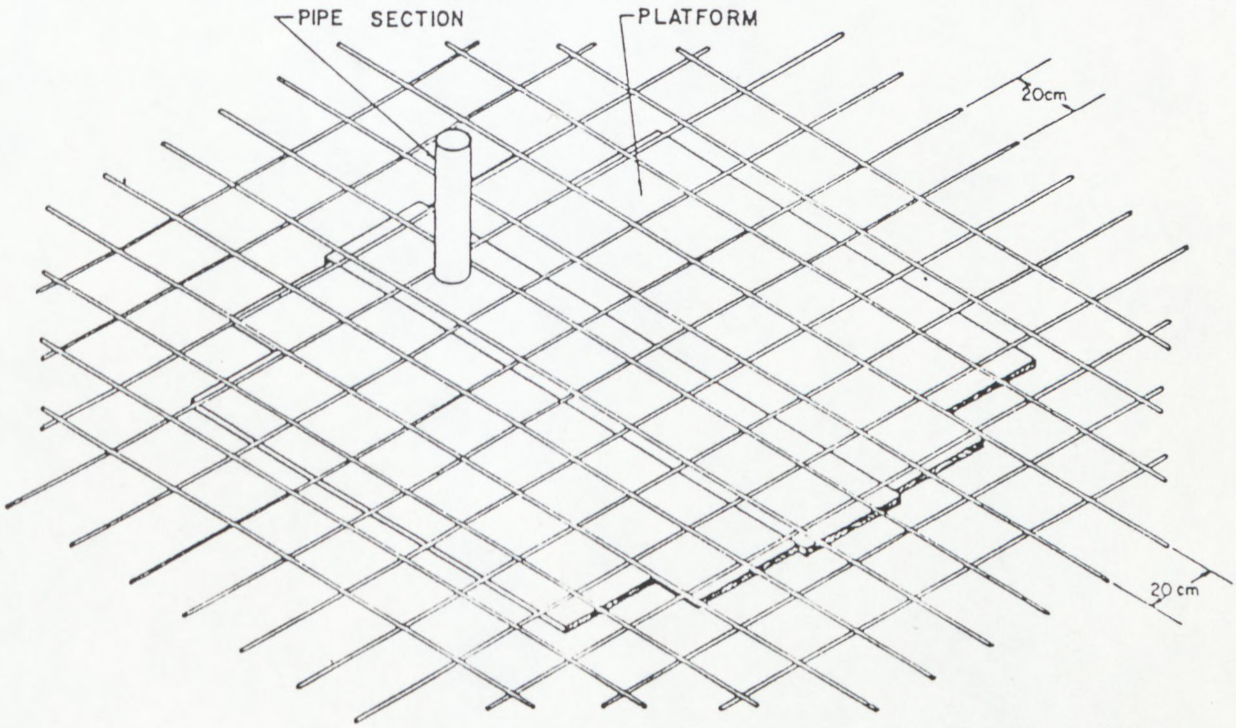

Fig. 33 : Reinforcement for Dug Wells

4. RAINWATER COLLECTION SYSTEM

Rainwater may be collected on a roof and diverted to storage tanks through gutters and downpipes.

