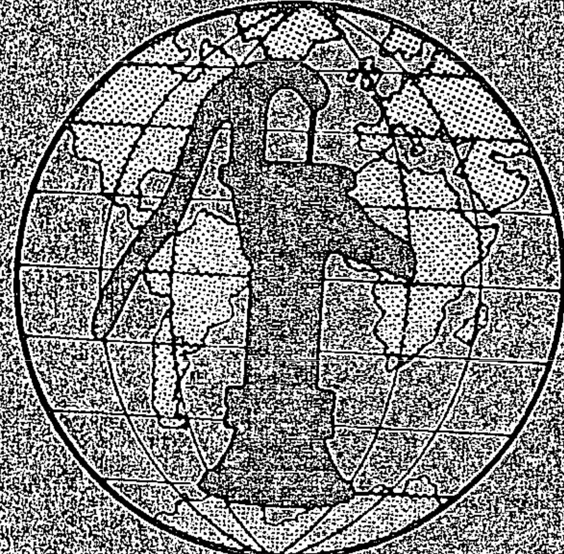
Rural Water/Sanitation Projects



Water for the World

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WS052

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Rural Water/Sanitation Projects

Water for the World

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Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and the National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, DC 20523, U.S.A.

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Water for the World

How to Use Technical Notes
Technical Note No. HR. G

"Water for the World" technical notes are intended for use in the developing nations by people who have field responsibility for water supply and sanitation programs in rural areas. There are 160 technical notes covering detailed topics on human resources, water supply, sanitation and disease. Some of the topics are complicated but most of the technical notes present materials in a way that a layperson with some knowledge of water supply and sanitation can carry out the activity described.

There are a number of possible uses of technical notes in addition to their primary purpose of providing useful information to people working directly in the field on water supply and sanitation projects. For example, the material can be translated as is into local languages and reproduced; it can be divided into more useful segments to meet a local situation's needs and made culture specific; it can be used as training materials; or it can be the basis for posters, radio spots, flyers, or other audio-visual aids for use in a community education effort or in other ways.

Other "Water for the World" Materials

Also a part of the "Water for the World" series is a book and three booklets. The book is titled Safe Water and Waste Disposal for Rural Health: A Program Guide. It was written for people in the developing nations who are interested in putting together a countrywide program for improving rural water supply and sanitation facilities. It does not contain as much specific technical information as the technical notes. Rather, it focuses on all of the elements that go into designing and implementing a successful water and waste disposal program.

The three booklets were written for policy-makers in the developing nations to highlight the need for action to improve water supplies and sanitation facilities. One of the booklets is a short summary of the Program Guide. The other two are titled "Program Planning for the Decade for Water" and "Program Implementation for the Decade for Water."

Organization of Technical Notes

The technical notes are divided into four broad categories: Human Resources (HR), Rural Water Supply (RWS), Sanitation (SAN), and Disease (DIS). The notes are organized as shown in Table 1. Each broad category is divided into two or more series, each of which is assigned a number. Then the numbered series are divided into methods (M), planning (P), design (D), construction (C), and operation and maintenance (O) for the Rural Water Supply and Sanitation categories; into methods (M), planning (P) and implementation (I) for the Human Resources category; and into methods (M) and planning (P) for the Disease category.

If possible, the technical notes should be read and used in order: methods first, then planning, then design, and so on. In this way, the person using the technical notes will have a thorough understanding of the subject covered and will be able to proceed with the activity in an orderly, logical way. The methods, planning and design technical notes were written for people with some experience in the subject covered who are responsible for project design and decision-making. The construction and operation and maintenance technical notes, in most cases, may be used by people with less experience since these activities involve little or no decision-making. Thus, the construction and operation and maintenance technical notes may be used by someone who is carrying out their tasks, but is working under another person who has consulted the methods, planning and design notes for that particular project.

All technical notes have both a title and a number which identifies where they fit on Table 1. For example, SAN.3.C.4, "Constructing a Biogas System" is in the Sanitation category (SAN), the Solid Waste Disposal series (3), and has to do with construction (C). It is the fourth kind of solid waste disposal system on which technical notes were written (4). All of the technical notes are cross-referenced by both title and number so that they will be easy to find. The following is a list of all of the "Water for the World" technical notes.

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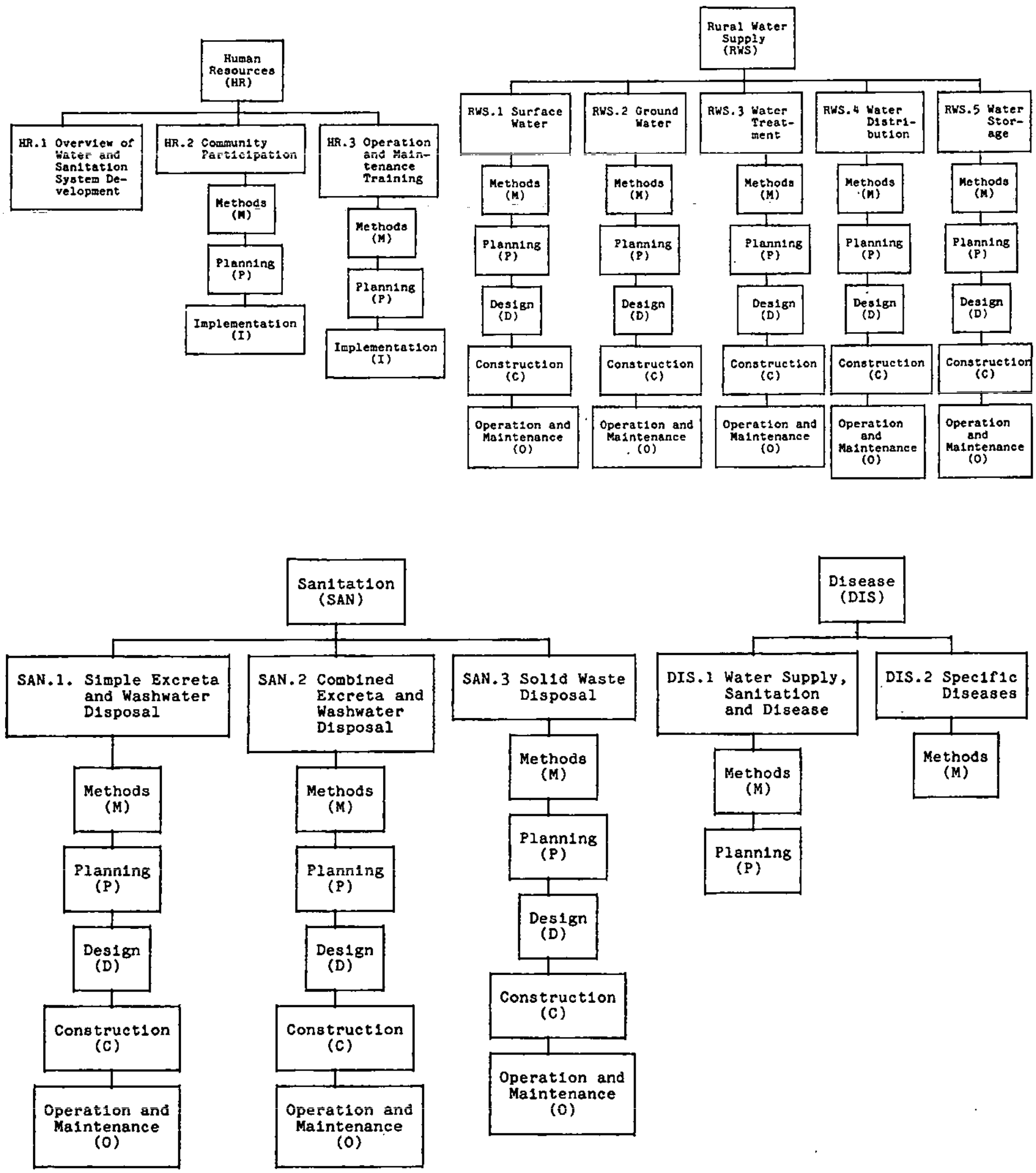
Table 1. Organization of Technical Notes



Water for the World

Means of Disease Transmission
Technical Note No. DIS. 1.M.1

Water- and sanitation- related diseases are major causes of illness and death among people in both rural and urban areas in many developing countries. The health and well being of people cannot be improved without understanding these diseases and knowing how they are transmitted from one person to another.

This technical note describes what causes these diseases, how they are spread and the factors influencing their transmission. Methods for preventing the transmission of the water- and sanitation- related diseases can be found in the technical note, "Methods of Improving Environmental Health Conditions," DIS.1.M.2.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

BACTERIA - One-celled microorganisms which multiply by simple division and which can only be seen with a microscope.

FECES - The waste from the body moved out through the bowels.

LARVAE - Young forms that come from the eggs of insects and worm parasites.

PARASITES - Worms, insects or mites which live in or on animals or people.

There are about 30 diseases that are related to water and sanitation. Table 1 lists the 21 which are most important. Each of them affects from millions to hundreds of millions of people every year. All of these diseases are caused by living organisms that must spend much of their life in or on a human body. They include viruses so tiny that they can pass through the finest filter, bacteria and protozoa that can be seen only with the aid of a microscope, tiny mites that are barely visible to the eye and worms that may be a meter long.

The transmission of all of these diseases is related in some way to water supply and sanitation, usually to inadequate disposal of human wastes and to contaminated water supplies. The diseases are transmitted through contact with or consumption of water, contact with infected soil, the bites of insects that breed in or near water and poor personal and family hygiene. Man is usually the source of the organisms that cause these diseases and human activity is an important factor in the transmission of them.

Following the order shown in Table 1, the transmission of the diseases will be discussed for each of the five categories.

Waterborne Diseases (Water Quality Related)

In the waterborne diseases, the microorganisms which cause the disease are swallowed with contaminated water. All but one, Guinea worm, are caused by organisms found in human excreta, the source of the contamination. The infective stage of Guinea worm is not from fecal contamination, but is from a tiny larva that develops in a water-flea after the larva is discharged into the water. The larva comes from a blister on the skin of a person infected with the meter-long adult worm.

Cholera and typhoid fever are the waterborne diseases which are most feared because, when untreated, they have high death rates. However, the diarrheas and dysenteries are more important because of the infant deaths and huge numbers of illnesses they cause. In the developing countries,

Table 1. Water and Sanitation-Related Diseases

Category	Disease: Common name	Disease: Medical name	Type of Organism	Transmission
Waterborne (Water quality related)	Cholera Typhoid fever Paratyphoid fever Bacillary dysentery Amebic dysentery Diarrhea Diarrhea Jaundice Guinea worm	Cholera Typhoid Paratyphoid Shigellosis Amebiasis Salmonellosis Giardiasis Hepatitis Dracunculiasis	Vibrio Bacteria Bacteria Bacteria Protozoan Bacteria Protozoan Virus Worm	By consuming (drinking) fecally contaminated raw water containing an infective dose of the vibrio, bacterium, protozoan or virus; except Guinea worm where transmission is by swallowing water flea infected with worm larva that was shed from skin blister on infected human.
Water-washed (Water quantity; and accessibility related)	Bacillary dysentery Diarrhea Viral diarrhea Trachoma Pink eye Itch	Shigellosis Salmonellosis Enteroviruses Trachoma Conjunctivitis Scabies	Bacteria Bacteria Virus Intracelluar bacteria Bacteria Mite	Anal-oral or skin-to-skin direct contact transmission resulting from poor personal cleanliness and hygiene caused from lack of water for sufficient washing, bathing and cleaning.
Water-contact (Body-of-water related)	Blood fluke disease	Schistosomiasis	Worm	Eggs in feces or urine hatch larvae in water, penetrate suitable snail, multiply greatly in snail, free-swimming larvae leave snail, penetrate skin when person has contact with infected water.
Water-related insect vectors (carriers) (Water-site related)	Yellow fever Malaria Filarial fever Sleeping sickness River blindness	Yellow fever Malaria Filiariasis Trypanosomiasis Onchocerciasis	Virus Protozoa Worm Protozoa Worm	Mosquitoes, tsetse flies and blackflies, which breed in or near water, pick up disease organisms when they bite infected person; organisms grow in vectors and are inoculated into another person when insect bites.
Sanitation-related (Fecal polluted soil related)	Hookworm Roundworm	Ancylostomiasis Ascariasis	Worm Worm	Eggs or larvae become infective when feces are deposited on soil; eggs are eaten from contaminated hands or vegetables, or larvae penetrate skin that comes in contact with infected soil.

the diarrheas and dysenteries cause hundreds of millions of illnesses and millions of infant deaths each year.

The basic transmission of waterborne disease is person to person. The microorganisms for infected people contaminate water which is consumed by other people. Figure 1 shows a common way that water becomes contaminated. The contamination of water supplies occurs:

1. Where latrines and privies are located uphill from or very close to a water source such as a spring, stream, pond or well. Liquids carrying the organisms seep from the latrines into the water supply.

2. Where privy pits, soakage pits, or sewage absorption systems penetrate the water table of an aquifer located near the surface and shallow wells and springs whose water comes from the aquifer are contaminated.

3. Where wells and springs are unprotected so that surface run-off enters these water sources. The run-off after rainfall carries disease-causing organisms into the water source.

4. Where sanitation is poor. If people defecate on the ground or in bodies of water rather than in safe latrines or privies, disease-causing organisms can get into water supplies.

5. Where Guinea worm occurs, water is contaminated when the skin of an infected person with a blister caused by the worm is immersed in water and great numbers of larvae are released into the water. Some of the larvae are eaten by tiny water fleas (Cyclops). The larvae in the water fleas grow, shed their skins, and become infective. When a water flea containing an infective larva is drunk with water from the contaminated source, the little worm is transmitted to a new person where it grows to maturity under the skin.

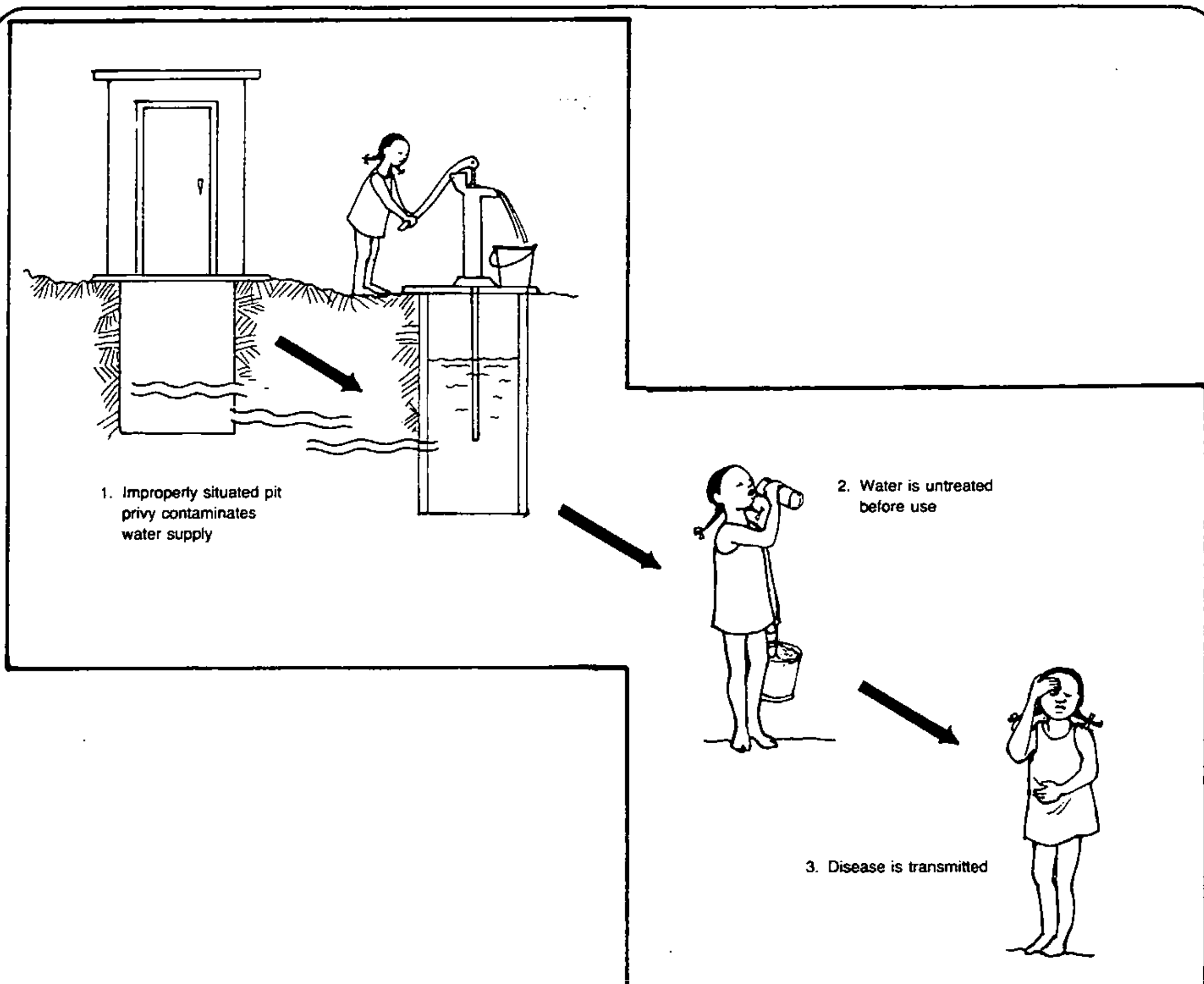


Figure 1. Transmission of Waterborne Disease

Water-Washed Diseases (Water Quantity and Accessibility Related)

Water-washed diseases are diseases whose transmission results from a lack of sufficient clean water for frequent bathing, hand washing before meals and after going to the toilet, and for washing clothes and household utensils. Several common diseases fall into this category. Shilgellosis (bacillary dysentery), salmonellosis (food poisoning), trachoma, and scabies are all diseases that can be passed by direct contact between people or by the direct contamination of food by dirty hands or flies. Figure 2 shows one way water-washed diseases are spread. The diseases in this group are transmitted:

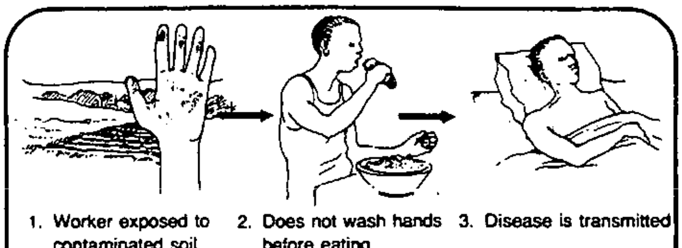


Figure 2. Transmission of Water-Washed Diseases

1. When a water supply produces insufficient quantities to meet peoples' needs or when the water supply is located at a distance from the users. The availability of only small amounts of water makes the practice of good personal and household hygiene difficult, or even impossible.

2. When feces are not disposed of in a sanitary way. Uncovered or unprotected latrines or stools passed on the ground are breeding places for flies and sources of bacteria. Bacteria and viruses are passed from feces to people by flies, contaminated fingers and food. Food contamination with salmonella quickly grows great numbers of the bacteria. When eaten, the food causes food-poisoning diarrhea with life-threatening consequences, especially for small children.

3. When people are ignorant of the need for personal hygiene and, for whatever set of reasons, either do not bathe frequently or use the same water and towels to wash more than one person, then trachoma and conjunctivitis are passed around within a family or other groups living together and scabies get passed from the skin of one person to the skin of another.

Water-Contact Diseases (Body-of-Water Related)

Water-contact diseases are diseases which are transmitted when people have contact with infected water. The single most important water-contact disease is Schistosomiasis (blood fluke disease). It is very widespread in Asia, Africa and South America with hundreds of millions of people at risk of getting the disease and millions suffering from it. Figure 3 shows how schistosomiasis is transmitted. Briefly, transmission is as follows: Schistosome eggs passed in urine or feces fall into water where a first stage larva hatches. The first stage larva, to survive, must find and penetrate a specific type of snail. In the snail, the first stage larva changes into a large number of sacs in which many thousands of forked-tailed second stage larva are produced over a period of months to years. Each day, several hundreds of these second stage larvae escape from the snail to swim about in the water seeking the warm skin of a human hand or food into which to penetrate. Once through the skin, the little worm enters the person's blood stream, grows to maturity (worms are about a centimeter long), works its way into the blood vessels of the intestine and urinary bladder, and lays its eggs in the wall of those organs. The eggs then cut their way through the tissues to the inside of the intestine or bladder and are passed with the feces or urine. So the transmission cycle continues.

Schistosomiasis is transmitted in areas:

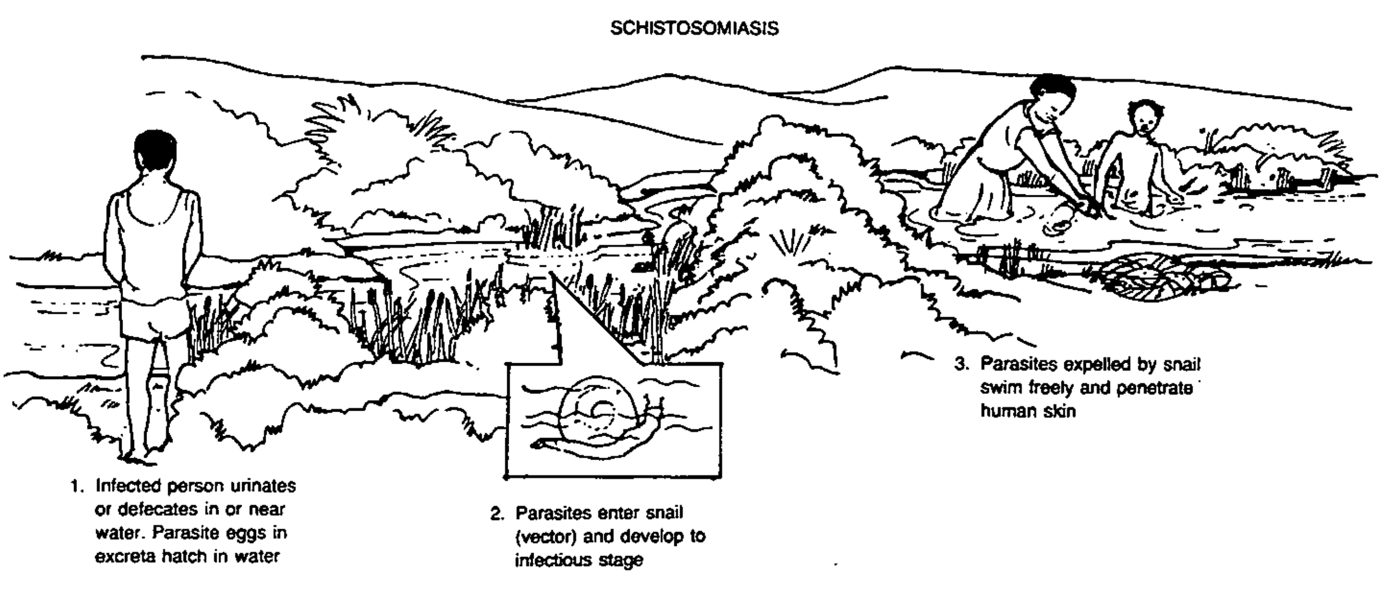


Figure 3. Transmission of Water-Bused/Water-Contact Diseases

1. Where poor sanitation is practiced so that feces or urine find their way into bodies of water that contain snails, or where rats or wild animals get the worms and keep the snails infected.

2. Where the appropriate type of snail is abundant and can become infected.

3. Where people enter infected water to bathe, wash clothes, dip up water, cultivate crops or swim.

4. Where irrigation projects or man-made lakes have extended the bodies of water in which snails can grow and have the chance to be infected from man or wild animals.

Water-Related/Insect Vector (Carrier) Diseases (Water Site Related)

Water-related insect vector diseases are those that are transmitted by insects which breed in or near water. Transmission occurs when the insect becomes infected with the disease organism from biting a person or animal, and then bites another person. The parasites are injected into the skin or bloodstream by the insect bite. The insects breed in water that is used as water supplies (streams and rivers) and, in the case of mosquitoes, in water storage jars, and water tanks, or in shaded high humidity areas near streams or lakes.

The most common diseases in this category are:

• African trypanosomiasis (sleeping sickness) which is transmitted by the tsetse fly which thrives on high humidity and breeds in river areas under lush vegetation growing at water sites.

• Onchocerciasis (river blindness) which is transmitted by blackflies which breed while attached to rocks and vegetation in fast-flowing rivers and streams. Figure 4 shows how onchocerciasis is transmitted.

• Malaria which is transmitted by female anopheline mosquitoes which breed in a wide variety of water collections.

• Arboviruses (yellow fever) which is also transmitted by mosquitoes. The type of mosquitoes that carries this disease is different from that which carries malaria. Mosquitoes that carry yellow fever breed in highly polluted stagnant water and usually rest in areas far from their breeding places.

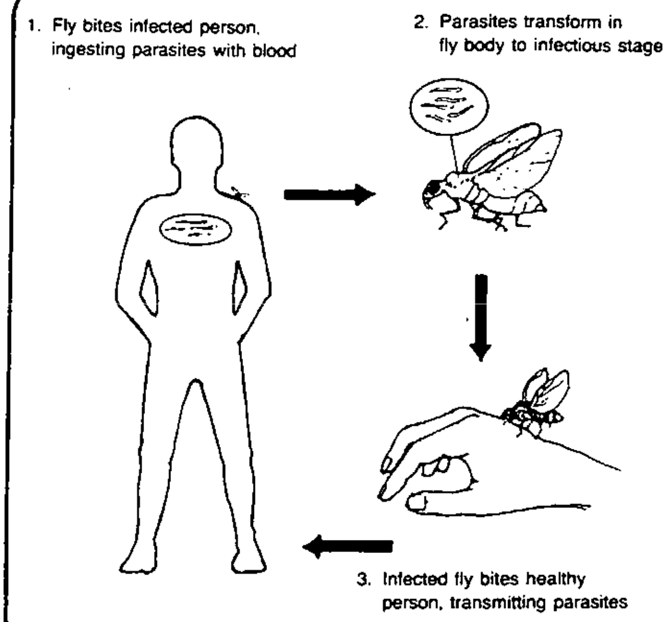


Figure 4. Transmission of Water-Related (Insect Carried) Diseases

• Filariasis which is a worm infection spread by mosquitoes. The mosquitoes that carry the parasite breed in any stagnant pond or pool or in water in cans, coconut husks, dishes, gutters or wherever water is standing.

The transmission of water-related insect vector diseases occurs in many types of situations in which the insect vectors are able to breed in large numbers, can bite persons infected with the protozoan or worm that causes the disease, and later, after the parasites have developed in them, have the opportunity to bite other people. In many situations, the water supply site where people come to get their water, is the place where the insects get their opportunity to bite both infected and other people. The household environment is also a place where some of these diseases are transmitted.

Sanitation-Related Diseases (Fecal Polluted Soil Related)

Sanitation-related diseases are specifically those that are transmitted by people lacking both sanitary facilities for waste disposal and knowledge of the need to dispose of wastes in a sanitary manner. The infective stage of the worm which causes those diseases develops in fecally contaminated soil. The most common diseases in this category are hookworm and roundworm.

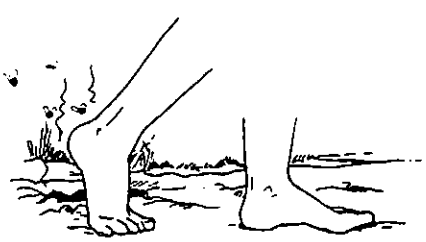
Hookworm larvae develop and live in damp soil that has been contaminated with feces containing hookworm eggs. They penetrate the bare feet of people walking or standing on the infected soil. See Figure 5. Entrance can also occur through the hands or other skin areas.

Roundworm or ascariasis is transmitted by swallowing eggs which have become infective by developing on polluted soil. The eggs are eaten by children who play on the infected soil, drop food on the soil and then eat it, or eat from dirty hands or eat contaminated raw vegetables.

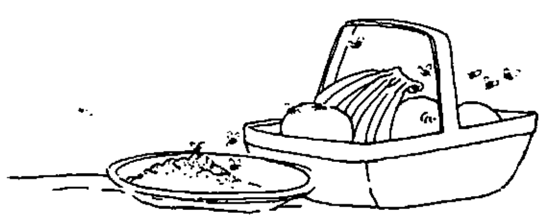
Both diseases occur:

1. Where there are not latrines and the soil is polluted, where latrines are not sanitary or where they are not used.

2. Where fresh untreated feces are used as fertilizer.



a. Hookworm is transmitted through the feet of people walking barefoot in contaminated soil



b. Roundworm is often transmitted by contaminated flies which land on food

Figure 5. Transmission of Sanitation-Related Diseases

3. Where people are not educated to wash their hands before eating.

Summary

This technical note has discussed several diseases which are common in many countries. They are all directly related to local environmental conditions and are all passed from person to person. The cycle, or chain of transmission, involves both direct transmission of the disease or else depends on an agent, or vector, for the transmission.

Once the chain of transmission is understood, means to break the chain should be adopted. Generally, relatively simple environmental measures need to be developed to stop the spread. The methods of doing this are discussed in "Methods of Improving Environmental Health Conditions," DIS.1.M.2.

Water for the World

Methods of Improving Environmental Health Conditions

Technical Note No. DIS. 1.M.2

The improvement of people's health may require that certain changes be made in the environment. Local conditions which contribute to the transmission of disease must be changed or eliminated. Water supplies have to be protected, improved or treated. Methods for the sanitary disposal of wastes must be used, insect vectors must be controlled, destroyed or guarded against, and educational programs must be instituted to make people aware of the need to prevent disease and teach them how to do so.

In the technical note, "Means of Disease Transmission," DIS.1.M.1, several categories of diseases were outlined and the specific mode of transmission of each was discussed. This technical note describes measures that can be taken to prevent the spread of water- and sanitation-related diseases.

Useful Definitions

HABITAT - A region or area where a plant or animal grows, lives or is ordinarily found.

SPILLWAY - A channel built to control the level of water in a dam reservoir; flood water is drained from a dam through spillways.

VECTOR - An animal or insect that transmits a disease-producing organism from one host to another.

Waterborne Diseases (Water Quality Related)

Waterborne diseases are those which are spread when the microorganisms causing them are consumed with contaminated water. Several methods of preventing water contamination and for improving the quality of water can be used. The need to biologically test the water for evidence of fecal contamination is of great importance. Water can be tested by collecting samples and taking them to a central laboratory or by performing tests in the field using special kits. (These methods are discussed in "Taking a Water Sample," RWS.3.P.2 and "Analyzing a Water Sample," RWS.3.P.3.)

In some locations, there may not be a way to test water because of long distance to testing laboratories and lack of field equipment. If testing is impossible, the assumption that the water is contaminated should be made if conditions at the water site are such that the source is not fully protected. Furthermore, measures to improve those conditions and prevent the spread of disease should be assumed to be needed. The following measures are important for improving local environmental conditions.

- Make sure that people have and use sanitary latrines. The community members should be educated about the need for latrines and how their use can reduce the spread of serious disease.

- Educate the people in where to locate latrines and how to construct them properly. All latrines should be located at least 15m from the nearest source of water. They should be at a lower elevation than the water source to ensure that contamination through seepage is prevented. See Figure 1.

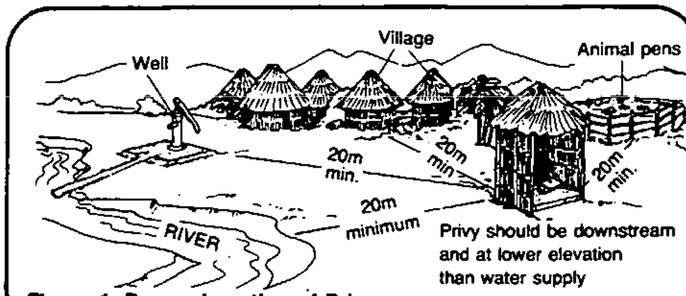


Figure 1. Proper Location of Privy

• Be sure that the pit does not puncture an aquifer. Latrine seepage that enters an aquifer can contaminate ground water (wells) and spring water supplies.

• Protect all wells and springs against contamination from surface run-off. Cap springs with spring boxes. Finish wells with a well head. Make sure that the well shaft is cased with concrete rings, pipe or brick. No surface water should seep into wells. See Figure 2.

• Control the breeding of flies by disposing of garbage and animal manure in a sanitary manner, and covering latrine openings when not in use. All community garbage should be disposed of in a sanitary landfill, while individual disposal can be achieved by digging small pits where rubbish can be burned and garbage buried. See Figure 3.

To control Guinea worm, eliminate all step-wells where the skin of water carriers can come into contact with

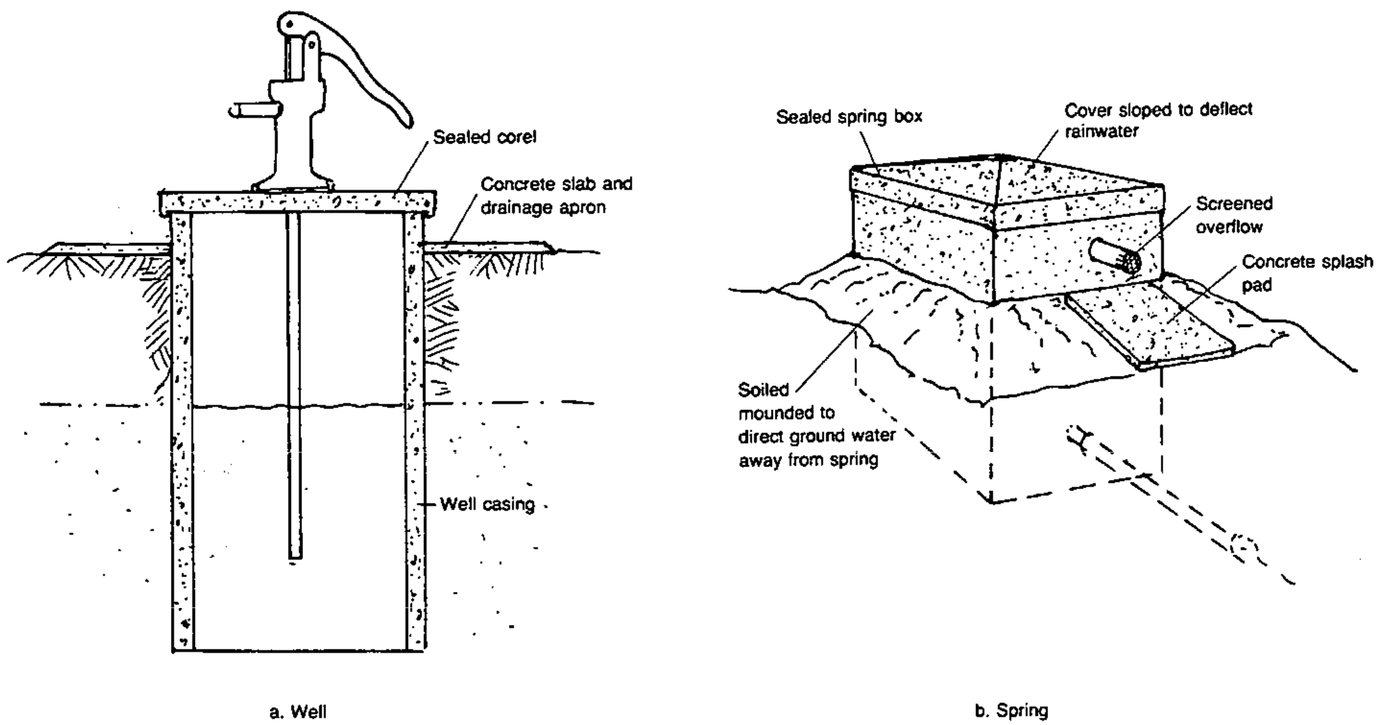


Figure 2. Proper Protection of Water Supplies

• For surface sources, especially those providing large quantities of water, set up an intake that allows for filtration of water before it enters storage. Filtration may not be sufficient to purify water and some form of treatment may be needed.

• Provide for treatment (further filtration or chlorination, for example) to purify water if needed. For household supplies, water can be boiled or chlorinated and stored in clean containers.

the water in the well thereby permitting the release of worm larvae into the water. Treat all water taken from open ponds or wells that might be contaminated with infected water fleas by filtering, chlorinating, or boiling it before drinking. These treatments will kill the larvae before they can infect a person.

Water-Washed Diseases (Water Quantity and Accessibility Related)

These diseases are ones which can be prevented by the provision of sufficient quantities of safe water. To

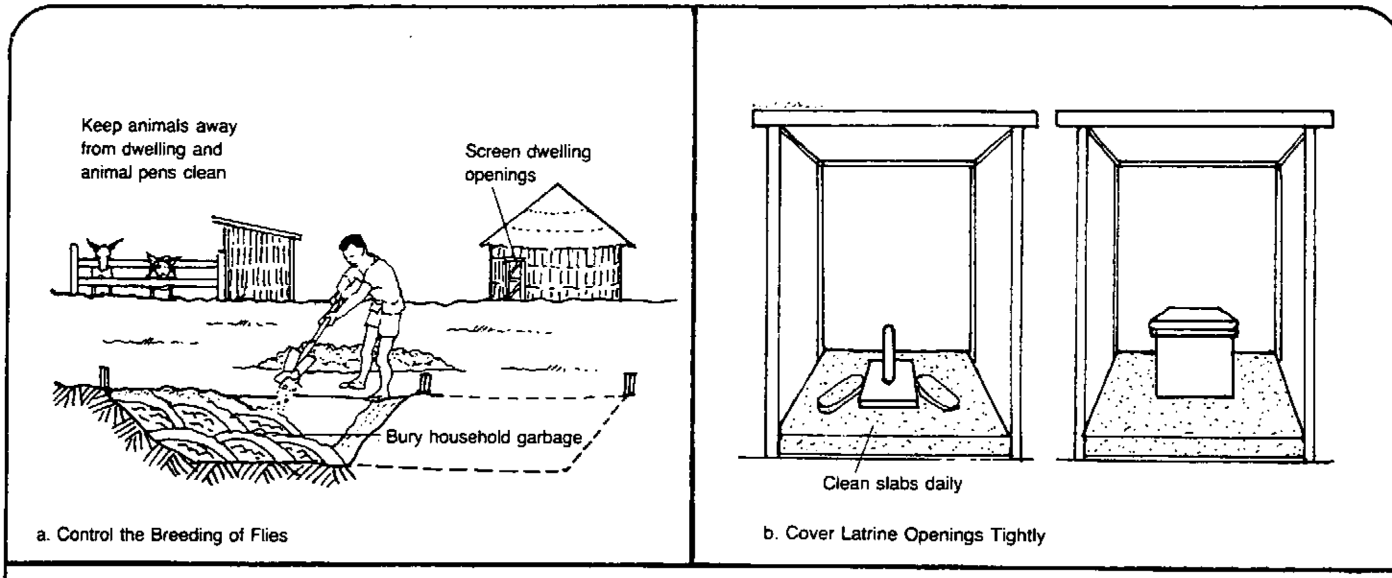


Figure 3. Proper Disposal of Wastes

prevent the spread of water-washed diseases, people should be educated and motivated to practice personal and family hygiene. Washing of hands and bathing in clean water are very important. Clothes and dishes should also be washed to ensure that skin diseases are not passed to people by contaminated hands, clothing, or utensils. The same wash water should not be used by more than one person. Common use of towels should be avoided.

In order to improve hygiene practices, sufficient, convenient quantities of water are needed. A method of developing a water supply of sufficient quantity, adequate quality and easy accessibility and reliability should be chosen with the involvement of the community. The source should be well-protected to prevent contamination of the water supply.

Water-Contact Diseases (Body-of-Water Related)

Water-contact diseases are those which people get from having skin contact with water containing larval worms. There are both environmental and chemical means for controlling the spread of water-contact diseases.

Schistosomiasis is the major disease in this category. Schistosomiasis is controlled by breaking the chain of transmission at several points. The following measures should be followed when attempting to control the spread of schistosomiasis.

- Encourage people to build sanitary facilities and use them. If the eggs in the feces and urine do not reach water they will die, preventing the infection of the snails. This method is useful but is only truly successful if everyone uses latrines for both urinating and defecating. Assurance that everyone over a large area would use them is impossible. Therefore, this method must be combined with a reduction of the snail population and by limiting human contact with infected waters.

- Reduce the snail population. In irrigation schemes, drainage ditches are better environments for snails than irrigation canals. Where drainage ditches are necessary, they must be treated regularly with chemicals that kill snails. When canals are built, line them with a smooth surface like concrete and provide for a rapid flow rate. Smooth surfaces are not attractive to snails and a fast flow of water removes them.

- Maintain the banks of all irrigation canals and bodies of water. Vegetation slows water flow and provides a good environment for snail growth. Keep vegetation and weeds away from canals and beach areas. See Figure 4.

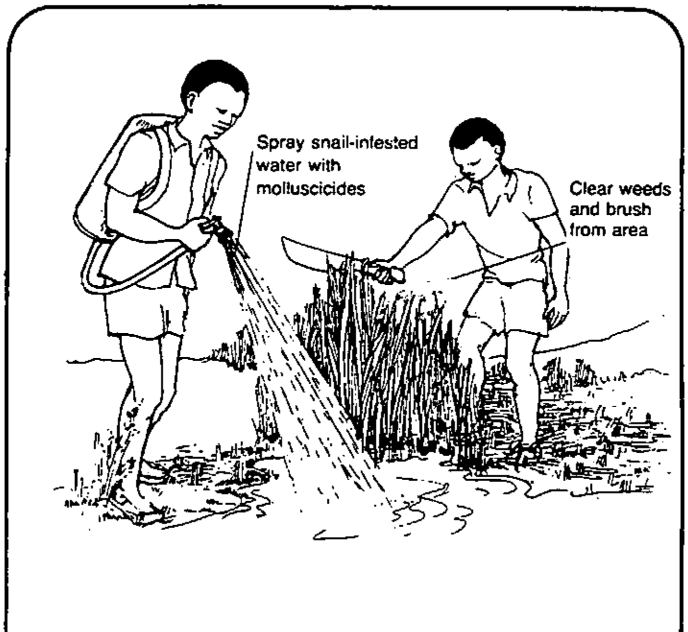


Figure 4. Chemical and Environmental Control of Schistosomiasis

• Drain large standing pools of water and fill in swampy areas to prevent the snails from breeding. Wherever possible, avoid the creation of small reservoirs or pools of water. These environments are very attractive to snails.

• Use chemicals that kill snails molluscicides. They are quite effective in controlling the snail population. Local spraying is the common method of applying molluscicides to water and is quite successful for irrigation projects. See Figure 4. Aerial spraying has also proved effective in many places. The application of molluscicides is less successful in large bodies of water because the water volume dilutes the molluscicides. Only if a specific local site on a large water body is treated with chemicals will success be achieved.

Swimming, bathing and clothes washing in infected water should be avoided. Whenever possible, houses and settlements should be located away from infected waters. In all settlements, both new and existing, potable, piped water systems should be developed. Safe water should be provided in sufficient quantities for drinking, bathing and washing.

Water-Related Insect Vectors (Water Site Related

Diseases that fall into this category are caused and spread by insects that breed in water or in damp, high humidity environments near water sources. Several measures can be taken to control the populations of mosquitoes, tsetse flies, and blackflies which spread malaria, yellow fever, sleeping sickness (trypanosomiasis) and river blindness (onchocerciasis).

Control of virtually all these diseases involves the elimination of the mosquitoes and flies through environmental or chemical means. Although the application of both aerial and ground spraying of insecticides has proved very effective, there are questions about the environmental effects of using them on a large-scale for a long time. Chemical control is sure to continue, but other methods should also be incorporated into vector control plans.

• Control of the tsetse fly which transmits sleeping sickness can be achieved by changing the environment where flies breed. One method is bush clearing along water courses and around villages. An attempt should be made to use cleared areas for permanent agriculture or settlement and thereby keep the land clean of bush.

• Blackflies, which spread river blindness (onchocerciasis), breed in rapidly flowing rivers. Chemical means are the best control for blackflies but some alternative measures can be developed. When dams are built in fast-flowing streams and rivers, the upstream lakes cover the rapids and destroy the breeding areas of the blackfly. Spillways should be built on the vertical face of the dam to avoid creating a new breeding place for the flies.

Mosquitoes transmit both malaria and yellow fever. The control of these insects is important both on a large-scale and an individual household basis.

Large-scale measures other than spraying chemicals include the draining and filling of wet, swampy places where mosquitoes breed.

Smaller-scale and individual measures should also be taken to control the breeding of mosquitoes. All possible standing water where mosquitoes could breed should be covered. Water storage jars and wells are particularly attractive breeding places for mosquitoes. Standing water in gutters should be removed and gutters should be sloped to remove water. At well sites, do not permit water to pool. Some sort of drainage should be built to move water away from the site and measures should be taken to prevent pools of water from developing. Remove any garbage where pools of water can collect and cover latrines so that mosquitoes cannot breed inside. Figure 5 shows some individual preventive measures.

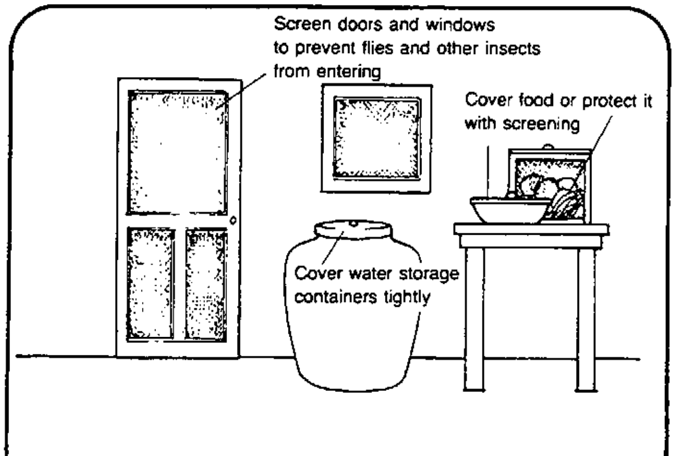


Figure 5. Individual Preventive Measures

These measures, coupled with spraying and a program of health, education will greatly help reduce the growth of the mosquito population.

Sanitation-Related Diseased (Fecal polluted soil related)

Diseases in this category, such as hookworm and roundworm, are a direct result in fecal pollution of soil and the lack of knowledge about good hygiene practices. These diseases can be controlled by relatively simple environmental improvements.

• Educate people on the need to use latrines and train children to use them at a very early age. Diseases are sure to be spread where human wastes are deposited on the ground or in rivers and streams.

• Make sure that all latrines have covers to prevent insects from breeding in the latrine pit.

• Provide sufficient quantities of water to ensure that people can practice personal hygiene. Make sure that people understand the need to wash their hands before eating and after defecating.

• Develop ways to keep flies off food. Screen areas where food is stored. Spraying the home periodically will keep flies and cockroaches away from food.

• Keep animals from entering the home and from coming into close contact with young children. Feces from animals can also spread disease.

Summary

Methods for controlling the spread of disease range from very simple and inexpensive family-oriented approaches to large-scale, more expensive community, regional and national programs. The choice of method will greatly depend on the circumstances, the problems to be remedied and the resources available. Generally, no single method will prove sufficient and a combination of methods is necessary.

The simplest methods of control are those which can be instituted by the construction of simple water systems and sanitary waste disposal systems. These systems are discussed at length in the technical notes on rural water supply and sanitation. See "How to Use Technical Notes," HR.G, for a full list of technical notes.

No successful control program can be developed unless people are educated about the need for a system. A thorough health education program must be developed so that people recognize the problem themselves and are stimulated to search for the appropriate solutions. Community participation is discussed in greater detail in the technical notes on human resources.

Notes

Water for the World

Methods of Controlling Enteric Diseases

Technical Note No. DIS. 2.M.4

Enteric diseases are those that affect the gastrointestinal tract of humans. They are caused by bacteria, parasites or viruses. The disease organisms are passed from infected people in their feces or urine. Others become infected when they take in the disease causing agents by eating soiled food or by drinking water contaminated with fecal matter. Enteric diseases are common throughout the world and, in most areas, some part of the population is always infected.

This technical note discusses measures which can be instituted to control the spread of enteric diseases. Special emphasis is given to basic preventive measures that should be taken to provide hygienic conditions in individual households and in the entire community.

Useful Definitions

DEHYDRATION - A condition in which the body loses more liquid than it takes in.

FECES - The waste from the body, moved out through the bowels.

PARASITE - Worms, insects or mites which live in or on animals or people.

STOOL - Human excrement, or a single bowel movement.

VIRUS - Germs smaller than bacteria which cause some infectious (easily spread) diseases.

Disease Transmission

The transmission of enteric diseases is by the fecal-oral route. The bacteria, parasites or viruses (germs) pass from the body of an infected person in excreta. The germs later enter the body of an uninfected person through the mouth. There are two main ways that germs can enter an uninfected person or re-enter the same person:

- Through the water that people drink. In many situations, water supplies are contaminated by enteric disease germs. If a person drinks fecally contaminated water, he is likely to suffer from an enteric disease.

- Through the consumption of food. Food can be contaminated by dirty hands or raw infected water, or by being exposed to fecally contaminated organic fertilizer or garden soil. Vegetables thus contaminated would only be safe to eat after being cooked or sterilized. Flies can carry germs to food. Flies that light on and taste food can inoculate food with germs that are consumed with the food.

Table 1 lists the principal enteric diseases and their routes of transmission. Diarrhea is a major symptom of all enteric disease. Many types of germs can grow on food if it is not refrigerated. Cholera and typhoid fever are dangerous to people of all ages. Cholera is an especially dangerous enteric disease. Among children, enteric diseases are a major cause of high mortality. Diarrhea is the leading killer of small children in most developing countries. It kills by dehydration.

Controlling Enteric Diseases

The control of enteric diseases involves three important interrelated activities: a health education program, a safe water and sanitation program, and home treatment of patients. These three activities should be implemented simultaneously and continuously.

Health Education

Most enteric diseases result from poor sanitation and a lack of safe (good quality) water in the community. Effective health education is necessary to help people understand the connection between improved hygiene and

Table 1. Principle Enteric Diseases and Their Common Transmission Routes

Diseases	Causative organisms	Common transmission route
Cholera	Vibrio cholerae, including biotype El Tor	Man - feces - water and food - man
Typhoid fever	Salmonella typhi	Man - feces - food and water - man
Paratyphoid fevers	Salmonella paratyphi: A, B, C,	Man - feces - food and water - man
Bacillary dysentry	Shigellae	Man - feces (flies) food (water) - man
Amoebic dysentry	Entamoeba histolytica	Man - feces (flies) food (water) - man
Infectious hepatitis	Hepatitus virus A	Man - feces - water and food - man
Diarrheal diseases	Shigellae, salmonellae, Escherichia coli, parasites, viruses	Man - feces (flies) food (water) - man

improved health. Health education aimed at eliminating the enteric disease should include the following:

- Formation of a community sanitation committee to coordinate the various activities and work needed to attack the problem.

- Participation of community groups. Teachers should be trained in the basics of disease transmission and prevention so that they can teach their students. Community groups, 4-H clubs, women's groups, other clubs, and the like should be active in health education.

- Development of audio-visual materials. Films, puppets, slides, songs, flashcards, and other methods can be used to make the problem and its solution clear to the members of the community. Students and clubs should be taught how to prepare their own audio-visual materials for demonstration.

- Implementation of specific education programs in clinics and hospitals.

Health education should start people thinking about the problem and create a desire to change their behavior to solve the problem. When people recognize the need to use a latrine and wash their hands, and understand the ways in which water is contaminated and the role of flies and other vectors in the spread of disease, they will be more willing to do something to change the situation.

Preventive Measures

Several measures can be taken to either remove sources of disease transmission or to prevent the sources from ever existing.

Latrines

- Build latrines at least 15m from any water supply or household. Be sure to site latrines so that they are downhill from any water source. Do not excavate pits into the water table. See Figure 1.

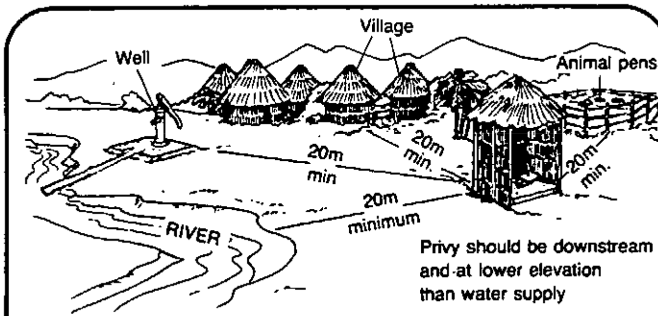


Figure 1. Proper Location of Privy

- Make sure that all latrines are sanitary. Ideally, the latrine should have a concrete floor. When not in use, the hole through the floor should be covered. Uncovered latrines permit the breeding of flies which can carry disease agents from feces to food. See Figure 2.

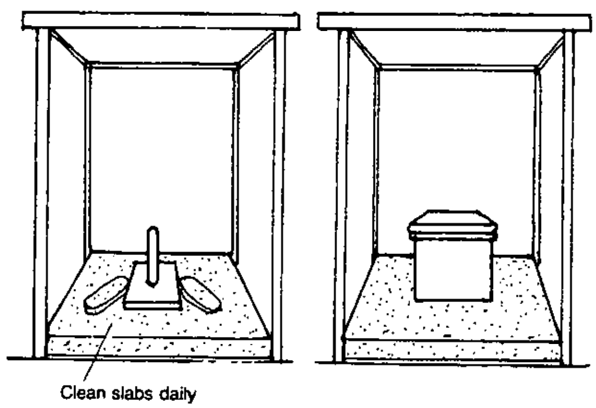


Figure 2. Cover Latrine Openings Tightly

• Accustom people to use latrines. One of the biggest problems is getting young children to use a latrine. Parents may use it but allow their children to defecate on the ground. Latrine openings should be sized so that children do not fear falling in. For more information on latrine design and construction, read the appropriate technical notes on sanitation. See "How to Use Technical Notes," HR.G, for a full list of technical notes. If latrines are not used, water sources can easily be contaminated by surface run-off.

Water Supply

• Provide for a safe supply of water for the community. Read the appropriate technical notes on rural water supply. Protect all wells from the entrance of surface run-off. A well-head and a pump should be installed in order to prevent contamination from entering the wells.

• Cap springs to prevent their contamination from surface run-off. See Figure 3.

• Where wells and springs are not protected or where surface water sources are used, water should be treated. Individual or community treatment should be used depending on the situation. Boiling and chlorination are the most common methods. For information on water treatment methods, see "Methods of Water Treatment," RWS.3.M.

Hygiene

Personal and household cleanliness is important for preserving health. The following practices are essential for controlling the spread of enteric diseases. Figure 4 shows some of these practices.

• Always wash hands with soap and water before eating and after using the latrine.

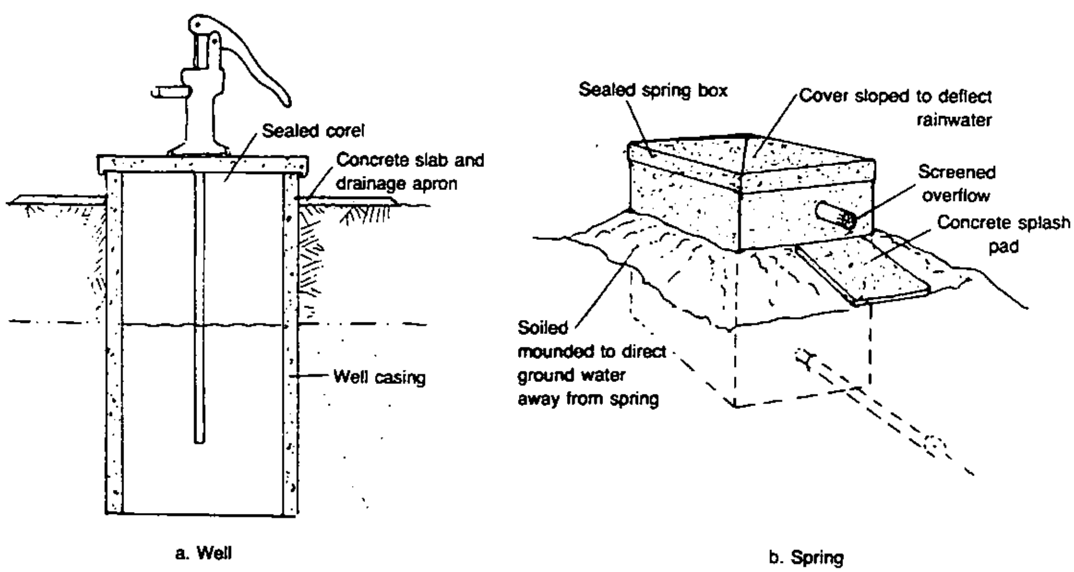


Figure 3. Proper Protection of Water Supplies

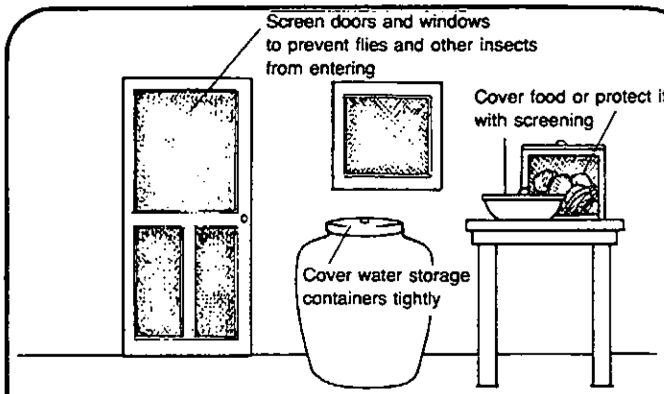


Figure 4. Individual Preventive Measures

• Wash fruits and vegetables before eating them. Be sure to scrub those vegetables which grow in ground that may be infected.

• Do not allow animals to enter the house.

• Store food in screened areas or in refrigerators and cover food with netting. These measures will keep flies away from food and help prevent the spread of disease.

• Keep the house clean by sweeping it daily.

• Require that food handlers are trained in personal hygiene and are aware of the need to store and cook food correctly.

• Dispose of all garbage properly. Make sure that garbage does not accumulate in such a way that flies can breed in it.

• Eat well. Diseases such as dysentery are more dangerous to people suffering from malnutrition.

Treatment Measures

At the same time that health education and preventive measures are being implemented, measures to treat patients with enteric diseases should be adopted. When diarrhea is present, liquid and salt are rapidly lost and must be restored to the body. Many children die from diarrhea or dysentary when they do not have enough water in their bodies. Persistently and frequently give liquids to a person with diarrhea. In severe cases in children, rehydration liquid should be given. Preparation of a rehydration drink: to a liter of boiled water, add two tablespoons of sugar, one-quarter teaspoon of salt, and one-quarter teaspoon of baking soda. Give the dehydrated person sips of this drink every five minutes, day and night, until he begins to urinate normally. An adult needs at

Table 2. Foods for a Person with Diarrhea

When the person is vomiting or feels too sick to eat, he should drink:	As soon as the person is able to eat, in addition to giving the drinks listed at the left, he should eat a balanced selection of the following foods or similar ones:	
teas	energy foods	body-building foods
ice water	ripe or cooked bananas crackers rice	milk (sometimes this causes problems)
chicken, meat, egg, or bean broth	oatmeal or other well-cooked grain	chicken (boiled or roasted) eggs (boiled)
Kool-Aid or similar sweetened drinks	fresh maize (well cooked and mashed potatoes	meat, well cooked, without fat or grease beans, lentils, or peas (well cooked and mashed)
REHYDRATION DRINK	applesauce (cooked) papaya	fish (well cooked)
Breast milk		
	DO NOT EAT OR DRINK	
fatty or greasy foods acidic raw fruits	beans cooked in fat highly seasoned food	alcoholic drinks any kind of laxative or purge

least 3 liters of water each day while a child needs 1 liter. Table 2 lists foods that should and should not be eaten by a person with diarrhea.

Where diarrhea is very severe and looks like it will not stop, keep giving liquids to the patient and seek medical help immediately. Seek medical help when:

- Diarrhea lasts more than four days and is not getting better or more than one day in a small child with severe diarrhea.

- A person is dehydrated and getting worse.

- A child vomits everything it drinks.

- The child begins to have fits or its feet and face swell.

- The person was sick or malnourished before the diarrhea began.

- There is blood in the stool.

Under these conditions, a more serious enteric disease may be present in the system and some type of drug treatment will be necessary.

Notes

Water for the World

Implementing Operation and Maintenance Training

Technical Note No. HR. 3.I.1

Training is very important to successful water and sanitation system operation. Training is necessary when a new operator begins a job, when an experienced operator needs to perform a new task, or when an operator does not have enough skill or knowledge to perform a job well.

Training must be directly applicable to local circumstances, understandable to local trainees, technically appropriate and technically correct. Training should be practical to the extent that trainees learn operational procedures on equipment identical to that which they will operate, if they are not trained on village equipment itself.

Training should take into account local learning techniques and educational methods so that credibility for teaching authority and prestige for training are created. Training should be conducted in a manner which meets local work standards and ethics, attaching a sense of dignity and pride to both the training process and the operation and maintenance job itself.

Training should be provided at appropriate levels for all personnel involved with the operation and maintenance of the water and sanitation system. This may include system operators, bookkeepers, local health educators and the village committee. Extensive training of this sort will provide a catalyst for wider community education and understanding of the water and sanitation system and will prevent one trained operator from monopolizing proper system operation. In case of the absence of one trained person, several other trained people will be available. There will also be a balance of power. For example, the village committee can select a system operator for training but the committee can also manage the water and sanitation system along with the system operator.

Management of Training Courses

Training programs must be well organized to work effectively. It is extremely important that trainers and trainees communicate well during the training sessions. The roles and responsibilities of both should be understood before training begins.

The roles of trainer and trainee are partially dependent on the location of the training program. See Table 1 in "Planning Operation and Maintenance Training," HR.3.P. Training in the village where the water and sanitation system will be operated has these advantages:

1. Trainees have more time for training sessions.

2. Trainees can learn on equipment they will actually be working on later. Special problems and conditions can be handled during training.

3. Local routines, people and conditions can be integrated into the training program.

4. The entire community can be helped to realize the importance of training.

Training at a central site has these management advantages:

1. Trainers are available to trainees at all times.

2. Operation and maintenance practices are taught in a standard manner to each trainee.

3. More teaching aids are available.

The role of the trainers and trainees may vary somewhat depending on where training takes place.

Roles and Responsibilities of Trainers

Trainers must be technically competent in the technology to be used. They must also be capable of handling administrative duties from both technical and management standpoints.

The training staff is responsible for determining the job tasks of all system personnel, determining the training course content based on those job tasks, organizing the material to be presented, selecting an instructional method and conducting the training programs.

Trainers responsibilities will be:

1. To learn the trainees' needs and adapt the training program to meet those needs.

Trainees may be divided into learning groups. Courses can then be molded to the needs of the individual groups while still covering necessary procedures. Trainers should personally examine local circumstances and determine what job tasks will need to be performed. They should then determine what the trainees already know and what they will need to be taught. Standard procedures for the defined tasks should be established and taught. Tool and equipment supplies should be adequately provided.

Operation and maintenance personnel with little mechanical background and little other education will probably need very structured and practical training programs. This is especially true if the system operators to be trained have not participated in the construction of the water and sanitation system they are being taught to maintain. Trainers must understand the procedures well and be able to explain them clearly to trainees in the trainees' own language.

If the operation and maintenance personnel have some mechanical background or are experienced in operation and maintenance, and have actively participated in the construction of the system and demonstrate a good understanding of its use, training may not need to be as regimented as it is for the inexperienced operation and maintenance trainee. The trainer can demonstrate procedures and have trainees practice them with trainer direction as needed for evaluation. One trainer can manage several trainees at the same time this way.

If trainees have been trained in the operation and maintenence procedures before, and demonstrate a good understanding and skill in their work, they may only need a refresher course. The trainer may only need to explain new types of equipment and procedures and be available to answer questions the trainees have while experimenting on their own.

2. To maintain a positive and helpful attitude toward trainees.

A "reward" may be established by the training co-ordinator as an incentive to create and maintain positive attitudes toward training. "Rewards" should be appropriate to local desires and circumstances. Public recognition, a special privilege, increased responsibility and pay increases are often used as incentives. Job security and official recognition for trainees by the village committee or regional center are usually more effective as incentives than financial benefits.

3. To help install local respect for the proper operation and maintenance of the water and sanitation system.

This may involve working with the entire village to some extent, and especially with community leaders and health educators. If training is taking place in the village, special efforts can be made to integrate local schedules, people and problems into the training program.

4. Creating and maintaining a desire for learning and understanding during training.

It is important that trainees understand that proper operation and maintenance can improve life in the village. It is also very important that trainers conduct training sessions in a manner that attaches a sense of pride and dignity to the training process which will be continued on the job.

Roles and Responsibilities of the Trainees

Trainees' responsibilities may be more circumstantial than trainer responsibilities. Overall, of course, the trainees' greatest responsibility is to learn how to operate and maintain the local water and sanitation system in order to provide good service to the rest of the community. Trainees' specific training duties may include:

- Clearly explaining to the trainer the extent of their experience with and knowledge of the water and sanitation system.

- Co-operating with the trainer's course structures.

- Actively participating in all training exercises and drills.

- Asking questions that are applicable to the trainee's local working situation.

- Maintaining a positive and co-operative attitude throughout training.

It is very important that the roles and responsibilities of all persons involved in the operation of the water and sanitation system be defined. Review those agreed upon during the planning stages of the system. Refer to "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.P. The responsibilities of the project planner, others in the action agency, the system operators, the village water and sanitation committee and the community as a whole should be clearly explained and agreed upon at the outset of the training program.

Content of Training Courses

The content of the training courses will be an explanation of the defined job tasks. See "Planning for Operation and Maintenance Training," HR.3.P.

Generally, the action agency is responsible for providing logistical support and major repair services. The community will be responsible for the administration, operation, preventive maintenance and basic repairs of the system. For each position on the local level, the trainer should identify:

- job tasks and responsibilities;

- the degree of authority the position holds;

- financial responsibilities;

- support responsibilities.

The action agency is responsible for providing training for project planners, trainers and all village personnel. The project planner will be responsible for providing action agency support to the village while the system is in use. Community personnel, especially system operators, will need outside assistance when facing problems they cannot solve themselves. Back-up resources, such as information, skilled assistance, tools and parts should be readily available in the regional office of the action agency. The project planner should be prepared to:

- provide maintenance and repair services which village system operators have not been trained to perform;

- provide system and water quality control checks;

- supervise, assist and instruct local operators in operation and maintenance procedure reviews;

- assist in extensions of systems.

The regional office of the action agency should:

- maintain replacement parts to supplement the local supply;

- provide dependable central services for ordering other materials and spare parts;

- provide transportation of personnel and materials to community.

It may be possible for a supervisor or team from the action agency to visit villages on a regular basis to supervise procedures, answer questions, check the condition of facilities, perform needed repairs and provide other preventive maintenance services. Qualified advisors who provide regular refresher training to local operation and maintenance personnel are useful. This will minimize costly breakdowns and the length of time systems are out of order and increase community satisfaction and use of the system. Action agency support should emphasize that preventive maintenance is essential to the long-term operation and use of the system.

The responsibilities of local personnel will vary with local arrangements and with the design of the local system. System operators should be supervised by the village water and sanitation committee and by the project planner and trainer of the action agency. System operators are generally responsible for:

- basic daily operation of equipment;
- preventive maintenance of water supply equipment and sanitation facilities;
- protection of the water source from pollutants, children, and animals;
- simple repairs;
- reporting to the village committee, requesting new parts and asking for action agency assistance when needed;
- recognizing and reporting major problems.

Operation and maintenance training must prepare system operators to help the village committee create respect for the facilities among the rest of the villagers so that the facilities are properly used. System operators should know where they can obtain help at either the local or the regional level.

The village water and sanitation committee is generally responsible for:

- demonstrating proper use of facilities;
- teaching villagers to understand and appreciate the advantages of safe water supply and sanitation systems;
- assisting individual households to care for individual facilities and installations;
- retaining a bookkeeper to maintain system finances;
- estaiblishing flat or metered rates for water supply and sanitation services;
- collecting and retaining fees;
- paying for operation and maintenance with collected fees;
- ordering and purchasing needed equipment, perhaps at an agreed price from the action agency;
- requesting the services of the action agency, including the purchase and provision of major materials.

Fix an Implementation Routine

Regular methods of operating and maintaining the local water supply and sanitation system should be established as part of a training course. Regular times (daily, weekly, monthly) for the procedures should also be established. Any preventive maintenance or cautionary procedures should be incorporated into the regular operation and maintenance routines.

System operators' performance on the job can often be improved by using job manuals and visual aids such as posters to remind them of the established routine. Manuals and aids can be introduced as part of training, and may even serve as the outline for a training course. They can help trainees avoid having to memorize information they may remember incorrectly.

A basic manual can:

- explain operation and maintenance procedures step by step, as simply as possible;

- include illustrations for procedures;

- list and illustrate tools, supplies and equipment needed to carry out procedures;

- stress the importance of potable water and sanitary waste disposal.

Visual aids, such as posters and picture manuals can replace written instructions for those unable to read well and supplement any manuals on the job. Training, operation and maintenance manuals and visual aids can be developed by the regional office of the action agency. The regional office staff should know better than the national office staff how the tools, equipment, supplies and procedures should be applied to the local situation.

Reports

Monthly reports on the functioning of the system should be made by the system operator. Oral reports can replace written reports for those who do not write well and can be given directly to the action agency maintenance supervisor or inspector. A system opertor who does not read or write well can be taught to check an illustated chart in order to make reports, or another member of the community can write up the system operator's oral report. Periodic inspections of the system should be made by the project promoter from the action agency.

Notes

Water for the World

Selecting a Source of Surface Water

Technical Note No. RWS. 1.P.3

The success of a water project depends on the suitability of the water source that is chosen to serve the community. The selection of the most appropriate source is very important and requires that all available water sources that could serve the community be identified, and the most appropriate source be selected. A source should be selected only if (a) it meets the needs of the users, (b) is easily accessible to them, and (c) can be developed at an affordable cost.

This technical note suggests guidelines for choosing the most appropriate surface water source for a community. It describes methods for measuring the quantity of water available from a surface source, and establishes four priorities for source selection that will help ensure the selection of the best source at the lowest development cost.

Useful Definitions

DISINFECTION - Destruction of harmful micro-organisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

HYDRAULIC RAM - A self-powered pump which uses the energy of falling water to lift some of this water to a level above the original source.

POTABLE WATER - Water that is free from harmful contaminants, is aesthetically appealing, and is good for drinking.

RECHARGE - Natural process by which quantities of water are added to a source to form a balance between inflow and outflow of water.

WATER BALANCE - Balance of input and output of water within a given defined hydrological area such as a pond or lake, taking into account changes caused by storage.

Determining Quantity of Water Available

In considering a water source, you must first find out how much water it yields, whether it provides enough water to meet community needs and whether it is reliable during the entire year.

Springs. To determine the suitability of a spring, it is necessary to know how much water it will yield, and how well it will keep up its flow in dry weather.

The yield is measured by a very simple method. First, channel the spring's flow into a small, hollowed-out collection basin that is dammed at one end. Make sure that the basin collects all available flow. Place an overflow pipe through the dam so that the collected water flows freely through the pipe, as shown in Figure 1. Make certain there is no

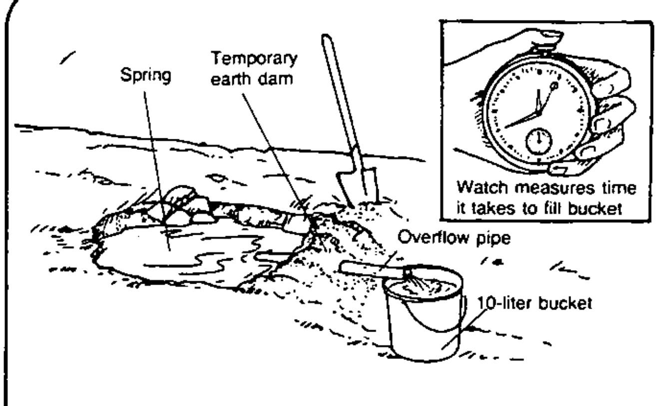


Figure 1. Measuring Spring Flow

leakage around the pipe. Then, put a bucket of a known volume (for example, a 10-liter bucket) under the pipe to catch the flow. With a watch, measure the amount of time it takes for the bucket to fill. Divide the volume of water by the amount of time to find the rate of flow in liters per minute. For example, if the 10-liter bucket fills in 45 seconds, the rate of flow is:

$$\frac{10 \text{ liters}}{45 \text{ seconds}} = 0.22 \text{ liters/second}$$

0.22 liters/second x 60 seconds/minute = 13.2 liters/minute

It is then easy to determine the volume of water available during a 24-hour period. Multiply the number of liters per minute by 60 minutes per hour to find liters per hour. For example:

13.2 liters/minute x 60 minutes = 792 liters/hour

Then, take the flow in liters per hour and multiply it by 24 hours per day to find the daily flow. For example:

792 liters/hour x 24 hours/day = 19008 liters per day

Compare this amount to the daily needs of the community. The daily need is computed by multiplying the number of users by the number of liters each person will use in one day. For example, if there are 300 people using 40 liters per day, the daily water usage is 12000 liters. A spring with a daily flow of 19008 liters and a storage tank would be more than enough to meet the needs of a community of this size.

Ponds, Lakes and Reservoirs. The amount of water available in a small pond, lake or reservoir can be roughly estimated by a simple method. An example to follow is shown in Figure 2.

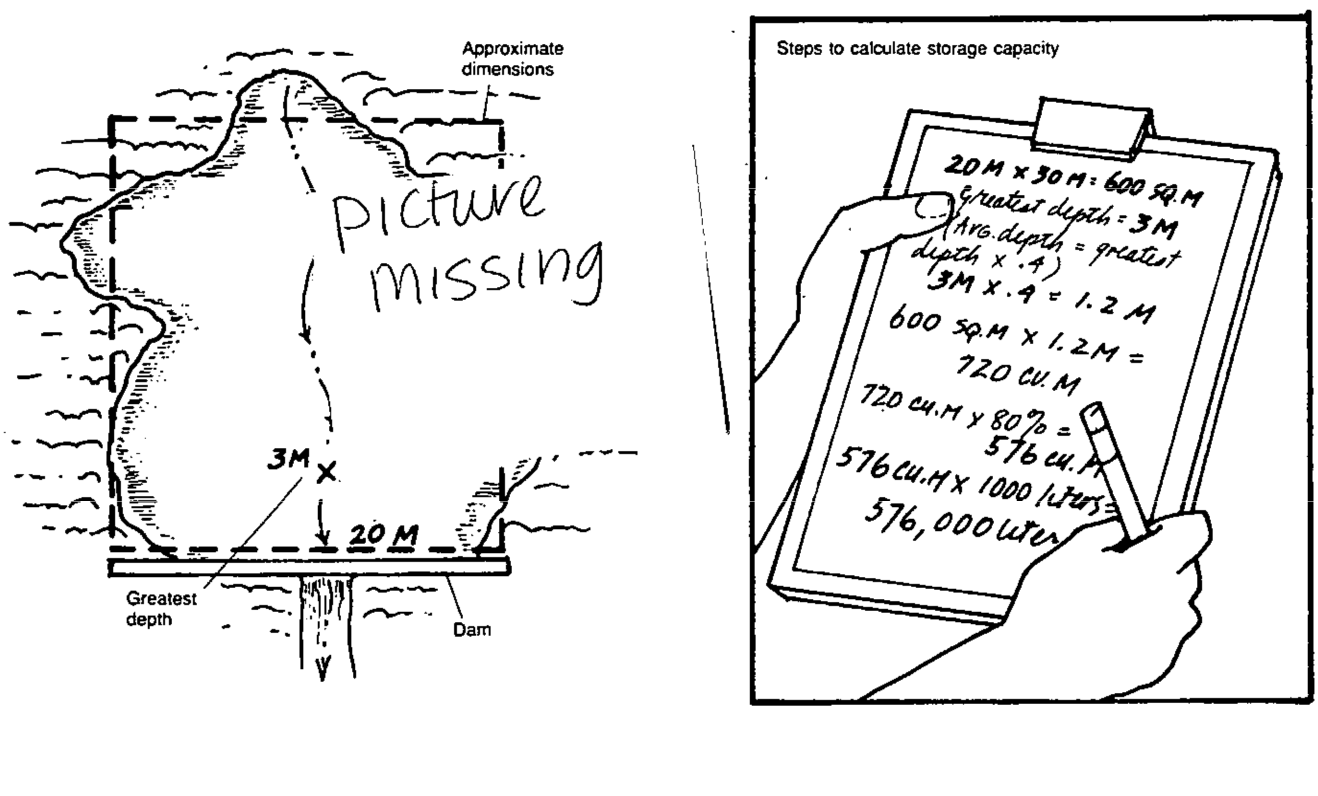


Figure 2. Estimating Storage Capacity of Small Lake or Pond

1. Lay out a rectangular shape around the body of water approximately its size.

2. Measure the length and width of the rectangle and multiply the two numbers to find the area of the rectangle in square meters. For example, if the length is 30m and the width 20m, the area is $600m^2$.

3. The depth of the source should be measured at the deepest point and the average depth calculated. The average depth is found by multiplying the greatest depth in meters by 0.4. If the deepest point in the pond measures 3m, the average depth is 3m x 0.4 = 1.2m.

4. The amount of water in the source is measured in cubic meters and is calculated by multiplying the area (m^2) by the average depth (m). In the example, the area is 600m and the average depth 1.2m. The volume of water is $600m^2$ x 1.2m = $720m^3$.

5. A basic rule to follow is that the volume of water available is generally about 80 percent of the total volume of water in the pond or lake. The other 20 percent is usually lost through evaporation, transpira tion, and seepage. To find the volume of water available for use, multiply the total volume of water by 80 per cent. For example, .80 x $720m^3$ = $576m^3$.

6. There are 1000 liters of water per cubic meter (1000 liters = $1m^3$). In the example, the water available for use in liters is:

$576m^3$ x 1000 = 576000 liters.

Compare the estimated amount of water available to the amount needed by the community and estimate how many months the source will provide water for a community without recharge. This determination will assist in planning for times when there is no rain. If possible, a source should contain at least a six-month storage supply. To refine further the estimate of the source's yield, find out its history during the wet and dry seasons. Note any major fluctuations in water level and be prepared for them when planning to develop the source.

For example, if 100 people use 40 liters per day each, or 4000 liters total, we can determine their monthly water usage and the number of months the pond will supply sufficient water. To do this, multiply the total daily usage by 30 days per month:

4000 liters x 30 days/month = 120000 liters/month

Then divide the total number of liters available by the number of liters used in a month to find the number of months the source will last without recharge:

$$\frac{576000 \text{ liters}}{120000 \text{ liters/month}} = 4.8 \text{ months}$$

In the example, the source would supply storage for approximately five months without normal recharge. That is, unless there were rain, the pond would dry up in five months. When considering pond or lake development, it is necessary to take into account rainfall and recharge rates to make sure the source is suitable.

Rivers and Streams. Simple methods are available for determining the flow of water in a stream or river. For smaller streams, the same method as for spring flow can be used. That is, a dam with an overflow pipe can be built and the flow can be found by seeing how long it takes for a bucket of known volume to fill with water.

There is another method for determining flow in small streams with slightly greater flow. It is called the V-notch method. A V-shaped notch with a 90^o angle is cut out of a flat piece of metal or wood and placed in the middle of a dam so water flows through the notch as shown in Figure 3. A gauging rod is placed in the stream 2 to 3m upstream from the dam. The zero point on the rod must be level with the bottom of the notch. The depth of the water from the bottom of the notch, the zero point, to the water level can be read from the gauge. Table 1 gives the flow per second for a given height. This information will help determine the amount of water available for an intake in a stream or river.

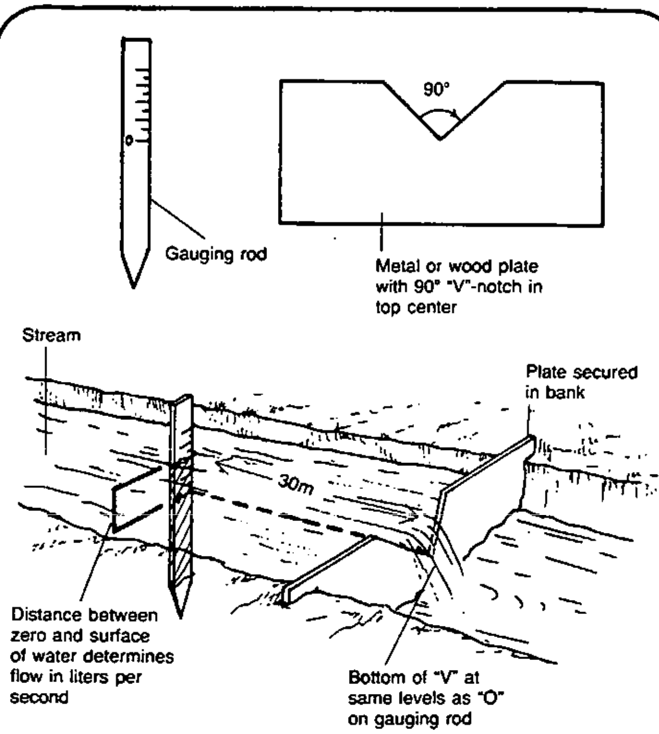


Figure 3. Measuring Stream Flow

If the flow is too great to use the V-notch, there is another, less accurate, method that can be used. This method is not nearly as accurate as the others and should be used only when measuring flow in larger streams. Find a straight, wide stretch of a stream and measure a length along the bank. Place a stake at each end of the measured distance as shown in Figure 4. Throw a floating object into the stream at the first stick and time how long it takes for the object to reach the

Table 1. Flow Over a 90° V-Notch

Height of Water (mm)	Flow (liters/ second)
50	0.8
60	1.2
70	1.9
80	2.6
90	3.4
100	4.5
110	5.6
120	7.0
130	8.6
140	10.3
150	12.3

second stick. Repeat this test three times and take the average. The flow in liters per second is calculated using the following formula:

$$850 \times \text{measured length} \times \text{width of the stream} \times \frac{\text{average depth}}{\text{average time}}$$

For example, to measure the flow of a stream 1m wide with an average depth of 0.3m, place two sticks on the bank approximately 3m apart. Throw a floating object into the middle of the stream at the first stake and measure how long it takes to travel the 3m distance. Take the measurement three times. Assuming the object takes an average of 20 seconds to float 3m, use the equation to deter mine river flow:

$$850 \times 3\text{m} \times 1\text{m} \times \frac{.3\text{m}}{20} = 38.25 \ \frac{\text{liters}}{\text{second}}$$

To find out if the flow will be sufficient, determine the daily demand for water and the volume of available water. The flow in liters per second can be converted to flow per day by using the following formula:

liters/second x 60 = liters/minute;
liters/minute x 60 = liters/per hour;
liters/hour x 24 = liters/day.

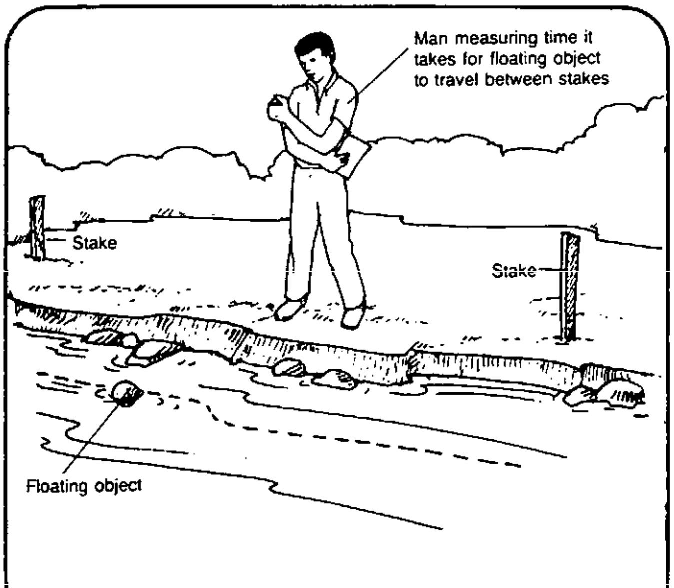


Figure 4. Measuring Large Stream Flow

Rain Catchments

When considering a rain catchment as a source for a water supply, first determine individual needs. This is done by multiplying the number of people in the family that will use the system by 15 liters per person. If there are six people in a family using 15 liters of water per person per day, the total demand for water is 90 liters:

15 liters/person/day x 6 persons = 90 liters/day.

The second step is to figure out how much water will be available. Determine the area of the catchment area by multiplying the length of the roof by the width. The width is the length of the base of the triangle formed by the roof. For example, if the length of the roof is 8m and the width is 6m, then the area of the roof is $48m^2$.

Next, determine the amount of annual rainfall for the region. This should be available from a local government agency, a weather station or an airport. Multiply the amount of annual rainfall by the area of the roof catchment to find the amount of water available for consumption. For example, assume that 750mm, or .75m, of rain falls on a $48m^2$ catchment area. The quantity of water available for use is $.75m \times 48m^2 = 36m^3$. To convert $36m^3$ to liters, multiply by 1000:

36 x 1000 = 36000 liters/year.

Not quite all the water will be collected. Some splashes to the ground and some evaporates. For planning purposes, assume that 20 percent of the water is lost. Then the amount of water actually available is 28800 liters. This is calculated by multiplying the amount available, 36000 liters, by 0.80:

36000 liters x .80 = 28800 liters.

To make the numbers easier to work with, divide the total quantity available either by 12 to get liters per month or by 365 to get liters per day:

$$\frac{\text{28800 liters/year}}{\text{12 months/year}} = \text{2400 liters/month}$$

$$\frac{\text{28800 liters/year}}{\text{365 days/year}} = \text{79 liters/day}$$

A cistern must be constructed to store the water collected by the catchment. For information about storage see "Methods of Storing Water," RWS.5.M, and "Determining the Need for Water Storage," RWS.5.P.1.

Compare the total available quantity to the demand for water and determine if family needs can be met using a roof catchment system. Each person should have 15 liters per day available, but in some cases demand for water from catchments may be less than 15 liters. If the quantity available ranges between 10 and 15 liters per person, the system is suitable.

Priorities for Source Selection

The quantity of water available from surface sources can now be determined. Quantity is an important factor but it is not the only one. A suitable source must provide good quality water, and it must be reliable. Another important factor is that water should be available to the user at the lowest possible cost.

When planning to select a suitable source, it is useful to have a set of guidelines. The first guideline discussed here is sufficient water quantity. If several sources offer adequate quantity, a choice must be made among sources. Table 2 lists priorities to consider when choosing a source.

Table 2. Priorities for Surface Water Source Selection

Priority	System
First	No treatment or pumping required
Second	No treatment but pumping is required
Third	Some treatment but no pumping is required
Fourth	Both treatment and pumping are required

These priorities are guidelines for selecting the most appropriate source among several alternative methods of surface water development. The priorities are established in order of ease of construction, maintenance, and financing of the system. Where no treatment or pumping is required, a system is easier to develop, operate and maintain. Moreover, the development costs should be lower than for systems requiring treatment and pumping. Once treatment and pumping are added to a water system, costs rise and a program for operation and maintenance must be established to ensure constant operation. These extra costs could make the development of the project difficult for a rural community. When following the basic guidelines, keep in mind other factors such as community preferences and available community resources.

No Treatment; No Pumping. A water source which supplies abundant water needing no treatment that can be delivered to the user by a gravity system should be the first source considered. Because no treatment or pumping is required, the cost of developing, operating and maintaining the system is relatively low.

If a spring of sufficient capacity is available in, or near, the community, it could prove to be the best source. Water from a protected spring generally needs no treatment. An initial disinfection applied after the source is protected will be sufficient to ensure good water quality. If springs are found in hilly areas, they can easily be developed to supply a community with water through a gravity flow system. Water from the spring flows downhill into storage and then to the distribution system.

Care must be taken to ensure that there is an adequate head so water will reach the users. Head is the difference in water levels between inflow and outflow ends and is an important concept in developing water systems. The possibility of loss of water pressure due to insufficient head is an important consideration in determining the suitability of a source. When planning to use any surface source, especially a gravity flow source where water is piped, see "Designing a System of Gravity Flow," RWS.4.D.1.

A stream or river in a highland region with few inhabitants is another source which probably will require neither treatment nor pumping. In an area where not many people live, fecal contamination is not a likely problem and treatment will not be necessary. In a hilly region, the water intake can be located at a higher elevation than the storage tank and the community. This will allow use of a gravity flow distribution system if head is sufficient. Costs should be low, but higher than for a spring because of the task of constructing a river intake. Maintenance should be simple.

Rivers and springs that do not require pumping or treatment are good sources of water for a community supply. Water from both sources is often cool and tastes good to the users. Generally, the source is accessible and is one that the community is accustomed to using. A project using water from these sources will normally be accepted by the community, and will offer them good water at low cost.

No Treatment; Pumping Required. When a first priority source is either not available or is inadequate, consideration should be given to a source that needs no treatment but requires pumping. Treatment can be very expensive and requires special skills, equipment, and a continued supply of treatment chemicals except where only simple settling is needed.

Pumping devices, on the other hand, can be simple, easy to install and inexpensive, such as hand pumps. They can also be quite complicated and expensive to operate and maintain, as is true of power pumps. Whenever any pump is installed, trained maintenance people with access to spare parts will be needed. Mechanical pumps require energy and either electric power or petroleum to operate.

In some cases, water from a natural lake or pond may not need treatment for use as a drinking source, especially if it is located away from uninhabited upland areas. Thorough testing of the water should be done before using it without treatment.

A river or stream is another source of water that possibly can be pumped without treatment. Several alternatives exist. A mechanical pump can easily be installed in a mountain stream where a gravity flow system is not feasible. Where there is sufficient fall and volume of water in the stream, an inexpensive hydraulic ram can be used to lift water to a storage tank.

An infiltration well or infiltration gallery may also provide water that needs no treatment. Infiltration intakes are located on the banks of streams and rivers. The stream water that enters them flows through the ground and is filtered. If properly planned and designed, infiltration wells and galleries can provide water needing no treatment.

A hand pump can be installed on the infiltration well and on the storage well of infiltration galleries, if water is to be used at the source. If water distribution is necessary, a windmill or fuel-powered pump can be installed.

Some Treatment; No Pumping Required. In some circumstances, the only surface sources available to a community will need treatment. Since treatment can be relatively expensive, a source which requires some treatment but no pumping should be the next source considered.

Rain catchments offer a relatively inexpensive method for providing water to individual users. Water from a rain catchment requires treatment because dirt, bird and animal excreta and other contaminants collect on the roofs of houses between rainfalls. During a rainfall, the contaminants are washed into gutters and pipes and then into the water collection cistern. To be safe, this water must be filtered and disinfected (see "Methods of Water Treatment," RWS.3.M). Rain catchments offer a variable yield and should only be considered where rainfall is adequate. Where rainfall is abundant, the system should prove reliable.

A contaminated river or stream in a hilly area is well-suited for a gravity flow system. Where treatment is necessary, water will flow through the intake, through treatment and into storage. This system may be very expensive due to construction and continuing treatment costs.

The source requiring the least treatment will cost less to develop. The amount of treatment a source will need must be determined before a source is selected.

Treatment and Pumping Required. Of all the alternatives mentioned, the most expensive is that which requires both treatment and pumping. Ponds, lakes and most streams fit into this category. Water from ponds and lakes usually must be pumped and usually requires treatment. If a pond is not exposed to fecal contamination, treatment may be a very simple process and not very costly.

A pond or lake can be a very good source of abundant and accessible water and may be the only source available to a community. With proper management of the watershed and with adequate treatment, a pond or lake will be a good source. An efficient system of operation and maintenance must also be established to ensure continued functioning of the system. Costs for this kind of system are likely to be high.

Small community ponds, especially where manmade, usually are highly contaminated from waste and contaminated run-off. Use of a contaminated community pond is risky and treatment must be very good to make the water potable. Water from this type of pond should not be used unless another good alternative does not exist.

Direct use of water from a river or stream usually requires that water be pumped from the source and treated before it is used by the community. Water from rivers and streams in lowland areas is especially likely to be contaminated. Water quality in rivers and streams should always be questioned because there are likely to be sources of contamination upstream. Only in mountain streams or where infiltration galleries are used is stream water likely to be good without treatment.

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Water for the World

Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources

Technical Note No. RWS. 1.P.2

A community interested in development of a community water supply may have several sources of surface water available to it. When a choice has to be made between sources, the quality of the water at the source and the quantity it produces must be considered. Methods for determining whether a surface source provides a sufficient quantity of water are discussed in "Selecting a Source of Surface Water," RWS.1.P.3. To determine water quality, a sanitary survey must be conducted.

A sanitary survey is a field evaluation of local health and environmental conditions. The goal of a sanitary survey is to detect all sources of existing and potential contamination, and to determine the suitability of the source for a community water supply. From information gathered in the survey, sources of contamination can be removed and water supplies protected. Information should be gathered through observation of local conditions, through sampling of water, and through interviews and conversations with local leaders, health officials and villagers. The following factors should be considered when doing the survey: (a) physical characteristics of the location which indicate potential contamination, (b) bacteriological quality of the water and (c) physical and chemical qualities of the water.

This technical note describes each of these factors and their importance in determining existing and potential sources of contamination of a water source. Worksheet A summarizes the questions to be answered by a sanitary survey.

Useful Definitions

ALGAE - Tiny green plants usually found floating in surface water; may form part of pond scum.

BACTERIA - One-celled micro-organisms which multiply by simple division and which can only be seen through a microscope.

COLIFORM - Bacteria found in the large intestine; a coliform count is often used as an indicator of fecal contamination in water supplies.

E. COLI - A type of coliform bacteria present in the intestine of man and animals, the presence of which in water in sufficient quantity indicates fecal contamination.

FECAL BACTERIA - Organisms in human and animal waste associated with disease.

FILTRATION - Process by which bacteria are removed from water as it flows through tight soil or fine sand.

FISSURE - A narrow, deep crack in rock.

LIMESTONE - A white rock consisting of mostly calcium carbonate.

SCUM - Floating impurities found on top of liquids or bodies of water.

Worksheet A. Questions to be Answered by a Sanitary Survey

	Yes	No
1. Do potential sources of surface contamination exist		
a) above the site or in the watershed?	____	____
b) at the site?	____	____

If yes, determine these sources and

a) remove sources of contamination, and/or

b) protect the water supply, or

c) find a more acceptable water supply.

	Yes	No
2. Do potential sources of fecal contamination exist		
a) above the site or on the watershed?	____	____
b) at the site?	____	____

If yes, determine these sources and

a) analyze the water, or

b) remove sources of contamination.

If level of coliform bacteria greater than 10 organisms per 100ml of water,

a) water must be treated or

b) alternative source must be found.

	Yes	No
3. Does the water source have unacceptable chemical or physical qualities such as:		
a) color?	____	____
b) turbidity (1) all the time?	____	____
(2) after a rainstorm?	____	____
c) unpleasant odor?	____	____
d) a lot of salt?	____	____
e) excessive algae?	____	____
f) excessive flourides?	____	____
g) hardness?	____	____

If the answer is YES to any of these questions, study the water source carefully and analyze the water if possible. Generally, these conditions will make water unacceptable to the users and the source must either be treated or abandoned for a new one.

Physical Characteristics of the Location

Physical characteristics that contribute to the contamination of surface water can be recognized through a sanitary survey. To determine if a source is acceptable, a thorough study of the site and nearby areas must be done. If conditions indicate that contamination is likely, the water source should be tested to see if treatment is necessary. (See "Determining the Need for Water Treatment," RWS.3.P.1). Contaminants must either be removed or the water supply protected against them. If protection or removal is impossible, a more suitable source should be found. Physical conditions contributing to contamination of different types of surface sources are discussed below.

Springs. Springs can provide a very good source of water for a community supply. Generally, water from springs can be used without treatment if the source is adequately protected with a spring box. Not all water from springs is free from contamination. A sanitary survey of the spring site will help determine whether contamination is likely.

The first step in a sanitary survey of a spring site is to determine the physical conditions above the point where the water flows from the ground. If there are large openings or fissures in the bedrock above the spring, contamination of the spring from surface runoff may occur. Surface runoff enters the ground through the fissures and contaminates the spring water underground.

Find the true source of the spring. Many times, a small stream disappears into the ground through a fissure and emerges again at a lower elevation. What appears to be a spring actually may be surface water that has flowed underground for a short distance. The water is generally contaminated and may flow only during the wet season.

Determine if there are sources of potential fecal contamination. Livestock areas, septic tanks and other sewage disposal sites are sources of contamination. If they are located above the source or closer than 100m to it, contamination may occur and disease-causing bacteria can enter the water.

The second step in a sanitary survey is to study the area at the spring site. The type of soil may indicate that contamination is likely. Filtration may be poor if permeable soil deeper than 3m is within 15m of the spring. Water passes quickly through coarse soils and impurities are not filtered out. If this condition exists, or if there is any suspicion of contamination, a water analysis must be done.

A spring flowing from limestone or highly fractured rock may be subject to contamination. Earth movements create fissures and cracks in limestone allowing surface run-off to enter the ground rapidly with little or no filtration of impurities. If a spring flows from a limestone bed, check the water after a heavy rain. If it appears turbid, suspect surface contamination and either analyze the water or choose a better site.

Community members must always be consulted during a sanitary survey. Information from local people should be added to the information collected through observation. They will know about spring yields and reliability and about other local conditions.

Ponds and Lakes. A study of the characteristics of the watershed must be done to determine whether there are potential sources of contamination of pond and lake water. The watershed is the area within which rainfall flows over the surface of the ground into rivers, streams, ponds and lakes. An acceptable watershed must be free from human and animal wastes. An area that has latrines, septic tanks or animals is not appropriate for a watershed feeding a drinking water supply. Such an area is a source of fecal contamination which may make water unsafe to drink. A study of the watershed should also determine that there are no contaminated streams entering ponds to be used as water sources. A contaminated stream flowing in the watershed could lead into the water supply and make the water unfit for drinking.

The watershed should not support farming. On some farms, pesticides and chemical fertilizers are used to increase crop production. Rainfall carries these elements from the fields into the water source and contaminates it. Find out if fertilizers and pesticides are used on farms in the watershed area before choosing the water source. If a watershed has farms that use fertilizers and pesticides, the water source fed by it will most likely be unsuitable without treatment. If there are farms, erosion is likely to occur. The soil that enters the pond or lake will settle to the bottom and may cause it to fill up rapidly. This reduces the amount of water available to the users and limits the life of the pond. A better site should be chosen or trees and grass should be planted in the watershed to prevent soil from entering the water supply.

Heavy growths of algae in water may indicate of possible contamination. Algae grow in water with a high concentration of organic material nitrates and phosphates. Water supporting excessive algal growth should not be used as a water source until its quality is determined.

Rivers and Streams. Like ponds and lakes, the quality of water in rivers and streams is dependent on the characteristics of the watershed. The major difference is that stream and river watersheds are more extensive and much more difficult to control. Above a river intake, the watershed may support sewage disposal, animal grazing and farming. People may use the river for laundry and bathing. Such practices will adversely affect the water quality downstream. Where an intake is located below an inhabited area, the water quality should not be trusted. Only where an intake is located above inhabited areas can efficient watershed management take place. If possible sources of contamination exist upstream, then treatment will be necessary.

Roof Catchments. A sanitary survey can indicate potential sources of contamination in catchment systems. The first step in the sanitary survey is to determine the roofing material available. Tile and corrugated metal make the best collectors for drinking water. Water from thatched, tarred or lead roofs is likely to be very contaminated and very dirty. Catchment systems should not be installed where houses have roofs made from these materials. Find out if a suitable cistern is available. The cistern should be clean and covered to protect the water quality.

Bacteriological Quality of Water

An untreated water source should be as free from bacteriological contamination as possible. The greatest and most widespread source of such contamination is human and animal wastes, which is called fecal contamination. A sanitary survey determines the degree to which water sources may be subject to fecal contamination. To find out if water contains fecal bac teria, it is necessary to take a water sample and have it analyzed. (See "Taking A Wate Sample," RWS.3.P.2; "Analyzing a Water Sample," RWS.3.P.3; and "Determining the Need for Water Treat-ment," RWS.3.P.1).

Most fecal bacteria are members of a group called coliforms which include the organism E. Coli. The presence of E. Coli and other coliforms in water are indicators of fecal contamination. For an untreated water source to be acceptable, the level of fecal contamination must be low. The level of fecal con tamination can only be determined by a laboratory analysis. The technical note "Analyzing a Water Sample," RWS.3.P.3, describes standards for acceptable amounts of coliforms in water and explains methods for testing water. Generally, standards are no more than three coliform organisms in a 100ml sample for piped systems and no more than 10 organisms in a 100ml sample for nonpiped systems. Any source having over 10 coliform organisms per 100ml should be abandoned or the water treated.

Equipment for testing water may not be available and water analysis may be impossible. If so, observation can reveal characteristics that indicate bacteriological contamination. If there is a layer of scum on the water surface, suspect contamination. If excessive algae are growing in a pond or lake, there are organic impurities which may indicate the presence of fecal matter in the water. Speak to local health officials and village leaders to find out if there is a large number of cases of diarrheal illnesses. Many cases of diarrhea, especially among young children, may be an indication of contamination in the water source.

By simple measures such as removing obvious sources of contamination from a catchment area, fecal contamination can be controlled and eliminated. If contamination is not reduced, then the water source should be considered unacceptable.

Physical and Chemical Quality of Water

The bacteriological quality of water is the most important factor in determining the acceptability of a source. Many times, though, water is bacteriologically safe, it has physical or chemical characteristics that make it unpleasant or unattractive to the users. To determine the exact physical and chemical quality of water, laboratory analysis must be done. An evaluation of physical and chemical conditions can be made by doing a sanitary survey. A thorough sanitary survey can detect turbidity, color, odors, and tastes and help determine the acceptability of the water source.

Turbidity. Turbidity is the presence of suspended material such as clay, silt, organic and inorganic material which clouds or muddies water. Turbid water may be potable but often it is aesthetically unacceptable to users. Turbidity may also indicate contamination. A laboratory analysis should be done, if possible.

Color. Dissolved organic material from decaying vegetation and some inorganic material cause color in water. An excessive algal growth may cause some color. Color in water is generally not harmful but it is objectionable and may cause users not to drink the water. Highly colored water needs treatment.

Odors and Tastes. Odors and tastes in water come from algae, decomposing organic material, dissolved gases, salts and chemicals. These may be from domestic, agricultural or natural sources. Water that has a bad odor or a disagreeable taste will be rejected by a community for a different source.

Certain chemical properties of water can make a source unacceptable to the users. The chemical quality of water can only be determined by an analysis in a well-equipped laboratory which is unlikely to be located in a rural area. Because an analysis may be impossible, it is important in the sanitary survey to recognize some chemical qualities of water which may make users reject a source.

Water that contains a high degree of calcium and magnesium carbonates is called "hard." Hard water requires a great deal of soap for cleaning and washing clothes because it does not lather. Extra soap, which is costly, must be purchased to clean with hard water. Extra time and work is involved in scrubbing with hard water. Pipes may even become clogged with deposits from the water. For basic economic reasons, people may reject hard water unless it is "softened."

Where algae are abundant, phosphates and nitrates are likely to be present.

These come from chemical fertilizer and sewage, and can be very dangerous to health. A high nitrate content in water may cause blood problems in infants being fed on reconstituted milk formulas. The babies become blue as oxygen in their blood is lost.

High concentrations of flouride in water cause dental problems. Flouride can cause teeth to become brown and mottled after several years. In severe cases, pitting occurs. If these dental problems exist, suspect high levels of flouride in the water and look for an alternative water source. Concentrations of 1-2 mg/liter of fluoride are beneficial as the incidence of tooth decay is reduced by 65-70 percent.

Good quality water must be available to ensure the health of the people in a community. The bacteriological quality of water is especially important. Water used for drinking must be free from disease-causing fecal contamination. Fecal contamination can be prevented by the protection of water sources, by the removal of sources of contamination, and by the treatment of water. A thorough sanitary survey must determine the potential sources of contamination of a water source so that measures to protect the source can be developed. If a need for treatment is apparent from the sanitary survey, a water analysis should be done (see "Determining the Need for Water Treatment," RWS.3.P.1).

The chemical and physical quality of water is important. The problem is that only some chemical and physical properties can be determined through a sanitary survey. Generally, competent laboratory testing is needed.

In many rural areas, access to a laboratory for water testing is impossible. The sanitary survey may be the only possible study of the suitability of a water source. Therefore, the survey must be thorough and must rely on very careful observation and on basic information collected from discussions with local villagers.

Water for the World

Choosing Between Gravity Flow and Pumps

Technical Note No. RWS. 4.P.1

Water can be delivered from one point to another in four basic ways: hauling, pumping, gravity flow or a combination of these methods. Hauling is the least efficient method. It is labor intensive, very costly, and provides only minimal quantities of water. Pumping may require a great deal of energy and usually is more expensive to operate and maintain than gravity flow. Gravity flow is efficient, requires no additional energy and is economical to operate and maintain. It may, however, be expensive to construct initially.

Gravity flow systems usually restrict the source to a specific location. Pump systems provide much more flexibility in locating a source. A source suitable for gravity flow is more likely to require treatment than one using a pump because it is likely to be a spring or a surface source. Because of its dependability and low operation and maintenance costs, if the water is of satisfactory quality gravity flow should always be considered. The final decision to use a particular means of moving water must be based on comparison of costs including operation and maintenance as well as construction costs.

Evaluating Gravity Flow Versus Pumps

To choose between gravity flow and pumps, each type of system should be evaluated. Factors which should be included in this evaluation are:

- The amount of water needed by the village,
- The amount of water the source can produce,
- The water quality,
- The difference in elevation between the source and the highest point in the system, usually the top of the storage tank,
- The distance between the source and the point of storage,
- The obstacles between the source and the village,
- The alternative water sources that are available or could be made available,
- The type of power available and its cost,
- The estimated pumping head.

Worksheet A can be used to tabulate the needed information for all sources. A map should be made of the area identifying the sources in relation to the homes to be served. Any good, clear existing map can be used. The map should show land elevations, existing homes and buildings, roads and streets. Swamps, high groundwater areas, and rock zones should be added to the map. Digging trenches for pipes in such places will be difficult and costly.

Once the necessary information is obtained, gravity flow and pumped transmission lines can be compared and cost estimates, including operation and maintenance costs, can be compared. See "Designing a System of Gravity Flow," RWS.4.D.1, and "Determining Pumping Requirements," RWS.4.D.2, for information about how to size the respective systems.

Worksheet B is a form that can be used to make cost estimates for the transmission line. Prepare an estimate for each possible source. Worksheet C can be used to compare the costs of developing one source among two, three or more possible sources. When a satisfactory source from which water can be moved by gravity is found, every effort should be made to use it. Added pipeline length which may be required will be less costly in the long run than a pumped transmission line.

Worksheet A. Data Required for Choosing Between Gravity Flow and Pumps

1. Estimated present water needs in liters:

	Number of		Unit use	Total
Population	Persons	_____ x	_____ =	_____
School	Students	_____ x	_____ =	_____
Church	Attendees	_____ x	_____ =	_____
Large animals such as cows, oxen		_____ x	_____ =	_____
Small animals such as sheep, goats		_____ x	_____ =	_____
Public watering fountains		_____ x	_____ =	_____

Total present needs = _____

2. Estimated future water use:

Use a 20 year design life. If no better information is available, use a population growth factor of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of water use of 2 times the present use.

Population	Present use _____ x 4 = _____ liters
Institutions & public fountains	Present use _____ x 2 = _____ liters
Animals	Present use _____ x 1.25 = _____ liters

Total future water use = _____ liters/day

3. For each possible water source, determine or judge:

Water quality	_____
Sustained yield in liters per day	_____
Difference in elevation between source and highest point in system	_____
Distance between source and storage	_____
Obstacles between source and village	_____
Ease of construction of source protection and pipeline	_____

Worksheet B. Estimated Cost of Transmission Line Pump/Gravity Flow Delivery System

Item	Quantity	Unit Cost	Total Cost
Transmission Line Materials			
8-inch PVC pipe	____m	____	____
6-inch PVC pipe	____m	____	____
8-inch gate valve & box	____	____	____
6-inch gate valve & box	____	____	____
4-inch flush valve	____	____	____
Pressure reducing valves	____	____	____
Power source (electricity)	____	____	____
(fuel engine)	____	____	____
Pump & Controls	____		____
Pumphouse	____	____	____
Storage tank (____m^3)	____	____	____
		Transmission Line Materials	____
Labor			
Lay water lines	____	____	____
Construct pumphouse	____	____	____
Construct storage tank	____	____	____
Construct water source	____	____	____
(dug well)	____	____	____
(spring)	____	____	____
(surface)	____	____	____
Install pump	____	____	____
Install motor	____	____	____
		Labor	____
Equipment			
Pickup truck	____	____	____
Dump truck	____	____	____
Front end loader	____	____	____
Trencher	____	____	____
Backhoe	____	____	____
Crawler tractor	____	____	____
Compressor	____	____	____
Other ________	____	____	____
________	____	____	____
		Equipment	____
Cost Summary			
Sub-total Materials			____
Sub-total Labor			____
Sub-total Equipment			____
Sub-total project cost			____
Add contingency 20%			____
Total Project Cost			____

Worksheet C. Comparison of Costs for Transmission Lines

Source	Type System Gravity/Pump/Both	Transmission Line Cost	O&M Cost
A. ________	________	________	________
B. ________	________	________	________
C. ________	________	________	________
D. ________	________	________	________
E. ________	________	________	________
F. ________	________	________	________
G. ________	________	________	________

Source Selected ____________________

Water for the World

Designing a System of Gravity Flow
Technical Note No. RWS. 4.D.1

This technical note provides information on designing a simple, gravity flow piping system from a water source to a point of use, such as a water storage tank serving an adjacent community distribution point. The design of a distribution system to multiple points or to homes throughout a village is covered in "Designing Community Distribution Systems," RWS.4.D.4.

Whenever the water source is at a higher level than the point of water use, it may be possible to avoid mechanical pumps and allow the force of gravity to deliver the water. This is the preferred method for water delivery since the cost of operating and maintaining pumps is avoided. To design a gravity system, it is first necessary to accurately determine the height of the source above the point of use. The source must be higher for a gravity system to work. The difference in elevation between the source and point of storage is called the system head. This is one of the controlling factors in determining the amount of water that can be delivered. Other factors are the pipe diameter, pipe length, pipe material and rate of flow in the pipe.

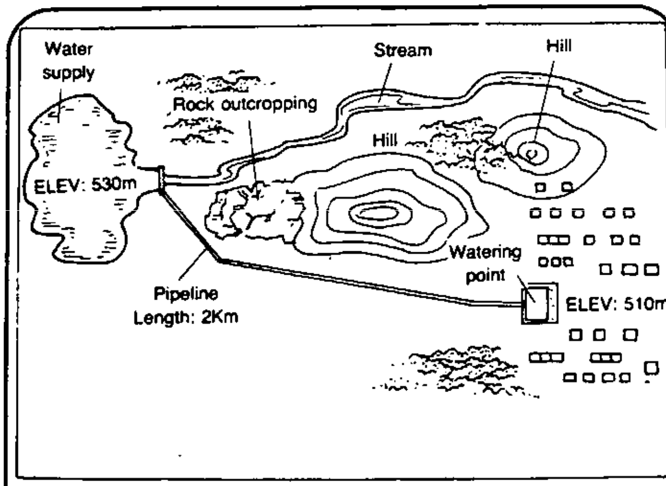

Figure 1. Location Map

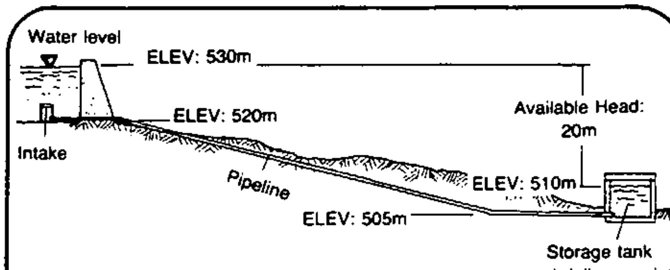

Figure 2. Profile of Pipeline

Preliminary Design Considerations

The first step in designing the system is to draw a map showing the location of the source in relation to the point of use and the distances in between. Obstacles should be shown, as should the elevations of land along the proposed conduit, particularly at the source, storage site, point of use and hills and washes in between. Figure 1 shows a map similar to that needed for a small project. Figure 2 is a profile showing elevations along the proposed conduit route.

There are two ways to conduct the water from the source to the point of use. These are open channel or piping under pressure. An open channel conduit is essentially a man-made stream. It should be carefully shaped and lined with concrete, bricks or indigenous material to make it more durable and enable the water to flow easily. This type of conduit can often be constructed using hand labor and indigenous materials. On the negative side, it must be built at a fairly uniform downhill slope. This condition may not exist due to barriers between the source and the point of use. More importantly, the water in an open conduit is open to contamination. For these reasons, a closed conduit or pressure pipeline is preferred.

A fundamental understanding of hydraulics is necessary to design a pressure pipeline. The force which pushes the water through a pipeline is known as "head" and is the height of water expressed as meters of water above any point being considered in the system. See Figure 2.

As water flows through the pipe, there is a small resistance to the flow caused by the roughness of the pipe material. This is known as "friction". Friction is also caused by sharp bends and constrictions in the pipeline. The energy required to overcome this friction is known as head loss. These losses increase as the amount of flow or the length of pipe is increased or as the diameter of pipe is decreased. This is shown in Figure 3.

A Design Example

As an example, suppose a rural community of 500 people is located as shown on the map in Figure 1 with the profile as shown in Figure 2. The small stream shown has an available flow of 10 liters per second as measured during the lowest flow. For the present, it has been decided to provide a public distribution point in conjunction with a storage tank. As soon as the community can find the resources, it plans to expand the system to serve individual homes. There are no buildings to be served other than private homes and water for animals will not be provided by the system. Based on this, it has been decided to size the transmission line and storage as if the system were to serve the individual homes right away. Water usage of 100 liters person/day is expected.

Using Worksheet A as a guide, follow these steps:

1. The estimated current daily water needed is 50000 liters/day.

2. Future use is estimated to be 200000 liters/day. This will be the volume of water used to size the tansmission line.

3. The storage reservoir is sized for future use at 200m^3. If this system were not to be expanded for a period of time, consideration would be given to providing less storage now with increased capacity to be added later.

4. The water supply has a continuous source and, because storage is being provided to meet peak demands, the transmission line can be sized to supply water over a 24-hour period.

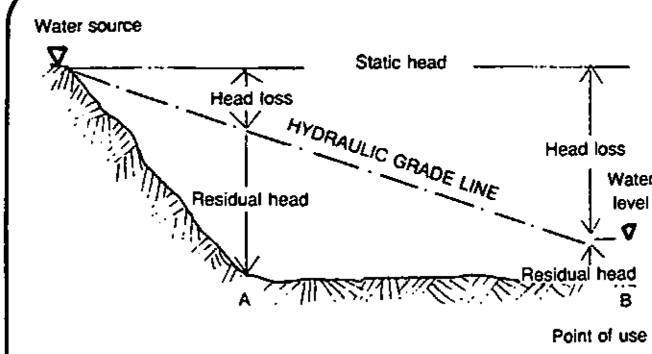

Figure 3. Available System Head

This allows for the minimum pipe size to be selected. In this case, a flow of 2.3 liters/second is needed. Since 10 liters/second is available, the source can provide the necessary flow.

5. Pipe size can now be determined based on the available head to drive the water to the point of use on the required flow and on the total length of pipe in the system.

a. The total length of pipe is determined by adding the measured length to the equivalent length including valves and fittings, shown in Table 2. The number of valves and fittings was estimated for this example. The total pipe length is 2038m.

b. The static head is the difference between the elevation of the source and the water level in the storage tank. In this case, it is 20m.

c. The head available to drive the water through the pipeline is the static head less a small amount of head held in reserve to help prevent a vacuum from occurring in the transmission line. It is recommended that at least 5m be available. This amount is used for this example so that available head is 9.8m.

d. Now use Table 1 to choose a pipe size. Read down the flow column to the flow required (2.3 liters/second). If the desired flow is listed, read across to the right as far as the first column which shows a lower head loss for that flow than is available from step 5c above. If the flow is not shown in the table, then follow the above steps for the next lower flow and the next higher flow. In this case, either flow

Table 1. Head Loss Table in Meters per 1000 Meters
Pipe Diameter in mm

Flow liters/ second	30 GI	30 AC/P	40 GI	40 AC/P	50 GI	50 AC/P	80 GI	80 AC/P	100 GI	100 AC/P
0.1	3.4	2.2	1.5	0.9	.34	0.22				
0.2	5.8	3.5	2.5	1.5	.59	.36	.12			
0.3	13	5.6	4.0	2.4	.9	.55	.12			
0.3	21	8	9	3	1.25	.75	.18	.1		
0.4	23	14	14	5.7	2.2	1.4	.3	.2		
0.5	34	21	19	8.6	3.4	2.1	.45	.3	.12	
0.6	48	30	20	12.5	4.6	3	.61	.4	.15	
0.7	61	39	27	16	6	3.9	.8	.51	.2	
0.8	80	50	35	22	8	5	1.2	7.0	.26	.17
0.9	100	61	42	27	9.9	6.1	1.4	0.9	.32	.2
1.0		75	51	32	13	7.5	1.7	1.1	.39	.4
1.1		90	62	38	15	9.4	2.0	1.3	.47	.3
1.2			73	45	18	11.0	2.5	1.5	.55	.35
1.3			83	54	20	13.5	2.75	1.75	.61	.4
1.4			100	60	24	15	3.2	2.1	.75	.48
1.5				68	28	17	3.7	2.4	.88	.55
1.6				75	30	19	4	2.6	.95	.60
1.7				88	34	22	4.6	2.9	1.1	.68
1.8				95	37	25	5.0	3.2	1.25	.72
1.9					40	27	5.6	3.5	1.3	.8
2.0					46	30	6.1	4.0	1.5	.90
2.5						44	8.7	6.0	2.2	1.35
3.0						60	14	8.4	3.0	1.9
3.5						75	18	11.5	6.2	2.5
4.0						105	23	15	8.3	3.3
5.0							37	26	12	5.0
6.0							50	31	16	7
7.0							67	42	20	9.5
10							130	80	30	18.5
15									70	45
20									125	70

[Note: Based on Hazen-Williams C of 130 for asbestos cement (AC) and plastic (P) and for a C of 100 for galvanized iron (GI).]

If the desired flow rate is not shown, then use an average of the actual flow rate to the next low and next high flow rate. EXAMPLE: For a flow rate of 4.6 liters/second and a 100mm pipe:

1. $\frac{4.0 \times 3.3}{4.6} = 2.9$

2. $\frac{5.0 \times 5.0}{4.6} = 5.4$

3. $\frac{2.9 + 5.4}{2} = 4.2$m head loss

Table 2. Friction Losses in Fittings
Equivalent Length of Straight Pipe Meters

Size mm	30	40	50	80	100
Gate valve-open	1.2	1.3	1.6	2.0	2.7
Elbow, 90 degree	6.7	7.5	8.6	11.1	13.1
Elbow, 45 degree	1.8	2.2	2.8	4.1	5.6
Tee, straight	4.7	5.7	7.8	12.1	17.1
Tee, through side	8.8	10.0	12.1	17.1	21.2
Check valve	13.1	15.2	19.1	27.1	38.2

requires the same pipe size, 80mm. If the next lower flow had allowed a smaller pipe size, then an interpolation would have been required, taking an average of the ratio of the actual flow to the next highest flow and the next lowest flow as shown in Table 1.

Other Factors in Designs

Factors other than pipe size must be considered when designing a transmission line. These include high and low points along the line and valving to facilitate operation and maintenance.

Even when a positive pressure is maintained by providing for a residual head, it is possible for air to collect at high points in a line. An air release valve should therefore be installed at the top of each rise as shown in Figure 4. Low points in the line should be equipped with a drain valve so that any sediment that collects can be flushed out. This is very important if the source contains sand or fine sediment.

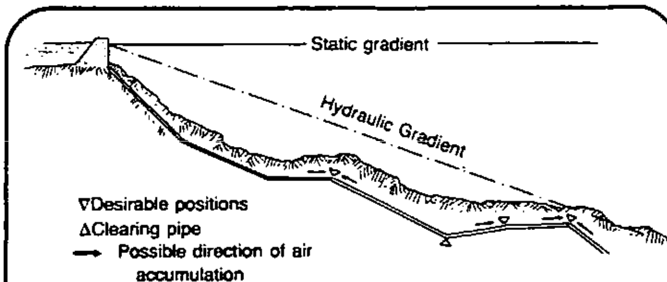

Figure 4. Desirable Positions for Air Valves on Pipeline

Gate valves should be placed in the line to permit system operation and repair. In a piped distribution network, valves are located so portions of the lines can be isolated for repair while the rest of the system is still in operation. With a simple gravity system, a failure anywhere in the line will put the entire system out of operation so a large number of valves are not needed. One valve should be placed at the source and a second near the storage tank or point of use. Additional valves located at intervals of 1000m may be desirable for quicker access to turn the system off should a break occur or to isolate portions of the line for testing purposes.

Worksheet A. Designing a System of Gravity Flow

1. Estimated present water needs in liters:

	Number of:		Unit Use	Total
Population	Persons	500	x 100	= 50000
School	Students	______	x ______	= ______
Church	Attendees	______	x ______	= ______
Commercial		______	x ______	= ______
Large animals (cows)		______	x ______	= ______
Small animals (sheep)		______	x ______	= ______
Public watering fountains		______	x ______	= ______

Total present water needs = 50000

2. Estimated future water use:

Use a 20-year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of use of 2 times.

Population	Present use 50,000	x 4 =	200000 liters
Institutions and public fountains	Present use ______	x 2 =	______ liters
Animals	Present use ______	x 1.25 =	______ liters

Total future water use = 200,000 liters/day

3. Storage tank:

Take the future water use and convert it to cubic meters:

Reservoir = $\frac{200{,}000}{1000}$ liters = 200 m^3

4. Source production requirements:

Determine the required production rate in liters/second

$$\text{Total daily demand} = \frac{200{,}000 \text{ liters}}{86400 \text{ second}} = 2.3 \text{ liters/second}$$

Assume water production over 24 hours or 86400 seconds

5. Pipe sizing:

a. To calculate the pipe size, first find the total equivalent length of pipe.

Total length = measured length + equivalent length of fittings

Equivalent length of pipe due to fittings (Table 2):

Fitting	Number	x	Equivalent length	=	
Gate valve	1	x	2.7m	=	2.7 m
Elbow, 90 degree	2	x	13.2	=	26.4 m
Elbow, 45 degree		x		=	m
Tee (straight)		x		=	m
Tee (through side)		x		=	m
Swing check valve	1	x	38.2	=	38.2 m

Total equivalent length = 67.3 m

Length of pipe from source to storage = 1971.0 m

Total pipe length = 2038 m

b. Determine static head:

Static head = elevation at source - elevation at top of storage

= 530 m - 510 m = 20 m

c. Find head available per 1000m to overcome friction:

$$\text{Head available} = \frac{\text{static head} - 5\text{m residual head}}{\text{Total pipe length in km}}$$

$$= \frac{20 \text{ m} - 5\text{m}}{2.038 \text{ km}} = 9.8 \text{ m/1000m}$$

d. Select a pipe size from Table 1 using the 24-hour flow in liters/second and the available head loss found in c. above.

	Flow liters per second	Head loss per 1000m	Pipe size	Type material	Select yes/no
Required	2.3	Available 9.8	mm		
Next low	2.0	6.1, 4.0	80 mm	GI P/AC	
Next high	2.5	8.7, 6.0	80 mm	CI P/AC	

From d. a pipe size of 80 mm is recommended for the transmission line as the head loss is too great for the next smaller pipe size.

Notes

Water for the World

Designing Structures for Springs
Technical Note No. RWS. 1.D.1

Protective structures are a very important part of developing springs as sources for a community water supply. A properly designed protective structure ensures an increased flow from the spring. To protect the spring, silt, clay and sand deposited at the spring outlet, and other material washed down from the slope by surface run-off, must be cleared away. When these materials are removed, water flow increases. Clearing away vegetation from the spring effluent will also allow better flow. A protective structure will improve the accessibility of the water. By channeling the spring flow into one collection area, a good quantity of water can be stored for the community. Spring water can be distributed to community standpipes or to individual houses. A third benefit of a protective structure is that it protects the spring water from contamination.

This technical note discusses the design of structures used to protect and develop springs for community water supplies and makes suggestions for spring development in a specific area. The design chosen for a particular project will depend on local conditions, materials available and spring yield. Read this entire technical note and refer to "Selecting a Source of Surface Water," RWS.1.P.3, before choosing a design that will best meet a community's needs.

The design process should result in the following three items which should be given to the construction supervisor:

1. A map of the area. Include the location of the spring; the locations of users' houses; distances from the spring to the users, elevations, and important landmarks. Figure 1 is a map of a small village with a spring located on high ground above it. A map of this type is useful in helping the people building the spring box locate the spring site.

Useful Definitions

DISCHARGE - The flow of water from an opening in the ground or from a pipe or other source.

EFFLUENT - At a spring site, the point from which water leaves the ground.

GROUT - A thin mortar used to fill chinks, as between tiles.

HEAD - Difference in water level between the inflow and outflow ends of a system.

HYDRAULIC GRADIENT - The measure of the decrease in head per unit of distance in the direction of flow.

MORTAR - A mixture of cement or lime with water in a basic proportion of 4 units of sand to 1 unit of cement or lime.

PERPENDICULAR - Exactly upright or vertical; at a right angle to a given line or plane.

PUDDLED CLAY - A mixture of clay with a little water so clay is workable.

REINFORCING ROD - Steel bars placed in concrete structures to give it tensile strength.

UNDERFLOW - Flow of water under a structure.

2. A list of all labor, materials and tools needed as shown in Table 1. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

3. A plan of the spring box with all dimensions as shown in Figure 2. This plan shows a top, side, and front view, and the dimensions of a cover for a spring box 1m x 1m x 1m.

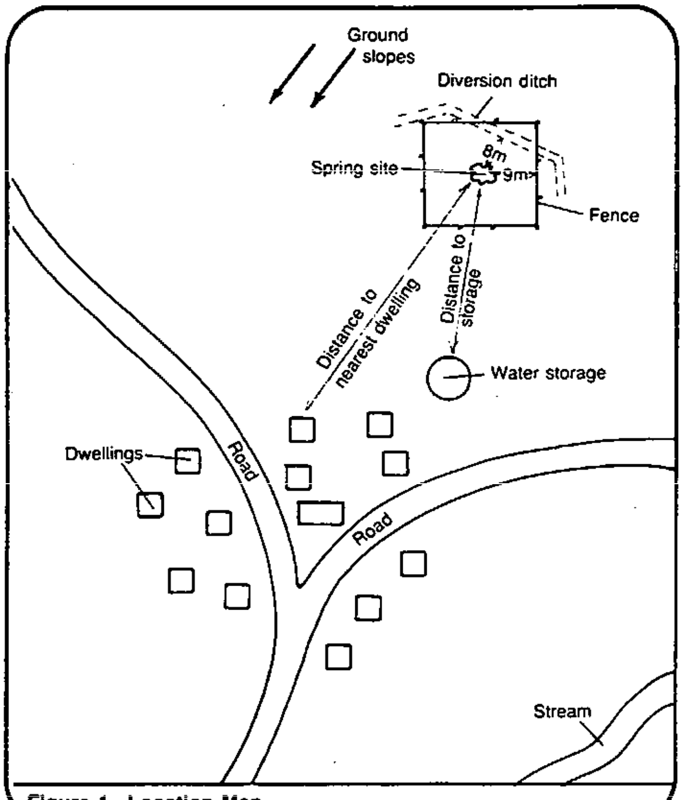

Figure 1. Location Map

Spring Box Design

There are several possible designs for spring boxes but, generally their basic features are similar. Spring boxes serve as collectors for spring water. They are sometimes used as storage tanks when a small number of people are being served and the source is located near the users. When larger numbers of people are served, the water collected in the spring box flows to larger storage tanks. The two basic types of spring boxes discussed in this paper are a box with one pervious side for collection of water from a hillside, and a box with a pervious bottom for collection of spring water flowing from a single opening on level ground. To determine which design to use dig out around the area until an impervious layer is reached, locate the source of the spring flow, and design to fit the situation.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	___	___
	Laborers	___	___
Supplies	Portland cement	___	___
	Clean sand and gravel, if available, or locally available sand and gravel	___	___
	Water (enough to make a stiff mixture)	___	___
	Wire mesh or reinforcing rods	___	___
	Galvanized steel or plastic pipe (for outlets, overflow, and collectors)	___	___
	Screening (for pipes)	___	___
	Boards and plywood (for building forms)	___	___
	Old motor oil or other lubricant (for oiling forms)	___	___
	Baling wire	___	___
	Nails	___	___
Tools	Shovels and picks (or other digging tools)	___	___
	Measuring tape or rods	___	___
	Hammer	___	___
	Saw	___	___
	Buckets	___	___
	Carpenter's square or equivalent (to make square edge)	___	___
	Mixing bin (for mixing concrete)	___	___
	Crowbar	___	___
	Pliers	___	___
	Pipe wrench	___	___
	Wheelbarrow	___	___
	Adjustable wrench	___	___
	Screwdriver	___	___
	Trowel	___	___

Total Estimated Cost ___

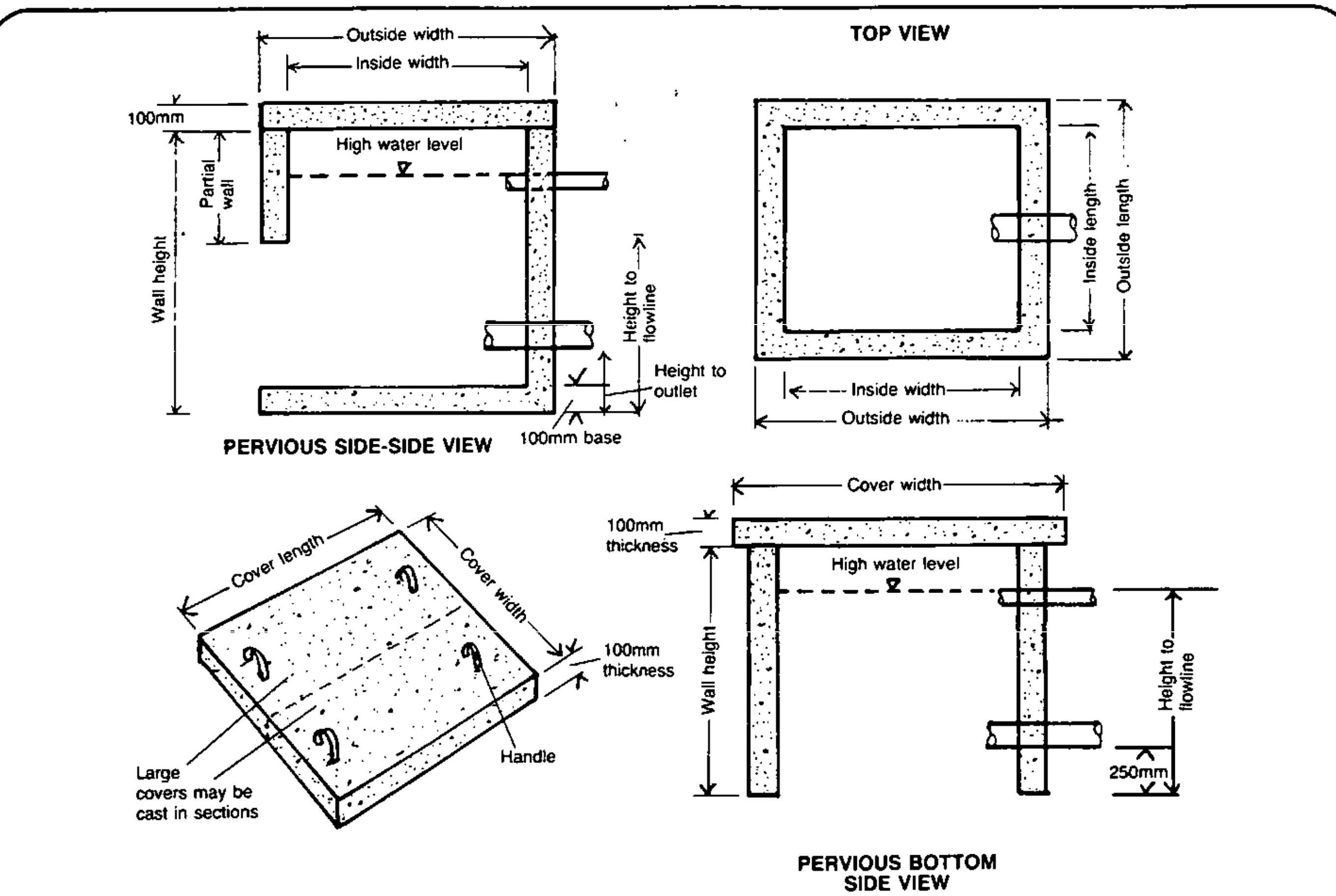

Figure 2. Spring Box Design

Spring Box with Open Side. A spring box with a pervious side is needed to protect springs flowing from hillsides. The area around the spring must be dug out so that all available flow is captured and channeled into the spring box.

After this has been done, a collection box can be built around the spring outlet as shown in Figure 3. The dug-out area should be lined with gravel. The gravel placed against the spring opening serves as a foundation for the box and prevents the spring water from washing soil away from the area. The gravel pack also filters suspended solids. The gravel-filled area should be between 0.5-1m wide depending on the size of the spring collection area. To ensure that no contamination reaches the water, the gravel pack should be at least 1m below the ground surface. This is done either by locating the spring catchment in the hillside or by raising the ground level with backfill.

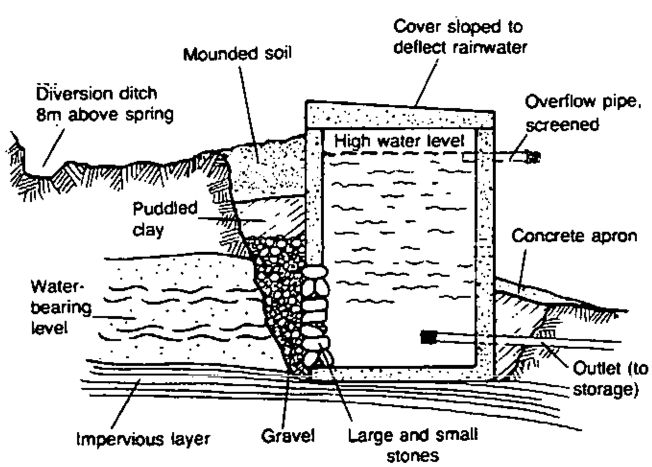

Figure 3. Spring Box with Open Side

Caution must be taken not to disturb ground formations when digging out around the spring. Without care, the flow of the spring may be deflected in another direction or into another fissure. The area must, however, be dug out enough so that the spring box fits into impermeable material. In cases where the box does not reach impermeable material, puddled clay should be used to seal the area around the sides of the spring box.

Spring Box with Open Bottom. If a spring flows through a fissure and emerges at one point on level ground, a spring box with an open bottom can be developed as shown in Figure 4. The area around the spring is dug out until an impermeable layer is reached. The area around the spring is then leveled and lined with gravel. The spring box is placed over the spring and gravel to collect the flow, and clay or concrete is packed around the box to prevent seepage between the ground and the box. Sometimes a small sump can be built at the bottom so that sediment settles in one place.

The design of both types of spring boxes is basically the same and includes the following features:

(a) a water-tight collection box constructed of concrete, brick, clay pipe or other material,
(b) a heavy removable cover that prevents contamination and provides access for cleaning,
(c) an overflow pipe, and
(d) a connection to a storage tank or directly to a distribution system.

The spring box with an open bottom is simpler and cheaper to construct. Generally, on level ground, flow from only one source must be captured and collection of all available flow is much easier. Costs are lower because less digging and fewer materials are required.

The spring box should be constructed at the spring site for easy installation. If the appropriate materials are available, the spring box should be made of concrete. Information on the use of concrete is included in Worksheet A. Three sides of the spring box must be impervious and depending on the type of spring selected for development, either the bottom or the

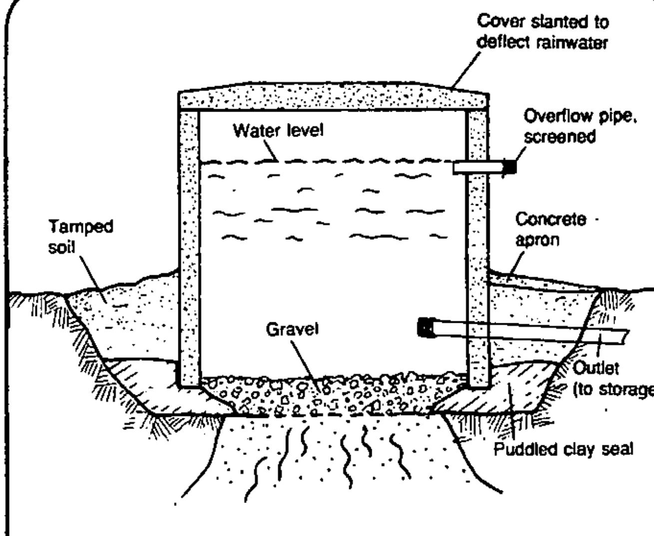

Figure 4. Spring Box with Open Bottom

upslope side must be pervious or open. The upslope side of an open sided spring box can be constructed partially with concrete and partially with large rocks and gravel as shown in Figure 3. Large rocks support the spring box and allow water to enter. Smaller stones should be used between the large rocks to close large openings so that sediment is filtered from the water.

If materials for building a concrete box are not available, or are expensive, there are alternatives that are particularly useful in developing a single source spring. Large prefabricated clay or concrete tubes, like regular spring boxes, can be placed around the spring. Water rises in the tube and flows out the outflow pipe. Rings for collecting spring water can even be constructed using bricks and mortar. Half or broken bricks can be used to build a ring as shown in Figure 5. The bricks are laid in a circular pattern, so that vertical joints do not line up. Spaces between the bricks are filled with gravel and mortar. Bricks are laid until a height of between 0.9-1.2m is reached. The diameter may vary but should be around 0.7-1.0m. An outlet and overflow pipe should be placed in the structure before installation and with reinforcement added. This type of structure is very practical and inexpensive to construct. Little cement is needed and locally available materials can be used.

Worksheet A. Calculating Quantities Needed for Concrete
(Calculations for a box 1m × 1m × 1.0m with open bottom)

Total volume of box = length (l) x width (w) x height (h)

Thickness of walls = 0.10m

1. Volume of top = l 1.2 m x w 1.2 m x t 0.10 m = 0.144 m^3
2. Volume of bottom = l 0 m x w 0 m x t 0 m = 0 m^2
3. Volume of two sides = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
4. Volume of two ends = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
5. Total volume = sum of steps 1, 2, 3, 4, 5 = 0.54 m^3
6. Unmixed volume of materials = total volume x 1.5; 0.54 m^3 x 1.5 = 0.81 m^3
7. Volume of each material (cement, sand, gravel, 1:2:3):

   cement: 0.167 x volume from Line 6 0.81 = 0.13 m^3 cement.
   sand: 0.33 x volume from Line 6 0.81 = 0.26 m^3 sand.
   gravel: 0.50 x volume from Line 6 0.81 = 0.4 m^3 gravel.

8. Number of 50kg bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$

   volume of cement 0.13m^3 - .033m^3/bag = 4 bags.

9. Volume of water = 28 liters x 4 bags of cement = 112 liters.

(NOTE: 1) Do not determine volume for an open side or bottom.
2) The top slab has a 0.1m overhang on each side.
3) The same calculations will be used to determine the quantity of materials for construction of a seepage wall.
4) To save cement a 1:2:4 mixture can be used.)

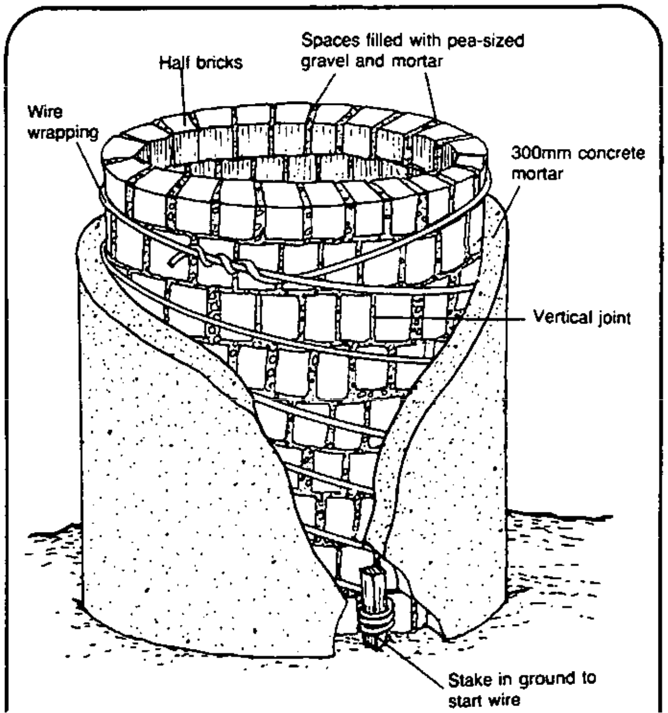

Figure 5. Brick Spring Box

The capacity of the spring box depends on whether it is being used for storage or pre-storage. If the spring box is used for storage, it should be large enough to hold a volume of water equal to the needs of the users over a 12-hour period. For example: If 100 people each use 25 liters of water per day, the amount of water consumed in 12 hours is 1250 liters. There are 1000 liters per m^3. Therefore the volume of the spring box should be 1.25m^3. (Volume = length x width x height). If the collection box is used only for pre-storage and water flows on to another storage tank, the collection box can be smaller.

A reinforced concrete cover must be constructed to protect the tank from outside contamination. The cover should be cast in place to ensure proper fit. It should extend over the spring box about 0.1m on each side so rain does not fall at the base of the spring box. The cover should be heavy enough so children cannot lift it off.

The spring box should have an overflow pipe. The pipe is placed a little below the maximum water level and at least 0.15m above the floor of the tank. If the pipe is above the maximum water level, water will not flow out and pressure is created in the tank. The pressure could cause a back-up and diversion of the spring. The overflow pipe should be covered with a screen fine enough to keep out mosquitoes and strong enough to keep out small animals. The size of the pipe depends on the flow of the spring. A rock drain or concrete slab should be placed outside the tank below the overflow pipe to prevent erosion near the base and to carry the water away from the spring. A pipe which extends 3-5m from the tank is desirable in order to keep the site free from still water.

An outlet pipe for connection to a distribution system should be located at least 0.1m above the bottom of the spring box to prevent a blockage due to sediment build-up. The pipe size depends on the grade to the storage tank and the spring flow. A general rule to follow is that at a one percent grade, a 30mm pipe should be used. A grade between 0.5 and one percent requires a 40mm pipe, while a 50mm pipe should be used for grades of less than 0.5 percent. In some cases the same pipe will be both outlet and overflow. The outlet pipe should slope downward for best flow.

After the spring box is installed, the space behind it must be filled with soil and gravel. The gravel is the bottom layer. On top of it, a water-tight layer should be formed to prevent the entrance of surface water. This can be done with concrete or puddled clay. Puddled clay is a mixture of clay and water formed into a layer 150mm thick. The layer is placed on the ground and worked in by trampling on it. Several layers of puddled clay should be placed behind the box.

After sealing the area, the box can either be completely covered with soil or stand above the ground surface. The box should be at least 0.30m above ground level so that run-off does not enter it. For further sanitary protection, a ditch should be dug at least 8m above the spring box to take surface water away from the area. The soil from the ditch should be piled on the downhill side to make a ridge and help keep surface water away. A fence around the area will keep animals from getting near the spring box and help prevent contamination and destruction of the area. The fence should have a radius of between 7-8m.

Seep Design

Designs for seep development are similar to those for spring boxes. Figure 6 shows the basic design. Intakes (collectors) are very important features of seep development. The collector system consists of small channels containing 100mm clay open-joint or 50mm plastic perforated pipe packed in gravel. The collectors are installed in the deepest part of the aquifer. They take advantage of the saturated ground above them for storage during times when the groundwater table is low. The perforations in the pipes must be about 5mm in diameter or large enough to collect sufficient water but small enough to prevent suspended matter from entering the pipes. In fine and medium-sized sand, perforated pipe should be packed in gravel but suspended material often will enter the pipe in spite of the gravel.

To prevent clogging, the collectors should be sized so that the velocity of water flow in them is between 0.5m per second and 1m per second. See "Methods of Delivering Water," RWS.4.M.

Water collected by the pipes is channeled to the spring box through a gravel pack. The collectors must extend across the entire width and length of the water-bearing zone and should be perpendicular to the flow of the aquifer. These intakes should extend below the water-bearing zones to collect the maximum amount of water and permit free flow into the collector. The advantage of a collector system is that water seeping over a large area can be channeled into a central storage basin.

Clean-out pipes to flush sediment from the collection pipes should be attached to the collection pipes. To install clean-out pipes, add a length of pipe to the far end of the collection pipe. At the end of this length, place an elbow joint facing upwards and attach a vertical length of pipe.

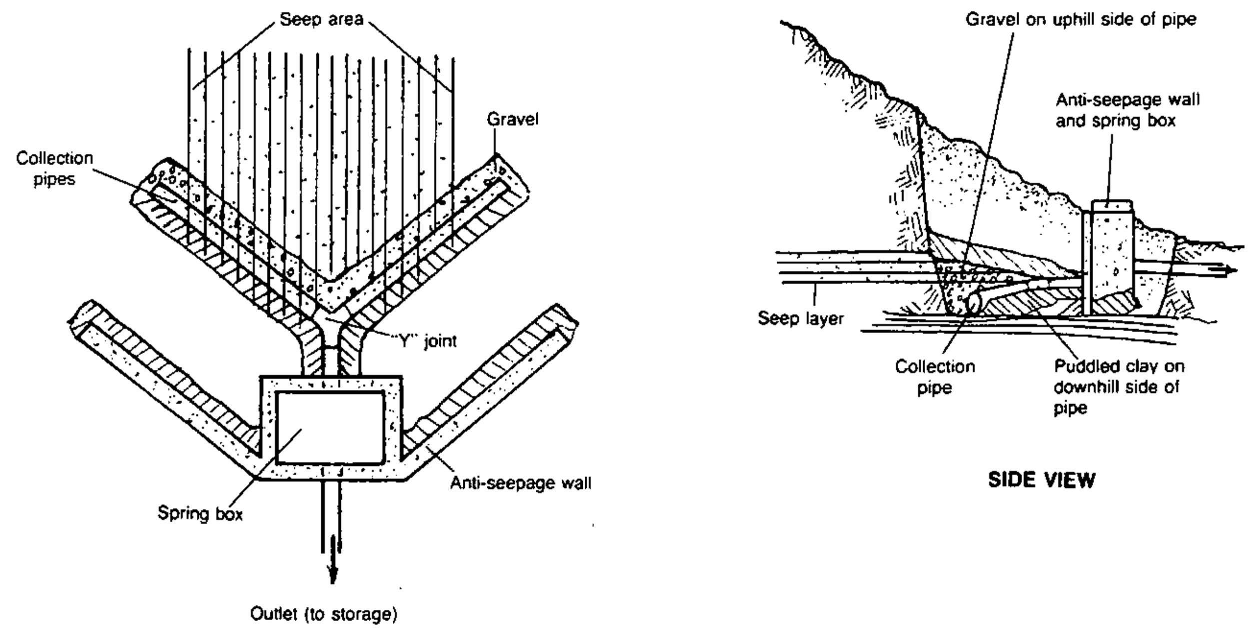

Figure 6. Seepage Collection System

The pipe should extend a little above the ground and be capped. If the collector system clogs, water can be added to the clean-out pipes to flush out the system.

For seep development, a cutoff wall of clay, concrete or other impervious material should be constructed. The cutoff is usually constructed as a large "V" pointing downhill with wing walls extending into the hill to prevent water from escaping. The cutoff should extend down into impervious material to force the flowing water to move to the collection point and to prevent loss of water due to underflow.

The use of concrete for the cutoff wall is best but most expensive. A wall 0.15m thick will ensure adequate strength against increased flow. The height of the cutoff wall depends on the size of the flow being collected. If desired, a spring box may be constructed inside the "V" shaped meeting of two walls as shown in Figure 7. The spring box will provide a settling basin for sediment removal and storage. The spring box should be designed so that water enters it

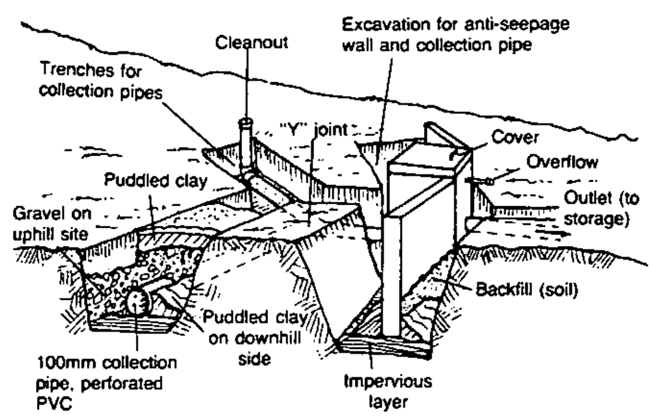

Figure 7. Basic Design Feature of a Seep Collection System

through openings in the upper wall. These openings must be screened to prevent entrance of debris.

Puddled clay instead of concrete can be used to form the cutoff wall. The clay is piled up and tamped down to form an impervious wall. It acts as a small dam which prevents spring water from flowing away from the collection area. The clay cutoff wall works as well as the cement wall and is much cheaper and easier to install. Good impervious clay should be available if this type of cutoff wall is chosen.

An outlet pipe is installed to move water from the collection point to storage. The diameter of the pipe depends on the grade to storage and will generally range between 30-50mm. To determine the correct pipe size, see "Methods of Delivering Water," RWS.4.M. The outlet pipe for a spring box or simple collection wall should be at least 150mm from the bottom of the collection area. A watertight connection should be made where the pipe leaves the spring box or goes through the cutoff wall. As in the case of spring boxes, the outlet pipe must be screened with small mesh wire. Because of the cost, this type of structure should be used only where seeps cover an extensive area. Skilled laborers will be needed for construction.

Horizontal Well Design

Horizontal wells are very simple and can be quite inexpensive. In order to use a horizontal well, an aquifer must have a steep slope or hydraulic gradient. Steep hydraulic gradients generally are found in chilly, sloping land and follow the ground surface. Horizontal wells, shown in Figure 8, are installed in much the same manner as vertical driven and jetted wells. See "Designing Driven Wells," RWS.2.D.2, and "Designing Jetted Wells," RWS.2.D.3 for specific design features.

A horizontal well can be driven if the spring flows from an aquifer in permeable ground. A pipe with an open end or with perforated drive points is driven into the aquifer horizontally or at a shallow slope to tap it at a point higher than its normal discharge. In some soils, the pipe can be driven by hand. Generally the pipe is driven using machinery.

"Designing Driven Wells," RWS.2.D.2, outlines the steps in designing a driven well. These same steps should be followed in designing horizontal wells. One design difference is that extra care must be taken

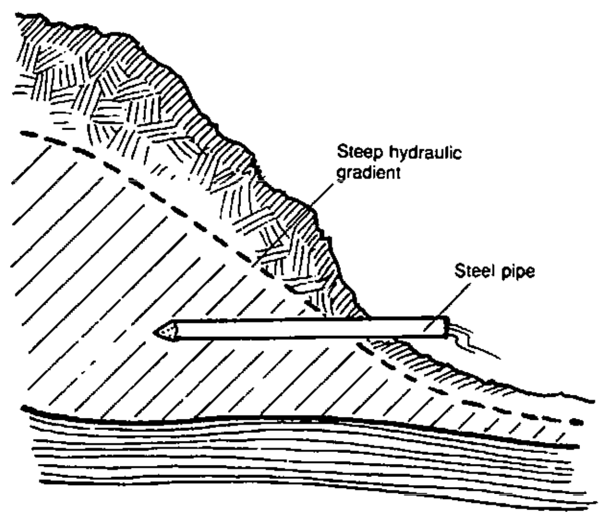

Figure 8. Horizontal Well

to avoid leakage between the driven pipe and the ground. If exterior flow occurs, it can be stopped by forcing clay or grout into the space, or by digging by hand 1m back along the pipe and installing a concrete cutoff wall. The wall should have a diameter of $0.6m^2$ and no more than 0.05m thick. After the concrete slab hardens, the dug-out area should be packed and backfilled with clay.

If the aquifer that feeds the spring is behind a rock layer, driving a horizontal well will be very difficult if not impossible. In this case, a jetted horizontal well will have to be installed. "Designing Jetted Wells," RWS.2.D.3, explains the process of jetting wells. The problem is that horizontal well drilling is different from vertical drilling, and may be too difficult for inexperienced people. Drilled horizontal wells should only be considered when there are no other reasonable alternatives.

Materials List

In addition to a location map and design drawings, give the person in charge of construction a materials list similar to Table 1 showing the number of laborers, types and quantities of materials needed to construct the spring protection. Some quantities will have to be determined in the field by the person in charge of construction.

Concrete. Concrete is the major material used in the construction of spring boxes and cutoff walls. Concrete is a mixture of Portland cement, clean sand, and gravel in a fixed proportion. The proportion generally used is one part cement, two parts sand, and three parts gravel (1:2:3). Water is used to mix the concrete. Twenty-eight liters of water should be used for each bag of cement. Worksheet A will help determine the amount of materials needed. Use the worksheet in making the following calculations.

1. Calculate the volume of mixed concrete needed (length x width x thickness; Worksheet A, Lines 1-5).

2. Multiply this number by 1.5 to get the total volume of dry loose material (cement, sand and gravel) needed (Worksheet A, Line 6).

3. Add the numbers in the proportion in order to find the fraction of the total needed for each material (1:2:3 = 6, so 1/6 of the mixture should be cement, 2/6 sand, and 3/6 gravel. In decimals, this is 0.167 cement, 0.33 sand, and 0.50 gravel).

4. Determine the amount of each material needed by multiplying the volume of dry mix from step 2 by the proportional amount for each material (1/6 x volume of dry mix = total amount of cement needed; Worksheet A, Line 7).

5. Divide the volume of cement needed by .033m^3 (33 liters), the amount of cement in a 50kg bag, to find the number of bags of cement required. When determining the amount of cement, figure to the largest whole number (Worksheet A, Line 8).

6. An extra quantity of cement should be figured into the total for use in grouting and sealing areas around the outlet pipes.

7. Calculate the amount of water needed to mix the concrete (28 liters of water per bag of cement; Worksheet A, Line 9).

8. Extra gravel will be needed for backfill of areas behind springs. Graded gravel is preferable, but local materials can be used if necessary. Calculate the volume of the area to be backfilled by taking length x width x height of area.

Reinforced Concrete. Concrete can be reinfored to give it extra strength. This is best done with wire mesh or specially made steel rods. Reinforced concrete sections must be at least 0.10cm thick. Reinforced concrete should be used for all spring box covers and for the walls of seep structures. If wire mesh is used, the quantity needed will be approximately equal to the area of the slab being constructed. If steel bars (rerod) are used, they should be placed in the wooden form before the concrete is poured. 10mm diameter rods should be used.

The reinforcing rod should be located as follows:

- So that the rods are at least 25mm (0.25m) from the form in all places;
- So that the rebar rests in the lower part of the cover; two-thirds the distance from the top or .70mm from the top of a 100mm slab;
- So that a 150mm (0.15m) space lies between a parallel rods in a grid pattern as shown in Figure 9.

Where the reinforcing rods cross, they should be tied together with wire at the point of intersection.

To determine the number of reinforcing bars, divide the total length or width of the spring box cover by 0.15m (distance between bars). For example, $\frac{1.2\text{m}}{0.15\text{m}}$ = 8 bars.

To determine the length of each bar, subtract 0.05m (0.025m each side) from the total length or width of the cover. For example, 1.2m - 0.05m = 1.15m.

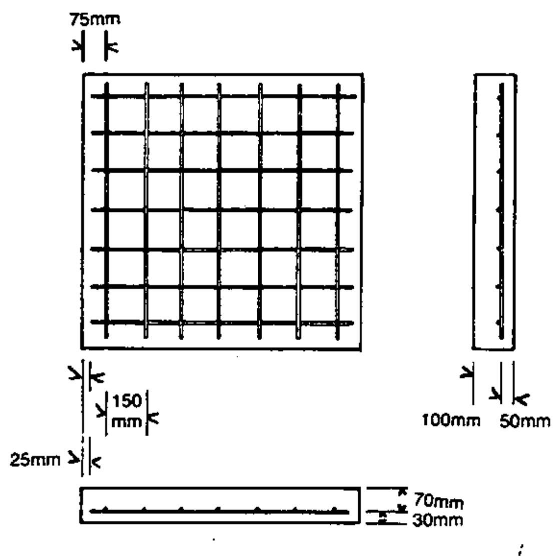

Figure 9. Placement of Rebar In Concrete Slab

Pipes. Outlet pipes can be of galvanized, steel, or plastic depending on what is available. Galvanized steel is preferable because of its strength. Steel pipe lasts longer and does not shatter like plastic pipe. Intake pipes should be either clay, perforated plastic open-joint cement or in some cases, bamboo. The choice again will depend on availability of materials and cost. The pipe should have a minimum diameter of 50mm to be sure that an adequate supply of water enters the collection system. All pipes must be laid at a uniform grade to prevent air lock in the system.

When labor requirements, materials, and tools have been decided on, prepare a materials list similar to Table 1 and give it to the construction supervisor.

Important Considerations

Spring protection should ensure that the source is always protected from contamination. Before attempting to develop a spring, conduct a sanitary survey as described in "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2. Follow the guidelines for measuring the quantity of available water present in "Selecting a Source of Surface Water," RWS.1.P.3, to be sure that the source will meet community needs. The preliminary work described in these technical notes should be done before designing a protective structure.

The choice of the structure for spring protection depends on the geologic conditions of the area, the type of spring, the materials available, and the skill level of available labor. Spring boxes are easy to design and require little construction expertise, although workers should have some construction experience. Driven horizontal wells are also easy and inexpensive to develop although some expertise is needed to complete a successful well.

Structures for seeps are more difficult to design and require that workers have a much higher level of construction experience. The cost of developing a seep may be very high depending on the length of the retaining wall and the amount of pipe needed for intakes.

Water for the World

Constructing Structures for Springs

Technical Note No. RWS. 1.C.1

There are two important reasons to build structures for springs and seeps. First, they protect the water from contamination caused by surface run-off and by contact with people or animals. Secondly, the structures provide a point of collection and storage for water. Water from springs and seeps is stored so it will be readily available to the users. This technical note discusses the construction of spring boxes and seep collection systems and outlines the construction steps to follow. The steps are basic to small construction projects and should be followed for the construction of most spring structures.

Useful Definitions

CONVEX - Curving outward like the surface of a sphere.

DISINFECTION - The process of destroying harmful bacteria.

EFFLUENCE - An opening from which water flows.

PUDDLED CLAY - A mixture of clay and a little bit of water used to make something watertight.

UNDERFLOW - Flow of water under a structure.

VOIDS - Open spaces in a material.

Materials Needed

Before construction begins, the project designer should give you the following items:

(1). A map of the area, including the location of the spring; locations of users' houses; and distances from the spring to the users, elevations,

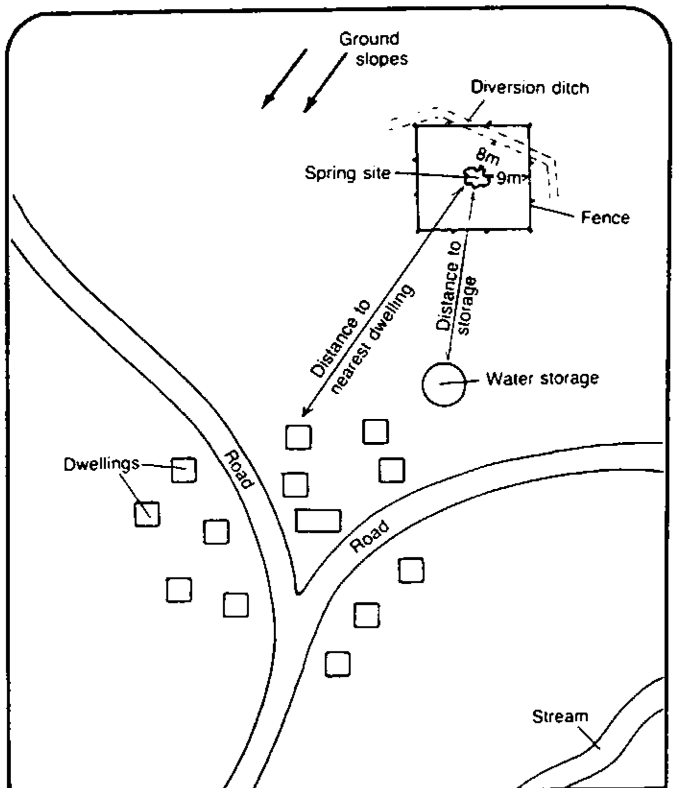

Figure 1. Location Map

and important landmarks. Figure 1 is a map of a small village with a spring located on high ground above it. Use your map to locate the construction site for the spring box.

(2) A list of all labor, materials and tools needed as shown in Table 1. Ensure that all needed materials are available and at the work site before work begins. Make sure that adequate quantities of materials are available to prevent construction delays.

(3) A plan of the spring box with all dimensions as shown in Figure 2. This plan shows a top, side, and front view, and the dimensions of a cover for a spring box 1m x 1m x 1m.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	___ ___	___ ___
Supplies	Portland cement Clean sand and gravel, if available, or locally available sand and gravel. Water (enough to make a stiff mixture) Wire mesh or reinforcing rods Galvanized steel or plastic pipe (for outlets, overflow, and collectors) Screening (for pipes) Boards and plywood (for building forms) Old motor oil or other lubricant (for oiling forms) Baling wire Nails	___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Tools	Shovels and picks (or other digging tools) Measuring tape or rods Hammer Saw Buckets Carpenter's square or equivalent (to make square edge) Mixing bin (for mixing concrete) Crowbar Pliers Pipe wrench Wheelbarrow Adjustable wrench Screwdriver Trowel	___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Total Estimated Cost ____

General Construction Steps

Follow the construction steps below. Refer to the diagrams noted during the construction process.

1. Locate the spring site and with measuring tape, cord and wooden stakes, or pointed sticks, mark out the construction area as shown in Figure 3.

2. Dig out and clean the area around the spring to ensure a good flow. If the spring flows from a hillside, dig into the hill far enough to determine the origin of the spring flow. Where water is flowing from more than one opening, dig back far enough to ensure that all the water flows into the collecting area. If the flow cannot be channeled to the collection area because openings are too separated, drains will have to be installed. Information on the installation of drains appears in the section on the development of seep collection systems.

Flow from several sources may be diverted to one opening by digging far enough back into the hill. When digging out around the spring, watch to see if flow from the major openings increases or if flow from minor seeps stops. These signs indicate that the spring flow is becoming centralized and that most of the water can be collected

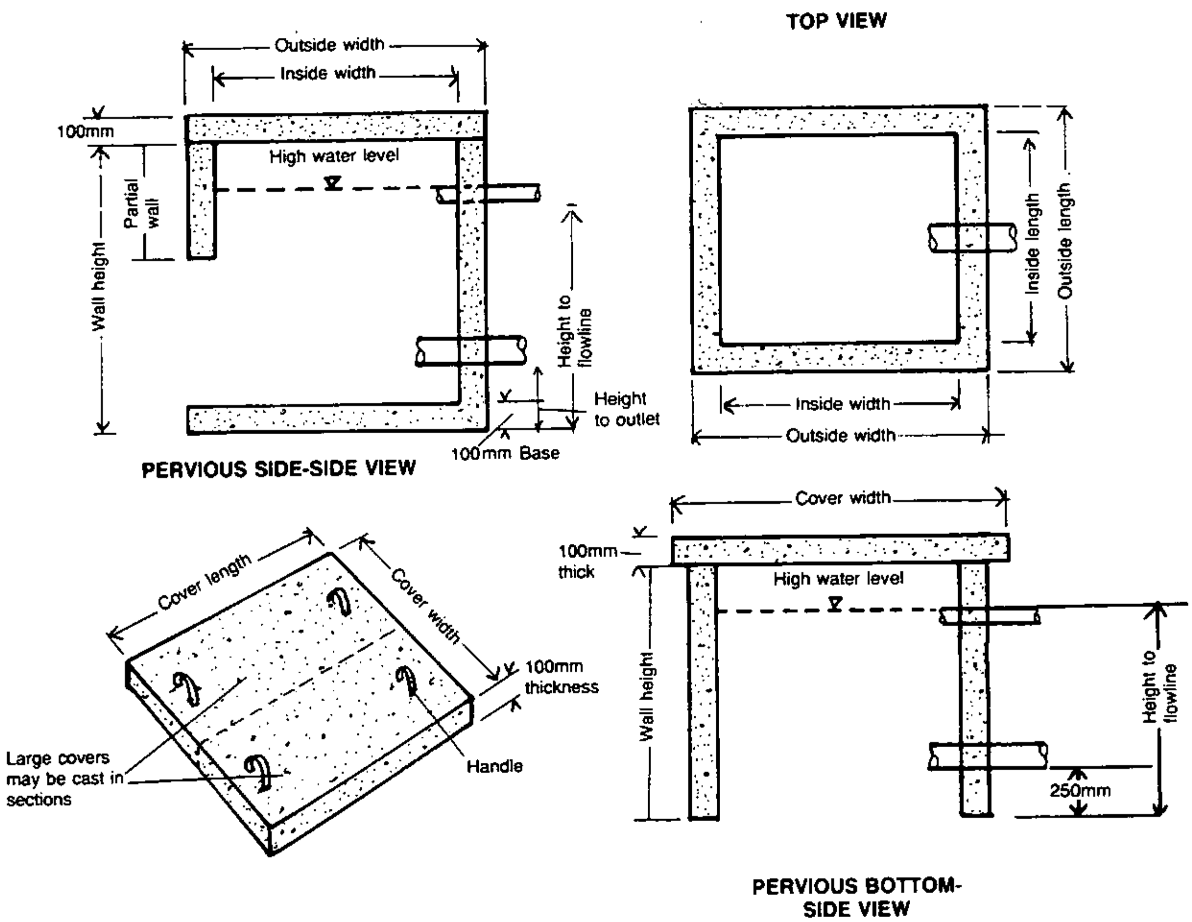

Figure 2. Spring Box Design

from one point. The goal is to collect all available water from the spring. It is generally easier to collect water from one opening than from several.

Dig down deep enough to reach an impervious layer. An impervious layer makes a good foundation for the spring box, and provides a better surface for a seal against underflow. If an impervious layer cannot be reached, attempt to construct the box in the most impermeable soil you can find.

3. Pile loose stones and gravel against the spring before putting in the spring box. The stones serve as a foundation for the spring box and help support the ground near the spring opening to prevent dirt from washing away. They also provide some sedimentation. For fast flowing springs, large stones with gravel between them should be placed around the spring to prepare a good solid base. Figure 4 shows an example of gravel and stone placed between the spring box and the spring.

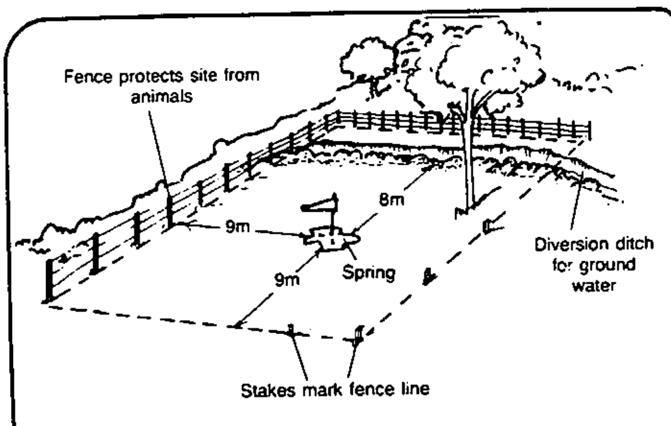

Figure 3. Preparation of Spring Box Site

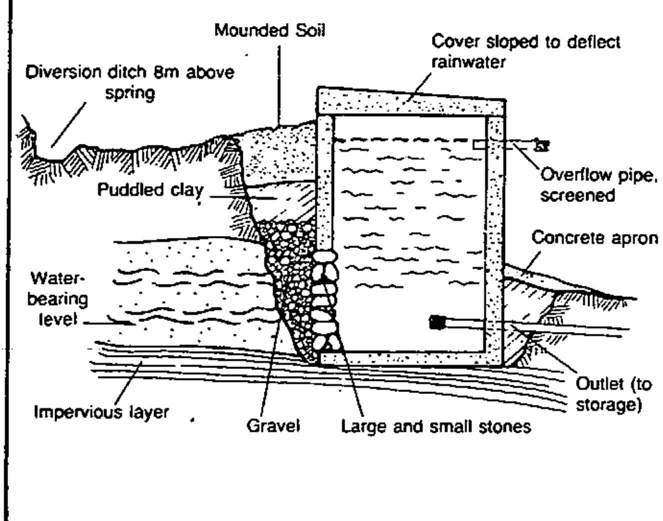

Figure 4. Spring Box with Open Side

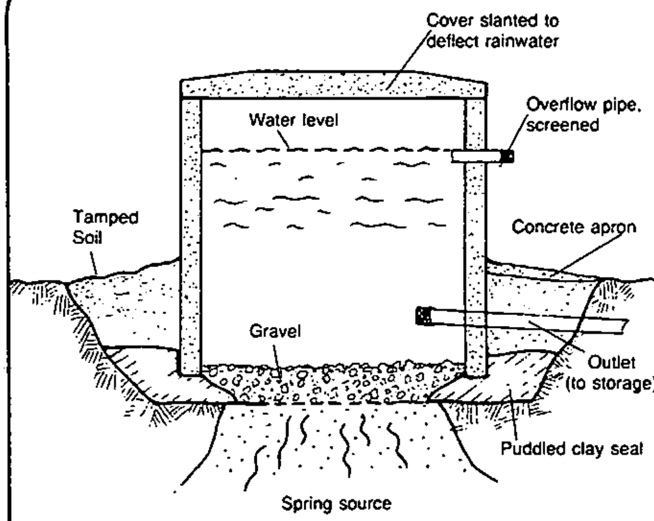

Figure 5. Spring Box with Open Bottom

If a spring flows from a single opening on level ground, dig out around the opening to form a basin. Be sure to dig down to impervious material to form the base. Line the basin with gravel so that the water flows through it before it enters the spring box. This is shown in Figure 5.

4. Approximately 8m above the spring site dig a trench for diverting surface run-off. The trench must be large enough to catch surface flows from heavy rains. If large stones are available in the construction area, use them to line the diversion trench to increase the rate of run-off and prevent erosion.

5. Mark off an area about 9m by 9m for a fence. Place the fence posts 1m apart and string the fence. A fence is useful to prevent animals from frequenting the spring site.

Concrete Construction Steps

In order to have a strong structure, concrete must cure at least seven days. Strength increases with curing time. Therefore, construction of the spring box should begin at the site during the first day of work. If the concrete is poured on the first day, seven days will be available for site preparation before the spring box is put in place. Be sure that all tools and materials needed to build the forms and mix the concrete are at the construction site.

1. Build wooden forms. Cut wood to the appropriate sizes and set up the forms on a level surface. The outside dimensions of the forms should be 0.1m larger than the inside dimensions. A form with an open bottom should be built for a spring flowing from one spot on level ground. For springs from hillsides, a spring box form with a partially open back must be constructed as shown in Figures 6 and 7. The size of the opening depends on the area which must be covered to collect the water. When building forms for a box with a bottom, be sure to set the inside forms 0.1m above the bottom for the floor. This is done by nailing the inside form to the outside form so that it hangs 0.1m above the floor. Make holes in the forms for the outflow and overflow pipes. Place small pieces of pipe in them so that correctly sized holes are left in the spring box as the concrete sets. A form for the spring box cover must also be built. Build all forms at the site.

Forms must be well secured and braced before pouring the concrete. Cement is heavy and the forms will separate if the bracing is not strong enough. One useful method is to tie the braces together with wire as shown in Figures 6 and 7. Drill holes in the forms and place wire through them. Using a stick, as shown, twist the wire to tighten it and force the forms together.

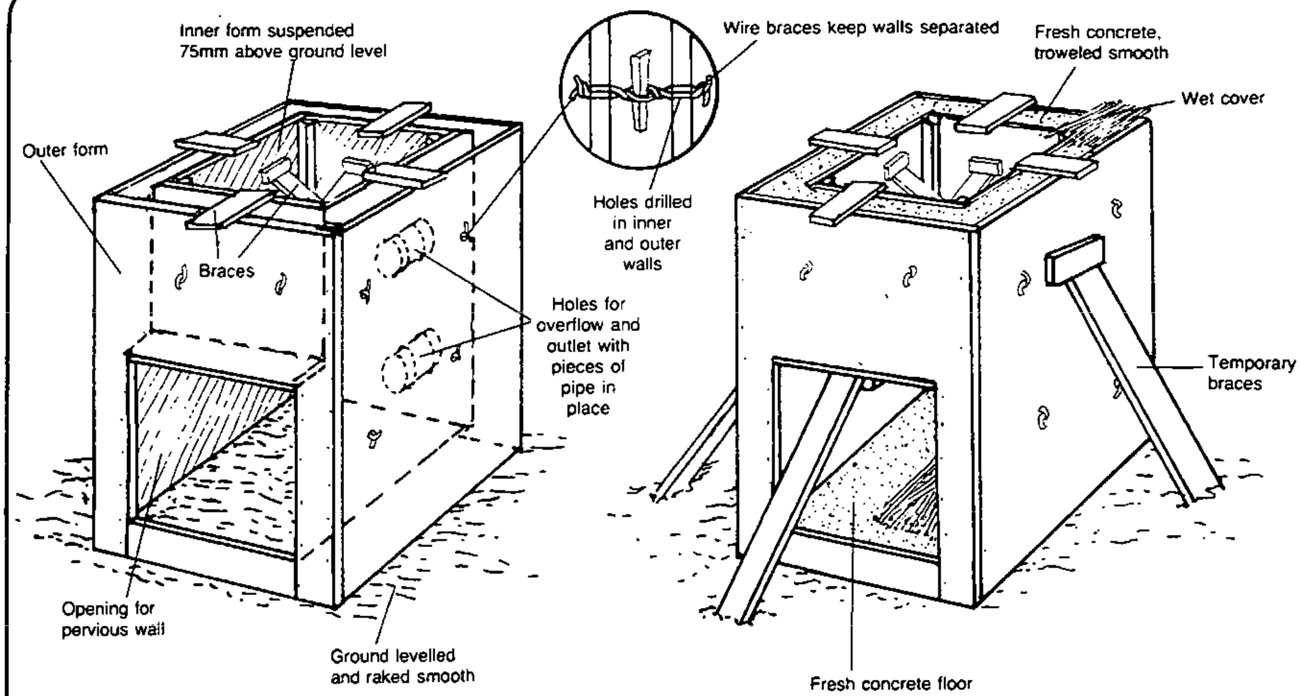

Figure 6. Forms for Spring Box with Open Side

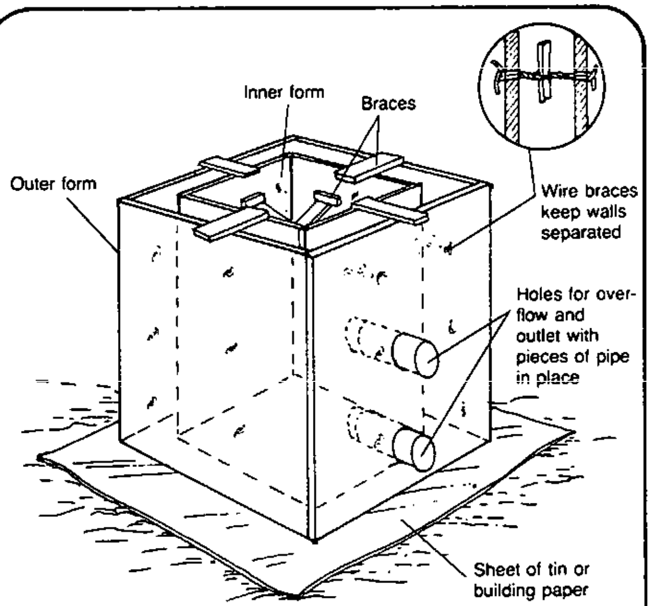

Figure 7. Forms for Spring Box with Open Bottom

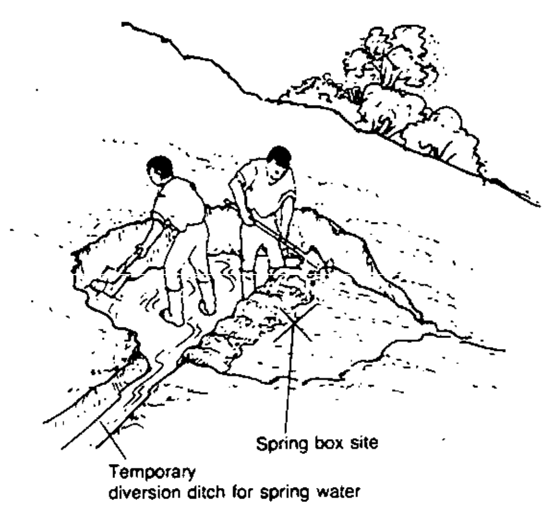

Figure 8. Excavating Spring Site

2. Set the forms in place. They should be either at the permanent site of the spring box or nearby so it will not be difficult to move the completed structure. If the forms are set and concrete is poured at the permanent site, water must be diverted from the area. This usually can be done easily by digging a small diversion ditch, as shown in Figure 8. Make sure that no water reaches the forms so that the concrete can cure.

If water diversion is difficult, build the forms and pour concrete on a level spot very near the spring. Once the concrete dries, remove the forms and set the completed structure in place. This will require six to eight people.

3. Oil the forms. Put old motor oil on the wooden forms so the concrete will not stick to them.

4. Prepare the reinforcing rods in a grid pattern for placement in the forms for the spring box cover. Make sure there is 0.15m between the parallel bars and that the rods are securely tied together with wire. Then position the reinforcing rods in the form. See Figure 9 for an example of reinforcing rod placement in the spring box cover. Major reinforcing is not needed for the spring box walls but some minor reinforcing around the perimeter of the walls is good to prevent small cracks in the cement. Four bars tied together to form a square should be placed in the forms.

5. Mix the concrete in a proportion of one part cement, two parts sand and three parts gravel (1:2:3). Add just enough water to form a thick paste. Too much water produces weak concrete. In order to save cement, a mixture of 1:2:4 can be used. This mixture is effective with high quality gravel.

6. Pour the concrete into the forms. Tamp the concrete to be sure that the forms are filled completely and that there are no voids or air pockets that can weaken it. Smooth all surfaces. Smooth the concrete for the spring box cover so the middle is a little higher than the sides (convex shape), as shown in Figure 10. This will allow water to run off the cover away from the spring box.

7. Cover the concrete with canvas, burlap, empty cement bags, plastic, straw or some other protective material to prevent it from losing moisture. The covering should be kept wet so water from the concrete is not absorbed. If concrete becomes dry, it no longer hardens, its strength is lost, and it begins to crack. Keep the cover on for seven days or as long as the concrete is curing.

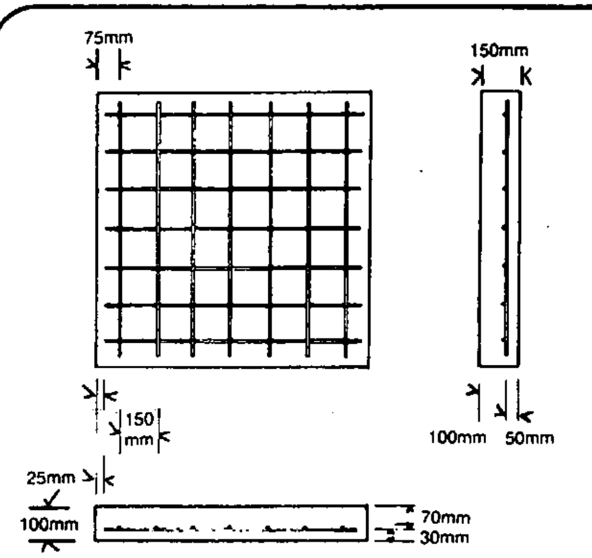

Figure 9. Placement of Rebar in Concrete Slab

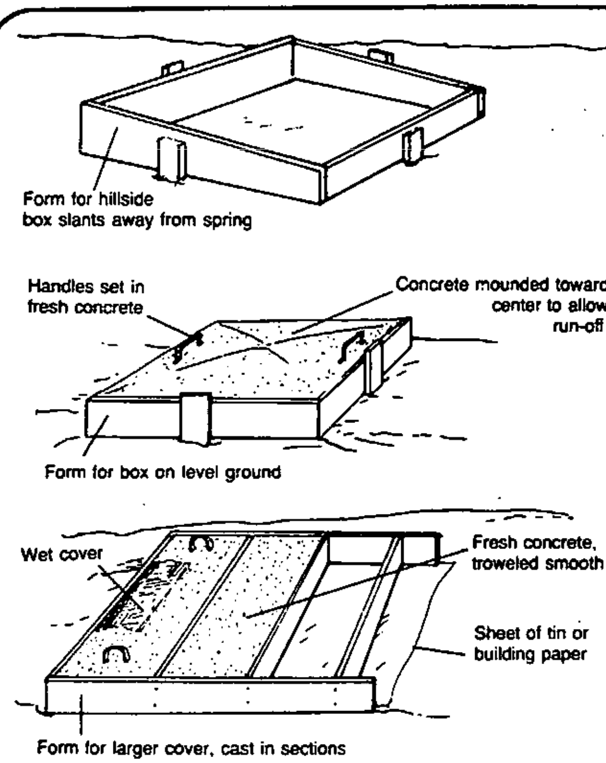

Figure 10. Forms for Spring Box Cover

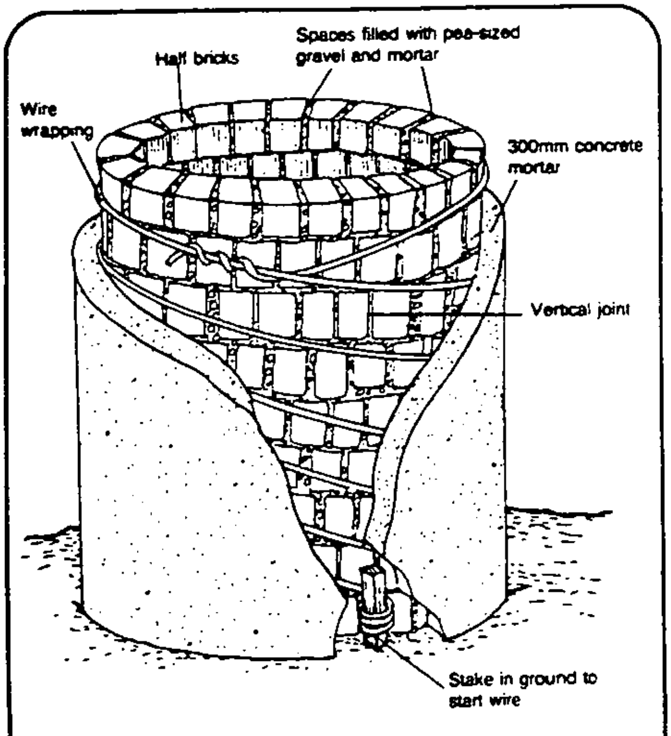

Figure 11. Brick Spring Box

8. Let the concrete structures set for seven days, wetting the concrete at least daily. After seven days, the forms can be removed and the box can be installed.

When constructing a masonry ring to protect a spring, follow the construction steps listed below.

1. Mark out a circle on the ground the diameter of the proposed masonry ring.

2. Using half bricks, place a circle of brick around the outside of the ring. Whole bricks broken in half or broken bricks can be used for the structure. In some places, broken bricks are available free.

3. Fill the spaces between the bricks with pea gravel and mortar mixed in a proportion of 1 part cement to 3 parts sand. As mortar is applied, add the next line of bricks. Be sure the vertical joints do not line up.

4. When reaching the desired height, strengthen the structure using baling, barbed or any available wire. Put a stake in the ground next to the ring and attach the wire to it. Wrap the wire around the ring several times as shown in Figure 11. Once the wire is wrapped around, secure and cut it.

5. Mix mortar in the proportion of 1 part cement to 3 parts sand. Cover the outside of the ring with a layer of mortar. The layer should be thick enough to cover the wire completely.

6. A circular cover should be built. Follow the same techniques as for the construction of concrete spring box covers.

Installing a Spring Box

The spring box must be installed correctly to ensure that it fits on a solid, impervious base and that a seal with the ground is created to prevent water seeping under the structure.

1. Place the spring box in position to collect the flow from the spring. If the flow comes from a hillside, the back of the spring box will be open. Stones should be placed at the back of the box to provide support for the structure and to allow water to enter the spring box. Figure 4 shows the placement of open-jointed rock in a completely installed spring box on a hillside. On level ground, be sure that the spring box has a solid foundation of imprevious material. Place gravel around the box or in the basin so that water flows through it before entering the box.

2. Seal the area where the spring box makes contact with the ground. Use concrete or puddled clay to form a seal that prevents water from seeping under the box.

3. Be sure that the area where the spring flows from the ground is well lined with gravel, then backfill the dug out area with gravel. The gravel fill should reach as high as the inlet opening in the spring box so that the water flowing into the structure passes though gravel. In Figure 4, the gravel layer reaches the same level as the open stone wall. For spring boxes on level ground, gravel backfill is unnecessary.

4. Place the pipes in the spring box. Remove the pipe pieces used to

form the holes and put in the pipe needed for outflow and overflow. On both sides of the wall, use concrete to seal around the pipes so water does not leak out from around them. Place screening over the pipe openings and secure it with wire.

5. Disinfect the inside of the spring box with a chlorine solution. Before the spring box is closed, wash its walls with chlorine. Follow the directions for disinfection in "Disinfecting Wells," RWS.2.C.9.

6. Place the cover on the spring box.

7. Backfill around the area with puddled clay and soil. On a hillside, place layers of puddled clay over the gravel so that they slope away from the spring box. The clay layer should nearly reach the top of the spring box and should be tamped down firmly to make the ground as impervious as possible. If only soil were used for backfill, it would have to be as least 1.5-2m deep so that contaminated water could not reach the gravel layer. For springs on level ground, clay should be placed around the box. The clay foundation should slope away from the spring box so that water runs away from the spring outlet.

8. Backfill the remaining areas with soil to complete the installation.

Constructing Seep Collection System

Sometimes springs flow from many openings over a large area. To collect the water, a system of collectors made of perforated pipe, an anti-seepage wall, and a spring box must be built.

The collectors must extend on both sides of the spring box and anti-seepage wall. Figure 12 shows an example. To install collectors dig trenches into the water-bearing soil until an impervious layer is reached. In this way, water is taken from the deepest part of the aquifer and most of the available water can be collected. The trenches should extend the necessary length for collecting all available water and should be about 1m wide.

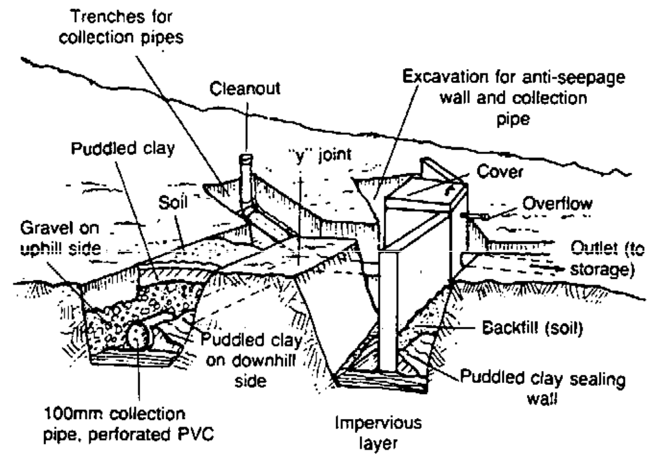

Figure 12. Seep Collection System

Lay 50-100mm diameter plastic perforated pipe or 100mm clay pipe in the trenches. Perforations in the plastic pipe should be about 3mm in diameter. On the uphill side of the trench, place enough gravel to cover the pipe. On the downhill side, build up a small clay wall to support the pipe. The pipe should have a 1 percent slope (0.01m slope per 1m distance) toward the point of collection. Flexible plastic tubing with slots already formed should be used if available. It is light and can be cut with a handsaw.

Clean-out pipes should be installed in the collection system. Attach lengths of pipe to the ends of the collection pipes. At the end of the clean-out pipes, place an elbow joint to which a vertical length of pipe is connected as shown in Figure 12. The pipe extends above ground level and is capped.

The next step is to build a concrete or impervious clay cutoff or anti-seepage wall. Dig down to an impervious layer for a good foundation. Make the forms for the cutoff wall 0.15m thick. Figure 13 shows a concrete cutoff wall 1.2m long and 0.9m high. Follow the same procedures for constructing the cutoff wall as for the spring box. There must be a good seal between the wall and the ground so that no water seeps underneath. Water must be

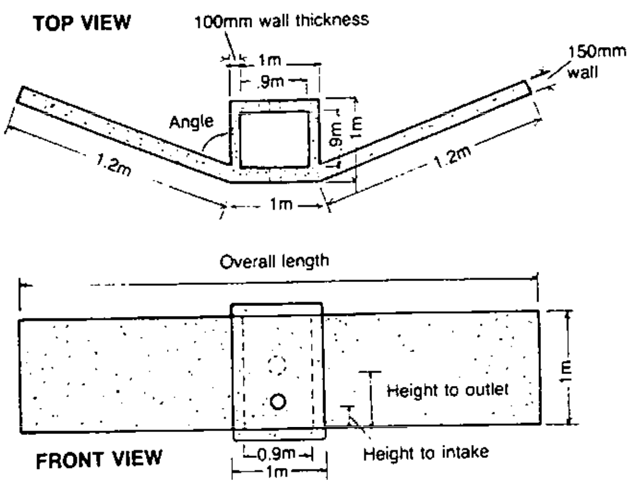

Figure 13. Anti-Seepage Wall and Collection Box

directed into the trenches and collectors. A small spring box can be built at the inside angle of the winged-wall with the wall forming two sides. If a spring box is built, the forms must be set at the same time as the cutoff wall. Water must be diverted from the construction area by small ditches for the seven days needed for the concrete to dry. Forms must be well braced and have holes for the inflow and outflow pipes as shown in Figure 14. Always pour the seep collection wall and spring box in place. The structure will be much too heavy to move after casting.

When using clay, be sure to remove any debris from the site and tamp the clay well so that the small dam or wall does not let water seep through. The clay walls should be built like walls of a dam with a 2:1 or 3:1 slope. Put

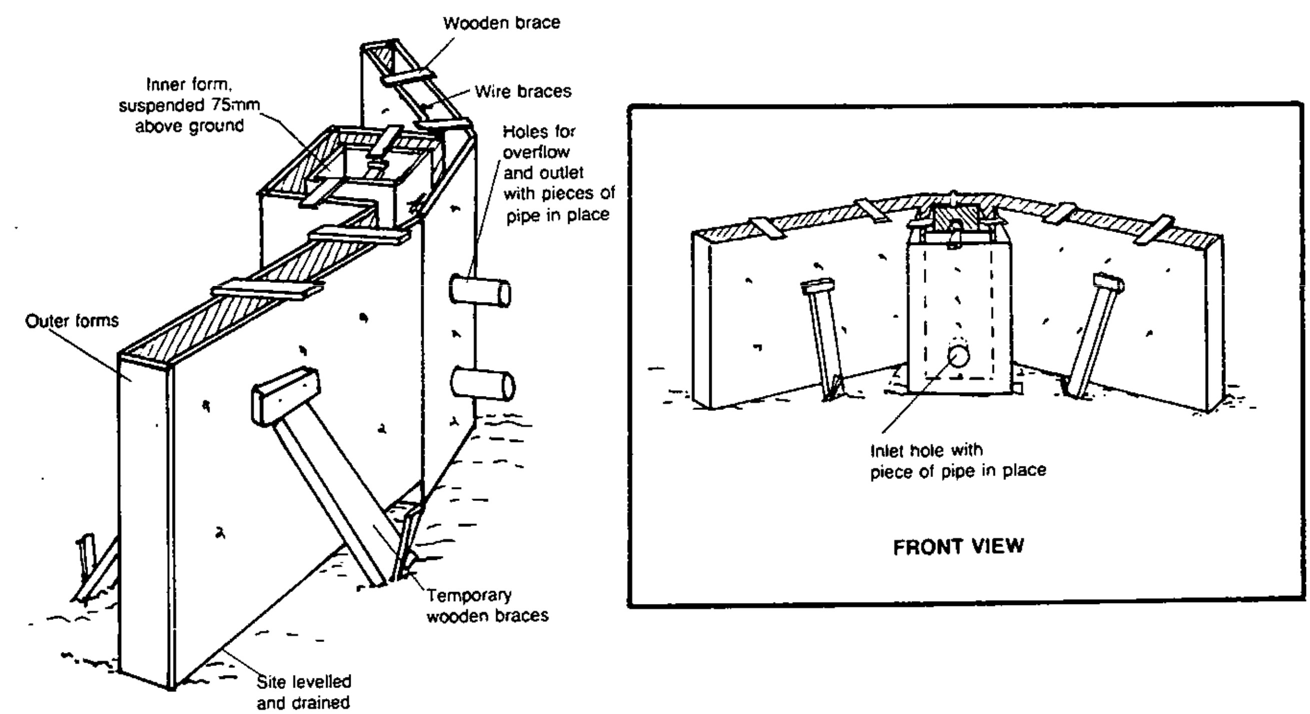

Figure 14. Forms for Anti-Seepage Wall and Collection Box

the clay down in layers 150mm thick and tamp each layer down well to ensure good compaction. Keep the clay moist. Lay and tamp each 150mm layer until the maximum height is reached. The walls should be well bonded to the spring box.

The construction of a seep collection system is more difficult and expensive than a simple spring box. Installation of collectors requires more work and some experience. Once the collectors are installed, however, the construction of the seep cutoff wall is no different from spring box construction. The same steps must be followed, the same mixture of concrete used and the same general rules for curing concrete and for placement must be followed.

Water for the World

Designing Intakes for Rivers and Streams

Technical Note No. RWS. 1.D.3

The installation of intakes makes water from rivers and streams more accessible. Water can easily be pumped from an intake to a community distribution system. Long walks to carry water are no longer necessary. The installation of an intake should lead to increased consumption of water which should, in turn, mean improved health for the community.

Intakes must be designed correctly if they are to function properly. A well-designed intake should provide good quality water in abundant quantities. An intake should be inexpensive to install and operate and require as little skilled supervision as possible for its construction and maintenance. This technical note describes the design of three types of intakes: infiltration intakes, gravity flow intakes, and direct pumping intakes. It should be used with "Choosing Where to Place Intakes," RWS.1.P.4, which discusses site selection for and placement of intakes.

The design process should result in the following three items which should be given to the construction supervisor:

1. A map showing the location of the proposed intake. Figure 1 is a sample location map for an infiltration gallery.

2. A list of all labor, materials and tools needed as shown in Tables 1, 2, and 3. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

3. Detail drawings of the intake to be constructed with all dimensions similar to the one shown for a winged-wall collector in Figure 8.

Useful Definitions

ABUTMENT - A structure supporting a bridge or walkway.

CASING - Lining for wells made either with concrete rings, bricks, or pipe to strengthen the walls of the well and prevent contaminants from entering.

GALLERIES - Long narrow trenches or ditches through which water passes.

INFILTRATION - The process of water passing from the surface through the soil and into groundwater reservoirs.

PRECAST - A concrete structure formed and cast somewhere other than its intended place of use and moved into place when ready.

REINFORCED CONCRETE - Concrete containing reinforcing bars or wire mesh to give it extra strength.

VITRIFIED CLAY PIPE - Clay that is baked and glazed in a very high heat.

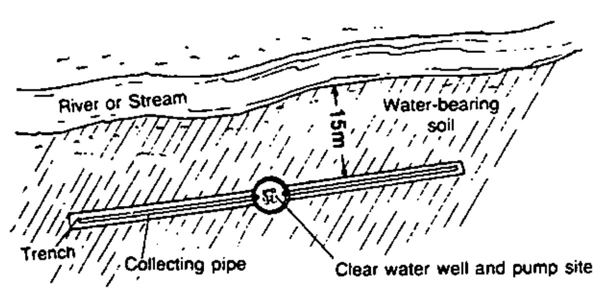

Figure 1. Location Map for Infiltration System

Table 1. Sample Materials List for Infiltration Systems

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Plastic (PVC) pipe, 50mm, or clay tile or concrete pipe, 10mm Hand or mechanical pump Sand and gravel (for filter beds) String Wooden stakes Sludge pump (if necessary)	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____
Tools	Shovels, picks, digging sticks (for digging well) Small hand drill Hammer Nails Measuring tape Carpenter's level Measuring rod Bucket	____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____

(NOTE: For additional materials needed, see "Constructing Dug Wells," RWS.2.C.1)

Table 2. Sample Materials List for Gravity Flow System

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Portland cement Clean sand and gravel, if available, or locally available sand and gravel Water (enough to make a stiff mixture) Reinforcing rod, 8mm Lumber (for forms) Nails Rope and pulley Tripod Tie wire or clamp Wire mesh screen, 10mm Pipe, plastic or galvanized	____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
Tools	Shovels, picks, digging sticks Measuring tape Wire cutters Hacksaw Hammer Bucket	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____

Table 3. Sample Materials List for Permanent Direct Pumping System

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Laborers	____	____
Supplies	Bricks - seconds can be used for half bricks	____	____
	Portland cement	____	____
	Clean sand and gravel, if available, or locally available sand and gravel	____	____
	Water (enough to make a stiff mixture)	____	____
	Lumber (2.5cm x 15cm; 5cm x 150cm; 10cm x 10cm)	____	____
	Tripod	____	____
	Rope and pulley	____	____
	Barbed wire	____	____
	Log	____	____
	Mechanical pump	____	____
	Pipe and elbow joint (couplings)	____	____
	Wire mesh screen, 10mm	____	____
	Tie wire	____	____
	Clamp	____	____
	Nails	____	____
	Pipe glue	____	____
Tools	Shovels, picks, digging sticks	____	____

Design of Infiltration Intakes

One type of intake is designed so that water from a stream or river passes through the ground and into storage. These are called infiltration intakes because the water collected is filtered as it passes through the ground. The water is generally free from contamination and needs no treatment. The two infiltration intake designs discussed in this section are a well dug in a river bank, and infiltration galleries.

Figure 2 shows a well dug in a river bank of sand and gravel. The well's distance from the stream depends on the type of soil in the stream bank. If the ground contains semi-porous material such as clay, the well can be located only a few meters from the bank. Filtration takes place rapidly in clay so the well can be located closer to the stream. Since water flow is slow in clay, a close location ensures adequate recharge. In more porous soils, such as coarse sand and gravel, the well should be located further than 15m from the bank. An average distance in semi-coarse soils made up of some clay and silt is 15m.

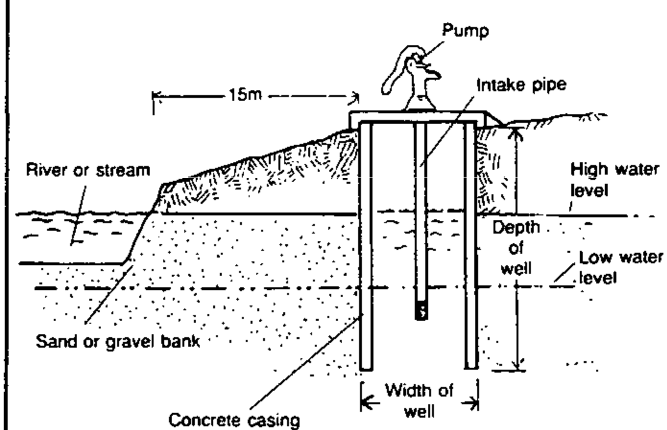

Figure 2. Riverside Well Intake

Water is pumped from the well to the users. During pumping the water enters the well and the groundwater table is lowered. When the groundwater table falls below river level, river water enters the aquifer. As pumping continues, this water flows through the ground, is filtered, and eventually enters the well.

The well should be dug at least 0.5m deeper than the floor of the stream bed and should be lined with concrete rings or bricks and mortar. A hand pump or power pump is installed to pump water from the well to the users. This design is good for small systems with fewer than 150 users. Design information for the well and different types of casing is in "Designing Dug Wells," RWS.2.D.1.

If the infiltration method is to be used to supply water to a larger population, infiltration galleries should be constructed. Infiltration galleries collect water from an area parallel to a river bank through collection pipes. These pipes move the water into a clear water well where it is held for pumping to a distribution system. Figures 3, 4 and 5 show examples of infiltration galleries. The primary design components are: (a) an excavated trench, (b) collecting pipes, (c) a filter bed, and (d) a clear water well.

Excavated Trenches. The infiltration gallery can be located on the stream bank as shown in Figure 3. Trenches should be parallel to the stream or river in water-bearing soil. The trenches' distance from the stream depends on the makeup of the soil. If the soil is a mixture of sand and gravel that is not very coarse, the infiltration galleries can be placed 15m from the stream. Follow the same rules in placing trenches as for riverside wells. The trench should be dug during the dry season when the water table is lowest to ensure that adequate quantities of water are tapped for year-round flow. A depth of 1m below the lowest water table level is sufficient. The trench must slope so that water runs into the storage well. A one percent slope is sufficient for the design (one percent slope = one centimeter per meter). Because trenches are dug below the water level, they must be bailed to keep them free of water during construction. The trenches can be bailed by hand using buckets, or a pump can be used to keep them dry.