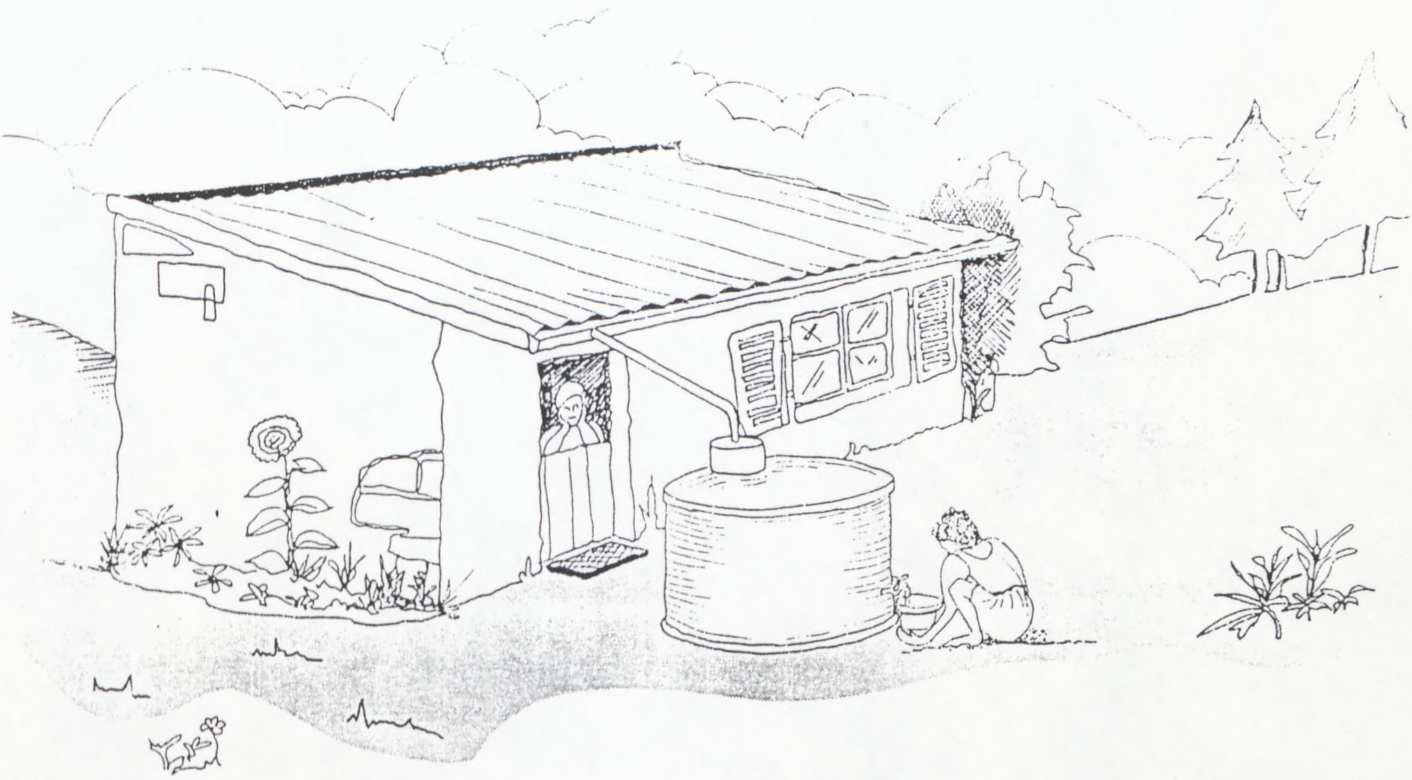

Fig.34 : Rainwater collection systems

The design of such a system will not be discussed but methods of preventing contamination will be discussed.

The first runoff from a roof after rainfall, accumulates dust, bird droppings and dirt and is referred to as the foul flush. In order to protect the rainwater collection system, the flush must be diverted before reaching the storage tanks. There are two types of flush devices.

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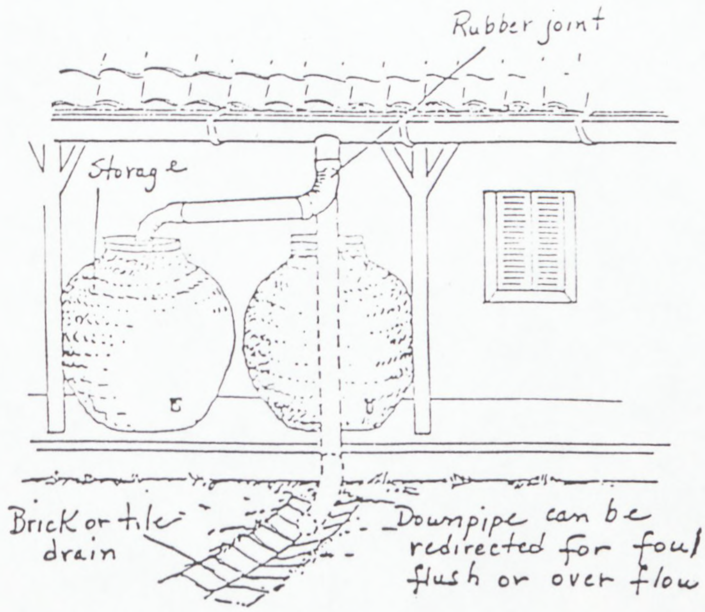
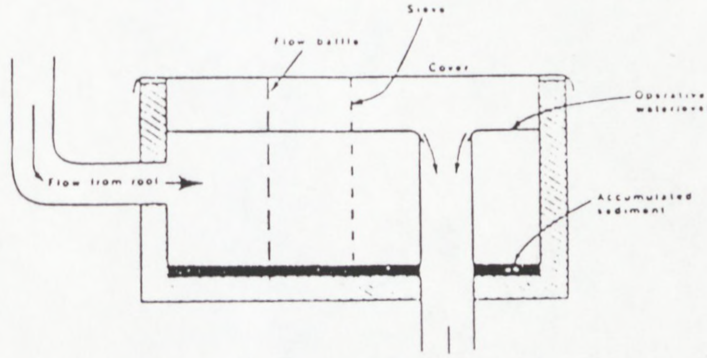
4.1 Manual Systems



INstitute for Rural Water, 1982 (draft), by permission

Fig. 35 : Manual Systems

This method consists of a rubber pipe connection between the gutter outlet and the downpipe. This allows the downpipe to be installed in different positions. The downpipe will remain in position to drain the water away from the roof. Once the rain starts and after the flush, the downpipe is placed into the storage tank.