Digging trenches in sandy soil is dangerous because the trenches will cave in as digging continues. Never dig trenches so that the edges are higher than a worker's head. If trenches must be dug deeply into the ground, slope the sides to prevent

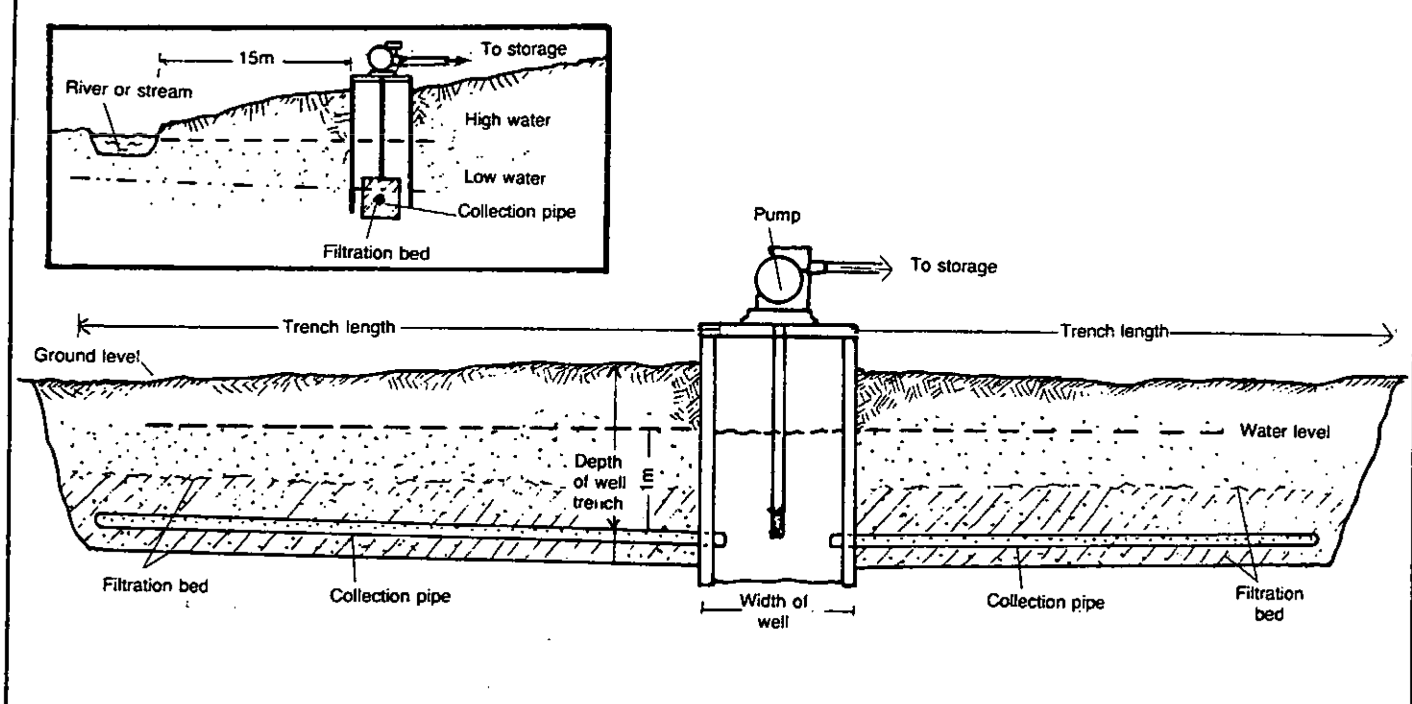

Figure 3. Riverside Infiltration Intake

cave-ins. In very sandy soils, it may be impossible to install trenches in the bank and an alternative should be chosen.

Figure 4 shows an infiltration gallery placed in the bed of a river. The stream is diverted so that a trench can be dug directly in the middle of the stream. The depth of the trench should be between 0.3 and 0.5m. It should be lined with gravel as described in the section on filter beds. Connect one end of the filter pipe to a pipe that runs into a clear water well located on the bank. Lay the pipe so that the slope is approximately one percent, permitting the water to flow easily into the clear well.

A clean-out pipe should be attached to the opposite end of the filter pipe. The clean-out pipe is simply a length of pipe attached to the perforated pipe which leads to the bank opposite the clear well. An elbow is attached to the length of pipe so that a vertical piece of pipe can be connected to it. The vertical section extends above ground level for easy access and is capped so that no debris can enter it. The clean-out system is used to flush out sediment if the collection pipe clogs.

Figure 5 shows another useful design for an infiltration gallery. Collecting pipes are driven from a well located in the bank into the bed of a stream below water level. In some soils, the pipes can be driven by hand using a hammer and drive pipe. In most cases, the pipes need to be driven with a pneumatic hammer braced against the wall of the well. The section of wall that supports the hammer should receive extra reinforcement to prevent it from breaking apart.

One useful technique is to drive large diameter steel pipe into the stream bed and then slide smaller diameter perforated plastic pipe into it, removing the steel pipe as the plastic pipe is put into place. This type of infiltration gallery is useful when sandy soil prevents the installation of trenches in the bank or when stream beds are difficult to excavate.

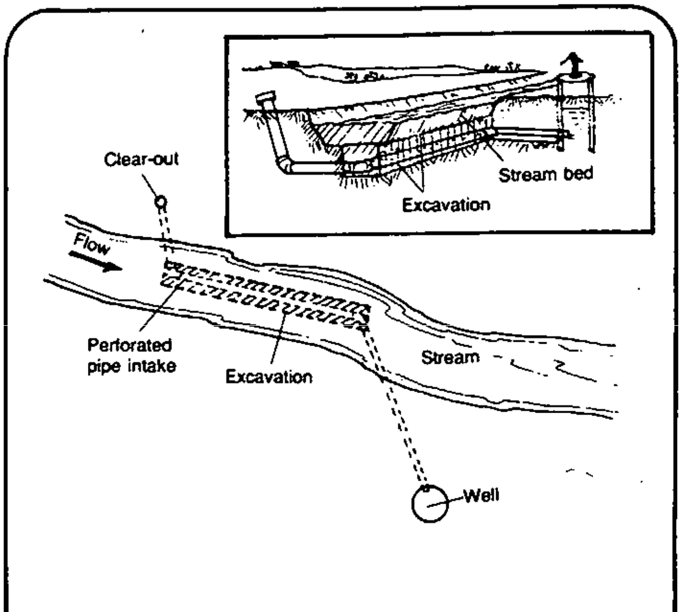

Figure 4. Infiltration System Below Stream Bed

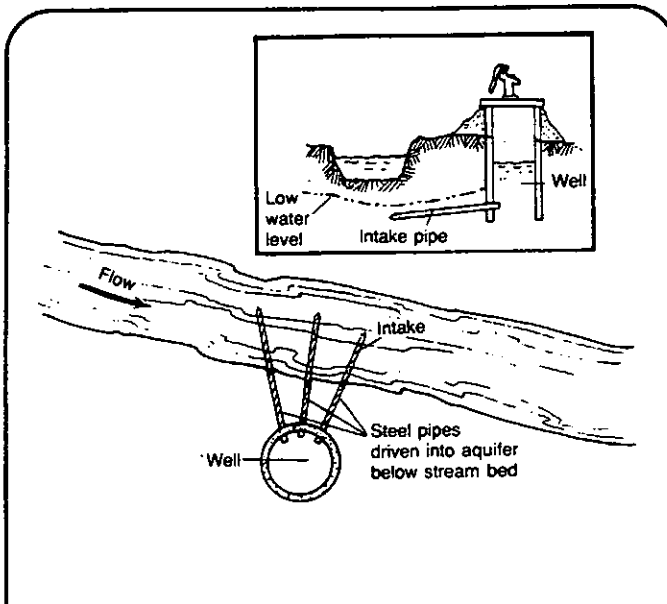

Figure 5. Multiple Pipe Infiltration System

Collecting Pipes. First, decide on the type of pipe. Rigid or flexible plastic, concrete, or vitrified clay pipe can be used. The choice depends on availability and cost. Next, choose the appropriate pipe diameter. This depends on the type of pipe chosen, its length, cost, and availability. If clay or tile pipe is used, 100mm diameter is the smallest available and should be used. If you are using plastic pipe, the diameter can range between 50mm and 100mm as long as flow is sufficient to meet community needs. If concrete is poured to make concrete pipes, the diameter of the form should be 200mm. Concrete pipe can be made with large gravel and a fluid sand and cement mix. The result is pipe with porous walls through which water flows easily. Careful curing is required. Large diameter pipe allows more water to flow into a system but it is more expensive and the community may not be able to afford it.

Decide on the appropriate size for the inlet holes. If concrete or clay pipe is used, no inlet holes are needed since water enters through openings at the pipe joints. The pipe joints should be at 1m intervals. Plastic pipe needs inlet holes or slots. Inlet holes 10mm in diameter or slots 25mm long can be made with a drill, nail, or small saw. Flexible polyethylene plastic pipe can be purchased with slots already made. Details of inlet hole sizes and the basic design are shown in Figure 6a.

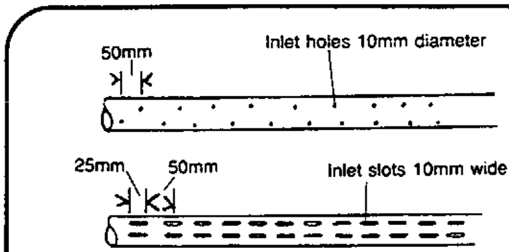

Figure 6a. Collection Pipe for Filtration System

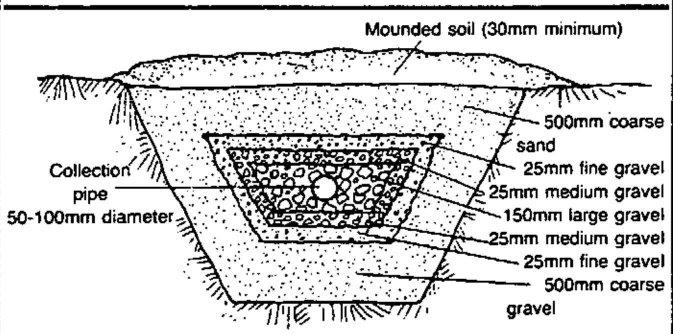

Figure 6b. Filtration Bed

Finally, choose the appropriate pipe length. This will depend on the amount of water needed and the type of soil in the water-bearing zone. Use a longer pipe in fine sand in order to collect greater quantities of water. To determine pipe length, the water flow must be observed. If flow is insufficient, either a larger diameter pipe must be installed or the trenches and collecting pipes must be lengthened to collect more water.

Filter Bed. A filter bed of stone, graded sand and gravel or other suitable filtering material should be built. The filtering material should be placed around the collecting pipe and built out to a width of 0.30-0.40m. Both the surrounding layers and side layers need to be graded to work effectively. Other layers of smaller filter material are added as shown in Figure 6b.

Clear Water Well. Use the design information for a riverside well given at the beginning of this technical note in designing the clear water well. This well serves the same purpose as the riverside well but collects water over a much larger area. Water is pumped from the well into the distribution system. If the infiltration gallery is well constructed, water may need only chlorination before it can be consumed. In some cases, more treatment will be necessary. Water in the clear well should be tested to determine its quality.

For all infiltration systems, water must be pumped to the users. In areas that are spread out or require a lot of water, smaller infiltration wells can be pumped by hand pumps for use at the source. Generally, when infiltration galleries are installed, water is pumped to the users through a distribution system. A pump, using a source of power, pumps water from the storage well to the main storage tank. See "Methods of Delivering Water," RWS.4.M.

Design of Gravity Flow Intakes

In mountainous or hilly regions, water from streams and rivers can be collected through intakes placed directly in streams. In higher elevations, a gravity flow system can be installed to deliver water if there is enough head for the water to reach the users. For an explanation of head and head loss in a system see "Designing a System of Gravity Flow," RWS.4.D.1.

If the intake is located above any inhabited area, the water may not require treatment. People and animals are the major sources of fecal contamination. If neither is present at the place where the water is collected, or upstream from the collection point, fecal contamination is unlikely.

Figure 7 shows a typical intake structure for a gravity flow system. The intake is located on a straight stretch of the river near a convex turn. The best location for the intake is where the bank and floor of the stream are stable.

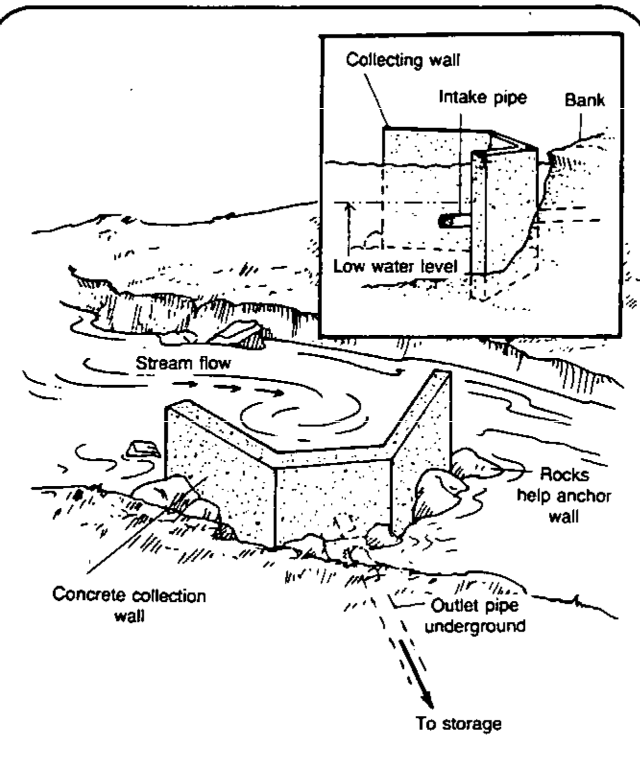

Figure 7. Gravity Flow Intake

The intake is made up of a screened intake pipe, and a reinforced concrete structure with winged-walls. To design this structure, first determine river flow, pipe diameter, pipe material, water level, and size of structure.

Determine the river flow using the methods described in "Selecting a Source of Surface Water," RWS.1.P.3. This measurement will indicate whether there is sufficient flow to meet community needs. Most streams that flow year round will provide ample water.

Determine the diameter of the pipe to be used in the system by using Table 4. Locate an approximate rate of flow for the river in the left hand column. Then look in either column 2 or column 3 to find the correct pipe diameter. For most rural areas, the velocity of water in the system ranges between 1.2-1.8m per second. For example, in a system where the river flow rate is 1 liter per second and the velocity is 1.2m per second, the correct size pipes would be 300mm. Check if the flow is sufficient by comparing the daily water needs (40 liters per day per person times number of people) and the daily flow. The daily flow must be equal to or larger than the daily water requirement.

Table 4. Determining Pipe Diameter

Q = Flow Liters/sec.	V (Velocity) = 1m/sec. - 1.5m/sec.	V (Velocity) = 1.5m/sec. - 2m/sec.
	Pipe Diameter (cm)	Pipe Diameter (cm)
0.63	25cm	25cm
0.83	30cm	30cm
1.0	30cm	30cm
1.3	40cm	30cm
1.6	50cm	40cm
2.0	50cm	50cm
2.3	50cm	50cm
2.6	60cm	50cm
3.0	60cm	50cm

Decide whether to use plastic or galvanized pipe depending on what is available. If the river is fast-flowing, or if flooding is likely to occur, galvanized steel pipe is preferable because of its strength. If the water is piped a long distance downhill to a community storage tank, flexible plastic pipe (polyethylene) is better. It is cheaper and easier to use because of its light weight and flexibility. The best method may be to place steel pipe in the structure for strength and then attach flexible plastic pipe to it for the distribution system.

Determine the level of the water at its lowest point during the year. The intake pipe must be placed in the upper third of the river when the river is at its lowest level. At this point, a water supply is provided all year and sediment from the river bottom will not enter the pipe.

The end of the intake pipe should be screened to prevent the entrance of leaves, stones, sticks, or other large material that could clog the pipe. Usually, 10mm mesh screen is a good size for the intake.

Determine the best size for the reinforced concrete structure. Size will depend on local conditions. The winged-walls must reach far enough into the stream to divert the water toward the intake into a pool which is always deep enough to submerge the intake pipe. The top of the structure stands above the riverbank so that the intake pipe is well supported in the walls and on the bank. The wall should be at least 0.15m-0.20m thick. The basic dimensions for the structure are shown in Figure 8.

Decide how to anchor the collection box and intake pipe. The box should be precast and lowered into a part of the stream where there are large rocks to support it. Digging into the stream bed 0.15m-0.20m will secure the bottom. One wall should be placed firmly against the stream bank and the unsupported side should be braced with large rocks as shown in Figure 7. The intake pipe should be anchored to the bank by digging a trench in the bank

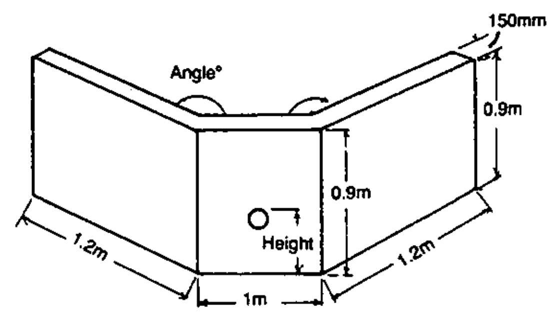

Figure 8. Design of Infiltration Wing-Wall Collector

and burying the pipe about 150-200mm in the ground. Both the intake pipe and collection box must be secure enough to avoid destruction caused by fast-flowing water, flooding, or moving rocks or logs.

Erosion of the bank opposite the winged-wall structure may occur as the stream flow is affected by the extension of the wall into the middle of the stream. To prevent the bank's erosion, reinforce it with rip-rap. The rip-rap should be placed on the bank where the force of water against the bank is greatest.

Construction of a winged-wall collection box requires skilled labor. This method should only be undertaken with the help of an engineer.

Design of Permanent Intakes for Direct Pumping

Water can be pumped straight from a stream or river to treatment and storage using direct pumping. There are many types of temporary intakes but permanent structures are better. Design of a permanent structure is shown in Figure 9. The intake consists of (a) a screened intake with a check valve, (b) a protective concrete ring with perforations, (c) a catwalk, and (d) a power pump. This type of intake should be used only in rivers that have a year-round depth of over 0.50m.

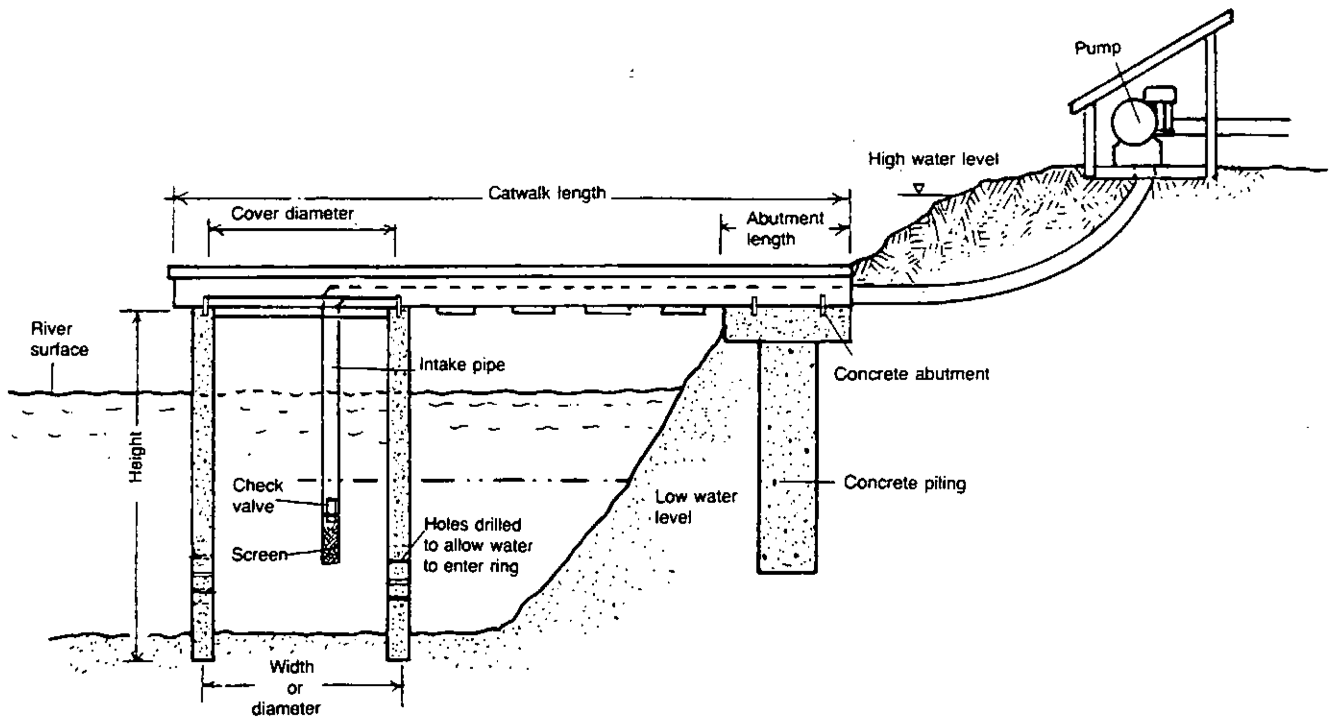

Figure 9. Direct Intake

Intake Pipe. A 50mm pipe with a 10mm wire mesh screen should be used for the intake pipe. The intake pipe is located in the concrete ring (pump well) and stands 300m above the stream bed in order to prevent large particles and sediment from entering the system. The pipe can be either plastic or galvanized steel. The choice depends upon what is available. Flexible plastic is much cheaper and needs no joints or couplings, but steel pipe may prove to be best because of its strength.

Determine the length of the pipe by measuring the distance from the pump to the end of the catwalk. Add to this the distance from the top of the catwalk to 0.30m above the bottom of the stream.

Concrete Rings. Determine the dimensions of the reinforced concrete ring. It should have a height of 1m and a diameter of 1.5m. The ring is precast and lowered into the stream. The ring should enter the stream bed 0.3-0.5m for adequate support. Weight may be a problem so a smaller ring may be designed. The ring should be large enough to protect the intake from water moving at high velocities and from large floating debris. Several small, 50-70mm diameter holes can be drilled in the ring to ensure an adequate water flow to the intake. A wooden cover fits over the ring to protect the intake pipe. When casting the ring, bolts should be placed in the cement so that the catwalks can be bolted to the ring. If the ring is bought, drill holes into the cement and place the bolts in the appropriate places, securing them with mortar. Because casting a ring is difficult, it is best to purchase one that is already made or build one using bricks and mortar as described in "Designing Structures for Springs," RWS.1.D.1. The intake should be located near the deepest part of the river or in a place where the water level is above 0.5m during the entire year. However, care should be shown to locate the intake fairly close to the shore. The design of the catwalk is more difficult the greater the distance from the shore to the intake.

Catwalk. Design a catwalk to connect the stream bank to the concrete ring and to support the intake pipe from the bank to the ring. The catwalk can be made of wood for easier construction. A concrete catwalk should only be designed by skilled engineers. Two timbers 0.10m by 0.10m should be used to connect the concrete ring to the shore. They are laid parallel, 1m apart and bolted to the concrete ring by attaching them to the bolts in the ring. The other end of each timber is attached to the abutment on the shore. Planks, 0.25m by 0.15m, are then nailed to the top to form a walkway as shown in Figure 10. Wooden pipe supports 1.5m apart are bolted to the bottom of the catwalk structure. A 0.5m by 0.15m plank is sufficient for the supports. A small strip of metal or rubber should be fastened to the support and around the pipe to keep it in place.

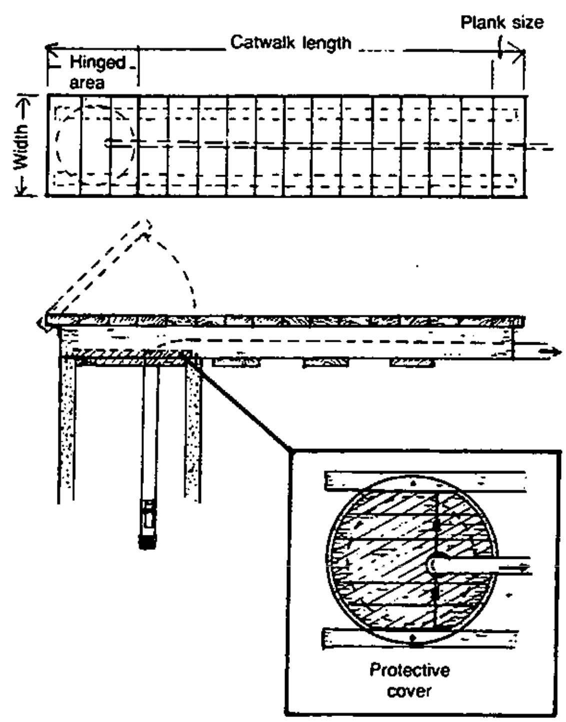

Figure 10. Catwalk and Cover Design

On the shore, build a concrete abutment 1.5m x 1m x 0.15m and level to the top of the concrete ring. This will support the catwalk. To build the abutment, dig out a level area to the desired size. The abutment should be attached to a piling to give the catwalk the needed support. The piling should be half the length and width of the abutment and should extend into the ground 0.5-1.0m. The hole is completely filled with concrete. The abutment and piling should be constructed as a single unit.

Install a pump and connect it to the intake pipe. Put the pump on level ground if possible, about 2m from the shore. To determine the type of pump needed, see "Determining Pumping Requirements," RWS.4.D.2, and "Installing Mechanical Pumps," RWS.4.C.2.

This type of intake structure is very difficult to build and trained technicians are needed. Materials which may be hard to obtain are required and these will raise the cost of the project. This design is only economically practical if many people are served by it.

For design, follow the steps described in Worksheet A. The volume of concrete needed can be determined by finding the volume of the concrete rings using the formula in Worksheet B.

If the concrete ring is too complicated to build a simpler design shown in Figure 11 can be attempted. A concrete base is built with a pipe inserted into it. An elbow is attached to the end and a vertical length of screened steel pipe is connected to it. The pipe in the concrete can be attached to flexible pipe for easy accessibility for maintenance. In deeper streams, a float can be attached to the intake to provide easy location.

Worksheet A. Determining the Amount of Concrete to be Used in Construction of Winged-Walled Intake Structure

1. Total volume = volume of side 1 + volume side 2 + volume side 3

   Volume side 1 = length 1.2 m x width 0.90 m x thickness 0.15 m = 0.162 m^3

   Volume side 2 = length 1 m x width 0.90 m x thickness 0.15 m = 0.135 m^3

   Volume side 3 = length 1.2 m x width 0.90 m x thickness 0.15 m = 0.162 m^3

   Total volume = 0.162 m^3 + 0.162 m^3 + 0.135 m^3 = 0.457 m^3

2. Total volume x 1.5 = volume of dry mix 0.457 cm^3 x 1.5 = 0.685 m^3

3. Cement mixture = 3 parts gravel, 2 parts sand, 1 part cement (50% gravel, 33% sand, 16.7% cement)

   Volume of gravel = 0.50 x total volume = 0.50 x 0.685 = 0.34 m^3

   Volume of sand = 0.33 x total volume = 0.33 x 0.685 = 0.22 m^3

   Volume of cement = 0.167 x total volume = 0.167 x 0.685 = 0.11 m^3

4. Volume of cement = 0.11 ÷ .033 m^3/bag = 3.5 bags of cement

5. Volume of water = 28 liters/bag of cement = 28 liters x 3.3 bags = 98 liters

6. Determine the number of lengths of reinforcing rod by using the following formulas:

   Divide the length of one side and the width of one side by 150mm, the distance between each bar.

   Length in mm ÷ 150mm = number of bars
   1200 mm ÷ 150m = 8 bars
   Width in mm ÷ 150m = number of bars
   900 mm ÷ 150m = 6 bars

   For the entire wall, 14 bars are needed and should be placed as shown in Figure 12.

   Do these calculations for each wall to determine the amount of rebar needed.

Worksheet B. Volume of a Concrete Ring

In the example given, the diameter of the ring is 1.5m and the thickness 0.10m.

a) Area = diameter^2

$$A = \frac{3.11}{4} \times 1.5^2$$

$$A = .785 \times 2.25$$

$$A = 1.76m^2$$

b) Volume = area x thickness. Use this volume in calculating concrete needed for the tube.

$$V = 1.76m^2 \times 0.10m$$

$$V = 0.176cm^3$$

All proportions of mixtures for gravel, sand and cement will be the same as in Worksheet A.

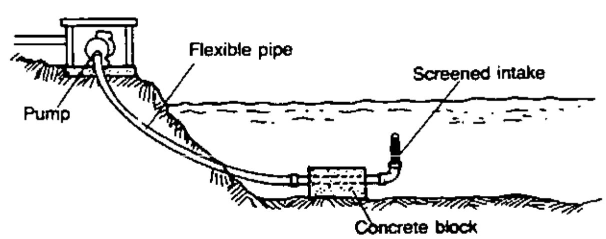

Figure 11. Simple Permanent Intake

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Water for the World

Evaluating Rainfall Catchments
Technical Note No. RWS. 1.P.5.

In some cases, rainwater may be the only acceptable source of surface water available to a community. If it is to be used for drinking water, it must be collected and stored in sufficient quantities to meet individual or community needs. Basically, there are two types of rainwater catchments: roof catchments and ground catchments.

This technical note describes each type of catchment system and discusses its advantages and disadvantages. Before deciding to use a rainfall catchment, be sure to determine that the quantity of water it will produce is sufficient to meet local or individual needs and that enough storage can be provided. The design of cisterns for the storage of rainwater is described in "Designing a Household Cistern," RWS.5.D.1.

Useful Definitions

ASPHALT - A black tar-like substance mixed with sand or gravel for paving.

CISTERN - A covered tank in which water is stored.

EVAPORATION - Loss of surface water to air; surface water is heated by the sun and rises to the atmosphere as vapor.

HECTARE - A measure of land area equal to 100m by 100m.

IMPERVIOUS - Not allowing liquid to pass through.

INFILTRATION - The process of water passing from the surface through the soil and into groundwater reservoirs.

PERVIOUS - Allowing liquid to pass through.

SOIL PORES - Tiny openings and spaces in soil which water enters.

TRANSPIRATION - Similar to evaporation except that the water loss comes from stored water in plants; vapor leaves plants through small pores.

Roof Catchments

Before deciding to use roof catchments with individual cisterns determine (a) if each family has adequate resources available, (b) which is the most effective cistern design, (c) the space available for building the cistern, and (d) the capability of the users to disinfect it and clean it periodically. Roof catchments differ from other sources of surface water because a great responsibility for operation and maintenance rests with the individual user rather than the community. Water quality will depend on the user cleaning the pipes and gutters and disinfecting the stored water. If rainfall catchments are installed, the users must be thoroughly trained in techniques of operation and maintenance.

Materials. Roof catchments can only be used where roofing materials are suitable. Do not plan to develop rain catchments on thatched, painted or lead roofs. The water running from them is likely to be very contaminated. Water is likely to seep into thatched roofs and be lost.

Determine if tiles, slate, or corrugated plastic, tin or aluminum sheets are available and can be acquired by the village. Generally, sheet metal is preferable because of its light weight and strength. Tiles are also good because they can be made locally. However, they are much heavier than sheet metal and need a strong roof structure to support them without sagging.

Water Availability. For a roof catchment to be worthwhile, there must be sufficient rainfall. The amount and monthly distribution of annual rainfall for a region should be available from a local agricultural or other governmental agency, or from an airport. If you know the amount of annual rainfall, it will be easy to determine the amount of water available from the catchment for consumption. Use monthly rainfall data if available. This data will help planning for storage capacity during the dry months. To find the amount of water available yearly or monthly, multiply the area of the catchment by the annual average rainfall. Then, multiply this amount by 80 percent. Only 80 percent of the total volume of rainfall generally is available for use because of evaporation and other losses. For example, if a region has an annual rainfall of 800mm per year and a home has a catchment area of 48 square meters (6m x 8m), then the amount of available rainfall is:

$800\text{mm} \times 48\text{m}^2 \times 0.80 = 30.72\text{m}^3$ per year.

There are 1000 liters in 1m^3, so $30.72\text{m}^3 \times 1000 = 307200$ liters per year.

$$\frac{30720 \text{ liters per year}}{12 \text{ months per year}} = 2560 \text{ liters per month;}$$

$$\frac{2560 \text{ liters per month}}{30 \text{ days per month}} = 85 \text{ liters per day.}$$

Compare the amount of water available to the amount of water needed to meet the users' needs. A catchment system must provide a minimum of 15 liters of water per person per day. In the example above, each member of a family of five would be able to use 17 liters of water per day. If the family had six members, each person would have 14 liters of water.

Storage. A cistern must be placed either above or below ground to collect water from the catchment. A cistern can be as simple as a 200-liter barrel, a tank constructed from reinforced concrete, as in Figure 1, or any other suitable collection container. The size of the cistern will depend on (a) the amount of water needed, (b) the amount and frequency of rainfall available, (c) the size of the collecting surface and (d) cost. The basic design features of a household cistern are discussed in "Designing a Household Cistern," RWS.5.D.1.

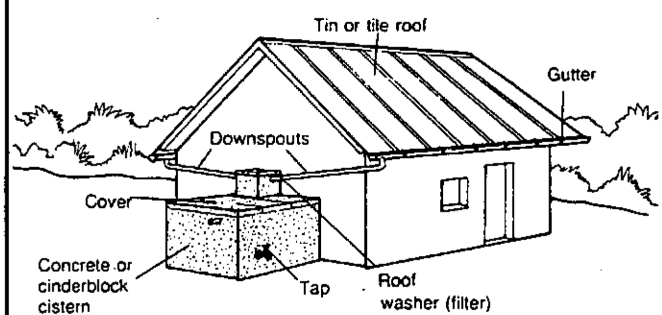


Figure 1. Rainfall Catchment with Cistern

If rainfall is evenly distributed throughout the year, the general rule is that a permanent cistern must be large enough to store a one month supply of water. In the example used above, 2560 liters per month are available for use. The cistern for this particular system should have a capacity of between 2.5 and 3.0m^3. A cistern with a capacity of 2.5m^3 can store 2500 liters and a 3m^3 capacity cistern, 3000 liters. If resources are not available to build a cistern of this capacity, the largest cistern possible should be built.

If rainfall is heavy during some months but there is a dry season with little or no rain, the size of the cistern can be increased to store water during the wet season for use in the dry. The problem is that if a dry season is three months long and a three-month supply must be stored, the cistern would have to be very large and would be very expensive to build. This would be impossible for most individual families. There are several alternatives, however.

One alternative is to use collected rainwater for drinking and cooking only and find another source for washing and bathing. In this way, water use from the cistern can be reduced. If rainwater is used only for drinking, then smaller, less expensive cisterns can be built. Also, other less permanent designs could be used. Figures 2 and 3 show cisterns that may be suitable for some regions.

Large clay, concrete or ferrocement jars that cannot be moved can be made to collect rainwater from the roof. These jars are frequently made locally and cost very little. The price is much less than for a reinforced concrete cistern. To collect enough water, use several jars placed near the roof. The downspout will have to be moved to fill the empty jar. Two or three jars can be made or bought for the cost of one small concrete cistern.

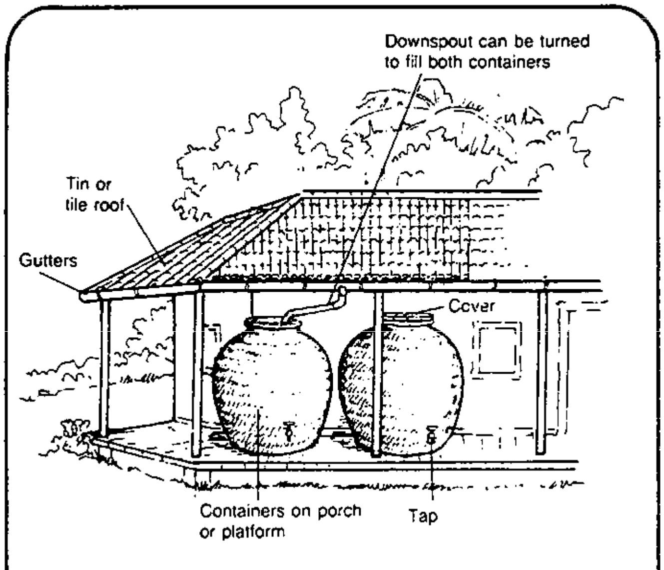


Figure 2. Large Water Storage Containers

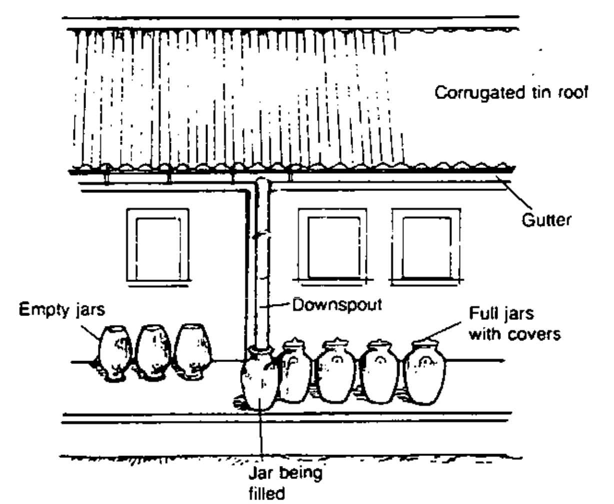


Figure 3. Small Clay Jars for Rainwater Collection

A similar technique is to use smaller, portable clay jars that can easily be moved under the downspout during a rainstorm. A family could have several 25-liter jars which can be filled during rainfalls. This system will work efficiently, but there will be little storage capacity for the dry months.

Ground Catchments

Ground catchments are areas prepared in a special way to collect rainfall for a water supply. The amount of water that can be collected will depend on the amount of rainfall, the area of the catchment, and the runoff characteristics of the surface. Ground catchments, if prepared properly, will provide more water than roof catchments since more surface area is used for collection. For this reason, they are more economical for a small community. If rainwater is the primary water source, a roof catchment on each roof in a community would be expensive and impractical. See Figure 4 for an example of a ground catchment.

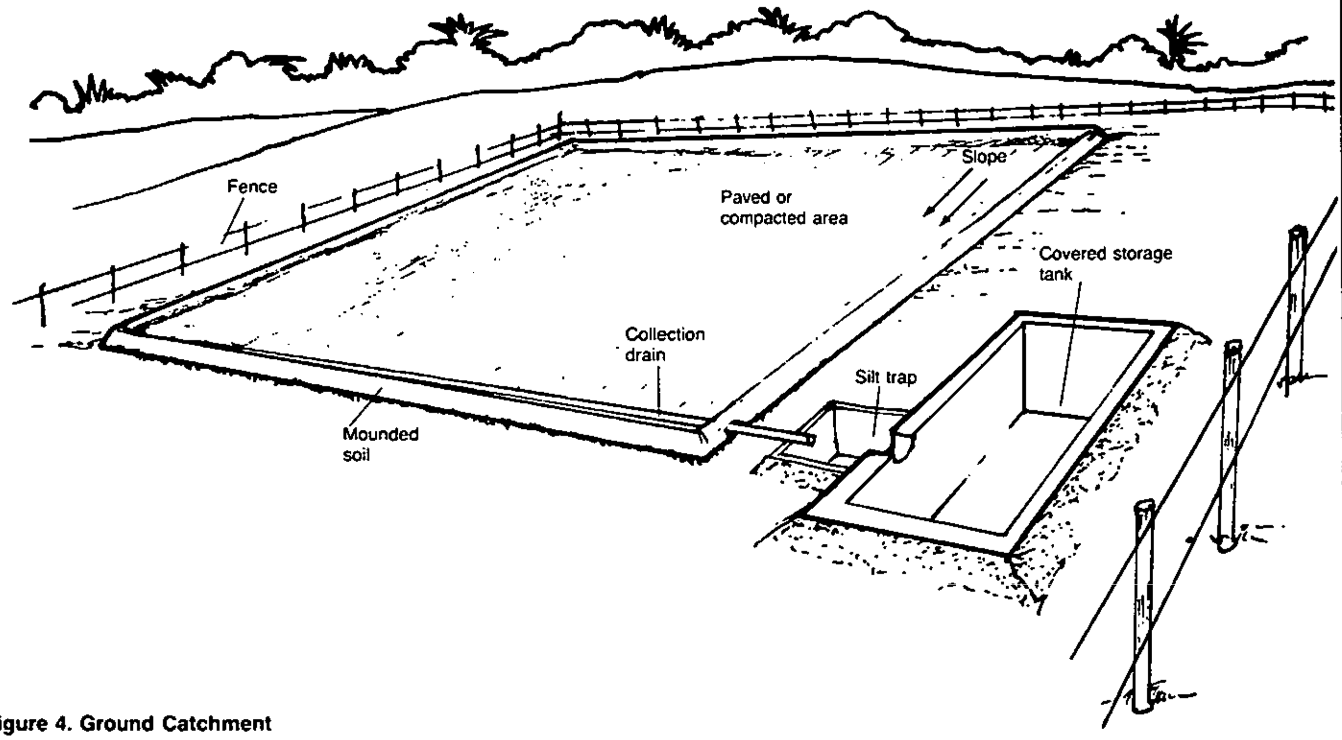


Figure 4. Ground Catchment

Materials. The ground catchment surface is very important in collecting rainwater efficiently. Catchment surfaces must be impervious to avoid water losses from infiltration and seepage. On pervious surfaces, much of the rain will be lost for community use. Part of it will wet the ground and part will be stored in small ground depressions; other water losses will occur through infiltration into the ground, evaporation into the air, and transpiration through plants.

One type of ground catchment is a surface that has been smoothed and cleaned of vegetation. Compacted clay soils make good catchment surfaces because the clay is relatively impervious and will need little or no treatment to seal soil pores. In areas where there is no impervious soil, various materials can be used to cover pervious ground surfaces to prevent water losses. Cement, asphalt or even polythene sheeting can be laid over the surface of the ground to prevent seepage and infiltration. The major problem is that the materials used to cover the ground surface are very expensive and may not be available in many rural areas. The need for storage in a cistern and for treatment adds to the total cost.

Chemical treatment of a catchment surface can help increase run-off by making the soil impervious. Sodium salts, which cause clay in soil to break down into small particles and seal soil pores, help make soil containing clay impervious so that run-off is increased. Tar or asphalt can also be used on catchment surfaces. These materials can be sprayed on the surface and effectively seal soil pores. Chemical treatment is usually not very expensive and the surface generally lasts for four or five years. However, in many rural areas, the chemicals for ground treatment may not be available or may be expensive. In this case, a simple catchment of compacted earth would be the best alternative.

Water Availability. The amount of water available for use from ground catchments depends on the amount of annual rainfall and the area of the catchment. Because catchment areas are large, a lot of water can be collected from a small amount of rainfall. If the area of the catchment is large enough, the surface impervious, and the slope steep enough to ensure rapid run-off and minimum losses to evaporation and transpiration, the needs of a small community can be met with as little as 80mm of annual rainfall.

Evaporation, infiltration, seepage and transpiration will all affect the amount of water reaching the catchment area that is available for use. If the catchment surface is pervious or poorly constructed, little or no water will be collected. In a well-designed and maintained catchment, up to 90 percent of the water reaching it can be collected. The ground catchment can be at least as efficient as a roof catchment. However, if the ground is poorly prepared or inadequately covered, losses through infiltration will be high. Careful catchment preparation is necessary.

Consider a catchment area one-quarter hectare in area (50m x 50m) in a region with an annual rainfall of only 100mm. Also assume that the catchment efficiency is only 80 percent, the same as the roof catchment. Multiply the average rainfall (100mm) by the catchment area ($2500m^2$) by 80 percent to get the amount of water available in liters:

$100mm \times 2500m^2 \times .80 = 200000$ liters per year.

This would be 16660 liters per month or 555 liters per day. If consumption is 15 liters per person per day, this system would supply enough water for 37 people.

Storage. Water from the ground catchment must flow into a storage tank to be available to users. Storage tanks for ground catchments are generally located in the ground and the water must be pumped from the cistern to the users using either a hand or power pump. Because ground catchments are built in areas where rainfall is scarce, the storage tank must be large enough to take advantage of all available rainfall during a month and store it during dry periods. The larger the storage tank, the more costly it will be to build. The best storage tank will meet the needs of the users during both wet and dry seasons. For example, a storage tank 1.5m x 1.5m x 1.5m will hold 3375 liters. In the example above, the amount of water available is 16660 liters per month. A storage tank with a capacity of $17m^3$ would have to be constructed to hold this amount of water. A storage tank of this size would be very costly to build and would be impractical in many areas. Possibly a cistern with half that capacity, 9000 liters, would be more reasonable. In each case the size of the cistern depends on the amount of water which must be stored. The cistern should be only as large as necessary and as resources permit.

The type of ground catchment used depends on the availability of materials, on soil type and on the resources available in the community. Because ground catchment systems are generally expensive they are rarely used for individual families. They can be effective for several families or a small community. Although costly, ground catchments may be the best alternative for water supply in areas of little rainfall where groundwater and other surface water sources are inaccessible.

Summary

The two types of rainfall catchments will provide water in areas where it is uneconomical or unsafe to use other sources of water for drinking. Roof catchments are practical in areas where rainfall is abundant and fairly evenly distributed throughout the year. They have the following advantages:

- they can be used in most places;
- materials for catchments are readily available;
- their design is simple;
- they are relatively inexpensive to develop;
- they are efficient collectors of rainwater; and
- they are easy to maintain.

Ground catchments are more expensive than roof catchments because of material and labor costs. They should be considered in areas where rainfall is very scarce and other sources are not available. Ground catchments are best suited for providing water for several families or for small community supplies, rather than individual families. Design of ground catchments is more difficult and greater skill is needed for construction. Ground catchments do, however, have the following advantages:

- large quantities of water can be collected for a community supply;
- they provide large quantities of water with little rainfall;
- if properly designed, they are very efficient collectors.

Water for the World

Designing Roof Catchments
Technical Note No. RWS. 1.D.4

Roof catchments collect rainfall from a roof and channel it through a gutter into storage for use by individual households. The amount of water available for use depends on three factors: the amount of annual rainfall, the size of the catchment area and the capacity of the storage tank. This technical note discusses how to design a roof catchment to take advantage of the maximum amount of rainfall available.

Useful Definition

FOUL FLUSH - The first run-off from a roof after a rainfall.

The design process should result in the following two items which should be given to the person in charge of construction:

1. A list of all labor, materials and tools needed as shown in Table 1. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

2. A plan of the roof catchment system with all dimensions as shown in Figure 1.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers		
Supplies	Corrugated sheet metal, plastic or tiles (for roofing) Metal gutters, wood or bamboo (for gutters) Wire, rope or local fiber (to secure gutters to roof) Tar or caulk (to seal gutter connection to downpipe) Nails Wire screen		
Tools	Hammer Machete (to split bamboo) Wire cutters Saw Chisel		

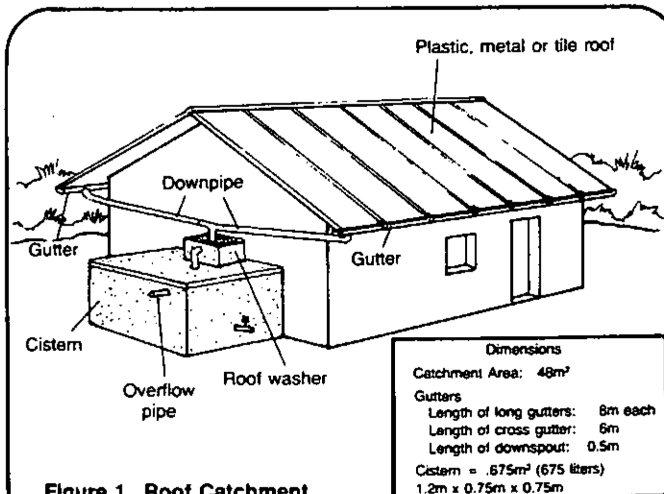


Figure 1. Roof Catchment

Annual Rainfall

Find the annual rainfall rates for the region. This information should be available from the national geographical institute, the Ministry of Agriculture, a meterological institute or university, or an airport. The amount of annual rainfall is measured in millimeters per year.

Catchment Areas

The roof of the house is the catchment area for the rainfall. To collect rainfall, the roof must be constructed of appropriate material, have sufficient surface area, and have adequate slope for water to run-off.

Corrugated galvanized steel or aluminum sheet metal, corrugated plastic or baked tile make the best catchment surfaces. Sheet metal is especially attractive because it is light-weight and requires little maintenance. Tiles also make excellent surfaces and are usually cheaper than sheet metal because they can be produced locally. The disadvantage of tile is the weight. A much stronger roof structure is needed to support tile. Tile roofs may even start to sag or leak after a time if structures are not strong enough.

To determine the amount of rainfall available for use as a water supply, it is necessary to know the area of the roof. Figure 2 shows how to determine the roof area available for water collection.

The effective roof area for collecting water is not the roof area itself but the ground area covered by the roof. In Figure 1, the effective water collecting area is $48m^2$ (8m x 6m = $48m^2$). The roof must slope as shown so that the water will flow into the gutter system installed to move the water to storage.

Using this information and the annual rainfall, it is easy to determine how much water will be available for use. Worksheet A shows how to make this calculation.

In the worksheet example, an average of 85 liters of water per day would be available to a family. For a family of six, each person would be able to use 14 liters per day. This is an average amount. During some months, more than 2560 liters will be available, while during the dry months, no rain may fall at all. A cistern will be needed to ensure adequate storage during the dry months.

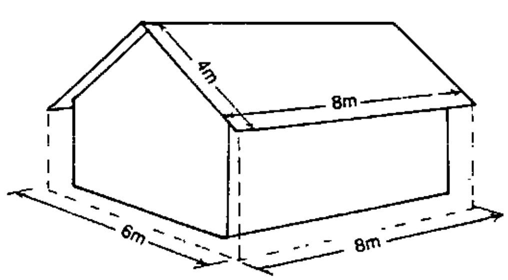


Figure 2. Roof Catchment Area

Worksheet A. Volume of Water Available from a Roof Catchment

Calculate the amount of water available from the catchment by following these steps and referring to Table 1. Figures used are the catchment size in Figure 2 and assumed rainfall of 800mm per year.

1. Multiply annual rainfall by the catchment area.

$\underline{48m^2}$ x $\underline{800mm}$ = $\underline{38400}$ liters/year.

2. Multiply this total by 80 percent. Not all water will be available because of losses due to evaporation and run-off that does not flow into the gutters. To be safe, figure a 20 percent loss for a rain catchment.

$\underline{38400}$ liters x .80 = $\underline{30720}$ liters/year.

3. Divide the total by 12 to get average monthly rainfall.

$\frac{30720 \text{ liters/year}}{12 \text{ months/year}}$ = $\underline{2560}$ liters/month.

4. Divide again by 30 to determine liters per day.

$\frac{2560 \text{ liters/month}}{30 \text{ days/month}}$ = $\underline{85}$ liters/day.

Gutters

Gutters must be installed on both sloping sides of the roof to collect all the run-off and channel it into the cistern. The gutters must be as long as the edge of the roof. Figure 1 shows a typical gutter design. There must also be a downpipe on a third side of the house so that water from both catchment surfaces is channeled to a single cistern. The design of gutters is quite simple and local materials can be used for them.

Metal gutters are the most durable and require the least maintenance, but are the most expensive. Gutters can be made of wood or bamboo. These materials are often available and inexpensive but will usually not last as long as metal because they will rot. Wood and bamboo gutters can be installed to overlap and can be tied together with wire, rope, or local fiber to avoid leakage. If wood is used, it should be hollowed out to form a channel. If bamboo is used, it must be split and the inside joint partitions removed. All gutters must have a small but uniform slope to prevent the formation of pools of water in the gutters. Still water can be a breeding place for mosquitoes.

A downpipe must be installed. The downpipe channels the water from the gutter into a cistern for storage. The joint where the downpipe and gutter connect must be sealed. If metal gutters are used, a connection can be sealed with a caulking compound. If bamboo is used, tar will prove the best material for sealing the connection.

During periods of no rain, dust, dead leaves, and bird droppings will accumulate on the roof. These materials are washed off with the first rain and will enter the cistern and contaminate the water if some basic steps are not taken.

To prevent leaves and other debris from entering the downpipe, a coarse mesh screen should be placed in the gutter over the downpipe. The mesh will catch the large debris but let the water through. The screen must be cleaned periodically to prevent clogging.

A downpipe that can be moved manually away from the cistern can be installed to divert the first flow of water from the roof. An example appears in Figure 3. When the pipe is moved away from the cistern, water simply runs to waste. For this method to be effective, someone must be at the house to move the pipe.

Several other techniques are available for diverting the first roof run-off from the storage tank. In Figure 4, water from the gutters runs through the downpipe and into a small box built on top of the cistern. The first run-off is caught by this box.

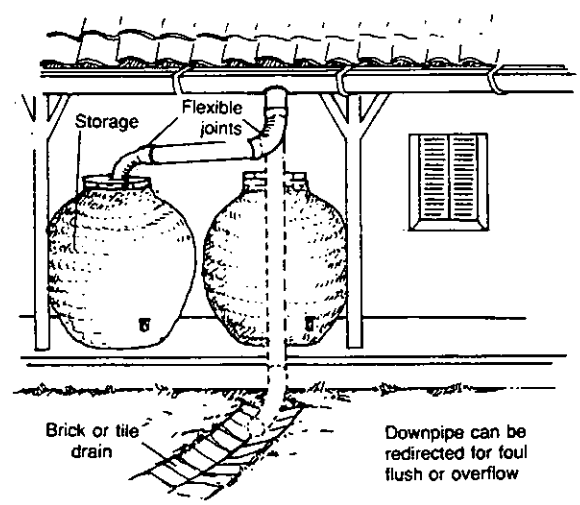


Figure 3. Flexible Downpipe

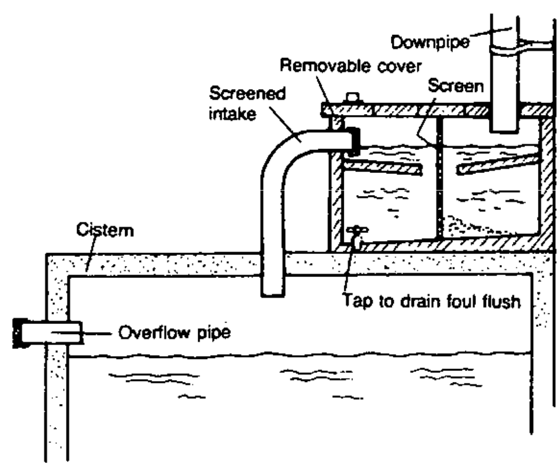


Figure 4. Foul Flush Box

When the box fills, water runs over the top of it into a channel that leads it to storage. A drain then empties the box of the dirty water. This small foul flush or first wash collection box can be made from concrete or from metal. It is most useful when permanent concrete cisterns are designed, because of the extra cost.

A small charcoal-sand filter box can also be installed as in Figure 5. As the rain water passes through the filter, sediment and debris are removed and clear water flows to storage. The advantage of this design and the box for the foul flush is that no one has to be present to divert the water flow from the roof.

Figure 6 offers another example of a useful and easily installed device for diversion of the foul flush. The downspout has two outlets. One runs to storage the other to waste. A lever on the outside is used to make water flow into one of the two channels. After the first wash flows to waste, the lever must be switched so that water runs into the cistern.

No matter which method is used to divert the first wash, the quality of water collected in the cistern must be checked. Water from roof catchments may need treatment before it can be consumed.

Cisterns

A cistern is an important part of a rainfall catchment system. There must be some type of cistern to collect and store rainwater. Several designs can be considered. The choice will depend on the amount of water needed, the amount of water available, rainfall distribution, cost, and availability of space. Basic design considerations and plans for household cisterns are shown in "Designing a Household Cistern," RWS.5.D.1, which should be used with this technical note to design an effective catchment system.

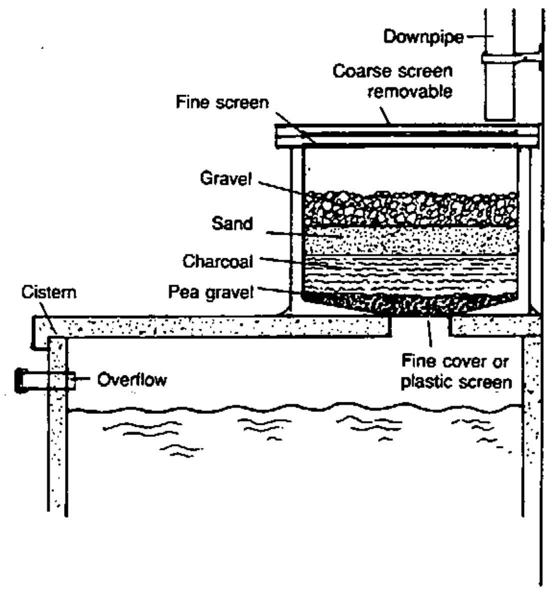


Figure 5. Filter System

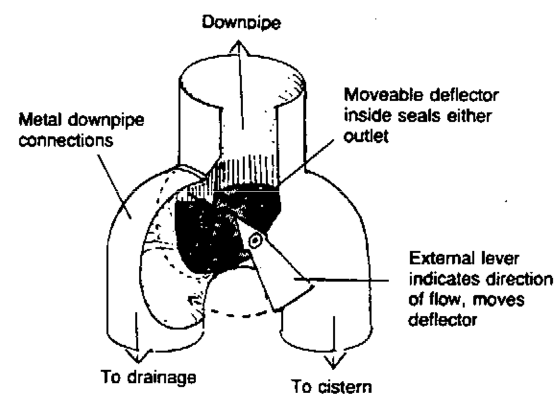


Figure 6. Roof Washer Device in Downpipe

Water for the World

Constructing, Operating and Maintaining Roof Catchments
Technical Note No. RWS. 1.C.4

The construction of a roof catchment in an individual home is not difficult and generally no special skilled labor is required. With the necessary tools and materials, a catchment system can be installed by a family at a modest cost. This technical note outlines the steps for installing roof catchments. Read the entire technical note before beginning the construction of the system.

Useful Definitions

CAULKING COMPOUND - A filler that seals cracks and seams and makes them watertight.

CISTERN - A storage tank for water.

FOUL FLUSH - The first run-off from a roof after a rainfall.

Before construction begins, the project designer should give you two items:

1. A list of all labor, materials and tools needed for construction similar to the sample list in Table 1.

2. A plan of the roof catchment system with all measurements as shown in Figure 1.

Obtain all materials needed for construction so delays can be prevented.

Construction of the cistern should begin at the same time as construction of the catchment system. For information about constructing cisterns, see "Constructing a Household Cistern," RWS.5.C.1.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Corrugated sheet metal, plastic or tiles (for roofing) Metal gutters, wood or bamboo (for gutters) Wire, rope or local fiber (to secure gutters to roof) Tar or caulk (to seal gutter connection to downpipe) Nails Wire screen	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____
Tools	Hammer Machete (to split bamboo) Wire cutters Saw Chisel	____ ____ ____ ____ ____	____ ____ ____ ____ ____

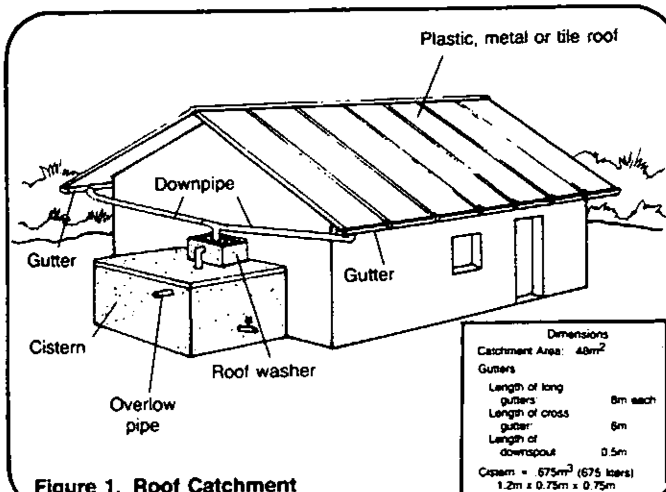


Figure 1. Roof Catchment

Installation

The installation process consists of three steps: construction of roof catchment structure, installation of gutters and connection of the downpipe to the cistern, and construction of a means to dispose of the foul flush.

Catchment Installation. For pre-existing houses, check the roof structure for strength. If the structure appears weak, it should be changed or reinforced. In new houses, or where an existing roof cannot be used, a completely new structure must be installed. The material used for roofing will determine the sizes and spacing of the rafters and cross-supports. Table 2 shows the dimensions of various types of roofing materials.

Table 2. Roofing Material Sizes

Materials	Width	Length
Galvanized steel roofing	0.6m	2.5-3.75m
Aluminum sheeting	0.9m or 1.2m	2.5-6.5m
Fiberglass sheeting	0.65m	2.5-3.75m
Tile	0.2m	0.4m

Place the roofing material on the structure starting from the bottom and working up. Tiles and sheets should overlap to prevent leaking. For tile roofs, cross-pieces should be placed close together so that all tiles have a firm base to rest on. For sheet metal or fiber glass roofs, use roofing nails to secure the sheets to the cross-pieces. If any leaking occurs through nail holes, seal them with a small amount of tar. See Figures 2 and 3 for examples of the installation of roofing materials.

Gutter Installation. Gutters must be installed to collect water from the roof surface. They can be made of metal, plastic, wood or bamboo.

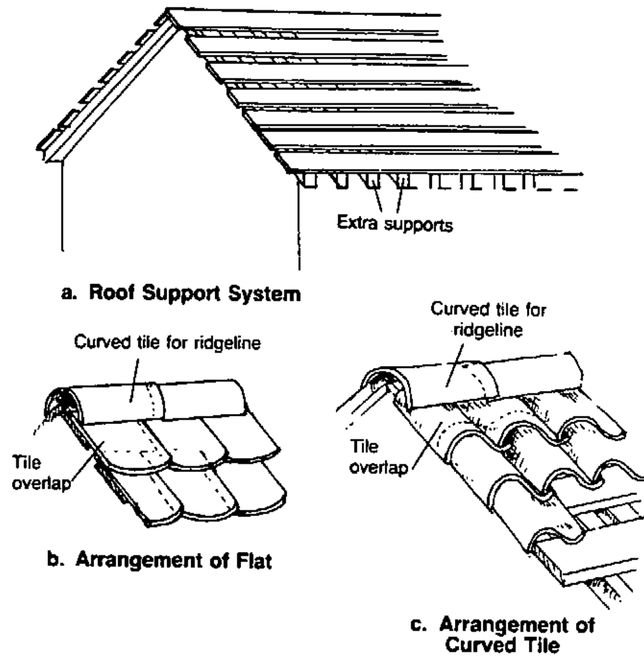


Figure 2. Tile Roofing for Catchment

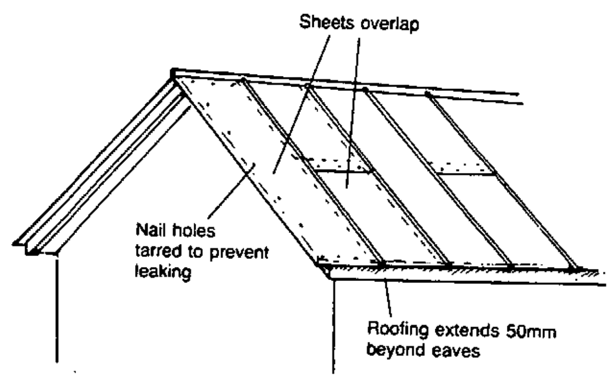


Figure 3. Metal Sheeting for Roof Catchment

Metal or plastic gutters must be bought, while wood or bamboo gutters can be made locally. If wood is used, it must be nailed into a trough and sealed with tar or a deep channel must be cut into the piece of wood to be used as a gutter. This channel must be deep enough to hold the collected water and prevent it from spilling out onto the ground. Bamboo gutters are made by splitting long lengths of bamboo down the middle and removing the inside joint partitions. The cut halves form very good collecting troughs, as shown in Figure 4. Follow these steps as you install the gutters.

1. Tie pieces of wire to the roof structure to support the gutters. The wires should be located 50cm apart to provide adequate support. Extra support should be given to wooden gutters because of their weight. Wrap the wire around the gutters to hold them in place.

2. Join the gutter sections together. Use specially made joints for metal and plastic gutters. There are several techniques for joining bamboo gutters. One simple method is to place a piece of rubber at the joint to hold the two pieces together. The rubber fits underneath the gutters and is secured to them with wire. Tar or caulking can then be used to seal the connection and make it watertight. Figure 5 illustrates this technique. Be sure that the two pieces of bamboo fit together closely before sealing the joint.

3. Begin installing the gutters on the side of the house opposite the cistern and install the downpipe on the third side. The gutter should slope enough so that all water flows from the roof to the downpipe. The required slope is 0.8-0.10m per meter of gutter. Another method of installation is to place the cistern on a side of the house where the roof peaks. Place gutters on both sides of the house sloping toward the cistern. Water runs from both gutters into a single downpipe. Gutter slope is very important since without enough slope, water will stand in the gutters. If the time between rains is more than eight to ten days, mosquitoes will breed in the standing water.

4. Install a downpipe from the gutter to the cistern. Connect the downpipe directly to the gutter. The downpipe can either be placed at the end of the gutter or a hole can be made in the gutter where the downpipe is connected. Seal the joint where the downpipe meets the gutter with tar or caulking compound.

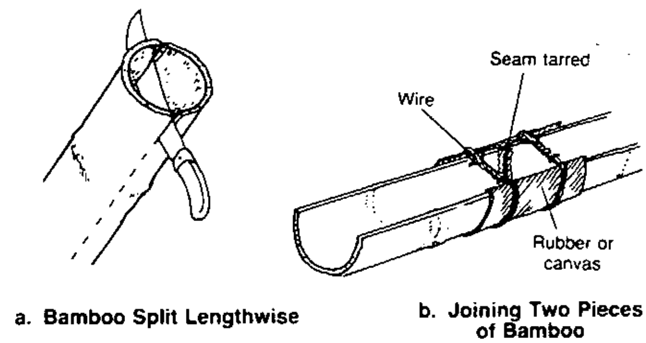


Figure 4. Making Gutters from Bamboo

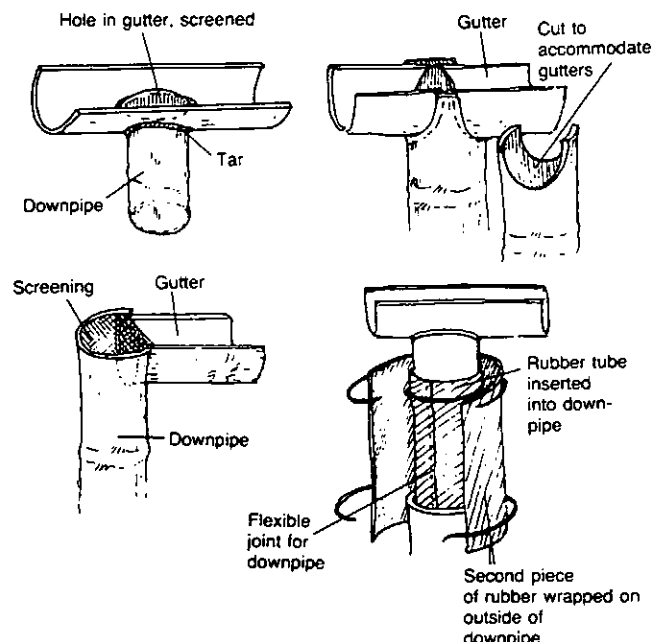


Figure 5. Joining Gutters and Downpipes

5. Place a small mesh wire screen over the opening of the downpipe so that leaves or other debris which could contaminate the water do not enter the cistern. The mesh should be large enough so that leaves and debris are caught but water continues to flow through.

Foul Flush Disposal. There are two ways to remove the foul flush or first wash from a roof. They are simple diversion and construction of a foul flush system.

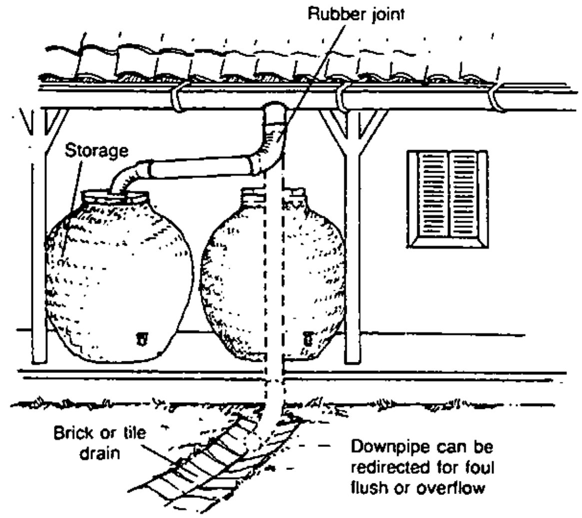


Figure 6. Flexible Joint in Downpipe

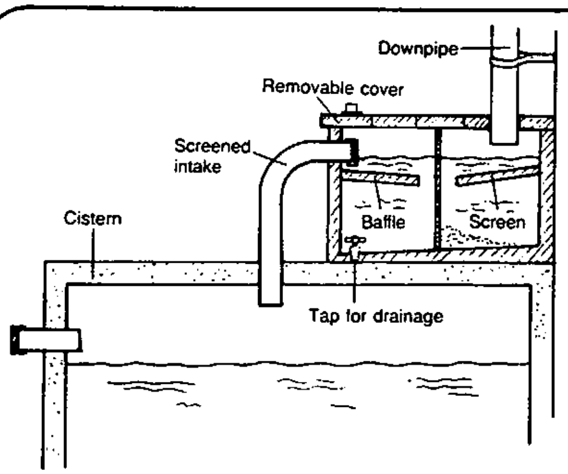


Figure 7. Collection Box for Foul Flush

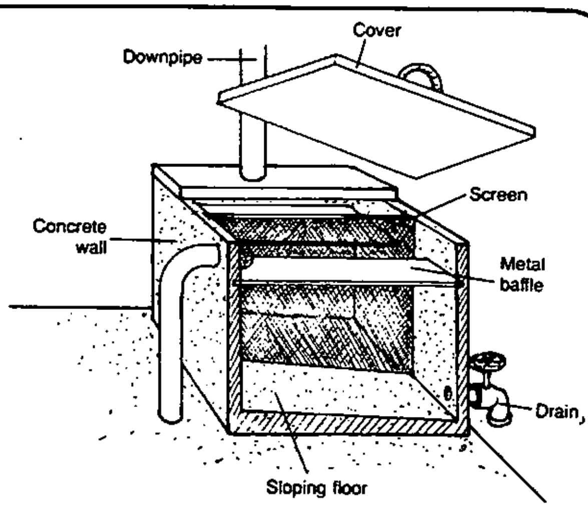


Figure 8. Detail of Collection Box for Foul Flush

For simple diversion, install a rope to the end of the downpipe. When the rain begins, the downpipe can be moved away from the cistern to let the dirty water flow to the ground. This method is useful when large jars are used for water storage. Someone must remember to move the spout at each rainfall. See Figure 6.

If the cistern and downpipe are connected, a small collection box can be built to collect the first run-off. See Figures 7 and 8 for details. The box can be as small as 250mm x 250mm x 250mm and should be made from impermeable material. Clean containers such as 20-liter cans can be used for receiving the first run-off from the roof. A filter system is made using a large can or filter box. Place a filter between the downpipe and the cistern. Line the filter bottom with pea gravel up to about 30mm, then place an equally thick layer of charcoal and on top of that a layer of sand 0.2-0.5mm in diameter. The sand layer should be between 30-50mm thick. On top of the sand place another layer of gravel as shown in Figure 9. Connect the downpipe to the box and connect an outlet pipe to the box and the cistern as shown. Place a screen at the very top of the box so that no large debris can enter. A tap or plug should be installed to empty out the dirty water after each rainfall. When the box fills, the cleaner water flows to the cistern.

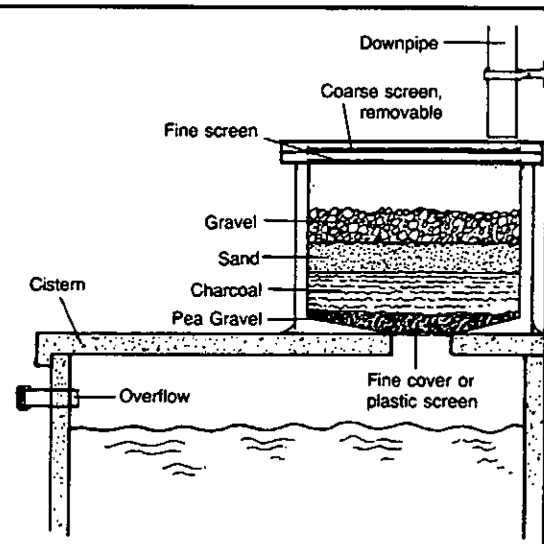


Figure 9. Filter System

Maintenance

Adequate maintenance of the catchment assures that the maximum amount of rainwater is collected and that the water is of good quality. Keep the catchment well maintained by doing the following:

1. Keep the roof in good condition. Repair any holes in the roofing material and change any broken tiles to prevent leaking. Seal any nail holes that are leaking.

2. Clean the roof between rains. Much debris and fecal matter from birds can be removed by sweeping off the roof often enough to keep it looking clean.

3. Keep the gutters in good condition. Be sure they are firmly tied to the roof and that they are well joined to prevent spilling. Repair any holes. If bamboo or wood is used for gutters, check them once a year for rotting. If there is any sign of rot, replace them.

4. Remove leaves and other debris from the gutters to avoid clogging. Check the screen on the downpipe to be sure it is not clogged. If a gutter clogs, water may spill over its sides and be wasted. Watch for leaks and overflow during a rain. See Figure 10.

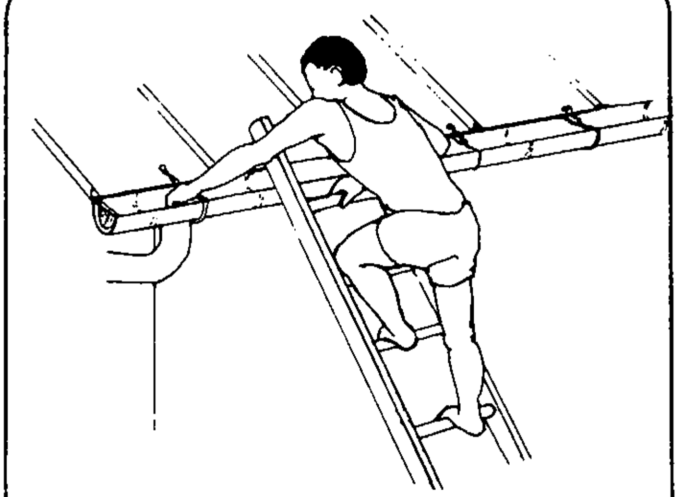


Figure 10. Cleaning Gutter and Screen

5. If a collection box for foul flush is used, clean it out after each heavy rain to remove any sediment or scum.

6. If a filter is used, clean the filter every several months. Wash and change the sand in the filter at least every six months.

Notes

Water for the World

Designing Hand Dug Wells
Technical Note No. RWS. 2.D.1

Proper design of hand dug wells is important to asure a year-round supply of water and to assure efficient use of personnel and materials. Designing involves determining the size and shape of the well; the method of lining the shaft; the type of intake; and the necessary personnel, materials, equipment, and tools. The products of the design process are drawings of the shaft and lining and a detailed materials list. These, along with a location map similar to Figure 1 ("Selecting a Well Site," RWS.2.P.3), should be given to the construction foreman before construction begins.

There are several good methods of designing and constructing hand dug wells; if you are familiar with a specific method, use it. This technical note describes one method of designing hand dug wells and arriving at the essential end-products. Read the entire technical note before beginning the design process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

KIBBLE - A large bucket for lifting materials when sinking a shaft; also called a hoppit or sinking bucket.

POROUS - Having tiny pores or spaces which can store water or allow water to pass through.

WATER TABLE - The top, or upper limit, of an aquifer.

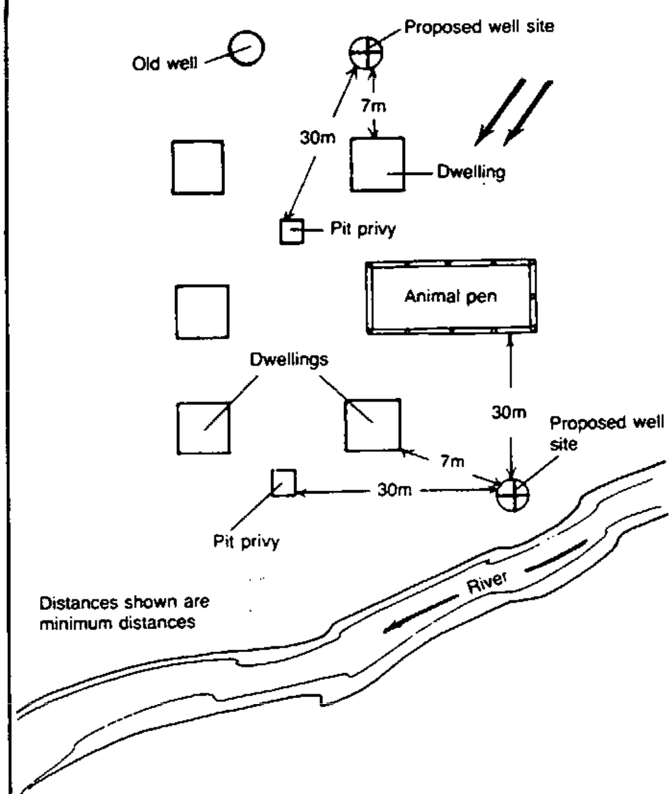


Figure 1. Location Map

Size and Shape

When viewed from the top, wells can be any shape but most of them are round. This is because a round well produces the greatest amount of water for the least amount of excavation, and a round lining is stronger than any other shape.

The size of the well refers to its depth and diameter. Although it is impossible to know the depth of a well before it is dug, an attempt should be made to estimate it. This will allow you to roughly calculate the quantities of materials needed for construction. Use information from test holes or existing wells in the area to estimate the depth of the water table.

For practical and economic reasons, well diameters are between 1.0m and 1.5m. The smaller diameter results in a savings in materials costs, and it requires less soil to be excavated. The larger diameter means a higher materials cost, but a more efficient work output, since two men rather than one can dig the shaft. A larger diameter provides a greater storage capacity and allows more water to enter the well. If pre-made forms or precast concrete rings are used, their size will determine the diameter of the well.

When the depth and diameter of the well shaft have been determined, write the dimensions on a design drawing similar to Figure 2.

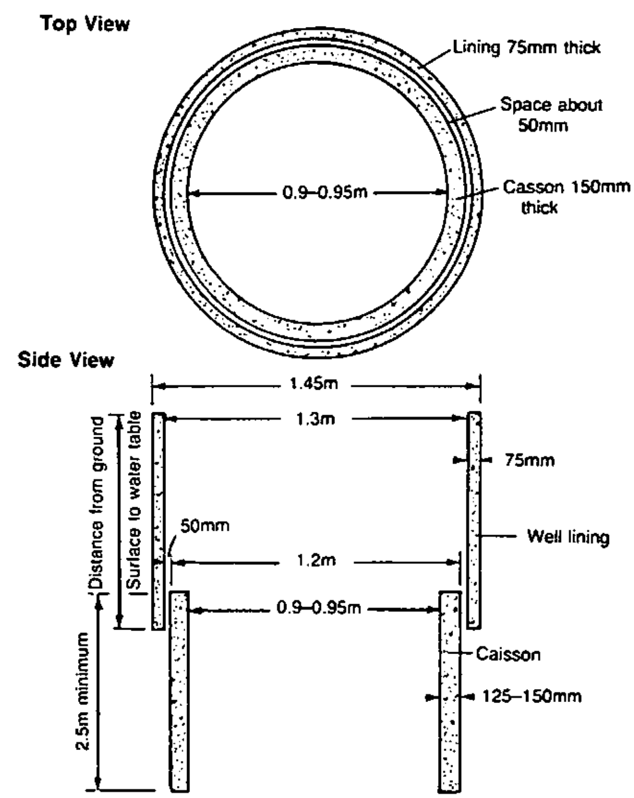


Figure 2. Design of Well Lining and Caisson

Lining the Shaft

Although various materials have been used to line well shafts, concrete is the best and most common lining. It is strong, long-lasting, and widely known.

The two basic methods of lining well shafts are dig-and-line and sink lining or caissoning. In dig-and-line, a portion of the shaft is excavated, shutters are set in place in the shaft, and concrete is poured behind the shutters. When the concrete hardens, the shutters are removed and the next portion of the shaft is excavated.

In sink lining, concrete rings called caissons are cast and cured in special molds at the surface. The rings are stacked on top of each other and attached together with bolts. As soil is excavated from beneath the rings, they sink into the earth and line the shaft.

Often, both methods are employed in a single well: dig-and-line is used until the water table is reached, then caissoning is used to sink the well into the aquifer. The lining is usually 75mm thick and the caisson rings are 125-150mm thick. The outside diameter of the rings is 50-100mm less than the inside diameter of the lining to allow the rings to freely move downward. Table 1 shows common dimensions of shaft, lining, and rings.

Write the dimensions that you determine are best for your well on the design drawing similar to Figure 2.

Intake

The caisson rings are sunk into the aquifer as far as possible; that is, until the water becomes too deep to

Table 1. Dimensions of Shaft, Lining and Caisson Rings

Feature	Dimension
Shaft diameter	1.45m
Lining, outside diameter	1.45m
Lining, inside diameter	1.30m
Lining, thickness	75mm
Caisson, outside diameter	1.20m
Caisson, inside diameter	0.90-0.95m
Caisson, thickness	125-150mm
Caisson, height	0.50m

continue the excavation. Ground water may then enter the well either (1) through the opening under the lowest caisson ring, or (2) through the rings themselves. In the first case, the rings are made of standard concrete which does not allow entry of water. In the second case, the rings are usually made of porous concrete which allows water to pass through. Another way to allow water to enter through the caisson rings is to build the rings from standard concrete and perforate them with seepage holes. For all types of intakes, the bottom of the shaft should be covered with a porous base plug made from porous concrete or layers of sand and gravel. The plug prevents aquifer material from rising into the well.

The type of caisson ring used depends on the nature of the aquifer. Normally, rings are made of porous concrete. However, if the aquifer is composed of fine sand, which would clog the pores or flow through the seepage holes, the rings should be made of standard concrete without perforations. It may not be possible to know which type of intake is needed until the aquifer is reached. But an attempt should be made to anticipate the necessary intake, based on test holes or other wells in the area.

When the type of intake has been determined, indicate it on the design drawing similar to Figure 2.

Personnel

The most important person involved with well construction is the foreman. He should have some experience. He must oversee all phases of construction, including excavating and lining the shaft, mixing concrete for the lining and caissons, and lowering the caissons into place. It is his responsibility to see that construction proceeds in a safe manner.

At least four workers are needed. One should have some experience with well digging and one should have experience with concrete construction. The workers must be reliable because the construction process may take several weeks or more.

Materials

The materials needed to line a hand dug well are concrete mix and reinforcing steel.

One common mix of concrete is one part cement to two parts sand to four parts gravel by volume and enough water to make a workable mix. The cement should be Portland cement, and it should be dry and free from hard lumps. Sand should be clean, and sized fine to 6mm. If porous concrete is used for the caisson rings, omit the sand. Gravel should be clean and sized 6-36mm (10-20mm for porous concrete). Water should be clean and clear.

Two sizes of reinforcing steel, called re-rods, are generally used: 8mm diameter for the lining and 15mm diameter for the caissons. The quantities of these materials needed can be roughly estimated.

For each meter of depth of the lining:

gravel = $0.5m^3$
sand = $0.25m^3$
cement = $0.125m^3$ (or about 190kg, assuming $0.00066m^3$ = 1.0kg)
8mm re-rod = 33m

For each meter of caisson rings:

gravel = $1.0m^3$ ($1.4m^3$ for porous concrete)
sand = $0.5m^3$ (none for porous concrete)
cement = $0.25m^3$ ($0.35m^3$ for porous concrete)
15mm re-rod = 4m

For example, suppose the estimated depth of the shaft and lining is 15m, the height of the caisson rings is 3m, and the rings are to be made from porous concrete. The quantities would be estimated in the following way.

For the lining:

gravel = $0.5m^3 \times 15 = 7.50m^3$
sand = $0.25m^3 \times 15 = 3.75m^3$
cement = $0.125m^3 \times 15 = 1.88m^3 = \dfrac{1.88m^3}{0.00066m^3/kg} = 2850kg$
8mm re-rod = 33m x 15 = 495m

For the porous concrete caissons:

gravel = $1.4m^3 \times 3 = 4.20m^3$
sand = none
cement = $0.35m^3 \times 3 = 1.05m^3 = \dfrac{1.05m^3}{0.00066m^3/kg} = 1590kg$
15mm re-rod = 4m x 3 = 12m

The total quantity of cement needed for the lining and the caisson rings = 2850kg + 1590kg = 4440kg. Cement is often packaged in 50kg sacks, so the number of sacks needed = $\dfrac{4440}{50}$ = 88.8 or 89 sacks. Worksheet A shows a further example of how to estimate quantities of materials needed for a hand dug well.

Other materials needed are those used to build a storage shed. Use locally available materials and traditional construction methods.

Equipment

The main piece of equipment needed is a headframe capable of lowering workers and caissons into the shaft and hoisting up excavated soil. The headframe must be able to support weights in excess of 350kg, the approximate weight of a concrete caisson. It should have a winch, a main pulley, and an auxiliary pulley.

At least three ropes are needed: one for lowering caissons, tensile strength of rope about $7kg/cm^2$, one for lowering and raising full kibbles and concrete buckets, and one for suspending trimming rods.

A heavy-duty stretcher with a U-bolt in the center is needed to lower caissons.

Steel shutters are needed to form the lining. For caissons, you will need steel molds and templates to position the re-rods.

Two kibbles are needed to hoist up water and excavated soil. The kibbles should be watertight and made of steel, with a safety latch on the handle to prevent them from tipping. They should be wider around the middle than around either end to prevent them from catching on any projections within the shaft.

Other equipment needed includes concrete buckets, a bosun's chair, top plumbing rod, long and short trimming rods, and hard hats.

Tools

The workers need tools for measuring, plumbing, excavating, and trimming the shaft; mixing, pouring, and finishing concrete; and positioning and securing re-rods. When you have determined all necessary personnel, materials, equipment, and tools, prepare a materials list similar to Table 2 and give it to the construction foreman. Give the construction foreman design drawings of the well, a detailed materials list, and a location map.

Worksheet A. Estimating Quantities of Materials for Hand Dug Wells

For the Lining:

1. Estimated depth of shaft = 15 m
2. Gravel = $0.50m^3$ x Line 1 = $0.50m^3$ x 15 = 7.50 m^3
3. Sand = $0.25m^3$ x Line 1 = $0.25m^3$ x 15 = 3.75 m^3
4. Cement (m^3) = $0.125m^3$ x Line 1 = $0.125m^3$ x 15 = 1.88 m^3
5. Cement (kg) = $\frac{\text{Line 4}}{0.00066m^3/kg}$ = $\frac{(1.88\ m^3)}{0.00066m^3/kg}$ = 2850 kg
6. 8mm re-rod = 33m x Line 1 = 33m x 15 = 495 m

For the Caisson Rings:

Type of concrete (check one): ☐ standard ☒ porous

Standard Concrete

7. Height of caisson rings = 3 m
8. Gravel = $1.0m^3$ x Line 7 = $1.0m^3$ x _____ = _____ m^3
9. Sand = $0.50m^3$ x Line 7 = $0.50m^3$ x _____ = _____ m^3
10. Cement (m^3) = $0.25m^3$ x Line 7 = $0.25m^3$ x _____ = _____ m^3
11. Cement (kg) = $\frac{\text{Line 10}}{0.00066m^3/kg}$ = $\frac{(\_\_\_\_\ m^3)}{0.00066m^3/kg}$ = _____ kg
12. 15mm re-rod = 4m x Line 7 = 4m x 3 = 12 m

Porous Concrete

13. Gravel = $1.40m^3$ x Line 7 = $1.40m^3$ x 3 = 4.20 m^3
14. Sand = none
15. Cement (m^3) = $0.35m^3$ x Line 7 = $0.35m^3$ x 3 = 1.05 m^3
16. Cement (kg) = $\frac{\text{Line 15}}{0.00066m^3/kg}$ = $\frac{(1.05\ m)}{0.00066m^3/kg}$ = 1590 kg

Total Amount of Cement for Lining and Caisson =

Line 5 + Line 11 + Line 16 = 2850 kg + – kg + 1590 kg = 4440 kg

Table 2. Sample Materials List

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	_____
	Worker, skilled in sinking well	1	_____
	Worker, experienced with concrete	1	_____
	Workers, unskilled	2-4	_____
Supplies	Cement (Portland)	_____kg	_____
	Sand (clean; fine to 6mm)	_____m^3	_____
	Gravel (clean; 6-36mm)	_____m^3	_____
	Water (clean and clear)	_____	_____
	Re-rod for lining: 8mm diameter	_____m	_____
	Re-rod for caissons: 15mm diameter	_____m	_____
	Materials for storage shed	_____	_____
Equipment	Headframe	_____	_____
	Rope for caissons; 100m x 12mm diameter, steel wire with fiber core tensil strength $7kg/cm^2$	_____	_____
	Rope for kibbles: 100 x 6mm diameter	_____	_____
	Rope for trimming rods: 100m x 3mm diameter	_____	_____
	Steel shutters (1.30m diameter x 0.5m high) with wedges and bolts	_____	_____
	Steel shutters (1.30m diameter x 1.0m high) with wedges and bolts	_____	_____
	Steel molds for caisson rings (1.20m outside diameter, 0.95m inside diameter, 0.5m high)	_____	_____
	Templates for molds	_____	_____
	Stretcher for caissons	_____	_____

Total Estimated Cost = _____

Water for the World

Constructing Hand Dug Wells
Technical Note No. RWS. 2.C.1

Proper construction of a hand dug well is important to ensure a year-round supply of water and to protect the water from contamination. Construction involves assembling all necessary personnel, materials, and tools; preparing the site; excavating the well shaft; and lining the shaft. Finishing the well is discussed in "Finishing Wells," RWS.2.C.8.

There are several good methods to construct a hand dug well; if you are familiar with a specific method, use it. This technical note describes one method of construction, using locally available materials, that has been employed successfully in a number of countries. Read the entire technical note before beginning construction.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria.

GROUND WATER - Water stored below the ground's surface.

KIBBLE - A large bucket for lifting materials when sinking a shaft; also called a hoppit or sinking bucket.

POROUS - Having tiny pores, or spaces which can store water or allow water to pass through.

WATER TABLE - The top, or upper limit, of an aquifer.

Materials Needed

The project designer must provide three papers before construction can begin:

1. A <u>location map</u> similar to Figure 1.

2. A <u>design drawing</u> similar to Figure 2.

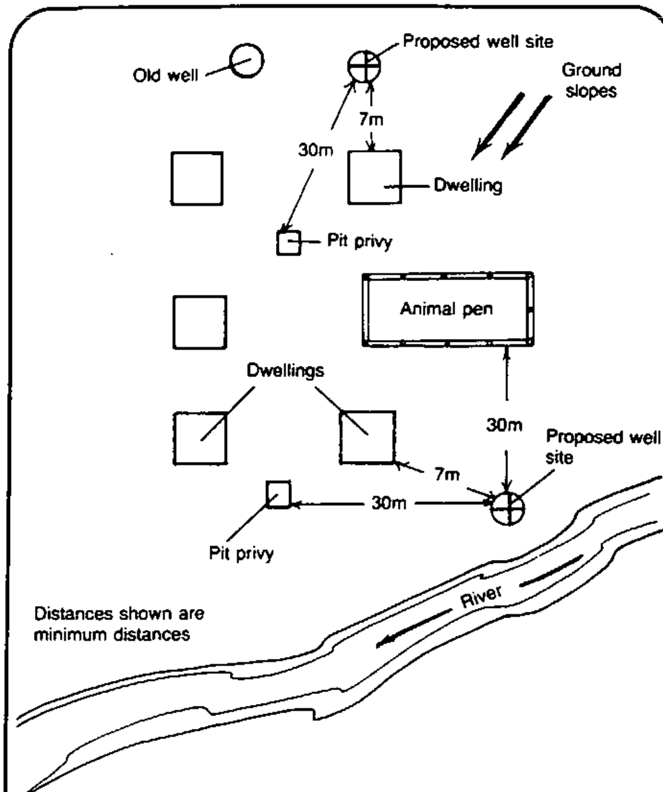


Figure 1. Location Map

3. A materials list similar to Table 1.

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary workers, supplies, and tools.

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when specific workers, materials, and tools must be available during the construction process. Draw up a work plan similar to Table 2 showing construction steps.

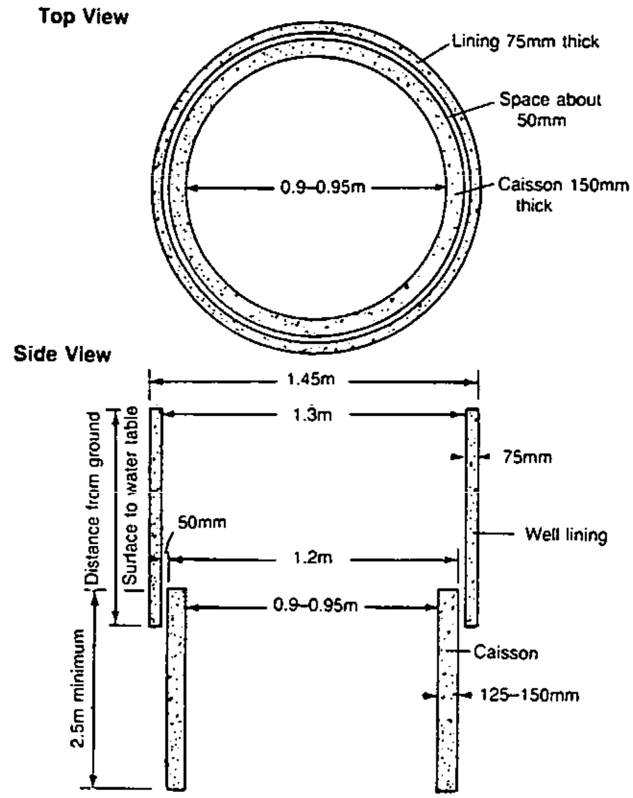


Figure 2. Design of Well Lining and Caisson

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	___
	Worker, skilled in sinking well	1	___
	Worker, experienced with concrete	1	___
	Workers, unskilled	2-4	___
Supplies	Cement (Portland)	___ kg	___
	Sand (clean; fine to 6mm)	___ m^3	___
	Gravel (clean; 6-36mm)	___ m^3	___
	Water (clean and clear)	___	___
	Re-rod for lining: 8mm diameter	___ m	___
	Re-rod for caissons: 15mm diameter	___ m	___
	Materials for storage shed	___	___
Equipment	Headframe	___	___
	Rope for caissons; 100m x 12mm diameter, steel wire with fiber core, tensil strength 7kg/cm^2	___	___
	Rope for kibbles: 100 x 6mm diameter	___	___
	Rope for trimming rods: 100m x 3mm diameter	___	___
	Steel shutters (1.3m diameter x 0.5m high) with wedges and bolts	___	___
	Steel shutters (1.3m diameter x 1.0m high) with wedges and bolts	___	___
	Steel molds for caisson rings (1.2m outside diameter, 0.95m inside diameter, 0.5m high)	___	___
	Templates for molds	___	___
	Stretcher for caissons	___	___

Total Estimated Cost = ___

Table 2. Sample Work Plan for a Hand Dug Well

Time Estimate	Day	Task	Personnel	Materials/Tools
1 day	1	Locate and prepare well site; assemble materials	Foreman (present during entire construction); 2-4 workers	Measuring tape; drawings; tools and materials for building shed
1 day	2	Erect headframe; set center point and offset pegs; build mixing slab	2-4 workers	Headframe; plumb bob; re-rod; cement, sand, gravel, water; trowel
4 hours	3	Dig shallow excavation; install temporary lining	2-4 workers	Shovels; shutters (1.3m diameter, 1.0m high) spirit level
7 days	3-9	Excavate and trim first lift	4 workers	Shovels; picks; mattock; kibble; top plumbing rod; trimming rods
2 hours	10	Install first set of shutters	4 workers	Shutters (1.3m diameter, 0.5m high); spirit level; trimming rods; shovel
6 hours	10	Install vertical and horizontal re-rods	4 workers	Lengths of re-rod; binding wire; spacing blocks and holding hooks; wire cutters
1 day	11	Install second set of shutters; pour concrete; build curb	4 workers	Oiled shutters (1.3m diameter, 1.0m high); cement, sand, gravel, water; tamping rod; re-rod; burlap covering; mattock
1 day	12	Install third and fourth sets of shutters; pour concrete	4 workers	Sets of oiled shutters; cement, sand, gravel, water
2 days	13-14	Widen top of well; add re-rods; install fifth and sixth sets of shutters; pour concrete; bend back rods and cover with layer of weak mortar	4 workers	Burlap covering; mattock; re-rod; binding wire; sets of oiled shutters; cement, sand, gravel, water
---	---	Construct second and third lifts and lining as needed	4 workers	Materials and tools as needed
1 day	15	Build caisson rings	4 workers	Molds; re-rods; oiled pipes; templates; cement; sand (none if porous concrete), gravel, water
10 days	16-25	Cure caisson rings	----	Wet burlap or straw
2 days	26-27	Install caisson rings	4 workers	Stretcher; spacers; heavy planks; wrench; mortar; trowel
2 days	28-29	Sink caissons into aquifer	4 workers	Shovels, kibble
2 hours	30	Install base plug	4 workers	Precast base plug

Caution!

1. Workers in the well shaft should wear hard hats for protection.

2. Workers at ground level must be careful not to accidentally drop or kick tools or other materials into the well shaft.

3. A kibble, rather than a bucket or basket, should be used to hoist soil out of the shaft.

4. The well must be dug at the exact location specified by the project designer.

Construction Steps

1. Using the location map and a measuring tape, locate the well site. Clear the area of any vegetation or debris that might interfere with work.

2. Assemble all laborers, materials, and tools needed to begin construction and arrange the materials in a fashion similar to Figure 3. A proper layout will save time and effort during later construction steps. A shelter should be built to protect tools and some materials from the weather, theft, or being misplaced.

Because the caisson rings must be cured for at least 10 days before they can be lowered into the well shaft, build them first even though they will not be needed until later in the construction process. See step #26.

3. Erect the headframe over the site of the well. The headframe must be sturdy enough to support the caisson rings, which may weigh over 350kg. One type of headframe that has been used successfully is shown in Figure 4. It is made of angle iron and equipped with a winch and brake. The four feet of the headframe must rest on solid ground--place stone slabs or pour concrete under them if necessary. It is important that the headframe not be moved once it is in position and the center point of the well has been fixed.

4. Build a slab for mixing concrete by first leveling an area about two meters square. Spread 50mm of well-tamped gravel, cover with a layer of cement mortar (4 parts sand to 1 part cement), and smooth with a trowel. Form a lip around the outer edge, cover the slab with wet burlap or straw, and keep moist for two or three days.

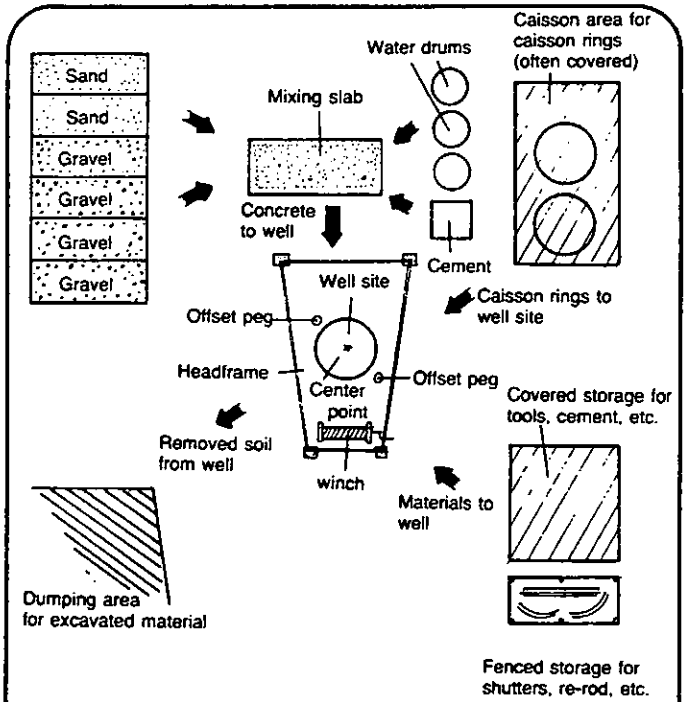


Figure 3. Layout of Well Site

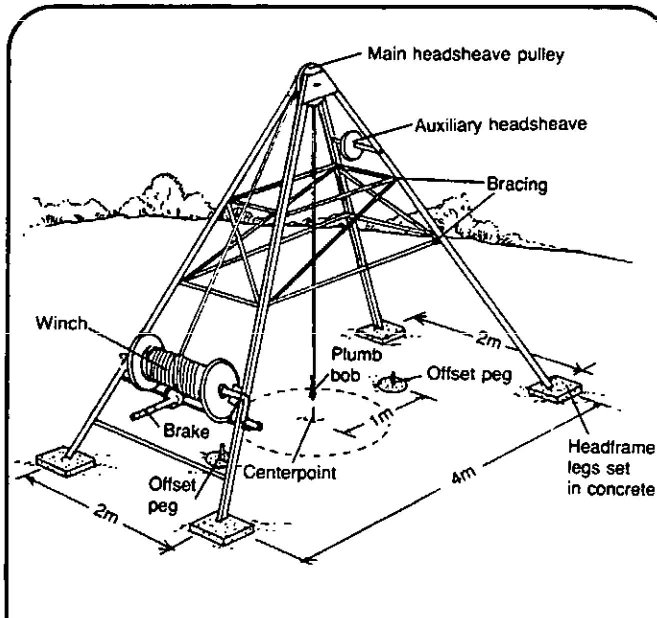


Figure 4. Headframe

5. Establish the center point of the well by lowering a plumb bob from the headsheave pulley on the side opposite the winch; that is, the side from which the main hoisting rope will descend. Mark this point on the ground with a short length of re-rod. Set offset pegs on opposite sides and exactly 1.0m from the center point. Make the top of these pegs at least 150mm above ground level to make allowance for the temporary lining that will be installed. These pegs should be set in concrete and positioned so that the top plumbing rod will fit over them as in Figure 4. Allow the concrete to set for several days before using the pegs.

6. Mark a circle of 650mm radius around the center point. Carefully excavate within this circle to a depth of 0.9m. Position a set of steel shutters 1.3m in diameter and 1.0m high inside this hole with 100mm projecting above ground to act as a temporary lining. See Figure 5. Be certain that the shutters are exactly in place and that the top is level. Firmly tamp soil around the outside. These shutters will prevent the top of the shaft from crumbling, and they will reduce the risk of tools or materials being accidentally kicked into the shaft.

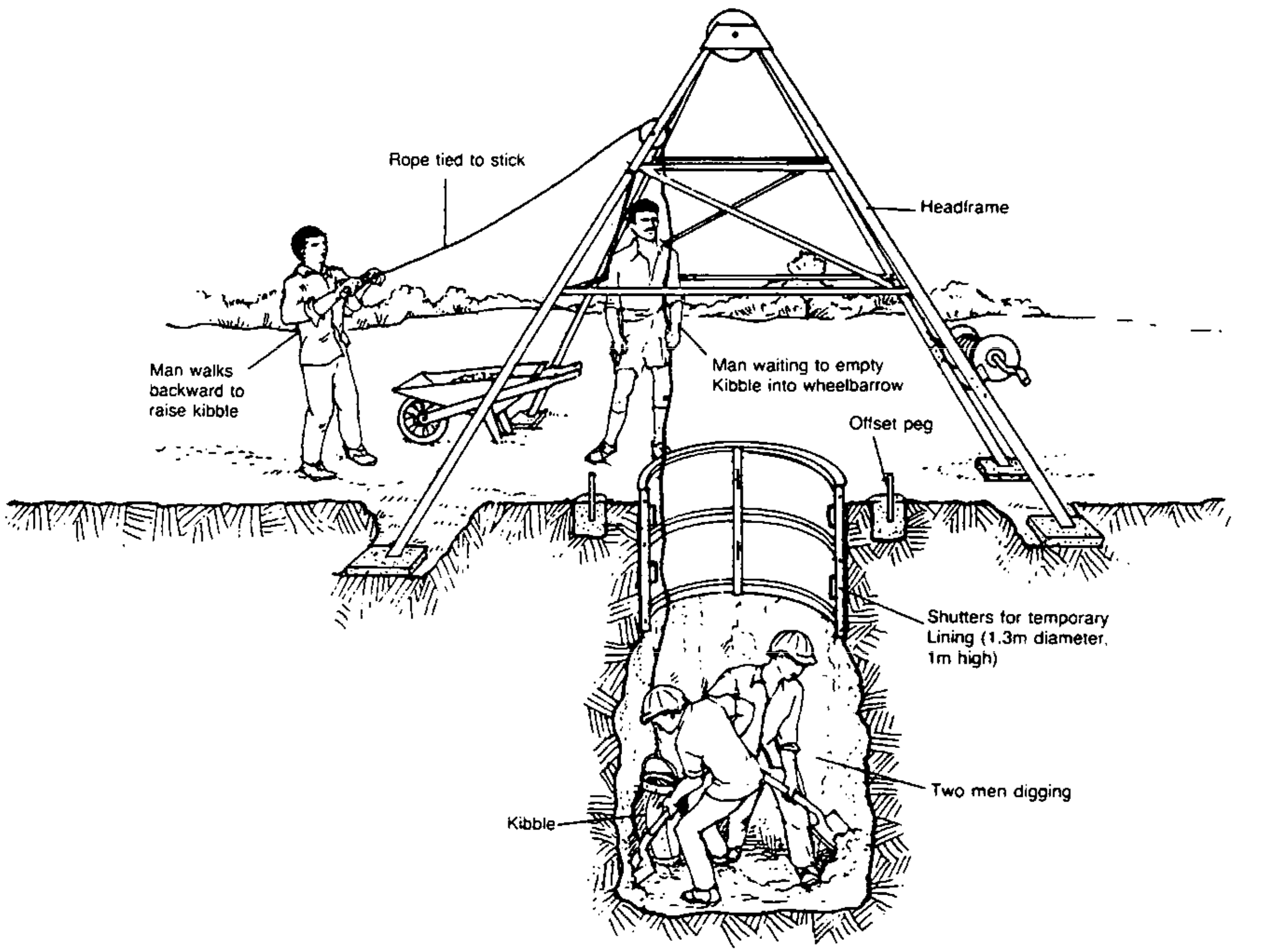


Figure 5. Excavating the Shaft

7. Begin excavating the first lift of the well. Normally, two workers using miner's picks and bars and short-handled shovels excavate the soil in layers about 100mm deep, and they keep the bottom of the excavation fairly level at all times. Soil is removed by hoisting it up in a kibble, as shown in Figure 5. The shaft is dug somewhat less than its finished diameter of 1.45m.

Every meter or so the long trimming rods, 1.45m long, are suspended from the top plumbing rod. The workers carefully trim the walls of the shaft so that the trimming rods can freely turn with their ends just missing the shaft walls, as shown in Figure 6. It is important that the trimming be done with extreme care, for even a small addition to the thickness of the lining will increase the amount of concrete used.

Depending on the condition of the soil, the first lift can be dug as deep as 5.0m, 4.1m below the bottom of the temporary lining. If the soil is crumbly or tends to cave in, the lift must be shallower. If water is struck, stop the excavation and proceed to step 25.

8. A set of shutters, 1.3m in diameter and 0.5m high, is oiled and then lowered to the bottom of the shaft. Set the shutters precisely in place by suspending the short trimming rods 1.3m long and lining up the edges of the shutters directly beneath the ends of the rods. Use a spirit level to be certain that the shutters are level. It is essential that these shutters be exactly in place and perfectly level, or else the entire lining will be out of line. See Figure 7.

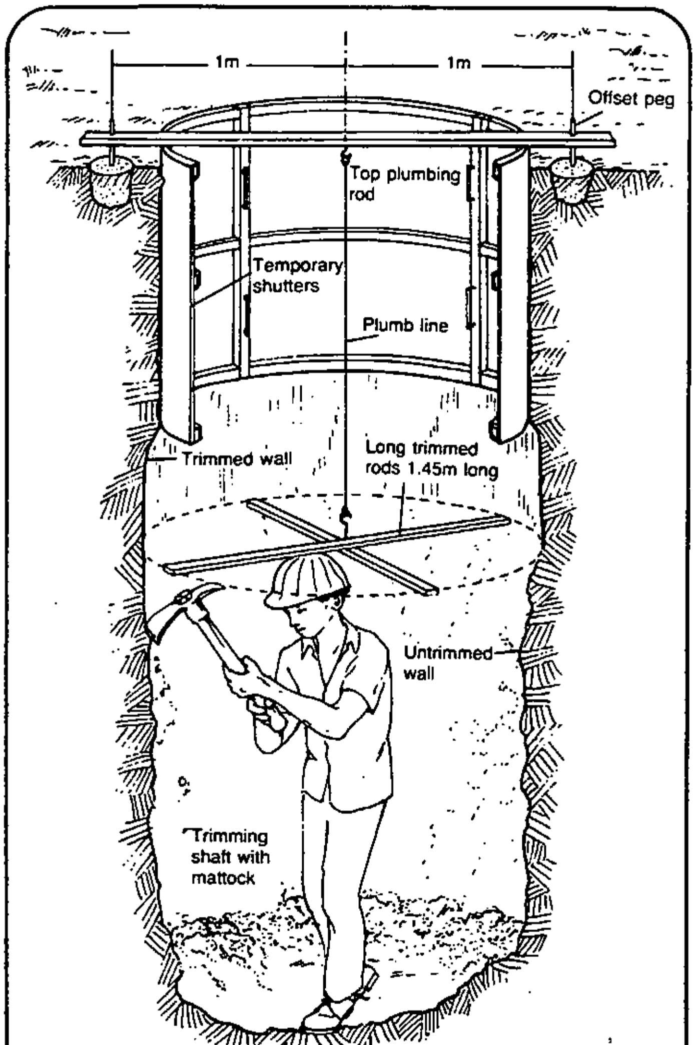


Figure 6. Trimming the Shaft

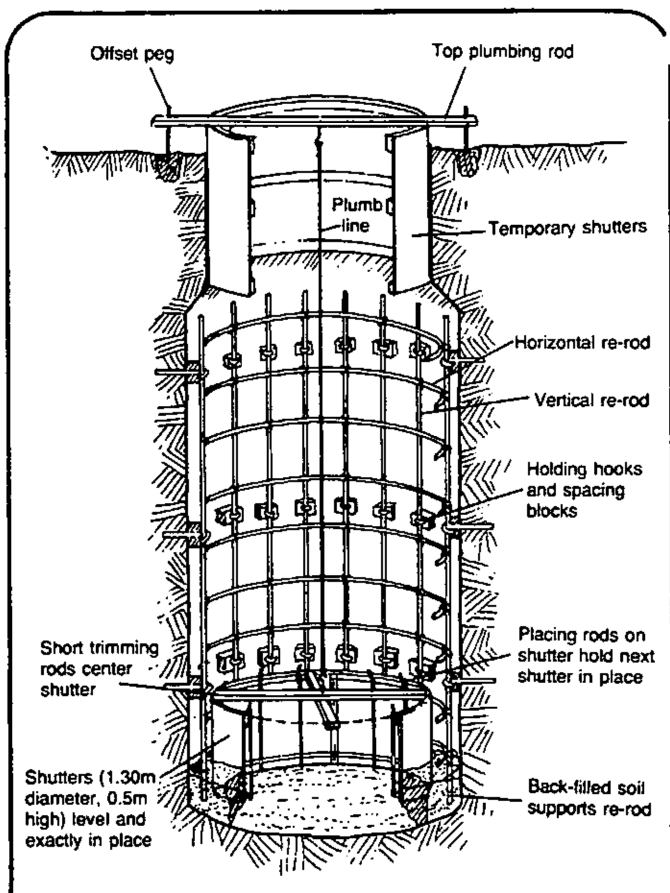


Figure 7. First Set of Shutters and Re-rod

9. Position 20 lengths of vertical re-rod, each length 4.0m long and 8mm in diameter, behind the shutters and around the shaft walls. Fix the rods to the walls about 200mm apart using spacing blocks and holding hooks. Backfill behind the shutters with soil to help hold the rods in place, as shown in Figure 7.

10. On the surface, shape horizontal re-rods into circles 1.38m in diameter. You will need three or four horizontal re-rods for each meter of depth. Lower the re-rods and fasten them to the inside of the vertical re-rods about 250-300mm apart, as shown in Figure 7. They will make the reinforcement cage strong and secure. Use a wire brush to remove all dirt from the re-rods.

11. Oil a set of shutters, 1.3m in diameter and 1.0m high, lower it into the shaft, and position it on top of the first set. Center the shutters with the short trimming rods, 1.3m long, check them with a spirit level, and bolt them in place, as shown in Figure 8.

12. Mix concrete on the mixing slab. Use one part cement, two parts sand, four parts gravel, and enough water to make a workable mix. Lower the concrete in a concrete bucket tied to a rope over the auxiliary headsheave. The main headsheave and a bosun's chair will be used later to raise and lower the workman pouring concrete. When lowering the bucket, be careful that it does not catch on any projection and spill its contents on the workers below.

Pour the concrete behind the shutters as shown in Figure 8. Pour it evenly and in shallow layers to prevent overloading one side. Tamp with a length of re-rod. Fill the space between the shutters and the shaft walls until the concrete is 10-20mm from the top of the shutters, and leave the top of the concrete rough. This will ensure a good bond with the next pour.

13. Temporarily cover the concrete with burlap or other material to keep off soil. Carefully excavate a triangular-shaped groove, 200mm deep and 200mm high at the well face, around the shaft walls just above the shutters. Set re-rod pins into the groove and fasten to the vertical re-rods. Remove the temporary cover. Fill in the groove with concrete as shown in Figure 8. This forms a curb which will help hold the lining in place and prevent it from slipping.

14. Oil the third set of shutters, 1.3m diameter and 1.0m high, lower it into the shaft, and position it on top of the second set. Center the shutters with the short trimming rods, check them with the spirit level, and bolt them in place. Pour concrete as before, and tamp to be certain all voids are filled with concrete.

15. Oil a fourth set of shutters and repeat the process of lowering and positioning them and pouring concrete as shown in Figure 8.

16. The top of the fourth set of shutters will be about 600mm below the bottom of the shutters being used for temporary top lining. Cover the concrete with burlap to keep off soil and remove the temporary lining. Excavate the sides of the well to a diameter of 1.6m from the surface of the ground down to the top of the fourth shutter. Attach lengths of vertical re-rod to the re-rod already in place. Bend the ends of all re-rods into hooks and overlap the lengths by

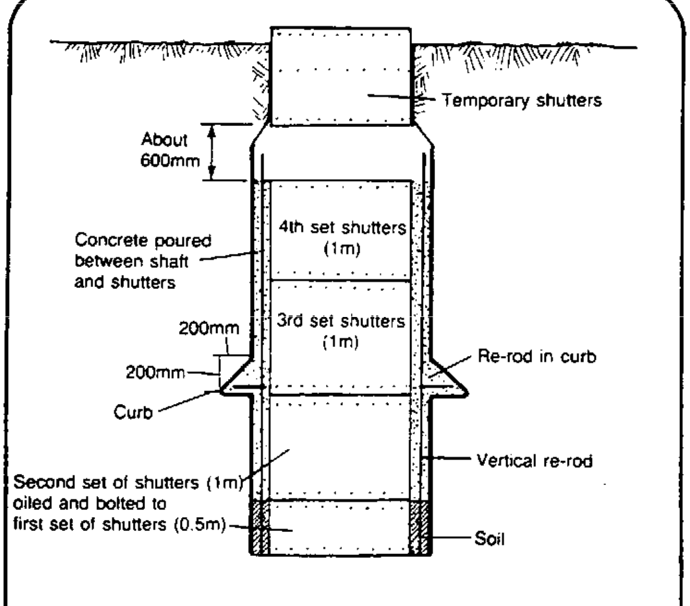


Figure 8. Shutters and Curb

at least 200mm as shown in Figure 9. The new re-rods should protrude above ground about 200mm. Position circles of horizontal re-rods 250-300mm apart and fasten them to the vertical re-rods. Remove the burlap from the concrete.

17. Oil the fifth and sixth sets of shutters in turn, set them in place, check their positioning with trimming rods and a spirit level, and bolt them together. Pour concrete as before, and carefully fill in the space behind the shutters up to ground level as shown in Figure 9. The extra thickness of concrete in the top 1.5m of the lining will provide a solid base for the wellhead. See "Finishing Wells," RWS.2.C.8.

18. Bend back the protruding vertical rods until they are level with the ground. Make a weak mortar mix (1 part cement to 15 parts sand), and use it to cover the re-rods and form a lip around the well as shown in Figure 9. This mortar layer will help keep surface water and debris out of the well, and it can be easily broken away when it is time to build the wellhead.

The first lift is now complete. Leave the shutters in place for about seven days to allow the concrete lining to cure. If you have more shutters, you can begin the second lift at once, leaving the first lift shutters in place. If not, you will have to wait seven days before beginning the second lift.

19. To begin the second lift, remove the earth-filled shutter at the bottom of the first lift, and clean the re-rods with a wire brush.

20. Excavate the second lift to a depth of 4.65m below the bottom of the concrete lining of the first lift. If ground water is encountered before you reach this depth, stop the excavation and proceed to step 25.

21. Position the vertical re-rods in the same manner used in the first lift. Bend the top ends of these re-rods into

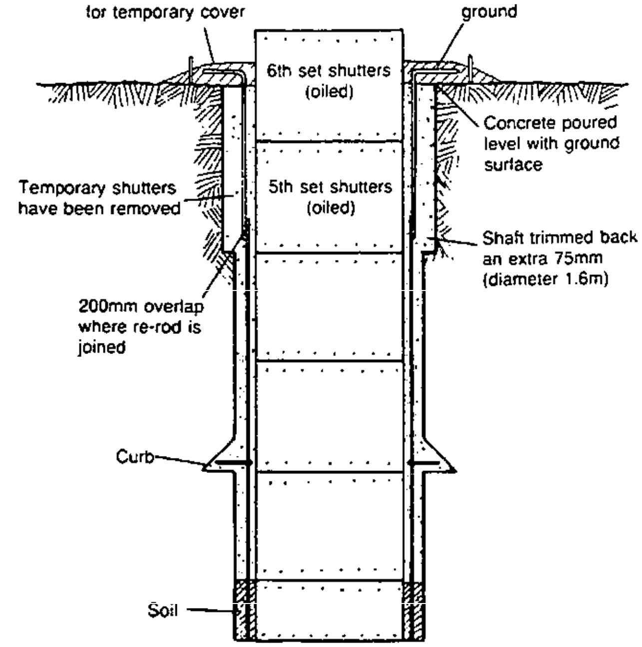


Figure 9. Completing the First Lift

hooks and leave the bottom ends of the re-rods protruding down from the concrete. The lengths should overlap by about 200mm. Fasten them together with wire. Position and fasten circular sections of horizontal re-rods in place.

22. Begin lining the second lift in the same manner as the first. Remember the first set of shutters is 0.5m high and backfilled with soil, and a concrete curb is built just above the second set of shutters.

23. There will be a gap of about 150mm between the top of the fourth set of shutters and the bottom of the concrete lining of the first lift, as shown in Figure 10. To pour concrete into this set of shutters you will need a funnel or scoop made from scrap metal. This will prevent spilling concrete.

24. The gap between lifts should be left open until the entire well is excavated and lined in case there is any movement or shifting of the lining.

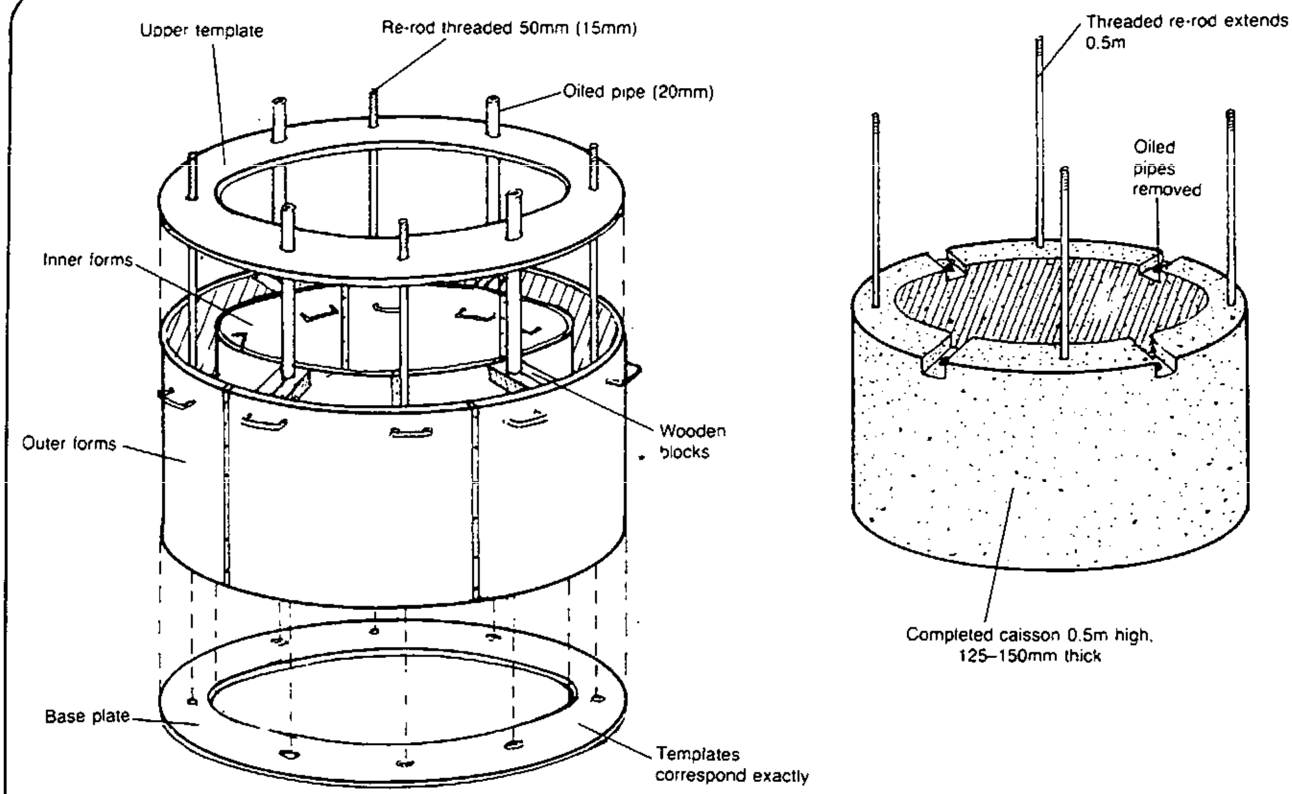


Figure 10. Casting Caissons

These gaps can be used to attach the pipe for a pump or the supports for an access ladder.

When it is time to fill the gaps, use concrete mortar and bricks or stones. Thoroughly seal the entire gap with a coating of plaster to prevent possible contamination by entry of surface water.

25. Continue the process of digging and lining until ground water is reached. If you encounter difficult ground or if the water table is reached before a full lift is excavated, the lift can be made as shallow as 650mm, 500mm for a small set of shutters and 150mm for the gap below the previous lining.

When the aquifer is reached, dig down into it to examine its composition and depth. An auger is a useful tool for this work. If the aquifer is a shallow perched layer, you must sink the well through it to a deeper aquifer. If you have indeed reached a main aquifer, line this last section of the shaft as before and build an extra-deep curb as shown in Figure 10.

26. The remainder of the well will be sunk using the caisson method. Before you can begin, the lining must be given time to harden so that you can remove the shutters. See Figure 2 for the way in which caisson rings fit into the lining.

The caisson rings may already have been cast as described in step 2. The type of rings used depends on the composition of the aquifer. The rings can be made of porous concrete, standard concrete, or standard concrete perforated with seepage holes.

26a. Cast all types of rings in a mold 0.5m high, with an outside diameter of 1.2m and an inside diameter of 0.90-0.95m. See Figure 10. If standard concrete is to be used, it can be the same mix as was used for the lining. If the rings are to have seepage holes, you must use special molds with perforations. If porous concrete is to be used, it should be made by mixing one part cement to four parts washed gravel and no sand. The mix must not be overly wet; use only enough water to make it workable. The gravel must be quite clean and of the correct size. It must all pass through a 20mm screen but none of it must pass through a 10mm screen.

26b. To ensure that the caisson rings will fit together when placed in the well shaft, equip each ring with four evenly-spaced re-rods, 15mm diameter and 1.0m long, and four evenly-spaced holes 20mm in diameter. When the rings are set one on top of the other, the re-rods from one ring will fit into the holes of the other. The holes are made with well-oiled pipes, and the pipes and re-rods are held in position by a template. A small block of wood with a hole for the pipe to pass through is positioned to form a recess in the caisson ring for a bolt which will be secured onto the end of each re-rod. Each re-rod is threaded at the top 50mm and has a hole drilled 25mm from the bottom end through which a nail or piece of thick wire is placed. This will prevent the rod from pulling out when weight is placed on it.

26c. Cast the caisson rings in the shade. Insert the re-rods and the pipes that will form the holes. If the rings are to have seepage holes, place rods or wooden pegs through the holes in the sides of the mold.

26d. When the concrete has been in the mold for 12-24 hours, remove the pipes for the holes and, if necessary, the rods or pegs for the seepage holes.

26e. The molds should not be removed for three days, and the caisson rings should not be moved during this time. If porous concrete is being used, the molds should be left in place for seven days.

26f. Remove the caisson rings from their molds. Cure the rings by keeping them moist and in the shade for seven days. If they are made from porous concrete, the rings should be cured for 14 days.

27. Roll the first caisson ring beside the well shaft and tip it on end so that the re-rods are pointing up. Lower the stretcher over two re-rods on opposite sides of the ring. The stretcher must be made of steel or wood and be capable of supporting the weight of the caisson rings, each of which may weigh over 350kg. Fit lengths of 20mm diameter pipes and washers over the re-rods so that the stretcher can be tightly bolted down as shown in Figure 10.

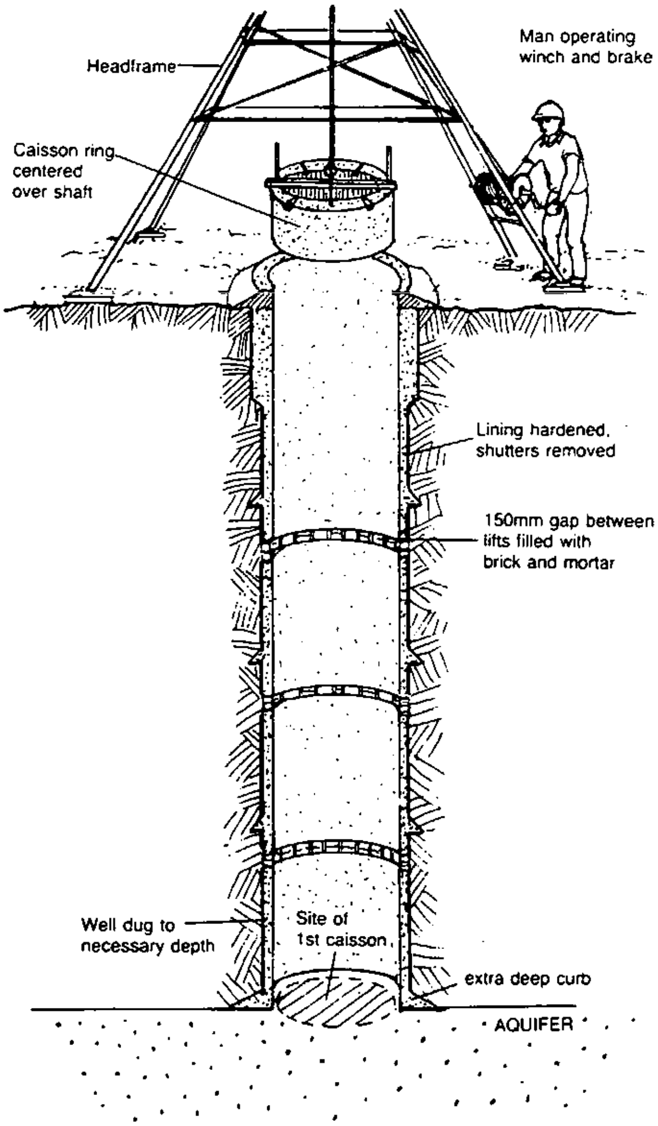
28. Cover the opening of the well shaft with stout logs or planks. Attach the main lowering rope to the U-bolt in the center of the stretcher. Carefully maneuver the caisson ring up onto the logs or planks until it is centered, raise it about 100mm, and remove the planks.

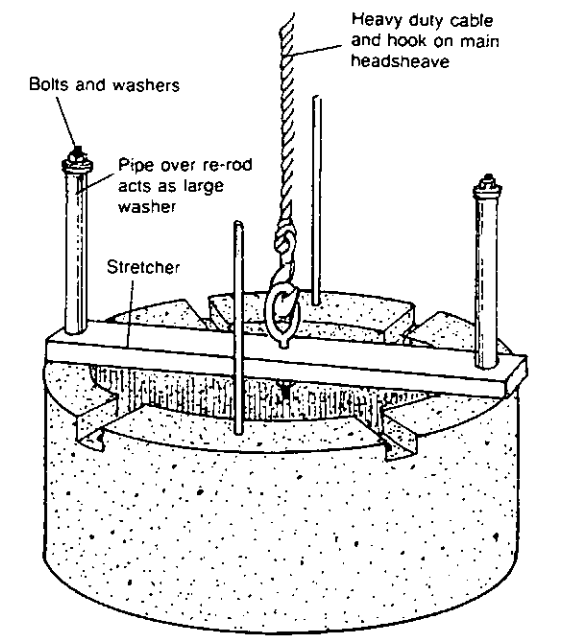
29. Slowly and carefully lower the ring to the bottom of the shaft. The ring must be level and perfectly centered, or you will have difficulty fitting on the other caisson rings. If necessary, raise the ring just off the bottom and wedge pieces of wood underneath until it is level and in position. Only then should you unbolt the stretcher. See Figure 11.

30. Lower the second ring in the same manner as the first. Just before it reaches the projecting re-rods of the first ring, a worker, perhaps sitting on the stretcher, must turn it so that its holes match the projecting re-rods. Partly lower the ring onto the re-rods, then spread a 10mm layer of cement mortar on the top edge of the first ring. Lower the second ring until it rests on the first. The rods of the first ring will project up into the recesses on the top edge of the second ring. Fix bolts on the threaded ends of the re-rods and tighten until the second ring is secure and level. Fill in the recesses and cover the bolt with cement mortar.

31. Continue lowering rings and fitting them together until there are five or six rings in the shaft. See Figure 11.

32. Probe the bottom of the shaft with a pointed length of re-rod to check for hard or soft spots. When excavation starts, there may be a





Method of Lowering Caisson into Well

Figure 11. Installing Caissons in Completed Lining

danger that the ground will suddenly give way and that several caisson rings will drop below the bottom of the lining. This is all right as long as the top ring does not drop below the lining.

33. Begin excavating in shallow layers, first in the center of the shaft and then under the ring. Dig evenly around the ring to prevent it from sinking out of line. As you excavate, the well shaft and the caisson rings will gradually sink into the aquifer and the shaft will begin to fill with water. Dig until the water becomes too deep for working, or until you are satisfied that the well will yield sufficient water. See Figure 11.

If you wish to remove water from the shaft while excavating, bail it out with a kibble. Do not pump out water with a mechanical pump, for that can cause the aquifer to collapse.

34. Set a base plug in the bottom of the shaft as shown in Figure 12. The plug can be made of porous concrete precast at ground level, or it can be made from layers of sand and gravel. If it is precast, it should have handles for lifting and removing it. The purpose of the plug is to prevent aquifer materials from rising into the well.

35. Unless the caisson rings have been sunk during the dry season, you may have to deepen the well during

the dry season. If so, you should add more caisson rings at that time.

36. Fill the space between the caisson rings and the concrete lining with small-sized gravel.

37. To build the wellhead and finish the well, see "Finishing Wells," RWS.2.C.8.

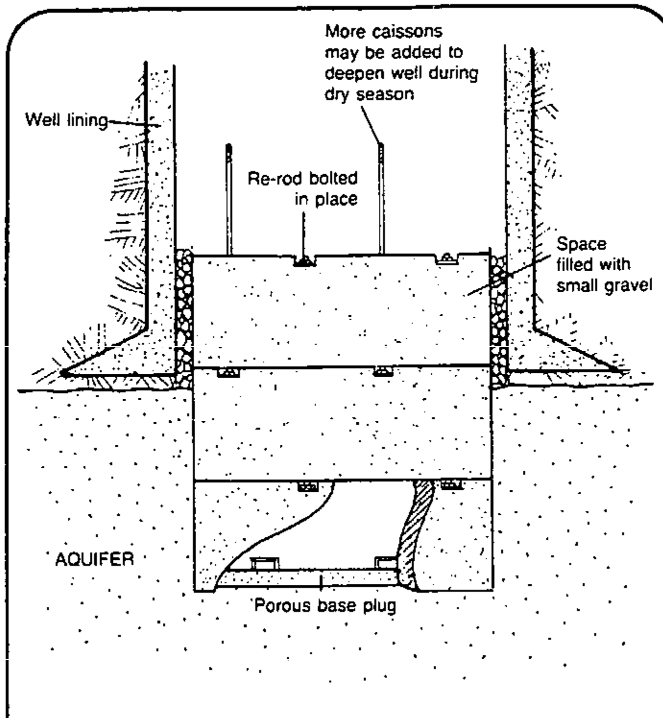


Figure 12. Caissons Sunk into Aquifer

Water for the World

Disinfecting Wells

Technical Note No. RWS. 2.C.9

Disinfecting a well is necessary to eliminate the contamination that was introduced by equipment, materials, or surface drainage during construction or repairs. A chlorine compound is generally used for the disinfectant. Disinfecting a well involves calculating the required amount of chlorine compound, mixing a chlorine solution, and applying the solution to the well.

This technical note describes how to disinfect a well. Read the entire technical note before beginning the disinfection process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

AVAILABLE CHLORINE - The amount of chlorine present in a chemical compound.

DISINFECTION - Destruction of harmful microorganisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

Materials Needed

To disinfect a well, you will need:

Chlorine compound such as calcium hypochlorite, bleaching powder, or liquid bleach,

Mixing container which should be rubber-lined or made from crockery or glass,

Stiff broom with a long handle, for hand dug wells,

Length of rope,

Length of perforated pipe, 0.5-1.0m long, 50-100mm in diameter, for deep-drilled wells with a high water table.

Caution!

Chlorine compounds or solutions may irritate skin and eyes upon contact. If possible, wear gloves, protective clothing, and glasses when handling chlorine. If you get chlorine on your skin or in your eyes, immediately wash it off with water.

General Information

The most easily obtainable and safest disinfectants are chlorine compounds. These compounds have various amounts of available chlorine, that is, chlorine that can be released to disinfect the water.

Calcium hypochlorite, also knows as high-test hypochlorite or HTH, has 70 percent available chlorine. It is produced as powder, granules, or tablets. Bleaching powders have 25-35 percent available chlorine. Common household laundry bleach, such as Clorox and Purex, has about 5 percent available chlorine.

Chlorine compounds should be stored in their original containers in a cool, dark place.

Calculating the Amount of Compound Needed

To disinfect a well properly, make a mix of available chlorine and water from the well in a ratio of 100 parts per million, ppm. To illustrate: 1 ml per 1000 liters equals 1 ppm; 100ml per 1000 liters equals 100ppm.

Table 1 shows the amounts of HTH, bleaching powder, and chlorine bleach that must be added to various volumes of well water to produce 100ppm of available chlorine. Before you can use the table, you must calculate the volume of water in the well.

The volume of water in a well equals the radius of the well squared times the depth of the water in the well times 3.1416.

$$V = r^2 \times D \times 3.1416$$

The radius, r, equals the diameter, d, of the well divided by two.

$$r = \frac{d}{2}$$

The diameter, d, can be measured directly or read from design drawings or from the driller's log described in "Maintaining Well Logs," RWS.2.C.6.

The depth, d, of the water in the well can be measured directly by lowering a rock tied to a length of twine to the bottom of the well, retrieving the twine, and measuring the wet portion. Or, it can be read from the driller's log.

For example, suppose the diameter of the well is 100mm (0.10m) and the depth of the water in the well is 12m. First, calculate the radius.

$r = \frac{d}{2}$ $\quad$ $r = \frac{0.10m}{2}$ $\quad$ $r = 0.05m$

Then calculate the volume of water.

$V = r^2 \times D \times 3.1416$
$V = 0.05m \times 0.05m \times 12m \times 3.1416$
$V = \text{about } 0.1m^3$

See Worksheet A Lines 1-4.

From Table 1, you can see that in order to disinfect this well you would need to use 0.2 liters of chlorine bleach, 5 percent available chlorine, or 33 grams of bleaching powder, 30 percent available chlorine, or 14 grams of high-test hypochlorite, 70 percent available chlorine.

For another example, suppose the diameter of the well is 1.2m and the depth of the water in the well is 2.6m. The radius equals the diameter divided by two = $\frac{1.2m}{2}$ = 0.6m Now calculate the volume.

$V = r^2 \times D \times 3.1416$
$V = 0.6 \times 0.6 \times 2.6 \times 3.1416$
$V = 2.9m^3$

See Worksheet A, Lines 5-8.

From Table 1, you can see that the nearest volume to this is $3.0m^3$, so to disinfect this well you would need to mix in 6.0 liters of chlorine bleach, or 1010 grams of bleaching powder, or 433 grams of HTH.

Table 1. Amounts of Chlorine Compounds for Well Disinfection

Water in Well (m^3)	Liquid Bleach 5% available chlorine (liters)	Bleaching Powder 30% available chlorine (grams)	Calcium Hypochlorite (HTH) 70% available chlorine (grams)
0.1	0.2	33	14
0.12	0.24	40	17
0.15	0.3	51	22
0.2	0.4	68	29
0.25	0.5	86	37
0.3	0.6	100	43
0.4	0.8	133	57
0.5	1.0	170	73
0.6	1.2	203	87
0.7	1.4	233	100
0.8	1.6	267	113
1.0	2.0	334	143
1.2	2.4	400	173
1.5	3.0	500	217
2.0	4.0	670	287
2.5	5.0	860	367
3.0	6.0	1010	433
4.0	8.0	1330	567
5	10	1700	730
6	12	2000	870
7	14	2300	1000
8	16	2600	1130
10	20	3300	1430
12	24	4000	1730
15	30	5000	2170
20	40	6700	2870

Worksheet A. Calculating the Volume of Water in a Well

Drilled Wells

1. Diameter of well = $\frac{(\underline{100}\ \text{mm})}{(1000\text{mm/m})}$ = $\underline{0.10}$ m

2. Radius of well = $\frac{\text{Line 1}}{2}$ = $\frac{(\underline{0.10}\ \text{m})}{2}$ = $\underline{0.05}$ m

3. Depth of water in well = $\underline{12}$ m

4. Volume of water in well = Line 2 x Line 2 x Line 3 x 3.1416 = $\underline{0.05}$ m x $\underline{0.05}$ m x $\underline{12}$ m x 3.14.6 = $\underline{0.09}$ m^3

Hand Dug Wells

5. Diameter of well = $\underline{1.2}$ m

6. Radius of well = $\frac{\text{Line 5}}{2}$ = $\frac{(\underline{1.2}\ \text{m})}{2}$ = $\underline{0.6}$ m

7. Depth of water in well = $\underline{2.6}$ m

8. Volume of water in well = Line 6 x Line 7 x 3.1416 = $\underline{0.6}$ m x $\underline{0.6}$ m x $\underline{2.6}$ m x 3.1416 = $\underline{2.9}$ m^3

Mixing the Solution

Do not pour the chlorine compound directly into the well. It will not mix properly. First make a chlorine solution.

To make a chlorine solution from chlorine bleach, mix one part of bleach with one part of water, then pour the entire solution into the well. In the second example, this would mean mixing 6.0 liters of chlorine bleach with 6.0 liters of water and pouring 12.0 liters of chlorine solution into the well.

To make a chlorine solution with HTH or bleaching powder, first mix the compound with enough water to form a smooth paste, then mix the paste with water in the ratio of one liter of water per 15 grams of compound. To calculate the amount of water needed to make a chlorine solution, divide the amount of chlorine compound by 15. In the second example,

$$\frac{\text{1010 grams of bleaching powder}}{\text{15 grams}} =$$

67 liters of water

$$\frac{\text{433 grams of HTH}}{\text{15 grams}} = \text{29 liters of water}$$

Mix the chlorine paste with the water for 10-15 minutes. Allow inert materials to settle and use only the clear chlorine solution. Discard the rest. Pour the clear chlorine solution, about 67 liters in the case of bleaching powder or about 29 liters in the case of HTH, into the well.

Do not mix chlorine solutions in metal containers. Mix them in clean containers that are rubber-lined or made from crockery or glass.

Disinfecting a Hand Dug Well

If the well has no cover, it should be disinfected every day, or as often as possible. If the well is covered it must be disinfected before the first use and every time it is opened for maintenance or repair.

For a dug well with pump and cover:

1. Prepare a chlorine solution to wash the inside of the well casing. Mix 10 liters of water with <u>one</u> of the following: 0.02 liters of chlorine bleach, or 3.3 grams of bleaching powder, or 1.4 grams of HTH.

2. Wash the exterior surface of the pump cylinder and drop pipe with the chlorine solution before they are lowered into the well.

3. Remove all equipment and materials that will not be a permanent part of the well.

4. Wash the inside surface of the well casing with a clean, stiff broom and the 10 liters of chlorine solution. See Figure 1.

5. Install the cover over the well.

6. Calculate the amount of chlorine solution needed to disinfect the well. Prepare the solution and poor it through the access hole in the cover, making sure that the solution covers as much of the surface of the water in the well as possible. See Figure 2.

7. Mix the chlorine solution with the water in the well by using a rope tied to a large, clean rock. Lower the rock into the well and move it up and down in the water.

8. Cover the access hole. Pump water from the well until you can smell chlorine.

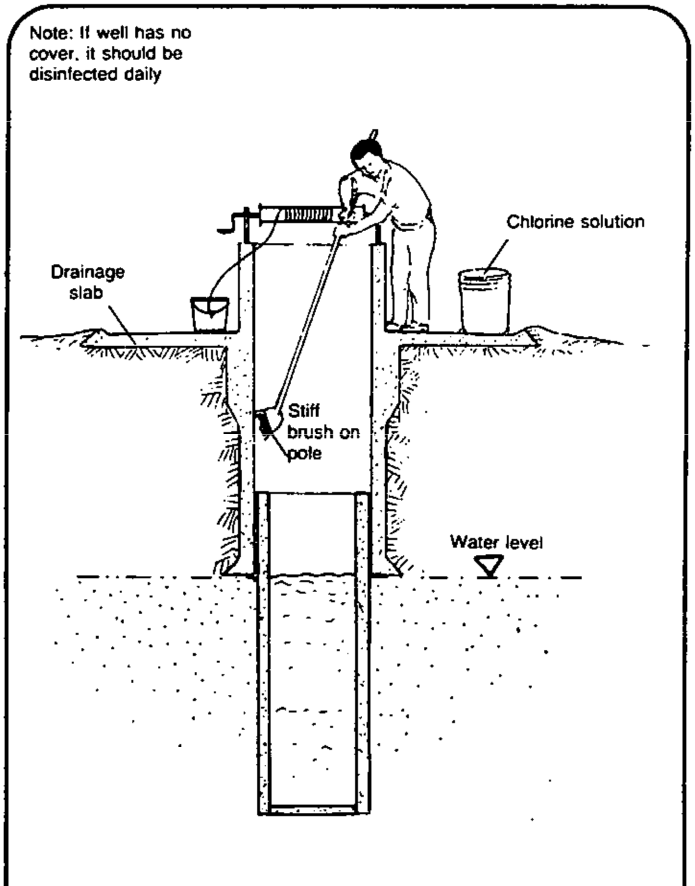


Figure 1. Washing Inside of Casing (Hand-dug well)

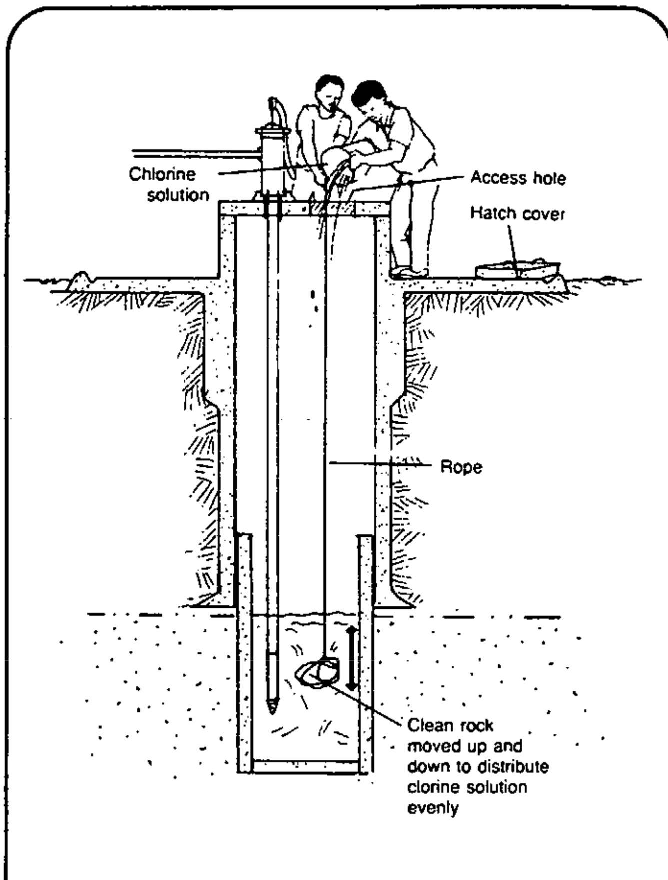


Figure 2. Pouring Chlorine Solution into Well

9. Allow the chlorine solution to remain in the well for 24 hours.

10. Pump water from the well until chlorine can no longer be smelled or tasted. Dispose of this water in a soakaway.

Disinfecting a Driven, Jetted, Bored, or Cable Tool Well

After the well has been tested for yield as described in "Testing the Yield of Wells," RWS.2.C.7, it must be disinfected before its first use and every time it is opened for maintenance or repair.

1. Remove the test pump from the well.

2. Calculate the amount of chlorine solution needed to disinfect the well. Prepare the solution and pour it into the well.

3. Mix the chlorine solution with the water in the well by using a rope tied to a clean rock. Lower the rock into the well and move it up and down in the water.

4. Add 40 liters of clean, chlorinated water to the well to force the solution into the aquifer. This solution can be made by mixing 40 liters of water with either one-half teaspoon of HTH or 20ml of chlorine bleach.

5. Prepare a chlorine solution to wash the pump cylinder and drop pipe. Mix 10 liters of water with one of the following: 0.02 liters of chlorine bleach, or 3.3 grams of bleaching powder, or 1.4 grams of HTH.

6. Wash the exterior surface of the pump cylinder and drop pipe as they are lowered into the well.

7. Pump water from the well until you can smell chlorine.

8. Allow the chlorine solution to remain in the well for 24 hours.

9. Pump water from the well until chlorine can no longer be smelled or tasted. Dispose of this water in a soakaway.

Deep Well with High Water Table

In the case of a deep well with a high water table, you need to take special steps to ensure that the chlorine and well water are properly mixed.

1. Drill a number of small holes through the sides of the pipe that is 0.5-1.0m long and 50-100mm in diameter. Cap one end of the pipe.

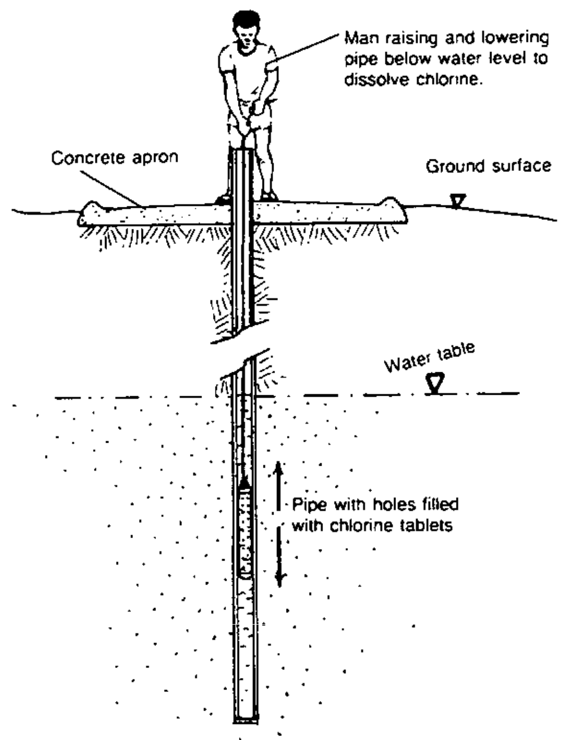


Figure 3. Disinfecting Deep Well with High Water Table

2. Pour the calculated amount of HTH granules or tablets into the pipe. Only HTH can be used in this method.

3. Fit the other end of the pipe with a threaded cap equipped with an eye loop.

4. Tie a rope to the eye loop, lower the pipe into the well, and alternately raise and lower the pipe in the water. Continue until the HTH has dissolved and the chlorine is distributed in the water. See Figure 3.

Notes

Water for the World

Manufacturing Hand Pumps Locally
Technical Note No. RWS. 4.P.6

Many villages need hand pumps but have limited local resources to purchase them. Even when hand pumps are obtained, repair parts may not be readily available. Many communities which have had hand pumps in the past have experienced failure due to the lack of repair parts.

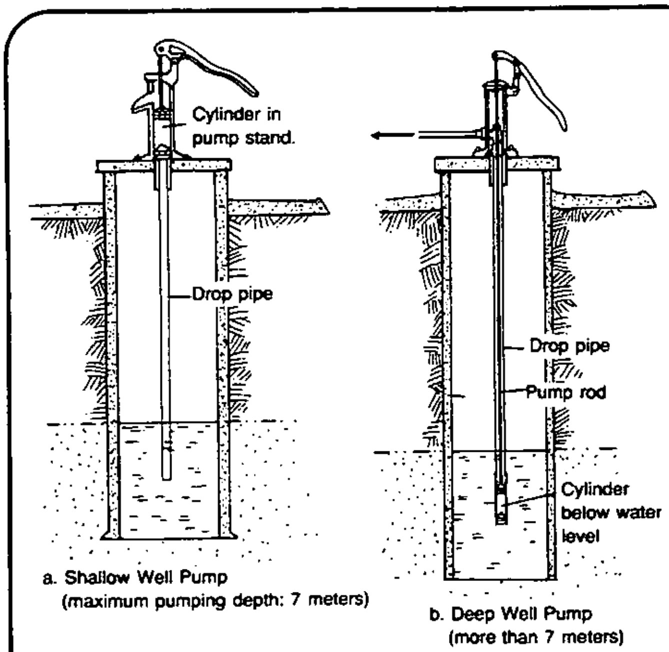
Because of this, there are compelling reasons for local manufacture of hand pumps so that both repair parts and skills are readily available. The alternatives to be considered are village manufacture of pumps which may be inefficient and have a short lifetime but are within the villagers' capability to understand and construct and the construction of long-lasting and relatively maintenance free pumps which require skilled workers and sophisticated equipment and must be built in a central location within a country. Another alternative is to have those parts of a pump which require accurate machining or casting made at a central location in-country and to construct the balance of the parts and assemble the pumps at the village level. These methods have been applied with success. The choice of options depend on the specific country and village.

Types of Hand Pumps

To evaluate alternatives, it is necessary to know what a hand pump is and what its component parts are. The most common hand pump is one which uses leverage to enable a person to lift water either by developing a vacuum or by positive displacement or a combination of both. These pumps are classified as shallow well pumps with a maximum pumping depth of 7m, or deep well pumps which can pump from depths over 7m. Shallow well pumps have the pump cylinder built into the pump stand as shown in Figure 1a. Deep well pumps have the pump cylinder located in the well, below water level. This requires a pump rod in the well. See Figure 1b.

The component parts of a hand pump are a pump cylinder, a drop pipe, a pump rod and pump stand, and a handle.

<u>Pump Cylinder</u>. Pump cylinders may be open or closed as shown in Figure 2. The advantage to an open cylinder is that the plunger can be removed without removing the drop pipe. The pump cylinder must be accurately machined. For this reason, it cannot readily be



a. Shallow Well Pump (maximum pumping depth: 7 meters)
b. Deep Well Pump (more than 7 meters)

Figure 1. Types of Hand Pumps

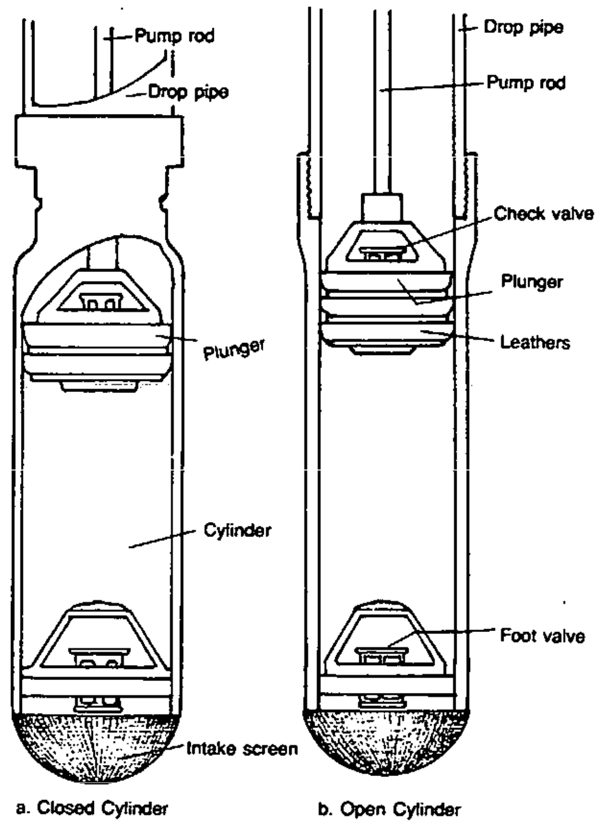


Figure 2. Pump Cylinders

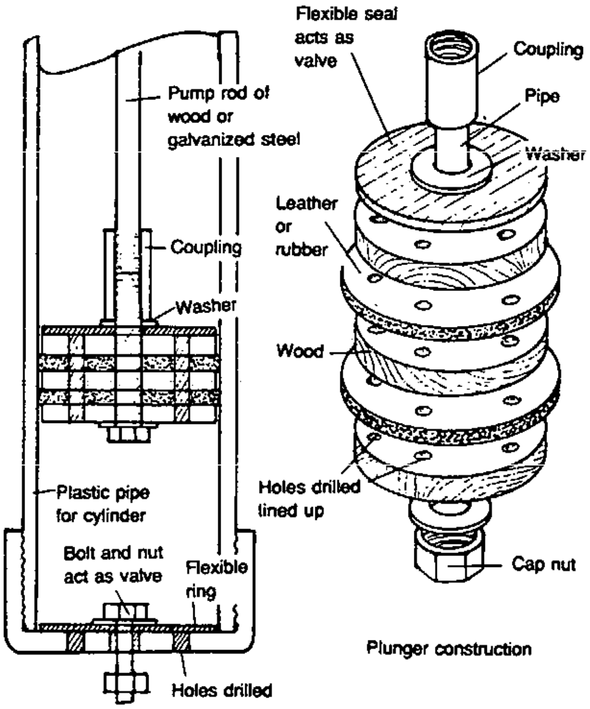


Figure 3. Locally Manufactured Cylinder and Plunger

constructed at the village level. Some development is underway using plastic pipe for the cylinder but the results are not yet complete. Pump cylinders are available in cast iron and brass. Both have long expected lives. The primary reason for failure is in the "leathers," which are easily replaced and can be made locally. Figure 3 shows a locally made pump cylinder.

Drop Pipe. The drop pipe is usually made of galvanized iron or rigid plastic for shallow depths. Galvanized iron pipe is much more commonly used. Neither can be manufactured at the local level.

Pump Rod. This is necessary for connecting to pump cylinders located in a well. Galvanized iron rod is common for wells up to 30m deep and wood rod for greater depths. These must be obtained from outside the immediate village area in most cases. Wood rod may be used if locally available. Reinforcing steel can be used as a pump rod but it is likely to rust.

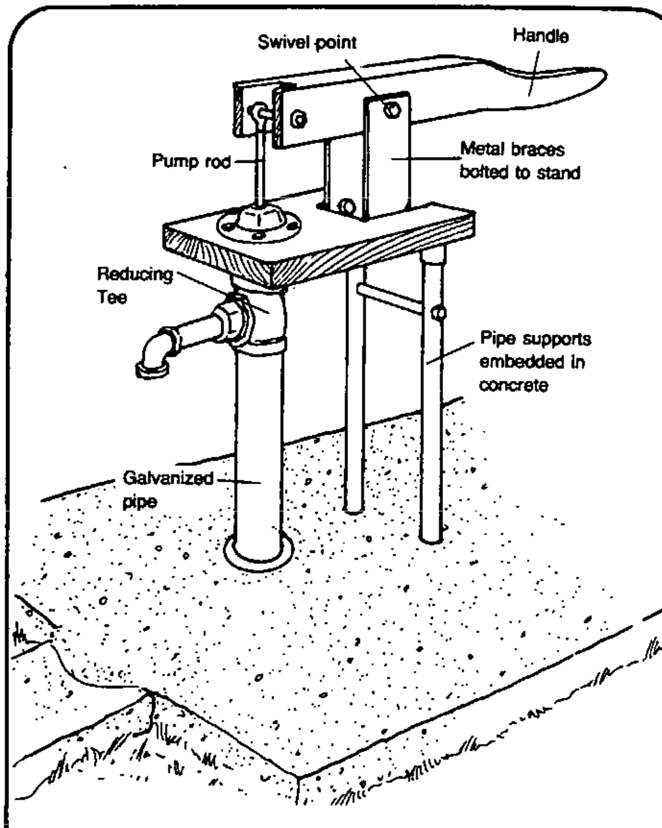


Figure 4. Pump Stand

Pump Stand. Pump stands may be cast, welded or fabricated from pipe or wood. Since the main points of wear are in the bearing areas, they should be made to close tolerances and of durable material to increase the life of the stand. This primarily involves the pump handle and the pivot point on the stand which supports the pump handle. The pump stand and handle usually are the first to wear out and are also relatively easy to build. For this reason, they should be considered the principle elements for local manufacture. Figure 4 shows one type of locally manufactured pump stand and handle.

Notes

1982

Water for the World

Installing Hand Pumps
Technical Note No. RWS. 4.C.3

Hand pumps may be used for shallow wells, less than 7m to water, or deep wells. Deep well pumps can be used in many shallow wells and are a good choice because the pump cylinder is in the water. With the cylinder in the water, the pump does not lose its prime and the pump leathers do not dry out. In shallow well pumps, the cylinder is in the pump body above ground.

A hand pump system consists of a hand pump stand, drop pipe, pump rod or sucker rod for deep wells, and a pump cylinder. For shallow wells, the cylinder is part of the hand pump stand. Some hand pump stands lift water to a spout or force it to a higher elevation or to a point located away from the well. Figure 1 shows both shallow well and deep well hand pumps. Hand pumps should be installed according to manufacturer's directions. This technical note only describes the basic steps in hand pump installation.

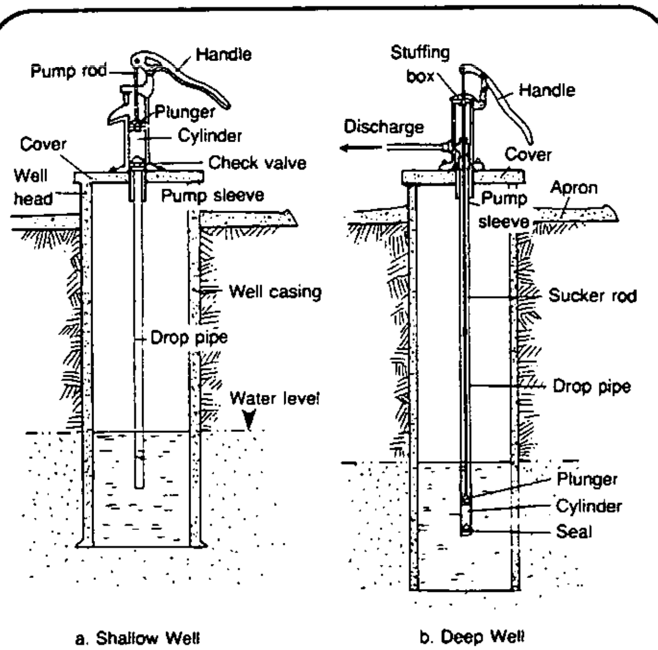


Figure 1. Hand Pump Systems

Useful Definitions

DEEP WELL PUMP - Any pump capable of pumping water from wells where the water level is more than 10m below the ground surface.

DROP PIPE - The pipe in the well connecting the water to the pump.

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

In all installations it is important that the water source not be contaminated. The top of the well should be fully enclosed with a well slab placed around the well. Only materials which are clean and made for use in potable water supplies should be used.

In preparing a materials list, careful measurements must be made to ensure sufficient material is available. Prior to cutting material for assembly, it is good practice to again make careful measurements. It is necessary to have the proper tools on site when installation begins. Table 1 lists the materials and tools needed for a typical hand pump installation.

As in all projects, careful preplanning will help assure that installation involves a minimum of wasted time. A sample work plan is shown in Table 2. This plan can be used to estimate the time needed to complete the job and to decide when materials and tools should be available. Figure 2 shows the installation of the drop pipe and cylinder using a tripod. Figure 3 shows the detail of installing a pump sleeve, and Figure 4 shows a finished dug well with a hand pump.

After the pump installation has been completed, but prior to bolting the pump stand to the mounting flange, the

Table 1. Sample Materials List for Hand Pump Installation

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	____
	Laborers	2	____
	(NOTE: Either the foreman or the laborers must have some experience in cutting and threading pipe)		
Supplies	32mm galvanized steel pipe with coupling	____m: enough to reach the desired depth in the well	____
	10mm galvanized steel pump rod	____m: enough to reach the desired depth in the well	____
	10mm pump rod couplings	____: one for each joint	____
	Well cylinder	____	____
	Hand pump stand with handle	____	____
	Pump mounting flange	____	____
	Packing material	____	____
	Small can of grease	____	____
	Cutting oil	____	____
	Chlorine solution	____	____
Tools	Portable pipe vise	____	____
	Large pipe wrenches	____	____
	Crescent wrenches (adjustable wrenches)	____	____
	Pliers	____	____
	Hacksaw with spare blades	____	____
	Metal file	____	____
	Pipe cutter	____	____
	Pipe threader, 10mm and 32mm	____	____
	Measuring tape, 3m and 12m	____	____
	Pipe holder	____	____
	Rope and pulley	____	____
	Tripod for lowering pipe	____	____
	Plumb bob and 50m of line	____	____

Total Estimated Cost ____

well should be pumped until the water is clear and a strong chlorine solution should be used to disinfect the well. This is accomplished by raising the pump assembly from the flange and pouring the solution down the well. After 12-24 hours, the well can be pumped out and the water used.

Table 2. Sample Work Plan for Installing a Hand Pump

Time Estimate	Day	Task	Personnel	Tools/Materials
1 hour	1	Delivery materials to site and unload	Foreman and 2 laborers	Shown in Table 1
1 hour	1	Set up tripod	Foreman and 2 laborers	Tripod, wrenches
1 hour	1	Cut and thread pipe and pump rod as measured	Foreman and 2 laborers	Pipe vise, cutter threader, cutting oil
3 hours	1	Attach pump rod and cylinder and lower into well; add pipe and rod as required until desired depth is reached	Foreman and 2 laborers	Pipe, pump rod, pipe holder and pipe wrenches
1 hour	1	Attach pump mounting flange to well casing, screw pipe into bushing and bushing into base of pump stand	Foreman and 2 laborers	Pump mounting flange, pipe bushing, pump stand and wrenches
1 hour	1	Check pump packing and packing nut; lubricate pump bearing points; work pump until water is clear; add chlorine solution to well and let stand overnight	Foreman and 2 laborers	Packing material, grease, wrenches chlorine solution
2 hours	2	Pump well until no chlorine solution remains; attach stand to flange		

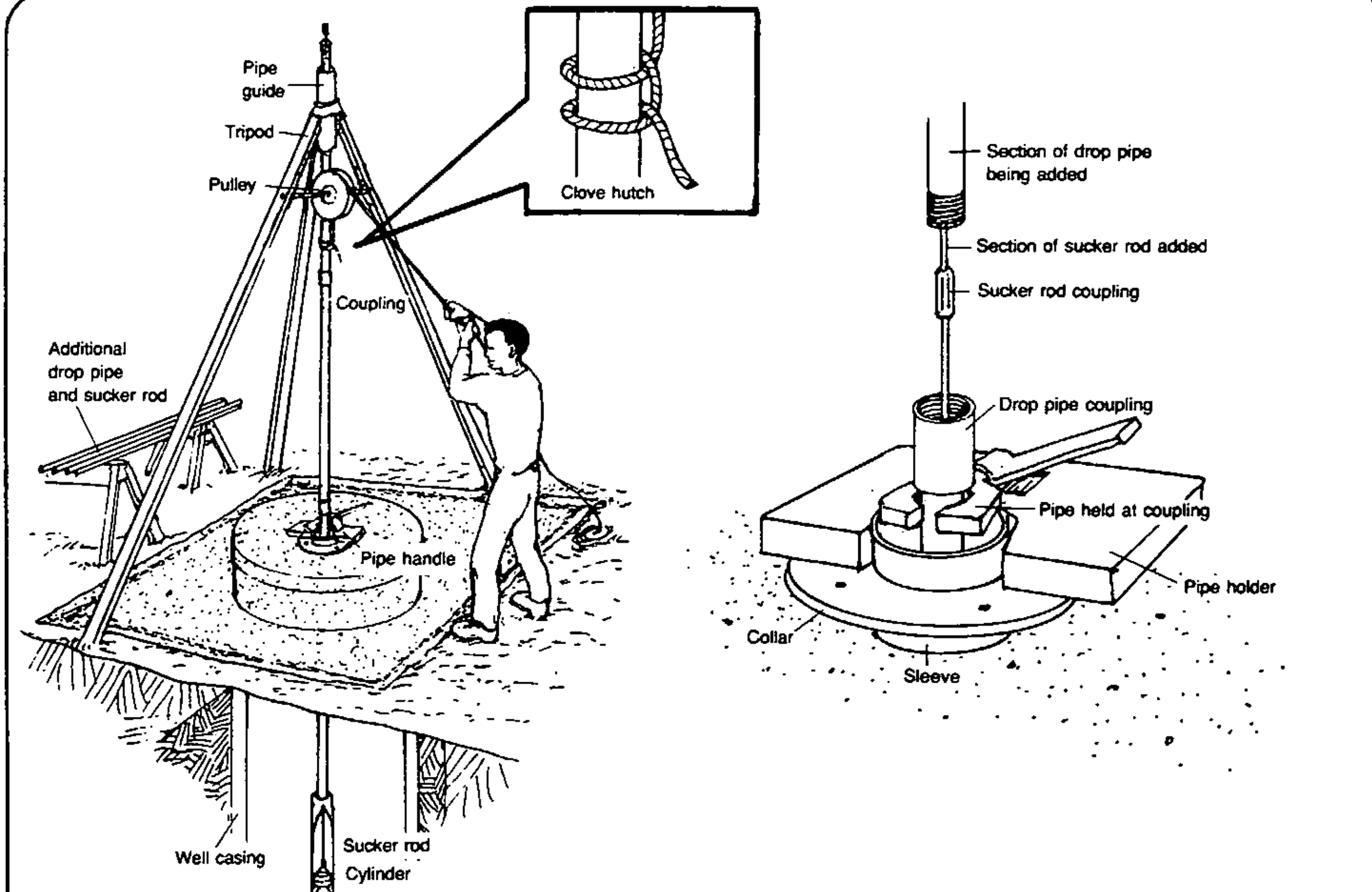


Figure 2. Installation of Drop Pipe and Cylinder

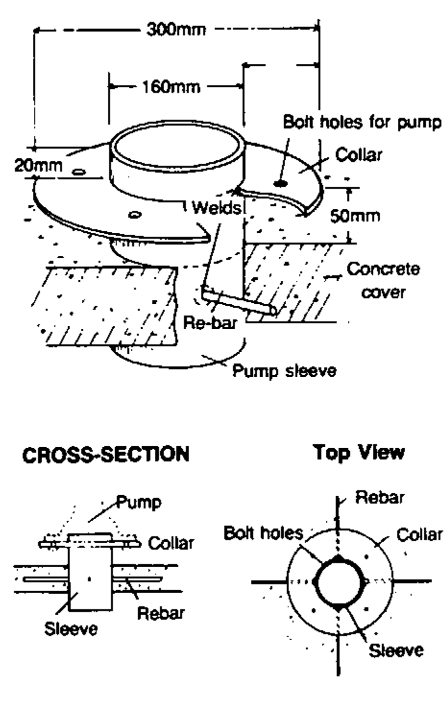


Figure 3. Installing Pump Sleeve

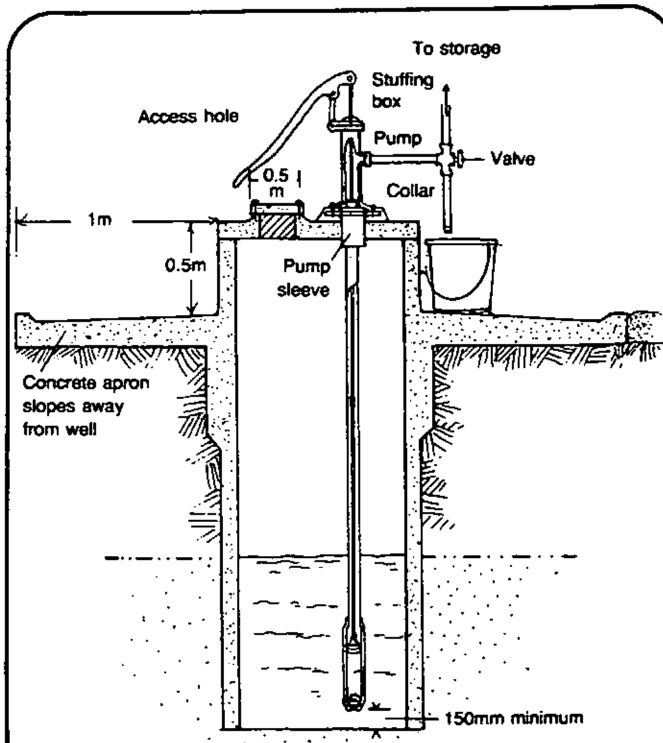


Figure 4. Finishing a Hand Dug Well

Notes

1982

Water for the World

Operating and Maintaining Hand Pumps
Technical Note No. RWS. 4.O.3

It is relatively easy to construct a water supply and to install the necessary pumping equipment to provide water to a village. A consideration too often overlooked is whether it will be operating one, two, five, or more years later. Too often, the system will become inoperative because of lack of knowledge of and attention to operation and maintenance.

Hand pumps have been installed in many villages throughout the world and in a number of different situations. Unfortunately many of them have become inoperative. As a result, there has been considerable effort to develop a better hand pump. This has led to worthwhile and necessary improvements but there is not now, nor is there likely to be, a "perfect" pump that will continue working without proper operation and maintenance. See Figures 1 and 2. The easier it is to

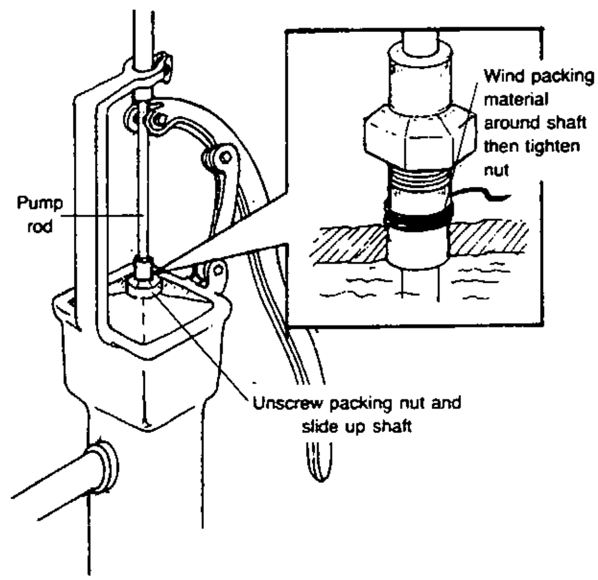


Figure 2. Repacking Stuffing Box

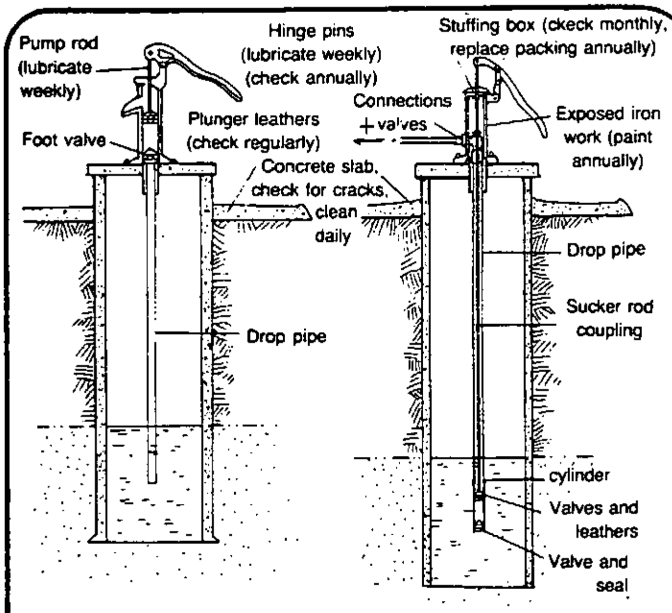


Figure 1. Maintenance Points on Hand Pumps

obtain water without a hand pump, the more likely it is that the pump will not be maintained and, once failure occurs, that the pump will not be repaired. For this reason it is essential that the village recognize the positive benefits of an improved water source. Only then will that village be motivated to see that the improvements are maintained or, as economics allow, increased.

Useful Definition

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

Operation and Maintenance Programs

Various programs have been proposed and implemented to assure proper operation and maintenance. When coupled with community involvement, all have a good chance of success. These programs range from the village being totally responsible for operation and maintenance of the system to a government unit taking full responsibility. An alternative is cooperation between the community and an agency of central government to provide needed operation and maintenance. The specific means adopted will vary from place to place, from country to country and, in some situations, from village to village. It is imperative that the community recognize the importance of operation and maintenance and support the improvement.

Whatever method is used to provide operation and maintenance, it is absolutely essential that the village play a role and that this role is understood and agreed to by the village. As discussed above, one method of providing for continued operation and maintenance is a cooperative agreement between a unit of government and the village. The following is an example covering preventive maintenance, major repairs and an educational program.

Example of Operational Procedures

Preventive Maintenance. Day-to-day maintenance of the hand pump is the responsibility of the village. In order to assure that this is accomplished, one of the villagers should be appointed the pump custodian. It is his or her responsibility to provide routine lubrication, keep the area around the pump clean and note wear for reporting to the field maintenance worker. Figures 1 and 2 identify key maintenance points.

A field maintenance worker should make routine inspections of all completed projects in the area. At the time of visits, he or she would determine what repairs could be made immediately. See Table 1 for examples of on-the-spot preventive maintenance repairs.

Table 1. Typical Preventive Maintenance Repairs by Field Maintenance Worker

1. Replace packing in hand pumps.
2. Replace worn bolts and cotter pins on pumps.
3. Replace worn or broken pump handles.
4. Replace washers in pump compression spouts.
5. Replace worn sucker rods.
6. Replace pump cylinders (worn leathers).
7. Replace defective valves at watering points.
8. Replace necessary fittings.
9. Replace manhole covers.

A member of the sanitation staff should accompany the field maintenance worker on the initial visit to each project to explain the project and make recommendations for a preventive maintenance schedule and procedure. The professional sanitation staff should assist the field maintenance worker in setting up routine inspection trips, advising on location and details of each project, and recommending methods of repair as shown in Figure 3. In addition, the professional sanitation staff should review inspection and repair reports so that they would be in a position to coordinate the field maintenance workers activities. The professional sanitation staff should notify the field maintenance worker upon the completion of a project and advise him or her of the details of all projects in the area. Table 2 is an example of an inspection report that can be used for the field work.

Major Repair of Breakdown. In case of major breakdown or failure of the project, the village leaders should notify the field maintenance worker who would then inspect the project and determine what is necessary for repairs. In the case of a major or unusual problem, the field maintenance worker should consult the professional sanitation staff and, if necessary, the professional sanitation staff should visit the project to make recommendations. If additional labor is necessary for repairs, the field maintenance worker will arrange hiring details with the village leaders. The necessary labor should be recruited from individuals who use the supply. The field maintenance worker would

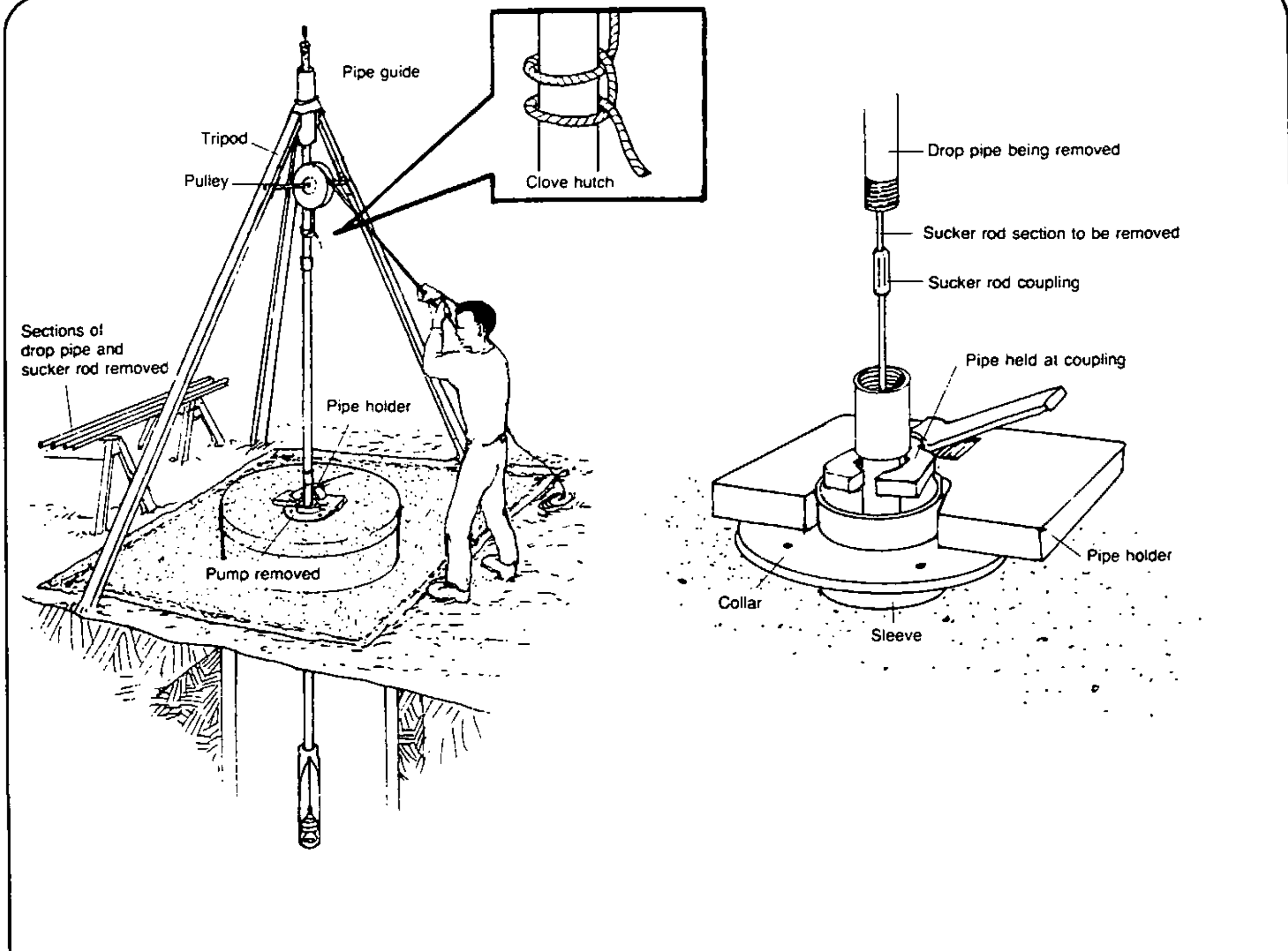


Figure 3. Raising Drop Pipe and Cylinder

estimate the labor and materials necessary for the repairs and submit this estimate to the professional sanitation staff for review and approval.

Educational Program. A cooperative effort between village community workers and the field maintenance worker should be undertaken to educate the village on preventive maintenance of the hand pump. They should inform the villagers of items to look for so that repairs can be made before they become too costly, and of the proper channels for requesting repairs, when necessary.

Table 2. Sample Inspection Report

Date ____________________

Region ______________________________ Village ____________________

Location ____

Type ____

Description: (Check items which are a part of the system).

hand pump ( ); well slab ( ); watering point ( ); spring box ( ); storage tank ( ); pipe line ( ); manhole cover ( ); diversion wall ( ); windmill ( ); stock through ( ); other ____________________

Hand Pump	Good Condition	Repair or Replace
packing	( )	( )
bolts	( )	( )
cotter pins	( )	( )
handle	( )	( )
shaft	( )	( )
compression spout	( )	( )
sucker rod	( )	( )
cylinder	( )	( )
mounting	( )	( )
Water Point		
valve	( )	( )
mill hose	( )	( )
fittings	( )	( )
stand	( )	( )
piping	( )	( )
vent	( )	( )
hose clamp	( )	( )
Storage Tank		
walls	( )	( )
cover	( )	( )
manhole cover	( )	( )
bottom	( )	( )
discharge	( )	( )
vent	( )	( )
valves	( )	( )
piping	( )	( )
fittings	( )	( )
Windmill		
packing	( )	( )
discharge	( )	( )
seal	( )	( )
Stock Through		
walls	( )	( )
piping	( )	( )
valve	( )	( )
apron	( )	( )

Well Slab	Repair or Replace
good condition	( )
cracked	( )
manhole cover in place	( )
manhole cover missing	( )
manhole cover replaced	( )
Spring Box	
good condition	( )
cracked	( )
manhole cover in place	( )
manhole cover missing	( )
manhole cover replaced	( )
overflow satisfactory	( )
overflow needs repair	( )
overflow repaired	( )
vent satisfactory	( )
vent needs repair	( )
vent repaired	( )
discharge satisfactory	( )
discharge unsatisfactory	( )
discharge repaired	( )
Pipeline	
good condition	( )
needs repair	( )
estimate made	( )
Diversion Wall	
condition good	( )
needs repair	( )
estimate made	( )
Other	
____________________	( )
____________________	( )
____________________	( )

____
Field Maintenance Worker

Water for the World

Determining the Need for Water Storage

Technical Note No. RWS. 5.P.1

Many water systems require some form of storage. Storage is necessary (1) when rainwater is collected for drinking water, (2) for most distribution systems where the source's continuous supply is barely sufficient or is insufficient to meet the daily demand and (3) where a single well serves a community through a distribution system. Storage ensures that an adequate quantity of water is always available to users and that water quality is protected.

This technical note describes the procedure to follow in determining whether storage should be provided for a water system and establishes methods to determine the quantity of storage required.

Several factors should be considered in determining water storage needs: (1) the source of water, (2) the amount of water available for consumption (3) the demand for water and (4) the materials available and economic resources of the families in the community. From this information, the most appropriate form of water storage can be chosen.

Rainfall Storage in a Cistern

Rainwater needs to be collected and stored if people are to use it for drinking. In order to plan for adequate storage and design the most appropriate type of storage facility data on the following items should be collected:

- amount of monthly rainfall,
- potential rainfall supply available each month,
- the amount of water likely to be consumed by the family.

With this information, the size of the cistern can be estimated.

Data on average monthly rainfall can be acquired from a national weather agency, the military, or an airport. Data for a specific location may not be available, but regional data can be used for an estimate. Table 1 and Figure 1 show an example of distribution of rain by month for a location receiving an average annual rainfall of 1032.5mm.

The potential available water supply depends on the amount of rainfall and the catchment surface area. If a catchment area has a length of 8m and a width of 6m, the area of the catchment is 8m x 6m or $48m^2$. To determine the amount of available water, multiply the monthly rainfall figures by $48m^2$ and then by 0.8, a loss factor which takes into account water that does not make it to storage from the catchment area. For example, using January rainfall figures, the total amount of water available to the family is 8678 liters. This amount is arrived at using the following formula:

Volume of water = Catchment area x rainfall x 0.8

Table 1. Average Monthly Rainfall in Millimeters

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
Rainfall	226	188	173	46	2.5	0	0	5	5	41	130	216	1032.5

This data can be represented graphically as shown in Figure 1.

MONTH	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
RAINFALL (in mmm.)	226	188	173	46	2.5	0	0	5	5	41	130	210	1,032.5

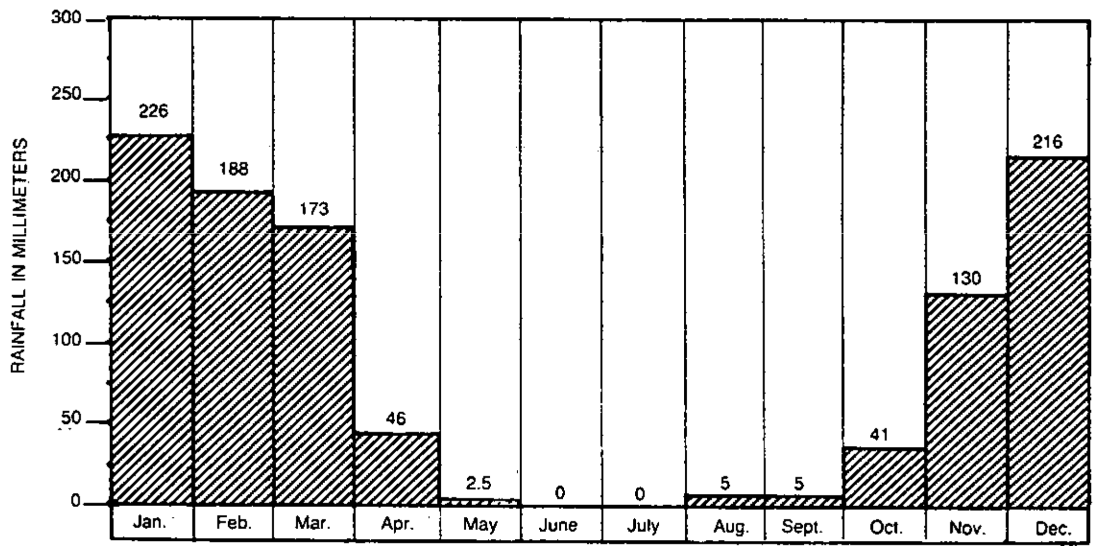


Figure 1. Average Monthly Rainfall in Millimeters

Volume = $48m^2$ x 226mm x 0.8

Volume = 8678 liters

Table 2 and Figure 2 give an example of the average amount of water available during each month of the year. Remember that these are average estimates that will differ with cyclical climatic changes. Each number is arrived at by taking the average monthly rainfall figure and using it in the above equation.

The next step in determining storage requirements is shown in Figure 3. First, a graph of the cumulative available rainfall is made. The graph represents the amount of rainfall run-off available from a catchment throughout the year. The heights of the bars are determined by adding a particular month's average rainfall to the sum of the rainfall for the previous months. For example, April shows a cumulative run-off of 24306 liters which is the sum of the run-off for January, February, March and April.

Secondly, a diagonal line representing yearly demand is drawn. The line assumes that people will use the same quantity of water each month, although generally greater quantities are used in the wet season and much less in the dry. The demand line should touch only one point on the run-off curve as shown. The desirable amount of storage is shown on the graph. It is the greatest distance between the demand line and the run-off curve. This amount of storage should be provided to ensure that water is available throughout the year at this level of consumption.

In this example, the yearly demand for water is 31000 liters, and average of approximately 2600 liters per month, or 87 liters per day per family. In order to supply a family with 87 liters per day throughout the entire year, a cistern or storage jar with a 16.5-17m^3 (16500 -17000 liters) capacity would be needed. Unless inexpensive ferrocement storage jars are constructed, the construction of a

Table 2. Potential Monthly Available Supply of Water

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (liters)	8678	7219	6643	1766	96	0	0	192	192	1574	4992	8294	39646

This data appears in graphical form in Figure 2.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

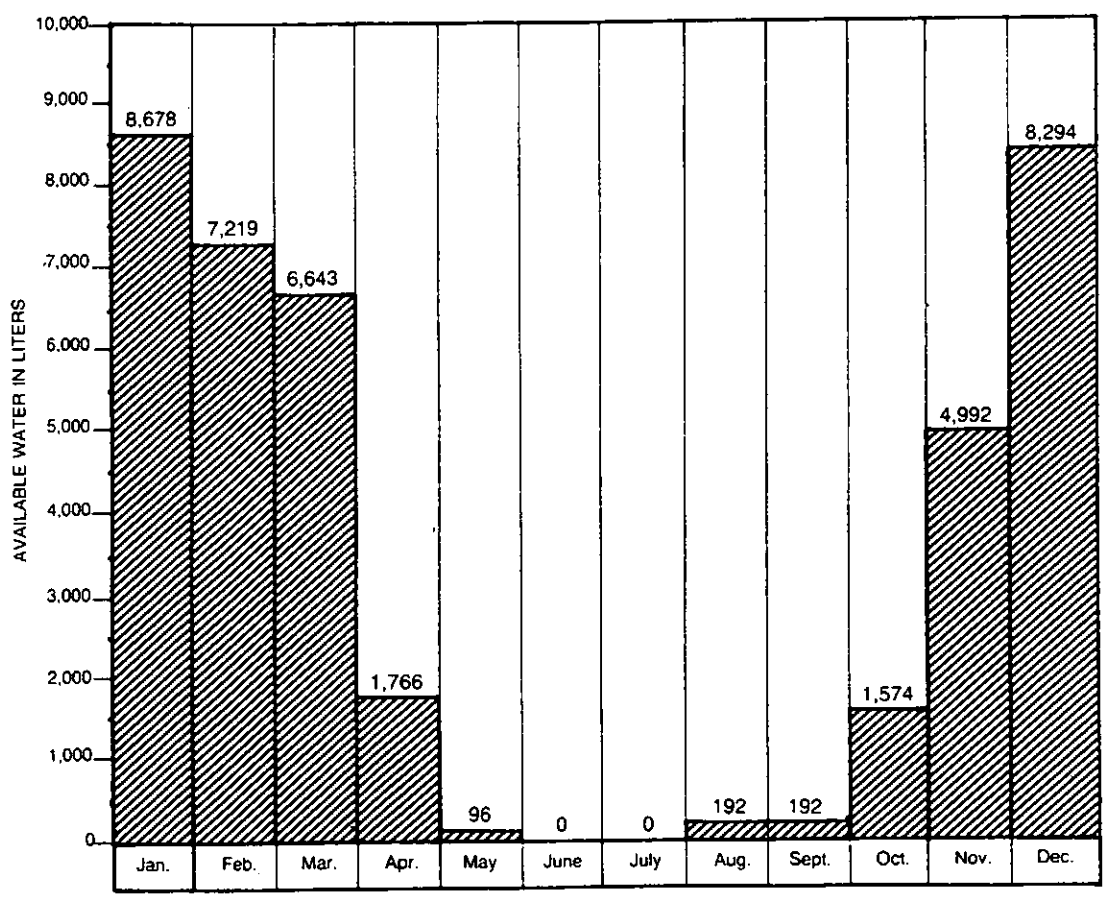


Figure 2. Available Monthly Water Supply in Liters

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall (millimeters)	226	188	173	46	2.5	0	0	5	5	41	130	216	1,032.5
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

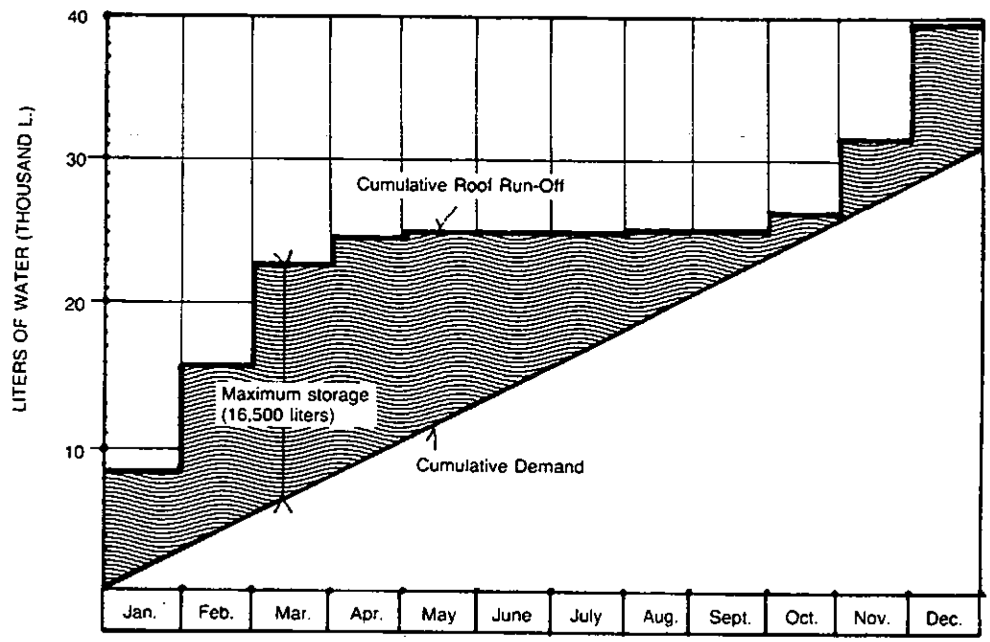


Figure 3. Determining Maximum Storage Capacity

cistern of such a large volume would be beyond the means of most families. A smaller structure would be designed instead. With a smaller cistern, water use during the dry season would have to be restricted to the essential minimum of drinking and some cooking.

Ideally, cisterns and storage jars should be large enough to store water for the entire year. Where economic conditions prevent this, special measures, like the use of storage jars, should be taken. Water should be collected during the rainy season and stored for use during the dry season. Special care should be taken to prevent water loss through evaporation. When planning a cistern or storage reservoir, attempt to build a cistern either of adequate volume or as close to the desired volume as economic resources permit. This is necessary when no other water source of suitable quantity, quality, accessibility or reliability is available.

Ground and Surface Water Storage for Distribution Systems

Storage of surface and ground water is necessary to provide sufficient quantities of water to the users. In some cases, a storage reservoir is not needed. When hand dug wells are installed in villages and water is extracted by buckets or hand pumps, no storage other than what the well holds is necessary. Where reservoirs are formed by dams, water sometimes can move from the reservoir to the users with no further storage. Usually, some sort of storage is required in systems where water is piped to the users.

To ensure that adequate storage capacity is provided, proper planning of the storage reservoir is necessary. The following factors should be considered in determining required storage capacity:

(1) Population served by the system taking into account population growth.

(2) Total daily demand for water in the community. This is found by multiplying the population to be served by the daily per capita consumption. Special consideration has to be shown for peak demand periods.

(3) Hourly demand and peak hour demand.

(4) The length of operation of the pump each day.

In planning for a water system and sufficient storage capacity for it, the number of people to be served should be determined. It is best to plan for a system that will operate effectively for 20 years. If a community has a present population of 1535 people who will be served by the system and the population growth is estimated at 2.5 percent per year, use Table 3 to determine the population in 20 years.

Table 3. Population Growth Factors

Design Period Years	Yearly Growth Rate (%)					
	1.5	2	2.5	3	3.5	4
7	1.1	1.15	1.19	1.23	1.27	1.32
10	1.16	1.22	1.28	1.34	1.41	1.48
15	1.25	1.35	1.45	1.56	1.68	1.80
20	1.35	1.49	1.64	1.81	1.99	2.19

Multiply the present population, 1535 in this example, by the population growth factor located in the row marked "20 years" under the column for a 2.5 percent yearly growth rate. This gives 1535 x 1.64 = 2520. The volume of the storage reservoir should be calculated assuming a population of 2520 people.

Next, the amount of water per day consumed by the population should be calculated. Assume that the average per capita daily consumption is 40 liters. Per capita water demand is:

Total consumption = Per capita consumption x population =
40 liters x 2520

Total consumption = 100800 liters per day.

To find hourly demand, use the following formula:

$$\text{Hourly demand} = \frac{100800 \text{ liters/day}}{24 \text{ hours}}$$

Hourly demand = 4200 liters per/ hour.

The peak hourly demand generally occurs in the morning with a second smaller peak later in the afternoon. The peak demand ranges between four and five times the hourly demand.

The length that the pump is in operation should be determined. In some cases, the pump may work for a few hours in the morning and a few in the afternoon or it may be operated continously for eight to ten hours. Assuming 10 hours continuous pumping between 7:00am and 5:00pm, the pumping rate necessary would be 10080 liters/ hour. From this information and the data on water demands as a percentage of the average hourly consumption rate, the required storage capacity can be determined. Table 4 shows a way to collect this information and determine the required storage. Figure 4 shows how this can be done graphically.

The storage capacity required is the sum of the excess supply of water after the pumping stops at 5:00pm, 32500 liters, and the maximum volume required during the morning. This volume is 13650 liters at 7:00am. The total storage required is 32550 + 13650 = 46200 liters or 46.2m^3. The same figure is arrived at graphically by looking at the distance between point A and point B on Figure 4.

In Figure 4, a diagonal line is drawn marking a continuous 24-hour pumping rate of 4200 liters per hour. Line PQ represents a pumping rate of 10800 liters per hour for ten hours. The curved line is the cumulative demand for water. To determine the storage capacity, draw a perpendicular line from the point at 7:00am (point Q) to the cumulative demand curve. From that point, draw a line parallel to PQ extending it to the vertical line at 17 hours, 5:00pm. Where this line ends is point A. Then draw a straight line

Table 4. Determining Storage Requirements

Daily Demand = 100800 liters

Average Hourly Demand = $\frac{100800 \text{ liter}}{24 \text{ hour}}$ = 4200 liters/hour

1	2	3	4	5	6	7
Time (hours)	Hourly Demand in Liters	Hourly Demand as % of Average Hour*	Cumulative Demand (liters)	Supply from Pump (liters/hour)	Supply Minus Draft Liters (5 - 2)	Storage Variation (liters) (6 + 7)
0-1	1050	25	1050	---	-1050	-1050
1-2	1050	25	2100	---	-1050	-2100
2-3	420	10	2520	---	-420	-2520
3-4	420	10	2940	---	-420	-2940
4-5	630	15	3570	---	-630	-3570
5-6	2520	60	6090	---	-2520	-6090
6-7	7560	180	13650	---	-7560	-13650
7-8	9660	230	23310	10080	420	-13230
8-9	4200	100	27510	10080	5880	-7350
9-10	4200	100	31710	10080	5880	-1470
10-11	5040	120	36750	10080	5040	+3570
11-12	6300	150	43050	10080	3780	+7350
12-13	6300	150	49350	10080	+3780	+11130
13-14	6300	150	55650	10080	+3780	+14910
14-15	5040	120	60690	10080	+5040	+19950
15-16	3780	90	64470	10080	+6300	+26250
16-17	3780	90	68250	10080	+6300	+32550
17-18	7770	185	76020	---	-7770	+24780
18-19	7140	170	83160	---	-7140	+17640
19-20	6300	150	89460	---	-6300	+11340
20-21	3780	90	93240	---	-3780	+7560
21-22	3150	75	96399	---	-3150	+4410
22-23	2310	55	98700	---	-2310	+2100
23-24	2100	50	100800	---	-2100	0

*Precentages are estimated averages.

**The storage capacity required is the sum the excess available at the end of the pumping period (32,550 liters) and the maximum volume during the morning hours (13,650 liters) or 32,550 + 13,650 = 46,200 liters.

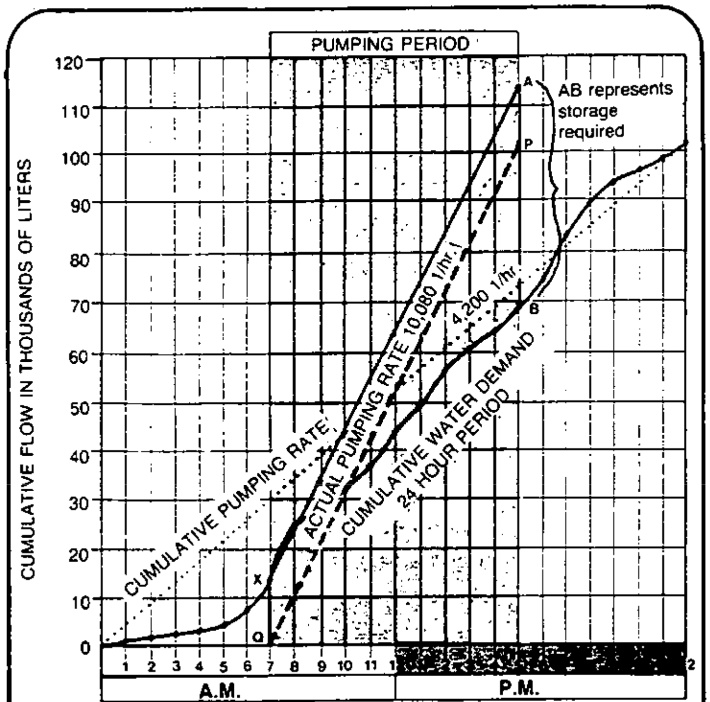


Figure 4. Determining Storage Requirements

from A through P to the cumulative demand curve, point B. The line AB represents the storage required, which is 46200 liters, or 46.2m^3. When designing the storage tank, some extra capacity can be included. In this case, a storage reservoir with a capacity of 50000 liters, 50m^3, would be appropriate.

Summary

Most water systems should have storage so that people can depend on a sufficient quantity, a certain quality and improved access and reliability. When rainwater roof run-off is used, storage is always necessary. For surface and ground water, either storage is provided for at the source or a storage reservoir must be constructed. Most water distribution systems rely on man-made storage reservoirs.

The most important factor in planning for the use of storage is determining the capacity of the reservoir. Capacity should be sufficient to adequately meet all water needs of the users throughout the year. The minimum goal should be to provide sufficient storage to at least meet basic drinking needs and minimal washing and cooking needs. Given scarce resources, these minimal needs may be all that can be met. When determining storage needs, follow the procedures outlined in Worksheet A.

It is desirable to project a storage capacity to meet needs caused by future population increases and water demand increases. In this example, 20 year future increase have been used. This requires a substantial commitment of money and materials. This may not be possible because funds are not available or the money may be needed for more immediate community needs. A careful review will help to make the best engineering and management decision. In any event, storage sites and facilities can be designed and built so that future expansion can be made readily and with least cost.

Worksheet A. Determining Water Storage Requirements

Identify water supply source ______

1. If rainfall roof catchment, determine:

   a. area of catchment ______

   b. number of people to be served ______

   c. materials available for cistern or storage tank construction ______

   d. economic resources of family ______

   e. capacity of storage reservoir from Figures 1, 2, 3 ______

2. If a ground water source:

   a. identify type of well--dug, bored, drilled ______

   b. determine best method of extraction--hand pump, windmill, fuel or electric pump ______

   c. determine well yield and well storage capacity ______

   d. find out how many people use the source for water supply and whether storage is sufficient to meet demand ______

   e. if there is a community well with a pump serving people who must carry water, evaluate whether a distribution system or public stand posts would most benefit the community ______

   f. evaluate whether the community has sufficient resources to install some sort of storage ______

   g. determine storage capacity required using the methods described in this technical note and demonstrated in Table 4 or Figure 4 ______

   h. choose the appropriate storage method for the community given resources and available materials ______

3. If a surface water source:

   a. identify the supply source ______

   b. determine the number of uses and calculate demand for water using 40 liters per capita per day ______

   c. determine whether sufficient storage is already provided; for example, a dam and reservoir may hold sufficient water to meet demand ______

   d. determine whether storage is necessary or how much storage is required, using Table 4 or Figure 4 ______

   e. choose the most appropriate design given available materials and resources, needs and topographical features ______

Water for the World

Constructing a Household Cistern

Technical Note No. RWS. 5.C.1

Well constructed cisterns play an important role in providing families with an accessible supply of potable water. Cisterns and storage jars constructed of locally available materials offer improved access to water supply in many areas where good supplies are limited. They also provide a means of controlling the water quality.

This technical note describes construction steps for building reinforced concrete cisterns, ferrocement tanks, and medium and large reinforced mortar storage jars. The steps discussed are offered as guidelines and can be changed to fit local needs and situations. Before attempting the construction of any cistern, seek advice and assistance from people experienced in working in concrete and ferrocement construction.

Useful Definitions

FERROCEMENT - An economical and simple-to-use type of reinforced concrete made of wire mesh, sand, water and cement.

VOIDS - Empty spaces; open areas between particles or substances.

Materials Needed

Before beginning the construction process, be sure to have the following items:

1. A plan of the cistern showing the design and dimensions as shown in Figure 1.

2. A list of materials, tools and other supplies needed to complete the job. Similar to the list in Table 1 or 2. All materials should be available before construction begins in order to avoid delays.

Table 1. Sample Materials List for a Reinforced Concrete Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers		
Supplies	Portland cement Clean sand and gravel Clean water for mixing cement Reinforcing rods Screened mesh Boards and plywood for forms Nails Old motor oil or lubricant for forms Galvanized pipe for overflow Tap for outlet Guttering		
Tools	Shovels and picks Measuring tape Hammers Saws Carpenter's square Pliers Wire cutters Mixing bin, mortar box Buckets Trowel Adjustable wrench Screw drivers Paint brush Level		

Total Estimated Costs = ____

Table 2. Sample Materials List for a Ferrocement Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers		
Supplies	Portland cement Plain wire, 2.5mm Chicken mesh, 1m wide Water pipe Water tap Overflow pipe Galvanized iron sheet and angle iron Sand Gravel Bolts Water		
Tools	Shovels and picks Wire cutters Wrenches, adjustable and open Screw drivers Paint brushes Trowels Mixing bin, mortar box Wheelbarrow Buckets Hacksaw and blades Hammers		

Total Estimated Cost = ____

Construction Steps for a Reinforced Concrete Cistern

Follow the construction steps below. Refer to the appropriate diagrams during the construction process.

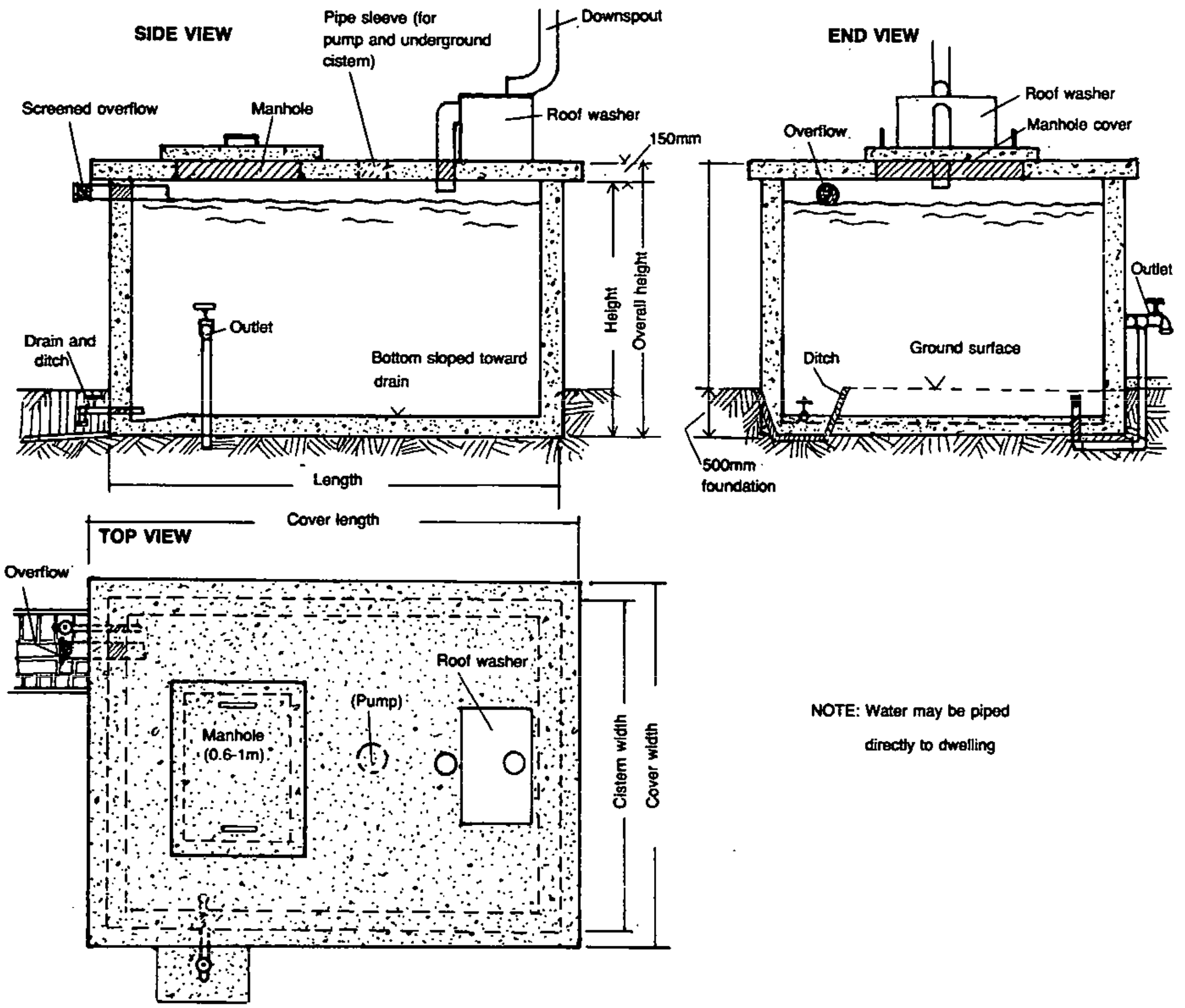


Figure 1. Plan for Household Cistern

1. Find the best location near the house to build the cistern. It should be located on high ground for good drainage and should not be located closer than 15m to the nearest waste disposal site. Once the site is located, mark it out using a measuring tape, wooden stakes and cord, as shown in Figure 2.

2. Dig out a base in the ground to fit the dimensions of the cistern. The hole should be only 50-100mm deep. This will allow installation of an outlet near the bottom of the cistern to take advantage of the entire volume of the cistern. Level the excavated area using flat-nosed shovels and scrapers made from wood.

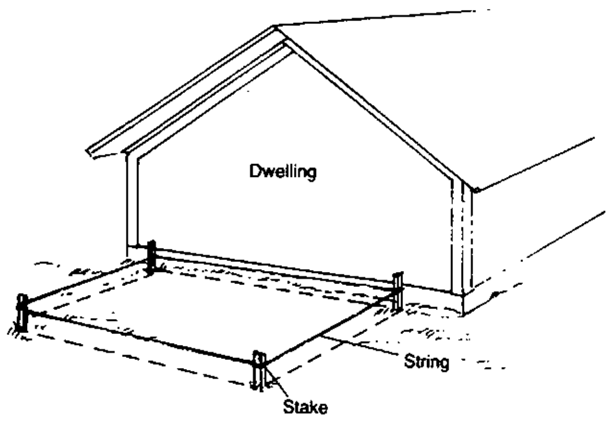


Figure 2. Marking Cistern Site

3. Prepare the forms for the structure. Use plywood sheets, if available, for the faces and small pieces of wood for bracing. All formwork for the cistern should be completed before any concrete is poured.

• Nail all forms together to the design size of the cistern. Walls should be 200mm thick.

• Brace the forms well. Place small holes in the forms and slide wire through them. At the end of each piece of wire, attach a stick to hold the wire in place. Then tighten the wire to create enough pressure to withstand the force of the poured concrete. See Figure 3. Dirt should also be piled up against the outside of the walls to give them support against the weight of the concrete.

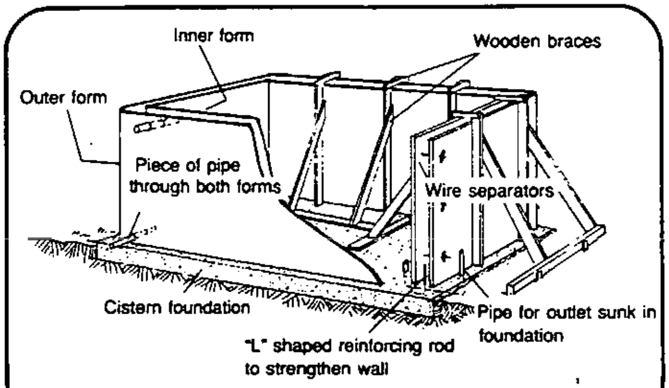


Figure 3. Forms for Cistern Walls

• Place reinforcing rods in the forms. For best results, lay the rod for the floor in a grid pattern as shown in Figure 4. The cross bars should be long enough to cross the entire length of width of the floor and extend at least 300mm into the wall. The reinforcing rods should be bent to fit into the wall forms to a height of 300mm. Other lengths of rod are then tied with these lengths to complete the installation of the reinforcing rod.

This technique is recommended to provide a solid connection between the wall and the floor. Figure 4 demonstrates the placement of reinforcing bars in concrete. The steel bars should be separated 150mm with the first cross bar laid 75mm from the edge of the pour. The bars should be placed one third of the distance from the outside or, as in the example given, about 70mm in from the outside edge.

4. Make holes in the form for placement of the overflow and outlet pipes. The pipes should be placed directly in the forms when pouring the concrete to ensure a good pipe installation.

5. Oil all forms before pouring concrete. Use old motor oil or other available lubricant to prevent the concrete from sticking to the forms.

6. Formwork and steel bar placement for the cover follow the same procedures as outlined above. After forms are complete, mix the cement, sand and gravel in a 1:2:3 ratio adding 23 liters of water for each bag of cement. These proportions will ensure a thick paste.

Pour the floor and about 200mm up the side of the wall in the first pour. Tamp down the cement with steel rods and shovels to make sure that all voids are filled. Once all reinforcing rods are attached, finish the pour, tamp the mixture well and smooth all surfaces.

Cover the concrete with canvas, burlap, empty cement bags, plastic or other protective material to prevent loss of moisture. Keep the covering wet so the concrete does not become dry and crack. When pouring the cover, be sure to leave an opening for access to the cistern. The opening should be fitted with a cover which either can be locked or is difficult to remove.

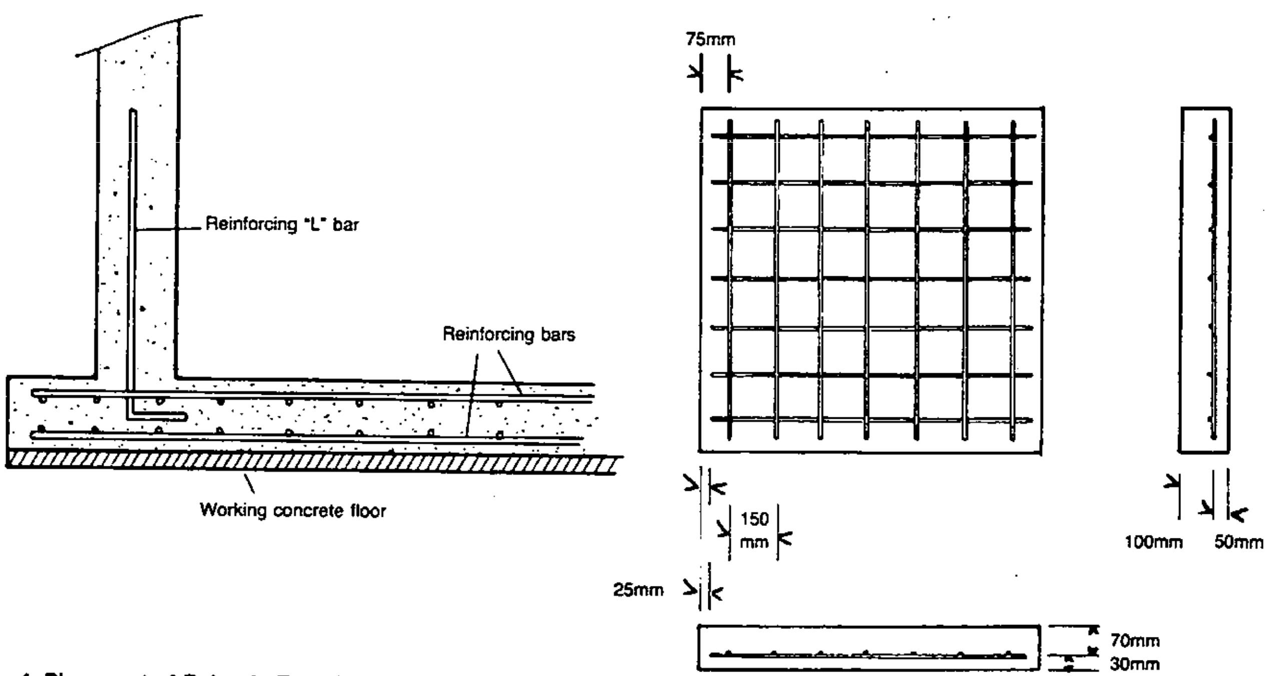


Figure 4. Placement of Rebar in Foundation and Walls

Reinforced concrete cisterns can be built underground. They are usually equipped with hand pumps for extraction of the stored water. To build an underground cistern, follow the same basic construction steps for above-ground cisterns. Make sure that the walls extend at least 300mm above the ground surface. A tight fitting cover with an access opening and a small base for a hand pump should be cast.

Other Types of Cisterns

Brick and masonry tanks can be used for rainwater storage. Skilled workers should construct them. Keep the following points in mind when constructing a masonry or brick tank:

- Make all walls at least 300mm thick.

- For shallow tanks, the walls can be built on the floor. For deep tanks, over 1.5m, a concrete footing or foundation built below the base should be constructed.

- Line the inside of the cistern with two layers of mortar each 10mm thick to prevent leaks. The mortar, and all mortar used in the construction process, should contain cement and sand in the proportion 1:3.

Ferrocement cisterns are generally circular in shape and made with locally available materials. Some experience and skill are needed. The construction steps described below are for relatively large capacity cisterns, about $10m^3$. Both smaller and larger cisterns can be constructed following the general construction guidelines.

1. Measure and stake out a circular area 2.8m in diameter. A easy way is to drive a stake into the ground at the center and attach to it a length of rope 1.4m, the radius. Tie a stick or pointed object to the other end and trace the circle on the ground. Dig out a base 300mm in the ground.

2. Place a 100mm layer of sand and gravel over the excavated area, and then a 75mm layer of concrete on top of this. Use a concrete mix of 1:2:4, cement: sand: gravel.

3. Before the concrete sets, cast a 1m length of 20mm steel pipe into the foundation, as shown in Figure 5. This will be the outlet. The pipe should extend 80-100mm above the tank floor, high enough above the ground on the outside of the tank to allow a bucket or ceramic container to sit underneath. A tap will be placed on the pipe when construction is completed.

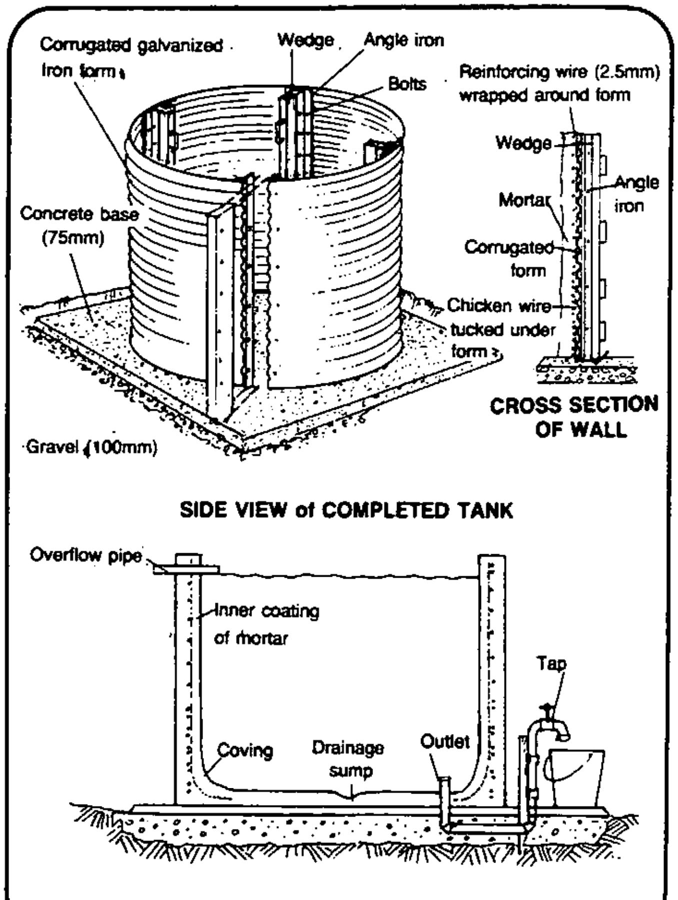


Figure 5. Ferrocement Cistern Construction

4. When the floor hardens, build the formwork for the tank. See Figure 5 for details on formwork preparation. Use 16 sheets of galvanized roofing iron 0.6mm thick. Place four sheets together to form four sections. Bolt the sections to angle iron verticals to form a circle. The steel angle iron, 40mm x 40mm x 5m, is bolted vertically on the inside face at the ends of each set of sheets. Place a wedge between the ends of each section. The wedge can be pulled out to dismantle the forms. Wood can be used for forms. A design similar to that shown in Figure 6 is useful in many areas. This design is especially good where materials such as roofing metal is not available.

5. Clean the forms, removing any dirt, and oil them. Then wrap 50mm wire mesh, chicken wire, around the forms. The netting should be wound around to a single thickness and tucked underneath the forms to hold it in place. The mesh provides vertical reinforcement and keeps the straight wire out of the corrugation.

6. Wrap 2.5mm straight galvanized iron wire tightly around the formwork starting at the base. Use the following spacings:

- two wires in each of the first eight corrugations from the bottom,
- one wire in each remaining corrugation except for the top one,
- two wires in the top currugation.

7. Plaster the outside of the forms with a layer of mortar that covers the wire. The mortar mix should be 1:3, cement:sand. When this layer begins to harden, trowel on mortar to cover the wire with a layer 15mm thick. Give the mortar a smooth finish.

8. Take apart the forms after the mortar has set for two or three days. Remove the holding bolts and wedges so that the forms are easily removed.

9. Place an overflow pipe 200mm long and about 80mm in diameter at the top of the tank. Then to finish the cistern, plaster the inside to fill in the corrugations. When this mortar dries, trowel on a final coat.

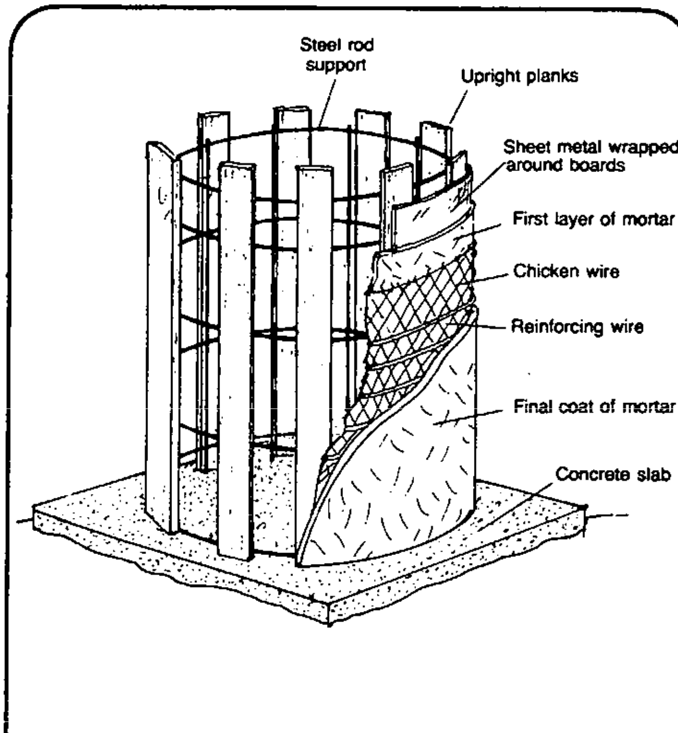


Figure 6. Ferrocement Tank Using Wooden Forms

10. Finally, place a 50mm thick layer of mortar on the floor of the tank. Before the mortar stiffens, make a shallow depression in the middle of the floor to act as a sediment trap for tank cleaning. Sediment can be swept into the sump and removed with a cup.

Roof Structures

Install a roof on the cistern to prevent the evaporation of water, the growth of algae and contamination by rubbbish, insects or rodents. A choice of two roof structures is possible as shown in Figure 7. Figure 7a shows a shell roof built of wire-reinforced mortar between 3-5mm thick. The structure is cast continiously with the walls. After the tank has dried for two days, lay mortar onto shaped form-work made with two layers of wire mesh supported from below by boards. Tie the wire mesh onto the mesh extending from the walls. Install an iron frame to form an access opening in the roof. Remove the frame after construction is completed. Trowel in a layer of mortar and allow three days for curing. After three days, or when the roof is strong enough, take off the formwork and trowel a layer of mortar onto the underside of the tank. Figure 7b shows a completed roof of this type. Let the roof cure for at least seven days. Keep the surfaces moist during the curing process.

Figure 7c shows a more traditional roof structure made from wood. Attach lightweight roofing such as a sheet aluminum or galvanized iron with wire. Screen any open areas between the tank and the roof to prevent the entrance of insects and debris.

Unreinforced Mortar Storage Jars

Unreinforced mortar storage jars can be constructed by people with little or no previous experience. The jars are an inexpensive and relatively easy way to store rainfall for drinking water. Small, 25m^3 capacity, as well as larger 4m^3 jars can be built following the basic construction steps given below. This example is for a 4m^3, 4000-liter, storage jar like the one shown in Figure 8.

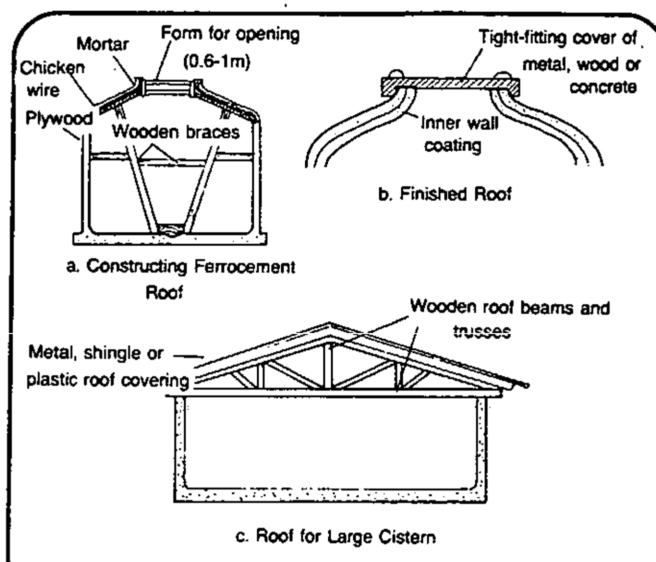


Figure 7. Cistern Roofs

1. The first step in the construction process involves preparation of the mold. Place two pieces of gunny cloth together and mark them out as shown in Figure 8. The bottom width should be marked at 1.2m and the top width at 2.0m. Draw a curved line along the sides connecting the top and the bottom and sew the sack together with heavy tread or twine. The sack height should be 1.7m.

2. Make a precast mortar bottom plate 1m in diameter and 15mm thick. To make forms for the plate, mark out a circle on the ground using a nail as a midpoint and a piece of twine 0.5m long. Trace the circle and lay half bricks or other suitable material around the outside of the circle to act as a form. Place paper, an empty cement bag or other material on the ground within the circle so the mortar does not stick to the ground. Make a mortar mixture of 1:2, cement:sand.

3. Once the bottom plate dries, place the sack narrow end down on the plate and begin filling it with sand, sawdust or rice husks. The weight of the filling material will hold the sack on the plate. Make sure the mortar base sticks out from under the sack, as shown in Figure 8.

4. Completely fill the sack, then fold the top and tie it into the desired shape. With a piece of wood, smooth and round out the jar. When the jar is in the final form spray it with water to completely dampen it.

5. Place a circular ring on the top of the sack to make an opening for the jar. The ring can be made from wood, precast mortar or other suitable material.

6. Begin placing a layer of mortar on the jar. The mortar should be about 5mm thick. Apply another 5mm layer of mortar, checking the thickness by pushing a sharp object like a nail into the side. Be sure to build up any thin spots and add mortar to weak places. Finally, build up the jar thickness and shape as shown in Figure 8. Place a small tap near the bottom of the jar.

7. Twenty-four hours after the jar is constructed, remove the contents of the sack. This operation is easier for small jars. When the jar is empty, check for defects and make any necessary repairs. Paint the inside with a wet mortar mix and then cure the jar outside for two weeks. For best results, cover the jar with damp sacks or plastic sheeting during the curing process.

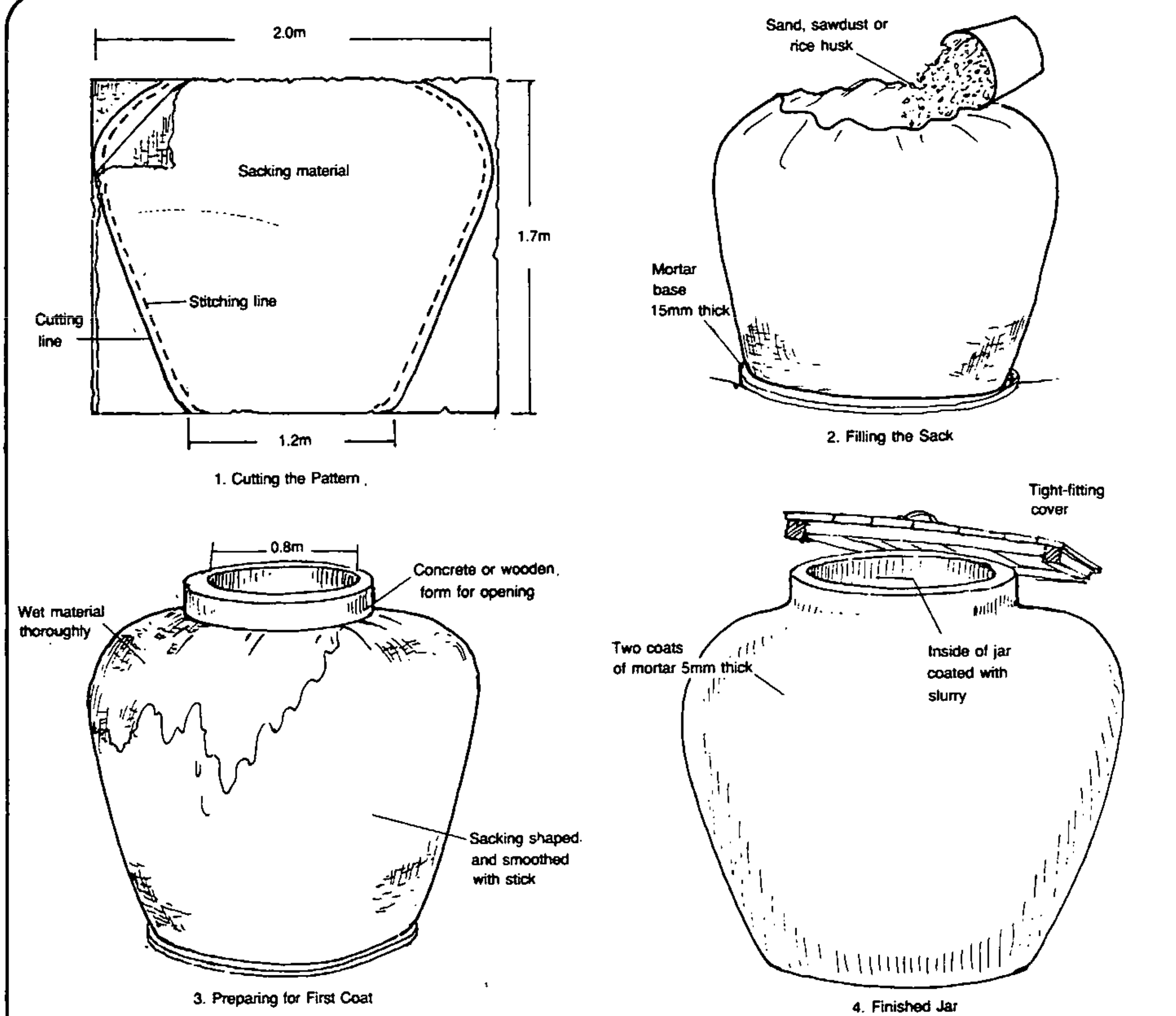


Figure 8. Constructing Mortar Storage Jars

Notes

Water for the World

Constructing a Ground Level Storage Tank
Technical Note No. RWS. 5.C.2

For effective water storage and water system operation, ground level storage tanks should be built for sufficient, and even excess, capacity and must be watertight to prevent leakage.

This technical note discusses the basic steps to follow in constructing a ground level storage tank. The actual construction process and materials used will differ with each situation or area. The construction of all storage tanks should be supervised by experienced builders or masons and, whenever possible, engineering assistance should be sought.

Useful Definition

ALGAE - Tiny green plants usually found floating in surface water.

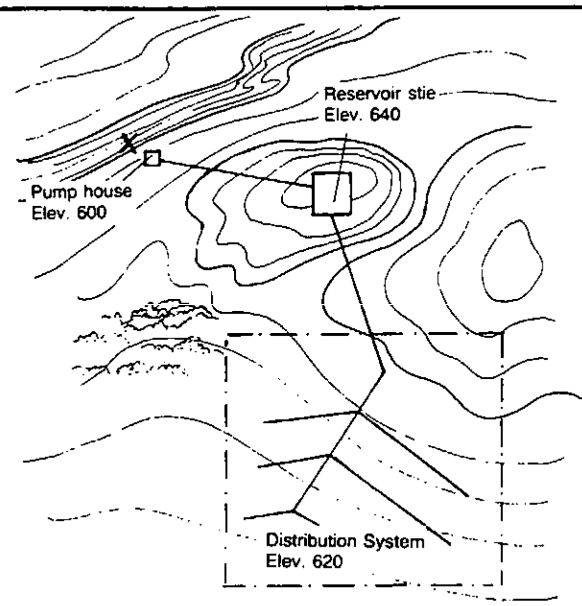


Figure 1. Location Map

Materials Needed

Before construction begins, the project designer should give you the following items:

1. A map of the area including the location of the reservoir, the distribution system, location of users, houses and elevations. Figure 1 is an example of a map showing these reference points.

2. A list of all labor materials and tools needed similar to that shown in Table 1. Ensure that all needed materials are available and at the work site before work begins to prevent construction delays.

3. A plan of the reservoir with all dimensions as shown in Figure 2. This plan shows a top, side and end view.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman		
	Laborers		
Supplies	Portland cement		
	Clean sand and gravel		
	Clean water		
	Reinforcing rod		
	Pipe for inlets, overflow and drain (PVC or steel)		
	Screening and wire mesh for pipes		
	Boards and lumber for forms		
	Lubricating oil		
	Rocks, if masonry tank		
	Float valve (if needed)		
	Cut-off valves		
	Lock for manhole cover		
	Iron for steps in tank		
	Lumber and rafters, if wooden tank		
	Cover structure		
	Shingles		
	Plywood		
	Rope or string		
	Nails, tie wire		
Tools	Shovels, picks and other digging tools		
	Measuring tape		
	Plumb tool		
	Hammer		
	Saw		
	Buckets		
	Carpenters square		
	Level		
	Mixing bin or machine		
	Pipe wrench		
	Adjustable wrench		
	Trowel		
	Hoe		
	Wheelbarrow		
	Sieve		

Total Estimated Cost =

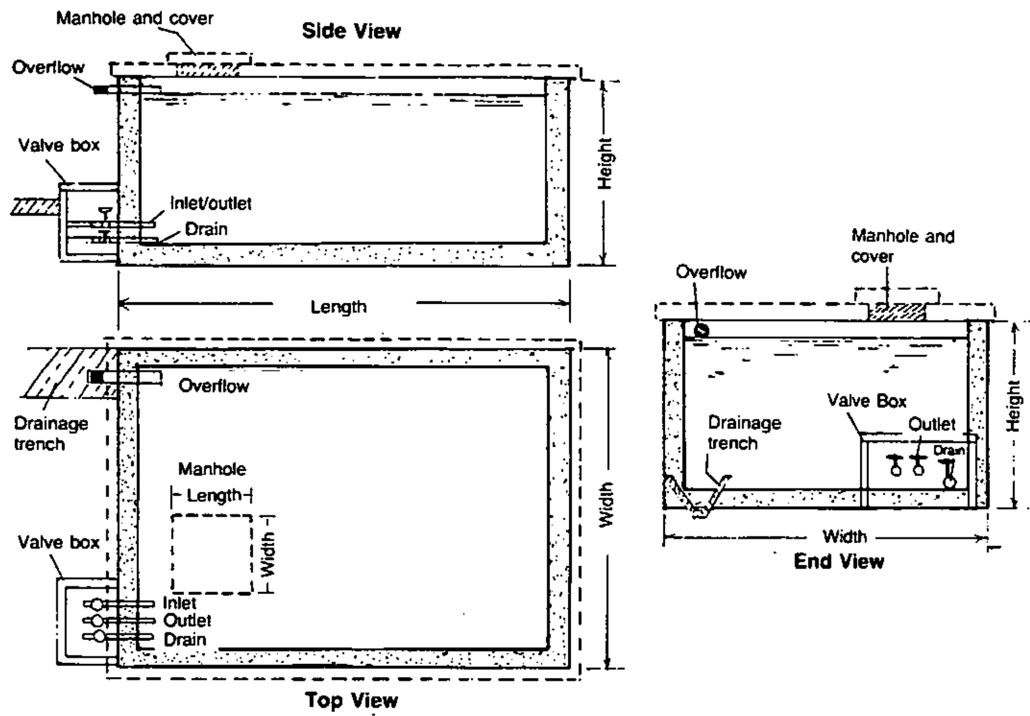


Figure 2. Storage Tank Design

General Construction Steps

Decide on the construction method to use. The reservoir can be completely built into the ground, partially in the ground, or completely above ground. Choice of the construction method will depend heavily on soil conditions and the desired height of the tank. If soil can easily be excavated, it may be best to at least partially bury the tank in order to provide support for the walls. A buried tank is effective as long as the height of the water does not fall below the minimum required to provide adequate pressure in the water system.

Follow the construction steps below. Refer to diagrams as indicated. Remember that the diagrams and construction steps are suggestions that should be adapted to local conditions.

1. Using measuring tape, cord and wooden stakes, mark out the construction site as shown in Figure 3.

2. Clean the area and begin excavation down to the level desired for the tank. If the tank is to be built above ground, or a steel tank is used, then a

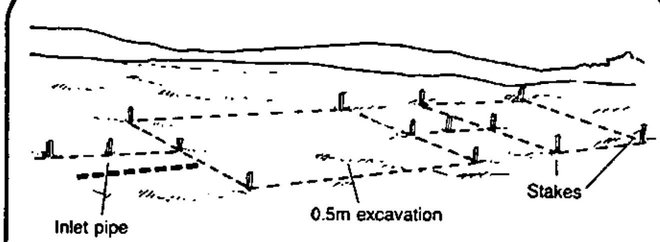


Figure 3. Stakes Marking Site of Storage Tank

shallow excavation which serves as foundation should be sufficient. For deeper excavations, walls can be excavated to slope or be built in a step form as shown in Figure 4. This type of design should be used when combined concrete and masonry are used as construction materials.

Once the level for the bottom of the tank is reached, dig out the area for the foundation. For both concrete and masonry tanks, a concrete foundation and floor is recommended. Make sure the excavation is level around the entire foundation and that plans are made to slope the floor three percent.

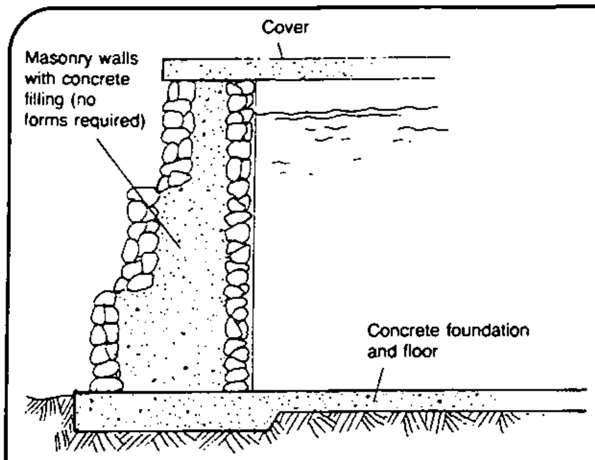


Figure 4. Example of Mass Concrete Wall Construction

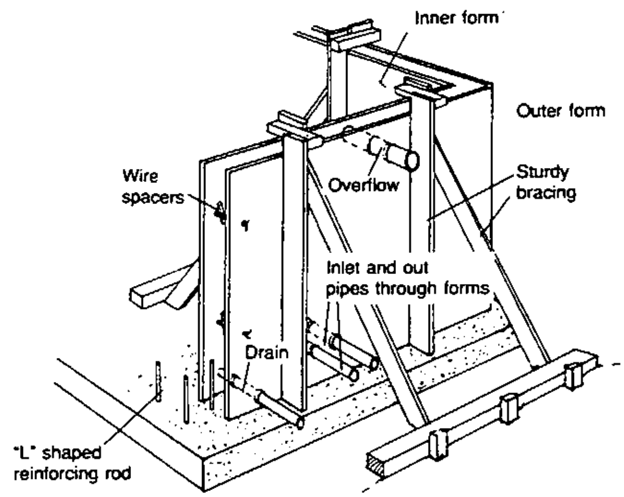


Figure 5. Detail of Forms for Walls Construction

Tank Construction

1. Once the foundation area has been dug out, begin preparing the formwork. Be sure to nail together the forms and secure them well at both top and bottom. It is especially important to brace the inside form, as the outside section will already be braced against the ground. The concrete will push out from the wall toward the inside and adequate pressure against this movement should be applied. See Figure 5.

2. Set up the reinforcing rod as shown in Figure 6. A raft foundation should be used for the structure. Install the rod so that a short length extends into the wall section. This is done by bending the rod at the base where the wall meets the floor. Before pouring the concrete:

• Make sure that all rods are tied together with wire at points of intersection;

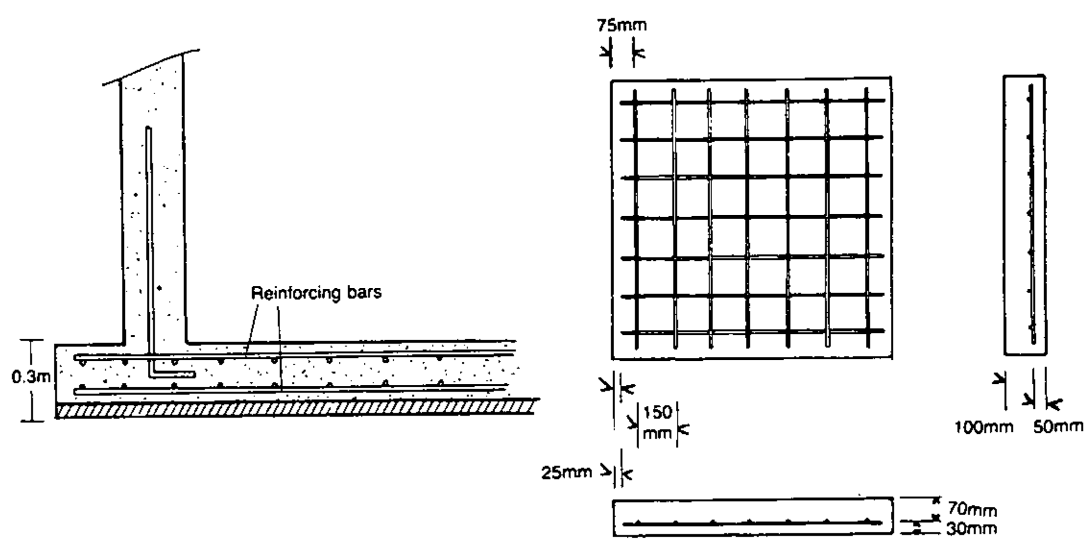


Figure 6. Placement of Rebar in Foundation and Walls

• Place small pebbles or stones under the reinforcing rod grid so that it does not rest on the ground;

• Oil the forms with a lubricant such as old motor oil;

• Cut holes and place pieces of pipe through the forms so that the intake and drain pipe can be installed.

3. Mix the cement in the proportion of one part cement, two parts sand and three or four parts gravel. Pour the entire foundation in a day so that the pour is smooth and drying is even. Smooth the top layer of cement to form the floor. At this time, build up the floor so there is a three percent slope. Hollow out a small channel for the drain pipe. The pipe should range in diameter between 40-70mm.

If structure is reinforced concrete, finish building the forms to the desired height. Remember all forms should be sturdily braced to withstand the force of the concrete. Wire placed in the forms and tightened helps in bracing. Wood braces and cross-pieces should be attached to the forms to provide adequate support. Lubricate all forms before pouring the concrete. Make a hole in the forms for a pipe ranging in size from 40-70mm in diameter. The larger the flow, the larger the pipe diameter should be. The holes in the forms should be located 150mm above the floor. Place the pipe directly into the forms before pouring. Follow the same technique for an overflow pipe. See Figure 5.

When stone masonry is used as construction material, no forms are required but skilled builders are needed. Adequate care should be taken to ensure that walls are straight (plumb) and are at least 300mm thick. A useful technique is to build the outside walls and fill the center of the wall with concrete. When building this type of structure use a step formation.

For both reinforced concrete and masonry-concrete tanks prepare a 1:2:3 or 1:2:4 concrete mixture and pour it evenly around the structure. If possible, use a portable cement mixer which will make the work move much more quickly than if the cement is mixed by hand.

Try to avoid making joints in the concrete. Leakages often occur in joints where a new layer of cement has been poured on a previous day's cement. When pouring from one day is over, leave the edge rough. The next day, clean the surface and paint over it with water and cement to form a good bond.

Once the concrete is poured, 10-14 days are needed for curing. During this time, the cement should be kept moist. A daily wetting of the structure is recommended. If cement dries too quickly, it may crack and leakage will be likely. Forms can be removed after the third or fourth day of curing. To ensure watertightness, the walls of the structure should be roughened with a trowel or a wire brush and painted with a mixture of mortar (one part cement to four parts sand).

Roof Structure

All reservoirs should be covered to prevent the entrance of contaminants, growth of algae and possible accidents. Covers can be made from reinforced concrete or lumber and shingles.

Covers cast in place are both expensive and difficult to construct. Very sophisticated formwork is needed for construction. A better method of construction using concrete is to cast sections as shown in Figure 7. Make several sections and place handles in the top so that they can be lifted into place. Construction of the slabs requires reinforcing rod and a 1:2:3 mixture of cement.

An access hole should be left in one of the covers and a lip built up to allow a cover to be secured to it. Possibly half a hole can be cut from two slabs. Once the slabs are in place, seal the joints between them with mortar to make them watertight.

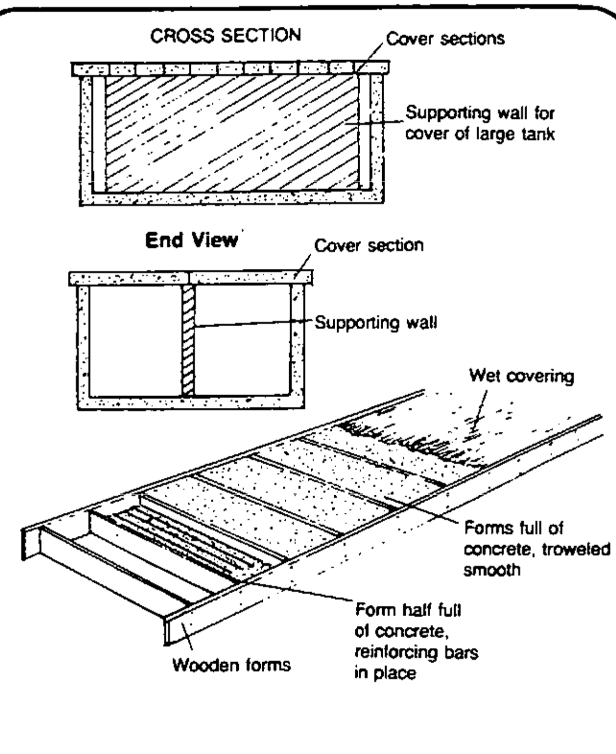


Figure 7. Casting Cover Sections

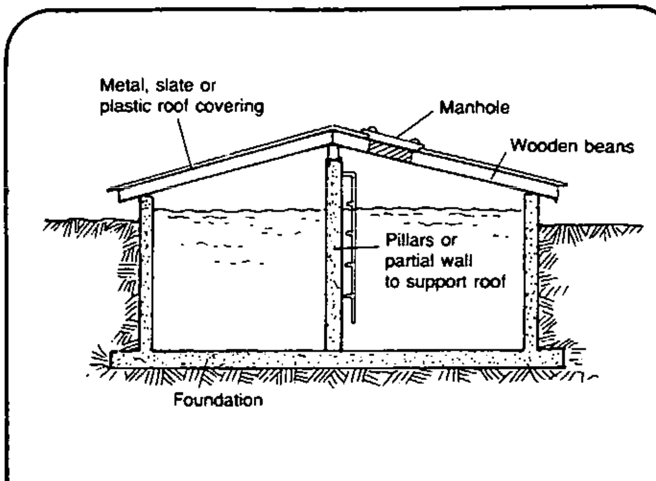


Figure 8. Cover for Large Storage Tank

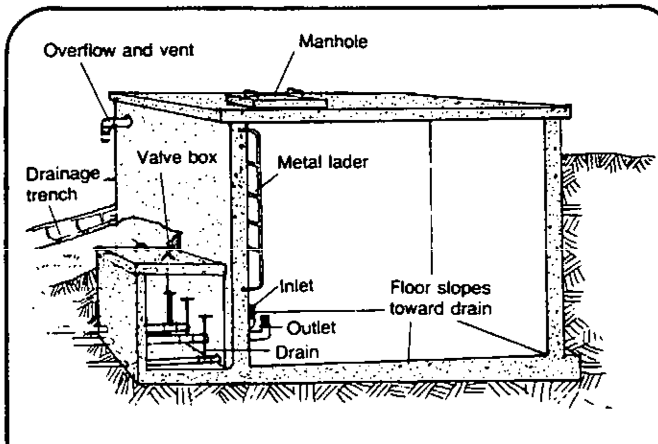


Figure 9. Ground Level Storage Tank

Another alternative is to build a roof structure as shown in Figure 8. The construction should be done by someone experienced in putting roofs on houses. The slope of the roof need not be as great as for a house but should be steep enough to allow water to run off it easily. The most important consideration is that the roof be watertight. Do not cover the roof with thatch or tile which are likely to leak. Use aluminum sheeting or slate or tar shingles for best results. Build up to the earth around the tank so that rainwater drains away from the storage area.

Valve Box

A small box to protect the valves that control inflow and outflow should be constructed at the side of the reservoir. The box can be made from stone masonry, reinforced concrete or wood. The box should have a cover and should be buried. The cover should both protect the valves and provide easy access to cut-off valves installed on the inlet and drain pipes. See Figure 9.

The valve box should be approximately 350-500mm high and can vary in length and width between 750-1500mm. Small globe and gate valves should be installed. The small box should not be difficult to construct. Construction steps can be similar to those followed for the large tank. Make sure that all valve covers are tight so that no water is wasted through leakage.

Notes

Water for the World

Designing Basic Household Water Treatment Systems

Technical Note No. RWS. 3.D.1

Basic household treatment systems are used to ensure the quality of individual water supplies that are subject to possible contamination. They are designed for supplies that cannot be included in a community treatment system due to lack of resources or distance from a central water supply. Basic household treatment systems are simple to use and relatively inexpensive. This technical note discusses the design of several simple household treatment methods useful for most water supplies. Read the entire technical note before deciding on the design that can meet your needs best.

Useful Definition

CHLORINE DOSAGE - The amount of chlorine added to a water supply for disinfection.

Hand or Batch Chlorination

Small amounts of clear, slightly contaminated water can be treated effectively by simple hand chlorination. First, you must know what type of chlorine is available and the amount of chlorine which must be added to treat the water adequately.

Find out what type of chlorine is available locally. In most rural areas, two basic types of chlorine are available for use in treatment: sodium hypochlorite and calcium hypochlorite.

Sodium hypochlorite is the main ingredient in liquid laundry bleaches. It comes in domestic and commercial strengths. The domestic strength is the most common and usually can be bought in local stores. This strength contains about five percent available chlorine but can be purchased with concentrations up to 12-15 percent. Sodium hypochlorite loses its strength gradually in two or three months after containers are opened. Calcium hypochlorite is available in powdered or tablet form and comes in strengths ranging between 30-75 percent available chlorine. A solution of 70 percent is most common. Like sodium hypochlorite, it slowly loses its strength with exposure to air. Calcium hypochlorite dissolves easily in solutions for water treatment.

To treat water prepare a one percent chlorine solution. Remember all chlorine must be stored in sealed containers in a cool dark place to retain its strength. Table 1 shows the availability of chlorine in different compounds of various strengths and the amount of each that must be mixed with one liter of water to make a one percent solution.

Table 1. Chlorine Strengths and Mixtures for a One Percent Solution

Material and Strength (percent available chlorine)	Amount of Material to Dissolve in One Liter of Water to Make a 1% Solution	
	Grams	Tablespoons (level full)
<u>Calcium Hypochlorites</u>		
High-Test Hypochlorite or		
Perchloron Powder (70%)	15	1.0
B - K Powder (50%)	18.6	1.5
Chlorinated Lime (35%)	37.5	2.5
<u>Sodium Hypochlorites</u>		
Liquid (12%)	78.2	5.5 = (½ cup or 120ml)
Chlorox (5%)	188.6	12.5 = (1 cup or 240ml)
Purex (3%)	307	20.5 = (2¼ cups or 540 ml)

To chlorinate water using a one percent solution, add three drops of the solution per liter of water or 30ml (2 tablespoons) per 145 liters of water. For example, to determine the amount of one percent chlorine solution to add to a cistern with a capacity of 500 liters, follow the steps outlined in Worksheet A.

After adding the correct chlorine dosage, wait 20 minutes or longer for the chlorine to take effect before using the water. If the water is not turbid but is colored or has a noticeable sulfur odor, the dosage should be doubled.

Chlorine is available in tablet form. When using the tablets, carefully follow all directions printed on the package to determine the correct chlorine dosage. When in doubt about the appropriate dosage, add enough chlorine to get a noticeable chlorine taste or odor.

Boiling

Water should be brought to a rolling boil rapidly for two to five minutes to destroy the disease-causing organisms in it. The amount of fuel needed to boil water depends on the type of fire, stove, and container used. An acceptable assumption is that 1kg of wood is needed to boil 1 liter of water. Water should be cooled and stored in the same container in which it is boiled. The boiled water should not be stirred or poured from one container to another in an attempt to add air and regain the taste lost by boiling. Stirring the water or changing containers may recontaminate the water.

Storage

If water is stored for several days, the level of disease causing bacteria in it is reduced. Usually, five or six days' water storage is enough to reduce the level of bacteria enough so

Worksheet A. Amount of One Percent Solution Needed for Disinfection of a Cistern

Example: Assume the cistern is 1m long, 0.8m wide, and 0.6m high.

1. Determine the volume of water that must be treated.

Volume of a rectangular cistern: V = Length x Width x Height

V = 1 m x 0.8 m x 0.6 m

V = 0.48 m^3 (1m^3 = 1000 liters)

V = 480 liters

2. Determine the amount of solution to add, using 30ml of 1% solution per 145 liters of water.

Volume of water - 145 liters = Times must add 30ml of solution

480 liters - 145 liters = 3.3
Multiply this figure by 30ml
3.3 x 30ml = 100 ml (0.1 liters)

3. Divide ml by 15 to get the number of tablespoons

100 ml - 15 = 7 tablespoons or
Multiply ml by .0042 to get the number of cups
100 ml x 0.0042 = 0.42 cups, (about one half cup or 120ml)

that people can safely drink the water. However, water quality should be checked. If water quality is poor, the length of storage should be much greater. Furthermore, certain bacteria are not affected by storage (i.e., giardia) and no length of storage will be sufficient to make water quality acceptable.

For basic four or five day storage, use two 200-liter steel barrels with spigots as shown in Figure 1. These two barrels should provide enough storage if the "treated" water is used only for drinking, cooking and minor bathing purposes. These barrels must be cleaned carefully. They may have contained oils, pesticides, chemical liquids or chemical powders. Such remains can be poisonous.

Fill both barrels and empty one completely before using water from the second. When use of water from the second barrel begins, refill the first barrel. Water from one barrel should not be used until the other barrel is empty.

To determine the amount of storage needed, multiply the number of people who will use the stored water by the average daily consumption rate. Assume that the water is used only for drinking, cooking and minor bathing purposes so that each person uses 10 liters per day. A family of six would then use 60 liters per day (6 people x 10 liters per person per day). Each 200-liter barrel would store enough water for just over three days. If less water is used, storage time will increase. Water from the second barrel will only be used on the fourth or fifth day which should be sufficient if water quality is not very bad.

If storage time in the barrels is insufficient, another form of storage must be found. For information on storage, refer to "Methods of Storing Water," RWS.5.M and "Designing a Household Cistern," RWS.5.D.1. If an alternative storage method is not available, chlorinate the water stored in the barrels. All storage containers must be covered to protect the stored water from contamination. Buckets or utensils should never be dipped into

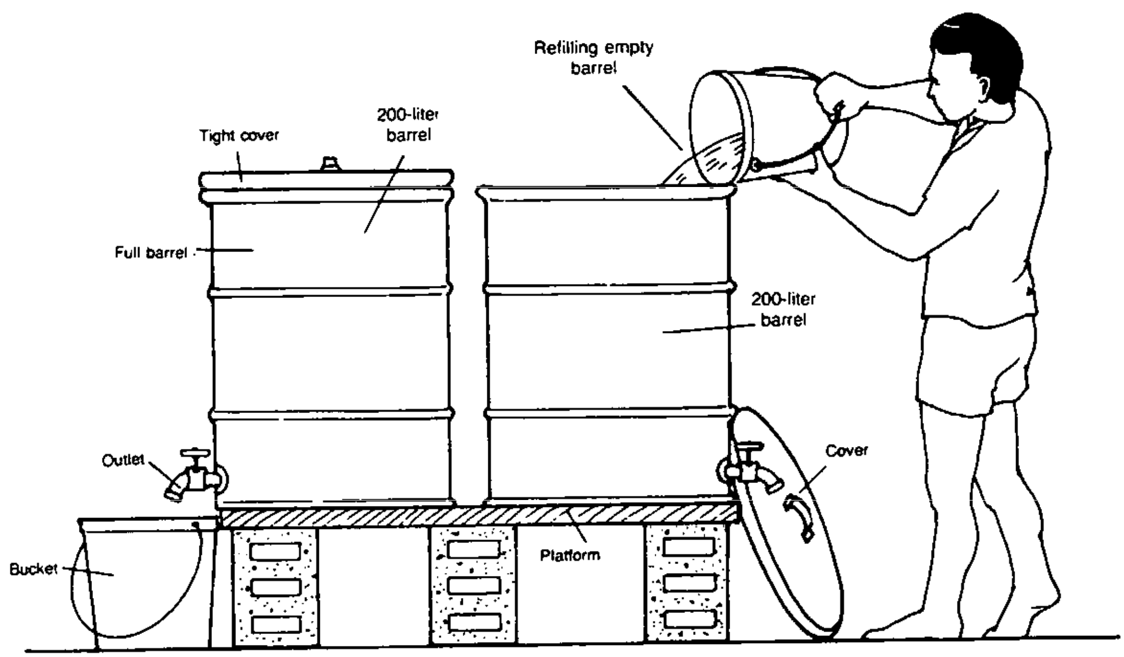


Figure 1. Using Barrels for Water Storage

storage containers. Remember, to be safe, water quality should be checked or water should be boiled or chlorinated.

Filtration

Household sand filters are very useful and popular devices for filtering water and providing basic treatment. They can be built with locally available materials. Household sand filters are relatively effective in removing most bacteria from water if a constant flow of water covers the sand at all times. Otherwise, the household filter will only remove turbidity and the water will need further treatment.

The design of a sand filter can fit local needs. Follow the design steps outlined below and refer to Figure 2. Table 2 is a list of materials needed.

A household sand filter requires a 200-liter steel barrel approximately 600mm in diameter and 750mm tall and enough clean sand to make a layer 600mm deep in the barrel. The sand layer should be about 750mm deep if a taller barrel is used. Sand size between 0.1-1.0mm is acceptable, but sand size from 0.2-0.5mm is preferred.

Determine the volume of sand needed for the filter by using the following formula:

$$V = \frac{\pi}{4} (d^2)(h)$$

where V = volume

π = 3.1

d = diameter of the barrel = (0.6m)

h = the height of the sand layer = (0.6m)

$$V = \frac{3.14}{4} (0.6m^2)(0.6m)$$

$$V = 0.785 (.36m^2)(0.6m)$$

$$V = 0.17m^3 \text{ or } 0.2m^3$$

For the filter, choose a fine grain sand. Generally, the finer the sand, the better the quality of water. Do not use coarse sands in the filter. Coarse sands allow organic matter and bacteria to pass through the filter.

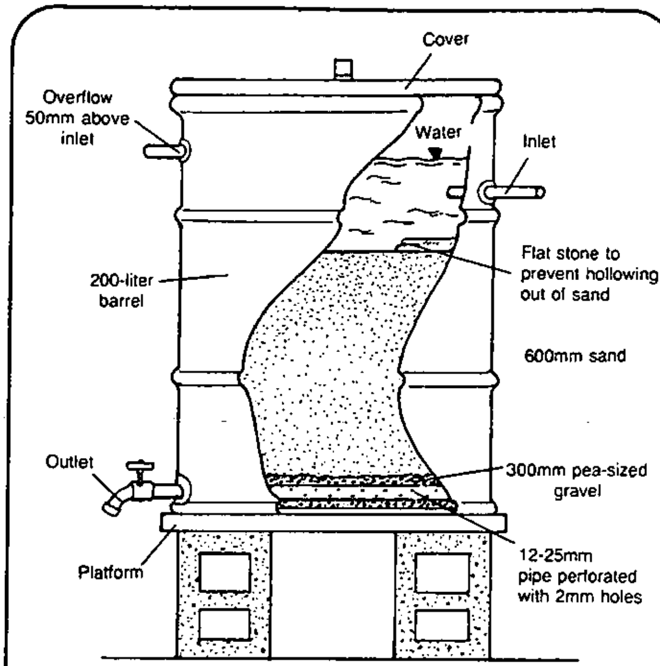


Figure 2. Household Sand Filter

Table 2. Materials List for Slow Sand Filter

Item	Quantity
Steel drum for filter (0.6m x 0.75m)	____
Pre-and post-filtration storage drums (200-liter capacity)	____
Clean sand, sized 0.1-1.0mm	____
Pea gravel	____
Sheet metal and wood, for cover	____
Polyethylene flexible pipe for inlets and outlet pipes	____
Valve to regulate water flow	____

Pea-sized stones should be used to line the bottom of the barrel where the outlet for the filter is located. The gravel layer should be 30-50mm thick. The filter outlet hole should be no more than 2mm in diameter.

If the sand filter is designed to receive a continuous flow of water, there should be an inlet hole and an overflow at the top of the barrel. The overflow should be about 50mm higher than the inlet.

Provide for a continuous flow of water through the filter sufficient to keep the filter full with a slight overflow. The maximum rate of flow through the filter should not be more than about 1 liter/minute. Water should flow from storage into the sand filter by gravity flow through flexible plastic pipe. A valve should be installed to regulate the flow. See Figure 3.

The sand in the filter should never be allowed to dry out. If the sand layer dries, the sand should be wasted or replaced. Dried sand may add bacteria to the water. Flow should be checked occasionally to ensure that the sand layer is always covered. An outlet pipe should be connected to the filter so that the water flows to a storage container.

It is much easier to use the sand filter only as a means of clarifying water rather than removing bacteria. The design of the sand filter is simpler when disinfection is not included. Operation and maintenance requirements are also less demanding.

For simple filtration, design the sand filter in the same way as described except do not include either an inlet or an outlet hole on the upper side of the steel barrel. To filter the water, the cover is removed and the desired quantity of water poured into the filter. Then the cover should be replaced. There is no need to keep the sand layer always submerged. Filtered water is collected in a storage vessel. Water filtered in this manner probably needs further treatment to disinfect it.

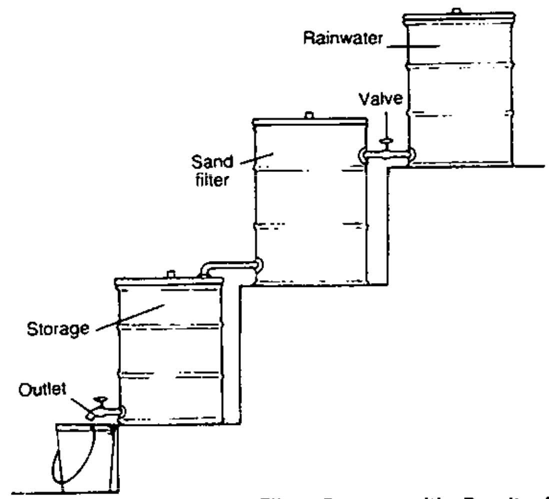


Figure 3. Household Sand Filter System with Gravity Flow and Storage

Summary

The design of most household treatment systems is simple and inexpensive. The choice of treatment method depends on available materials for construction, the users' access to chemicals, and the quality of the water supply. Proper design and proper use of chemicals are very important in ensuring that water quality is suitable. If questions or doubts about the use of a treatment process arise, an expert should be consulted to assist in the development of the most appropriate treatment method. If this is not possible, water should be boiled to disinfect it until a more permanent solution to the problem is found.

Notes

Water for the World

Constructing a Household Sand Filter

Technical Note No. RWS. 3.C.1

A household sand filter can be used to treat water for individual households. There are two different designs for household sand filters. One design simply is used to filter turbidity from water and does not affect the bacteriological quality of the water. This type of filter is easier and cheaper to construct, operate and maintain. The other sand filter design not only removes turbidity but also removes some of the bacteria. However, further treatment may be necessary. The construction, operation and maintenance required for this filter type is more expensive and more difficult than for the first type mentioned.

This technical note describes the construction of both types of slow sand filters. Construction does not require any special skills.

Useful Definitions

INTAKE - The point where water enters a supply or treatment system.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

Before beginning construction, be sure that the people building the filter have the following:

1. Detailed plans of the sand filter to be constructed as shown in Figure 1.

2. A complete list of all materials that will be needed. A sample list appears in Table 1.

Table 1. Materials List for Household Sand Filter

Item	Description	Quantity	Estimated Cost
Labor	Household members	____	____
Supplies	Steel drum	____	____
	Sand (0.2-0.5mm diameter)	____	____
	Flexible pipe	____	____
	Gravel	____	____
	Pipe glue	____	____
	Nails	____	____
	Framing wood	____	____
	Sheet metal	____	____
	Blocks	____	____
Tools	Shovel	____	____
	Hammer	____	____
	Saw	____	____

Total Estimated Cost =

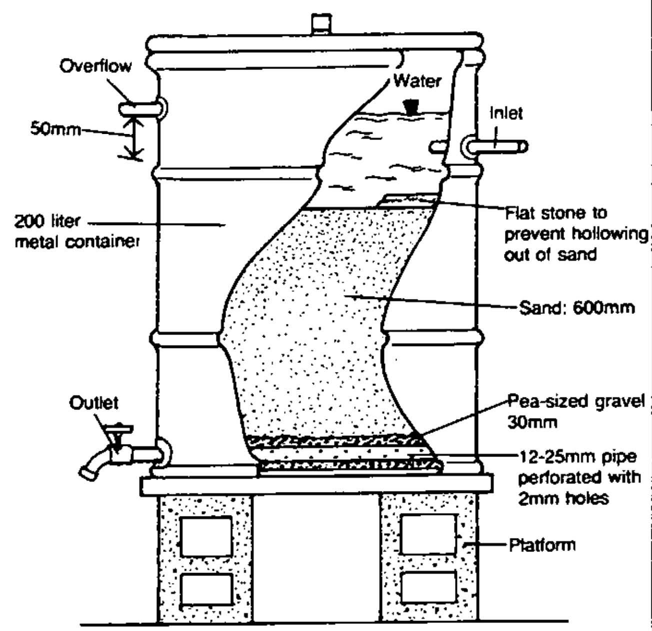


Figure 1. Household Sand Filter

Construction Steps

Follow these steps in building a household sand filter:

1. Prepare a steel barrel approximately 600mm in diameter and 750mm tall to be used for the filter. Remove the top cover and wash the barrel thoroughly and rinse with a one percent chlorine solution to disinfect it. See "Designing Basic Household Treatment Systems," RWS.3.D.1, for information on the preparation of chlorine solutions. Keep the chlorine rinse water in the barrel for at least 30 minutes to ensure proper disinfection.

2. At the bottom of the wall of the barrel drill or cut a 7-10mm hole. This hole will be the outlet for the filtered water. Do not make the hole larger than 7-10mm. Place a pipe joint and pipe in the hole so that water can flow either to storage or further treatment. Seal around the pipe and the barrel with pipe cement if plastic pipe is used. If steel pipe is used and soldering equipment is available, solder the pipe to the barrel. A good seal is needed to prevent leaks.

Another way to make an outlet is to place a perforated pipe in the gravel layer at the bottom of the barrel as shown in Figure 1. Use a small diameter pipe, 12-25mm, and make small holes in it. This method may prove easier because leakage around the pipe is less likely.

3. Line the bottom of the barrel with pea-sized gravel. The gravel layer should be about 30mm thick.

4. Fill the barrel with sand to within approximately 100mm from the top. Approximately $0.2m^3$ of sand is needed for a barrel 600mm in diameter. This will give a sand bed 600mm thick.

To determine the volume of sand needed for a layer of sand 600mm thick in a barrel 600mm in diameter, use the following formula:

Volume of sand = .785 $(\text{diameter})^2$ x height

Volume of sand = .785 $(0.6m^2)$ x (0.6m)

Volume of sand = .785 (.36m) x (0.6m)

Volume of sand = $0.2m^3$

Use fine sand for the filter. To size the sand, make a sieve using window screen and small pieces of wood as shown in Figure 2. The window screen is 16-mesh which has openings of 1.6mm. The sand that passes through the window screen will be less than 1.6mm in diameter and generally a satisfactory size. One problem is that all sand grains less than 1.6mm in diameter will pass through the sieve and an attempt to use the coarser sand should be made. If too much very fine sand is used, the filter system may clog quickly.

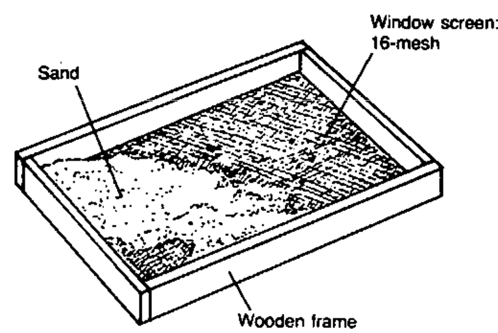


Figure 2. Sand Sieve

Grain sizes larger than 1.6mm should not be used because filtration may not be adequate in coarser sand. When choosing the sand to use in the household sand filter, only use sand that passes through the screen and from this sand, try not to use the finest grains.

To ensure effective operation, be sure that the sand is clean. Washing the sand before placing it in the filter drum is recommended. Wash the sand by placing it in a box and slowly pumping water in at the bottom. Continue this process, raking the sand to distribute it evenly, until water overflowing the box is clean.

5. If water is poured into the filter from a bucket, an overflow is not necessary. However, if water flows into the filter from an intake pipe, an overflow should be installed. For the overflow, make a 50mm hole near the top rim of the barrel and install a pipe. Locate the overflow approximately 50mm above the inlet.

6. Cover the filter. Provide a cover for the intake that adequately protects the filter. The cover should be easy to remove in order to clean the filter.

For the cover, use a piece of sheet metal nailed to a wooden frame. The frame should fit tightly over the barrel and have an overhang of about 20mm to prevent dust and rain from getting into the filter. Make the length and width of the cover frame 20mm greater than the outside diameter of the barrel. Hammer nails into the wooden form as shown in Figure 3 so that some air can circulate under the filter cover.

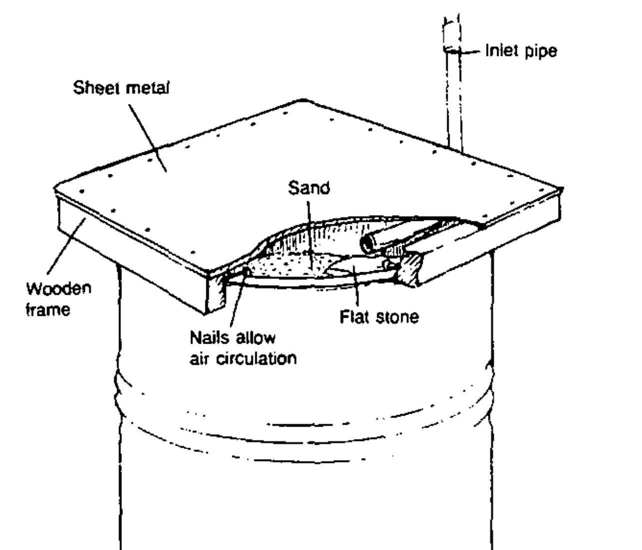


Figure 3. Cover for Sand Filter

7. When water is simply poured into the filter, no inlet other than removing the cover is necessary for filling the filter. However, if water is supplied from a cistern or other type of storage tank, an inlet can be provided. Place the inlet in either the cover or the side near the top of the barrel. Connect flexible pipe from the water source to the filter. Under the inlet pipe, place a small flat stone so that water hits it without disturbing the sand layer.

For easy access to the filtered water, place the sand filter on at least three blocks so that water can be easily collected from the outlet pipe. When constructing a household sand filter in which the sand will always be covered, a gravity flow system like the one in Figure 4 can be installed. Wooden or brick platforms can be constructed so that water flows from the pre-treatment storage to the filter and to the filtered water storage by gravity. This structure is more complicated and expensive to build and the sand layer must constantly be under water. If this system is used, taps should be installed on all outlet pipes so that water flow can be controlled.

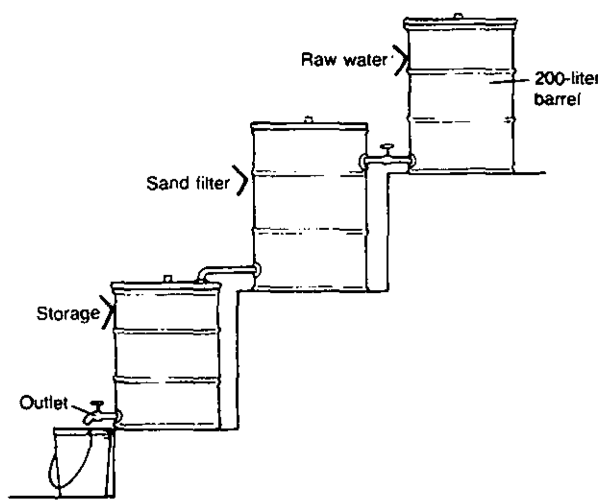


Figure 4. Gravity Flow Filter and Storage System

Caution!

If water is bacteriologically contaminated, further treatment may be necessary. The household sand filter removes bacteria if care is taken to keep the filter bed under water and if sand is fairly uniform in size. However, the sand filter may not remove all bacteria and the quality of the water should be determined before it is used. In some cases, water must be chlorinated after filtration to be of acceptable quality.

Summary

Household sand filters are a good way to remove turbidity and some bacteria from water. They can be constructed at a low cost and with locally available materials and labor. In fact, a household sand filter can be made wherever there is good sand available. Sand filters work very well if they are properly maintained.

Water for the World

Constructing a Disinfection Unit
Technical Note No. RWS. 3.C.4

Disinfection units can be constructed for both large and small water supply systems. For most disinfection purposes, chlorine compounds are used as the disinfecting agent. Chlorine is available in most countries and can be obtained in many regions at a relatively low price.

This technical note discusses the construction of simple chlorination units for small water supplies. Each unit can be built using local materials and local labor. Read the entire technical note before beginning construction.

Useful Definition

DISINFECTION - Destruction of harmful microorganisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

Materials Needed

Before beginning the construction process, the following items should be available:

1. A list of all materials and tools needed as shown in Table 1. All of these materials should be available when construction begins in order to avoid delays in the project.

2. A plan of the disinfection unit similar to Figures 1, 2 or 3 which show a pot chlorinator, a drip feed chlorinator, and a floating bowl chlorinator.

Follow the construction steps described below when building a disinfection unit. Refer to the appropriate diagram throughout the construction process.

Table 1. Materials List for Floating Bowl Chlorinator

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Workers	____	____
Supplies	200-liter steel drum	____	____
	Rubber or cork stopper	____	____
	3 small tubes 6-9mm and 3mm	____	____
	Flexible hose	____	____
	String	____	____
	Wood or plastic bowl	____	____
	Drain plug	____	____
	Outlet connection	____	____
	Small stones	____	____
	Planks and other wood for platform	____	____
	Paint	____	____
	Latex or rubber base	____	____
Tools	Hardware	____	____
	Saw	____	____
	Nails	____	____
	Drill	____	____
	Knife	____	____
	Buckets	____	____
	Paint brush	____	____

Total Estimated Cost = ____

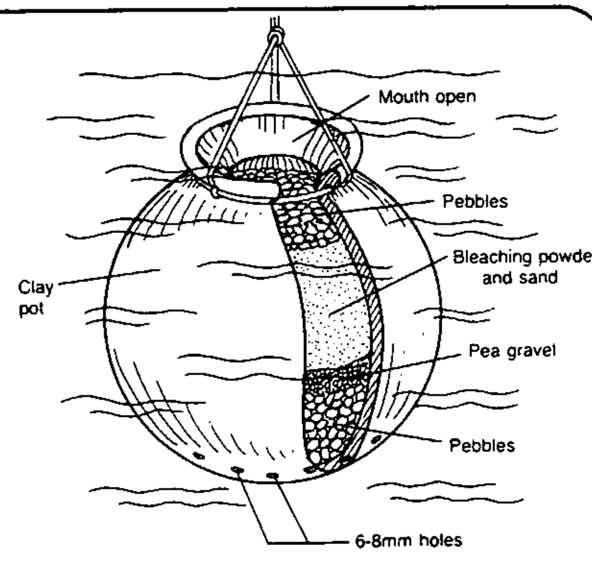


Figure 1. Pot Chlorinator

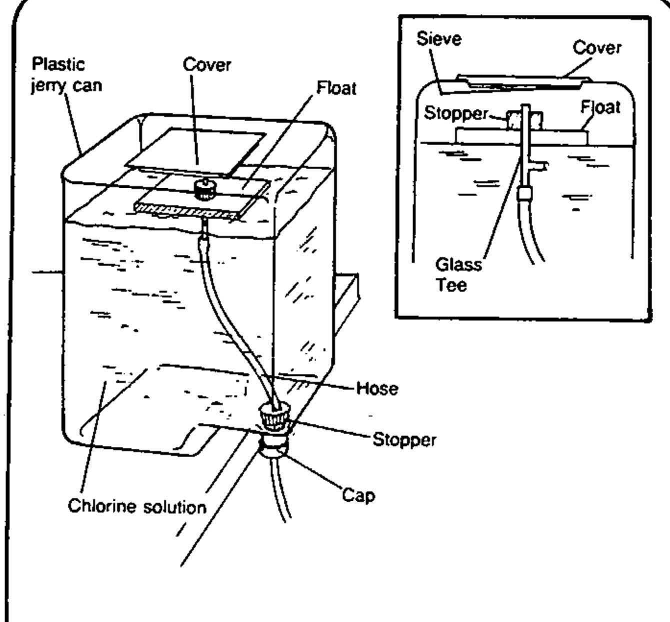


Figure 2. Chlorine Feeder

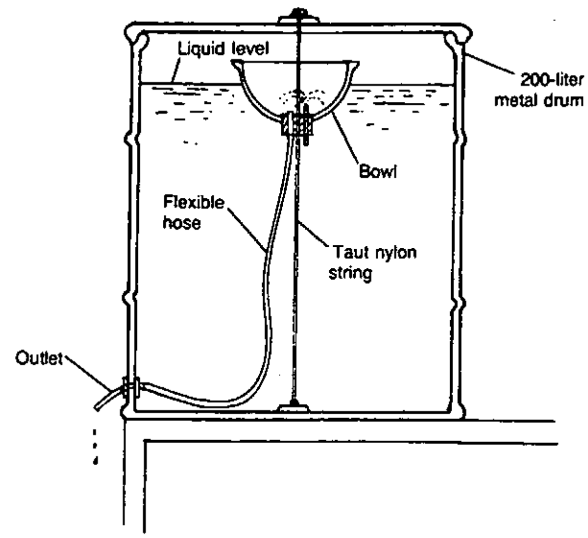


Figure 3. Floating Bowl Chlorinator

Pot Chlorinators

A pot chlorinator, shown in Figure 1, is effective for disinfecting water in shallow dug wells. To make one, follow the steps below and refer to Figure 1.

1. Use a ceramic, plastic or earthen jar or urn with a capacity of 7-10 liters. The jar does not need a cover.

2. With a sharp object, chisel or hand drill, make seven 6-8mm holes along the bottom of the jar.

3. Fill about half the jar with pebbles and pea gravel 20-40mm in size. The gravel should form a level layer in the pot. Then make a mixture of bleaching powder and sand. Add one part bleaching powder to two parts sand. Usually, 1.5kg of bleaching powder is sufficient for making a pot chlorinator.

4. Add the chlorine and sand mixture to the pot. Then use pebbles to fill the space between the layer of bleaching powder and sand and the neck of the jar.

5. Finally, attach wire or rope to the jar as shown so that the pot can be attached to a rope or hook and lowered into the well. Be sure that the pot is firmly secured to prevent it from being lost in the well.

Drip Chlorinators

A drip chlorinator can be used to disinfect water in wells, cisterns and other small reservoirs. To make a drip chlorinator, follow the steps listed below and refer to Figure 2.

1. Use a plastic can or bottle to make the drip chlorinator. The spout of the container will act as the outlet for the chlorine solution.

2. Cut open the bottom of the jar to provide a solution inlet and for access to the inside of the can.

3. Prepare the chlorine feed equipment that will fit in the plastic can. Use a piece of plastic, styrofoam, or wood for a float. In the center of the float, place a rubber stopper or cork and pass a piece of hard tubing through it. Glass, copper, brass or rigid

plastic tubing can be used. The tubing should be long enough to extend a little above the rubber stopper but below the float. In the part of the hard tubing below the float, make a small hole. This hole is the inlet for the chlorine solution which will fill the container. Use a tee, as shown in Figure 2, if one is available.

4. Attach a piece of small diameter rubber hose to the tubing. Connect the tubing below the inlet hole as shown.

5. Prepare the outlet for the drip chlorinator in the spout of the bottle. Make a hole in a plastic cap or the cover of the bottle spout so that the hose can pass through it. Pass the hose through a rubber stopper or cork that securely fits in the spout. Place the stopper in the neck of the container as shown, and put a cap or cover on the container spout.

6. Fill the plastic jar with chlorine bleach. Domestic chlorine beach contains 2-5 percent available chlorine. Fill the container until the float reaches the top. Then cover the top of the jar.

7. To control the flow, use a small clamp or make one from two pieces of aluminum and two aluminum nuts and bolts. Place the clamp around the hose and tighten it to cut off all flow during installation. Loosen the clamp to get the rate of flow desired.

8. Install the plastic can over the well or reservoir using wire. The wire can be attached to the well head or lip of the cistern and the container hung inside. The rubber outlet hose should reach into the water.

Floating Bowl Chlorinators

Floating bowl chlorinators hold a much larger volume of chlorine solution than the drip type used for disinfecting water in wells and small reservoirs. Floating bowl chlorinators are used to add chlorine at a constant rate to water in a tank or in a low pressure pipeline. Floating bowl chlorinators can be constructed with local materials and local labor. Refer to Figure 3 as you read the construction steps.

1. Prepare a 200-liter barrel for storing the chlorine solution. Remove the top cover and clean out the barrel by washing it with a one percent chlorine solution. Let the chlorine stand in the barrel for at least thirty minutes. Empty the barrel and, when it is dry, paint the inside with a latex or rubber base paint. This type of paint is not affected by chlorine.

Once the paint is dry, place a small outlet hole in the side of the barrel as shown in Figure 3. Make the hole 6mm in diameter. Make another hole approximately 10mm in diameter at the bottom of the barrel to serve as the tank's drainage.

2. To feed the chlorine into the water supply, make a floating bowl like that shown in Figures 4 or 5. Use a wooden or plastic bowl or cut the bottom out of a plastic bottle to form a bowl and use it as a float.

3. Using a stopper borer or hand drill, make a hole in the middle of the float to fit a medium-sized rubber or cork stopper. The rubber or cork stopper must be wedged into the opening to fit securely without leaking. Before placing the stopper in the opening, push three short tubes through

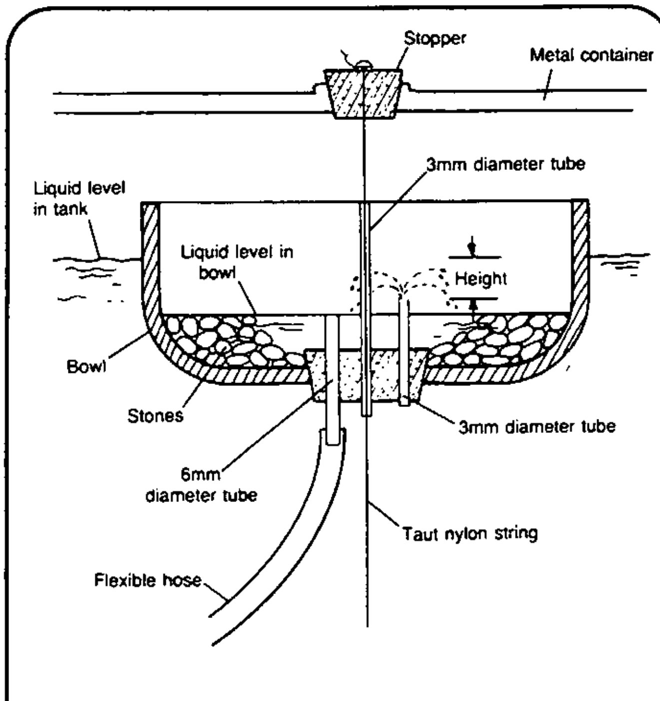


Figure 4. Floating Bowl Chlorinator

the stopper. Use glass, copper, brass or hard plastic tubing. Use two 3mm and one 6-9mm diameter tubes. One 3mm tube should go through the center of the stopper and the other two tubes should be placed to either side of the center. The tube through the center which will carry the guide string shown in Figure 4 should extend to the top of the bowl. The other 3mm tube should reach just below the liquid level in the tank. The 6-9mm diameter tube should reach no higher than the top of the stopper or the layer of small stones used for weights.

4. To install the floating bowl in the tank, first connect one end of the flexible rubber hose to the largest diameter tube. Connect the other end of the hose to a small drip outlet. The drip outlet can be made of plastic or a watertight joint. Or, flow can be controlled by placing a clamp over the flexible tube. Tightening the clamp will slow the flow; loosening it will increase the flow.

5. Secure one end of a nylon string to the bottom of the tank. Take the free end and thread it through the 3mm tube passing through the center of the stopper. Pull the string as tight as possible, and attach it to a wooden cross piece over the top of the barrel. Secure it well so it can be separated from the cover to refill the barrel without disconnecting the bowl. The string serves as a guide for the bowl so that it does not hit the sides of the tank. Figure 5 shows a bowl without a guide string. The chlorinator is easier to make without the guide string, but the bowl may drift to the sides of the barrel. If there are no ridges or plugs in the sides that could keep the bowl from moving downward as the chlorine solution is used, the chlorinator will work.

6. Fill the tank almost to the top with a one percent chlorine solution. To determine the amount of chlorine compound needed to prepare a one percent solution, use the following equation.

Amount of chlorine needed:

$$\frac{\text{Percent strength of solution desired} \times \text{Liters of solution required}}{\text{Percent available in compound}}$$

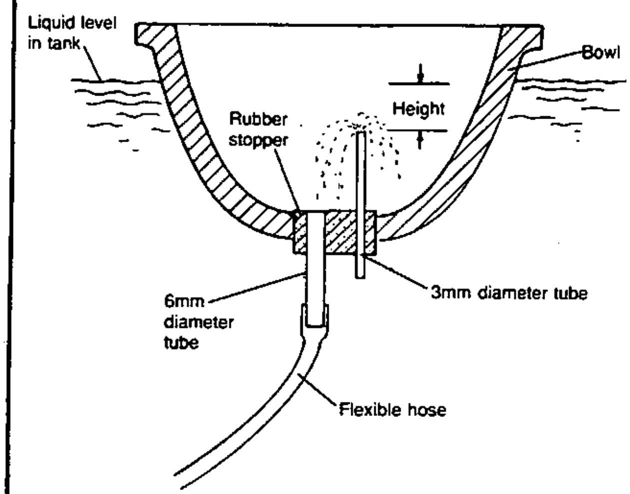


Figure 5. Floating Bowl Chorinator

To prepare 200 liters of a one percent solution using bleaching powder with 35 percent available chlorine, the amount of bleaching powder which should be used is:

$$Q \text{ chlorine} = \frac{1\% \times 200 \text{ liters}}{35\%}$$

$$Q \text{ chlorine} = \frac{.01 \times 200}{.35}$$

$$Q = 5.5\text{kg}.$$

Approximately 5.5kg of bleaching powder should be added to the water in the tank. Stir gently but well for at least five minutes.

7. To control the flow of the solution from the tank, one of three methods can be used. To reduce the flow, raise the tube that lets water into the bowl to the height near the water level in the tank. Lowering the tube increases the flow. The second method is to reduce the size of the opening to the bowl in the top of the inlet tube. A glass tube can be heated and drawn out. A brass or copper tube can be flattened out. Third, small stones or gravel can be placed in the bowl to increase flow. The stones act as weights and force larger amounts of water to flow into the bowl through the tube. Weights may be added or removed to control the rate of flow.

The tank should be checked often to be sure that the tank always contains chlorine solution. The water being treated should be tested periodically to ensure that there is adequate chlorine residual. A color comparator tester is needed to do this. The addition of a reacting agent called orthotolidine produces a yellow color which increases with chlorine content and indicates the amount of chlorine in the water.

Summary

Several simple methods are available for chlorinating small supplies of water. The pot chlorinator, the drip feed chlorinator and the floating bowl chlorinator can all be constructed using locally available supplies and labor. These methods are useful for chlorinating small water supplies but in order to be assured of their effectiveness, water should be tested after chlorination. Where water cannot be tested, make sure that the treated water has a slight chlorine taste and odor. Insufficient chlorination does not provide protection from disease-causing bacteria.

Notes

Water for the World

Operating and Maintaining Household Treatment Systems

Technical Note No. RWS. 3.O.1

The operation and maintenance of household treatment systems requires the attention of individual families. Proper operation and maintenance will ensure that adequate water treatment is performed and that storage containers are cleaned and protected against the entry of contaminants.

This technical note describes several measures to follow for effective operation and maintenance of household treatment systems. These measures will help maintain good water quality in the household when chlorination, boiling, storage or household sand filtration is used.

Chlorination

For effective chlorination to take place, sufficient stocks of chlorine should be available and correct chlorine dosages should be applied. The best way to ensure that an adequate amount of chlorine is available is to prepare a large quantity of one percent stock solution and store it in jars in a cool dark place for future use. To determine the amount of chlorine to add to a certain volume of water, use the following formula:

Kg of chlorine required =

$$\frac{\text{Percent strength of solution desired} \times \text{Liters of solution desired}}{\text{Percent available chlorine}}$$

For example, to prepare a 50-liter supply of one percent solution using bleaching powder with 35 percent available chlorine, the amount of powder which must be added to the 50 liters of water is:

$$\frac{.01 \times 50 \text{ liters}}{.35} = 1.4\text{kg.}$$

Thus, 1.4kg of bleaching powder should be added to 50 liters of water to make a one percent stock solution. Using this formula, both larger and smaller volumes of one percent solution may be made. As the stock solution becomes low, be sure that more chlorine is available.

Whenever possible, test the water to ensure that chlorination is adequate. Under most conditions, such testing will not be practical. Check with local health officials to see whether testing kits are available or whether someone from a regional or national center tests water in the area periodically. If testing is impossible, the dosage outlined in "Designing Basic Household Water Treatment Systems," RWS.3.D.1, should prove sufficient.

Boiling

To produce good quality water through boiling and ensure that it does not become contaminated, follow these steps:

- Always store the boiled water in the same container in which it is boiled. Changing containers increases the risk of re-contamination. The only exception to this is if a household has a ceramic filter. In that case, pour the water into the filter for storage.

- Use containers that have covers or can be covered adequately. Dust, dirt and other debris can easily get into uncovered containers. Children and animals are more likely to come into contact with water left in uncovered containers.

- If possible, attach a spigot to the container so that there is no need to dip cups or other utensils into the water. If a spigot cannot be attached, always pour the water from the storage container rather than dip utensils into it. Figure 1 shows a sample design for a tap that can help prevent re-contamination of stored water.

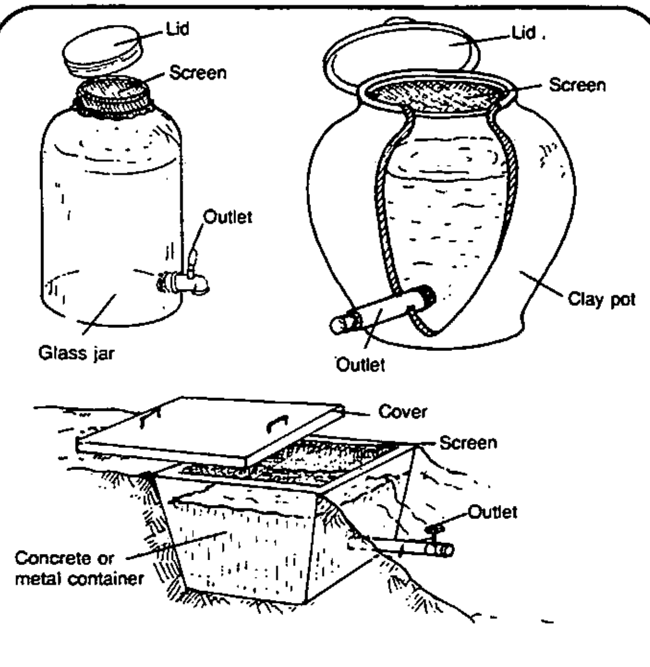


Figure 1. Methods of Storing Water

Storage

To ensure good water quality, clean storage containers after they are emptied each time. Remove the sediment from the bottom and sides of the containers. At least once a month, wash the containers with a chlorine solution. Keep the storage containers covered at all times. Never dip buckets or cups into them.

Household Sand Filter

Operation and maintenance requirements for a household sand filter depend on the type of filtration system constucted. Two designs are available: one that provides a continuous flow of water and keeps the sand layer submerged, and another which does not have a continuous flow of water and does not always keep the sand layer under water.

For filters that are designed for continuous flow, effective operation and maintenance should ensure that there is a continuous flow of water through the filter at all times. To ensure that this occurs, be sure to set up the intake so that there is always a small overflow from the filter. The small overflow indicates that the filter is full and the sand layer completely submerged.

For both continuous flow and non-continuous flow filters:

• Keep household sand filters covered so that it is completely dark inside the filter. Light may cause growths of green algae on the surface of the sand. Place the cover on the filter with a small space left so that some air may circulate. See Figure 2. Air circulation will help the growth of the biological layer on the sand in continuous flow filters.

• Clean the filter when water flow from it slows down greatly. To clean the sand, scrape off a layer approximately 5mm thick and throw it out. See

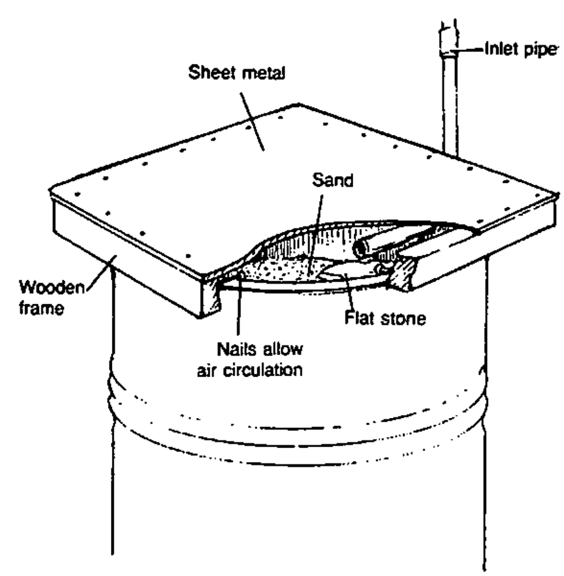


Figure 2. Cover for Sand Filter

Figure 3. Then rake or scratch the surface lightly. Cleaning should only take place once every several weeks so as not to disturb the biological layer on the surface of the sand. After four or five cleanings, clean sand should be added to bring the layer of sand back to its normal height. Before adding new sand, scrape the old sand clean. Then add either new sand or sand from the filter that has been thoroughly washed.

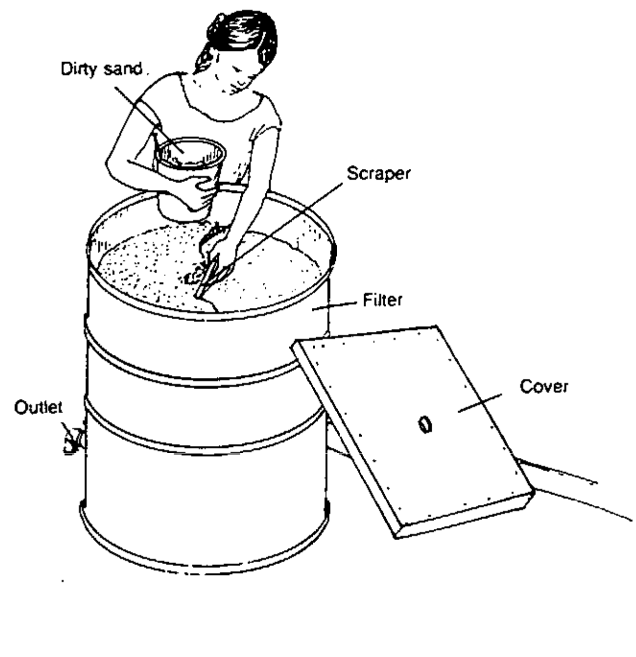


Figure 3. Scraping the Sand Filter

Notes

Water for the World

Simple Methods of Excreta Disposal
Technical Note No. SAN. 1.M.1

Simple methods of excreta disposal use a pit, vault, or bucket to hold the excreta. This reduces the chance of contaminating water supplies and of spreading diseases caused by poor sanitation (see "Means of Disease Transmission," DIS.1.M.1). These methods also help control the spread of disease by keeping animals and insects away from excreta. Simple methods of excreta disposal are easy to build, inexpensive, and can be made from locally available materials.

This technical note describes five simple methods of excreta disposal: pit privy, pit privy with improvements, aqua privy, compost toilet, and bucket latrine.

Useful Definitions

COMPOST - A dark, fairly dry, crumbly, odorless material that is produced by sealing excreta, ashes, woodchips, straw, and vegetable waste for 6-12 months; compost can be used to fertilize crops.

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria from excreta.

EXCRETA - Human body wastes.

PERMEABLE - Allowing liquid to soak in.

SLUDGE - Solids settled from water-carried wastes.

Pit Privy

Pit privies are probably the cheapest and easiest excreta disposal method to build and the simplest to maintain. The four main features of a pit privy are the shelter, pit, slab with hole or seat, and lid. See Figure 1.

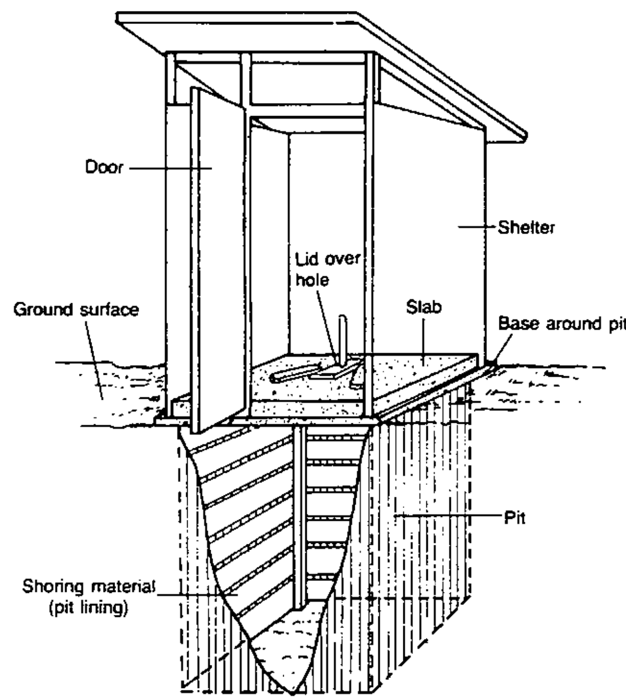


Figure 1. Pit Privy

The shelter gives the user privacy and, depending on the design, may protect the user and the privy from the weather. It should be made from local materials such as palm thatch, bamboo, wood, or bricks. It can have a screening wall or door, depending on local preference.

The pit is dug in permeable soil and holds the excreta. The bottom of the pit must be at least 1m above groundwater levels. The size of the pit will vary, depending on the number of users, the type of anal-cleaning material used, and the desired lifetime of the pit. For example, a pit that is 1m square and 1.5m deep can be used by a family of five for about six years.

The pit has a base for the slab and sometimes a lining, as well, depending on the type of soil in which it is dug. The lining shores up the sides of the pit. It is made from bamboo, boards, brick, or select field stones. The base encircles the top of the pit and supports the slab. It is made of logs, bricks, or concrete.

The slab covers the pit and has a hole near the center through which to defecate. It can have either a squatting hole or a seat and pedestal, depending on local preference. The slab can be made from bamboo, wood, or concrete.

The lid covers the hole in the slab when the privy is not in use. It is made of local material, and it should fit tightly over the hole to keep flies and other insects out of the pit.

The pit will eventually fill with excreta. When it is filled to within 0.5m below the slab, the slab and shelter are moved to a new pit and the old pit is filled with dirt.

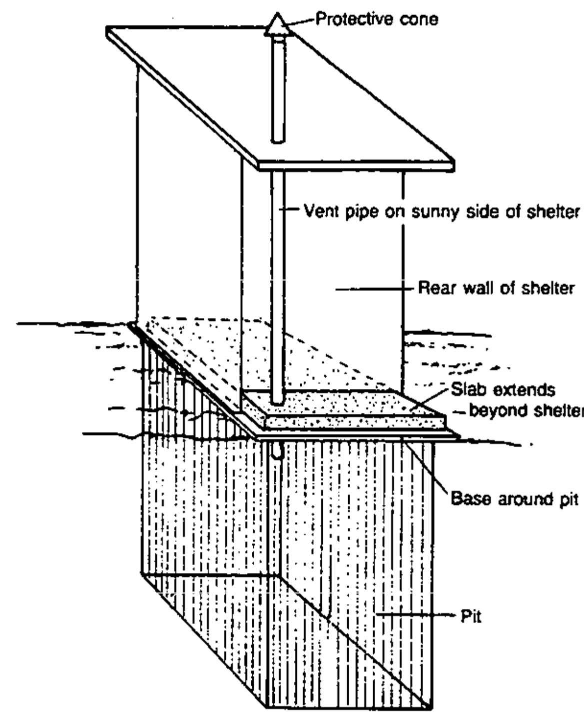


Figure 2. Privy with Vent Pipe

Privies with Improvements

Improved privies have all the features of a pit privy plus either a vent pipe, pour-flush bowl, off-set pit, or some combination of the three. Like pit privies, improved privies must be no deeper than 1m above groundwater levels, and they will eventually fill with excreta. These privies cost about one-and-a-half times as much as a pit privy.

A vent pipe is 75-150mm in diameter, usually metal painted black, and topped with a fly-proof screen and cone-shaped cover to keep out rain. See Figure 2. The purpose of the vent pipe is to remove odors from the privy. The vent pipe is installed outside the shelter, on its sunny side. The pipe's bottom end is mortared to a hole in the slab and the top end is attached to the roof of the shelter. The sun heats the pipe causing an updraft. As a result, air moves down through the squatting hole or seat, through the pit, and up the vent. The screen on the top end of the vent pipe traps flies that may get into the pit.

A pour-flush bowl is a bowl with a U-shaped pipe attached below the squatting slab or the seat and pedestal, as shown in Figure 3. After each use, 1-3 liters of water are poured into the bowl. Part of the water flushes excreta into the pit, and part forms a water seal in the bowl to prevent odors from rising from the pit into the shelter.

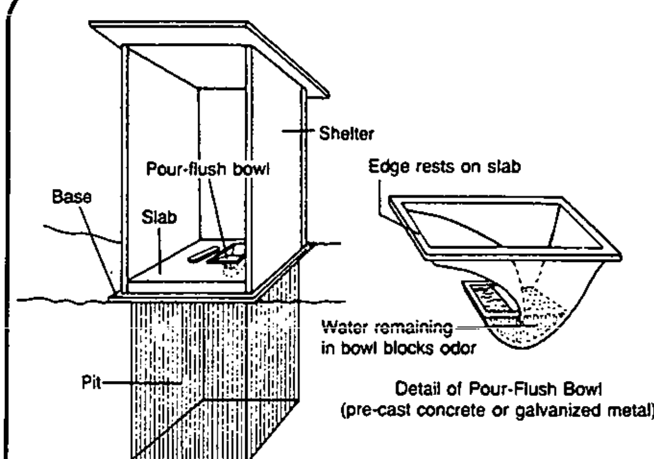


Figure 3. Privy with Pour-Flush Bowl

A pour-flush bowl requires a water source, such as a standpipe, near the privy. Washwater can also be used to operate a pour-flush bowl. Bulky anal-cleansing materials should not be used because they will clog the pipe.

An off-set pit is not directly under the slab and shelter and can be larger than a standard pit, as shown in Figure 4. Off-set pits are at least 1m wide, 1.5m long, and 3.0m deep. Because of their size, they last longer than standard pits. Another feature, which may be considered an advantage, is that the excreta in the pit cannot be seen.

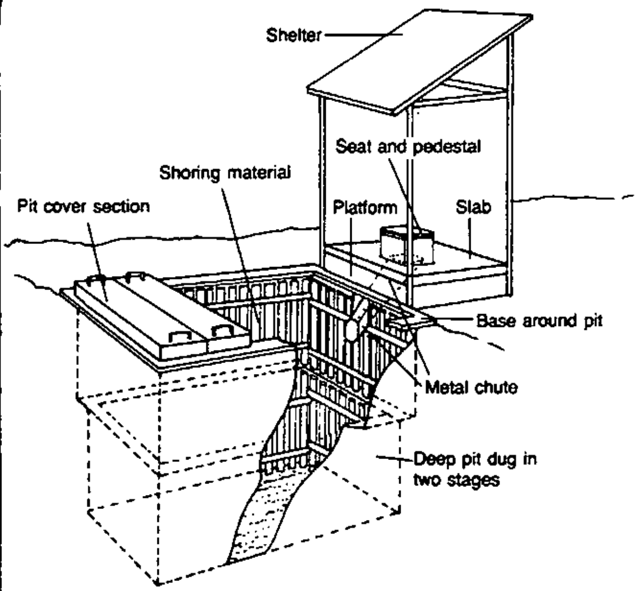


Figure 4. Privy with Off-Set Pit

An off-set pit can be fitted with a pour-flush bowl or a chute and cover. The chute, usually made of galvanized metal, carries excreta downward from the squatting hole or seat to the pit. The cover is generally made of concrete.

Aqua Privy

An aqua privy costs about twice as much as a pit privy. Its four main features are a water-tight vault, slab, shelter, and soakaway as shown in Figure 5.

The vault is about 1m square and 1-2m deep. It is made of reinforced concrete or brick and mortar, and is

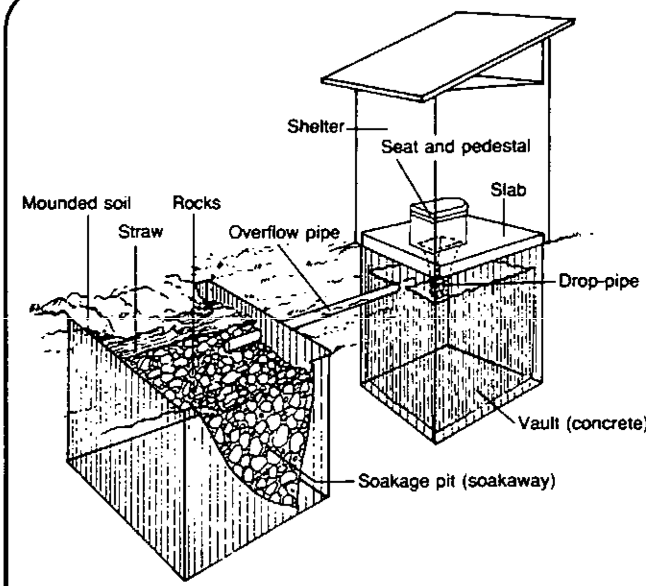


Figure 5. Aqua Privy

installed underground and filled with water. Excreta passes from a drop-pipe in the slab into the vault. The bacteria in the vault breaks down the excreta, and the solids settle to the bottom. The excess liquid flows through an overflow pipe from the vault to a soakaway.

The slab covers the vault and has a metal drop-pipe that extends from the squatting hole or seat down into the water in the vault. The water in the drop-pipe forms a seal, much like a pour-flush bowl, and prevents odors from rising into the shelter.

The shelter is the same as the shelter for a pit privy or improved privy.

The soakaway can be a soakage pit or trench (see "Simple Methods of Washwater Disposal," SAN.1.M.2). It receives excess liquid run-off from the vault through an overflow pipe.

The water level in the vault and the water seal in the drop-pipe must be maintained or there will be severe problems with odors, flies, and mosquitoes. Enough water, possibly washwater, must be added to the vault to replace any water that evaporates. This will vary from 1-10 liters per day.

The vault will gradually fill with sludge. The sludge must be cleaned out and buried when the vault is about two-thirds full and the vault must be refilled with water. This will occur every two to six years.

Compost Toilet

The compost toilet described here is the double-vault type. It costs about twice as much as a pit privy. The five main features of a compost toilet are two water-tight vaults, two slabs, and a shelter, as shown in Figure 6.

The shelter is larger than a shelter for a pit privy, because it must enclose two slabs.

The slabs are the same as for a pit privy, and may have squatting holes or seats and pedestals.

The vaults, which may really be one large vault divided in half, are made of reinforced concrete or brick and mortar. They rest above ground on a concrete or brick base and are each about 1m square and 1m high.

Only one vault is used at a time. It holds the excreta, to which is added ashes, sawdust, woodchips, or vegetable wastes. When the vault becomes two-thirds full, which takes six to 12 months, it is filled with dirt and sealed. The second vault is then used until it becomes two-thirds full. At that time, it is filled with dirt and sealed, and the first vault is opened. The contents of the first vault will have changed into compost material. The compost is removed from the first vault through the door at the back and used to fertilize crops. The first vault is now ready to use again.

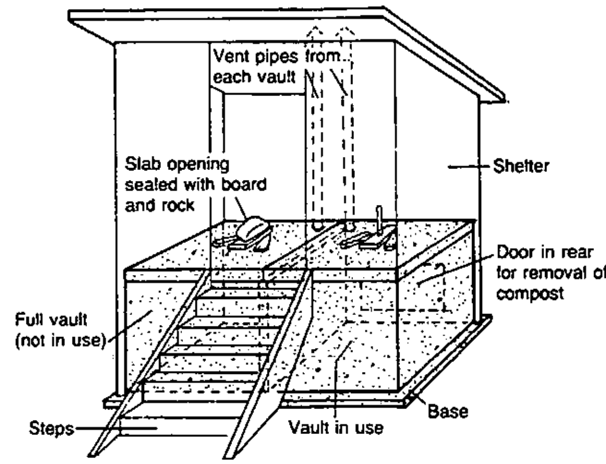


Figure 6. Compost Toilet

Bucket Latrine

The construction cost of a bucket latrine is about the same as a pit privy. However, operating costs can make a bucket latrine the most expensive excreta disposal method described in this technical note. The four main features of a bucket latrine are a platform, slab, shelter, and bucket, as shown in Figure 7.

The platform can be made of wood, concrete, or brick and mortar. It elevates the slab and encloses the bucket.

The slab is the same as for a pit privy, and may have a squatting hole or a seat and pedestal.

The shelter is the same as for a pit privy, with the addition of a fly-proof door in the rear wall for removal of the bucket.

The bucket is made of rubber, enamel, galvanized metal, or lacquered wood. It is placed under the slab, in the compartment created by the platform.

The bucket holds excreta and must be emptied every one to three days, preferably every day. A laborer replaces the bucket with a clean one, empties the excreta into a larger container, and takes it to a trenching ground where the excreta is buried. Water must be available at the trenching ground so the laborer can wash the containers and buckets. It is also possible to compost the excreta.

This method of excreta disposal can be unpleasant and unsanitary. There is a risk of spreading disease because the excreta and excreta containers must be handled continually. This method also can be quite expensive because

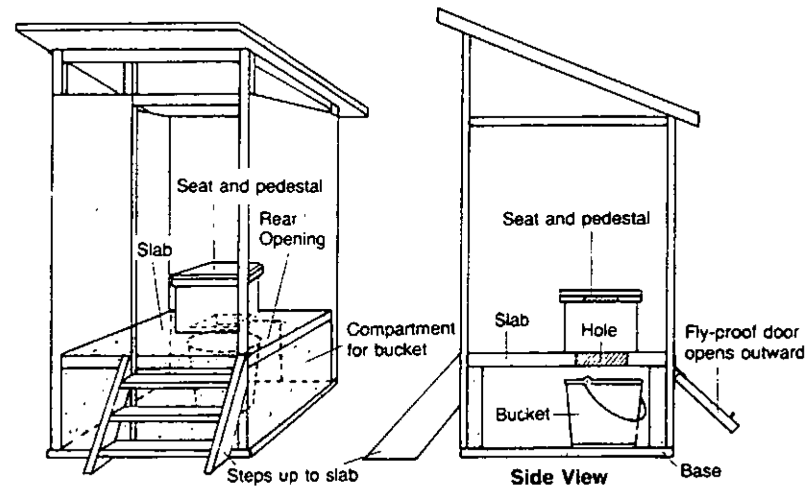


Figure 7. Bucket Latrine

workers must be paid to empty the buckets and bury the excreta. In some regions, however, the excreta is composted successfully with no odor, flies or disease. It is then used to fertilize crops. In most circumstances bucket latrines should probably only be used where there is a dense population on rocky ground or as a temporary solution to an emergency situation. Existing bucket latrines should be replaced with other, more sanitary means of excreta disposal as soon as possible.

Comparison of Methods

Table 1 summarizes each of the five simple methods of excreta disposal. The methods are listed across the top of the chart, and the factors to be compared are listed down the left side. The table can be used as an aid in selecting a method (see "Planning Simple Systems of Excreta and Washwater Disposal," SAN.1.P).

Table 1. Comparison of Simple Methods of Excreta Disposal

Factor	Disposal Method				
	Pit Privy	Pit Privy with Improvements	Aqua Privy	Compost Toilet	Bucket Latrine
Cost	None	1½ times pit privy	2 times pit privy	2 times pit privy	No construction cost but operation may be costly depending on community
Design Features	Pit; slab (squat or seat); lid; shelter	Same as pit privy plus either pour-flush bowl, vent pipe, off-set pit, or combination	Vault; slab (squat or seat); shelter; soakaway	Double vault; two slabs (squat or seat); shelter	Platform; slab (squat or seat); bucket; shelter; large containers' cart
Construction Skills	Minimal	Minimal	Some masonry	Some masonry	Minimal
Slab Material	Bamboo, wood, or concrete	Bamboo, wood, concrete, ceramic, or plastic	Concrete	Concrete	Bamboo, wood, or concrete
Water Requirement	No	No, except for pour-flush	Yes	No	No for operation, but yes for washing at trenching ground
Handling of Wastes	None	None	Every 2-6 years as sludge	Every 6-12 months as compost	Every 1-3 days as excreta
Maintenance	Clean slab weekly; dig new pit and move slab and shelter every 4-6 years	Same as pit privy; if off-set pit, clean chute weekly and dig new pit every 10 or more years	Maintain water level in vault; clean slab weekly; remove sludge and refill with water every 2-6 years	Clean slab weekly; alternate use of vaults every 6-12 months by removing compost, cleaning one vault, sealing the other	Clean slab weekly; remove excreta every 1-3 days; clean buckets every 1-3 days; cart excreta to trenching ground and bury it or to composting area

Notes

Water for the World

Designing Pits for Privies
Technical Note No. SAN. 1.D.2.

Designing a pit for a privy involves selecting its location, calculating its size, and determining the labor, materials, and tools needed for construction. The products of the design process are: (1) a location map, (2) technical drawings of the pit, (3) sketches of the pit lining, if needed, and base for the slab, and (4) a materials list. These products should be given to the construction supervisor before construction begins.

This technical note describes how to design a pit and arrive at these three end-products. Read the entire technical note before beginning the design process.

Useful Definitions

DECOMPOSE - To decay and become reduced in volume due to bacterial action; this happens to excreta in a pit.

IMPERVIOUS - Not allowing liquid to pass through.

PERMEABLE - Allowing liquid to soak in.

Materials Needed

Measuring tape - To obtain accurate field information for a location map.

Ruler - To draw a location map.

Location

The major factors in selecting a location for a privy are: (1) location of water supplies, dwellings, and property lines, (2) soil type, (3) groundwater levels, and (4) impervious layers.

Location of Water Supplies, Dwellings, and Property Lines. A pit privy should be downhill from water wells. It should be at least:

20m from the nearest well or stream,
6m from the nearest dwelling,
3m from the nearest property line.

For the sake of convenience, the privy should be no farther than 30m from the building to be served. It should be on fairly level ground. When a proposed site has been selected, determine the soil type.

Soil Type. A pit should be dug in permeable soil so the liquid part of the excreta can soak into the ground. The rate at which liquid soaks in depends on the type of soil. If the rate is too fast or too slow, the soil is not suitable for a pit. The main types of soil are sand, sandy loam, loam, silt loam, clay loam, and clay. For a detailed description of soil types see "Determining Soil Suitability," SAN.2.P.4.

When the soil at the pit site has been identified, use the following chart to determine its suitability.

Table 1. Soil Suitability

Soil Type	Suitability
Sand	No
Sandy Loam	Yes
Loam	Yes
Silt Loam	Yes
Clay Loam	No
Clay	No

If the soil is not suitable, select another location for the pit. If no good location can be found, design an alternative excreta disposal system (see "Simple Methods of Excreta Disposal," SAN.1.M.1). If the soil is suitable, proceed to the next step.

Groundwater Levels. The bottom of the pit must be at least 1m above the groundwater level during the wettest season of the year. This information may be available from local residents, water well owners, or water well drillers. If the information is not available or reliable, field tests must be made. These tests are described in detail in "Determining Soil Suitability," SAN.2.P.4. In brief, a hole must be dug 1m deeper than the proposed pit. Dig the test hole during the wettest season. If no groundwater is observed, groundwater levels are suitable.

If groundwater levels are not suitable, select another location for the pit. If no acceptable location can be found, design an alternative excreta disposal system (see "Simple Methods of Excreta Disposal," SAN.1.M.1).

Impervious Layers. The bottom of a pit must be at least 1m above impervious layers such as creviced rock, hardpan, shale, or clay. The same test hole dug for determining groundwater levels can be used to check for impervious layers. If there are impervious layers in the test hole, the site is unacceptable for a pit and a new site must be found. If no suitable site can be found, design an alternative excreta disposal system (see "Simple Methods of Excreta Disposal," SAN.1.M.1).

When a suitable site has been found, draw a location map similar to Figure 1, showing the pit site and distances to water supplies, streams, dwellings, property lines, and any other nearby structures or prominent geographical features.

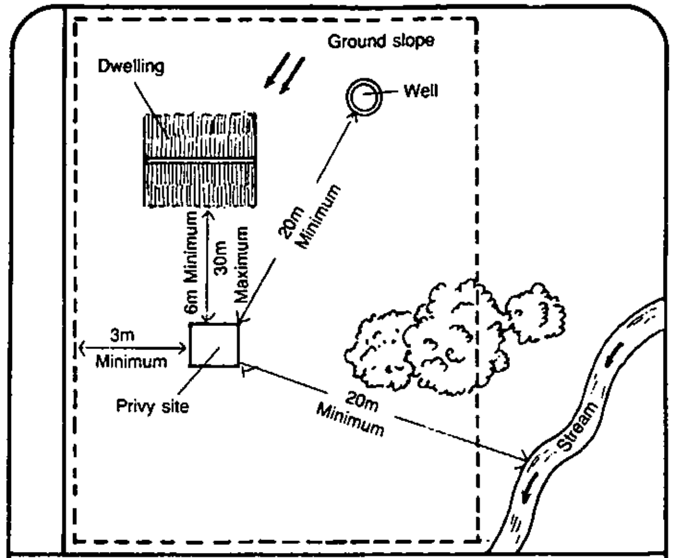


Figure 1. Location Map

Determining Pit Size

To determine the length, width and depth of a pit, first calculate the capacity. The capacity, or volume, of a pit is determined by the number of users of the privy, the number of years the pit is expected to last, whether the privy will have a pour-flush bowl, and the type of anal cleansing material used. Worksheet A shows a sample calculation of the size of a pit.

The number of users equals the number of persons living in or using the building to be served (Worksheet A, Line 1).

The pit should be designed to last 5 to 10 years, preferably 10 (Worksheet A, Line 2).

If the privy will have a pour-flush bowl, the pit can be smaller because the water used to flush the bowl will cause the excreta in the pit to decompose more rapidly (Worksheet A, Line 4).

The capacity of the pit is calculated as follows:

For a pit <u>without</u> a pour-flush: number of persons times number of years times 0.06 equals volume in cubic meters (Worksheet A, Line 5).

For a pit <u>with</u> a pour-flush: number of persons times number of years times 0.04 equals volume in cubic meters (Worksheet A, Line 6).

Worksheet A. Calculations for Privy Pit, Lining, and Base

Capacity of Pit

1. Number of users = 6
2. Designed life of pit in years = 8
3. Line 1 x Line 2 = 48
4. Is there a pour-flush bowl? ☒ no ☐ yes
5. If "no," then Line 3 x 0.06 = 2.8 m^3
6. If "yes," then Line 3 x 0.04 = ______ m^3
7. Do anal cleansing materials readily decompose? ☒ yes ☐ no
8. If "yes," then capacity = Line 5 (or Line 6) = 2.8 m^3
9. If "no," then capacity = 1.5 x (Line 5 or Line 6) = ______ m^3

Dimensions of Pit

10. Capacity (from Line 8 or Line 9) = 2.8 m^3
11. Pit is for (check one): ☐ pit privy ☒ ventilated pit privy ☐ offset pit privy
12. Width (from Table 2) = 1.1 m
13. Length (from Table 2) = 1.2 m
14. Line 12 x Line 13 = 1.32 m^2
15. Depth = $\frac{\text{Line 10}}{\text{Line 14}}$ = 2.1 m

Quantity of Lining Material (area of pit walls)

16. 2 x Line 12 = 2.2 m
17. 2 x Line 13 = 2.4 m
18. Line 16 + Line 17 = 4.6 m
19. Area of walls = Line 15 x Line 18 = 9.7 m_2

Distance Around Pit (periphery)

20. Periphery = Line 16 + Line 17 = 4.6 m

Volume of Poured Concrete Base

21. Width of base = 0.15 m
22. Thickness of base = 0.05 m
23. Volume = Line 20 x Line 21 x Line 22 = 0.03 m^3

Lengths for Wood or Log Base

24. Line 12 + 1.0m = 2.1 m
25. Line 13 + 1.0m = 2.1 m
26. Lengths of the four logs or wood beams:

(1) Line 24 = 2.1 m
(2) Line 24 = 2.1 m
(3) Line 25 = 2.2 m
(4) Line 25 = 2.2 m

Example 1. Suppose a pit privy without a pour-flush is being designed for a family of six and is to last eight years. Then the capacity of the pit equals:

$6 \times 8 \times 0.06 = 2.8$ cubic meters (Worksheet A, Lines 1-5).

Example 2. Suppose a pit privy with a pour-flush is being designed for a family of six for eight years. Then the capacity of the pit equals:

$6 \times 8 \times 0.04 = 1.9$ cubic meters (Worksheet A, Lines 1-6).

If anal cleansing materials that do not readily decompose such as grass, leaves, corncobs or mudballs are used, the capacity of the pit should be multiplied by 1.5 (Worksheet A, Line 7). For example, if the capacity of the pit was calculated to be 3.0 cubic meters and corncobs are the usual anal cleansing material, the required capacity of the pit is:

$3.0m^3 \times 1.5 = 4.5$ cubic meters (Worksheet A, Line 9).

When the capacity has been calculated, determine the dimensions of the pit. First, find the length and width. They depend on the type of slab and shelter being used (see "Designing Slabs for Privies," SAN.1.D.1 and "Designing Privy Shelters," SAN.1.D.3).

In general, a pit for a privy is square and is directly beneath the slab and shelter. A pit for a ventilated pit privy is either slightly offset or slightly longer than it is wide to accommodate the vent pipe. A pit for an offset pit privy is longer than it is wide and larger than a pit that is not offset.

(NOTE: A pour-flush bowl is generally used with a ventilated pit privy or an offset pit privy.)

Table 2 shows the general width and length and the minimum depth of the pit for each type of privy.

Determine the correct depth by dividing the design capacity by the width times the length (Worksheet A, Lines 10-15).

Table 2. Privy Type and Pit Dimensions

Privy Type	Pit Dimensions		
	Width	Length	Depth
Pit Privy	1.0-1.2m	1.0-1.2m	at least 1.5m
Ventilated Pit	1.0-1.2m	1.1-1.5m	at least 1.5m
Offset Pit	1.0-1.2m	1.5-2.0m	at least 3.0m

For example, calculate the correct depth of a ventilated privy with a capacity of 2.8 cubic meters, a width of 1.1 meters, and a length of 1.2 meters.

$$\text{depth} = \frac{2.8m^3}{1.1m \times 1.2m}$$

$$= \frac{2.8m^3}{1.32m}$$

$$= 2.1m$$

For pits 2.5-3.5m deep, add 0.15m to the length and 0.15m to the width to accommodate a step or ledge left in the walls during construction. For safety reasons, do not design a pit to be dug by hand deeper than 3.5m.

When the dimensions of the pit have been determined, make a technical drawing similar to Figure 2 showing length, width, and depth. For an offset pit privy, which requires a chute from the squatting slab to the pit, make a drawing similar to Figure 3 showing length, width, and depth of pit, and excavation for the chute. Give these drawings to the construction supervisor.

If the soil is such that the walls of the pit will not stand on their own in both the wet and dry seasons, the pit must have a lining. All pits need a base to support the slab (see "Designing Slabs for Privies," SAN.1.D.1).

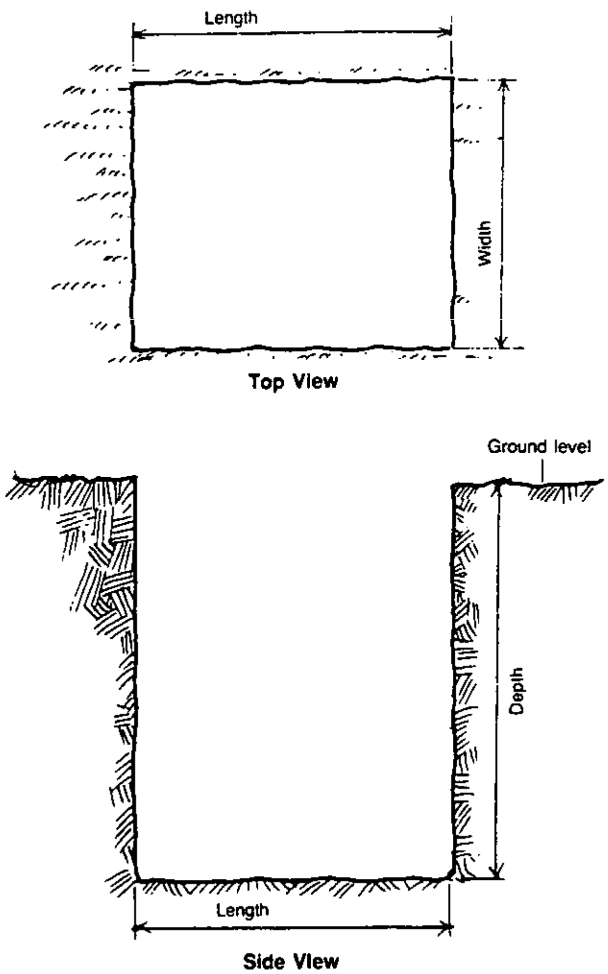


Figure 2. Dimensions for Pit Privy or Ventilated Privy

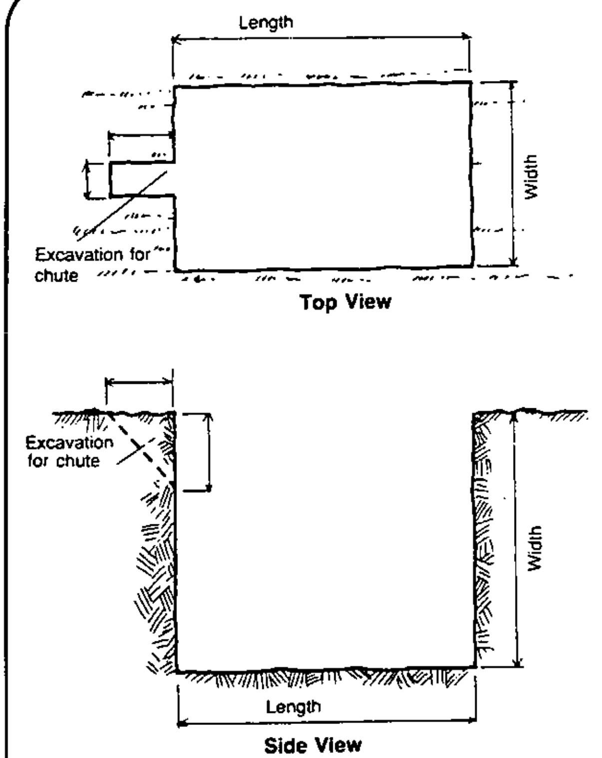


Figure 3. Dimensions for Offset Pit Privy

Caution!

Before the pit is excavated, design and construct the slab or, if it is an offset pit, the cover (see "Designing Slabs for Privies," SAN.1.D.1 and "Constructing Slabs for Privies," SAN.1.C.1). This is necessary so that when the pit is constructed, it can be covered immediately. A pit left open and unattended is a serious hazard. Whenever workers leave the site, they should cover the pit with the slab.

The lining can be made of bamboo, logs, poles, boards, bricks, concrete blocks, or select field stones. Whatever material is used, it must have slits or open spaces to allow the liquid part of excreta to pass through to the soil. For an offset pit privy, a space must be left in the lining to allow for the chute.

Prepare a sketch similar to one of those in Figure 4 showing the lining material and a sketch similar to one of those in Figure 5 showing the materials to be used for the base, and give both of them to the construction supervisor.

Materials List

Prepare a materials list similar to Table 3, showing labor requirements, types and quantities of materials and tools, and the estimated funds needed to construct the pit, including lining and base. This technical note provides the means of determining some quantities. The remaining quantities will have to be determined by you as the project designer or by the construction supervisor.

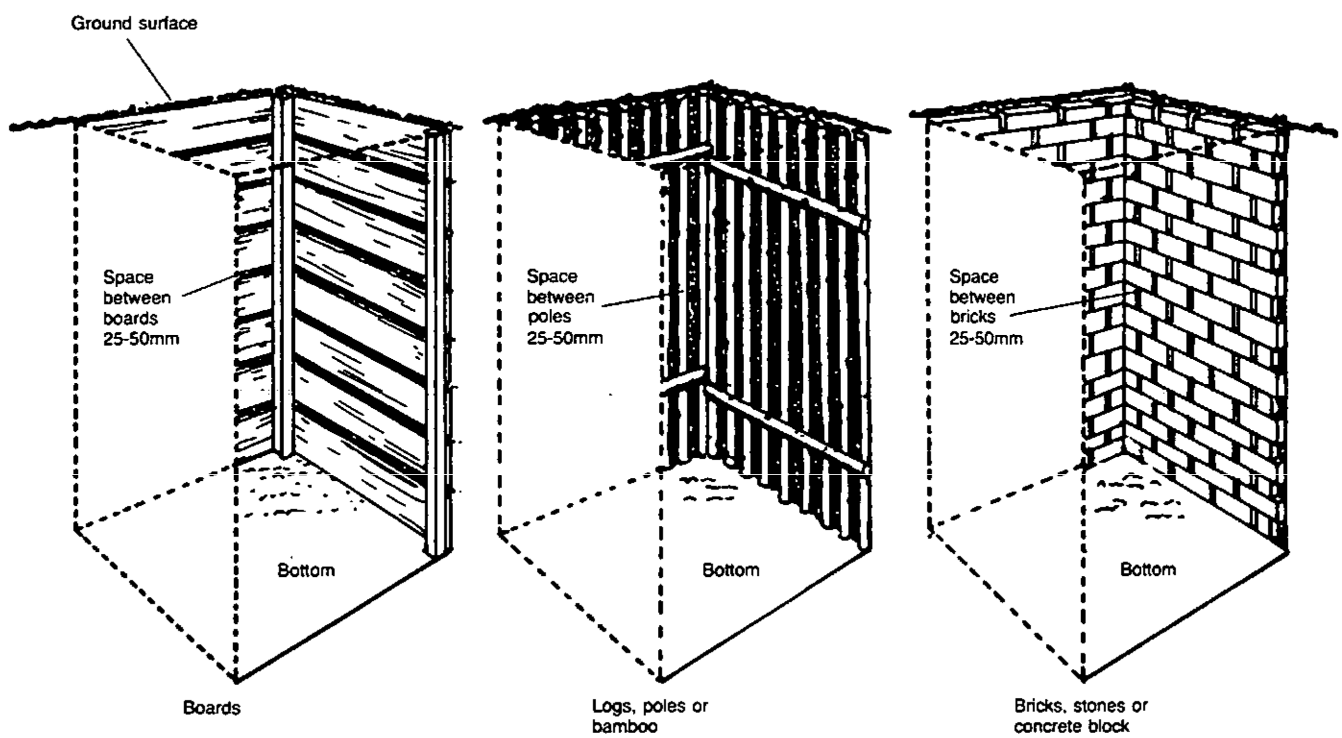


Figure 4. Pit Linings

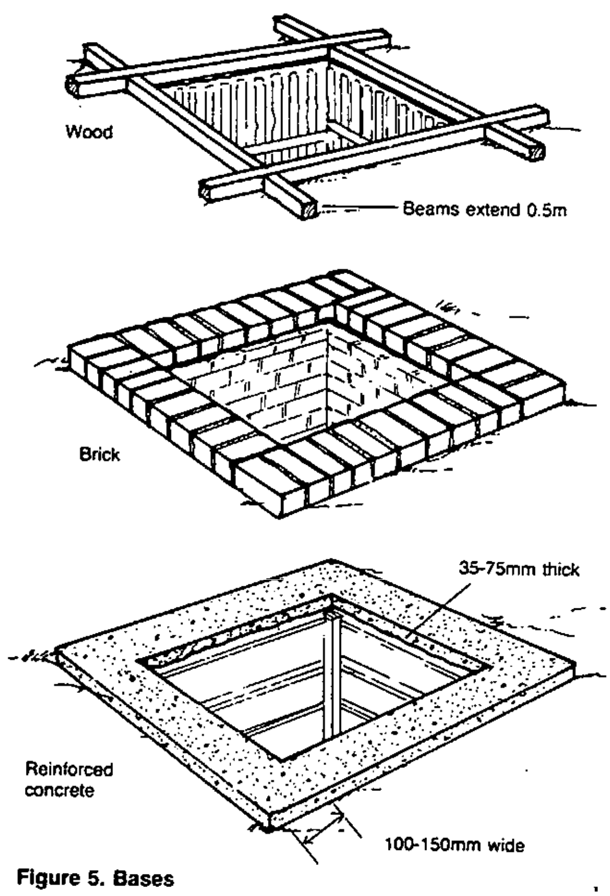


Figure 5. Bases

Labor. Ideally, there should be at least two laborers to dig the pit. If the pit lining or base is wood, one worker should have some carpentry skills; if the lining or base is brick or concrete block, one worker should have some masonry skills; if the base is poured concrete, one worker should have some concrete skills. If this number of laborers is not available, you can certainly make do with fewer. The person in charge of construction should be present during all stages of construction.

Lining. The material used for the lining, if needed, can be bamboo, logs, poles, boards, bricks, concrete blocks, or select field stones. Use a material that is readily available and that laborers are familiar with. The quantity depends on the type of material and the size of the pit. One way to estimate the quantity is to calculate the area of the pit walls, since the lining must cover nearly the entire wall area except for the spaces between the boards, poles, or bricks.

Table 3. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	______
	Laborers (one experienced with carpentry, stone masonry, or poured concrete, whichever applies)	2 (at least)	______
Supplies	For laying out the system: wooden stakes or sticks	____	______
	For the lining: bamboo, poles logs, boards, bricks, concrete blocks, select field stones	____	______
	For the base: wood, bricks, concrete blocks	____	______
	For poured concrete or mortar:		
	Cement	____	______
	Sand	____	______
	Gravel	____	______
	Water	____	______
	Other	____	______
Tools and Equipment	Box or bucket	1	______
	Sturdy rope or ladder	1	______
	Measuring tape	1	______
	Shovels	2 (at least)	______
	Wheelbarrow	1	______
	Hammer	1	______
	Saw	1	______
	Nails	--	______
	Trowel	1	______
	Plumb line (string and rock)	1	______
	Hatchet or machete	1	______
	Container (for mixing mortar)	1	______
	Concrete slab	1	______
	Other	--	______

Total Estimated Cost = ______

The area of the pit walls equals two times the width plus two times the length multiplied by the depth (Worksheet A, Lines 16-19).

For example, suppose a pit is 1.1 meters wide, 1.2 meters long, and 2.1 meters deep. Then the area equals:

$$(2 \times 1.1) + (2 \times 1.2) \times 2.1$$
$$= (2.2 + 2.4) \times 2.1$$
$$= 4.6 \times 2.1$$
$$= 9.7 m^2$$

The lining material must cover an area equal to about 9.7 square meters.

Base. The material used for the base can be wood, bricks, concrete blocks, or poured concrete. Use a material that is readily available and that the laborers are familiar with. Figure 5 shows three different types of bases.

(NOTE: A wood base may not last as long as a brick, concrete block, or poured concrete base.)

The quantity depends on the type of material and the size of the pit. One way to estimate the quantity for a brick, concrete block, or poured concrete base is to calculate the distance around the top of the pit. This distance is called the periphery; it is equal to twice the length plus twice the width (Worksheet A, Line 20).

For a base made of bricks or concrete blocks, there must be a sufficient quantity to place the bricks or blocks side by side for a distance equal to the periphery of the pit.

For example, suppose a brick base is needed for a pit 1.1 meters wide and 1.3 meters long. Then the periphery equals:

$$(2 \times 1.1) + (2 \times 1.3)$$
$$= 2.2 + 2.4$$
$$= 4.6 m$$

There must be enough bricks to be placed side by side around a periphery of 4.6 meters.

For a poured concrete base, the quantity of poured concrete is equal to the periphery of the pit times the width of the base times the thickness of the base (Worksheet A, Lines 21-23).

For example, suppose a concrete base 0.15 meters wide and 0.05 meters thick is needed for a pit with a periphery of 4.6 meters. Then the quantity of concrete equals:

$$4.6m \times 0.15m \times 0.05m$$

$$= 0.03m^3$$

For a wood base, four logs or sturdy wooden beams are needed, one for each side of the pit. Each log should be 1 meter longer than the side of the pit on which it will be laid, as shown in Figure 5 (Worksheet A, Lines 24-26). For example, suppose a wood base is needed for a pit that is 1.2 meters wide and 1.3 meters long. Then the lengths of the four logs would be:

$$(1.2+1.0),(1.2+1.0),(1.3+1.0),(1.3+1.0)$$

$$= 2.2m,\ 2.2m,\ 2.3m,\ 2.3m.$$

Tools. The tools required will vary according to the type of pit lining and base. All types of pits require at least two shovels (one per laborer) or other digging implements. A wheelbarrow is useful for carting away excavated dirt and for bringing other material to the pit site. A saw and nails are needed if the lining or base is made of wood, logs or boards. If the lining or base is made of bricks or concrete blocks, or the base is made of poured concrete, a container for mixing the concrete or mortar and a trowel for applying and smoothing concrete or mortar are needed.

Also needed are a measuring tape to help determine the exact location of the pit, and wooden stakes or sticks to lay it out on the ground. A plumb line (long string with a rock tied to the end) will be useful to ensure that the pit walls are dug vertically. A sturdy rope or ladder should be available for the laborers to get into and out of the pit.

Cost. The cost of the pit depends on a number of variables: which materials are available and which must be purchased; how much labor will be volunteered and how much must be paid for; prices and wage rates; and so on. Make your best estimate based on local conditions.

When all calculations, determinations, and estimates have been made, prepare a materials list similar to Table 3, and give it to the construction supervisor. In summary, give the construction supervisor: (1) a location map similar to Figure 1, showing the location of the pit in relation to all nearby structures and geographical features; (2) a technical drawing similar to either Figure 2 or Figure 3, depending on the type of pit privy, showing correct dimensions of the pit; (3) sketches similar to those in Figure 4 and Figure 5, showing the general configuration of the pit lining and base; and (4) a materials list similar to Table 3 showing the labor, materials, tools, and money needed to construct the pit, lining, and base.

Water for the World

Constructing Pits for Privies
Technical Note No. SAN. 1.C.2

The pit beneath a privy receives and holds excreta. The pit prevents contamination of groundwater and the spread of disease by keeping the excreta away from humans, animals and insects. At the top, the pit has a base for the slab. The pit often has a lining, also. If the pit walls will not stand on their own, a lining prevents them from caving in. Lining is installed after the pit is dug. Shoring, similar to lining, must be put in place during excavation of deeper pits and pits in crumbly soils to protect workers from cave-ins. The base supports the slab or cover (see "Constructing Slabs for Privies," SAN.1.C.1) and privy shelter (see, "Constructing Privy Shelters," SAN.1.C.3). Constructing a pit involves assembling laborers, materials, and tools to do the job, excavating the pit at the correct location, lining the pit walls, if necessary, and building a base for the slab.

A properly constructed pit will last 5 to 10 years. This technical note describes each step in constructing a pit. Read the entire technical note before beginning construction.

Useful Definitions

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria from excreta.

EXCRETA - Human body waste.

GROUNDWATER - Water stored below the ground's surface.

Materials Needed

The project designer must provide four items before construction can begin:

1. Location map, similar to Figure 1, showing the correct site where the pit is to be excavated. The map will show distances from the pit to nearby dwellings, sources of drinking water, property lines, and any other structures or prominent geographical features.

2. Technical drawings, similar to Figures 2 and 3, showing the correct dimensions of the pit.

3. Sketches, similar to Figures 4 and 5, showing the materials and general configuration of the pit lining and base.

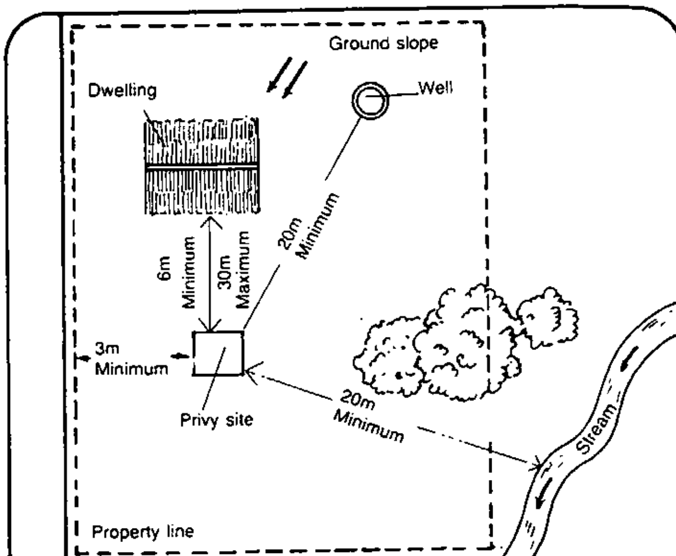


Figure 1. Location Map

4. Materials list, similar to Table 1, describing all labor, supplies, and tools needed to construct the pit, lining, and base.

You will also need a slab or cover (see "Constructing Slabs for Privies," SAN.1.C.1) to cover the pit immediately after the base and lining are in place.

(NOTE: Figures 1,2 and 3 and Table 1 are samples only and cannot be used to build the pit. The documents you need will be provided by the project designer.)

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary workmen, supplies, and tools.

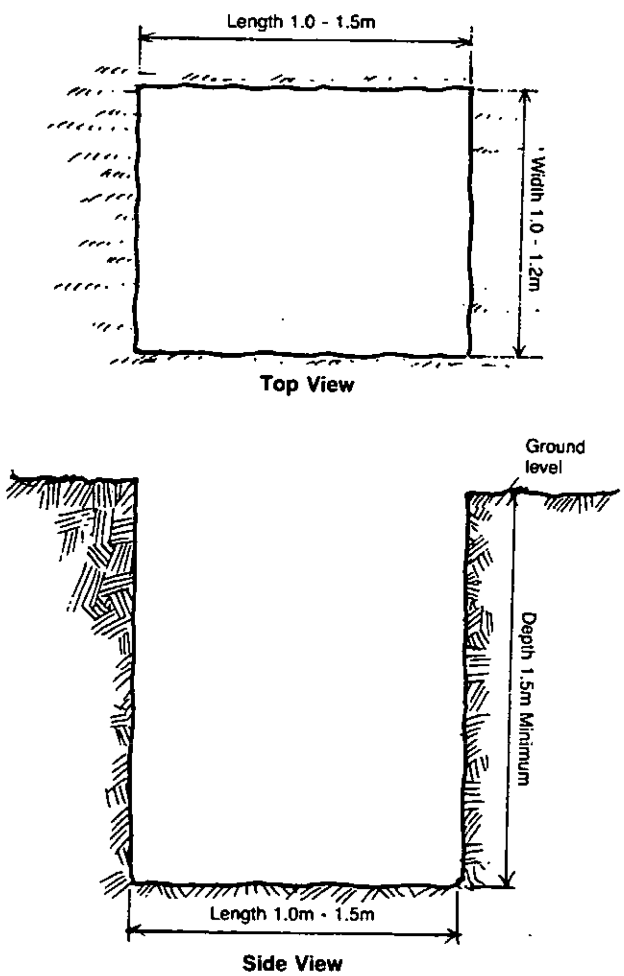


Figure 2. Dimensions for Pit Privy or Ventilated Privy

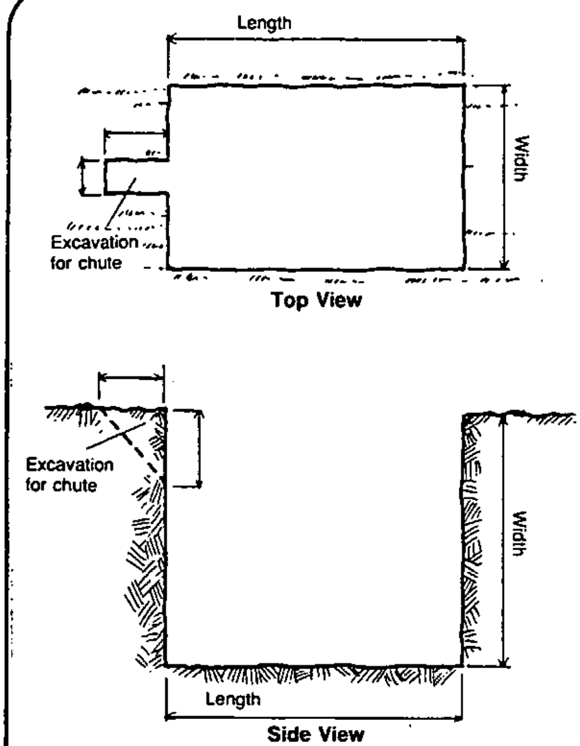


Figure 3. Dimensions for Offset Pit Privy

Caution!

1. If the pit is deeper than about 1.5m, the walls must be shored during excavation to prevent a cave-in that could be fatal to a worker in the pit.

2. Do not hand-dig a pit deeper than about 3.5m.

3. All pits must be dug at the exact site and to the dimensions specified by the project designer to protect groundwater and other sources of drinking water.

4. A pit must be covered with a slab or cover (see "Constructing Slabs for Privies," SAN.1.C.1) during construction when it is not attended and immediately after it is excavated and the lining and base are in place. A pit left open and unattended is a serious hazard.

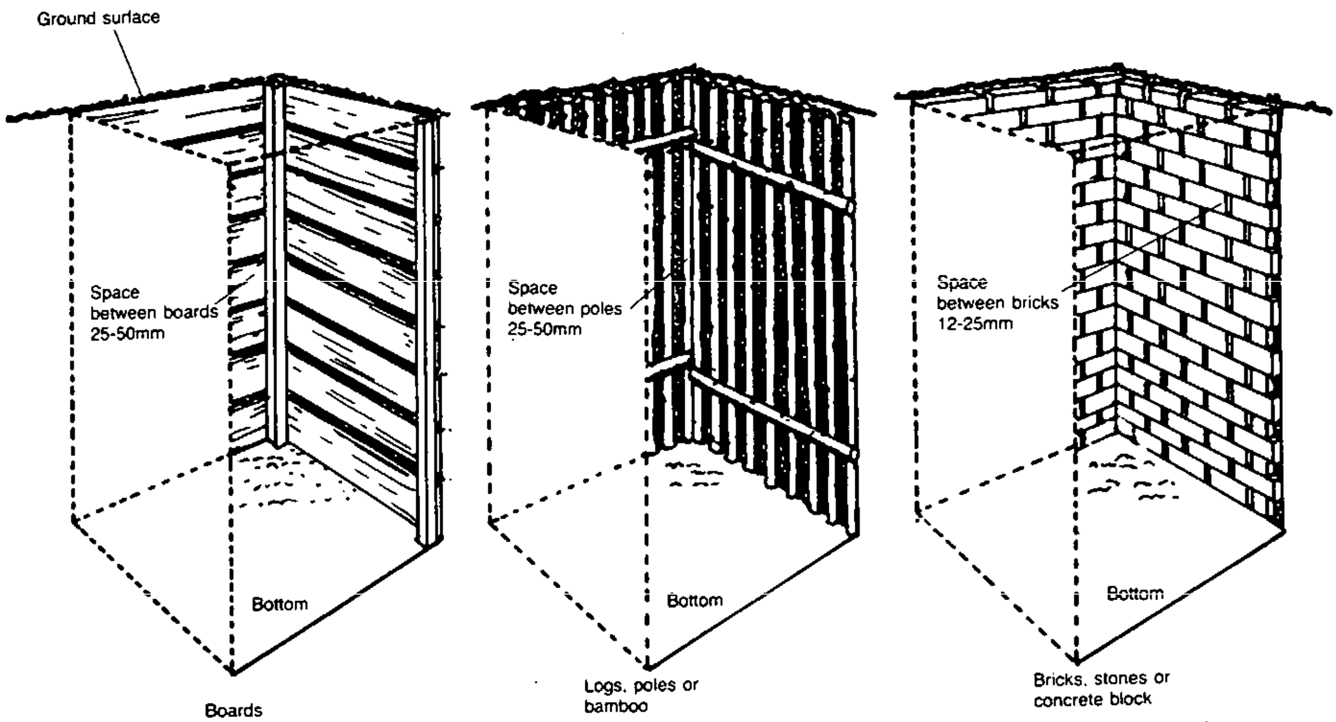


Figure 4. Pit Linings

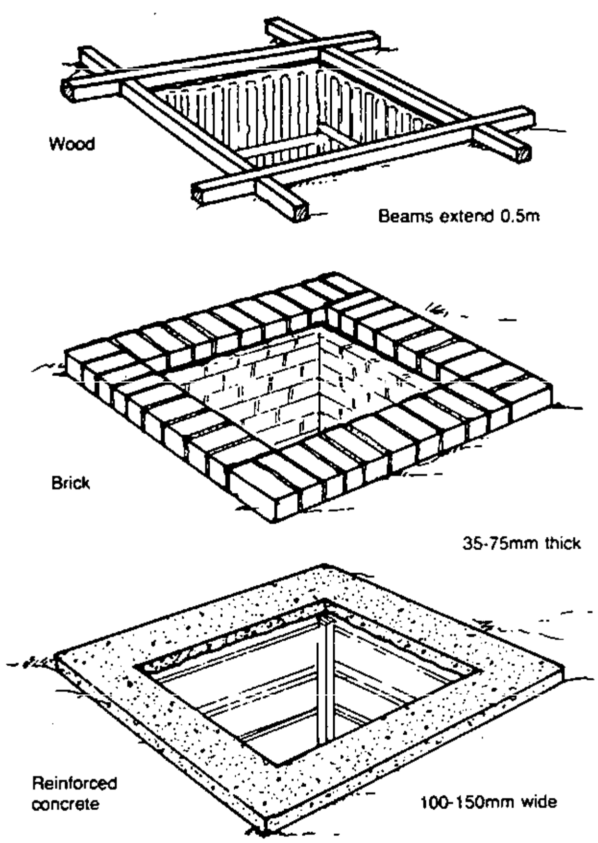


Figure 5. Bases

Construction Steps

Depending on local conditions, availability of materials, skills of workers, and so on, some construction steps will take only a few hours, while others may take a day or more. Table 2 shows a sample work plan for building a pit including time estimates for each step. Draw up a similar work plan with rough time estimates based on local conditions. You will then have an idea of when specific workmen, supplies and tools must be available during the construction process. The following are construction steps for building a pit.

1. Assemble all laborers, materials, tools, and drawings needed to begin construction. Study all diagrams carefully.

2. Determine the correct location of the pit, using the location map similar to Figure 1 and a measuring tape. Clear the area of any vegetation that might hinder construction. Lay out on the ground the correct dimensions of the pit, as shown in the technical drawing, and mark each corner of

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	____
	Laborers (one experienced with carpentry, stone masonry, or poured concrete, whichever applies)	2 (at least)	____
Supplies	For laying out the system; wooden stakes or sticks	____	____
	For the lining: bamboo, poles, logs, boards, bricks, concrete blocks, select field stones	____	____
	For the base: wood, bricks, concrete blocks	____	____
	For poured concrete or mortar:		
	Cement	____	____
	Sand	____	____
	Gravel	____	____
	Water	____	____
	Other	____	____
Tools and Equipment	Box or bucket	1	____
	Sturdy rope or ladder	1	____
	Measuring tape	1	____
	Shovels	2 (at least)	____
	Wheelbarrow	1	____
	Hammer	1	____
	Saw	1	____
	Nails	--	____
	Trowel	1	____
	Plumb line (string and rock)	1	____
	Hatchet or machete	1	____
	Container (for mixing mortar)	1	____
	Concrete slab	1	____
	Other	--	____

Total Estimated Cost = ____

Table 2. Sample Work Plan for Constructing Pit, Lining, and Base

Time Estimate	Day	Task	Personnel	Tools/Materials
2 hours	1	Mark pit location	Foreman and 1 laborer (NOTE: Foreman present during all construction steps)	Location map, and measuring tape, wooden stakes or sticks
6 hours	1	Build base	Skilled worker (familiar with masonry)	Bricks, container (for mixing mortar), cement, sand, gravel, water, shovel, trowel
2 days	2-3	Allow mortar to set		
2 days	4-5	Excavate pit	2 laborers (at least)	2 shovels, ladder, long rope, bucket or box, wheelbarrow, plumb line
4 hours	6	Line pit	1 laborer, 1 skilled worker (familiar with carpentry)	Boards, hammer, saw, nails
1 hour	6	Cover pit	2 laborers	Concrete slab
1 hour	6	Waterproof edges of slab; mound dirt around base and slab	1 laborer	Tar, shovel

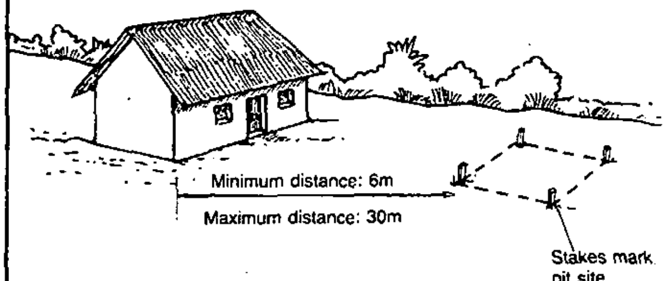


Figure 6. Locating Pit Site

the pit with a wooden stake or pointed stick as shown in Figure 6. Mark the excavation for the chute, if it is an offset pit.

3. Build the base around the pit site. This is done before digging the pit to prevent the top of the pit walls from crumbling and to ensure that the slab or cover can be put in place immediately after the pit is dug and lined. The corners of the base should be square.

For a wood base:

3a. Cut four logs, poles, or wood beams to the length determined by the project designer. Cut two notches halfway through each log, as shown in Figure 7, so the logs will fit together to form the base around the pit site. Bind the logs with heavy cord or twine or nail them together.

For a concrete block or brick base:

3b. Lay a straight row of bricks or blocks along each side of the pit site as shown in Figure 8. The blocks should either be mortared together or fit tightly. See "Constructing Septic Tanks," SAN.2.C.3, for details on mixing and applying mortar. Tamp the blocks in place or scrape away dirt to ensure that the rows of blocks are level. If the blocks or bricks are mortared together, cover them with damp straw, leaves, or grass and allow a few days for the mortar to set. Keep the cover material damp until the concrete has set.

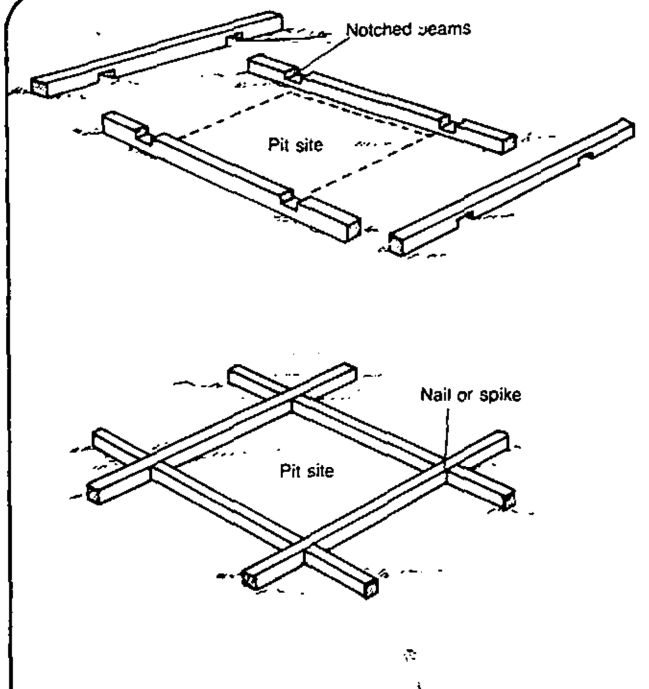


Figure 7. Wood Base

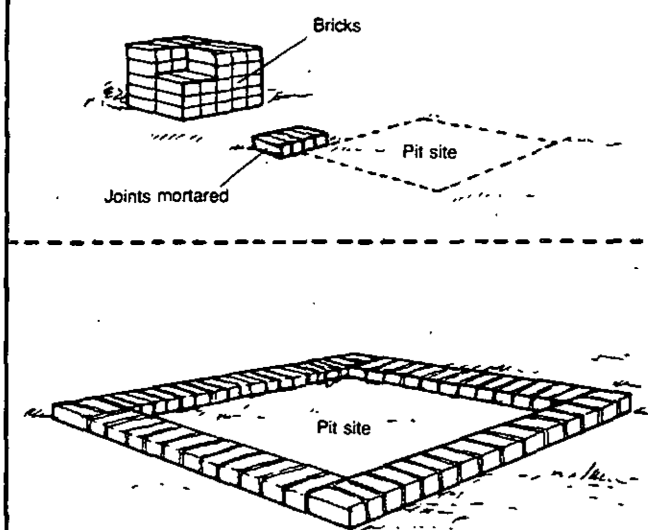


Figure 8. Block or Brick Base

For a poured concrete base:

3c. See "Constructing Septic Tanks," SAN.2.C.3, for details on concrete. Dig a shallow, level trench around the pit site. Make the trench about 150mm wide and 50 to 75mm deep as shown in Figure 9. The width and depth of this trench determine the width and thickness of the base. The trench lines should be straight, the bottom tamped, and the sides and bottom clean and free of loose dirt. Mix the concrete and pour it evenly around the trench until the trench is about half full. Lay reinforcing material such as steel bars, wire mesh, or bamboo in place. Pour concrete until the trench is full. Smooth the surface with a trowel. Cover with wet straw, leaves, grass, burlap, or other material and allow three to seven days for the concrete to set. Keep the cover material damp until the concrete has set.

4. Begin digging the pit after the base has been constructed and is securely in place. Make the sides straight and smooth. Use a plumb line (string tied to rock or weight) to check the sides during excavation, as shown in Figure 10. Pile the dirt at least 1m away from the edge of the pit to prevent it from falling back in. For an offset pit, make the additional small excavation for the chute.

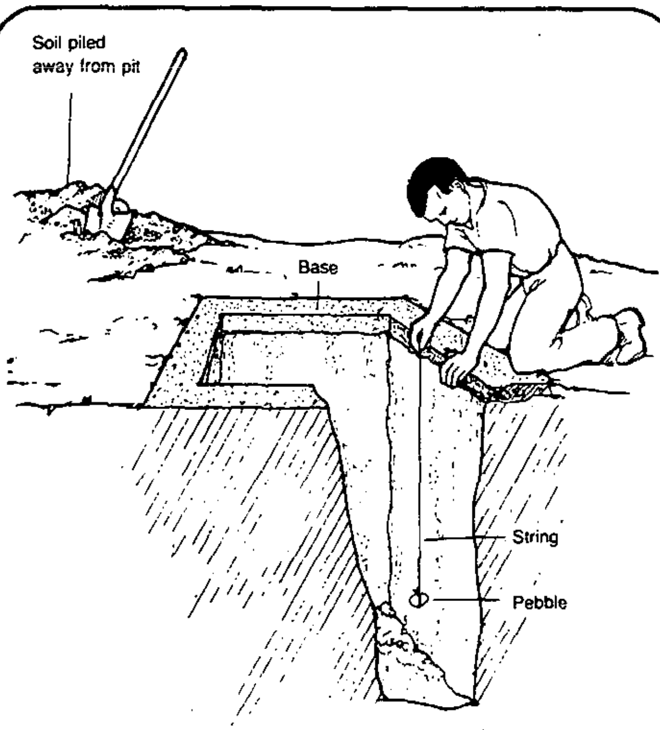


Figure 10. Checking Pit Sides with a Plumb Line

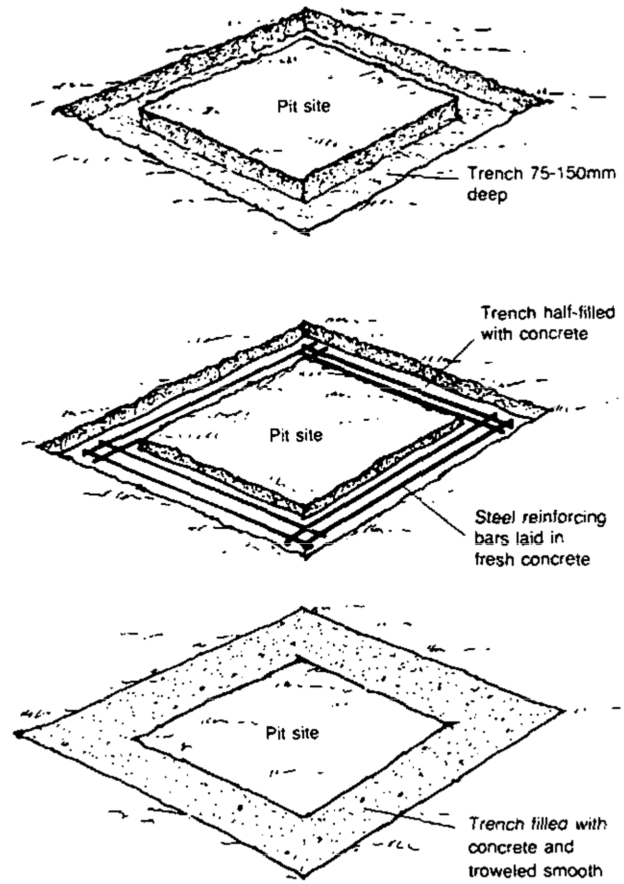


Figure 9. Poured Concrete Base

(NOTE: Depending on the dimensions of the pit, it is likely that there will be space for only one laborer to dig. Have laborers rotate every 20 to 40 minutes--one in the pit, one or two outside. When the pit reaches about shoulder level, it may be helpful to lower a bucket or box tied to a rope into the pit. The laborer in the pit can fill the container with dirt, and the laborer outside can haul the full container up and out. This method of excavation will be necessary for pits deeper than about 1.5m. Have a sturdy rope or ladder readily available for laborers to get in and out of the pit.)

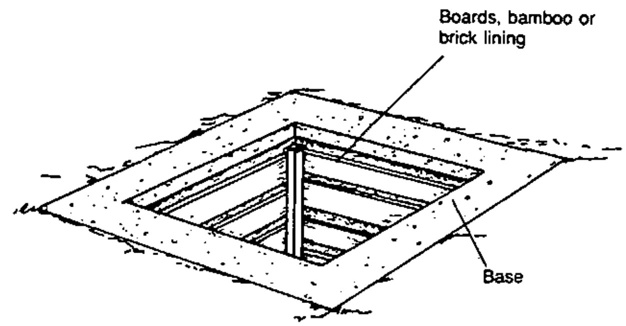


Figure 11. Pit with Shored Sides

5. Shore up the sides of the pit to prevent possible cave-ins when excavating deeper than about 2m, as shown in Figure 11. Secure the sides with logs, poles, boards, bamboo, or other material when the depth reaches about 2m. Continue digging, leaving a 75 to 100mm step or ledge around the walls to support the shoring material as shown in Figure 12. Shore up the lower walls when the pit reaches the correct depth. Do not hand dig a pit deeper than about 3.5m.

6. Measure the depth as the pit is being dug. Make the pit floor fairly level when the correct depth has been reached.

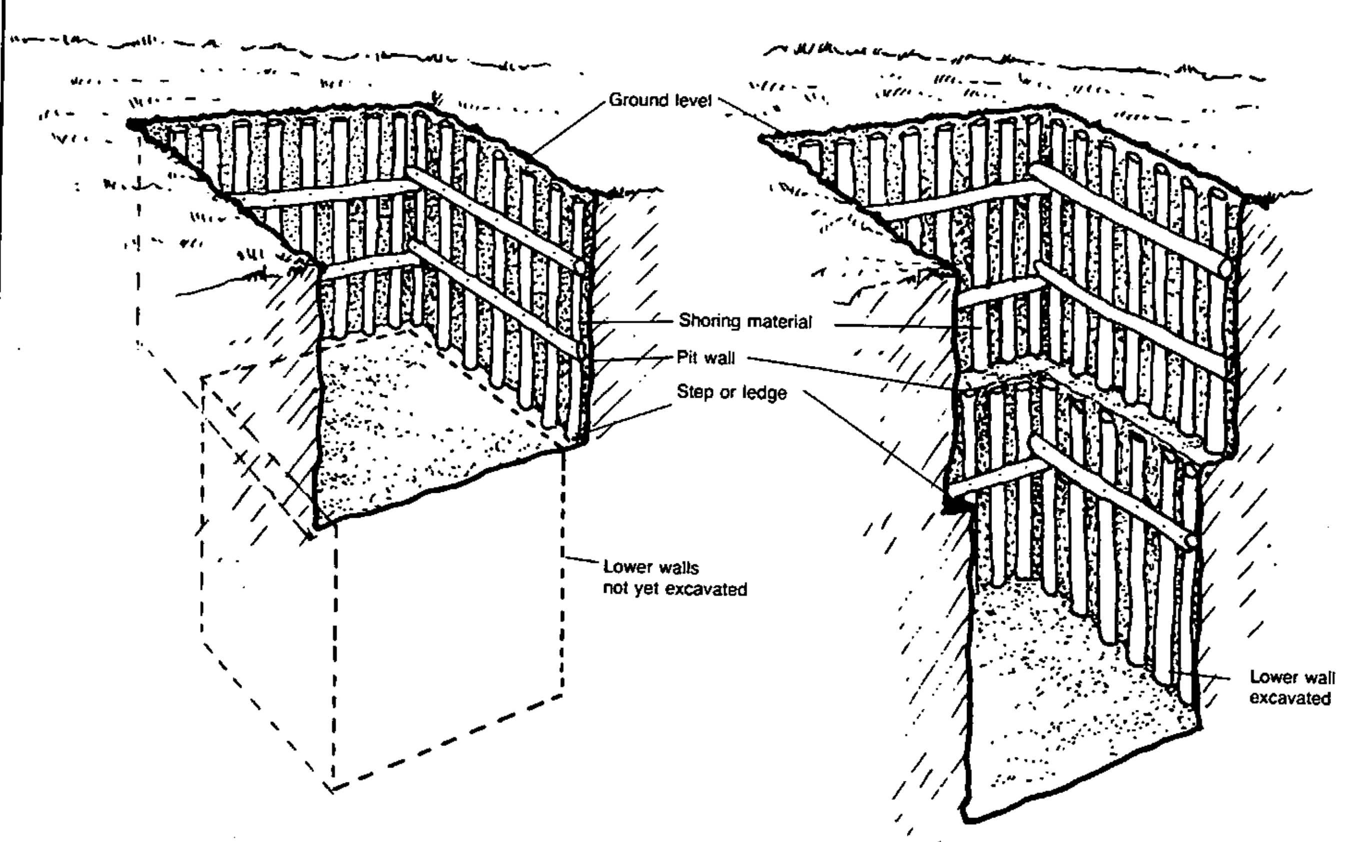


Figure 12. Shoring a Deep Pit

7. Install the lining, if needed, after the pit is fully excavated. The lining should extend from the bottom of the pit to the base. If the pit has been shored, the shoring material can be left in place and serve as the lining.

For a log, pole, or bamboo lining:

7a. Cut logs or poles to a length equal to the depth of the pit. Place the logs or poles vertically along the sides of the pit. The poles should reach from the bottom of the pit to the base and should be placed 25 to 75mm apart. Cut four cross poles equal to the length of the pit, and four cross poles equal to the width. Nail or tie the cross poles in place about 0.5m from the top and bottom of the pit walls to secure the vertical poles, as shown in Figure 4.

For a wood or board lining:

7b. Place the boards either vertically or horizontally. To place them vertically, use the same methods as for log, pole, or bamboo linings. To place them horizontally, cut boards to lengths equal to both the length and width of the pit. Cut four long boards or beams to a length equal to the depth of the pit. Put a long board or beam in each corner of the pit and place the shorter side boards horizontally along the pit walls and nail them to the corner beams. The side boards should be spaced about 25 to 75mm apart, as shown in Figure 4.

For a concrete block or brick lining:

7c. Stack the blocks or bricks up the sides of the pit as shown in Figure 4. Leave spaces between the bricks. <u>Do not mortar</u>. Stack the bricks up to the base. For additional strength, mortar the top two courses of bricks.

8. Remove any tools, equipment, or scrap material from the pit after the lining is in place.

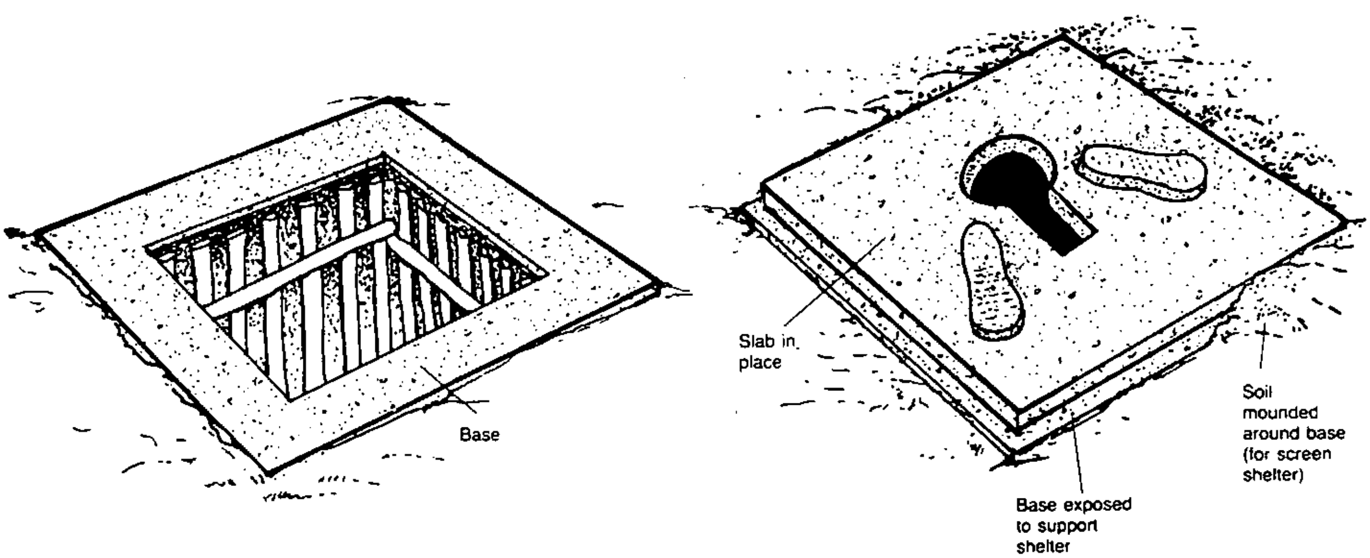


Figure 13. Placing Slab Over Pit

9. Set the slab or cover in place over the pit as shown in Figure 13. If the slab or cover is in sections, use tar, oakum or other material to waterproof where the sections fit together.

10. Waterproof around the edges of the slab or cover where it rests on the base. Do not mortar the slab or cover to the base because in 5 to 10 years, depending on the size of the pit, the slab or cover will be moved to a new pit.

11. Place dirt around the edges of the base and slab or cover, and tamp. This dirt will help seal the pit.

12. Set or build in place a privy shelter (see "Constructing Privy Shelters," SAN.1.C.3).

13. Place dirt around the edges of the shelter, and tamp.

Water for the World

Designing Slabs for Privies

Technical Note No. SAN.1.D.1

The slab is the floor of the privy. It covers the pit and has a hole through which to defecate. Designing a slab involves selecting the type of slab (squatting or sitting), deciding which improvements the privy will have, calculating the dimensions of the slab, and determining the materials, labor, and tools needed to build it. The products of this process are design drawings of the slab and improvements, if any, and a detailed materials list. These items should be given to the person in charge of construction.

This technical note describes how to design a slab and arrive at these end-products. Read the entire technical note before beginning the design process.

Materials Needed

Measuring tape - To check dimensions of previously constructed items (pit, base around pit, or pour-flush bowl, for instance)

Selecting Slab Type

The type of slab selected depends on whether the users prefer to squat or sit when defecating.

Squatting Slab. The main features of a squatting slab are a hole, a pair of footrests, and a lid to cover the hole. See Figures 1 and 2.

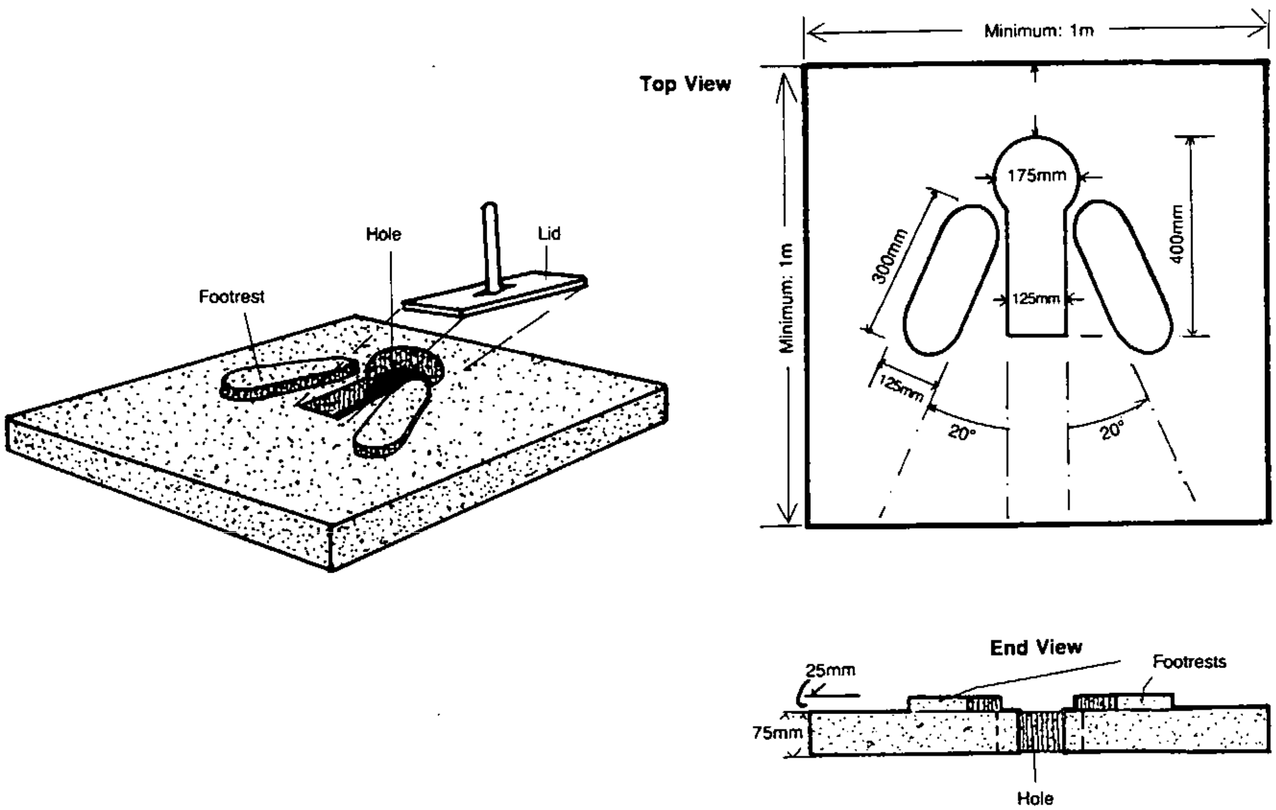


Figure 1. Squatting Slab

The hole is generally key-hole shaped, about 400mm long, and 125mm wide at the narrow end. The wide end is a circle 175mm in diameter. The back edge of the hole usually should be about 150mm from the back wall of the privy which, depending on the design, may be at the edge of the slab. If the distance between the wall and the hole is less than 150mm, there may not be enough space to squat. If the distance is more, there is a greater risk of soiling the floor. The distance between the edge of the hole and the edge of the slab may be greater than 150mm if the privy has a vent pipe.

Since the footrests ensure that the privy user is positioned correctly over the hole, their placement is important. They are oval-shaped, about 300mm long, 125mm wide, and 25mm high.

The lid should cover the hole but not fit inside it. It should have a handle. See Figure 2.

Sitting Slab. The main features of a sitting slab are a hole, a pedestal or riser, a seat, and a lid to cover the seat.

The hole is 250-300mm in diameter and should be about 150mm from the back wall of the privy which may be at the back edge of the slab, depending on the design. See Figure 3.

The pedestal is 275-350mm high and has the same inside diameter as the hole. The thickness of the pedestal walls depends on the materials used.

The seat is attached to the top of the pedestal. Its outside measurements are equal to or greater than the outside measurements of the pedestal. The seat has a hole in the center 200mm in diameter. A second seat with a smaller hole (150mm) in diameter can be included for children.

The lid covers the seat and is often attached to the back of the seat with a hinge. See Figure 3.

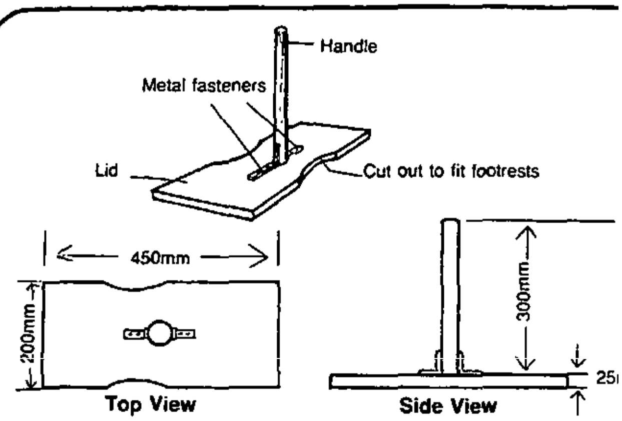


Figure 2. Lid for Squatting Slab

Determining Improvements

The main improvements to a privy are a vent pipe, a pour-flush bowl, an off-set pit, or a combination of the three. Any privy improvement will modify the slab design.

Vent Pipe. If the privy is to have a vent pipe, the pit must be abo 300mm longer than a pit for an unimproved privy (see "Designing Pits for Privies," SAN.1.D.2). The slab must also be longer by about 300mm. This means that the distance from the back edge of the squatting hole to the edge of the slab is 450mm--150mm for the basic design plus 300mm for the vent pipe. See Figure 4. The slab has a hole 100-150mm in diameter, depending on the size of the vent pipe, and is positioned as in Figure 5. The vent pipe can be made from a sheet of tin or galvanized metal and should be topped with a fly-proof screen.

Pour-Flush Bowl. If the privy is to have a pour-flush bowl, the squatting hole may not be key-hole shaped. The shape of the hole must conform to that of the bowl, and often the bowls are prefabricated as shown in Figure 6. The bowl should be positioned to flush forward, to prevent erosion of the pit wall.

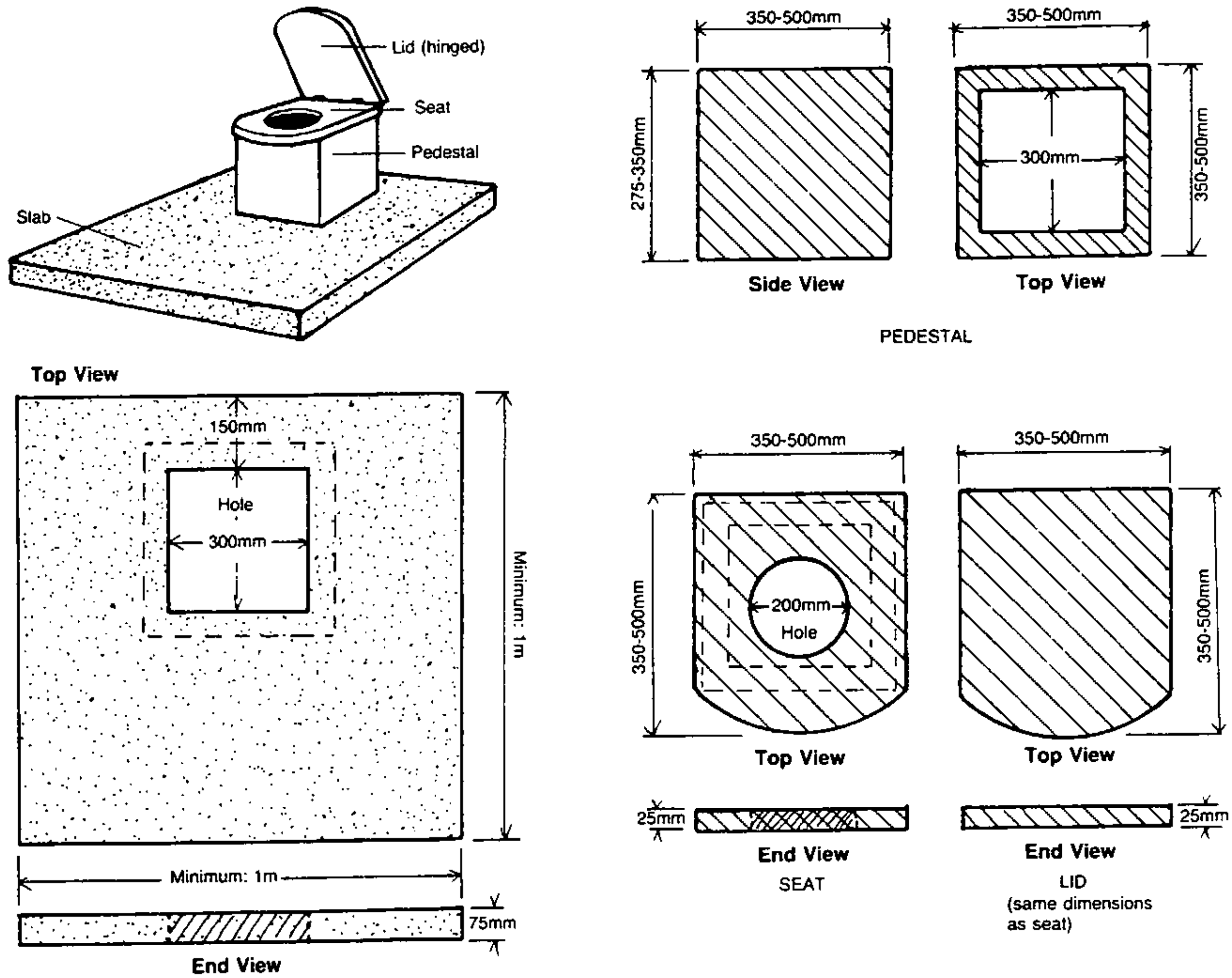


Figure 3. Sitting Slab with Pedestal, Seat and Lid

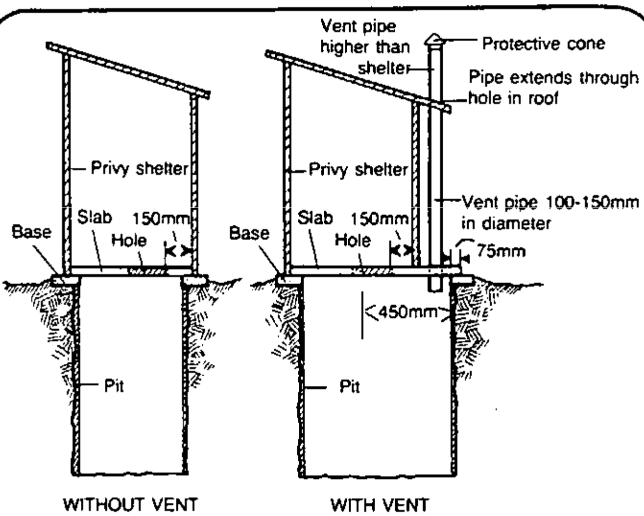


Figure 4. Comparison of Privies with and without Vent

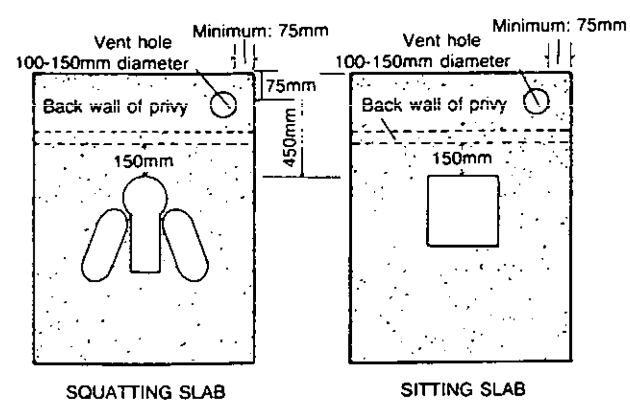


Figure 5. Top View of Slabs Showing Vent Hole Placement

Off-Set Pit. The slab for an off-set pit rests on a platform made of wood, bricks, or concrete and has a metal chute attached to the hole. The chute can be made from a sheet of tin or galvanized metal. It enters the pit below ground level at a downward angle of 50° to 60°. The upper end is mortared to the bottom of the slab and encircles the squatting hole. The lower end narrows to about 200mm in diameter and extends about 100mm beyond the pit wall. See Figure 7. The pit must have a cover which can be made in one piece or in sections. If the cover is made of concrete, it should be made in sections for easier handling as shown in Figure 8. The cover must be strong enough to prevent persons from falling into the pit.

Combination. If there is a combination of improvements, each improvement will modify the design of the slab as described above. For example, a privy with a vent pipe and a pour-flush bowl must have a longer slab to accommodate the vent and a specially shaped hole for the bowl. There is one exception. The slab design for an off-set pit is the same whether or not the pit has a vent pipe, because a vent pipe used with an off-set pit extends through the pit cover, not through the slab. See Figures 7 and 8.

Calculating Dimensions

Unimproved, ventilated, or pour-flush privies must have slabs that cover the pit and overlap each edge

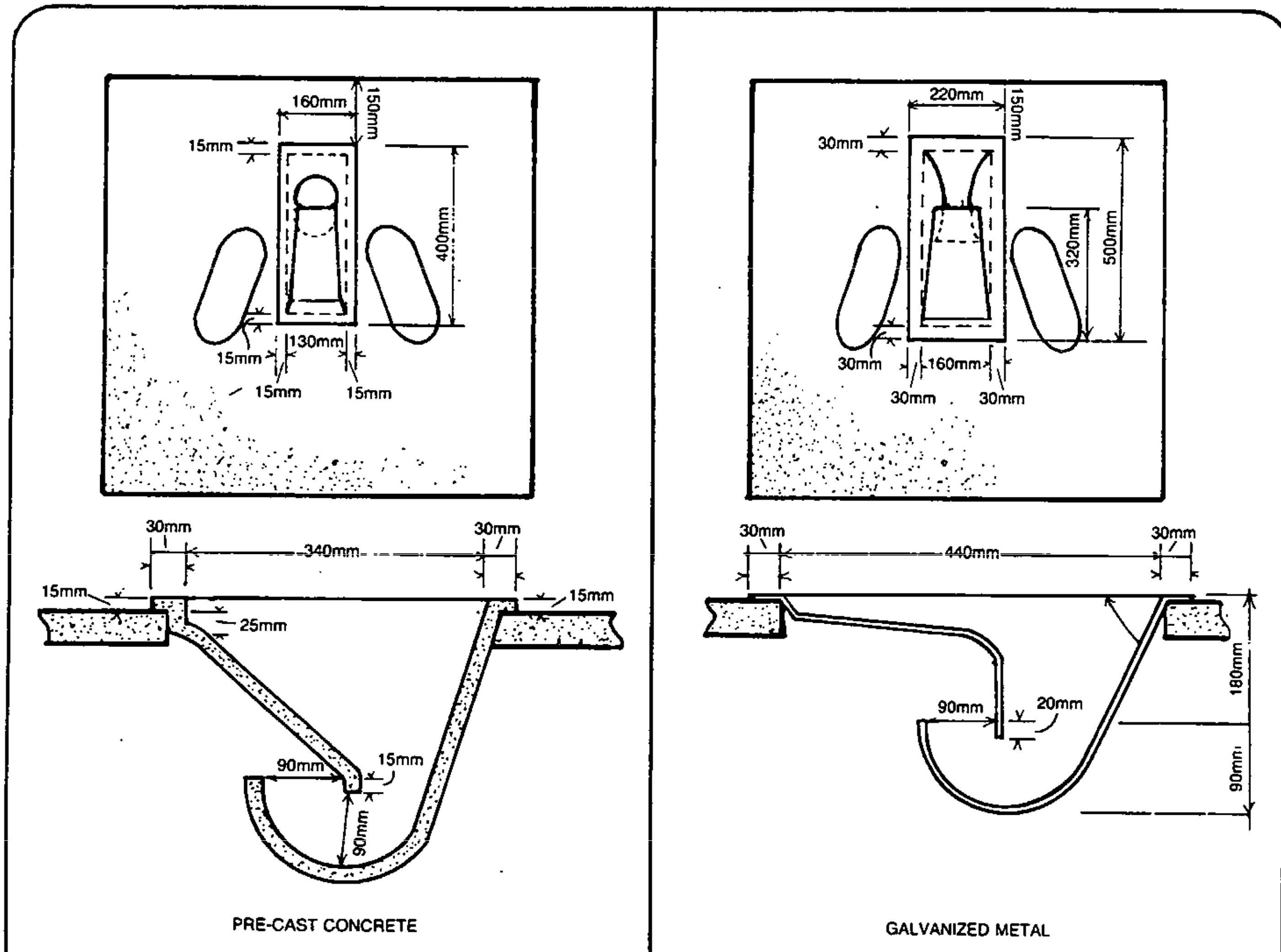


Figure 6. Pour-flush Bowls for Squatting Slabs

by at least 75mm. The length of the slab for these kinds of privies equals the length of the pit plus 150mm and the width of the slab equals the width of the pit plus 150mm. Worksheet A shows the steps in calculating slab dimensions. For example, suppose the pit is 1.5m long and 1.2m wide. Then the length of the slab is 1.5m + 0.15m = 1.65m. The width of the slab is 1.2m + 0.15m = 1.35m. See Worksheet A, step #1. For an off-set pit, the slab should be about 1m square. The thickness of a slab depends on the material used to make it. A reinforced concrete slab is 50-75mm thick.

The cover for an off-set pit must be large enough to cover the pit and overlap each edge by at least 75mm. The length of the cover equals the length of the pit plus 150mm, and the width of the cover equals the width of the pit plus 150mm. For example, suppose the pit is 1.7m long and 1.2m wide. Then the length of the cover is 1.7m + 0.15m = 1.85m. The width of the cover is 1.2m + 0.15m = 1.35m. See Worksheet A, step #3.

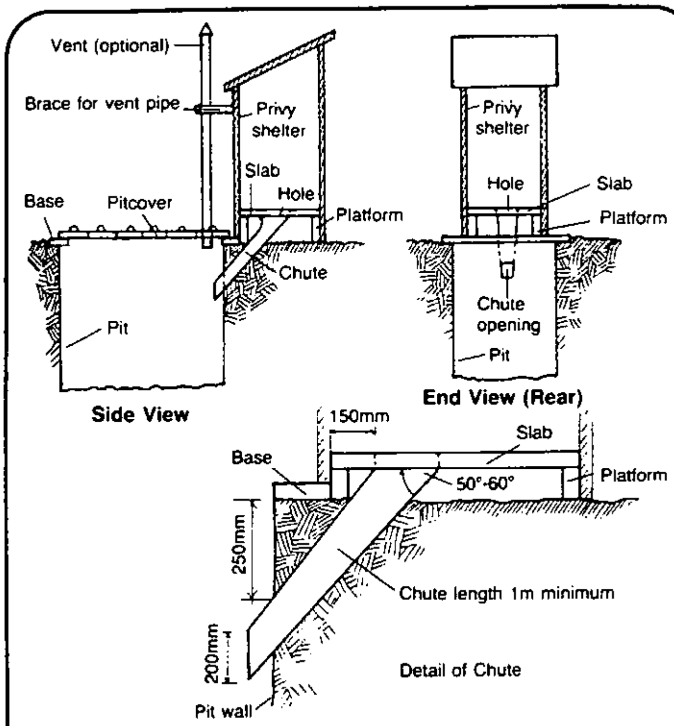


Figure 7. Off-Set Pit Privy

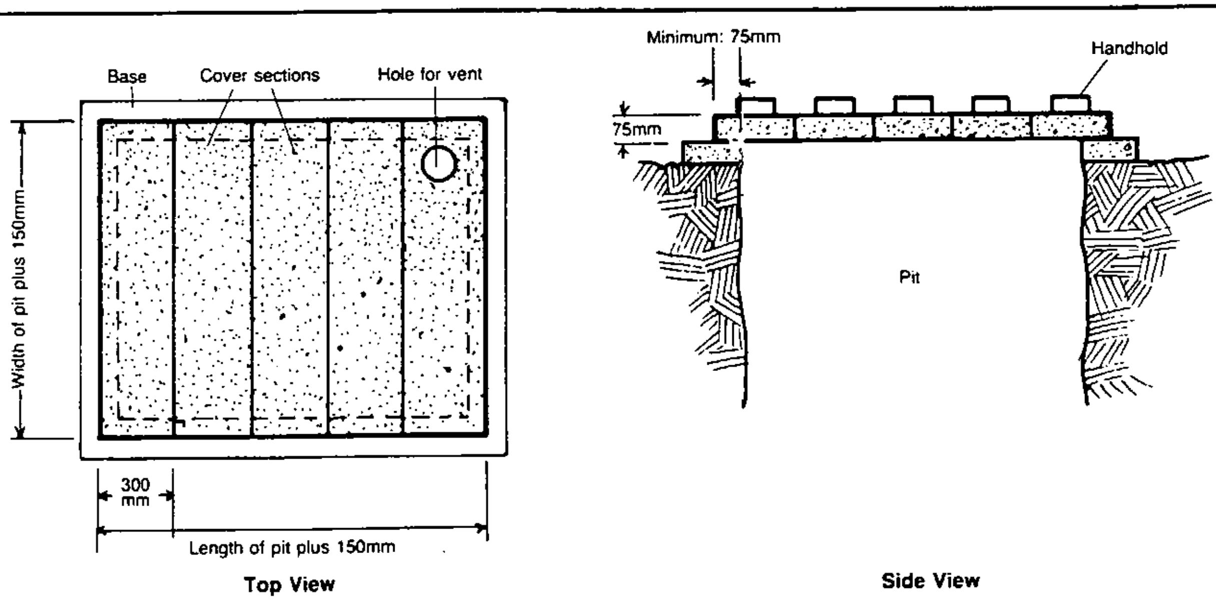


Figure 8. Cover for Off-Set Pit

Worksheet A. Calculating Dimensions

1. Slab (sitting or squatting) for unimproved, ventilated, or pour-flush privy:

   Length of slab = length of pit 1.5 m + 0.15m = 1.65 m
   Width of slab = width of pit 1.2 m + 0.15m = 1.35 m
   Thickness of slab (if concrete) = 50-75mm

2. Slab (sitting or squatting) for off-set pit privy:

   Length of slab = 1.0m
   Width of slab = 1.0m
   Thickness of slab (if concrete) = 50-75mm

3. Cover for off-set pit:

   Length of cover = length of pit 1.7 m + 0.15m = 1.85 m
   Width of cover = width of pit 1.2 m + 0.15m = 1.35 m
   Thickness of cover (if concrete) = 75mm

4. If cover is in sections:

   Length of each section = width of cover = 1.35 m
   Width of each section except one = 300mm
   Width of one section = 300mm plus necessary width to total entire length of the cover = 300mm + 50 mm = 350 mm
   Combined widths of sections = total length of cover = 300 + 300 + 300 + 300 + 300 + 350mm = 1850mm

(NOTE: To calculate quantities of concrete, see "Designing Septic Tanks," SAN.2.D.3.)

If the cover is reinforced concrete, it should be made in sections. The length of each section equals the width of the pit plus 150mm and the width of each section, except for one end section, is 300mm. The width of one end section must be 300mm plus whatever measurement is necessary to add up to the total length of the cover. For example, suppose the total length of the cover must be 1850mm. Then the cover would be made in six sections with widths of 300 + 300 + 300 + 300 + 300 + 350mm = 1850mm. See Worksheet A, step #4.

The thickness of a cover for an off-set pit depends on the material it is made from. A reinforced concrete cover should be about 75mm thick.

A vent pipe is 2-2.5m long and 100-150mm in diameter. A chute for an off-set pit is at least 1m long, with an average width of 200mm. Worksheet B shows how to calculate the dimensions of the materials needed to make vent pipes and chutes for off-set pits.

Worksheet B. Calculating Quantities of Material for Vent Pipe and Chute

Vent Pipe

Generally made from a sheet of tin or galvanized metal. The size of the sheet:

Length = height of privy shelter (from "Designing Privy Shelters," SAN.1.D.3) plus 0.6m
Width = diameter of vent pipe times 3.3

Example: Suppose that the height of the privy shelter is 2m and the diameter of the vent pipe is 150mm. Then the sheet of tin needed to make the pipe will have these dimensions:

Length = 2m + 0.6m = 2.6m
Width = 150mm x 3.3 = 500mm
(NOTE: The method used to calculate the width allows the edges of the sheet to overlap about 25mm when the pipe is made.)

Chute (for off-set pit)

Generally made from a sheet of heavy tin or galvanized metal. The size of the sheet:

Length = 1.5 times the distance from the front edge of the pit to the farthest edge of the hole in the slab.
Width = distance around the hole plus 25mm
(NOTE: The distance around the hole equals 2 times the length plus the width.)

Example: Suppose the hole in the slab is 150mm wide and 400mm long, and that the distance from the pit to the edge of the hole farthest from the pit is 700mm. Then the sheet of tin needed to make the chute will have these dimensions:

Length = 1.5 x 700mm = 1050mm
Width = distance around hole + 25mm
= 2 x (150mm + 400mm) + 25mm
= 1125mm
(NOTE: The "width" of the sheet may be longer than the "length.")

When the type of improvements and dimensions have been determined, prepare design drawings similar to Figures 1-9, showing correct dimensions and top and side views of, the slab and improvements. Give these drawings to the person in charge of construction.

Materials List

Slabs can be made from a variety of materials, including reinforced concrete, wood or bamboo. Generally, they are made from concrete, because concrete is strong, long-lasting, and easy to clean.

A common mix by volume for concrete is one part cement, two parts sand, three parts gravel, and about 2/3 part water or enough water to make a fairly stiff mix. The cement should be Portland cement. The sand should be clean and sized fine to 6mm. The gravel should be clean and sized 6-25mm. The water should be clear. For details on calculating quantities for concrete mix, see "Designing Septic Tanks," SAN.2.D.3.

A concrete slab must have reinforcing material, such as steel bars 10mm in diameter, wire mesh, or split bamboo. To calculate the quantity of steel bars needed, draw a sketch similar to Figure 9, showing bars in place, and count the number and lengths of the bars. If wire mesh is used, the quantity is approximately equal to the area of the slab (length times width).

The reinforcing material must not block the hole in the slab. No part of it should stick out through the concrete.

The tools and labor required to build a slab depend on the materials used. If it is made of reinforced concrete, at least one worker should have some knowledge of or experience with concrete (mixing, pouring, and building forms). Common tools for working with concrete include hammer, saw, and nails for building forms; container, shovel, tamping rod, and trowel for mixing, pouring, and smoothing concrete.

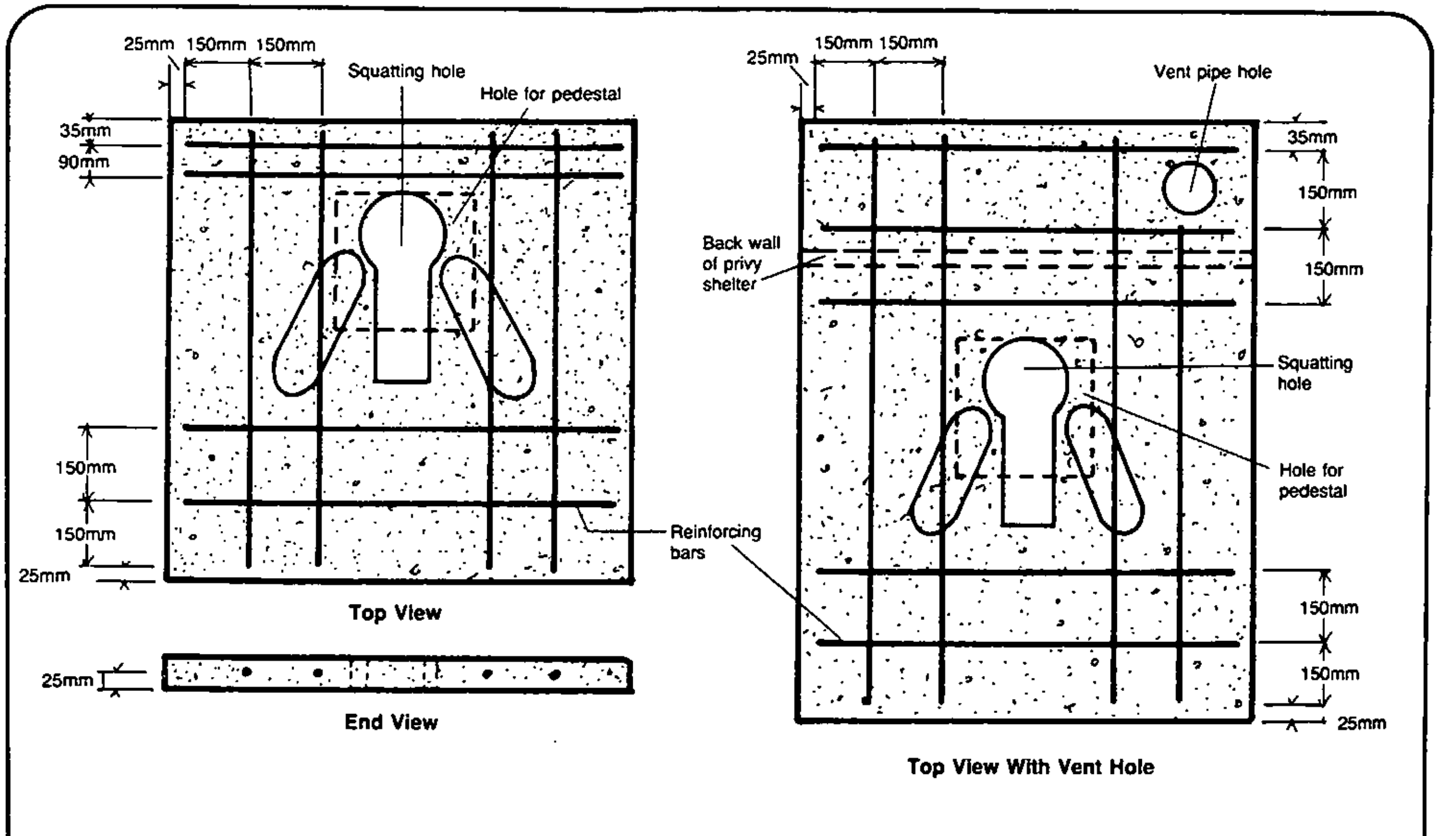


Figure 9. Placement of Reinforcing Bars in Concrete Slab

If the slab has a seat and pedestal, the pedestal can be made from brick, concrete blocks, or wood, and the seat can be made from wood. One-piece, ceramic seat-and-pedestal units may be available.