UNEP (1979)
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Fig. 36 : Automatic Systems

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4.2 Automatic Systems

These systems consist mainly of a small tank on top of the storage tank. This little tank has the capacity of the flush and allows dirt to settle and clean water to overflow into the storage tank. The capacity of the fowl flush tank must be 10 litres for every 30 square metres of roof area. [7]

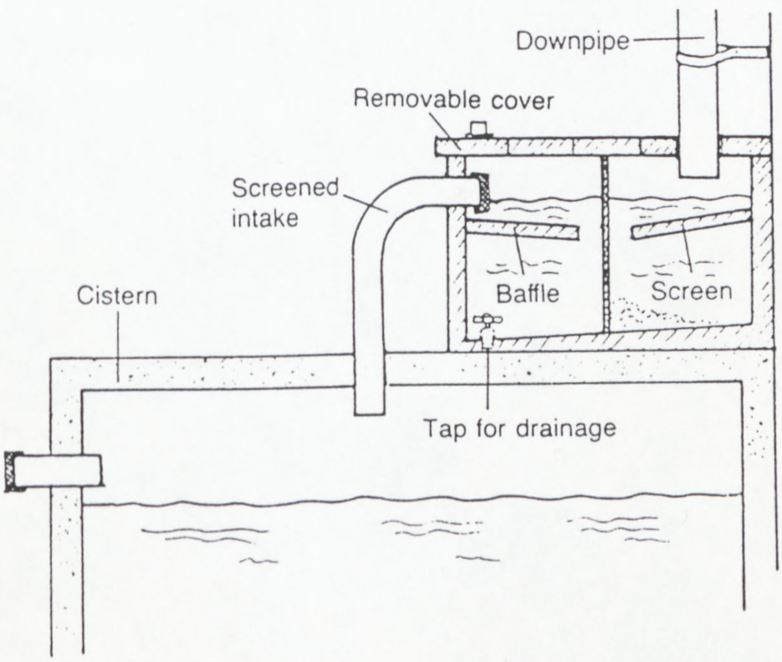

Fig. 37 : Collection Box for Foul Flush

Rainwater collection systems require adequate maintenance to protect the source from pollution.

(i) The roof, gutters and down pipes should be in good condition.

(ii) Clean the roof and gutters to avoid clogging.

(iii) Clean the flush devise after each rainfall.

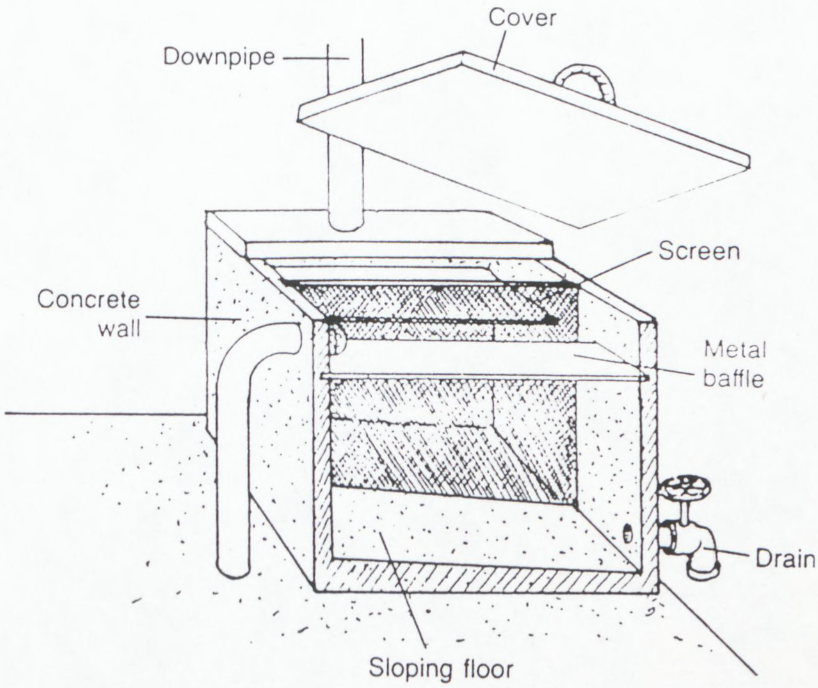

Fig. 38 : Detail of Collection Box for Foul Flush

The normal apron and drainage system should be constructed at the top of the storage tank.* The tank cover should seal tightly.