A cover made from wood should be provided for both sitting-type and squatting-type slabs. The cover for the seat and pedestal may be attached to the back of the seat with hinges.

A pour-flush bowl may be made from galvanized metal, concrete, molded rubber, or ceramic material. These units may be prefabricated and ready to install. A skilled craftsman could produce a galvanized metal or concrete pour-flush bowl using the design information in Figure 6. A metal bowl must have smooth, rounded edges dulled by a file. A concrete bowl must be cured in water for a week. A pour-flush bowl can be secured to the slab with concrete mortar.

A vent pipe can be made of galvanized metal by a semi-skilled workman using tinsnips, pliers, metal screws and a screw driver (or other means of securing the metal), and black paint and a brush to paint the pipe black. Or, a section of bamboo with the nodes knocked out could be used as a vent pipe.

A chute for an off-set pit can be made of galvanized metal by a semi-skilled workman using tinsnips, pliers, metal screws and a screwdriver, or other means of securing the metal.

A cover for an off-set pit can be made from wood, metal, or reinforced concrete. If concrete is used, the tools and skills of the workmen are the same as for a concrete slab.

When the materials needed have been determined, prepare a detailed materials list, similar to the sample in Table 1, showing types and quantities of all materials, tools, and labor needed to construct the slab and improvements, and the estimated costs based on local prices. Give the materials list and design drawings, similar to Figures 1-9, to the person in charge of construction.

Table 1. Sample Materials List

ITEM	DESCRIPTION	QUANTITY	ESTIMATED COST
Labor	Foreman	1	____
	Laborer (some experience with concrete)	1	____
	Laborers (to move constructed slab)	4-6	____
Supplies	Portland cement	____ m^3	____
	Sand: Clean, size fine to 6mm	____ m^3	____
	Gravel: Clean, size 6-38mm	____ m^3	____
	Water: Clear, drinking water preferred	____ liters	____
	Wood (for concrete forms)	____	____
	Nails (for concrete forms)	____	____
	Reinforcing bars ____mm long	____	____
	____mm long	____	____
	(or wire mesh)	____ m^2	____
	Wood (for lid)	____	____
	If seat and pedestal:		
	Bricks (for pedestal)	____	____
	Mortar (cement, sand, water)	____ m^3	____
	Wood (for seat and lid)	____	____
	Pour-flush bowl (prefabricated)	____	____
	Galvanized metal (for vent pipe)	____ m^2	____
	Galvanized metal (for chute)	____ m^2	____
	Metal screws or bands	____	____
	Screen (for vent)	____	____
Tools	Measuring tape	1	____
	Shovel	2	____
	Bucket	1	____
	Container for mixing concrete	1	____
	Trowel	1	____
	Saw	1	____
	Hammer	1	____
	Tinsnips	1	____
	Pliers	1	____
	Screwdriver	1	____
	Other	____	____

Total Estimated Cost = ____

Notes

Water for the World

Constructing Slabs for Privies
Technical Note No. SAN.1.C.1

The slab is the floor of the privy. It covers the pit and has a hole through which to defecate. Constructing a slab involves assembling materials, tools, and labor, and building either a squatting slab or a sitting slab (seat and pedestal) to the correct dimensions. It may also involve building a cover for an off-set pit and building or installing improvements (vent pipe, pour-flush bowl, or chute).

This technical note decribes each step in constructing a slab. Read the entire technical note before beginning construction.

Materials Needed

The project designer must provide several documents before construction can begin:

1. Technical drawings similar to Figures 1-9, showing correct dimensions of the slab, lid, pit cover (if off-set pit), and any improvements;

2. Materials list, similar to the sample shown in Table 1, noting all supplies, tools, and labor needed to construct the slab.

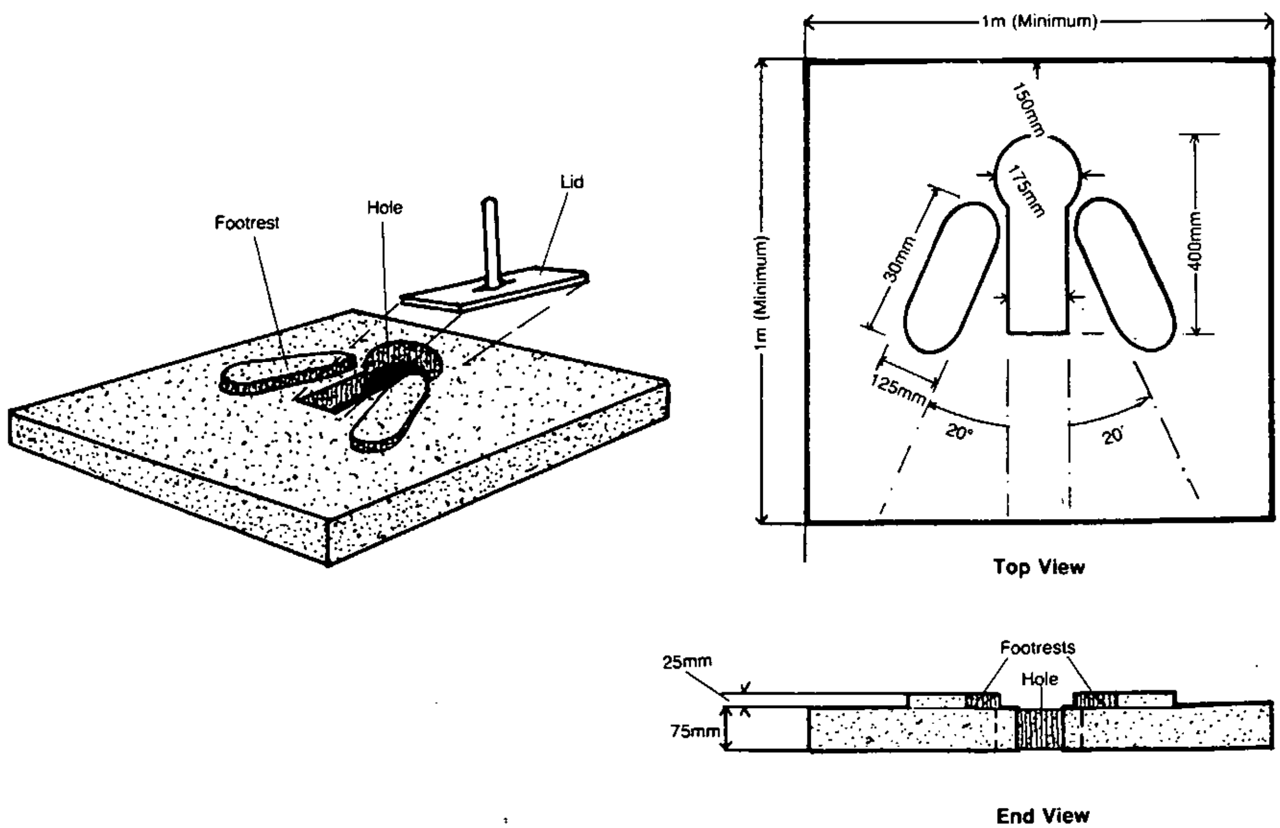


Figure 1. Squatting Slab

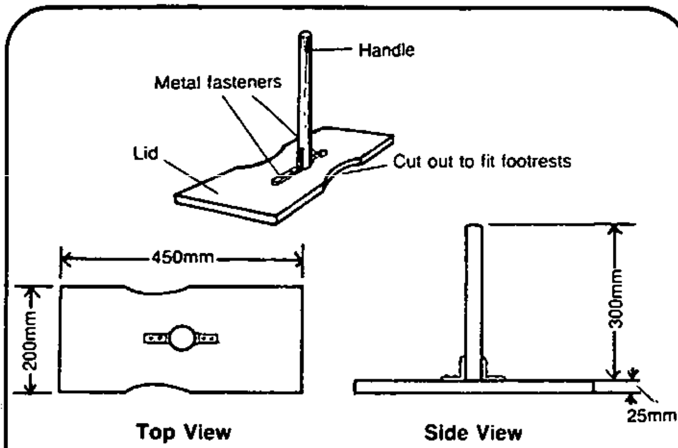


Figure 2. Lid for Squatting Slab

Caution!

1. Wear gloves to prevent cuts when working with tin or galvanized metal sheets which may have sharp edges.

2. Pick up all metal scraps and nails after construction to prevent injuries to people walking barefoot in the area.

3. Avoid back and hand injuries when moving a completed slab into place. The slab may weigh over 180 kilos and will require four to eight men to move.

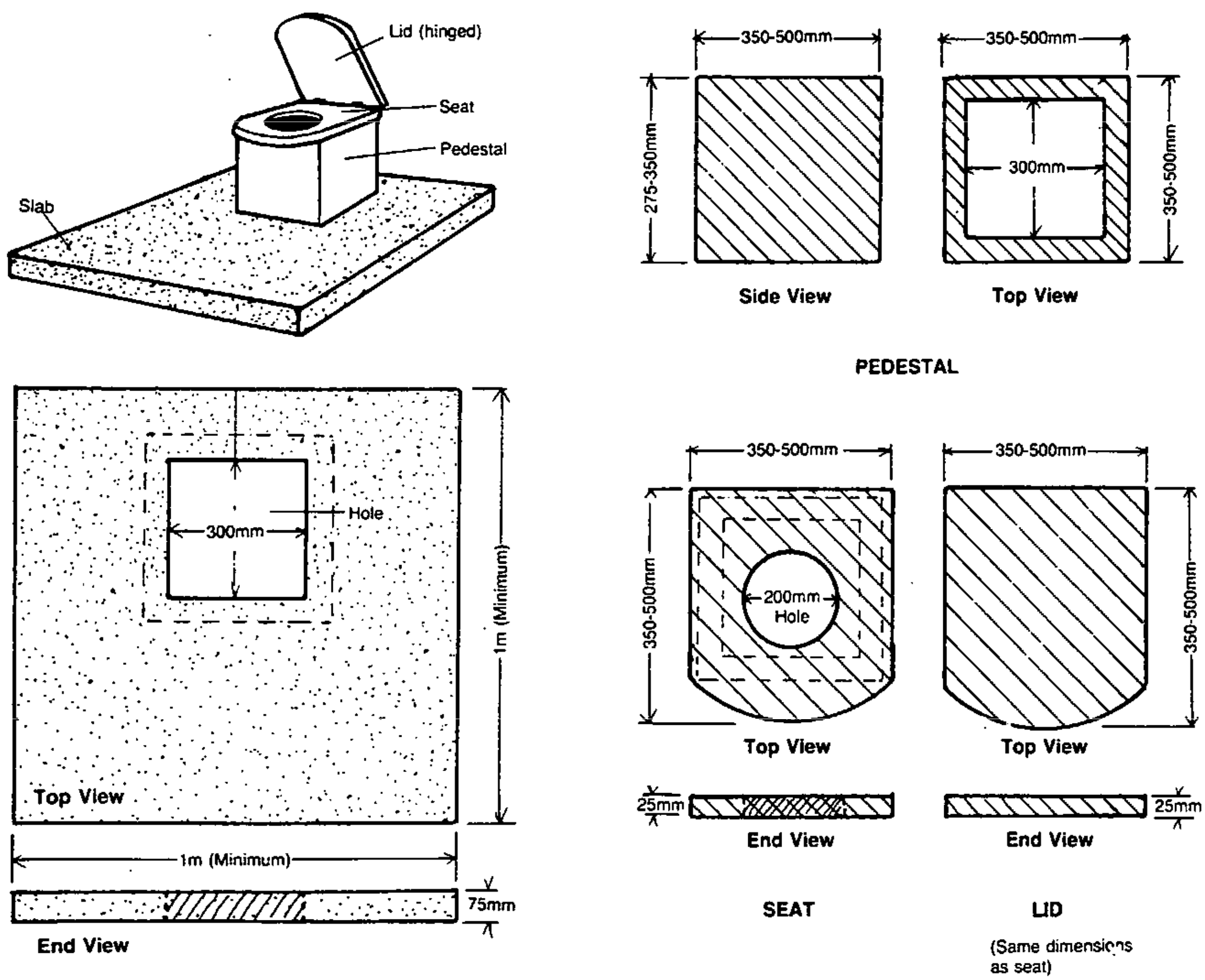


Figure 3. Sitting Slab with Pedestal, Seat and Lid

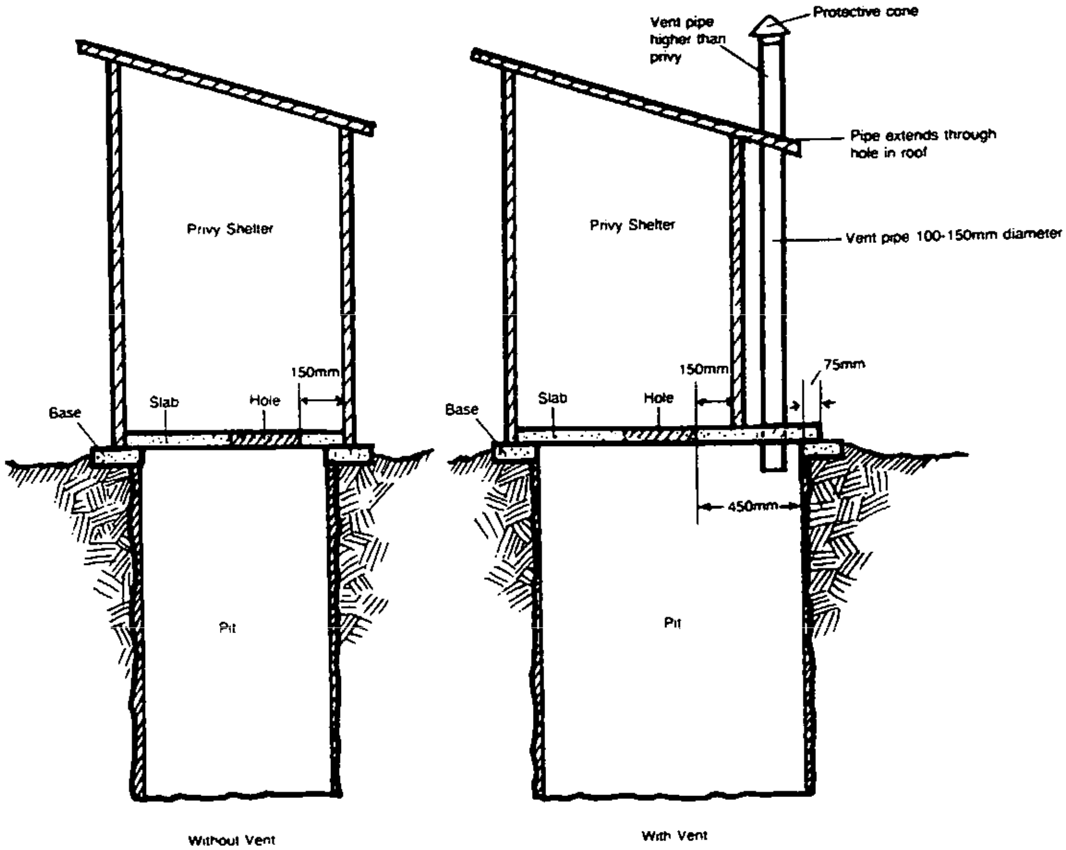


Figure 4. Comparison of Privies with and without Vent

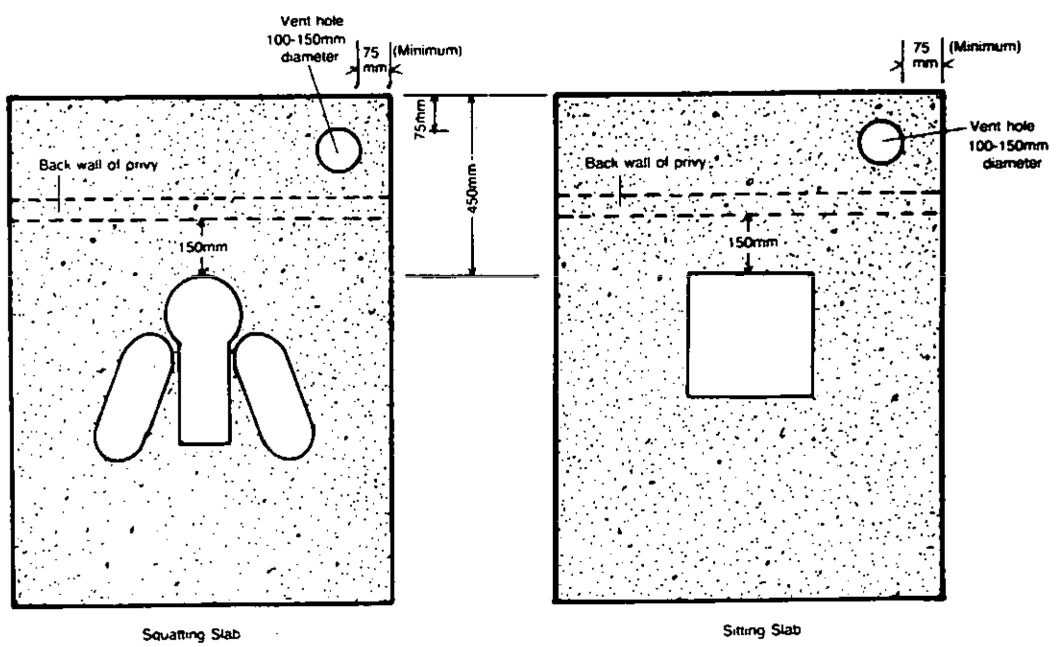
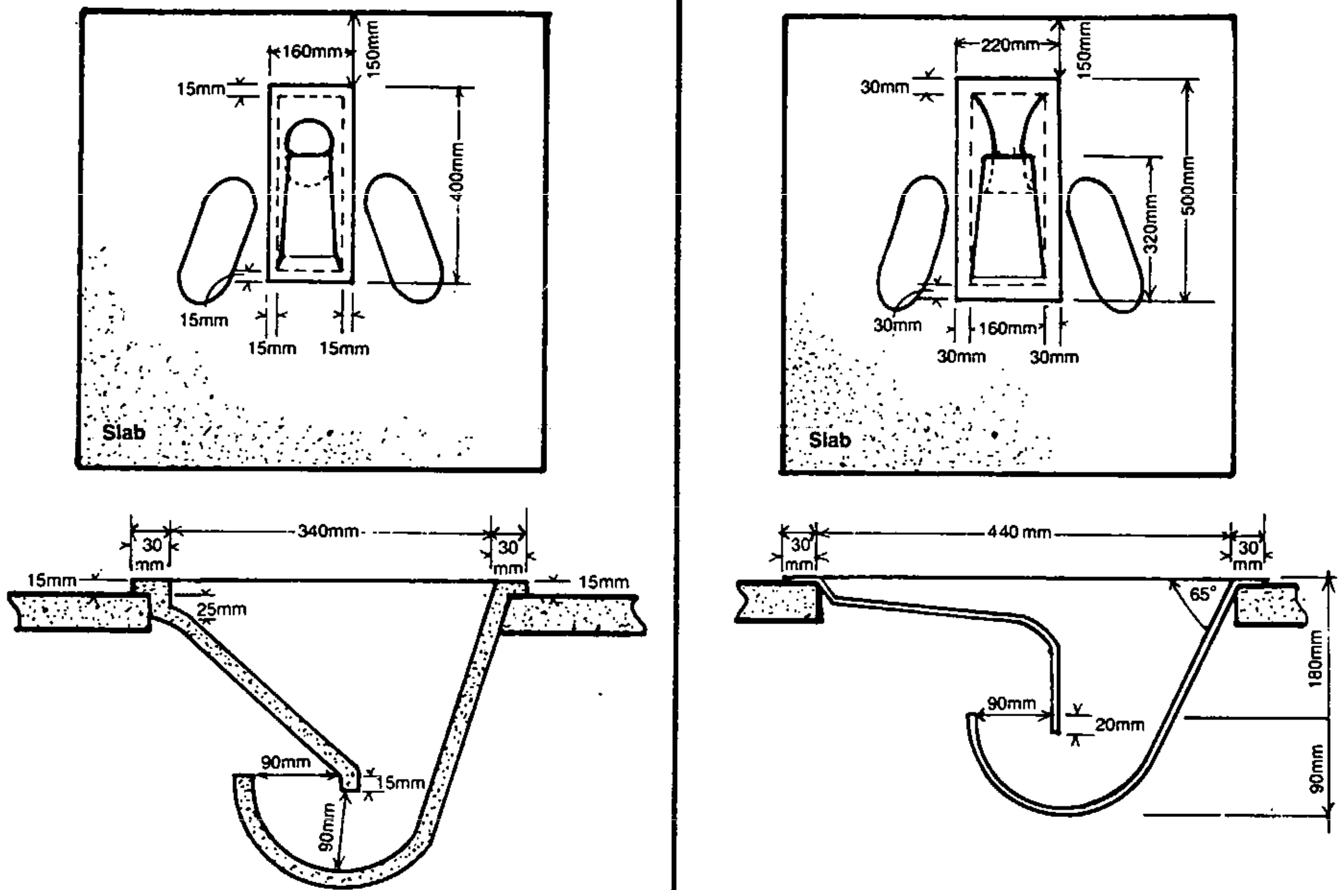


Figure 5. Top View of Slabs Showing Vent Hole Placement



a. Pre-cast Concrete

b. Galvanized Metal

Figure 6. Pour-Flush Bowls for Squatting Slabs

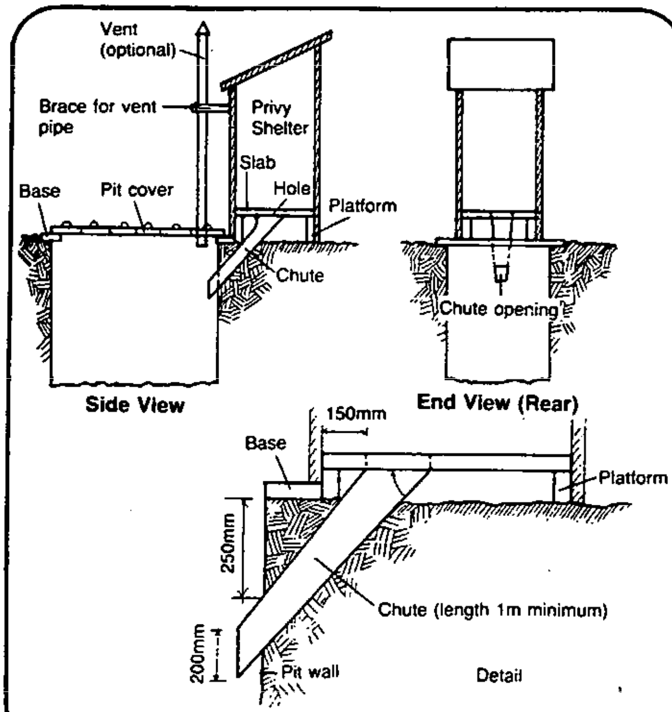


Figure 7. Off-Set Privy

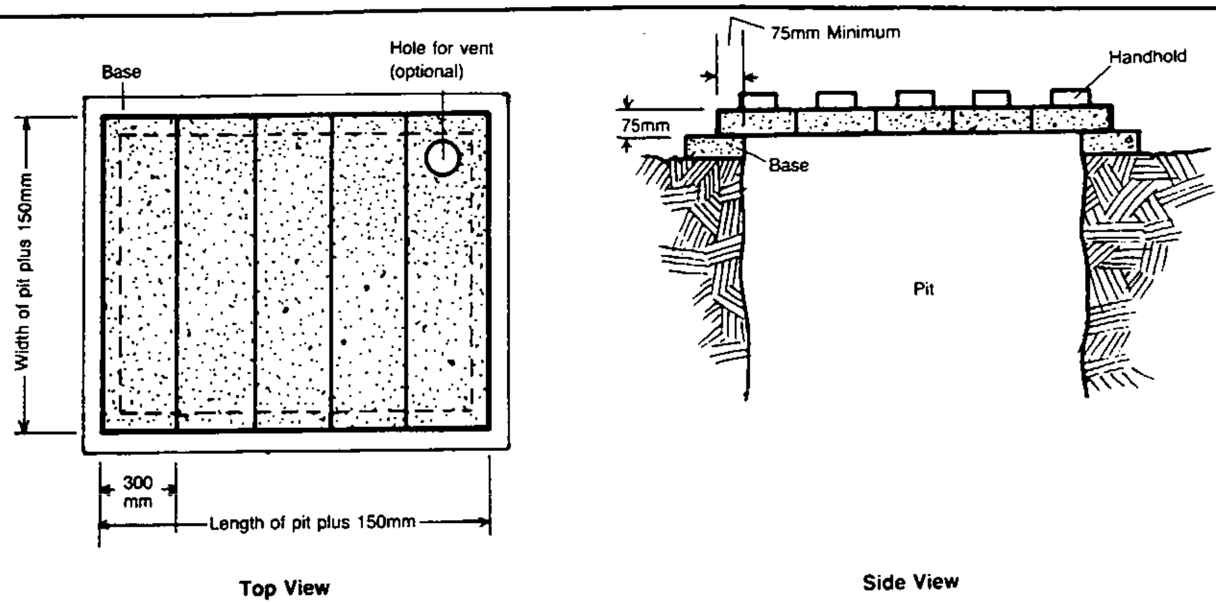


Figure 8. Cover for Offset Pit

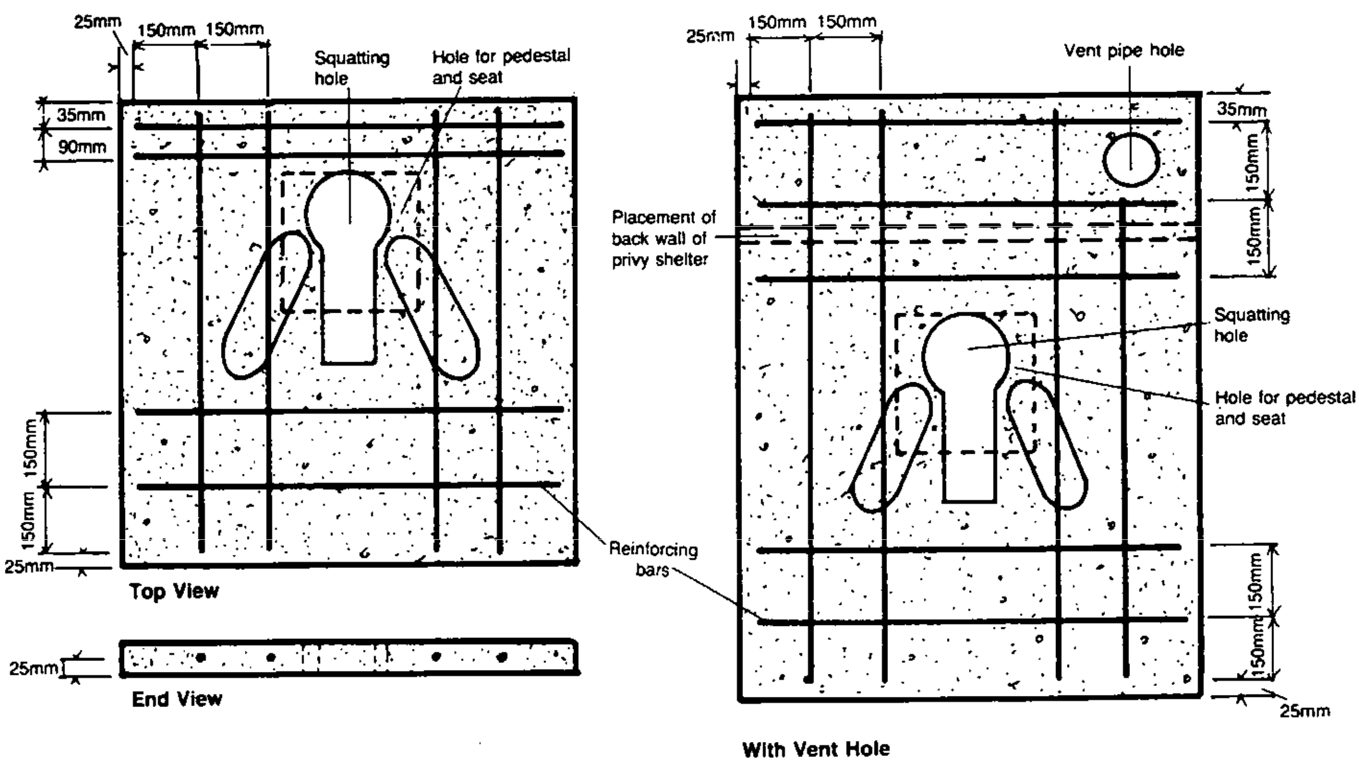


Figure 9. Placement of Reinforced Bars in Concrete Slab

Table 1. Sample Materials List

ITEM	DESCRIPTION	QUANTITY	ESTIMATED COST
Labor	Foreman	1	______
	Laborer (some experience with concrete)	1	______
	Laborers (to move constructed slab)	4-6	______
Supplies	Portland cement	____m^3	______
	Sand: Clean, size fine to 6mm	____m^3	______
	Gravel: Clean, size 6-38mm	____m^3	______
	Water: Clear, drinking water preferred	____liters	______
	Wood (for concrete forms)	______	______
	Nails (for concrete forms)	______	______
	Reinforcing bars _____mm long	______	______
	_____mm long	______	______
	(or wire mesh)	____m^2	______
	Wood (for lid)	______	______

	If seat and pedestal:		
	Bricks (for pedestal)	______	______
	Mortar (cement, sand, water)	____m^3	______
	Wood (for seat and lid)	______	______

	Pour-flush bowl (prefabricated)	______	______
	Galvanized metal (for vent pipe)	____m^2	______
	Galvanized metal (for chute)	____m^2	______
	Metal screws	______	______
	Screen (for vent)	______	______
Tools	Measuring tape	1	______
	Shovel	2	______
	Bucket	1	______
	Container for mixing concrete	1	______
	Trowel	1	______
	Saw	1	______
	Hammer	1	______
	Tinsnips	1	______
	Pliers	1	______
	Screwdriver	1	______
	Other	______	______

Total Estimated Cost = ______

Table 2. Sample Work Plan for Constructing Reinforced Concrete Squatting Slab

Time Estimate	Day Number	Task	Personnel	Tools/Materials
5 hours	1	Build wooden forms for the slab	Foreman and one skilled workman (Note: Foreman present during all phases of construction)	Measuring tape, wood, saw, hammer, nails, oil
5 hours	2	Mix and pour concrete; set reinforcing material	1 skilled workman, 2 laborers	Cement, sand, gravel, water, reinforcing material, container for mixing, 2 shovels, trowel
½ hour	2	Cover concrete and keep moist	1 laborer	Wet straw
½ hour	3	Remove wood plug for squatting hole, after concrete has taken initial set	1 laborer	None
5 days	3-7	Keep concrete covered and moist	1 laborer	Wet straw
3 hours	8	Separate slab from wooden forms; place slab over pit	4-8 laborers	Hammer (or nail-puller)
2 hours	8	Build lid for squatting hole; set in place	1 skilled workman	Measuring tape, wood, hammer, saw, nails

Construction Steps

Depending on local conditions, availability of materials, skills of workers, and so on, some construction steps will take only a few hours, while others may require a day or more. Read the construction steps and make a rough estimate of the time required for each step, based on local conditions. You will then have an idea of when during the construction process specific laborers, supplies, and tools must be available. Draw up a work plan similar to Table 2 showing the construction steps and the time estimated for each.

Assemble all laborers, supplies, tools, and drawings needed to begin construction. Study all diagrams carefully.

For a reinforced concrete squatting slab:

1. Build wooden forms similar to Figure 10. For a ventilated privy see the inset on Figure 10. Note that the squatting hole and the hole for the vent pipe are produced from solid wood blocks and the raised footrests from holes cut in the form. The slab is made upside down. If the slab is to have a pour-flush bowl, the shape of the hole must conform to the shape of the bowl unit. Check all measurements from drawings provided by the project designer.

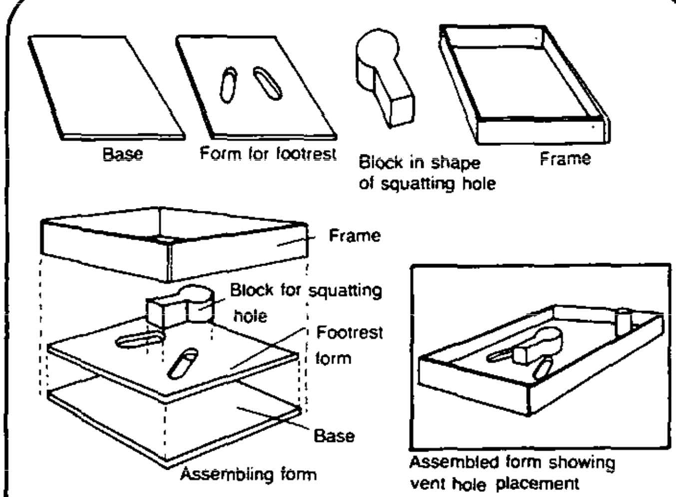


Figure 10. Forms for Concrete Squatting Slab

2. Treat the forms with oil or grease to make it easier to remove the slab after the concrete has set as shown in Figure 11.

3. Mix concrete with the correct proportions of cement, sand, gravel and water. A common mix by volume is one part cement, two parts sand, three parts gravel, and enough water to make a fairly stiff mix. The cement should be Portland cement. Remove any hard lumps of cement before mixing. The sand should be clean and sized fine to 6mm. The gravel should be clean and sized 6-25mm. The water should be clean and clear drinking water, if possible.

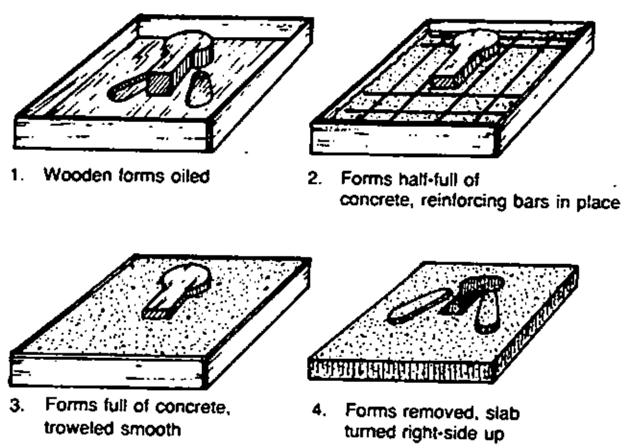


Figure 11. Constructing Concrete Squatting Slab

4. Pour concrete in the form to a depth of about 50mm and smooth surface with trowel. See Figure 11.

5. Set reinforcing material--bars or wire mesh--in place. Be sure the reinforcing material is positioned according to drawings supplied by the project designer and that the material does not touch the sides of the forms or the wooden block used to produce the squatting hole.

6. Pour in the remaining depth of concrete, about 25mm, and smooth surface with trowel. See Figure 11.

7. Cover concrete with wet straw or burlap bags. Keep shaded for one or two days until concrete takes its initial set.

8. Remove wood block used to produce squatting hole. See Figure 11. Keep concrete covered and wet for four to six days until it has firmly set. During this period, work can begin on the pit and the pit lining and base (see "Constructing Pits for Privies," SAN.1.C.2).

9. After the concrete has set firmly, remove the slab from the wood form See Figure 11. Set it in place on the base around the pit.

10. Build a lid for the squatting hole and set it in place.

For a wood or bamboo squatting slab:

1. Build a gridwork of notched poles or stout bamboo as shown in Figure 12. The space for the squatting hole is 50mm longer and 50mm wider than the finished hole. Nail or tie the poles together.

2. Place poles, bamboo, or boards across gridwork as shown in Figure 12. Poles or boards overlap space for squatting hole so that actual hole is 400mm long and 150mm wide. Fasten together ends of poles, bamboo, or boards with binding or nails.

3. Place second layer of poles, bamboo, or boards across the first as shown in Figure 12. Secure each pole or board to the first layer with binding or nails.

4. Cut wood blocks or boards for footrests and nail them in place.

5. Set the completed slab in place over the pit.

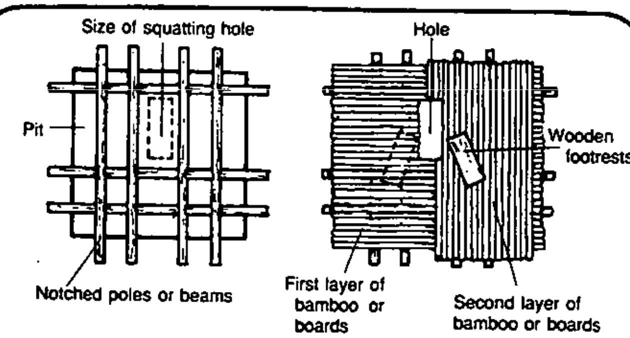


Figure 12. Wood Squatting Slab

6. Build a wooden lid to cover the squatting hole and set it in place.

For a concrete sitting slab with a brick and mortar pedestal:

1. Build wooden forms similar to Figure 13. For a ventilated privy, see Figure 13. Note that the hole for defecation is produced by a square wood frame. Do not pour concrete inside this frame.

2. Follow steps 2 through 9 for a reinforced concrete squatting slab. See Figure 14.

3. Mix concrete mortar with one part cement, three parts sand, and enough water to make a workable mix.

4. Lay bricks or selected stones around the hole in the slab as shown in Figure 14. Mortar the bricks to the slab and mortar them together.

5. Overlap the second row of bricks as shown in Figure 14. Continue laying bricks until the pedestal reaches 275-350mm.

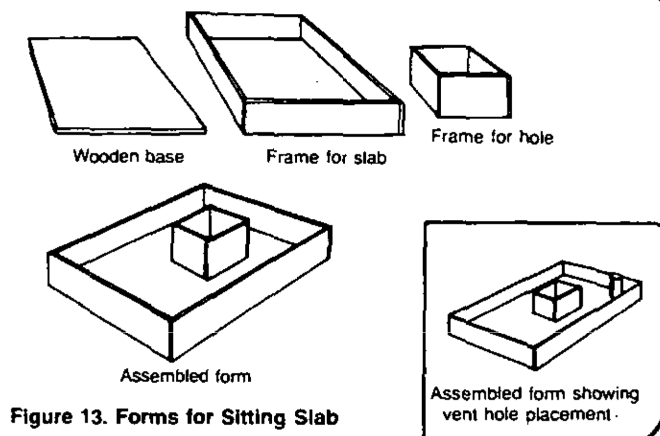


Figure 13. Forms for Sitting Slab

6. Wet the inside of the brick pedestal and plaster the inside with a 12mm thick layer of cement mortar. Smooth the mortar coating with a trowel.

7. Build a wood seat and lid similar to Figure 14 and set in place. Mortar seat to pedestal.

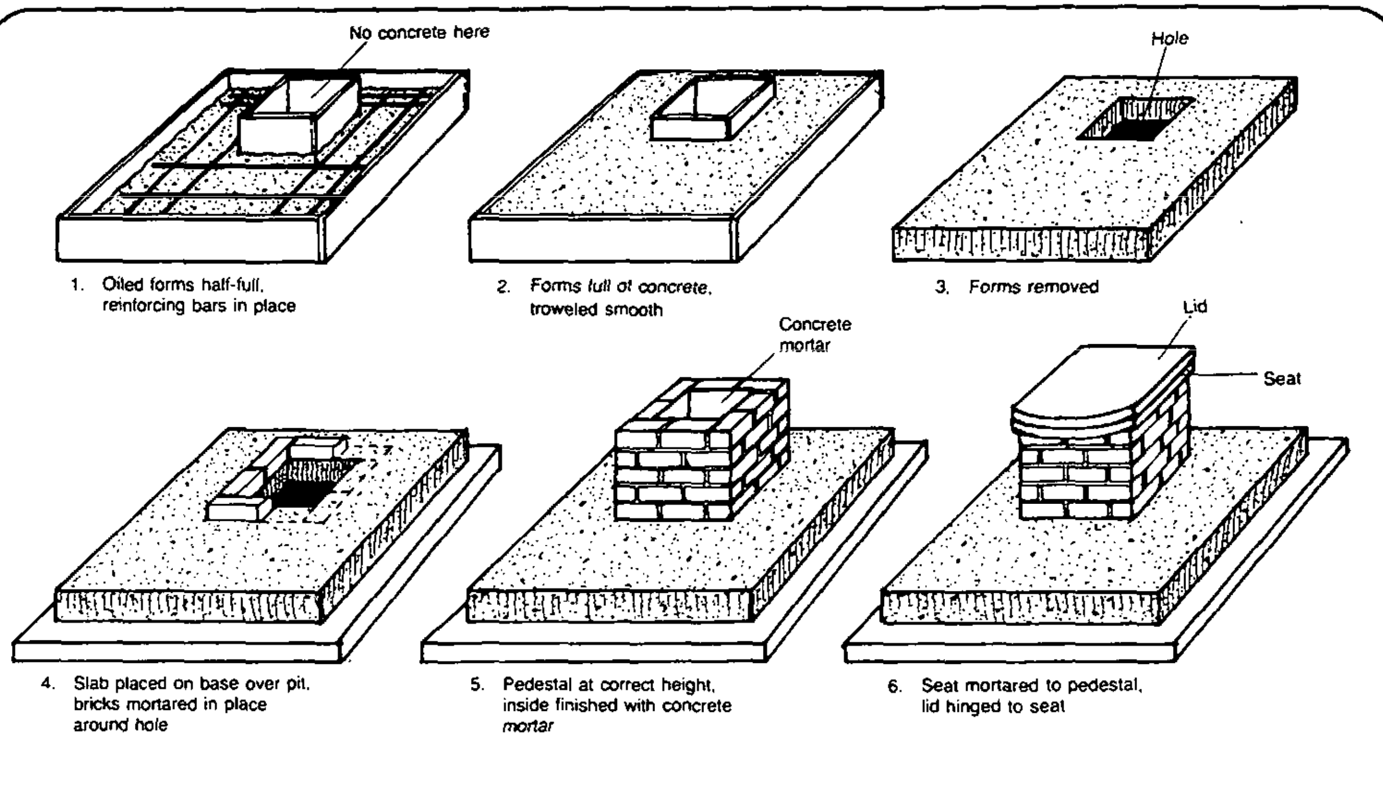


Figure 14. Constructing a Concrete Sitting Slab with Brick and Mortar Pedestal

For a wood sitting slab with a wood pedestal:

1. Cut two stout poles or beams the length of the pit plus 150-200mm. The beams should be 100mm by 100mm in size. Lay the beams on the base on each side of the pit as shown in Figure 15.

2. Nail 25mm thick boards to the beams as shown in Figure 15. The open space toward the rear of the slab should be about 450mm wide.

3. Build a bench 350-400mm high from 25mm thick boards. See Figure 15. The bench may have one or two holes for defecation. If two holes, make one 200-250mm diameter for adults and one about 150mm diameter for children. The edges of the holes should be sanded and free from splinters.

4. Build a hinged lid for each hole and attach in place.

5. Nail a board to each end of the privy floor to seal the pit. See Figure 15.

For a vent pipe:

1. Cut a rectangular sheet of tin to the dimensions provided by the project designer. See Figure 16.

2. Bend the tin to form the vent pipe. Overlap the edges about 25mm and fasten with metal screws. See Figure 16.

3. Cover one end of the pipe with fly-proof screen. See Figure 16.

4. A cone-shaped vent cover which is optional, but recommended in rainy regions, may be made from a round piece of tin about 250mm in diameter. Cut out a wedge with a base of about 150mm, bend tin to form a cone, and fasten with metal screws. See Figure 16. Attach the cone to the end of the vent pipe with metal struts to leave free air space.

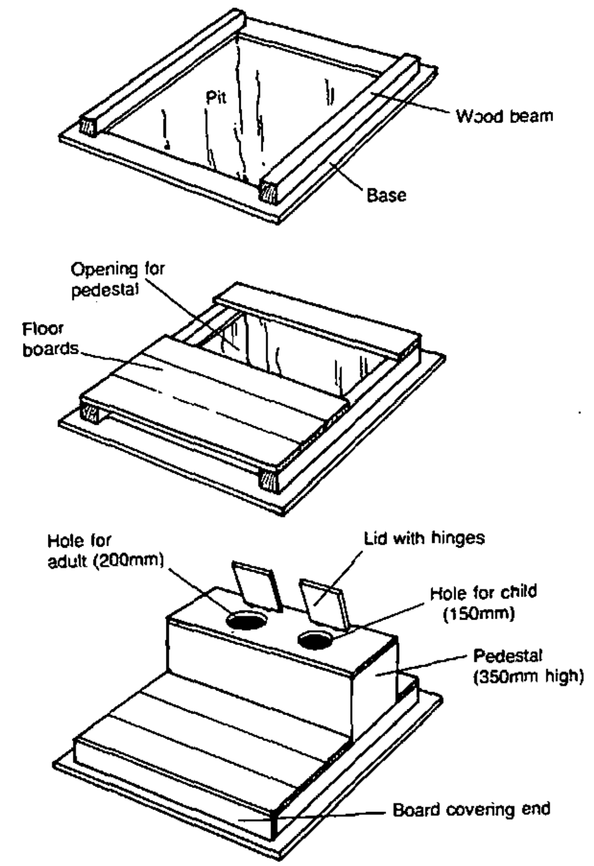


Figure 15. Wooden Sitting Slab with Wooden Pedestal

5. The vent pipe should not be installed until after the privy shelter is in place (see "Constructing Privy Shelters," SAN.1.C.3). Place the open end of the vent pipe in the hole in the slab and make the edges air-tight with mortar or tar. Secure the vent pipe to the privy structure. The screened end of the pipe should be 0.3-0.6m above the roof of the privy.

For a pour-flush bowl:

1. Pour-flush bowls are often prefabricated units made from galvanized metal, concrete, molded rubber, or ceramic material. They are built to fairly exact specifications and may be difficult to produce in the field. A skilled craftsman could possibly build a concrete bowl using Figure 6a or, a galvanized metal pour-flush bowl usin the design information in Figure 6b.

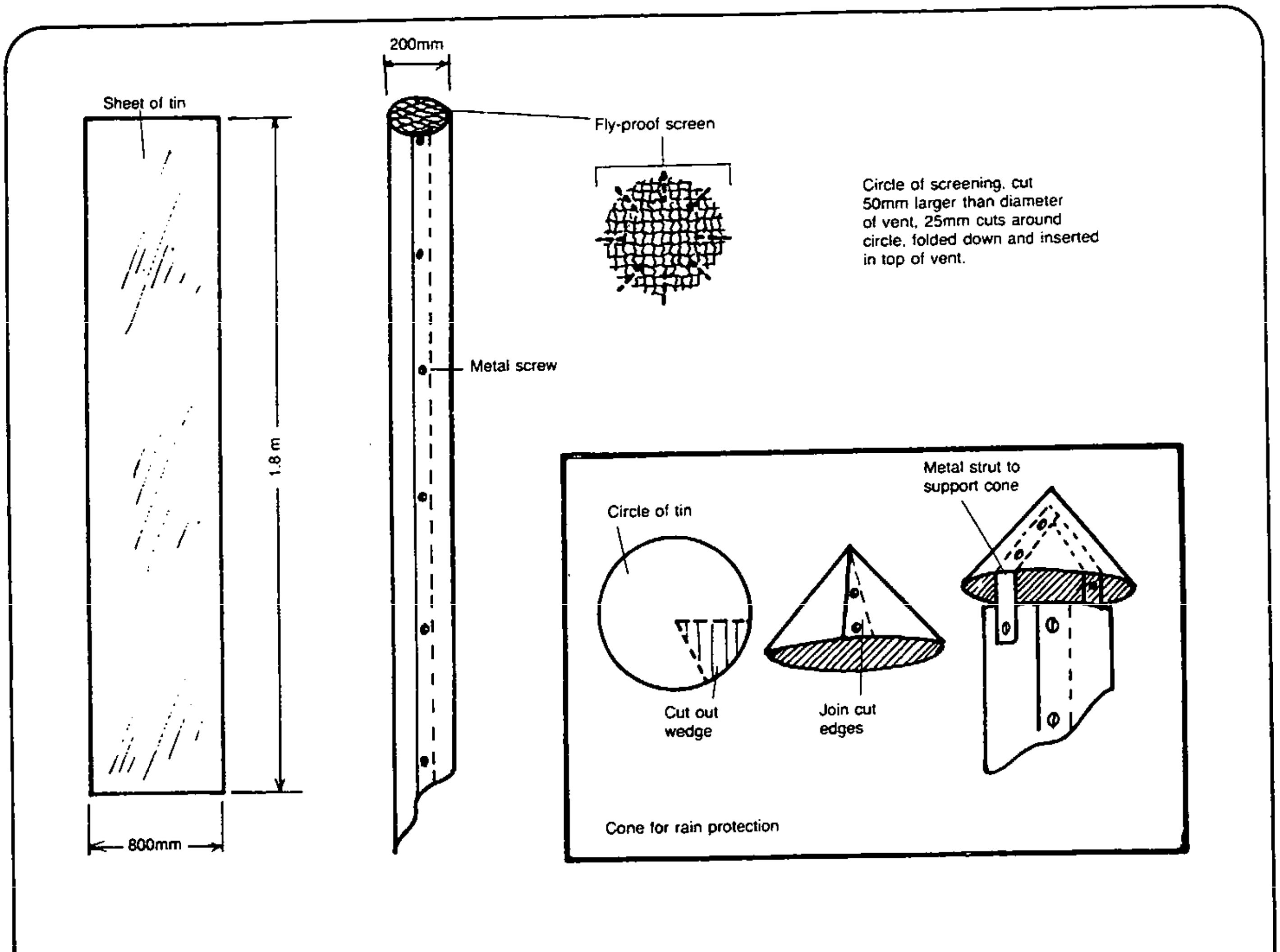


Figure 16. Constructing a Vent Pipe

This technical note does not describe how to build a pour-flush unit, but if you try it keep the following two points in mind: the edges of a galvanized metal bowl should be rounded or dulled by a file; and a concrete bowl is generally cast in two halves in wooden molds, the halves mortared together, and the entire unit cured under water for a week.

2. Secure the pour-flush bowl to the slab with cement mortar and allow two or three days to set before use.

For a chute for an off-set pit:

1. Cut a rectangular sheet of tin or galvanized metal to the dimensions provided by the project designer. See Figure 17.

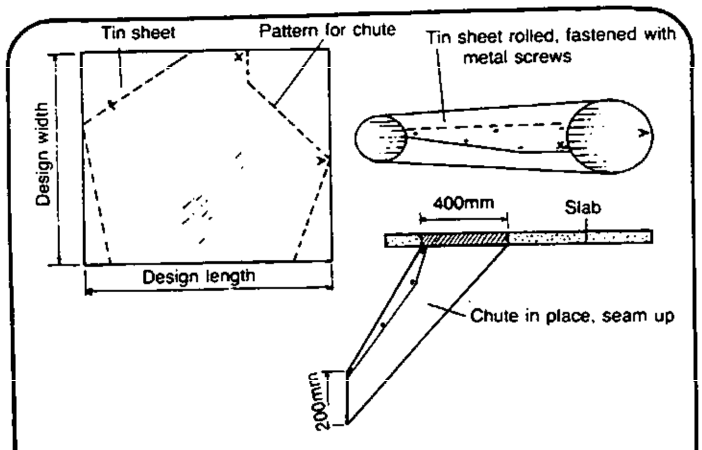


Figure 17. Constructing a Chute

2. Bend the sheet of tin to form the chute. Overlap the edges so that the overlapping seam is along the top edge and fasten with metal screws. Cut the sheet of tin in a shape like that shown in Figure 17 prior to bending.

3. Mortar the upper end of the chute in place below the squatting slab or seat, circling the squatting hole or the hole in the seat. See Figure 17.

For a wood platform for an off-set pit:

1. Build a framework to the dimensions of the slab, or slightly smaller, using poles or beams at least 50mm in diameter. See Figure 18a.

2. Add one or more rows of poles or beams to the framework, nailing or binding each row to the one below, until the correct height is reached. When the slab is in place, its top should be about 200mm above ground level. For example, if the slab is 75mm thick, the framework should be 125mm high: 75mm + 125mm = 200mm.

3. When the platform reaches the correct height, nail or tie corner pieces inside each corner to further secure it. See Figure 18a.

4. When the platform is completed, place the slab on top. See Figure 18a.

For a brick and mortar platform for an off-set pit:

1. Lay a row of bricks, mortared together, to the dimensions of the slab at the desired slab location. See Figure 18b.

2. Continue mortaring rows of bricks in place until the correct height is reached as described in step 2 for wood platform. See Figure 18b.

3. After the mortar has set for two or three days, mortar the slab on top of the platform. See Figure 18b.

For a concrete platform for an off-set pit:

1. Build wooden forms for the concrete platform to the correct height as described in step 2 for wood platform and to the dimensions of the slab. Build the forms in place and so that the finished platform will have walls at least 75mm thick. See Figure 18c.

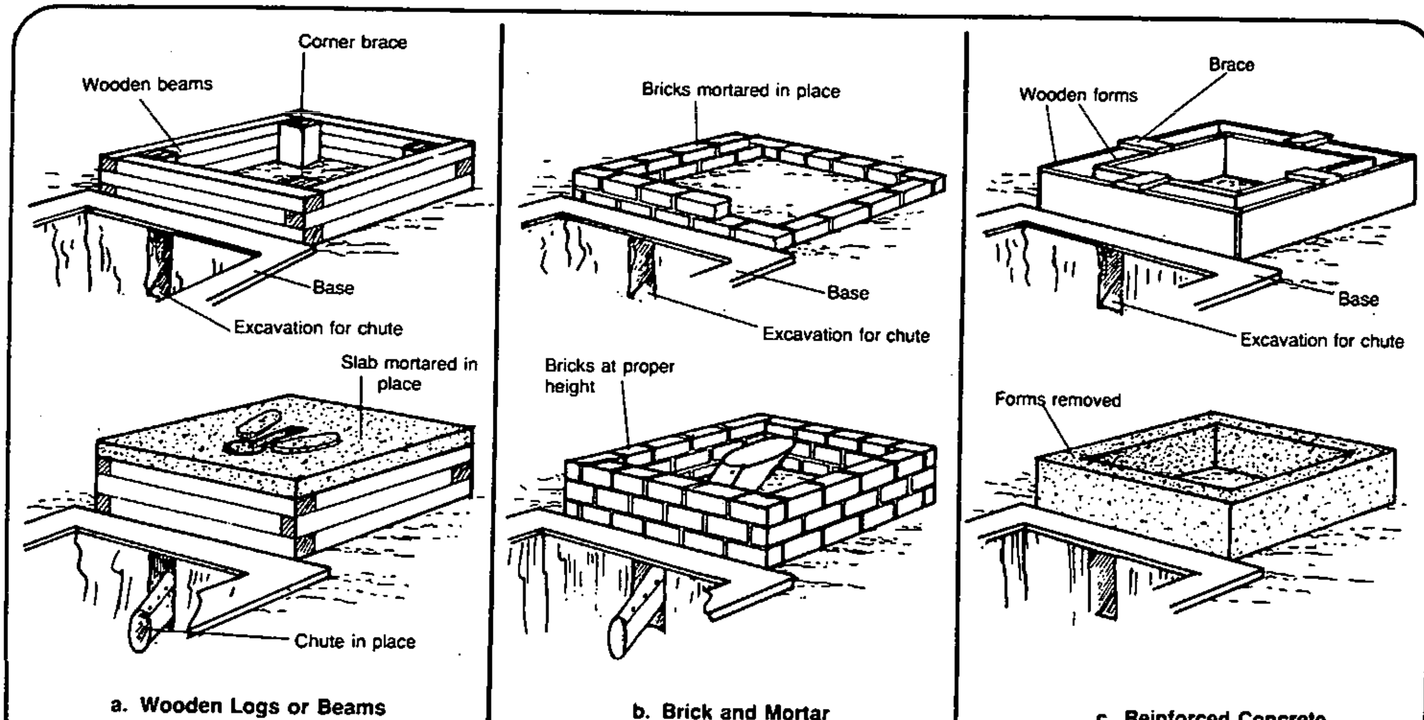


Figure 18. Platforms for Off-Set Privy

2. Mix concrete using the correct proportions of cement, sand, gravel and water as described in step 3 for a reinforced concrete squatting slab.

3. Pour concrete in the forms to about half their depth.

4. Lay reinforcing material in place.

5. Pour in the remaining depth of concrete and smooth the surface with a trowel.

6. Cover concrete with wet straw or burlap bags and allow it to set for three to seven days. Then, remove wood forms. See Figure 18c.

7. Mortar the slab on top of the platform.

For a reinforced concrete cover for an off-set pit:

1. Build wooden forms for the cover. See Figure 19. The cover is made in sections with each section about 75mm thick. The length of each section equals the width of the pit plus 150-200mm so that the sections overlap the pit on each side by 75-100mm. All sections but one are 300mm wide. One section is 300mm wide plus whatever measurement is necessary to add up to the total length of the pit plus 150mm. The width of this last section should be provided by the project designer or calculated in the field. For example, if the pit is 1500mm long, then the total widths of the sections should equal 1500mm plus 150mm, or 1650mm. The widths of the sections would be:

300mm + 300mm + 300mm + 300mm + 450mm = 1650mm

2. Mix concrete using the correct proportions of cement, sand, gravel and water as described in step 3 for a reinforced concrete squatting slab.

3. Pour concrete in the forms to about half their depth.

4. Lay reinforcing material in place.

5. Pour in the remaining depth of concrete and smooth the surface with a trowel.

6. Set handholds into the concrete near both ends of each section. See Figure 19.

7. Cover the concrete with wet straw or burlap bags and keep moist for five to seven days to allow concrete to set.

8. Remove wooden forms and place sections over the pit. Do not mortar. Waterproof between each section, and between the sections and the base around the pit, with tar or other material. See Figure 19.

9. Mound with soil. See Figure 19.

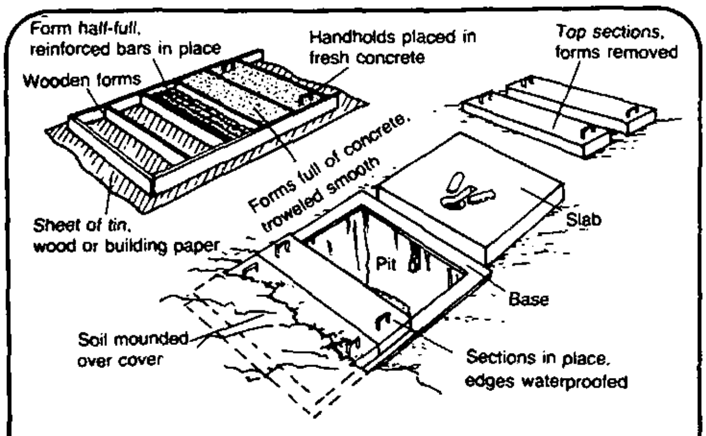


Figure 19. Cover for Off-Set Pit

Notes

Water for the World

Designing Privy Shelters
Technical Note No. SAN 1.D.3

A privy shelter is a screen or structure that gives the person using the privy privacy. Depending on the design, a shelter can protect the privy and the user from the weather and keep out flies, rats, scavenging dogs, and other pests. Designing a shelter involves selecting the type of shelter; determining shape, size, and special features; and selecting materials, tools, and labor. The products of the design process are (1) a plan view of the shelter; (2) a detailed view of any special features; and (3) a detailed materials list. This technical note describes how to design a privy shelter and produce these three products.

Read the entire technical note before beginning design procedures.

Materials Needed

Measuring tape - To obtain field measurements.

Scale - To draw accurate diagrams.

Selecting the Type of Shelter

The three basic types of privy shelters are a simple screen, a shelter with a roof, and a shelter with a roof and door. Figures 1, 2 and 3 show the types of privy shelters.

The most important factors in selecting a type of shelter are local customs and personal preferences of the users. Determine how much privacy people want and whether or not a roof and door are acceptable or desired. Other factors that influence selection are available money, materials, and skilled labor, and the extent to which control of pests is important. Table 1 compares these factors for each type of shelter.

Determining Shape, Size, and Special Features

Shape. The shelter can be square, rectangular, circular, or spiral-shaped, as shown in Figures 1 and 2,

Table 1. Comparison of Shelter Types

Shelter Type	Advantages	Disadvantages
Simple Screen	User privacy; very inexpensive and easy to build	No protection from weather; not suitable for ventilated privy, compost toilet, bucket latrine, or aqua privy; no pest control*
With Roof	User privacy; suitable for all privies; protection from weather	Slightly more expensive; some construction skills needed; no pest control*
Roof and Door	Complete user privacy; suitable for all privies; protection from weather; pest control*	Moderately expensive; construction skills required

*All privies must have a lid for the hole. This keeps pests out of the pit, but not out of the shelter.

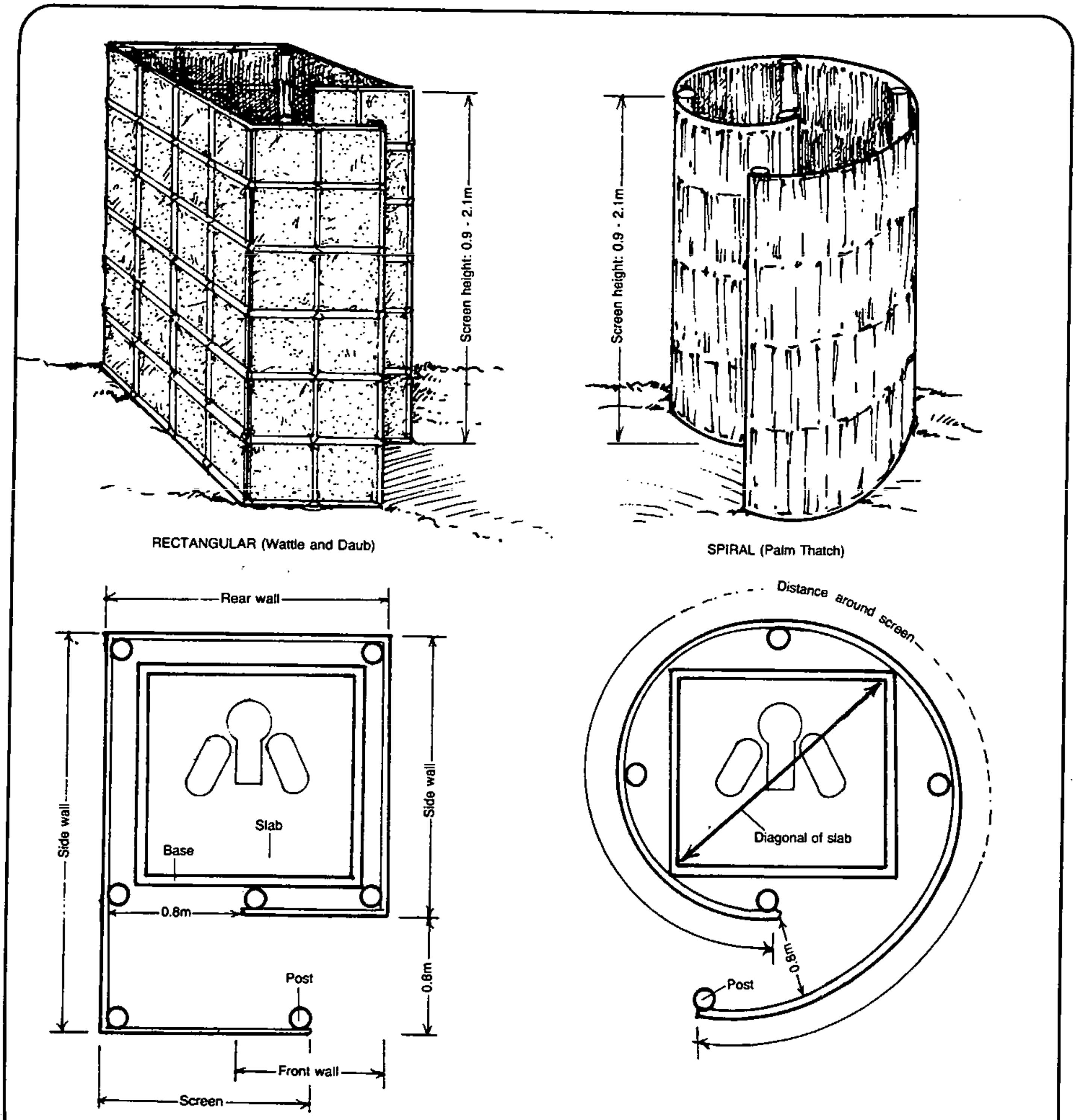


Figure 1. Simple Screen Shelters

depending on local preference. The screen or walls should be vertical. The roof should slope to the rear or sides of the shelter to allow rainwater to run off.

Size. The area inside the shelter should be 1.0-2.3m^2. This allows enough room for the user without wasting building materials. Unless the privy is ventilated with a vent pipe, the shelter should completely enclose the privy slab. For a ventilated privy, the part of the slab that holds the vent pipe will be outside the shelter, as shown in Figure 4. The back wall of the shelter should be 150-200mm from the defecation hole.

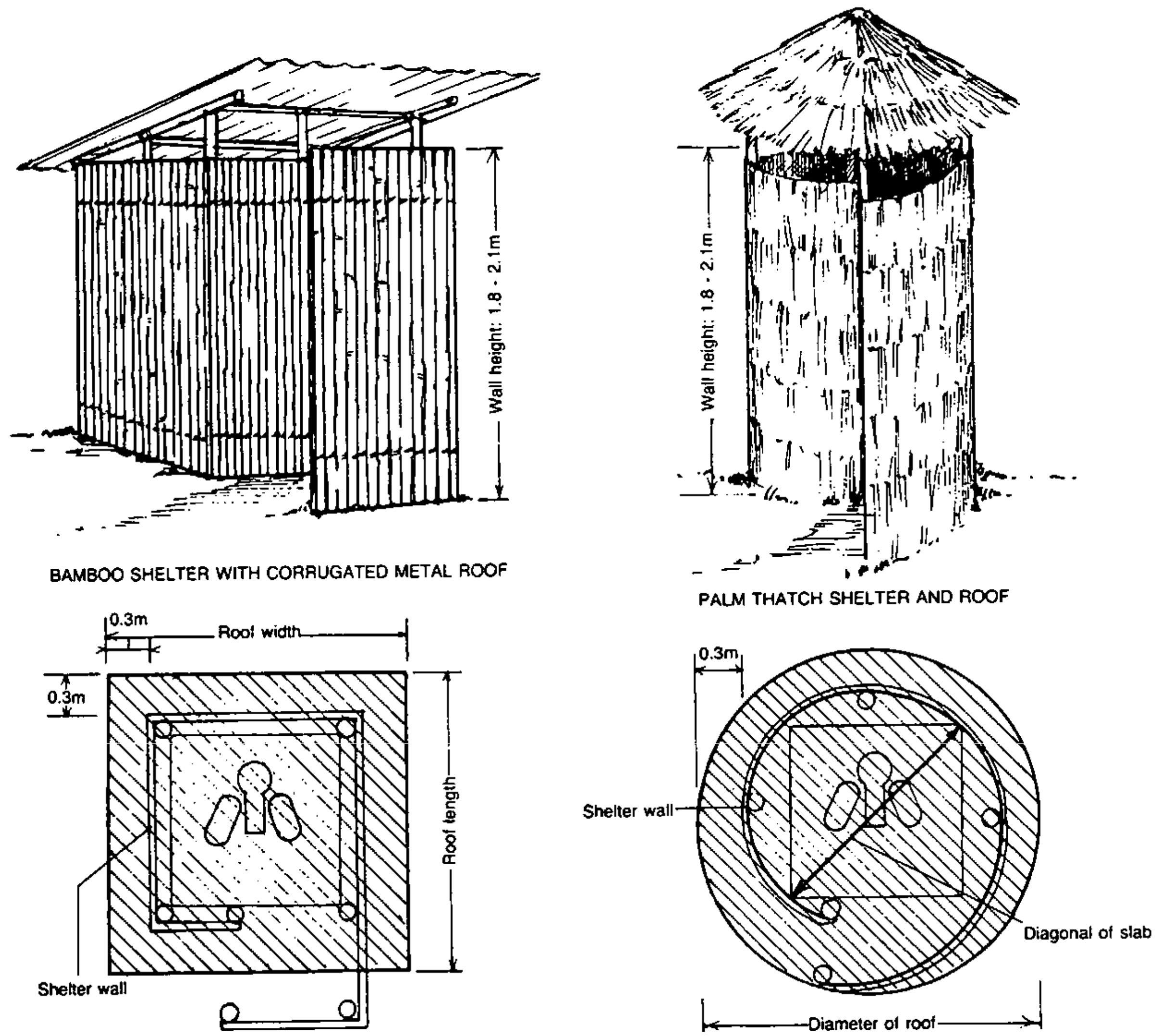


Figure 2. Privy Shelters with Roof

The shelter can be designed to rest on the base around the pit with the walls bordering the slab. With this design, the size of the slab determines the area within the shelter.

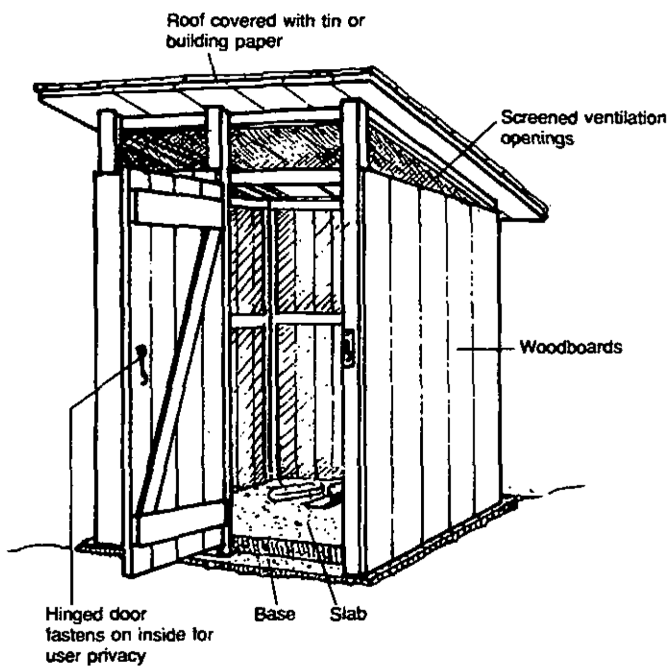
If the shelter is a simple screen with no roof, the bottom of the screen should touch the ground. The screen can be 1-2m high. If the shelter has a roof, the walls should be 1.8-2.1m high to allow enough headroom. The walls should rest on the ground.

Table 2 summarizes some requirements for a shelter.

Special Features. If the shelter has a roof, it should also have ventilation openings. The openings should be at least 100mm by 200mm and spaced along the top of the walls. One design has the entire roof raised above the walls on the corner posts, as shown in Figures 2 and 3.

Table 2. Shelter Requirements

Feature	Requirement
Walls	Vertical; touch ground
Wall Height (simple screen)	1-2m
Wall Height (with roof)	1.8-2.1m
Rear Wall	150-200mm from defecation hole
Roof	Sloped to rear or sides
Area in Shelter	1.0-2.3m^2



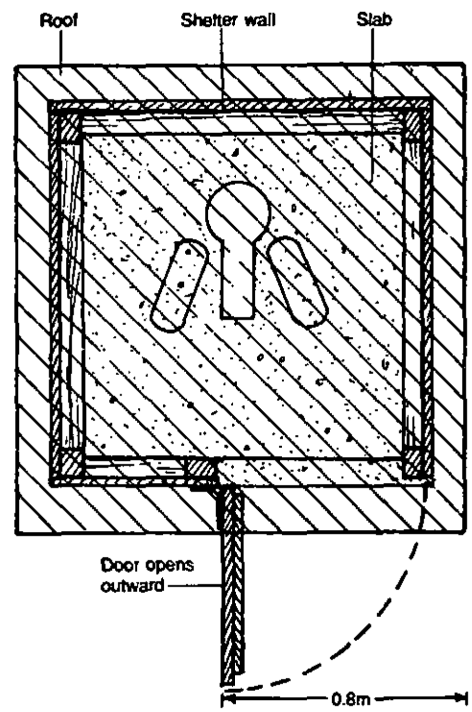
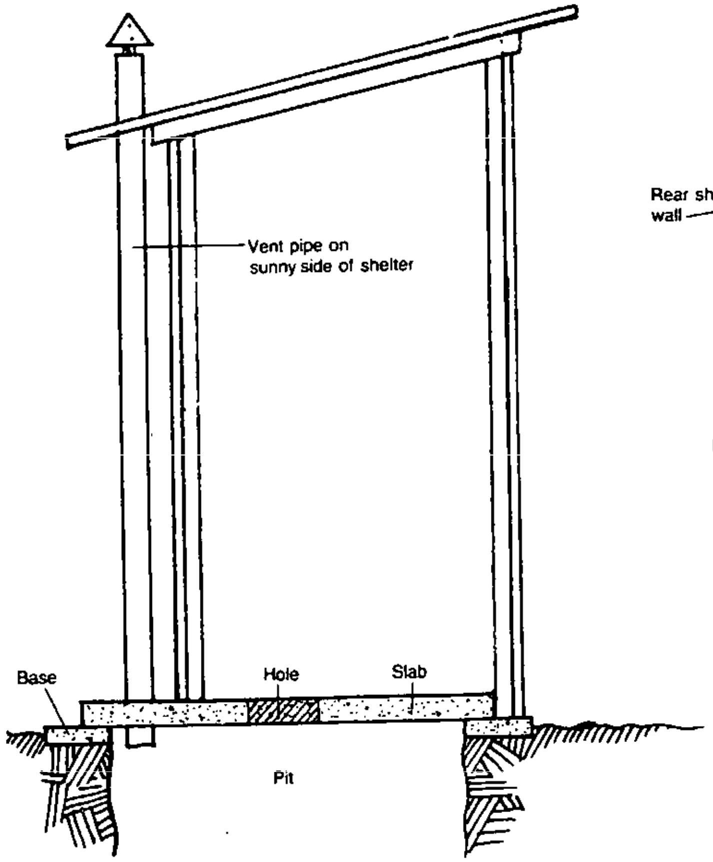


Figure 3. Fly-Proof Shelter with Screening and Door

If the shelter has a door, it must have sturdy hinges to keep the door in the correct position. An inside latch is needed to keep the door closed when the privy is in use. Figure 5 shows a well-designed privy door. The door may open from the right or left, but it should open outward unless this violates local custom. Ventilation openings are required. If pests are to be kept out of the shelter, screens must cover all ventilation openings and the door must fit tightly, as shown in Figure 6.

If the shelter is for a ventilated privy, the vent pipe must be attached to an outside wall or to the roof, as shown in Figure 4.



4. Shelter for Ventilated Privy

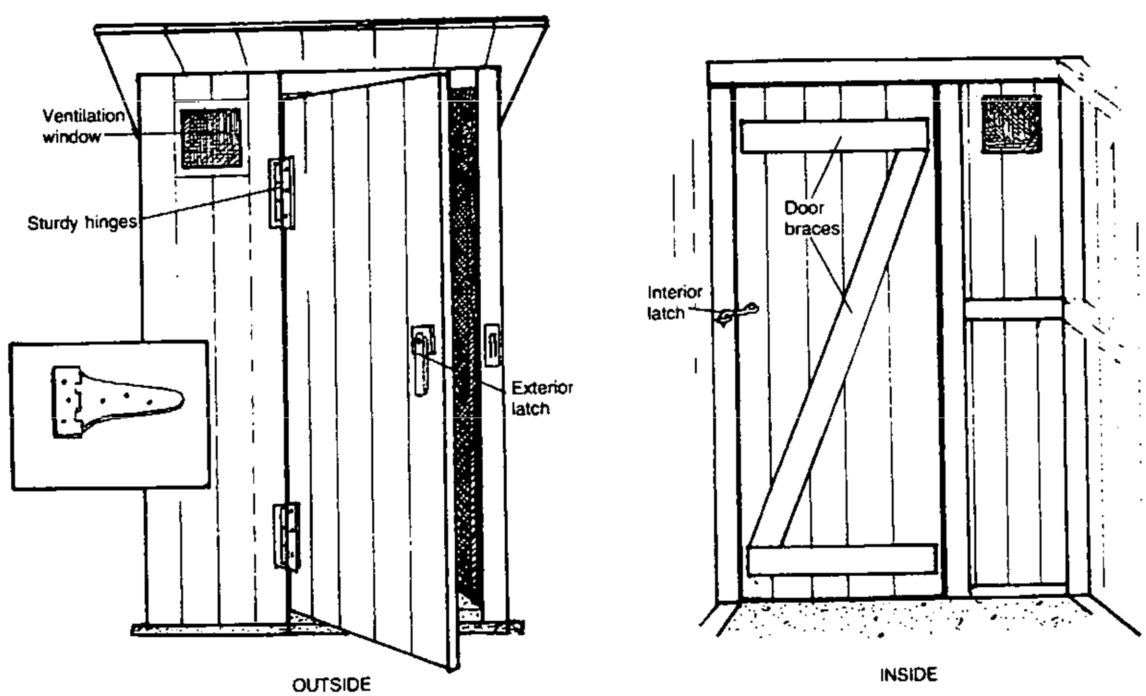


Figure 5. Detail of Door for Fly-Proof Shelter

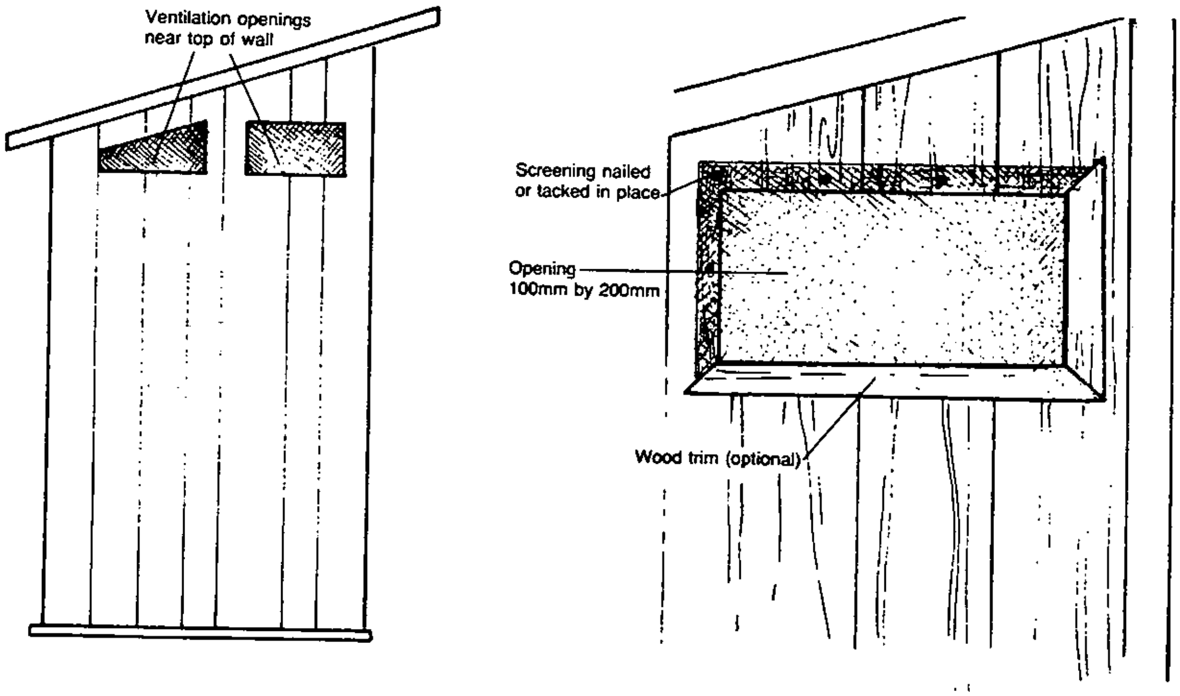


Figure 6. Fly-Proof Screening Covering Ventilation Openings

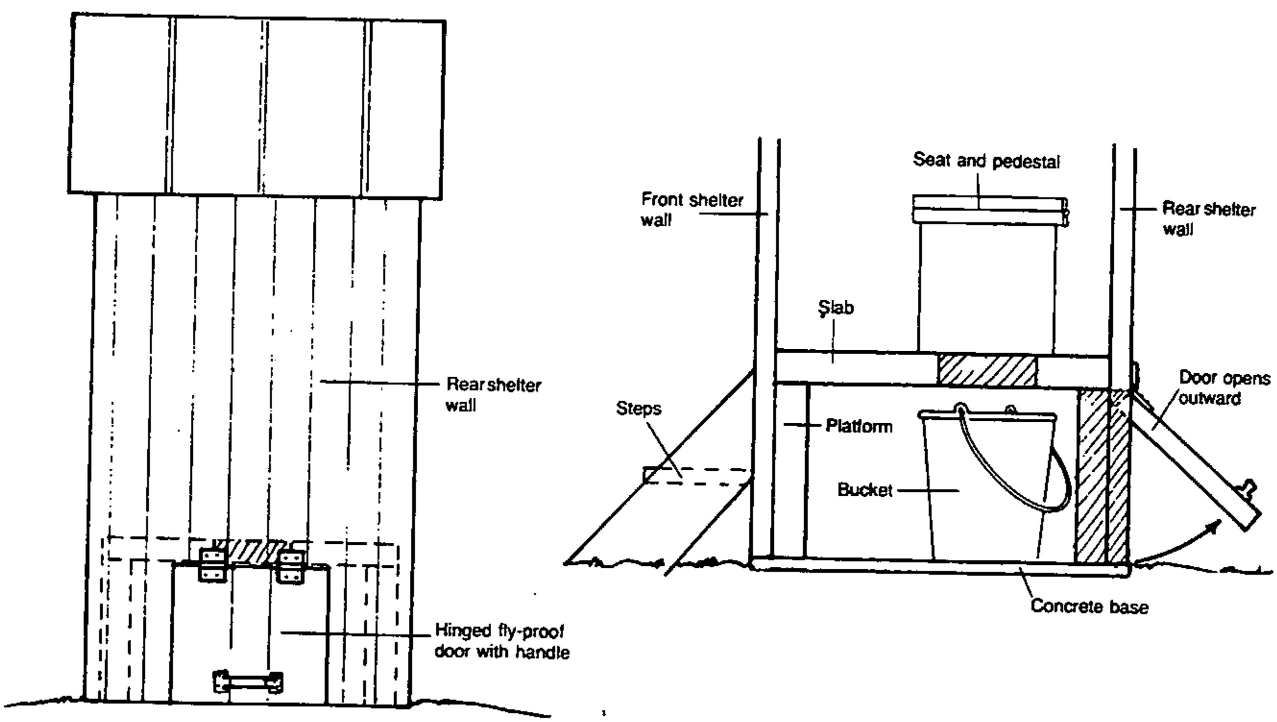


Figure 7. Detail of Shelter for Bucket Latrine

Table 3. Special Feature Requirements

Feature	Requirement
Ventilation Openings	At least 100 x 200mm; spaced along top of walls
Screens	Fly-proof; cover <u>all</u> openings
Door	Opens outward; sturdy hinges; inside latch
Vent Pipe	Attached to outside wall or roof
Privy Slab on Platform	Shelter rests on ground

Table 4. Combinations of Materials for a Shelter

	Feature		
	Walls	Roof	Door
Materials	Mud and Wattle	Palm Thatch	Mud and Wattle, Palm Thatch, or Bamboo
	Bamboo	Palm Thatch	Mud and Wattle, Palm Thatch, or Bamboo
	Palm Thatch	Palm Thatch	Mud and Wattle, Palm Thatch, or Bamboo
	Wooden Boards	Wooden Boards or Corrugated Metal	Wooden Boards
	Brick and Mortar or Concrete Block and Mortar	Wooden Boards or Corrugated Metal	Wooden Boards

If the shelter is for a privy with a <u>platform</u>, such as an off-set pit, compost toilet, or bucket latrine, the walls should rest on the ground and enclose the platform. The height of the platform must be added to the height of the wall shown in Table 2. For a compost toilet or bucket latrine, the rear wall of the shelter must have a small door. It must be fly-proof for a bucket latrine and air-tight for a compost toilet. The door will allow for removal of the bucket or compost. This is shown in Figure 7.

Table 3 summarizes special feature requirements.

When the type of shelter, its shape, size, and special features have been decided, draw a plan view of the shelter showing all dimensions. Also prepare a detailed drawing of any special features. Give these drawings to the construction foreman before construction of the shelter begins.

Selecting Materials

In general, a privy shelter should be built using locally available materials, tools, and labor. The sturdier the materials, the longer the life of the shelter.

A <u>simple screen shelter</u> can be bamboo, palm thatch, mud and wattle, or poles supporting canvas or fabric. A shelter with a <u>roof</u>, or <u>roof and door</u>, can be built from a variety of materials, some of which are shown in Table 4. The roof should be waterproof.

Depending on the area, termites may be a problem if wood structures are to be used. Special protection, such as a brick or concrete base, may be required to keep wood from coming into contact with the soil and giving termites access to the wood.

Worksheet A. Calculating Quantities for a Privy Shelter

Shelter Type (check one): ☒ simple screen ☒ roof ☒ roof and door

Simple Screen Shelter

1. Height of screen = 1.8 m
2. Length of sides = 0.3 m + 1.2 m + 1.2 m + 2.0 m + 1.2 m = 5.9 m
3. Quantity for screen = Line 1 x Line 2 = 1.8 m x 5.9 m = 10.6 m^2

---

4. Distance around screen (for circular or spiral screen) = 6.1 m
5. Quantity for circular = Line 1 x Line 4 = 1.8 m x 6.1 m = 11.0 m^2

---

6. Number of corner posts (or uprights) from drawing = 7
7. Minimum length of posts = Line 1 + 0.3m = 1.8 m + 0.3m = 2.1 m

---

Shelter with Roof

8. Width of shelter + 0.6m = 1.4 m + 0.6m = 2.0 m
9. Length of shelter + 0.6m = 1.5 m + 0.6m = 2.1 m
10. Quantity for roof = Line 8 x Line 10 = 2.0 m x 2.1 m = 4.2 m^2

---

11. Diagonal of privy slab (measured in field) = 2.0 m
12. Diameter of circular roof = Line 11 + 0.9m = 2.0 m + 0.9m = 2.9 m
13. Quantity for circular roof = $\frac{\text{Line 12}}{2}$ x $\frac{\text{Line 12}}{2}$ x 3.1 = $\frac{2.9}{2}$ m x $\frac{2.9}{2}$ m x 3.1 = 1.45 m x 1.45 m x 3.1 = 6.5 m^2

---

14. Rear wall = height times width = 1.6 m x 1.4 m = 2.2 m^2
15. Side wall = height times width = 1.8 m x 1.5 m = 2.7 m^2
16. Side wall = height times width = 1.8 m x 1.5 m = 2.7 m^2
17. Front wall = height times width = 2.0 m x 0.6 m = 1.2 m^2
18. Screening wall = height times width = 2.0 m x 0.8 m = 1.6 m^2
19. Screening wall = height times width = 2.0 m x 1.4 m = 2.8 m^2
20. Quantity for shelter walls =

Line 14 + Line 15 + Line 16 + Line 17 + Line 18 + Line 19 =

2.2 m^2 + 2.7 m^2 + 2.7 m^2 + 1.2 m^2 + 1.6 m^2 + 2.8 m^2 = 13.2 m^2

Shelter with Roof and Door

For roof and walls, use Lines 8 through 20.

21. Quantity for door = height times width 1.8 m x 0.9 m = 1.6 m^2.

Calculating Quantities of Materials

The quantities of materials needed depend on the type and size of the shelter. Most quantities are calculated in square meters and then converted to material units such as numbers of bricks, numbers of bamboo poles, and numbers and lengths of boards. Other quantities are determined by measurements made on plan view drawings.

Simple Screen Shelter. Materials include screening material and corner posts, or an upright post for a circular or spiral screen. Calculate the amount of screening material needed by adding the lengths of each section of the screen and multiplying the total by the height, as shown in Figure 1. For example, suppose the height of the screen is 1.8m and the lengths of the sections are 0.3m, 1.2m, 1.2m, 2.0m, and 1.2m. Then the quantity of screen needed is (0.3m + 1.2m + 1.2m +2.0m +1.2m) x 1.8m = 5.9m x 1.8m = 10.6m^2. See Worksheet A, Lines 1, 2 and 3. For a circular or spiral screen multiply the distance around the screen as shown in Figure 1, times the height. For example, if the distance around the screen is 6.1m and the height is 1.8m, the quantity of screen needed is 6.1m x 1.8m = 11.0m^2. See Worksheet A, Lines 4 and 5.

A corner post is needed at the end of each section of screen. Count the number of posts in the plan view. In the example above there are seven posts as shown in Figure 1. The post near the center of the longest section is for added stability. For circular or spiral screens, place upright posts 0.9-1.2m apart. Posts should be 0.3-0.6m longer than the height of the screen. This extra length will be driven or buried in the ground to hold the screen securely. In the example above, the length of the posts should be at least 1.8m + 0.3m = 2.1m. See Worksheet A, Lines 6 and 7.

Shelter with Roof. Materials include roof and wall materials, corner posts or uprights, cross poles, rafters, and foundation.

Roof materials are calculated by multiplying the width of the shelter plus 0.6m times the length of the shelter plus 0.6m. For example, if the shelter is 1.4m wide and 1.5m long, the quantity of materials is (1.4m + 0.6m) x (1.5m + 0.6m) = 2.0m x 2.1m = 4.2m^2. See Worksheet A, Lines 8, 9 and 10.

To calculate the quantity of materials for a circular roof, which may be desirable for a circular or spiral-shaped shelter, first obtain the diagonal dimension of the privy slab by measuring it, as shown in Figure 2. The diagonal plus 0.9m is the diameter of the roof. The quantity of materials equals the diameter divided by 2, multiplied by the diameter divided by 2, multiplied by 3.1. For example, suppose the diagonal of the privy slab is 2.0m. Then the diameter of the roof is 2.0m + 0.9m = 2.9m. The quantity of materials is $\left(\frac{2.9\text{m}}{2} \times \frac{2.9\text{m}}{2}\right) \times 3.1 =$ (1.45m x 1.45m) x 3.1 = 2.1m^2 x 3.1 = 6.5m^2. See Worksheet A, Lines 11, 12 and 13.

Wall materials are calculated by adding together the area of each wall, including the screening wall, if there is one. The area of a wall is its height times its width. If the top of the wall is sloped, use the height in the middle. For a circular or spiral-shaped shelter, the area of the wall is calculated the same way as for a simple screen shelter. That is, the distance around the shelter is multiplied by the height. For example, suppose a shelter is to have a screening wall, and the roof and sidewalls slope from front to back as in Figure 2, and the wall dimensions are as follows:

rear wall	=	1.6m by 1.4m
side walls	=	1.8m by 1.5m and 1.8m by 1.5m
front wall	=	2.0m by 0.6m
screening walls	=	2.0m by 0.8m and 2.0m by 1.4m

Then the wall area and the quantity of materials needed = (1.6m x 1.4m) + (1.8m x 1.5m) + (1.8m x 1.5m) + (2.0m x 0.6m) + 2.0m x 0.8m) + (2.0m x 1.4m) = 2.2m^2 + 2.7m^2 + 2.7m^2 + 1.2m^2 + 1.6m^2 + 2.8m^2 = 13.2m^2. See Worksheet A, Lines 14-20.

The materials needed for cross poles, corner posts, rafters, and foundations, shown in Figures 8a and 8b are best calculated by drawing an accurate plan view and measuring lengths from the drawing. The length of each log, pole, or board used for the foundation equals the width of the wall it supports. The length of each corner post or upright equals the height of the wall it supports. If the entire roof is to be raised above the walls for ventilation, add 0.15m to the length of each corner post or upright.

Shelter with Roof and Door. The materials needed for the roof are the same as those just discussed (see Worksheet A, Lines 8-20). Additional materials needed for the door are door braces, hinges, and latch.

Door materials are calculated by multiplying the height of the door times the width. For example, if the door is 1.8m high and 0.9m wide, the quantity of materials is 1.8m x 0.9m = $1.6m^2$. See Worksheet A, Line 21.

The quantities of materials for the door braces are best obtained by drawing an accurate plan view similar to Figure 3 and measuring lengths from the drawing. One inside latch and two hinges are needed.

Materials List

The skills of the laborers and the tools needed depend on the materials used. For example, a wooden shelter requires a laborer with some carpentry skills and a hammer, saw, and nails. A brick-and-mortar shelter requires a laborer with some masonry skills and a shovel, mixing container, and trowel. When the materials, tools, and labor requirements have been determined, draw up a materials list similar to Table 5 and give it to the construction foreman.

In summary, give the construction foreman design drawings similar to Figures 1 through 8b, and a materials list similar to Table 5.

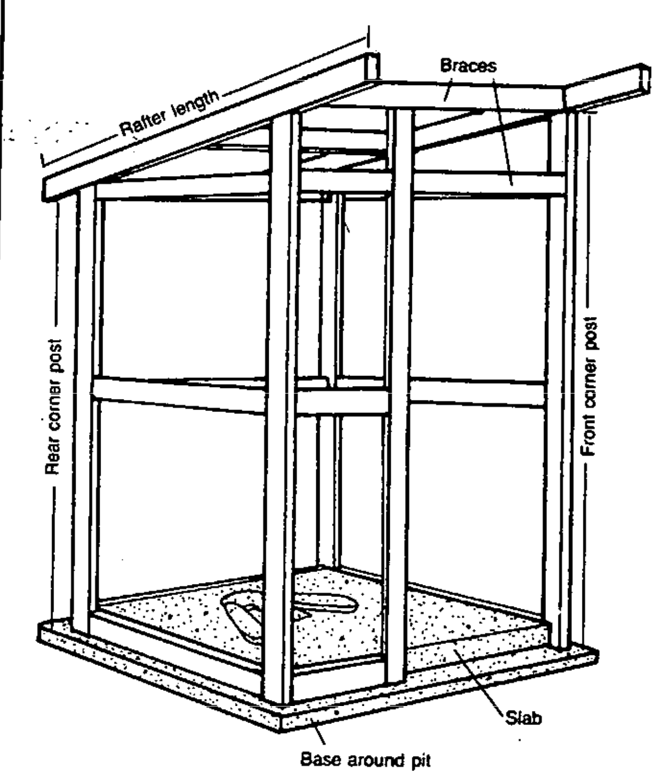


Figure 8a. Typical Shelter Framework Using Lumber

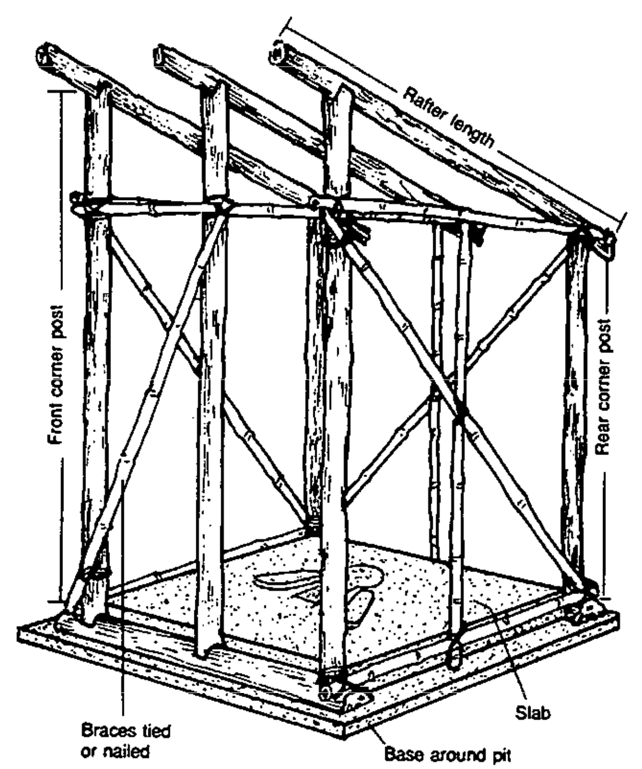


Figure 8b. Typical Shelter Framework Using Logs, Poles or Bamboo

Table 5. Sample Materials List for Privy Shelter

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	______
	Laborer (carpentry skills)	1	______
Supplies	Foundation: logs, 1.5m long, 100mm diam.	4	______
	Corner posts: wood beams, 1.8m long, 50mm diam.	4	______
	Walls: wood boards, various lengths, 25mm thick	$13.2m^2$	______
	Roof: Corrugated metal	$4.2m^2$	______
	Screens (flyproof) for ventilation openings, 150 x 250mm	12	______
	Metal hinges	2	______
	Latch	1	______
	Nails	______	______
	Other	______	______
Tools	Measuring tape	1	______
	Hammer	1	______
	Saw	1	______
	Carpenter's level or equivalent (not essential but very useful)	1	______
	Carpenter's square or equivalent (not essential but very useful)	1	______
	Other	______	______

Total Cost = ______

Do Not Use the Quantities in the Sample - Calculate Your Own

Notes

1982

Water for the World

Constructing Privy Shelters
Technical Note No. SAN. 1.C.3

A privy shelter is a screen or structure that gives the person using the privy privacy. Depending on the design, a shelter can protect the user from the weather and keep out flies, rats, scavenging dogs, and other pests. Constructing a privy shelter involves assembling necessary labor, materials, and tools; building the shelter to the dimensions specified by the project designer; and building any special features.

A properly constructed shelter can last 5-10 years or more. This technical note describes each step in building a shelter. Read the entire technical note before beginning construction.

Materials Needed

The project designer must provide three papers before construction can begin:

1. A plan view of the shelter similar to one or more of Figures 1-4, and 8a and 8b, showing the correct dimensions of the shelter.

2. A detailed view of any special features similar to one or more of Figures 5-7.

3. A detailed materials list similar to Table 1, showing all necessary labor, supplies and tools.

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary laborers, supplies and tools.

Construction Steps

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Table 2 shows a sample work plan for building a privy shelter including time estimates for each step. Draw up a similar work plan with rough time estimates based on local conditions. You will then have an idea of when specific workmen, supplies, and tools must be available during the construction process.

For a simple screen shelter:

1. Assemble all laborers, supplies, tools, and drawings needed to begin construction. Study all drawings carefully.

2. Cut corner posts or uprights to the correct lengths.

3. Set corner posts or uprights firmly in the ground in a vertical position around the privy slab to a depth of 0.3-0.6m as shown in Figure 9a. Thoroughly tamp the ground after the posts are in place.

4. Build or weave together the screening material and secure it to the corner posts with vine, wire, or equivalent. Begin at the end corner post and work your way around the screen. The screen should touch the ground and be as high as the tops of the corner posts as shown in Figure 9b.

For a bamboo shelter with roof or roof and door:

1. Assemble all laborers, supplies, tools, and diagrams needed to begin construction. Study all diagrams carefully.

2. Build a foundation around the privy slab from bamboo poles 50-100mm in diameter. Notch the ends of the poles, fit them together, and tie them with wire or vine, as shown in Figure 10a.

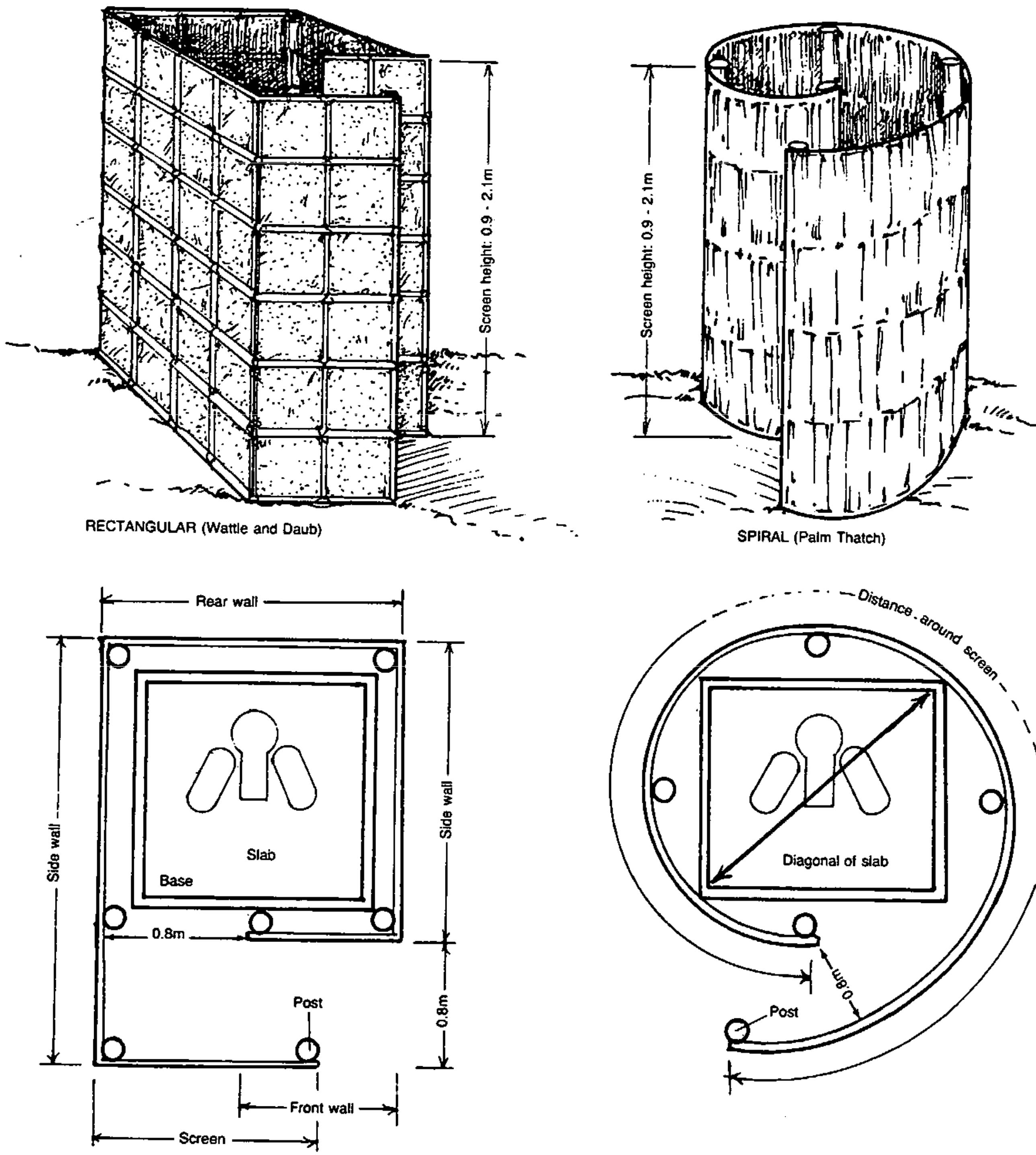


Figure 1. Simple Screen Shelters

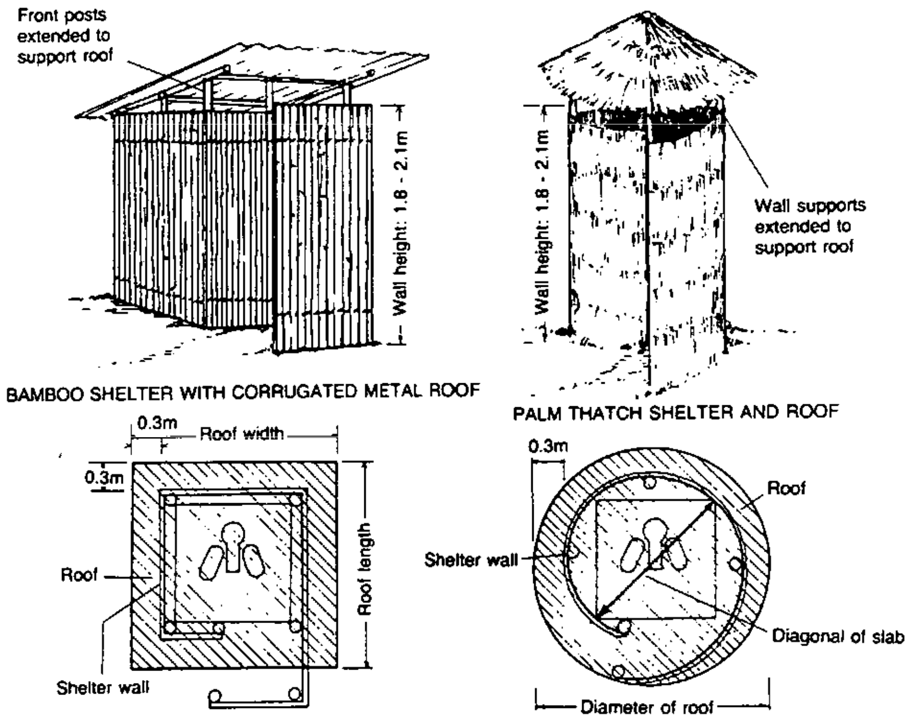


Figure 2. Privy Shelters with Roof

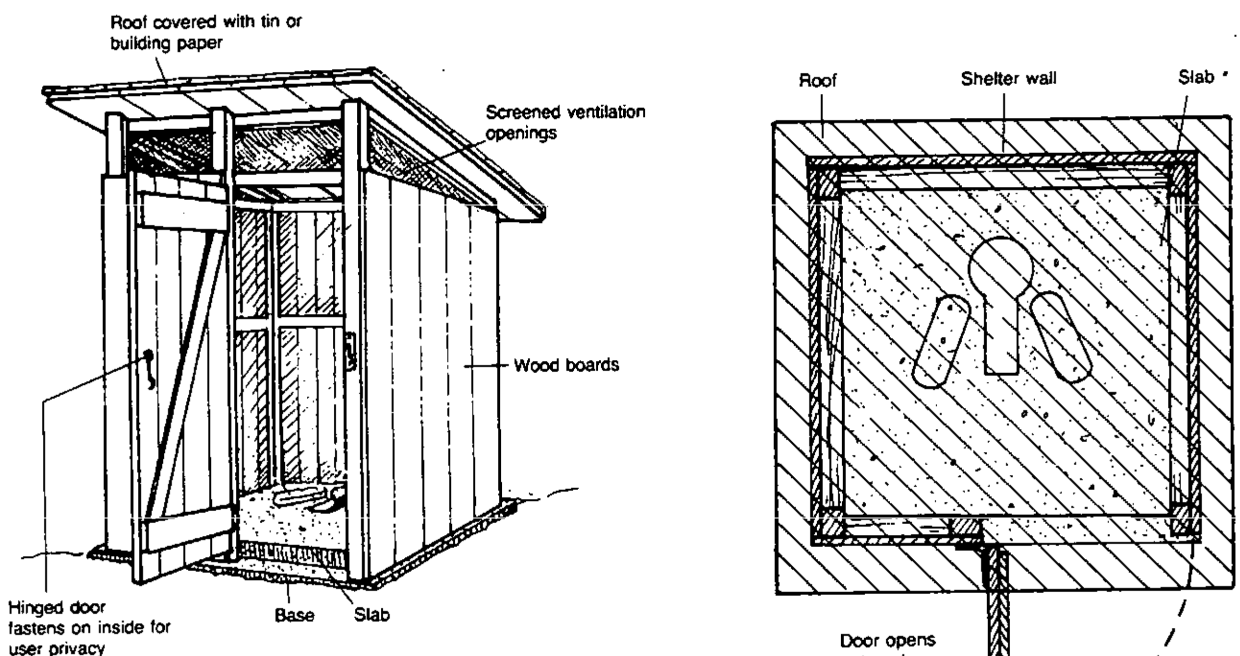


Figure 3. Fly-Proof with Screening and Door

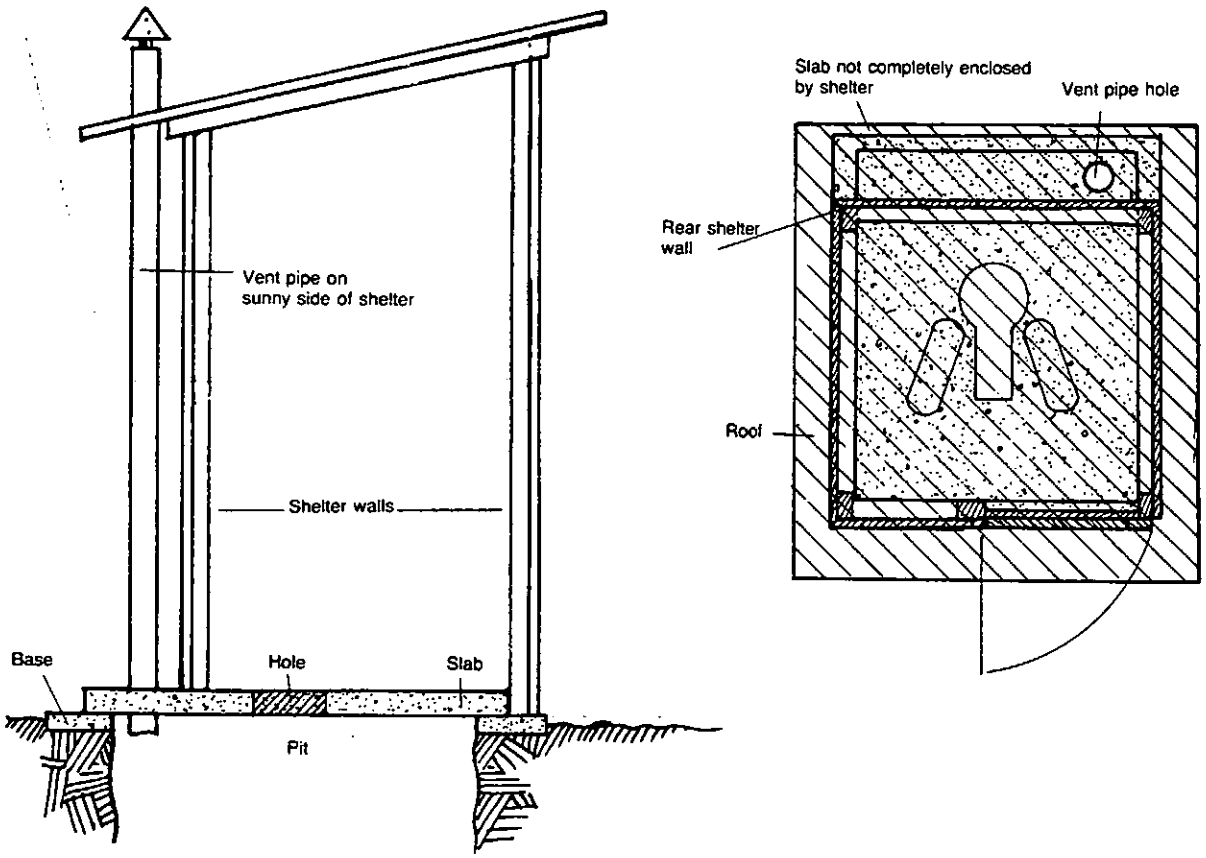


Figure 4. Shelter for Ventilated Privy

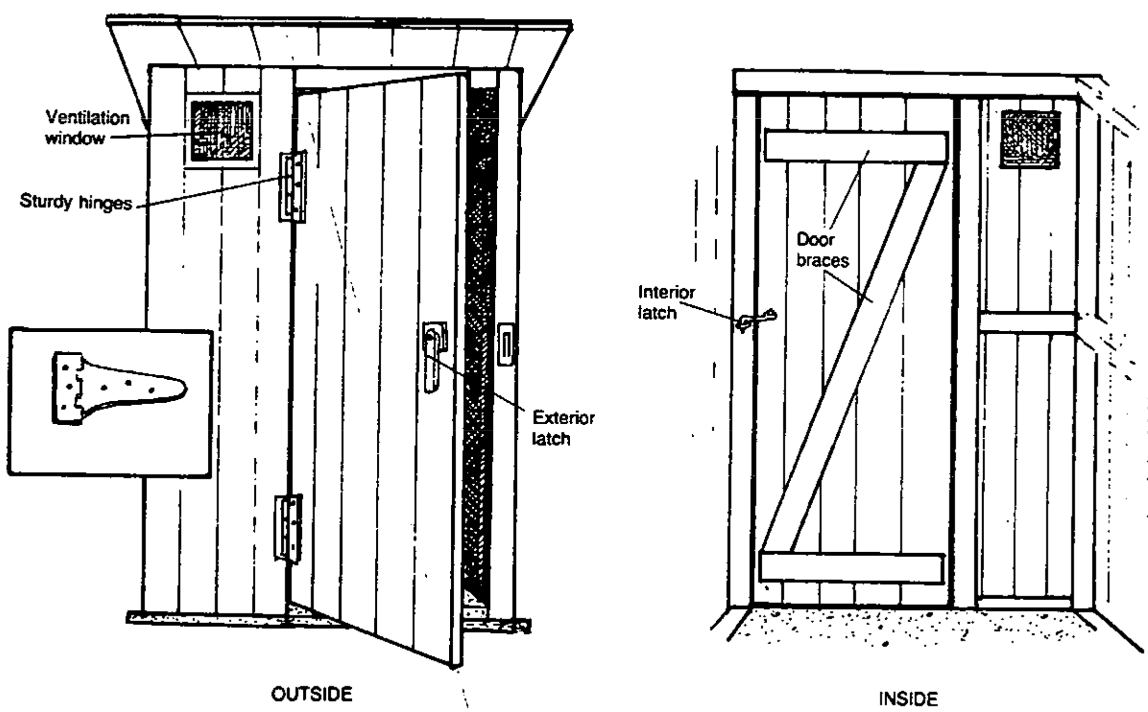


Figure 5. Detail of Door for Fly-Proof Shelter

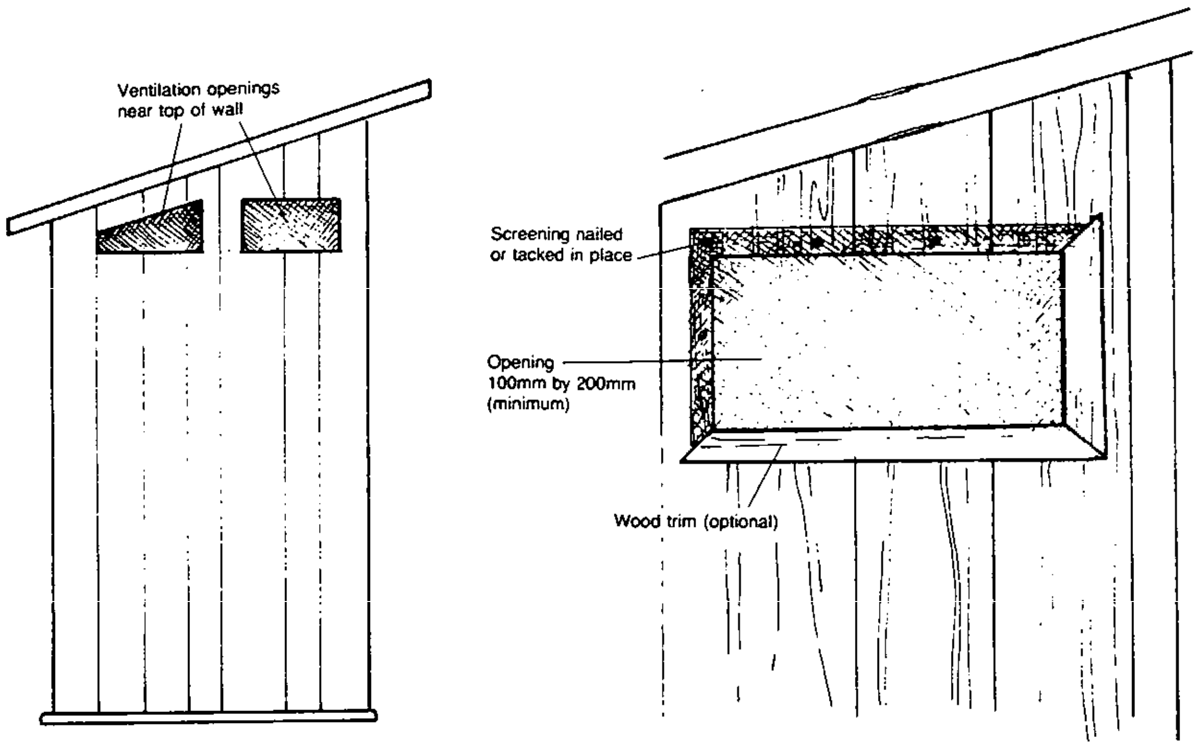


Figure 6. Fly-Proof Screening Covering Ventilation Openings

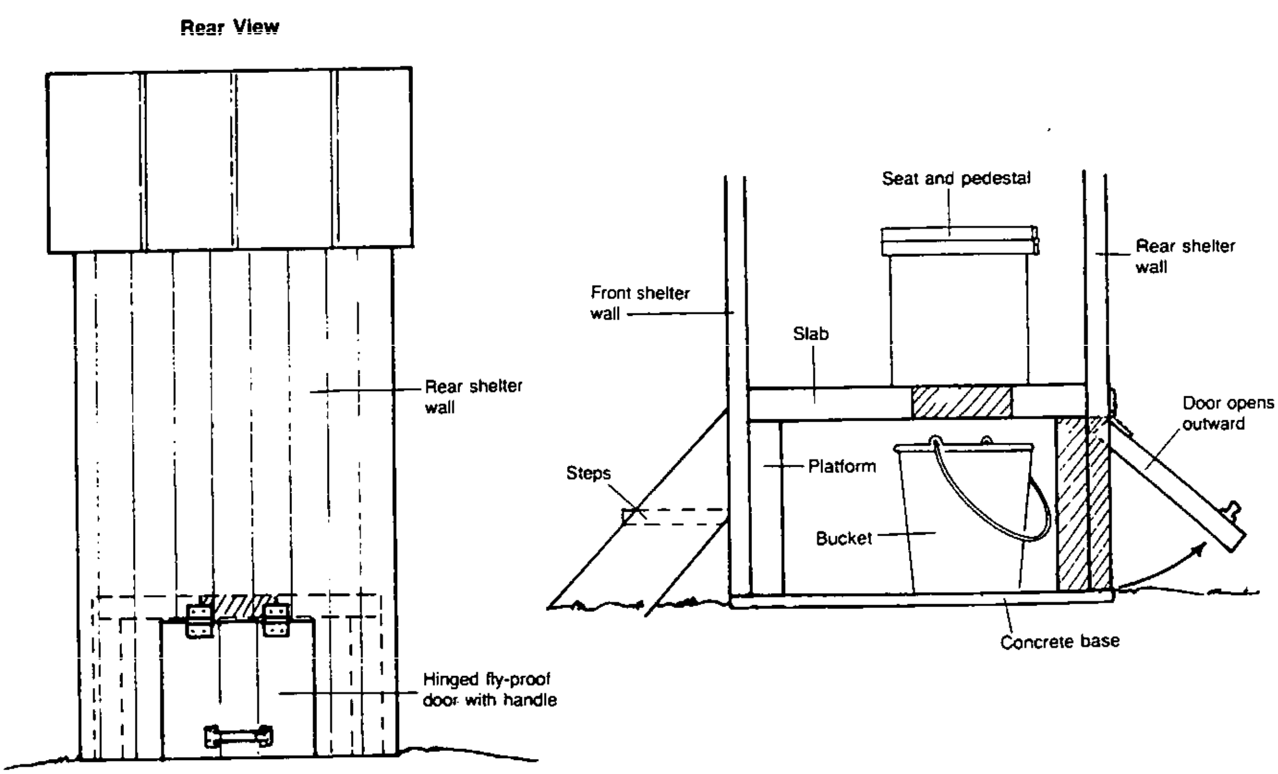


Figure 7. Detail of Shelter for Bucket Latrine

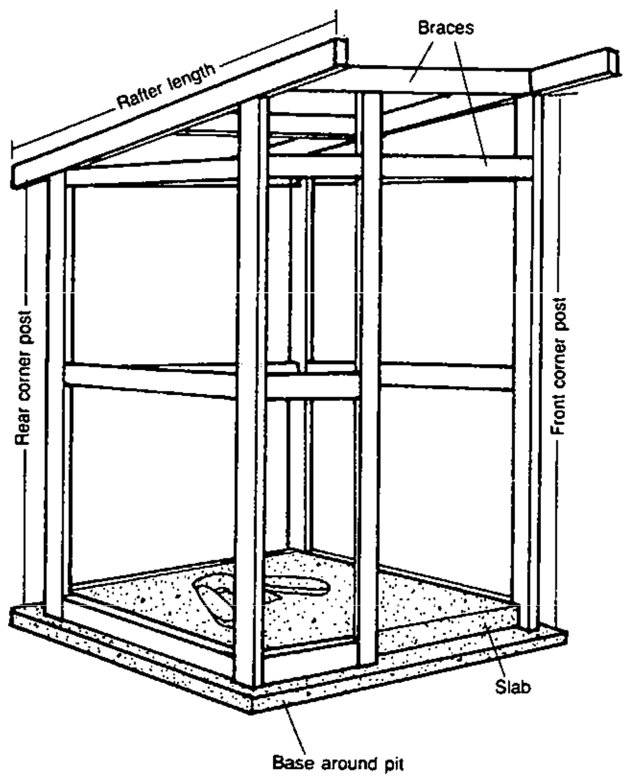


Figure 8a. Typical Shelter Framework Using Lumber

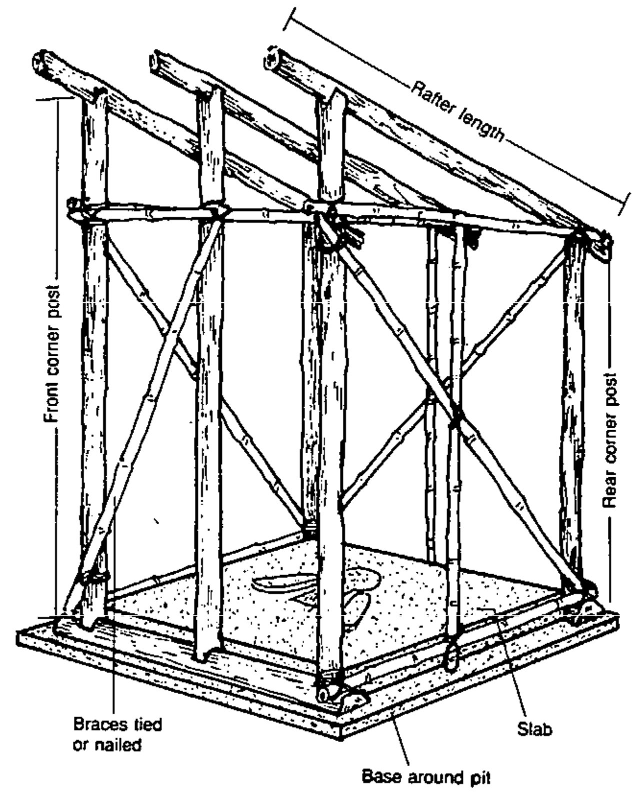


Figure 8b. Typical Shelter Framework Using Logs, Poles or Bamboo

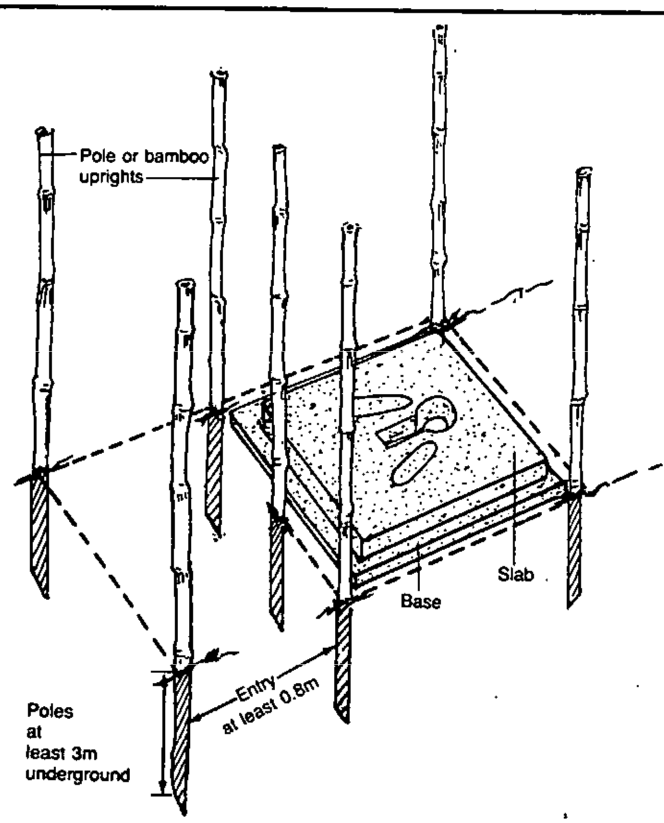


Figure 9a. Cornerposts for Screen Shelter

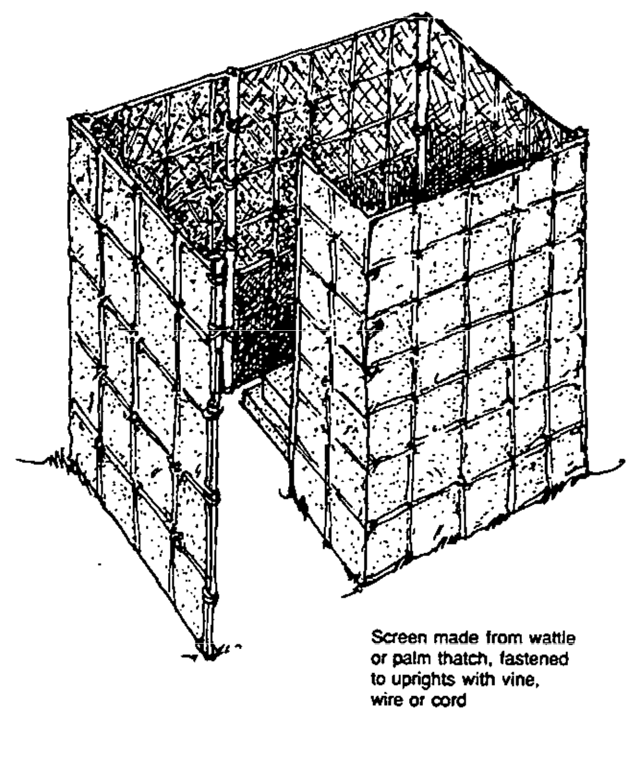
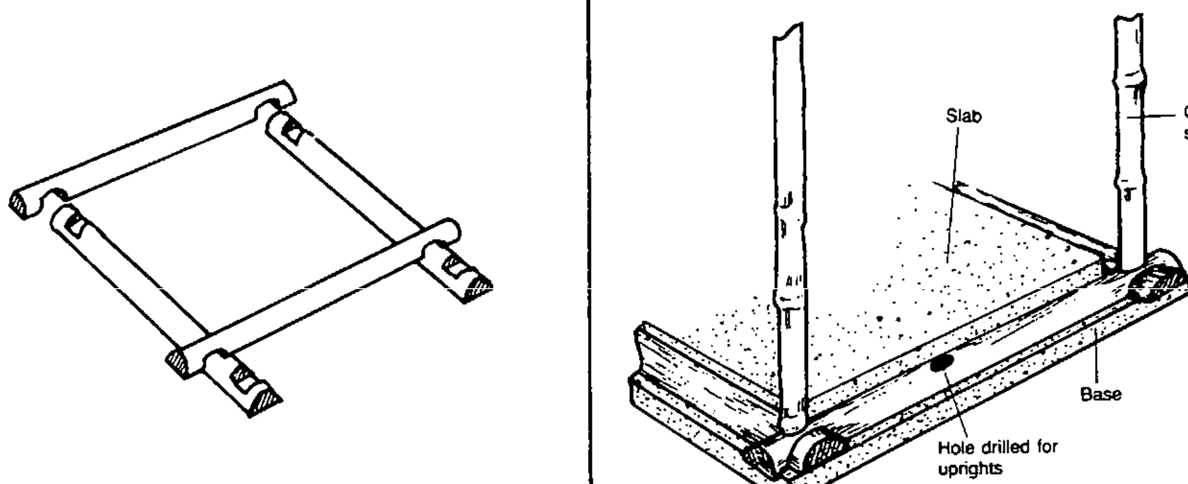


Figure 9b. Completed Screen Shelter



a. Poles notched to fit together

b. Poles on concrete base

Figure 10. Foundation for Bamboo Shelter

Table 1. Sample Materials List for Privy Shelter

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	______
	Laborer (carpentry skills)	1	______
Supplies	Foundation: logs, 1.5m long, 100mm diam.	4	______
	Corner posts: wood beams, 1.8m long, 50mm diam.	4	______
	Walls: wood boards, various lengths, 25mm thick	$13.2m^2$	______
	Roof: Corrugated metal	$4.2m^2$	______
	Screens flyproof for ventilation openings, 150 x 250mm	12	______
	Metal hinges	2	______
	Latch	1	______
	Nails	______	______
	Other	______	______
Tools	Measuring tape	1	______
	Hammer	1	______
	Saw	1	______
	Carpenter's level or equivalent (not essential but very useful)	1	______
	Carpenter's square or equivalent (not essential but very useful)	1	______
	Other	______	______

Total Cost = ______

Do Not Use The Quantities in the Sample - Calculate your Own

Table 2. Sample Work Plan for Building a Wood Privy with a Door

Time Estimate	Day	Task	Personnel	Tools and Materials
1 hour	1	Build foundation	Foreman; laborer with some carpentry skills	2 hammers; saw; nails; measuring tape (these will be needed throughout construction); 4 wood beams, 100mm by 100mm
1½ hours	1	Erect corner posts, uprights, and crossbraces	"	8 boards, 50mm by 100mm; 10 boards, 50mm by 50mm
½ hour	1	Build rafters	"	2 boards, 50mm by 100mm
3 hours	1	Build walls	"	14 square meters of boards, 25mm by 150mm
2 hours	2	Build roof	"	4 boards, 50mm by 50mm; 5 square meters of tin sheets; tin snips
1 hour	2	Build door and attach hinges and latch	"	1.7 square meters of boards, 25mm by 150mm; 3 boards, 25mm by 100mm; 2 metal hinges; screws and screwdriver; eyelet-and-hook latch
½ hour	2	Pick up scrap lumber, nails, and other leftover material	"	

3. Drill or cut holes in the foundation for the corner posts and uprights. Erect the posts, making sure they are vertical, and secure them to the foundation with wire or vine. Leave at least 0.8m space for the entryway or doorway. See Figure 10b. For a shelter with a door, the corner post and upright on each side of the doorway serve as the door frame.

4. Secure the crosspoles to the corner posts with wire or vine. The top crosspoles should be placed at the designed height of the walls. If the roof is raised for ventilation, the top crosspoles will be 100-150mm below the tops of the corner posts. For a shelter with a door, one crosspole will define the top of the doorway, which should be at least 2.0m high.

5. Secure the rafters to the corner posts with wire or vine. Rafters should extend about 0.3m beyond the front and rear walls.

6. Begin the screening wall, if there is one, by erecting two uprights as shown in Figure 11a. Bury the ends at least 0.3m in the ground and thoroughly tamp. Secure the crosspoles to the uprights.

7. Build the shelter walls and screening wall with bamboo, as shown in Figure 11b. Secure the bamboo to the crosspoles and uprights with wire or vine.

8. Build the roof with bamboo strips and palm thatch, as shown in Figure 11b. Start at the lower edge of the roof and work toward the higher edge, overlapping the thatch or palm leaves. The roof should extend about 0.3m beyond all walls.

9. Build a door, if there is one, with bamboo as shown in Figure 12. Attach the hinges, fasten the door to the door frame, and attach a latch, as described in the section on building special features.

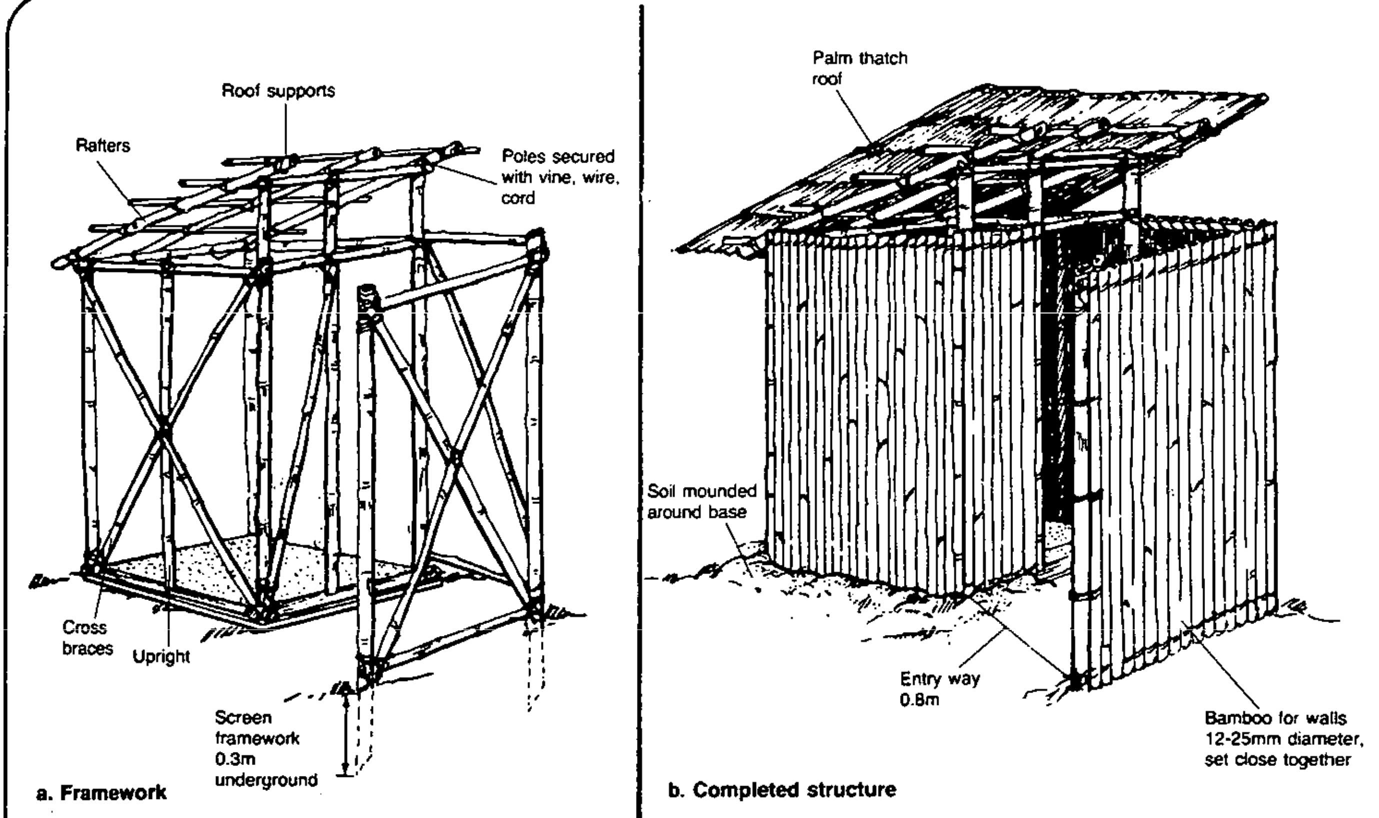


Figure 11. Construction of Bamboo Shelter with Screen and Roof

10. If the shelter has a door and is to be made fly-proof, cover all ventilation openings with screens, as described in the section on building special features.

11. Mound soil around the bottom of the walls to help keep out pests.

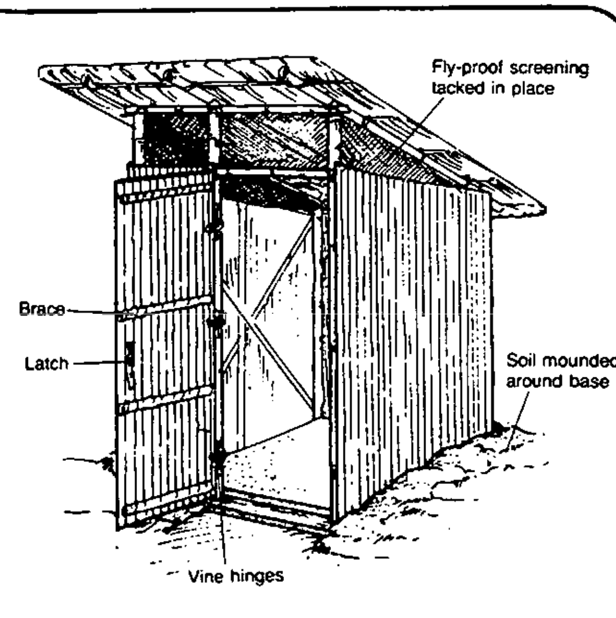


Figure 12. Bamboo Shelter with Door

For a wood shelter with a roof or roof and door:

1. Assemble all laborers, supplies, tools, and diagrams needed to begin construction. Study all diagrams carefully.

2. Build a foundation around the privy slab from wood beams 50-100mm in diameter as shown in Figures 13a and 13b.

3. Erect the corner posts and uprights, making sure they are vertical, and nail them securely to the

foundation. Leave at least 0.8m space for the entryway or doorway, as shown in Figure 14. For a shelter with a door, the corner post and upright on each side of the doorway serve as the door frame.

4. Nail crossbraces to the inside edges of the corner posts and uprights. The top crossbrace should be at the designed height of the walls. If the roof is to be raised for ventilation, the top crossbraces will be 100-150mm below the tops of the corner posts. For a shelter with a door, one crossbrace will define the top of the doorway, which should be at least 2.0m high.

5. Nail the rafters on top of the cornerposts. The rafters should extend about 0.3m beyond the shelter walls.

6. Begin the screening wall, if there is one, by erecting two uprights as shown in Figure 14. Bury the ends 0.3-0.6m in the ground and thoroughly tamp. Nail crossbraces to the inside edges of the uprights.

7. Build the walls and screening wall by nailing boards to the outside edges of the corner posts and uprights, as shown in Figure 15.

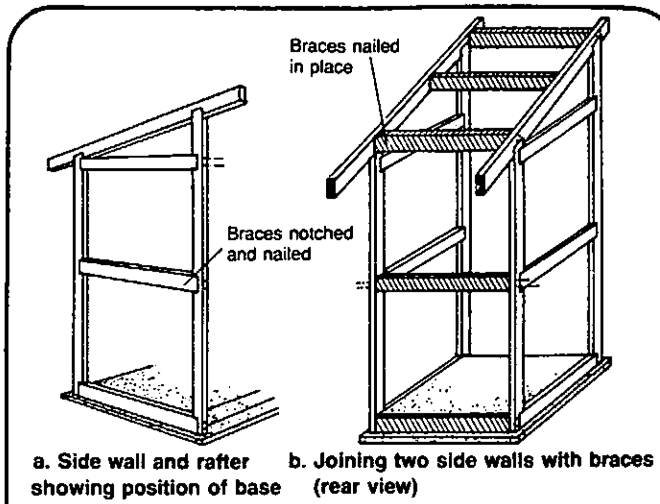


Figure 13. Framework for Wooden Shelter

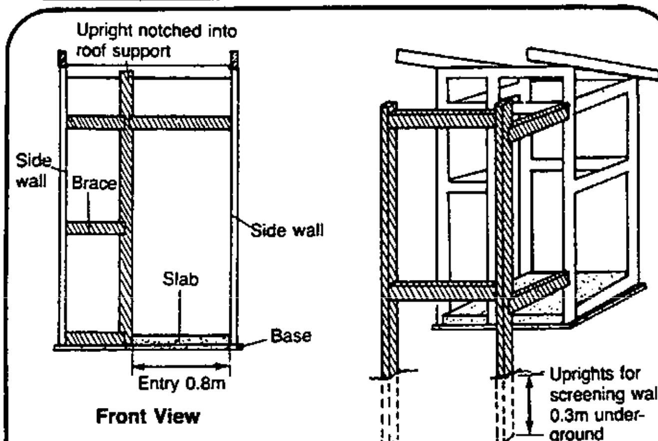


Figure 14. Framework for Wooden Shelter with Screen

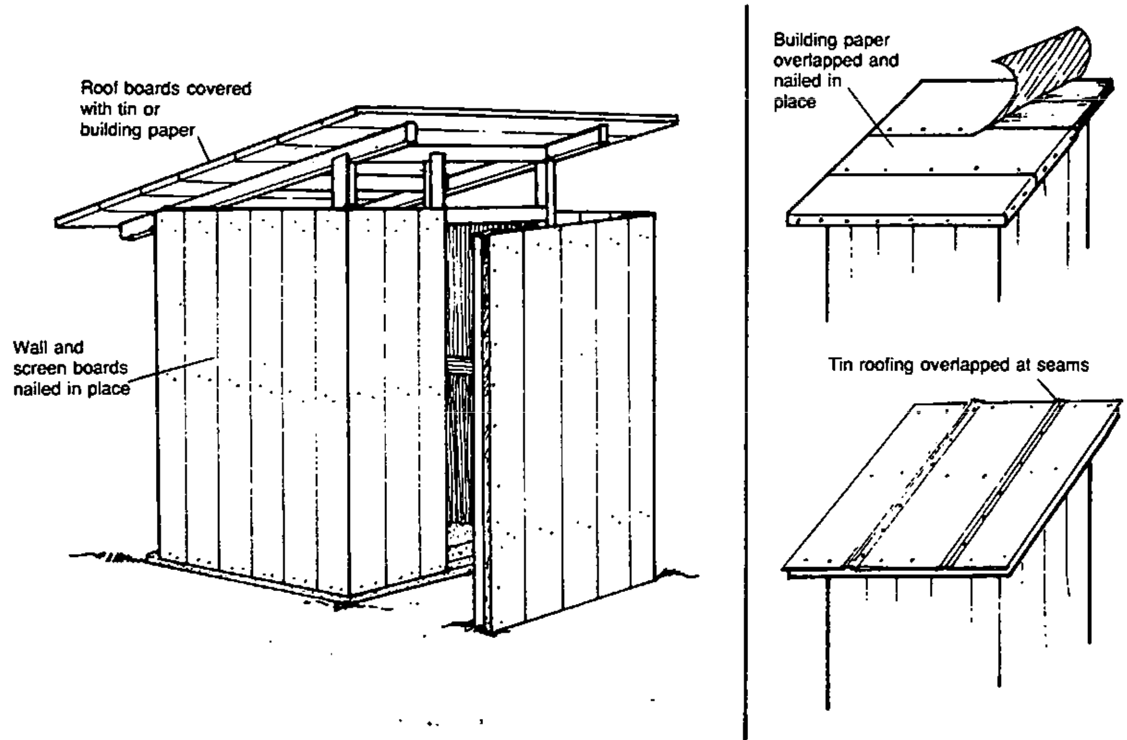


Figure 15. Completed Shelter

8. Build the roof by nailing crosspieces to the rafters, then nailing tin sheets to the crosspieces. Start from the lower edge of the roof and work toward the higher edge, overlapping the tin sheets as shown in Figure 15. The roof should extend about 0.3m beyond all walls.

9. Build a door, if there is one, with wood boards as shown in Figures 3 and 5. Attach the hinges, fasten the door to the door frame, and put on a latch as described in the section on building special features.

10. If the shelter has a door and is to be made fly-proof, cover all ventilation openings with screens as described in the section on building special features.

For a brick and mortar shelter with a roof or roof and door:

Since brick and mortar shelters should stand for more than 10 years, they are recommended for use with offset pit privies or compost toilets, which generally last that long. Because of the weight of brick and mortar shelters, they are not recommended for use with ventilated pit privies in which the back wall of the privy rests on the privy slab.

1. Assemble all laborers, supplies, tools, and diagrams needed to begin construction. Study all diagrams carefully.

2. Mortar a row of bricks to the base of the pit, mortaring the inside edge of the bricks to the privy slab.

3. Mortar a second row of bricks overlapping the first row as shown in Figure 16. Leave at least 0.8m space for the entry.

4. For a shelter with a door, build the door frame with wood beams 50mm thick by 100mm wide, and set it in place with a temporary brace as shown in Figure 17. Fasten L-shaped metal strips to each side of the door frame with nails or screws. The horizontal part of the strip will be mortared between the rows of bricks to hold the frame in place. Attach a second pair of L-shaped strips when the walls reach about half their height, and a third pair when the walls reach nearly the total height.

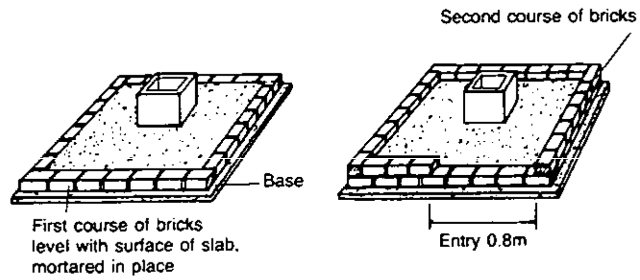


Figure 16. Foundation for Brick Shelter

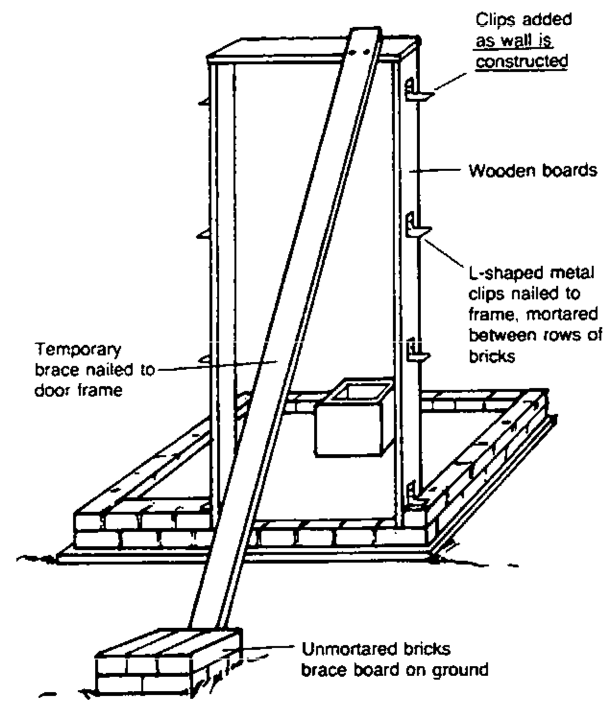


Figure 17. Framework for Entry or Door

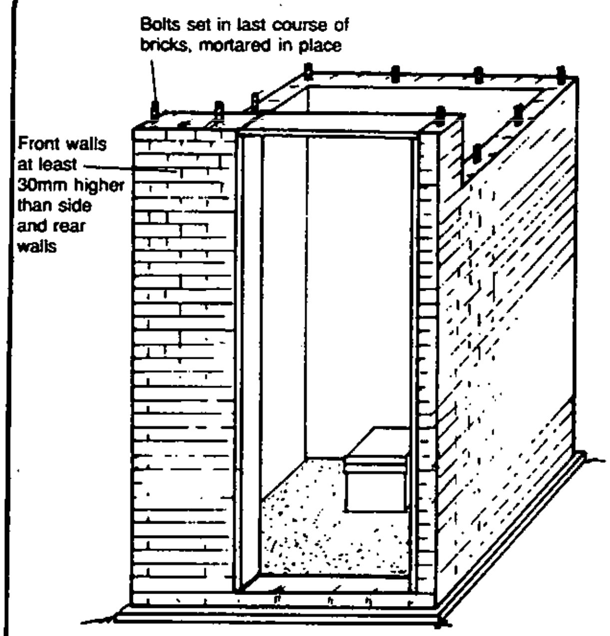


Figure 18. Constructing Brick Shelter

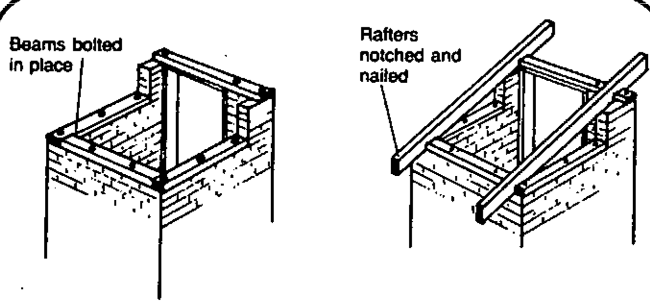


Figure 19. Roof for Brick Shelter

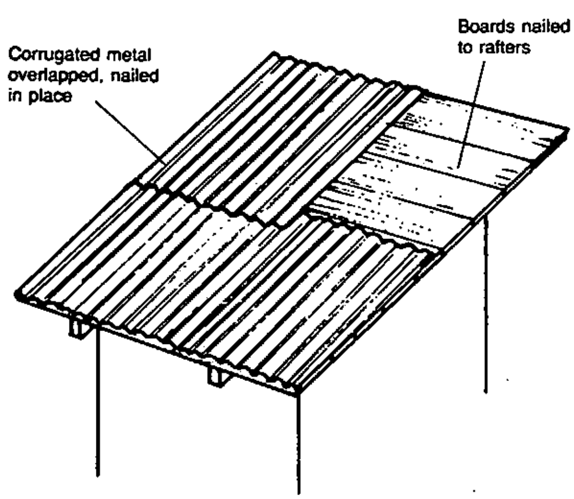


Figure 20. Corrugated Roofing

5. Continue laying rows of bricks up to the design height of the walls, being careful to keep the walls vertical.

6. Place bolts about 12mm diameter by at least 100mm long in the top bricks near the corners of each wall as shown in Figure 18. Mortar the bolts in place with the threaded ends up.

7. Allow a day or two for the mortar to set. Remove the temporary brace.

8. Drill or burn holes in wood beams 50mm thick by 100mm wide, matching the size and location of the holes to the bolts sticking up from the bricks. Set these top beams in place and fasten them to the bolts securely using nuts as shown in Figure 19.

9. Nail the rafters to the top beams. The rafters should extend about 0.3m beyond the walls as shown in Figure 19.

10. Build the roof by nailing cross-pieces to the rafters and nailing corrugated metal sheets to the cross-pieces. The furrows in the metal should be lined up in the direction of the roof slope. Start from the lower edge of the roof and work toward the higher edge, overlapping the corrugated sheets as shown in Figure 20. The roof should extend about 0.3m beyond all walls.

11. Build a screening wall, if there is one, by nailing uprights to the wood beam foundation. Nail the crossbraces to the uprights and to the top beam of the shelter. Nail the boards to the uprights as shown in Figure 21a.

12. Build a door, if there is one, with wood boards as shown in Figure 21b. Attach the hinges, fasten the door to the door frame, and put on a latch, as described in the section on building special features.

13. If the shelter has a door and is to be made fly-proof, cover all ventilation openings with screen as described in the section on building special features.

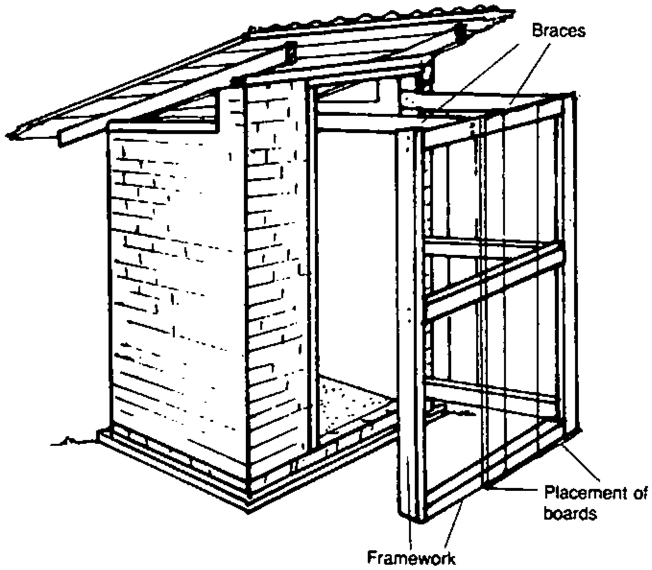


Figure 21a. Brick Shelter with Screening Wall

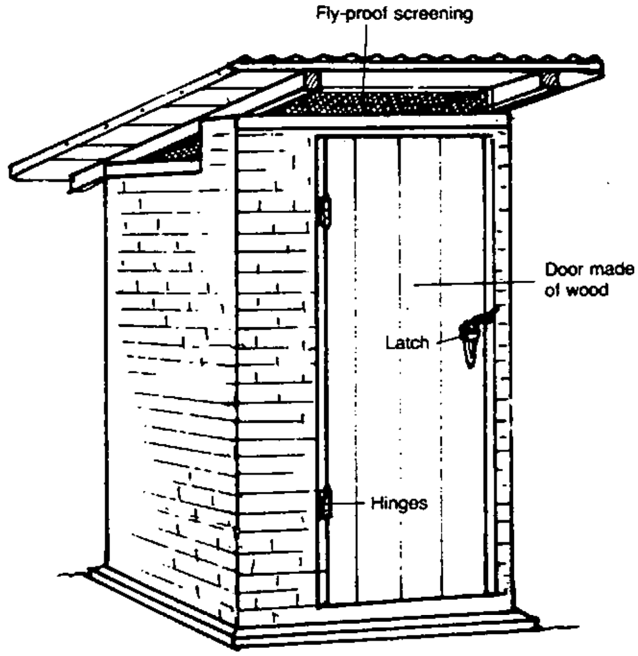


Figure 21b. Brick Shelter with Door

Building Special Features

Ventilation Openings. If the roof is not raised above the walls for ventilation, and ventilation openings are desired, cut openings near the tops of the walls. The openings should be about 200mm wide by 100mm high and spaced around the walls about 150mm apart as shown in Figure 6.

Screens. Screens covering ventilation openings must have mesh no larger than 2mm in order to keep out flies. Screens should be made of rust-proof material such as bronze, copper, plastic, or aluminum. If the screens are not rust-proof, paint them to prevent rust.

To cover a ventilation opening, cut a section of screen large enough to overlap the opening by 25mm on all sides and nail it in place as shown in Figure 6.

Door Hinges. Before attaching the hinges, hold the door in place and mark the door and the door frame where the hinges should be placed. Hinges should be about 150mm from the top of the door and 250mm from the bottom. They should be placed so that the door opens outward, if this is culturally acceptable.

If you are using prefabricated metal hinges with removeable pins, remove the pin from each hinge and separate the two halves. Attach one half with screws or nails to the door frame and the other half to the door. Raise the door in place, fit the halves of the hinges together, and reinsert the pin in each hinge.

If you are using a strap hinge, install it on the door. Lift the door into place and use a temporary support to hold it off the floor in its correct position. Accurately mark the proper location of the hinge on the door frame. Take the hinge apart and install the frame half. Then, hang the door.

For hinges of stiff leather such as soles of discarded boots or sandals, nail the hinges to the door, raise the door in place, and nail the hinges to the door frame.

For hinges made of vine, raise the door in place and tie the vine around the bamboo poles of the door and door frame. Leave enough slack so the door can be easily opened and closed.

Door Latch. For an eyelet-and-hook latch, secure the eyelet to the inside

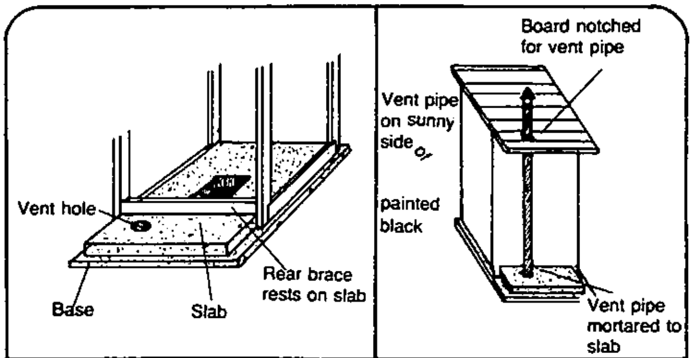


Figure 22. Constructing a Ventilated Shelter

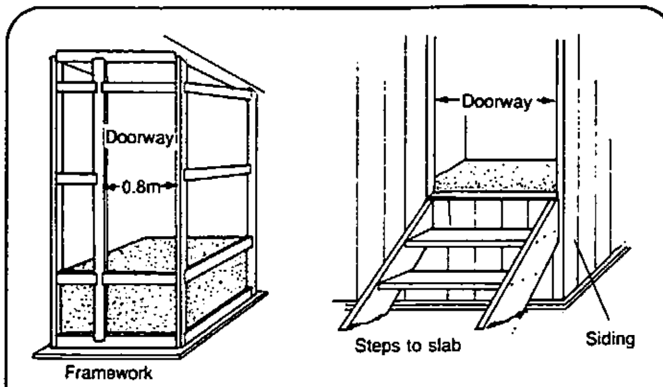


Figure 23. Construction of Shelter for Bucket Latrine

of the door frame, and attach the hook to the inside of the door. The latch should be just above the middle of the door. For a bar latch, nail a piece of wood to the inside of the door. For a peg-and-loop latch, fasten the bamboo peg to the inside of the door frame and tie the vine loop to the inside of the door.

Vent Pipe. The vent pipe is mortared to the vent hole in the privy slab and attached to the shelter roof or the wall, if extra support is needed. The pipe should be vertical. If the roof overhangs the vent hole, cut a hole or notch in the roof to accommodate the vent pipe as shown in Figure 22. Attach the vent pipe to the roof and wall with either a metal band and screws, wood and nails, wire, or vine.

Shelter for Off-set Pit Privy. The foundation for the shelter must rest on the ground and abut the platform which supports the privy slab. Level the ground and thoroughly tamp it before building the foundation. The bottom of the privy walls begin at the foundation and completely enclose the platform. The bottom of the doorway or entryway begins at the privy slab and is higher than the foundation. For additional details see "Constructing Slabs for Privies," SAN.1.C.1.

Shelter for Bucket Latrine. The foundation for the shelter rests on the platform base and abuts the platform. Build the shelter walls to completely enclose the platform. The bottom of the entryway is level with the privy slab as shown in Figure 23. A fly-proof door for removal of the bucket

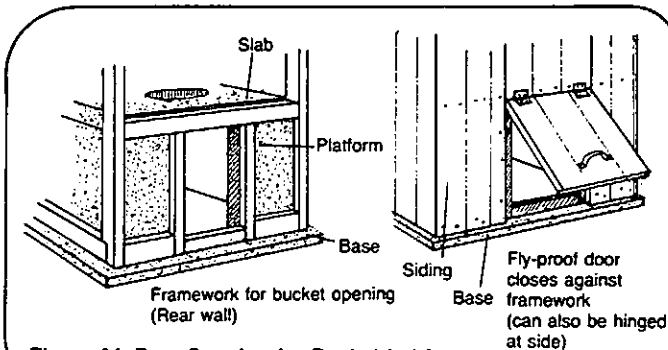


Figure 24. Rear Opening for Bucket Latrine

must be built into either the rear of the platform or the rear wall of the shelter. The door should have hinges and a latch to keep it tightly closed. If the door is built into the platform, leave an opening in the rear shelter wall as shown in Figure 24. For additional details, see "Constructing Bucket Latrines," SAN.1.C.5.

Shelter for a Compost Toilet. The foundation for the shelter rests on the base of the double vault and abuts the vault. Build the shelter walls to completely enclose the platform. The bottom of the entryway is level with the privy slab as shown in Figure 25. Airtight doors will be built into the rear of the vault. Leave openings in the rear shelter wall to allow access to these doors as shown in Figure 25. For additional details, see "Constructing Compost Toilets," SAN.1.C.6.

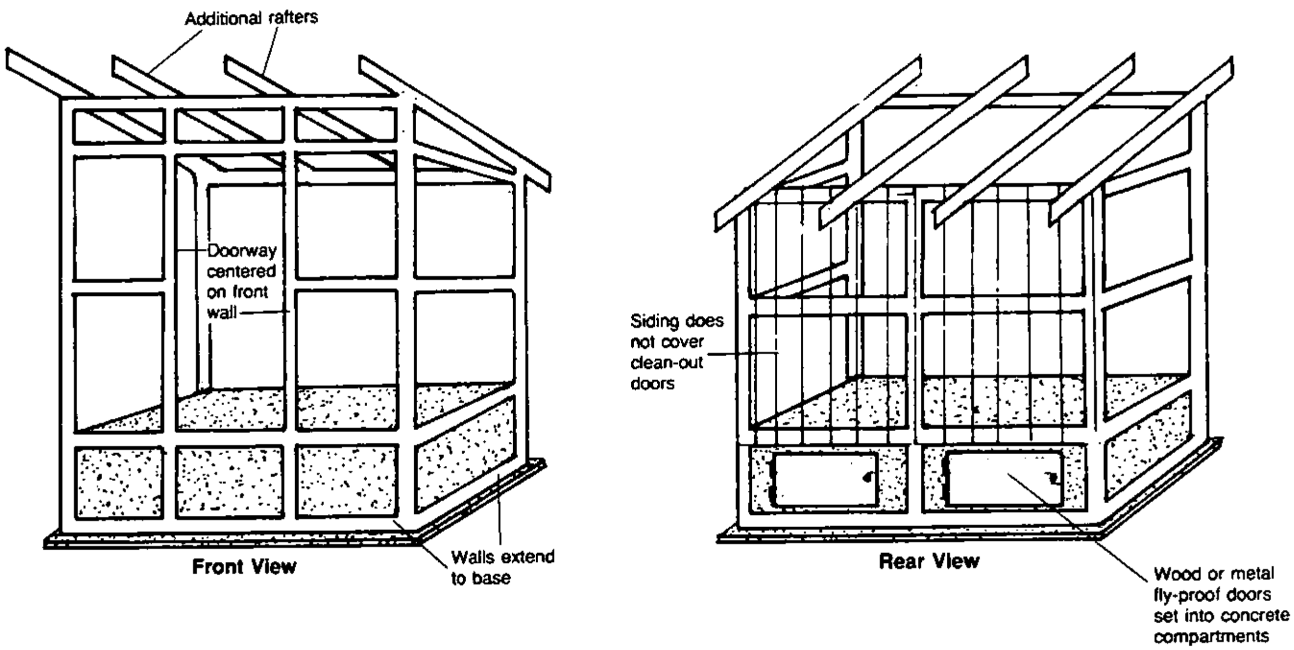


Figure 25. Framework Pattern for Composting Toilet

Notes

Water for the World

Designing Compost Toilets
Technical Note No. SAN. 1.D.6

A compost toilet consists of a pair of waterproof vaults that receive excreta, ashes, sawdust, straw, and grass. Each vault is equipped with a slab for defecating, a rear opening for removing compost, and a hole for a vent pipe. Designing a compost toilet involves selecting a location, calculating the size of the vaults, and determining the labor, materials, and tools needed for construction. The products of the design process are: (1) a location map, (2) design drawings of the compost toilet, and (3) a materials list. These products should be given to the construction foreman before construction begins.

This technical note describes how to design a compost toilet and arrive at these three end-products. Read the entire technical note before beginning the design process.

Useful Definitions

BACTERIAL ACTION - The process of organic matter being digested and broken down by tiny organisms.

COMPOST - A dark, fairly dry, crumbly, odorless material that is produced by sealing excreta, ashes, woodchips, straw, and vegetable wastes for 6-12 months in the vault of a compost toilet. Compost can be used to fertilize crops.

Materials Needed

Measuring tape - To obtain accurate field information for a location map.

Ruler - To draw a location map.

Location

The compost toilet should be on fairly level ground and at least:

6m from the nearest dwelling,
6m from the nearest water supply,
3m from the nearest property line.

Select a site that allows easy access to the toilet for use and for removing compost. If possible, the site should be downwind from the dwelling as there will be an odor. When the site has been selected, draw a location map similar to Figure 1 showing correct distances from the compost toilet to dwellings, water supplies, property lines, and roads. Give this map to the construction foreman before construction begins.

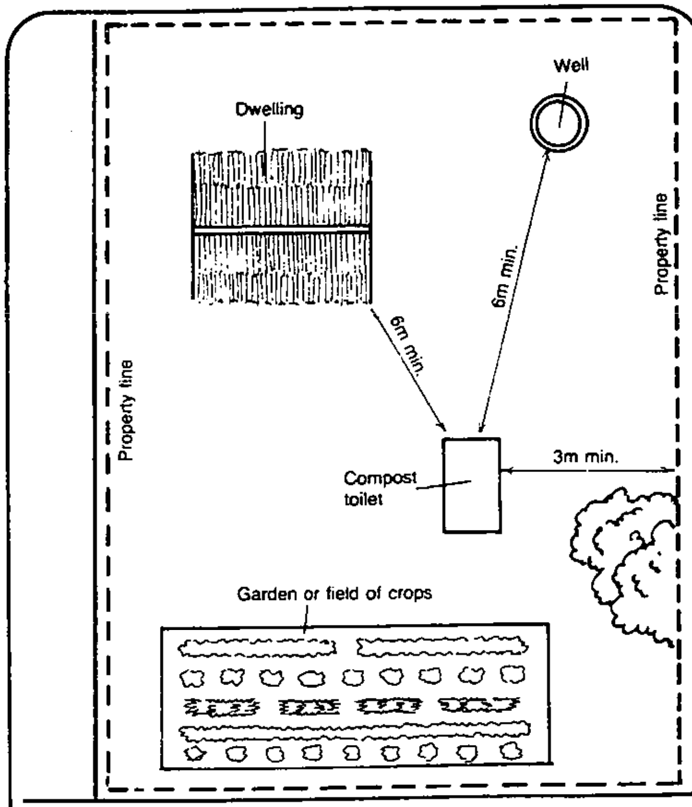


Figure 1. Location Map

General Design Information

A double-vault compost toilet is usually made from reinforced concrete or brick and mortar, and it rests on a base of similar material. See Figure 2. The vaults must be waterproof. If they are made from brick and mortar, the inside walls should be coated with a 12-25mm thick coating of cement plaster. The minimum thickness of the walls and base are shown in Table 1.

Table 1. Walls and Base Design Criteria

Feature	Minimum Thickness
Outside Wall	75mm
Inside Wall (between vaults)	150mm
Base	100mm

Design the vaults to be the same size. The maximum dimensions of each vault are shown in Table 2.

The rear wall of each vault must have an opening at least 0.4m by 0.4m for removal of compost, and a hole about 100mm in diameter for a vent pipe. The openings must have wood or metal covers that are larger than the openings themselves. The covers should be braced. The vent pipes are generally 100mm in diameter and made of galvanized metal.

The compost toilet may have two vent pipes which are permanently installed, or one vent pipe which is moved to whichever vault is in use. The vent hole in the vault not in use must be covered with wood or metal.

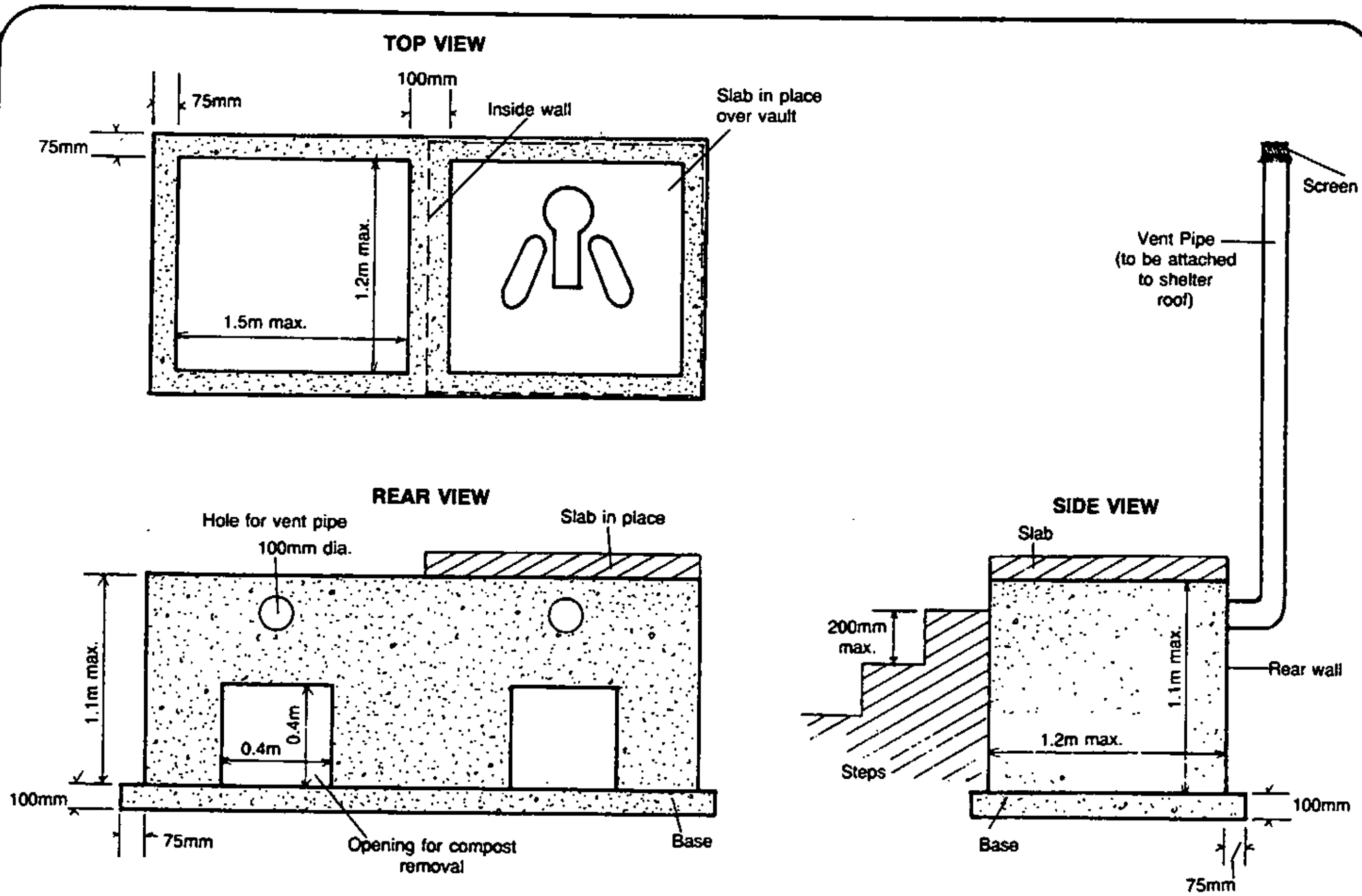


Figure 2. Compost Toilet

Table 2. Vault Dimensions

Feature	Maximum Dimension
Inside Height	1.1m
Inside Length (front to rear)	1.2m
Inside Width	1.5m

Design the steps leading up to the compost toilet so that the maximum height of each step is 200mm. See Figure 2.

Design the slab so that it is flush with the outside walls of the compost toilet. For details, see "Designing Slabs for Privies," SAN.1.D.1.

Calculating Size

Volume. Each vault must be large enough so that it takes about one year to become 3/4 full. Each person produces about $0.2m^3$ of waste per year, taking into account volume reduction to excreta and grass clippings by bacterial action. This number is multiplied by 1.33 because the vault is filled with soil and sealed when it becomes 3/4 full. Therefore, the volume factor equals:

$0.2m^3 \times 1.33 = 0.27m^3$ per person.

To calculate the required volume of each vault, multiply the volume factor times the number of persons using the compost toilet. For example, if the toilet is to serve a family of five, the volume of each vault must be five times $0.27m^3$:

$5 \times 0.27m^3 = 1.35m^3$ (Worksheet A, Lines 1-2).

Because of the limitations on dimensions shown in Table 2, this type of compost toilet will serve a maximum of seven persons. If eight or more persons must be served, design more than one toilet.

Inside Dimensions of Each Vault. Determine the inside dimensions of each vault based on the required volume and on the information in Table 2. The volume equals the inside height times the inside length times the inside width. For example, if the required volume of each vault is $1.35m^3$, the inside dimensions could be:

1.00m (height) x 1.10m (length) x 1.23m (width) = $1.35m^3$ (Worksheet A, Lines 3-5).

Outside Dimensions of Toilet. The outside dimensions of the toilet depend on the inside dimensions of each vault and on the information in Table 1.

The outside height equals the inside height.

The outside length (front to rear) equals the inside length plus two times the outside wall thickness.

The outside width equals two times the inside width plus two times the outside wall thickness plus the thickness of the inside wall between the vaults.

For example, if the inside dimensions of each vault are:

height = 1.00m, length = 1.10m, width = 1.23m, then the outside dimensions of the compost toilet are:

outside height = 1.00m;
outside length = 1.10m + (2 x 0.075m) = 1.10m + 0.15m = 1.25m;
outside width = (2 x 1.23m) + (2 x 0.075m) + 0.15m = 2.46m + 0.15m + 0.15m = 2.76m (Worksheet A, Lines 6-8).

Dimensions of Base. The dimensions of the base are as follows:

length (front to rear) = toilet length plus 0.15m,
width = toilet width plus 0.15m.

This leaves a 75mm area around the base to support the privy shelter. For example, if the outside dimensions of the toilet are:

length = 1.25m, width = 2.76m, then the dimensions of the base are:

length (front to rear) = 1.25m + 0.15m = 1.40m,
width = 2.76m + 0.15m = 2.91m (Worksheet A, Lines 9-10).

Dimensions of Slabs. Each vault is covered with a squatting or sitting slab. For design criteria, see "Designing Slabs for Privies," SAN.1.D.1. The outside dimensions of each slab are as follows:

length (front to rear) = compost toilet length;
width = compost toilet width divided by two. For example, if the dimensions of the toilet are:

length = 1.25m, width = 2.76m, then the dimensions of the slab are:

length = 1.25m
width = $\frac{2.76m}{2}$ = 1.38m (Worksheet A, Lines 11-12).

When all dimensions have been calculated, draw up a plan view similar to Figure 2 showing correct inside and outside dimensions. Give this drawing to the construction foreman before construction begins.

Determining Materials, Tools and Labor

The walls and base of a compost toilet are made from reinforced concrete or brick and mortar. The slab is made from reinforced concrete. Concrete walls and base require cement, sand, gravel, and water; containers and tools for mixing and smoothing concrete; reinforcing materials; wood, hammer, saw, and nails for building forms; and at least one worker with some experience with concrete. See "Designing Septic Tanks," SAN.2.D.3, for complete details and specifications on concrete ingredients and reinforcing materials.

Brick and mortar walls and base require bricks or concrete blocks; cement, sand, and water for mortar and cement plaster; containers and tools for mixing and spreading mortar; and at least one worker with some experience with concrete.

A concrete slab requires the same materials, tools, and workers as for concrete walls and base.

Quantities. The quantities of materials needed can be estimated by adding the volumes of the slabs, outside walls, inside wall, and base.

Volume of slabs: see "Designing Slabs for Privies," SAN.1.D.1.
Volume of outside walls = 2 x [(length x height x thickness) + (width x height x thickness)].
Volume of inside wall = height times length times wall thickness (0.15m).
Volume of base = base length times base width times base thickness (0.10m).

For example, if the outside dimensions of the compost toilet are: height = 1.00m, length = 1.25m, width = 2.76m, base length = 0.40m, base width = 2.91m, then the approximate volume of materials equals:

volume of slabs

+ volume of outside walls = 2 x [(1.25m x 1.00m x 0.075m) + (2.76m x 1.00m x 0.075m)] = 2 x (0.094 + 0.207) = $0.60m^3$

+ volume of inside wall = 1.00m x 1.25m x 0.15m = $0.19m^3$

+ volume of base = 1.4m x 2.91m x 0.10m = $0.41m^3$.

Total volume equals volume of slabs + $0.60m^3$ + $0.19m^3$ + $0.41m^3$ = volume of slabs + $1.20m^3$ (Worksheet A, Lines 13-17).

When all materials, tools, and labor requirements have been determined, draw up a materials list similar to Table 3 and give it to the construction foreman before construction begins.

In summary, give the construction foreman a location map similar to Figure 1, design drawings similar to Figure 2, and a materials list similar to Table 3.

Table 3. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	____
	Laborer (skilled with concrete)	1	____
	Laborer (unskilled)	1	____
Supplies	Wood (for forms)	____	____
	Nails (for forms)	____	____
	Cement (Portland)	____	____
	Sand (clean, sized fine to 6mm)	____	____
	Gravel (clean, sized 6-25mm)	____	____
	Water (clear)	____	____
	Reinforcing material	____	____
	Squatting slabs	____	____
	Vent pipes (with screens)	____	____
	Tin sheets (to cover rear wall openings)	____	____
	Other		
Tools	Measuring tape	1	____
	Hammer	1	____
	Saw	1	____
	Shovels	2	____
	Trowel	1	____
	Container for mixing concrete	2	____
	Carpenter's level or equivalent (optional)	1	____
	Carpenter's square or equivalent (optional)	1	____
	Tar or equivalent (for sealing covers over rear openings)	____	____
	Other		

Total Estimated Cost = ____

Worksheet A. Compost Toilet Calculations

1. Number of persons using compost toilet = 5

2. Volume of each vault = $0.27m^3$ x Line 1 = $0.27m^3$ x 5 = 1.35 m^3

Inside Dimensions of Each Vault

3. Proposed height = 100 m

4. Proposed length (front to rear) = 1.10 m

5. Required width = $\frac{\text{Line 2}}{\text{Line 3 x Line 4}} = \frac{(1.35m^3)}{(1.00m) \times (1.10m)}$ = 1.23 m

Outside Dimensions of Compost Toilet

6. Height = Line 3 = 1.00 m

7. Length (front to rear) = Line 4 + (2 x 0.075m) = 1.10 m + 0.15m + 1.25 m

8. Width = (2 x Line 5) + (2 x 0.075m) + 0.15m = (2 x 1.23 m) + 0.15m + 1.15m = 2.46 m + 0.30m = 2.76 m

Dimensions of Base

9. Length (front to rear) = Line 7 + 0.15m = 1.25 m + 0.15m = 1.40 m

10. Width = Line 8 + 0.15m = 2.76 m + 0.15m = 2.91 m

Dimensions of Each Slab

11. Length (front to rear) = Line 7 = 1.25 m

12. Width = $\frac{\text{Line 8}}{2} = \frac{(276m)}{2}$ = 1.38 m

Quantities

13. Volume of slabs - see "Designing Slabs for Privies," SAN.1.D.1

14. Volume of outside walls = 2 x [(Line 6 x Line 7 x 0.075m) + (Line 6 x Line 8 x 0.075m)]

= 2 x [(1.00 m x 1.25 m x 0.075m) + (100 m x 2.76 m x 0.075m)]

= 2 x (0.09 m^3 + 0.21 m^3) = 2 x 0.30 m^3 = 0.60 m^3

15. Volume of inside wall = Line 6 x Line 7 x 0.15m = 1.00 m x 1.25 m x 0.15m = 0.19 m^3

16. Volume of base = Line 9 x Line 10 x 0.10m = 1.40 m x 2.91 m x 0.10m = 0.41 m^3

17. Total volume - volume of slabs + line 14 + Line 15 + Line 16 =
volume of slabs + 0.60 m^3 + 0.19 m^3 + 0.41 m^3 =
volume of slabs + 1.20 m^3

Water for the World

Simple Methods of Washwater Disposal

Technical Note No. SAN. 1.M.2

Some method of washwater disposal is important wherever water is used inside or near a dwelling for bathing, washing, or cooking. Simple disposal methods confine washwater to a sump, pit, or trench and allow it to soak safely into the ground. This reduces the chance of contaminating water supplies and prevents mosquitoes from breeding by eliminating surface pools. All of these methods are inexpensive, easy to build, and can be made from locally available materials.

This technical note describes three simple methods of washwater disposal: sump, soakage pit, and soakage trench.

Useful Definitions

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria from washwater.

PERMEABLE - Allowing liquid to soak in.

WASHWATER - Water that has been used for bathing or washing clothes, dishes or kitchen utensils.

Sump

There are two types of sump: pit and drum. The pit-type, shown in Figure 1, is a hole 0.5-1m deep dug in permeable soil, lined with concrete blocks, bricks or stones, and covered with a lid to keep out flies and mosquitoes and to prevent children from falling in. The bottom of the sump is covered with 50-100mm of gravel or crushed rock.

The drum-type sump shown in Figure 2 uses a 200-liter steel drum with holes punched in the sides and bottom. A hole large enough to hold the drum is dug in permeable soil, and the drum is lowered into it and covered with a lid.

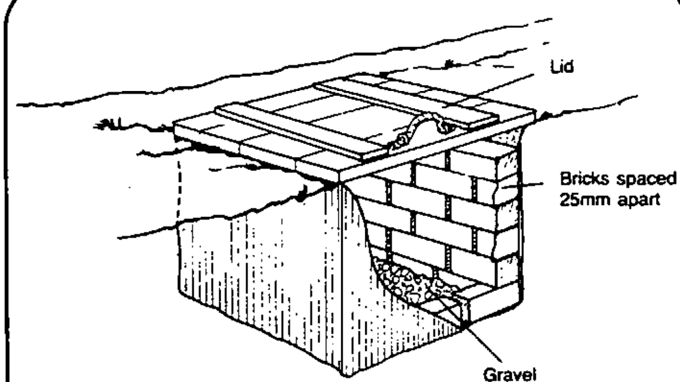


Figure 1. Pit-Type Sump

Washwater is poured directly into a sump and gradually soaks into the ground. Sumps are to be used only where there are 5 liters or less of washwater per person per day. Larger quantities of washwater require a soakage pit or soakage trench.

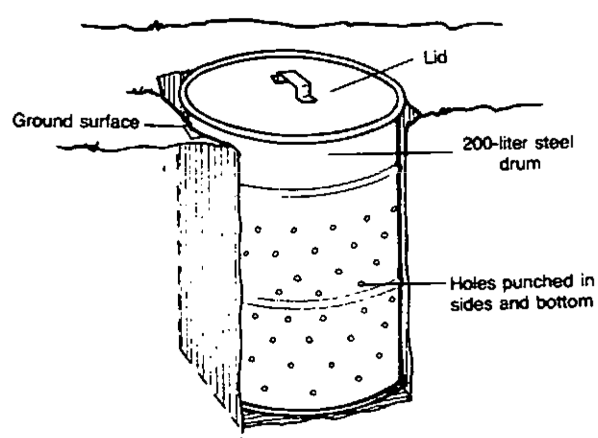


Figure 2. Drum-Type Sump

Soakage Pit

A soakage pit, shown in Figure 3, is a medium to large hole in permeable soil that is filled with rocks, equipped with a pipeline, covered with straw, and mounded with dirt. The rocks prevent the pit walls from collapsing and allow washwater to drain through to the sides and bottom of the pit. The straw prevents soil from sifting between the rocks and clogging the flow of washwater. The pipe carries washwater from a sink or drain in the dwelling, or excess liquid run-off from an aqua privy. The pipe extends to the top center of the pit.

Soakage pits may be round, square, or rectangular. They vary in size from 1-3m in diameter and from 1-3m deep, depending on the quantities of washwater and the permeability of the soil. The bottom of the pit must be at least 1m above groundwater levels.

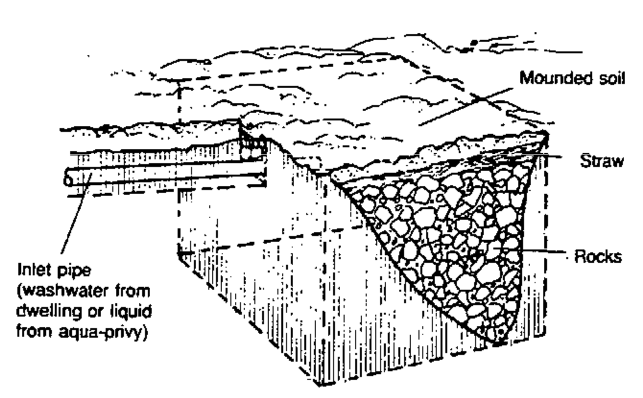


Figure 3. Soakage Pit

Soakage Trench

A soakage trench, shown in Figure 4, is a relatively long, narrow, sloping hole dug in permeable soil. It is partly filled with gravel or crushed rock, equipped with a pipeline and a perforated or open-jointed distribution pipe, covered with straw, and mounded with dirt. The gravel prevents the sides of the trench from collapsing and allows washwater to flow through and drain to the bottom of the trench. If distribution pipe is not available, concrete blocks can be used instead. The straw prevents soil from sifting down and clogging the flow of washwater. The pipeline carries washwater from a sink or drain in the dwelling, or excess liquid run-off from an aqua privy. The pipe extends into the higher end of the trench.

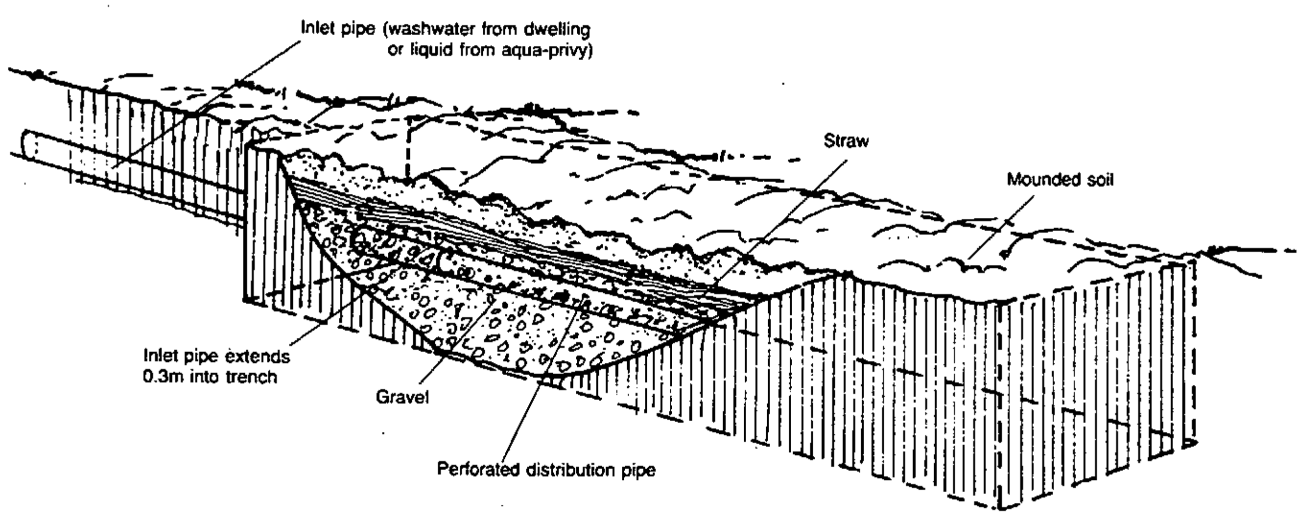


Figure 4. Soakage Trench

Soakage trenches are 0.6-1m wide, 0.6-1m deep, and vary in length from 6-30m depending on the quantities of washwater and the permeability of the soil. The bottom of the trench must be at least 1m above groundwater levels, and it must slope gradually downward away from the inlet end.

Comparison of Methods

Table 1 summarizes each of the three methods of washwater disposal. The methods are listed across the top of the chart, and the factors to be compared are listed down the left side. The table can be used as an aid in selecting a method (see "Planning Simple Excreta and Washwater Disposal Systems," SAN.1.P).

Table 1. Comparison of Washwater Disposal Methods

Factor	Disposal Method			
	Sump		Soakage Pit	Soakage Trench
	Pit-type	Drum-type		
Depth	0.5-1m	Height of drum	1-3m	0.6-1m
Diameter, or Length and Width	0.5-1m diameter	Diameter of drum	1-3m in diameter	0.6-1m wide and 6-30m
Materials Required	Concrete blocks, bricks, or stones; gravel or pebbles; wood or metal lid	200-liter steel drum; wood or metal lid	Rocks; straw, hay, or grass; length of clay, plastic, or galvanized metal pipe extending from dwelling or aqua privy to pit	Gravel, pebbles, concre blocks, open-joint or p forated sewer pipe; str hay, or grass; length of clay, plastic, or ga vanized metal pipe exte ing from dwelling or aq privy to trench
Operation	Remove lid, pour washwater into pit	Remove lid, pour washwater into drum	Pour or drain washwater into sink, pipe, or aqua privy	Pour or drain washwater into sink, pipe, or aqu privy
Suitability	Low quantities of washwater (5 liters per person per day or less)	Low quantities of washwater (5 liters per person per day or less)	Small plot size or low groundwater levels	Large plot size or higl groundwater levels

Notes

Water for the World

Water Treatment in Emergencies

Technical Note No. RWS. 3.D.5

The treatment of water supplies in emergency situations is important to protect people's health. When natural disasters, drought, or social unrest cause a loss of supply of potable water or when, for any other reason, a water supply is disrupted or a supply change is necessary, measures should be taken quickly to provide for a safe water supply.

This technical note discusses the use of several methods for emergency water treatment. Many are similar to simple household purification methods which are described in "Designing Basic Household Water Treatment Systems," RWS.3.D.1. Community members should be instructed in the best methods to use to make water potable during emergencies. Read the entire technical note to evaluate the type of treatment most appropriate to local circumstances.

The design process for emergency water treatment should result in a list of materials needed to provide the appropriate disinfection of water during the time potable supplies are cut off. A sample list for a water boiler appears in Table 1. A list of sources of chlorine and their strengths is in Table 2.

Table 1. Sample Materials List for Boiler System

Item	Description	Quantity	Estimated Cost
Labor	Emergency workers	___	___
	Unskilled labor	___	___
Supplies	200-liter steel drum	___	___
	20mm pipe nipple	___	___
	Valve	___	___
	Large funnel	___	___
	Cement blocks or bricks	___	___
	Filler plug	___	___
	Solder	___	___
Tools	Drill or punch	___	___

Total Estimated Cost = ___

Useful Definitions

CLARIFICATION - The process of removing suspended matter and other forms of turbidity from water.

CONTAMINANT - An impurity which makes water unfit for human consumption or domestic use.

DISINFECTION - Destruction of harmful microorganisms present in water through physical (such as boiling) or chemical (such as chlorination) means.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

When dealing with a disruption in the water supply, the major effort should to go toward getting the system back into operation as quickly as possible. Until operation can begin again, emergency treatment measures should be undertaken.

Usually a source of water that must be used in an emergency is contaminated. Therefore, the water should be disinfected before people drink it. Various methods are available for disinfection during emergenices. The choice of methods will depend on the resources available in each community or region.

Boiling

Boiling destroys all forms of disease organisms in water. It can be used whether water is clear or turbid and even if it contains a large amount of organic matter. For boiling to be effective, water must be brought to a rolling boil; that is, the water must be bubbling rapidly. Boiling water to disinfect it is a very good method of disinfection if fuel is available to heat the water. Individuals can boil

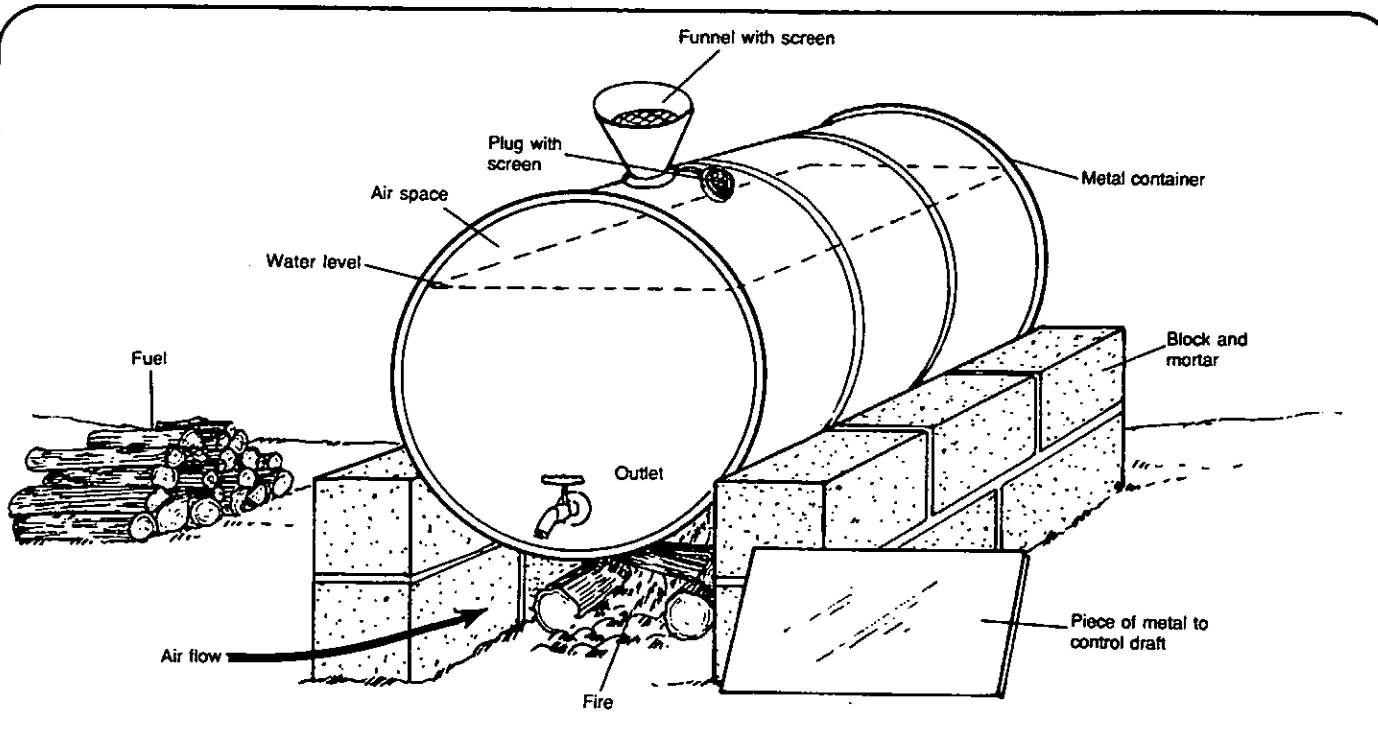


Figure 1. Boiler For Drinking Water

water in small containers. Water should be stored in the same container in which it is boiled to prevent any contamination that could occur from pouring water into a different container.

To boil a large quantity of water that can serve a large group of people, a boiler similar to that shown in Figure 1 can be built. For the boiler, build a simple brick or concrete block fireplace and position it so that the prevailing wind goes between the bricks from the front to the back of the tank. Then, place a 200-liter steel drum or another suitable tank over the fireplace. Laying the tank on its side, make a hole approximately 20mm in diameter on the top side close to the outlet edge as shown. This hole will serve as the inlet. Use a funnel with a small filter screen placed in the hole to fill the tank with water.

Place a valve on the front of the tank. Use a metal valve that can withstand the heat of the boiling water. A small plug should be placed in the inlet hole when the funnel is removed. The plug should fit loosely so that steam can escape during boiling.

The boiler system is good not only for boiling but also for storage. A large amount of fuel is needed, however, to boil the large quantities of water in the tank. Where fuel is abundant, this method is a very good form of disinfection for two or three days. Where fuel is in short supply, another method must be chosen.

Chemical Disinfection

Chlorination of water is one of the most widely accepted methods of chemically disinfecting water under emergency situations. Before chlorinating water from an emergency supply, water may need to be filtered. Chlorine is ineffective against organisms embedded in solid particles. Before turbid water is chlorinated, it should either be poured through a clean cloth or stored to permit the settling of particles. The clarified water can then be disinfected. In some cases, a small temporary dam can be built across a small stream. The reservoir formed can provide adequate settling. The reservoir will provide easy access to the water either manually or through installation of an intake and a pump. Whenever possible, choose an emergency source that is not subject to high levels of contamination. Water collected from an emergency source should be stored in clean containers after clarification. Small storage tanks, cisterns or barrels are appropriate for this. Chlorine is then added to the stored water.

Chlorine is available in liquid, powdered and tablet form. For emergency situations, especially when water is highly contaminated, use a dosage of about 50 parts per million (ppm), sometimes called 50 milligrams per liter (mg/l). To determine the amount of chlorine to add to a given quantity of water to make a 50ppm dosage use the following formula:

$$\text{Amount of chlorine} = \frac{\text{Dosage (ppm)} \times \text{Quantity of water}}{\text{Percent available chlorine}}$$

For example, the amount of chlorinated lime, 35 percent available chlorine, that must be added to 100 liters of water to provide a dosage of 50ppm is:

$$\text{Amount of chlorine} = \frac{\text{50ppm (0.05)} \times \text{100 liters}}{0.35}$$

Amount of chlorine = 14 grams

In this example, 14 grams of chlorinated lime must be added to 100 liters of water to make a 50ppm dosage. Dosage can be reduced for cleaner waters to avoid high residuals and strong taste and odors. Table 2 lists various types of chlorine and their percentage available chlorine.

After dosing, let the chlorine stay in the water for 30 minutes. After that time, a check for chlorine residual should be done if equipment is available. There should be a residual of approximately 1.0ppm. Where no testing equipment is available, make sure that the treated water has a slight chlorine odor and taste. If the test shows no chlorine residual, or if there is no chlorine taste or odor, repeat the dosage and wait 15 minutes.

Table 2. Chlorine Strengths

	Percent Available Chlorine
Calcium Hypochlorites	
High Test Hypochlorite	70%
Percloron Powder	70%
B-K Powder	50%
Chlorinated Lime	35%
Sodium Hypochlorites (Liquid)	
Chlorox	5%
Purex	3%
Zonite	1%

If the treated water has too strong a chlorine taste, allow it to stand for a few hours. Contact with the air offsets the taste and smell of the chlorine.

Chlorine is available in tablet form and can easily be applied to contaminated water. Chlorine tablets are available in many areas. To use them, follow the instructions on the package. If no instructions are listed, use one tablet for each liter of water to be treated.

Iodine is another chemical which can be used for disinfection in an emergency situation. Iodine is available in liquid form from pharmacies or small stores, and is used generally for first aid purposes. Most liquids contain two percent iodine. To disinfect clear water, add about five drops of iodine to each liter of water. When treating turbid water, add 10 drops per liter and allow the water to stand for 30 minutes. Reduce the dose if the iodine taste is strong.

Iodine tablets are made commercially and may be available in many areas. For water disinfection, follow the instructions on the packets. If instructions do not come with the iodine, a general rule to follow is to add one tablet to each liter of water.

Summary

Water which is used for drinking, cooking or brushing teeth should be properly disinfected to prevent sickness. Therefore, adequate planning is necessary to ensure that sufficient quantities of potable water are available for all who need it. The guidelines below should be followed when attempting to provide water for people in emergency situations.

1. Restrict the use of the available potable water to basic needs. People may have to bathe less often and ration the amount of water used for cooking and drinking. Never let supplies fall to a dangerously low level if possible.

2. Attempt to either put the old system into operation quickly or else search for a new source. If a new source is chosen, make sure that it is either well-protected from contamination or can be protected, and that water can effectively be delivered to those who need it.

3. If a protected source is not available, dig a temporary well or choose a source which is accessible and can be easily treated. Before choosing a source, make sure that there is a way to disinfect it. Water must either be boiled or chemically disinfected before it can be drunk.