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APPENDIX A

Concrete is used in all water source protection projects. It is therefore of major importance to know how to obtain concrete of sufficient strenght.

Concrete consists of sand, stone, cement and water. The strength of the concrete depends on the quantity and quality of these materials and in what proportion they are mixed.

QUALITY

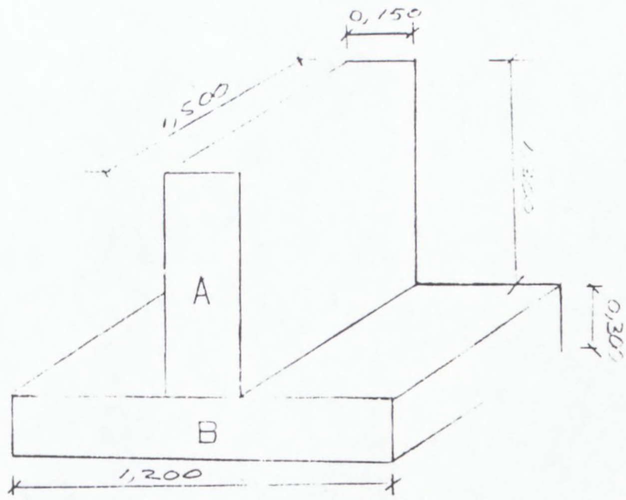
The sand and stone should be free of organic matter such as leaves, wood and grass. Cement should be dry and powdery. Always use new cement bags. Cement bags should be stored in a dry place - never use old cement.

Water that is fit to drink is suitable to use in concrete.

MIX

Determine the amount of concrete to be mixed by calculating the volume at the structure to be built. Once the volume of the springbox or retaining wall is known the quantity of cement, sand and stone can be determined by using the table below :

Typical Project	Mix proportions			Quantities for 1 m^3 concrete		
	Cement (tins)	Sand (tins)	Stone (tins)	Cement (50 kg bags)	Sand	Stone
Drainage ditch	1	2	2	6 1/2 bags	0,67 m^3	0,67 m^3
Retaining wall	1	3	3	4 1/2 bags	0,71 m^3	0,71 m^3
Foundations	1	4	4	3 1/2 bags	0,73 m^3	0,73 m^3



1. Determine the volume of the structure.

A) Area x length

= (1,3 m x 0,150 m) x 1,5 m

= 0,293 m^3

B) Area x length

= (1,2 m x 0,300 m) x 1,5 m

= 0,540 m^3

Volume A + B = 0,833 m^3.

If the volume of the structure retaining wall or springbox is less or more than 1,0 m^3 the volumes should be increased or decreased accordingly.

Where and how to hand-mix concrete

It is best to work on a smooth, hard, non-obsorbent surface like a concrete slab or steel sheet as close to the building site as possible.

Measure and mix the concrete in convenient quantities - do not mix the concrete for a structure all at once.

36/...

Spread the sand in a layer 100 mm thich, add the stone and spread the cement on top, mix thoroughly.

Now make a heap with the mix and make a hole in the middle of the heap. Add small quantities of water. (Remember that water plays a major role in the strengh of the concrete - the concrete should just be workable. Mix the concrete till a stiff porridge is obtained.

Placing the concrete

Pump the concrete as close to its final position. The soil should be damp, but without any standing water, when the concrete is placed. The concrete should be well compacted. Work the concrete right into the corners and along the edges of the formwork. To compact concrete slab or apron, use a wooden beam that spans across the slab. First use a chopping action and then a sawing action. Next "woodfloat" the concrete to obtain an even surface.

Curing

Once it has stiffened cover the concrete in the Framework with plastic sheeting or hessian or sacking that is kept wet so that it can stay damp. Keep the concrete covered for 5 - 7 days.

(From : Concrete at home and on the farm. Published by the Portland Cement Institute, Halfway House Revised August 1982. Reprinted September 1983).

APPENDIX B

FIELDWORK WATER SOURCE PROTECTION IN SOUTHERN KWAZULU

Report on visit to southern Kwazulu 22 to 26 July 1985.

1. <u>CSIR PERSONNEL</u>

The following CSIR personnel were involved in the whole or part of the visit to KwaZulu.