FACT SHEET LISTING

RURAL WATER SUPPLY

RWS. 1 Surface Water Systems
RWS. 2 Groundwater Systems
RWS. 3 Water Treatment
RWS. 4 Water Distribution
RWS. 5 Water Storage

SANITATION

SAN. 1 Simple Excreta Disposal
SAN. 2 Combined Washwater and Excreta Disposal
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DIS. 2 Controlling Schistosomiasis
DIS. 3 Controlling Trypanosomiasis
DIS. 4 Controlling Enteric Viruses
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DIS. 6 Controlling Leptospirosis

HUMAN RESOURCE DEVELOPMENT

HR. 1 Community Participation
HR. 2 Training Personnel

TECHNICAL NOTES

Methods		User	Priority
RWS.1.M	Methods of developing sources of surface water	PD	1
Planning			
RWS.1.P.1	Planning how to use sources of surface water	PD	1
RWS.1.P.2	Locating sources of acceptable surface water and conducting a sanitary survey	PD/TFW	1
RWS.1.P.3	Selecting a source of surface water	PD	1
RWS.1.P.4	Choosing where to place intakes	PD	1
RWS.1.P.5	Evaluating artificial catchments	PD	2
Design			
RWS.1.D.1	Designing structures for springs	PD	1
RWS.1.D.2	Designing intakes for ponds, lakes and reservoirs	PD	1
RWS.1.D.3	Designing intakes for streams and rivers	PD	1
RWS.1.D.4	Designing roof catchments	PD	2
RWS.1.D.5	Designing small dams and water impoundments	PD	2
RWS.1.D.6	Designing improved rainfall catchments	PD	3
Construction			
RWS.1.C.1	Construction structures for springs	TFW	1
RWS.1.C.2	Constructing intakes for ponds, lakes and reservoirs	TFW	1
RWS.1.C.3	Constructing intakes for streams and rivers	TFW	1
RWS.1.C.4	Constructing roof catchments	TFW	2
RWS.1.C.5	Constructing small dams and water impoundments	TFW	3
RWS.1.C.6	Constructing improved rainfall catchments	TFW	3
Operation and Maintenance			
RWS.1.O.1	Maintaining structures for springs	TFW	1
RWS.1.O.2	Maintaining intakes	TFW	1
RWS.1.O.3	Maintaining roof catchments	TFW	2
RWS.1.O.4	Maintaining small dams and water impoundments	TFW	2
RWS.1.O.5	Maintaining improved rainfall catchments	TFW	3
Methods			
RWS.2.M	Methods of developing sources of ground water	PD	1

Planning		User	Priority
RWS.2.P.1	Planning how to use sources of ground water	PD	1
RWS.2.P.2	Selecting a method of well construction	PD	1
RWS.2.P.3	Selecting a well site	PD	1
Design			
RWS.2.D.1	Designing dug wells	PD	1
RWS.2.D.2	Designing a driven well	PD	1
RWS.2.D.3	Designing a jetted well	PD	2
RWS.2.D.4	Designing a bored or augered well	PD	2
RWS.2.D.5	Designing cable tool wells	PD	2
RWS.2.D.6	Designing hydraulic percussion or hydraulic rotary wells	PD	3
Construction			
RWS.2.C.1	Disinfecting wells	TFW	1
RWS.2.C.2	Constructing dug wells	TFW	1
RWS.2.C.3	Constructing jetted or driven wells	TFW	1
RWS.2.C.4	Constructing bored or augered wells	TFW	2
RWS.2.C.5	Constructing cable tool wells	TFW	2
RWS.2.C.6	Constructing hydraulic percussion or hydraulic rotary wells	TFW	3
RWS.2.C.7	Maintaining drilling logs	TFW	2
RWS.2.C.8	Testing the yield of wells	TFW	2
RWS.2.C.9	Installing casing in wells	TFW	2
RWS.2.C.10	Finishing wells	TFW	2
RWS.2.C.11	Providing sanitary protection for wells	TFW	2
Methods			
RWS.3.M	Methods of water treatment	PD	1
Planning			
RWS.3.P.1	Determining the need for water treatment	PD	1
RWS.3.P.2	Taking a water sample	PD/TFW	1
RWS.3.P.3	Analyzing a water sample	PD/TFW	1
RWS.3.P.4	Planning a water treatment system	PD	1

Design

		User	Priority
RWS.3.D.1	Designing basic household water treatment systems	PD/TFW	1
RWS.3.D.2	Designing a small community sedimentation basin	PD	1
RWS.3.D.3	Designing a slow sand filter	PD	1
RWS.3.D.4	Designing a small community disinfection unit	PD	1
RWS.3.D.5	Water treatment in emergencies	PD/TFW	1

Construction

RWS.3.C.1	Constructing a household sand filter	TFW	1
RWS.3.C.2	Constructing a sedimentation basin	TFW	2
RWS.3.C.3	Constructing a slow sand filter	TFW	2
RWS.3.C.4	Constructing a disinfection unit	TFW	1

Operation and Maintenance

RWS.3.O.1	Operating and maintaining household treatments	TFW	1
RWS.3.O.2	Maintaining a household sand filter	TFW	1
RWS.3.O.3	Operating and maintaining a sedimentation basin	TFW	2
RWS.3.O.4	Operating and maintaining a slow sand filter	TFW	2
RWS.3.O.5	Operating and maintaining a chemical disinfection unit	TFW	1

Methods

RWS.4.M	Methods of delivering water	PD	1

Planning

RWS.4.P.1	Choosing between gravity flow and pumps	PD	1
RWS.4.P.2	Choosing between communal distribution systems and household water connections	PD	1
RWS.4.P.3	Selecting pipe materials	PD	1
RWS.4.P.4	Selecting a power source for pumps	PD	1
RWS.4.P.5	Selecting pumps	PD	1
RWS.4.P.6	Manufacturing hand pumps locally	PD	2

Design

RWS.4.D.1	Designing a system of gravity flow	PD	1
RWS.4.D.2	Determining pumping requirements	PD	1
RWS.4.D.3	Designing a transmission main	PD	1
RWS.4.D.4	Designing communal distribution systems	PD	1
RWS.4.D.5	Selecting a hydraulic ram pump	PD	3

Construction		User	Priority
RWS.4.C.1	Installing pipes	TFW	1
RWS.4.C.2	Constructing communal distribution systems	TFW	1
RWS.4.C.3	Installing mechanical pumps	TFW	1
RWS.4.C.4	Installing hand pumps	TFW	1
RWS.4.C.5	Constructing a distribution system with household connections	TFW	2

Operation and Maintenance

RWS.4.O.1	Detecting and correcting leaking pipes	TFW	1
RWS.4.O.2	Operating and maintaining mechanical pumps	TFW	1
RWS.4.O.3	Operating and maintaining hand pumps	TFW	1
RWS.4.O.4	Operating and maintaining household water connections	TFW	2

Methods

RWS.5.M	Methods of storing water	PD	1

Planning

RWS.5.P.1	Determining the need for storage of water	PD	1

Design

RWS.5.D.1	Designing a household cistern	PD	1
RWS.5.D.2	Designing a ground level storage tank	PD	1
RWS.5.D.3	Designing an elevated storage tank	PD	2

Construction

RWS.5.C.1	Constructing a household cistern	TFW	1
RWS.5.C.2	Constructing a ground level storage tank	TFW	1
RWS.5.C.3	Constructing an elevated storage tank	TFW	2

Operation and Maintenance

RWS.5.O.1	Maintaining water storage tanks	TFW	1

SANITATION

SAN.1 SIMPLE EXCRETA DISPOSAL

Methods		Priority	User
SAN.1.M.1	Simple methods of excreta disposal	1	PD
SAN.1.M.2	Simple methods of washwater disposal	1	PD

Planning

SAN.1.P	Planning simple excreta and washwater disposal systems	1	PD

Design, Construction, Operation and Maintenance

SAN.1.D.1	Designing slabs for privies	1	PD
SAN.1.C.1	Constructing slabs for privies	1	TFW
SAN.1.D.2	Designing pits for privies	1	PD
SAN.1.C.2	Constructing pits for privies	1	TFW
SAN.1.D.3	Designing privy shelters	1	PD
SAN.1.C.3	Constructing privy shelters	1	TFW
SAN.1.O.3	Operating and maintaining privies	1	TFW/VW
SAN.1.D.4	Designing aqua privies	2	PD
SAN.1.C.4	Constructing aqua privies	2	VW
SAN.1.O.4	Operating and maintaining aqua privies	2	TFW/VW
SAN.1.D.5	Designing bucket latrines	2	PD
SAN.1.C.5	Constructing bucket latrines	2	TFW
SAN.1.O.5	Operating and maintaining bucket latrines	2	TFW/VW
SAN.1.D.6	Designing compost toilets	3	PD
SAN.1.C.6	Constructing compost toilets	3	TFW
SAN.1.O.6	Operating and maintaining compost toilets	3	TFW/VW
SAN.1.D.7	Designing sumps, soakage pits and trenches	1	PD
SAN.1.C.7	Constructing, operating and maintaining sumps, soakage pits, and trenches	1	PD

SAN.2 COMBINED WASHWATER AND EXCRETA DISPOSAL

Methods

SAN.2.M.	Methods of combined washwater and excreta disposal	1	PD

Planning

SAN.2.P.1	Planning combined washwater and excreta disposal systems	1	PD
SAN.2.P.2	Selecting a combined washwater and excreta disposal system	1	PD
SAN.2.P.3	Estimating sewage or washwater flows	1	PD
SAN.2.P.4	Determining soil suitability	1	TFW

Design, Construction, Operation and Maintenance		Priority	User
SAN.2.D.1	Designing subsurface absorption systems	2	PD
SAN.2.C.1	Constructing, operating and maintaining subsurface absorption systems	2	TFW
SAN.2.D.2	Designing cesspools	2	PD
SAN.2.C.2	Constructing cesspools	2	TFW
SAN.2.0.2	Operating and maintaining cesspools	2	TFW/VW
SAN.2.D.3	Designing septic tanks	1	PD
SAN.2.C.3	Constructing septic tanks	1	TFW
SAN.2.0.3	Operating and maintaining septic tanks	1	TFW/VW
SAN.2.D.4	Designing sewer systems	2	PD
SAN.2.C.4	Constructing sewer systems	2	TFW
SAN.2.0.4	Operating and maintaining sewer systems	2	TFW/VW
SAN.2.D.5	Designing stabilization ponds	2	PD
SAN.2.C.5	Constructing stabilization ponds	2	TFW
SAN.2.0.5	Operating and maintaining stabilization ponds	2	TFW/VW
SAN.2.D.6	Designing lagoon systems	2	PD
SAN.2.D.7	Designing mechanically aerated lagoons and ditches	3	PD
SAN.2.C.7	Constructing mechanically aerated lagoons and ditches	3	TFW
SAN.2.0.7	Operating and maintaining mechanically aerated lagoons and ditches	3	TFW/VW
SAN.2.D.8	Designing non-conventional washwater and excreta disposal systems	3	PD
SAN.2.C.8	Constructing non-conventional washwater and excreta disposal systems	3	TFW

SAN.3 SOLID WASTE MANAGEMENT

Methods			
SAN.3.M	Methods of solid waste management	1	PD

Planning			
SAN.3.P	Planning solid waste management systems	1	PD

Design, Construction, Operation and Maintenance			
SAN.3.D.1	Designing a landfill	1	PD
SAN.3.0.1	Operating and maintaining a composting system	1	TFW/VW
SAN.3.D.2	Designing a composting system	2	PD
SAN.3.0.2	Operating and maintaining a composting system	2	TFW/VW
SAN.3.D.3	Designing a solid waste collection system	2	PD
SAN.3.0.3	Operating a solid waste collection system	2	TFW/VW
SAN.3.D.4	Designing a biogas system	3	PD
SAN.3.C.4	Constructing a biogas system	3	TFW
SAN.3.0.4	Operating and maintaining a biogas system	3	TFW/VW

HUMAN RESOURCE DEVELOPMENT

HR.1 COMMUNITY PARTICIPATION

Methods		Priority	User
HR.1.M	Methods of community participation in water supply and sanitation programs	1	PP

Implementation			
HR.1.I.1	Organizing community support for water supply and sanitation programs	1	TFW
HR.1.I.2	Setting up a community education program in water supply and sanitation	1	PP
HR.1.I.3	Dealing with community customs in water supply and sanitation	2	PP

HR.2 TRAINING PERSONNEL

Methods			
HR.2.M	Methods of operation and maintenance training programs	1	RP

Planning			
HR.2.P.1	Planning operation and maintenance training programs	2	RP
HR.2.P.2	Evaluating system management, operation, and maintenance	3	PP

Implementation			
HR.2.I.1	Implementing an operation and maintenance training program	2	PP

TROPICAL DISEASES

DIS.1 IMPROVING ENVIRONMENTAL HEALTH

Methods			
DIS.1.M.1	Means of disease transmission	1	RP
DIS.1.M.2	Methods of improving environmental health conditions	1	RP

Planning		Priority	User
DIS.1.P	Planning disease control programs	1	RP

Implementation			
DIS.1.I.1	Establishing drinking water standards	2	RP
DIS.1.I.2	Establishing guidelines for wastewater disposal	2	RP
DIS.1.I.3	Establishing guidelines for solid waste management	2	RP

DIS.2 CONTROLLING SCHISTOSOMIASIS

Methods			
DIS.2.M	Methods of controlling schistosomiasis	1	PD

Implementation			
DIS.2.I.1	Controlling schistosomiasis with environmental means	1	TFW

DIS.3 CONTROLLING TRYPANOSOMIASIS

Methods			
DIS.3.M	Methods of controlling trypanosomiasis	2	PD

Implementation			
DIS.3.I.1	Controlling trypanosomiasis with environmental means	2	TFW

DIS.4 CONTROLLING ENTERIC VIRUSES

Methods			
DIS.4.M	Methods of controlling enteric viruses	2	PD

Implementation			
DIS.4.I.1	Controlling enteric viruses with environmental means	2	TFW

TROPICAL DISEASES

DIS.5 CONTROLLING ONCHOCERCIASIS

Methods		Priority	User
DIS.5.M	Methods of controlling onchocerciasis	2	PD
Implementation			
DIS.t.I.1	Controlling onchoceriasis with environmental means	2	TFW

DIS.6 CONTROLLING LEPTOSPIROSIS

Methods		Priority	User
DIS.6.M	Methods of controlling leptospirosis	3	PD
Implementation			
DIS.6.I.1	Controlling leptospirosis with environmental means	3	TFW

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RURAL WATER/SANITATION PROJECTS

Hi Sue:
Here is WS052
(and WS053 Just in case)
Plus R0106
(R0010 is HTML only)

WATER FOR THE WORLD

WS052

WATER SANITATION

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

RURAL WATER/SANITATION PROJECTS

Selected Technical Fact Sheets

From

<u>WATER FOR THE WORLD</u>

USAID

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OFFICE OF PROGRAM DEVELOPMENT
MAY 1983

CONTENTS

Water for the World

How to Use Technical Notes

Technical Note No. HR. G

"Water for the World" technical notes are intended for use in the developing nations by people who have field responsibility for water supply and sanitation programs in rural areas. There are 160 technical notes covering detailed topics on human resources, water supply, sanitation and disease. Some of the topics are complicated but most of the technical notes present materials in a way that a layperson with some knowledge of water supply and sanitation can carry out the activity described.

There are a number of possible uses of technical notes in addition to their primary purpose of providing useful information to people working directly in the field on water supply and sanitation projects. For example, the material can be translated as is into local languages and reproduced; it can be divided into more useful segments to meet a local situation's needs and made culture specific; it can be used as training materials; or it can be the basis for posters, radio spots, flyers,or other audio-visual aids for use in a community education effort or in other ways.

Other "Water for the World" Materials

Also a part of the "Water for the World" series is a book and three booklets. The book is titled Safe Water and Waste Disposal for Rural Health: A Program Guide. It was written for people in the developing nations who are interested in putting together a countrywide program for improving rural water supply and sanitation facilities. It does not contain as much specific technical information as the technical notes. Rather, it focuses on all of the elements that go into designing and implementing a successful water and waste disposal program.

The three booklets were written for policy-makers in the developing nations to highlight the need for action to improve water supplies and sanitation facilities. One of the booklets is a short summary of the Program Guide. The other two are titled "Program Planning for the Decade for Water" and "Program Implementation for the Decade for Water."

Organization of Technical Notes

The technical notes are divided into four broad categories: Human Resources (HR), Rural Water Supply (RWS), Sanitation (SAN), and Disease (DIS). The notes are organized as shown in Table 1. Each broad category is divided into two or more series, each of which is assigned a number. Then the numbered series are divided into methods (M), planning (P), design (D), construction (C), and operation and maintenance (O) for the Rural Water Supply and Sanitation categories; into methods (M), planning (P) and implementation (I) for the Human Resources category; and into methods (M) and planning (P) for the Disease category.

If possible, the technical notes should be read and used in order: methods first, then planning, then design, and so on. In this way, the person using the technical notes will have a thorough understanding of the subject covered and will be able to proceed with the activity in an orderly, logical way. The methods, planning and design technical notes were written for people with some experience in the subject covered who are responsible for project design and decision-making. The construction and operation and maintenance technical notes, in most cases, may be used by people with less experience since these activities involve little or no decision-making. Thus, the construction and operation and maintenance technical notes may be used by someone who is carrying out their tasks, but is working under another person who has consulted the methods, planning and design notes for that particular project.

All technical notes have both a title and a number which identifies where they fit on Table 1. For example, SAN.3.C.4, "Constructing a Biogas System" is in the Sanitation category (SAN), the Solid Waste Disposal series (3), and has to do with construction (C). It is the fourth kind of solid waste disposal system on which technical notes were written (4). All of the technical notes are cross-referenced by both title and number so that they will be easy to find. The following is a list of all of the "Water for the World" technical notes.

List of Technical Notes

HUMAN RESOURCES

RURAL WATER SUPPLY

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RWS.2.M	Methods of Developing Sources of Ground Water

Planning

RWS.2.P.1	Planning How to Use Sources of Ground Water
RWS.2.P.2	Selecting a Method of Well Construction
RWS.2.P.3	Selecting a Well Site

Design

RWS.2.D.1	Designing Dug Wells
RWS.2.D.2	Designing Driven Wells
RWS.2.D.3	Designing Jetted Wells
RWS.2.D.4	Designing Bored or Augered Wells
RWS.2.D.5	Designing Cable Tool Wells

Construction

RWS.2.C.1	Constructing Dug Wells
RWS.2.C.2	Constructing Driven Wells
RWS.2.C.3	Constructing Jetted Wells
RWS.2.C.4	Constructing Bored or Augered Wells
RWS.2.C.5	Constructing Cable Tool Wells
RWS.2.C.6	Maintaining Well Logs
RWS.2.C.7	Testing the Yield of Wells
RWS.2.C.8	Finishing Wells
RWS.2.C.9	Disinfecting Wells

RWS. 3 Water Treatment

Methods

RWS.3.M	Methods of Water Treatment

Planning

RWS.3.P.1	Determining the Need for Water Treatment
RWS.3.P.2	Taking a Water Sample
RWS.3.P.3	Analyzing a Water Sample
RWS.3.P.4	Planning a Water Treatment System

RWS.4.D.4	Designing Community Distribution Systems
RWS.4.D.5	Designing a Hydraulic Ram Pump

<u>Construction</u>

RWS.4.C.1	Installing Pipes
RWS.4.C.2	Installing Mechanical Pumps
RWS.4.C.3	Installing Hand Pumps
RWS.4.C.4	Constructing Community Distribution Systems
RWS.4.C.5	Constructing a Distribution System with Household Connections

<u>Operation and Maintenance</u>

RWS.4.O.1	Detecting and Correcting Leaking Pipes
RWS.4.O.2	Operating and Maintaining Mechanical Pumps
RWS.4.O.3	Operating and Maintaining Hand Pumps
RWS.4.O.5	Operating and Maintaining Household Water Connections

RWS. 5 Water Storage

<u>Methods</u>

RWS.5.M	Methods of Storing Water

<u>Planning</u>

RWS.5.P.1	Determining the Need for Water Storage

<u>Design</u>

RWS.5.D.1	Designing a Household Cistern
RWS.5.D.2	Designing a Ground Level Storage Tank
RWS.5.D.3	Designing an Elevated Storage Tank

<u>Construction</u>

RWS.5.C.1	Constructing a Household Cistern
RWS.5.C.2	Constructing a Ground Level Storage Tank
RWS.5.C.3	Constructing an Elevated Storage Tank

<u>Operation and Maintenance</u>

RWS.5.O.1	Maintaining Water Storage Tanks

SANITATION

SAN. 2 Combined Excreta and Washwater Disposal

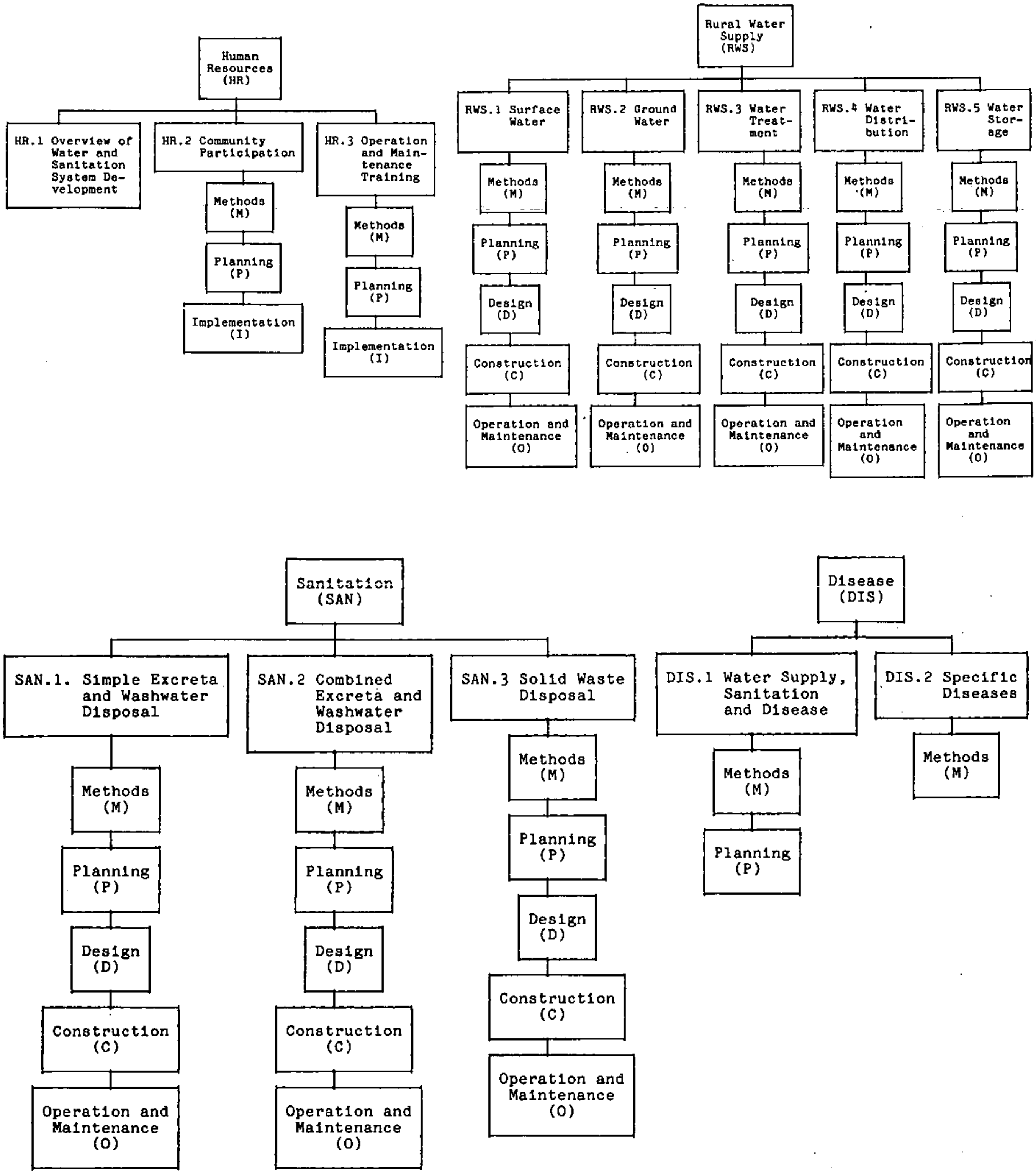
SAN. 3 Solid Waste Disposal

DISEASE

DIS. 1 Water Supply, Sanitation and Disease

DIS. 2 Specific Diseases

Table 1. Organization of Technical Notes



Water for the World

Means of Disease Transmission

Technical Note No. DIS. 1.M.1

Water- and sanitation- related diseases are major causes of illness and death among people in both rural and urban areas in many developing countries. The health and well being of people cannot be improved without understanding these diseases and knowing how they are transmitted from one person to another.

This technical note describes what causes these diseases, how they are spread and the factors influencing their transmission. Methods for preventing the transmission of the water- and sanitation- related diseases can be found in the technical note, "Methods of Improving Environmental Health Conditions," DIS.1.M.2.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

BACTERIA - One-celled microorganisms which multiply by simple division and which can only be seen with a microscope.

FECES - The waste from the body moved out through the bowels.

LARVAE - Young forms that come from the eggs of insects and worm parasites.

PARASITES - Worms, insects or mites which live in or on animals or people.

There are about 30 diseases that are related to water and sanitation. Table 1 lists the 21 which are most important. Each of them affects from millions to hundreds of millions of people every year. All of these diseases are caused by living organisms that must spend much of their life in or on a human body. They include viruses so tiny that they can pass through the finest filter, bacteria and protozoa that can be seen only with the aid of a microscope, tiny mites that are barely visible to the eye and worms that may be a meter long.

The transmission of all of these diseases is related in some way to water supply and sanitation, usually to inadequate disposal of human wastes and to contaminated water supplies. The diseases are transmitted through contact with or consumption of water, contact with infected soil, the bites of insects that breed in or near water and poor personal and family hygiene. Man is usually the source of the organisms that cause these diseases and human activity is an important factor in the transmission of them.

Following the order shown in Table 1, the transmission of the diseases will be discussed for each of the five categories.

Waterborne Diseases (Water Quality Related)

In the waterborne diseases, the microorganisms which cause the disease are swallowed with contaminated water. All but one, Guinea worm, are caused by organisms found in human excreta, the source of the contamination. The infective stage of Guinea worm is not from fecal contamination, but is from a tiny larva that develops in a water-flea after the larva is discharged into the water. The larva comes from a blister on the skin of a person infected with the meter-long adult worm.

Cholera and typhoid fever are the waterborne diseases which are most feared because, when untreated, they have high death rates. However, the diarrheas and dysenteries are more important because of the infant deaths and huge numbers of illnesses they cause. In the developing countries,

Table 1. Water and Sanitation-Related Diseases				
Category	Disease Common name	 Medical name	Type of Organism	Transmission
Waterborne (Water quality related)	Cholera Typhoid fever Paratyphoid fever Bacillary dysentery Amebic dysentery Diarrhea Diarrhea Jaundice Guinea worm	Cholera Typhoid Paratyphoid Shigellosis Amebiasis Salmonellosis Giardiasis Hepatitis Dracunculiasis	Vibrio Bacteria Bacteria Bacteria Protozoan Bacteria Protozoan Virus Worm	By consuming (drinking) fecally contaminated raw water containing an infective dose of the vibrio, bacterium, protozoan or virus; except Guinea worm where transmission is by swallowing water flea infected with worm larva that was shed from skin blister on infected human.
Water-washed (Water quantity; and accessibility related)	Bacillary dysentery Diarrhea Viral diarrhea Trachoma Pink eye Itch	Shigellosis Salmonellosis Enteroviruses Trachoma Conjunctivitis Scabies	Bacteria Bacteria Virus Intracelluar bacteria Bacteria Mite	Anal-oral or skin-to-skin direct contact transmission resulting from poor personal cleanliness and hygiene caused from lack of water for sufficient washing, bathing and cleaning.
Water-contact (Body-of-water related)	Blood fluke disease	Schistosomiasis	Worm	Eggs in feces or urine hatch larvae in water, penetrate suitable snail, multiply greatly in snail, free-swimming larvae leave snail, penetrate skin when person has contact with infected water.
Water-related insect vectors (carriers) (Water-site related)	Yellow fever Malaria Filarial fever Sleeping sickness River blindness	Yellow fever Malaria Filiariasis Trypanosomiasis Onchocerciasis	Virus Protozoa Worm Protozoa Worm	Mosquitoes, tsetse flies and blackflies, which breed in or near water, pick up disease organisms when they bite infected person; organisms grow in vectors and are inoculated into another person when insect bites.
Sanitation-related (Fecal polluted soil related)	Hookworm Roundworm	Ancylostomiasis Ascariasis	Worm Worm	Eggs or larvae become infective when feces are deposited on soil; eggs are eaten from contaminated hands or vegetables, or larvae penetrate skin that comes in contact with infected soil.

the diarrheas and dysenteries cause hundreds of millions of illnesses and millions of infant deaths each year.

The basic transmission of waterborne disease is person to person. The microorganisms for infected people contaminate water which is consumed by other people. Figure 1 shows a common way that water becomes contaminated. The contamination of water supplies occurs:

1. Where latrines and privies are located uphill from or very close to a water source such as a spring, stream, pond or well. Liquids carrying the organisms seep from the latrines into the water supply.

2. Where privy pits, soakage pits, or sewage absorption systems penetrate the water table of an aquifer located near the surface and shallow wells and springs whose water comes from the aquifer are contaminated.

3. Where wells and springs are unprotected so that surface run-off enters these water sources. The run-off after rainfall carries disease-causing organisms into the water source.

4. Where sanitation is poor. If people defecate on the ground or in bodies of water rather than in safe latrines or privies, disease-causing organisms can get into water supplies.

5. Where Guinea worm occurs, water is contaminated when the skin of an infected person with a blister caused by the worm is immersed in water and great numbers of larvae are released into the water. Some of the larvae are eaten by tiny water fleas (Cyclops). The larvae in the water fleas grow, shed their skins, and become infective. When a water flea containing an infective larva is drunk with water from the contaminated source, the little worm is transmitted to a new person where it grows to maturity under the skin.

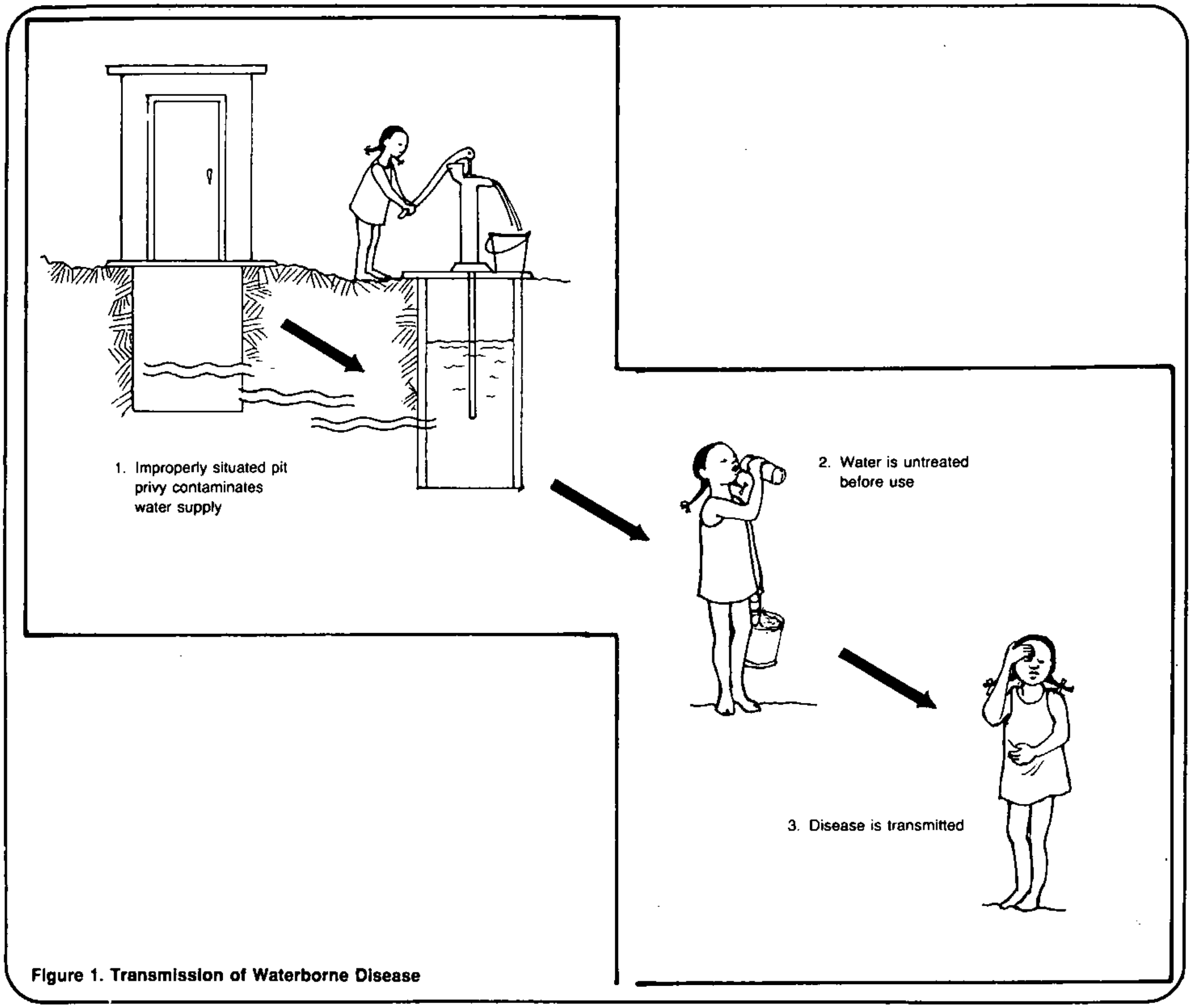


Figure 1. Transmission of Waterborne Disease

Water-Washed Diseases (Water Quantity and Accessibility Related)

Water-washed diseases are diseases whose transmission results from a lack of sufficient clean water for frequent bathing, hand washing before meals and after going to the toilet, and for washing clothes and household utensils. Several common diseases fall into this category. Shilgellosis (bacillary dysentery), salmonellosis (food poisoning), trachoma, and scabies are all diseases that can be passed by direct contact between people or by the direct contamination of food by dirty hands or flies. Figure 2 shows one way water-washed diseases are spread. The diseases in this group are transmitted:

Figure 2. Transmission of Water-Washed Diseases

1. When a water supply produces insufficient quantities to meet peoples' needs or when the water supply is located at a distance from the users. The availability of only small amounts of water makes the practice of good personal and household hygiene difficult, or even impossible.

2. When feces are not disposed of in a sanitary way. Uncovered or unprotected latrines or stools passed on the ground are breeding places for flies and sources of bacteria. Bacteria and viruses are passed from feces to people by flies, contaminated fingers and food. Food contamination with salmonella quickly grows great numbers of the bacteria. When eaten, the food causes food-poisoning diarrhea with life-threatening consequences, especially for small children.

3. When people are ignorant of the need for personal hygiene and, for whatever set of reasons, either do not bathe frequently or use the same water and towels to wash more than one person, then trachoma and conjunctivitis are passed around within a family or other groups living together and scabies get passed from the skin of one person to the skin of another.

Water-Contact Diseases (Body-of-Water Related)

Water-contact diseases are diseases which are transmitted when people have contact with infected water. The single most important water-contact disease is Schistosomiasis (blood fluke disease). It is very widespread in Asia, Africa and South America with hundreds of millions of people at risk of getting the disease and millions suffering from it. Figure 3 shows how schistosomiasis is transmitted. Briefly, transmission is as follows: Schistosome eggs passed in urine or feces fall into water where a first stage larva hatches. The first stage larva, to survive, must find and penetrate a specific type of snail. In the snail, the first stage larva changes into a large number of sacs in which many thousands of forked-tailed second stage larva are produced over a period of months to years. Each day, several hundreds of these second stage larvae escape from the snail to swim about in the water seeking the warm skin of a human hand or food into which to penetrate. Once through the skin, the little worm enters the person's blood stream, grows to maturity (worms are about a centimeter long), works its way into the blood vessels of the intestine and urinary bladder, and lays its eggs in the wall of those organs. The eggs then cut their way through the tissues to the inside of the intestine or bladder and are passed with the feces or urine. So the transmission cycle continues.

Schistosomiasis is transmitted in areas:

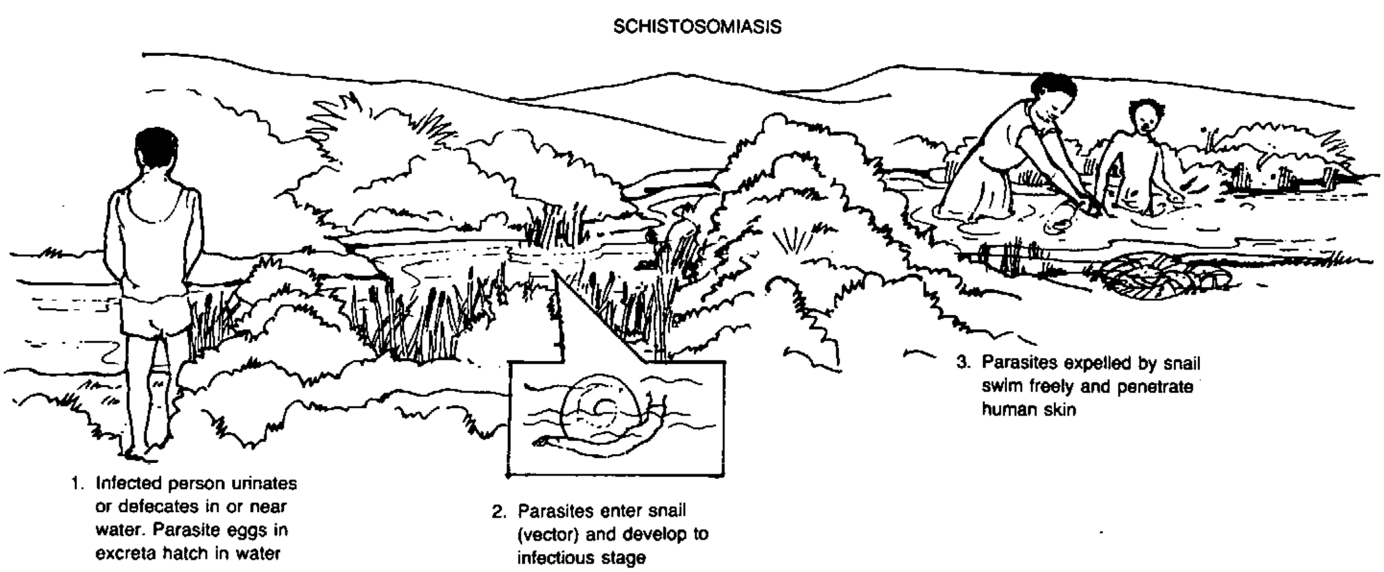


Figure 3. Transmission of Water-Bused/Water-Contact Diseases

1. Where poor sanitation is practiced so that feces or urine find their way into bodies of water that contain snails, or where rats or wild animals get the worms and keep the snails infected.

2. Where the appropriate type of snail is abundant and can become infected.

3. Where people enter infected water to bathe, wash clothes, dip up water, cultivate crops or swim.

4. Where irrigation projects or man-made lakes have extended the bodies of water in which snails can grow and have the chance to be infected from man or wild animals.

Water-Related/Insect Vector (Carrier) Diseases (Water Site Related)

Water-related insect vector diseases are those that are transmitted by insects which breed in or near water. Transmission occurs when the insect becomes infected with the disease organism from biting a person or animal, and then bites another person. The parasites are injected into the skin or bloodstream by the insect bite. The insects breed in water that is used as water supplies (streams and rivers) and, in the case of mosquitoes, in water storage jars, and water tanks, or in shaded high humidity areas near streams or lakes.

The most common diseases in this category are:

• African trypanosomiasis (sleeping sickness) which is transmitted by the tsetse fly which thrives on high humidity and breeds in river areas under lush vegetation growing at water sites.

• Onchocerciasis (river blindness) which is transmitted by blackflies which breed while attached to rocks and vegetation in fast-flowing rivers and streams. Figure 4 shows how onchocerciasis is transmitted.

• Malaria which is transmitted by female anopheline mosquitoes which breed in a wide variety of water collections.

• Arboviruses (yellow fever) which is also transmitted by mosquitoes. The

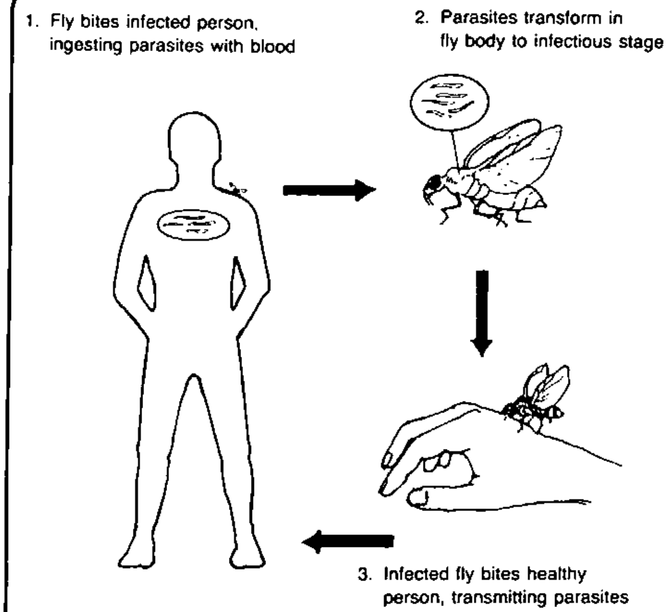


Figure 4. Transmission of Water-Related (Insect Carried) Diseases

type of mosquitoes that carries this disease is different from that which carries malaria. Mosquitoes that carry yellow fever breed in highly polluted stagnant water and usually rest in areas far from their breeding places.

• Filariasis which is a worm infection spread by mosquitoes. The mosquitoes that carry the parasite breed in any stagnant pond or pool or in water in cans, coconut husks, dishes, gutters or wherever water is standing.

The transmission of water-related insect vector diseases occurs in many types of situations in which the insect vectors are able to breed in large numbers, can bite persons infected with the protozoan or worm that causes the disease, and later, after the parasites have developed in them, have the opportunity to bite other people. In many situations, the water supply site where people come to get their water, is the place where the insects get their opportunity to bite both infected and other people. The household environment is also a place where some of these diseases are transmitted.

Sanitation-Related Diseases (Fecal Polluted Soil Related)

Sanitation-related diseases are specifically those that are transmitted by people lacking both sanitary facilities for waste disposal and knowledge of the need to dispose of wastes in a sanitary manner. The infective stage of the worm which causes those diseases develops in fecally contaminated soil. The most common diseases in this category are hookworm and roundworm.

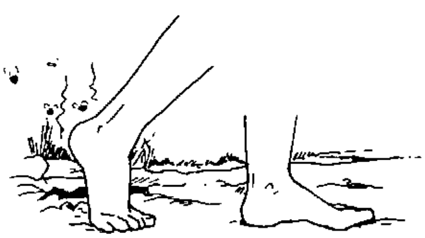
Hookworm larvae develop and live in damp soil that has been contaminated with feces containing hookworm eggs. They penetrate the bare feet of people walking or standing on the infected soil. See Figure 5. Entrance can also occur through the hands or other skin areas.

Roundworm or ascariasis is transmitted by swallowing eggs which have become infective by developing on polluted soil. The eggs are eaten by children who play on the infected soil, drop food on the soil and then eat it, or eat from dirty hands or eat contaminated raw vegetables.

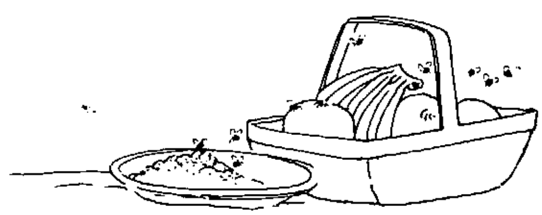
Both diseases occur:

1. Where there are not latrines and the soil is polluted, where latrines are not sanitary or where they are not used.

2. Where fresh untreated feces are used as fertilizer.



a. Hookworm is transmitted through the feet of people walking barefoot in contaminated soil



b. Roundworm is often transmitted by contaminated flies which land on food

Figure 5. Transmission of Sanitation-Related Diseases

3. Where people are not educated to wash their hands before eating.

Summary

This technical note has discussed several diseases which are common in many countries. They are all directly related to local environmental conditions and are all passed from person to person. The cycle, or chain of transmission, involves both direct transmission of the disease or else depends on an agent, or vector, for the transmission.

Once the chain of transmission is understood, means to break the chain should be adopted. Generally, relatively simple environmental measures need to be developed to stop the spread. The methods of doing this are discussed in "Methods of Improving Environmental Health Conditions," DIS.1.M.2.

Water for the World

Methods of Improving Environmental Health Conditions

Technical Note No. DIS. 1.M.2

The improvement of people's health may require that certain changes be made in the environment. Local conditions which contribute to the transmission of disease must be changed or eliminated. Water supplies have to be protected, improved or treated. Methods for the sanitary disposal of wastes must be used, insect vectors must be controlled, destroyed or guarded against, and educational programs must be instituted to make people aware of the need to prevent disease and teach them how to do so.

In the technical note, "Means of Disease Transmission," DIS.1.M.1, several categories of diseases were outlined and the specific mode of transmission of each was discussed. This technical note describes measures that can be taken to prevent the spread of water- and sanitation-related diseases.

Useful Definitions

HABITAT - A region or area where a plant or animal grows, lives or is ordinarily found.

SPILLWAY - A channel built to control the level of water in a dam reservoir; flood water is drained from a dam through spillways.

VECTOR - An animal or insect that transmits a disease-producing organism from one host to another.

Waterborne Diseases (Water Quality Related)

Waterborne diseases are those which are spread when the microorganisms causing them are consumed with contaminated water. Several methods of preventing water contamination and for improving the quality of water can be used. The need to biologically test the water for evidence of fecal contamination is of great importance. Water can be tested by collecting samples and taking them to a central laboratory or by performing tests in the field using special kits. (These methods are discussed in "Taking a Water Sample," RWS.3.P.2 and "Analyzing a Water Sample," RWS.3.P.3.)

In some locations, there may not be a way to test water because of long distance to testing laboratories and lack of field equipment. If testing is impossible, the assumption that the water is contaminated should be made if conditions at the water site are such that the source is not fully protected. Furthermore, measures to improve those conditions and prevent the spread of disease should be assumed to be needed. The following measures are important for improving local environmental conditions.

- Make sure that people have and use sanitary latrines. The community members should be educated about the need for latrines and how their use can reduce the spread of serious disease.

- Educate the people in where to locate latrines and how to construct them properly. All latrines should be located at least 15m from the nearest source of water. They should be at a lower elevation than the water source to ensure that contamination through seepage is prevented. See Figure 1.

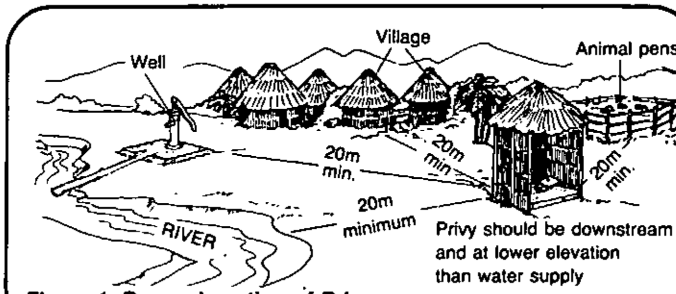


Figure 1. Proper Location of Privy

• Be sure that the pit does not puncture an aquifer. Latrine seepage that enters an aquifer can contaminate ground water (wells) and spring water supplies.

• Protect all wells and springs against contamination from surface run-off. Cap springs with spring boxes. Finish wells with a well head. Make sure that the well shaft is cased with concrete rings, pipe or brick. No surface water should seep into wells. See Figure 2.

• Control the breeding of flies by disposing of garbage and animal manure in a sanitary manner, and covering latrine openings when not in use. All community garbage should be disposed of in a sanitary landfill, while individual disposal can be achieved by digging small pits where rubbish can be burned and garbage buried. See Figure 3.

To control Guinea worm, eliminate all step-wells where the skin of water carriers can come into contact with

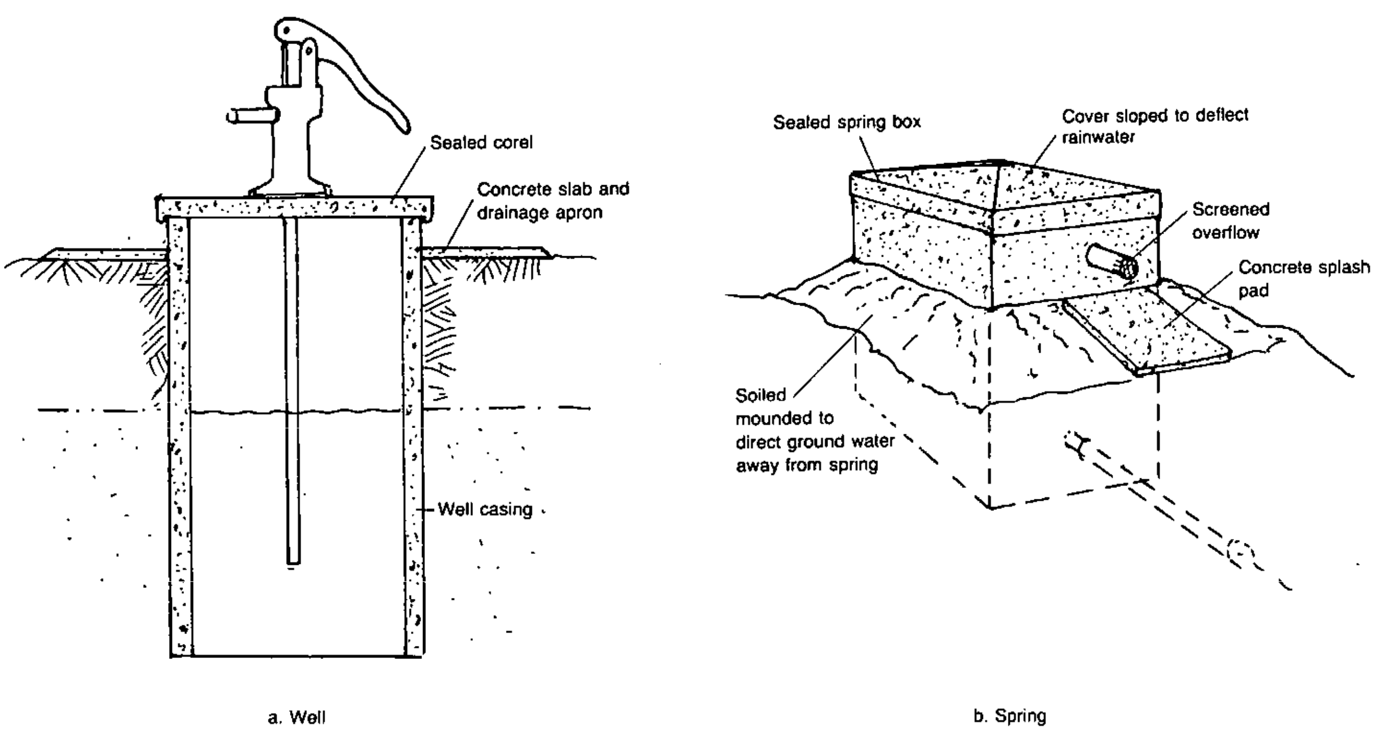


Figure 2. Proper Protection of Water Supplies

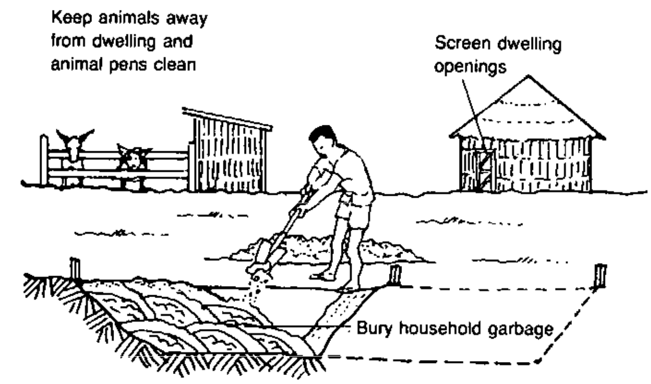
• For surface sources, especially those providing large quantities of water, set up an intake that allows for filtration of water before it enters storage. Filtration may not be sufficient to purify water and some form of treatment may be needed.

• Provide for treatment (further filtration or chlorination, for example) to purify water if needed. For household supplies, water can be boiled or chlorinated and stored in clean containers.

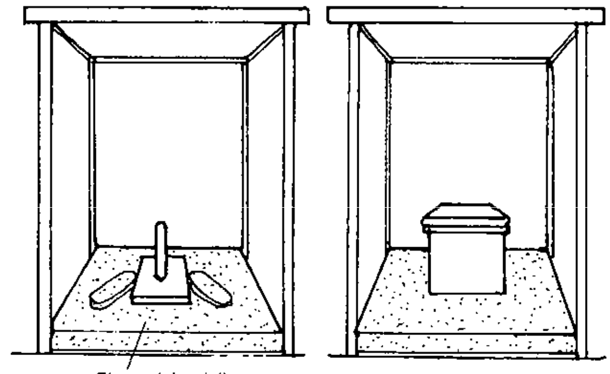
the water in the well thereby permitting the release of worm larvae into the water. Treat all water taken from open ponds or wells that might be contaminated with infected water fleas by filtering, chlorinating, or boiling it before drinking. These treatments will kill the larvae before they can infect a person.

Water-Washed Diseases (Water Quantity and Accessibility Related)

These diseases are ones which can be prevented by the provision of sufficient quantities of safe water. To



a. Control the Breeding of Flies



b. Cover Latrine Openings Tightly

Figure 3. Proper Disposal of Wastes

prevent the spread of water-washed diseases, people should be educated and motivated to practice personal and family hygiene. Washing of hands and bathing in clean water are very important. Clothes and dishes should also be washed to ensure that skin diseases are not passed to people by contaminated hands, clothing, or utensils. The same wash water should not be used by more than one person. Common use of towels should be avoided.

In order to improve hygiene practices, sufficient, convenient quantities of water are needed. A method of developing a water supply of sufficient quantity, adequate quality and easy accessibility and reliability should be chosen with the involvement of the community. The source should be well-protected to prevent contamination of the water supply.

Water-Contact Diseases (Body-of-Water Related)

Water-contact diseases are those which people get from having skin contact with water containing larval worms. There are both environmental and chemical means for controlling the spread of water-contact diseases.

Schistosomiasis is the major disease in this category. Schistosomiasis is controlled by breaking the chain of transmission at several points. The following measures should be followed when attempting to control the spread of schistosomiasis.

- Encourage people to build sanitary facilities and use them. If the eggs in the feces and urine do not reach water they will die, preventing the infection of the snails. This method is useful but is only truly successful if everyone uses latrines for both urinating and defecating. Assurance that everyone over a large area would use them is impossible. Therefore, this method must be combined with a reduction of the snail population and by limiting human contact with infected waters.

- Reduce the snail population. In irrigation schemes, drainage ditches are better environments for snails than irrigation canals. Where drainage ditches are necessary, they must be treated regularly with chemicals that kill snails. When canals are built, line them with a smooth surface like concrete and provide for a rapid flow rate. Smooth surfaces are not attractive to snails and a fast flow of water removes them.

- Maintain the banks of all irrigation canals and bodies of water. Vegetation slows water flow and provides a good environment for snail growth. Keep vegetation and weeds away from canals and beach areas. See Figure 4.

Figure 4. Chemical and Environmental Control of Schistosomiasis

• Drain large standing pools of water and fill in swampy areas to prevent the snails from breeding. Wherever possible, avoid the creation of small reservoirs or pools of water. These environments are very attractive to snails.

• Use chemicals that kill snails molluscicides. They are quite effective in controlling the snail population. Local spraying is the common method of applying molluscicides to water and is quite successful for irrigation projects. See Figure 4. Aerial spraying has also proved effective in many places. The application of molluscicides is less successful in large bodies of water because the water volume dilutes the molluscicides. Only if a specific local site on a large water body is treated with chemicals will success be achieved.

Swimming, bathing and clothes washing in infected water should be avoided. Whenever possible, houses and settlements should be located away from infected waters. In all settlements, both new and existing, potable, piped water systems should be developed. Safe water should be provided in sufficient quantities for drinking, bathing and washing.

Water-Related Insect Vectors (Water Site Related

Diseases that fall into this category are caused and spread by insects that breed in water or in damp, high humidity environments near water sources. Several measures can be taken to control the populations of mosquitoes, tsetse flies, and blackflies which spread malaria, yellow fever, sleeping sickness (trypanosomiasis) and river blindness (onchocerciasis).

Control of virtually all these diseases involves the elimination of the mosquitoes and flies through environmental or chemical means. Although the application of both aerial and ground spraying of insecticides has proved very effective, there are questions about the environmental effects of using them on a large-scale for a long time. Chemical control is sure to continue, but other methods should also be incorporated into vector control plans.

• Control of the tsetse fly which transmits sleeping sickness can be achieved by changing the environment where flies breed. One method is bush clearing along water courses and around villages. An attempt should be made to use cleared areas for permanent agriculture or settlement and thereby keep the land clean of bush.

• Blackflies, which spread river blindness (onchocerciasis), breed in rapidly flowing rivers. Chemical means are the best control for blackflies but some alternative measures can be developed. When dams are built in fast-flowing streams and rivers, the upstream lakes cover the rapids and destroy the breeding areas of the blackfly. Spillways should be built on the vertical face of the dam to avoid creating a new breeding place for the flies.

Mosquitoes transmit both malaria and yellow fever. The control of these insects is important both on a large-scale and an individual household basis.

Large-scale measures other than spraying chemicals include the draining and filling of wet, swampy places where mosquitoes breed.

Smaller-scale and individual measures should also be taken to control the breeding of mosquitoes. All possible standing water where mosquitoes could breed should be covered. Water storage jars and wells are particularly attractive breeding places for mosquitoes. Standing water in gutters should be removed and gutters should be sloped to remove water. At well sites, do not permit water to pool. Some sort of drainage should be built to move water away from the site and measures should be taken to prevent pools of water from developing. Remove any garbage where pools of water can collect and cover latrines so that mosquitoes cannot breed inside. Figure 5 shows some individual preventive measures.

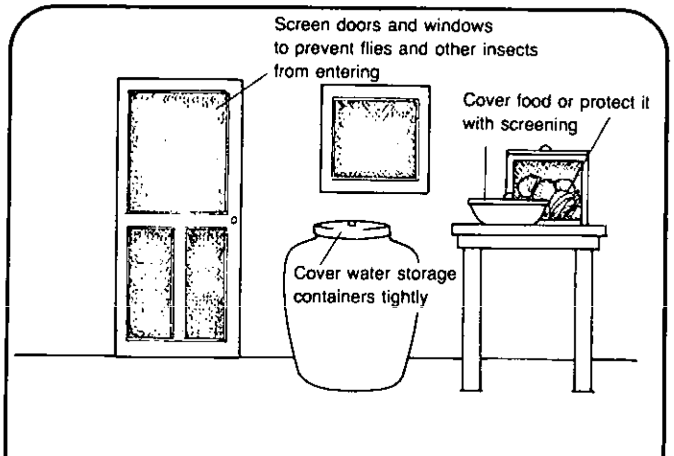


Figure 5. Individual Preventive Measures

These measures, coupled with spraying and a program of health, education will greatly help reduce the growth of the mosquito population.

Sanitation-Related Diseased (Fecal polluted soil related)

Diseases in this category, such as hookworm and roundworm, are a direct result in fecal pollution of soil and the lack of knowledge about good hygiene practices. These diseases can be controlled by relatively simple environmental improvements.

- Educate people on the need to use latrines and train children to use them at a very early age. Diseases are sure to be spread where human wastes are deposited on the ground or in rivers and streams.

- Make sure that all latrines have covers to prevent insects from breeding in the latrine pit.

- Provide sufficient quantities of water to ensure that people can practice personal hygiene. Make sure that people understand the need to wash their hands before eating and after defecating.

- Develop ways to keep flies off food. Screen areas where food is stored. Spraying the home periodically will keep flies and cockroaches away from food.

- Keep animals from entering the home and from coming into close contact with young children. Feces from animals can also spread disease.

Summary

Methods for controlling the spread of disease range from very simple and inexpensive family-oriented approaches to large-scale, more expensive community, regional and national programs. The choice of method will greatly depend on the circumstances, the problems to be remedied and the resources available. Generally, no single method will prove sufficient and a combination of methods is necessary.

The simplest methods of control are those which can be instituted by the construction of simple water systems and sanitary waste disposal systems. These systems are discussed at length in the technical notes on rural water supply and sanitation. See "How to Use Technical Notes," HR.G, for a full list of technical notes.

No successful control program can be developed unless people are educated about the need for a system. A thorough health education program must be developed so that people recognize the problem themselves and are stimulated to search for the appropriate solutions. Community participation is discussed in greater detail in the technical notes on human resources.

Notes

Water for the World

Methods of Controlling Enteric Diseases

Technical Note No. DIS. 2.M.4

Enteric diseases are those that affect the gastrointestinal tract of humans. They are caused by bacteria, parasites or viruses. The disease organisms are passed from infected people in their feces or urine. Others become infected when they take in the disease causing agents by eating soiled food or by drinking water contaminated with fecal matter. Enteric diseases are common throughout the world and, in most areas, some part of the population is always infected.

This technical note discusses measures which can be instituted to control the spread of enteric diseases. Special emphasis is given to basic preventive measures that should be taken to provide hygienic conditions in individual households and in the entire community.

Useful Definitions

DEHYDRATION - A condition in which the body loses more liquid than it takes in.

FECES - The waste from the body, moved out through the bowels.

PARASITE - Worms, insects or mites which live in or on animals or people.

STOOL - Human excrement, or a single bowel movement.

VIRUS - Germs smaller than bacteria which cause some infectious (easily spread) diseases.

Disease Transmission

The transmission of enteric diseases is by the fecal-oral route. The bacteria, parasites or viruses (germs) pass from the body of an infected person in excreta. The germs later enter the body of an uninfected person through the mouth. There are two main ways that germs can enter an uninfected person or re-enter the same person:

• Through the water that people drink. In many situations, water supplies are contaminated by enteric disease germs. If a person drinks fecally contaminated water, he is likely to suffer from an enteric disease.

• Through the consumption of food. Food can be contaminated by dirty hands or raw infected water, or by being exposed to fecally contaminated organic fertilizer or garden soil. Vegetables thus contaminated would only be safe to eat after being cooked or sterilized. Flies can carry germs to food. Flies that light on and taste food can inoculate food with germs that are consumed with the food.

Table 1 lists the principal enteric diseases and their routes of transmission. Diarrhea is a major symptom of all enteric disease. Many types of germs can grow on food if it is not refrigerated. Cholera and typhoid fever are dangerous to people of all ages. Cholera is an especially dangerous enteric disease. Among children, enteric diseases are a major cause of high mortality. Diarrhea is the leading killer of small children in most developing countries. It kills by dehydration.

Controlling Enteric Diseases

The control of enteric diseases involves three important interrelated activities: a health education program, a safe water and sanitation program, and home treatment of patients. These three activities should be implemented simultaneously and continuously.

Health Education

Most enteric diseases result from poor sanitation and a lack of safe (good quality) water in the community. Effective health education is necessary to help people understand the connection between improved hygiene and

Table 1. Principle Enteric Diseases and Their Common Transmission Routes

Diseases	Causative organisms	Common transmission route
Cholera	Vibrio cholerae, including biotype El Tor	Man - feces - water and food - man
Typhoid fever	Salmonella typhi	Man - feces - food and water - man
Paratyphoid fevers	Salmonella paratyphi: A, B, C,	Man - feces - food and water - man
Bacillary dysentry	Shigellae	Man - feces (flies) food (water) - man
Amoebic dysentry	Entamoeba histolytica	Man - feces (flies) food (water) - man
Infectious hepatitis	Hepatitus virus A	Man - feces - water and food - man
Diarrheal diseases	Shigellae, salmonellae, Escherichia coli, parasites, viruses	Man - feces (flies) food (water) - man

improved health. Health education aimed at eliminating the enteric disease should include the following:

- Formation of a community sanitation committee to coordinate the various activities and work needed to attack the problem.

- Participation of community groups. Teachers should be trained in the basics of disease transmission and prevention so that they can teach their students. Community groups, 4-H clubs, women's groups, other clubs, and the like should be active in health education.

- Development of audio-visual materials. Films, puppets, slides, songs, flashcards, and other methods can be used to make the problem and its solution clear to the members of the community. Students and clubs should be taught how to prepare their own audio-visual materials for demonstration.

- Implementation of specific education programs in clinics and hospitals.

Health education should start people thinking about the problem and create a desire to change their behavior to solve the problem. When people recognize the need to use a latrine and wash their hands, and understand the ways in which water is contaminated and the role of flies and other vectors in the spread of disease, they will be more willing to do something to change the situation.

Preventive Measures

Several measures can be taken to either remove sources of disease transmission or to prevent the sources from ever existing.

Latrines

- Build latrines at least 15m from any water supply or household. Be sure to site latrines so that they are downhill from any water source. Do not excavate pits into the water table. See Figure 1.

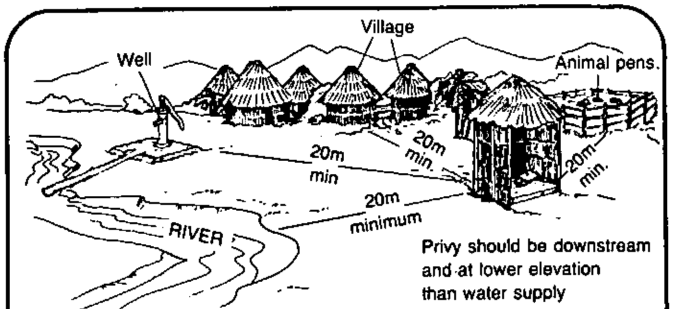


Figure 1. Proper Location of Privy

- Make sure that all latrines are sanitary. Ideally, the latrine should have a concrete floor. When not in use, the hole through the floor should be covered. Uncovered latrines permit the breeding of flies which can carry disease agents from feces to food. See Figure 2.

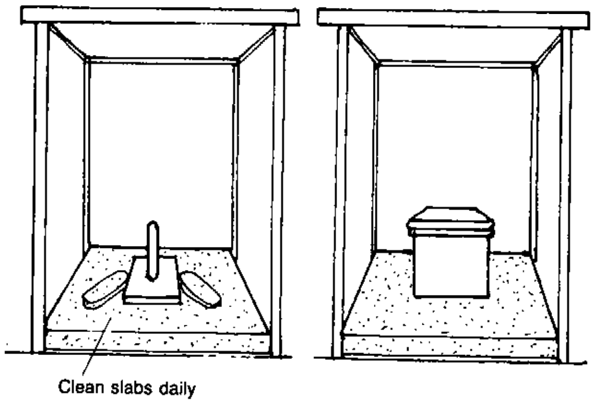


Figure 2. Cover Latrine Openings Tightly

• Accustom people to use latrines. One of the biggest problems is getting young children to use a latrine. Parents may use it but allow their children to defecate on the ground. Latrine openings should be sized so that children do not fear falling in. For more information on latrine design and construction, read the appropriate technical notes on sanitation. See "How to Use Technical Notes," HR.G, for a full list of technical notes. If latrines are not used, water sources can easily be contaminated by surface run-off.

Water Supply

• Provide for a safe supply of water for the community. Read the appropriate technical notes on rural water supply. Protect all wells from the entrance of surface run-off. A well-head and a pump should be installed in order to prevent contamination from entering the wells.

• Cap springs to prevent their contamination from surface run-off. See Figure 3.

• Where wells and springs are not protected or where surface water sources are used, water should be treated. Individual or community treatment should be used depending on the situation. Boiling and chlorination are the most common methods. For information on water treatment methods, see "Methods of Water Treatment," RWS.3.M.

Hygiene

Personal and household cleanliness is important for preserving health. The following practices are essential for controlling the spread of enteric diseases. Figure 4 shows some of these practices.

• Always wash hands with soap and water before eating and after using the latrine.

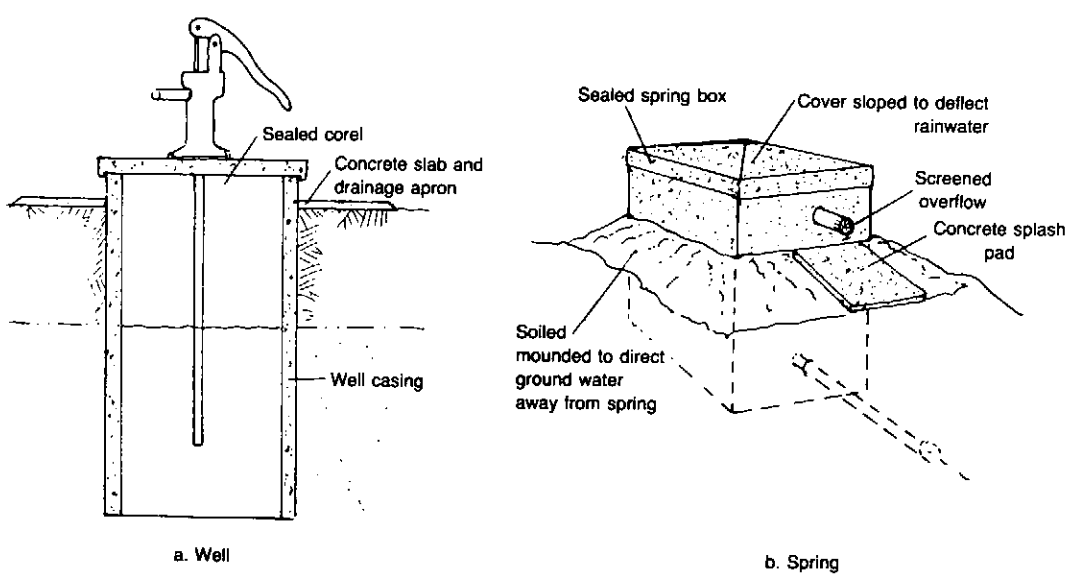


Figure 3. Proper Protection of Water Supplies

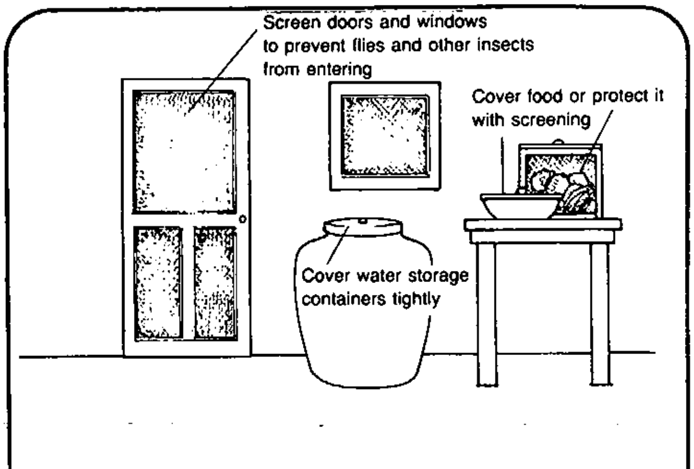


Figure 4. Individual Preventive Measures

• Wash fruits and vegetables before eating them. Be sure to scrub those vegetables which grow in ground that may be infected.

• Do not allow animals to enter the house.

• Store food in screened areas or in refrigerators and cover food with netting. These measures will keep flies away from food and help prevent the spread of disease.

• Keep the house clean by sweeping it daily.

• Require that food handlers are trained in personal hygiene and are aware of the need to store and cook food correctly.

• Dispose of all garbage properly. Make sure that garbage does not accumulate in such a way that flies can breed in it.

• Eat well. Diseases such as dysentery are more dangerous to people suffering from malnutrition.

Treatment Measures

At the same time that health education and preventive measures are being implemented, measures to treat patients with enteric diseases should be adopted. When diarrhea is present, liquid and salt are rapidly lost and must be restored to the body. Many children die from diarrhea or dysentary when they do not have enough water in their bodies. Persistently and frequently give liquids to a person with diarrhea. In severe cases in children, rehydration liquid should be given. Preparation of a rehydration drink: to a liter of boiled water, add two tablespoons of sugar, one-quarter teaspoon of salt, and one-quarter teaspoon of baking soda. Give the dehydrated person sips of this drink every five minutes, day and night, until he begins to urinate normally. An adult needs at

Table 2. Foods for a Person with Diarrhea

When the person is vomiting or feels too sick to eat, he should drink:	As soon as the person is able to eat, in addition to giving the drinks listed at the left, he should eat a balanced selection of the following foods or similar ones:	
teas	energy foods	body-building foods
ice water	ripe or cooked bananas	milk (sometimes this causes problems)
chicken, meat, egg, or bean broth	crackers	chicken (boiled or roasted)
Kool-Aid or similar sweetened drinks	rice	eggs (boiled)
REHYDRATION DRINK	oatmeal or other well-cooked grain	meat, well cooked, without fat or grease
Breast milk	fresh maize (well cooked and mashed	beans, lentils, or peas (well cooked and mashed)
	potatoes	fish (well cooked)
	applesauce (cooked)	
	papaya	
DO NOT EAT OR DRINK		
fatty or greasy foods	beans cooked in fat	alcoholic drinks
acidic raw fruits	highly seasoned food	any kind of laxative or purge

least 3 liters of water each day while a child needs 1 liter. Table 2 lists foods that should and should not be eaten by a person with diarrhea.

Where diarrhea is very severe and looks like it will not stop, keep giving liquids to the patient and seek medical help immediately. Seek medical help when:

- Diarrhea lasts more than four days and is not getting better or more than one day in a small child with severe diarrhea.

- A person is dehydrated and getting worse.

- A child vomits everything it drinks.

- The child begins to have fits or its feet and face swell.

- The person was sick or malnourished before the diarrhea began.

- There is blood in the stool.

Under these conditions, a more serious enteric disease may be present in the system and some type of drug treatment will be necessary.

Notes

Water for the World

Implementing Operation and Maintenance Training

Technical Note No. HR. 3.I.1

Training is very important to successful water and sanitation system operation. Training is necessary when a new operator begins a job, when an experienced operator needs to perform a new task, or when an operator does not have enough skill or knowledge to perform a job well.

Training must be directly applicable to local circumstances, understandable to local trainees, technically appropriate and technically correct. Training should be practical to the extent that trainees learn operational procedures on equipment identical to that which they will operate, if they are not trained on village equipment itself.

Training should take into account local learning techniques and educational methods so that credibility for teaching authority and prestige for training are created. Training should be conducted in a manner which meets local work standards and ethics, attaching a sense of dignity and pride to both the training process and the operation and maintenance job itself.

Training should be provided at appropriate levels for all personnel involved with the operation and maintenance of the water and sanitation system. This may include system operators, bookkeepers, local health educators and the village committee. Extensive training of this sort will provide a catalyst for wider community education and understanding of the water and sanitation system and will prevent one trained operator from monopolizing proper system operation. In case of the absence of one trained person, several other trained people will be available. There will also be a balance of power. For example, the village committee can select a system operator for training but the committee can also manage the water and sanitation system along with the system operator.

Management of Training Courses

Training programs must be well organized to work effectively. It is extremely important that trainers and trainees communicate well during the training sessions. The roles and responsibilities of both should be understood before training begins.

The roles of trainer and trainee are partially dependent on the location of the training program. See Table 1 in "Planning Operation and Maintenance Training," HR.3.P. Training in the village where the water and sanitation system will be operated has these advantages:

1. Trainees have more time for training sessions.

2. Trainees can learn on equipment they will actually be working on later. Special problems and conditions can be handled during training.

3. Local routines, people and conditions can be integrated into the training program.

4. The entire community can be helped to realize the importance of training.

Training at a central site has these management advantages:

1. Trainers are available to trainees at all times.

2. Operation and maintenance practices are taught in a standard manner to each trainee.

3. More teaching aids are available.

The role of the trainers and trainees may vary somewhat depending on where training takes place.

Roles and Responsibilities of Trainers

Trainers must be technically competent in the technology to be used. They must also be capable of handling administrative duties from both technical and management standpoints.

The training staff is responsible for determining the job tasks of all system personnel, determining the training course content based on those job tasks, organizing the material to be presented, selecting an instructional method and conducting the training programs.

Trainers responsibilities will be:

1. <u>To learn the trainees' needs and adapt the training program to meet those needs</u>.

Trainees may be divided into learning groups. Courses can then be molded to the needs of the individual groups while still covering necessary procedures. Trainers should personally examine local circumstances and determine what job tasks will need to be performed. They should then determine what the trainees already know and what they will need to be taught. Standard procedures for the defined tasks should be established and taught. Tool and equipment supplies should be adequately provided.

Operation and maintenance personnel with little mechanical background and little other education will probably need very structured and practical training programs. This is especially true if the system operators to be trained have not participated in the construction of the water and sanitation system they are being taught to maintain. Trainers must understand the procedures well and be able to explain them clearly to trainees in the trainees' own language.

If the operation and maintenance personnel have some mechanical background or are experienced in operation and maintenance, and have actively participated in the construction of the system and demonstrate a good understanding of its use, training may not need to be as regimented as it is for the inexperienced operation and maintenance trainee. The trainer can demonstrate procedures and have trainees practice them with trainer direction as needed for evaluation. One trainer can manage several trainees at the same time this way.

If trainees have been trained in the operation and maintenence procedures before, and demonstrate a good understanding and skill in their work, they may only need a refresher course. The trainer may only need to explain new types of equipment and procedures and be available to answer questions the trainees have while experimenting on their own.

2. <u>To maintain a positive and helpful attitude toward trainees</u>.

A "reward" may be established by the training co-ordinator as an incentive to create and maintain positive attitudes toward training. "Rewards" should be appropriate to local desires and circumstances. Public recognition, a special privilege, increased responsibility and pay increases are often used as incentives. Job security and official recognition for trainees by the village committee or regional center are usually more effective as incentives than financial benefits.

3. <u>To help install local respect for the proper operation and maintenance of the water and sanitation system</u>.

This may involve working with the entire village to some extent, and especially with community leaders and health educators. If training is taking place in the village, special efforts can be made to integrate local schedules, people and problems into the training program.

4. <u>Creating and maintaining a desire for learning and understanding during training</u>.

It is important that trainees understand that proper operation and maintenance can improve life in the village. It is also very important that trainers conduct training sessions in a manner that attaches a sense of pride and dignity to the training process which will be continued on the job.

Roles and Responsibilities of the Trainees

Trainees' responsibilities may be more circumstantial than trainer responsibilities. Overall, of course, the trainees' greatest responsibility is to learn how to operate and maintain the local water and sanitation system in order to provide good service to the rest of the community. Trainees' specific training duties may include:

- Clearly explaining to the trainer the extent of their experience with and knowledge of the water and sanitation system.

- Co-operating with the trainer's course structures.

- Actively participating in all training exercises and drills.

- Asking questions that are applicable to the trainee's local working situation.

- Maintaining a positive and co-operative attitude throughout training.

It is very important that the roles and responsibilities of all persons involved in the operation of the water and sanitation system be defined. Review those agreed upon during the planning stages of the system. Refer to "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.P. The responsibilities of the project planner, others in the action agency, the system operators, the village water and sanitation committee and the community as a whole should be clearly explained and agreed upon at the outset of the training program.

Content of Training Courses

The content of the training courses will be an explanation of the defined job tasks. See "Planning for Operation and Maintenance Training," HR.3.P. Generally, the action agency is responsible for providing logistical support and major repair services. The community will be responsible for the administration, operation, preventive maintenance and basic repairs of the system. For each position on the local level, the trainer should identify:

- job tasks and responsibilities;

- the degree of authority the position holds;

- financial responsibilities;

- support responsibilities.

The action agency is responsible for providing training for project planners, trainers and all village personnel. The project planner will be responsible for providing action agency support to the village while the system is in use. Community personnel, especially system operators, will need outside assistance when facing problems they cannot solve themselves. Back-up resources, such as information, skilled assistance, tools and parts should be readily available in the regional office of the action agency. The project planner should be prepared to:

- provide maintenance and repair services which village system operators have not been trained to perform;

- provide system and water quality control checks;

- supervise, assist and instruct local operators in operation and maintenance procedure reviews;

- assist in extensions of systems.

The regional office of the action agency should:

- maintain replacement parts to supplement the local supply;

- provide dependable central services for ordering other materials and spare parts;

- provide transportation of personnel and materials to community.

It may be possible for a supervisor or team from the action agency to visit villages on a regular basis to supervise procedures, answer questions, check the condition of facilities, perform needed repairs and provide other preventive maintenance services. Qualified advisors who provide regular refresher training to local operation and maintenance personnel are useful. This will minimize costly breakdowns and the length of time systems are out of order and increase community satisfaction and use of the system. Action agency support should emphasize that preventive maintenance is essential to the long-term operation and use of the system.

The responsibilities of local personnel will vary with local arrangements and with the design of the local system. System operators should be supervised by the village water and sanitation committee and by the project planner and trainer of the action agency. System operators are generally responsible for:

- basic daily operation of equipment;
- preventive maintenance of water supply equipment and sanitation facilities;
- protection of the water source from pollutants, children, and animals;
- simple repairs;
- reporting to the village committee, requesting new parts and asking for action agency assistance when needed;
- recognizing and reporting major problems.

Operation and maintenance training must prepare system operators to help the village committee create respect for the facilities among the rest of the villagers so that the facilities are properly used. System operators should know where they can obtain help at either the local or the regional level.

The village water and sanitation committee is generally responsible for:

- demonstrating proper use of facilities;
- teaching villagers to understand and appreciate the advantages of safe water supply and sanitation systems;
- assisting individual households to care for individual facilities and installations;
- retaining a bookkeeper to maintain system finances;
- estaiblishing flat or metered rates for water supply and sanitation services;
- collecting and retaining fees;
- paying for operation and maintenance with collected fees;
- ordering and purchasing needed equipment, perhaps at an agreed price from the action agency;
- requesting the services of the action agency, including the purchase and provision of major materials.

Fix an Implementation Routine

Regular methods of operating and maintaining the local water supply and sanitation system should be established as part of a training course. Regular times (daily, weekly, monthly) for the procedures should also be established. Any preventive maintenance or cautionary procedures should be incorporated into the regular operation and maintenance routines.

System operators' performance on the job can often be improved by using job manuals and visual aids such as posters to remind them of the established routine. Manuals and aids can be introduced as part of training, and may even serve as the outline for a training course. They can help trainees avoid having to memorize information they may remember incorrectly.

A basic manual can:

- explain operation and maintenance procedures step by step, as simply as possible;

- include illustrations for procedures;

- list and illustrate tools, supplies and equipment needed to carry out procedures;

- stress the importance of potable water and sanitary waste disposal.

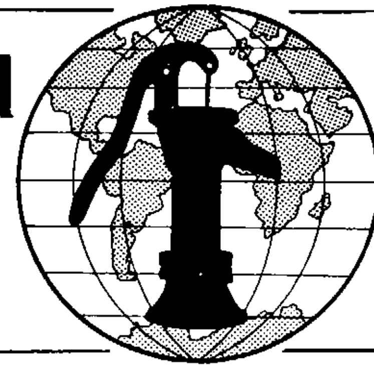
Visual aids, such as posters and picture manuals can replace written instructions for those unable to read well and supplement any manuals on the job. Training, operation and maintenance manuals and visual aids can be developed by the regional office of the action agency. The regional office staff should know better than the national office staff how the tools, equipment, supplies and procedures should be applied to the local situation.

Reports

Monthly reports on the functioning of the system should be made by the system operator. Oral reports can replace written reports for those who do not write well and can be given directly to the action agency maintenance supervisor or inspector. A system opertor who does not read or write well can be taught to check an illustated chart in order to make reports, or another member of the community can write up the system operator's oral report. Periodic inspections of the system should be made by the project promoter from the action agency.

Notes

Water for the World



Selecting a Source of Surface Water

Technical Note No. RWS. 1.P.3

The success of a water project depends on the suitability of the water source that is chosen to serve the community. The selection of the most appropriate source is very important and requires that all available water sources that could serve the community be identified, and the most appropriate source be selected. A source should be selected only if (a) it meets the needs of the users, (b) is easily accessible to them, and (c) can be developed at an affordable cost.

This technical note suggests guidelines for choosing the most appropriate surface water source for a community. It describes methods for measuring the quantity of water available from a surface source, and establishes four priorities for source selection that will help ensure the selection of the best source at the lowest development cost.

Determining Quantity of Water Available

In considering a water source, you must first find out how much water it yields, whether it provides enough water to meet community needs and whether it is reliable during the entire year.

Springs. To determine the suitability of a spring, it is necessary to know how much water it will yield, and how well it will keep up its flow in dry weather.

The yield is measured by a very simple method. First, channel the spring's flow into a small, hollowed-out collection basin that is dammed at one end. Make sure that the basin collects all available flow. Place an overflow pipe through the dam so that the collected water flows freely through the pipe, as shown in Figure 1. Make certain there is no

Useful Definitions

DISINFECTION - Destruction of harmful micro-organisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

HYDRAULIC RAM - A self-powered pump which uses the energy of falling water to lift some of this water to a level above the original source.

POTABLE WATER - Water that is free from harmful contaminants, is aesthetically appealing, and is good for drinking.

RECHARGE - Natural process by which quantities of water are added to a source to form a balance between inflow and outflow of water.

WATER BALANCE - Balance of input and output of water within a given defined hydrological area such as a pond or lake, taking into account changes caused by storage.

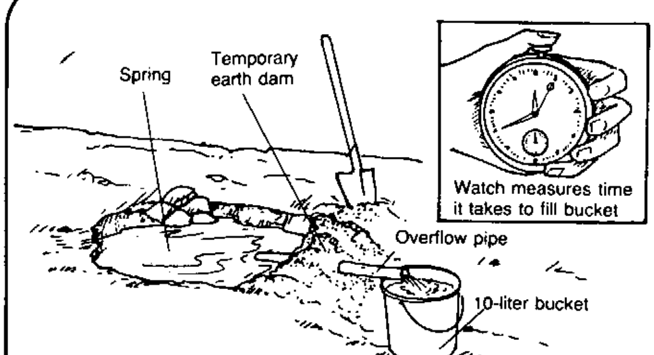


Figure 1. Measuring Spring Flow

leakage around the pipe. Then, put a bucket of a known volume (for example, a 10-liter bucket) under the pipe to catch the flow. With a watch, measure the amount of time it takes for the bucket to fill. Divide the volume of water by the amount of time to find the rate of flow in liters per minute. For example, if the 10-liter bucket fills in 45 seconds, the rate of flow is:

$$\frac{10 \text{ liters}}{45 \text{ seconds}} = 0.22 \text{ liters/second}$$

0.22 liters/second x 60 seconds/minute = 13.2 liters/minute

It is then easy to determine the volume of water available during a 24-hour period. Multiply the number of liters per minute by 60 minutes per hour to find liters per hour. For example:

13.2 liters/minute x 60 minutes = 792 liters/hour

Then, take the flow in liters per hour and multiply it by 24 hours per day to find the daily flow. For example:

792 liters/hour x 24 hours/day = 19008 liters per day

Compare this amount to the daily needs of the community. The daily need is computed by multiplying the number of users by the number of liters each person will use in one day. For example, if there are 300 people using 40 liters per day, the daily water usage is 12000 liters. A spring with a daily flow of 19008 liters and a storage tank would be more than enough to meet the needs of a community of this size.

Ponds, Lakes and Reservoirs. The amount of water available in a small pond, lake or reservoir can be roughly estimated by a simple method. An example to follow is shown in Figure 2.

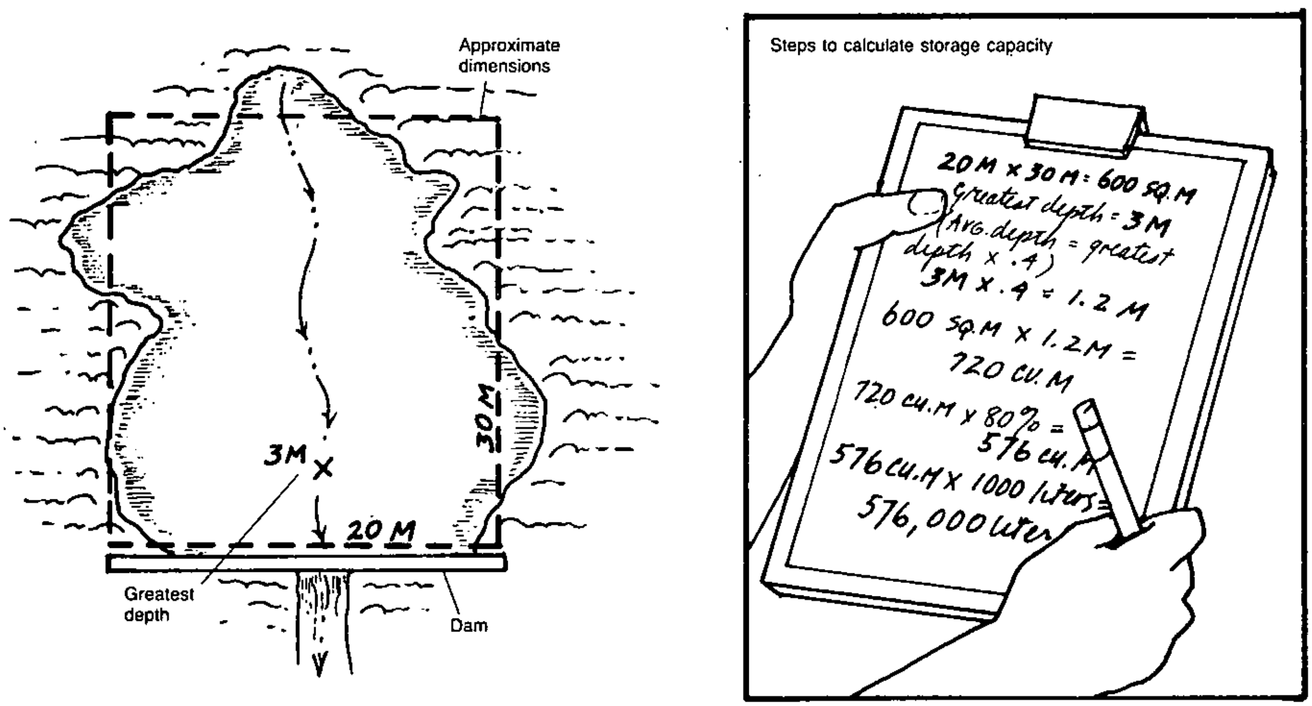


Figure 2. Estimating Storage Capacity of Small Lake or Pond

1. Lay out a rectangular shape around the body of water approximately its size.

2. Measure the length and width of the rectangle and multiply the two numbers to find the area of the rectangle in square meters. For example, if the length is 30m and the width 20m, the area is $600m^2$.

3. The depth of the source should be measured at the deepest point and the average depth calculated. The average depth is found by multiplying the greatest depth in meters by 0.4. If the deepest point in the pond measures 3m, the average depth is 3m x 0.4 = 1.2m.

4. The amount of water in the source is measured in cubic meters and is calculated by multiplying the area (m^2) by the average depth (m). In the example, the area is 600m and the average depth 1.2m. The volume of water is $600m^2$ x 1.2m = $720m^3$.

5. A basic rule to follow is that the volume of water available is generally about 80 percent of the total volume of water in the pond or lake. The other 20 percent is usually lost through evaporation, transpira tion, and seepage. To find the volume of water available for use, multiply the total volume of water by 80 per cent. For example, .80 x $720m^3$ = $576m^3$.

6. There are 1000 liters of water per cubic meter (1000 liters = $1m^3$). In the example, the water available for use in liters is:

$576m^3$ x 1000 = 576000 liters.

Compare the estimated amount of water available to the amount needed by the community and estimate how many months the source will provide water for a community without recharge. This determination will assist in planning for times when there is no rain. If possible, a source should contain at least a six-month storage supply. To refine further the estimate of the source's yield, find out its history during the wet and dry seasons. Note any major fluctuations in water level and be prepared for them when planning to develop the source.

For example, if 100 people use 40 liters per day each, or 4000 liters total, we can determine their monthly water usage and the number of months the pond will supply sufficient water. To do this, multiply the total daily usage by 30 days per month:

4000 liters x 30 days/month = 120000 liters/month

Then divide the total number of liters available by the number of liters used in a month to find the number of months the source will last without recharge:

$$\frac{576000 \text{ liters}}{120000 \text{ liters/month}} = 4.8 \text{ months}$$

In the example, the source would supply storage for approximately five months without normal recharge. That is, unless there were rain, the pond would dry up in five months. When considering pond or lake development, it is necessary to take into account rainfall and recharge rates to make sure the source is suitable.

Rivers and Streams. Simple methods are available for determining the flow of water in a stream or river. For smaller streams, the same method as for spring flow can be used. That is, a dam with an overflow pipe can be built and the flow can be found by seeing how long it takes for a bucket of known volume to fill with water.

There is another method for determining flow in small streams with slightly greater flow. It is called the V-notch method. A V-shaped notch with a 90^{o} angle is cut out of a flat piece of metal or wood and placed in the middle of a dam so water flows through the notch as shown in Figure 3. A gauging rod is placed in the stream 2 to 3m upstream from the dam. The zero point on the rod must be level with the bottom of the notch. The depth of the water from the bottom of the notch, the zero point, to the water level can be read from the gauge. Table 1 gives the flow per second for a given height. This information will help determine the amount of water available for an intake in a stream or river.

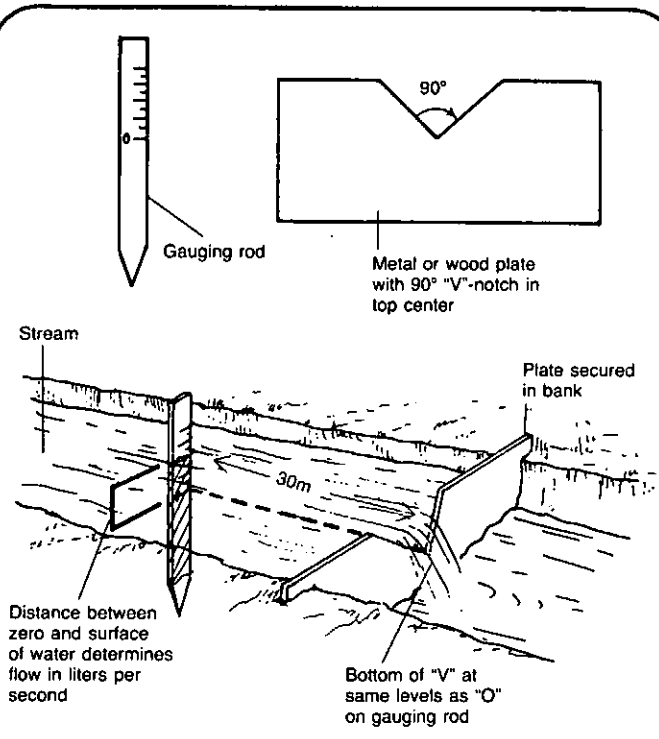


Figure 3. Measuring Stream Flow

If the flow is too great to use the V-notch, there is another, less accurate, method that can be used. This method is not nearly as accurate as the others and should be used only when measuring flow in larger streams. Find a straight, wide stretch of a stream and measure a length along the bank. Place a stake at each end of the measured distance as shown in Figure 4. Throw a floating object into the stream at the first stick and time how long it takes for the object to reach the

Table 1. Flow Over a 90° V-Notch

Height of Water (mm)	Flow (liters/ second)
50	0.8
60	1.2
70	1.9
80	2.6
90	3.4
100	4.5
110	5.6
120	7.0
130	8.6
140	10.3
150	12.3

second stick. Repeat this test three times and take the average. The flow in liters per second is calculated using the following formula:

$$850 \times \text{measured length} \times \text{width of the stream} \times \frac{\text{average depth}}{\text{average time}}$$

For example, to measure the flow of a stream 1m wide with an average depth of 0.3m, place two sticks on the bank approximately 3m apart. Throw a floating object into the middle of the stream at the first stake and measure how long it takes to travel the 3m distance. Take the measurement three times. Assuming the object takes an average of 20 seconds to float 3m, use the equation to deter mine river flow:

$$850 \times 3\text{m} \times 1\text{m} \times \frac{.3\text{m}}{20} = 38.25\ \text{liters/second}$$

To find out if the flow will be sufficient, determine the daily demand for water and the volume of available water. The flow in liters per second can be converted to flow per day by using the following formula:

liters/second x 60 = liters/minute;
liters/minute x 60 = liters/per hour;
liters/hour x 24 = liters/day.

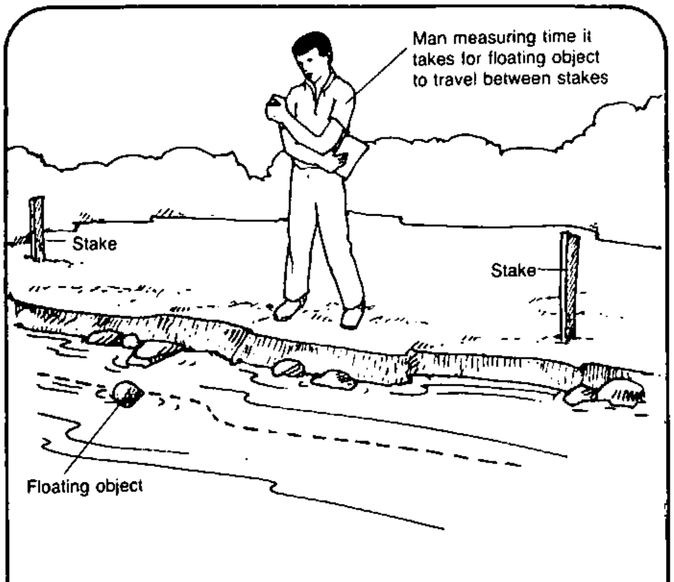


Figure 4. Measuring Large Stream Flow

Rain Catchments

When considering a rain catchment as a source for a water supply, first determine individual needs. This is done by multiplying the number of people in the family that will use the system by 15 liters per person. If there are six people in a family using 15 liters of water per person per day, the total demand for water is 90 liters:

15 liters/person/day x 6 persons = 90 liters/day.

The second step is to figure out how much water will be available. Determine the area of the catchment area by multiplying the length of the roof by the width. The width is the length of the base of the triangle formed by the roof. For example, if the length of the roof is 8m and the width is 6m, then the area of the roof is $48m^2$.

Next, determine the amount of annual rainfall for the region. This should be available from a local government agency, a weather station or an airport. Multiply the amount of annual rainfall by the area of the roof catchment to find the amount of water available for consumption. For example, assume that 750mm, or .75m, of rain falls on a $48m^2$ catchment area. The quantity of water available for use is $.75m \times 48m^2 = 36m^3$. To convert $36m^3$ to liters, multiply by 1000:

36 x 1000 = 36000 liters/year.

Not quite all the water will be collected. Some splashes to the ground and some evaporates. For planning purposes, assume that 20 percent of the water is lost. Then the amount of water actually available is 28800 liters. This is calculated by multiplying the amount available, 36000 liters, by 0.80:

36000 liters x .80 = 28800 liters.

To make the numbers easier to work with, divide the total quantity available either by 12 to get liters per month or by 365 to get liters per day:

$$\frac{28800 \text{ liters/year}}{12 \text{ months/year}} = 2400 \text{ liters/month}$$

$$\frac{28800 \text{ liters/year}}{365 \text{ days/year}} = 79 \text{ liters/day}$$

A cistern must be constructed to store the water collected by the catchment. For information about storage see "Methods of Storing Water," RWS.5.M, and "Determining the Need for Water Storage," RWS.5.P.1.

Compare the total available quantity to the demand for water and determine if family needs can be met using a roof catchment system. Each person should have 15 liters per day available, but in some cases demand for water from catchments may be less than 15 liters. If the quantity available ranges between 10 and 15 liters per person, the system is suitable.

Priorities for Source Selection

The quantity of water available from surface sources can now be determined. Quantity is an important factor but it is not the only one. A suitable source must provide good quality water, and it must be reliable. Another important factor is that water should be available to the user at the lowest possible cost.

When planning to select a suitable source, it is useful to have a set of guidelines. The first guideline discussed here is sufficient water quantity. If several sources offer adequate quantity, a choice must be made among sources. Table 2 lists priorities to consider when choosing a source.

Table 2. Priorities for Surface Water Source Selection

Priority	System
First	No treatment or pumping required
Second	No treatment but pumping is required
Third	Some treatment but no pumping is required
Fourth	Both treatment and pumping are required

These priorities are guidelines for selecting the most appropriate source among several alternative methods of surface water development. The priorities are established in order of ease of construction, maintenance, and financing of the system. Where no treatment or pumping is required, a system is easier to develop, operate and maintain. Moreover, the development costs should be lower than for systems requiring treatment and pumping. Once treatment and pumping are added to a water system, costs rise and a program for operation and maintenance must be established to ensure constant operation. These extra costs could make the development of the project difficult for a rural community. When following the basic guidelines, keep in mind other factors such as community preferences and available community resources.

No Treatment; No Pumping. A water source which supplies abundant water needing no treatment that can be delivered to the user by a gravity system should be the first source considered. Because no treatment or pumping is required, the cost of developing, operating and maintaining the system is relatively low.

If a spring of sufficient capacity is available in, or near, the community, it could prove to be the best source. Water from a protected spring generally needs no treatment. An initial disinfection applied after the source is protected will be sufficient to ensure good water quality. If springs are found in hilly areas, they can easily be developed to supply a community with water through a gravity flow system. Water from the spring flows downhill into storage and then to the distribution system.

Care must be taken to ensure that there is an adequate head so water will reach the users. Head is the difference in water levels between inflow and outflow ends and is an important concept in developing water systems. The possibility of loss of water pressure due to insufficient head is an important consideration in determining the suitability of a source. When planning to use any surface source, especially a gravity flow source where water is piped, see "Designing a System of Gravity Flow," RWS.4.D.1.

A stream or river in a highland region with few inhabitants is another source which probably will require neither treatment nor pumping. In an area where not many people live, fecal contamination is not a likely problem and treatment will not be necessary. In a hilly region, the water intake can be located at a higher elevation than the storage tank and the community. This will allow use of a gravity flow distribution system if head is sufficient. Costs should be low, but higher than for a spring because of the task of constructing a river intake. Maintenance should be simple.

Rivers and springs that do not require pumping or treatment are good sources of water for a community supply. Water from both sources is often cool and tastes good to the users. Generally, the source is accessible and is one that the community is accustomed to using. A project using water from these sources will normally be accepted by the community, and will offer them good water at low cost.

No Treatment; Pumping Required. When a first priority source is either not available or is inadequate, consideration should be given to a source that needs no treatment but requires pumping. Treatment can be very expensive and requires special skills, equipment, and a continued supply of treatment chemicals except where only simple settling is needed.

Pumping devices, on the other hand, can be simple, easy to install and inexpensive, such as hand pumps. They can also be quite complicated and expensive to operate and maintain, as is true of power pumps. Whenever any pump is installed, trained maintenance people with access to spare parts will be needed. Mechanical pumps require energy and either electric power or petroleum to operate.

In some cases, water from a natural lake or pond may not need treatment for use as a drinking source, especially if it is located away from uninhabited upland areas. Thorough testing of the water should be done before using it without treatment.

A river or stream is another source of water that possibly can be pumped without treatment. Several alternatives exist. A mechanical pump can easily be installed in a mountain stream where a gravity flow system is not feasible. Where there is sufficient fall and volume of water in the stream, an inexpensive hydraulic ram can be used to lift water to a storage tank.

An infiltration well or infiltration gallery may also provide water that needs no treatment. Infiltration intakes are located on the banks of streams and rivers. The stream water that enters them flows through the ground and is filtered. If properly planned and designed, infiltration wells and galleries can provide water needing no treatment.

A hand pump can be installed on the infiltration well and on the storage well of infiltration galleries, if water is to be used at the source. If water distribution is necessary, a windmill or fuel-powered pump can be installed.

Some Treatment; No Pumping Required. In some circumstances, the only surface sources available to a community will need treatment. Since treatment can be relatively expensive, a source which requires some treatment but no pumping should be the next source considered.

Rain catchments offer a relatively inexpensive method for providing water to individual users. Water from a rain catchment requires treatment because dirt, bird and animal excreta and other contaminants collect on the roofs of houses between rainfalls. During a rainfall, the contaminants are washed into gutters and pipes and then into the water collection cistern. To be safe, this water must be filtered and disinfected (see "Methods of Water Treatment," RWS.3.M). Rain catchments offer a variable yield and should only be considered where rainfall is adequate. Where rainfall is abundant, the system should prove reliable.

A contaminated river or stream in a hilly area is well-suited for a gravity flow system. Where treatment is necessary, water will flow through the intake, through treatment and into storage. This system may be very expensive due to construction and continuing treatment costs.

The source requiring the least treatment will cost less to develop. The amount of treatment a source will need must be determined before a source is selected.

Treatment and Pumping Required. Of all the alternatives mentioned, the most expensive is that which requires both treatment and pumping. Ponds, lakes and most streams fit into this category. Water from ponds and lakes usually must be pumped and usually requires treatment. If a pond is not exposed to fecal contamination, treatment may be a very simple process and not very costly.

A pond or lake can be a very good source of abundant and accessible water and may be the only source available to a community. With proper management of the watershed and with adequate treatment, a pond or lake will be a good source. An efficient system of operation and maintenance must also be established to ensure continued functioning of the system. Costs for this kind of system are likely to be high.

Small community ponds, especially where manmade, usually are highly contaminated from waste and contaminated run-off. Use of a contaminated community pond is risky and treatment must be very good to make the water potable. Water from this type of pond should not be used unless another good alternative does not exist.

Direct use of water from a river or stream usually requires that water be pumped from the source and treated before it is used by the community. Water from rivers and streams in lowland areas is especially likely to be contaminated. Water quality in rivers and streams should always be questioned because there are likely to be sources of contamination upstream. Only in mountain streams or where infiltration galleries are used is stream water likely to be good without treatment.

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Water for the World

Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources

Technical Note No. RWS. 1.P.2

A community interested in development of a community water supply may have several sources of surface water available to it. When a choice has to be made between sources, the quality of the water at the source and the quantity it produces must be considered. Methods for determining whether a surface source provides a sufficient quantity of water are discussed in "Selecting a Source of Surface Water," RWS.1.P.3. To determine water quality, a sanitary survey must be conducted.

A sanitary survey is a field evaluation of local health and environmental conditions. The goal of a sanitary survey is to detect all sources of existing and potential contamination, and to determine the suitability of the source for a community water supply. From information gathered in the survey, sources of contamination can be removed and water supplies protected. Information should be gathered through observation of local conditions, through sampling of water, and through interviews and conversations with local leaders, health officials and villagers. The following factors should be considered when doing the survey; (a) physical characteristics of the location which indicate potential contamination, (b) bacteriological quality of the water and (c) physical and chemical qualities of the water.

This technical note describes each of these factors and their importance in determining existing and potential sources of contamination of a water source. Worksheet A summarizes the questions to be answered by a sanitary survey.

Useful Definitions

ALGAE - Tiny green plants usually found floating in surface water; may form part of pond scum.

BACTERIA - One-celled micro-organisms which multiply by simple division and which can only be seen through a microscope.

COLIFORM - Bacteria found in the large intestine; a coliform count is often used as an indicator of fecal contamination in water supplies.

E. COLI - A type of coliform bacteria present in the intestine of man and animals, the presence of which in water in sufficient quantity indicates fecal contamination.

FECAL BACTERIA - Organisms in human and animal waste associated with disease.

FILTRATION - Process by which bacteria are removed from water as it flows through tight soil or fine sand.

FISSURE - A narrow, deep crack in rock.

LIMESTONE - A white rock consisting of mostly calcium carbonate.

SCUM - Floating impurities found on top of liquids or bodies of water.

Worksheet A. Questions to be Answered by a Sanitary Survey

1. Do potential sources of surface contamination exist — Yes / No

    a) above the site or in the watershed? ____ ____

    b) at the site? ____ ____

   If yes, determine these sources and

    a) remove sources of contamination, and/or

    b) protect the water supply, or

    c) find a more acceptable water supply.

2. Do potential sources of fecal contamination exist — Yes / No

    a) above the site or on the watershed? ____ ____

    b) at the site? ____ ____

   If yes, determine these sources and

    a) analyze the water, or

    b) remove sources of contamination.

   If level of coliform bacteria greater than 10 organisms per 100ml of water,

    a) water must be treated or

    b) alternative source must be found.

3. Does the water source have unacceptable chemical or physical qualities such as: — Yes / No

    a) color? ____ ____

    b) turbidity (1) all the time? ____ ____

    (2) after a rainstorm? ____ ____

    c) unpleasant odor? ____ ____

    d) a lot of salt? ____ ____

    e) excessive algae? ____ ____

    f) excessive flourides? ____ ____

    g) hardness? ____ ____

   If the answer is YES to any of these questions, study the water source carefully and analyze the water if possible. Generally, these conditions will make water unacceptable to the users and the source must either be treated or abandoned for a new one.

Physical Characteristics of the Location

Physical characteristics that contribute to the contamination of surface water can be recognized through a sanitary survey. To determine if a source is acceptable, a thorough study of the site and nearby areas must be done. If conditions indicate that contamination is likely, the water source should be tested to see if treatment is necessary. (See "Determining the Need for Water Treatment," RWS.3.P.1). Contaminants must either be removed or the water supply protected against them. If protection or removal is impossible, a more suitable source should be found. Physical conditions contributing to contamination of different types of surface sources are discussed below.

Springs. Springs can provide a very good source of water for a community supply. Generally, water from springs can be used without treatment if the source is adequately protected with a spring box. Not all water from springs is free from contamination. A sanitary survey of the spring site will help determine whether contamination is likely.

The first step in a sanitary survey of a spring site is to determine the physical conditions above the point where the water flows from the ground. If there are large openings or fissures in the bedrock above the spring, contamination of the spring from surface runoff may occur. Surface runoff enters the ground through the fissures and contaminates the spring water underground.

Find the true source of the spring. Many times, a small stream disappears into the ground through a fissure and emerges again at a lower elevation. What appears to be a spring actually may be surface water that has flowed underground for a short distance. The water is generally contaminated and may flow only during the wet season.

Determine if there are sources of potential fecal contamination. Livestock areas, septic tanks and other sewage disposal sites are sources of contamination. If they are located above the source or closer than 100m to it, contamination may occur and disease-causing bacteria can enter the water.

The second step in a sanitary survey is to study the area at the spring site. The type of soil may indicate that contamination is likely. Filtration may be poor if permeable soil deeper than 3m is within 15m of the spring. Water passes quickly through coarse soils and impurities are not filtered out. If this condition exists, or if there is any suspicion of contamination, a water analysis must be done.

A spring flowing from limestone or highly fractured rock may be subject to contamination. Earth movements create fissures and cracks in limestone allowing surface run-off to enter the ground rapidly with little or no filtration of impurities. If a spring flows from a limestone bed, check the water after a heavy rain. If it appears turbid, suspect surface contamination and either analyze the water or choose a better site.

Community members must always be consulted during a sanitary survey. Information from local people should be added to the information collected through observation. They will know about spring yields and reliability and about other local conditions.

Ponds and Lakes. A study of the characteristics of the watershed must be done to determine whether there are potential sources of contamination of pond and lake water. The watershed is the area within which rainfall flows over the surface of the ground into rivers, streams, ponds and lakes. An acceptable watershed must be free from human and animal wastes. An area that has latrines, septic tanks or animals is not appropriate for a watershed feeding a drinking water supply. Such an area is a source of fecal contamination which may make water unsafe to drink. A study of the watershed should also determine that there are no contaminated streams entering ponds to be used as water sources. A contaminated stream flowing in the watershed could lead into the water supply and make the water unfit for drinking.

The watershed should not support farming. On some farms, pesticides and chemical fertilizers are used to increase crop production. Rainfall carries these elements from the fields into the water source and contaminates it. Find out if fertilizers and pesticides are used on farms in the watershed area before choosing the water source. If a watershed has farms that use fertilizers and pesticides, the water source fed by it will most likely be unsuitable without treatment. If there are farms, erosion is likely to occur. The soil that enters the pond or lake will settle to the bottom and may cause it to fill up rapidly. This reduces the amount of water available to the users and limits the life of the pond. A better site should be chosen or trees and grass should be planted in the watershed to prevent soil from entering the water supply.

Heavy growths of algae in water may indicate of possible contamination. Algae grow in water with a high concentration of organic material nitrates and phosphates. Water supporting excessive algal growth should not be used as a water source until its quality is determined.

Rivers and Streams. Like ponds and lakes, the quality of water in rivers and streams is dependent on the characteristics of the watershed. The major difference is that stream and river watersheds are more extensive and much more difficult to control. Above a river intake, the watershed may support sewage disposal, animal grazing and farming. People may use the river for laundry and bathing. Such practices will adversely affect the water quality downstream. Where an intake is located below an inhabited area, the water quality should not be trusted. Only where an intake is located above inhabited areas can efficient watershed management take place. If possible sources of contamination exist upstream, then treatment will be necessary.

Roof Catchments. A sanitary survey can indicate potential sources of contamination in catchment systems. The first step in the sanitary survey is to determine the roofing material available. Tile and corrugated metal make the best collectors for drinking water. Water from thatched, tarred or lead roofs is likely to be very contaminated and very dirty. Catchment systems should not be installed where houses have roofs made from these materials. Find out if a suitable cistern is available. The cistern should be clean and covered to protect the water quality.

Bacteriological Quality of Water

An untreated water source should be as free from bacteriological contamination as possible. The greatest and most widespread source of such contamination is human and animal wastes, which is called fecal contamination. A sanitary survey determines the degree to which water sources may be subject to fecal contamination. To find out if water contains fecal bac teria, it is necessary to take a water sample and have it analyzed. (See "Taking A Wate Sample," RWS.3.P.2; "Analyzing a Water Sample," RWS.3.P.3; and "Determining the Need for Water Treat-ment," RWS.3.P.1).

Most fecal bacteria are members of a group called coliforms which include the organism E. Coli. The presence of E. Coli and other coliforms in water are indicators of fecal contamination. For an untreated water source to be acceptable, the level of fecal contamination must be low. The level of fecal con tamination can only be determined by a laboratory analysis. The technical note "Analyzing a Water Sample," RWS.3.P.3, describes standards for acceptable amounts of coliforms in water and explains methods for testing water. Generally, standards are no more than three coliform organisms in a 100ml sample for piped systems and no more than 10 organisms in a 100ml sample for nonpiped systems. Any source having over 10 coliform organisms per 100ml should be abandoned or the water treated.

Equipment for testing water may not be available and water analysis may be impossible. If so, observation can reveal characteristics that indicate bacteriological contamination. If there is a layer of scum on the water surface, suspect contamination. If excessive algae are growing in a pond or lake, there are organic impurities which may indicate the presence of fecal matter in the water. Speak to local health officials and village leaders to find out if there is a large number of cases of diarrheal illnesses. Many cases of diarrhea, especially among young children, may be an indication of contamination in the water source.

By simple measures such as removing obvious sources of contamination from a catchment area, fecal contamination can be controlled and eliminated. If contamination is not reduced, then the water source should be considered unacceptable.

Physical and Chemical Quality of Water

The bacteriological quality of water is the most important factor in determining the acceptability of a source. Many times, though, water is bacteriologically safe, it has physical or chemical characteristics that make it unpleasant or unattractive to the users. To determine the exact physical and chemical quality of water, laboratory analysis must be done. An evaluation of physical and chemical conditions can be made by doing a sanitary survey. A thorough sanitary survey can detect turbidity, color, odors, and tastes and help determine the acceptability of the water source.

Turbidity. Turbidity is the presence of suspended material such as clay, silt, organic and inorganic material which clouds or muddies water. Turbid water may be potable but often it is aesthetically unacceptable to users. Turbidity may also indicate contamination. A laboratory analysis should be done, if possible.

Color. Dissolved organic material from decaying vegetation and some inorganic material cause color in water. An excessive algal growth may cause some color. Color in water is generally not harmful but it is objectionable and may cause users not to drink the water. Highly colored water needs treatment.

Odors and Tastes. Odors and tastes in water come from algae, decomposing organic material, dissolved gases, salts and chemicals. These may be from domestic, agricultural or natural sources. Water that has a bad odor or a disagreeable taste will be rejected by a community for a different source.

Certain chemical properties of water can make a source unacceptable to the users. The chemical quality of water can only be determined by an analysis in a well-equipped laboratory which is unlikely to be located in a rural area. Because an analysis may be impossible, it is important in the sanitary survey to recognize some chemical qualities of water which may make users reject a source.

Water that contains a high degree of calcium and magnesium carbonates is called "hard." Hard water requires a great deal of soap for cleaning and washing clothes because it does not lather. Extra soap, which is costly, must be purchased to clean with hard water. Extra time and work is involved in scrubbing with hard water. Pipes may even become clogged with deposits from the water. For basic economic reasons, people may reject hard water unless it is "softened."

Where algae are abundant, phosphates and nitrates are likely to be present.

These come from chemical fertilizer and sewage, and can be very dangerous to health. A high nitrate content in water may cause blood problems in infants being fed on reconstituted milk formulas. The babies become blue as oxygen in their blood is lost.

High concentrations of flouride in water cause dental problems. Flouride can cause teeth to become brown and mottled after several years. In severe cases, pitting occurs. If these dental problems exist, suspect high levels of flouride in the water and look for an alternative water source. Concentrations of 1-2 mg/liter of fluoride are beneficial as the incidence of tooth decay is reduced by 65-70 percent.

Good quality water must be available to ensure the health of the people in a community. The bacteriological quality of water is especially important. Water used for drinking must be free from disease-causing fecal contamination. Fecal contamination can be prevented by the protection of water sources, by the removal of sources of contamination, and by the treatment of water. A thorough sanitary survey must determine the potential sources of contamination of a water source so that measures to protect the source can be developed. If a need for treatment is apparent from the sanitary survey, a water analysis should be done (see "Determining the Need for Water Treatment," RWS.3.P.1).

The chemical and physical quality of water is important. The problem is that only some chemical and physical properties can be determined through a sanitary survey. Generally, competent laboratory testing is needed.

In many rural areas, access to a laboratory for water testing is impossible. The sanitary survey may be the only possible study of the suitability of a water source. Therefore, the survey must be thorough and must rely on very careful observation and on basic information collected from discussions with local villagers.

Water for the World

Choosing Between Gravity Flow and Pumps

Technical Note No. RWS. 4.P.1

Water can be delivered from one point to another in four basic ways: hauling, pumping, gravity flow or a combination of these methods. Hauling is the least efficient method. It is labor intensive, very costly, and provides only minimal quantities of water. Pumping may require a great deal of energy and usually is more expensive to operate and maintain than gravity flow. Gravity flow is efficient, requires no additional energy and is economical to operate and maintain. It may, however, be expensive to construct initially.

Gravity flow systems usually restrict the source to a specific location. Pump systems provide much more flexibility in locating a source. A source suitable for gravity flow is more likely to require treatment than one using a pump because it is likely to be a spring or a surface source. Because of its dependability and low operation and maintenance costs, if the water is of satisfactory quality gravity flow should always be considered. The final decision to use a particular means of moving water must be based on comparison of costs including operation and maintenance as well as construction costs.

Evaluating Gravity Flow Versus Pumps

To choose between gravity flow and pumps, each type of system should be evaluated. Factors which should be included in this evaluation are:

- The amount of water needed by the village,
- The amount of water the source can produce,
- The water quality,
- The difference in elevation between the source and the highest point in the system, usually the top of the storage tank,
- The distance between the source and the point of storage,
- The obstacles between the source and the village,
- The alternative water sources that are available or could be made available,
- The type of power available and its cost,
- The estimated pumping head.

Worksheet A can be used to tabulate the needed information for all sources. A map should be made of the area identifying the sources in relation to the homes to be served. Any good, clear existing map can be used. The map should show land elevations, existing homes and buildings, roads and streets. Swamps, high groundwater areas, and rock zones should be added to the map. Digging trenches for pipes in such places will be difficult and costly.

Once the necessary information is obtained, gravity flow and pumped transmission lines can be compared and cost estimates, including operation and maintenance costs, can be compared. See "Designing a System of Gravity Flow," RWS.4.D.1, and "Determining Pumping Requirements," RWS.4.D.2, for information about how to size the respective systems.

Worksheet B is a form that can be used to make cost estimates for the transmission line. Prepare an estimate for each possible source. Worksheet C can be used to compare the costs of developing one source among two, three or more possible sources. When a satisfactory source from which water can be moved by gravity is found, every effort should be made to use it. Added pipeline length which may be required will be less costly in the long run than a pumped transmission line.

Worksheet A. Data Required for Choosing Between Gravity Flow and Pumps

1. Estimated present water needs in liters:

	Number of		Unit use		Total
Population	Persons ____	x	____	=	____
School	Students ____	x	____	=	____
Church	Attendees ____	x	____	=	____
Large animals such as cows, oxen	____	x	____	=	____
Small animals such as sheep, goats	____	x	____	=	____
Public watering fountains	____	x	____	=	____

Total present needs = ____

2. Estimated future water use:

Use a 20 year design life. If no better information is available, use a population growth factor of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of water use of 2 times the present use.

Population	Present use ____ x 4 = ____ liters
Institutions & public fountains	Present use ____ x 2 = ____ liters
Animals	Present use ____ x 1.25 = ____ liters

Total future water use = ____ liters/day

3. For each possible water source, determine or judge:

Water quality	____________
Sustained yield in liters per day	____________
Difference in elevation between source and highest point in system	____________
Distance between source and storage	____________
Obstacles between source and village	____________
Ease of construction of source protection and pipeline	____________

Worksheet B. Estimated Cost of Transmission Line Pump/Gravity Flow Delivery System

Item	Quantity	Unit Cost	Total Cost
Transmission Line Materials			
8-inch PVC pipe	____m	____	____
6-inch PVC pipe	____m	____	____
8-inch gate valve & box	____	____	____
6-inch gate valve & box	____	____	____
4-inch flush valve	____	____	____
Pressure reducing valves	____	____	____
Power source (electricity)	____	____	____
(fuel engine)	____	____	____
Pump & Controls	____		____
Pumphouse	____	____	____
Storage tank (____m^3)	____	____	____
		Transmission Line Materials	____
Labor			
Lay water lines	____	____	____
Construct pumphouse	____	____	____
Construct storage tank	____	____	____
Construct water source	____	____	____
(dug well)	____	____	____
(spring)	____	____	____
(surface)	____	____	____
Install pump	____	____	____
Install motor	____	____	____
		Labor	____
Equipment			
Pickup truck	____	____	____
Dump truck	____	____	____
Front end loader	____	____	____
Trencher	____	____	____
Backhoe	____	____	____
Crawler tractor	____	____	____
Compressor	____	____	____
Other ________	____	____	____
________	____	____	____
		Equipment	____
Cost Summary			
Sub-total Materials			____
Sub-total Labor			____
Sub-total Equipment			____
Sub-total project cost			____
Add contingency 20%			____
Total Project Cost			____

Worksheet C. Comparison of Costs for Transmission Lines

Source	Type System Gravity/Pump/Both	Transmission Line Cost	O&M Cost
A. ________	________	________	________
B. ________	________	________	________
C. ________	________	________	________
D. ________	________	________	________
E. ________	________	________	________
F. ________	________	________	________
G. ________	________	________	________

Source Selected ________________

Water for the World

Designing a System of Gravity Flow

Technical Note No. RWS. 4.D.1

This technical note provides information on designing a simple, gravity flow piping system from a water source to a point of use, such as a water storage tank serving an adjacent community distribution point. The design of a distribution system to multiple points or to homes throughout a village is covered in "Designing Community Distribution Systems," RWS.4.D.4.

Whenever the water source is at a higher level than the point of water use, it may be possible to avoid mechanical pumps and allow the force of gravity to deliver the water. This is the preferred method for water delivery since the cost of operating and maintaining pumps is avoided. To design a gravity system, it is first necessary to accurately determine the height of the source above the point of use. The source must be higher for a gravity system to work. The difference in elevation between the source and point of storage is called the system head. This is one of the controlling factors in determining the amount of water that can be delivered. Other factors are the pipe diameter, pipe length, pipe material and rate of flow in the pipe.

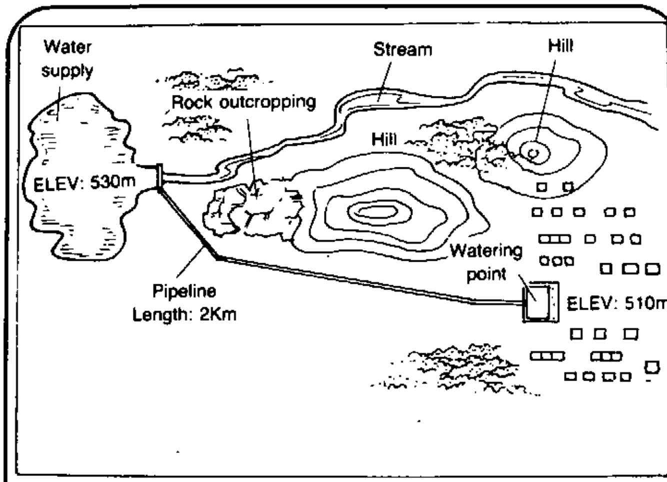


Figure 1. Location Map

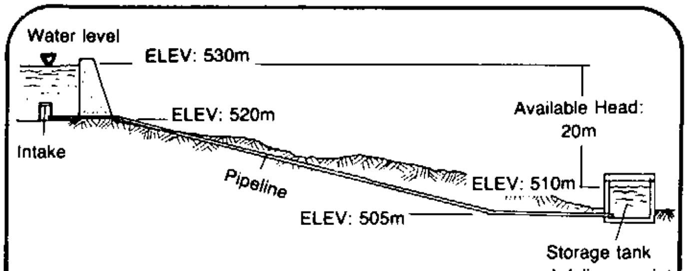


Figure 2. Profile of Pipeline

Preliminary Design Considerations

The first step in designing the system is to draw a map showing the location of the source in relation to the point of use and the distances in between. Obstacles should be shown, as should the elevations of land along the proposed conduit, particularly at the source, storage site, point of use and hills and washes in between. Figure 1 shows a map similar to that needed for a small project. Figure 2 is a profile showing elevations along the proposed conduit route.

There are two ways to conduct the water from the source to the point of use. These are open channel or piping under pressure. An open channel conduit is essentially a man-made stream. It should be carefully shaped and lined with concrete, bricks or indigenous material to make it more durable and enable the water to flow easily. This type of conduit can often be constructed using hand labor and indigenous materials. On the negative side, it must be built at a fairly uniform downhill slope. This condition may not exist due to barriers between the source and the point of use. More importantly, the water in an open conduit is open to contamination. For these reasons, a closed conduit or pressure pipeline is preferred.

A fundamental understanding of hydraulics is necessary to design a pressure pipeline. The force which pushes the water through a pipeline is known as "head" and is the height of water expressed as meters of water above any point being considered in the system. See Figure 2.

As water flows through the pipe, there is a small resistance to the flow caused by the roughness of the pipe material. This is known as "friction". Friction is also caused by sharp bends and constrictions in the pipeline. The energy required to overcome this friction is known as head loss. These losses increase as the amount of flow or the length of pipe is increased or as the diameter of pipe is decreased. This is shown in Figure 3.

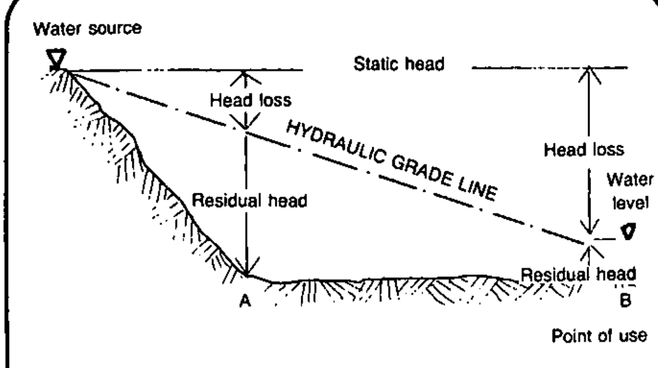


Figure 3. Available System Head

A Design Example

As an example, suppose a rural community of 500 people is located as shown on the map in Figure 1 with the profile as shown in Figure 2. The small stream shown has an available flow of 10 liters per second as measured during the lowest flow. For the present, it has been decided to provide a public distribution point in conjunction with a storage tank. As soon as the community can find the resources, it plans to expand the system to serve individual homes. There are no buildings to be served other than private homes and water for animals will not be provided by the system. Based on this, it has been decided to size the transmission line and storage as if the system were to serve the individual homes right away. Water usage of 100 liters person/day is expected.

Using Worksheet A as a guide, follow these steps:

1. The estimated current daily water needed is 50000 liters/day.

2. Future use is estimated to be 200000 liters/day. This will be the volume of water used to size the tansmission line.

3. The storage reservoir is sized for future use at 200m^3. If this system were not to be expanded for a period of time, consideration would be given to providing less storage now with increased capacity to be added later.

4. The water supply has a continuous source and, because storage is being provided to meet peak demands, the transmission line can be sized to supply water over a 24-hour period. This allows for the minimum pipe size to be selected. In this case, a flow of 2.3 liters/second is needed. Since 10 liters/second is available, the source can provide the necessary flow.

5. Pipe size can now be determined based on the available head to drive the water to the point of use on the required flow and on the total length of pipe in the system.

a. The total length of pipe is determined by adding the measured length to the equivalent length including valves and fittings, shown in Table 2. The number of valves and fittings was estimated for this example. The total pipe length is 2038m.

b. The static head is the difference between the elevation of the source and the water level in the storage tank. In this case, it is 20m.

c. The head available to drive the water through the pipeline is the static head less a small amount of head held in reserve to help prevent a vacuum from occurring in the transmission line. It is recommended that at least 5m be available. This amount is used for this example so that available head is 9.8m.

d. Now use Table 1 to choose a pipe size. Read down the flow column to the flow required (2.3 liters/second). If the desired flow is listed, read across to the right as far as the first column which shows a lower head loss for that flow than is available from step 5c above. If the flow is not shown in the table, then follow the above steps for the next lower flow and the next higher flow. In this case, either flow

Table 1. Head Loss Table in Meters per 1000 Meters
Pipe Diameter in mm

Flow liters/ second	30 GI	30 AC/P	40 GI	40 AC/P	50 GI	50 AC/P	80 GI	80 AC/P	100 GI	100 AC/P
0.1	3.4	2.2	1.5	0.9	.34	0.22				
0:2	5.8	3.5	2.5	1.5	.59	.36	.12			
0.3	13	5.6	4.0	2.4	.9	.55	.12			
0.3	21	8	9	3	1.25	.75	.18	.1		
0.4	23	14	14	5.7	2.2	1.4	.3	.2		
0.5	34	21	19	8.6	3.4	2.1	.45	.3	.12	
0.6	48	30	20	12.5	4.6	3	.61	.4	.15	
0.7	61	39	27	16	6	3.9	.8	.51	.2	
0.8	80	50	35	22	8	5	1.2	7.0	.26	.17
0.9	100	61	42	27	9.9	6.1	1.4	0.9	.32	.2
1.0		75	51	32	13	7.5	1.7	1.1	.39	.4
1.1		90	62	38	15	9.4	2.0	1.3	.47	.3
1.2			73	45	18	11.0	2.5	1.5	.55	.35
1.3			83	54	20	13.5	2.75	1.75	.61	.4
1.4			100	60	24	15	3.2	2.1	.75	.48
1.5				68	28	17	3.7	2.4	.88	.55
1.6				75	30	19	4	2.6	.95	.60
1.7				88	34	22	4.6	2.9	1.1	.68
1.8				95	37	25	5.0	3.2	1.25	.72
1.9					40	27	5.6	3.5	1.3	.8
2.0					46	30	6.1	4.0	1.5	.90
2.5						44	8.7	6.0	2.2	1.35
3.0						60	14	8.4	3.0	1.9
3.5						75	18	11.5	6.2	2.5
4.0						105	23	15	8.3	3.3
5.0							37	26	12	5.0
6.0							50	31	16	7
7.0							67	42	20	9.5
10							130	80	30	18.5
15									70	45
20									125	70

[Note: Based on Hazen-Williams C of 130 for asbestos cement (AC) and plastic (P) and for a C of 100 for galvanized iron (GI).]

If the desired flow rate is not shown, then use an average of the actual flow rate to the next low and next high flow rate. EXAMPLE: For a flow rate of 4.6 liters/second and a 100mm pipe:

1. $\frac{4.0 \times 3.3}{4.6} = 2.9$

2. $\frac{5.0 \times 5.0}{4.6} = 5.4$

3. $\frac{2.9 + 5.4}{2} = 4.2$m head loss

Table 2. Friction Losses in Fittings
Equivalent Length of Straight Pipe Meters

Size mm	30	40	50	80	100
Gate valve-open	1.2	1.3	1.6	2.0	2.7
Elbow, 90 degree	6.7	7.5	8.6	11.1	13.1
Elbow, 45 degree	1.8	2.2	2.8	4.1	5.6
Tee, straight	4.7	5.7	7.8	12.1	17.1
Tee, through side	8.8	10.0	12.1	17.1	21.2
Check valve	13.1	15.2	19.1	27.1	38.2

requires the same pipe size, 80mm. If the next lower flow had allowed a smaller pipe size, then an inter-polation would have been required, taking an average of the ratio of the actual flow to the next highest flow and the next lowest flow as shown in Table 1.

Other Factors in Designs

Factors other than pipe size must be considered when designing a transmission line. These include high and low points along the line and valving to facilitate operation and maintenance.

Even when a positive pressure is maintained by providing for a residual head, it is possible for air to collect at high points in a line. An air release valve should therefore be installed at the top of each rise as shown in Figure 4. Low points in the line should be equipped with a drain valve so that any sediment that collects can be flushed out. This is very important if the source contains sand or fine sediment.

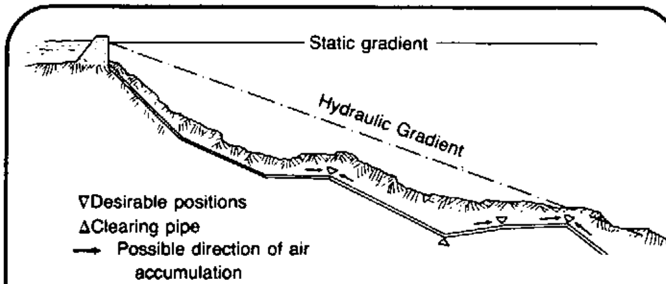


Figure 4. Desirable Positions for Air Valves on Pipeline

Gate valves should be placed in the line to permit system operation and repair. In a piped distribution net-work, valves are located so portions of the lines can be isolated for repair while the rest of the system is still in operation. With a simple gravity system, a failure anywhere in the line will put the entire system out of operation so a large number of valves are not needed. One valve should be placed at the source and a second near the storage tank or point of use. Additional valves located at intervals of 1000m may be desirable for quicker access to turn the system off should a break occur or to isolate portions of the line for testing purposes.

Worksheet A. Designing a System of Gravity Flow

1. Estimated present water needs in liters:

	Number of:			Unit Use		Total
Population	Persons	500	x	100	=	50,000
School	Students	______	x	______	=	______
Church	Attendees	______	x	______	=	______
Commercial		______	x	______	=	______
Large animals (cows)		______	x	______	=	______
Small animals (sheep)		______	x	______	=	______
Public watering fountains		______	x	______	=	______

Total present water needs = 50000

2. Estimated future water use:

Use a 20-year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of use of 2 times.

Population — Present use 50,000 x 4 = 200,000 liters

Institutions and public fountains — Present use ______ x 2 = ______ liters

Animals — Present use ______ x 1.25 = ______ liters

Total future water use = 200,000 liters/day

3. Storage tank:

Take the future water use and convert it to cubic meters:

Reservoir = $\frac{200{,}000}{1000}$ liters = 200 m^3

4. Source production requirements:

Determine the required production rate in liters/second

Total daily demand = $\frac{200{,}000 \text{ liters}}{86400 \text{ second}}$ = 2.3 liters/second

Assume water production over 24 hours or 86400 seconds

5. Pipe sizing:

a. To calculate the pipe size, first find the total equivalent length of pipe.

Total length = measured length + equivalent length of fittings

Equivalent length of pipe due to fittings (Table 2):

Fitting	Number	x	Equivalent length	=	
Gate valve	1	x	2.7m	=	2.7 m
Elbow, 90 degree	2	x	13.2	=	26.4 m
Elbow, 45 degree		x		=	m
Tee (straight)		x		=	m
Tee (through side)		x		=	m
Swing check valve	1	x	38.2	=	38.2 m

Total equivalent length = 67.3 m

Length of pipe from source to storage = 1971.0 m

Total pipe length = 2038 m

b. Determine static head:

Static head = elevation at source - elevation at top of storage

= 530 m - 510 m = 20 m

c. Find head available per 1000m to overcome friction:

Head available = $\frac{\text{static head - 5m residual head}}{\text{Total pipe length in km}}$

= $\frac{20 \text{ m} - 5\text{m}}{2.038 \text{ km}}$ = 9.8 m/1000m

d. Select a pipe size from Table 1 using the 24-hour flow in liters/second and the available head loss found in c. above.

	Flow liters per second	Head loss per 1000m	Pipe size	Type material	Select yes/no
Required	2.3	Available 9.8	mm		
Next low	2.0	6.1, 4.0	80 mm	GI P/AC	
Next high	2.5	8.7, 6.0	80 mm	CI P/AC	

From d. a pipe size of 80 mm is recommended for the transmission line as the head loss is too great for the next smaller pipe size.

Notes

Water for the World

Designing Structures for Springs
Technical Note No. RWS. 1.D.1

Protective structures are a very important part of developing springs as sources for a community water supply. A properly designed protective structure ensures an increased flow from the spring. To protect the spring, silt, clay and sand deposited at the spring outlet, and other material washed down from the slope by surface run-off, must be cleared away. When these materials are removed, water flow increases. Clearing away vegetation from the spring effluent will also allow better flow. A protective structure will improve the accessibility of the water. By channeling the spring flow into one collection area, a good quantity of water can be stored for the community. Spring water can be distributed to community standpipes or to individual houses. A third benefit of a protective structure is that it protects the spring water from contamination.

This technical note discusses the design of structures used to protect and develop springs for community water supplies and makes suggestions for spring development in a specific area. The design chosen for a particular project will depend on local conditions, materials available and spring yield. Read this entire technical note and refer to "Selecting a Source of Surface Water," RWS.1.P.3, before choosing a design that will best meet a community's needs.

The design process should result in the following three items which should be given to the construction supervisor:

1. A map of the area. Include the location of the spring; the locations of users' houses; distances from the spring to the users, elevations, and important landmarks. Figure 1 is a map of a small village with a spring located on high ground above it. A map of this type is useful in helping the people building the spring box locate the spring site.

Useful Definitions

DISCHARGE - The flow of water from an opening in the ground or from a pipe or other source.

EFFLUENT - At a spring site, the point from which water leaves the ground.

GROUT - A thin mortar used to fill chinks, as between tiles.

HEAD - Difference in water level between the inflow and outflow ends of a system.

HYDRAULIC GRADIENT - The measure of the decrease in head per unit of distance in the direction of flow.

MORTAR - A mixture of cement or lime with water in a basic proportion of 4 units of sand to 1 unit of cement or lime.

PERPENDICULAR - Exactly upright or vertical; at a right angle to a given line or plane.

PUDDLED CLAY - A mixture of clay with a little water so clay is workable.

REINFORCING ROD - Steel bars placed in concrete structures to give it tensile strength.

UNDERFLOW - Flow of water under a structure.

2. A list of all labor, materials and tools needed as shown in Table 1. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

3. A plan of the spring box with all dimensions as shown in Figure 2. This plan shows a top, side, and front view, and the dimensions of a cover for a spring box 1m x 1m x 1m.

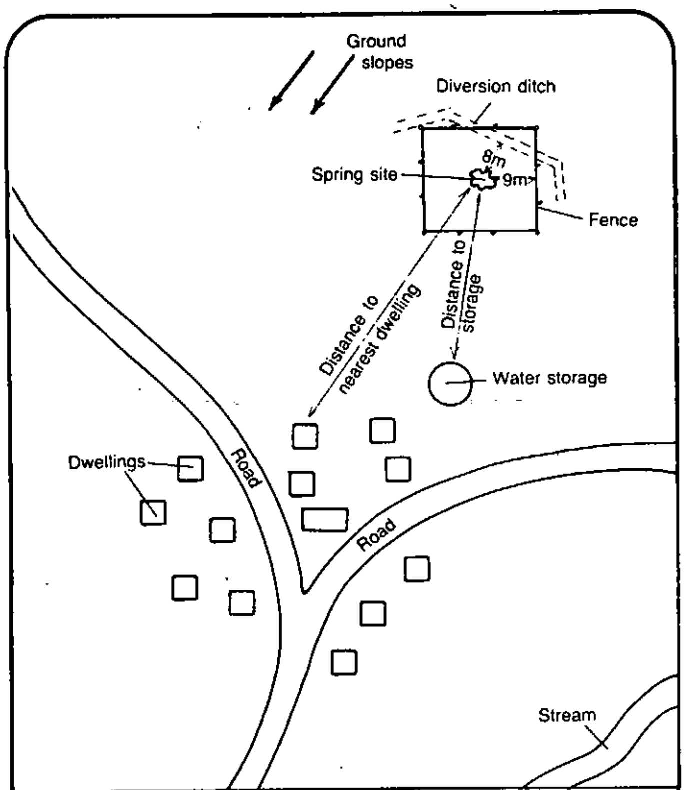


Figure 1. Location Map

Spring Box Design

There are several possible designs for spring boxes but, generally their basic features are similar. Spring boxes serve as collectors for spring water. They are sometimes used as storage tanks when a small number of people are being served and the source is located near the users. When larger numbers of people are served, the water collected in the spring box flows to larger storage tanks. The two basic types of spring boxes discussed in this paper are a box with one pervious side for collection of water from a hillside, and a box with a pervious bottom for collection of spring water flowing from a single opening on level ground. To determine which design to use dig out around the area until an impervious layer is reached, locate the source of the spring flow, and design to fit the situation.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	___ ___	___ ___
Supplies	Portland cement Clean sand and gravel, if available, or locally available sand and gravel Water (enough to make a stiff mixture) Wire mesh or reinforcing rods Galvanized steel or plastic pipe (for outlets, overflow, and collectors) Screening (for pipes) Boards and plywood (for building forms) Old motor oil or other lubricant (for oiling forms) Baling wire Nails	___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Tools	Shovels and picks (or other digging tools) Measuring tape or rods Hammer Saw Buckets Carpenter's square or equivalent (to make square edge) Mixing bin (for mixing concrete) Crowbar Pliers Pipe wrench Wheelbarrow Adjustable wrench Screwdriver Trowel	___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Total Estimated Cost ____

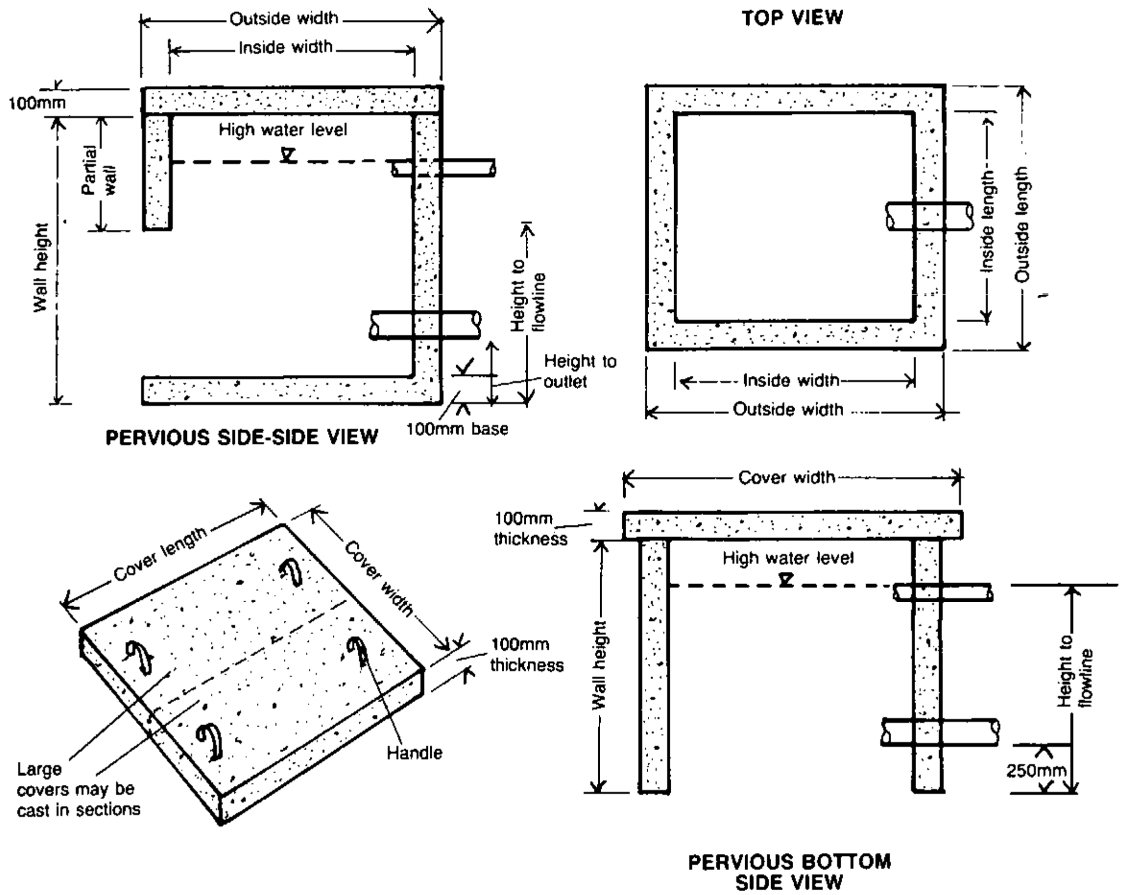


Figure 2. Spring Box Design

Spring Box with Open Side. A spring box with a pervious side is needed to protect springs flowing from hill-sides. The area around the spring must be dug out so that all available flow is captured and channeled into the spring box.

After this has been done, a collection box can be built around the spring outlet as shown in Figure 3. The dug-out area should be lined with gravel. The gravel placed against the spring opening serves as a foundation for the box and prevents the spring water from washing soil away from the area. The gravel pack also filters suspended solids. The gravel-filled area should be between 0.5-1m wide depending on the size of the spring collection area. To ensure that no contamination reaches the water, the gravel pack should be at least 1m below the ground surface. This is done either by locating the spring catchment in the hillside or by raising the ground level with backfill.

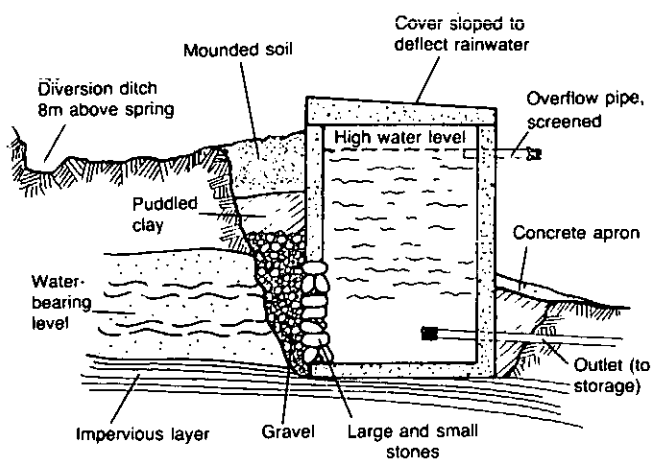


Figure 3. Spring Box with Open Side

Caution must be taken not to disturb ground formations when digging out around the spring. Without care, the flow of the spring may be deflected in another direction or into another fissure. The area must, however, be dug out enough so that the spring box fits into impermeable material. In cases where the box does not reach impermeable material, puddled clay should be used to seal the area around the sides of the spring box.

<u>Spring Box with Open Bottom</u>. If a spring flows through a fissure and emerges at one point on level ground, a spring box with an open bottom can be developed as shown in Figure 4. The area around the spring is dug out until an impermeable layer is reached. The area around the spring is then leveled and lined with gravel. The spring box is placed over the spring and gravel to collect the flow, and clay or concrete is packed around the box to prevent seepage between the ground and the box. Sometimes a small sump can be built at the bottom so that sediment settles in one place.

The design of both types of spring boxes is basically the same and includes the following features:

(a) a water-tight collection box constructed of concrete, brick, clay pipe or other material,
(b) a heavy removable cover that prevents contamination and provides access for cleaning,
(c) an overflow pipe, and
(d) a connection to a storage tank or directly to a distribution system.

The spring box with an open bottom is simpler and cheaper to construct. Generally, on level ground, flow from only one source must be captured and collection of all available flow is much easier. Costs are lower because less digging and fewer materials are required.

The spring box should be constructed at the spring site for easy installation. If the appropriate materials are available, the spring box should be made of concrete. Information on the use of concrete is included in Worksheet A. Three sides of the spring box must be impervious and depending on the type of spring selected for development, either the bottom or the upslope side must be pervious or open. The upslope side of an open sided spring box can be constructed partially with concrete and partially with large rocks and gravel as shown in Figure 3. Large rocks support the spring box and allow water to enter. Smaller stones should be used between the large rocks to close large openings so that sediment is filtered from the water.

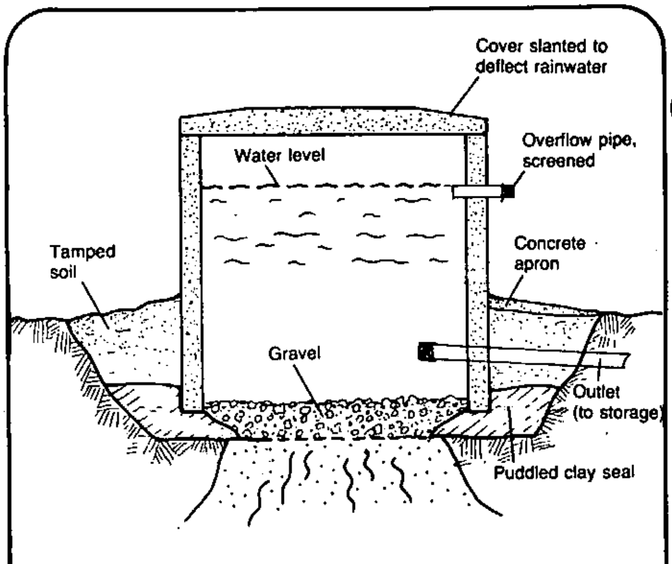


Figure 4. Spring Box with Open Bottom

If materials for building a concrete box are not available, or are expensive, there are alternatives that are particularly useful in developing a single source spring. Large prefabricated clay or concrete tubes, like regular spring boxes, can be placed around the spring. Water rises in the tube and flows out the outflow pipe. Rings for collecting spring water can even be constructed using bricks and mortar. Half or broken bricks can be used to build a ring as shown in Figure 5. The bricks are laid in a circular pattern, so that vertical joints do not line up. Spaces between the bricks are filled with gravel and mortar. Bricks are laid until a height of between 0.9-1.2m is reached. The diameter may vary but should be around 0.7-1.0m. An outlet and overflow pipe should be placed in the structure before installation and with reinforcement added. This type of structure is very practical and inexpensive to construct. Little cement is needed and locally available materials can be used.

Worksheet A. Calculating Quantities Needed for Concrete

(Calculations for a box 1m × 1m × 1.0m with open bottom)

Total volume of box = length (l) x width (w) x height (h)

Thickness of walls = 0.10m

1. Volume of top = l 1.2 m x w 1.2 m x t 0.10 m = 0.144 m^3
2. Volume of bottom = l 0 m x w 0 m x t 0 m = 0 m^2
3. Volume of two sides = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
4. Volume of two ends = l 1 m x w 1 m x t 0.10 m x 2 = 0.20 m^3
5. Total volume = sum of steps 1, 2, 3, 4, 5 = 0.54 m^3
6. Unmixed volume of materials = total volume x 1.5; 0.54 m^3 x 1.5 = 0.81 m^3
7. Volume of each material (cement, sand, gravel, 1:2:3):

   cement: 0.167 x volume from Line 6 0.81 = 0.13 m^3 cement.
   sand: 0.33 x volume from Line 6 0.81 = 0.26 m^3 sand.
   gravel: 0.50 x volume from Line 6 0.81 = 0.4 m^3 gravel.

8. Number of 50kg bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$

   volume of cement 0.13m^3 - .033m^3/bag = 4 bags.

9. Volume of water = 28 liters x 4 bags of cement = 112 liters.

(NOTE: 1) Do not determine volume for an open side or bottom.
2) The top slab has a 0.1m overhang on each side.
3) The same calculations will be used to determine the quantity of materials for construction of a seepage wall.
4) To save cement a 1:2:4 mixture can be used.)

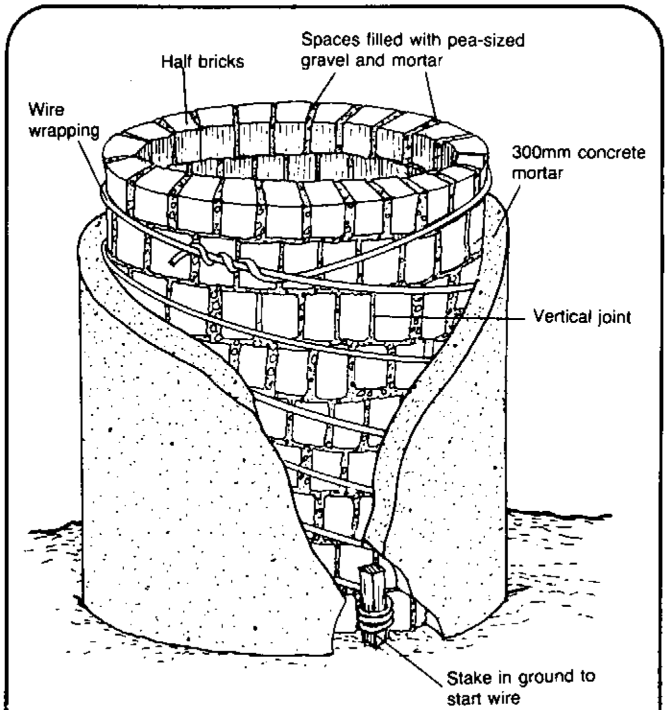


Figure 5. Brick Spring Box

The capacity of the spring box depends on whether it is being used for storage or pre-storage. If the spring box is used for storage, it should be large enough to hold a volume of water equal to the needs of the users over a 12-hour period. For example: If 100 people each use 25 liters of water per day, the amount of water consumed in 12 hours is 1250 liters. There are 1000 liters per m^3. Therefore the volume of the spring box should be 1.25m^3. (Volume = length x width x height). If the collection box is used only for pre-storage and water flows on to another storage tank, the collection box can be smaller.

A reinforced concrete cover must be constructed to protect the tank from outside contamination. The cover should be cast in place to ensure proper fit. It should extend over the spring box about 0.1m on each side so rain does not fall at the base of the spring box. The cover should be heavy enough so children cannot lift it off.

The spring box should have an overflow pipe. The pipe is placed a little below the maximum water level and at least 0.15m above the floor of the tank. If the pipe is above the maximum water level, water will not flow out and pressure is created in the tank. The pressure could cause a back-up and diversion of the spring. The overflow pipe should be covered with a screen fine enough to keep out mosquitoes and strong enough to keep out small animals. The size of the pipe depends on the flow of the spring. A rock drain or concrete slab should be placed outside the tank below the overflow pipe to prevent erosion near the base and to carry the water away from the spring. A pipe which extends 3-5m from the tank is desirable in order to keep the site free from still water.

An outlet pipe for connection to a distribution system should be located at least 0.1m above the bottom of the spring box to prevent a blockage due to sediment build-up. The pipe size depends on the grade to the storage tank and the spring flow. A general rule to follow is that at a one percent grade, a 30mm pipe should be used. A grade between 0.5 and one percent requires a 40mm pipe, while a 50mm pipe should be used for grades of less than 0.5 percent. In some cases the same pipe will be both outlet and overflow. The outlet pipe should slope downward for best flow.

After the spring box is installed, the space behind it must be filled with soil and gravel. The gravel is the bottom layer. On top of it, a water-tight layer should be formed to prevent the entrance of surface water. This can be done with concrete or puddled clay. Puddled clay is a mixture of clay and water formed into a layer 150mm thick. The layer is placed on the ground and worked in by trampling on it. Several layers of puddled clay should be placed behind the box.

After sealing the area, the box can either be completely covered with soil or stand above the ground surface. The box should be at least 0.30m above ground level so that run-off does not enter it. For further sanitary protection, a ditch should be dug at least 8m above the spring box to take surface water away from the area. The soil from the ditch should be piled on the downhill side to make a ridge and help keep surface water away. A fence around the area will keep animals from getting near the spring box and help prevent contamination and destruction of the area. The fence should have a radius of between 7-8m.

Seep Design

Designs for seep development are similar to those for spring boxes. Figure 6 shows the basic design. Intakes (collectors) are very important features of seep development. The collector system consists of small channels containing 100mm clay open-joint or 50mm plastic perforated pipe packed in gravel. The collectors are installed in the deepest part of the aquifer. They take advantage of the saturated ground above them for storage during times when the groundwater table is low. The perforations in the pipes must be about 5mm in diameter or large enough to collect sufficient water but small enough to prevent suspended matter from entering the pipes. In fine and medium-sized sand, perforated pipe should be packed in gravel but suspended material often will enter the pipe in spite of the gravel.

To prevent clogging, the collectors should be sized so that the velocity of water flow in them is between 0.5m per second and 1m per second. See "Methods of Delivering Water," RWS.4.M.

Water collected by the pipes is channeled to the spring box through a gravel pack. The collectors must extend across the entire width and length of the water-bearing zone and should be perpendicular to the flow of the aquifer. These intakes should extend below the water-bearing zones to collect the maximum amount of water and permit free flow into the collector. The advantage of a collector system is that water seeping over a large area can be channeled into a central storage basin.

Clean-out pipes to flush sediment from the collection pipes should be attached to the collection pipes. To install clean-out pipes, add a length of pipe to the far end of the collection pipe. At the end of this length, place an elbow joint facing upwards and attach a vertical length of pipe.

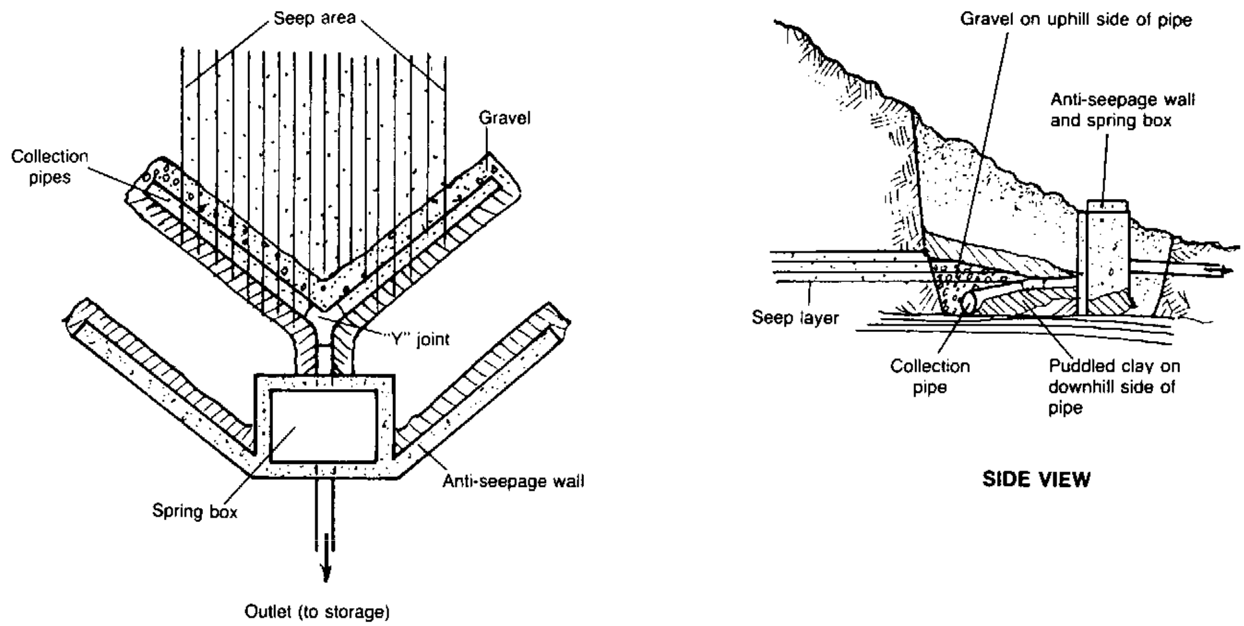


Figure 6. Seepage Collection System

The pipe should extend a little above the ground and be capped. If the collector system clogs, water can be added to the clean-out pipes to flush out the system.

For seep development, a cutoff wall of clay, concrete or other impervious material should be constructed. The cutoff is usually constructed as a large "V" pointing downhill with wing walls extending into the hill to prevent water from escaping. The cutoff should extend down into impervious material to force the flowing water to move to the collection point and to prevent loss of water due to underflow.

The use of concrete for the cutoff wall is best but most expensive. A wall 0.15m thick will ensure adequate strength against increased flow. The height of the cutoff wall depends on the size of the flow being collected. If desired, a spring box may be constructed inside the "V" shaped meeting of two walls as shown in Figure 7. The spring box will provide a settling basin for sediment removal and storage. The spring box should be designed so that water enters it

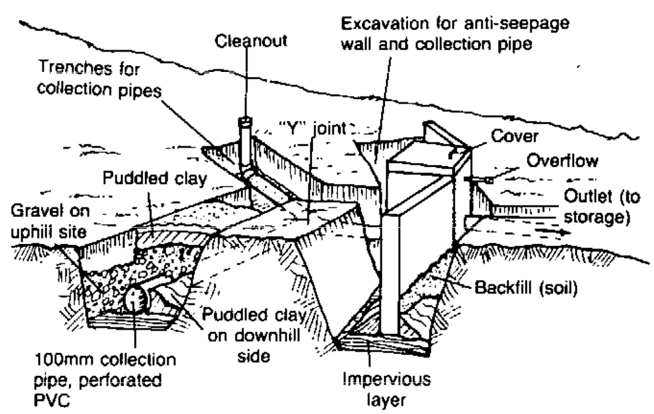


Figure 7. Basic Design Feature of a Seep Collection System

through openings in the upper wall. These openings must be screened to prevent entrance of debris.

Puddled clay instead of concrete can be used to form the cutoff wall. The clay is piled up and tamped down to form an impervious wall. It acts as a small dam which prevents spring water from flowing away from the collection area. The clay cutoff wall works as well as the cement wall and is much cheaper and easier to install. Good impervious clay should be available if this type of cutoff wall is chosen.

An outlet pipe is installed to move water from the collection point to storage. The diameter of the pipe depends on the grade to storage and will generally range between 30-50mm. To determine the correct pipe size, see "Methods of Delivering Water," RWS.4.M. The outlet pipe for a spring box or simple collection wall should be at least 150mm from the bottom of the collection area. A watertight connection should be made where the pipe leaves the spring box or goes through the cutoff wall. As in the case of spring boxes, the outlet pipe must be screened with small mesh wire. Because of the cost, this type of structure should be used only where seeps cover an extensive area. Skilled laborers will be needed for construction.

Horizontal Well Design

Horizontal wells are very simple and can be quite inexpensive. In order to use a horizontal well, an aquifer must have a steep slope or hydraulic gradient. Steep hydraulic gradients generally are found in chilly, sloping land and follow the ground surface. Horizontal wells, shown in Figure 8, are installed in much the same manner as vertical driven and jetted wells. See "Designing Driven Wells," RWS.2.D.2, and "Designing Jetted Wells," RWS.2.D.3 for specific design features.

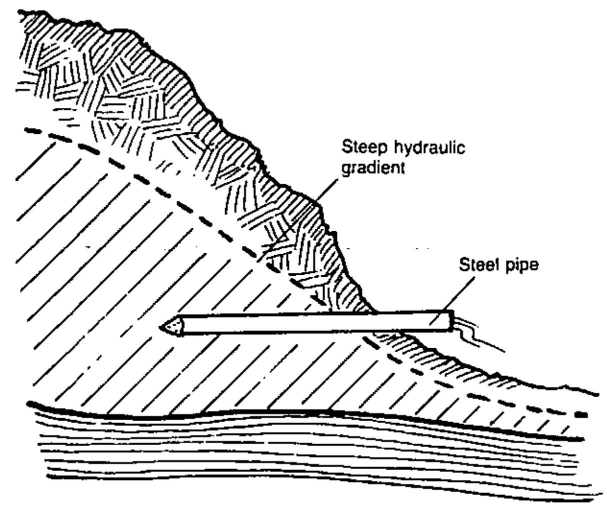


Figure 8. Horizontal Well

A horizontal well can be driven if the spring flows from an aquifer in permeable ground. A pipe with an open end or with perforated drive points is driven into the aquifer horizontally or at a shallow slope to tap it at a point higher than its normal discharge. In some soils, the pipe can be driven by hand. Generally the pipe is driven using machinery.

"Designing Driven Wells," RWS.2.D.2, outlines the steps in designing a driven well. These same steps should be followed in designing horizontal wells. One design difference is that extra care must be taken to avoid leakage between the driven pipe and the ground. If exterior flow occurs, it can be stopped by forcing clay or grout into the space, or by digging by hand 1m back along the pipe and installing a concrete cutoff wall. The wall should have a diameter of $0.6m^2$ and no more than 0.05m thick. After the concrete slab hardens, the dug-out area should be packed and backfilled with clay.

If the aquifer that feeds the spring is behind a rock layer, driving a horizontal well will be very difficult if not impossible. In this case, a jetted horizontal well will have to be installed. "Designing Jetted Wells," RWS.2.D.3, explains the process of jetting wells. The problem is that horizontal well drilling is different from vertical drilling, and may be too difficult for inexperienced people. Drilled horizontal wells should only be considered when there are no other reasonable alternatives.

Materials List

In addition to a location map and design drawings, give the person in charge of construction a materials list similar to Table 1 showing the number of laborers, types and quantities of materials needed to construct the spring protection. Some quantities will have to be determined in the field by the person in charge of construction.

Concrete. Concrete is the major material used in the construction of spring boxes and cutoff walls. Concrete is a mixture of Portland cement, clean sand, and gravel in a fixed proportion. The proportion generally used is one part cement, two parts sand, and three parts gravel (1:2:3). Water is used to mix the concrete. Twenty-eight liters of water should be used for each bag of cement. Worksheet A will help determine the amount of materials needed. Use the worksheet in making the following calculations.

1. Calculate the volume of mixed concrete needed (length x width x thickness; Worksheet A, Lines 1-5).

2. Multiply this number by 1.5 to get the total volume of dry loose material (cement, sand and gravel) needed (Worksheet A, Line 6).

3. Add the numbers in the proportion in order to find the fraction of the total needed for each material (1:2:3 = 6, so 1/6 of the mixture should be cement, 2/6 sand, and 3/6 gravel. In decimals, this is 0.167 cement, 0.33 sand, and 0.50 gravel).

4. Determine the amount of each material needed by multiplying the volume of dry mix from step 2 by the proportional amount for each material (1/6 x volume of dry mix = total amount of cement needed; Worksheet A, Line 7).

5. Divide the volume of cement needed by .033m^3 (33 liters), the amount of cement in a 50kg bag, to find the number of bags of cement required. When determining the amount of cement, figure to the largest whole number (Worksheet A, Line 8).

6. An extra quantity of cement should be figured into the total for use in grouting and sealing areas around the outlet pipes.

7. Calculate the amount of water needed to mix the concrete (28 liters of water per bag of cement; Worksheet A, Line 9).

8. Extra gravel will be needed for backfill of areas behind springs. Graded gravel is preferable, but local materials can be used if necessary. Calculate the volume of the area to be backfilled by taking length x width x height of area.

Reinforced Concrete. Concrete can be reinfored to give it extra strength. This is best done with wire mesh or specially made steel rods. Reinforced concrete sections must be at least 0.10cm thick. Reinforced concrete should be used for all spring box covers and for the walls of seep structures. If wire mesh is used, the quantity needed will be approximately equal to the area of the slab being constructed. If steel bars (rerod) are used, they should be placed in the wooden form before the concrete is poured. 10mm diameter rods should be used.

The reinforcing rod should be located as follows:

- So that the rods are at least 25mm (0.25m) from the form in all places;
- So that the rebar rests in the lower part of the cover; two-thirds the distance from the top or .70mm from the top of a 100mm slab;
- So that a 150mm (0.15m) space lies between a parallel rods in a grid pattern as shown in Figure 9.

Where the reinforcing rods cross, they should be tied together with wire at the point of intersection.

To determine the number of reinforcing bars, divide the total length or width of the spring box cover by 0.15m (distance between bars). For example, $\frac{1.2m}{0.15m} = 8$ bars.

To determine the length of each bar, subtract 0.05m (0.025m each side) from the total length or width of the cover. For example, 1.2m - 0.05m = 1.15m.

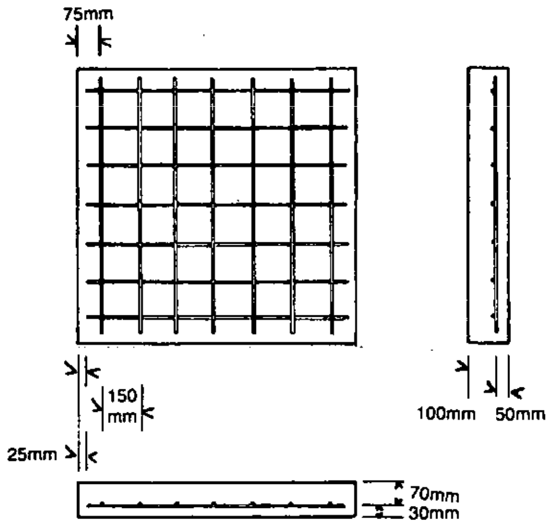


Figure 9. Placement of Rebar in Concrete Slab

Pipes. Outlet pipes can be of galvanized steel, or plastic depending on what is available. Galvanized steel is preferable because of its strength. Steel pipe lasts longer and does not shatter like plastic pipe. Intake pipes should be either clay, perforated plastic open-joint cement or in some cases, bamboo. The choice again will depend on availability of materials and cost. The pipe should have a minimum diameter of 50mm to be sure that an adequate supply of water enters the collection system. All pipes must be laid at a uniform grade to prevent air lock in the system.

When labor requirements, materials, and tools have been decided on, prepare a materials list similar to Table 1 and give it to the construction supervisor

Important Considerations

Spring protection should ensure that the source is always protected from contamination. Before attempting to develop a spring, conduct a sanitary survey as described in "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2. Follow the guidelines for measuring the quantity of available water present in "Selecting a Source of Surface Water," RWS.1.P.3, to be sure that the source will meet community needs. The preliminary work described in these technical notes should be done before designing a protective structure.

The choice of the structure for spring protection depends on the geologic conditions of the area, the type of spring, the materials available, and the skill level of available labor. Spring boxes are easy to design and require little construction expertise, although workers should have some construction experience. Driven horizontal wells are also easy and inexpensive to develop although some expertise is needed to complete a successful well.

Structures for seeps are more difficult to design and require that workers have a much higher level of construction experience. The cost of developing a seep may be very high depending on the length of the retaining wall and the amount of pipe needed for intakes.

Water for the World

Constructing Structures for Springs

Technical Note No. RWS. 1.C.1

There are two important reasons to build structures for springs and seeps. First, they protect the water from contamination caused by surface run-off and by contact with people or animals. Secondly, the structures provide a point of collection and storage for water. Water from springs and seeps is stored so it will be readily available to the users. This technical note discusses the construction of spring boxes and seep collection systems and outlines the construction steps to follow. The steps are basic to small construction projects and should be followed for the construction of most spring structures.

Useful Definitions

CONVEX - Curving outward like the surface of a sphere.

DISINFECTION - The process of destroying harmful bacteria.

EFFLUENCE - An opening from which water flows.

PUDDLED CLAY - A mixture of clay and a little bit of water used to make something watertight.

UNDERFLOW - Flow of water under a structure.

VOIDS - Open spaces in a material.

Materials Needed

Before construction begins, the project designer should give you the following items:

(1). A map of the area, including the location of the spring; locations of users' houses; and distances from the spring to the users, elevations,

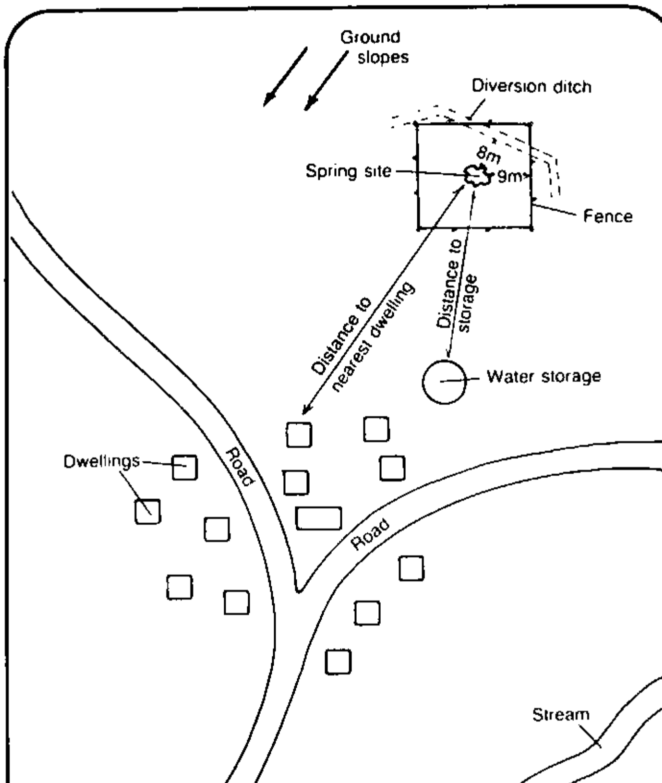


Figure 1. Location Map

and important landmarks. Figure 1 is a map of a small village with a spring located on high ground above it. Use your map to locate the construction site for the spring box.

(2) A list of all labor, materials and tools needed as shown in Table 1. Ensure that all needed materials are available and at the work site before work begins. Make sure that adequate quantities of materials are available to prevent construction delays.

(3) A plan of the spring box with all dimensions as shown in Figure 2. This plan shows a top, side, and front view, and the dimensions of a cover for a spring box 1m x 1m x 1m.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Portland cement Clean sand and gravel, if available, or locally available sand and gravel. Water (enough to make a stiff mixture) Wire mesh or reinforcing rods Galvanized steel or plastic pipe (for outlets, overflow, and collectors) Screening (for pipes) Boards and plywood (for building forms) Old motor oil or other lubricant (for oiling forms) Baling wire Nails		
Tools	Shovels and picks (or other digging tools) Measuring tape or rods Hammer Saw Buckets Carpenter's square or equivalent (to make square edge) Mixing bin (for mixing concrete) Crowbar Pliers Pipe wrench Wheelbarrow Adjustable wrench Screwdriver Trowel		

Total Estimated Cost ____

General Construction Steps

Follow the construction steps below. Refer to the diagrams noted during the construction process.

1. Locate the spring site and with measuring tape, cord and wooden stakes, or pointed sticks, mark out the construction area as shown in Figure 3.

2. Dig out and clean the area around the spring to ensure a good flow. If the spring flows from a hillside, dig into the hill far enough to determine the origin of the spring flow. Where water is flowing from more than one opening, dig back far enough to ensure that all the water flows into the collecting area. If the flow cannot be channeled to the collection area because openings are too separated, drains will have to be installed. Information on the installation of drains appears in the section on the development of seep collection systems.

Flow from several sources may be diverted to one opening by digging far enough back into the hill. When digging out around the spring, watch to see if flow from the major openings increases or if flow from minor seeps stops. These signs indicate that the spring flow is becoming centralized and that most of the water can be collected

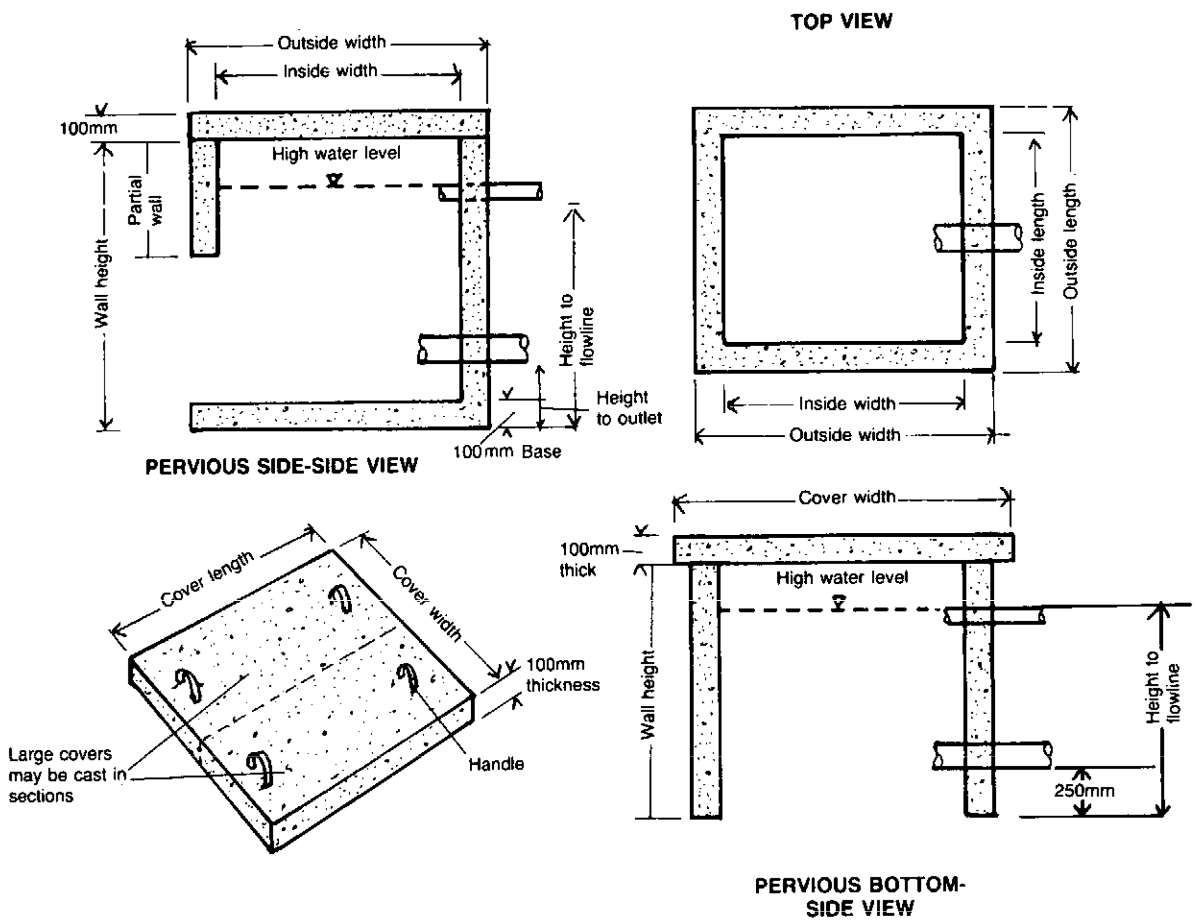


Figure 2. Spring Box Design

from one point. The goal is to collect all available water from the spring. It is generally easier to collect water from one opening than from several.

Dig down deep enough to reach an impervious layer. An impervious layer makes a good foundation for the spring box, and provides a better surface for a seal against underflow. If an impervious layer cannot be reached, attempt to construct the box in the most impermeable soil you can find.

3. Pile loose stones and gravel against the spring before putting in the spring box. The stones serve as a foundation for the spring box and help support the ground near the spring opening to prevent dirt from washing away. They also provide some sedimentation. For fast flowing springs, large stones with gravel between them should be placed around the spring to prepare a good solid base. Figure 4 shows an example of gravel and stone placed between the spring box and the spring.

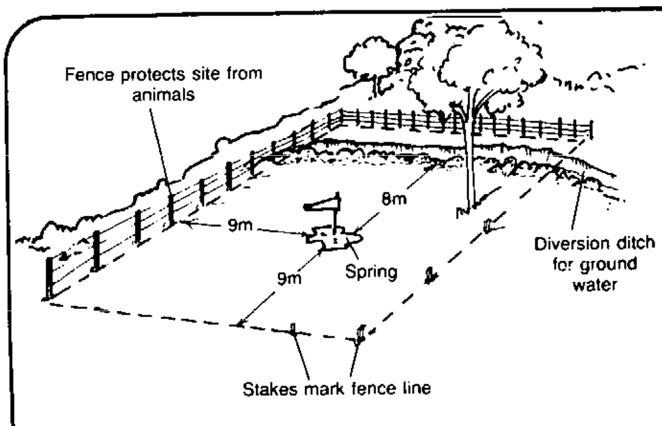


Figure 3. Preparation of Spring Box Site

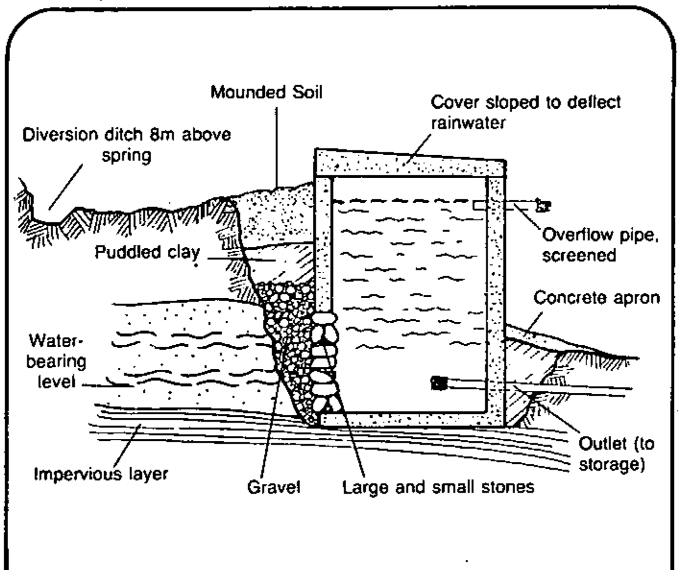


Figure 4. Spring Box with Open Side

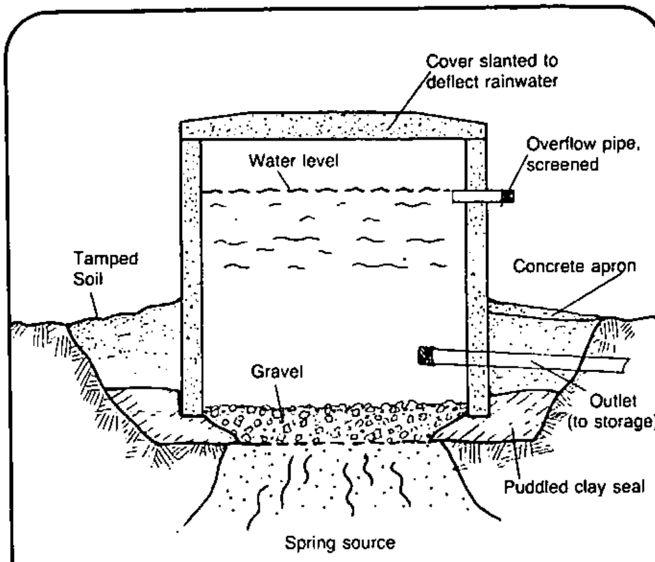


Figure 5. Spring Box with Open Bottom

If a spring flows from a single opening on level ground, dig out around the opening to form a basin. Be sure to dig down to impervious material to form the base. Line the basin with gravel so that the water flows through it before it enters the spring box. This is shown in Figure 5.

4. Approximately 8m above the spring site dig a trench for diverting surface run-off. The trench must be large enough to catch surface flows from heavy rains. If large stones are available in the construction area, use them to line the diversion trench to increase the rate of run-off and prevent erosion.

5. Mark off an area about 9m by 9m for a fence. Place the fence posts 1m apart and string the fence. A fence is useful to prevent animals from frequenting the spring site.

Concrete Construction Steps

In order to have a strong structure, concrete must cure at least seven days. Strength increases with curing time. Therefore, construction of the spring box should begin at the site during the first day of work. If the concrete is poured on the first day, seven days will be available for site preparation before the spring box is put in place. Be sure that all tools and materials needed to build the forms and mix the concrete are at the construction site.

1. Build wooden forms. Cut wood to the appropriate sizes and set up the forms on a level surface. The outside dimensions of the forms should be 0.1m larger than the inside dimensions. A form with an open bottom should be built for a spring flowing from one spot on level ground. For springs from hillsides, a spring box form with a partially open back must be constructed as shown in Figures 6 and 7. The size of the opening depends on the area which must be covered to collect the water. When building forms for a box with a bottom, be sure to set the inside forms 0.1m above the bottom for the floor. This is done by nailing the inside form to the outside form so that it hangs 0.1m above the floor. Make holes in the forms for the outflow and overflow pipes. Place small pieces of pipe in them so that correctly sized holes are left in the spring box as the concrete sets. A form for the spring box cover must also be built. Build all forms at the site.

Forms must be well secured and braced before pouring the concrete. Cement is heavy and the forms will separate if the bracing is not strong enough. One useful method is to tie the braces together with wire as shown in Figures 6 and 7. Drill holes in the forms and place wire through them. Using a stick, as shown, twist the wire to tighten it and force the forms together.

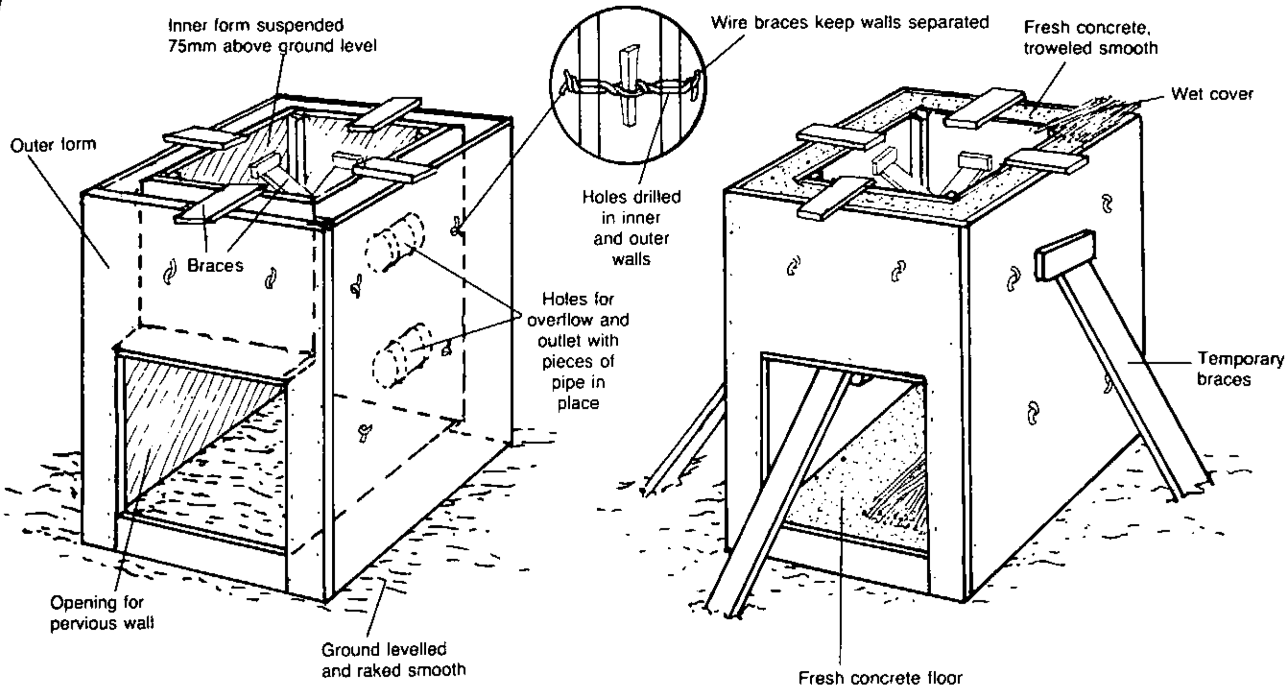


Figure 6. Forms for Spring Box with Open Side

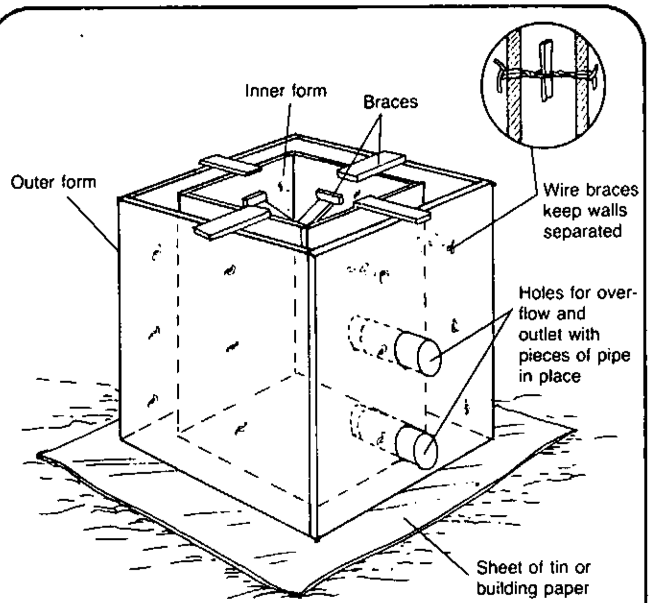


Figure 7. Forms for Spring Box with Open Bottom

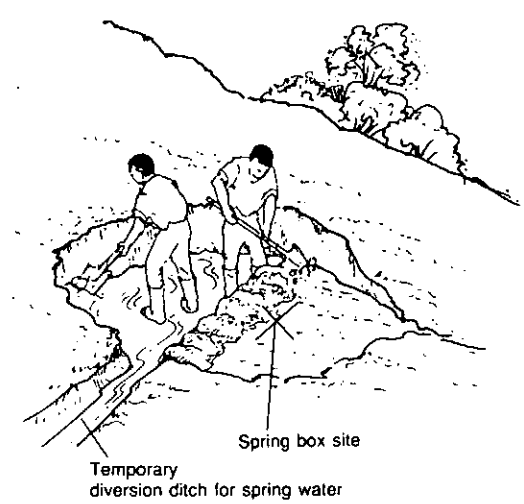


Figure 8. Excavating Spring Site

2. Set the forms in place. They should be either at the permanent site of the spring box or nearby so it will not be difficult to move the completed structure. If the forms are set and concrete is poured at the permanent site, water must be diverted from the area. This usually can be done easily by digging a small diversion ditch, as shown in Figure 8. Make sure that no water reaches the forms so that the concrete can cure.

If water diversion is difficult, build the forms and pour concrete on a level spot very near the spring. Once the concrete dries, remove the forms and set the completed structure in place. This will require six to eight people.

3. Oil the forms. Put old motor oil on the wooden forms so the concrete will not stick to them.

4. Prepare the reinforcing rods in a grid pattern for placement in the forms for the spring box cover. Make sure there is 0.15m between the parallel bars and that the rods are securely tied together with wire. Then position the reinforcing rods in the form. See Figure 9 for an example of reinforcing rod placement in the spring box cover. Major reinforcing is not needed for the spring box walls but some minor reinforcing around the perimeter of the walls is good to prevent small cracks in the cement. Four bars tied together to form a square should be placed in the forms.

5. Mix the concrete in a proportion of one part cement, two parts sand and three parts gravel (1:2:3). Add just enough water to form a thick paste. Too much water produces weak concrete. In order to save cement, a mixture of 1:2:4 can be used. This mixture is effective with high quality gravel.

6. Pour the concrete into the forms. Tamp the concrete to be sure that the forms are filled completely and that there are no voids or air pockets that can weaken it. Smooth all surfaces. Smooth the concrete for the spring box cover so the middle is a little higher than the sides (convex shape), as shown in Figure 10. This will allow water to run off the cover away from the spring box.

7. Cover the concrete with canvas, burlap, empty cement bags, plastic, straw or some other protective material to prevent it from losing moisture. The covering should be kept wet so water from the concrete is not absorbed. If concrete becomes dry, it no longer hardens, its strength is lost, and it begins to crack. Keep the cover on for seven days or as long as the concrete is curing.

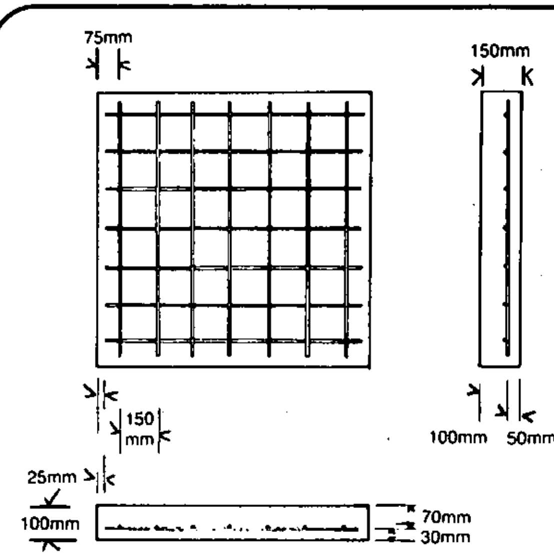


Figure 9. Placement of Rebar in Concrete Slab

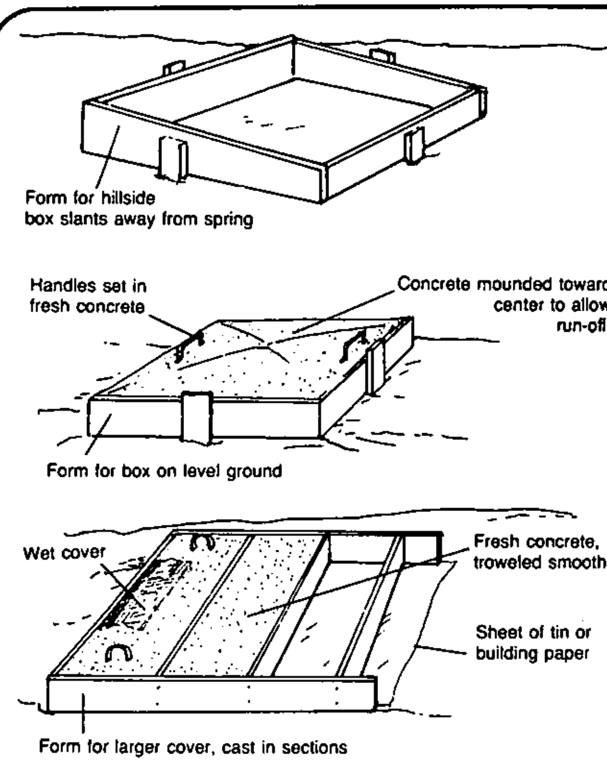


Figure 10. Forms for Spring Box Cover

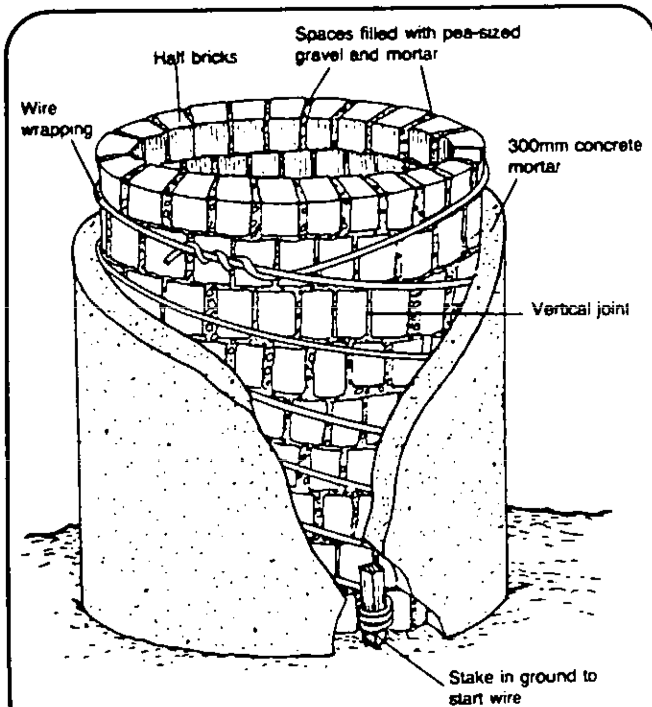


Figure 11. Brick Spring Box

8. Let the concrete structures set for seven days, wetting the concrete at least daily. After seven days, the forms can be removed and the box can be installed.

When constructing a masonry ring to protect a spring, follow the construction steps listed below.

1. Mark out a circle on the ground the diameter of the proposed masonry ring.

2. Using half bricks, place a circle of brick around the outside of the ring. Whole bricks broken in half or broken bricks can be used for the structure. In some places, broken bricks are available free.

3. Fill the spaces between the bricks with pea gravel and mortar mixed in a proportion of 1 part cement to 3 parts sand. As mortar is applied, add the next line of bricks. Be sure the vertical joints do not line up.

4. When reaching the desired height, strengthen the structure using baling, barbed or any available wire. Put a stake in the ground next to the ring and attach the wire to it. Wrap the wire around the ring several times as shown in Figure 11. Once the wire is wrapped around, secure and cut it.

5. Mix mortar in the proportion of 1 part cement to 3 parts sand. Cover the outside of the ring with a layer of mortar. The layer should be thick enough to cover the wire completely.

6. A circular cover should be built. Follow the same techniques as for the construction of concrete spring box covers.

Installing a Spring Box

The spring box must be installed correctly to ensure that it fits on a solid, impervious base and that a seal with the ground is created to prevent water seeping under the structure.

1. Place the spring box in position to collect the flow from the spring. If the flow comes from a hillside, the back of the spring box will be open. Stones should be placed at the back of the box to provide support for the structure and to allow water to enter the spring box. Figure 4 shows the placement of open-jointed rock in a completely installed spring box on a hillside. On level ground, be sure that the spring box has a solid foundation of imprevious material. Place gravel around the box or in the basin so that water flows through it before entering the box.

2. Seal the area where the spring box makes contact with the ground. Use concrete or puddled clay to form a seal that prevents water from seeping under the box.

3. Be sure that the area where the spring flows from the ground is well lined with gravel, then backfill the dug out area with gravel. The gravel fill should reach as high as the inlet opening in the spring box so that the water flowing into the structure passes though gravel. In Figure 4, the gravel layer reaches the same level as the open stone wall. For spring boxes on level ground, gravel backfill is unnecessary.

4. Place the pipes in the spring box. Remove the pipe pieces used to

form the holes and put in the pipe needed for outflow and overflow. On both sides of the wall, use concrete to seal around the pipes so water does not leak out from around them. Place screening over the pipe openings and secure it with wire.

5. Disinfect the inside of the spring box with a chlorine solution. Before the spring box is closed, wash its walls with chlorine. Follow the directions for disinfection in "Disinfecting Wells," RWS.2.C.9.

6. Place the cover on the spring box.

7. Backfill around the area with puddled clay and soil. On a hillside, place layers of puddled clay over the gravel so that they slope away from the spring box. The clay layer should nearly reach the top of the spring box and should be tamped down firmly to make the ground as impervious as possible. If only soil were used for backfill, it would have to be as least 1.5-2m deep so that contaminated water could not reach the gravel layer. For springs on level ground, clay should be placed around the box. The clay foundation should slope away from the spring box so that water runs away from the spring outlet.

8. Backfill the remaining areas with soil to complete the installation.

Constructing Seep Collection System

Sometimes springs flow from many openings over a large area. To collect the water, a system of collectors made of perforated pipe, an anti-seepage wall, and a spring box must be built.

The collectors must extend on both sides of the spring box and anti-seepage wall. Figure 12 shows an example. To install collectors dig trenches into the water-bearing soil until an impervious layer is reached. In this way, water is taken from the deepest part of the aquifer and most of the available water can be collected. The trenches should extend the necessary length for collecting all available water and should be about 1m wide.

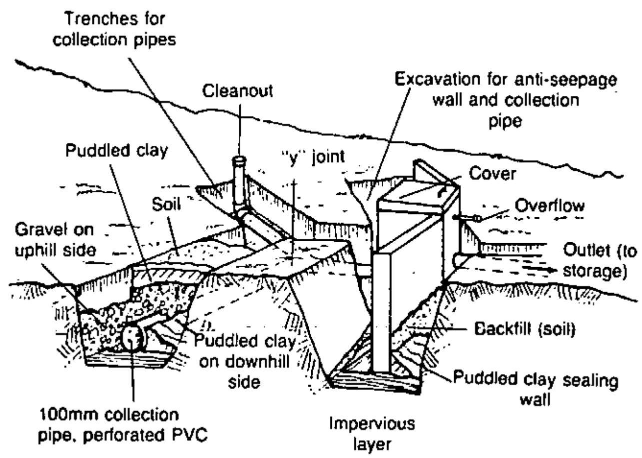


Figure 12. Seep Collection System

Lay 50-100mm diameter plastic perforated pipe or 100mm clay pipe in the trenches. Perforations in the plastic pipe should be about 3mm in diameter. On the uphill side of the trench, place enough gravel to cover the pipe. On the downhill side, build up a small clay wall to support the pipe. The pipe should have a 1 percent slope (0.01m slope per 1m distance) toward the point of collection. Flexible plastic tubing with slots already formed should be used if available. It is light and can be cut with a handsaw.

Clean-out pipes should be installed in the collection system. Attach lengths of pipe to the ends of the collection pipes. At the end of the clean-out pipes, place an elbow joint to which a vertical length of pipe is connected as shown in Figure 12. The pipe extends above ground level and is capped.

The next step is to build a concrete or impervious clay cutoff or anti-seepage wall. Dig down to an impervious layer for a good foundation. Make the forms for the cutoff wall 0.15m thick. Figure 13 shows a concrete cutoff wall 1.2m long and 0.9m high. Follow the same procedures for constructing the cutoff wall as for the spring box. There must be a good seal between the wall and the ground so that no water seeps underneath. Water must be

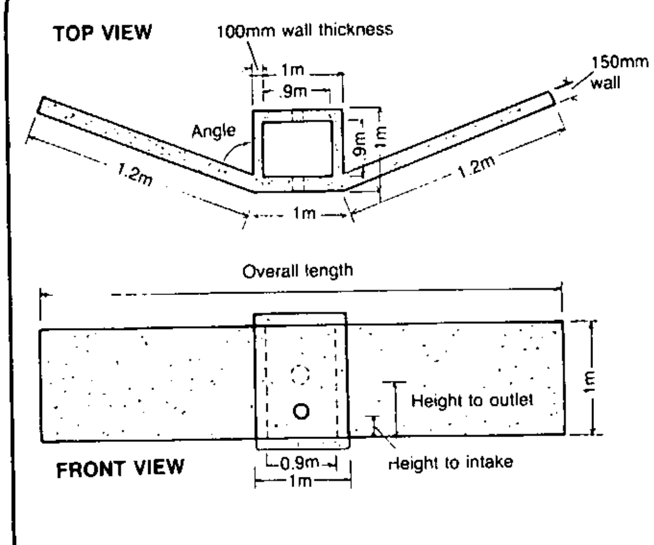


Figure 13. Anti-Seepage Wall and Collection Box

directed into the trenches and collectors. A small spring box can be built at the inside angle of the winged-wall with the wall forming two sides. If a spring box is built, the forms must be set at the same time as the cutoff wall. Water must be diverted from the construction area by small ditches for the seven days needed for the concrete to dry. Forms must be well braced and have holes for the inflow and outflow pipes as shown in Figure 14. Always pour the seep collection wall and spring box in place. The structure will be much too heavy to move after casting.

When using clay, be sure to remove any debris from the site and tamp the clay well so that the small dam or wall does not let water seep through. The clay walls should be built like walls of a dam with a 2:1 or 3:1 slope. Put

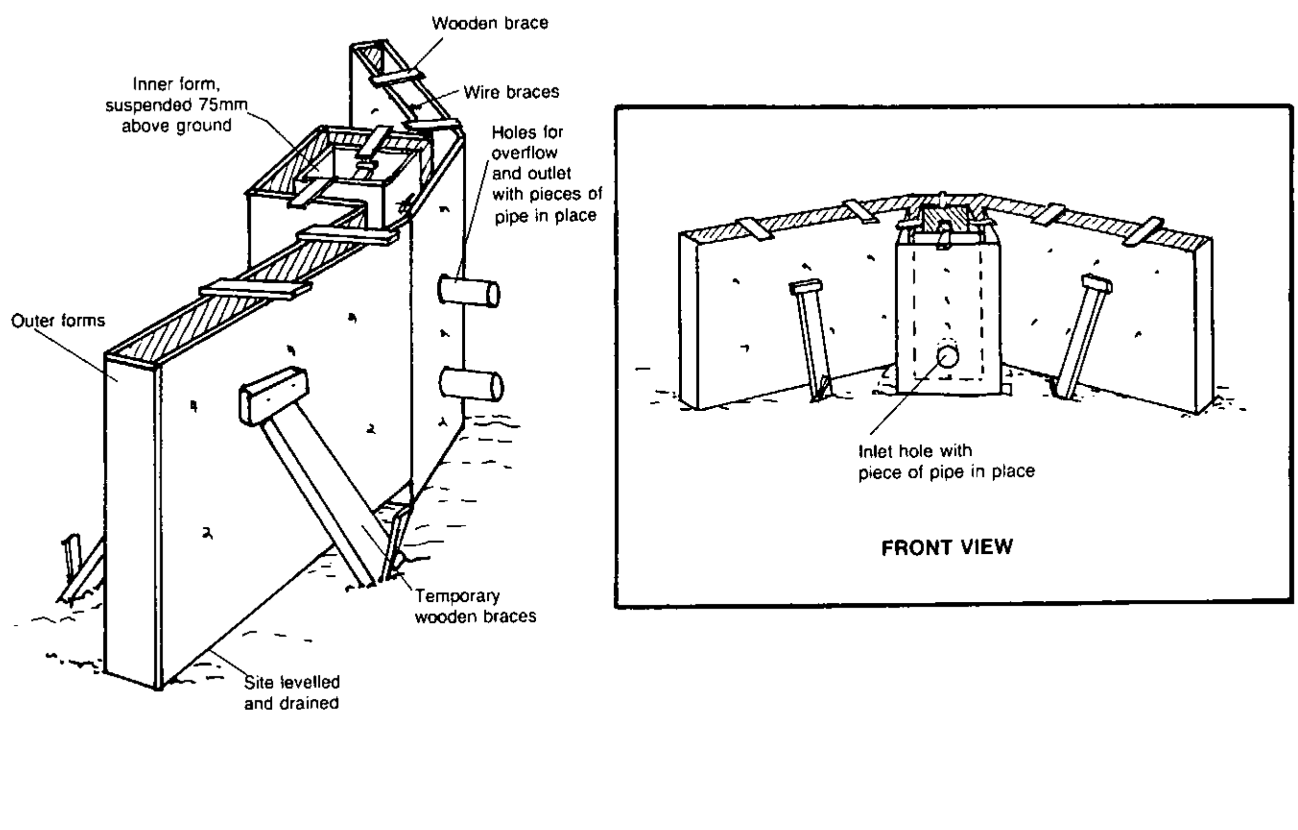


Figure 14. Forms for Anti-Seepage Wall and Collection Box

the clay down in layers 150mm thick and tamp each layer down well to ensure good compaction. Keep the clay moist. Lay and tamp each 150mm layer until the maximum height is reached. The walls should be well bonded to the spring box.

The construction of a seep collection system is more difficult and expensive than a simple spring box. Installation of collectors requires more work and some experience. Once the collectors are installed, however, the construction of the seep cutoff wall is no different from spring box construction. The same steps must be followed, the same mixture of concrete used and the same general rules for curing concrete and for placement must be followed.

Water for the World

Designing Intakes for Rivers and Streams
Technical Note No. RWS. 1.D.3

The installation of intakes makes water from rivers and streams more accessible. Water can easily be pumped from an intake to a community distribution system. Long walks to carry water are no longer necessary. The installation of an intake should lead to increased consumption of water which should, in turn, mean improved health for the community.

Intakes must be designed correctly if they are to function properly. A well-designed intake should provide good quality water in abundant quantities. An intake should be inexpensive to install and operate and require as little skilled supervision as possible for its construction and maintenance. This technical note describes the design of three types of intakes: infiltration intakes, gravity flow intakes, and direct pumping intakes. It should be used with "Choosing Where to Place Intakes," RWS.1.P.4, which discusses site selection for and placement of intakes.

The design process should result in the following three items which should be given to the construction supervisor:

1. A map showing the location of the proposed intake. Figure 1 is a sample location map for an infiltration gallery.

2. A list of all labor, materials and tools needed as shown in Tables 1, 2, and 3. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

3. Detail drawings of the intake to be constructed with all dimensions similar to the one shown for a winged-wall collector in Figure 8.

Useful Definitions

ABUTMENT - A structure supporting a bridge or walkway.

CASING - Lining for wells made either with concrete rings, bricks, or pipe to strengthen the walls of the well and prevent contaminants from entering.

GALLERIES - Long narrow trenches or ditches through which water passes.

INFILTRATION - The process of water passing from the surface through the soil and into groundwater reservoirs.

PRECAST - A concrete structure formed and cast somewhere other than its intended place of use and moved into place when ready.

REINFORCED CONCRETE - Concrete containing reinforcing bars or wire mesh to give it extra strength.

VITRIFIED CLAY PIPE - Clay that is baked and glazed in a very high heat.

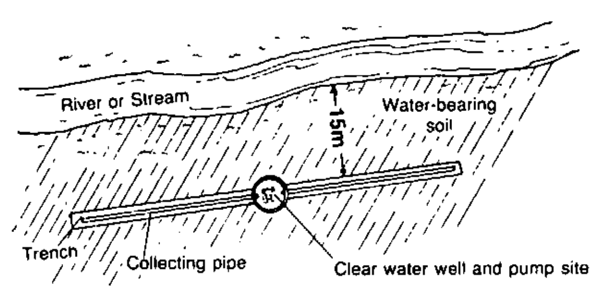


Figure 1. Location Map for Infiltration System

Table 1. Sample Materials List for Infiltration Systems

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers		
Supplies	Plastic (PVC) pipe, 50mm, or clay tile or concrete pipe, 10mm Hand or mechanical pump Sand and gravel (for filter beds) String Wooden stakes Sludge pump (if necessary)		
Tools	Shovels, picks, digging sticks (for digging well) Small hand drill Hammer Nails Measuring tape Carpenter's level Measuring rod Bucket		

(NOTE: For additional materials needed, see "Constructing Dug Wells," RWS.2.C.1)

Table 2. Sample Materials List for Gravity Flow System

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers		
Supplies	Portland cement Clean sand and gravel, if available, or locally available sand and gravel Water (enough to make a stiff mixture) Reinforcing rod, 8mm Lumber (for forms) Nails Rope and pulley Tripod Tie wire or clamp Wire mesh screen, 10mm Pipe, plastic or galvanized		
Tools	Shovels, picks, digging sticks Measuring tape Wire cutters Hacksaw Hammer Bucket		

Table 3. Sample Materials List for Permanent Direct Pumping System

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	___ ___	___ ___
Supplies	Bricks - seconds can be used for half bricks Portland cement Clean sand and gravel, if available, or locally available sand and gravel Water (enough to make a stiff mixture) Lumber (2.5cm x 15cm; 5cm x 150cm; 10cm x 10cm) Tripod Rope and pulley Barbed wire Log Mechanical pump Pipe and elbow joint (couplings) Wire mesh screen, 10mm Tie wire Clamp Nails Pipe glue		
Tools	Shovels, picks, digging sticks		

Design of Infiltration Intakes

One type of intake is designed so that water from a stream or river passes through the ground and into storage. These are called infiltration intakes because the water collected is filtered as it passes through the ground. The water is generally free from contamination and needs no treatment. The two infiltration intake designs discussed in this section are a well dug in a river bank, and infiltration galleries.

Figure 2 shows a well dug in a river bank of sand and gravel. The well's distance from the stream depends on the type of soil in the stream bank. If the ground contains semi-porous material such as clay, the well can be located only a few meters from the bank. Filtration takes place rapidly in clay so the well can be located closer to the stream. Since water flow is slow in clay, a close location ensures adequate recharge. In more porous soils, such as coarse sand and gravel, the well should be located further than 15m from the bank. An average distance in semi-coarse soils made up of some clay and silt is 15m.

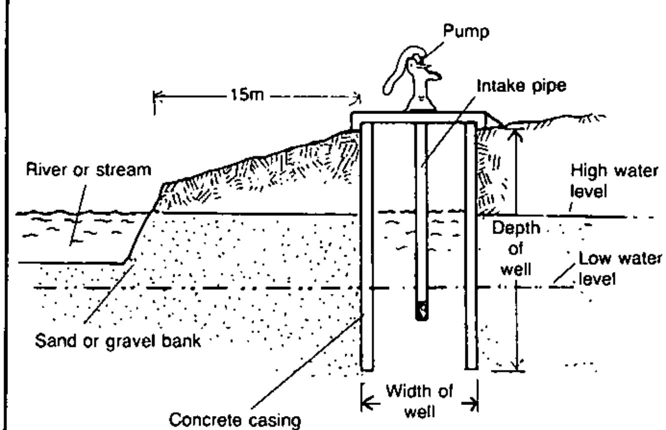


Figure 2. Riverside Well Intake

Water is pumped from the well to the users. During pumping the water enters the well and the groundwater table is lowered. When the groundwater table falls below river level, river water enters the aquifer. As pumping continues, this water flows through the ground, is filtered, and eventually enters the well.

The well should be dug at least 0.5m deeper than the floor of the stream bed and should be lined with concrete rings or bricks and mortar. A hand pump or power pump is installed to pump water from the well to the users. This design is good for small systems with fewer than 150 users. Design information for the well and different types of casing is in "Designing Dug Wells," RWS.2.D.1.

If the infiltration method is to be used to supply water to a larger population, infiltration galleries should be constructed. Infiltration galleries collect water from an area parallel to a river bank through collection pipes. These pipes move the water into a clear water well where it is held for pumping to a distribution system. Figures 3, 4 and 5 show examples of infiltration galleries. The primary design components are: (a) an excavated trench, (b) collecting pipes, (c) a filter bed, and (d) a clear water well.

Excavated Trenches. The infiltration gallery can be located on the stream bank as shown in Figure 3. Trenches should be parallel to the stream or river in water-bearing soil. The trenches' distance from the stream depends on the makeup of the soil. If the soil is a mixture of sand and gravel that is not very coarse, the infiltration galleries can be placed 15m from the stream. Follow the same rules in placing trenches as for riverside wells. The trench should be dug during the dry season when the water table is lowest to ensure that adequate quantities of water are tapped for year-round flow. A depth of 1m below the lowest water table level is sufficient. The trench must slope so that water runs into the storage well. A one percent slope is sufficient for the design (one percent slope = one centimeter per meter). Because trenches are dug below the water level, they must be bailed to keep them free of water during construction. The trenches can be bailed by hand using buckets, or a pump can be used to keep them dry.

Digging trenches in sandy soil is dangerous because the trenches will cave in as digging continues. Never dig trenches so that the edges are higher than a worker's head. If trenches must be dug deeply into the ground, slope the sides to prevent

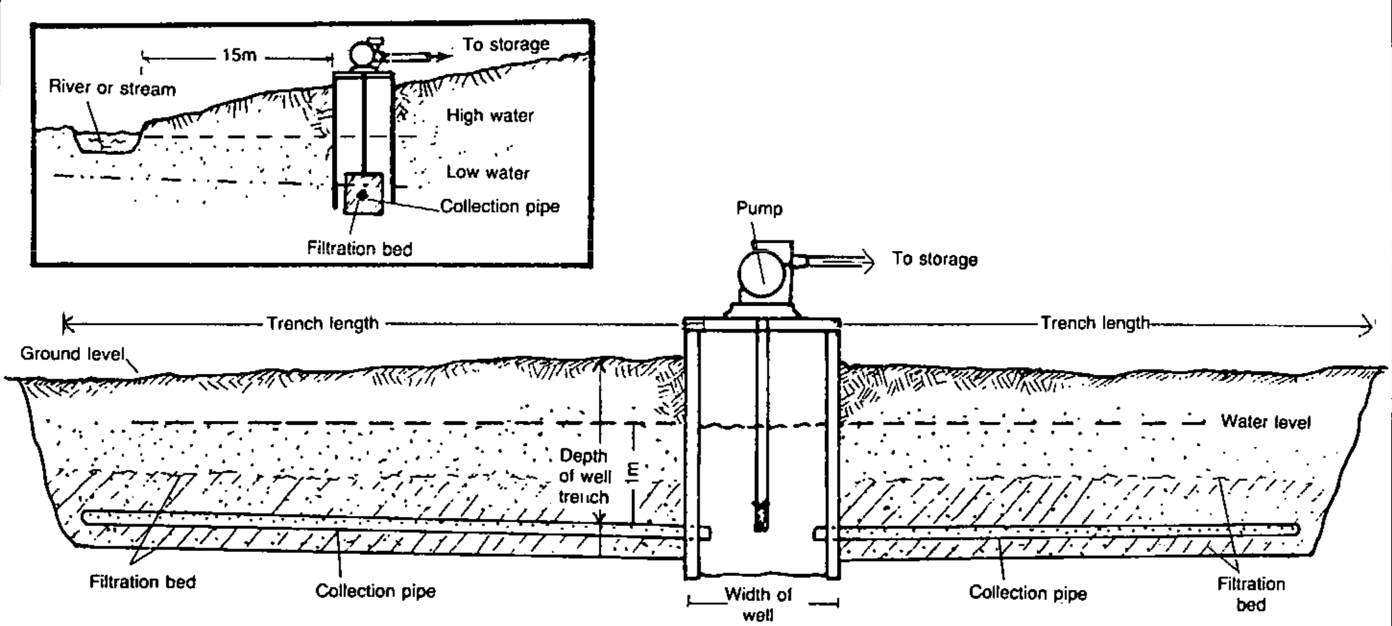


Figure 3. Riverside Infiltration Intake

cave-ins. In very sandy soils, it may be impossible to install trenches in the bank and an alternative should be chosen.

Figure 4 shows an infiltration gallery placed in the bed of a river. The stream is diverted so that a trench can be dug directly in the middle of the stream. The depth of the trench should be between 0.3 and 0.5m. It should be lined with gravel as described in the section on filter beds. Connect one end of the filter pipe to a pipe that runs into a clear water well located on the bank. Lay the pipe so that the slope is approximately one percent, permitting the water to flow easily into the clear well.

A clean-out pipe should be attached to the opposite end of the filter pipe. The clean-out pipe is simply a length of pipe attached to the perforated pipe which leads to the bank opposite the clear well. An elbow is attached to the length of pipe so that a vertical piece of pipe can be connected to it. The vertical section extends above ground level for easy access and is capped so that no debris can enter it. The clean-out system is used to flush out sediment if the collection pipe clogs.

Figure 5 shows another useful design for an infiltration gallery. Collecting pipes are driven from a well located in the bank into the bed of a stream below water level. In some soils, the pipes can be driven by hand using a hammer and drive pipe. In most cases, the pipes need to be driven with a pneumatic hammer braced against the wall of the well. The section of wall that supports the hammer should receive extra reinforcement to prevent it from breaking apart.

One useful technique is to drive large diameter steel pipe into the stream bed and then slide smaller diameter perforated plastic pipe into it, removing the steel pipe as the plastic pipe is put into place. This type of infiltration gallery is useful when sandy soil prevents the installation of trenches in the bank or when stream beds are difficult to excavate.

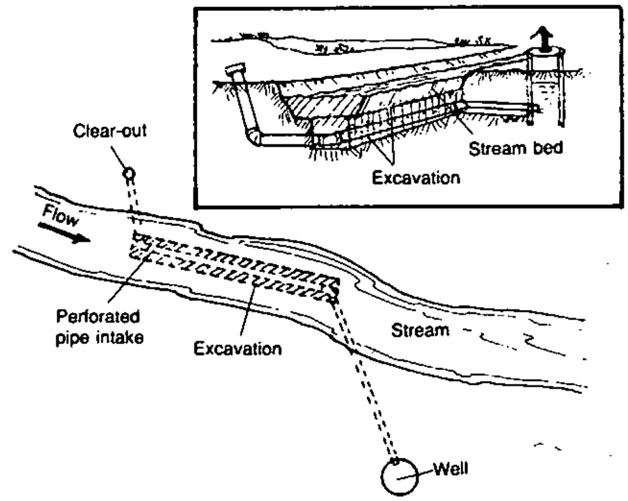


Figure 4. Infiltration System Below Stream Bed

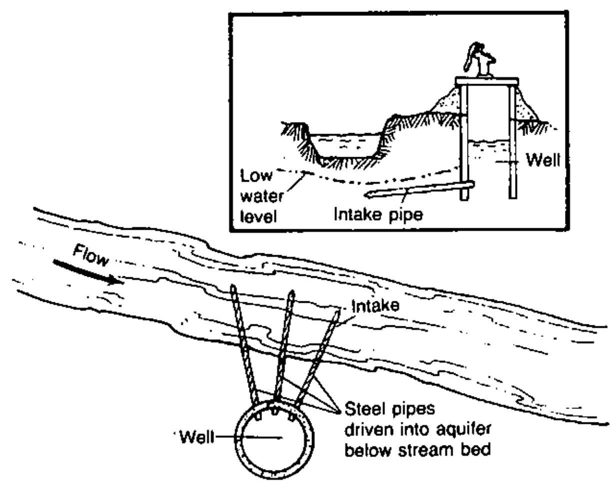


Figure 5. Multiple Pipe Infiltration System

Collecting Pipes. First, decide on the type of pipe. Rigid or flexible plastic, concrete, or vitrified clay pipe can be used. The choice depends on availability and cost. Next, choose the appropriate pipe diameter. This depends on the type of pipe chosen, its length, cost, and availability. If clay or tile pipe is used, 100mm diameter is the smallest available and should be used. If you are using plastic pipe, the diameter can range between 50mm and 100mm as long as flow is sufficient to meet community needs. If concrete is poured to make concrete pipes, the diameter of the form should be 200mm. Concrete pipe can be made with large gravel and a fluid sand and cement mix. The result is pipe with porous walls through which water flows easily. Careful curing is required. Large diameter pipe allows more water to flow into a system but it is more expensive and the community may not be able to afford it.

Decide on the appropriate size for the inlet holes. If concrete or clay pipe is used, no inlet holes are needed since water enters through openings at the pipe joints. The pipe joints should be at 1m intervals. Plastic pipe needs inlet holes or slots. Inlet holes 10mm in diameter or slots 25mm long can be made with a drill, nail, or small saw. Flexible polyethylene plastic pipe can be purchased with slots already made. Details of inlet hole sizes and the basic design are shown in Figure 6a.

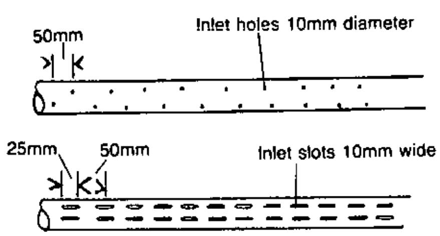


Figure 6a. Collection Pipe for Filtration System

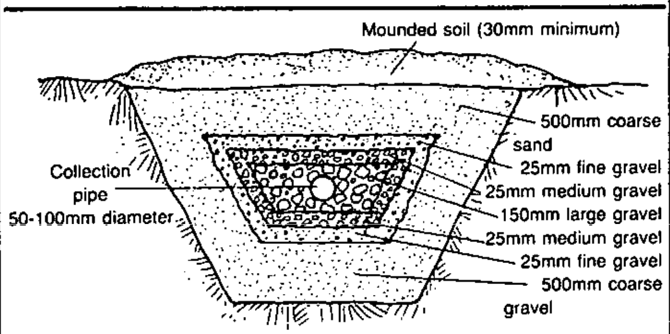


Figure 6b. Filtration Bed

Finally, choose the appropriate pipe length. This will depend on the amount of water needed and the type of soil in the water-bearing zone. Use a longer pipe in fine sand in order to collect greater quantities of water. To determine pipe length, the water flow must be observed. If flow is insufficient, either a larger diameter pipe must be installed or the trenches and collecting pipes must be lengthened to collect more water.

Filter Bed. A filter bed of stone, graded sand and gravel or other suitable filtering material should be built. The filtering material should be placed around the collecting pipe and built out to a width of 0.30-0.40m. Both the surrounding layers and side layers need to be graded to work effectively. Other layers of smaller filter material are added as shown in Figure 6b.

Clear Water Well. Use the design information for a riverside well given at the beginning of this technical note in designing the clear water well. This well serves the same purpose as the riverside well but collects water over a much larger area. Water is pumped from the well into the distribution system. If the infiltration gallery is well constructed, water may need only chlorination before it can be consumed. In some cases, more treatment will be necessary. Water in the clear well should be tested to determine its quality.

For all infiltration systems, water must be pumped to the users. In areas that are spread out or require a lot of water, smaller infiltration wells can be pumped by hand pumps for use at the source. Generally, when infiltration galleries are installed, water is pumped to the users through a distribution system. A pump, using a source of power, pumps water from the storage well to the main storage tank. See "Methods of Delivering Water," RWS.4.M.

Design of Gravity Flow Intakes

In mountainous or hilly regions, water from streams and rivers can be collected through intakes placed directly in streams. In higher elevations, a gravity flow system can be installed to deliver water if there is enough head for the water to reach the users. For an explanation of head and head loss in a system see "Designing a System of Gravity Flow," RWS.4.D.1.

If the intake is located above any inhabited area, the water may not require treatment. People and animals are the major sources of fecal contamination. If neither is present at the place where the water is collected, or upstream from the collection point, fecal contamination is unlikely.

Figure 7 shows a typical intake structure for a gravity flow system. The intake is located on a straight stretch of the river near a convex turn. The best location for the intake is where the bank and floor of the stream are stable.

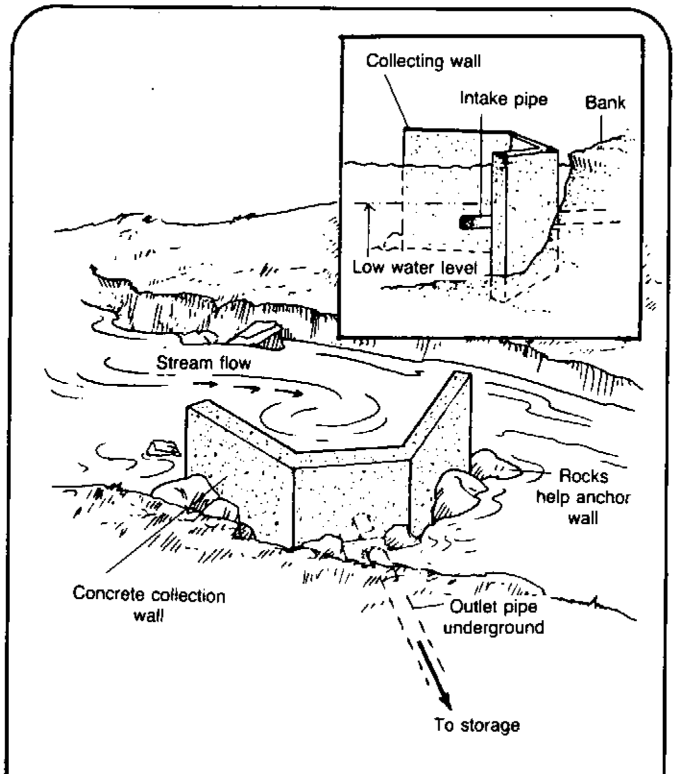


Figure 7. Gravity Flow Intake

The intake is made up of a screened intake pipe, and a reinforced concrete structure with winged-walls. To design this structure, first determine river flow, pipe diameter, pipe material, water level, and size of structure.

Determine the river flow using the methods described in "Selecting a Source of Surface Water," RWS.1.P.3. This measurement will indicate whether there is sufficient flow to meet community needs. Most streams that flow year round will provide ample water.

Determine the diameter of the pipe to be used in the system by using Table 4. Locate an approximate rate of flow for the river in the left hand column. Then look in either column 2 or column 3 to find the correct pipe diameter. For most rural areas, the velocity of water in the system ranges between 1.2-1.8m per second. For example, in a system where the river flow rate is 1 liter per second and the velocity is 1.2m per second, the correct size pipes would be 300mm. Check if the flow is sufficient by comparing the daily water needs (40 liters per day per person times number of people) and the daily flow. The daily flow must be equal to or larger than the daily water requirement.

Table 4. Determining Pipe Diameter

Q = Flow Liters/sec.	V (Velocity) = 1m/sec. - 1.5m/sec.	V (Velocity) = 1.5m/sec. - 2m/sec.
	Pipe Diameter (cm)	Pipe Diameter (cm)
0.63	25cm	25cm
0.83	30cm	30cm
1.0	30cm	30cm
1.3	40cm	30cm
1.6	50cm	40cm
2.0	50cm	50cm
2.3	50cm	50cm
2.6	60cm	50cm
3.0	60cm	50cm

Decide whether to use plastic or galvanized pipe depending on what is available. If the river is fast-flowing, or if flooding is likely to occur, galvanized steel pipe is preferable because of its strength. If the water is piped a long distance downhill to a community storage tank, flexible plastic pipe (polyethylene) is better. It is cheaper and easier to use because of its light weight and flexibility. The best method may be to place steel pipe in the structure for strength and then attach flexible plastic pipe to it for the distribution system.

Determine the level of the water at its lowest point during the year. The intake pipe must be placed in the upper third of the river when the river is at its lowest level. At this point, a water supply is provided all year and sediment from the river bottom will not enter the pipe.

The end of the intake pipe should be screened to prevent the entrance of leaves, stones, sticks, or other large material that could clog the pipe. Usually, 10mm mesh screen is a good size for the intake.

Determine the best size for the reinforced concrete structure. Size will depend on local conditions. The winged-walls must reach far enough into the stream to divert the water toward the intake into a pool which is always deep enough to submerge the intake pipe. The top of the structure stands above the riverbank so that the intake pipe is well supported in the walls and on the bank. The wall should be at least 0.15m-0.20m thick. The basic dimensions for the structure are shown in Figure 8.

Decide how to anchor the collection box and intake pipe. The box should be precast and lowered into a part of the stream where there are large rocks to support it. Digging into the stream bed 0.15m-0.20m will secure the bottom. One wall should be placed firmly against the stream bank and the unsupported side should be braced with large rocks as shown in Figure 7. The intake pipe should be anchored to the bank by digging a trench in the bank

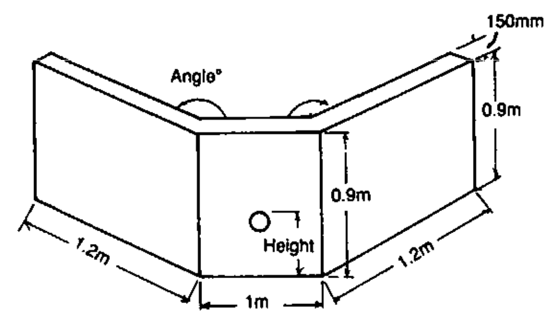


Figure 8. Design of Infiltration Wing-Wall Collector

and burying the pipe about 150-200mm in the ground. Both the intake pipe and collection box must be secure enough to avoid destruction caused by fast-flowing water, flooding, or moving rocks or logs.

Erosion of the bank opposite the winged-wall structure may occur as the stream flow is affected by the extension of the wall into the middle of the stream. To prevent the bank's erosion, reinforce it with rip-rap. The rip-rap should be placed on the bank where the force of water against the bank is greatest.

Construction of a winged-wall collection box requires skilled labor. This method should only be undertaken with the help of an engineer.

Design of Permanent Intakes for Direct Pumping

Water can be pumped straight from a stream or river to treatment and storage using direct pumping. There are many types of temporary intakes but permanent structures are better. Design of a permanent structure is shown in Figure 9. The intake consists of (a) a screened intake with a check valve, (b) a protective concrete ring with perforations, (c) a catwalk, and (d) a power pump. This type of intake should be used only in rivers that have a year-round depth of over 0.50m.

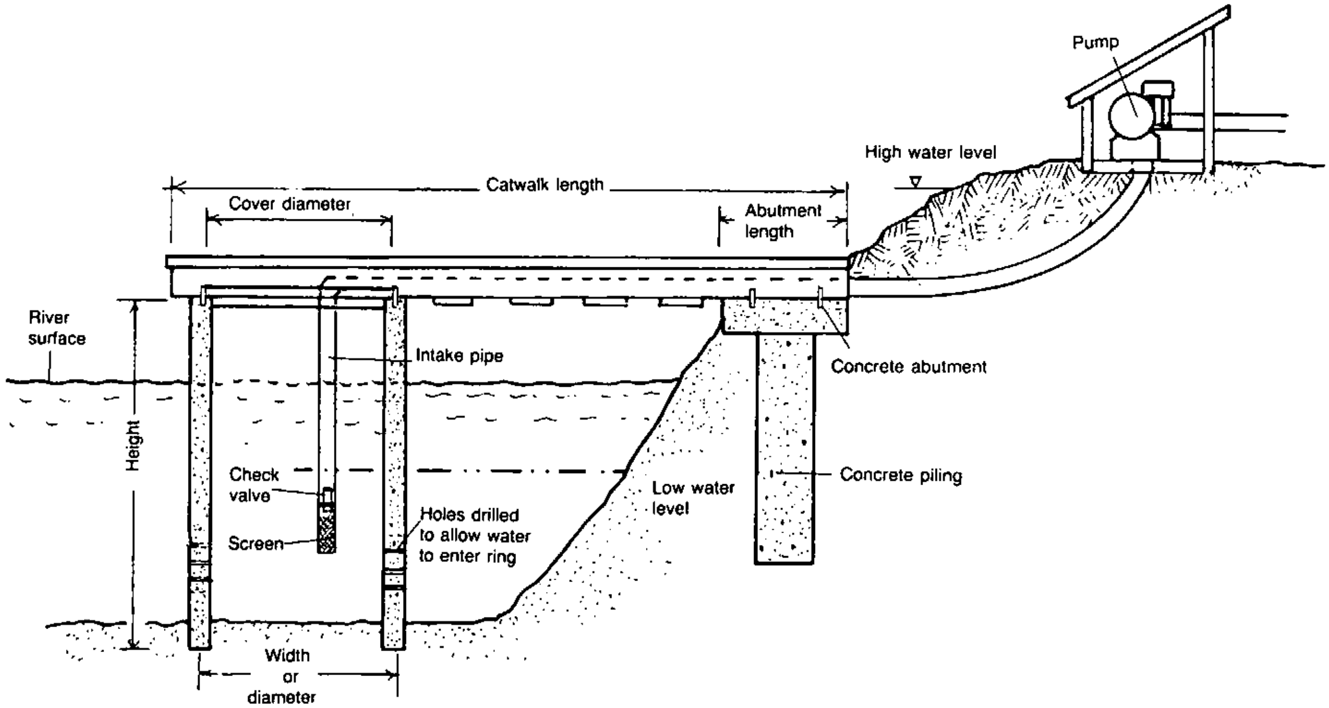


Figure 9. Direct Intake

Intake Pipe. A 50mm pipe with a 10mm wire mesh screen should be used for the intake pipe. The intake pipe is located in the concrete ring (pump well) and stands 300m above the stream bed in order to prevent large particles and sediment from entering the system. The pipe can be either plastic or galvanized steel. The choice depends upon what is available. Flexible plastic is much cheaper and needs no joints or couplings, but steel pipe may prove to be best because of its strength.

Determine the length of the pipe by measuring the distance from the pump to the end of the catwalk. Add to this the distance from the top of the catwalk to 0.30m above the bottom of the stream.

Concrete Rings. Determine the dimensions of the reinforced concrete ring. It should have a height of 1m and a diameter of 1.5m. The ring is precast and lowered into the stream. The ring should enter the stream bed 0.3-0.5m for adequate support. Weight may be a problem so a smaller ring may be designed. The ring should be large enough to protect the [illegible] from water moving at high velocities and from large floating debris. Several small, 50-70mm diameter holes can be drilled in the ring to ensure an adequate water flow to the intake. A wooden cover fits over the ring to protect the intake pipe. When casting the ring, bolts should be placed in the cement so that the catwalks can be bolted to the ring. If the ring is bought, drill holes into the cement and place the bolts in the appropriate places, securing them with mortar. Because casting a ring is difficult, it is best to purchase one that is already made or build one using bricks and mortar as described in "Designing Structures for Springs," RWS.1.D.1. The intake should be located near the deepest part of the river or in a place where the water level is above 0.5m during the entire year. However, care should be shown to locate the intake fairly close to the shore. The design of the catwalk is more difficult the greater the distance from the shore to the intake.

Catwalk. Design a catwalk to connect the stream bank to the concrete ring and to support the intake pipe from the bank to the ring. The catwalk can be made of wood for easier construction. A concrete catwalk should only be designed by skilled engineers. Two timbers 0.10m by 0.10m should be used to connect the concrete ring to the shore. They are laid parallel, 1m apart and bolted to the concrete ring by attaching them to the bolts in the ring. The other end of each timber is attached to the abutment on the shore. Planks, 0.25m by 0.15m, are then nailed to the top to form a walkway as shown in Figure 10. Wooden pipe supports 1.5m apart are bolted to the bottom of the catwalk structure. A 0.5m by 0.15m plank is sufficient for the supports. A small strip of metal or rubber should be fastened to the support and around the pipe to keep it in place.

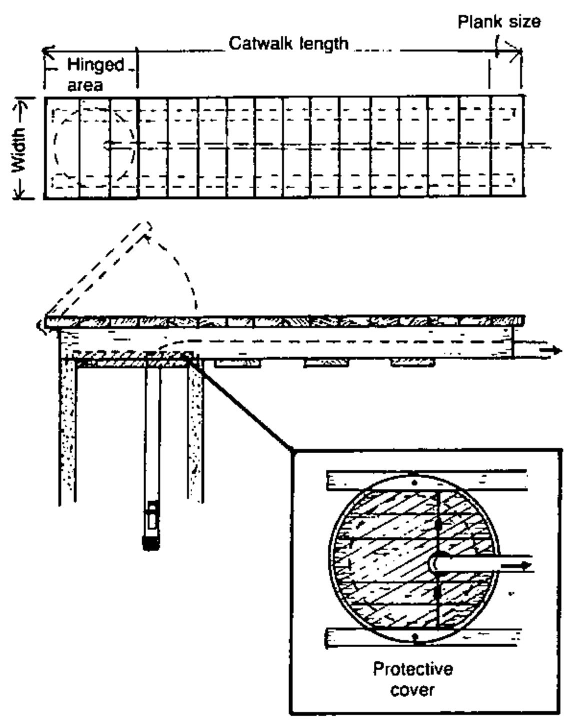


Figure 10. Catwalk and Cover Design

On the shore, build a concrete abutment 1.5m x 1m x 0.15m and level to the top of the concrete ring. This will support the catwalk. To build the abutment, dig out a level area to the desired size. The abutment should be attached to a piling to give the catwalk the needed support. The piling should be half the length and width of the abutment and should extend into the ground 0.5-1.0m. The hole is completely filled with concrete. The abutment and piling should be constructed as a single unit.

Install a pump and connect it to the intake pipe. Put the pump on level ground if possible, about 2m from the shore. To determine the type of pump needed, see "Determining Pumping Requirements," RWS.4.D.2, and "Installing Mechanical Pumps," RWS.4.C.2.

This type of intake structure is very difficult to build and trained technicians are needed. Materials which may be hard to obtain are required and these will raise the cost of the project. This design is only economically practical if many people are served by it.

For design, follow the steps described in Worksheet A. The volume of concrete needed can be determined by finding the volume of the concrete rings using the formula in Worksheet B.

If the concrete ring is too complicated to build a simpler design shown in Figure 11 can be attempted. A concrete base is built with a pipe inserted into it. An elbow is attached to the end and a vertical length of screened steel pipe is connected to it. The pipe in the concrete can be attached to flexible pipe for easy accessibility for maintenance. In deeper streams, a float can be attached to the intake to provide easy location.

Worksheet A. Determining the Amount of Concrete to be Used in Construction of Winged-Walled Intake Structure

1. Total volume = volume of side 1 + volume side 2 + volume side 3

   Volume side 1 = length 1.2 m x width 0.90 m x thickness 0.15 m = 0.162 m^3

   Volume side 2 = length 1 m x width 0.90 m x thickness 0.15 m = 0.135 m^3

   Volume side 3 = length 1.2 m x width 0.90 m x thickness 0.15 m = 0.162 m^3

   Total volume = 0.162 m^3 + 0.162 m^3 + 0.135 m^3 = 0.457 m^3

2. Total volume x 1.5 = volume of dry mix 0.457 cm^3 x 1.5 = 0.685 m^3

3. Cement mixture = 3 parts gravel, 2 parts sand, 1 part cement (50% gravel, 33% sand, 16.7% cement)

   Volume of gravel = 0.50 x total volume = 0.50 x 0.685 = 0.34 m^3

   Volume of sand = 0.33 x total volume = 0.33 x 0.685 = 0.22 m^3

   Volume of cement = 0.167 x total volume = 0.167 x 0.685 = 0.11 m^3

4. Volume of cement = 0.11 ÷ .033 m^3/bag = 3.5 bags of cement

5. Volume of water = 28 liters/bag of cement = 28 liters x 3.3 bags = 98 liters

6. Determine the number of lengths of reinforcing rod by using the following formulas:

   Divide the length of one side and the width of one side by 150mm, the distance between each bar.

   Length in mm ÷ 150mm = number of bars
   1200 mm ÷ 150m = 8 bars
   Width in mm ÷ 150m = number of bars
   900 mm ÷ 150m = 6 bars

   For the entire wall, 14 bars are needed and should be placed as shown in Figure 12.

   Do these calculations for each wall to determine the amount of rebar needed.

Worksheet B. Volume of a Concrete Ring

In the example given, the diameter of the ring is 1.5m and the thickness 0.10m.

a) Area = diameter²

$$A = \frac{3.11}{4} \times 1.5^2$$

$$A = .785 \times 2.25$$

$$A = 1.76 m^2$$

b) Volume = area x thickness. Use this volume in calculating concrete needed for the tube.

$$V = 1.76 m^2 \times 0.10 m$$

$$V = 0.176 cm^3$$

All proportions of mixtures for gravel, sand and cement will be the same as in Worksheet A.

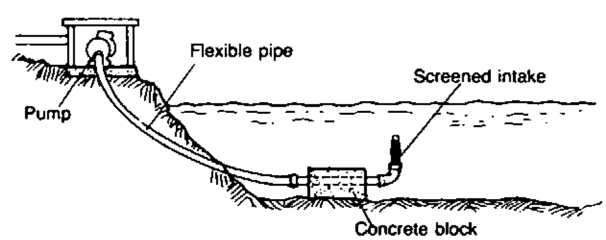


Figure 11. Simple Permanent Intake

Notes

Water for the World

Evaluating Rainfall Catchments
Technical Note No. RWS. 1.P.5.

In some cases, rainwater may be the only acceptable source of surface water available to a community. If it is to be used for drinking water, it must be collected and stored in sufficient quantities to meet individual or community needs. Basically, there are two types of rainwater catchments: roof catchments and ground catchments.

This technical note describes each type of catchment system and discusses its advantages and disadvantages. Before deciding to use a rainfall catchment, be sure to determine that the quantity of water it will produce is sufficient to meet local or individual needs and that enough storage can be provided. The design of cisterns for the storage of rainwater is described in "Designing a Household Cistern," RWS.5.D.1.

Roof Catchments

Before deciding to use roof catchments with individual cisterns determine (a) if each family has adequate resources available, (b) which is the most effective cistern design, (c) the space available for building the cistern, and (d) the capability of the users to disinfect it and clean it periodically. Roof catchments differ from other sources of surface water because a great responsibility for operation and maintenance rests with the individual user rather than the community. Water quality will depend on the user cleaning the pipes and gutters and disinfecting the stored water. If rainfall catchments are installed, the users must be thoroughly trained in techniques of operation and maintenance.

Useful Definitions

ASPHALT - A black tar-like substance mixed with sand or gravel for paving.

CISTERN - A covered tank in which water is stored.

EVAPORATION - Loss of surface water to air; surface water is heated by the sun and rises to the atmosphere as vapor.

HECTARE - A measure of land area equal to 100m by 100m.

IMPERVIOUS - Not allowing liquid to pass through.

INFILTRATION - The process of water passing from the surface through the soil and into groundwater reservoirs.

PERVIOUS - Allowing liquid to pass through.

SOIL PORES - Tiny openings and spaces in soil which water enters.

TRANSPIRATION - Similar to evaporation except that the water loss comes from stored water in plants; vapor leaves plants through small pores.

Materials. Roof catchments can only be used where roofing materials are suitable. Do not plan to develop rain catchments on thatched, painted or lead roofs. The water running from them is likely to be very contaminated. Water is likely to seep into thatched roofs and be lost.

Determine if tiles, slate, or corrugated plastic, tin or aluminum sheets are available and can be acquired by the village. Generally, sheet metal is preferable because of its light weight and strength. Tiles are also good because they can be made locally. However, they are much heavier than sheet metal and need a strong roof structure to support them without sagging.

Water Availability. For a roof catchment to be worthwhile, there must be sufficient rainfall. The amount and monthly distribution of annual rainfall for a region should be available from a local agricultural or other governmental agency, or from an airport. If you know the amount of annual rainfall, it will be easy to determine the amount of water available from the catchment for consumption. Use monthly rainfall data if available. This data will help planning for storage capacity during the dry months. To find the amount of water available yearly or monthly, multiply the area of the catchment by the annual average rainfall. Then, multiply this amount by 80 percent. Only 80 percent of the total volume of rainfall generally is available for use because of evaporation and other losses. For example, if a region has an annual rainfall of 800mm per year and a home has a catchment area of 48 square meters (6m x 8m), then the amount of available rainfall is:

$800mm \times 48m^2 \times 0.80 = 30.72m^3$ per year.

There are 1000 liters in $1m^3$, so $30.72m^3 \times 1000 = 307200$ liters per year.

$$\frac{30720 \text{ liters per year}}{12 \text{ months per year}} = 2560 \text{ liters per month;}$$

$$\frac{2560 \text{ liters per month}}{30 \text{ days per month}} = 85 \text{ liters per day.}$$

Compare the amount of water available to the amount of water needed to meet the users' needs. A catchment system must provide a minimum of 15 liters of water per person per day. In the example above, each member of a family of five would be able to use 17 liters of water per day. If the family had six members, each person would have 14 liters of water.

Storage. A cistern must be placed either above or below ground to collect water from the catchment. A cistern can be as simple as a 200-liter barrel, a tank constructed from reinforced concrete, as in Figure 1, or any other suitable collection container. The size of the cistern will depend on (a) the amount of water needed, (b) the amount and frequency of rainfall available, (c) the size of the collecting surface and (d) cost. The basic design features of a household cistern are discussed in "Designing a Household Cistern," RWS.5.D.1.

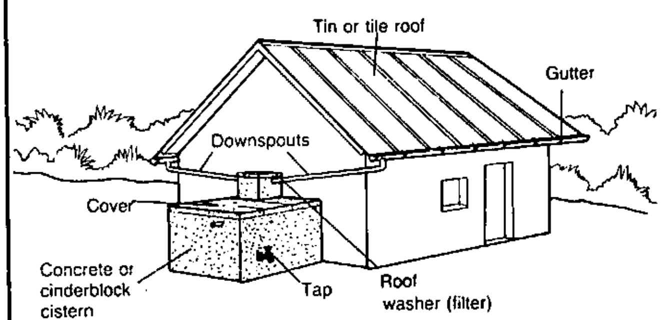


Figure 1. Rainfall Catchment with Cistern

If rainfall is evenly distributed throughout the year, the general rule is that a permanent cistern must be large enough to store a one month supply of water. In the example used above, 2560 liters per month are available for use. The cistern for this particular system should have a capacity of between 2.5 and $3.0m^3$. A cistern with a capacity of $2.5m^3$ can store 2500 liters and a $3m^3$ capacity cistern, 3000 liters. If resources are not available to build a cistern of this capacity, the largest cistern possible should be built.

If rainfall is heavy during some months but there is a dry season with little or no rain, the size of the cistern can be increased to store water during the wet season for use in the dry. The problem is that if a dry season is three months long and a three-month supply must be stored, the cistern would have to be very large and would be very expensive to build. This would be impossible for most individual families. There are several alternatives, however.

One alternative is to use collected rainwater for drinking and cooking only and find another source for washing and bathing. In this way, water use from the cistern can be reduced. If rainwater is used only for drinking, then smaller, less expensive cisterns can be built. Also, other less permanent designs could be used. Figures 2 and 3 show cisterns that may be suitable for some regions.

Large clay, concrete or ferrocement jars that cannot be moved can be made to collect rainwater from the roof. These jars are frequently made locally and cost very little. The price is much less than for a reinforced concrete cistern. To collect enough water, use several jars placed near the roof. The downspout will have to be moved to fill the empty jar. Two or three jars can be made or bought for the cost of one small concrete cistern.

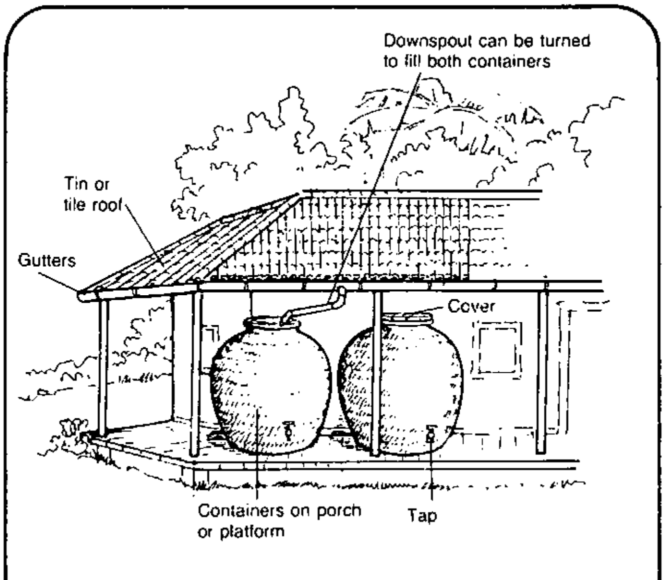


Figure 2. Large Water Storage Containers

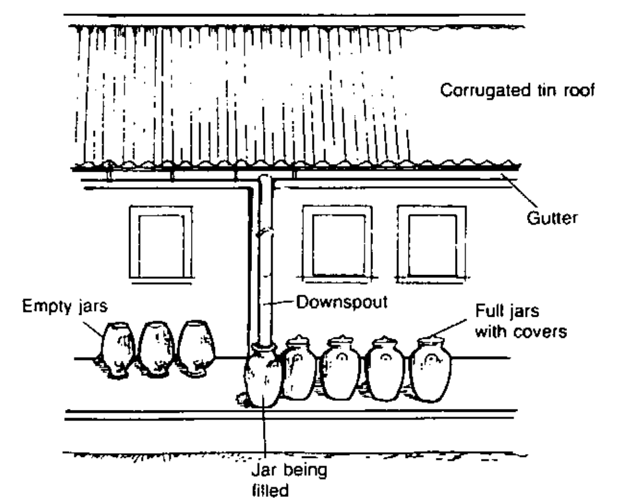


Figure 3. Small Clay Jars for Rainwater Collection

A similar technique is to use smaller, portable clay jars that can easily be moved under the downspout during a rainstorm. A family could have several 25-liter jars which can be filled during rainfalls. This system will work efficiently, but there will be little storage capacity for the dry months.

Ground Catchments

Ground catchments are areas prepared in a special way to collect rainfall for a water supply. The amount of water that can be collected will depend on the amount of rainfall, the area of the catchment, and the runoff characteristics of the surface. Ground catchments, if prepared properly, will provide more water than roof catchments since more surface area is used for collection. For this reason, they are more economical for a small community. If rainwater is the primary water source, a roof catchment on each roof in a community would be expensive and impractical. See Figure 4 for an example of a ground catchment.

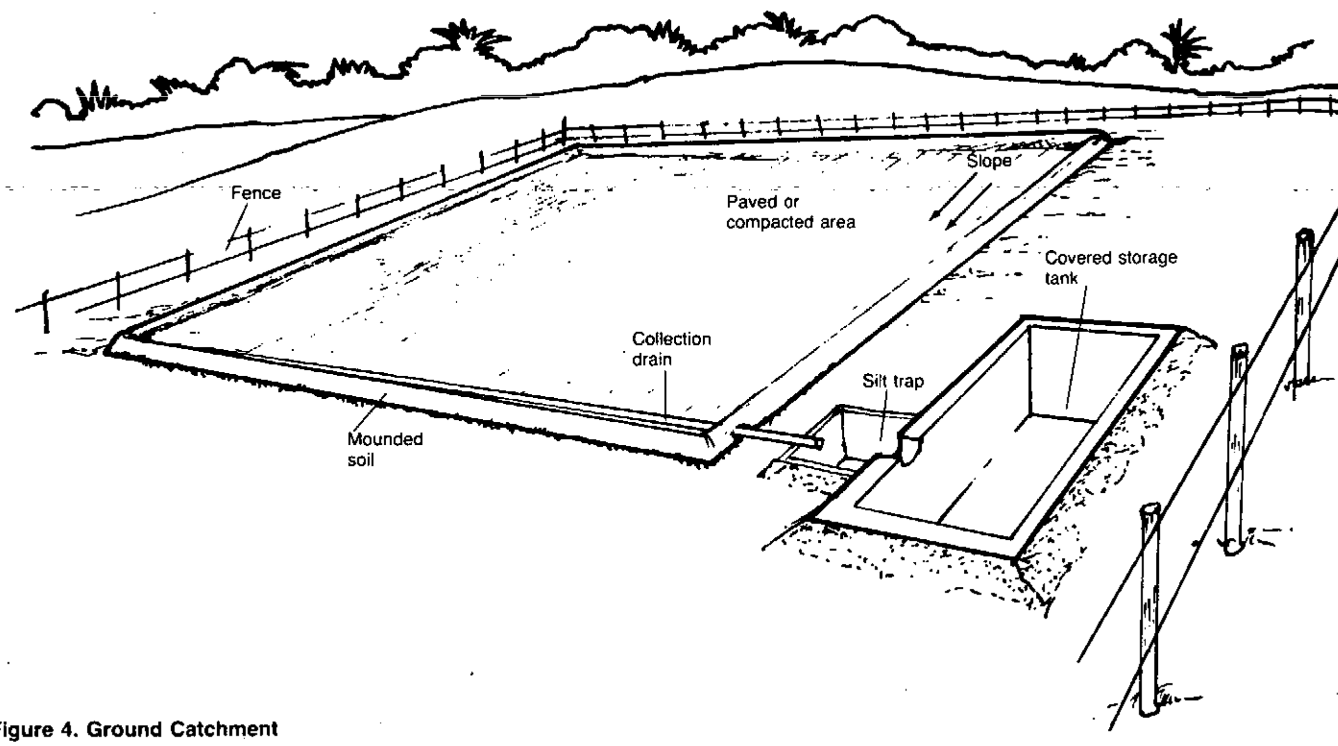


Figure 4. Ground Catchment

Materials. The ground catchment surface is very important in collecting rainwater efficiently. Catchment surfaces must be impervious to avoid water losses from infiltration and seepage. On pervious surfaces, much of the rain will be lost for community use. Part of it will wet the ground and part will be stored in small ground depressions; other water losses will occur through infiltration into the ground, evaporation into the air, and transpiration through plants.

One type of ground catchment is a surface that has been smoothed and cleaned of vegetation. Compacted clay soils make good catchment surfaces because the clay is relatively impervious and will need little or no treatment to seal soil pores. In areas where there is no impervious soil, various materials can be used to cover pervious ground surfaces to prevent water losses. Cement, asphalt or even polythene sheeting can be laid over the surface of the ground to prevent seepage and infiltration. The major problem is that the materials used to cover the ground surface are very expensive and may not be available in many rural areas. The need for storage in a cistern and for treatment adds to the total cost.

Chemical treatment of a catchment surface can help increase run-off by making the soil impervious. Sodium salts, which cause clay in soil to break down into small particles and seal soil pores, help make soil containing clay impervious so that run-off is increased. Tar or asphalt can also be used on catchment surfaces. These materials can be sprayed on the surface and effectively seal soil pores. hemical treatment is usually not very expensive and the surface generally lasts for four or five years. However, in many rural areas, the chemicals for ground treatment may not be available or may be expensive. In this case, a simple catchment of compacted earth would be the best alternative.

Water Availability. The amount of water available for use from ground catchments depends on the amount of annual rainfall and the area of the catchment. Because catchment areas are large, a lot of water can be collected from a small amount of rainfall. If the area of the catchment is large enough, the surface impervious, and the slope steep enough to ensure rapid run-off and minimum losses to evaporation and transpiration, the needs of a small community can be met with as little as 80mm of annual rainfall.

Evaporation, infiltration, seepage and transpiration will all affect the amount of water reaching the catchment area that is available for use. If the catchment surface is pervious or poorly constructed, little or no water will be collected. In a well-designed and maintained catchment, up to 90 percent of the water reaching it can be collected. The ground catchment can be at least as efficient as a roof catchment. However, if the ground is poorly prepared or inadequately covered, losses through infiltration will be high. Careful catchment preparation is necessary.

Consider a catchment area one-quarter hectare in area (50m x 50m) in a region with an annual rainfall of only 100mm. Also assume that the catchment efficiency is only 80 percent, the same as the roof catchment. Multiply the average rainfall (100mm) by the catchment area ($2500m^2$) by 80 percent to get the amount of water available in liters:

$100mm \times 2500m^2 \times .80 = 200000$ liters per year.

This would be 16660 liters per month or 555 liters per day. If consumption is 15 liters per person per day, this system would supply enough water for 37 people.

Storage. Water from the ground catchment must flow into a storage tank to be available to users. Storage tanks for ground catchments are generally located in the ground and the water must be pumped from the cistern to the users using either a hand or power pump. Because ground catchments are built in areas where rainfall is scarce, the storage tank must be large enough to take advantage of all available rainfall during a month and store it during dry periods. The larger the storage tank, the more costly it will be to build. The best storage tank will meet the needs of the users during both wet and dry seasons. For example, a storage tank 1.5m x 1.5m x 1.5m will hold 3375 liters. In the example above, the amount of water available is 16660 liters per month. A storage tank with a capacity of $17m^3$ would have to be constructed to hold this amount of water. A storage tank of this size would be very costly to build and would be impractical in many areas. Possibly a cistern with half that capacity, 9000 liters, would be more reasonable. In each case the size of the cistern depends on the amount of water which must be stored. The cistern should be only as large as necessary and as resources permit.

The type of ground catchment used depends on the availability of materials, on soil type and on the resources available in the community. Because ground catchment systems are generally expensive they are rarely used for individual families. They can be effective for several families or a small community. Although costly, ground catchments may be the best alternative for water supply in areas of little rainfall where groundwater and other surface water sources are inaccessible.

Summary

The two types of rainfall catchments will provide water in areas where it is uneconomical or unsafe to use other sources of water for drinking. Roof catchments are practical in areas where rainfall is abundant and fairly evenly distributed throughout the year. They have the following advantages:

- they can be used in most places;
- materials for catchments are readily available;
- their design is simple;
- they are relatively inexpensive to develop;
- they are efficient collectors of rainwater; and
- they are easy to maintain.

Ground catchments are more expensive than roof catchments because of material and labor costs. They should be considered in areas where rainfall is very scarce and other sources are not available. Ground catchments are best suited for providing water for several families or for small community supplies, rather than individual families. Design of ground catchments is more difficult and greater skill is needed for construction. Ground catchments do, however, have the following advantages:

- large quantities of water can be collected for a community supply;
- they provide large quantities of water with little rainfall;
- if properly designed, they are very efficient collectors.

Water for the World

Designing Roof Catchments
Technical Note No. RWS. 1.D.4

Roof catchments collect rainfall from a roof and channel it through a gutter into storage for use by individual households. The amount of water available for use depends on three factors: the amount of annual rainfall, the size of the catchment area and the capacity of the storage tank. This technical note discusses how to design a roof catchment to take advantage of the maximum amount of rainfall available.

Useful Definition

FOUL FLUSH - The first run-off from a roof after a rainfall.

The design process should result in the following two items which should be given to the person in charge of construction:

1. A list of all labor, materials and tools needed as shown in Table 1. This will help make sure that adequate quantities of materials are available so construction delays can be prevented.

2. A plan of the roof catchment system with all dimensions as shown in Figure 1.

Annual Rainfall

Find the annual rainfall rates for the region. This information should be available from the national geographical institute, the Ministry of Agriculture, a meterological institute or university, or an airport. The amount of annual rainfall is measured in millimeters per year.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers		
Supplies	Corrugated sheet metal, plastic or tiles (for roofing) Metal gutters, wood or bamboo (for gutters) Wire, rope or local fiber (to secure gutters to roof) Tar or caulk (to seal gutter connection to downpipe) Nails Wire screen		
Tools	Hammer Machete (to split bamboo) Wire cutters Saw Chisel		

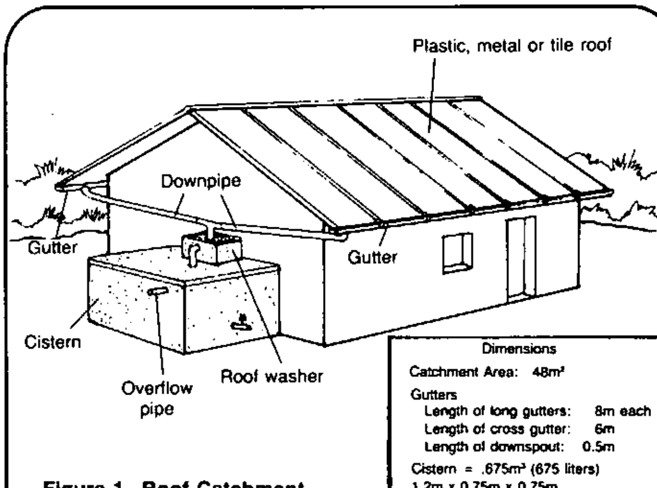


Figure 1. Roof Catchment

Catchment Areas

The roof of the house is the catchment area for the rainfall. To collect rainfall, the roof must be constructed of appropriate material, have sufficient surface area, and have adequate slope for water to run-off.

Corrugated galvanized steel or aluminum sheet metal, corrugated plastic or baked tile make the best catchment surfaces. Sheet metal is especially attractive because it is light-weight and requires little maintenance. Tiles also make excellent surfaces and are usually cheaper than sheet metal because they can be produced locally. The disadvantage of tile is the weight. A much stronger roof structure is needed to support tile. Tile roofs may even start to sag or leak after a time if structures are not strong enough.

To determine the amount of rainfall available for use as a water supply, it is necessary to know the area of the roof. Figure 2 shows how to determine the roof area available for water collection.

The effective roof area for collecting water is not the roof area itself but the ground area covered by the roof. In Figure 1, the effective water collecting area is $48m^2$ (8m x 6m = $48m^2$). The roof must slope as shown so that the water will flow into the gutter system installed to move the water to storage.

Using this information and the annual rainfall, it is easy to determine how much water will be available for use. Worksheet A shows how to make this calculation.

In the worksheet example, an average of 85 liters of water per day would be available to a family. For a family of six, each person would be able to use 14 liters per day. This is an average amount. During some months, more than 2560 liters will be available, while during the dry months, no rain may fall at all. A cistern will be needed to ensure adequate storage during the dry months.

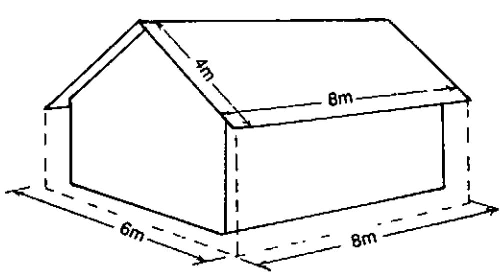


Figure 2. Roof Catchment Area

Worksheet A. Volume of Water Available from a Roof Catchment

Calculate the amount of water available from the catchment by following these steps and referring to Table 1. Figures used are the catchment size in Figure 2 and assumed rainfall of 800mm per year.

1. Multiply annual rainfall by the catchment area.

$\underline{48m^2}$ x $\underline{800mm}$ = $\underline{38400}$ liters/year.

2. Multiply this total by 80 percent. Not all water will be available because of losses due to evaporation and run-off that does not flow into the gutters. To be safe, figure a 20 percent loss for a rain catchment.

$\underline{38400}$ liters x .80 = $\underline{30720}$ liters/year.

3. Divide the total by 12 to get average monthly rainfall.

$\frac{30720 \text{ liters/year}}{12 \text{ months/year}} = \underline{2560}$ liters/month.

4. Divide again by 30 to determine liters per day.

$\frac{2560 \text{ liters/month}}{30 \text{ days/month}} = \underline{85}$ liters/day.

Gutters

Gutters must be installed on both sloping sides of the roof to collect all the run-off and channel it into the cistern. The gutters must be as long as the edge of the roof. Figure 1 shows a typical gutter design. There must also be a downpipe on a third side of the house so that water from both catchment surfaces is channeled to a single cistern. The design of gutters is quite simple and local materials can be used for them.

Metal gutters are the most durable and require the least maintenance, but are the most expensive. Gutters can be made of wood or bamboo. These materials are often available and inexpensive but will usually not last as long as metal because they will rot. Wood and bamboo gutters can be installed to overlap and can be tied together with wire, rope, or local fiber to avoid leakage. If wood is used, it should be hollowed out to form a channel. If bamboo is used, it must be split and the inside joint partitions removed. All gutters must have a small but uniform slope to prevent the formation of pools of water in the gutters. Still water can be a breeding place for mosquitoes.

A downpipe must be installed. The downpipe channels the water from the gutter into a cistern for storage. The joint where the downpipe and gutter connect must be sealed. If metal gutters are used, a connection can be sealed with a caulking compound. If bamboo is used, tar will prove the best material for sealing the connection.

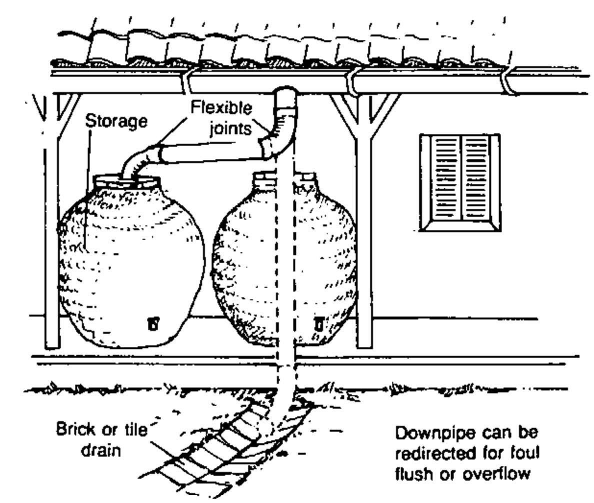


Figure 3. Flexible Downpipe

During periods of no rain, dust, dead leaves, and bird droppings will accumulate on the roof. These materials are washed off with the first rain and will enter the cistern and contaminate the water if some basic steps are not taken.

To prevent leaves and other debris from entering the downpipe, a coarse mesh screen should be placed in the gutter over the downpipe. The mesh will catch the large debris but let the water through. The screen must be cleaned periodically to prevent clogging.

A downpipe that can be moved manually away from the cistern can be installed to divert the first flow of water from the roof. An example appears in Figure 3. When the pipe is moved away from the cistern, water simply runs to waste. For this method to be effective, someone must be at the house to move the pipe.

Several other techniques are available for diverting the first roof run-off from the storage tank. In Figure 4, water from the gutters runs through the downpipe and into a small box built on top of the cistern. The first run-off is caught by this box.

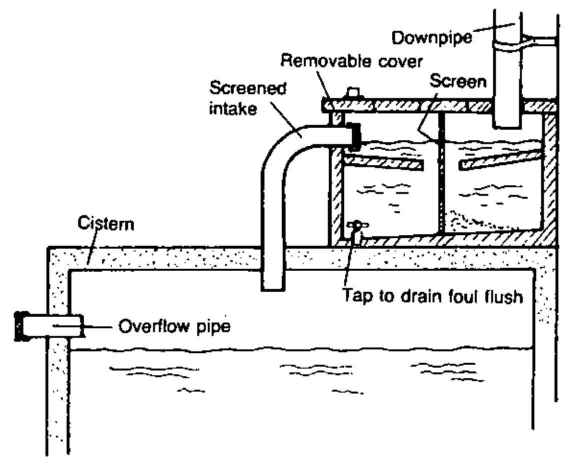


Figure 4. Foul Flush Box

When the box fills, water runs over the top of it into a channel that leads it to storage. A drain then empties the box of the dirty water. This small foul flush or first wash collection box can be made from concrete or from metal. It is most useful when permanent concrete cisterns are designed, because of the extra cost.

A small charcoal-sand filter box can also be installed as in Figure 5. As the rain water passes through the filter, sediment and debris are removed and clear water flows to storage. The advantage of this design and the box for the foul flush is that no one has to be present to divert the water flow from the roof.

Figure 6 offers another example of a useful and easily installed device for diversion of the foul flush. The downspout has two outlets. One runs to storage the other to waste. A lever on the outside is used to make water flow into one of the two channels. After the first wash flows to waste, the lever must be switched so that water runs into the cistern.

No matter which method is used to divert the first wash, the quality of water collected in the cistern must be checked. Water from roof catchments may need treatment before it can be consumed.

Cisterns

A cistern is an important part of a rainfall catchment system. There must be some type of cistern to collect and store rainwater. Several designs can be considered. The choice will depend on the amount of water needed, the amount of water available, rainfall distribution, cost, and availability of space. Basic design considerations and plans for household cisterns are shown in "Designing a Household Cistern," RWS.5.D.1, which should be used with this technical note to design an effective catchment system.

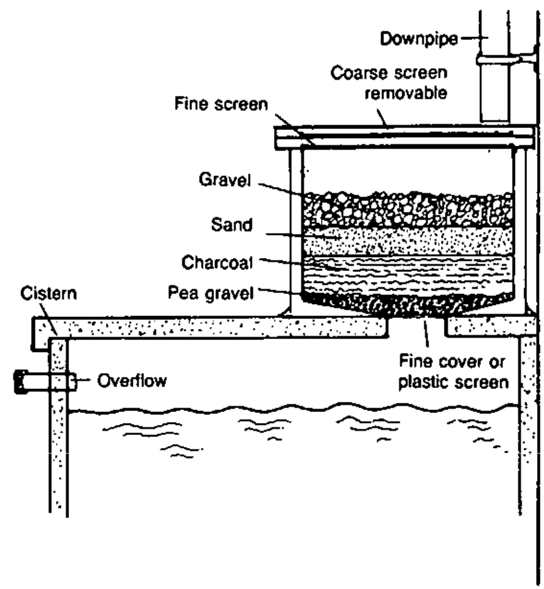


Figure 5. Filter System

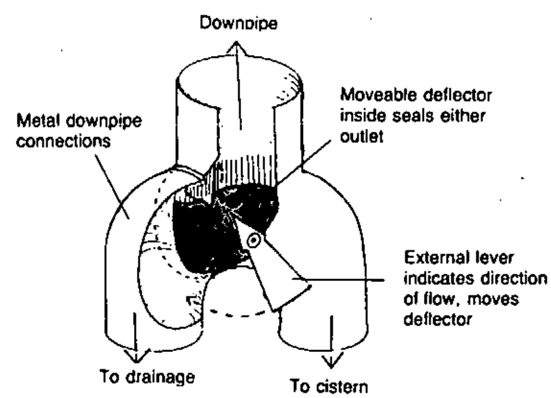


Figure 6. Roof Washer Device in Downpipe

Water for the World

Constructing, Operating and Maintaining Roof Catchments

Technical Note No. RWS. 1.C.4

The construction of a roof catchment in an individual home is not difficult and generally no special skilled labor is required. With the necessary tools and materials, a catchment system can be installed by a family at a modest cost. This technical note outlines the steps for installing roof catchments. Read the entire technical note before beginning the construction of the system.

Useful Definitions

CAULKING COMPOUND - A filler that seals cracks and seams and makes them watertight.

CISTERN - A storage tank for water.

FOUL FLUSH - The first run-off from a roof after a rainfall.

Before construction begins, the project designer should give you two items:

1. A list of all labor, materials and tools needed for construction similar to the sample list in Table 1.

2. A plan of the roof catchment system with all measurements as shown in Figure 1.

Obtain all materials needed for construction so delays can be prevented.

Construction of the cistern should begin at the same time as construction of the catchment system. For information about constructing cisterns, see "Constructing a Household Cistern," RWS.5.C.1.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	___ ___	___ ___
Supplies	Corrugated sheet metal, plastic or tiles (for roofing) Metal gutters, wood or bamboo (for gutters) Wire, rope or local fiber (to secure gutters to roof) Tar or caulk (to seal gutter connection to downpipe) Nails Wire screen	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___
Tools	Hammer Machete (to split bamboo) Wire cutters Saw Chisel	___ ___ ___ ___ ___	___ ___ ___ ___ ___

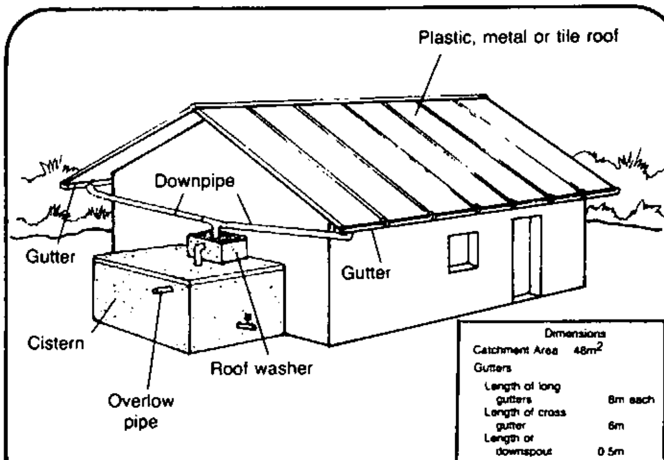


Figure 1. Roof Catchment

Installation

The installation process consists of three steps: construction of roof catchment structure, installation of gutters and connection of the downpipe to the cistern, and construction of a means to dispose of the foul flush.

Catchment Installation. For pre-existing houses, check the roof structure for strength. If the structure appears weak, it should be changed or reinforced. In new houses, or where an existing roof cannot be used, a completely new structure must be installed. The material used for roofing will determine the sizes and spacing of the rafters and cross-supports. Table 2 shows the dimensions of various types of roofing materials.

Table 2. Roofing Material Sizes

Materials	Width	Length
Galvanized steel roofing	0.6m	2.5-3.75m
Aluminum sheeting	0.9m or 1.2m	2.5-6.5m
Fiberglass sheeting	0.65m	2.5-3.75m
Tile	0.2m	0.4m

Place the roofing material on the structure starting from the bottom and working up. Tiles and sheets should overlap to prevent leaking. For tile roofs, cross-pieces should be placed close together so that all tiles have a firm base to rest on. For sheet metal or fiber glass roofs, use roofing nails to secure the sheets to the cross-pieces. If any leaking occurs through nail holes, seal them with a small amount of tar. See Figures 2 and 3 for examples of the installation of roofing materials.

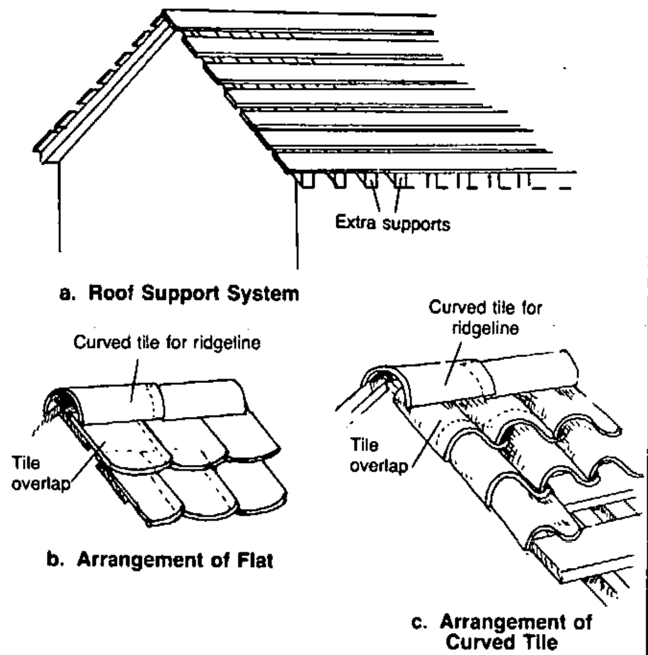


Figure 2. Tile Roofing for Catchment

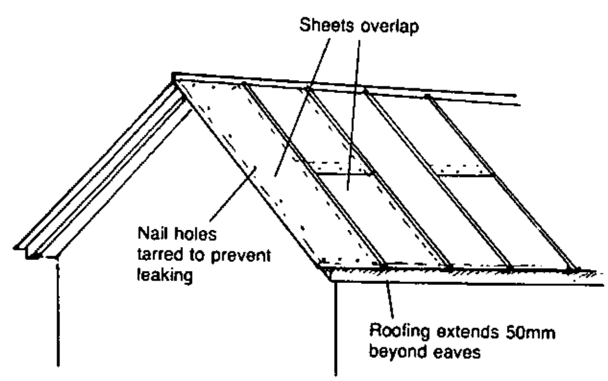


Figure 3. Metal Sheeting for Roof Catchment

Gutter Installation. Gutters must be installed to collect water from the roof surface. They can be made of metal, plastic, wood or bamboo.

Metal or plastic gutters must be bought, while wood or bamboo gutters can be made locally. If wood is used, it must be nailed into a trough and sealed with tar or a deep channel must be cut into the piece of wood to be used as a gutter. This channel must be deep enough to hold the collected water and prevent it from spilling out onto the ground. Bamboo gutters are made by splitting long lengths of bamboo down the middle and removing the inside joint partitions. The cut halves form very good collecting troughs, as shown in Figure 4. Follow these steps as you install the gutters.

1. Tie pieces of wire to the roof structure to support the gutters. The wires should be located 50cm apart to provide adequate support. Extra support should be given to wooden gutters because of their weight. Wrap the wire around the gutters to hold them in place.

2. Join the gutter sections together. Use specially made joints for metal and plastic gutters. There are several techniques for joining bamboo gutters. One simple method is to place a piece of rubber at the joint to hold the two pieces together. The rubber fits underneath the gutters and is secured to them with wire. Tar or caulking can then be used to seal the connection and make it watertight. Figure 5 illustrates this technique. Be sure that the two pieces of bamboo fit together closely before sealing the joint.

3. Begin installing the gutters on the side of the house opposite the cistern and install the downpipe on the third side. The gutter should slope enough so that all water flows from the roof to the downpipe. The required slope is 0.8-0.10m per meter of gutter. Another method of installation is to place the cistern on a side of the house where the roof peaks. Place gutters on both sides of the house sloping toward the cistern. Water runs from both gutters into a single downpipe. Gutter slope is very important since without enough slope, water will stand in the gutters. If the time between rains is more than eight to ten days, mosquitoes will breed in the standing water.

4. Install a downpipe from the gutter to the cistern. Connect the downpipe directly to the gutter. The downpipe can either be placed at the end of the gutter or a hole can be made in the gutter where the downpipe is connected. Seal the joint where the downpipe meets the gutter with tar or caulking compound.

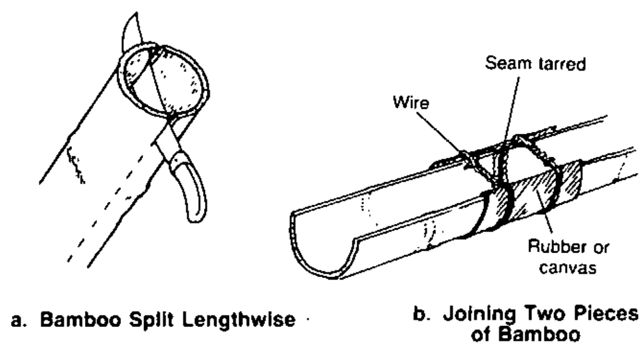


Figure 4. Making Gutters from Bamboo

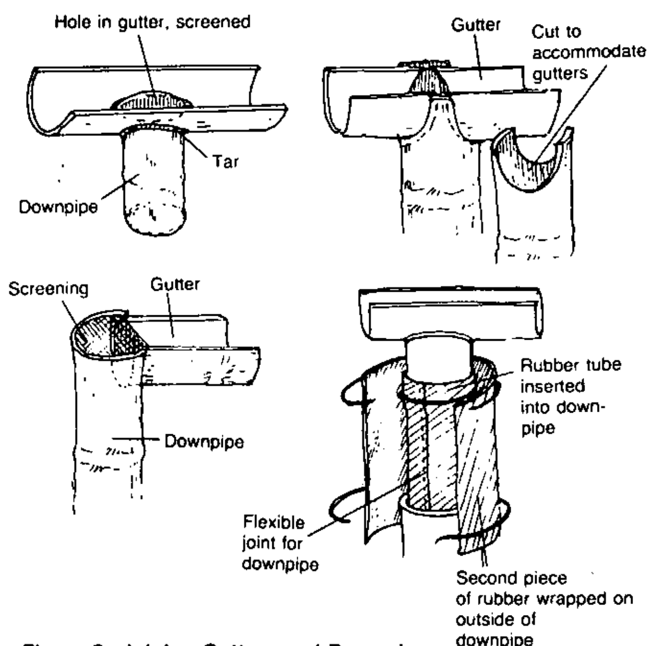


Figure 5. Joining Gutters and Downpipes

5. Place a small mesh wire screen over the opening of the downpipe so that leaves or other debris which could contaminate the water do not enter the cistern. The mesh should be large enough so that leaves and debris are caught but water continues to flow through.

Foul Flush Disposal. There are two ways to remove the foul flush or first wash from a roof. They are simple diversion and construction of a foul flush system.

For simple diversion, install a rope to the end of the downpipe. When the rain begins, the downpipe can be moved away from the cistern to let the dirty water flow to the ground. This method is useful when large jars are used for water storage. Someone must remember to move the spout at each rainfall. See Figure 6.

If the cistern and downpipe are connected, a small collection box can be built to collect the first run-off. See Figures 7 and 8 for details. The box can be as small as 250mm x 250mm x 250mm and should be made from impermeable material. Clean containers such as 20-liter cans can be used for receiving the first run-off from the roof. A filter system is made using a large can or filter box. Place a filter between the downpipe and the cistern. Line the filter bottom with pea gravel up to about 30mm, then place an equally thick layer of charcoal and on top of that a layer of sand 0.2-0.5mm in diameter. The sand layer should be between 30-50mm thick. On top of the sand place another layer of gravel as shown in Figure 9. Connect the downpipe to the box and connect an outlet pipe to the box and the cistern as shown. Place a screen at the very top of the box so that no large debris can enter. A tap or plug should be installed to empty out the dirty water after each rainfall. When the box fills, the cleaner water flows to the cistern.

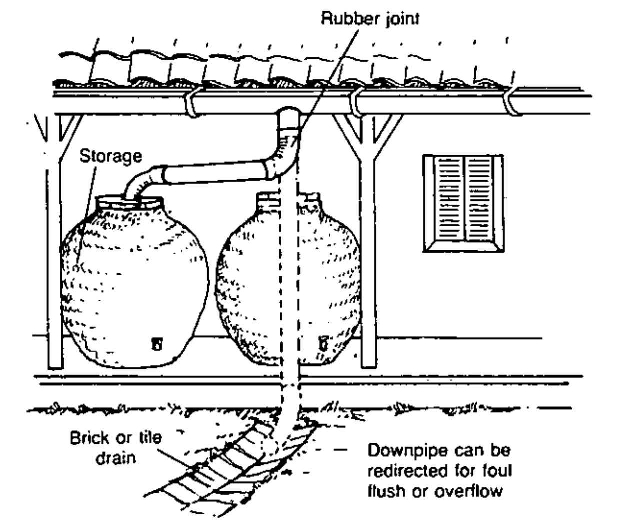


Figure 6. Flexible Joint in Downpipe

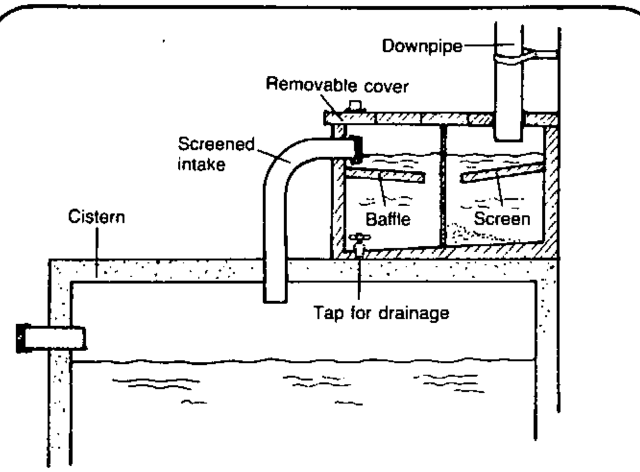


Figure 7. Collection Box for Foul Flush

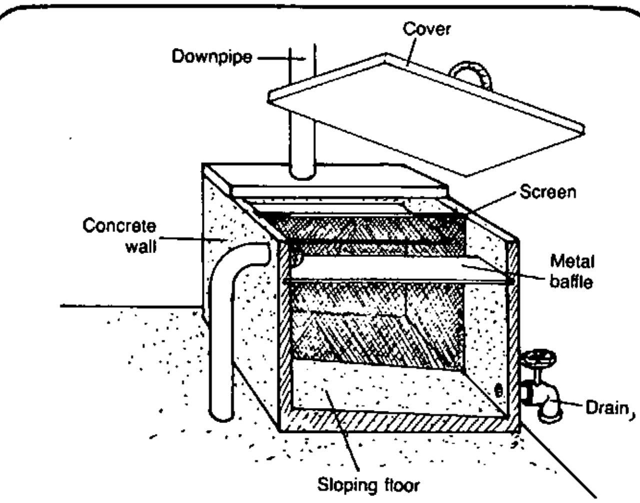


Figure 8. Detail of Collection Box for Foul Flush

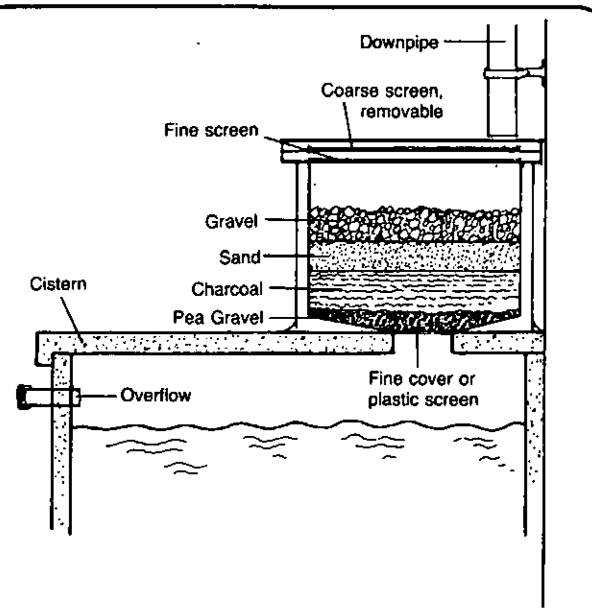


Figure 9. Filter System

Maintenance

Adequate maintenance of the catchment assures that the maximum amount of rainwater is collected and that the water is of good quality. Keep the catchment well maintained by doing the following:

1. Keep the roof in good condition. Repair any holes in the roofing material and change any broken tiles to prevent leaking. Seal any nail holes that are leaking.

2. Clean the roof between rains. Much debris and fecal matter from birds can be removed by sweeping off the roof often enough to keep it looking clean.

3. Keep the gutters in good condition. Be sure they are firmly tied to the roof and that they are well joined to prevent spilling. Repair ai holes. If bamboo or wood is used for gutters, check them once a year for rotting. If there is any sign of rot, replace them.

4. Remove leaves and other debris from the gutters to avoid clogging. Check the screen on the downpipe to be sure it is not clogged. If a gutter clogs, water may spill over its sides and be wasted. Watch for leaks and overflow during a rain. See Figure 10.

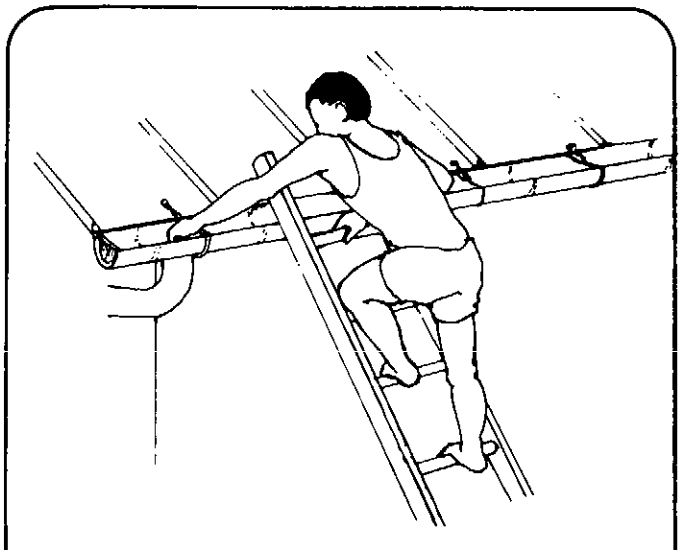


Figure 10. Cleaning Gutter and Screen

5. If a collection box for foul flush is used, clean it out after each heavy rain to remove any sediment or scum.

6. If a filter is used, clean the filter every several months. Wash and change the sand in the filter at least every six months.

Notes

Water for the World

Designing Hand Dug Wells
Technical Note No. RWS. 2.D.1

Proper design of hand dug wells is important to asure a year-round supply of water and to assure efficient use of personnel and materials. Designing involves determining the size and shape of the well; the method of lining the shaft; the type of intake; and the necessary personnel, materials, equipment, and tools. The products of the design process are drawings of the shaft and lining and a detailed materials list. These, along with a location map similar to Figure 1 ("Selecting a Well Site," RWS.2.P.3), should be given to the construction foreman before construction begins.

There are several good methods of designing and constructing hand dug wells; if you are familiar with a specific method, use it. This technical note describes one method of designing hand dug wells and arriving at the essential end-products. Read the entire technical note before beginning the design process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

KIBBLE - A large bucket for lifting materials when sinking a shaft; also called a hoppit or sinking bucket.

POROUS - Having tiny pores or spaces which can store water or allow water to pass through.

WATER TABLE - The top, or upper limit, of an aquifer.

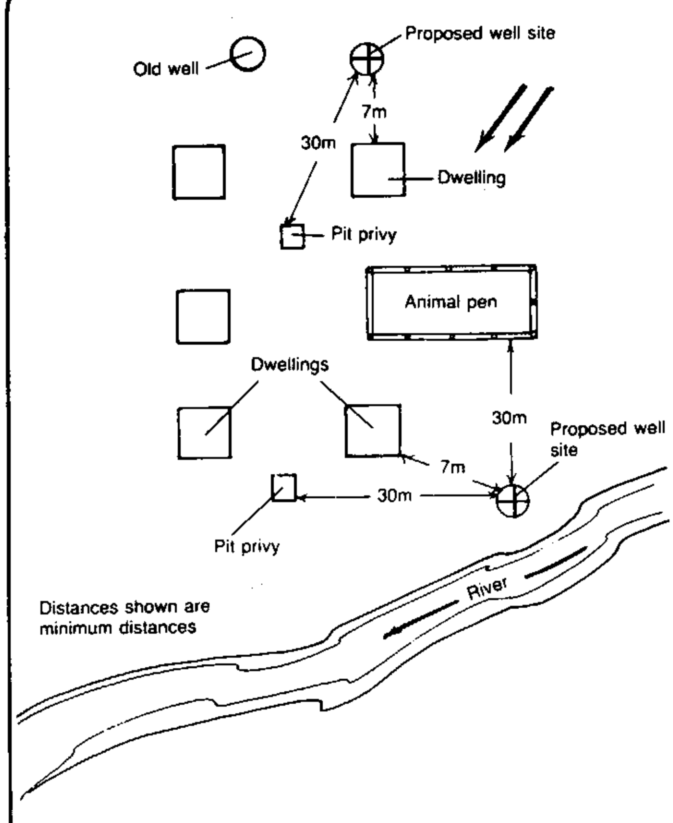


Figure 1. Location Map

Size and Shape

When viewed from the top, wells can be any shape but most of them are round. This is because a round well produces the greatest amount of water for the least amount of excavation, and a round lining is stronger than any other shape.

The size of the well refers to its depth and diameter. Although it is impossible to know the depth of a well before it is dug, an attempt should be made to estimate it. This will allow you to roughly calculate the quantities of materials needed for construction. Use information from test holes or existing wells in the area to estimate the depth of the water table.

For practical and economic reasons, well diameters are between 1.0m and 1.5m. The smaller diameter results in a savings in materials costs, and it requires less soil to be excavated. The larger diameter means a higher materials cost, but a more efficient work output, since two men rather than one can dig the shaft. A larger diameter provides a greater storage capacity and allows more water to enter the well. If pre-made forms or precast concrete rings are used, their size will determine the diameter of the well.

When the depth and diameter of the well shaft have been determined, write the dimensions on a design drawing similar to Figure 2.

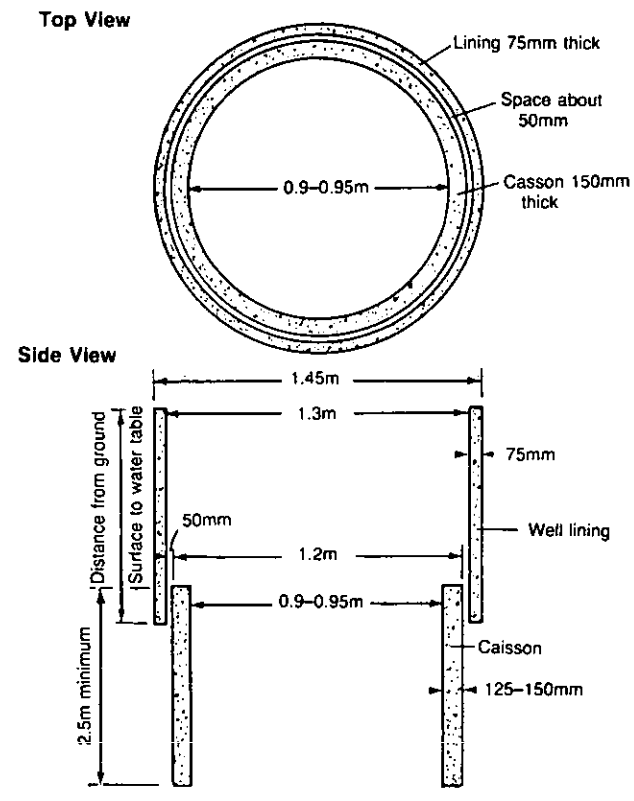


Figure 2. Design of Well Lining and Caisson

Lining the Shaft

Although various materials have been used to line well shafts, concrete is the best and most common lining. It is strong, long-lasting, and widely known.

The two basic methods of lining well shafts are dig-and-line and sink lining or caissoning. In dig-and-line, a portion of the shaft is excavated, shutters are set in place in the shaft, and concrete is poured behind the shutters. When the concrete hardens, the shutters are removed and the next portion of the shaft is excavated.

In sink lining, concrete rings called caissons are cast and cured in special molds at the surface. The rings are stacked on top of each other and attached together with bolts. As soil is excavated from beneath the rings, they sink into the earth and line the shaft.

Often, both methods are employed in a single well: dig-and-line is used until the water table is reached, then caissoning is used to sink the well into the aquifer. The lining is usually 75mm thick and the caisson rings are 125-150mm thick. The outside diameter of the rings is 50-100mm less than the inside diameter of the lining to allow the rings to freely move downward. Table 1 shows common dimensions of shaft, lining, and rings.

Write the dimensions that you determine are best for your well on the design drawing similar to Figure 2.

Intake

The caisson rings are sunk into the aquifer as far as possible; that is, until the water becomes too deep to

Table 1. Dimensions of Shaft, Lining and Caisson Rings

Feature	Dimension
Shaft diameter	1.45m
Lining, outside diameter	1.45m
Lining, inside diameter	1.30m
Lining, thickness	75mm
Caisson, outside diameter	1.20m
Caisson, inside diameter	0.90-0.95m
Caisson, thickness	125-150mm
Caisson, height	0.50m

continue the excavation. Ground water may then enter the well either (1) through the opening under the lowest caisson ring, or (2) through the rings themselves. In the first case, the rings are made of standard concrete which does not allow entry of water. In the second case, the rings are usually made of porous concrete which allows water to pass through. Another way to allow water to enter through the caisson rings is to build the rings from standard concrete and perforate them with seepage holes. For all types of intakes, the bottom of the shaft should be covered with a porous base plug made from porous concrete or layers of sand and gravel. The plug prevents aquifer material from rising into the well.

The type of caisson ring used depends on the nature of the aquifer. Normally, rings are made of porous concrete. However, if the aquifer is composed of fine sand, which would clog the pores or flow through the seepage holes, the rings should be made of standard concrete without perforations. It may not be possible to know which type of intake is needed until the aquifer is reached. But an attempt should be made to anticipate the necessary intake, based on test holes or other wells in the area.

When the type of intake has been determined, indicate it on the design drawing similar to Figure 2.

Personnel

The most important person involved with well construction is the foreman. He should have some experience. He must oversee all phases of construction, including excavating and lining the shaft, mixing concrete for the lining and caissons, and lowering the caissons into place. It is his responsibility to see that construction proceeds in a safe manner.

At least four workers are needed. One should have some experience with well digging and one should have experience with concrete construction. The workers must be reliable because the construction process may take several weeks or more.

Materials

The materials needed to line a hand dug well are concrete mix and reinforcing steel.

One common mix of concrete is one part cement to two parts sand to four parts gravel by volume and enough water to make a workable mix. The cement should be Portland cement, and it should be dry and free from hard lumps. Sand should be clean, and sized fine to 6mm. If porous concrete is used for the caisson rings, omit the sand. Gravel should be clean and sized 6-36mm (10-20mm for porous concrete). Water should be clean and clear.

Two sizes of reinforcing steel, called re-rods, are generally used: 8mm diameter for the lining and 15mm diameter for the caissons. The quantities of these materials needed can be roughly estimated.

For each meter of depth of the lining:

gravel = $0.5m^3$
sand = $0.25m^3$
cement = $0.125m^3$ (or about 190kg, assuming $0.00066m^3$ = 1.0kg)
8mm re-rod = 33m

For each meter of caisson rings:

gravel = $1.0m^3$ ($1.4m^3$ for porous concrete)
sand = $0.5m^3$ (none for porous concrete)
cement = $0.25m^3$ ($0.35m^3$ for porous concrete)
15mm re-rod = 4m

For example, suppose the estimated depth of the shaft and lining is 15m, the height of the caisson rings is 3m, and the rings are to be made from porous concrete. The quantities would be estimated in the following way.

For the lining:

gravel = $0.5m^3 \times 15 = 7.50m^3$
sand = $0.25m^3 \times 15 = 3.75m^3$
cement = $0.125m^3 \times 15 = 1.88m^3 = \dfrac{1.88m^3}{0.00066m^3/kg} = 2850kg$
8mm re-rod = 33m x 15 = 495m

For the porous concrete caissons:

gravel = $1.4m^3 \times 3 = 4.20m^3$
sand = none
cement = $0.35m^3 \times 3 = 1.05m^3 = \dfrac{1.05m^3}{0.00066m^3/kg} = 1590kg$
15mm re-rod = 4m x 3 = 12m

The total quantity of cement needed for the lining and the caisson rings = 2850kg + 1590kg = 4440kg. Cement is often packaged in 50kg sacks, so the number of sacks needed = $\dfrac{4440}{50}$ = 88.8 or 89 sacks. Worksheet A shows a further example of how to estimate quantities of materials needed for a hand dug well.

Other materials needed are those used to build a storage shed. Use locally available materials and traditional construction methods.

Equipment

The main piece of equipment needed is a headframe capable of lowering workers and caissons into the shaft and hoisting up excavated soil. The headframe must be able to support weights in excess of 350kg, the approximate weight of a concrete caisson. It should have a winch, a main pulley, and an auxiliary pulley.

At least three ropes are needed: one for lowering caissons, tensile strength of rope about $7kg/cm^2$, one for lowering and raising full kibbles and concrete buckets, and one for suspending trimming rods.

A heavy-duty stretcher with a U-bolt in the center is needed to lower caissons.

Steel shutters are needed to form the lining. For caissons, you will need steel molds and templates to position the re-rods.

Two kibbles are needed to hoist up water and excavated soil. The kibbles should be watertight and made of steel, with a safety latch on the handle to prevent them from tipping. They should be wider around the middle than around either end to prevent them from catching on any projections within the shaft.

Other equipment needed includes concrete buckets, a bosun's chair, top plumbing rod, long and short trimming rods, and hard hats.

Tools

The workers need tools for measuring, plumbing, excavating, and trimming the shaft; mixing, pouring, and finishing concrete; and positioning and securing re-rods. When you have determined all necessary personnel, materials, equipment, and tools, prepare a materials list similar to Table 2 and give it to the construction foreman. Give the construction foreman design drawings of the well, a detailed materials list, and a location map.

Worksheet A. Estimating Quantities of Materials for Hand Dug Wells

For the Lining:

1. Estimated depth of shaft = 15 m
2. Gravel = $0.50m^3$ x Line 1 = $0.50m^3$ x 15 = 7.50 m^3
3. Sand = $0.25m^3$ x Line 1 = $0.25m^3$ x 15 = 3.75 m^3
4. Cement (m^3) = $0.125m^3$ x Line 1 = $0.125m^3$ x 15 = 1.88 m^3
5. Cement (kg) = $\frac{\text{Line 4}}{0.00066m^3/kg}$ = $\frac{(1.88\ m^3)}{0.00066m^3/kg}$ = 2850 kg
6. 8mm re-rod = 33m x Line 1 = 33m x 15 = 495 m

For the Caisson Rings:

Type of concrete (check one): ☐ standard ☒ porous

Standard Concrete

7. Height of caisson rings = 3 m
8. Gravel = $1.0m^3$ x Line 7 = $1.0m^3$ x _____ = _____ m^3
9. Sand = $0.50m^3$ x Line 7 = $0.50m^3$ x _____ = _____ m^3
10. Cement (m^3) = $0.25m^3$ x Line 7 = $0.25m^3$ x _____ = _____ m^3
11. Cement (kg) = $\frac{\text{Line 10}}{0.00066m^3/kg}$ = $\frac{(\_\_\_\_\ m^3)}{0.00066m^3/kg}$ = _____ kg
12. 15mm re-rod = 4m x Line 7 = 4m x 3 = 12 m

Porous Concrete

13. Gravel = $1.40m^3$ x Line 7 = $1.40m^3$ x 3 = 4.20 m^3
14. Sand = none
15. Cement (m^3) = $0.35m^3$ x Line 7 = $0.35m^3$ x 3 = 1.05 m^3
16. Cement (kg) = $\frac{\text{Line 15}}{0.00066m^3/kg}$ = $\frac{(1.05\ m)}{0.00066m^3/kg}$ = 1590 kg

Total Amount of Cement for Lining and Caisson =

Line 5 + Line 11 + Line 16 = 2850 kg + – kg + 1590 kg = 4440 kg

Table 2. Sample Materials List

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	_____
	Worker, skilled in sinking well	1	_____
	Worker, experienced with concrete	1	_____
	Workers, unskilled	2-4	_____
Supplies	Cement (Portland)	_____kg	_____
	Sand (clean; fine to 6mm)	_____m^3	_____
	Gravel (clean; 6-36mm)	_____m^3	_____
	Water (clean and clear)	_____	_____
	Re-rod for lining: 8mm diameter	_____m	_____
	Re-rod for caissons: 15mm diameter	_____m	_____
	Materials for storage shed	_____	_____
Equipment	Headframe	_____	_____
	Rope for caissons; 100m x 12mm diameter, steel wire with fiber core tensil strength 7kg/cm^2	_____	_____
	Rope for kibbles: 100 x 6mm diameter	_____	_____
	Rope for trimming rods: 100m x 3mm diameter	_____	_____
	Steel shutters (1.30m diameter x 0.5m high) with wedges and bolts	_____	_____
	Steel shutters (1.30m diameter x 1.0m high) with wedges and bolts	_____	_____
	Steel molds for caisson rings (1.20m outside diameter, 0.95m inside diameter, 0.5m high)	_____	_____
	Templates for molds	_____	_____
	Stretcher for caissons	_____	_____

Total Estimated Cost = _____

Water for the World

Constructing Hand Dug Wells
Technical Note No. RWS. 2.C.1

Proper construction of a hand dug well is important to ensure a year-round supply of water and to protect the water from contamination. Construction involves assembling all necessary personnel, materials, and tools; preparing the site; excavating the well shaft; and lining the shaft. Finishing the well is discussed in "Finishing Wells," RWS.2.C.8.

There are several good methods to construct a hand dug well; if you are familiar with a specific method, use it. This technical note describes one method of construction, using locally available materials, that has been employed successfully in a number of countries. Read the entire technical note before beginning construction.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria.

GROUND WATER - Water stored below the ground's surface.

KIBBLE - A large bucket for lifting materials when sinking a shaft; also called a hoppit or sinking bucket.

POROUS - Having tiny pores, or spaces which can store water or allow water to pass through.

WATER TABLE - The top, or upper limit, of an aquifer.

Materials Needed

The project designer must provide three papers before construction can begin:

1. A location map similar to Figure 1.

2. A design drawing similar to Figure 2.

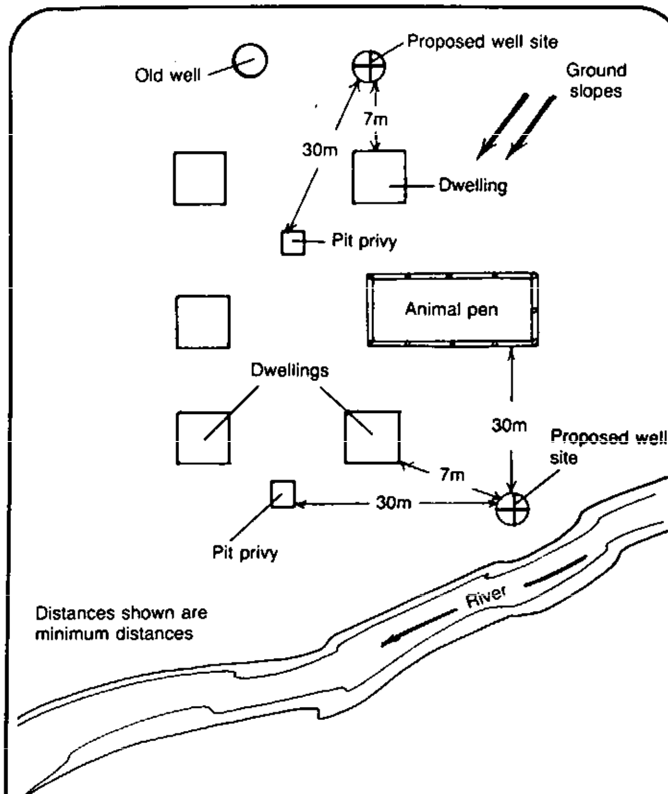


Figure 1. Location Map

3. A materials list similar to Table 1.

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary workers, supplies, and tools.

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when specific workers, materials, and tools must be available during the construction process. Draw up a work plan similar to Table 2 showing construction steps.

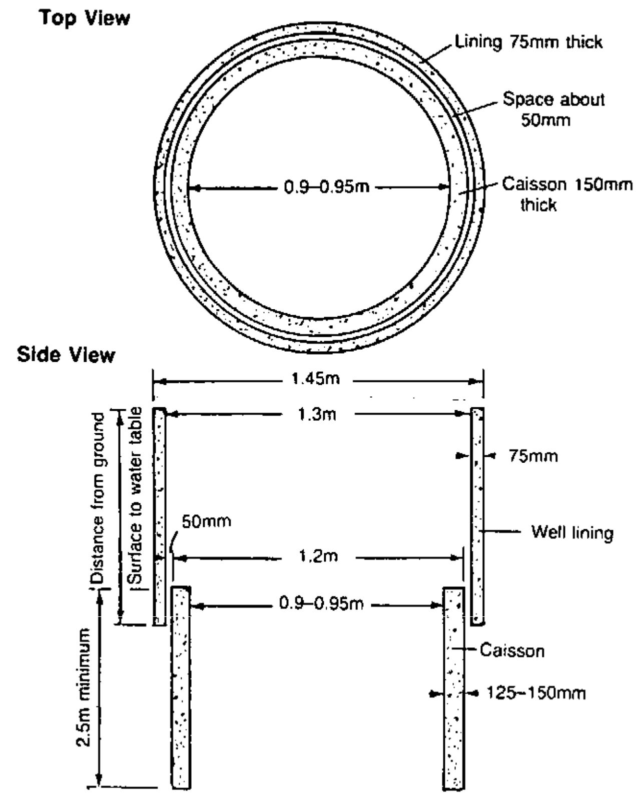


Figure 2. Design of Well Lining and Caisson

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	____
	Worker, skilled in sinking well	1	____
	Worker, experienced with concrete	1	____
	Workers, unskilled	2-4	____
Supplies	Cement (Portland)	____kg	____
	Sand (clean; fine to 6mm)	____m^3	____
	Gravel (clean; 6-36mm)	____m^3	____
	Water (clean and clear)	____	____
	Re-rod for lining: 8mm diameter	____m	____
	Re-rod for caissons: 15mm diameter	____m	____
	Materials for storage shed	____	____
Equipment	Headframe	____	____
	Rope for caissons; 100m x 12mm diameter, steel wire with fiber core, tensil strength 7kg/cm^2	____	____
	Rope for kibbles: 100 x 6mm diameter	____	____
	Rope for trimming rods: 100m x 3mm diameter	____	____
	Steel shutters (1.3m diameter x 0.5m high) with wedges and bolts	____	____
	Steel shutters (1.3m diameter x 1.0m high) with wedges and bolts	____	____
	Steel molds for caisson rings (1.2m outside diameter, 0.95m inside diameter, 0.5m high)	____	____
	Templates for molds	____	____
	Stretcher for caissons	____	____

Total Estimated Cost = ____

Table 2. Sample Work Plan for a Hand Dug Well

Time Estimate	Day	Task	Personnel	Materials/Tools
1 day	1	Locate and prepare well site; assemble materials	Foreman (present during entire construction); 2-4 workers	Measuring tape; drawings; tools and materials for building shed
1 day	2	Erect headframe; set center point and offset pegs; build mixing slab	2-4 workers	Headframe; plumb bob; re-rod; cement, sand, gravel, water; trowel
4 hours	3	Dig shallow excavation; install temporary lining	2-4 workers	Shovels; shutters (1.3m diameter, 1.0m high) spirit level
7 days	3-9	Excavate and trim first lift	4 workers	Shovels; picks; mattock; kibble; top plumbing rod; trimming rods
2 hours	10	Install first set of shutters	4 workers	Shutters (1.3m diameter, 0.5m high); spirit level; trimming rods; shovel
6 hours	10	Install vertical and horizontal re-rods	4 workers	Lengths of re-rod; binding wire; spacing blocks and holding hooks; wire cutters
1 day	11	Install second set of shutters; pour concrete; build curb	4 workers	Oiled shutters (1.3m diameter, 1.0m high); cement, sand, gravel, water; tamping rod; re-rod; burlap covering; mattock
1 day	12	Install third and fourth sets of shutters; pour concrete	4 workers	Sets of oiled shutters; cement, sand, gravel, water
2 days	13-14	Widen top of well; add re-rods; install fifth and sixth sets of shutters; pour concrete; bend back rods and cover with layer of weak mortar	4 workers	Burlap covering; mattock; re-rod; binding wire; sets of oiled shutters; cement, sand, gravel, water
---	---	Construct second and third lifts and lining as needed	4 workers	Materials and tools as needed
1 day	15	Build caisson rings	4 workers	Molds; re-rods; oiled pipes; templates; cement; sand (none if porous concrete), gravel, water
10 days	16-25	Cure caisson rings	----	Wet burlap or straw
2 days	26-27	Install caisson rings	4 workers	Stretcher; spacers; heavy planks; wrench; mortar; trowel
2 days	28-29	Sink caissons into aquifer	4 workers	Shovels, kibble
2 hours	30	Install base plug	4 workers	Precast base plug

Caution!

1. Workers in the well shaft should wear hard hats for protection.

2. Workers at ground level must be careful not to accidentally drop or kick tools or other materials into the well shaft.

3. A kibble, rather than a bucket or basket, should be used to hoist soil out of the shaft.

4. The well must be dug at the exact location specified by the project designer.

Construction Steps

1. Using the location map and a measuring tape, locate the well site. Clear the area of any vegetation or debris that might interfere with work.

2. Assemble all laborers, materials, and tools needed to begin construction and arrange the materials in a fashion similar to Figure 3. A proper layout will save time and effort during later construction steps. A shelter should be built to protect tools and some materials from the weather, theft, or being misplaced.

Because the caisson rings must be cured for at least 10 days before they can be lowered into the well shaft, build them first even though they will not be needed until later in the construction process. See step #26.

3. Erect the headframe over the site of the well. The headframe must be sturdy enough to support the caisson rings, which may weigh over 350kg. One type of headframe that has been used successfully is shown in Figure 4. It is made of angle iron and equipped with a winch and brake. The four feet of the headframe must rest on solid ground--place stone slabs or pour concrete under them if necessary. It is important that the headframe not be moved once it is in position and the center point of the well has been fixed.

4. Build a slab for mixing concrete by first leveling an area about two meters square. Spread 50mm of well-tamped gravel, cover with a layer of cement mortar (4 parts sand to 1 part cement), and smooth with a trowel. Form a lip around the outer edge, cover the slab with wet burlap or straw, and keep moist for two or three days.

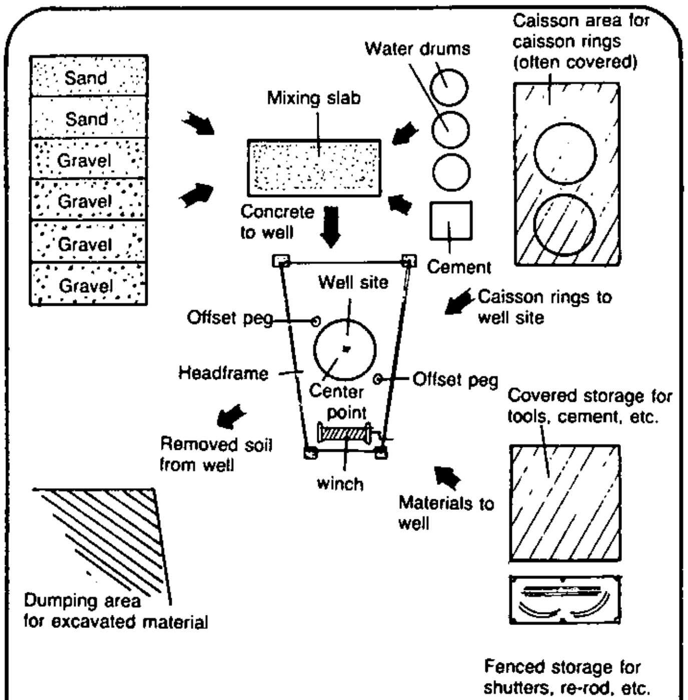


Figure 3. Layout of Well Site

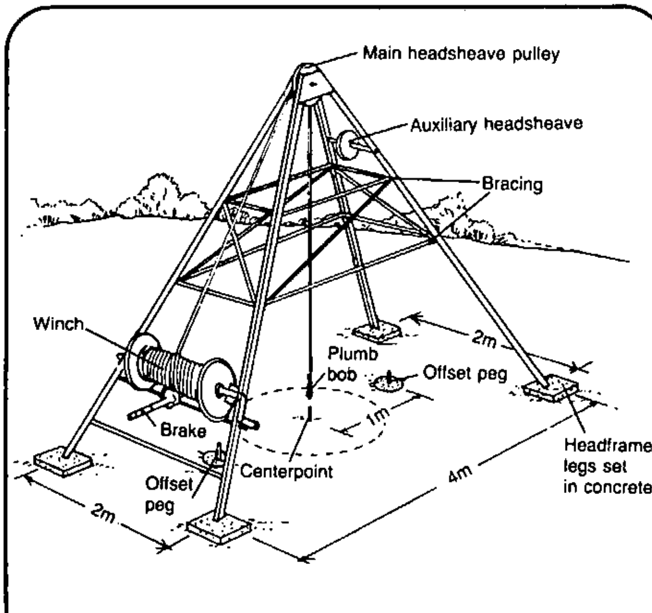


Figure 4. Headframe

5. Establish the center point of the well by lowering a plumb bob from the headsheave pulley on the side opposite the winch; that is, the side from which the main hoisting rope will descend. Mark this point on the ground with a short length of re-rod. Set offset pegs on opposite sides and exactly 1.0m from the center point. Make the top of these pegs at least 150mm above ground level to make allowance for the temporary lining that will be installed. These pegs should be set in concrete and positioned so that the top plumbing rod will fit over them as in Figure 4. Allow the concrete to set for several days before using the pegs.

6. Mark a circle of 650mm radius around the center point. Carefully excavate within this circle to a depth of 0.9m. Position a set of steel shutters 1.3m in diameter and 1.0m high inside this hole with 100mm projecting above ground to act as a temporary lining. See Figure 5. Be certain that the shutters are exactly in place and that the top is level. Firmly tamp soil around the outside. These shutters will prevent the top of the shaft from crumbling, and they will reduce the risk of tools or materials being accidentally kicked into the shaft.

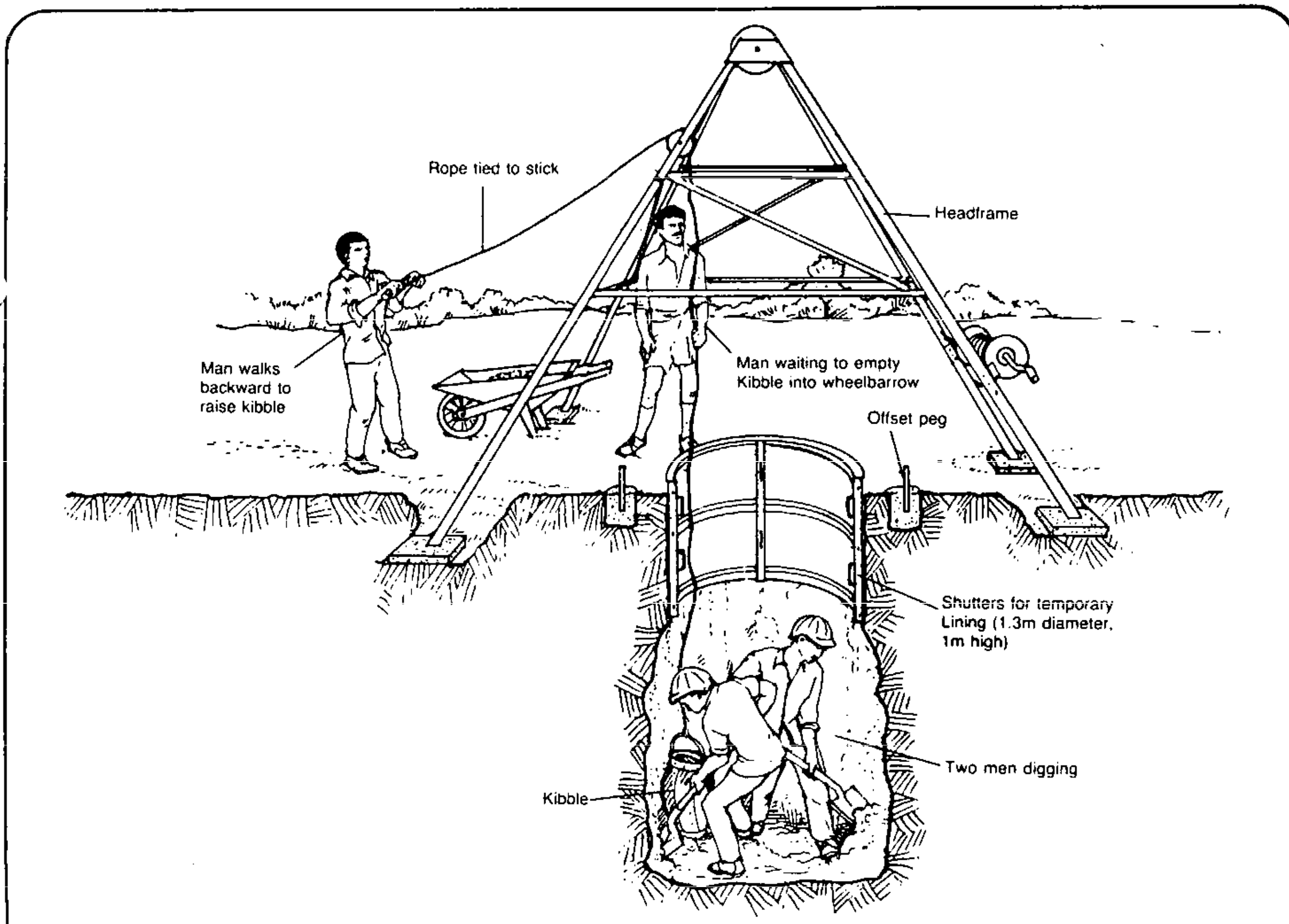


Figure 5. Excavating the Shaft

7. Begin excavating the first lift of the well. Normally, two workers using miner's picks and bars and short-handled shovels excavate the soil in layers about 100mm deep, and they keep the bottom of the excavation fairly level at all times. Soil is removed by hoisting it up in a kibble, as shown in Figure 5. The shaft is dug somewhat less than its finished diameter of 1.45m.

Every meter or so the long trimming rods, 1.45m long, are suspended from the top plumbing rod. The workers carefully trim the walls of the shaft so that the trimming rods can freely turn with their ends just missing the shaft walls, as shown in Figure 6. It is important that the trimming be done with extreme care, for even a small addition to the thickness of the lining will increase the amount of concrete used.

Depending on the condition of the soil, the first lift can be dug as deep as 5.0m, 4.1m below the bottom of the temporary lining. If the soil is crumbly or tends to cave in, the lift must be shallower. If water is struck, stop the excavation and proceed to step 25.

8. A set of shutters, 1.3m in diameter and 0.5m high, is oiled and then lowered to the bottom of the shaft. Set the shutters precisely in place by suspending the short trimming rods 1.3m long and lining up the edges of the shutters directly beneath the ends of the rods. Use a spirit level to be certain that the shutters are level. It is essential that these shutters be exactly in place and perfectly level, or else the entire lining will be out of line. See Figure 7.

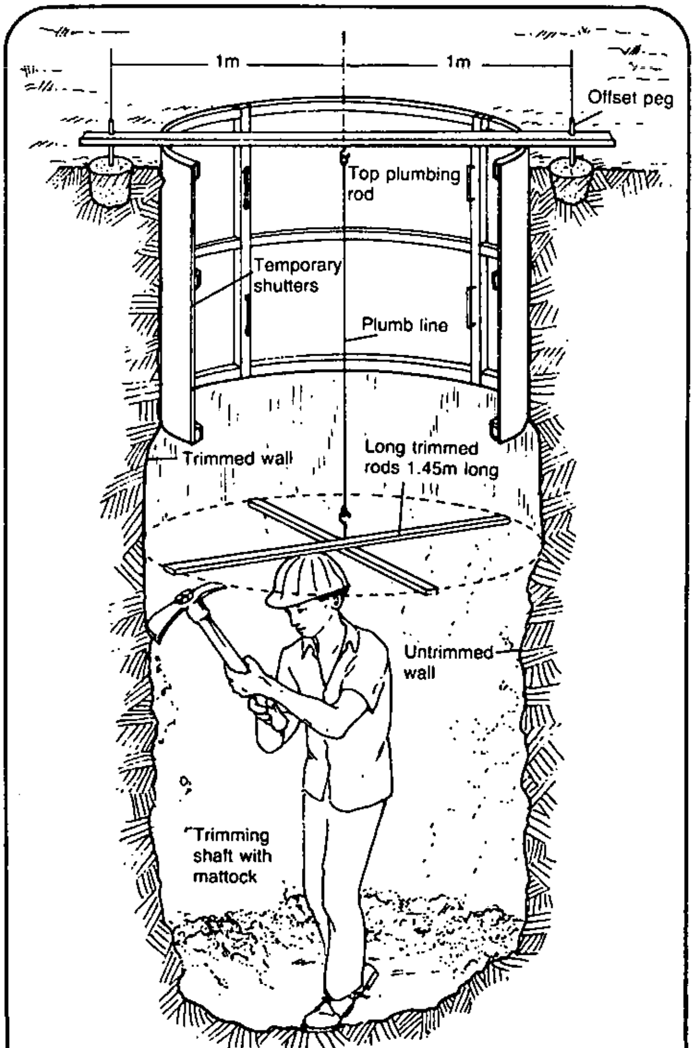


Figure 6. Trimming the Shaft

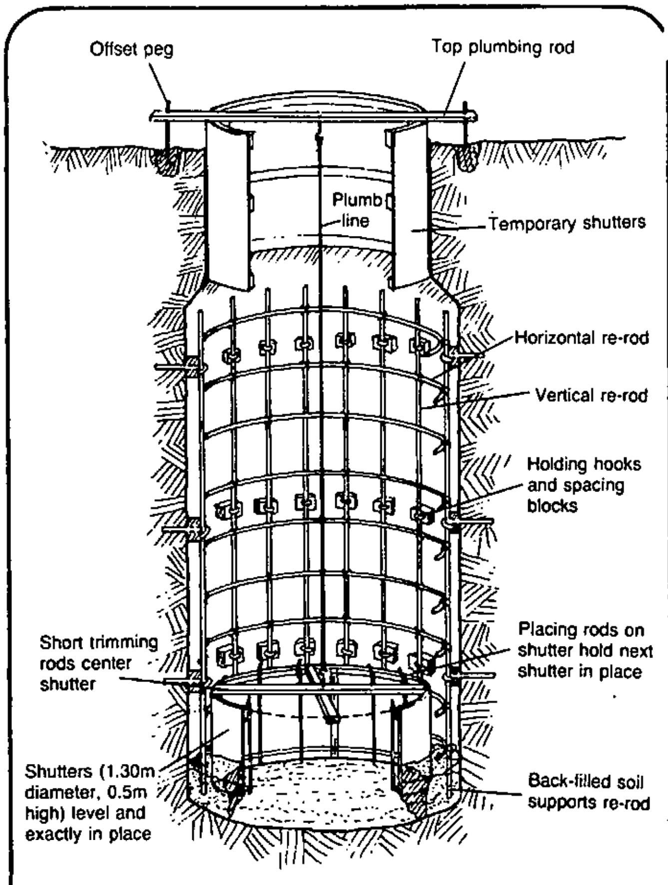


Figure 7. First Set of Shutters and Re-rod

9. Position 20 lengths of vertical re-rod, each length 4.0m long and 8mm in diameter, behind the shutters and around the shaft walls. Fix the rods to the walls about 200mm apart using spacing blocks and holding hooks. Backfill behind the shutters with soil to help hold the rods in place, as shown in Figure 7.

10. On the surface, shape horizontal re-rods into circles 1.38m in diameter. You will need three or four horizontal re-rods for each meter of depth. Lower the re-rods and fasten them to the inside of the vertical re-rods about 250-300mm apart, as shown in Figure 7. They will make the reinforcement cage strong and secure. Use a wire brush to remove all dirt from the re-rods.

11. Oil a set of shutters, 1.3m in diameter and 1.0m high, lower it into the shaft, and position it on top of the first set. Center the shutters with the short trimming rods, 1.3m long, check them with a spirit level, and bolt them in place, as shown in Figure 8.

12. Mix concrete on the mixing slab. Use one part cement, two parts sand, four parts gravel, and enough water to make a workable mix. Lower the concrete in a concrete bucket tied to a rope over the auxiliary headsheave. The main headsheave and a bosun's chair will be used later to raise and lower the workman pouring concrete. When lowering the bucket, be careful that it does not catch on any projection and spill its contents on the workers below.

Pour the concrete behind the shutters as shown in Figure 8. Pour it evenly and in shallow layers to prevent overloading one side. Tamp with a length of re-rod. Fill the space between the shutters and the shaft walls until the concrete is 10-20mm from the top of the shutters, and leave the top of the concrete rough. This will ensure a good bond with the next pour.

13. Temporarily cover the concrete with burlap or other material to keep off soil. Carefully excavate a triangular-shaped groove, 200mm deep and 200mm high at the well face, around the shaft walls just above the shutters. Set re-rod pins into the groove and fasten to the vertical re-rods. Remove the temporary cover. Fill in the groove with concrete as shown in Figure 8. This forms a curb which will help hold the lining in place and prevent it from slipping.

14. Oil the third set of shutters, 1.3m diameter and 1.0m high, lower it into the shaft, and position it on top of the second set. Center the shutters with the short trimming rods, check them with the spirit level, and bolt them in place. Pour concrete as before, and tamp to be certain all voids are filled with concrete.

15. Oil a fourth set of shutters and repeat the process of lowering and positioning them and pouring concrete as shown in Figure 8.

16. The top of the fourth set of shutters will be about 600mm below the bottom of the shutters being used for temporary top lining. Cover the concrete with burlap to keep off soil and remove the temporary lining. Excavate the sides of the well to a diameter of 1.6m from the surface of the ground down to the top of the fourth shutter. Attach lengths of vertical re-rod to the re-rod already in place. Bend the ends of all re-rods into hooks and overlap the lengths by

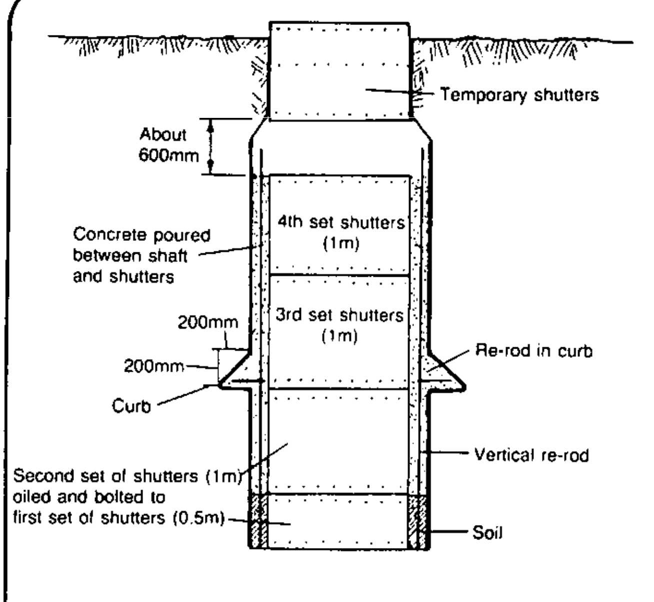


Figure 8. Shutters and Curb

at least 200mm as shown in Figure 9. The new re-rods should protrude above ground about 200mm. Position circles of horizontal re-rods 250-300mm apart and fasten them to the vertical re-rods. Remove the burlap from the concrete.

17. Oil the fifth and sixth sets of shutters in turn, set them in place, check their positioning with trimming rods and a spirit level, and bolt them together. Pour concrete as before, and carefully fill in the space behind the shutters up to ground level as shown in Figure 9. The extra thickness of concrete in the top 1.5m of the lining will provide a solid base for the wellhead. See "Finishing Wells," RWS.2.C.8.

18. Bend back the protruding vertical rods until they are level with the ground. Make a weak mortar mix (1 part cement to 15 parts sand), and use it to cover the re-rods and form a lip around the well as shown in Figure 9. This mortar layer will help keep surface water and debris out of the well, and it can be easily broken away when it is time to build the wellhead.

The first lift is now complete. Leave the shutters in place for about seven days to allow the concrete lining to cure. If you have more shutters, you can begin the second lift at once, leaving the first lift shutters in place. If not, you will have to wait seven days before beginning the second lift.

19. To begin the second lift, remove the earth-filled shutter at the bottom of the first lift, and clean the re-rods with a wire brush.

20. Excavate the second lift to a depth of 4.65m below the bottom of the concrete lining of the first lift. If ground water is encountered before you reach this depth, stop the excavation and proceed to step 25.

21. Position the vertical re-rods in the same manner used in the first lift. Bend the top ends of these re-rods into hooks and leave the bottom ends of the re-rods protruding down from the concrete. The lengths should overlap by about 200mm. Fasten them together with wire. Position and fasten circular sections of horizontal re-rods in place.

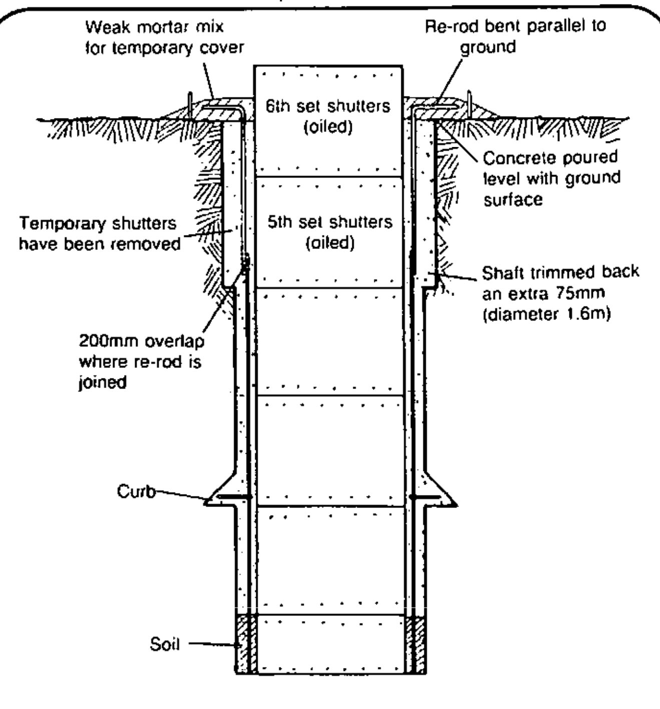


Figure 9. Completing the First Lift

22. Begin lining the second lift in the same manner as the first. Remember the first set of shutters is 0.5m high and backfilled with soil, and a concrete curb is built just above the second set of shutters.

23. There will be a gap of about 150mm between the top of the fourth set of shutters and the bottom of the concrete lining of the first lift, as shown in Figure 10. To pour concrete into this set of shutters you will need a funnel or scoop made from scrap metal. This will prevent spilling concrete.

24. The gap between lifts should be left open until the entire well is excavated and lined in case there is any movement or shifting of the lining.

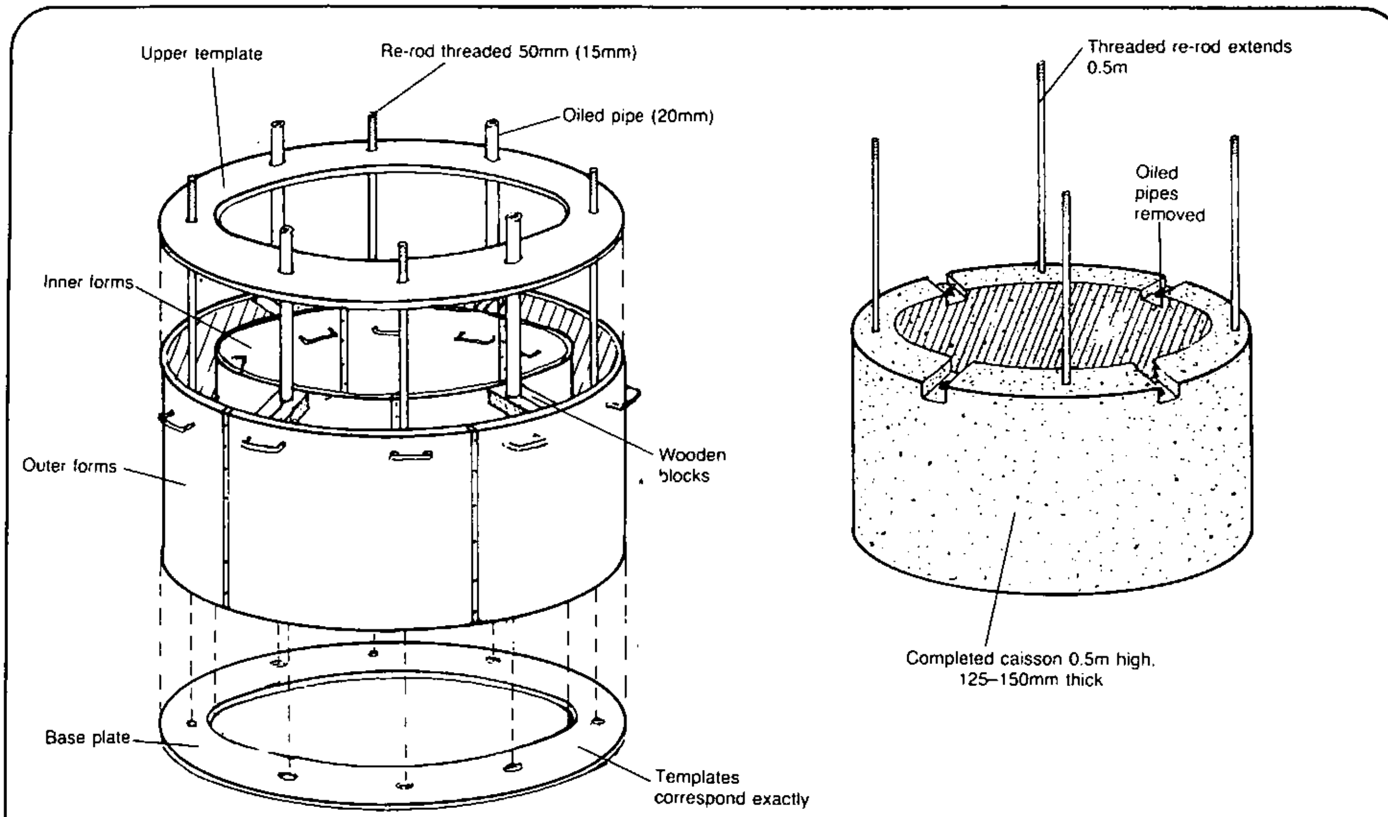


Figure 10. Casting Caissons

These gaps can be used to attach the pipe for a pump or the supports for an access ladder.

When it is time to fill the gaps, use concrete mortar and bricks or stones. Thoroughly seal the entire gap with a coating of plaster to prevent possible contamination by entry of surface water.

25. Continue the process of digging and lining until ground water is reached. If you encounter difficult ground or if the water table is reached before a full lift is excavated, the lift can be made as shallow as 650mm, 500mm for a small set of shutters and 150mm for the gap below the previous lining.

When the aquifer is reached, dig down into it to examine its composition and depth. An auger is a useful tool for this work. If the aquifer is a shallow perched layer, you must sink the well through it to a deeper aquifer. If you have indeed reached a main aquifer, line this last section of the shaft as before and build an extra-deep curb as shown in Figure 10.

26. The remainder of the well will be sunk using the caisson method. Before you can begin, the lining must be given time to harden so that you can remove the shutters. See Figure 2 for the way in which caisson rings fit into the lining.

The caisson rings may already have been cast as described in step 2. The type of rings used depends on the composition of the aquifer. The rings can be made of porous concrete, standard concrete, or standard concrete perforated with seepage holes.

26a. Cast all types of rings in a mold 0.5m high, with an outside diameter of 1.2m and an inside diameter of 0.90-0.95m. See Figure 10. If standard concrete is to be used, it can be the same mix as was used for the lining. If the rings are to have seepage holes, you must use special molds with perforations. If porous concrete is to be used, it should be made by mixing one part cement to four parts washed gravel and no sand. The mix must not be overly wet; use only enough water to make it workable. The gravel must be quite clean and of the correct size. It must all pass through a 20mm screen but none of it must pass through a 10mm screen.

26b. To ensure that the caisson rings will fit together when placed in the well shaft, equip each ring with four evenly-spaced re-rods, 15mm diameter and 1.0m long, and four evenly-spaced holes 20mm in diameter. When the rings are set one on top of the other, the re-rods from one ring will fit into the holes of the other. The holes are made with well-oiled pipes, and the pipes and re-rods are held in position by a template. A small block of wood with a hole for the pipe to pass through is positioned to form a recess in the caisson ring for a bolt which will be secured onto the end of each re-rod. Each re-rod is threaded at the top 50mm and has a hole drilled 25mm from the bottom end through which a nail or piece of thick wire is placed. This will prevent the rod from pulling out when weight is placed on it.

26c. Cast the caisson rings in the shade. Insert the re-rods and the pipes that will form the holes. If the rings are to have seepage holes, place rods or wooden pegs through the holes in the sides of the mold.

26d. When the concrete has been in the mold for 12-24 hours, remove the pipes for the holes and, if necessary, the rods or pegs for the seepage holes.

26e. The molds should not be removed for three days, and the caisson rings should not be moved during this time. If porous concrete is being used, the molds should be left in place for seven days.

26f. Remove the caisson rings from their molds. Cure the rings by keeping them moist and in the shade for seven days. If they are made from porous concrete, the rings should be cured for 14 days.

27. Roll the first caisson ring beside the well shaft and tip it on end so that the re-rods are pointing up. Lower the stretcher over two re-rods on opposite sides of the ring. The stretcher must be made of steel or wood and be capable of supporting the weight of the caisson rings, each of which may weigh over 350kg. Fit lengths of 20mm diameter pipes and washers over the re-rods so that the stretcher can be tightly bolted down as shown in Figure 10.

28. Cover the opening of the well shaft with stout logs or planks. Attach the main lowering rope to the U-bolt in the center of the stretcher. Carefully maneuver the caisson ring up onto the logs or planks until it is centered, raise it about 100mm, and remove the planks.

29. Slowly and carefully lower the ring to the bottom of the shaft. The ring must be level and perfectly centered, or you will have difficulty fitting on the other caisson rings. If necessary, raise the ring just off the bottom and wedge pieces of wood underneath until it is level and in position. Only then should you unbolt the stretcher. See Figure 11.

30. Lower the second ring in the same manner as the first. Just before it reaches the projecting re-rods of the first ring, a worker, perhaps sitting on the stretcher, must turn it so that its holes match the projecting re-rods. Partly lower the ring onto the re-rods, then spread a 10mm layer of cement mortar on the top edge of the first ring. Lower the second ring until it rests on the first. The rods of the first ring will project up into the recesses on the top edge of the second ring. Fix bolts on the threaded ends of the re-rods and tighten until the second ring is secure and level. Fill in the recesses and cover the bolt with cement mortar.

31. Continue lowering rings and fitting them together until there are five or six rings in the shaft. See Figure 11.

32. Probe the bottom of the shaft with a pointed length of re-rod to check for hard or soft spots. When excavation starts, there may be a

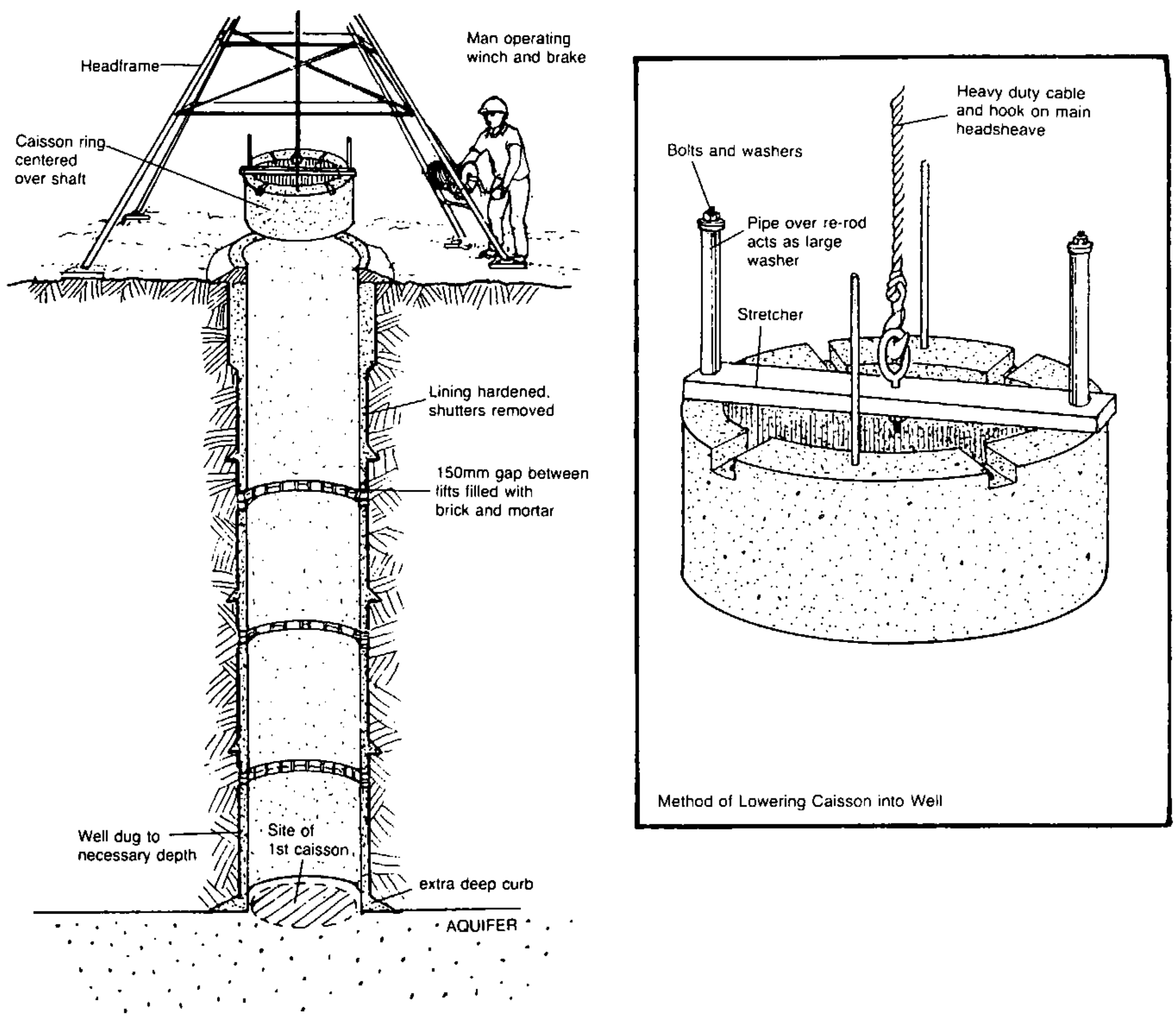


Figure 11. Installing Caissons in Completed Lining

danger that the ground will suddenly give way and that several caisson rings will drop below the bottom of the lining. This is all right as long as the top ring does not drop below the lining.

33. Begin excavating in shallow layers, first in the center of the shaft and then under the ring. Dig evenly around the ring to prevent it from sinking out of line. As you excavate, the well shaft and the caisson rings will gradually sink into the aquifer and the shaft will begin to fill with water. Dig until the water becomes too deep for working, or until you are satisfied that the well will yield sufficient water. See Figure 11.

If you wish to remove water from the shaft while excavating, bail it out with a kibble. Do not pump out water with a mechanical pump, for that can cause the aquifer to collapse.

34. Set a base plug in the bottom of the shaft as shown in Figure 12. The plug can be made of porous concrete precast at ground level, or it can be made from layers of sand and gravel. If it is precast, it should have handles for lifting and removing it. The purpose of the plug is to prevent aquifer materials from rising into the well.

35. Unless the caisson rings have been sunk during the dry season, you may have to deepen the well during

the dry season. If so, you should add more caisson rings at that time.

36. Fill the space between the caisson rings and the concrete lining with small-sized gravel.

37. To build the wellhead and finish the well, see "Finishing Wells," RWS.2.C.8.

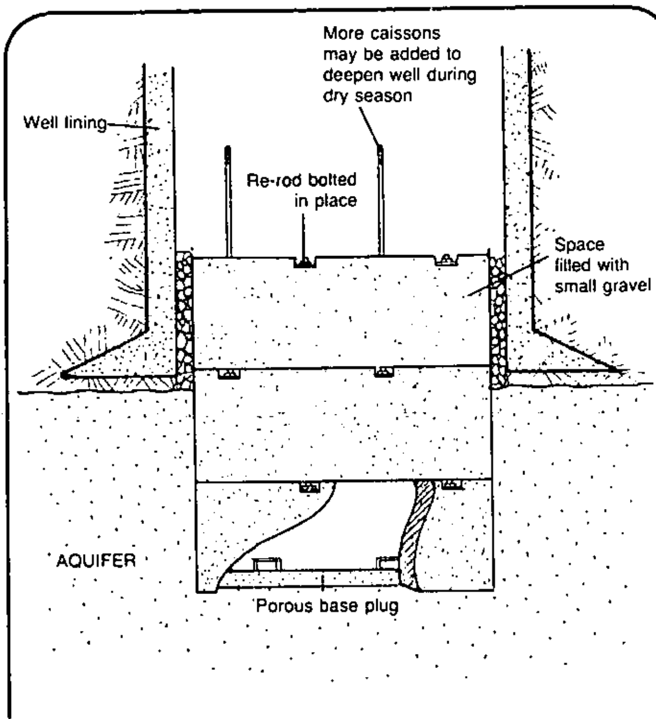


Figure 12. Caissons Sunk into Aquifer

Water for the World

Disinfecting Wells

Technical Note No. RWS. 2.C.9

Disinfecting a well is necessary to eliminate the contamination that was introduced by equipment, materials, or surface drainage during construction or repairs. A chlorine compound is generally used for the disinfectant. Disinfecting a well involves calculating the required amount of chlorine compound, mixing a chlorine solution, and applying the solution to the well.

This technical note describes how to disinfect a well. Read the entire technical note before beginning the disinfection process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

AVAILABLE CHLORINE - The amount of chlorine present in a chemical compound.

DISINFECTION - Destruction of harmful microorganisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

Materials Needed

To disinfect a well, you will need:

Chlorine compound such as calcium hypochlorite, bleaching powder, or liquid bleach,

Mixing container which should be rubber-lined or made from crockery or glass,

Stiff broom with a long handle, for hand dug wells,

Length of rope,

Length of perforated pipe, 0.5-1.0m long, 50-100mm in diameter, for deep-drilled wells with a high water table.

Caution!

Chlorine compounds or solutions may irritate skin and eyes upon contact. If possible, wear gloves, protective clothing, and glasses when handling chlorine. If you get chlorine on your skin or in your eyes, immediately wash it off with water.

General Information

The most easily obtainable and safest disinfectants are chlorine compounds. These compounds have various amounts of available chlorine, that is, chlorine that can be released to disinfect the water.

Calcium hypochlorite, also knows as high-test hypochlorite or HTH, has 70 percent available chlorine. It is produced as powder, granules, or tablets. Bleaching powders have 25-35 percent available chlorine. Common household laundry bleach, such as Clorox and Purex, has about 5 percent available chlorine.

Chlorine compounds should be stored in their original containers in a cool, dark place.

Calculating the Amount of Compound Needed

To disinfect a well properly, make a mix of available chlorine and water from the well in a ratio of 100 parts per million, ppm. To illustrate: 1 ml per 1000 liters equals 1 ppm; 100ml per 1000 liters equals 100ppm.

Table 1 shows the amounts of HTH, bleaching powder, and chlorine bleach that must be added to various volumes of well water to produce 100ppm of available chlorine. Before you can use the table, you must calculate the volume of water in the well.

The volume of water in a well equals the radius of the well squared times the depth of the water in the well times 3.1416.

$$V = r^2 \times D \times 3.1416$$

The radius, r, equals the diameter, d, of the well divided by two.

$$r = \frac{d}{2}$$

The diameter, d, can be measured directly or read from design drawings or from the driller's log described in "Maintaining Well Logs," RWS.2.C.6.

The depth, d, of the water in the well can be measured directly by lowering a rock tied to a length of twine to the bottom of the well, retrieving the twine, and measuring the wet portion. Or, it can be read from the driller's log.

For example, suppose the diameter of the well is 100mm (0.10m) and the depth of the water in the well is 12m. First, calculate the radius.

$$r = \frac{d}{2} \qquad r = \frac{0.10\text{m}}{2} \qquad r = 0.05\text{m}$$

Then calculate the volume of water.

$$V = r^2 \times D \times 3.1416$$
$$V = 0.05\text{m} \times 0.05\text{m} \times 12\text{m} \times 3.1416$$
$$V = \text{about } 0.1\text{m}^3$$

See Worksheet A Lines 1-4.

From Table 1, you can see that in order to disinfect this well you would need to use 0.2 liters of chlorine bleach, 5 percent available chlorine, or 33 grams of bleaching powder, 30 percent available chlorine, or 14 grams of high-test hypochlorite, 70 percent available chlorine.

For another example, suppose the diameter of the well is 1.2m and the depth of the water in the well is 2.6m. The radius equals the diameter divided by two = $\frac{1.2\text{m}}{2}$ = 0.6m Now calculate the volume.

$$V = r^2 \times D \times 3.1416$$
$$V = 0.6 \times 0.6 \times 2.6 \times 3.1416$$
$$V = 2.9\text{m}^3$$

See Worksheet A, Lines 5-8.

From Table 1, you can see that the nearest volume to this is 3.0m^3, so to disinfect this well you would need to mix in 6.0 liters of chlorine bleach, or 1010 grams of bleaching powder, or 433 grams of HTH.

Table 1. Amounts of Chlorine Compounds for Well Disinfection

Water in Well (m^3)	Liquid Bleach 5% available chlorine (liters)	Bleaching Powder 30% available chlorine (grams)	Calcium Hypochlorite (HTH) 70% available chlorine (grams)
0.1	0.2	33	14
0.12	0.24	40	17
0.15	0.3	51	22
0.2	0.4	68	29
0.25	0.5	86	37
0.3	0.6	100	43
0.4	0.8	133	57
0.5	1.0	170	73
0.6	1.2	203	87
0.7	1.4	233	100
0.8	1.6	267	113
1.0	2.0	334	143
1.2	2.4	400	173
1.5	3.0	500	217
2.0	4.0	670	287
2.5	5.0	860	367
3.0	6.0	1010	433
4.0	8.0	1330	567
5	10	1700	730
6	12	2000	870
7	14	2300	1000
8	16	2600	1130
10	20	3300	1430
12	24	4000	1730
15	30	5000	2170
20	40	6700	2870

Worksheet A. Calculating the Volume of Water in a Well

<u>Drilled Wells</u>

1. Diameter of well = $\frac{(\ 100\ \text{mm})}{(1000\text{mm/m})}$ = 0.10 m

2. Radius of well = $\frac{\text{Line 1}}{2}$ = $\frac{(\ 0.10\ \text{m})}{2}$ = 0.05 m

3. Depth of water in well = 12 m

4. Volume of water in well = Line 2 x Line 2 x Line 3 x 3.1416 =
   0.05 m x 0.05 m x 12 m x 3.14.6 = 0.09 m^3

<u>Hand Dug Wells</u>

5. Diameter of well = 1.2 m

6. Radius of well = $\frac{\text{Line 5}}{2}$ = $\frac{(\ 1.2\ \text{m})}{2}$ = 0.6 m

7. Depth of water in well = 2.6 m

8. Volume of water in well = Line 6 x Line 7 x 3.1416 =
   0.6 m x 0.6 m x 2.6 m x 3.1416 = 2.9 m^3

Mixing the Solution

Do not pour the chlorine compound directly into the well. It will not mix properly. First make a chlorine solution.

To make a chlorine solution from chlorine bleach, mix one part of bleach with one part of water, then pour the entire solution into the well. In the second example, this would mean mixing 6.0 liters of chlorine bleach with 6.0 liters of water and pouring 12.0 liters of chlorine solution into the well.

To make a chlorine solution with HTH or bleaching powder, first mix the compound with enough water to form a smooth paste, then mix the paste with water in the ratio of one liter of water per 15 grams of compound. To calculate the amount of water needed to make a chlorine solution, divide the amount of chlorine compound by 15. In the second example,

$$\frac{\text{1010 grams of bleaching powder}}{\text{15 grams}} =$$

67 liters of water

$$\frac{\text{433 grams of HTH}}{\text{15 grams}} = \text{29 liters of water}$$

Mix the chlorine paste with the water for 10-15 minutes. Allow inert materials to settle and use only the clear chlorine solution. Discard the rest. Pour the clear chlorine solution, about 67 liters in the case of bleaching powder or about 29 liters in the case of HTH, into the well.

Do not mix chlorine solutions in metal containers. Mix them in clean containers that are rubber-lined or made from crockery or glass.

Disinfecting a Hand Dug Well

If the well has no cover, it should be disinfected every day, or as often as possible. If the well is covered it must be disinfected before the first use and every time it is opened for maintenance or repair.

For a dug well with pump and cover:

1. Prepare a chlorine solution to wash the inside of the well casing. Mix 10 liters of water with <u>one</u> of the following: 0.02 liters of chlorine bleach, or 3.3 grams of bleaching powder, or 1.4 grams of HTH.

2. Wash the exterior surface of the pump cylinder and drop pipe with the chlorine solution before they are lowered into the well.

3. Remove all equipment and materials that will not be a permanent part of the well.

4. Wash the inside surface of the well casing with a clean, stiff broom and the 10 liters of chlorine solution. See Figure 1.

5. Install the cover over the well.

6. Calculate the amount of chlorine solution needed to disinfect the well. Prepare the solution and poor it through the access hole in the cover, making sure that the solution covers as much of the surface of the water in the well as possible. See Figure 2.

7. Mix the chlorine solution with the water in the well by using a rope tied to a large, clean rock. Lower the rock into the well and move it up and down in the water.

8. Cover the access hole. Pump water from the well until you can smell chlorine.

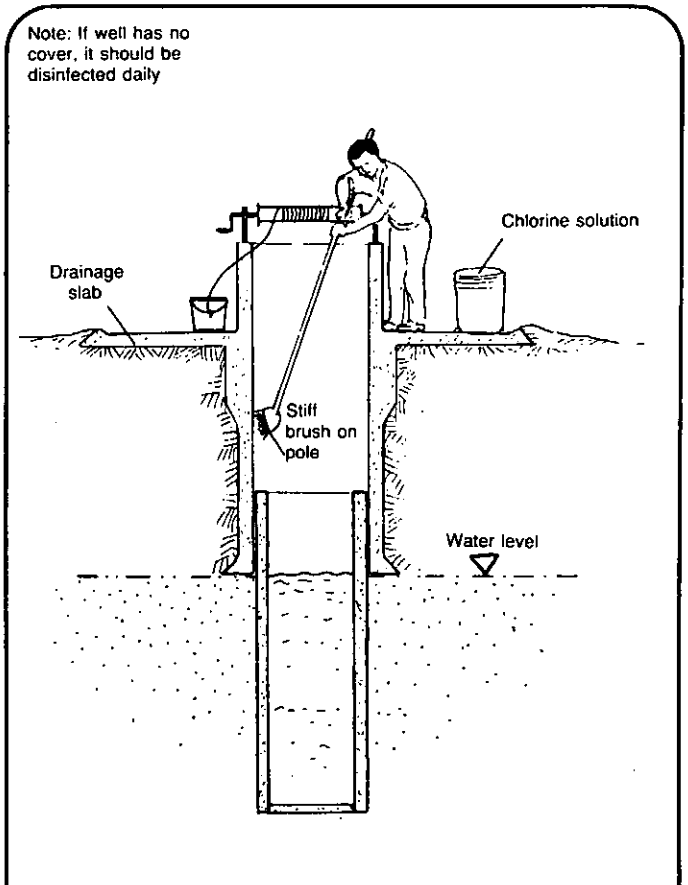


Figure 1. Washing Inside of Casing (Hand-dug well)

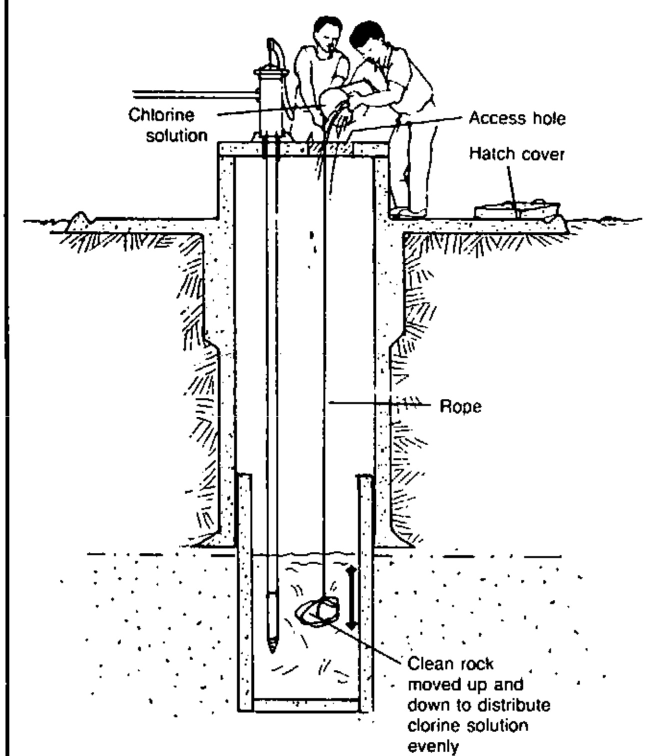


Figure 2. Pouring Chlorine Solution into Well

9. Allow the chlorine solution to remain in the well for 24 hours.

10. Pump water from the well until chlorine can no longer be smelled or tasted. Dispose of this water in a soakaway.

Disinfecting a Driven, Jetted, Bored, or Cable Tool Well

After the well has been tested for yield as described in "Testing the Yield of Wells," RWS.2.C.7, it must be disinfected before its first use and every time it is opened for maintenance or repair.

1. Remove the test pump from the well.

2. Calculate the amount of chlorine solution needed to disinfect the well. Prepare the solution and pour it into the well.

3. Mix the chlorine solution with the water in the well by using a rope tied to a clean rock. Lower the rock into the well and move it up and down in the water.

4. Add 40 liters of clean, chlorinated water to the well to force the solution into the aquifer. This solution can be made by mixing 40 liters of water with either one-half teaspoon of HTH or 20ml of chlorine bleach.

5. Prepare a chlorine solution to wash the pump cylinder and drop pipe. Mix 10 liters of water with one of the following: 0.02 liters of chlorine bleach, or 3.3 grams of bleaching powder, or 1.4 grams of HTH.

6. Wash the exterior surface of the pump cylinder and drop pipe as they are lowered into the well.

7. Pump water from the well until you can smell chlorine.

8. Allow the chlorine solution to remain in the well for 24 hours.

9. Pump water from the well until chlorine can no longer be smelled or tasted. Dispose of this water in a soakaway.

Deep Well with High Water Table

In the case of a deep well with a high water table, you need to take special steps to ensure that the chlorine and well water are properly mixed.

1. Drill a number of small holes through the sides of the pipe that is 0.5-1.0m long and 50-100mm in diameter. Cap one end of the pipe.

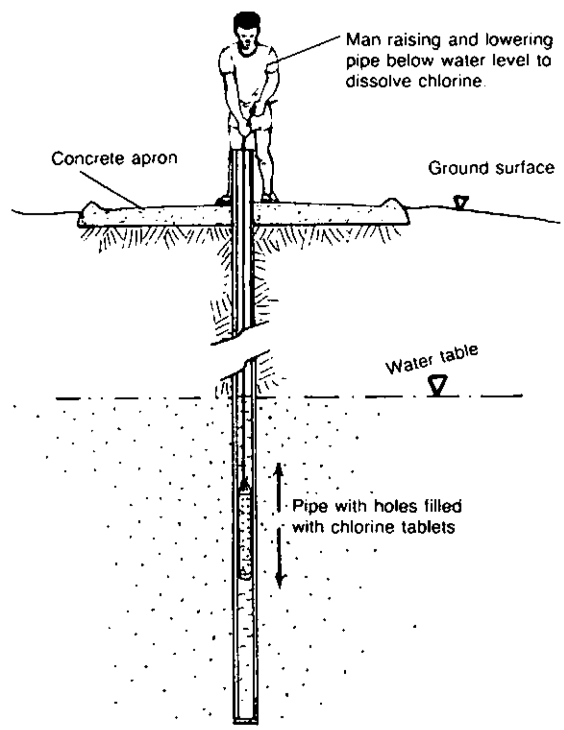


Figure 3. Disinfecting Deep Well with High Water Table

2. Pour the calculated amount of HTH granules or tablets into the pipe. Only HTH can be used in this method.

3. Fit the other end of the pipe with a threaded cap equipped with an eye loop.

4. Tie a rope to the eye loop, lower the pipe into the well, and alternately raise and lower the pipe in the water. Continue until the HTH has dissolved and the chlorine is distributed in the water. See Figure 3.

Notes

Water for the World

Manufacturing Hand Pumps Locally

Technical Note No. RWS. 4.P.6

Many villages need hand pumps but have limited local resources to purchase them. Even when hand pumps are obtained, repair parts may not be readily available. Many communities which have had hand pumps in the past have experienced failure due to the lack of repair parts.

Because of this, there are compelling reasons for local manufacture of hand pumps so that both repair parts and skills are readily available. The alternatives to be considered are village manufacture of pumps which may be inefficient and have a short lifetime but are within the villagers' capability to understand and construct and the construction of long-lasting and relatively maintenance free pumps which require skilled workers and sophisticated equipment and must be built in a central location within a country. Another alternative is to have those parts of a pump which require accurate machining or casting made at a central location in-country and to construct the balance of the parts and assemble the pumps at the village level. These methods have been applied with success. The choice of options depend on the specific country and village.

Types of Hand Pumps

To evaluate alternatives, it is necessary to know what a hand pump is and what its component parts are. The most common hand pump is one which uses leverage to enable a person to lift water either by developing a vacuum or by positive displacement or a combination of both. These pumps are classified as shallow well pumps with a maximum pumping depth of 7m, or deep well pumps which can pump from depths over 7m. Shallow well pumps have the pump cylinder built into the pump stand as shown in Figure 1a. Deep well pumps have the pump cylinder located in the well, below water level. This requires a pump rod in the well. See Figure 1b.

The component parts of a hand pump are a pump cylinder, a drop pipe, a pump rod and pump stand, and a handle.

Pump Cylinder. Pump cylinders may be open or closed as shown in Figure 2. The advantage to an open cylinder is that the plunger can be removed without removing the drop pipe. The pump cylinder must be accurately machined. For this reason, it cannot readily be

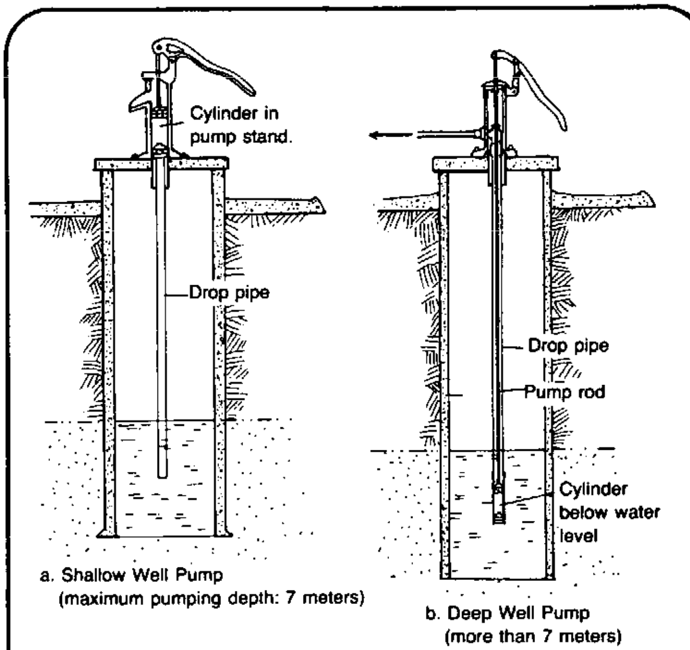


Figure 1. Types of Hand Pumps

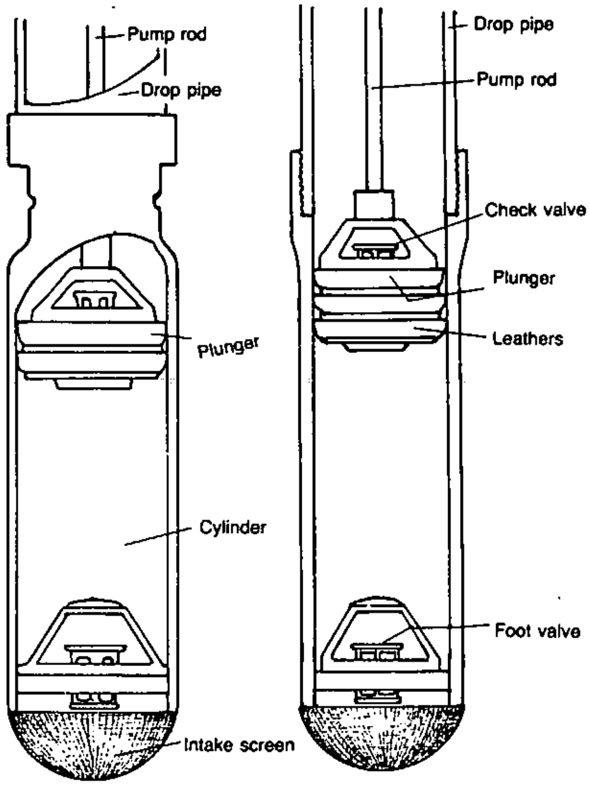


Figure 2. Pump Cylinders

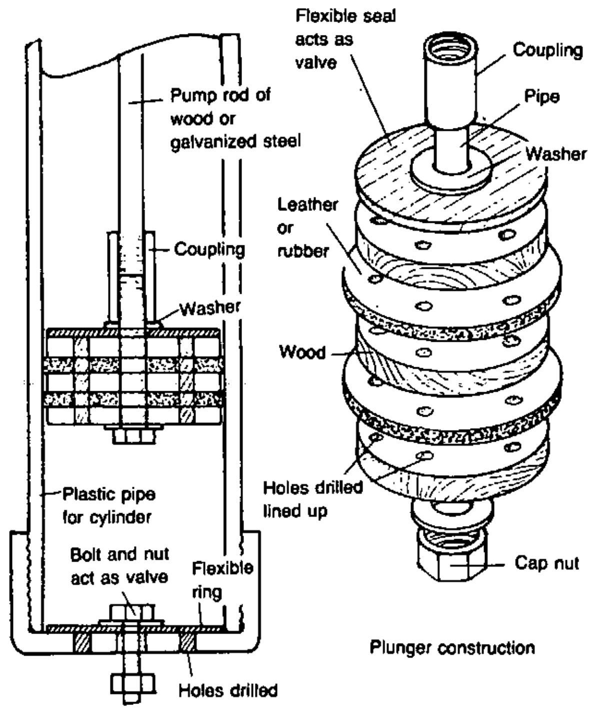


Figure 3. Locally Manufactured Cylinder and Plunger

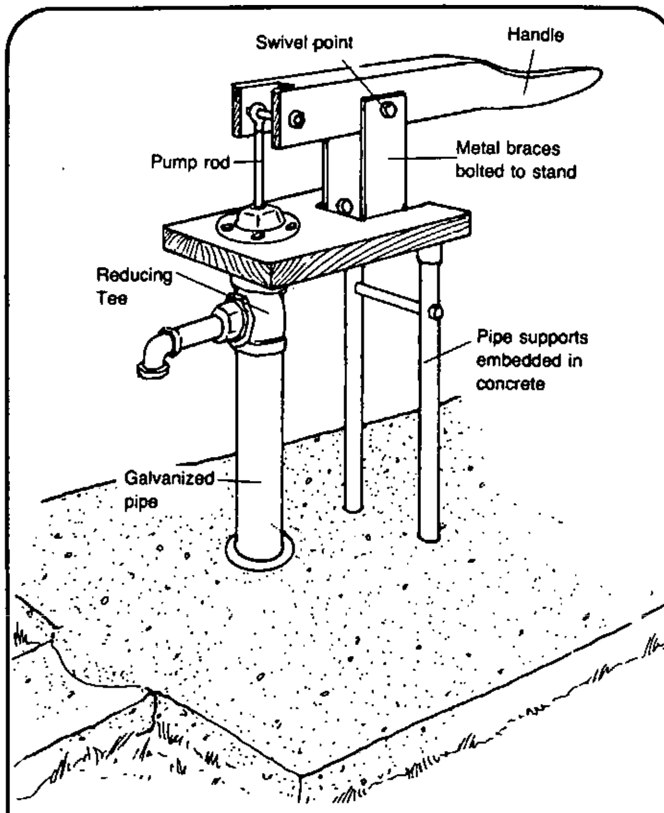


Figure 4. Pump Stand

constructed at the village level. Some development is underway using plastic pipe for the cylinder but the results are not yet complete. Pump cylinders are available in cast iron and brass. Both have long expected lives. The primary reason for failure is in the "leathers," which are easily replaced and can be made locally. Figure 3 shows a locally made pump cylinder.

Drop Pipe. The drop pipe is usually made of galvanized iron or rigid plastic for shallow depths. Galvanized iron pipe is much more commonly used. Neither can be manufactured at the local level.

Pump Rod. This is necessary for connecting to pump cylinders located in a well. Galvanized iron rod is common for wells up to 30m deep and wood rod for greater depths. These must be obtained from outside the immediate village area in most cases. Wood rod may be used if locally available. Reinforcing steel can be used as a pump rod but it is likely to rust.

Pump Stand. Pump stands may be cast, welded or fabricated from pipe or wood. Since the main points of wear are in the bearing areas, they should be made to close tolerances and of durable material to increase the life of the stand. This primarily involves the pump handle and the pivot point on the stand which supports the pump handle. The pump stand and handle usually are the first to wear out and are also relatively easy to build. For this reason, they should be considered the principle elements for local manufacture. Figure 4 shows one type of locally manufactured pump stand and handle.

Notes

1982

Water for the World

Installing Hand Pumps

Technical Note No. RWS. 4.C.3

Hand pumps may be used for shallow wells, less than 7m to water, or deep wells. Deep well pumps can be used in many shallow wells and are a good choice because the pump cylinder is in the water. With the cylinder in the water, the pump does not lose its prime and the pump leathers do not dry out. In shallow well pumps, the cylinder is in the pump body above ground.

A hand pump system consists of a hand pump stand, drop pipe, pump rod or sucker rod for deep wells, and a pump cylinder. For shallow wells, the cylinder is part of the hand pump stand. Some hand pump stands lift water to a spout or force it to a higher elevation or to a point located away from the well. Figure 1 shows both shallow well and deep well hand pumps. Hand pumps should be installed according to manufacturer's directions. This technical note only describes the basic steps in hand pump installation.

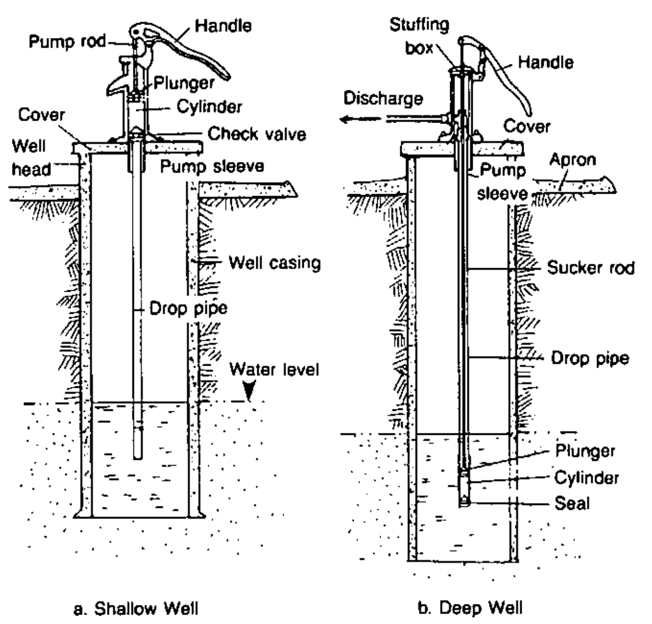


Figure 1. Hand Pump Systems

Useful Definitions

DEEP WELL PUMP - Any pump capable of pumping water from wells where the water level is more than 10m below the ground surface.

DROP PIPE - The pipe in the well connecting the water to the pump.

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

In all installations it is important that the water source not be contaminated. The top of the well should be fully enclosed with a well slab placed around the well. Only materials which are clean and made for use in potable water supplies should be used.

In preparing a materials list, careful measurements must be made to ensure sufficient material is available. Prior to cutting material for assembly, it is good practice to again make careful measurements. It is necessary to have the proper tools on site when installation begins. Table 1 lists the materials and tools needed for a typical hand pump installation.

As in all projects, careful preplanning will help assure that installation involves a minimum of wasted time. A sample work plan is shown in Table 2. This plan can be used to estimate the time needed to complete the job and to decide when materials and tools should be available. Figure 2 shows the installation of the drop pipe and cylinder using a tripod. Figure 3 shows the detail of installing a pump sleeve, and Figure 4 shows a finished dug well with a hand pump.

After the pump installation has been completed, but prior to bolting the pump stand to the mounting flange, the well should be pumped until the water is clear and a strong chlorine solution should be used to disinfect the well. This is accomplished by raising the pump assembly from the flange and pouring the solution down the well. After 12-24 hours, the well can be pumped out and the water used.

Table 1. Sample Materials List for Hand Pump Installation

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	___
	Laborers	2	___
	(NOTE: Either the foreman or the laborers must have some experience in cutting and threading pipe)		
Supplies	32mm galvanized steel pipe with coupling	___m: enough to reach the desired depth in the well	___
	10mm galvanized steel pump rod	___m: enough to reach the desired depth in the well	___
	10mm pump rod couplings	___: one for each joint	___
	Well cylinder	___	___
	Hand pump stand with handle	___	___
	Pump mounting flange	___	___
	Packing material	___	___
	Small can of grease	___	___
	Cutting oil	___	___
	Chlorine solution	___	___
Tools	Portable pipe vise	___	___
	Large pipe wrenches	___	___
	Crescent wrenches (adjustable wrenches)	___	___
	Pliers	___	___
	Hacksaw with spare blades	___	___
	Metal file	___	___
	Pipe cutter	___	___
	Pipe threader, 10mm and 32mm	___	___
	Measuring tape, 3m and 12m	___	___
	Pipe holder	___	___
	Rope and pulley	___	___
	Tripod for lowering pipe	___	___
	Plumb bob and 50m of line	___	___
		Total Estimated Cost	___

Table 2. Sample Work Plan for Installing a Hand Pump

Time Estimate	Day	Task	Personnel	Tools/Materials
1 hour	1	Delivery materials to site and unload	Foreman and 2 laborers	Shown in Table 1
1 hour	1	Set up tripod	Foreman and 2 laborers	Tripod, wrenches
1 hour	1	Cut and thread pipe and pump rod as measured	Foreman and 2 laborers	Pipe vise, cutter threader, cutting oil
3 hours	1	Attach pump rod and cylinder and lower into well; add pipe and rod as required until desired depth is reached	Foreman and 2 laborers	Pipe, pump rod, pipe holder and pipe wrenches
1 hour	1	Attach pump mounting flange to well casing, screw pipe into bushing and bushing into base of pump stand	Foreman and 2 laborers	Pump mounting flange, pipe bushing, pump stand and wrenches
1 hour	1	Check pump packing and packing nut; lubricate pump bearing points; work pump until water is clear; add chlorine solution to well and let stand overnight	Foreman and 2 laborers	Packing material, grease, wrenches chlorine solution
2 hours	2	Pump well until no chlorine solution remains; attach stand to flange		

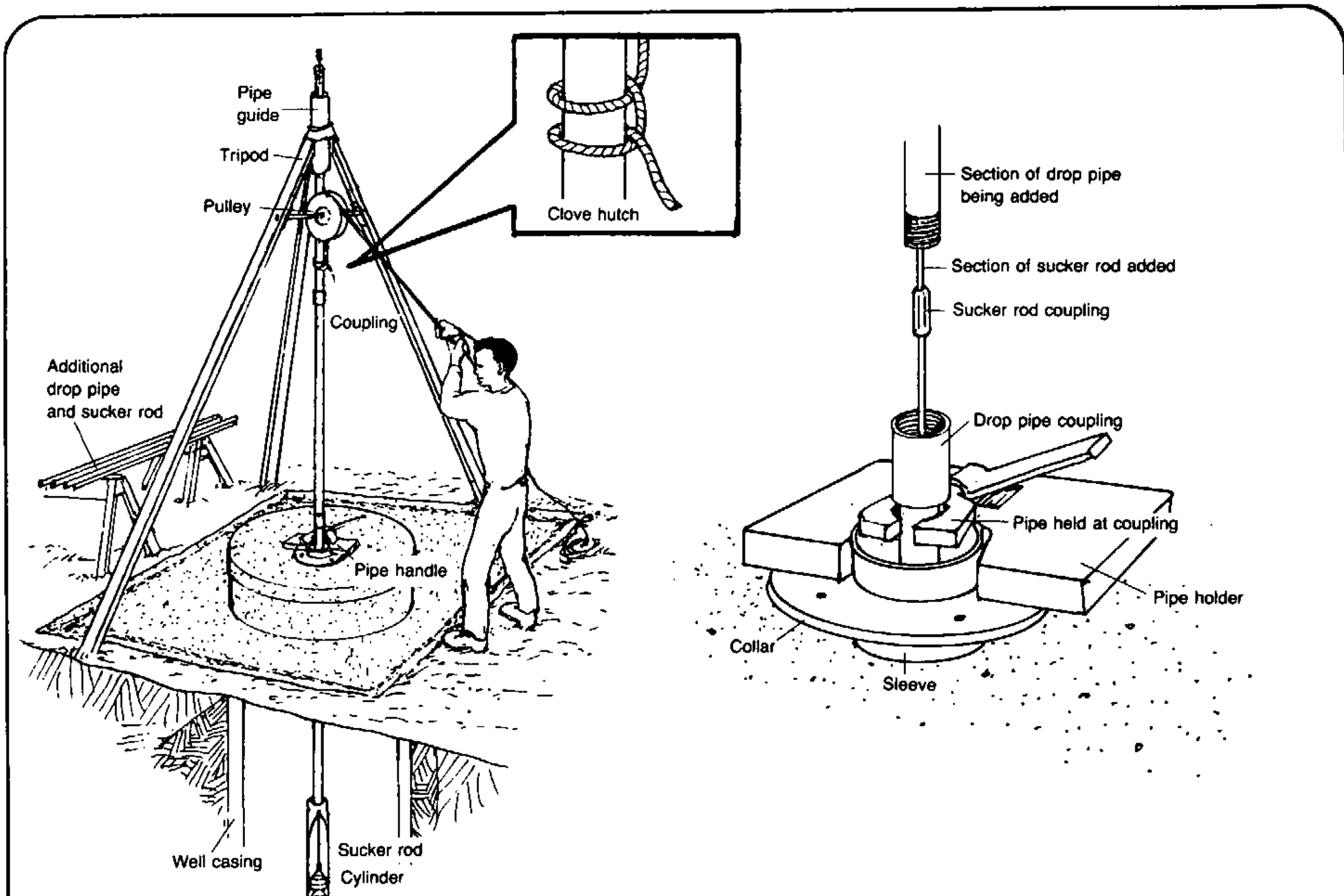


Figure 2. Installation of Drop Pipe and Cylinder

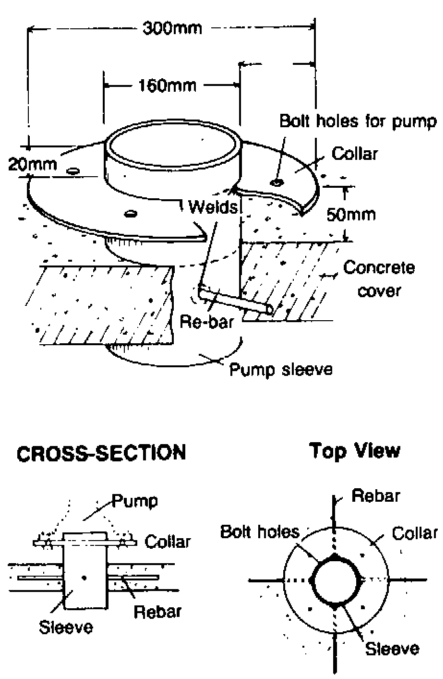


Figure 3. Installing Pump Sleeve

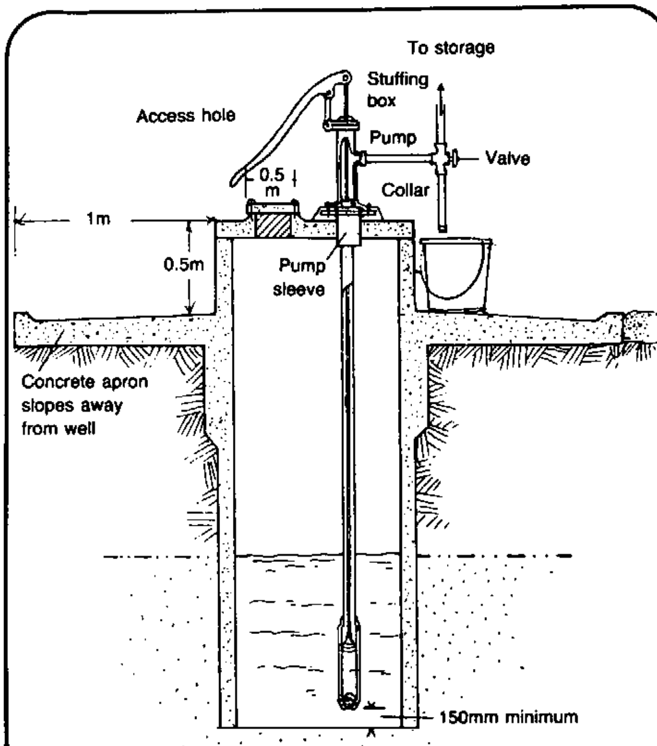


Figure 4. Finishing a Hand Dug Well

Notes

1982

Water for the World

Operating and Maintaining Hand Pumps
Technical Note No. RWS. 4.O.3

It is relatively easy to construct a water supply and to install the necessary pumping equipment to provide water to a village. A consideration too often overlooked is whether it will be operating one, two, five, or more years later. Too often, the system will become inoperative because of lack of knowledge of and attention to operation and maintenance.

Hand pumps have been installed in many villages throughout the world and in a number of different situations. Unfortunately many of them have become inoperative. As a result, there has been considerable effort to develop a better hand pump. This has led to worthwhile and necessary improvements but there is not now, nor is there likely to be, a "perfect" pump that will continue working without proper operation and maintenance. See Figures 1 and 2. The easier it is to

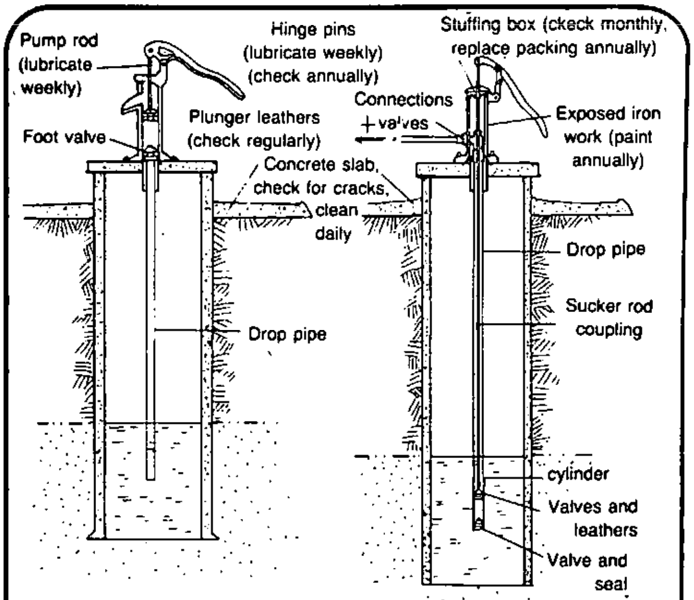


Figure 1. Maintenance Points on Hand Pumps

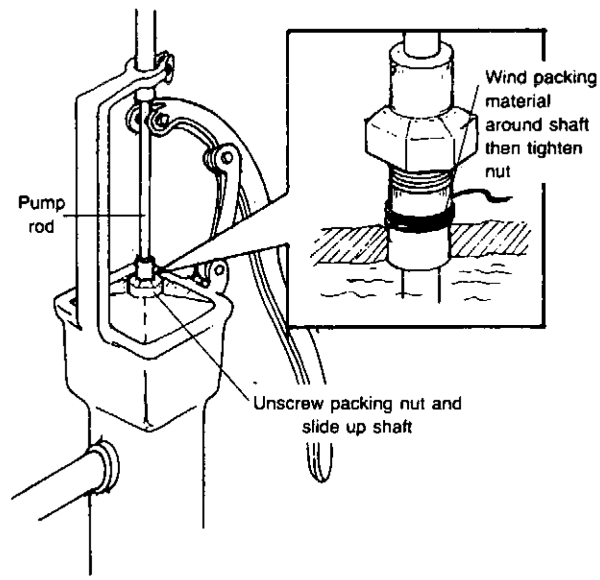


Figure 2. Repacking Stuffing Box

obtain water without a hand pump, the more likely it is that the pump will not be maintained and, once failure occurs, that the pump will not be repaired. For this reason it is essential that the village recognize the positive benefits of an improved water source. Only then will that village be motivated to see that the improvements are maintained or, as economics allow, increased.

Useful Definition

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

Operation and Maintenance Programs

Various programs have been proposed and implemented to assure proper operation and maintenance. When coupled with community involvement, all have a good chance of success. These programs range from the village being totally responsible for operation and maintenance of the system to a government unit taking full responsibility. An alternative is cooperation between the community and an agency of central government to provide needed operation and maintenance. The specific means adopted will vary from place to place, from country to country and, in some situations, from village to village. It is imperative that the community recognize the importance of operation and maintenance and support the improvement.

Whatever method is used to provide operation and maintenance, it is absolutely essential that the village play a role and that this role is understood and agreed to by the village. As discussed above, one method of providing for continued operation and maintenance is a cooperative agreement between a unit of government and the village. The following is an example covering preventive maintenance, major repairs and an educational program.

Example of Operational Procedures

Preventive Maintenance. Day-to-day maintenance of the hand pump is the responsibility of the village. In order to assure that this is accomplished, one of the villagers should be appointed the pump custodian. It is his or her responsibility to provide routine lubrication, keep the area around the pump clean and note wear for reporting to the field maintenance worker. Figures 1 and 2 identify key maintenance points.

A field maintenance worker should make routine inspections of all completed projects in the area. At the time of visits, he or she would determine what repairs could be made immediately. See Table 1 for examples of on-the-spot preventive maintenance repairs.

Table 1. Typical Preventive Maintenance Repairs by Field Maintenance Worker

1. Replace packing in hand pumps.
2. Replace worn bolts and cotter pins on pumps.
3. Replace worn or broken pump handles.
4. Replace washers in pump compression spouts.
5. Replace worn sucker rods.
6. Replace pump cylinders (worn leathers).
7. Replace defective valves at watering points.
8. Replace necessary fittings.
9. Replace manhole covers.

A member of the sanitation staff should accompany the field maintenance worker on the initial visit to each project to explain the project and make recommendations for a preventive maintenance schedule and procedure. The professional sanitation staff should assist the field maintenance worker in setting up routine inspection trips, advising on location and details of each project, and recommending methods of repair as shown in Figure 3. In addition, the professional sanitation staff should review inspection and repair reports so that they would be in a position to coordinate the field maintenance workers activities. The professional sanitation staff should notify the field maintenance worker upon the completion of a project and advise him or her of the details of all projects in the area. Table 2 is an example of an inspection report that can be used for the field work.

Major Repair of Breakdown. In case of major breakdown or failure of the project, the village leaders should notify the field maintenance worker who would then inspect the project and determine what is necessary for repairs. In the case of a major or unusual problem, the field maintenance worker should consult the professional sanitation staff and, if necessary, the professional sanitation staff should visit the project to make recommendations. If additional labor is necessary for repairs, the field maintenance worker will arrange hiring details with the village leaders. The necessary labor should be recruited from individuals who use the supply. The field maintenance worker would

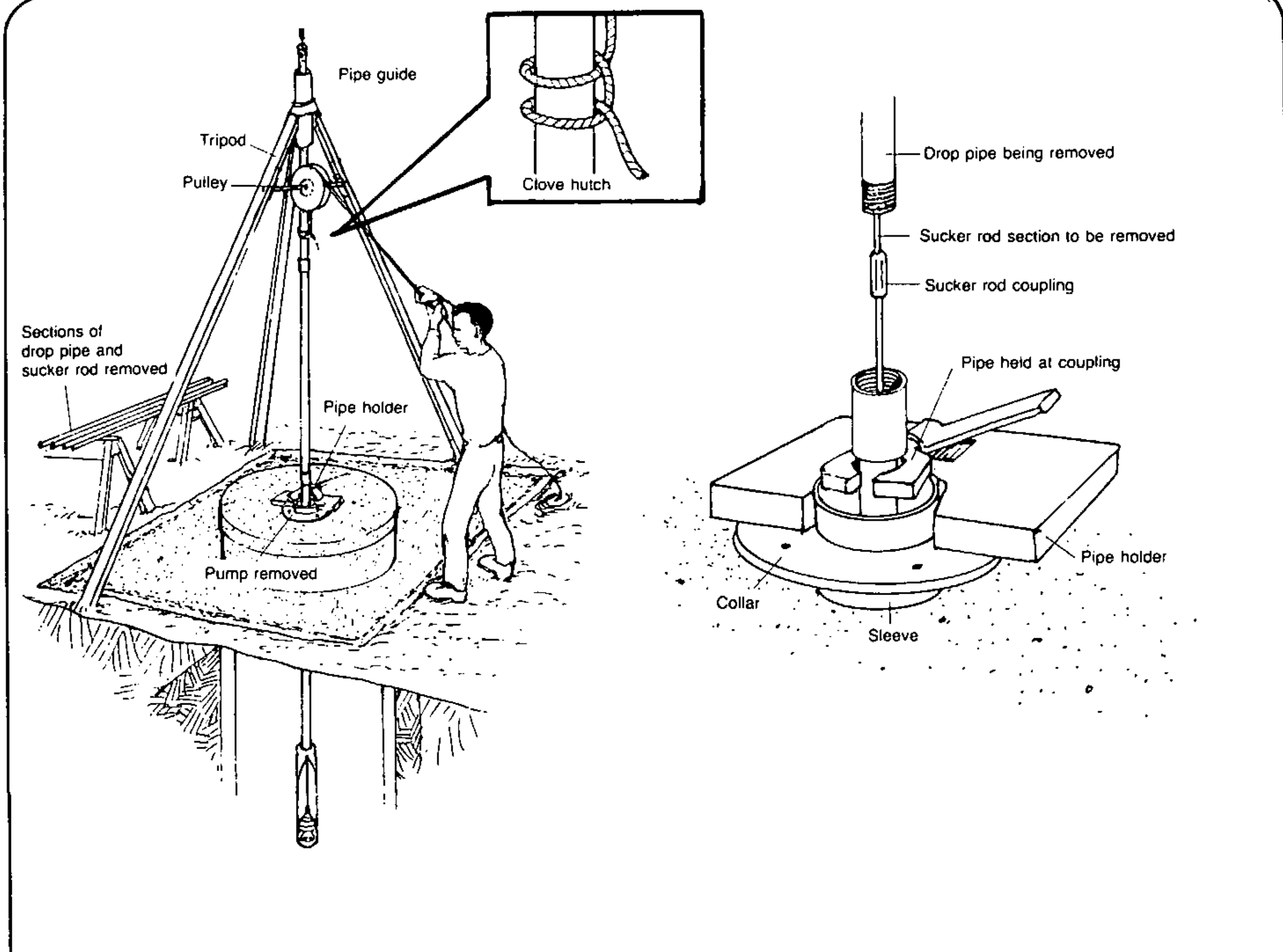


Figure 3. Raising Drop Pipe and Cylinder

estimate the labor and materials necessary for the repairs and submit this estimate to the professional sanitation staff for review and approval.

Educational Program. A cooperative effort between village community workers and the field maintenance worker should be undertaken to educate the village on preventive maintenance of the hand pump. They should inform the villagers of items to look for so that repairs can be made before they become too costly, and of the proper channels for requesting repairs, when necessary.

Table 2. Sample Inspection Report

Date________

Region______________________ Village______________________

Location______________________

Type______________________

Description: (Check items which are a part of the system).

hand pump ( ); well slab ( ); watering point ( ); spring box ( ); storage tank ( ); pipe line ( ); manhole cover ( ); diversion wall ( ); windmill ( ); stock through ( ); other______________________

Hand Pump	Good Condition	Repair or Replace
packing	( )	( )
bolts	( )	( )
cotter pins	( )	( )
handle	( )	( )
shaft	( )	( )
compression spout	( )	( )
sucker rod	( )	( )
cylinder	( )	( )
mounting	( )	( )

Water Point	Good Condition	Repair or Replace
valve	( )	( )
mill hose	( )	( )
fittings	( )	( )
stand	( )	( )
piping	( )	( )
vent	( )	( )
hose clamp	( )	( )

Storage Tank	Good Condition	Repair or Replace
walls	( )	( )
cover	( )	( )
manhole cover	( )	( )
bottom	( )	( )
discharge	( )	( )
vent	( )	( )
valves	( )	( )
piping	( )	( )
fittings	( )	( )

Windmill	Good Condition	Repair or Replace
packing	( )	( )
discharge	( )	( )
seal	( )	( )

Stock Through	Good Condition	Repair or Replace
walls	( )	( )
piping	( )	( )
valve	( )	( )
apron	( )	( )

Well Slab	Repair or Replace
good condition	( )
cracked	( )
manhole cover in place	( )
manhole cover missing	( )
manhole cover replaced	( )

Spring Box	
good condition	( )
cracked	( )
manhole cover in place	( )
manhole cover missing	( )
manhole cover replaced	( )
overflow satisfactory	( )
overflow needs repair	( )
overflow repaired	( )
vent satisfactory	( )
vent needs repair	( )
vent repaired	( )
discharge satisfactory	( )
discharge unsatisfactory	( )
discharge repaired	( )

Pipeline	
good condition	( )
needs repair	( )
estimate made	( )

Diversion Wall	
condition good	( )
needs repair	( )
estimate made	( )

Other	
______________________	( )
______________________	( )
______________________	( )

____
Field Maintenance Worker

Water for the World

Determining the Need for Water Storage

Technical Note No. RWS. 5.P.1

Many water systems require some form of storage. Storage is necessary (1) when rainwater is collected for drinking water, (2) for most distribution systems where the source's continuous supply is barely sufficient or is insufficient to meet the daily demand and (3) where a single well serves a community through a distribution system. Storage ensures that an adequate quantity of water is always available to users and that water quality is protected.

This technical note describes the procedure to follow in determining whether storage should be provided for a water system and establishes methods to determine the quantity of storage required.

Several factors should be considered in determining water storage needs: (1) the source of water, (2) the amount of water available for consumption (3) the demand for water and (4) the materials available and economic resources of the families in the community. From this information, the most appropriate form of water storage can be chosen.

Rainfall Storage in a Cistern

Rainwater needs to be collected and stored if people are to use it for drinking. In order to plan for adequate storage and design the most appropriate type of storage facility data on the following items should be collected:

- amount of monthly rainfall,
- potential rainfall supply available each month,
- the amount of water likely to be consumed by the family.

With this information, the size of the cistern can be estimated.

Data on average monthly rainfall can be acquired from a national weather agency, the military, or an airport. Data for a specific location may not be available, but regional data can be used for an estimate. Table 1 and Figure 1 show an example of distribution of rain by month for a location receiving an average annual rainfall of 1032.5mm.

The potential available water supply depends on the amount of rainfall and the catchment surface area. If a catchment area has a length of 8m and a width of 6m, the area of the catchment is 8m x 6m or $48m^2$. To determine the amount of available water, multiply the monthly rainfall figures by $48m^2$ and then by 0.8, a loss factor which takes into account water that does not make it to storage from the catchment area. For example, using January rainfall figures, the total amount of water available to the family is 8678 liters. This amount is arrived at using the following formula:

Volume of water = Catchment area x rainfall x 0.8

Table 1. Average Monthly Rainfall in Millimeters

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
Rainfall	226	188	173	46	2.5	0	0	5	5	41	130	216	1032.5

This data can be represented graphically as shown in Figure 1.

MONTH	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
RAINFALL (in mmm.)	226	188	173	46	2.5	0	0	5	5	41	130	210	1,032.5

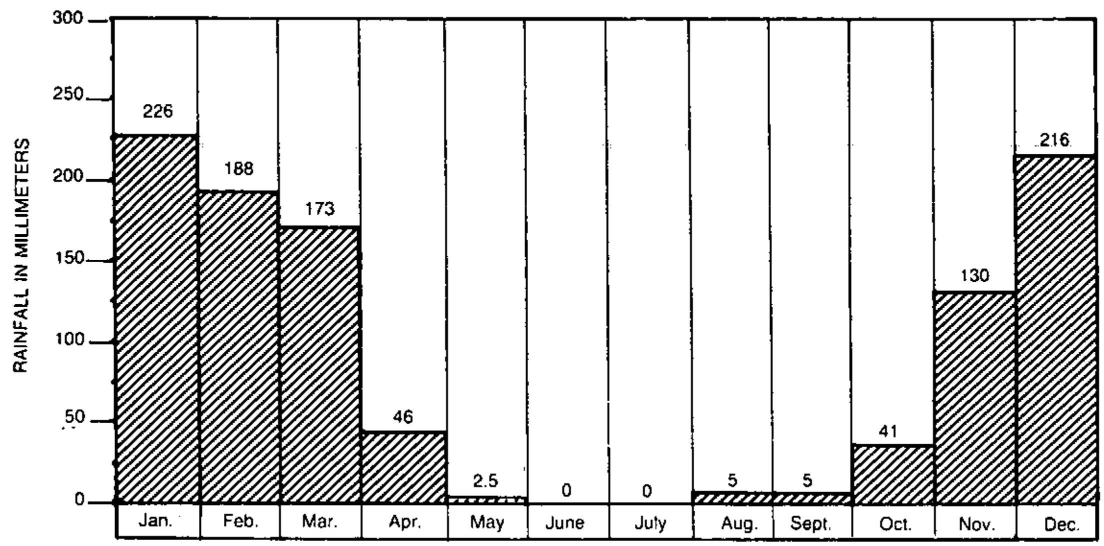


Figure 1. Average Monthly Rainfall in Millimeters

Volume = $48m^2$ x 226mm x 0.8

Volume = 8678 liters

Table 2 and Figure 2 give an example of the average amount of water available during each month of the year. Remember that these are average estimates that will differ with cyclical climatic changes. Each number is arrived at by taking the average monthly rainfall figure and using it in the above equation.

The next step in determining storage requirements is shown in Figure 3. First, a graph of the cumulative available rainfall is made. The graph represents the amount of rainfall run-off available from a catchment throughout the year. The heights of the bars are determined by adding a particular month's average rainfall to the sum of the rainfall for the previous months. For example, April shows a cumulative run-off of 24306 liters which is the sum of the run-off for January, February, March and April.

Secondly, a diagonal line representing yearly demand is drawn. The line assumes that people will use the same quantity of water each month, although generally greater quantities are used in the wet season and much less in the dry. The demand line should touch only one point on the run-off curve as shown. The desirable amount of storage is shown on the graph. It is the greatest distance between the demand line and the run-off curve. This amount of storage should be provided to ensure that water is available throughout the year at this level of consumption.

In this example, the yearly demand for water is 31000 liters, and average of approximately 2600 liters per month, or 87 liters per day per family. In order to supply a family with 87 liters per day throughout the entire year, a cistern or storage jar with a 16.5-17m^3 (16500 -17000 liters) capacity would be needed. Unless inexpensive ferrocement storage jars are constructed, the construction of a

Table 2. Potential Monthly Available Supply of Water

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (liters)	8678	7219	6643	1766	96	0	0	192	192	1574	4992	8294	39646

This data appears in graphical form in Figure 2.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

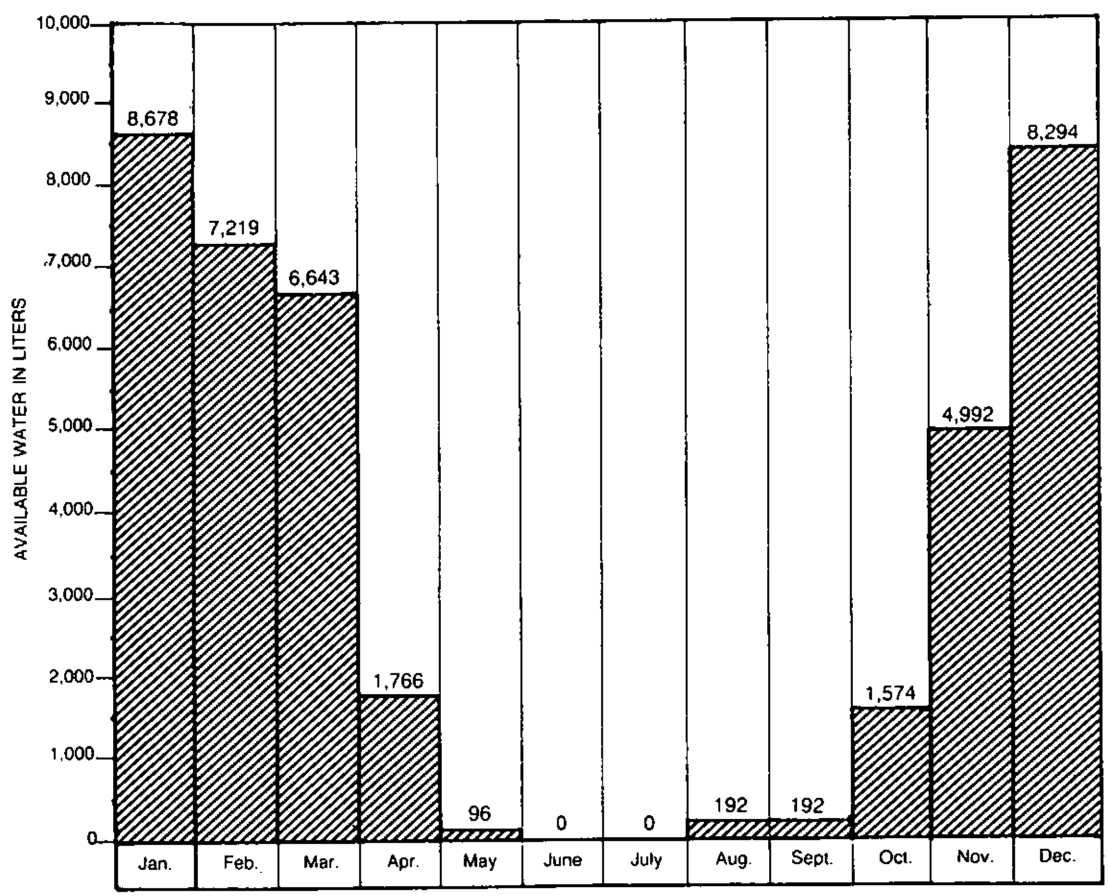


Figure 2. Available Monthly Water Supply in Liters

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall (millimeters)	226	188	173	46	2.5	0	0	5	5	41	130	216	1,032.5
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

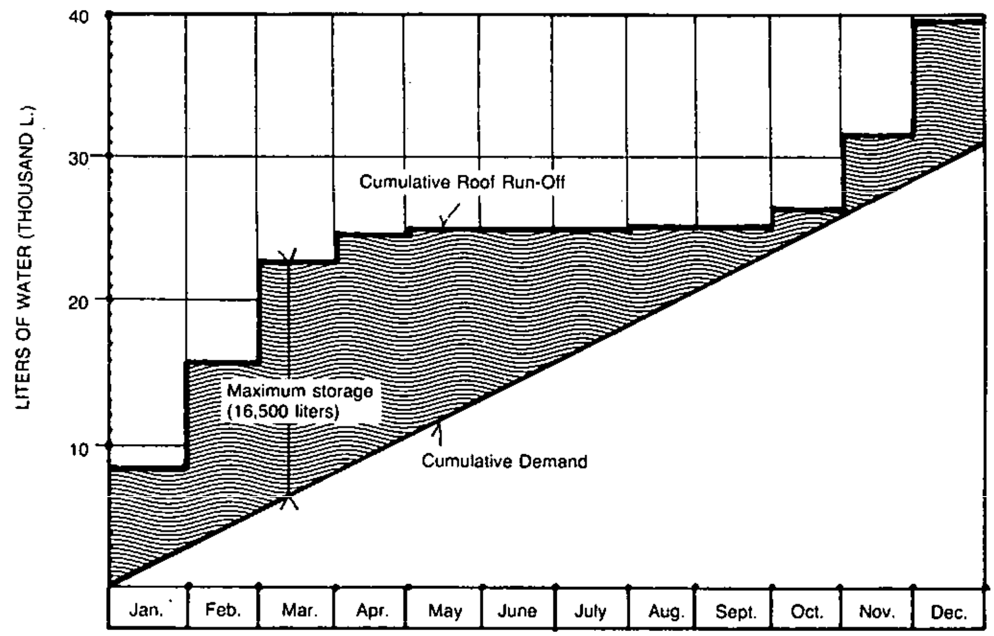


Figure 3. Determining Maximum Storage Capacity

cistern of such a large volume would be beyond the means of most families. A smaller structure would be designed instead. With a smaller cistern, water use during the dry season would have to be restricted to the essential minimum of drinking and some cooking.