Mr P Williams	-	NIWR, Pretoria
Mr P Sadzik	-	NIWR, Pretoria
Mr A Crousé	-	NIWR, Pretoria (student employee)
Dr J Hemens	-	NIWR, Durban (morning of 22 July only)
Dr D Livingstone	-	NIWR, Durban (morning of 22 July only)
Mr J Botha	-	NBRI, Pretoria (22 and 23 July only)
Mr D de Villiers	-	NBRI, Pretoria
Mr M Heap	-	NBRI, Pretoria

2. <u>THE VALLEY TRUST</u> (22 July)

(a) <u>General</u>

The Valley Trust is located at Botha's Hill, approximately 30 km from Durban and adjacent to the Valley of a Thousand Hills in KwaZulu.

(b) <u>Morning tour</u>

During the morning we did the standard tour of the Trust's area to gain an overall impression of their work. The following Trust personnel addressed us:

Mr M Mthiyane	-	Community Liaison Officer
Mrs Hlatshuago	-	Nutrition Educationist
Mr P Myeni	-	Senior Agricultural Officer
Mr Mthembu	-	Technical Officer, Appropriate Technology
Mr Bruzas	-	Ecological Officer

The Trust believes in a holistic approach to health care, and therefore promotes methods of growing better food crops as well as health services, hygiene education and appropriate technology in water supply and sanitation. Two examples of this education are the food composition table and the charts comparing crop yields using different cultivation techniques

(c) <u>Afternoon meeting</u>

During the afternoon we met with Mr Mann, Director (Administration) of the Trust and Mr Mthembu to discuss appropriate technology in water supply and sanitation. The following matters were raised during the discussion and the Trust's slide show:

(i) As far as water supply is concerned, The Valley Trust is primarily involved in spring protection works and construction of ferro-cement tanks.

(ii) There are difficulties in transfer of technology. This is partly due to the fact that technologists are specialists in their own field, and generally do not have the overall picture. The Trust believes that the best approach is to encourage the local people to establish a water committee and for this committee to approach The Trust for technical advice (Mr Mann)

(iii) The CSIR depends on organizations such as the Valley Trust to provide practical information on problems and whether suggested solutions are practical. This is because the CSIR is not intimately involved in day to day situations in the field (P Williams)

(iv) Curing of ferro-cement tanks could be improved by draping black plastic sheeting over the tanks whilst the concrete is drying. This would be better than the hession which is used at present (P Williams)

(d) <u>Site visit</u>

After the meeting we visited the Amaoladi tribal authority court-house to inspect a ferro-cement tank (H-3) and then a protected spring at Vukuzakhe community garden (FCC* 2/100 mℓ from tap, 40/100 mℓ from bucket filled from tap, G-1 & 2).

* FCC is faecal coliform count.

3. <u>S A DEPARTMENT OF NATIONAL HEALTH AND POPULATION DEVELOPMENT</u> (23 July, morning)

(a) <u>Meeting</u>

We met the following persons at the Department's office in Durban:

Mr D Bezuidenhout - Chief Health Inspector
Mr J Maniram - Senior Health Inspector
Mr R Short - Senior Health Inspector
Mr A Madlala - Technical Assistent
(see Appendix A for address)

(b) <u>Site visits</u>

All except Mr Bezuidenhout accompanied us on a tour to areas north of Durban, during which the following places were visited:

(i) *Tongaat* - to inspect a prefabricated VIP pit latrine. This latrine had been incorrectly installed. A water sample from a rainwater tank was also taken (FCC 1/100 mℓ, G-3, H-4, 5 & 6).

(ii) *Grouteville* - Informal settlement where water is supplied by mobile tankers to galvinised steel storage tanks (H-7 & 8).

(iii) *Lloyds Higher Primary School* - uncovered rainwater tanks filled by a mobile tanker during the dry season, such as at the time of this visit (FCC 11/100 mℓ, G-4, H-9).

(iv) *Etete* - an old trailer-mounted water tank is kept permanently on site and is filled daily by a mobile tanker (H-10).

(v) *Nkobongo* - a house in a village with a rainwater tank (FCC nil/100 mℓ, G-5, H-11).

(vi) *Driefontein* - Concrete pipe sunk into bed of a small stream. Used as a water collection point (FCC >500/100 mℓ, G-6, H-12)

(vii) *Isnembe Secondary School* - Borehole water is faecally polluted according to the health inspector. A malfunctioning 'Thomas Tube' chlorinator is installed. Possible cause of contamination is the aqua-privy latrine, approximately 200 m from the borehole (G-7).

(viii) *General comments*

When disinfecting water it is best to use some chemical which causes a physical change in the water (i.e. colour), otherwise the local people do not understand that anything has been done to the water.

There is uncertainty in the black areas visited whether they will be incorporated into KwaZulu. This was the reason given for the living standards not being upgraded at present.