Ideally, cisterns and storage jars should be large enough to store water for the entire year. Where economic conditions prevent this, special measures, like the use of storage jars, should be taken. Water should be collected during the rainy season and stored for use during the dry season. Special care should be taken to prevent water loss through evaporation. When planning a cistern or storage reservoir, attempt to build a cistern either of adequate volume or as close to the desired volume as economic resources permit. This is necessary when no other water source of suitable quantity, quality, accessibility or reliability is available.

Ground and Surface Water Storage for Distribution Systems

Storage of surface and ground water is necessary to provide sufficient quantities of water to the users. In some cases, a storage reservoir is not needed. When hand dug wells are installed in villages and water is extracted by buckets or hand pumps, no storage other than what the well holds is necessary. Where reservoirs are formed by dams, water sometimes can move from the reservoir to the users with no further storage. Usually, some sort of storage is required in systems where water is piped to the users.

To ensure that adequate storage capacity is provided, proper planning of the storage reservoir is necessary. The following factors should be considered in determining required storage capacity:

(1) Population served by the system taking into account population growth.

(2) Total daily demand for water in the community. This is found by multiplying the population to be served by the daily per capita consumption. Special consideration has to be shown for peak demand periods.

(3) Hourly demand and peak hour demand.

(4) The length of operation of the pump each day.

In planning for a water system and sufficient storage capacity for it, the number of people to be served should be determined. It is best to plan for a system that will operate effectively for 20 years. If a community has a present population of 1535 people who will be served by the system and the population growth is estimated at 2.5 percent per year, use Table 3 to determine the population in 20 years.

Table 3. Population Growth Factors

Design Period Years	Yearly Growth Rate (%)					
	1.5	2	2.5	3	3.5	4
7	1.1	1.15	1.19	1.23	1.27	1.32
10	1.16	1.22	1.28	1.34	1.41	1.48
15	1.25	1.35	1.45	1.56	1.68	1.80
20	1.35	1.49	1.64	1.81	1.99	2.19

Multiply the present population, 1535 in this example, by the population growth factor located in the row marked "20 years" under the column for a 2.5 percent yearly growth rate. This gives 1535 x 1.64 = 2520. The volume of the storage reservoir should be calculated assuming a population of 2520 people.

Next, the amount of water per day consumed by the population should be calculated. Assume that the average per capita daily consumption is 40 liters. Per capita water demand is:

Total consumption = Per capita consumption x population =
40 liters x 2520

Total consumption = 100800 liters per day.

To find hourly demand, use the following formula:

$$\text{Hourly demand} = \frac{100800 \text{ liters/day}}{24 \text{ hours}}$$

Hourly demand = 4200 liters per/hour.

The peak hourly demand generally occurs in the morning with a second smaller peak later in the afternoon. The peak demand ranges between four and five times the hourly demand.

The length that the pump is in operation should be determined. In some cases, the pump may work for a few hours in the morning and a few in the afternoon or it may be operated contlnously for eight to ten hours. Assuming 10 hours continuous pumping between 7:00am and 5:00pm, the pumping rate necessary would be 10080 liters/hour. From this information and the data on water demands as a percentage of the average hourly consumption rate, the required storage capacity can be determined. Table 4 shows a way to collect this information and determine the required storage. Figure 4 shows how this can be done graphically.

The storage capacity required is the sum of the excess supply of water after the pumping stops at 5:00pm, 32500 liters, and the maximum volume required during the morning. This volume is 13650 liters at 7:00am. The total storage required is 32550 + 13650 = 46200 liters or 46.2m^3. The same figure is arrived at graphically by looking at the distance between point A and point B on Figure 4.

In Figure 4, a diagonal line is drawn marking a continuous 24-hour pumping rate of 4200 liters per hour. Line PQ represents a pumping rate of 10800 liters per hour for ten hours. The curved line is the cumulative demand for water. To determine the storage capacity, draw a perpendicular line from the point at 7:00am (point Q) to the cumulative demand curve. From that point, draw a line parallel to PQ extending it to the vertical line at 17 hours, 5:00pm. Where this line ends is point A. Then draw a straight line

Table 4. Determining Storage Requirements

Daily Demand = 100800 liters

Average Hourly Demand = $\frac{100800 \text{ liter}}{24 \text{ hour}}$ = 4200 liters/hour

1	2	3	4	5	6	7
Time (hours)	Hourly Demand in Liters	Hourly Demand as % of Average Hour*	Cumulative Demand (liters)	Supply from Pump (liters/hour)	Supply Minus Draft Liters (5 - 2)	Storage Variation (liters) (6 + 7)
0-1	1050	25	1050	---	-1050	-1050
1-2	1050	25	2100	---	-1050	-2100
2-3	420	10	2520	---	-420	-2520
3-4	420	10	2940	---	-420	-2940
4-5	630	15	3570	---	-630	-3570
5-6	2520	60	6090	---	-2520	-6090
6-7	7560	180	13650	---	-7560	-13650
7-8	9660	230	23310	10080	420	-13230
8-9	4200	100	27510	10080	5880	-7350
9-10	4200	100	31710	10080	5880	-1470
10-11	5040	120	36750	10080	5040	+3570
11-12	6300	150	43050	10080	3780	+7350
12-13	6300	150	49350	10080	+3780	+11130
13-14	6300	150	55650	10080	+3780	+14910
14-15	5040	120	60690	10080	+5040	+19950
15-16	3780	90	64470	10080	+6300	+26250
16-17	3780	90	68250	10080	+6300	+32550
17-18	7770	185	76020	---	-7770	+24780
18-19	7140	170	83160	---	-7140	+17640
19-20	6300	150	89460	---	-6300	+11340
20-21	3780	90	93240	---	-3780	+7560
21-22	3150	75	96399	---	-3150	+4410
22-23	2310	55	98700	---	-2310	+2100
23-24	2100	50	100800	---	-2100	0

*Precentages are estimated averages.

**The storage capacity required is the sum the excess available at the end of the pumping period (32,550 liters) and the maximum volume during the morning hours (13,650 liters) or 32,550 + 13,650 = 46,200 liters.

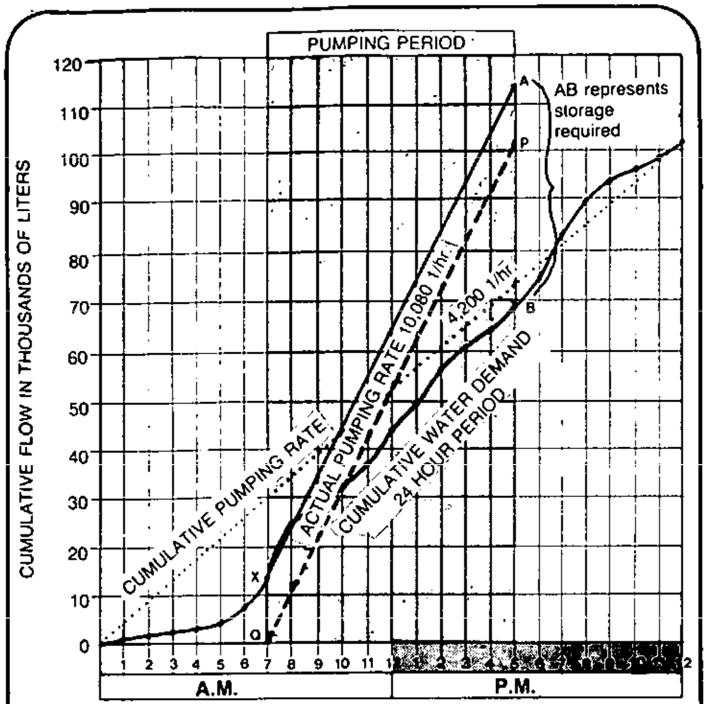


Figure 4. Determining Storage Requirements

from A through P to the cumulative demand curve, point B. The line AB represents the storage required, which is 46200 liters, or 46.2m³. When designing the storage tank, some extra capacity can be included. In this case, a storage reservoir with a capacity of 50000 liters, 50m³, would be appropriate.

Summary

Most water systems should have storage so that people can depend on a sufficient quantity, a certain quality and improved access and reliability. When rainwater roof run-off is used, storage is always necessary. For surface and ground water, either storage is provided for at the source or a storage reservoir must be constructed. Most water distribution systems rely on man-made storage reservoirs.

The most important factor in planning for the use of storage is determining the capacity of the reservoir. Capacity should be sufficient to adequately meet all water needs of the users throughout the year. The minimum goal should be to provide sufficient storage to at least meet basic drinking needs and minimal washing and cooking needs. Given scarce resources, these minimal needs may be all that can be met. When determining storage needs, follow the procedures outlined in Worksheet A.

It is desirable to project a storage capacity to meet needs caused by future population increases and water demand increases. In this example, 20 year future increase have been used. This requires a substantial commitment of money and materials. This may not be possible because funds are not available or the money may be needed for more immediate community needs. A careful review will help to make the best engineering and management decision. In any event, storage sites and facilities can be designed and built so that future expansion can be made readily and with least cost.

Worksheet A. Determining Water Storage Requirements

Identify water supply source ____________________

1. If rainfall roof catchment, determine:

   a. area of catchment ____________________

   b. number of people to be served ____________________

   c. materials available for cistern or storage tank construction __________

   d. economic resources of family ____________________

   e. capacity of storage reservoir from Figures 1, 2, 3 ____________________

2. If a ground water source:

   a. identify type of well--dug, bored, drilled ____________________

   b. determine best method of extraction--hand pump, windmill, fuel or electric pump ____________________

   c. determine well yield and well storage capacity ____________________

   d. find out how many people use the source for water supply and whether storage is sufficient to meet demand ____________________

   e. if there is a community well with a pump serving people who must carry water, evaluate whether a distribution system or public stand posts would most benefit the community ____________________

   f. evaluate whether the community has sufficient resources to install some sort of storage ____________________

   g. determine storage capacity required using the methods described in this technical note and demonstrated in Table 4 or Figure 4 ____________________

   h. choose the appropriate storage method for the community given resources and available materials ____________________

3. If a surface water source:

   a. identify the supply source ____________________

   b. determine the number of uses and calculate demand for water using 40 liters per capita per day ____________________

   c. determine whether sufficient storage is already provided; for example, a dam and reservoir may hold sufficient water to meet demand __________

   d. determine whether storage is necessary or how much storage is required, using Table 4 or Figure 4 ____________________

   e. choose the most appropriate design given available materials and resources, needs and topographical features ____________________

Water for the World

Constructing a Household Cistern

Technical Note No. RWS. 5.C.1

Well constructed cisterns play an important role in providing families with an accessible supply of potable water. Cisterns and storage jars constructed of locally available materials offer improved access to water supply in many areas where good supplies are limited. They also provide a means of controlling the water quality.

This technical note describes construction steps for building reinforced concrete cisterns, ferrocement tanks, and medium and large reinforced mortar storage jars. The steps discussed are offered as guidelines and can be changed to fit local needs and situations. Before attempting the construction of any cistern, seek advice and assistance from people experienced in working in concrete and ferrocement construction.

Useful Definitions

FERROCEMENT - An economical and simple-to-use type of reinforced concrete made of wire mesh, sand, water and cement.

VOIDS - Empty spaces; open areas between particles or substances.

Materials Needed

Before beginning the construction process, be sure to have the following items:

1. A plan of the cistern showing the design and dimensions as shown in Figure 1.

2. A list of materials, tools and other supplies needed to complete the job. Similar to the list in Table 1 or 2. All materials should be available before construction begins in order to avoid delays.

Table 1. Sample Materials List for a Reinforced Concrete Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers	____	____
Supplies	Portland cement	____	____
	Clean sand and gravel	____	____
	Clean water for mixing cement	____	____
	Reinforcing rods	____	____
	Screened mesh	____	____
	Boards and plywood for forms	____	____
	Nails	____	____
	Old motor oil or lubricant for forms	____	____
	Galvanized pipe for overflow	____	____
	Tap for outlet	____	____
	Guttering	____	____
Tools	Shovels and picks	____	____
	Measuring tape	____	____
	Hammers	____	____
	Saws	____	____
	Carpenter's square	____	____
	Pliers	____	____
	Wire cutters	____	____
	Mixing bin, mortar box	____	____
	Buckets	____	____
	Trowel	____	____
	Adjustable wrench	____	____
	Screw drivers	____	____
	Paint brush	____	____
	Level	____	____

Total Estimated Costs = ____

Table 2. Sample Materials List for a Ferrocement Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers	____	____
Supplies	Portland cement	____	____
	Plain wire, 2.5mm	____	____
	Chicken mesh, 1m wide	____	____
	Water pipe	____	____
	Water tap	____	____
	Overflow pipe	____	____
	Galvanized iron sheet and angle iron	____	____
	Sand	____	____
	Gravel	____	____
	Bolts	____	____
	Water	____	____
Tools	Shovels and picks	____	____
	Wire cutters	____	____
	Wrenches, adjustable and open	____	____
	Screw drivers	____	____
	Paint brushes	____	____
	Trowels	____	____
	Mixing bin, mortar box	____	____
	Wheelbarrow	____	____
	Buckets	____	____
	Hacksaw and blades	____	____
	Hammers	____	____

Total Estimated Cost = ____

Construction Steps for a Reinforced Concrete Cistern

Follow the construction steps below. Refer to the appropriate diagrams during the construction process.

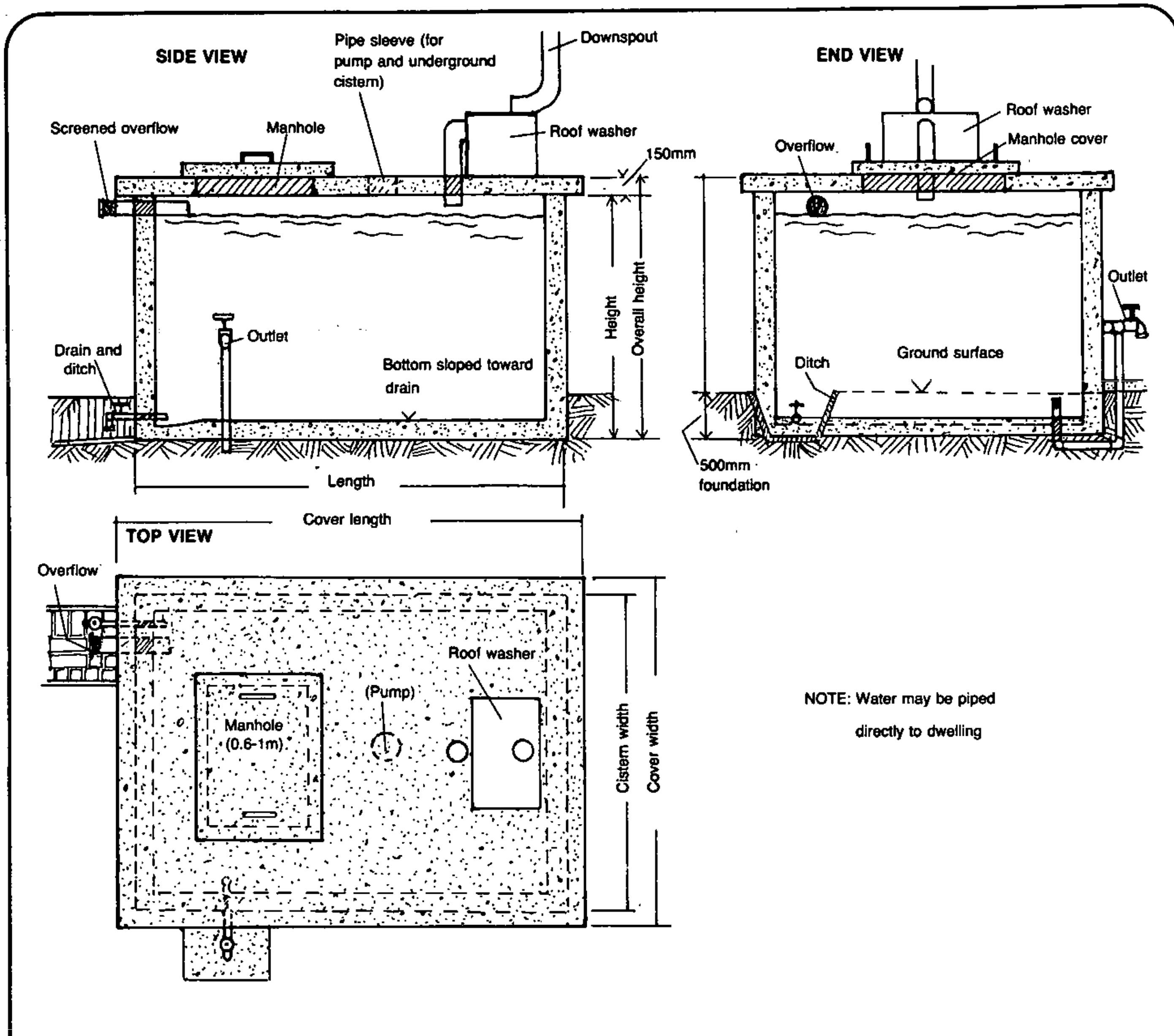


Figure 1. Plan for Household Cistern

1. Find the best location near the house to build the cistern. It should be located on high ground for good drainage and should not be located closer than 15m to the nearest waste disposal site. Once the site is located, mark it out using a measuring tape, wooden stakes and cord, as shown in Figure 2.

2. Dig out a base in the ground to fit the dimensions of the cistern. The hole should be only 50-100mm deep. This will allow installation of an outlet near the bottom of the cistern to take advantage of the entire volume of the cistern. Level the excavated area using flat-nosed shovels and scrapers made from wood.

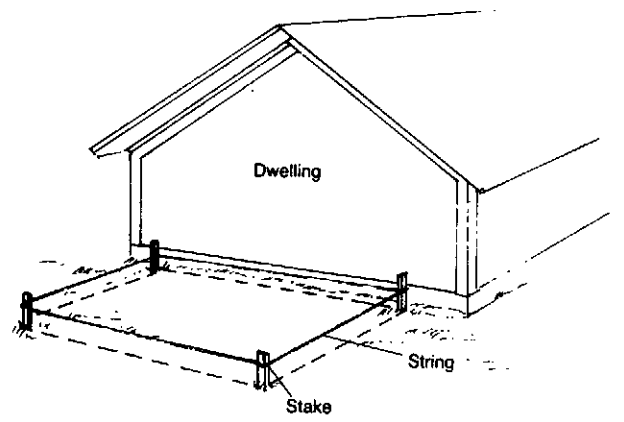


Figure 2. Marking Cistern Site

3. Prepare the forms for the structure. Use plywood sheets, if available, for the faces and small pieces of wood for bracing. All formwork for the cistern should be completed before any concrete is poured.

• Nail all forms together to the design size of the cistern. Walls should be 200mm thick.

• Brace the forms well. Place small holes in the forms and slide wire through them. At the end of each piece of wire, attach a stick to hold the wire in place. Then tighten the wire to create enough pressure to withstand the force of the poured concrete. See Figure 3. Dirt should also be piled up against the outside of the walls to give them support against the weight of the concrete.

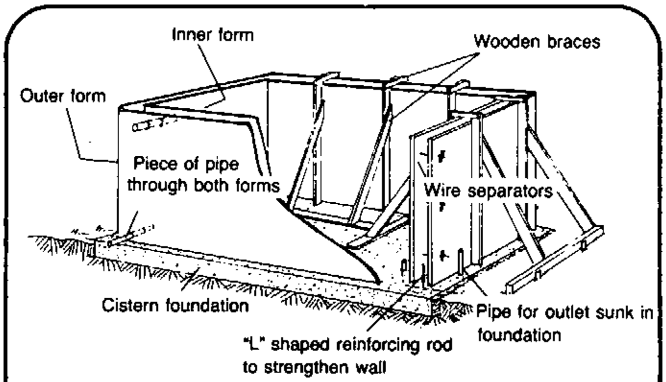


Figure 3. Forms for Cistern Walls

• Place reinforcing rods in the forms. For best results, lay the rod for the floor in a grid pattern as shown in Figure 4. The cross bars should be long enough to cross the entire length of width of the floor and extend at least 300mm into the wall. The reinforcing rods should be bent to fit into the wall forms to a height of 300mm. Other lengths of rod are then tied with these lengths to complete the installation of the reinforcing rod.

This technique is recommended to provide a solid connection between the wall and the floor. Figure 4 demonstrates the placement of reinforcing bars in concrete. The steel bars should be separated 150mm with the first cross bar laid 75mm from the edge of the pour. The bars should be placed one third of the distance from the outside or, as in the example given, about 70mm in from the outside edge.

4. Make holes in the form for placement of the overflow and outlet pipes. The pipes should be placed directly in the forms when pouring the concrete to ensure a good pipe installation.

5. Oil all forms before pouring concrete. Use old motor oil or other available lubricant to prevent the concrete from sticking to the forms.

6. Formwork and steel bar placement for the cover follow the same procedures as outlined above. After forms are complete, mix the cement, sand and gravel in a 1:2:3 ratio adding 23 liters of water for each bag of cement. These proportions will ensure a thick paste.

Pour the floor and about 200mm up the side of the wall in the first pour. Tamp down the cement with steel rods and shovels to make sure that all voids are filled. Once all reinforcing rods are attached, finish the pour, tamp the mixture well and smooth all surfaces.

Cover the concrete with canvas, burlap, empty cement bags, plastic or other protective material to prevent loss of moisture. Keep the covering wet so the concrete does not become dry and crack. When pouring the cover, be sure to leave an opening for access to the cistern. The opening should be fitted with a cover which either can be locked or is difficult to remove.

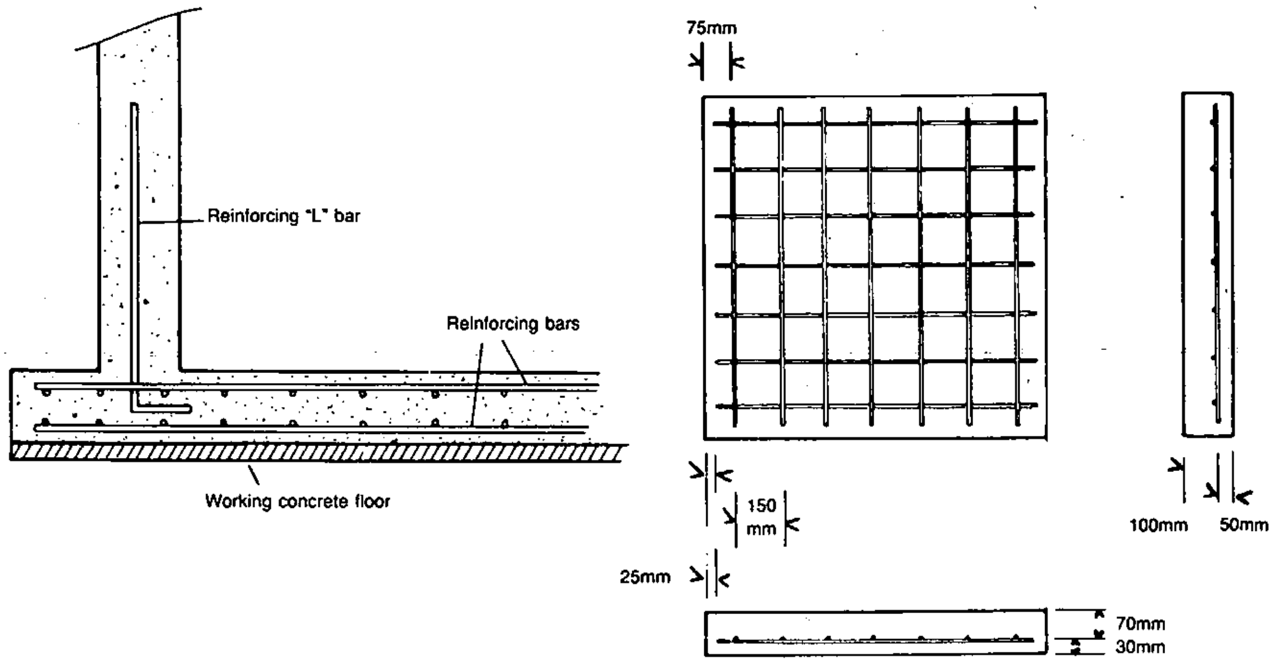


Figure 4. Placement of Rebar in Foundation and Walls

Reinforced concrete cisterns can be built underground. They are usually equipped with hand pumps for extraction of the stored water. To build an underground cistern, follow the same basic construction steps for above-ground cisterns. Make sure that the walls extend at least 300mm above the ground surface. A tight fitting cover with an access opening and a small base for a hand pump should be cast.

Other Types of Cisterns

Brick and masonry tanks can be used for rainwater storage. Skilled workers should construct them. Keep the following points in mind when constructing a masonry or brick tank:

- Make all walls at least 300mm thick.

- For shallow tanks, the walls can be built on the floor. For deep tanks, over 1.5m, a concrete footing or foundation built below the base should be constructed.

- Line the inside of the cistern with two layers of mortar each 10mm thick to prevent leaks. The mortar, and all mortar used in the construction process, should contain cement and sand in the proportion 1:3.

Ferrocement cisterns are generally circular in shape and made with locally available materials. Some experience and skill are needed. The construction steps described below are for relatively large capacity cisterns, about $10m^3$. Both smaller and larger cisterns can be constructed following the general construction guidelines.

1. Measure and stake out a circular area 2.8m in diameter. A easy way is to drive a stake into the ground at the center and attach to it a length of rope 1.4m, the radius. Tie a stick or pointed object to the other end and trace the circle on the ground. Dig out a base 300mm in the ground.

2. Place a 100mm layer of sand and gravel over the excavated area, and then a 75mm layer of concrete on top of this. Use a concrete mix of 1:2:4, cement: sand: gravel.

3. Before the concrete sets, cast a 1m length of 20mm steel pipe into the foundation, as shown in Figure 5. This will be the outlet. The pipe should extend 80-100mm above the tank floor, high enough above the ground on the outside of the tank to allow a bucket or ceramic container to sit underneath. A tap will be placed on the pipe when construction is completed.

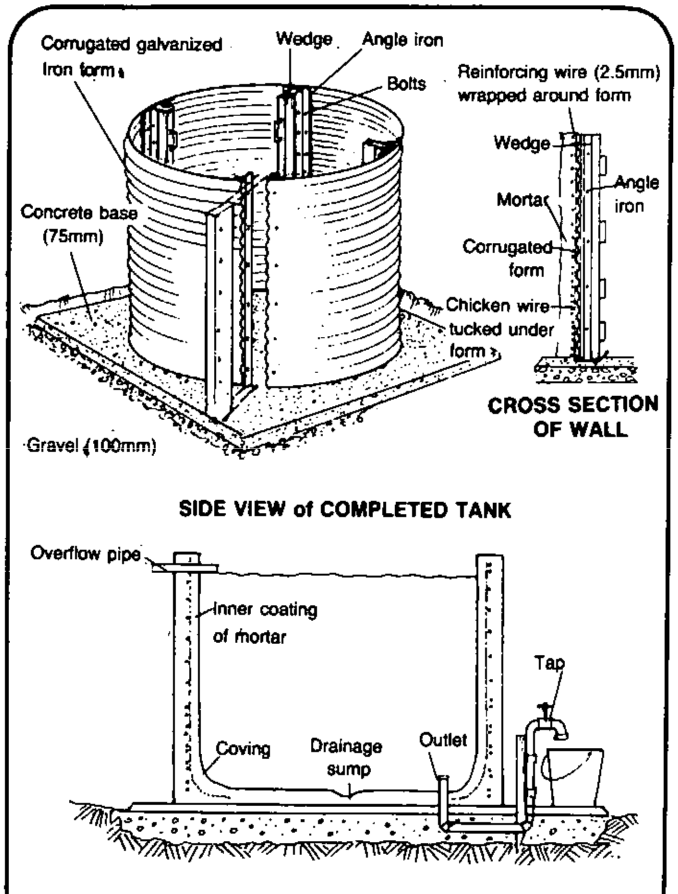


Figure 5. Ferrocement Cistern Construction

4. When the floor hardens, build the formwork for the tank. See Figure 5 for details on formwork preparation. Use 16 sheets of galvanized roofing iron 0.6mm thick. Place four sheets together to form four sections. Bolt the sections to angle iron verticals to form a circle. The steel angle iron, 40mm x 40mm x 5m, is bolted vertically on the inside face at the ends of each set of sheets. Place a wedge between the ends of each section. The wedge can be pulled out to dismantle the forms. Wood can be used for forms. A design similar to that shown in Figure 6 is useful in many areas. This design is especially good where materials such as roofing metal is not available.

5. Clean the forms, removing any dirt, and oil them. Then wrap 50mm wire mesh, chicken wire, around the forms. The netting should be wound around to a single thickness and tucked underneath the forms to hold it in place. The mesh provides vertical reinforcement and keeps the straight wire out of the corrugation.

6. Wrap 2.5mm straight galvanized iron wire tightly around the formwork starting at the base. Use the following spacings:

- two wires in each of the first eight corrugations from the bottom,
- one wire in each remaining corrugation except for the top one,
- two wires in the top currugation.

7. Plaster the outside of the forms with a layer of mortar that covers the wire. The mortar mix should be 1:3, cement:sand. When this layer begins to harden, trowel on mortar to cover the wire with a layer 15mm thick. Give the mortar a smooth finish.

8. Take apart the forms after the mortar has set for two or three days. Remove the holding bolts and wedges so that the forms are easily removed.

9. Place an overflow pipe 200mm long and about 80mm in diameter at the top of the tank. Then to finish the cistern, plaster the inside to fill in the corrugations. When this mortar dries, trowel on a final coat.

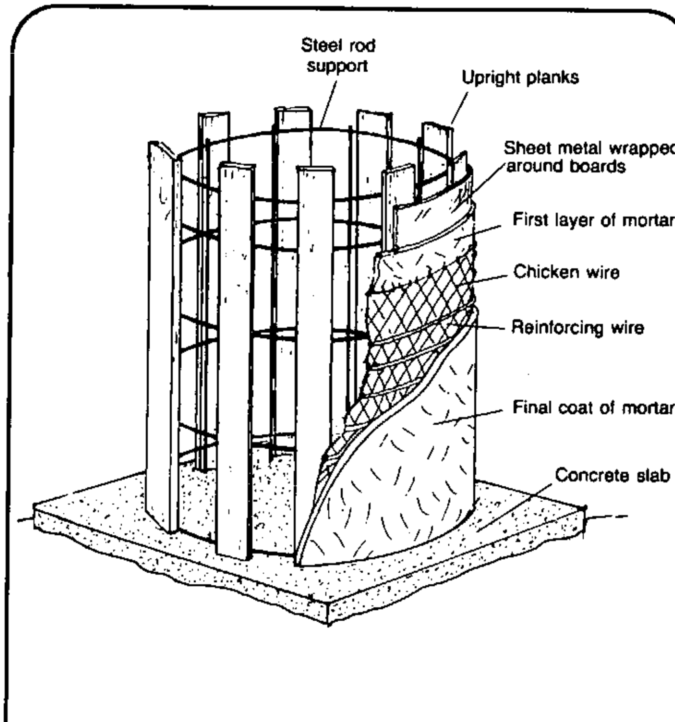


Figure 6. Ferrocement Tank Using Wooden Forms

10. Finally, place a 50mm thick layer of mortar on the floor of the tank. Before the mortar stiffens, make a shallow depression in the middle of the floor to act as a sediment trap for tank cleaning. Sediment can be swept into the sump and removed with a cup.

Roof Structures

Install a roof on the cistern to prevent the evaporation of water, the growth of algae and contamination by rubbbish, insects or rodents. A choice of two roof structures is possible as shown in Figure 7. Figure 7a shows a shell roof built of wire-reinforced mortar between 3-5mm thick. The structure is cast continiously with the walls. After the tank has dried for two days, lay mortar onto shaped formwork made with two layers of wire mesh supported from below by boards. Tie the wire mesh onto the mesh extending from the walls. Install an iron frame to form an access opening in the roof. Remove the frame after construction is completed. Trowel in a layer of mortar and allow three days for curing. After three days, or when the roof is strong enough, take off the formwork and trowel a layer of mortar onto the underside of the tank. Figure 7b shows a completed roof of this type. Let the roof cure for at least seven days. Keep the surfaces moist during the curing process.

Figure 7c shows a more traditional roof structure made from wood. Attach lightweight roofing such as a sheet aluminum or galvanized iron with wire. Screen any open areas between the tank and the roof to prevent the entrance of insects and debris.

Unreinforced Mortar Storage Jars

Unreinforced mortar storage jars can be constructed by people with little or no previous experience. The jars are an inexpensive and relatively easy way to store rainfall for drinking water. Small, 25m^3 capacity, as well as larger 4m^3 jars can be built following the basic construction steps given below. This example is for a 4m^3, 4000-liter, storage jar like the one shown in Figure 8.

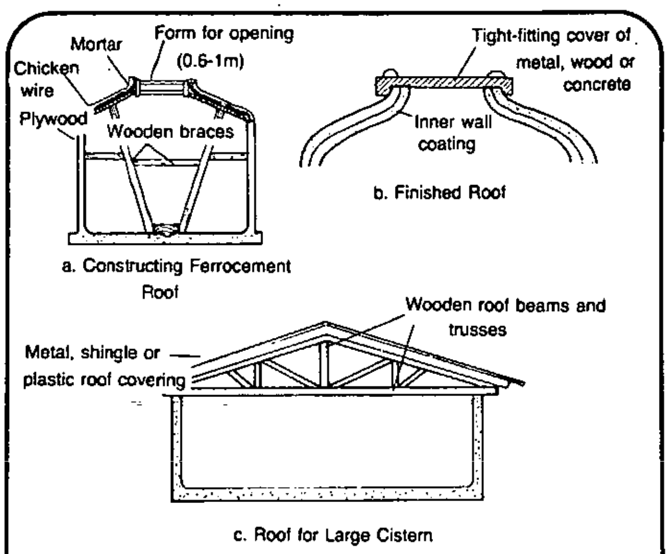


Figure 7. Cistern Roofs

1. The first step in the construction process involves preparation of the mold. Place two pieces of gunny cloth together and mark them out as shown in Figure 8. The bottom width should be marked at 1.2m and the top width at 2.0m. Draw a curved line along the sides connecting the top and the bottom and sew the sack together with heavy tread or twine. The sack height should be 1.7m.

2. Make a precast mortar bottom plate 1m in diameter and 15mm thick. To make forms for the plate, mark out a circle on the ground using a nail as a midpoint and a piece of twine 0.5m long. Trace the circle and lay half bricks or other suitable material around the outside of the circle to act as a form. Place paper, an empty cement bag or other material on the ground within the circle so the mortar does not stick to the ground. Make a mortar mixture of 1:2, cement:sand.

3. Once the bottom plate dries, place the sack narrow end down on the plate and begin filling it with sand, sawdust or rice husks. The weight of the filling material will hold the sack on the plate. Make sure the mortar base sticks out from under the sack, as shown in Figure 8.

4. Completely fill the sack, then fold the top and tie it into the desired shape. With a piece of wood, smooth and round out the jar. When the jar is in the final form spray it with water to completely dampen it.

5. Place a circular ring on the top of the sack to make an opening for the jar. The ring can be made from wood, precast mortar or other suitable material.

6. Begin placing a layer of mortar on the jar. The mortar should be about 5mm thick. Apply another 5mm layer of mortar, checking the thickness by pushing a sharp object like a nail into the side. Be sure to build up any thin spots and add mortar to weak places. Finally, build up the jar thickness and shape as shown in Figure 8. Place a small tap near the bottom of the jar.

7. Twenty-four hours after the jar is constructed, remove the contents of the sack. This operation is easier for small jars. When the jar is empty, check for defects and make any necessary repairs. Paint the inside with a wet mortar mix and then cure the jar outside for two weeks. For best results, cover the jar with damp sacks or plastic sheeting during the curing process.

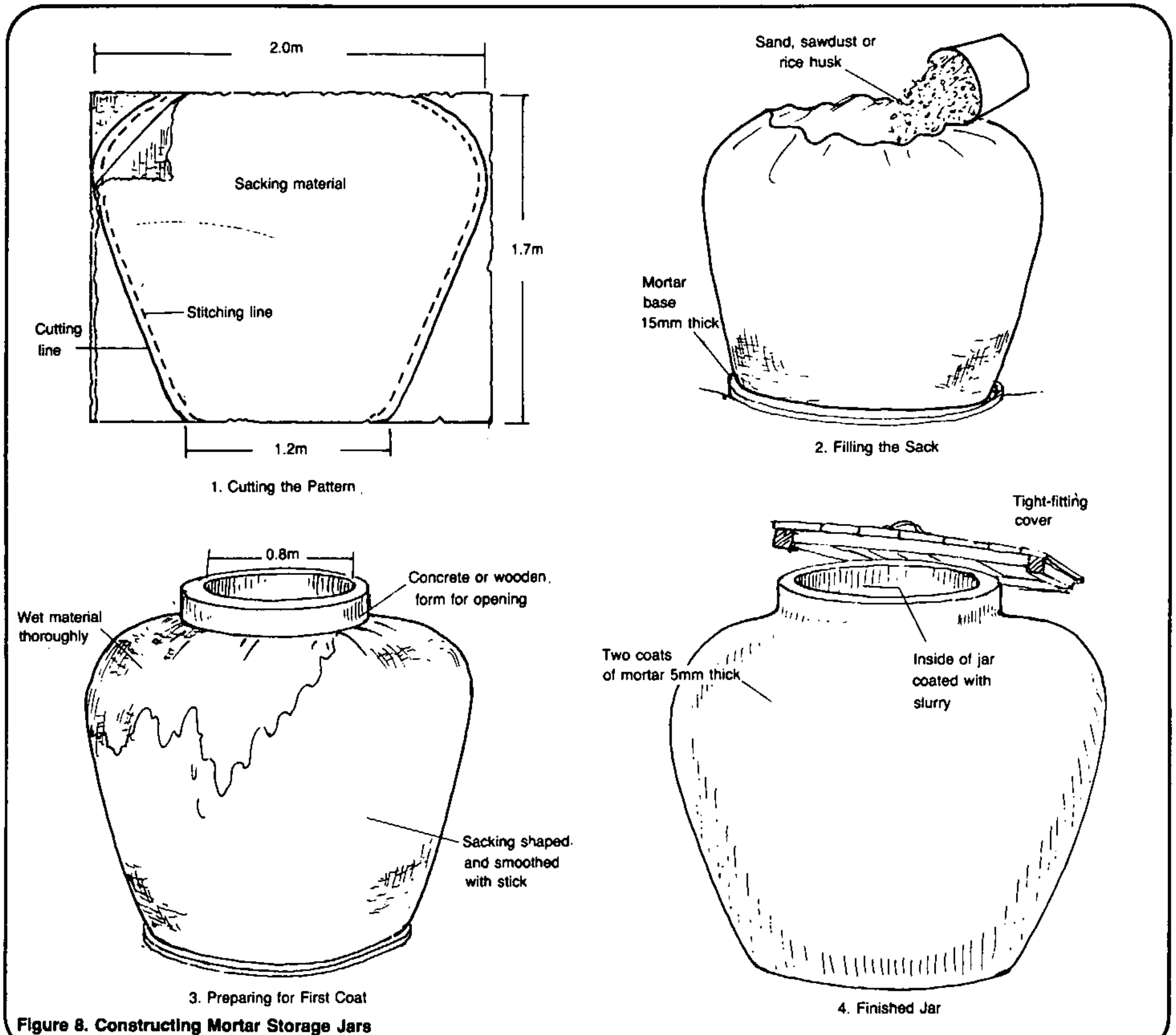


Figure 8. Constructing Mortar Storage Jars

Notes

Water for the World

Constructing a Ground Level Storage Tank
Technical Note No. RWS. 5.C.2

For effective water storage and water system operation, ground level storage tanks should be built for sufficient, and even excess, capacity and must be watertight to prevent leakage.

This technical note discusses the basic steps to follow in constructing a ground level storage tank. The actual construction process and materials used will differ with each situation or area. The construction of all storage tanks should be supervised by experienced builders or masons and, whenever possible, engineering assistance should be sought.

Useful Definition

ALGAE - Tiny green plants usually found floating in surface water.

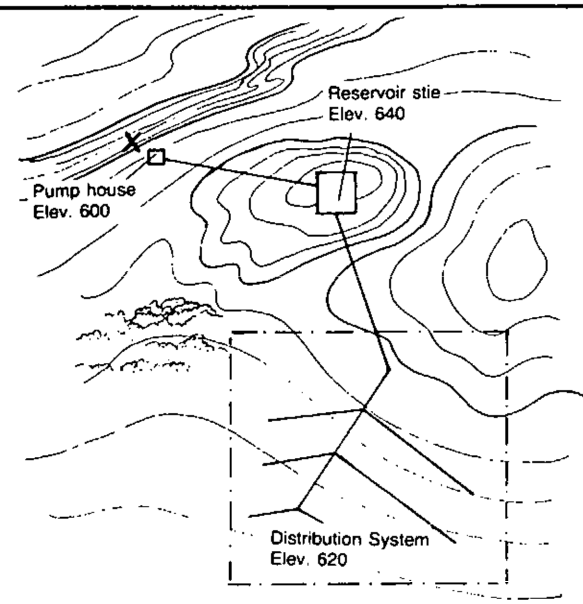


Figure 1. Location Map

Materials Needed

Before construction begins, the project designer should give you the following items:

1. A map of the area including the location of the reservoir, the distribution system, location of users, houses and elevations. Figure 1 is an example of a map showing these reference points.

2. A list of all labor materials and tools needed similar to that shown in Table 1. Ensure that all needed materials are available and at the work site before work begins to prevent construction delays.

3. A plan of the reservoir with all dimensions as shown in Figure 2. This plan shows a top, side and end view.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman		
	Laborers		
Supplies	Portland cement		
	Clean sand and gravel		
	Clean water		
	Reinforcing rod		
	Pipe for inlets, overflow and drain (PVC or steel)		
	Screening and wire mesh for pipes		
	Boards and lumber for forms		
	Lubricating oil		
	Rocks, if masonry tank		
	Float valve (if needed)		
	Cut-off valves		
	Lock for manhole cover		
	Iron for steps in tank		
	Lumber and rafters, if wooden tank		
	Cover structure		
	Shingles		
	Plywood		
	Rope or string		
	Nails, tie wire		
Tools	Shovels, picks and other digging tools		
	Measuring tape		
	Plumb tool		
	Hammer		
	Saw		
	Buckets		
	Carpenters square		
	Level		
	Mixing bin or machine		
	Pipe wrench		
	Adjustable wrench		
	Trowel		
	Hoe		
	Wheelbarrow		
	Sieve		
		Total Estimated Cost =	

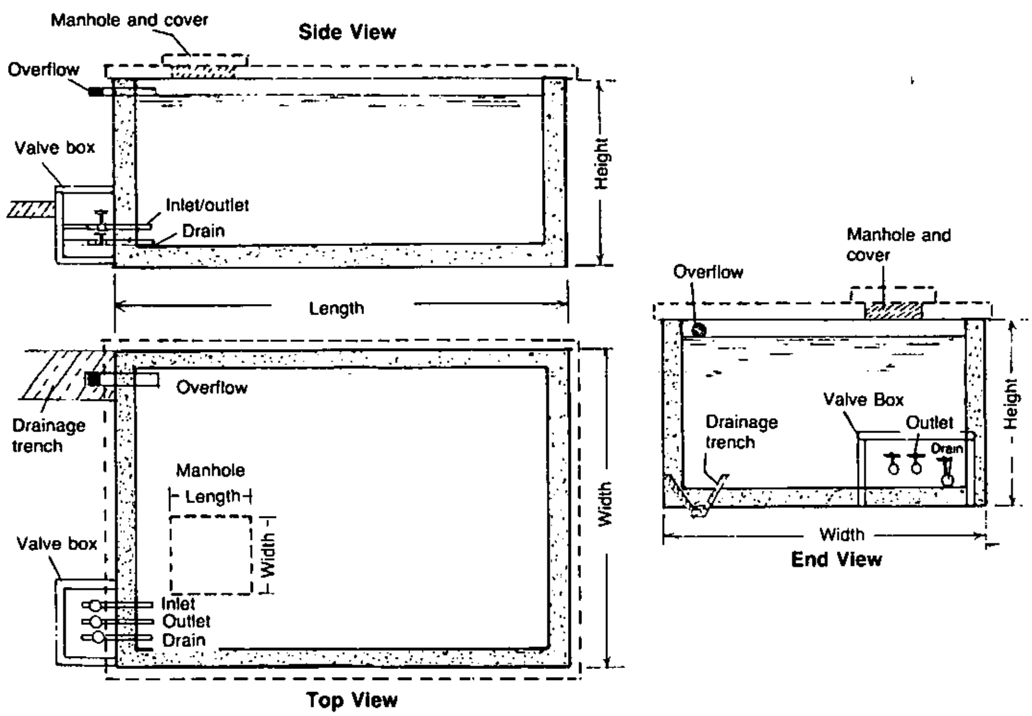


Figure 2. Storage Tank Design

General Construction Steps

Decide on the construction method to use. The reservoir can be completely built into the ground, partially in the ground, or completely above ground. Choice of the construction method will depend heavily on soil conditions and the desired height of the tank. If soil can easily be excavated, it may be best to at least partially bury the tank in order to provide support for the walls. A buried tank is effective as long as the height of the water does not fall below the minimum required to provide adequate pressure in the water system.

Follow the construction steps below. Refer to diagrams as indicated. Remember that the diagrams and construction steps are suggestions that should be adapted to local conditions.

1. Using measuring tape, cord and wooden stakes, mark out the construction site as shown in Figure 3.

2. Clean the area and begin excavation down to the level desired for the tank. If the tank is to be built above ground, or a steel tank is used, then a shallow excavation which serves as foundation should be sufficient. For deeper excavations, walls can be excavated to slope or be built in a step form as shown in Figure 4. This type of design should be used when combined concrete and masonry are used as construction materials.

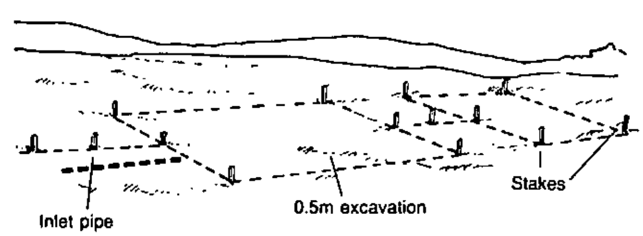


Figure 3. Stakes Marking Site of Storage Tank

Once the level for the bottom of the tank is reached, dig out the area for the foundation. For both concrete and masonry tanks, a concrete foundation and floor is recommended. Make sure the excavation is level around the entire foundation and that plans are made to slope the floor three percent.

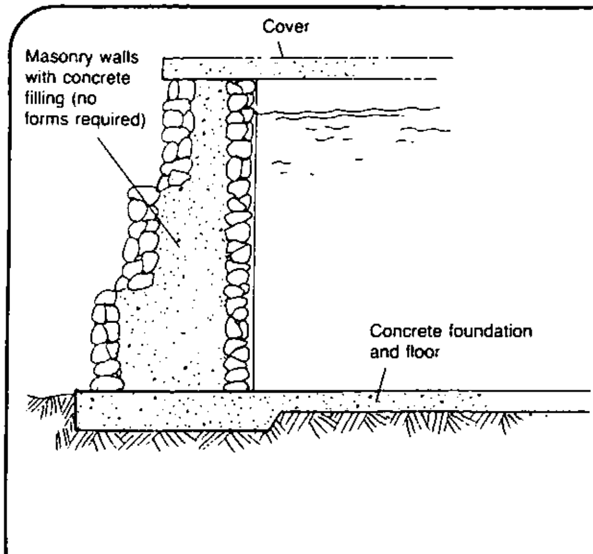


Figure 4. Example of Mass Concrete Wall Construction

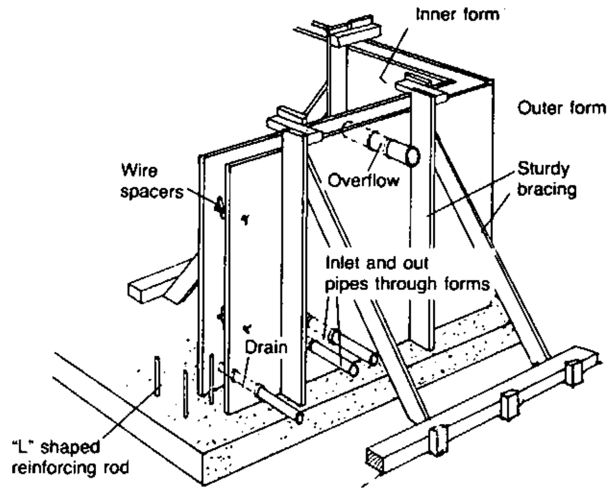


Figure 5. Detail of Forms for Walls Construction

Tank Construction

1. Once the foundation area has been dug out, begin preparing the formwork. Be sure to nail together the forms and secure them well at both top and bottom. It is especially important to brace the inside form, as the outside section will already be braced against the ground. The concrete will push out from the wall toward the inside and adequate pressure against this movement should be applied. See Figure 5.

2. Set up the reinforcing rod as shown in Figure 6. A raft foundation should be used for the structure. Install the rod so that a short length extends into the wall section. This is done by bending the rod at the base where the wall meets the floor. Before pouring the concrete:

• Make sure that all rods are tied together with wire at points of intersection;

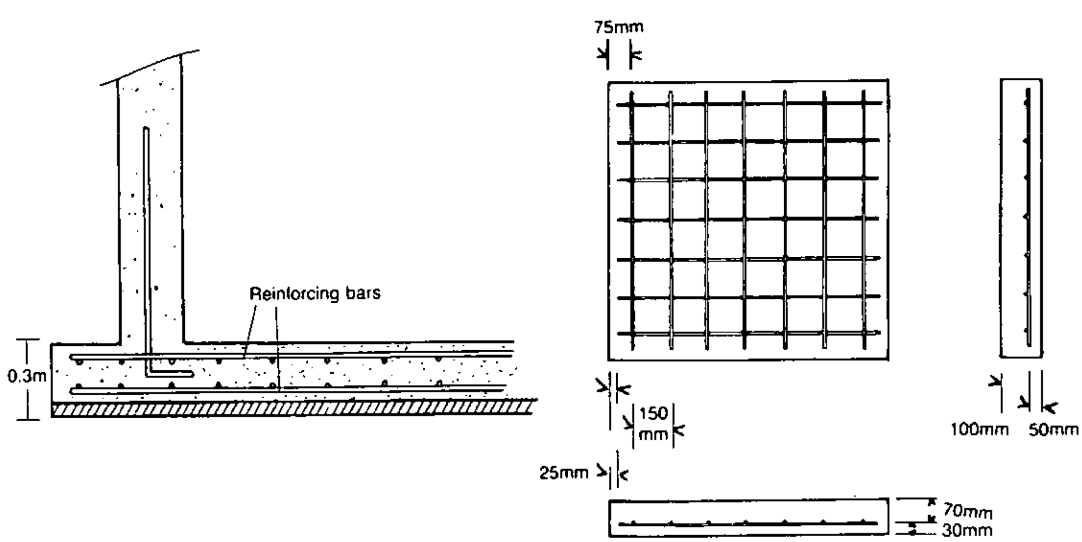


Figure 6. Placement of Rebar in Foundation and Walls

• Place small pebbles or stones under the reinforcing rod grid so that it does not rest on the ground;

• Oil the forms with a lubricant such as old motor oil;

• Cut holes and place pieces of pipe through the forms so that the intake and drain pipe can be installed.

3. Mix the cement in the proportion of one part cement, two parts sand and three or four parts gravel. Pour the entire foundation in a day so that the pour is smooth and drying is even. Smooth the top layer of cement to form the floor. At this time, build up the floor so there is a three percent slope. Hollow out a small channel for the drain pipe. The pipe should range in diameter between 40-70mm.

If structure is reinforced concrete, finish building the forms to the desired height. Remember all forms should be sturdily braced to withstand the force of the concrete. Wire placed in the forms and tightened helps in bracing. Wood braces and cross-pieces should be attached to the forms to provide adequate support. Lubricate all forms before pouring the concrete. Make a hole in the forms for a pipe ranging in size from 40-70mm in diameter. The larger the flow, the larger the pipe diameter should be. The holes in the forms should be located 150mm above the floor. Place the pipe directly into the forms before pouring. Follow the same technique for an overflow pipe. See Figure 5.

When stone masonry is used as construction material, no forms are required but skilled builders are needed. Adequate care should be taken to ensure that walls are straight (plumb) and are at least 300mm thick. A useful technique is to build the outside walls and fill the center of the wall with concrete. When building this type of structure use a step formation.

For both reinforced concrete and masonry-concrete tanks prepare a 1:2:3 or 1:2:4 concrete mixture and pour it evenly around the structure. If possible, use a portable cement mixer which will make the work move much more quickly than if the cement is mixed by hand.

Try to avoid making joints in the concrete. Leakages often occur in joints where a new layer of cement has been poured on a previous day's cement. When pouring from one day is over, leave the edge rough. The next day, clean the surface and paint over it with water and cement to form a good bond.

Once the concrete is poured, 10-14 days are needed for curing. During this time, the cement should be kept moist. A daily wetting of the structure is recommended. If cement dries too quickly, it may crack and leakage will be likely. Forms can be removed after the third or fourth day of curing. To ensure watertightness, the walls of the structure should be roughened with a trowel or a wire brush and painted with a mixture of mortar (one part cement to four parts sand).

Roof Structure

All reservoirs should be covered to prevent the entrance of contaminants, growth of algae and possible accidents. Covers can be made from reinforced concrete or lumber and shingles.

Covers cast in place are both expensive and difficult to construct. Very sophisticated formwork is needed for construction. A better method of construction using concrete is to cast sections as shown in Figure 7. Make several sections and place handles in the top so that they can be lifted into place. Construction of the slabs requires reinforcing rod and a 1:2:3 mixture of cement.

An access hole should be left in one of the covers and a lip built up to allow a cover to be secured to it. Possibly half a hole can be cut from two slabs. Once the slabs are in place, seal the joints between them with mortar to make them watertight.

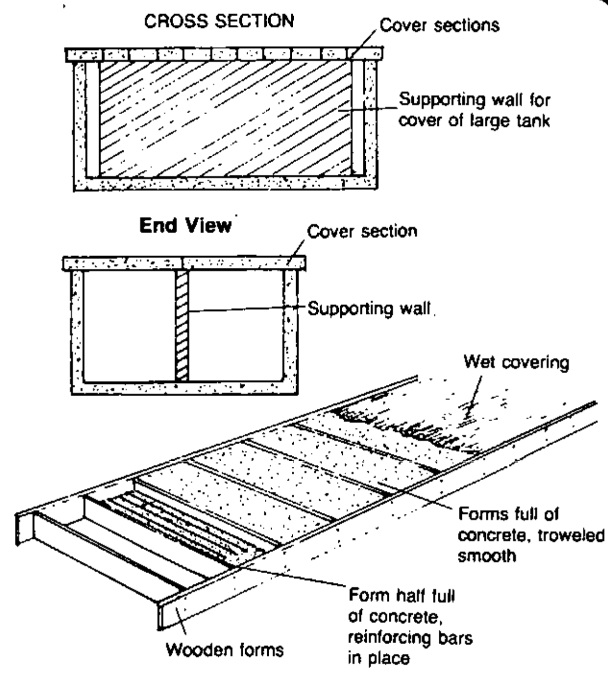


Figure 7. Casting Cover Sections

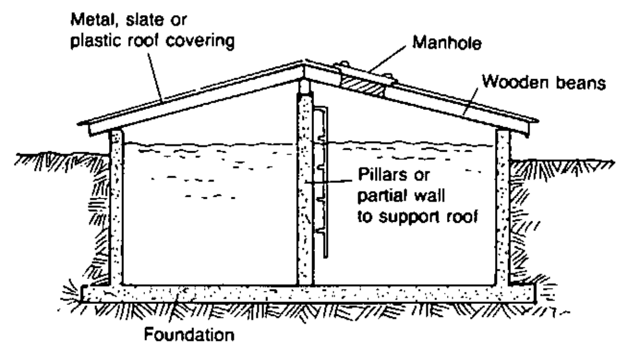


Figure 8. Cover for Large Storage Tank

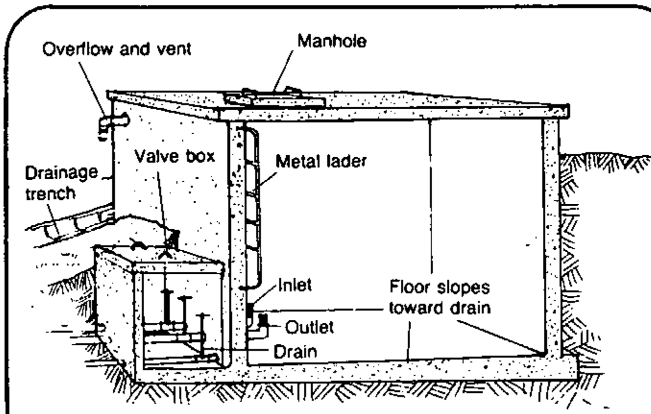


Figure 9. Ground Level Storage Tank

Another alternative is to build a roof structure as shown in Figure 8. The construction should be done by someone experienced in putting roofs on houses. The slope of the roof need not be as great as for a house but should be steep enough to allow water to run off it easily. The most important consideration is that the roof be watertight. Do not cover the roof with thatch or tile which are likely to leak. Use aluminum sheeting or slate or tar shingles for best results. Build up to the earth around the tank so that rainwater drains away from the storage area.

Valve Box

A small box to protect the valves that control inflow and outflow should be constructed at the side of the reservoir. The box can be made from stone masonry, reinforced concrete or wood. The box should have a cover and should be buried. The cover should both protect the valves and provide easy access to cut-off valves installed on the inlet and drain pipes. See Figure 9.

The valve box should be approximately 350-500mm high and can vary in length and width between 750-1500mm. Small globe and gate valves should be installed. The small box should not be difficult to construct. Construction steps can be similar to those followed for the large tank. Make sure that all valve covers are tight so that no water is wasted through leakage.

Notes

Water for the World

Designing Basic Household Water Treatment Systems

Technical Note No. RWS. 3.D.1

Basic household treatment systems are used to ensure the quality of individual water supplies that are subject to possible contamination. They are designed for supplies that cannot be included in a community treatment system due to lack of resources or distance from a central water supply. Basic household treatment systems are simple to use and relatively inexpensive. This technical note discusses the design of several simple household treatment methods useful for most water supplies. Read the entire technical note before deciding on the design that can meet your needs best.

Useful Definition

CHLORINE DOSAGE - The amount of chlorine added to a water supply for disinfection.

Hand or Batch Chlorination

Small amounts of clear, slightly contaminated water can be treated effectively by simple hand chlorination. First, you must know what type of chlorine is available and the amount of chlorine which must be added to treat the water adequately.

Find out what type of chlorine is available locally. In most rural areas, two basic types of chlorine are available for use in treatment: sodium hypochlorite and calcium hypochlorite.

Sodium hypochlorite is the main ingredient in liquid laundry bleaches. It comes in domestic and commercial strengths. The domestic strength is the most common and usually can be bought in local stores. This strength contains about five percent available chlorine but can be purchased with concentrations up to 12-15 percent. Sodium hypochlorite loses its strength gradually in two or three months after containers are opened. Calcium hypochlorite is available in powdered or tablet form and comes in strengths ranging between 30-75 percent available chlorine. A solution of 70 percent is most common. Like sodium hypochlorite, it slowly loses its strength with exposure to air. Calcium hypochlorite dissolves easily in solutions for water treatment.

To treat water prepare a one percent chlorine solution. Remember all chlorine must be stored in sealed containers in a cool dark place to retain its strength. Table 1 shows the availability of chlorine in different compounds of various strengths and the amount of each that must be mixed with one liter of water to make a one percent solution.

Table 1. Chlorine Strengths and Mixtures for a One Percent Solution

Material and Strength (percent available chlorine)	Amount of Material to Dissolve in One Liter of Water to Make a 1% Solution	
	Grams	Tablespoons (level full)
Calcium Hypochlorites		
High-Test Hypochlorite or		
Perchloron Powder (70%)	15	1.0
B - K Powder (50%)	18.6	1.5
Chlorinated Lime (35%)	37.5	2.5
Sodium Hypochlorites		
Liquid (12%)	78.2	5.5 = (1/2 cup or 120ml)
Chlorox (5%)	188.6	12.5 = (1 cup or 240ml)
Purex (3%)	307	20.5 = (2 1/4 cups or 540 ml)

To chlorinate water using a one percent solution, add three drops of the solution per liter of water or 30ml (2 tablespoons) per 145 liters of water. For example, to determine the amount of one percent chlorine solution to add to a cistern with a capacity of 500 liters, follow the steps outlined in Worksheet A.

After adding the correct chlorine dosage, wait 20 minutes or longer for the chlorine to take effect before using the water. If the water is not turbid but is colored or has a noticeable sulfur odor, the dosage should be doubled.

Chlorine is available in tablet form. When using the tablets, carefully follow all directions printed on the package to determine the correct chlorine dosage. When in doubt about the appropriate dosage, add enough chlorine to get a noticeable chlorine taste or odor.

Boiling

Water should be brought to a rolling boil rapidly for two to five minutes to destroy the disease-causing organisms in it. The amount of fuel needed to boil water depends on the type of fire, stove, and container used. An acceptable assumption is that 1kg of wood is needed to boil 1 liter of water. Water should be cooled and stored in the same container in which it is boiled. The boiled water should not be stirred or poured from one container to another in an attempt to add air and regain the taste lost by boiling. Stirring the water or changing containers may recontaminate the water.

Storage

If water is stored for several days, the level of disease causing bacteria in it is reduced. Usually, five or six days' water storage is enough to reduce the level of bacteria enough so

Worksheet A. Amount of One Percent Solution Needed for Disinfection of a Cistern

Example: Assume the cistern is 1m long, 0.8m wide, and 0.6m high.

1. Determine the volume of water that must be treated.

   Volume of a rectangular cistern: V = Length x Width x Height

   V = __1__ m x __0.8__ m x __0.6__ m

   V = __0.48__ m^3 ($1m^3$ = 1000 liters)

   V = __480__ liters

2. Determine the amount of solution to add, using 30ml of 1% solution per 145 liters of water.

   Volume of water - 145 liters = Times must add 30ml of solution

   __480__ liters - 145 liters = __3.3__
   Multiply this figure by 30ml
   __3.3__ x 30ml = __100__ ml (__0.1__ liters)

3. Divide ml by 15 to get the number of tablespoons

   __100__ ml - 15 = __7__ tablespoons or
   Multiply ml by .0042 to get the number of cups
   __100__ ml x 0.0042 = __0.42__ cups, (about one half cup or 120ml)

that people can safely drink the water. However, water quality should be checked. If water quality is poor, the length of storage should be much greater. Furthermore, certain bacteria are not affected by storage (i.e., giardia) and no length of storage will be sufficient to make water quality acceptable.

For basic four or five day storage, use two 200-liter steel barrels with spigots as shown in Figure 1. These two barrels should provide enough storage if the "treated" water is used only for drinking, cooking and minor bathing purposes. These barrels must be cleaned carefully. They may have contained oils, pesticides, chemical liquids or chemical powders. Such remains can be poisonous.

Fill both barrels and empty one completely before using water from the second. When use of water from the second barrel begins, refill the first barrel. Water from one barrel should not be used until the other barrel is empty.

To determine the amount of storage needed, multiply the number of people who will use the stored water by the average daily consumption rate. Assume that the water is used only for drinking, cooking and minor bathing purposes so that each person uses 10 liters per day. A family of six would then use 60 liters per day (6 people x 10 liters per person per day). Each 200-liter barrel would store enough water for just over three days. If less water is used, storage time will increase. Water from the second barrel will only be used on the fourth or fifth day which should be sufficient if water quality is not very bad.

If storage time in the barrels is insufficient, another form of storage must be found. For information on storage, refer to "Methods of Storing Water," RWS.5.M and "Designing a Household Cistern," RWS.5.D.1. If an alternative storage method is not available, chlorinate the water stored in the barrels. All storage containers must be covered to protect the stored water from contamination. Buckets or utensils should never be dipped into

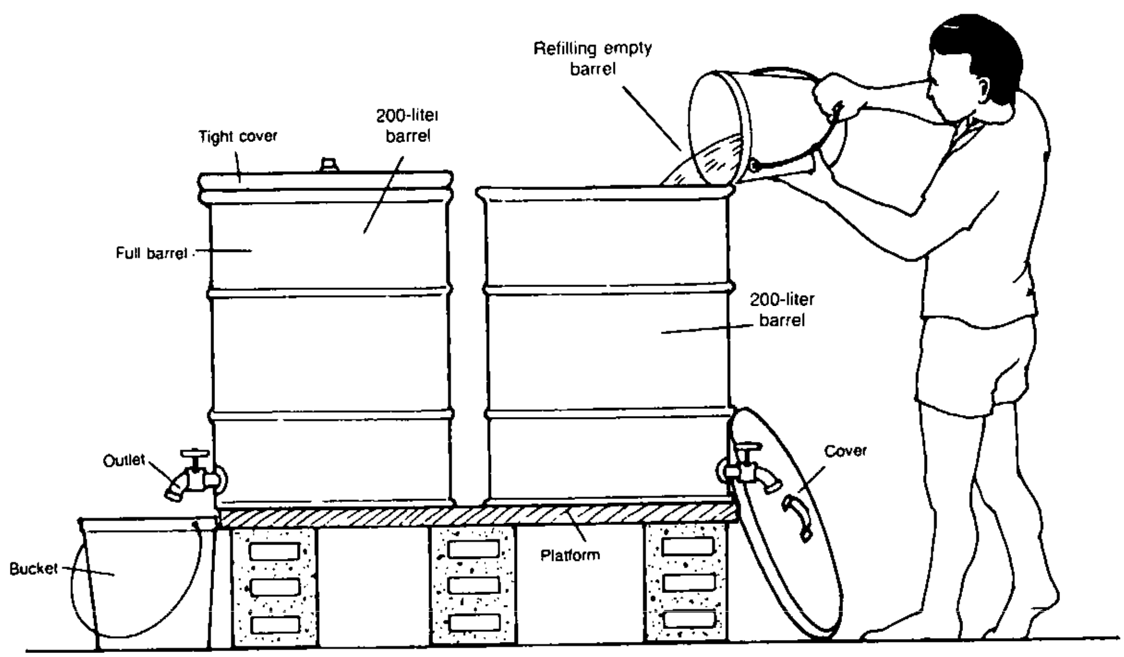


Figure 1. Using Barrels for Water Storage

storage containers. Remember, to be safe, water quality should be checked or water should be boiled or chlorinated.

Filtration

Household sand filters are very useful and popular devices for filtering water and providing basic treatment. They can be built with locally available materials. Household sand filters are relatively effective in removing most bacteria from water if a constant flow of water covers the sand at all times. Otherwise, the household filter will only remove turbidity and the water will need further treatment.

The design of a sand filter can fit local needs. Follow the design steps outlined below and refer to Figure 2. Table 2 is a list of materials needed.

A household sand filter requires a 200-liter steel barrel approximately 600mm in diameter and 750mm tall and enough clean sand to make a layer 600mm deep in the barrel. The sand layer should be about 750mm deep if a taller barrel is used. Sand size between 0.1-1.0mm is acceptable, but sand size from 0.2-0.5mm is preferred.

Determine the volume of sand needed for the filter by using the following formula:

$$V = \frac{\pi}{4}(d^2)(h)$$

where V = volume

π = 3.1

d = diameter of the barrel = (0.6m)

h = the height of the sand layer = (0.6m)

$$V = \frac{3.14}{4}(0.6m^2)(0.6m)$$

$$V = 0.785(.36m^2)(0.6m)$$

$$V = 0.17m^3 \text{ or } 0.2m^3$$

For the filter, choose a fine grain sand. Generally, the finer the sand, the better the quality of water. Do not use coarse sands in the filter. Coarse sands allow organic matter and bacteria to pass through the filter.

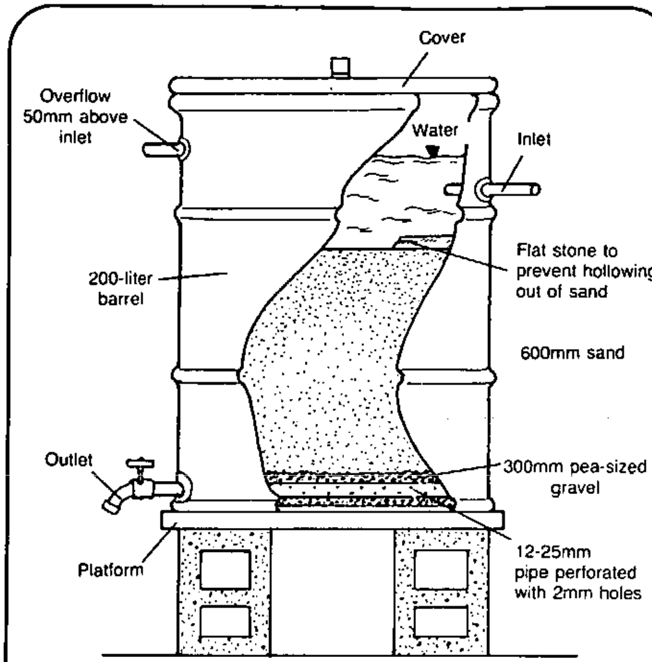


Figure 2. Household Sand Filter

Table 2. Materials List for Slow Sand Filter

Item	Quantity
Steel drum for filter (0.6m x 0.75m)	____
Pre-and post-filtration storage drums (200-liter capacity)	____
Clean sand, sized 0.1-1.0mm	____
Pea gravel	____
Sheet metal and wood, for cover	____
Polyethylene flexible pipe for inlets and outlet pipes	____
Valve to regulate water flow	____

Pea-sized stones should be used to line the bottom of the barrel where the outlet for the filter is located. The gravel layer should be 30-50mm thick. The filter outlet hole should be no more than 2mm in diameter.

If the sand filter is designed to receive a continuous flow of water, there should be an inlet hole and an overflow at the top of the barrel. The overflow should be about 50mm higher than the inlet.

Provide for a continuous flow of water through the filter sufficient to keep the filter full with a slight overflow. The maximum rate of flow through the filter should not be more than about 1 liter/minute. Water should flow from storage into the sand filter by gravity flow through flexible plastic pipe. A valve should be installed to regulate the flow. See Figure 3.

The sand in the filter should never be allowed to dry out. If the sand layer dries, the sand should be wasted or replaced. Dried sand may add bacteria to the water. Flow should be checked occasionally to ensure that the sand layer is always covered. An outlet pipe should be connected to the filter so that the water flows to a storage container.

It is much easier to use the sand filter only as a means of clarifying water rather than removing bacteria. The design of the sand filter is simpler when disinfection is not included. Operation and maintenance requirements are also less demanding.

For simple filtration, design the sand filter in the same way as described except do not include either an inlet or an outlet hole on the upper side of the steel barrel. To filter the water, the cover is removed and the desired quantity of water poured into the filter. Then the cover should be replaced. There is no need to keep the sand layer always submerged. Filtered water is collected in a storage vessel. Water filtered in this manner probably needs further treatment to disinfect it.

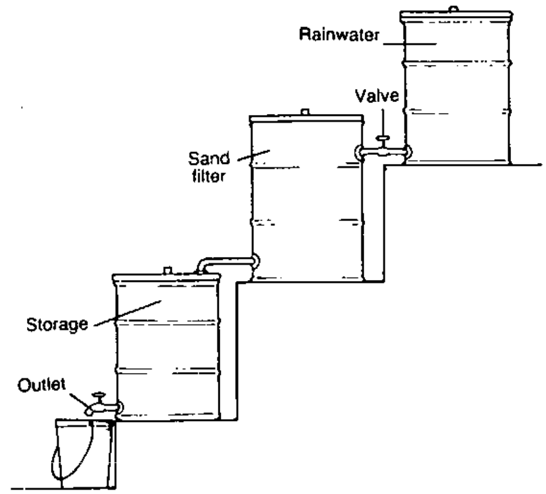


Figure 3. Household Sand Filter System with Gravity Flow and Storage

Summary

The design of most household treatment systems is simple and inexpensive. The choice of treatment method depends on available materials for construction, the users' access to chemicals, and the quality of the water supply. Proper design and proper use of chemicals are very important in ensuring that water quality is suitable. If questions or doubts about the use of a treatment process arise, an expert should be consulted to assist in the development of the most appropriate treatment method. If this is not possible, water should be boiled to disinfect it until a more permanent solution to the problem is found.

Notes

Water for the World

Constructing a Household Sand Filter
Technical Note No. RWS. 3.C.1

A household sand filter can be used to treat water for individual households. There are two different designs for household sand filters. One design simply is used to filter turbidity from water and does not affect the bacteriological quality of the water. This type of filter is easier and cheaper to construct, operate and maintain. The other sand filter design not only removes turbidity but also removes some of the bacteria. However, further treatment may be necessary. The construction, operation and maintenance required for this filter type is more expensive and more difficult than for the first type mentioned.

This technical note describes the construction of both types of slow sand filters. Construction does not require any special skills.

Useful Definitions

INTAKE - The point where water enters a supply or treatment system.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

Before beginning construction, be sure that the people building the filter have the following:

1. Detailed plans of the sand filter to be constructed as shown in Figure 1.

2. A complete list of all materials that will be needed. A sample list appears in Table 1.

Table 1. Materials List for Household Sand Filter

Item	Description	Quantity	Estimated Cost
Labor	Household members		
Supplies	Steel drum Sand (0.2-0.5mm diameter) Flexible pipe Gravel Pipe glue Nails Framing wood Sheet metal Blocks		
Tools	Shovel Hammer Saw		

Total Estimated Cost =

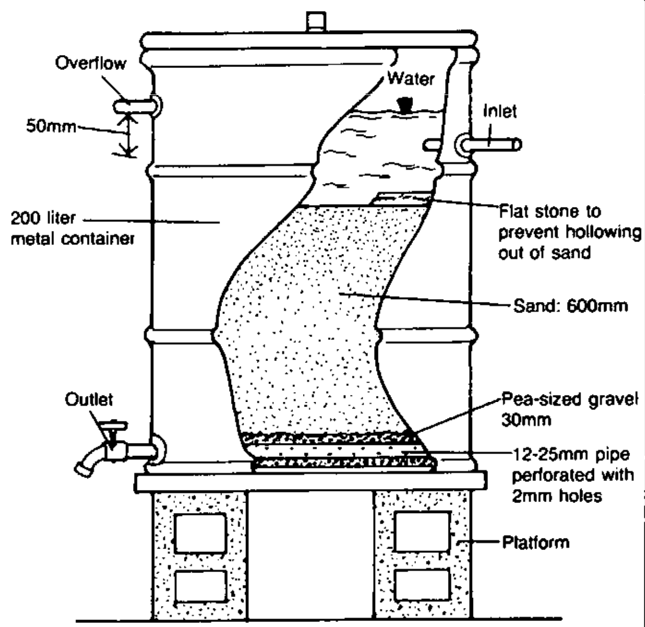


Figure 1. Household Sand Filter

Construction Steps

Follow these steps in building a household sand filter:

1. Prepare a steel barrel approximately 600mm in diameter and 750mm tall to be used for the filter. Remove the top cover and wash the barrel thoroughly and rinse with a one percent chlorine solution to disinfect it. See "Designing Basic Household Treatment Systems," RWS.3.D.1, for information on the preparation of chlorine solutions. Keep the chlorine rinse water in the barrel for at least 30 minutes to ensure proper disinfection.

2. At the bottom of the wall of the barrel drill or cut a 7-10mm hole. This hole will be the outlet for the filtered water. Do not make the hole larger than 7-10mm. Place a pipe joint and pipe in the hole so that water can flow either to storage or further treatment. Seal around the pipe and the barrel with pipe cement if plastic pipe is used. If steel pipe is used and soldering equipment is available, solder the pipe to the barrel. A good seal is needed to prevent leaks.

Another way to make an outlet is to place a perforated pipe in the gravel layer at the bottom of the barrel as shown in Figure 1. Use a small diameter pipe, 12-25mm, and make small holes in it. This method may prove easier because leakage around the pipe is less likely.

3. Line the bottom of the barrel with pea-sized gravel. The gravel layer should be about 30mm thick.

4. Fill the barrel with sand to within approximately 100mm from the top. Approximately $0.2m^3$ of sand is needed for a barrel 600mm in diameter. This will give a sand bed 600mm thick.

To determine the volume of sand needed for a layer of sand 600mm thick in a barrel 600mm in diameter, use the following formula:

Volume of sand = .785 $(\text{diameter})^2$ x height

Volume of sand = .785 $(0.6m^2)$ x (0.6m)

Volume of sand = .785 (.36m) x (0.6m)

Volume of sand = $0.2m^3$

Use fine sand for the filter. To size the sand, make a sieve using window screen and small pieces of wood as shown in Figure 2. The window screen is 16-mesh which has openings of 1.6mm. The sand that passes through the window screen will be less than 1.6mm in diameter and generally a satisfactory size. One problem is that all sand grains less than 1.6mm in diameter will pass through the sieve and an attempt to use the coarser sand should be made. If too much very fine sand is used, the filter system may clog quickly.

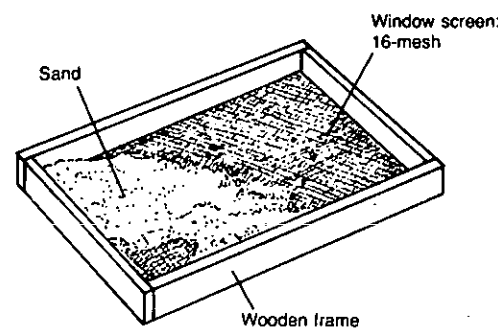


Figure 2. Sand Sieve

Grain sizes larger than 1.6mm should not be used because filtration may not be adequate in coarser sand. When choosing the sand to use in the household sand filter, only use sand that passes through the screen and from this sand, try not to use the finest grains.

To ensure effective operation, be sure that the sand is clean. Washing the sand before placing it in the filter drum is recommended. Wash the sand by placing it in a box and slowly pumping water in at the bottom. Continue this process, raking the sand to distribute it evenly, until water overflowing the box is clean.

5. If water is poured into the filter from a bucket, an overflow is not necessary. However, if water flows into the filter from an intake pipe, an overflow should be installed. For the overflow, make a 50mm hole near the top rim of the barrel and install a pipe. Locate the overflow approximately 50mm above the inlet.

6. Cover the filter. Provide a cover for the intake that adequately protects the filter. The cover should be easy to remove in order to clean the filter.

For the cover, use a piece of sheet metal nailed to a wooden frame. The frame should fit tightly over the barrel and have an overhang of about 20mm to prevent dust and rain from getting into the filter. Make the length and width of the cover frame 20mm greater than the outside diameter of the barrel. Hammer nails into the wooden form as shown in Figure 3 so that some air can circulate under the filter cover.

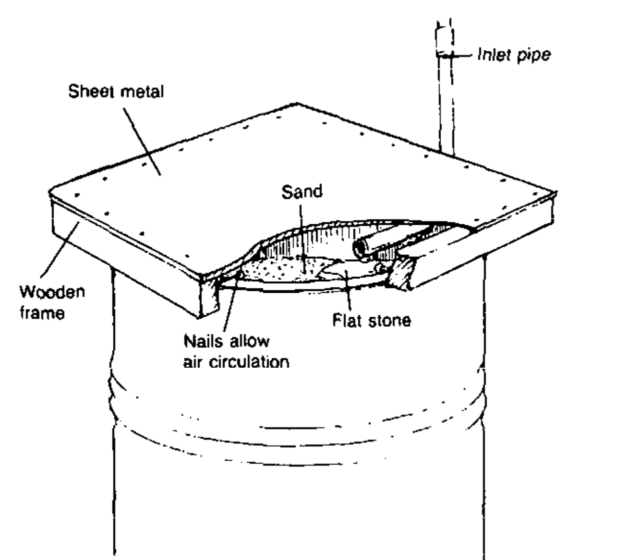


Figure 3. Cover for Sand Filter

7. When water is simply poured into the filter, no inlet other than removing the cover is necessary for filling the filter. However, if water is supplied from a cistern or other type of storage tank, an inlet can be provided. Place the inlet in either the cover or the side near the top of the barrel. Connect flexible pipe from the water source to the filter. Under the inlet pipe, place a small flat stone so that water hits it without disturbing the sand layer.

For easy access to the filtered water, place the sand filter on at least three blocks so that water can be easily collected from the outlet pipe. When constructing a household sand filter in which the sand will always be covered, a gravity flow system like the one in Figure 4 can be installed. Wooden or brick platforms can be constructed so that water flows from the pre-treatment storage to the filter and to the filtered water storage by gravity. This structure is more complicated and expensive to build and the sand layer must constantly be under water. If this system is used, taps should be installed on all outlet pipes so that water flow can be controlled.

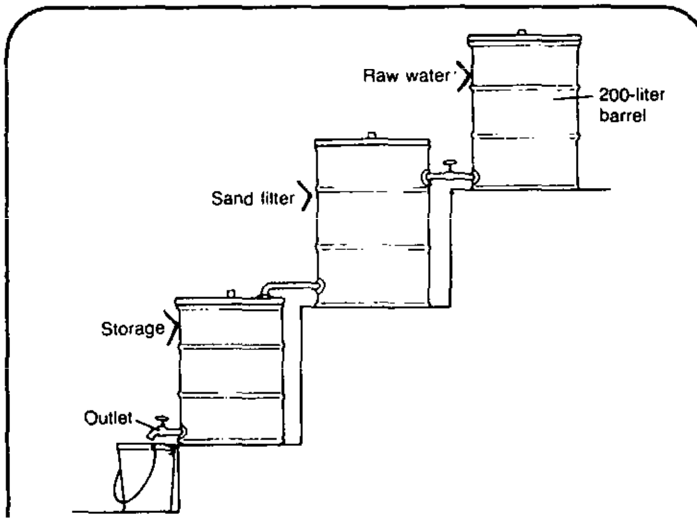


Figure 4. Gravity Flow Filter and Storage System

Caution!

If water is bacteriologically contaminated, further treatment may be necessary. The household sand filter removes bacteria if care is taken to keep the filter bed under water and if sand is fairly uniform in size. However, the sand filter may not remove all bacteria and the quality of the water should be determined before it is used. In some cases, water must be chlorinated after filtration to be of acceptable quality.

Summary

Household sand filters are a good way to remove turbidity and some bacteria from water. They can be constructed at a low cost and with locally available materials and labor. In fact, a household sand filter can be made wherever there is good sand available. Sand filters work very well if they are properly maintained.

Water for the World

Constructing a Disinfection Unit
Technical Note No. RWS. 3.C.4

Disinfection units can be constructed for both large and small water supply systems. For most disinfection purposes, chlorine compounds are used as the disinfecting agent. Chlorine is available in most countries and can be obtained in many regions at a relatively low price.

This technical note discusses the construction of simple chlorination units for small water supplies. Each unit can be built using local materials and local labor. Read the entire technical note before beginning construction.

Useful Definition

DISINFECTION - Destruction of harmful microorganisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

Materials Needed

Before beginning the construction process, the following items should be available:

1. A list of all materials and tools needed as shown in Table 1. All of these materials should be available when construction begins in order to avoid delays in the project.

2. A plan of the disinfection unit similar to Figures 1, 2 or 3 which show a pot chlorinator, a drip feed chlorinator, and a floating bowl chlorinator.

Follow the construction steps described below when building a disinfection unit. Refer to the appropriate diagram throughout the construction process.

Table 1. Materials List for Floating Bowl Chlorinator

Item	Description	Quantity	Estimated Cost
Labor	Foreman Workers		
Supplies	200-liter steel drum Rubber or cork stopper 3 small tubes 6-9mm and 3mm Flexible hose String Wood or plastic bowl Drain plug Outlet connection Small stones Planks and other wood for platform Paint Latex or rubber base		
Tools	Hardware Saw Nails Drill Knife Buckets Paint brush		

Total Estimated Cost = ____

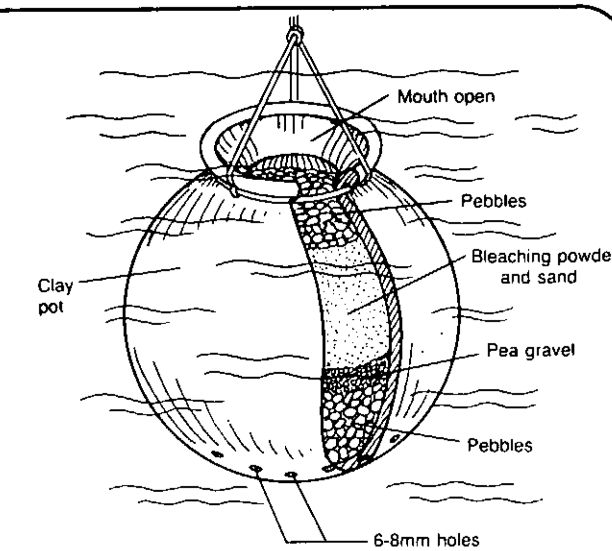


Figure 1. Pot Chlorinator

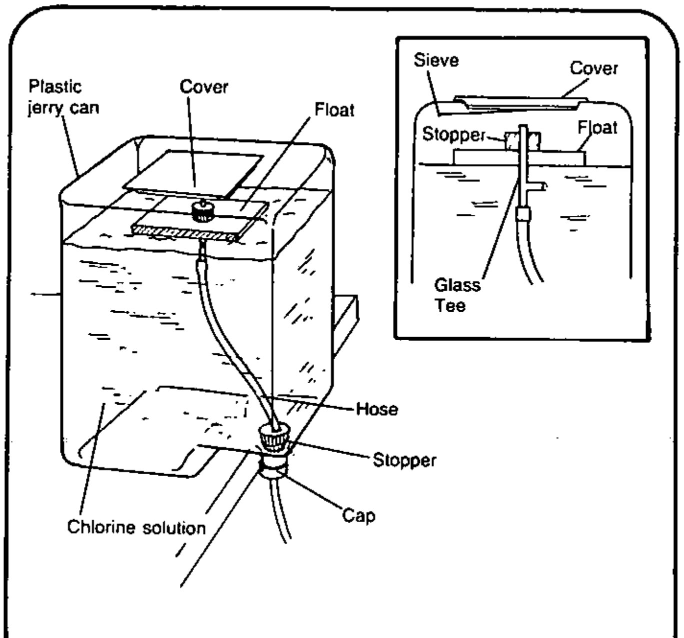


Figure 2. Chlorine Feeder

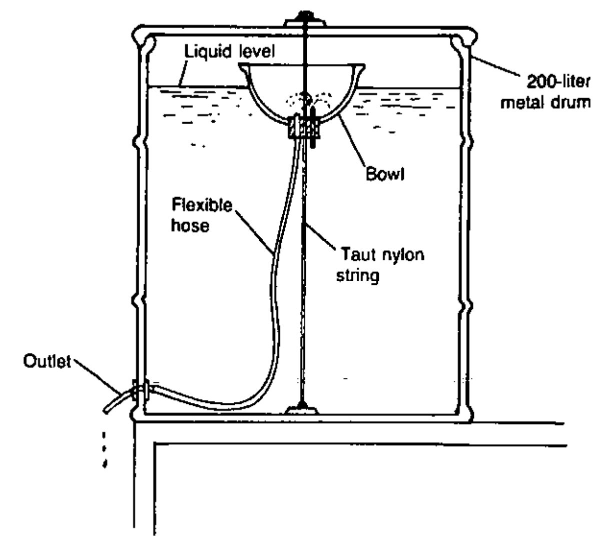


Figure 3. Floating Bowl Chlorinator

Pot Chlorinators

A pot chlorinator, shown in Figure 1, is effective for disinfecting water in shallow dug wells. To make one, follow the steps below and refer to Figure 1.

1. Use a ceramic, plastic or earthen jar or urn with a capacity of 7-10 liters. The jar does not need a cover.

2. With a sharp object, chisel or hand drill, make seven 6-8mm holes along the bottom of the jar.

3. Fill about half the jar with pebbles and pea gravel 20-40mm in size. The gravel should form a level layer in the pot. Then make a mixture of bleaching powder and sand. Add one part bleaching powder to two parts sand. Usually, 1.5kg of bleaching powder is sufficient for making a pot chlorinator.

4. Add the chlorine and sand mixture to the pot. Then use pebbles to fill the space between the layer of bleaching powder and sand and the neck of the jar.

5. Finally, attach wire or rope to the jar as shown so that the pot can be attached to a rope or hook and lowered into the well. Be sure that the pot is firmly secured to prevent it from being lost in the well.

Drip Chlorinators

A drip chlorinator can be used to disinfect water in wells, cisterns and other small reservoirs. To make a drip chlorinator, follow the steps listed below and refer to Figure 2.

1. Use a plastic can or bottle to make the drip chlorinator. The spout of the container will act as the outlet for the chlorine solution.

2. Cut open the bottom of the jar to provide a solution inlet and for access to the inside of the can.

3. Prepare the chlorine feed equipment that will fit in the plastic can. Use a piece of plastic, styrofoam, or wood for a float. In the center of the float, place a rubber stopper or cork and pass a piece of hard tubing through it. Glass, copper, brass or rigid

plastic tubing can be used. The tubing should be long enough to extend a little above the rubber stopper but below the float. In the part of the hard tubing below the float, make a small hole. This hole is the inlet for the chlorine solution which will fill the container. Use a tee, as shown in Figure 2, if one is available.

4. Attach a piece of small diameter rubber hose to the tubing. Connect the tubing below the inlet hole as shown.

5. Prepare the outlet for the drip chlorinator in the spout of the bottle. Make a hole in a plastic cap or the cover of the bottle spout so that the hose can pass through it. Pass the hose through a rubber stopper or cork that securely fits in the spout. Place the stopper in the neck of the container as shown, and put a cap or cover on the container spout.

6. Fill the plastic jar with chlorine bleach. Domestic chlorine beach contains 2-5 percent available chlorine. Fill the container until the float reaches the top. Then cover the top of the jar.

7. To control the flow, use a small clamp or make one from two pieces of aluminum and two aluminum nuts and bolts. Place the clamp around the hose and tighten it to cut off all flow during installation. Loosen the clamp to get the rate of flow desired.

8. Install the plastic can over the well or reservoir using wire. The wire can be attached to the well head or lip of the cistern and the container hung inside. The rubber outlet hose should reach into the water.

Floating Bowl Chlorinators

Floating bowl chlorinators hold a much larger volume of chlorine solution than the drip type used for disinfecting water in wells and small reservoirs. Floating bowl chlorinators are used to add chlorine at a constant rate to water in a tank or in a low pressure pipeline. Floating bowl chlorinators can be constructed with local materials and local labor. Refer to Figure 3 as you read the construction steps.

1. Prepare a 200-liter barrel for storing the chlorine solution. Remove the top cover and clean out the barrel by washing it with a one percent chlorine solution. Let the chlorine stand in the barrel for at least thirty minutes. Empty the barrel and, when it is dry, paint the inside with a latex or rubber base paint. This type of paint is not affected by chlorine.

Once the paint is dry, place a small outlet hole in the side of the barrel as shown in Figure 3. Make the hole 6mm in diameter. Make another hole approximately 10mm in diameter at the bottom of the barrel to serve as the tank's drainage.

2. To feed the chlorine into the water supply, make a floating bowl like that shown in Figures 4 or 5. Use a wooden or plastic bowl or cut the bottom out of a plastic bottle to form a bowl and use it as a float.

3. Using a stopper borer or hand drill, make a hole in the middle of the float to fit a medium-sized rubber or cork stopper. The rubber or cork stopper must be wedged into the opening to fit securely without leaking. Before placing the stopper in the opening, push three short tubes through

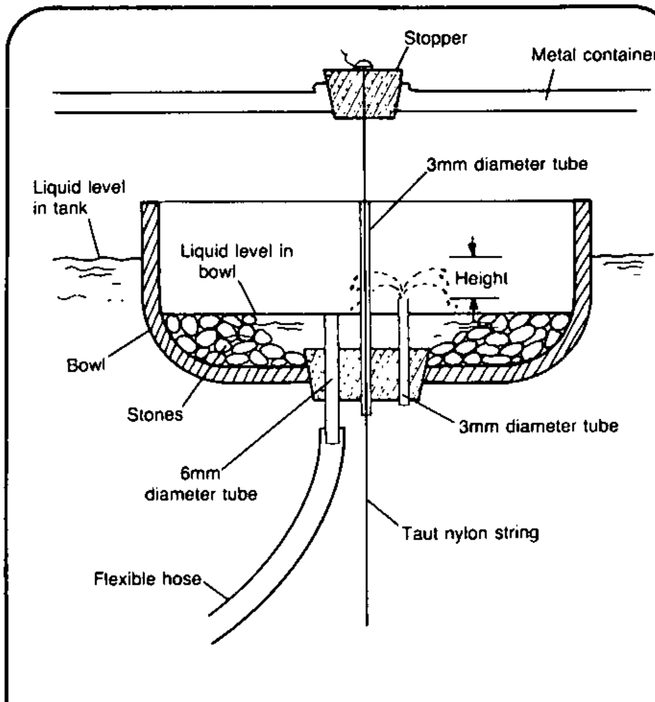


Figure 4. Floating Bowl Chlorinator

the stopper. Use glass, copper, brass or hard plastic tubing. Use two 3mm and one 6-9mm diameter tubes. One 3mm tube should go through the center of the stopper and the other two tubes should be placed to either side of the center. The tube through the center which will carry the guide string shown in Figure 4 should extend to the top of the bowl. The other 3mm tube should reach just below the liquid level in the tank. The 6-9mm diameter tube should reach no higher than the top of the stopper or the layer of small stones used for weights.

4. To install the floating bowl in the tank, first connect one end of the flexible rubber hose to the largest diameter tube. Connect the other end of the hose to a small drip outlet. The drip outlet can be made of plastic or a watertight joint. Or, flow can be controlled by placing a clamp over the flexible tube. Tightening the clamp will slow the flow; loosening it will increase the flow.

5. Secure one end of a nylon string to the bottom of the tank. Take the free end and thread it through the 3mm tube passing through the center of the stopper. Pull the string as tight as possible, and attach it to a wooden cross piece over the top of the barrel. Secure it well so it can be separated from the cover to refill the barrel without disconnecting the bowl. The string serves as a guide for the bowl so that it does not hit the sides of the tank. Figure 5 shows a bowl without a guide string. The chlorinator is easier to make without the guide string, but the bowl may drift to the sides of the barrel. If there are no ridges or plugs in the sides that could keep the bowl from moving downward as the chlorine solution is used, the chlorinator will work.

6. Fill the tank almost to the top with a one percent chlorine solution. To determine the amount of chlorine compound needed to prepare a one percent solution, use the following equation.

Amount of chlorine needed:

$$\frac{\text{Percent strength of solution desired} \times \text{Liters of solution required}}{\text{Percent available in compound}}$$

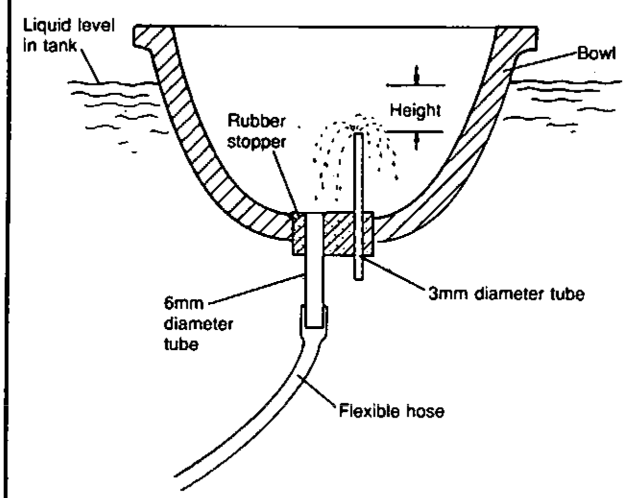


Figure 5. Floating Bowl Chorinator

To prepare 200 liters of a one percent solution using bleaching powder with 35 percent available chlorine, the amount of bleaching powder which should be used is:

$$Q \text{ chlorine} = \frac{1\% \times 200 \text{ liters}}{35\%}$$

$$Q \text{ chlorine} = \frac{.01 \times 200}{.35}$$

$$Q = 5.5\text{kg.}$$

Approximately 5.5kg of bleaching powder should be added to the water in the tank. Stir gently but well for at least five minutes.

7. To control the flow of the solution from the tank, one of three methods can be used. To reduce the flow, raise the tube that lets water into the bowl to the height near the water level in the tank. Lowering the tube increases the flow. The second method is to reduce the size of the opening to the bowl in the top of the inlet tube. A glass tube can be heated and drawn out. A brass or copper tube can be flattened out. Third, small stones or gravel can be placed in the bowl to increase flow. The stones act as weights and force larger amounts of water to flow into the bowl through the tube. Weights may be added or removed to control the rate of flow.

The tank should be checked often to be sure that the tank always contains chlorine solution. The water being treated should be tested periodically to ensure that there is adequate chlorine residual. A color comparator tester is needed to do this. The addition of a reacting agent called orthotolidine produces a yellow color which increases with chlorine content and indicates the amount of chlorine in the water.

Summary

Several simple methods are available for chlorinating small supplies of water. The pot chlorinator, the drip feed chlorinator and the floating bowl chlorinator can all be constructed using locally available supplies and labor. These methods are useful for chlorinating small water supplies but in order to be assured of their effectiveness, water should be tested after chlorination. Where water cannot be tested, make sure that the treated water has a slight chlorine taste and odor. Insufficient chlorination does not provide protection from disease-causing bacteria.

Notes

Water for the World

Operating and Maintaining Household Treatment Systems

Technical Note No. RWS. 3.O.1

The operation and maintenance of household treatment systems requires the attention of individual families. Proper operation and maintenance will ensure that adequate water treatment is performed and that storage containers are cleaned and protected against the entry of contaminants.

This technical note describes several measures to follow for effective operation and maintenance of household treatment systems. These measures will help maintain good water quality in the household when chlorination, boiling, storage or household sand filtration is used.

Chlorination

For effective chlorination to take place, sufficient stocks of chlorine should be available and correct chlorine dosages should be applied. The best way to ensure that an adequate amount of chlorine is available is to prepare a large quantity of one percent stock solution and store it in jars in a cool dark place for future use. To determine the amount of chlorine to add to a certain volume of water, use the following formula:

Kg of chlorine required =

$$\frac{\text{Percent strength of solution desired} \times \text{Liters of solution desired}}{\text{Percent available chlorine}}$$

For example, to prepare a 50-liter supply of one percent solution using bleaching powder with 35 percent available chlorine, the amount of powder which must be added to the 50 liters of water is:

$$\frac{.01 \times 50 \text{ liters}}{.35} = 1.4\text{kg.}$$

Thus, 1.4kg of bleaching powder should be added to 50 liters of water to make a one percent stock solution. Using this formula, both larger and smaller volumes of one percent solution may be made. As the stock solution becomes low, be sure that more chlorine is available.

Whenever possible, test the water to ensure that chlorination is adequate. Under most conditions, such testing will not be practical. Check with local health officials to see whether testing kits are available or whether someone from a regional or national center tests water in the area periodically. If testing is impossible, the dosage outlined in "Designing Basic Household Water Treatment Systems," RWS.3.D.1, should prove sufficient.

Boiling

To produce good quality water through boiling and ensure that it does not become contaminated, follow these steps:

- Always store the boiled water in the same container in which it is boiled. Changing containers increases the risk of re-contamination. The only exception to this is if a household has a ceramic filter. In that case, pour the water into the filter for storage.

- Use containers that have covers or can be covered adequately. Dust, dirt and other debris can easily get into uncovered containers. Children and animals are more likely to come into contact with water left in uncovered containers.

- If possible, attach a spigot to the container so that there is no need to dip cups or other utensils into the water. If a spigot cannot be attached, always pour the water from the storage container rather than dip utensils into it. Figure 1 shows a sample design for a tap that can help prevent re-contamination of stored water.

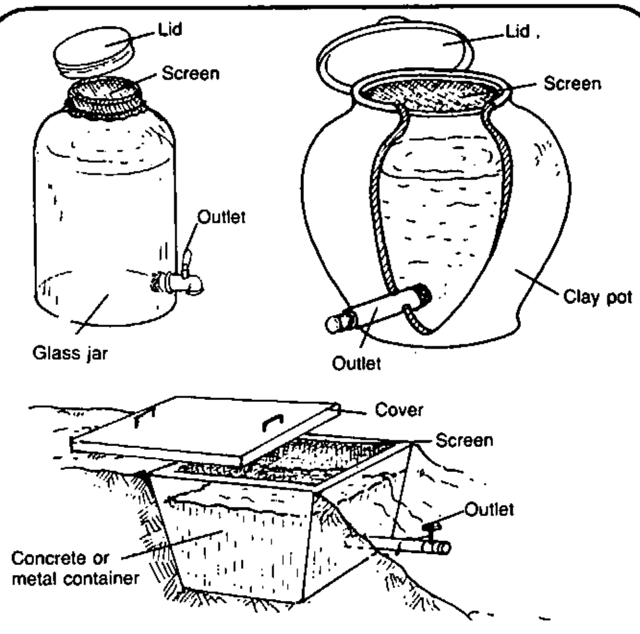


Figure 1. Methods of Storing Water

Storage

To ensure good water quality, clean storage containers after they are emptied each time. Remove the sediment from the bottom and sides of the containers. At least once a month, wash the containers with a chlorine solution. Keep the storage containers covered at all times. Never dip buckets or cups into them.

Household Sand Filter

Operation and maintenance requirements for a household sand filter depend on the type of filtration system constucted. Two designs are available: one that provides a continuous flow of water and keeps the sand layer submerged, and another which does not have a continuous flow of water and does not always keep the sand layer under water.

For filters that are designed for continuous flow, effective operation and maintenance should ensure that there is a continuous flow of water through the filter at all times. To ensure that this occurs, be sure to set up the intake so that there is always a small overflow from the filter. The small overflow indicates that the filter is full and the sand layer completely submerged.

For both continuous flow and non-continuous flow filters:

- Keep household sand filters covered so that it is completely dark inside the filter. Light may cause growths of green algae on the surface of the sand. Place the cover on the filter with a small space left so that some air may circulate. See Figure 2. Air circulation will help the growth of the biological layer on the sand in continuous flow filters.

- Clean the filter when water flow from it slows down greatly. To clean the sand, scrape off a layer approximately 5mm thick and throw it out. See

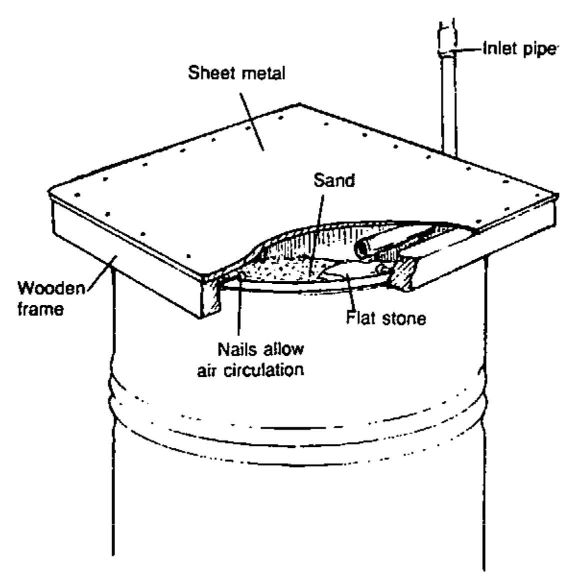


Figure 2. Cover for Sand Filter

Figure 3. Then rake or scratch the surface lightly. Cleaning should only take place once every several weeks so as not to disturb the biological layer on the surface of the sand. After four or five cleanings, clean sand should be added to bring the layer of sand back to its normal height. Before adding new sand, scrape the old sand clean. Then add either new sand or sand from the filter that has been thoroughly washed.

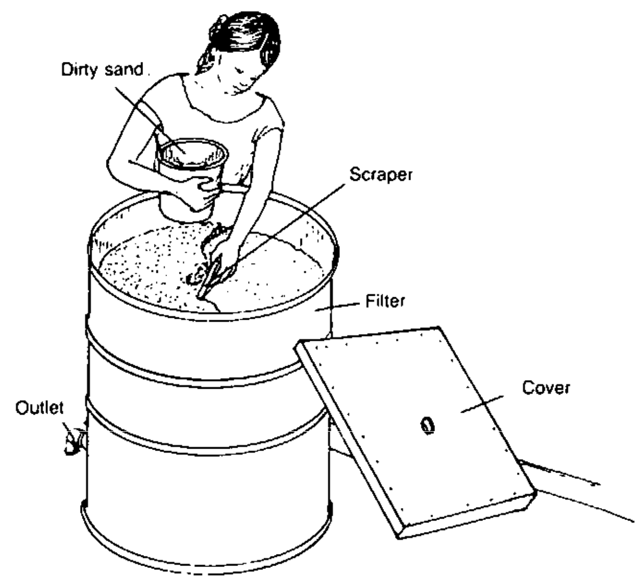


Figure 3. Scraping the Sand Filter

Notes

Water for the World

Simple Methods of Excreta Disposal
Technical Note No. SAN. 1.M.1

Simple methods of excreta disposal use a pit, vault, or bucket to hold the excreta. This reduces the chance of contaminating water supplies and of spreading diseases caused by poor sanitation (see "Means of Disease Transmission," DIS.1.M.1). These methods also help control the spread of disease by keeping animals and insects away from excreta. Simple methods of excreta disposal are easy to build, inexpensive, and can be made from locally available materials.

This technical note describes five simple methods of excreta disposal: pit privy, pit privy with improvements, aqua privy, compost toilet, and bucket latrine.

Useful Definitions

COMPOST - A dark, fairly dry, crumbly, odorless material that is produced by sealing excreta, ashes, woodchips, straw, and vegetable waste for 6-12 months; compost can be used to fertilize crops.

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria from excreta.

EXCRETA - Human body wastes.

PERMEABLE - Allowing liquid to soak in.

SLUDGE - Solids settled from water-carried wastes.

Pit Privy

Pit privies are probably the cheapest and easiest excreta disposal method to build and the simplest to maintain. The four main features of a pit privy are the shelter, pit, slab with hole or seat, and lid. See Figure 1.

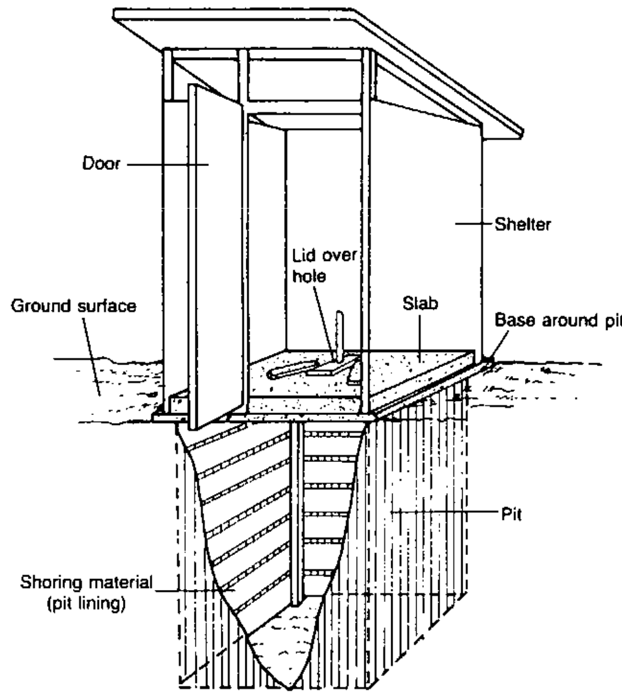


Figure 1. Pit Privy

The shelter gives the user privacy and, depending on the design, may protect the user and the privy from the weather. It should be made from local materials such as palm thatch, bamboo, wood, or bricks. It can have a screening wall or door, depending on local preference.

The pit is dug in permeable soil and holds the excreta. The bottom of the pit must be at least 1m above groundwater levels. The size of the pit will vary, depending on the number of users, the type of anal-cleaning material used, and the desired lifetime of the pit. For example, a pit that is 1m square and 1.5m deep can be used by a family of five for about six years.

The pit has a base for the slab and sometimes a lining, as well, depending on the type of soil in which it is dug. The lining shores up the sides of the pit. It is made from bamboo, boards, brick, or select field stones. The base encircles the top of the pit and supports the slab. It is made of logs, bricks, or concrete.

The slab covers the pit and has a hole near the center through which to defecate. It can have either a squatting hole or a seat and pedestal, depending on local preference. The slab can be made from bamboo, wood, or concrete.

The lid covers the hole in the slab when the privy is not in use. It is made of local material, and it should fit tightly over the hole to keep flies and other insects out of the pit.

The pit will eventually fill with excreta. When it is filled to within 0.5m below the slab, the slab and shelter are moved to a new pit and the old pit is filled with dirt.

Privies with Improvements

Improved privies have all the features of a pit privy plus either a vent pipe, pour-flush bowl, off-set pit, or some combination of the three. Like pit privies, improved privies must be no deeper than 1m above groundwater levels, and they will eventually fill with excreta. These privies cost about one-and-a-half times as much as a pit privy.

A vent pipe is 75-150mm in diameter, usually metal painted black, and topped with a fly-proof screen and cone-shaped cover to keep out rain. See Figure 2. The purpose of the vent pipe is to remove odors from the privy. The vent pipe is installed outside the shelter, on its sunny side. The pipe's bottom end is mortared to a hole in the slab and the top end is attached to the roof of the shelter. The sun heats the pipe causing an updraft. As a result, air moves down through the squatting hole or seat, through the pit, and up the vent. The screen on the top end of the vent pipe traps flies that may get into the pit.

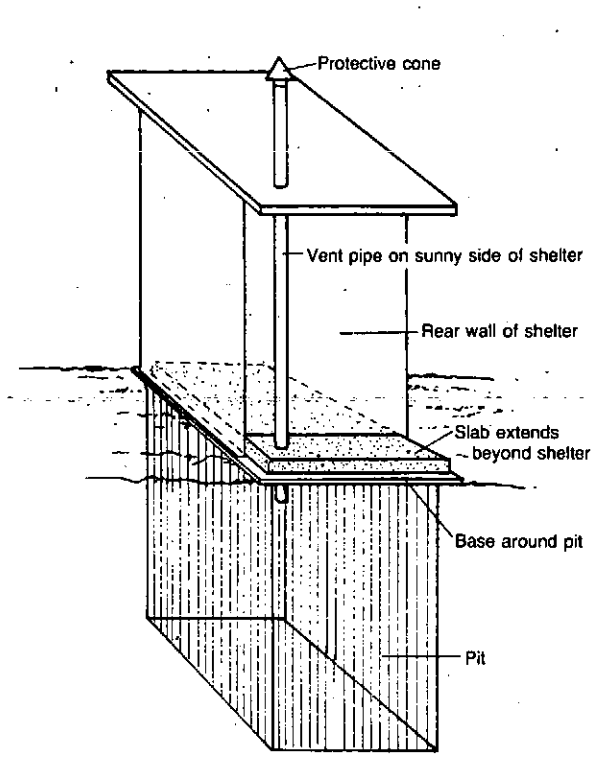


Figure 2. Privy with Vent Pipe

A pour-flush bowl is a bowl with a U-shaped pipe attached below the squatting slab or the seat and pedestal, as shown in Figure 3. After each use, 1-3 liters of water are poured into the bowl. Part of the water flushes excreta into the pit, and part forms a water seal in the bowl to prevent odors from rising from the pit into the shelter.

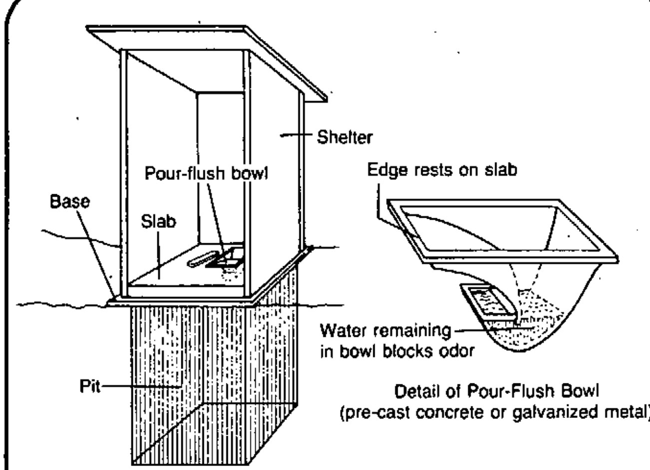


Figure 3. Privy with Pour-Flush Bowl

A pour-flush bowl requires a water source, such as a standpipe, near the privy. Washwater can also be used to operate a pour-flush bowl. Bulky anal-cleansing materials should not be used because they will clog the pipe.

An off-set pit is not directly under the slab and shelter and can be larger than a standard pit, as shown in Figure 4. Off-set pits are at least 1m wide, 1.5m long, and 3.0m deep. Because of their size, they last longer than standard pits. Another feature, which may be considered an advantage, is that the excreta in the pit cannot be seen.

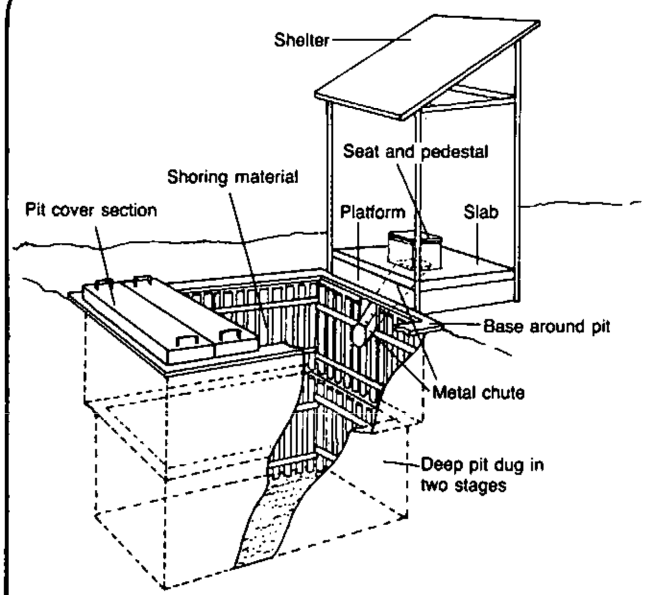


Figure 4. Privy with Off-Set Pit

An off-set pit can be fitted with a pour-flush bowl or a chute and cover. The chute, usually made of galvanized metal, carries excreta downward from the squatting hole or seat to the pit. The cover is generally made of concrete.

Aqua Privy

An aqua privy costs about twice as much as a pit privy. Its four main features are a water-tight vault, slab, shelter, and soakaway as shown in Figure 5.

The vault is about 1m square and 1-2m deep. It is made of reinforced concrete or brick and mortar, and is

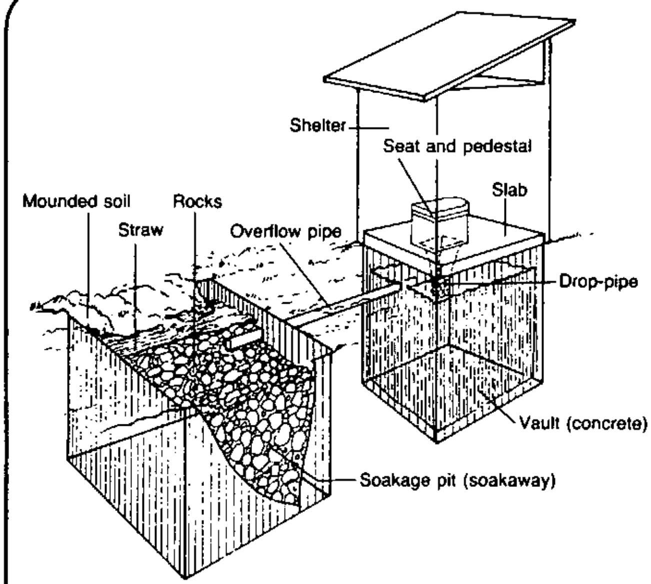


Figure 5. Aqua Privy

installed underground and filled with water. Excreta passes from a drop-pipe in the slab into the vault. The bacteria in the vault breaks down the excreta, and the solids settle to the bottom. The excess liquid flows through an overflow pipe from the vault to a soakaway.

The slab covers the vault and has a metal drop-pipe that extends from the squatting hole or seat down into the water in the vault. The water in the drop-pipe forms a seal, much like a pour-flush bowl, and prevents odors from rising into the shelter.

The shelter is the same as the shelter for a pit privy or improved privy.

The soakaway can be a soakage pit or trench (see "Simple Methods of Washwater Disposal," SAN.1.M.2). It receives excess liquid run-off from the vault through an overflow pipe.

The water level in the vault and the water seal in the drop-pipe must be maintained or there will be severe problems with odors, flies, and mosquitoes. Enough water, possibly washwater, must be added to the vault to replace any water that evaporates. This will vary from 1-10 liters per day.

The vault will gradually fill with sludge. The sludge must be cleaned out and buried when the vault is about two-thirds full and the vault must be refilled with water. This will occur every two to six years.

Compost Toilet

The compost toilet described here is the double-vault type. It costs about twice as much as a pit privy. The five main features of a compost toilet are two water-tight vaults, two slabs, and a shelter, as shown in Figure 6.

The shelter is larger than a shelter for a pit privy, because it must enclose two slabs.

The slabs are the same as for a pit privy, and may have squatting holes or seats and pedestals.

The vaults, which may really be one large vault divided in half, are made of reinforced concrete or brick and mortar. They rest above ground on a concrete or brick base and are each about 1m square and 1m high.

Only one vault is used at a time. It holds the excreta, to which is added ashes, sawdust, woodchips, or vegetable wastes. When the vault becomes two-thirds full, which takes six to 12 months, it is filled with dirt and sealed. The second vault is then used until it becomes two-thirds full. At that time, it is filled with dirt and sealed, and the first vault is opened. The contents of the first vault will have changed into compost material. The compost is removed from the first vault through the door at the back and used to fertilize crops. The first vault is now ready to use again.

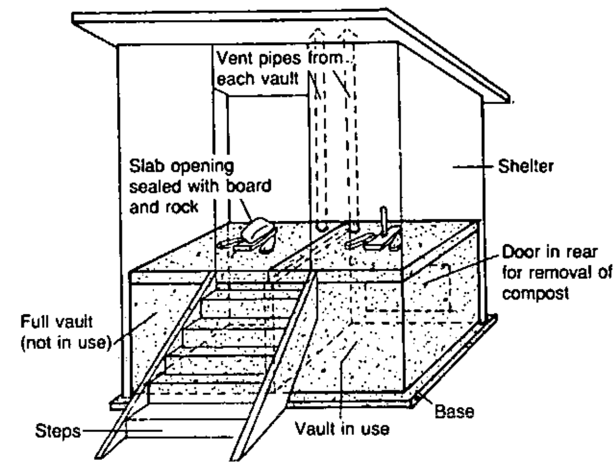


Figure 6. Compost Toilet

Bucket Latrine

The construction cost of a bucket latrine is about the same as a pit privy. However, operating costs can make a bucket latrine the most expensive excreta disposal method described in this technical note. The four main features of a bucket latrine are a platform, slab, shelter, and bucket, as shown in Figure 7.

The platform can be made of wood, concrete, or brick and mortar. It elevates the slab and encloses the bucket.

The slab is the same as for a pit privy, and may have a squatting hole or a seat and pedestal.

The shelter is the same as for a pit privy, with the addition of a fly-proof door in the rear wall for removal of the bucket.

The bucket is made of rubber, enamel, galvanized metal, or lacquered wood. It is placed under the slab, in the compartment created by the platform.

The bucket holds excreta and must be emptied every one to three days, preferably every day. A laborer replaces the bucket with a clean one, empties the excreta into a larger container, and takes it to a trenching ground where the excreta is buried. Water must be available at the trenching ground so the laborer can wash the containers and buckets. It is also possible to compost the excreta.

This method of excreta disposal can be unpleasant and unsanitary. There is a risk of spreading disease because the excreta and excreta containers must be handled continually. This method also can be quite expensive because

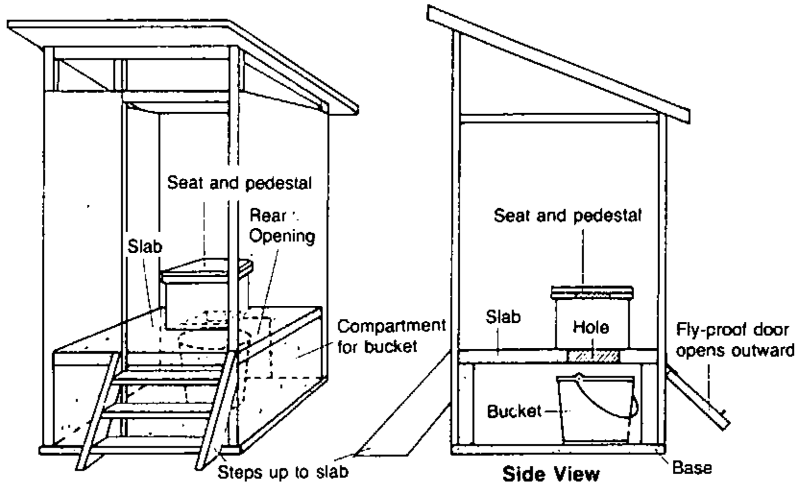


Figure 7. Bucket Latrine

workers must be paid to empty the buckets and bury the excreta. In some regions, however, the excreta is composted successfully with no odor, flies or disease. It is then used to fertilize crops. In most circumstances bucket latrines should probably only be used where there is a dense population on rocky ground or as a temporary solution to an emergency situation. Existing bucket latrines should be replaced with other, more sanitary means of excreta disposal as soon as possible.

Comparison of Methods

Table 1 summarizes each of the five simple methods of excreta disposal. The methods are listed across the top of the chart, and the factors to be compared are listed down the left side. The table can be used as an aid in selecting a method (see "Planning Simple Systems of Excreta and Washwater Disposal," SAN.1.P).

Table 1. Comparison of Simple Methods of Excreta Disposal

Factor	Disposal Method				
	Pit Privy	Pit Privy with Improvements	Aqua Privy	Compost Toilet	Bucket Latrine
Cost	None	1½ times pit privy	2 times pit privy	2 times pit privy	No construction cost but operation may be costly depending on community
Design Features	Pit; slab (squat or seat); lid; shelter	Same as pit privy plus either pour-flush bowl, vent pipe, off-set pit, or combination	Vault; slab (squat or seat); shelter; soakaway	Double vault; two slabs (squat or seat); shelter	Platform; slab (squat or seat); bucket; shelter; large containers' cart
Construction Skills	Minimal	Minimal	Some masonry	Some masonry	Minimal
Slab Material	Bamboo, wood, or concrete	Bamboo, wood, concrete, ceramic, or plastic	Concrete	Concrete	Bamboo, wood, or concrete
Water Requirement	No	No, except for pour-flush	Yes	No	No for operation, but yes for washing at trenching ground
Handling of Wastes	None	None	Every 2-6 years as sludge	Every 6-12 months as compost	Every 1-3 days as excreta
Maintenance	Clean slab weekly; dig new pit and move slab and shelter every 4-6 years	Same as pit privy; if off-set pit, clean chute weekly and dig new pit every 10 or more years	Maintain water level in vault; clean slab weekly; remove sludge and refill with water every 2-6 years	Clean slab weekly; alternate use of vaults every 6-12 months by removing compost, cleaning one vault, sealing the other	Clean slab weekly; remove excreta every 1-3 days; clean buckets every 1-3 days; cart excreta to trenching ground and bury it or to composting crea

Notes

Water for the World

Designing Pits for Privies
Technical Note No. SAN. 1.D.2.

Designing a pit for a privy involves selecting its location, calculating its size, and determining the labor, materials, and tools needed for construction. The products of the design process are: (1) a location map, (2) technical drawings of the pit, (3) sketches of the pit lining, if needed, and base for the slab, and (4) a materials list. These products should be given to the construction supervisor before construction begins.

This technical note describes how to design a pit and arrive at these three end-products. Read the entire technical note before beginning the design process.

Useful Definitions

DECOMPOSE - To decay and become reduced in volume due to bacterial action; this happens to excreta in a pit.

IMPERVIOUS - Not allowing liquid to pass through.

PERMEABLE - Allowing liquid to soak in.

Materials Needed

Measuring tape - To obtain accurate field information for a location map.

Ruler - To draw a location map.

Location

The major factors in selecting a location for a privy are: (1) location of water supplies, dwellings, and property lines, (2) soil type, (3) groundwater levels, and (4) impervious layers.

Location of Water Supplies, Dwellings, and Property Lines. A pit privy should be downhill from water wells. It should be at least:

20m from the nearest well or stream,
6m from the nearest dwelling,
3m from the nearest property line.

For the sake of convenience, the privy should be no farther than 30m from the building to be served. It should be on fairly level ground. When a proposed site has been selected, determine the soil type.

Soil Type. A pit should be dug in permeable soil so the liquid part of the excreta can soak into the ground. The rate at which liquid soaks in depends on the type of soil. If the rate is too fast or too slow, the soil is not suitable for a pit. The main types of soil are sand, sandy loam, loam, silt loam, clay loam, and clay. For a detailed description of soil types see "Determining Soil Suitability," SAN.2.P.4.

When the soil at the pit site has been identified, use the following chart to determine its suitability.

Table 1. Soil Suitability

Soil Type	Suitability
Sand	No
Sandy Loam	Yes
Loam	Yes
Silt Loam	Yes
Clay Loam	No
Clay	No

If the soil is not suitable, select another location for the pit. If no good location can be found, design an alternative excreta disposal system (see "Simple Methods of Excreta Disposal," SAN.1.M.1). If the soil is suitable, proceed to the next step.

Groundwater Levels. The bottom of the pit must be at least 1m above the groundwater level during the wettest season of the year. This information may be available from local residents, water well owners, or water well drillers. If the information is not available or reliable, field tests must be made. These tests are described in detail in "Determining Soil Suitability," SAN.2.P.4. In brief, a hole must be dug 1m deeper than the proposed pit. Dig the test hole during the wettest season. If no groundwater is observed, groundwater levels are suitable.

If groundwater levels are not suitable, select another location for the pit. If no acceptable location can be found, design an alternative excreta disposal system (see "Simple Methods of Excreta Disposal," SAN.1.M.1).

Impervious Layers. The bottom of a pit must be at least 1m above impervious layers such as creviced rock, hardpan, shale, or clay. The same test hole dug for determining groundwater levels can be used to check for impervious layers. If there are impervious layers in the test hole, the site is unacceptable for a pit and a new site must be found. If no suitable site can be found, design an alternative excreta disposal system (see "Simple Methods of Excreta Disposal," SAN.1.M.1).

When a suitable site has been found, draw a location map similar to Figure 1, showing the pit site and distances to water supplies, streams, dwellings, property lines, and any other nearby structures or prominent geographical features.

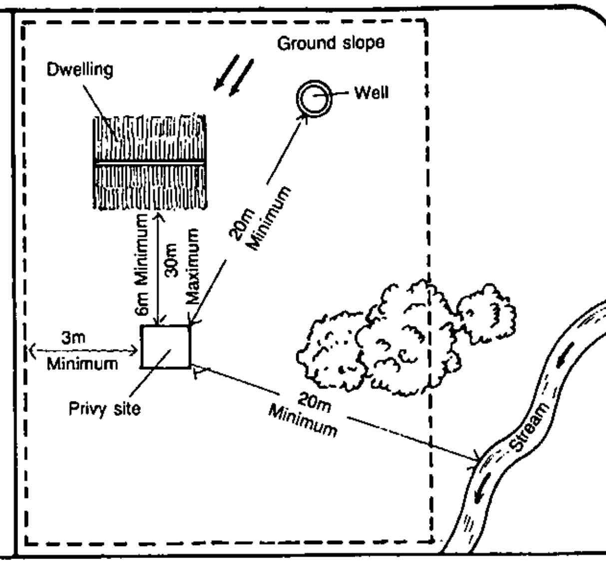


Figure 1. Location Map

Determining Pit Size

To determine the length, width and depth of a pit, first calculate the capacity. The capacity, or volume, of a pit is determined by the number of users of the privy, the number of years the pit is expected to last, whether the privy will have a pour-flush bowl, and the type of anal cleansing material used. Worksheet A shows a sample calculation of the size of a pit.

The number of users equals the number of persons living in or using the building to be served (Worksheet A, Line 1).

The pit should be designed to last 5 to 10 years, preferably 10 (Worksheet A, Line 2).

If the privy will have a pour-flush bowl, the pit can be smaller because the water used to flush the bowl will cause the excreta in the pit to decompose more rapidly (Worksheet A, Line 4).

The capacity of the pit is calculated as follows:

For a pit without a pour-flush: number of persons times number of years times 0.06 equals volume in cubic meters (Worksheet A, Line 5).

For a pit with a pour-flush: number of persons times number of years times 0.04 equals volume in cubic meters (Worksheet A, Line 6).

Worksheet A. Calculations for Privy Pit, Lining, and Base

Capacity of Pit

1. Number of users = 6
2. Designed life of pit in years = 8
3. Line 1 x Line 2 = 48
4. Is there a pour-flush bowl? ☒ no ☐ yes
5. If "no," then Line 3 x 0.06 = 2.8 m^3
6. If "yes," then Line 3 x 0.04 = ______ m^3
7. Do anal cleansing materials readily decompose? ☒ yes ☐ no
8. If "yes," then capacity = Line 5 (or Line 6) = 2.8 m^3
9. If "no," then capacity = 1.5 x (Line 5 or Line 6) = ______ m^3

Dimensions of Pit

10. Capacity (from Line 8 or Line 9) = 2.8 m^3
11. Pit is for (check one): ☐ pit privy ☒ ventilated pit privy ☐ offset pit privy
12. Width (from Table 2) = 1.1 m
13. Length (from Table 2) = 1.2 m
14. Line 12 x Line 13 = 1.32 m^2
15. Depth = $\frac{\text{Line 10}}{\text{Line 14}}$ = 2.1 m

Quantity of Lining Material (area of pit walls)

16. 2 x Line 12 = 2.2 m
17. 2 x Line 13 = 2.4 m
18. Line 16 + Line 17 = 4.6 m
19. Area of walls = Line 15 x Line 18 = 9.7 m_2

Distance Around Pit (periphery)

20. Periphery = Line 16 + Line 17 = 4.6 m

Volume of Poured Concrete Base

21. Width of base = 0.15 m
22. Thickness of base = 0.05 m
23. Volume = Line 20 x Line 21 x Line 22 = 0.03 m^3

Lengths for Wood or Log Base

24. Line 12 + 1.0m = 2.1 m
25. Line 13 + 1.0m = 2.1 m
26. Lengths of the four logs or wood beams:

(1) Line 24 = 2.1 m
(2) Line 24 = 2.1 m
(3) Line 25 = 2.2 m
(4) Line 25 = 2.2 m

Example 1. Suppose a pit privy without a pour-flush is being designed for a family of six and is to last eight years. Then the capacity of the pit equals:

6 x 8 x 0.06 = 2.8 cubic meters (Worksheet A, Lines 1-5).

Example 2. Suppose a pit privy with a pour-flush is being designed for a family of six for eight years. Then the capacity of the pit equals:

6 x 8 x 0.04 = 1.9 cubic meters (Worksheet A, Lines 1-6).

If anal cleansing materials that do not readily decompose such as grass, leaves, corncobs or mudballs are used, the capacity of the pit should be multiplied by 1.5 (Worksheet A, Line 7). For example, if the capacity of the pit was calculated to be 3.0 cubic meters and corncobs are the usual anal cleansing material, the required capacity of the pit is:

$3.0m^3$ x 1.5 = 4.5 cubic meters (Worksheet A, Line 9).

When the capacity has been calculated, determine the dimensions of the pit. First, find the length and width. They depend on the type of slab and shelter being used (see "Designing Slabs for Privies," SAN.1.D.1 and "Designing Privy Shelters," SAN.1.D.3).

In general, a pit for a privy is square and is directly beneath the slab and shelter. A pit for a ventilated pit privy is either slightly offset or slightly longer than it is wide to accommodate the vent pipe. A pit for an offset pit privy is longer than it is wide and larger than a pit that is not offset.

(NOTE: A pour-flush bowl is generally used with a ventilated pit privy or an offset pit privy.)

Table 2 shows the general width and length and the minimum depth of the pit for each type of privy.

Determine the correct depth by dividing the design capacity by the width times the length (Worksheet A, Lines 10-15).

Table 2. Privy Type and Pit Dimensions

Privy Type	Pit Dimensions		
	Width	Length	Depth
Pit Privy	1.0-1.2m	1.0-1.2m	at least 1.5m
Ventiliated Pit	1.0-1.2m	1.1-1.5m	at least 1.5m
Offset Pit	1.0-1.2m	1.5-2.0m	at least 3.0m

For example, calculate the correct depth of a ventilated privy with a capacity of 2.8 cubic meters, a width of 1.1 meters, and a length of 1.2 meters.

$$\text{depth} = \frac{2.8m^3}{1.1m \times 1.2m}$$

$$= \frac{2.8m^3}{1.32m}$$

$$= 2.1m$$

For pits 2.5-3.5m deep, add 0.15m to the length and 0.15m to the width to accommodate a step or ledge left in the walls during construction. For safety reasons, do not design a pit to be dug by hand deeper than 3.5m.

When the dimensions of the pit have been determined, make a technical drawing similar to Figure 2 showing length, width, and depth. For an offset pit privy, which requires a chute from the squatting slab to the pit, make a drawing similar to Figure 3 showing length, width, and depth of pit, and excavation for the chute. Give these drawings to the construction supervisor.

If the soil is such that the walls of the pit will not stand on their own in both the wet and dry seasons, the pit must have a lining. All pits need a base to support the slab (see "Designing Slabs for Privies," SAN.1.D.1).

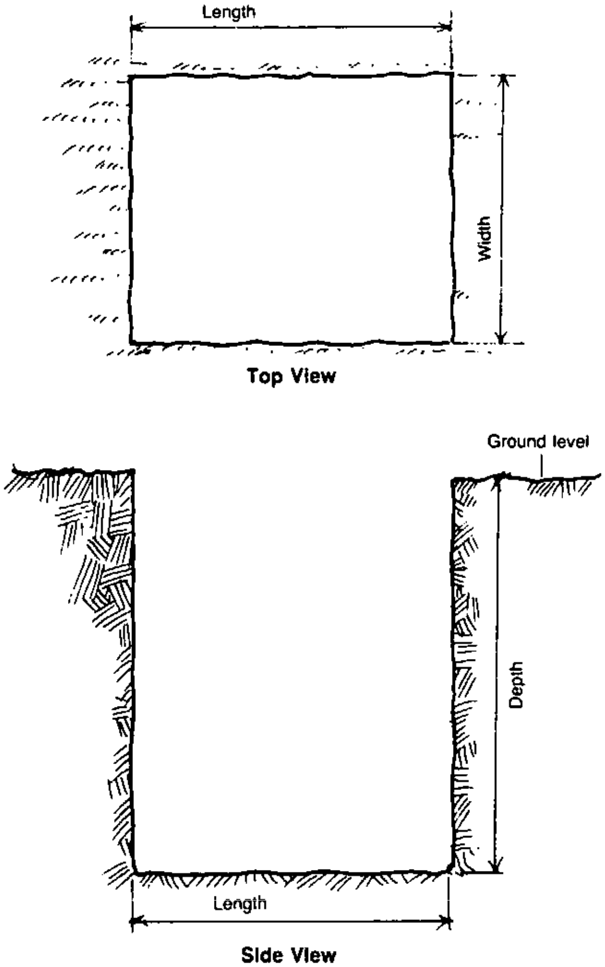


Figure 2. Dimensions for Pit Privy or Ventilated Privy

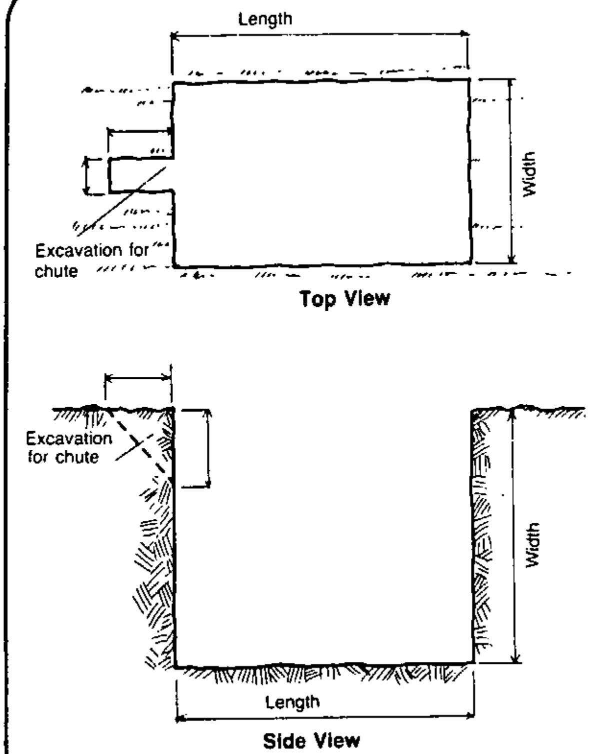


Figure 3. Dimensions for Offset Pit Privy

Caution!

Before the pit is excavated, design and construct the slab or, if it is an offset pit, the cover (see "Designing Slabs for Privies," SAN.1.D.1 and "Constructing Slabs for Privies," SAN.1.C.1). This is necessary so that when the pit is constructed, it can be covered immediately. A pit left open and unattended is a serious hazard. Whenever workers leave the site, they should cover the pit with the slab.

The lining can be made of bamboo, logs, poles, boards, bricks, concrete blocks, or select field stones. Whatever material is used, it must have slits or open spaces to allow the liquid part of excreta to pass through to the soil. For an offset pit privy, a space must be left in the lining to allow for the chute.

Prepare a sketch similar to one of those in Figure 4 showing the lining material and a sketch similar to one of those in Figure 5 showing the materials to be used for the base, and give both of them to the construction supervisor.

Materials List

Prepare a materials list similar to Table 3, showing labor requirements, types and quantities of materials and tools, and the estimated funds needed to construct the pit, including lining and base. This technical note provides the means of determining some quantities. The remaining quantities will have to be determined by you as the project designer or by the construction supervisor.

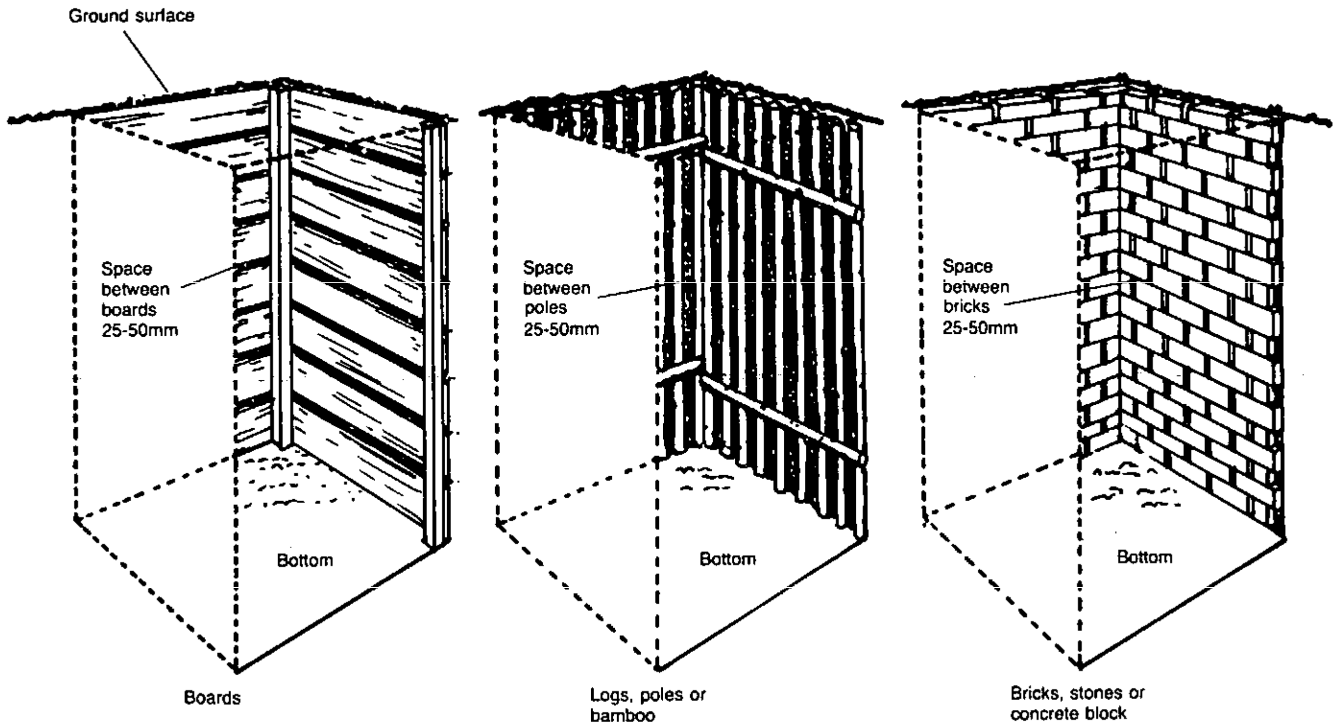


Figure 4. Pit Linings

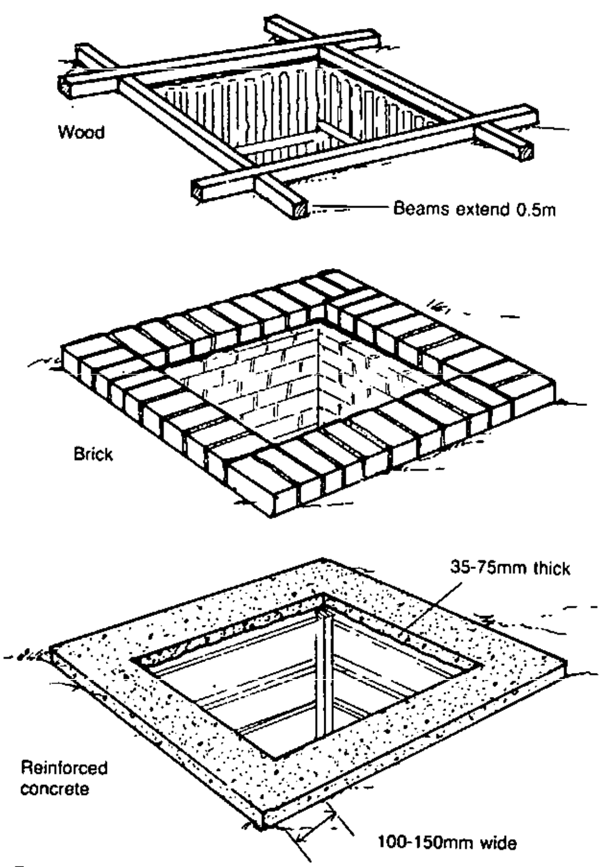


Figure 5. Bases

Labor. Ideally, there should be at least two laborers to dig the pit. If the pit lining or base is wood, one worker should have some carpentry skills; if the lining or base is brick or concrete block, one worker should have some masonry skills; if the base is poured concrete, one worker should have some concrete skills. If this number of laborers is not available, you can certainly make do with fewer. The person in charge of construction should be present during all stages of construction.

Lining. The material used for the lining, if needed, can be bamboo, logs, poles, boards, bricks, concrete blocks, or select field stones. Use a material that is readily available and that laborers are familiar with. The quantity depends on the type of material and the size of the pit. One way to estimate the quantity is to calculate the area of the pit walls, since the lining must cover nearly the entire wall area except for the spaces between the boards, poles, or bricks.

Table 3. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers (one experienced with carpentry, stone masonry, or poured concrete, whichever applies)	1 2 (at least)	____ ____
Supplies	For laying out the system: wooden stakes or sticks	____	____
	For the lining: bamboo, poles logs, boards, bricks, concrete blocks, select field stones	____	____
	For the base: wood, bricks, concrete blocks	____	____
	For poured concrete or mortar:		
	Cement Sand Gravel Water	____ ____ ____ ____	____ ____ ____ ____
	Other	____	____
Tools and Equipment	Box or bucket Sturdy rope or ladder Measuring tape Shovels Wheelbarrow Hammer Saw Nails Trowel Plumb line (string and rock) Hatchet or machete Container (for mixing mortar) Concrete slab	1 1 1 2 (at least) 1 1 1 -- 1 1 1 1 1	____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
	Other	--	____

Total Estimated Cost = ____

The area of the pit walls equals two times the width plus two times the length multiplied by the depth (Worksheet A, Lines 16-19).

For example, suppose a pit is 1.1 meters wide, 1.2 meters long, and 2.1 meters deep. Then the area equals:

$$(2 \times 1.1) + (2 \times 1.2) \times 2.1$$
$$= (2.2 + 2.4) \times 2.1$$
$$= 4.6 \times 2.1$$
$$= 9.7\text{m}^2$$

The lining material must cover an area equal to about 9.7 square meters.

Base. The material used for the base can be wood, bricks, concrete blocks, or poured concrete. Use a material that is readily available and that the laborers are familiar with. Figure 5 shows three different types of bases.

(NOTE: A wood base may not last as long as a brick, concrete block, or poured concrete base.)

The quantity depends on the type of material and the size of the pit. One way to estimate the quantity for a brick, concrete block, or poured concrete base is to calculate the distance around the top of the pit. This distance is called the periphery; it is equal to twice the length plus twice the width (Worksheet A, Line 20).

For a base made of bricks or concrete blocks, there must be a sufficient quantity to place the bricks or blocks side by side for a distance equal to the periphery of the pit.

For example, suppose a brick base is needed for a pit 1.1 meters wide and 1.3 meters long. Then the periphery equals:

$$(2 \times 1.1) + (2 \times 1.3)$$
$$= 2.2 + 2.4$$
$$= 4.6\text{m}$$

There must be enough bricks to be placed side by side around a periphery of 4.6 meters.

For a poured concrete base, the quantity of poured concrete is equal to the periphery of the pit times the width of the base times the thickness of the base (Worksheet A, Lines 21-23).

For example, suppose a concrete base 0.15 meters wide and 0.05 meters thick is needed for a pit with a periphery of 4.6 meters. Then the quantity of concrete equals:

$$4.6m \times 0.15m \times 0.05m$$

$$= 0.03m^3$$

For a wood base, four logs or sturdy wooden beams are needed, one for each side of the pit. Each log should be 1 meter longer than the side of the pit on which it will be laid, as shown in Figure 5 (Worksheet A, Lines 24-26). For example, suppose a wood base is needed for a pit that is 1.2 meters wide and 1.3 meters long. Then the lengths of the four logs would be:

$$(1.2+1.0),(1.2+1.0),(1.3+1.0),(1.3+1.0)$$

$$= 2.2m,\ 2.2m,\ 2.3m,\ 2.3m.$$

Tools. The tools required will vary according to the type of pit lining and base. All types of pits require at least two shovels (one per laborer) or other digging implements. A wheelbarrow is useful for carting away excavated dirt and for bringing other material to the pit site. A saw and nails are needed if the lining or base is made of wood, logs or boards. If the lining or base is made of bricks or concrete blocks, or the base is made of poured concrete, a container for mixing the concrete or mortar and a trowel for applying and smoothing concrete or mortar are needed.

Also needed are a measuring tape to help determine the exact location of the pit, and wooden stakes or sticks to lay it out on the ground. A plumb line (long string with a rock tied to the end) will be useful to ensure that the pit walls are dug vertically. A sturdy rope or ladder should be available for the laborers to get into and out of the pit.

Cost. The cost of the pit depends on a number of variables: which materials are available and which must be purchased; how much labor will be volunteered and how much must be paid for; prices and wage rates; and so on. Make your best estimate based on local conditions.

When all calculations, determinations, and estimates have been made, prepare a materials list similar to Table 3, and give it to the construction supervisor. In summary, give the construction supervisor: (1) a location map similar to Figure 1, showing the location of the pit in relation to all nearby structures and geographical features; (2) a technical drawing similar to either Figure 2 or Figure 3, depending on the type of pit privy, showing correct dimensions of the pit; (3) sketches similar to those in Figure 4 and Figure 5, showing the general configuration of the pit lining and base; and (4) a materials list similar to Table 3 showing the labor, materials, tools, and money needed to construct the pit, lining, and base.

Water for the World

Constructing Pits for Privies
Technical Note No. SAN. 1.C.2

The pit beneath a privy receives and holds excreta. The pit prevents contamination of groundwater and the spread of disease by keeping the excreta away from humans, animals and insects. At the top, the pit has a base for the slab. The pit often has a lining, also. If the pit walls will not stand on their own, a lining prevents them from caving in. Lining is installed after the pit is dug. Shoring, similar to lining, must be put in place during excavation of deeper pits and pits in crumbly soils to protect workers from cave-ins. The base supports the slab or cover (see "Constructing Slabs for Privies," SAN.1.C.1) and privy shelter (see, "Constructing Privy Shelters," SAN.1.C.3). Constructing a pit involves assembling laborers, materials, and tools to do the job, excavating the pit at the correct location, lining the pit walls, if necessary, and building a base for the slab.

A properly constructed pit will last 5 to 10 years. This technical note describes each step in constructing a pit. Read the entire technical note before beginning construction.

Useful Definitions

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria from excreta.

EXCRETA - Human body waste.

GROUNDWATER - Water stored below the ground's surface.

Materials Needed

The project designer must provide four items before construction can begin:

1. Location map, similar to Figure 1, showing the correct site where the pit is to be excavated. The map will show distances from the pit to nearby dwellings, sources of drinking water, property lines, and any other structures or prominent geographical features.

2. Technical drawings, similar to Figures 2 and 3, showing the correct dimensions of the pit.

3. Sketches, similar to Figures 4 and 5, showing the materials and general configuration of the pit lining and base.

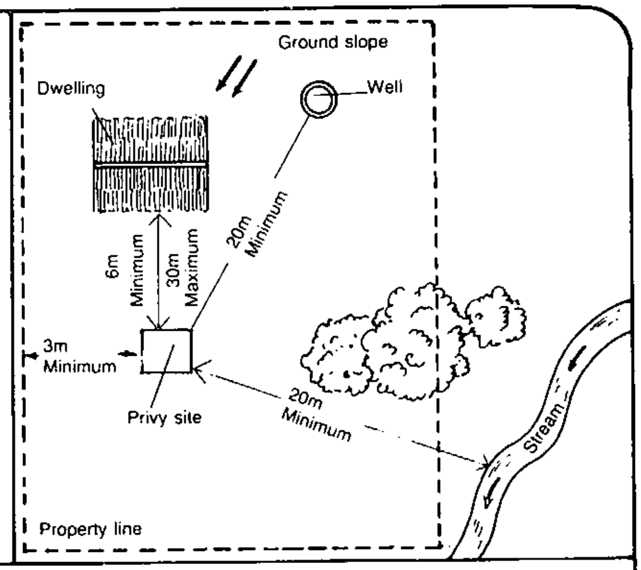


Figure 1. Location Map

4. Materials list, similar to Table 1, describing all labor, supplies, and tools needed to construct the pit, lining, and base.

You will also need a slab or cover (see "Constructing Slabs for Privies," SAN.1.C.1) to cover the pit immediately after the base and lining are in place.

(NOTE: Figures 1,2 and 3 and Table 1 are samples only and cannot be used to build the pit. The documents you need will be provided by the project designer.)

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary workmen, supplies, and tools.

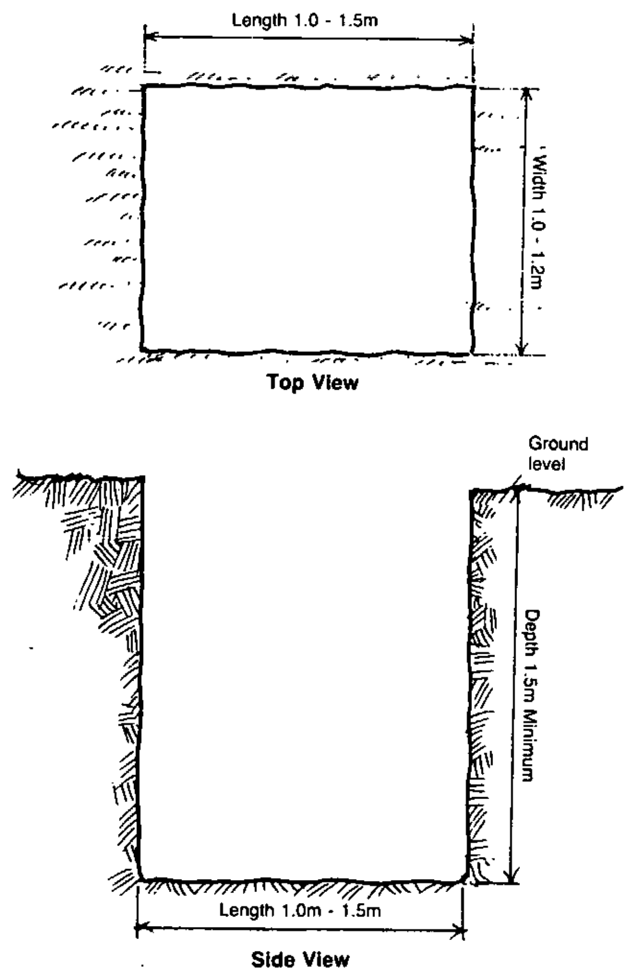


Figure 2. Dimensions for Pit Privy or Ventilated Privy

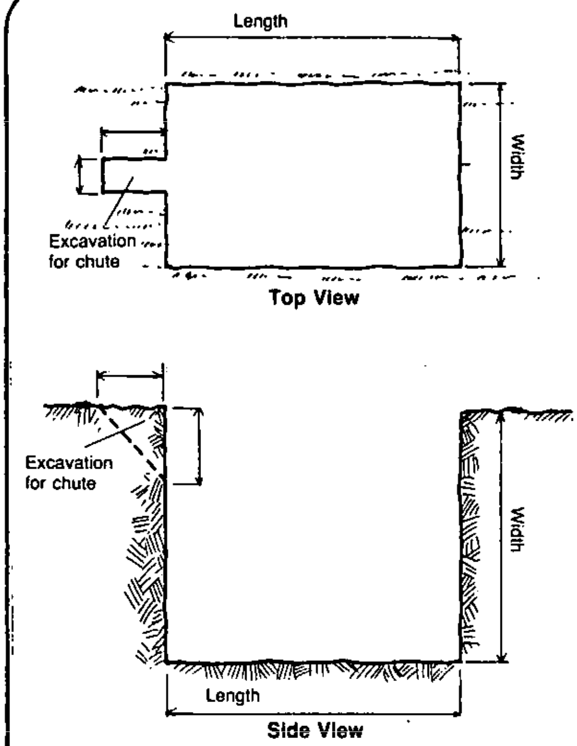


Figure 3. Dimensions for Offset Pit Privy

Caution!

1. If the pit is deeper than about 1.5m, the walls must be shored during excavation to prevent a cave-in that could be fatal to a worker in the pit.

2. Do not hand-dig a pit deeper than about 3.5m.

3. All pits must be dug at the exact site and to the dimensions specified by the project designer to protect groundwater and other sources of drinking water.

4. A pit must be covered with a slab or cover (see "Constructing Slabs for Privies," SAN.1.C.1) during construction when it is not attended and immediately after it is excavated and the lining and base are in place. A pit left open and unattended is a serious hazard.

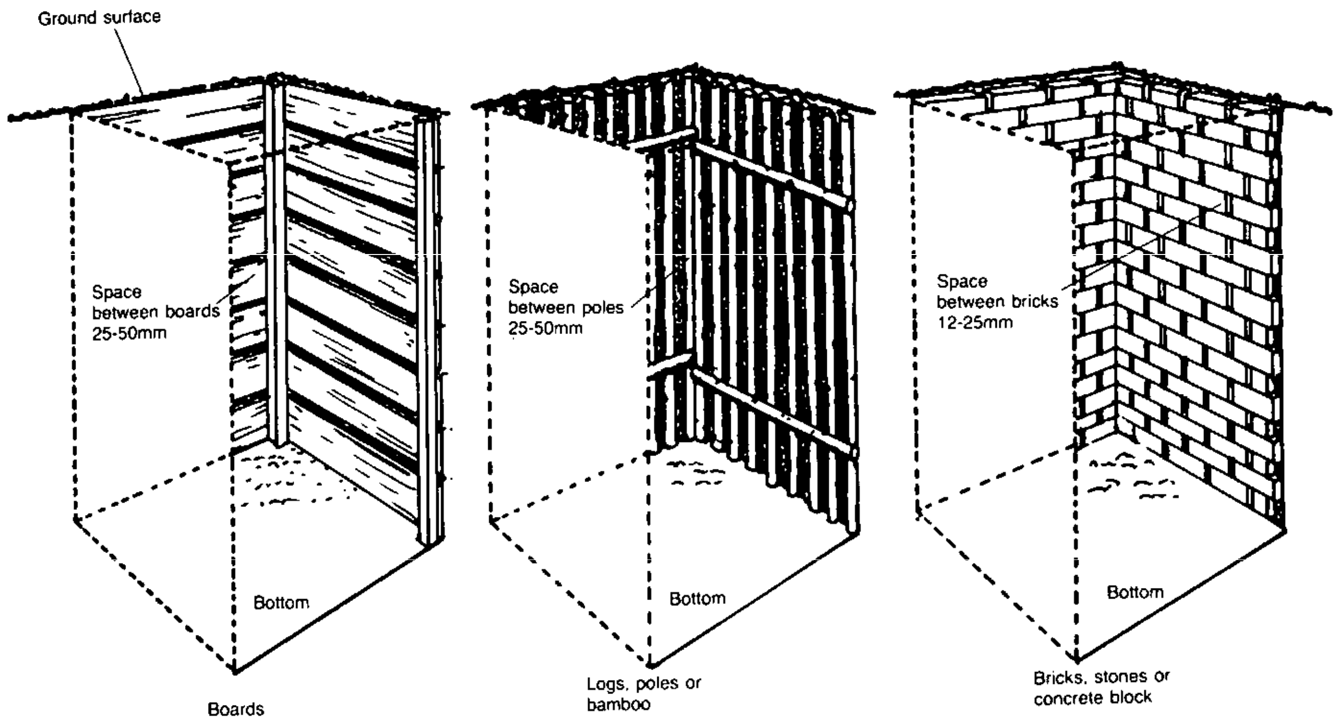


Figure 4. Pit Linings

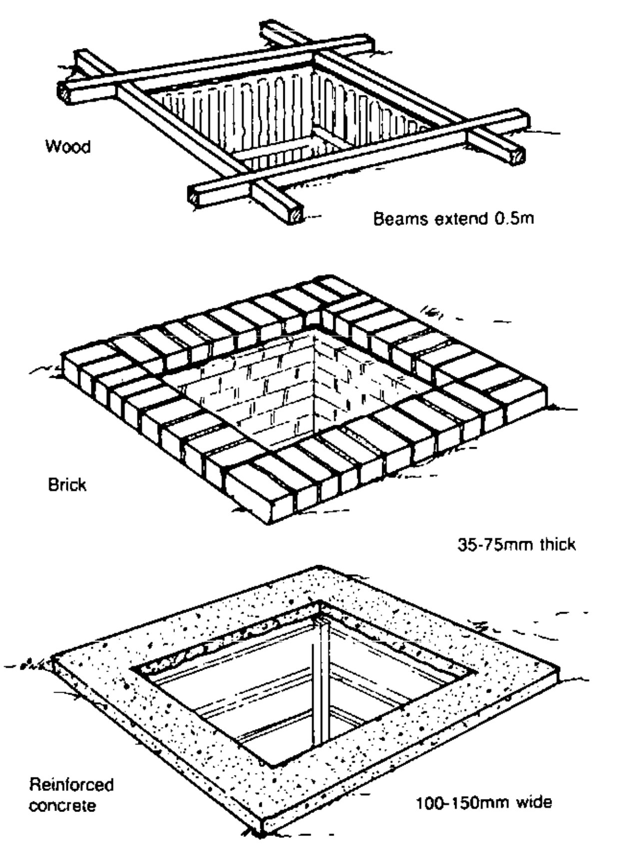


Figure 5. Bases

Construction Steps

Depending on local conditions, availability of materials, skills of workers, and so on, some construction steps will take only a few hours, while others may take a day or more. Table 2 shows a sample work plan for building a pit including time estimates for each step. Draw up a similar work plan with rough time estimates based on local conditions. You will then have an idea of when specific workmen, supplies and tools must be available during the construction process. The following are construction steps for building a pit.

1. Assemble all laborers, materials, tools, and drawings needed to begin construction. Study all diagrams carefully.

2. Determine the correct location of the pit, using the location map similar to Figure 1 and a measuring tape. Clear the area of any vegetation that might hinder construction. Lay out on the ground the correct dimensions of the pit, as shown in the technical drawing, and mark each corner of

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	____
	Laborers (one experienced with carpentry, stone masonry, or poured concrete, whichever applies)	2 (at least)	____
Supplies	For laying out the system; wooden stakes or sticks	____	____
	For the lining: bamboo, poles, logs, boards, bricks, concrete blocks, select field stones	____	____
	For the base: wood, bricks, concrete blocks	____	____
	For poured concrete or mortar:		
	Cement	____	____
	Sand	____	____
	Gravel	____	____
	Water	____	____
	Other	____	____
Tools and Equipment	Box or bucket	1	____
	Sturdy rope or ladder	1	____
	Measuring tape	1	____
	Shovels	2 (at least)	____
	Wheelbarrow	1	____
	Hammer	1	____
	Saw	1	____
	Nails	--	____
	Trowel	1	____
	Plumb line (string and rock)	1	____
	Hatchet or machete	1	____
	Container (for mixing mortar)	1	____
	Concrete slab	1	____
	Other	--	____

Total Estimated Cost = ____

Table 2. Sample Work Plan for Constructing Pit, Lining, and Base

Time Estimate	Day	Task	Personnel	Tools/Materials
2 hours	1	Mark pit location	Foreman and 1 laborer (NOTE: Foreman present during all construction steps)	Location map, and measuring tape, wooden stakes or sticks
6 hours	1	Build base	Skilled worker (familiar with masonry)	Bricks, container (for mixing mortar), cement, sand, gravel, water, shovel, trowel
2 days	2-3	Allow mortar to set		
2 days	4-5	Excavate pit	2 laborers (at least)	2 shovels, ladder, long rope, bucket or box, wheelbarrow, plumb line
4 hours	6	Line pit	1 laborer, 1 skilled worker (familiar with carpentry)	Boards, hammer, saw, nails
1 hour	6	Cover pit	2 laborers	Concrete slab
1 hour	6	Waterproof edges of slab; mound dirt around base and slab	1 laborer	Tar, shovel

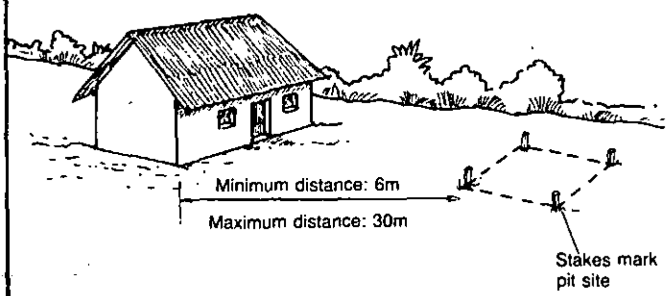


Figure 6. Locating Pit Site

the pit with a wooden stake or pointed stick as shown in Figure 6. Mark the excavation for the chute, if it is an offset pit.

3. Build the base around the pit site. This is done before digging the pit to prevent the top of the pit walls from crumbling and to ensure that the slab or cover can be put in place immediately after the pit is dug and lined. The corners of the base should be square.

For a wood base:

3a. Cut four logs, poles, or wood beams to the length determined by the project designer. Cut two notches halfway through each log, as shown in Figure 7, so the logs will fit together to form the base around the pit site. Bind the logs with heavy cord or twine or nail them together.

For a concrete block or brick base:

3b. Lay a straight row of bricks or blocks along each side of the pit site as shown in Figure 8. The blocks should either be mortared together or fit tightly. See "Constructing Septic Tanks," SAN.2.C.3, for details on mixing and applying mortar. Tamp the blocks in place or scrape away dirt to ensure that the rows of blocks are level. If the blocks or bricks are mortared together, cover them with damp straw, leaves, or grass and allow a few days for the mortar to set. Keep the cover material damp until the concrete has set.

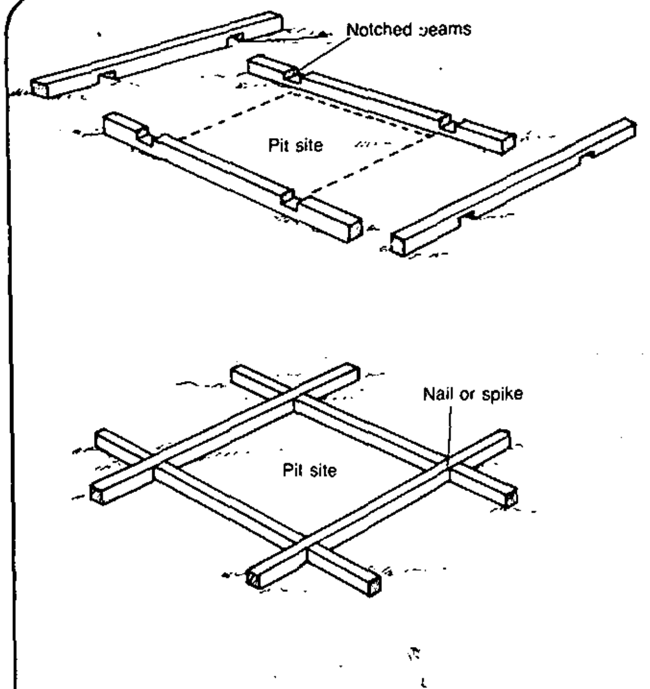


Figure 7. Wood Base

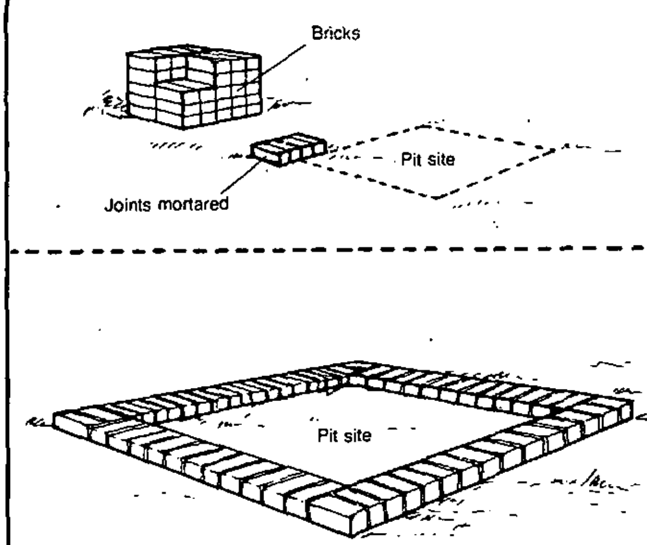


Figure 8. Block or Brick Base

For a poured concrete base:

3c. See "Constructing Septic Tanks," SAN.2.C.3, for details on concrete. Dig a shallow, level trench around the pit site. Make the trench about 150mm wide and 50 to 75mm deep as shown in Figure 9. The width and depth of this trench determine the width and thickness of the base. The trench lines should be straight, the bottom tamped, and the sides and bottom clean and free of loose dirt. Mix the concrete and pour it evenly around the trench until the trench is about half full. Lay reinforcing material such as steel bars, wire mesh, or bamboo in place. Pour concrete until the trench is full. Smooth the surface with a trowel. Cover with wet straw, leaves, grass, burlap, or other material and allow three to seven days for the concrete to set. Keep the cover material damp until the concrete has set.

4. Begin digging the pit after the base has been constructed and is securely in place. Make the sides straight and smooth. Use a plumb line (string tied to rock or weight) to check the sides during excavation, as shown in Figure 10. Pile the dirt at least 1m away from the edge of the pit to prevent it from falling back in. For an offset pit, make the additional small excavation for the chute.

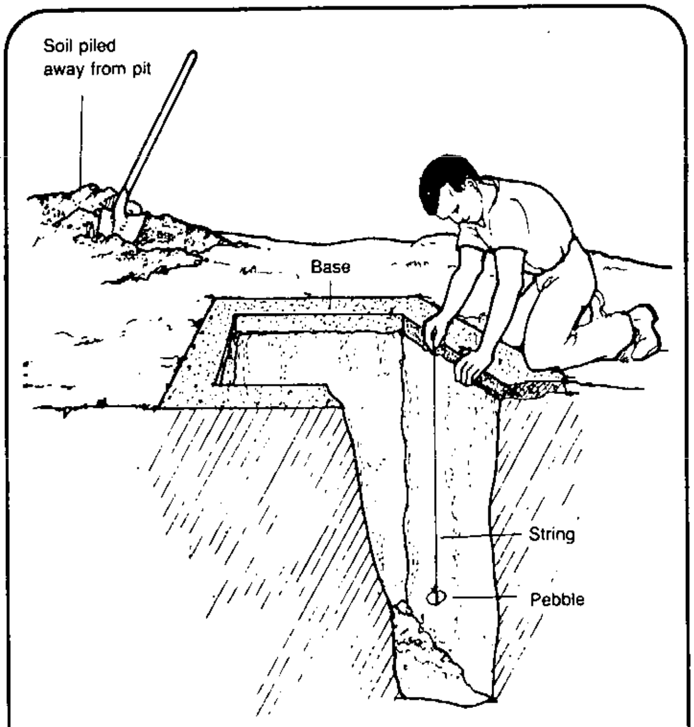


Figure 10. Checking Pit Sides with a Plumb Line

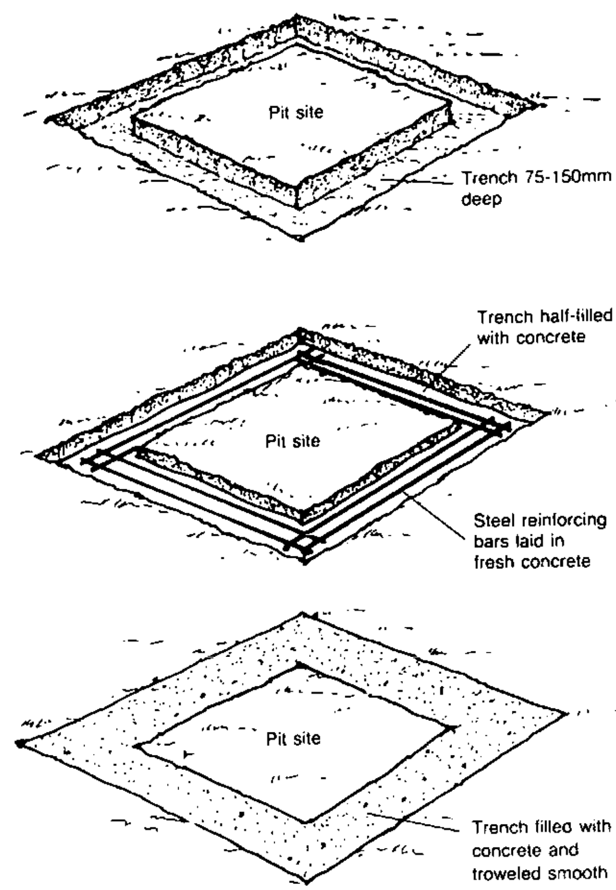


Figure 9. Poured Concrete Base

(NOTE: Depending on the dimensions of the pit, it is likely that there will be space for only one laborer to dig. Have laborers rotate every 20 to 40 minutes--one in the pit, one or two outside. When the pit reaches about shoulder level, it may be helpful to lower a bucket or box tied to a rope into the pit. The laborer in the pit can fill the container with dirt, and the laborer outside can haul the full container up and out. This method of excavation will be necessary for pits deeper than about 1.5m. Have a sturdy rope or ladder readily available for laborers to get in and out of the pit.)

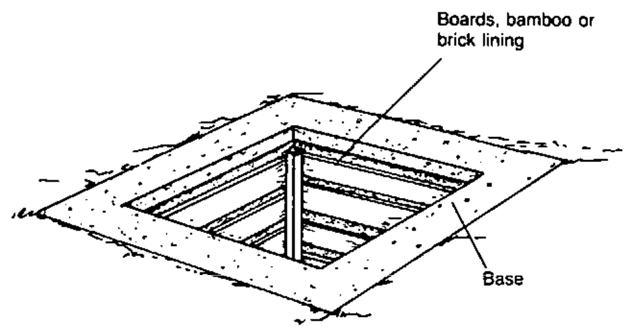


Figure 11. Pit with Shored Sides

5. Shore up the sides of the pit to prevent possible cave-ins when excavating deeper than about 2m, as shown in Figure 11. Secure the sides with logs, poles, boards, bamboo, or other material when the depth reaches about 2m. Continue digging, leaving a 75 to 100mm step or ledge around the walls to support the shoring material as shown in Figure 12. Shore up the lower walls when the pit reaches the correct depth. Do not hand dig a pit deeper than about 3.5m.

6. Measure the depth as the pit is being dug. Make the pit floor fairly level when the correct depth has been reached.

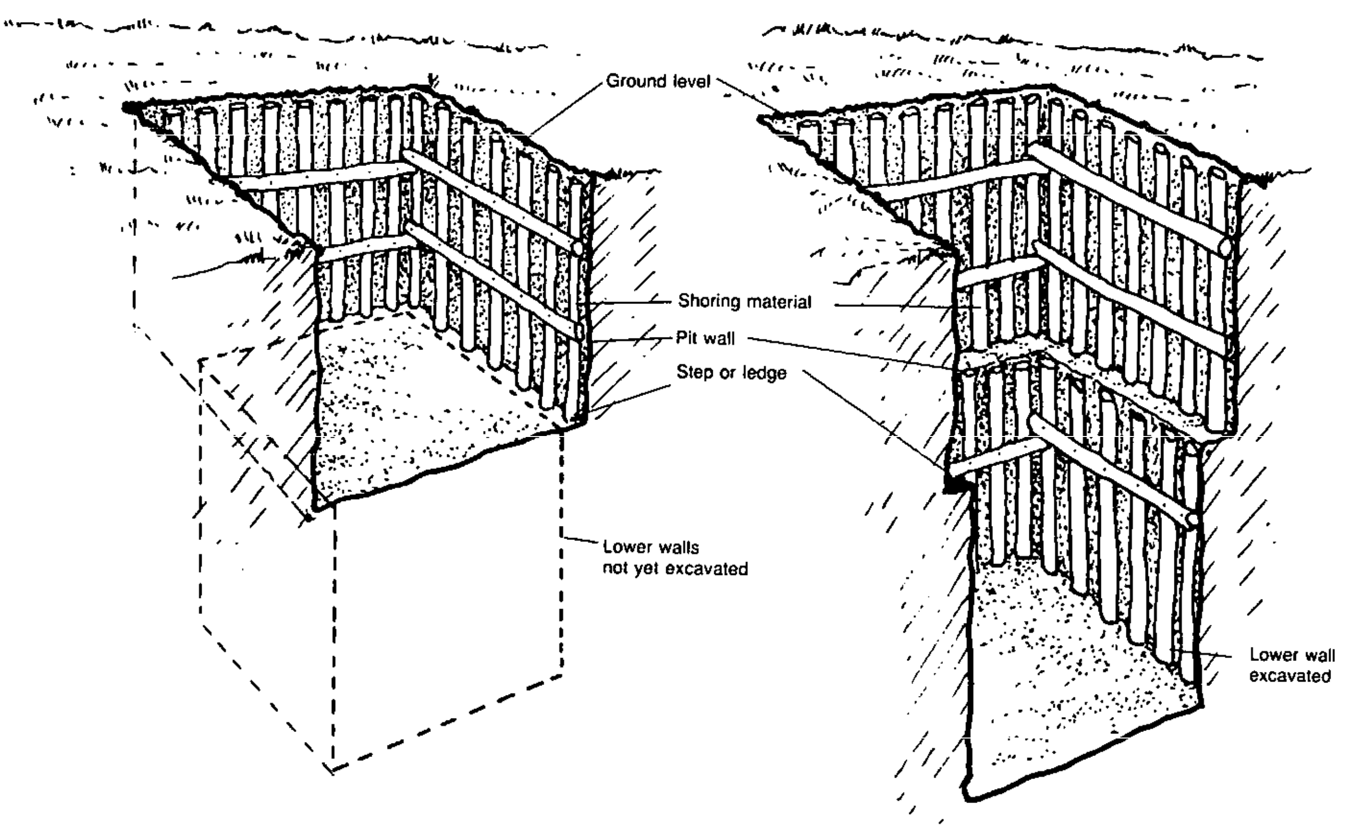


Figure 12. Shoring a Deep Pit

7. Install the lining, if needed, after the pit is fully excavated. The lining should extend from the bottom of the pit to the base. If the pit has been shored, the shoring material can be left in place and serve as the lining.

For a log, pole, or bamboo lining:

7a. Cut logs or poles to a length equal to the depth of the pit. Place the logs or poles vertically along the sides of the pit. The poles should reach from the bottom of the pit to the base and should be placed 25 to 75mm apart. Cut four cross poles equal to the length of the pit, and four cross poles equal to the width. Nail or tie the cross poles in place about 0.5m from the top and bottom of the pit walls to secure the vertical poles, as shown in Figure 4.

For a wood or board lining:

7b. Place the boards either vertically or horizontally. To place them vertically, use the same methods as for log, pole, or bamboo linings. To place them horizontally, cut boards to lengths equal to both the length and width of the pit. Cut four long boards or beams to a length equal to the depth of the pit. Put a long board or beam in each corner of the pit and place the shorter side boards horizontally along the pit walls and nail them to the corner beams. The side boards should be spaced about 25 to 75mm apart, as shown in Figure 4.

For a concrete block or brick lining:

7c. Stack the blocks or bricks up the sides of the pit as shown in Figure 4. Leave spaces between the bricks. Do not mortar. Stack the bricks up to the base. For additional strength, mortar the top two courses of bricks.

8. Remove any tools, equipment, or scrap material from the pit after the lining is in place.

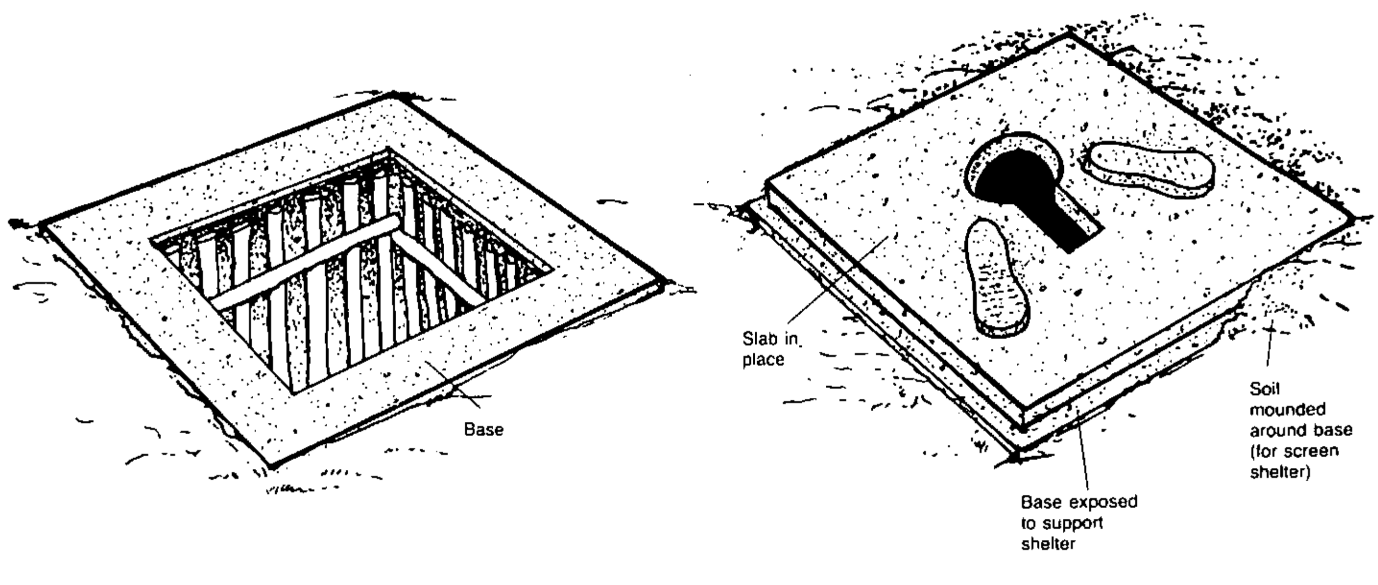


Figure 13. Placing Slab Over Pit

9. Set the slab or cover in place over the pit as shown in Figure 13. If the slab or cover is in sections, use tar, oakum or other material to waterproof where the sections fit together.

10. Waterproof around the edges of the slab or cover where it rests on the base. Do not mortar the slab or cover to the base because in 5 to 10 years, depending on the size of the pit, the slab or cover will be moved to a new pit.

11. Place dirt around the edges of the base and slab or cover, and tamp. This dirt will help seal the pit.

12. Set or build in place a privy shelter (see "Constructing Privy Shelters," SAN.1.C.3).

13. Place dirt around the edges of the shelter, and tamp.

Water for the World

Designing Slabs for Privies

Technical Note No. SAN. 1.D.1

The slab is the floor of the privy. It covers the pit and has a hole through which to defecate. Designing a slab involves selecting the type of slab (squatting or sitting), deciding which improvements the privy will have, calculating the dimensions of the slab, and determining the materials, labor, and tools needed to build it. The products of this process are design drawings of the slab and improvements, if any, and a detailed materials list. These items should be given to the person in charge of construction.

This technical note describes how to design a slab and arrive at these end-products. Read the entire technical note before beginning the design process.

Materials Needed

Measuring tape - To check dimensions of previously constructed items (pit, base around pit, or pour-flush bowl, for instance)

Selecting Slab Type

The type of slab selected depends on whether the users prefer to squat or sit when defecating.

Squatting Slab. The main features of a squatting slab are a hole, a pair of footrests, and a lid to cover the hole. See Figures 1 and 2.

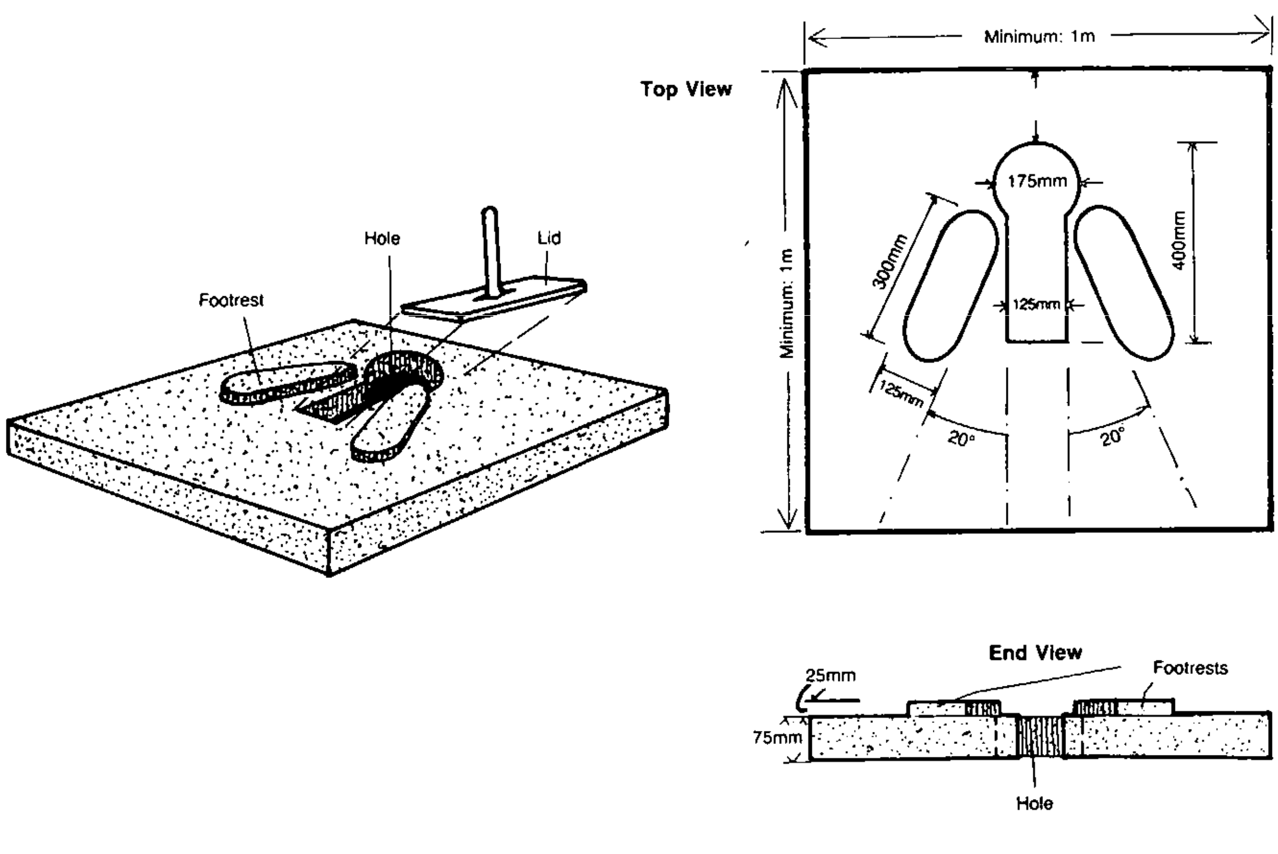


Figure 1. Squatting Slab

The hole is generally key-hole shaped, about 400mm long, and 125mm wide at the narrow end. The wide end is a circle 175mm in diameter. The back edge of the hole usually should be about 150mm from the back wall of the privy which, depending on the design, may be at the edge of the slab. If the distance between the wall and the hole is less than 150mm, there may not be enough space to squat. If the distance is more, there is a greater risk of soiling the floor. The distance between the edge of the hole and the edge of the slab may be greater than 150mm if the privy has a vent pipe.

Since the footrests ensure that the privy user is positioned correctly over the hole, their placement is important. They are oval-shaped, about 300mm long, 125mm wide, and 25mm high.

The lid should cover the hole but not fit inside it. It should have a handle. See Figure 2.

Sitting Slab. The main features of a sitting slab are a hole, a pedestal or riser, a seat, and a lid to cover the seat.

The hole is 250-300mm in diameter and should be about 150mm from the back wall of the privy which may be at the back edge of the slab, depending on the design. See Figure 3.

The pedestal is 275-350mm high and has the same inside diameter as the hole. The thickness of the pedestal walls depends on the materials used.

The seat is attached to the top of the pedestal. Its outside measurements are equal to or greater than the outside measurements of the pedestal. The seat has a hole in the center 200mm in diameter. A second seat with a smaller hole (150mm) in diameter can be included for children.

The lid covers the seat and is often attached to the back of the seat with a hinge. See Figure 3.

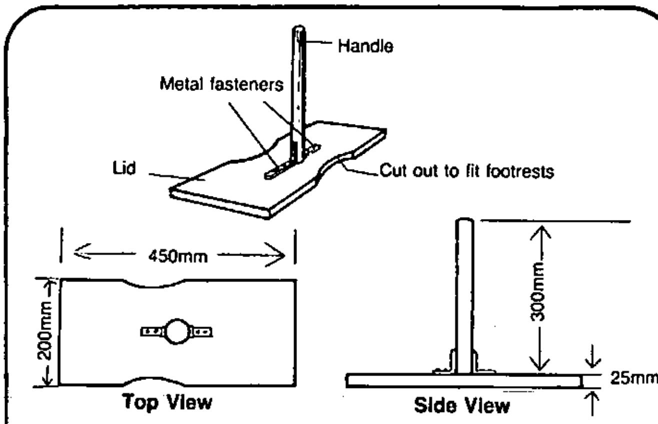


Figure 2. Lid for Squatting Slab

Determining Improvements

The main improvements to a privy are a vent pipe, a pour-flush bowl, an off-set pit, or a combination of the three. Any privy improvement will modify the slab design.

Vent Pipe. If the privy is to have a vent pipe, the pit must be about 300mm longer than a pit for an unimproved privy (see "Designing Pits for Privies," SAN.1.D.2). The slab must also be longer by about 300mm. This means that the distance from the back edge of the squatting hole to the edge of the slab is 450mm--150mm for the basic design plus 300mm for the vent pipe. See Figure 4. The slab has a hole 100-150mm in diameter, depending on the size of the vent pipe, and is positioned as in Figure 5. The vent pipe can be made from a sheet of tin or galvanized metal and should be topped with a fly-proof screen.

Pour-Flush Bowl. If the privy is to have a pour-flush bowl, the squatting hole may not be key-hole shaped. The shape of the hole must conform to that of the bowl, and often the bowls are prefabricated as shown in Figure 6. The bowl should be positioned to flush forward, to prevent erosion of the pit wall.

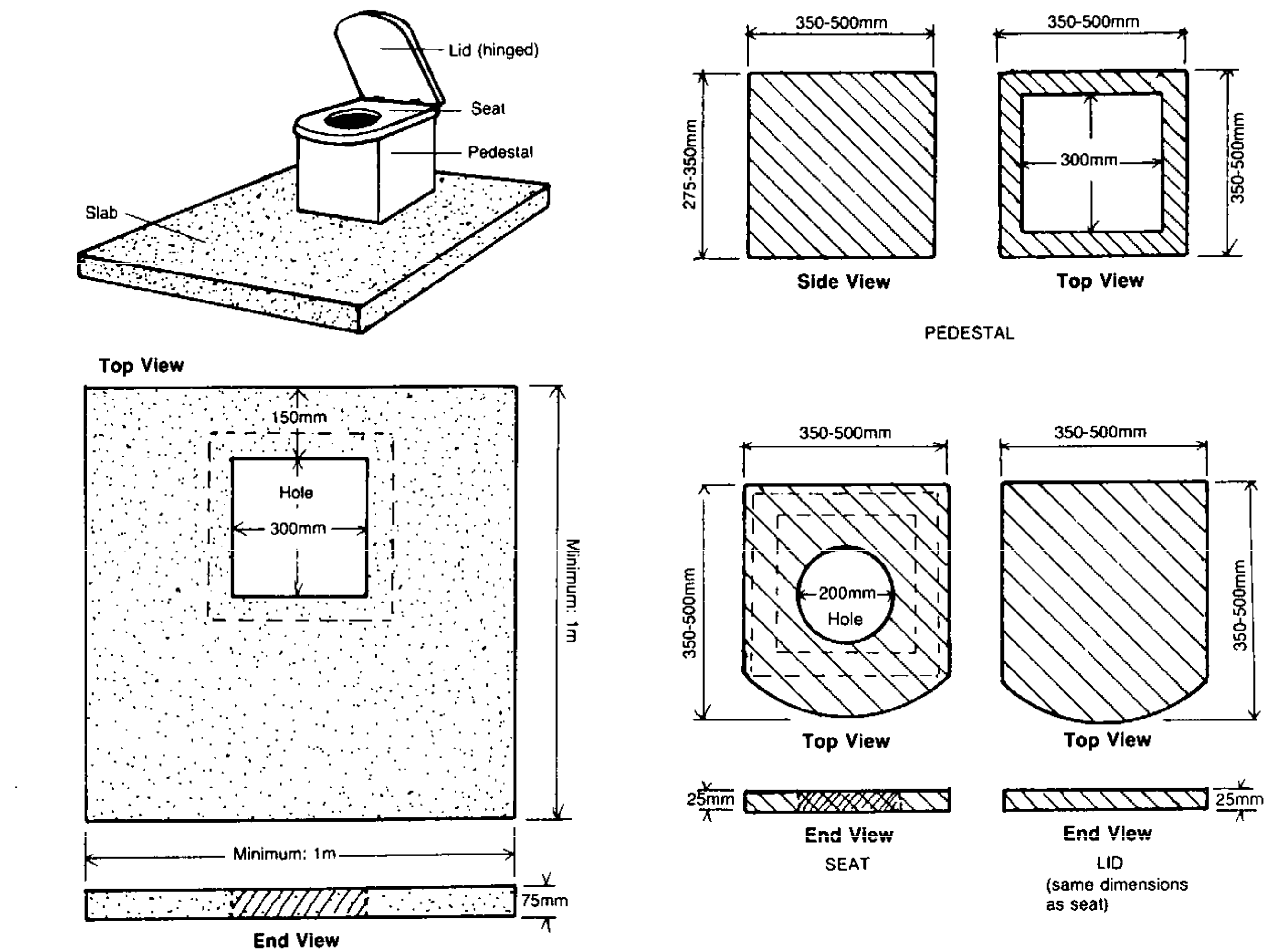


Figure 3. Sitting Slab with Pedestal, Seat and Lid

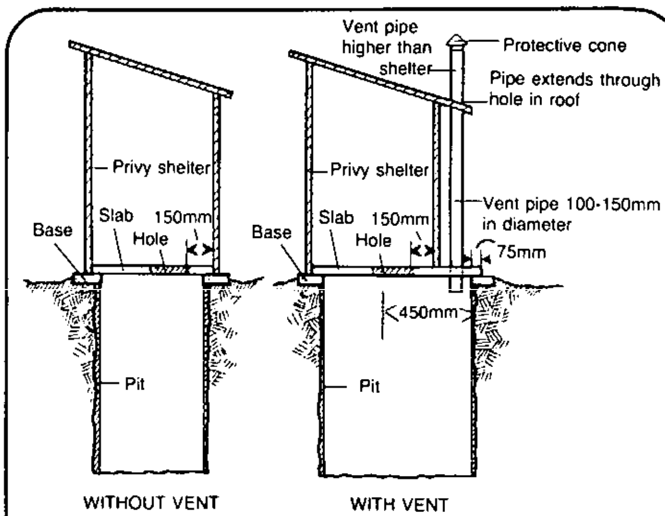


Figure 4. Comparison of Privies with and without Vent

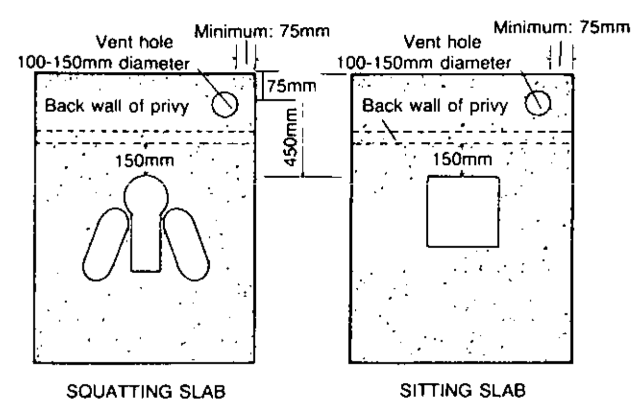


Figure 5. Top View of Slabs Showing Vent Hole Placement

Off-Set Pit. The slab for an off-set pit rests on a platform made of wood, bricks, or concrete and has a metal chute attached to the hole. The chute can be made from a sheet of tin or galvanized metal. It enters the pit below ground level at a downward angle of 50° to 60°. The upper end is mortared to the bottom of the slab and encircles the squatting hole. The lower end narrows to about 200mm in diameter and extends about 100mm beyond the pit wall. See Figure 7. The pit must have a cover which can be made in one piece or in sections. If the cover is made of concrete, it should be made in sections for easier handling as shown in Figure 8. The cover must be strong enough to prevent persons from falling into the pit.

Combination. If there is a combination of improvements, each improvement will modify the design of the slab as described above. For example, a privy with a vent pipe and a pour-flush bowl must have a longer slab to accommodate the vent and a specially shaped hole for the bowl. There is one exception. The slab design for an off-set pit is the same whether or not the pit has a vent pipe, because a vent pipe used with an off-set pit extends through the pit cover, not through the slab. See Figures 7 and 8.

Calculating Dimensions

Unimproved, ventilated, or pour-flush privies must have slabs that cover the pit and overlap each edge

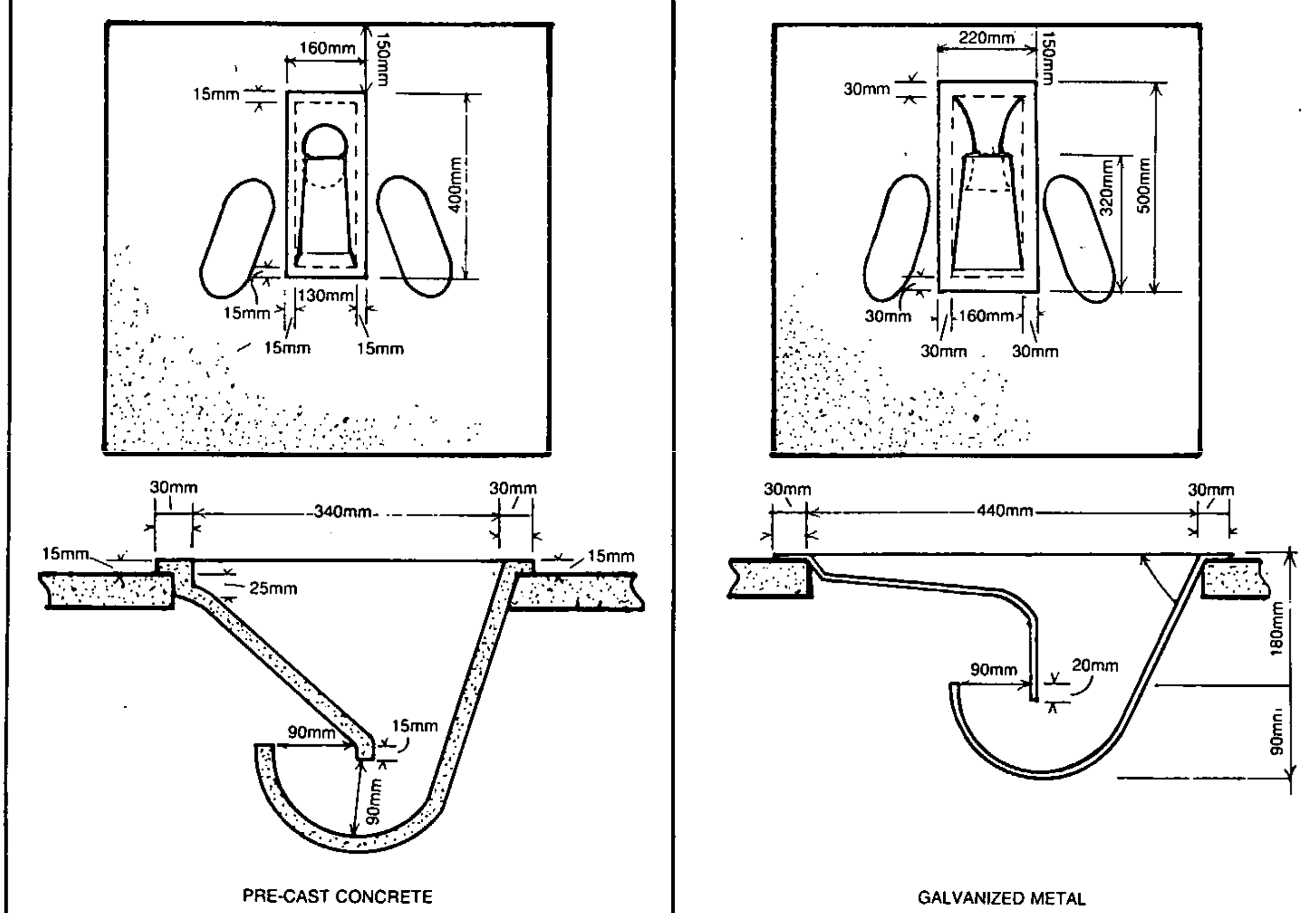


Figure 6. Pour-flush Bowls for Squatting Slabs

by at least 75mm. The length of the slab for these kinds of privies equals the length of the pit plus 150mm and the width of the slab equals the width of the pit plus 150mm. Worksheet A shows the steps in calculating slab dimensions. For example, suppose the pit is 1.5m long and 1.2m wide. Then the length of the slab is 1.5m + 0.15m = 1.65m. The width of the slab is 1.2m + 0.15m = 1.35m. See Worksheet A, step #1. For an off-set pit, the slab should be about 1m square. The thickness of a slab depends on the material used to make it. A reinforced concrete slab is 50-75mm thick.

The cover for an off-set pit must be large enough to cover the pit and overlap each edge by at least 75mm. The length of the cover equals the length of the pit plus 150mm, and the width of the cover equals the width of the pit plus 150mm. For example, suppose the pit is 1.7m long and 1.2m wide. Then the length of the cover is 1.7m + 0.15m = 1.85m. The width of the cover is 1.2m + 0.15m = 1.35m. See Worksheet A, step #3.