4. INANDA VISIT (23 July, afternoon)

During the afternoon we visited the black township of Inanda, near Durban. We met Mr Antoni from Theron Burke and Isaacs Inc. and Mr Reinecke from the Department of Development Aid (formerly Department of Cooperation and Development). Mr Antoni is responsible for coordinating the development of this township. The water supply is piped from Durban, but there is no waterborne sewerage system. We visited several sites of trial pit latrines.

5. PIETERMARITZBURG VISIT (24 July)

(a) Meeting

Held discussions at the Institute of National Resources, Pietermaritzburg, with the following persons:

Institute of National Resources

Dr J Erskine - Co-ordinator of Rural Development
Mr J S S Anderson - Manager of the Water and Sanitation Development Unit

KwaZulu Department of Agriculture and Forestry

Mr K J Fourie - Chief Engineer
Mr L D Rodgers - Senior Foreman
Mr Walker - Artisan

African Co-operative Action Trust

Mr M Atherstone

(See Appendix A for addresses)

The following matters were discussed:

(i) The Department of Agriculture and Forestry supply the materials for spring protection, and a trained person to supervise the work. The village which will benefit supplies the labour, free of charge.

(ii) Boreholes are drilled by private contractors (Tiger Drilling and Mr R Bates of the Sugar Association Fund for Drilling). It is intended to plot boreholes and protected springs on a map.

(iii) The Institute of Natural Resources will work on:

(a) Field and social research
(b) Demonstrations to the local people
(c) Training. A Zulu training officer will be appointed.
(d) Establish a data bank on KwaZulu.

(iv) The organizations represented at this meeting should cooperate, so that they complement each other rather than compete. There is an opportunity for joint publications based on research by CSIR and field testing by the Institute of Natural Resources and the Department of Agriculture.

(v) A liaison group had been formed which included all people and organizations involved in community work. The purpose is to exchange information. Two meetings had been held to date. A copy of the minutes of the second meeting is attached

(b) Site visits

Several spring protection works in the Wulindulu area were visited, as detailed below:

Location	Appendices		
	C Faecal coliform results per 100 mℓ	G Water source sheets No.	H Photos Nos
Mvundlweni	Nil	8	13,14,15,16
Kwashishi	Nil	9	17,18
Nxymululu	–	10	19
Mbubu – water hole in stream bed	>100	11	20
Mbubu – unprotected unused spring*	Nil	12	21,22

(c) Water storage tanks

The Department of Agriculture and Forestry prefers to construct reinforced concrete water storage tanks, with 150 mm thick walls, rather than the ferro-cement tanks which are favoured by The Valley Trust, for the following reasons:

(i) They are less likely to leak. The ferro-cement tanks are only successful if they are constructed by skilled persons.

(ii) The cost of the tanks is not much more than ferro-cement, as the standard steel framework is provided free of charge

6. **EMBO/NQCOLOSI WATER SUPPLY PROJECT** (25 July)

(a) Meeting

Held discussions with the following persons:

Dr G W Short	-	Deputy Director of Health Services, KwaZulu Department of Health
Mr J C Rivett-Carnac*	-	Consulting Engineer, Appropriate Technology
Mr NgoNgoma*	-	Secretary of the Embo/Nqcolosi Water Committee

The following matters were discussed:

(i) The Embo/Nqcolosi and the Emolweni water supply projects were initiated by Mr Rivett-Carnac when he was working for the Urban Foundation. Treated water is drawn from the Pinetown water supply system. It is metered in bulk, and it is the responsibility of the local water committees to recover the cost of the water, as well as the cost of the reticulation and standpipe system, from the consumers. A copy of the 1983, 1984 and 1985 financial statements is attached

(ii) The people have to purchase books of coupons from the local store, and pay for the water by coupons. The cost is 7 cents per 25 ℓ .

(iii) A water bailiff at each standpipe is responsible for collecting coupons, and is paid R40/month. There is a water meter at each standpipe, and the number of coupons collected should correspond to the quantity of water supplied. Water can be collected between 06h00 to 10h00 and 15h00 to 18h00 each day.

(iv) The Secretary of each committee is paid R80/month.

(v) The design criterion used for sizing the water supply system was 12,5 ℓ per person per day.

(vi) The success of these water supply schemes depends largely upon the competence and integrity of the committee chairman and secretary. The Embo/Nqcolosi scheme is successful because it is well managed, hence the profits made each year. However, the Emlweni scheme has had financial problems (loss in 1984) due to poor management, although this appears to have been overcome now.

(b) <u>Site visit</u>

The Embo/Nqcolosi scheme was visited.

Photos H-25 and 26 show a typical standpipe inside a 600 mm diameter asbestos cement pipe with a lockable lid.

Photos H-27 and 28 show another type of standpipe with taps that require a special keyed handle. This handle is held by the water bailiff. There is also a shut-off valve located in the lockable valve box.

7. KWAZULU DEPARTMENT OF HEALTH (26 July)

(a) Meeting

Held brief discussions in Dr Short's office at Prince Mshiyeni Hospital, Umlazi, with the following persons:

Dr G W Short	-	Deputy Director Health Services, KwaZulu
Mr R M Ganca*	-	Senior Health Inspector
Mr B E G Shabalala*	-	Health Inspector
Mr J A Voysey*	-	Consulting Engineer, Horne Glasson & Partners

(b) Site visits

(i) *Mbongintwine* - This is a squatter camp where about 80% of the people are from Transkei. A Blair handpump was initially installed on a borehole here, but this proved to be too weak and did not deliver sufficient water. (The foot valve part of this pump is shown in photo H-30). This pump has since been replaced with a wheel type of handpump (H-31 and 32, cost R400). However, at the time of our visit this pump could not deliver any water. The reason for this malfunction was not known, but could have been a leaking pump seal. The people were collecting water from a nearby stream which was probably polluted.

The borehole water had been previously tested and found to be faecally polluted. P Williams advised that, if the new pump was operable, and provided that a competent person could take responsibility for the pump, then it would be suitable for the installation of a Flowrite chlorinator.

(ii) *Eziko* - Borehole with two-handled mono pump, which was very difficult to operate

(iii) *Mbongintwine* - Squatter settlement. Water is supplied to a standpipefrom a factory across the road. However, this standpipe has been vandalised, probably by persons who sell water and want to prevent the free water supply from the standpipe (H-34 & 35).

Another source of water is a small spring at the bottom of the road cutting (H-36 & 37).

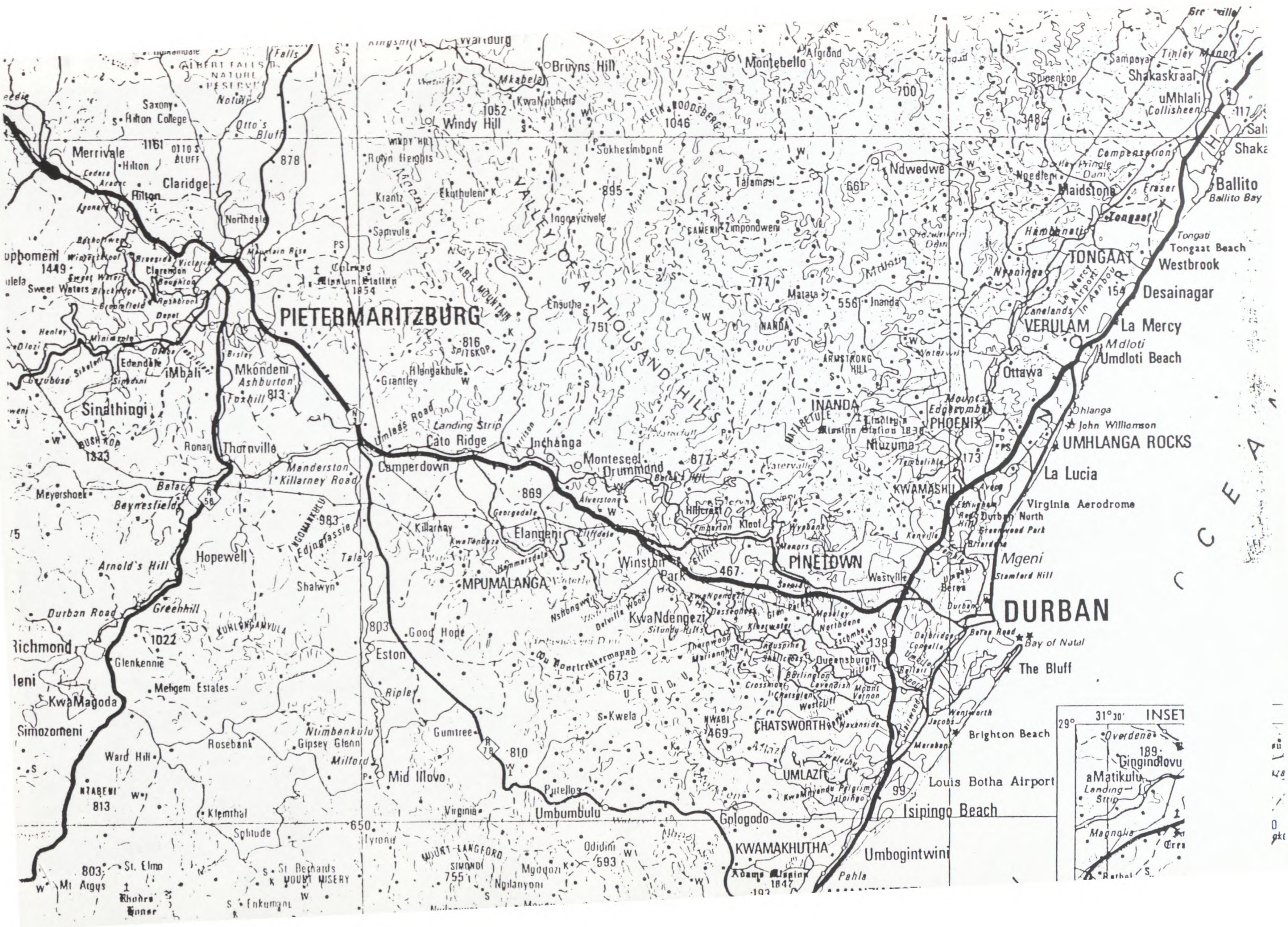
(iv) *Adam's Mission* - Met Mr B H Ngwabi, Agricultural Officer, KwaZulu Department of Agriculture and Forestry (H-38). He said that there are 14 boreholes in the vicinity of Adam's Mission, only two of which were operating at the time of the visit. No maintenance was done on any of the pumps.

One of the boreholes had a single-handled mono pump (H-39). The water from this borehole became yellow-brown after it had been standing for about half an hour. A sample of this water was taken and analysed at NIWR. The results showed that it had 3000 $\mu g/\ell$ iron and 600 $\mu g/\ell$ manganese. Therefore the discolouration is obviously due to the very high iron content. A letter was sent to Dr Short (21 August) advising that the water quality could be improved by aeration, followed by settling overnight in a 200 ℓ drum. Further improvement could be achieved by filtering the settled water through a bed of sand, also using a 200 ℓ drum. Sketches were included with the letter.

KWAZULU VISIT

SUMMARY OF FAECAL COLIFORM ANALYSES OF WATER SAMPLES

Location	Water source	Faecal coliform results/100 mℓ
Vukuzakhe	Protected spring (i) Sample from tap (ii) Sample from bucket filled from tap	 2 40
Tongaat	Covered rainwater tank at cemetry	1
Lloyds higher primary school	Uncovered rainwater tank filled by mobile tanker	11
Nkobongo	Covered rainwater tank in village	Nil
Driefontein	Concrete pipe sunk into bed of small stream	>500
Mvundlweni	Protected spring. Sample from tap	Nil
Kwashishi	Protected spring. Sample from tap	Nil
Mbubu	Water hole in stream bed	>100
Mbubu	Unprotected spring which is unused and in uninhabited area	*Nil*



PIETERMARITZBURG
DURBAN
VALLEY OF A THOUSAND HILLS
PINETOWN
UMHLANGA ROCKS
TONGAAT
VERULAM
PHOENIX
INANDA
KWAMASHU
CHATSWORTH
UMLAZI
KWAMAKHUTHA
MPUMALANGA
Merrivale
Hilton
Hilton College
Saxony
Claridge
Northdale
Otto's Bluff
Windy Hill
Bruyns Hill
Montebello
Ndwedwe
Shakaskraal
uMhlali
Collisheen
Ballito
Ballito Bay
Shaka
Tongaat Beach
Westbrook
Desainagar
La Mercy
Mdloti
Umdloti Beach
Ottawa
Maidstone
Compensation
Mount Edgecombe
Ohlanga
John Williamson
La Lucia
Virginia Aerodrome
Durban North
Greenwood Park
Mgeni
Stamford Hill
Berea
Westville
Bay of Natal
The Bluff
Brighton Beach
Louis Botha Airport
Isipingo Beach
Umbogintwini
Queensburgh
Mkondeni
Ashburton
Thornville
Camperdown
Cato Ridge
Landing Strip
Inchanga
Monteseel
Drummond
Hillcrest
Kloof
Winston Park
KwaNdengezi
Elangeni
Killarney
Hopewell
Arnold's Hill
Greenhill
Richmond
Glenkennie
Melhgem Estates
KwaMagoda
Simozomeni
Ward Hill
Rosebank
Gipsey Glenn
Milford
Mid Illovo
Gumtree
Good Hope
Eston
Ripley
Umbumbulu
Golgodo
Solitude
St. Elmo
St. Bechards
Mount Misery
Meyershoek
Beynesfield
Durban Road
Sinathingi
iMbali
Edendale
Sweet Waters
Table Mountain
Spitskop
Grantley
Krantz
Ekuthuleni
Sokhesimbone
Inanda
Nkuzuma
Isipingo
Kwela
Manderston
Killarney Road
INSET
Gingindlovu
aMatikulu
Landing Strip