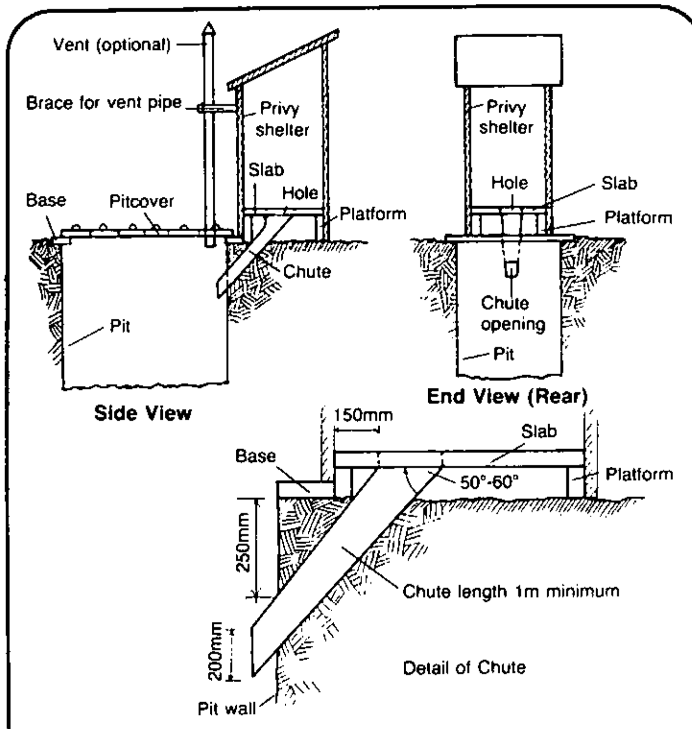


Figure 7. Off-Set Pit Privy

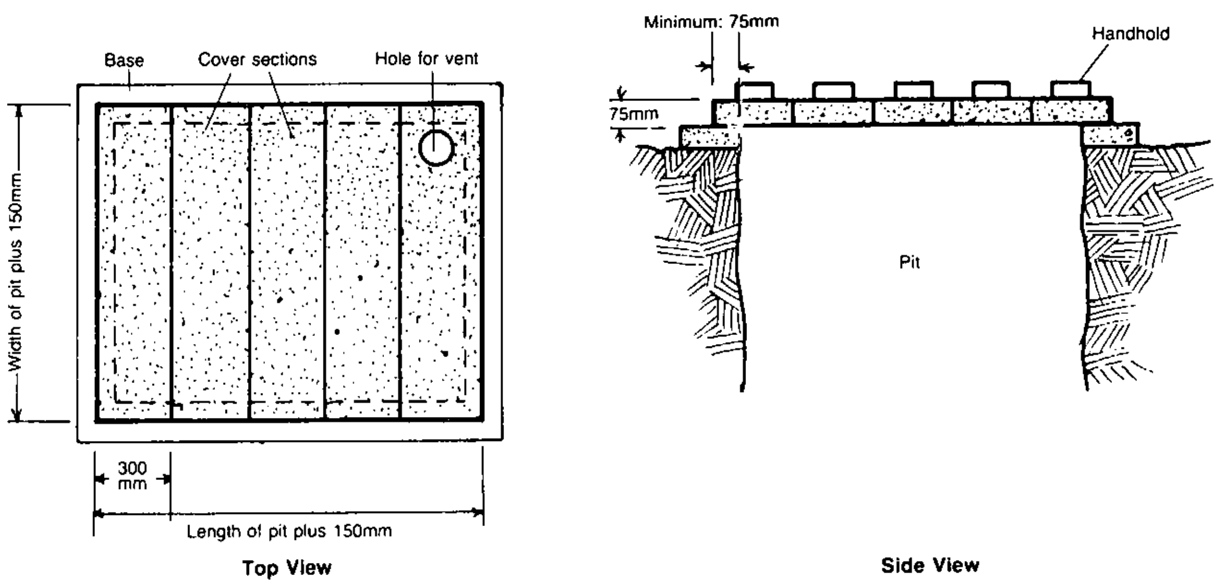


Figure 8. Cover for Off-Set Pit

Worksheet A. Calculating Dimensions

1. Slab (sitting or squatting) for unimproved, ventilated, or pour-flush privy:

   Length of slab = length of pit 1.5 m + 0.15m = 1.65 m
   Width of slab = width of pit 1.2 m + 0.15m = 1.35 m
   Thickness of slab (if concrete) = 50-75mm

2. Slab (sitting or squatting) for off-set pit privy:

   Length of slab = 1.0m
   Width of slab = 1.0m
   Thickness of slab (if concrete) = 50-75mm

3. Cover for off-set pit:

   Length of cover = length of pit 1.7 m + 0.15m = 1.85 m
   Width of cover = width of pit 1.2 m + 0.15m = 1.35 m
   Thickness of cover (if concrete) = 75mm

4. If cover is in sections:

   Length of each section = width of cover = 1.35 m
   Width of each section except one = 300mm
   Width of one section = 300mm plus necessary width to total entire length of the cover = 300mm + 50 mm = 350 mm
   Combined widths of sections = total length of cover = 300 + 300 + 300 + 300 + 300 + 350mm = 1850mm

(NOTE: To calculate quantities of concrete, see "Designing Septic Tanks," SAN.2.D.3.)

If the cover is reinforced concrete, it should be made in sections. The length of each section equals the width of the pit plus 150mm and the width of each section, except for one end section, is 300mm. The width of one end section must be 300mm plus whatever measurement is necessary to add up to the total length of the cover. For example, suppose the total length of the cover must be 1850mm. Then the cover would be made in six sections with widths of 300 + 300 + 300 + 300 + 300 + 350mm = 1850mm. See Worksheet A, step #4.

The thickness of a cover for an off-set pit depends on the material it is made from. A reinforced concrete cover should be about 75mm thick.

A vent pipe is 2-2.5m long and 100-150mm in diameter. A chute for an off-set pit is at least 1m long, with an average width of 200mm. Worksheet B shows how to calculate the dimensions of the materials needed to make vent pipes and chutes for off-set pits.

Worksheet B. Calculating Quantities of Material for Vent Pipe and Chute

Vent Pipe

Generally made from a sheet of tin or galvanized metal. The size of the sheet:

Length = height of privy shelter (from "Designing Privy Shelters," SAN.1.D.3) plus 0.6m
Width = diameter of vent pipe times 3.3

Example: Suppose that the height of the privy shelter is 2m and the diameter of the vent pipe is 150mm. Then the sheet of tin needed to make the pipe will have these dimensions:

Length = 2m + 0.6m = 2.6m
Width = 150mm x 3.3 = 500mm
(NOTE: The method used to calculate the width allows the edges of the sheet to overlap about 25mm when the pipe is made.)

Chute (for off-set pit)

Generally made from a sheet of heavy tin or galvanized metal. The size of the sheet:

Length = 1.5 times the distance from the front edge of the pit to the farthest edge of the hole in the slab.
Width = distance around the hole plus 25mm
(NOTE: The distance around the hole equals 2 times the length plus the width.)

Example: Suppose the hole in the slab is 150mm wide and 400mm long, and that the distance from the pit to the edge of the hole farthest from the pit is 700mm. Then the sheet of tin needed to make the chute will have these dimensions:

Length = 1.5 x 700mm = 1050mm
Width = distance around hole + 25mm
= 2 x (150mm + 400mm) + 25mm
= 1125mm
(NOTE: The "width" of the sheet may be longer than the "length.")

When the type of improvements and dimensions have been determined, prepare design drawings similar to Figures 1-9, showing correct dimensions and top and side views of, the slab and improvements. Give these drawings to the person in charge of construction.

Materials List

Slabs can be made from a variety of materials, including reinforced concrete, wood or bamboo. Generally, they are made from concrete, because concrete is strong, long-lasting, and easy to clean.

A common mix by volume for concrete is one part cement, two parts sand, three parts gravel, and about 2/3 part water or enough water to make a fairly stiff mix. The cement should be Portland cement. The sand should be clean and sized fine to 6mm. The gravel should be clean and sized 6-25mm. The water should be clear. For details on calculating quantities for concrete mix, see "Designing Septic Tanks," SAN.2.D.3.

A concrete slab must have reinforcing material, such as steel bars 10mm in diameter, wire mesh, or split bamboo. To calculate the quantity of steel bars needed, draw a sketch similar to Figure 9, showing bars in place, and count the number and lengths of the bars. If wire mesh is used, the quantity is approximately equal to the area of the slab (length times width).

The reinforcing material must not block the hole in the slab. No part of it should stick out through the concrete.

The tools and labor required to build a slab depend on the materials used. If it is made of reinforced concrete, at least one worker should have some knowledge of or experience with concrete (mixing, pouring, and building forms). Common tools for working with concrete include hammer, saw, and nails for building forms; container, shovel, tamping rod, and trowel for mixing, pouring, and smoothing concrete.

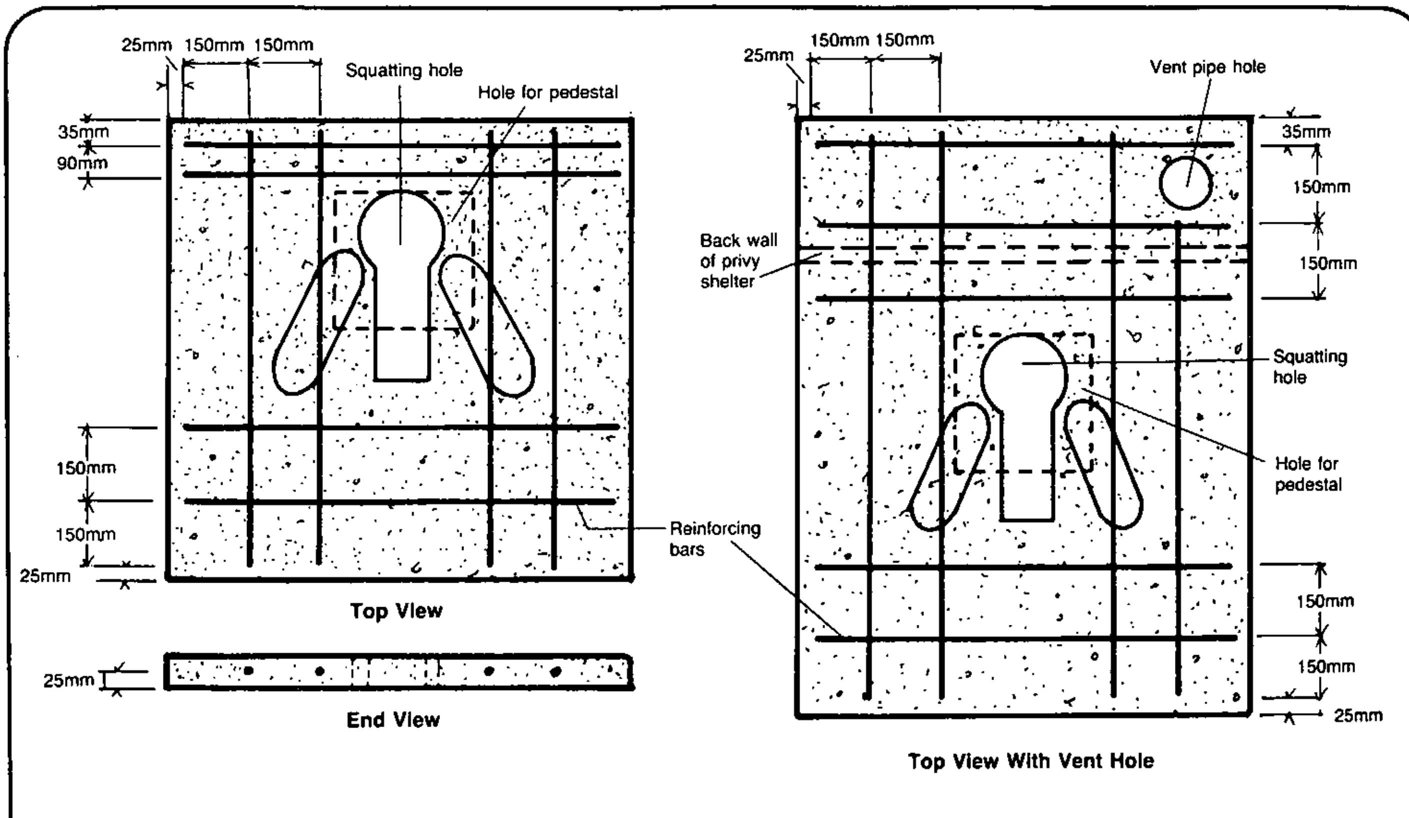


Figure 9. Placement of Reinforcing Bars in Concrete Slab

If the slab has a seat and pedestal, the pedestal can be made from brick, concrete blocks, or wood, and the seat can be made from wood. One-piece, ceramic seat-and-pedestal units may be available.

A cover made from wood should be provided for both sitting-type and squatting-type slabs. The cover for the seat and pedestal may be attached to the back of the seat with hinges.

A pour-flush bowl may be made from galvanized metal, concrete, molded rubber, or ceramic material. These units may be prefabricated and ready to install. A skilled craftsman could produce a galvanized metal or concrete pour-flush bowl using the design information in Figure 6. A metal bowl must have smooth, rounded edges dulled by a file. A concrete bowl must be cured in water for a week. A pour-flush bowl can be secured to the slab with concrete mortar.

A vent pipe can be made of galvanized metal by a semi-skilled workman using tinsnips, pliers, metal screws and a screw driver (or other means of securing the metal), and black paint and a brush to paint the pipe black. Or, a section of bamboo with the nodes knocked out could be used as a vent pipe.

A chute for an off-set pit can be made of galvanized metal by a semi-skilled workman using tinsnips, pliers, metal screws and a screwdriver, or other means of securing the metal.

A cover for an off-set pit can be made from wood, metal, or reinforced concrete. If concrete is used, the tools and skills of the workmen are the same as for a concrete slab.

When the materials needed have been determined, prepare a detailed materials list, similar to the sample in Table 1, showing types and quantities of all materials, tools, and labor needed to construct the slab and improvements, and the estimated costs based on local prices. Give the materials list and design drawings, similar to Figures 1-9, to the person in charge of construction.

Table 1. Sample Materials List

ITEM	DESCRIPTION	QUANTITY	ESTIMATED COST
Labor	Foreman	1	____
	Laborer (some experience with concrete)	1	____
	Laborers (to move constructed slab)	4-6	____
Supplies	Portland cement	____ m^3	____
	Sand: Clean, size fine to 6mm	____ m^3	____
	Gravel: Clean, size 6-38mm	____ m^3	____
	Water: Clear, drinking water preferred	____ liters	____
	Wood (for concrete forms)	____	____
	Nails (for concrete forms)	____	____
	Reinforcing bars ____ mm long	____	____
	____ mm long	____	____
	(or wire mesh)	____ m^2	____
	Wood (for lid)	____	____

	If seat and pedestal:		
	Bricks (for pedestal)	____	____
	Mortar (cement, sand, water)	____ m^3	____
	Wood (for seat and lid)	____	____

	Pour-flush bowl (prefabricated)	____	____
	Galvanized metal (for vent pipe)	____ m^2	____
	Galvanized metal (for chute)	____ m^2	____
	Metal screws or bands	____	____
	Screen (for vent)	____	____
Tools	Measuring tape	1	____
	Shovel	2	____
	Bucket	1	____
	Container for mixing concrete	1	____
	Trowel	1	____
	Saw	1	____
	Hammer	1	____
	Tinsnips	1	____
	Pliers	1	____
	Screwdriver	1	____
	Other	____	____

Total Estimated Cost = ____

Notes

Water for the World

Constructing Slabs for Privies

Technical Note No. SAN.1.C.1

The slab is the floor of the privy. It covers the pit and has a hole through which to defecate. Constructing a slab involves assembling materials, tools, and labor, and building either a squatting slab or a sitting slab (seat and pedestal) to the correct dimensions. It may also involve building a cover for an off-set pit and building or installing improvements (vent pipe, pour-flush bowl, or chute).

This technical note decribes each step in constructing a slab. Read the entire technical note before beginning construction.

Materials Needed

The project designer must provide several documents before construction can begin:

1. Technical drawings similar to Figures 1-9, showing correct dimensions of the slab, lid, pit cover (if off-set pit), and any improvements;

2. Materials list, similar to the sample shown in Table 1, noting all supplies, tools, and labor needed to construct the slab.

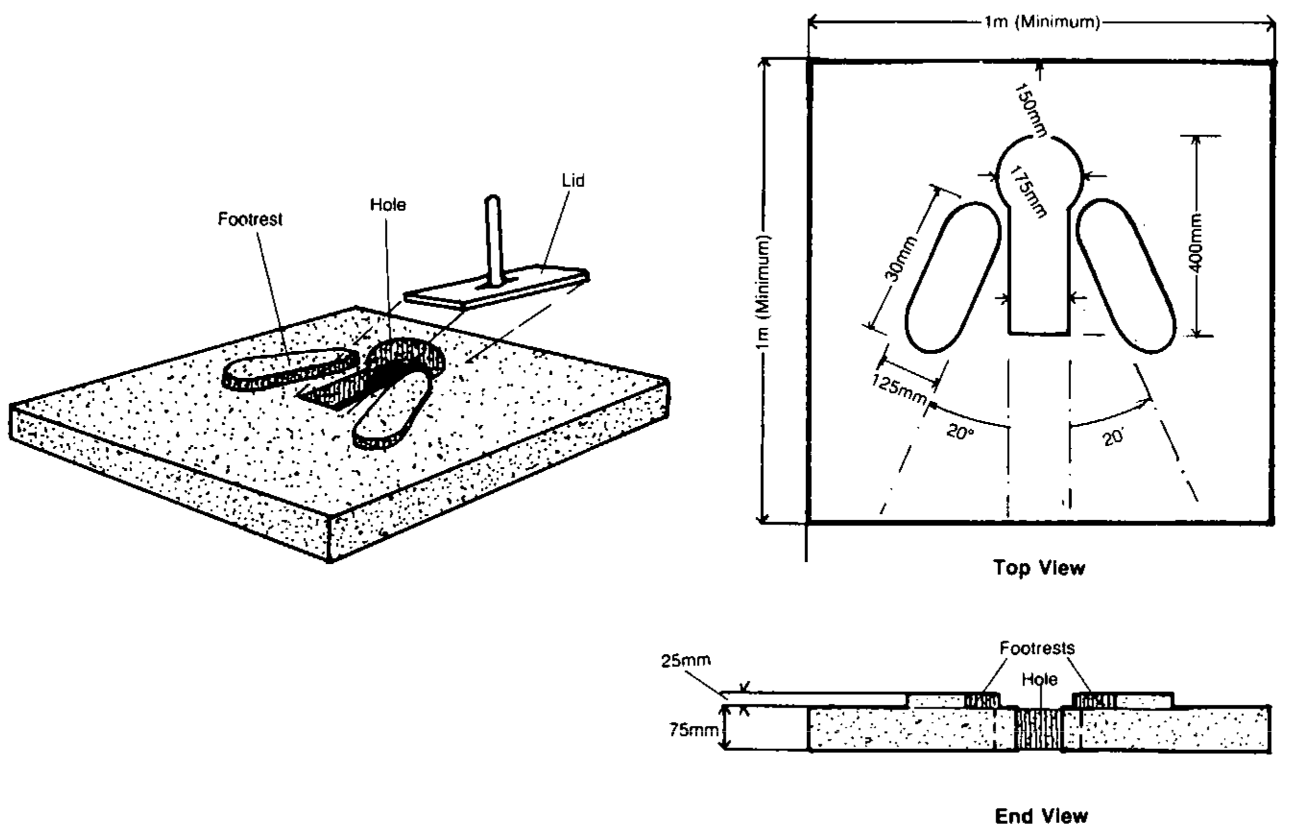


Figure 1. Squatting Slab

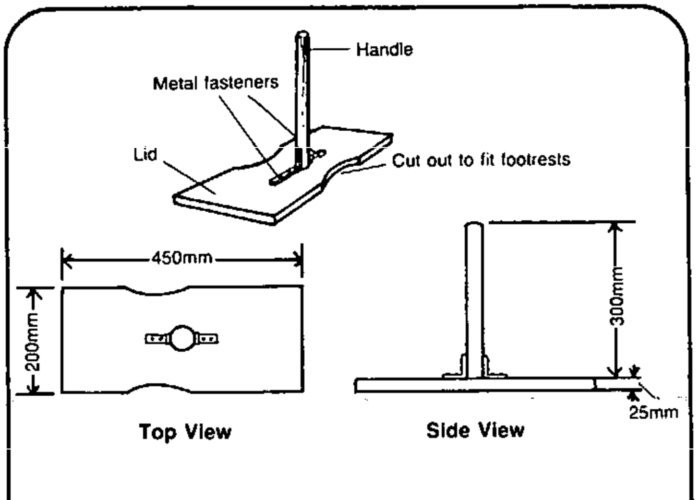


Figure 2. Lid for Squatting Slab

Caution!

1. Wear gloves to prevent cuts when working with tin or galvanized metal sheets which may have sharp edges.

2. Pick up all metal scraps and nails after construction to prevent injuries to people walking barefoot in the area.

3. Avoid back and hand injuries when moving a completed slab into place. The slab may weigh over 180 kilos and will require four to eight men to move.

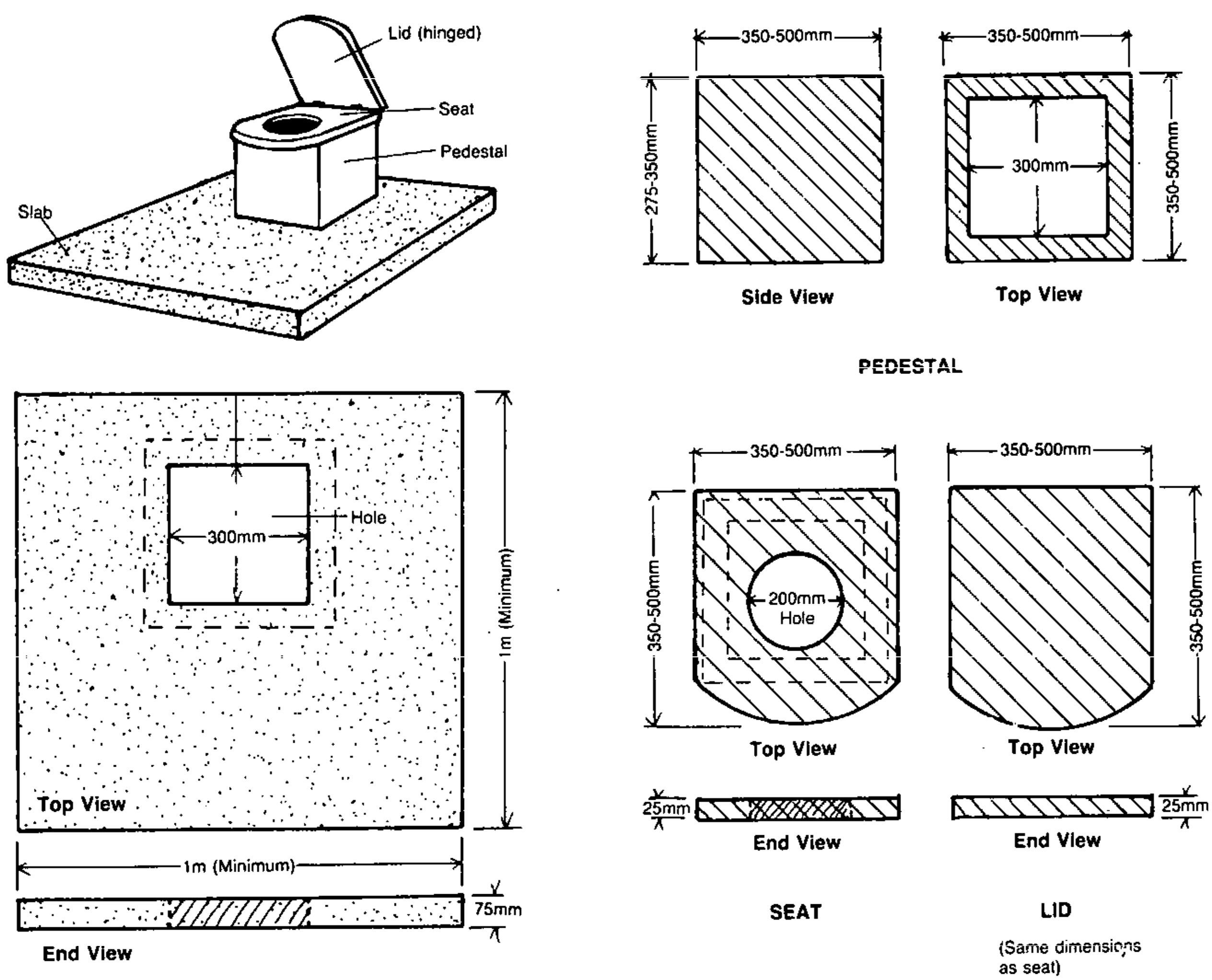


Figure 3. Sitting Slab with Pedestal, Seat and Lid

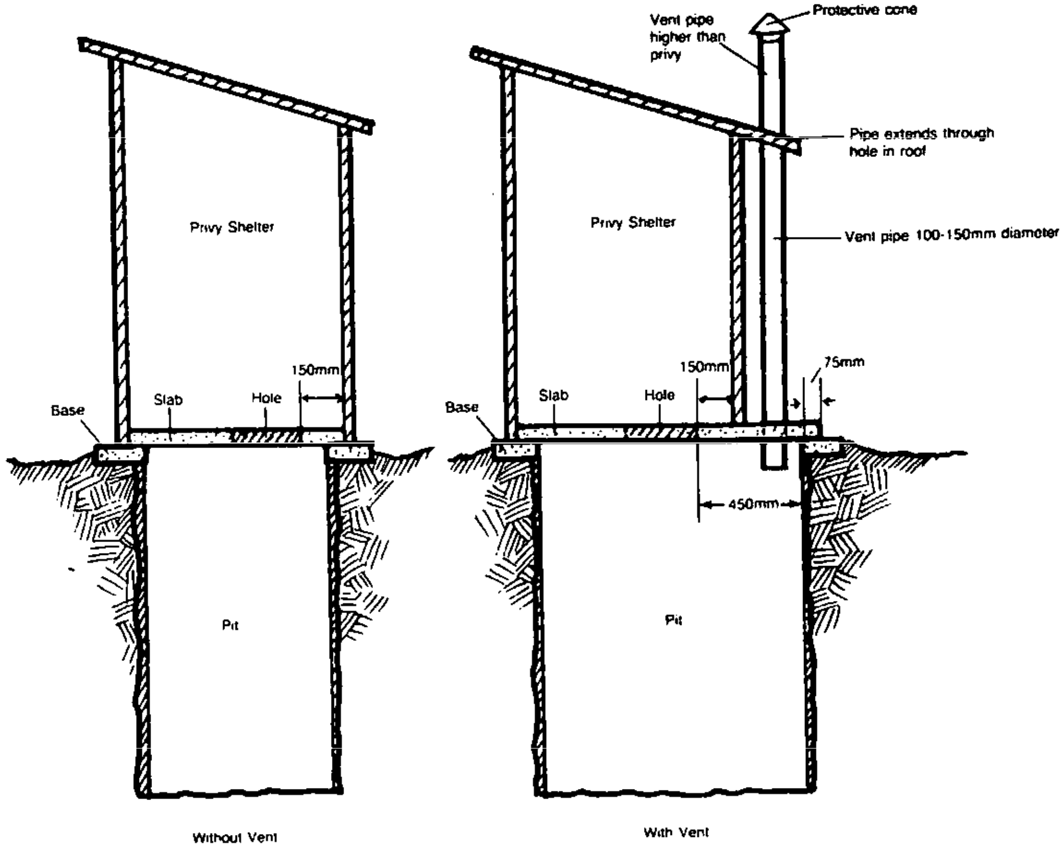


Figure 4. Comparison of Privies with and without Vent

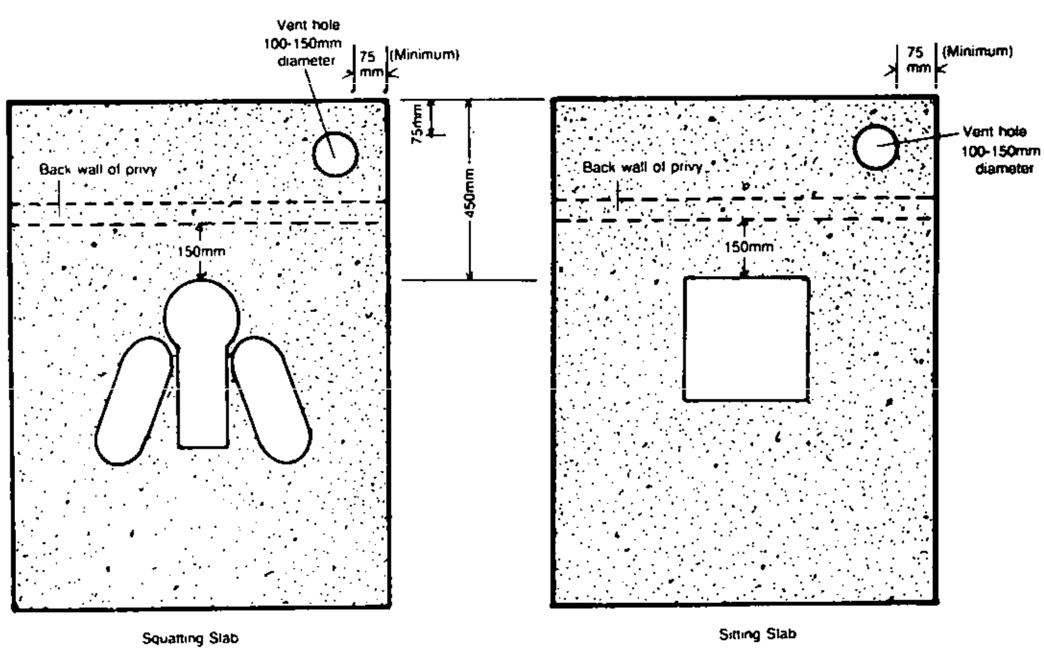


Figure 5. Top View of Slabs Showing Vent Hole Placement

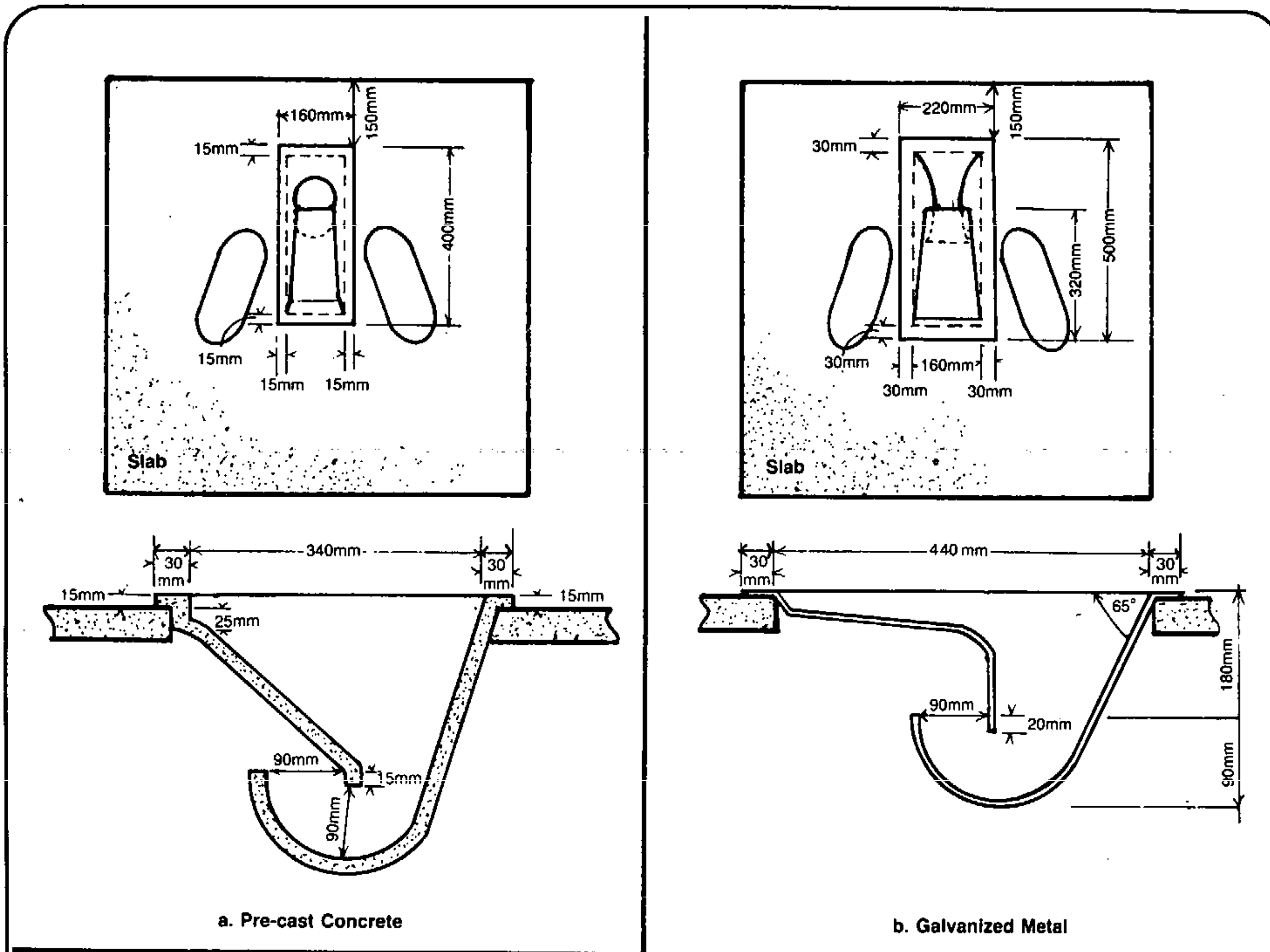


Figure 6. Pour-Flush Bowls for Squatting Slabs

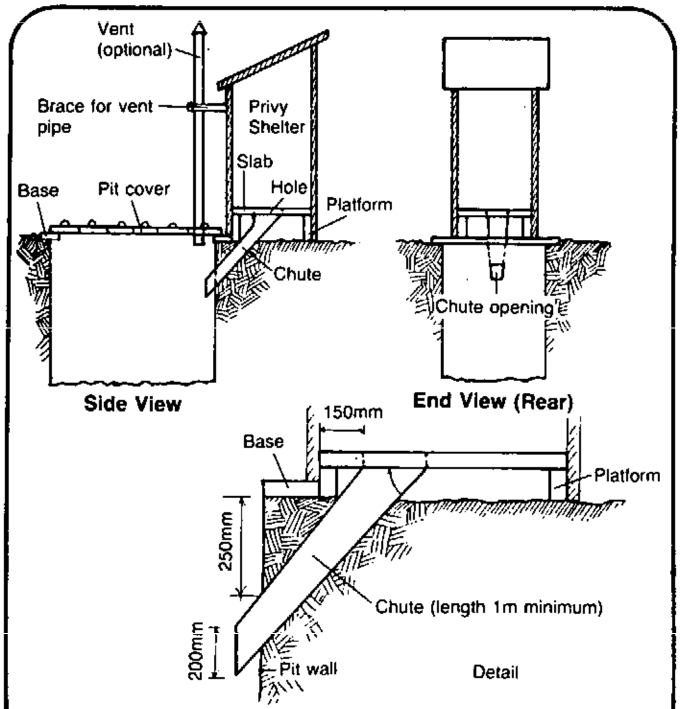


Figure 7. Off-Set Privy

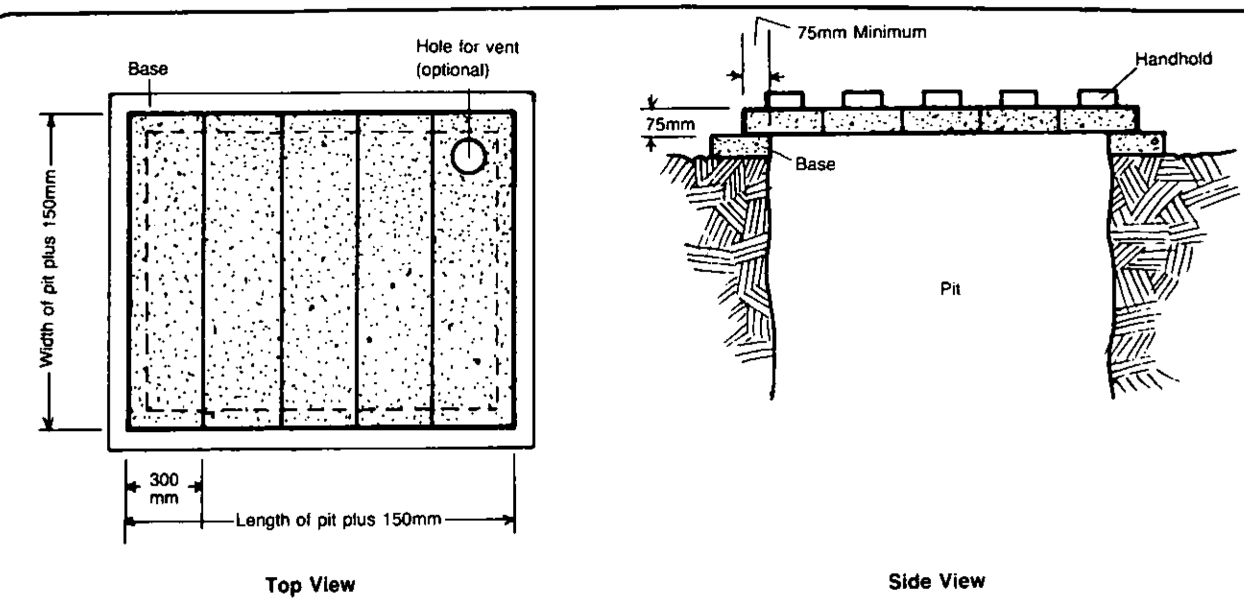


Figure 8. Cover for Offset Pit

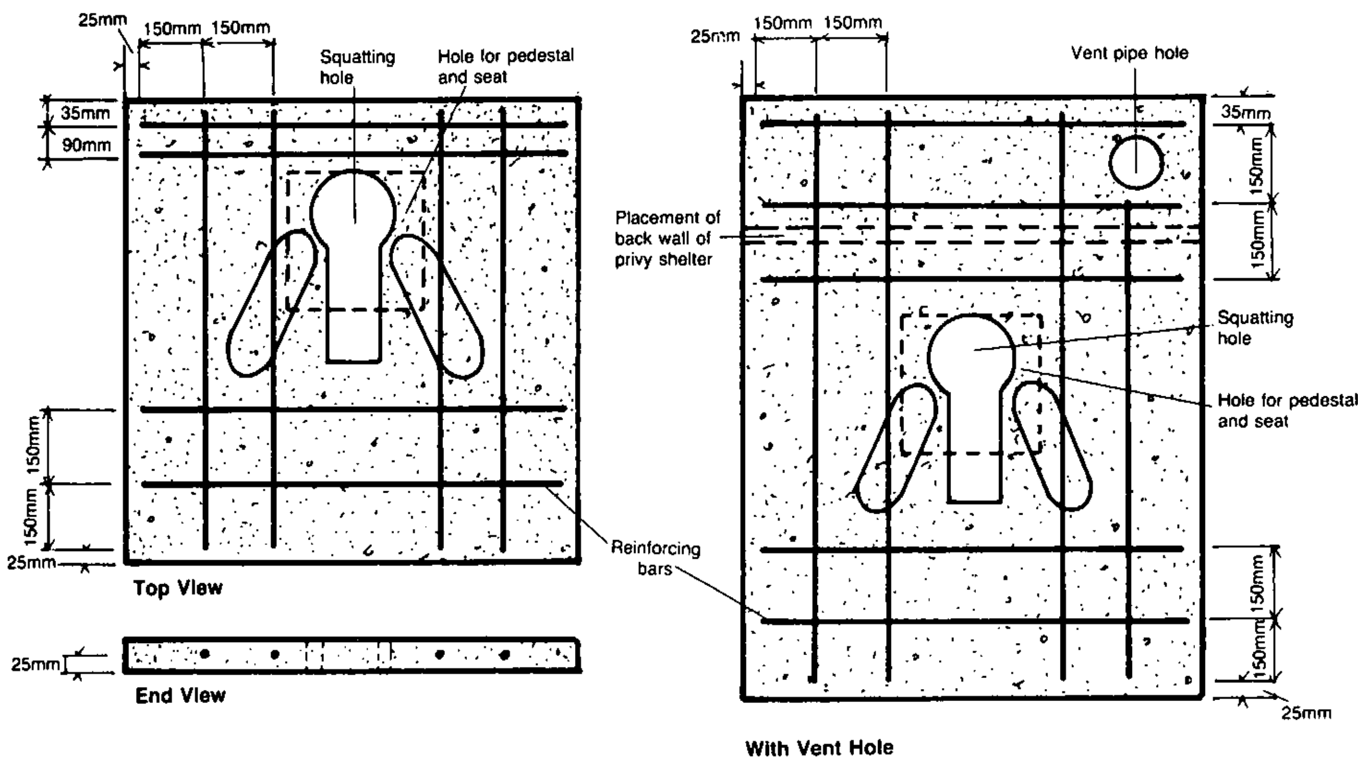


Figure 9. Placement of Reinforced Bars in Concrete Slab

Table 1. Sample Materials List

ITEM	DESCRIPTION	QUANTITY	ESTIMATED COST
Labor	Foreman	1	______
	Laborer (some experience with concrete)	1	______
	Laborers (to move constructed slab)	4-6	______
Supplies	Portland cement	____ m^3	______
	Sand: Clean, size fine to 6mm	____ m^3	______
	Gravel: Clean, size 6-38mm	____ m^3	______
	Water: Clear, drinking water preferred	____ liters	______
	Wood (for concrete forms)	______	______
	Nails (for concrete forms)	______	______
	Reinforcing bars _____mm long	______	______
	_____mm long	______	______
	(or wire mesh)	____ m^2	______
	Wood (for lid)	______	______
	--		
	If seat and pedestal:		
	Bricks (for pedestal)	______	______
	Mortar (cement, sand, water)	____ m^3	______
	Wood (for seat and lid)	______	______
	--		
	Pour-flush bowl (prefabricated)	______	______
	Galvanized metal (for vent pipe)	____ m^2	______
	Galvanized metal (for chute)	____ m^2	______
	Metal screws	______	______
	Screen (for vent)	______	______
Tools	Measuring tape	1	______
	Shovel	2	______
	Bucket	1	______
	Container for mixing concrete	1	______
	Trowel	1	______
	Saw	1	______
	Hammer	1	______
	Tinsnips	1	______
	Pliers	1	______
	Screwdriver	1	______
	Other	______	______

Total Estimated Cost = ______

Table 2. Sample Work Plan for Constructing Reinforced Concrete Squatting Slab

Time Estimate	Day Number	Task	Personnel	Tools/Materials
5 hours	1	Build wooden forms for the slab	Foreman and one skilled workman (Note: Foreman present during all phases of construction)	Measuring tape, wood, saw, hammer, nails, oil
5 hours	2	Mix and pour concrete; set reinforcing material	1 skilled workman, 2 laborers	Cement, sand, gravel, water, reinforcing material, container for mixing, 2 shovels, trowel
½ hour	2	Cover concrete and keep moist	1 laborer	Wet straw
½ hour	3	Remove wood plug for squatting hole, after concrete has taken initial set	1 laborer	None
5 days	3-7	Keep concrete covered and moist	1 laborer	Wet straw
3 hours	8	Separate slab from wooden forms; place slab over pit	4-8 laborers	Hammer (or nail-puller)
2 hours	8	Build lid for squatting hole; set in place	1 skilled workman	Measuring tape, wood, hammer, saw, nails

Construction Steps

Depending on local conditions, availability of materials, skills of workers, and so on, some construction steps will take only a few hours, while others may require a day or more. Read the construction steps and make a rough estimate of the time required for each step, based on local conditions. You will then have an idea of when during the construction process specific laborers, supplies, and tools must be available. Draw up a work plan similar to Table 2 showing the construction steps and the time estimated for each.

Assemble all laborers, supplies, tools, and drawings needed to begin construction. Study all diagrams carefully.

For a reinforced concrete squatting slab:

1. Build wooden forms similar to Figure 10. For a ventilated privy see the inset on Figure 10. Note that the squatting hole and the hole for the vent pipe are produced from solid wood blocks and the raised footrests from holes cut in the form. The slab is made upside down. If the slab is to have a pour-flush bowl, the shape of the hole must conform to the shape of the bowl unit. Check all measurements from drawings provided by the project designer.

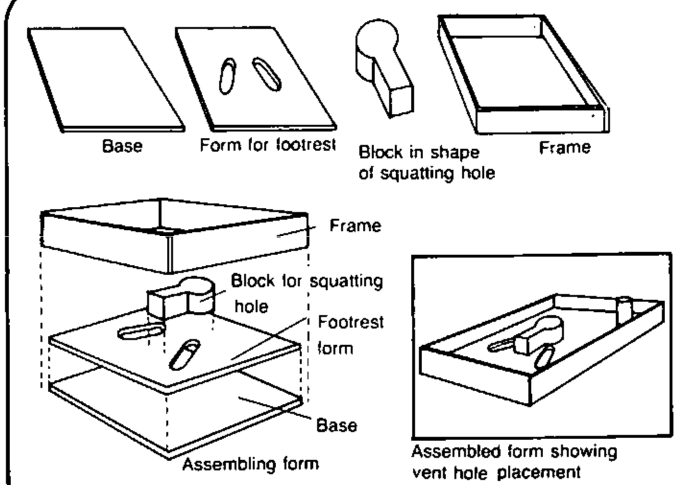


Figure 10. Forms for Concrete Squatting Slab

2. Treat the forms with oil or grease to make it easier to remove the slab after the concrete has set as shown in Figure 11.

3. Mix concrete with the correct proportions of cement, sand, gravel and water. A common mix by volume is one part cement, two parts sand, three parts gravel, and enough water to make a fairly stiff mix. The cement should be Portland cement. Remove any hard lumps of cement before mixing. The sand should be clean and sized fine to 6mm. The gravel should be clean and sized 6-25mm. The water should be clean and clear drinking water, if possible.

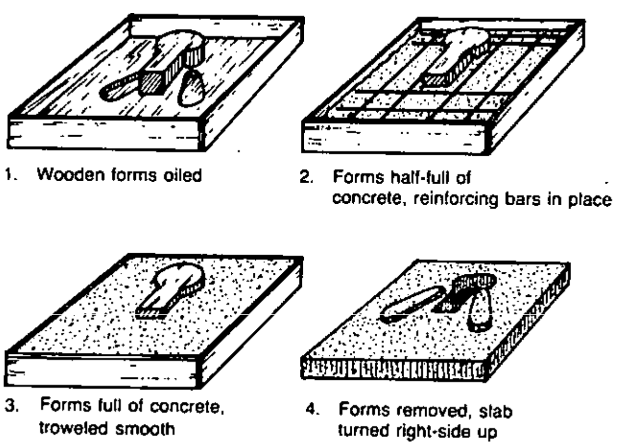


Figure 11. Constructing Concrete Squatting Slab

4. Pour concrete in the form to a depth of about 50mm and smooth surface with trowel. See Figure 11.

5. Set reinforcing material--bars or wire mesh--in place. Be sure the reinforcing material is positioned according to drawings supplied by the project designer and that the material does not touch the sides of the forms or the wooden block used to produce the squatting hole.

6. Pour in the remaining depth of concrete, about 25mm, and smooth surface with trowel. See Figure 11.

7. Cover concrete with wet straw or burlap bags. Keep shaded for one or two days until concrete takes its initial set.

8. Remove wood block used to produce squatting hole. See Figure 11. Keep concrete covered and wet for four to six days until it has firmly set. During this period, work can begin on the pit and the pit lining and base (see "Constructing Pits for Privies," SAN.1.C.2).

9. After the concrete has set firmly, remove the slab from the wood form See Figure 11. Set it in place on the base around the pit.

10. Build a lid for the squatting hole and set it in place.

For a wood or bamboo squatting slab:

1. Build a gridwork of notched poles or stout bamboo as shown in Figure 12. The space for the squatting hole is 50mm longer and 50mm wider than the finished hole. Nail or tie the poles together.

2. Place poles, bamboo, or boards across gridwork as shown in Figure 12. Poles or boards overlap space for squatting hole so that actual hole is 400mm long and 150mm wide. Fasten together ends of poles, bamboo, or boards with binding or nails.

3. Place second layer of poles, bamboo, or boards across the first as shown in Figure 12. Secure each pole or board to the first layer with binding or nails.

4. Cut wood blocks or boards for footrests and nail them in place.

5. Set the completed slab in place over the pit.

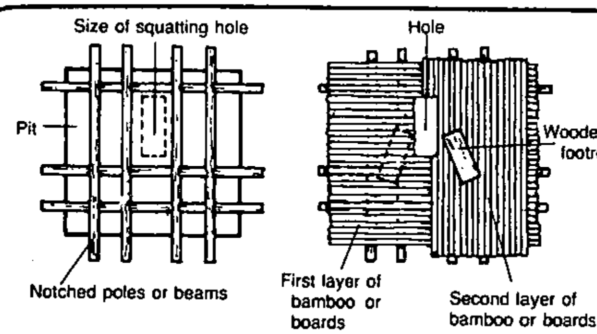


Figure 12. Wood Squatting Slab

6. Build a wooden lid to cover the squatting hole and set it in place.

For a concrete sitting slab with a brick and mortar pedestal:

1. Build wooden forms similar to Figure 13. For a ventilated privy, see Figure 13. Note that the hole for defecation is produced by a square wood frame. Do not pour concrete inside this frame.

2. Follow steps 2 through 9 for a reinforced concrete squatting slab. See Figure 14.

3. Mix concrete mortar with one part cement, three parts sand, and enough water to make a workable mix.

4. Lay bricks or selected stones around the hole in the slab as shown in Figure 14. Mortar the bricks to the slab and mortar them together.

5. Overlap the second row of bricks as shown in Figure 14. Continue laying bricks until the pedestal reaches 275-350mm.

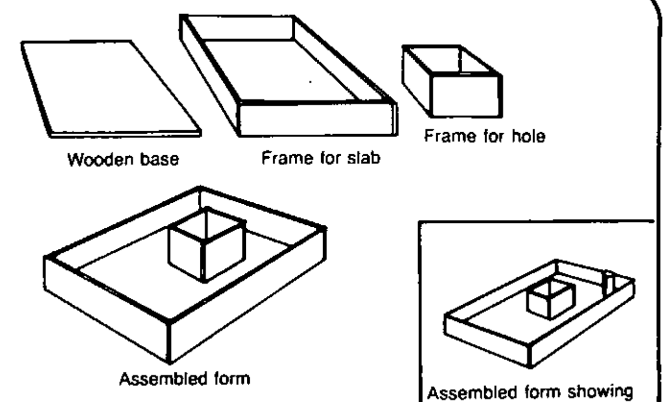


Figure 13. Forms for Sitting Slab

6. Wet the inside of the brick pedestal and plaster the inside with a 12mm thick layer of cement mortar. Smooth the mortar coating with a trowel.

7. Build a wood seat and lid similar to Figure 14 and set in place. Mortar seat to pedestal.

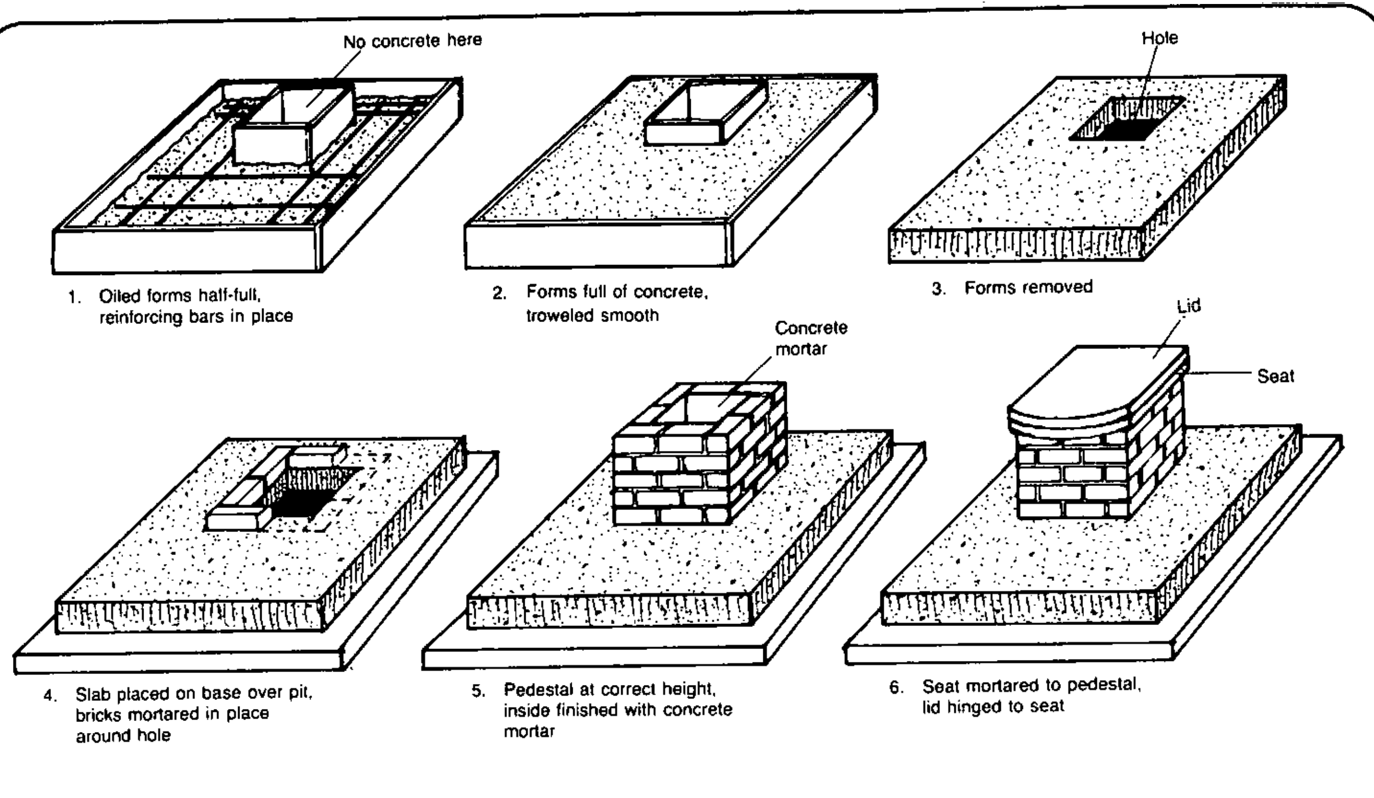


Figure 14. Constructing a Concrete Sitting Slab with Brick and Mortar Pedestal

For a wood sitting slab with a wood pedestal:

1. Cut two stout poles or beams the length of the pit plus 150-200mm. The beams should be 100mm by 100mm in size. Lay the beams on the base on each side of the pit as shown in Figure 15.

2. Nail 25mm thick boards to the beams as shown in Figure 15. The open space toward the rear of the slab should be about 450mm wide.

3. Build a bench 350-400mm high from 25mm thick boards. See Figure 15. The bench may have one or two holes for defecation. If two holes, make one 200-250mm diameter for adults and one about 150mm diameter for children. The edges of the holes should be sanded and free from splinters.

4. Build a hinged lid for each hole and attach in place.

5. Nail a board to each end of the privy floor to seal the pit. See Figure 15.

For a vent pipe:

1. Cut a rectangular sheet of tin to the dimensions provided by the project designer. See Figure 16.

2. Bend the tin to form the vent pipe. Overlap the edges about 25mm and fasten with metal screws. See Figure 16.

3. Cover one end of the pipe with fly-proof screen. See Figure 16.

4. A cone-shaped vent cover which is optional, but recommended in rainy regions, may be made from a round piece of tin about 250mm in diameter. Cut out a wedge with a base of about 150mm, bend tin to form a cone, and fasten with metal screws. See Figure 16. Attach the cone to the end of the vent pipe with metal struts to leave free air space.

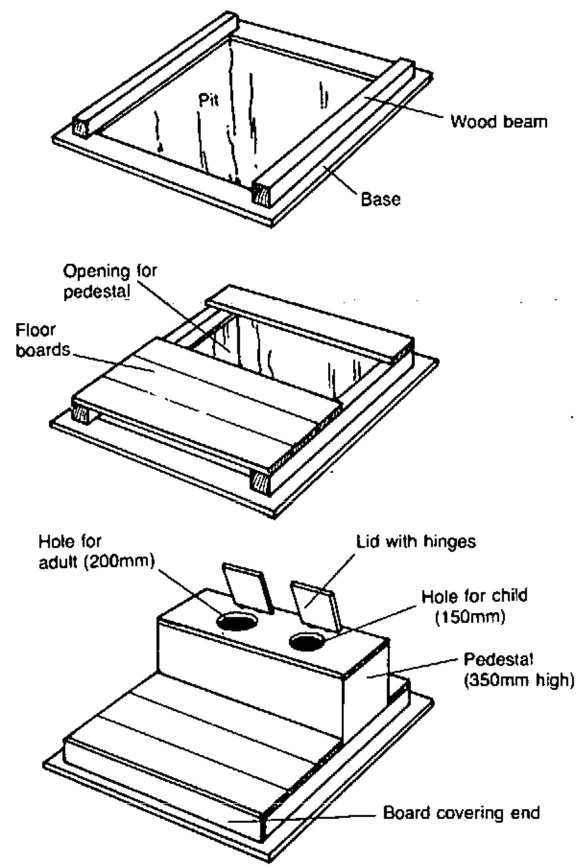


Figure 15. Wooden Sitting Slab with Wooden Pedestal

5. The vent pipe should not be installed until <u>after</u> the privy shelter is in place (see "Constructing Privy Shelters," SAN.1.C.3). Place the open end of the vent pipe in the hole in the slab and make the edges airtight with mortar or tar. Secure the vent pipe to the privy structure. The screened end of the pipe should be 0.3-0.6m above the roof of the privy.

For a pour-flush bowl:

1. Pour-flush bowls are often prefabricated units made from galvanized metal, concrete, molded rubber, or ceramic material. They are built to fairly exact specifications and may be difficult to produce in the field. A skilled craftsman could possibly build a concrete bowl using Figure 6a or, a galvanized metal pour-flush bowl using the design information in Figure 6b.

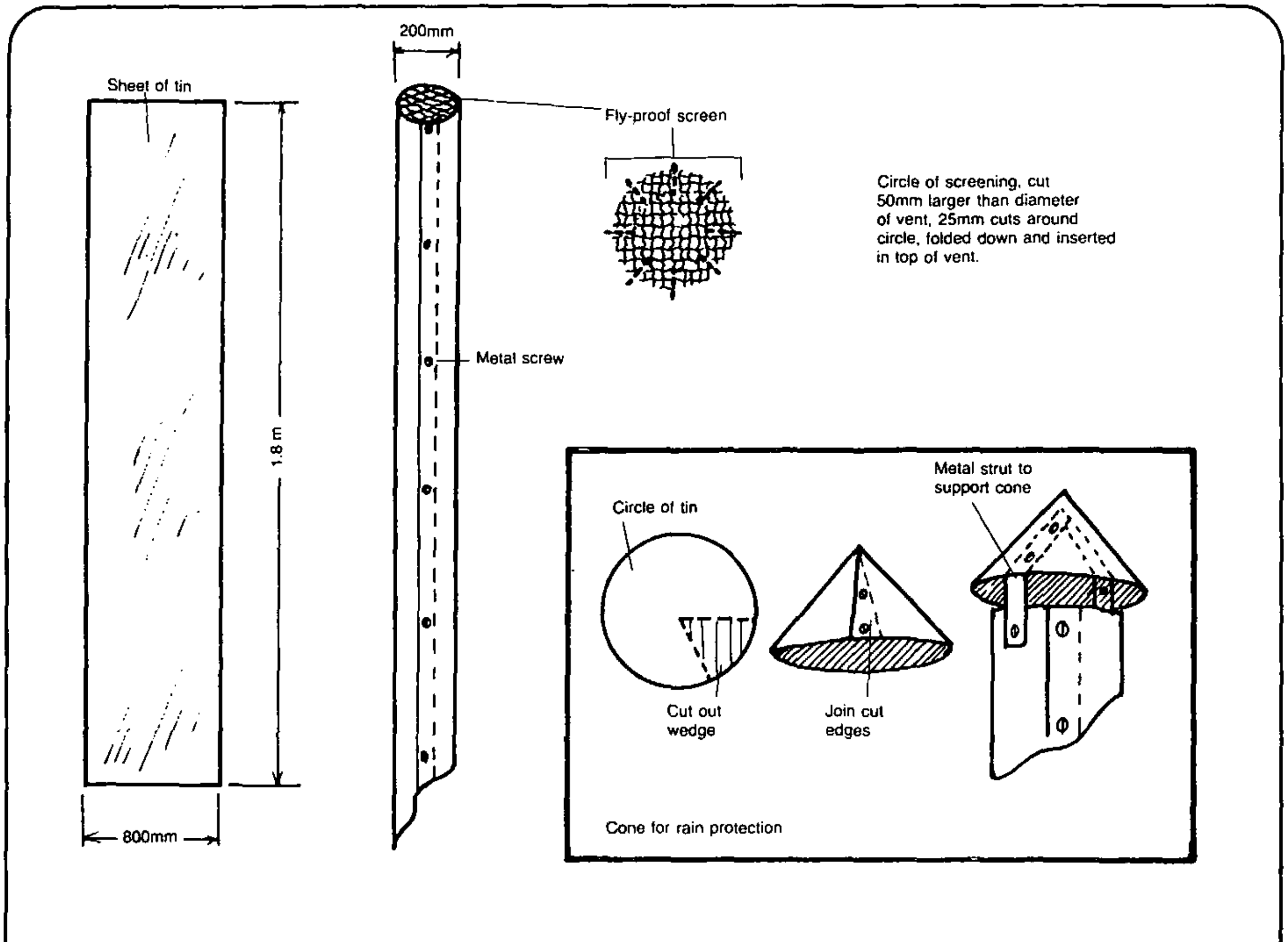


Figure 16. Constructing a Vent Pipe

This technical note does not describe how to build a pour-flush unit, but if you try it keep the following two points in mind: the edges of a galvanized metal bowl should be rounded or dulled by a file; and a concrete bowl is generally cast in two halves in wooden molds, the halves mortared together, and the entire unit cured under water for a week.

2. Secure the pour-flush bowl to the slab with cement mortar and allow two or three days to set before use.

For a chute for an off-set pit:

1. Cut a rectangular sheet of tin or galvanized metal to the dimensions provided by the project designer. See Figure 17.

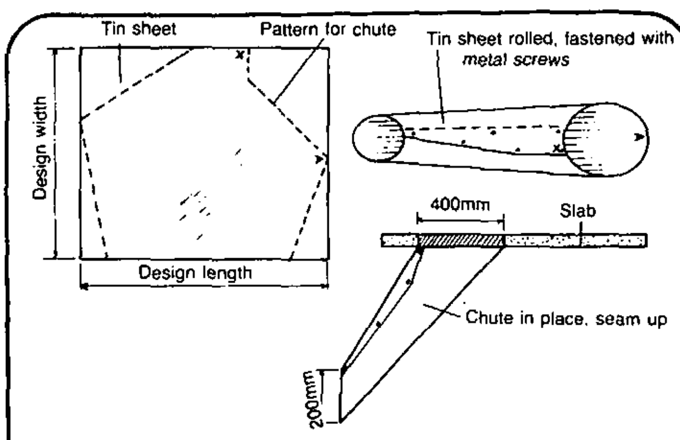


Figure 17. Constructing a Chute

2. Bend the sheet of tin to form the chute. Overlap the edges so that the overlapping seam is along the top edge and fasten with metal screws. Cut the sheet of tin in a shape like that shown in Figure 17 prior to bending.

3. Mortar the upper end of the chute in place below the squatting slab or seat, circling the squatting hole or the hole in the seat. See Figure 17.

For a wood platform for an off-set pit:

1. Build a framework to the dimensions of the slab, or slightly smaller, using poles or beams at least 50mm in diameter. See Figure 18a.

2. Add one or more rows of poles or beams to the framework, nailing or binding each row to the one below, until the correct height is reached. When the slab is in place, its top should be about 200mm above ground level. For example, if the slab is 75mm thick, the framework should be 125mm high: 75mm + 125mm = 200mm.

3. When the platform reaches the correct height, nail or tie corner pieces inside each corner to further secure it. See Figure 18a.

4. When the platform is completed, place the slab on top. See Figure 18a.

For a brick and mortar platform for an off-set pit:

1. Lay a row of bricks, mortared together, to the dimensions of the slab at the desired slab location. See Figure 18b.

2. Continue mortaring rows of bricks in place until the correct height is reached as described in step 2 for wood platform. See Figure 18b.

3. After the mortar has set for two or three days, mortar the slab on top of the platform. See Figure 18b.

For a concrete platform for an off-set pit:

1. Build wooden forms for the concrete platform to the correct height as described in step 2 for wood platform and to the dimensions of the slab. Build the forms in place and so that the finished platform will have walls at least 75mm thick. See Figure 18c.

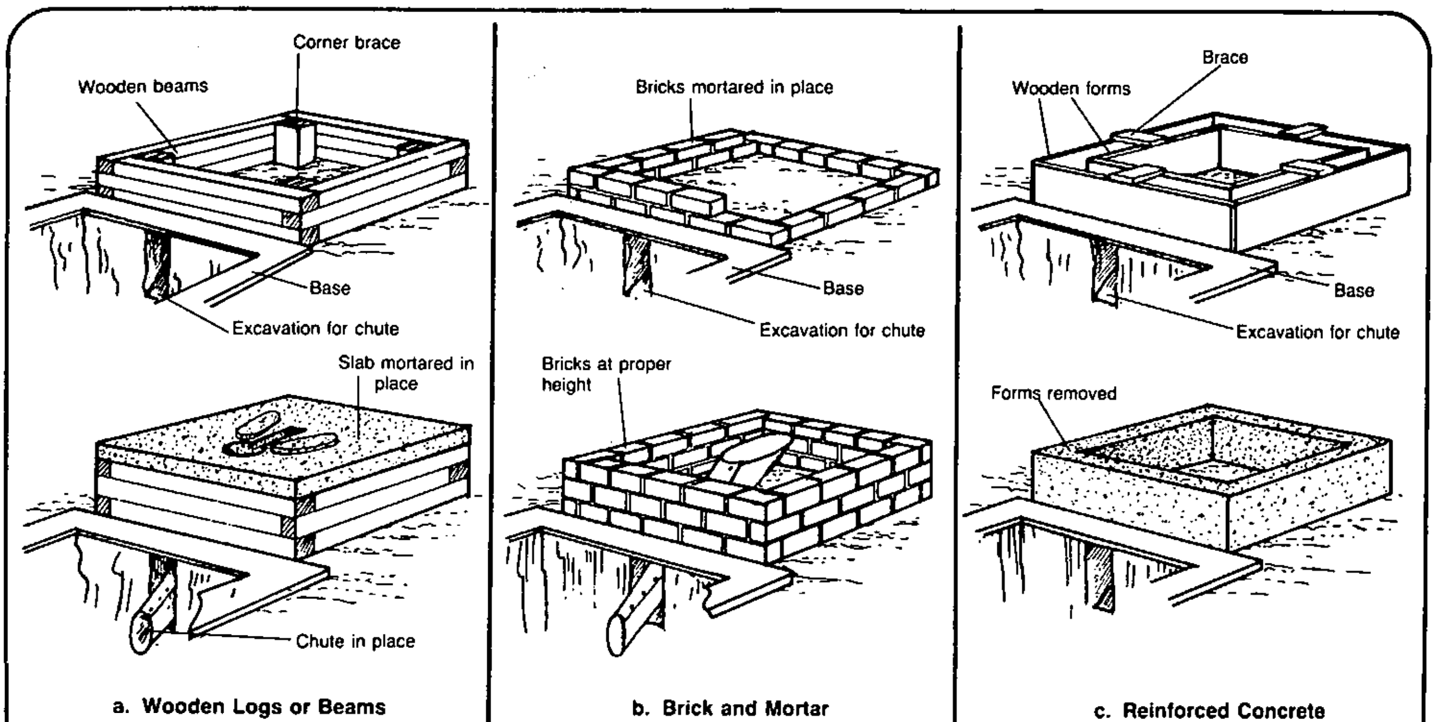


Figure 18. Platforms for Off-Set Privy

2. Mix concrete using the correct proportions of cement, sand, gravel and water as described in step 3 for a reinforced concrete squatting slab.

3. Pour concrete in the forms to about half their depth.

4. Lay reinforcing material in place.

5. Pour in the remaining depth of concrete and smooth the surface with a trowel.

6. Cover concrete with wet straw or burlap bags and allow it to set for three to seven days. Then, remove wood forms. See Figure 18c.

7. Mortar the slab on top of the platform.

For a reinforced concrete cover for an off-set pit:

1. Build wooden forms for the cover. See Figure 19. The cover is made in sections with each section about 75mm thick. The length of each section equals the width of the pit plus 150-200mm so that the sections overlap the pit on each side by 75-100mm. All sections but one are 300mm wide. One section is 300mm wide plus whatever measurement is necessary to add up to the total length of the pit plus 150mm. The width of this last section should be provided by the project designer or calculated in the field. For example, if the pit is 1500mm long, then the total widths of the sections should equal 1500mm plus 150mm, or 1650mm. The widths of the sections would be:

300mm + 300mm + 300mm + 300mm + 450mm = 1650mm

2. Mix concrete using the correct proportions of cement, sand, gravel and water as described in step 3 for a reinforced concrete squatting slab.

3. Pour concrete in the forms to about half their depth.

4. Lay reinforcing material in place.

5. Pour in the remaining depth of concrete and smooth the surface with a trowel.

6. Set handholds into the concrete near both ends of each section. See Figure 19.

7. Cover the concrete with wet straw or burlap bags and keep moist for five to seven days to allow concrete to set.

8. Remove wooden forms and place sections over the pit. Do not mortar. Waterproof between each section, and between the sections and the base around the pit, with tar or other material. See Figure 19.

9. Mound with soil. See Figure 19.

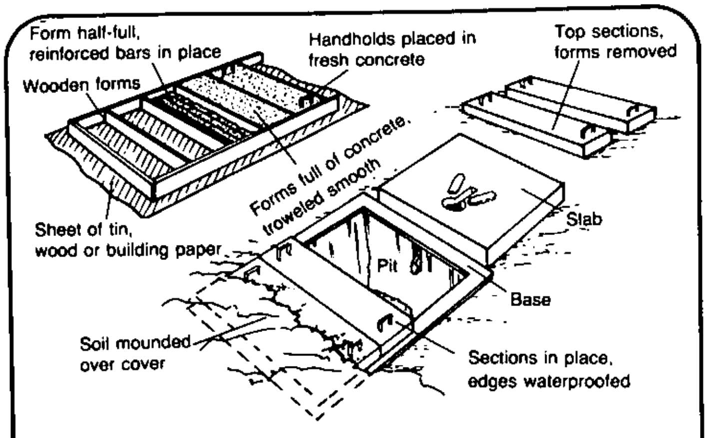


Figure 19. Cover for Off-Set Pit

Notes

Water for the World

Designing Privy Shelters
Technical Note No. SAN 1.D.3

A privy shelter is a screen or structure that gives the person using the privy privacy. Depending on the design, a shelter can protect the privy and the user from the weather and keep out flies, rats, scavenging dogs, and other pests. Designing a shelter involves selecting the type of shelter; determining shape, size, and special features; and selecting materials, tools, and labor. The products of the design process are (1) a plan view of the shelter; (2) a detailed view of any special features; and (3) a detailed materials list. This technical note describes how to design a privy shelter and produce these three products.

Read the entire technical note before beginning design procedures.

Materials Needed

Measuring tape - To obtain field measurements.

Scale - To draw accurate diagrams.

Selecting the Type of Shelter

The three basic types of privy shelters are a simple screen, a shelter with a roof, and a shelter with a roof and door. Figures 1, 2 and 3 show the types of privy shelters.

The most important factors in selecting a type of shelter are local customs and personal preferences of the users. Determine how much privacy people want and whether or not a roof and door are acceptable or desired. Other factors that influence selection are available money, materials, and skilled labor, and the extent to which control of pests is important. Table 1 compares these factors for each type of shelter.

Determining Shape, Size, and Special Features

Shape. The shelter can be square, rectangular, circular, or spiral-shaped, as shown in Figures 1 and 2,

Table 1. Comparison of Shelter Types

Shelter Type	Advantages	Disadvantages
Simple Screen	User privacy; very inexpensive and easy to build	No protection from weather; not suitable for ventilated privy, compost toilet, bucket latrine, or aqua privy; no pest control*
With Roof	User privacy; suitable for all privies; protection from weather	Slightly more expensive; some construction skills needed; no pest control*
Roof and Door	Complete user privacy; suitable for all privies; protection from weather; pest control*	Moderately expensive; construction skills required

*All privies must have a lid for the hole. This keeps pests out of the pit, but not out of the shelter.

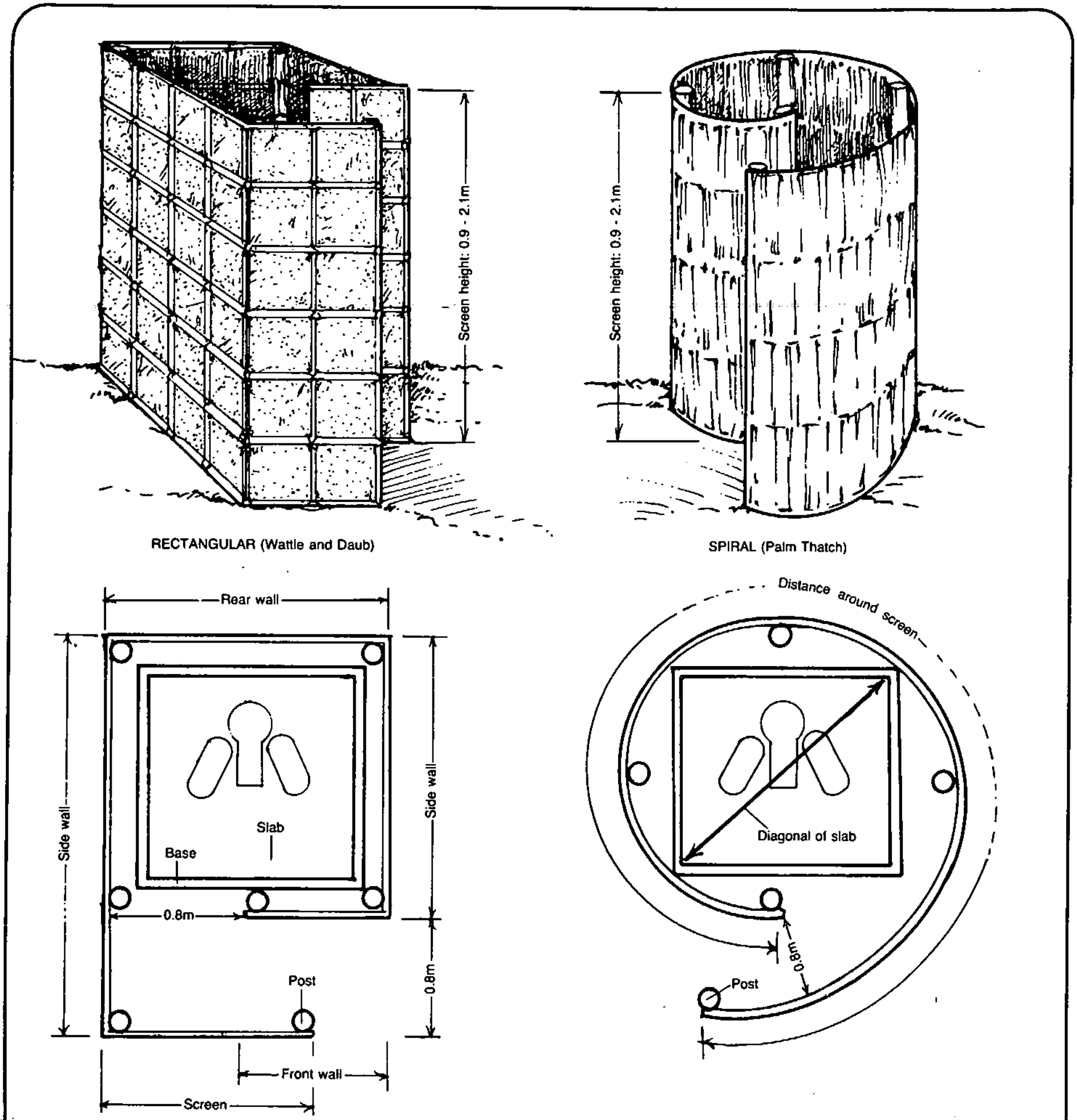


Figure 1. Simple Screen Shelters

depending on local preference. The screen or walls should be vertical. The roof should slope to the rear or sides of the shelter to allow rainwater to run off.

Size. The area inside the shelter should be 1.0-2.3m^2. This allows enough room for the user without wasting building materials. Unless the privy is ventilated with a vent pipe, the shelter should completely enclose the privy slab. For a ventilated privy, the part of the slab that holds the vent pipe will be outside the shelter, as shown in Figure 4. The back wall of the shelter should be 150-200mm from the defecation hole.

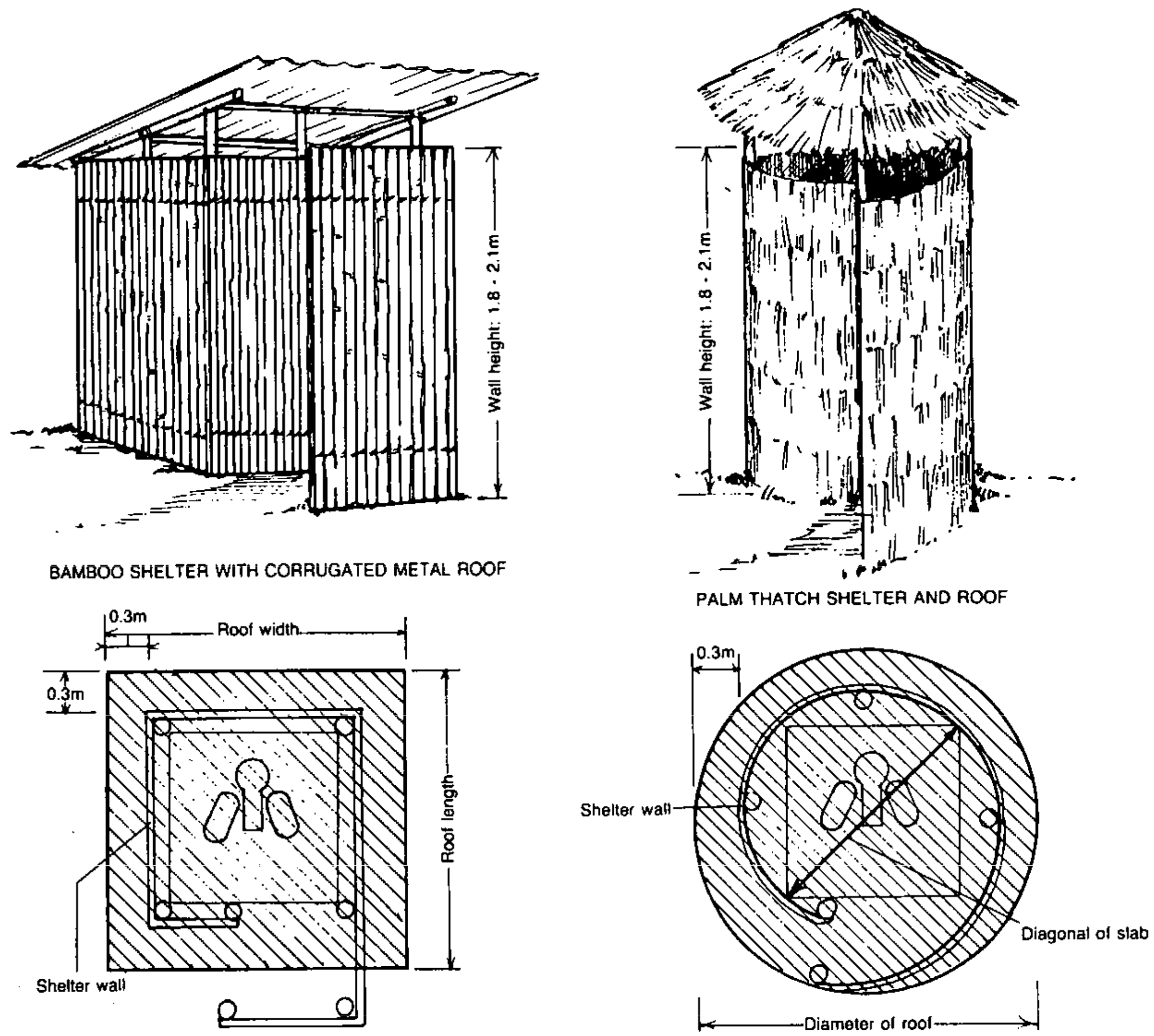


Figure 2. Privy Shelters with Roof

The shelter can be designed to rest on the base around the pit with the walls bordering the slab. With this design, the size of the slab determines the area within the shelter.

If the shelter is a simple screen with no roof, the bottom of the screen should touch the ground. The screen can be 1-2m high. If the shelter has a roof, the walls should be 1.8-2.1m high to allow enough headroom. The walls should rest on the ground.

Table 2 summarizes some requirements for a shelter.

Special Features. If the shelter has a roof, it should also have ventilation openings. The openings should be at least 100mm by 200mm and spaced along the top of the walls. One design has the entire roof raised above the walls on the corner posts, as shown in Figures 2 and 3.

Table 2. Shelter Requirements

Feature	Requirement
Walls	Vertical; touch ground
Wall Height (simple screen)	1-2m
Wall Height (with roof)	1.8-2.1m
Rear Wall	150-200mm from defecation hole
Roof	Sloped to rear or sides
Area in Shelter	1.0-2.3m^2

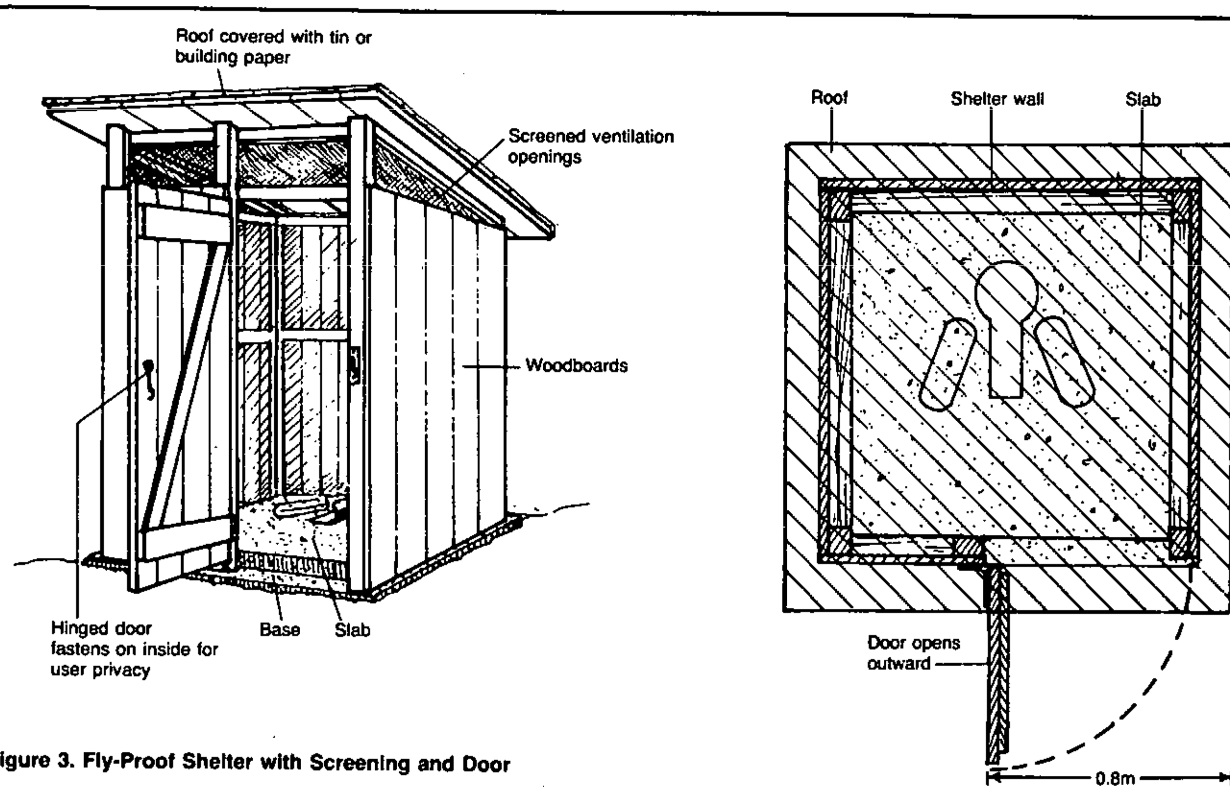
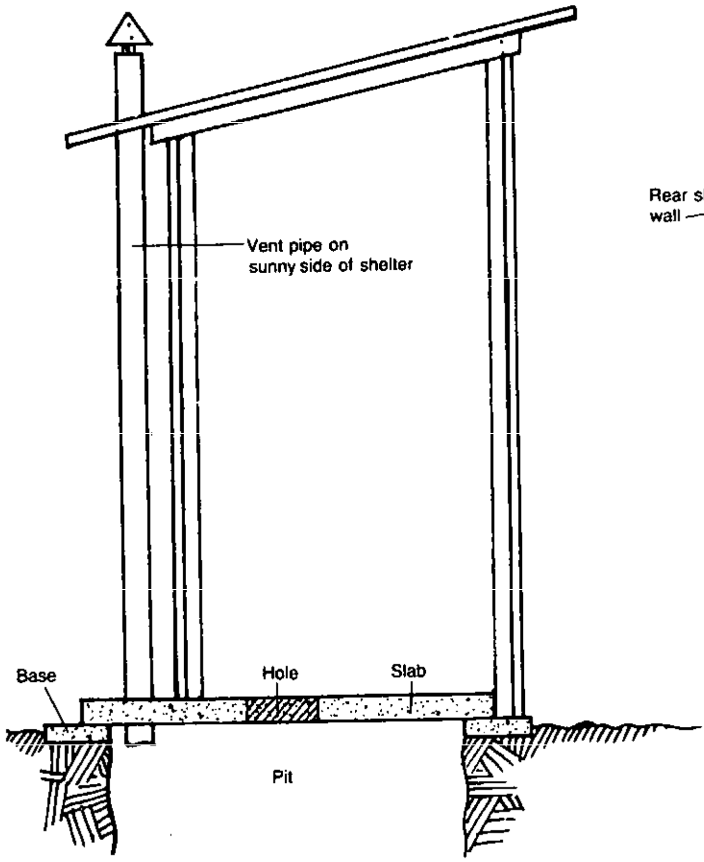
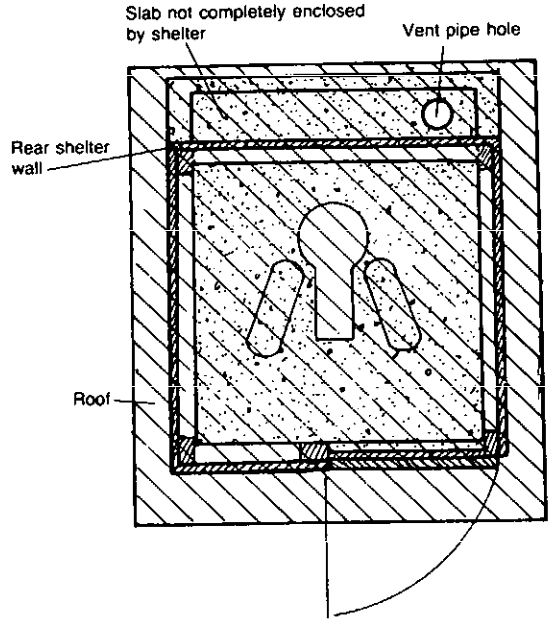


Figure 3. Fly-Proof Shelter with Screening and Door

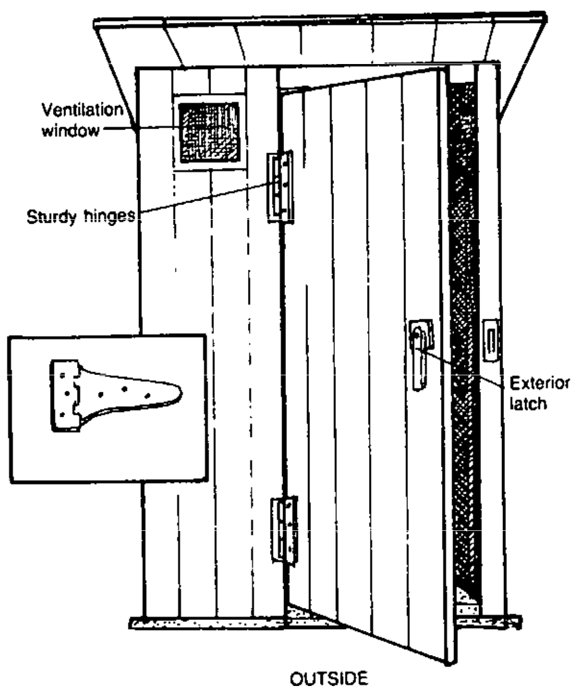
If the shelter has a door, it must have sturdy hinges to keep the door in the correct position. An inside latch is needed to keep the door closed when the privy is in use. Figure 5 shows a well-designed privy door. The door may open from the right or left, but it should open outward unless this violates local custom. Ventilation openings are required. If pests are to be kept out of the shelter, screens must cover all ventilation openings and the door must fit tightly, as shown in Figure 6.

If the shelter is for a ventilated privy, the vent pipe must be attached to an outside wall or to the roof, as shown in Figure 4.





4. Shelter for Ventilated Privy



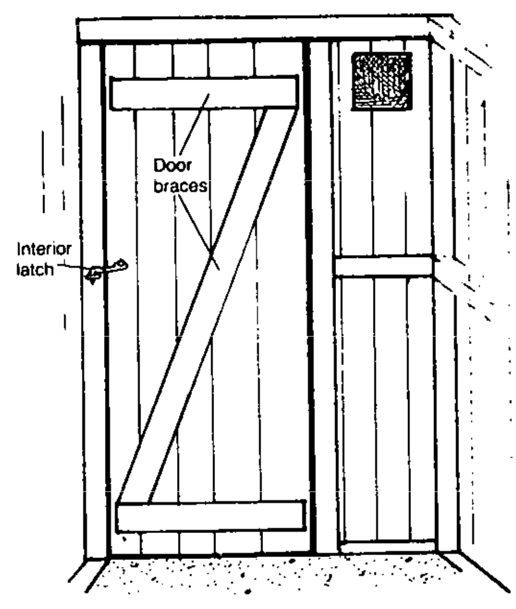


Figure 5. Detail of Door for Fly-Proof Shelter

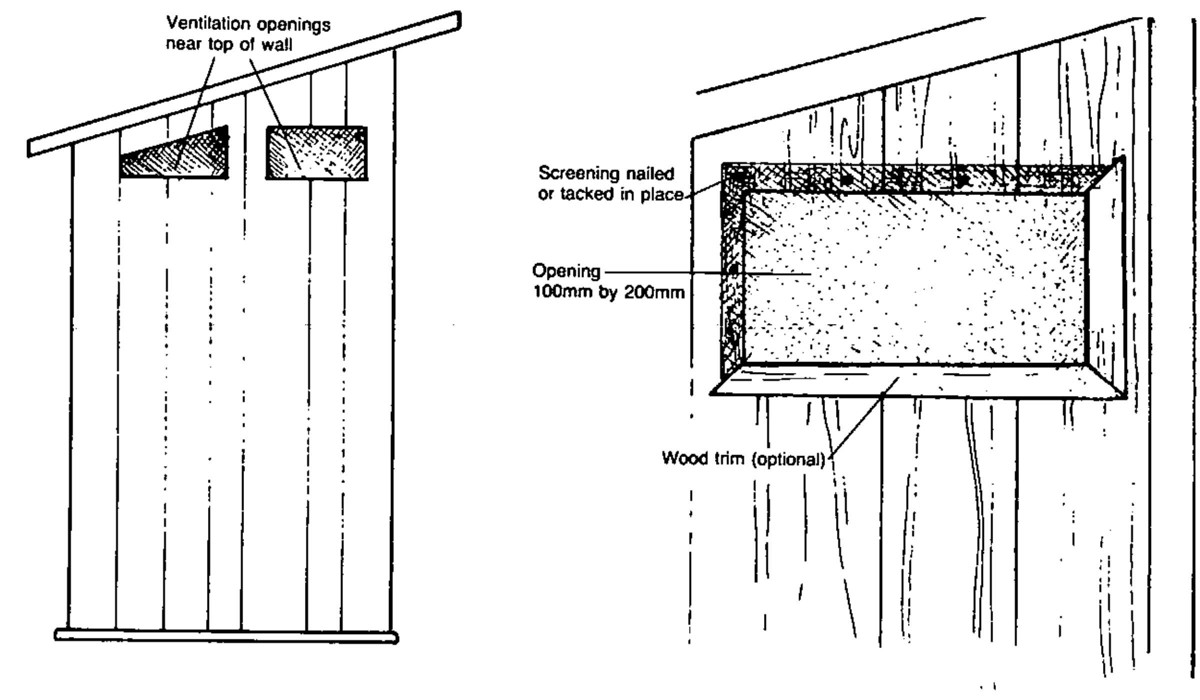


Figure 6. Fly-Proof Screening Covering Ventilation Openings

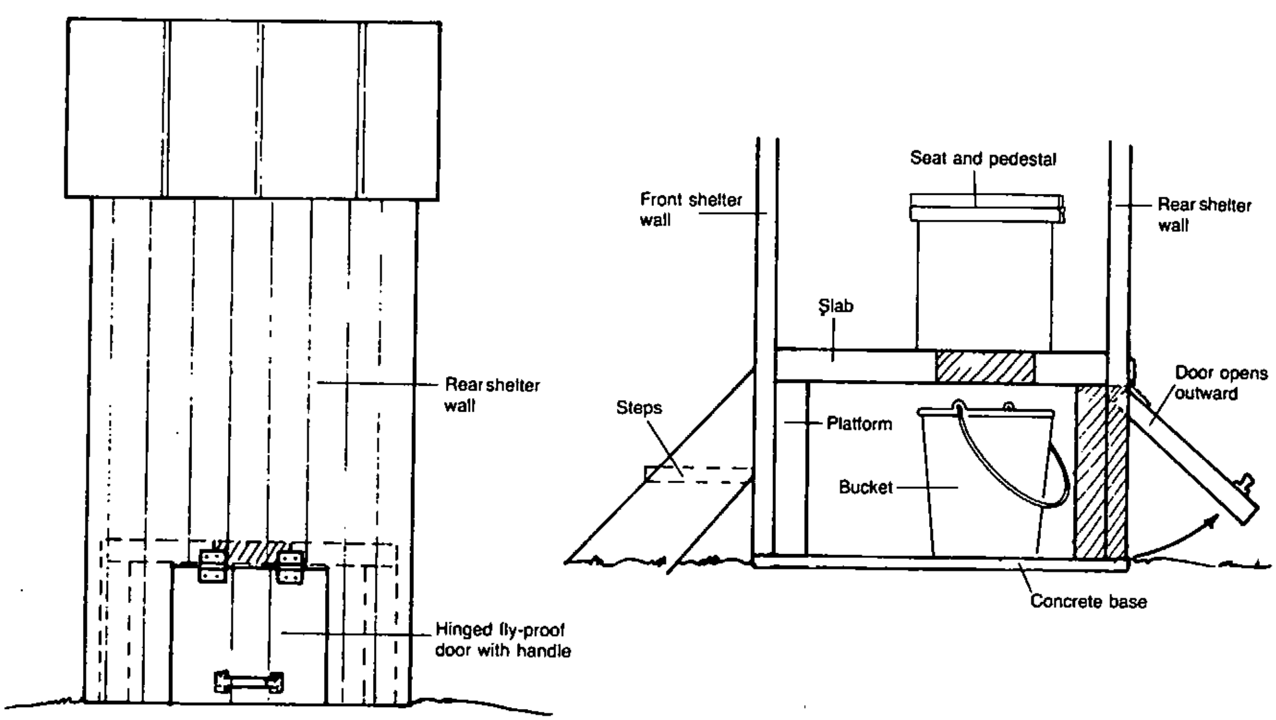


Figure 7. Detail of Shelter for Bucket Latrine

Table 3. Special Feature Requirements

Feature	Requirement
Ventilation Openings	At least 100 x 200mm; spaced along top of walls
Screens	Fly-proof; cover all openings
Door	Opens outward; sturdy hinges; inside latch
Vent Pipe	Attached to outside wall or roof
Privy Slab on Platform	Shelter rests on ground

Table 4. Combinations of Materials for a Shelter

	Feature		
	Walls	Roof	Door
Materials	Mud and Wattle	Palm Thatch	Mud and Wattle, Palm Thatch, or Bamboo
	Bamboo	Palm Thatch	Mud and Wattle, Palm Thatch, or Bamboo
	Palm Thatch	Palm Thatch	Mud and Wattle, Palm Thatch, or Bamboo
	Wooden Boards	Wooden Boards or Corrugated Metal	Wooden Boards
	Brick and Mortar or Concrete Block and Mortar	Wooden Boards or Corrugated Metal	Wooden Boards

If the shelter is for a privy with a platform, such as an off-set pit, compost toilet, or bucket latrine, the walls should rest on the ground and enclose the platform. The height of the platform must be added to the height of the wall shown in Table 2. For a compost toilet or bucket latrine, the rear wall of the shelter must have a small door. It must be fly-proof for a bucket latrine and air-tight for a compost toilet. The door will allow for removal of the bucket or compost. This is shown in Figure 7.

Table 3 summarizes special feature requirements.

When the type of shelter, its shape, size, and special features have been decided, draw a plan view of the shelter showing all dimensions. Also prepare a detailed drawing of any special features. Give these drawings to the construction foreman before construction of the shelter begins.

Selecting Materials

In general, a privy shelter should be built using locally available materials, tools, and labor. The sturdier the materials, the longer the life of the shelter.

A simple screen shelter can be bamboo, palm thatch, mud and wattle, or poles supporting canvas or fabric. A shelter with a roof, or roof and door, can be built from a variety of materials, some of which are shown in Table 4. The roof should be waterproof.

Depending on the area, termites may be a problem if wood structures are to be used. Special protection, such as a brick or concrete base, may be required to keep wood from coming into contact with the soil and giving termites access to the wood.

Worksheet A. Calculating Quantities for a Privy Shelter

Shelter Type (check one): [X] simple screen [X] roof [X] roof and door

Simple Screen Shelter

1. Height of screen = 1.8 m
2. Length of sides = 0.3 m + 1.2 m + 1.2 m + 2.0 m + 1.2 m = 5.9 m
3. Quantity for screen = Line 1 x Line 2 = 1.8 m x 5.9 m = 10.6 m^2

---

4. Distance around screen (for circular or spiral screen) = 6.1 m
5. Quantity for circular = Line 1 x Line 4 = 1.8 m x 6.1 m = 11.0 m^2

---

6. Number of corner posts (or uprights) from drawing = 7
7. Minimum length of posts = Line 1 + 0.3m = 1.8 m + 0.3m = 2.1 m

---

Shelter with Roof

8. Width of shelter + 0.6m = 1.4 m + 0.6m = 2.0 m
9. Length of shelter + 0.6m = 1.5 m + 0.6m = 2.1 m
10. Quantity for roof = Line 8 x Line 10 = 2.0 m x 2.1 m = 4.2 m^2

---

11. Diagonal of privy slab (measured in field) = 2.0 m
12. Diameter of circular roof = Line 11 + 0.9m = 2.0 m + 0.9m = 2.9 m
13. Quantity for circular roof = $\frac{\text{Line 12}}{2}$ x $\frac{\text{Line 12}}{2}$ x 3.1 = $\frac{2.9}{2}$ m x $\frac{2.9}{2}$ m x 3.1 = 1.45 m x 1.45 m x 3.1 = 6.5 m^2

---

14. Rear wall = height times width = 1.6 m x 1.4 m = 2.2 m^2
15. Side wall = height times width = 1.8 m x 1.5 m = 2.7 m^2
16. Side wall = height times width = 1.8 m x 1.5 m = 2.7 m^2
17. Front wall = height times width = 2.0 m x 0.6 m = 1.2 m^2
18. Screening wall = height times width = 2.0 m x 0.8 m = 1.6 m^2
19. Screening wall = height times width = 2.0 m x 1.4 m = 2.8 m^2
20. Quantity for shelter walls =

    Line 14 + Line 15 + Line 16 + Line 17 + Line 18 + Line 19 =

    2.2 m^2 + 2.7 m^2 + 2.7 m^2 + 1.2 m^2 + 1.6 m^2 + 2.8 m^2 = 13.2 m^2

Shelter with Roof and Door

For roof and walls, use Lines 8 through 20.

21. Quantity for door = height times width 1.8 m x 0.9 m = 1.6 m^2.

Calculating Quantities of Materials

The quantities of materials needed depend on the type and size of the shelter. Most quantities are calculated in square meters and then converted to material units such as numbers of bricks, numbers of bamboo poles, and numbers and lengths of boards. Other quantities are determined by measurements made on plan view drawings.

Simple Screen Shelter. Materials include screening material and corner posts, or an upright post for a circular or spiral screen. Calculate the amount of screening material needed by adding the lengths of each section of the screen and multiplying the total by the height, as shown in Figure 1. For example, suppose the height of the screen is 1.8m and the lengths of the sections are 0.3m, 1.2m, 1.2m, 2.0m, and 1.2m. Then the quantity of screen needed is (0.3m + 1.2m + 1.2m +2.0m +1.2m) x 1.8m = 5.9m x 1.8m = 10.6m^2. See Worksheet A, Lines 1, 2 and 3. For a circular or spiral screen multiply the distance around the screen as shown in Figure 1, times the height. For example, if the distance around the screen is 6.1m and the height is 1.8m, the quantity of screen needed is 6.1m x 1.8m = 11.0m^2. See Worksheet A, Lines 4 and 5.

A corner post is needed at the end of each section of screen. Count the number of posts in the plan view. In the example above there are seven posts as shown in Figure 1. The post near the center of the longest section is for added stability. For circular or spiral screens, place upright posts 0.9-1.2m apart. Posts should be 0.3-0.6m longer than the height of the screen. This extra length will be driven or buried in the ground to hold the screen securely. In the example above, the length of the posts should be at least 1.8m + 0.3m = 2.1m. See Worksheet A, Lines 6 and 7.

Shelter with Roof. Materials include roof and wall materials, corner posts or uprights, cross poles, rafters, and foundation.

Roof materials are calculated by multiplying the width of the shelter plus 0.6m times the length of the shelter plus 0.6m. For example, if the shelter is 1.4m wide and 1.5m long, the quantity of materials is (1.4m + 0.6m) x (1.5m + 0.6m) = 2.0m x 2.1m = 4.2m^2. See Worksheet A, Lines 8, 9 and 10.

To calculate the quantity of materials for a circular roof, which may be desirable for a circular or spiral-shaped shelter, first obtain the diagonal dimension of the privy slab by measuring it, as shown in Figure 2. The diagonal plus 0.9m is the diameter of the roof. The quantity of materials equals the diameter divided by 2, multiplied by the diameter divided by 2, multiplied by 3.1. For example, suppose the diagonal of the privy slab is 2.0m. Then the diameter of the roof is 2.0m + 0.9m = 2.9m. The quantity of materials is $\left(\frac{2.9m}{2} \times \frac{2.9m}{2}\right) \times 3.1$ = (1.45m x 1.45m) x 3.1 = 2.1m^2 x 3.1 = 6.5m^2. See Worksheet A, Lines 11, 12 and 13.

Wall materials are calculated by adding together the area of each wall, including the screening wall, if there is one. The area of a wall is its height times its width. If the top of the wall is sloped, use the height in the middle. For a circular or spiral-shaped shelter, the area of the wall is calculated the same way as for a simple screen shelter. That is, the distance around the shelter is multiplied by the height. For example, suppose a shelter is to have a screening wall, and the roof and sidewalls slope from front to back as in Figure 2, and the wall dimensions are as follows:

rear wall	= 1.6m by 1.4m
side walls	= 1.8m by 1.5m and 1.8m by 1.5m
front wall	= 2.0m by 0.6m
screening walls	= 2.0m by 0.8m and 2.0m by 1.4m

Then the wall area and the quantity of materials needed = (1.6m x 1.4m) + (1.8m x 1.5m) + (1.8m x 1.5m) + (2.0m x 0.6m) + 2.0m x 0.8m) + (2.0m x 1.4m) = 2.2m^2 + 2.7m^2 + 2.7m^2 + 1.2m^2 + 1.6m^2 + 2.8m^2 = 13.2m^2. See Worksheet A, Lines 14-20.

The materials needed for cross poles, corner posts, rafters, and foundations, shown in Figures 8a and 8b are best calculated by drawing an accurate plan view and measuring lengths from the drawing. The length of each log, pole, or board used for the foundation equals the width of the wall it supports. The length of each corner post or upright equals the height of the wall it supports. If the entire roof is to be raised above the walls for ventilation, add 0.15m to the length of each corner post or upright.

Shelter with Roof and Door. The materials needed for the roof are the same as those just discussed (see Worksheet A, Lines 8-20). Additional materials needed for the door are door braces, hinges, and latch.

Door materials are calculated by multiplying the height of the door times the width. For example, if the door is 1.8m high and 0.9m wide, the quantity of materials is 1.8m x 0.9m = 1.6m^2. See Worksheet A, Line 21.

The quantities of materials for the door braces are best obtained by drawing an accurate plan view similar to Figure 3 and measuring lengths from the drawing. One inside latch and two hinges are needed.

Materials List

The skills of the laborers and the tools needed depend on the materials used. For example, a wooden shelter requires a laborer with some carpentry skills and a hammer, saw, and nails. A brick-and-mortar shelter requires a laborer with some masonry skills and a shovel, mixing container, and trowel. When the materials, tools, and labor requirements have been determined, draw up a materials list similar to Table 5 and give it to the construction foreman.

In summary, give the construction foreman design drawings similar to Figures 1 through 8b, and a materials list similar to Table 5.

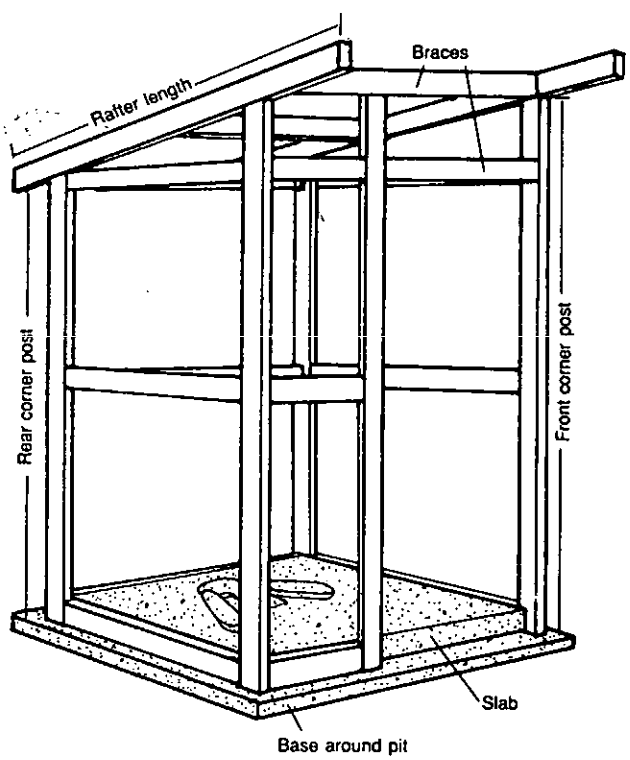


Figure 8a. Typical Shelter Framework Using Lumber

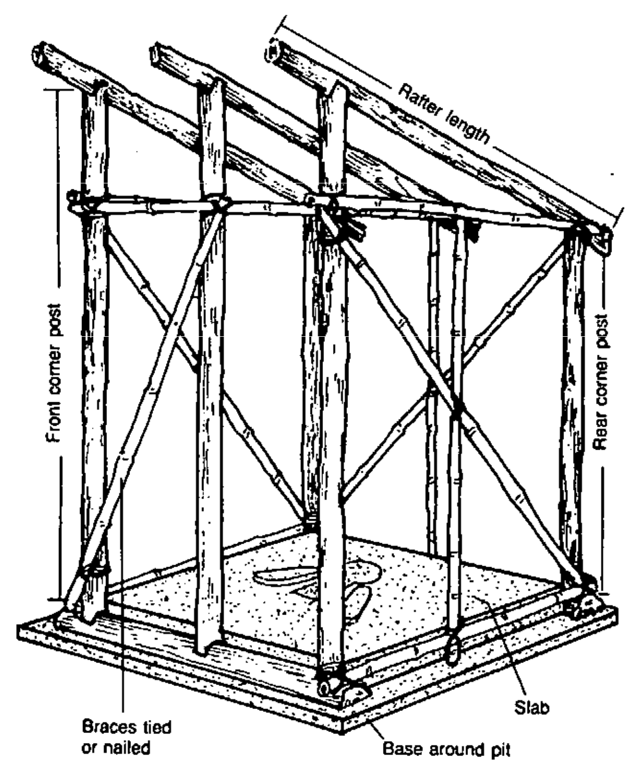


Figure 8b. Typical Shelter Framework Using Logs, Poles or Bamboo

Table 5. Sample Materials List for Privy Shelter

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborer (carpentry skills)	1 1	_____ _____
Supplies	Foundation: logs, 1.5m long, 100mm diam. Corner posts: wood beams, 1.8m long, 50mm diam. Walls: wood boards, various lengths, 25mm thick Roof: Corrugated metal Screens (flyproof) for ventilation openings, 150 x 250mm Metal hinges Latch Nails Other	4 4 13.2m^2 4.2m^2 12 2 1 _____ _____	_____ _____ _____ _____ _____ _____ _____ _____ _____
Tools	Measuring tape Hammer Saw Carpenter's level or equivalent (not essential but very useful) Carpenter's square or equivalent (not essential but very useful) Other	1 1 1 1 1 _____	_____ _____ _____ _____ _____ _____

Total Cost = _____

Do Not Use the Quantities in the Sample - Calculate Your Own

Notes

Water for the World

Constructing Privy Shelters

Technical Note No. SAN. 1.C.3

A privy shelter is a screen or structure that gives the person using the privy privacy. Depending on the design, a shelter can protect the user from the weather and keep out flies, rats, scavenging dogs, and other pests. Constructing a privy shelter involves assembling necessary labor, materials, and tools; building the shelter to the dimensions specified by the project designer; and building any special features.

A properly constructed shelter can last 5-10 years or more. This technical note describes each step in building a shelter. Read the entire technical note before beginning construction.

Materials Needed

The project designer must provide three papers before construction can begin:

1. A plan view of the shelter similar to one or more of Figures 1-4, and 8a and 8b, showing the correct dimensions of the shelter.

2. A detailed view of any special features similar to one or more of Figures 5-7.

3. A detailed materials list similar to Table 1, showing all necessary labor, supplies and tools.

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary laborers, supplies and tools.

Construction Steps

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Table 2 shows a sample work plan for building a privy shelter including time estimates for each step. Draw up a similar work plan with rough time estimates based on local conditions. You will then have an idea of when specific workmen, supplies, and tools must be available during the construction process.

For a simple screen shelter:

1. Assemble all laborers, supplies, tools, and drawings needed to begin construction. Study all drawings carefully.

2. Cut corner posts or uprights to the correct lengths.

3. Set corner posts or uprights firmly in the ground in a vertical position around the privy slab to a depth of 0.3-0.6m as shown in Figure 9a. Thoroughly tamp the ground after the posts are in place.

4. Build or weave together the screening material and secure it to the corner posts with vine, wire, or equivalent. Begin at the end corner post and work your way around the screen. The screen should touch the ground and be as high as the tops of the corner posts as shown in Figure 9b.

For a bamboo shelter with roof or roof and door:

1. Assemble all laborers, supplies, tools, and diagrams needed to begin construction. Study all diagrams carefully.

2. Build a foundation around the privy slab from bamboo poles 50-100mm in diameter. Notch the ends of the poles, fit them together, and tie them with wire or vine, as shown in Figure 10a.

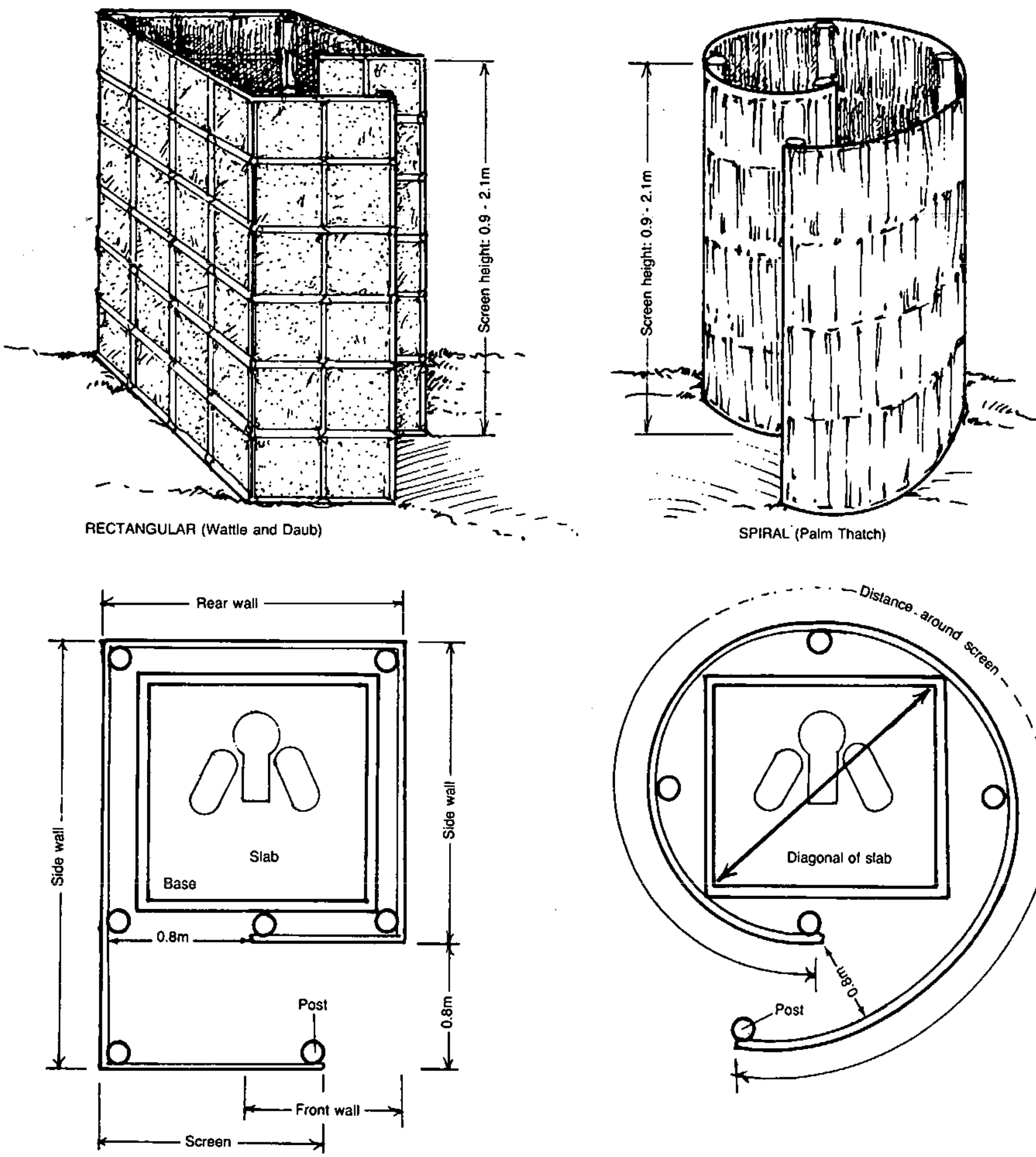


Figure 1. Simple Screen Shelters

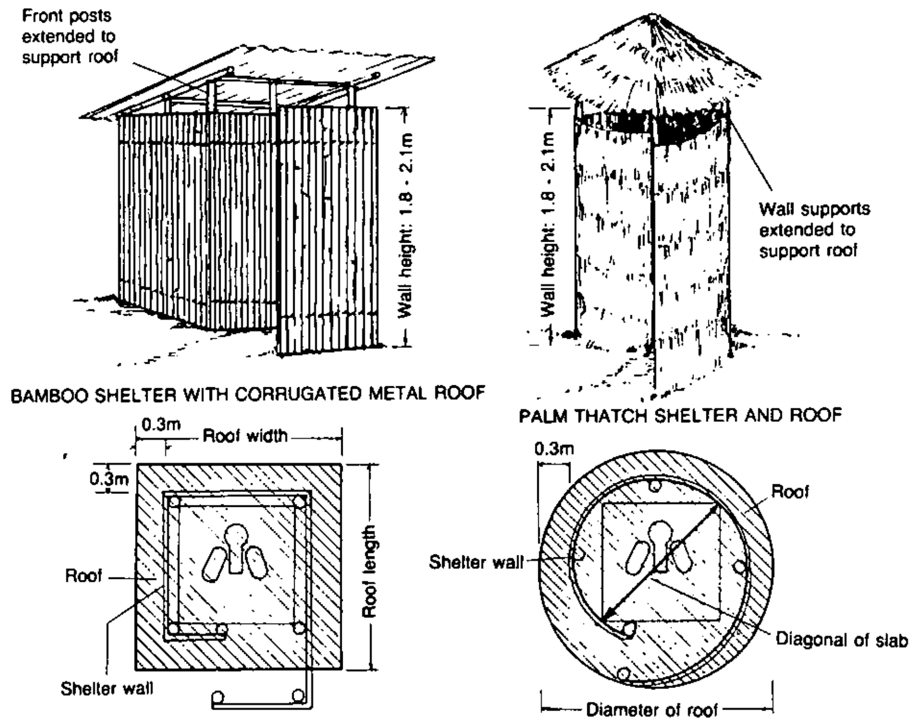


Figure 2. Privy Shelters with Roof

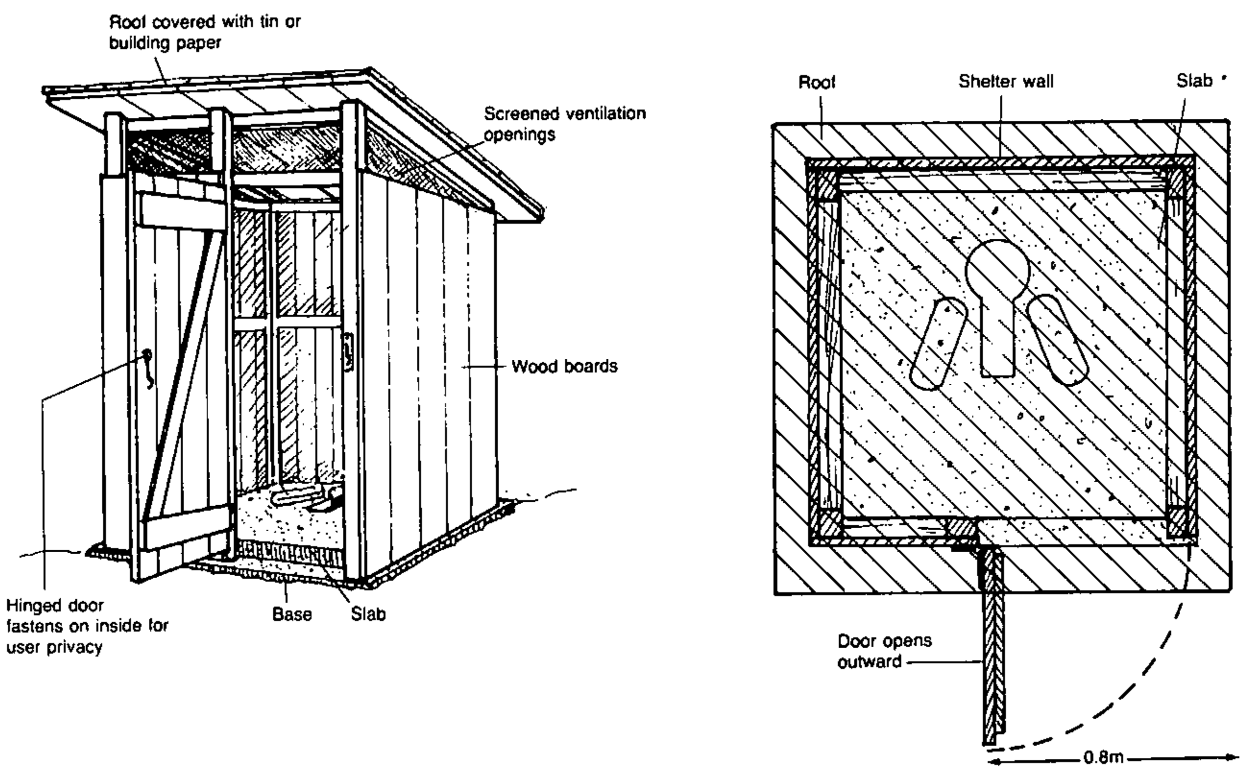


Figure 3. Fly-Proof with Screening and Door

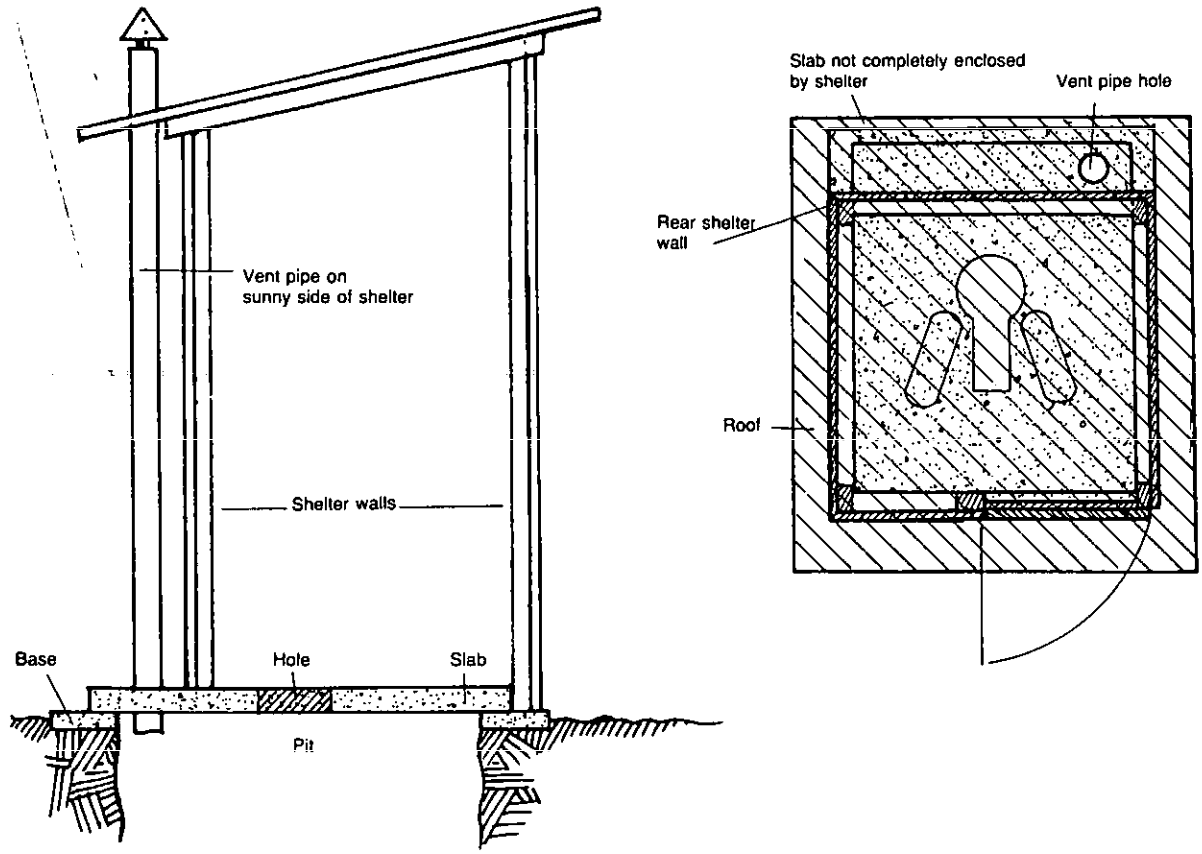


Figure 4. Shelter for Ventilated Privy

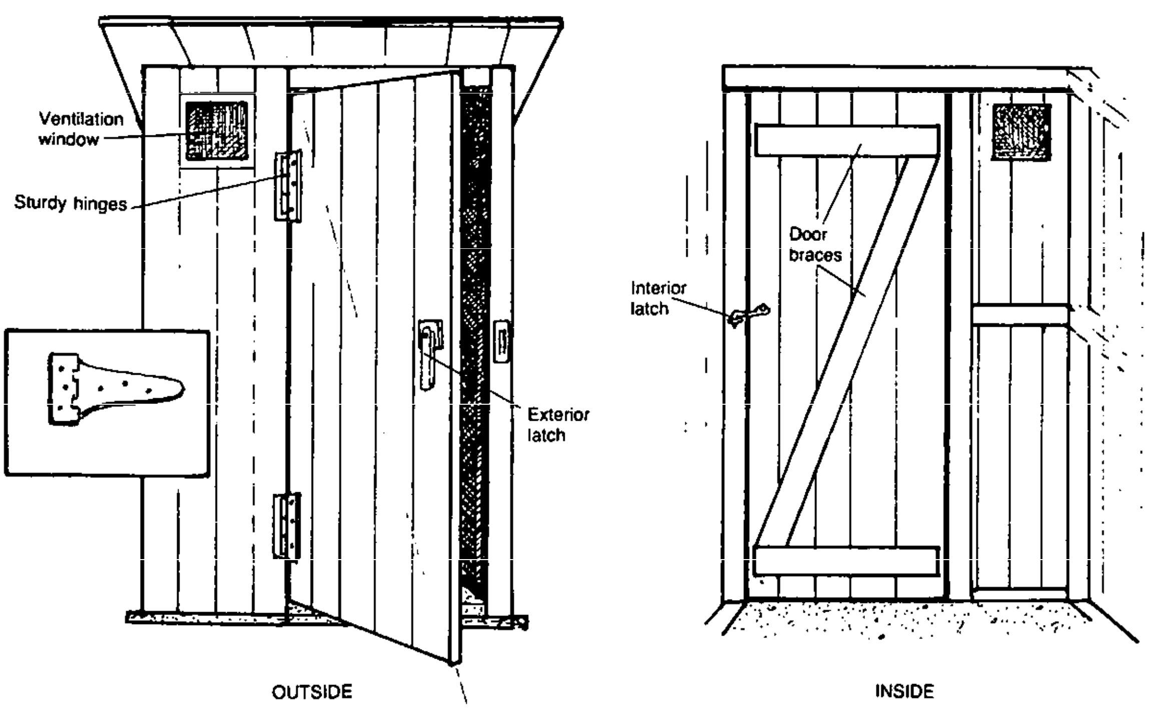


Figure 5. Detail of Door for Fly-Proof Shelter

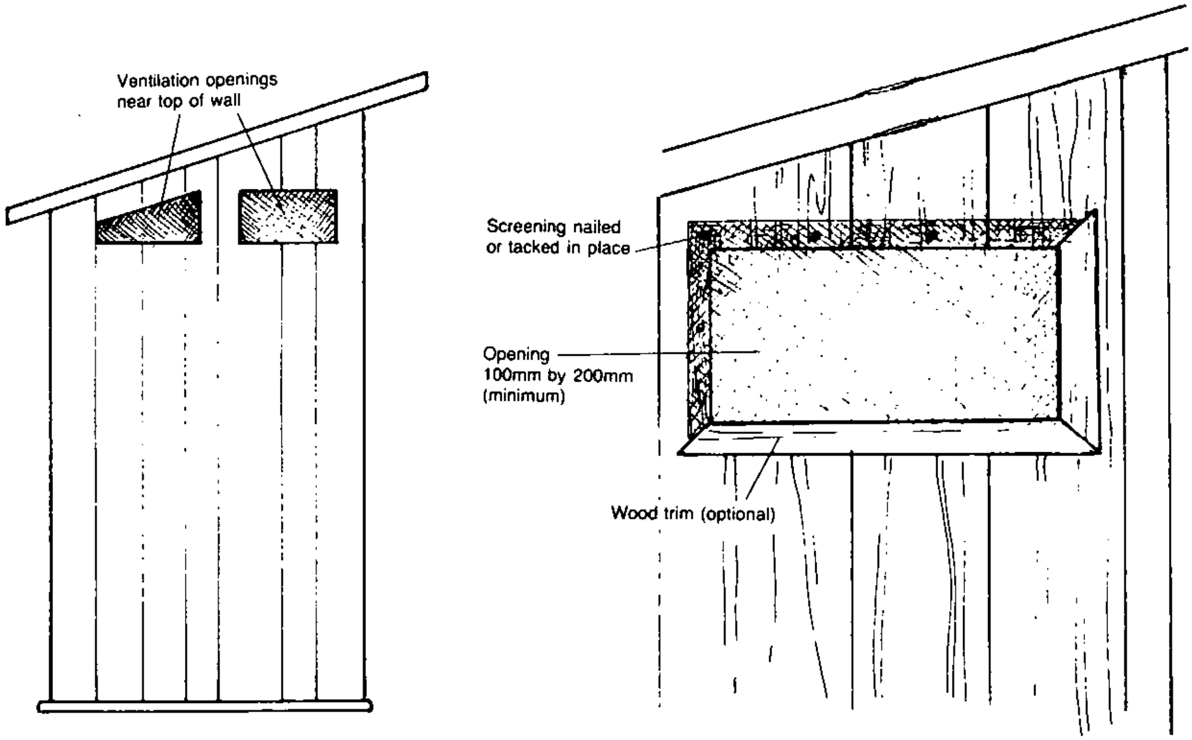


Figure 6. Fly-Proof Screening Covering Ventilation Openings

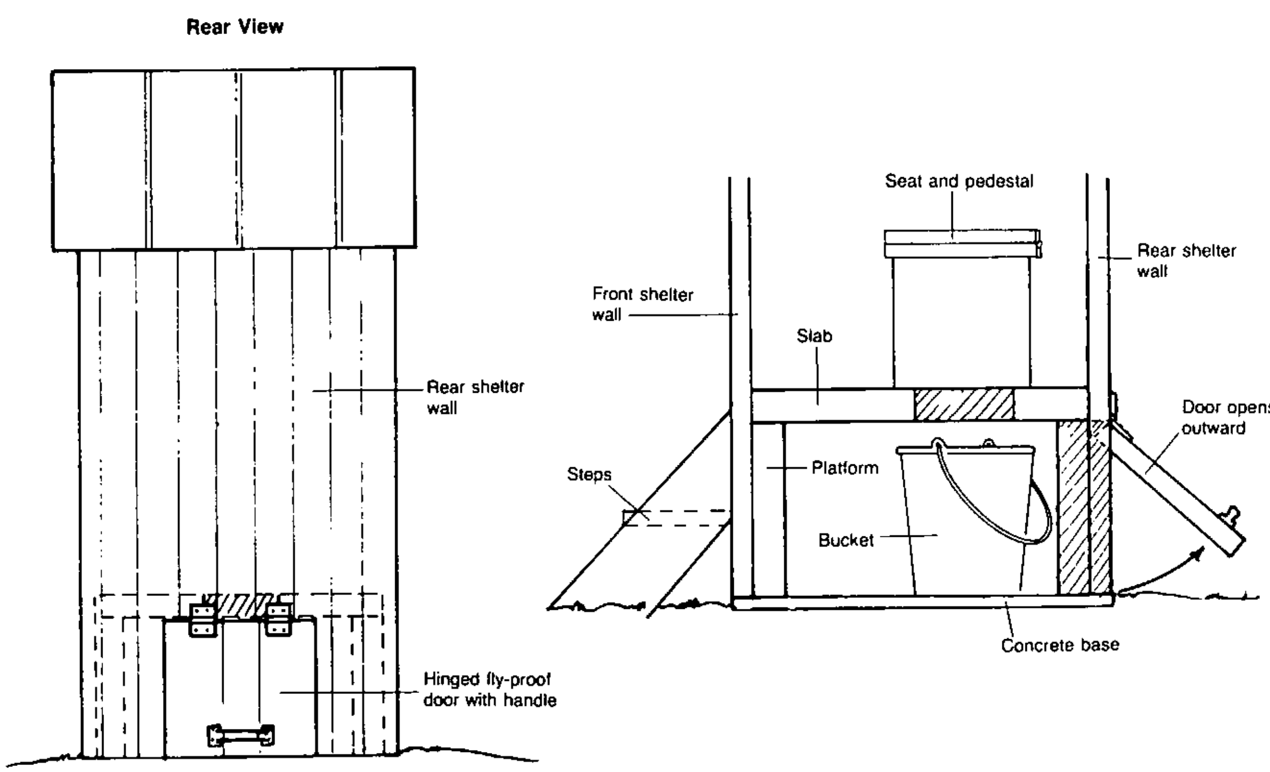


Figure 7. Detail of Shelter for Bucket Latrine

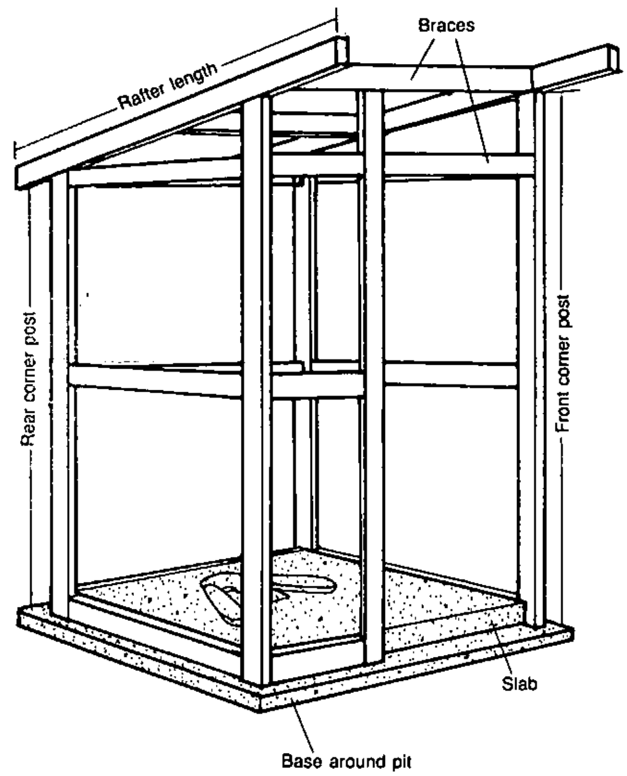


Figure 8a. Typical Shelter Framework Using Lumber

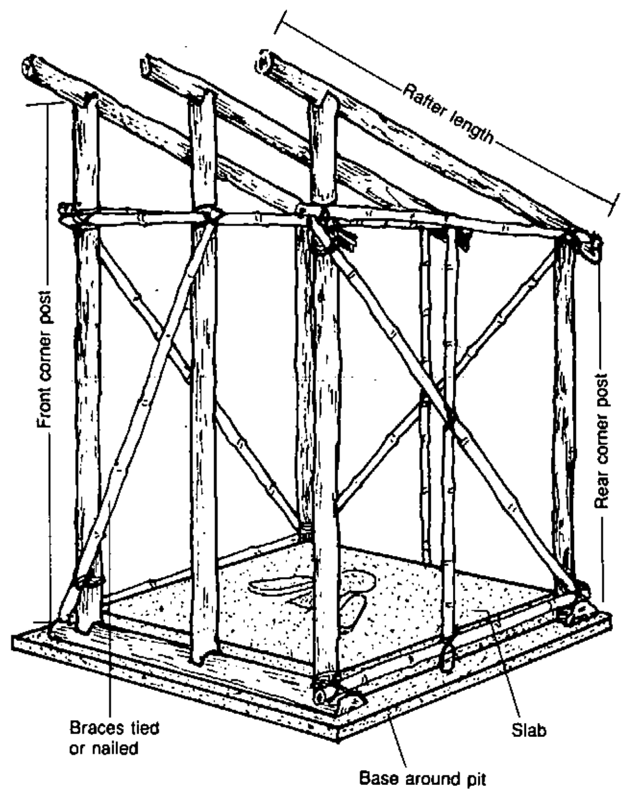


Figure 8b. Typical Shelter Framework Using Logs, Poles or Bamboo

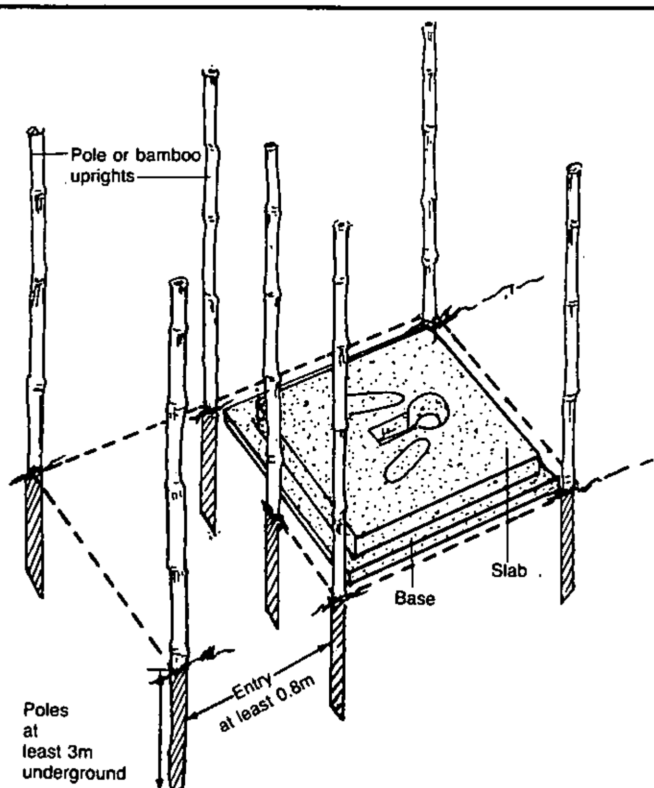


Figure 9a. Cornerposts for Screen Shelter

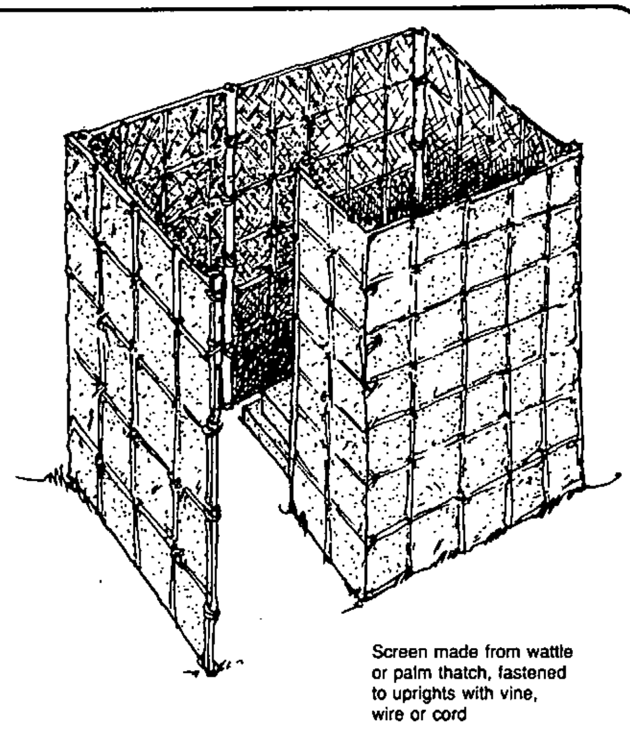
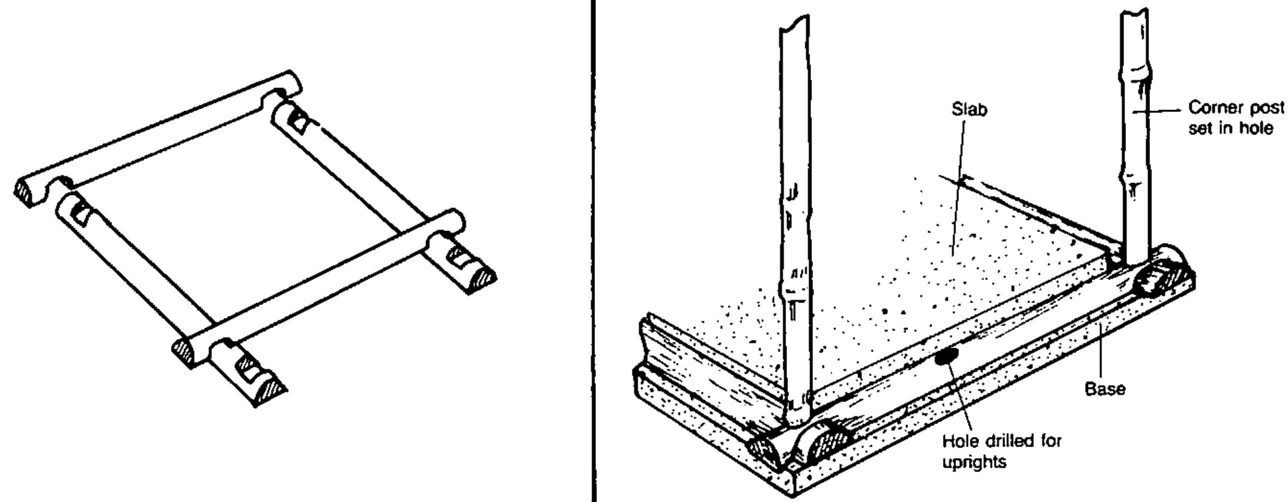


Figure 9b. Completed Screen Shelter



a. Poles notched to fit together

b. Poles on concrete base

Figure 10. Foundation for Bamboo Shelter

Table 1. Sample Materials List for Privy Shelter

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	______
	Laborer (carpentry skills)	1	______
Supplies	Foundation: logs, 1.5m long, 100mm diam.	4	______
	Corner posts: wood beams, 1.8m long, 50mm diam.	4	______
	Walls: wood boards, various lengths, 25mm thick	$13.2m^2$	______
	Roof: Corrugated metal	$4.2m^2$	______
	Screens flyproof for ventilation openings, 150 x 250mm	12	______
	Metal hinges	2	______
	Latch	1	______
	Nails	______	______
	Other	______	______
Tools	Measuring tape	1	______
	Hammer	1	______
	Saw	1	______
	Carpenter's level or equivalent (not essential but very useful)	1	______
	Carpenter's square or equivalent (not essential but very useful)	1	______
	Other	______	______

Total Cost = ______

Do Not Use The Quantities in the Sample - Calculate your Own

Table 2. Sample Work Plan for Building a Wood Privy with a Door

Time Estimate	Day	Task	Personnel	Tools and Materials
1 hour	1	Build foundation	Foreman; laborer with some carpentry skills	2 hammers; saw; nails; measuring tape (these will be needed throughout construction); 4 wood beams, 100mm by 100mm
1½ hours	1	Erect corner posts, uprights, and crossbraces	"	8 boards, 50mm by 100mm; 10 boards, 50mm by 50mm
½ hour	1	Build rafters	"	2 boards, 50mm by 100mm
3 hours	1	Build walls	"	14 square meters of boards, 25mm by 150mm
2 hours	2	Build roof	"	4 boards, 50mm by 50mm; 5 square meters of tin sheets; tin snips
1 hour	2	Build door and attach hinges and latch	"	1.7 square meters of boards, 25mm by 150mm; 3 boards, 25mm by 100mm; 2 metal hinges; screws and screwdriver; eyelet-and-hook latch
½ hour	2	Pick up scrap lumber, nails, and other leftover material	"	

3. Drill or cut holes in the foundation for the corner posts and uprights. Erect the posts, making sure they are vertical, and secure them to the foundation with wire or vine. Leave at least 0.8m space for the entryway or doorway. See Figure 10b. For a shelter with a door, the corner post and upright on each side of the doorway serve as the door frame.

4. Secure the crosspoles to the corner posts with wire or vine. The top crosspoles should be placed at the designed height of the walls. If the roof is raised for ventilation, the top crosspoles will be 100-150mm below the tops of the corner posts. For a shelter with a door, one crosspole will define the top of the doorway, which should be at least 2.0m high.

5. Secure the rafters to the corner posts with wire or vine. Rafters should extend about 0.3m beyond the front and rear walls.

6. Begin the screening wall, if there is one, by erecting two uprights as shown in Figure 11a. Bury the ends at least 0.3m in the ground and thoroughly tamp. Secure the crosspoles to the uprights.

7. Build the shelter walls and screening wall with bamboo, as shown in Figure 11b. Secure the bamboo to the crosspoles and uprights with wire or vine.

8. Build the roof with bamboo strips and palm thatch, as shown in Figure 11b. Start at the lower edge of the roof and work toward the higher edge, overlapping the thatch or palm leaves. The roof should extend about 0.3m beyond all walls.

9. Build a door, if there is one, with bamboo as shown in Figure 12. Attach the hinges, fasten the door to the door frame, and attach a latch, as described in the section on building special features.

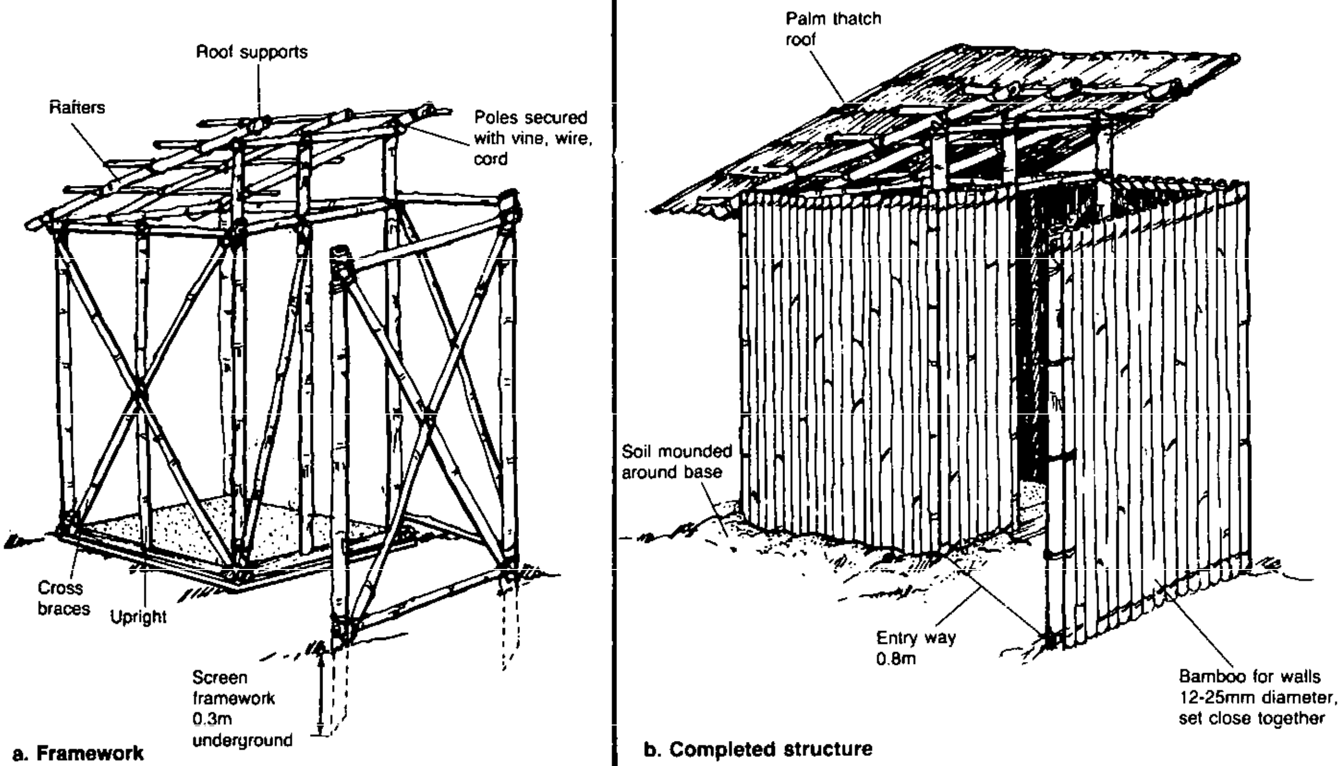


Figure 11. Construction of Bamboo Shelter with Screen and Roof

10. If the shelter has a door and is to be made fly-proof, cover all ventilation openings with screens, as described in the section on building special features.

11. Mound soil around the bottom of the walls to help keep out pests.

For a wood shelter with a roof or roof and door:

1. Assemble all laborers, supplies, tools, and diagrams needed to begin construction. Study all diagrams carefully.

2. Build a foundation around the privy slab from wood beams 50-100mm in diameter as shown in Figures 13a and 13b.

3. Erect the corner posts and uprights, making sure they are vertical, and nail them securely to the

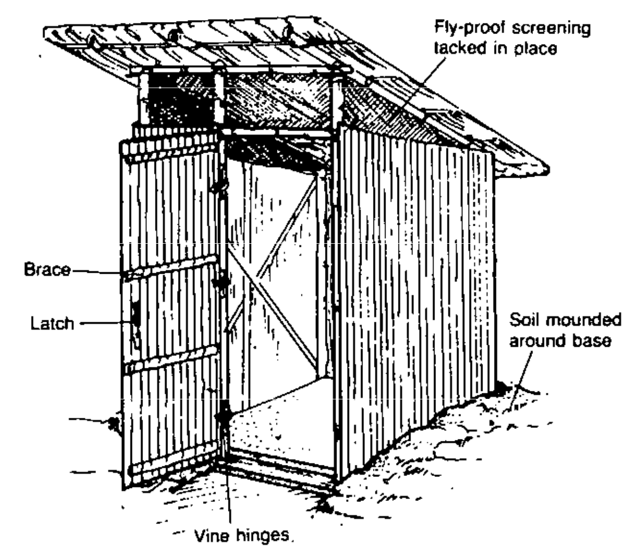


Figure 12. Bamboo Shelter with Door

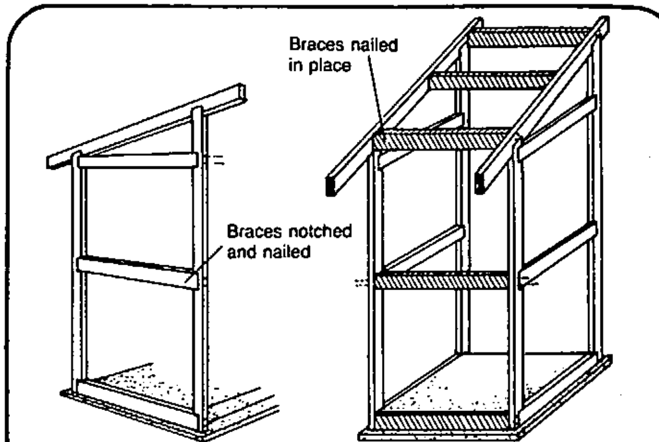
foundation. Leave at least 0.8m space for the entryway or doorway, as shown in Figure 14. For a shelter with a door, the corner post and upright on each side of the doorway serve as the door frame.

4. Nail crossbraces to the inside edges of the corner posts and uprights. The top crossbrace should be at the designed height of the walls. If the roof is to be raised for ventilation, the top crossbraces will be 100-150mm below the tops of the corner posts. For a shelter with a door, one crossbrace will define the top of the doorway, which should be at least 2.0m high.

5. Nail the rafters on top of the cornerposts. The rafters should extend about 0.3m beyond the shelter walls.

6. Begin the screening wall, if there is one, by erecting two uprights as shown in Figure 14. Bury the ends 0.3-0.6m in the ground and thoroughly tamp. Nail crossbraces to the inside edges of the uprights.

7. Build the walls and screening wall by nailing boards to the outside edges of the corner posts and uprights, as shown in Figure 15.



a. Side wall and rafter showing position of base
b. Joining two side walls with braces (rear view)

Figure 13. Framework for Wooden Shelter

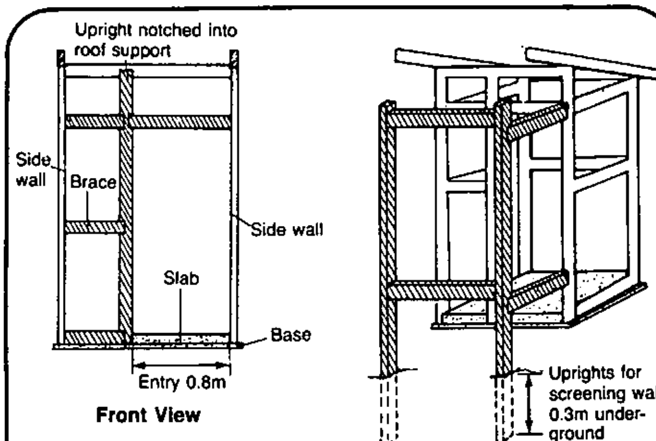


Figure 14. Framework for Wooden Shelter with Screen

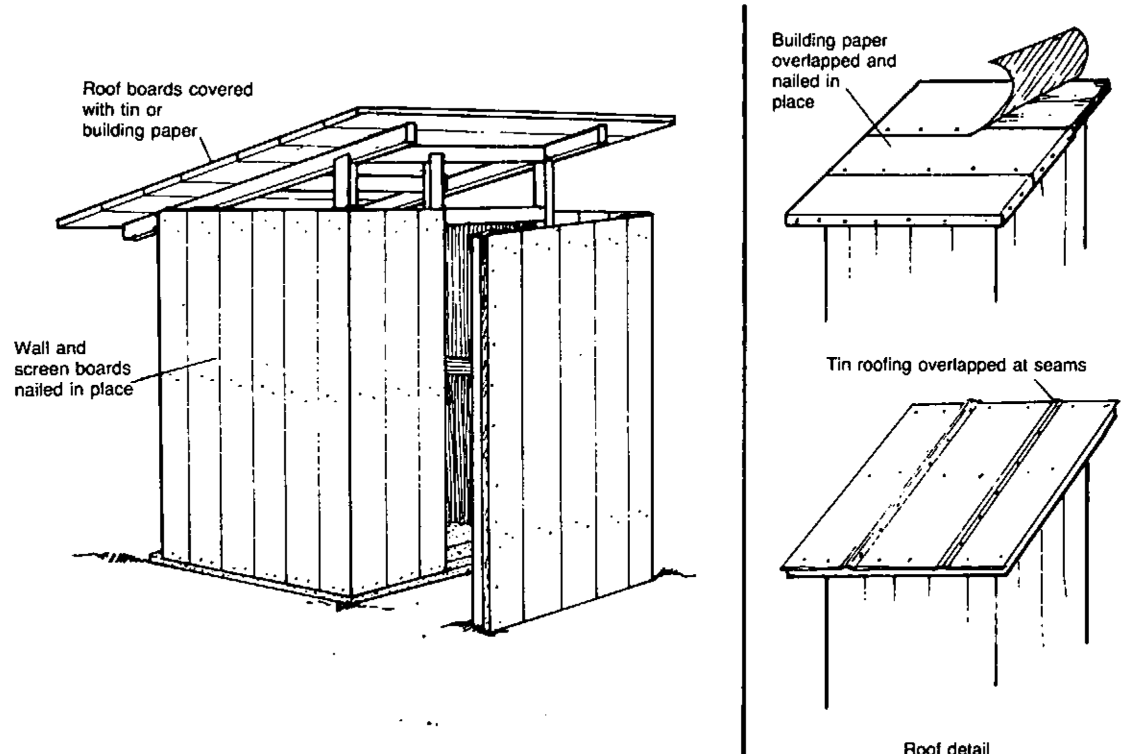


Figure 15. Completed Shelter

8. Build the roof by nailing crosspieces to the rafters, then nailing tin sheets to the crosspieces. Start from the lower edge of the roof and work toward the higher edge, overlapping the tin sheets as shown in Figure 15. The roof should extend about 0.3m beyond all walls.

9. Build a door, if there is one, with wood boards as shown in Figures 3 and 5. Attach the hinges, fasten the door to the door frame, and put on a latch as described in the section on building special features.

10. If the shelter has a door and is to be made fly-proof, cover all ventilation openings with screens as described in the section on building special features.

For a brick and mortar shelter with a roof or roof and door:

Since brick and mortar shelters should stand for more than 10 years, they are recommended for use with offset pit privies or compost toilets, which generally last that long. Because of the weight of brick and mortar shelters, they are not recommended for use with ventilated pit privies in which the back wall of the privy rests on the privy slab.

1. Assemble all laborers, supplies, tools, and diagrams needed to begin construction. Study all diagrams carefully.

2. Mortar a row of bricks to the base of the pit, mortaring the inside edge of the bricks to the privy slab.

3. Mortar a second row of bricks overlapping the first row as shown in Figure 16. Leave at least 0.8m space for the entry.

4. For a shelter with a door, build the door frame with wood beams 50mm thick by 100mm wide, and set it in place with a temporary brace as shown in Figure 17. Fasten L-shaped metal strips to each side of the door frame with nails or screws. The horizontal part of the strip will be mortared between the rows of bricks to hold the frame in place. Attach a second pair of L-shaped strips when the walls reach about half their height, and a third pair when the walls reach nearly the total height.

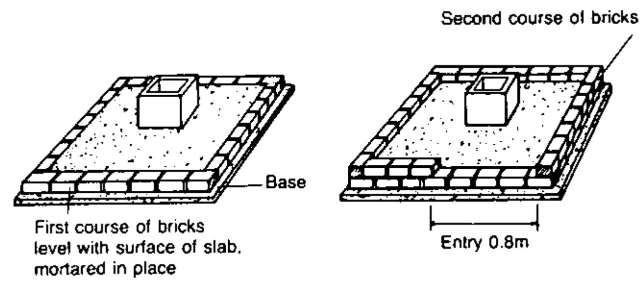


Figure 16. Foundation for Brick Shelter

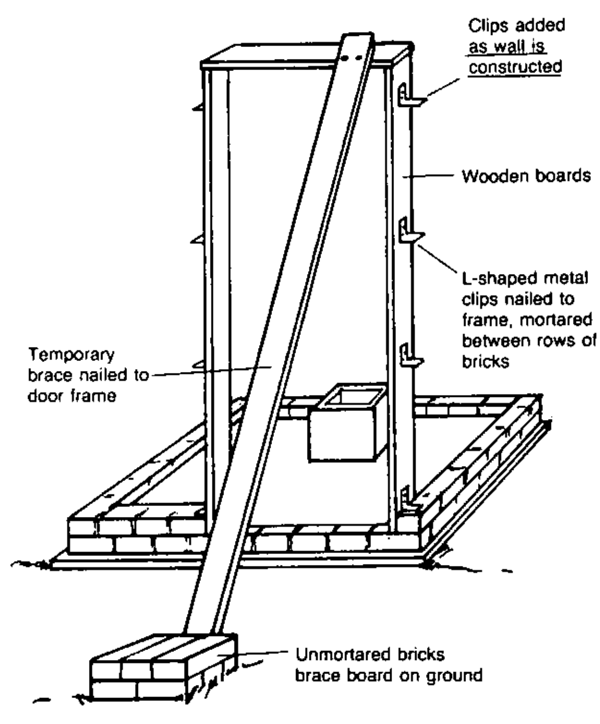


Figure 17. Framework for Entry or Door

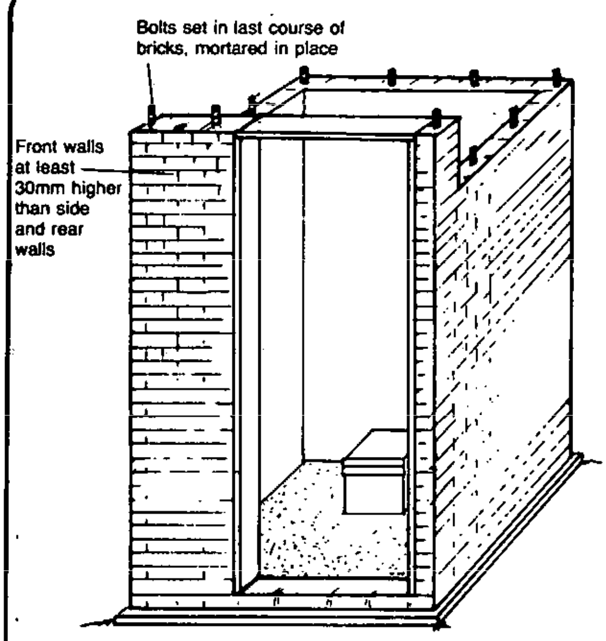


Figure 18. Constructing Brick Shelter

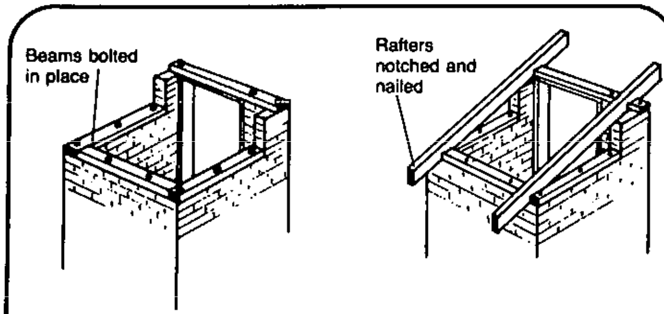


Figure 19. Roof for Brick Shelter

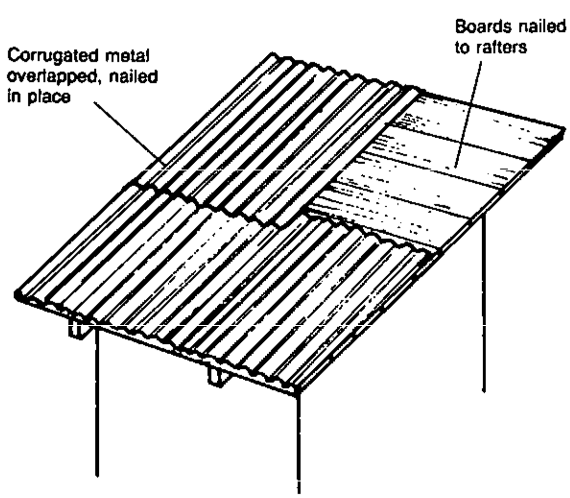


Figure 20. Corrugated Roofing

5. Continue laying rows of bricks up to the design height of the walls, being careful to keep the walls vertical.

6. Place bolts about 12mm diameter by at least 100mm long in the top bricks near the corners of each wall as shown in Figure 18. Mortar the bolts in place with the threaded ends up.

7. Allow a day or two for the mortar to set. Remove the temporary brace.

8. Drill or burn holes in wood beams 50mm thick by 100mm wide, matching the size and location of the holes to the bolts sticking up from the bricks. Set these top beams in place and fasten them to the bolts securely using nuts as shown in Figure 19.

9. Nail the rafters to the top beams. The rafters should extend about 0.3m beyond the walls as shown in Figure 19.

10. Build the roof by nailing cross-pieces to the rafters and nailing corrugated metal sheets to the cross-pieces. The furrows in the metal should be lined up in the direction of the roof slope. Start from the lower edge of the roof and work toward the higher edge, overlapping the corrugated sheets as shown in Figure 20. The roof should extend about 0.3m beyond all walls.

11. Build a screening wall, if there is one, by nailing uprights to the wood beam foundation. Nail the crossbraces to the uprights and to the top beam of the shelter. Nail the boards to the uprights as shown in Figure 21a.

12. Build a door, if there is one, with wood boards as shown in Figure 21b. Attach the hinges, fasten the door to the door frame, and put on a latch, as described in the section on building special features.

13. If the shelter has a door and is to be made fly-proof, cover all ventilation openings with screen as described in the section on building special features.

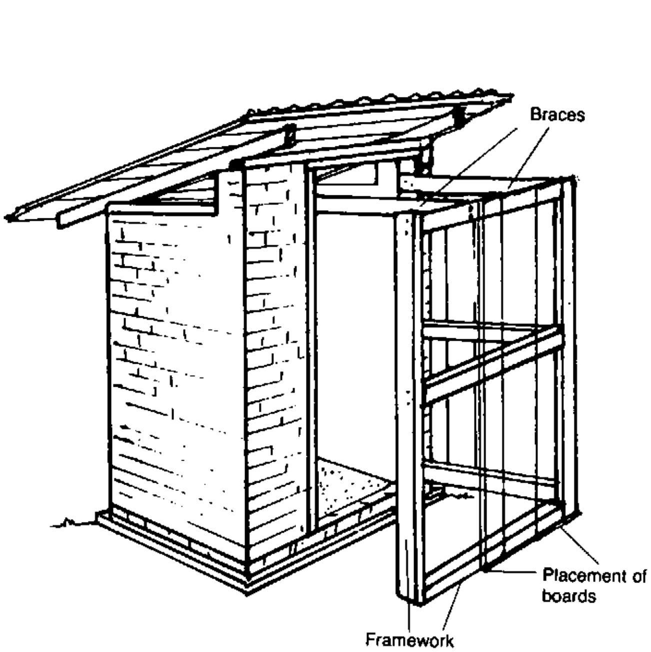


Figure 21a. Brick Shelter with Screening Wall

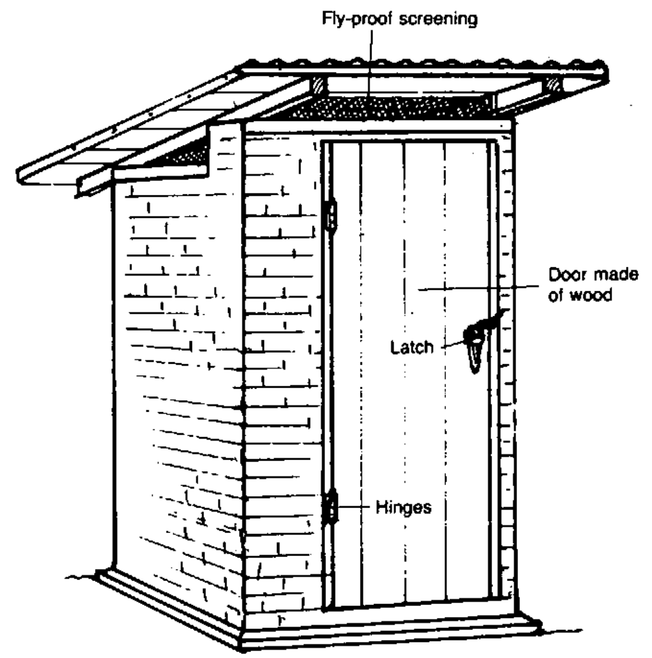


Figure 21b. Brick Shelter with Door

Building Special Features

Ventilation Openings. If the roof is not raised above the walls for ventilation, and ventilation openings are desired, cut openings near the tops of the walls. The openings should be about 200mm wide by 100mm high and spaced around the walls about 150mm apart as shown in Figure 6.

Screens. Screens covering ventilation openings must have mesh no larger than 2mm in order to keep out flies. Screens should be made of rust-proof material such as bronze, copper, plastic, or aluminum. If the screens are not rust-proof, paint them to prevent rust.

To cover a ventilation opening, cut a section of screen large enough to overlap the opening by 25mm on all sides and nail it in place as shown in Figure 6.

Door Hinges. Before attaching the hinges, hold the door in place and mark the door and the door frame where the hinges should be placed. Hinges should be about 150mm from the top of the door and 250mm from the bottom. They should be placed so that the door opens outward, if this is culturally acceptable.

If you are using prefabricated metal hinges with removeable pins, remove the pin from each hinge and separate the two halves. Attach one half with screws or nails to the door frame and the other half to the door. Raise the door in place, fit the halves of the hinges together, and reinsert the pin in each hinge.

If you are using a strap hinge, install it on the door. Lift the door into place and use a temporary support to hold it off the floor in its correct position. Accurately mark the proper location of the hinge on the door frame. Take the hinge apart and install the frame half. Then, hang the door.

For hinges of stiff leather such as soles of discarded boots or sandals, nail the hinges to the door, raise the door in place, and nail the hinges to the door frame.

For hinges made of vine, raise the door in place and tie the vine around the bamboo poles of the door and door frame. Leave enough slack so the door can be easily opened and closed.

Door Latch. For an eyelet-and-hook latch, secure the eyelet to the inside

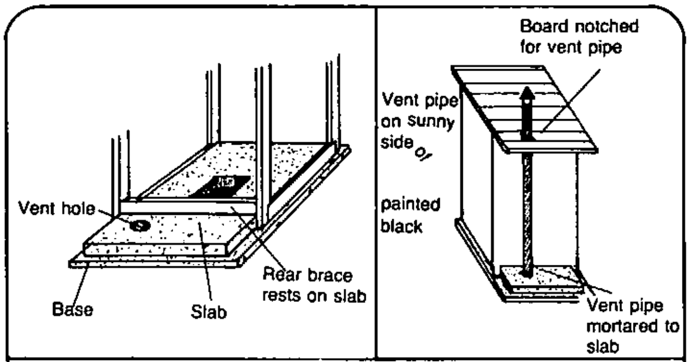


Figure 22. Constructing a Ventilated Shelter

of the door frame, and attach the hook to the inside of the door. The latch should be just above the middle of the door. For a bar latch, nail a piece of wood to the inside of the door. For a peg-and-loop latch, fasten the bamboo peg to the inside of the door frame and tie the vine loop to the inside of the door.

Vent Pipe. The vent pipe is mortared to the vent hole in the privy slab and attached to the shelter roof or the wall, if extra support is needed. The pipe should be vertical. If the roof overhangs the vent hole, cut a hole or notch in the roof to accommodate the vent pipe as shown in Figure 22. Attach the vent pipe to the roof and wall with either a metal band and screws, wood and nails, wire, or vine.

Shelter for Off-set Pit Privy. The foundation for the shelter must rest on the ground and abut the platform which supports the privy slab. Level the ground and thoroughly tamp it before building the foundation. The bottom of the privy walls begin at the foundation and completely enclose the platform. The bottom of the doorway or entryway begins at the privy slab and is higher than the foundation. For additional details see "Constructing Slabs for Privies," SAN.1.C.1.

Shelter for Bucket Latrine. The foundation for the shelter rests on the platform base and abuts the platform. Build the shelter walls to completely enclose the platform. The bottom of the entryway is level with the privy slab as shown in Figure 23. A fly-proof door for removal of the bucket

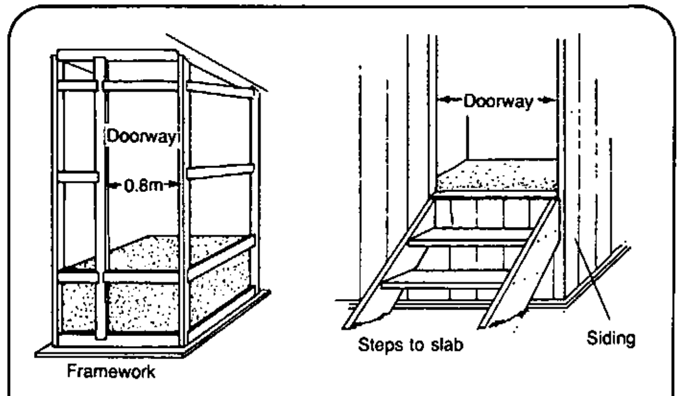


Figure 23. Construction of Shelter for Bucket Latrine

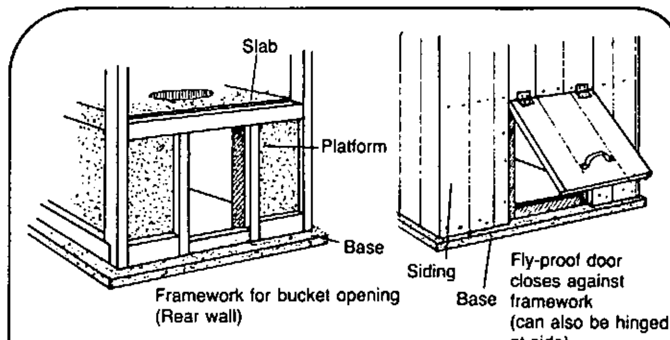


Figure 24. Rear Opening for Bucket Latrine

must be built into either the rear of the platform or the rear wall of the shelter. The door should have hinges and a latch to keep it tightly closed. If the door is built into the platform, leave an opening in the rear shelter wall as shown in Figure 24. For additional details, see "Constructing Bucket Latrines," SAN.1.C.5.

Shelter for a Compost Toilet. The foundation for the shelter rests on the base of the double vault and abuts the vault. Build the shelter walls to completely enclose the platform. The bottom of the entryway is level with the privy slab as shown in Figure 25. Airtight doors will be built into the rear of the vault. Leave openings in the rear shelter wall to allow access to these doors as shown in Figure 25. For additional details, see "Constructing Compost Toilets," SAN.1.C.6.

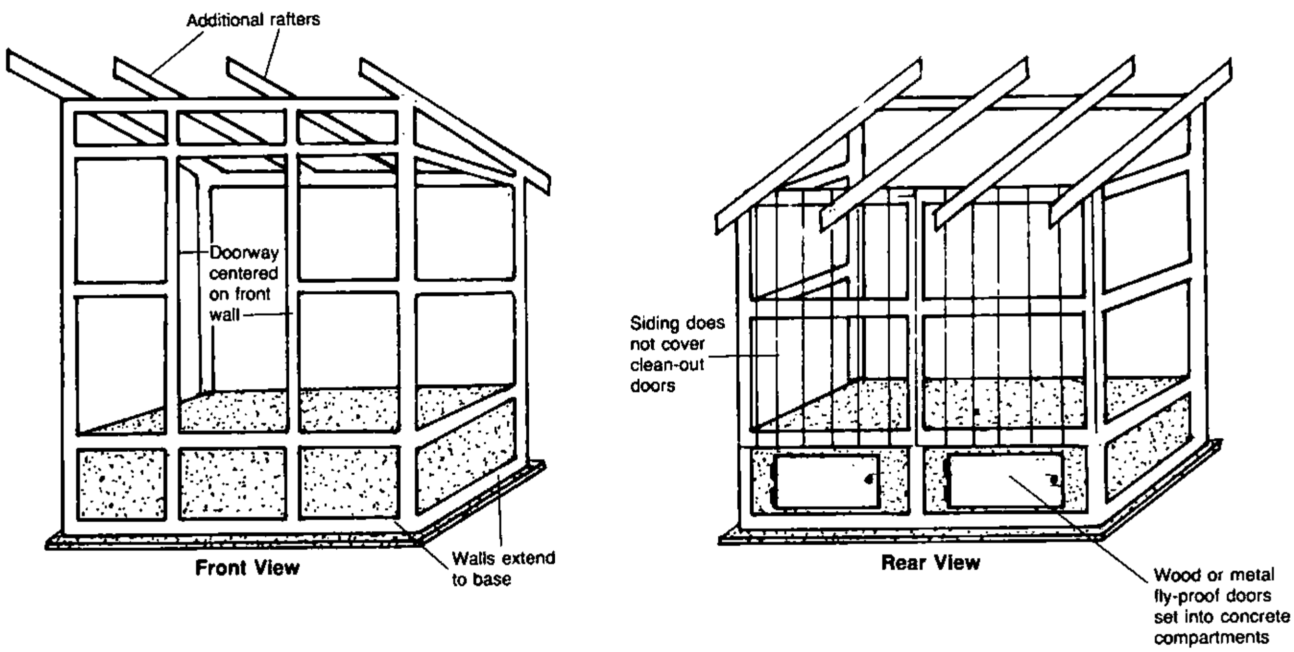


Figure 25. Framework Pattern for Composting Toilet

Notes

Water for the World

Designing Compost Toilets
Technical Note No. SAN. 1.D.6

A compost toilet consists of a pair of waterproof vaults that receive excreta, ashes, sawdust, straw, and grass. Each vault is equipped with a slab for defecating, a rear opening for removing compost, and a hole for a vent pipe. Designing a compost toilet involves selecting a location, calculating the size of the vaults, and determining the labor, materials, and tools needed for construction. The products of the design process are: (1) a location map, (2) design drawings of the compost toilet, and (3) a materials list. These products should be given to the construction foreman before construction begins.

This technical note describes how to design a compost toilet and arrive at these three end-products. Read the entire technical note before beginning the design process.

Useful Definitions

BACTERIAL ACTION - The process of organic matter being digested and broken down by tiny organisms.

COMPOST - A dark, fairly dry, crumbly, odorless material that is produced by sealing excreta, ashes, woodchips, straw, and vegetable wastes for 6-12 months in the vault of a compost toilet. Compost can be used to fertilize crops.

Materials Needed

Measuring tape - To obtain accurate field information for a location map.

Ruler - To draw a location map.

Location

The compost toilet should be on fairly level ground and at least:

6m from the nearest dwelling,
6m from the nearest water supply,
3m from the nearest property line.

Select a site that allows easy access to the toilet for use and for removing compost. If possible, the site should be downwind from the dwelling as there will be an odor. When the site has been selected, draw a location map similar to Figure 1 showing correct distances from the compost toilet to dwellings, water supplies, property lines, and roads. Give this map to the construction foreman before construction begins.

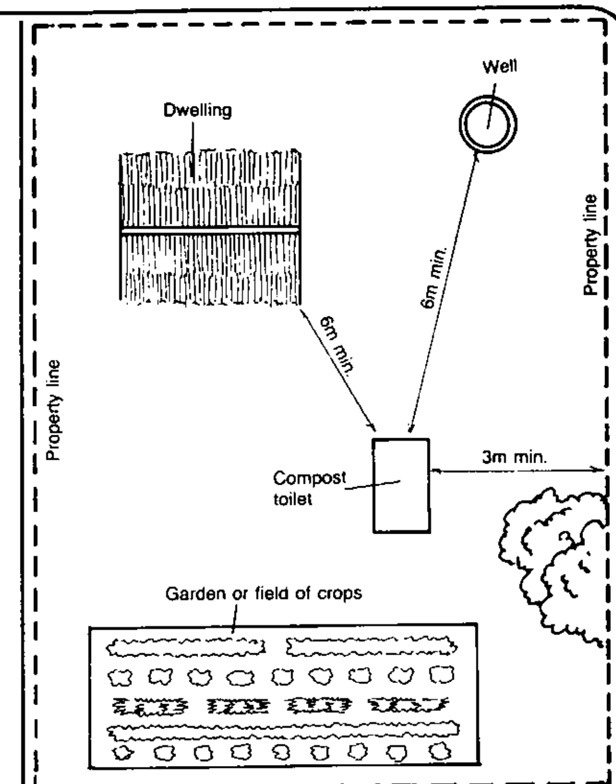


Figure 1. Location Map

General Design Information

A double-vault compost toilet is usually made from reinforced concrete or brick and mortar, and it rests on a base of similar material. See Figure 2. The vaults must be waterproof. If they are made from brick and mortar, the inside walls should be coated with a 12-25mm thick coating of cement plaster. The minimum thickness of the walls and base are shown in Table 1.

Design the vaults to be the same size. The maximum dimensions of each vault are shown in Table 2.

The rear wall of each vault must have an opening at least 0.4m by 0.4m for removal of compost, and a hole about 100mm in diameter for a vent pipe. The openings must have wood or metal covers that are larger than the openings themselves. The covers should be braced. The vent pipes are generally 100mm in diameter and made of galvanized metal.

Table 1. Walls and Base Design Criteria

Feature	Minimum Thickness
Outside Wall	75mm
Inside Wall (between vaults)	150mm
Base	100mm

The compost toilet may have two vent pipes which are permanently installed, or one vent pipe which is moved to whichever vault is in use. The vent hole in the vault not in use must be covered with wood or metal.

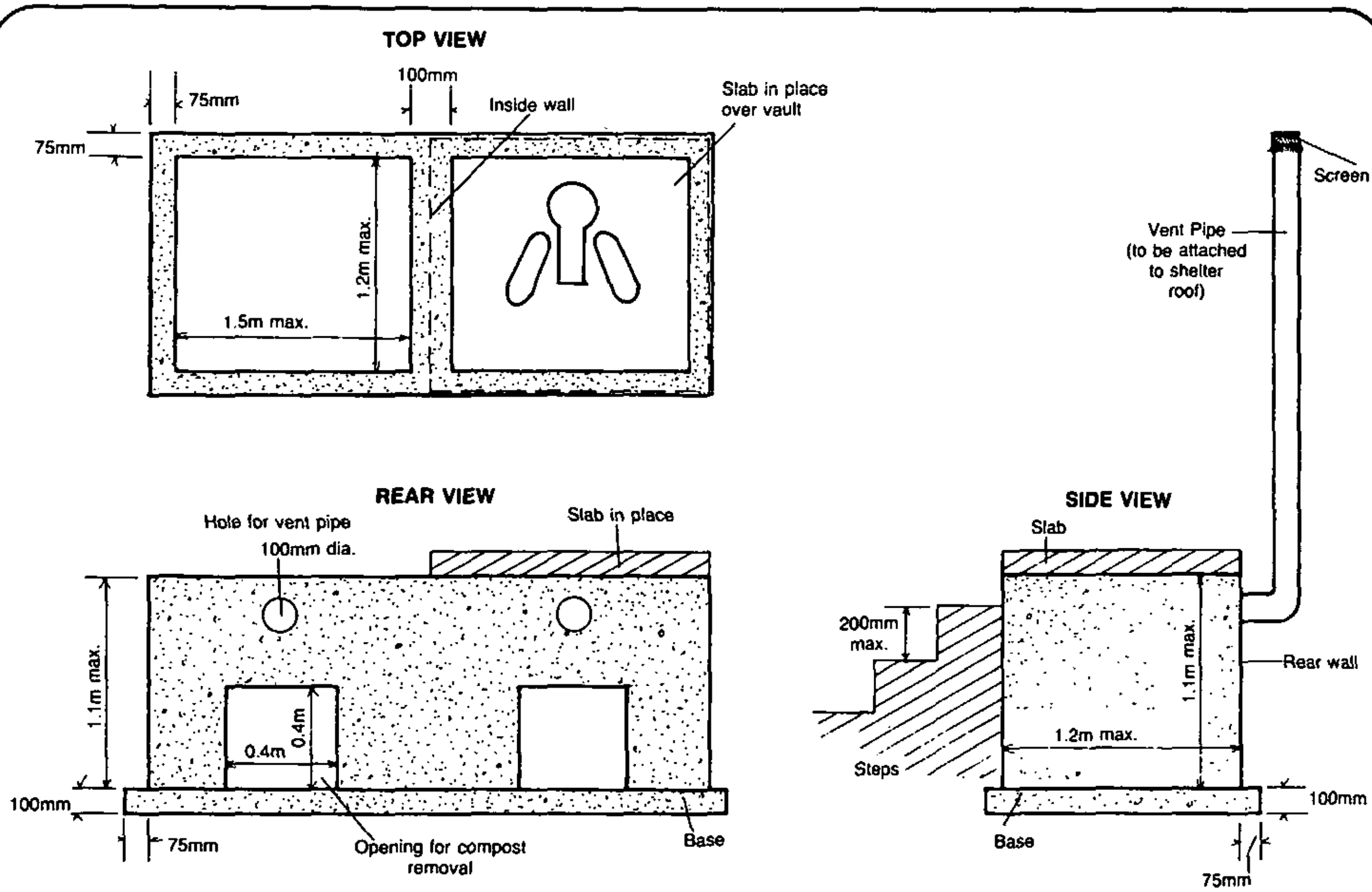


Figure 2. Compost Toilet

Table 2. Vault Dimensions

Feature	Maximum Dimension
Inside Height	1.1m
Inside Length (front to rear)	1.2m
Inside Width	1.5m

Design the steps leading up to the compost toilet so that the maximum height of each step is 200mm. See Figure 2.

Design the slab so that it is flush with the outside walls of the compost toilet. For details, see "Designing Slabs for Privies," SAN.1.D.1.

Calculating Size

Volume. Each vault must be large enough so that it takes about one year to become 3/4 full. Each person produces about $0.2m^3$ of waste per year, taking into account volume reduction to excreta and grass clippings by bacterial action. This number is multiplied by 1.33 because the vault is filled with soil and sealed when it becomes 3/4 full. Therefore, the volume factor equals:

$0.2m^3 \times 1.33 = 0.27m^3$ per person.

To calculate the required volume of each vault, multiply the volume factor times the number of persons using the compost toilet. For example, if the toilet is to serve a family of five, the volume of each vault must be five times $0.27m^3$:

$5 \times 0.27m^3 = 1.35m^3$ (Worksheet A, Lines 1-2).

Because of the limitations on dimensions shown in Table 2, this type of compost toilet will serve a maximum of seven persons. If eight or more persons must be served, design more than one toilet.

Inside Dimensions of Each Vault. Determine the inside dimensions of each vault based on the required volume and on the information in Table 2. The volume equals the inside height times the inside length times the inside width. For example, if the required volume of each vault is $1.35m^3$, the inside dimensions could be:

1.00m (height) x 1.10m (length) x 1.23m (width) = $1.35m^3$ (Worksheet A, Lines 3-5).

Outside Dimensions of Toilet. The outside dimensions of the toilet depend on the inside dimensions of each vault and on the information in Table 1.

The outside height equals the inside height.

The outside length (front to rear) equals the inside length plus two times the outside wall thickness.

The outside width equals two times the inside width plus two times the outside wall thickness plus the thickness of the inside wall between the vaults.

For example, if the inside dimensions of each vault are:

height = 1.00m, length = 1.10m, width = 1.23m, then the outside dimensions of the compost toilet are:

outside height = 1.00m;
outside length = 1.10m + (2 x 0.075m) = 1.10m + 0.15m = 1.25m;
outside width = (2 x 1.23m) + (2 x 0.075m) + 0.15m = 2.46m + 0.15m + 0.15m = 2.76m (Worksheet A, Lines 6-8).

Dimensions of Base. The dimensions of the base are as follows:

length (front to rear) = toilet length plus 0.15m,
width = toilet width plus 0.15m.

This leaves a 75mm area around the base to support the privy shelter. For example, if the outside dimensions of the toilet are:

length = 1.25m, width = 2.76m, then the dimensions of the base are:

length (front to rear) = 1.25m + 0.15m = 1.40m,
width = 2.76m + 0.15m = 2.91m (Worksheet A, Lines 9-10).

Dimensions of Slabs. Each vault is covered with a squatting or sitting slab. For design criteria, see "Designing Slabs for Privies," SAN.1.D.1. The outside dimensions of each slab are as follows:

length (front to rear) = compost toilet length;
width = compost toilet width divided by two. For example, if the dimensions of the toilet are:

length = 1.25m, width = 2.76m, then the dimensions of the slab are:

length = 1.25m
width = $\frac{2.76m}{2}$ = 1.38m (Worksheet A, Lines 11-12).

When all dimensions have been calculated, draw up a plan view similar to Figure 2 showing correct inside and outside dimensions. Give this drawing to the construction foreman before construction begins.

Determining Materials, Tools and Labor

The walls and base of a compost toilet are made from reinforced concrete or brick and mortar. The slab is made from reinforced concrete. Concrete walls and base require cement, sand, gravel, and water; containers and tools for mixing and smoothing concrete; reinforcing materials; wood, hammer, saw, and nails for building forms; and at least one worker with some experience with concrete. See "Designing Septic Tanks," SAN.2.D.3, for complete details and specifications on concrete ingredients and reinforcing materials.

Brick and mortar walls and base require bricks or concrete blocks; cement, sand, and water for mortar and cement plaster; containers and tools for mixing and spreading mortar; and at least one worker with some experience with concrete.

A concrete slab requires the same materials, tools, and workers as for concrete walls and base.

Quantities. The quantities of materials needed can be estimated by adding the volumes of the slabs, outside walls, inside wall, and base.

Volume of slabs: see "Designing Slabs for Privies," SAN.1.D.1.
Volume of outside walls = 2 x [(length x height x thickness) + (width x height x thickness)].
Volume of inside wall = height times length times wall thickness (0.15m).
Volume of base = base length times base width times base thickness (0.10m).

For example, if the outside dimensions of the compost toilet are: height = 1.00m, length = 1.25m, width = 2.76m, base length = 0.40m, base width = 2.91m, then the approximate volume of materials equals:

volume of slabs

+ volume of outside walls = 2 x [(1.25m x 1.00m x 0.075m) + (2.76m x 1.00m x 0.075m)] = 2 x (0.094 + 0.207) = $0.60m^3$

+ volume of inside wall = 1.00m x 1.25m x 0.15m = $0.19m^3$

+ volume of base = 1.4m x 2.91m x 0.10m = $0.41m^3$.

Total volume equals volume of slabs + $0.60m^3$ + $0.19m^3$ + $0.41m^3$ = volume of slabs + $1.20m^3$ (Worksheet A, Lines 13-17).

When all materials, tools, and labor requirements have been determined, draw up a materials list similar to Table 3 and give it to the construction foreman before construction begins.

In summary, give the construction foreman a location map similar to Figure 1, design drawings similar to Figure 2, and a materials list similar to Table 3.

Table 3. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	____
	Laborer (skilled with concrete)	1	____
	Laborer (unskilled)	1	____
Supplies	Wood (for forms)	____	____
	Nails (for forms)	____	____
	Cement (Portland)	____	____
	Sand (clean, sized fine to 6mm)	____	____
	Gravel (clean, sized 6-25mm)	____	____
	Water (clear)	____	____
	Reinforcing material	____	____
	Squatting slabs	____	____
	Vent pipes (with screens)	____	____
	Tin sheets (to cover rear wall openings)	____	____
	Other		
Tools	Measuring tape	1	____
	Hammer	1	____
	Saw	1	____
	Shovels	2	____
	Trowel	1	____
	Container for mixing concrete	2	____
	Carpenter's level or equivalent (optional)	1	____
	Carpenter's square or equivalent (optional)	1	____
	Tar or equivalent (for sealing covers over rear openings)	____	____
	Other		

Total Estimated Cost = ____

Worksheet A. Compost Toilet Calculations

1. Number of persons using compost toilet = 5

2. Volume of each vault = $0.27m^3$ x Line 1 = $0.27m^3$ x 5 = 1.35 m^3

Inside Dimensions of Each Vault

3. Proposed height = 100 m

4. Proposed length (front to rear) = 1.10 m

5. Required width = $\frac{\text{Line 2}}{\text{Line 3 x Line 4}} = \frac{(1.35m^3)}{(1.00m) \times (1.10m)}$ = 1.23 m

Outside Dimensions of Compost Toilet

6. Height = Line 3 = 1.00 m

7. Length (front to rear) = Line 4 + (2 x 0.075m) = 1.10 m + 0.15m + 1.25 m

8. Width = (2 x Line 5) + (2 x 0.075m) + 0.15m = (2 x 1.23 m) + 0.15m + 1.15m = 2.46 m + 0.30m = 2.76 m

Dimensions of Base

9. Length (front to rear) = Line 7 + 0.15m = 1.25 m + 0.15m = 1.40 m

10. Width = Line 8 + 0.15m = 2.76 m + 0.15m = 2.91 m

Dimensions of Each Slab

11. Length (front to rear) = Line 7 = 1.25 m

12. Width = $\frac{\text{Line 8}}{2} = \frac{(276m)}{2}$ = 1.38 m

Quantities

13. Volume of slabs - see "Designing Slabs for Privies," SAN.1.D.1

14. Volume of outside walls = 2 x [(Line 6 x Line 7 x 0.075m) + (Line 6 x Line 8 x 0.075m)]

= 2 x [(1.00 m x 1.25 m x 0.075m) + (100 m x 2.76 m x 0.075m)]

= 2 x (0.09 m^3 + 0.21 m^3) = 2 x 0.30 m^3 = 0.60 m^3

15. Volume of inside wall = Line 6 x Line 7 x 0.15m = 1.00 m x 1.25 m x 0.15m = 0.19 m^3

16. Volume of base = Line 9 x Line 10 x 0.10m = 1.40 m x 2.91 m x 0.10m = 0.41 m^3

17. Total volume - volume of slabs + line 14 + Line 15 + Line 16 =
volume of slabs + 0.60 m^3 + 0.19 m^3 + 0.41 m^3 =
volume of slabs + 1.20 m^3

Water for the World

Simple Methods of Washwater Disposal
Technical Note No. SAN. 1.M.2

Some method of washwater disposal is important wherever water is used inside or near a dwelling for bathing, washing, or cooking. Simple disposal methods confine washwater to a sump, pit, or trench and allow it to soak safely into the ground. This reduces the chance of contaminating water supplies and prevents mosquitoes from breeding by eliminating surface pools. All of these methods are inexpensive, easy to build, and can be made from locally available materials.

This technical note describes three simple methods of washwater disposal: sump, soakage pit, and soakage trench.

Useful Definitions

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria from washwater.

PERMEABLE - Allowing liquid to soak in.

WASHWATER - Water that has been used for bathing or washing clothes, dishes or kitchen utensils.

Sump

There are two types of sump: pit and drum. The pit-type, shown in Figure 1, is a hole 0.5-1m deep dug in permeable soil, lined with concrete blocks, bricks or stones, and covered with a lid to keep out flies and mosquitoes and to prevent children from falling in. The bottom of the sump is covered with 50-100mm of gravel or crushed rock.

The drum-type sump shown in Figure 2 uses a 200-liter steel drum with holes punched in the sides and bottom. A hole large enough to hold the drum is dug in permeable soil, and the drum is lowered into it and covered with a lid.

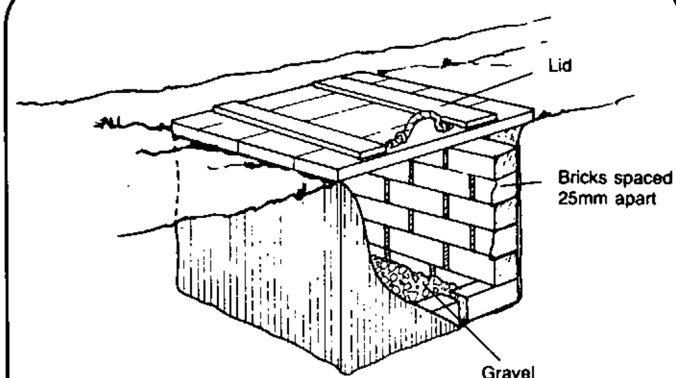


Figure 1. Pit-Type Sump

Washwater is poured directly into a sump and gradually soaks into the ground. Sumps are to be used only where there are 5 liters or less of washwater per person per day. Larger quantities of washwater require a soakage pit or soakage trench.

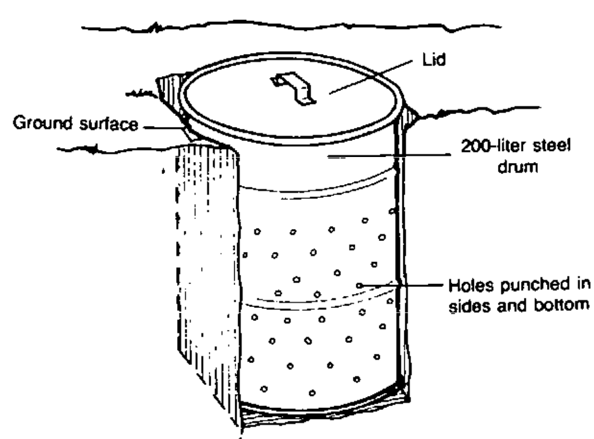


Figure 2. Drum-Type Sump

Soakage Pit

A soakage pit, shown in Figure 3, is a medium to large hole in permeable soil that is filled with rocks, equipped with a pipeline, covered with straw, and mounded with dirt. The rocks prevent the pit walls from collapsing and allow washwater to drain through to the sides and bottom of the pit. The straw prevents soil from sifting between the rocks and clogging the flow of washwater. The pipe carries washwater from a sink or drain in the dwelling, or excess liquid run-off from an aqua privy. The pipe extends to the top center of the pit.

Soakage pits may be round, square, or rectangular. They vary in size from 1-3m in diameter and from 1-3m deep, depending on the quantities of washwater and the permeability of the soil. The bottom of the pit must be at least 1m above groundwater levels.

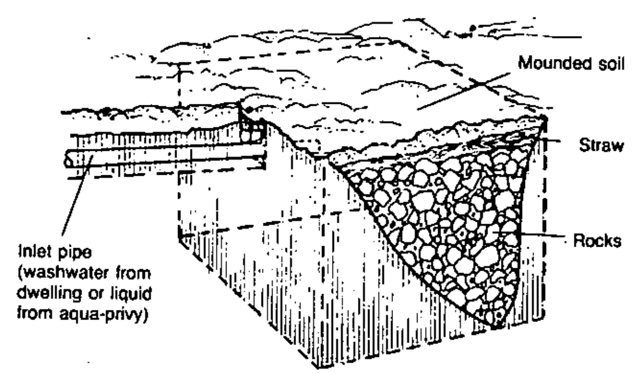


Figure 3. Soakage Pit

Soakage Trench

A soakage trench, shown in Figure 4, is a relatively long, narrow, sloping hole dug in permeable soil. It is partly filled with gravel or crushed rock, equipped with a pipeline and a perforated or open-jointed distribution pipe, covered with straw, and mounded with dirt. The gravel prevents the sides of the trench from collapsing and allows washwater to flow through and drain to the bottom of the trench. If distribution pipe is not available, concrete blocks can be used instead. The straw prevents soil from sifting down and clogging the flow of washwater. The pipeline carries washwater from a sink or drain in the dwelling, or excess liquid run-off from an aqua privy. The pipe extends into the higher end of the trench.

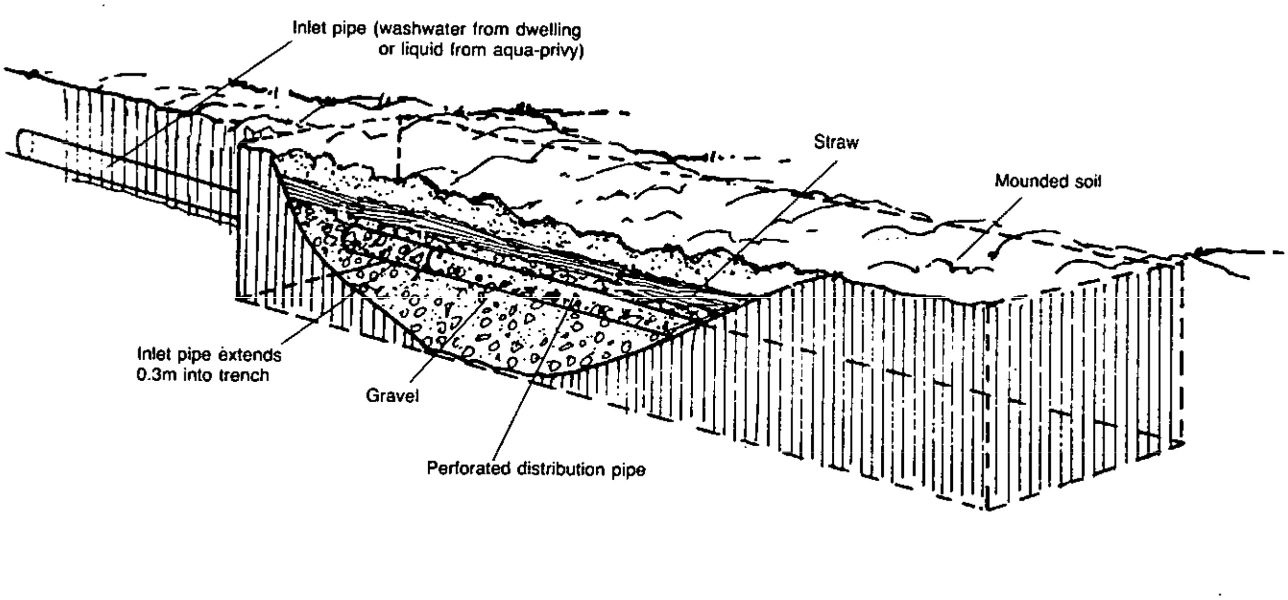


Figure 4. Soakage Trench

Soakage trenches are 0.6-1m wide, 0.6-1m deep, and vary in length from 6-30m depending on the quantities of washwater and the permeability of the soil. The bottom of the trench must be at least 1m above groundwater levels, and it must slope gradually downward away from the inlet end.

Comparison of Methods

Table 1 summarizes each of the three methods of washwater disposal. The methods are listed across the top of the chart, and the factors to be compared are listed down the left side. The table can be used as an aid in selecting a method (see "Planning Simple Excreta and Washwater Disposal Systems," SAN.1.P).

Table 1. Comparison of Washwater Disposal Methods

Factor	Disposal Method			
	Sump		Soakage Pit	Soakage Trench
	Pit-type	Drum-type		
Depth	0.5-1m	Height of drum	1-3m	0.6-1m
Diameter, or Length and Width	0.5-1m diameter	Diameter of drum	1-3m in diameter	0.6-1m wide and 6-30m
Materials Required	Concrete blocks, bricks, or stones; gravel or pebbles; wood or metal lid	200-liter steel drum; wood or metal lid	Rocks; straw, hay, or grass; length of clay, plastic, or galvanized metal pipe extending from dwelling or aqua privy to pit	Gravel, pebbles, concre blocks, open-joint or p forated sewer pipe; str hay, or grass; length of clay, plastic, or ga vanized metal pipe exte ing from dwelling or aq privy to trench
Operation	Remove lid, pour washwater into pit	Remove lid, pour washwater into drum	Pour or drain washwater into sink, pipe, or aqua privy	Pour or drain washwater into sink, pipe, or aqu privy
Suitability	Low quantities of washwater (5 liters per person per day or less)	Low quantities of washwater (5 liters per person per day or less)	Small plot size or low groundwater levels	Large plot size or high groundwater levels

Notes

1982

Water for the World

Water Treatment in Emergencies
Technical Note No. RWS. 3.D.5

The treatment of water supplies in emergency situations is important to protect people's health. When natural disasters, drought, or social unrest cause a loss of supply of potable water or when, for any other reason, a water supply is disrupted or a supply change is necessary, measures should be taken quickly to provide for a safe water supply.

This technical note discusses the use of several methods for emergency water treatment. Many are similar to simple household purification methods which are described in "Designing Basic Household Water Treatment Systems," RWS.3.D.1. Community members should be instructed in the best methods to use to make water potable during emergencies. Read the entire technical note to evaluate the type of treatment most appropriate to local circumstances.

The design process for emergency water treatment should result in a list of materials needed to provide the appropriate disinfection of water during the time potable supplies are cut off. A sample list for a water boiler appears in Table 1. A list of sources of chlorine and their strengths is in Table 2.

Table 1. Sample Materials List for Boiler System

Item	Description	Quantity	Estimated Cost
Labor	Emergency workers	____	____
	Unskilled labor	____	____
Supplies	200-liter steel drum	____	____
	20mm pipe nipple	____	____
	Valve	____	____
	Large funnel	____	____
	Cement blocks or bricks	____	____
	Filler plug	____	____
	Solder	____	____
Tools	Drill or punch	____	____

Total Estimated Cost = ____

Useful Definitions

CLARIFICATION - The process of removing suspended matter and other forms of turbidity from water.

CONTAMINANT - An impurity which makes water unfit for human consumption or domestic use.

DISINFECTION - Destruction of harmful microorganisms present in water through physical (such as boiling) or chemical (such as chlorination) means.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

When dealing with a disruption in the water supply, the major effort should to go toward getting the system back into operation as quickly as possible. Until operation can begin again, emergency treatment measures should be undertaken.

Usually a source of water that must be used in an emergency is contaminated. Therefore, the water should be disinfected before people drink it. Various methods are available for disinfection during emergencies. The choice of methods will depend on the resources available in each community or region.

Boiling

Boiling destroys all forms of disease organisms in water. It can be used whether water is clear or turbid and even if it contains a large amount of organic matter. For boiling to be effective, water must be brought to a rolling boil; that is, the water must be bubbling rapidly. Boiling water to disinfect it is a very good method of disinfection if fuel is available to heat the water. Individuals can boil

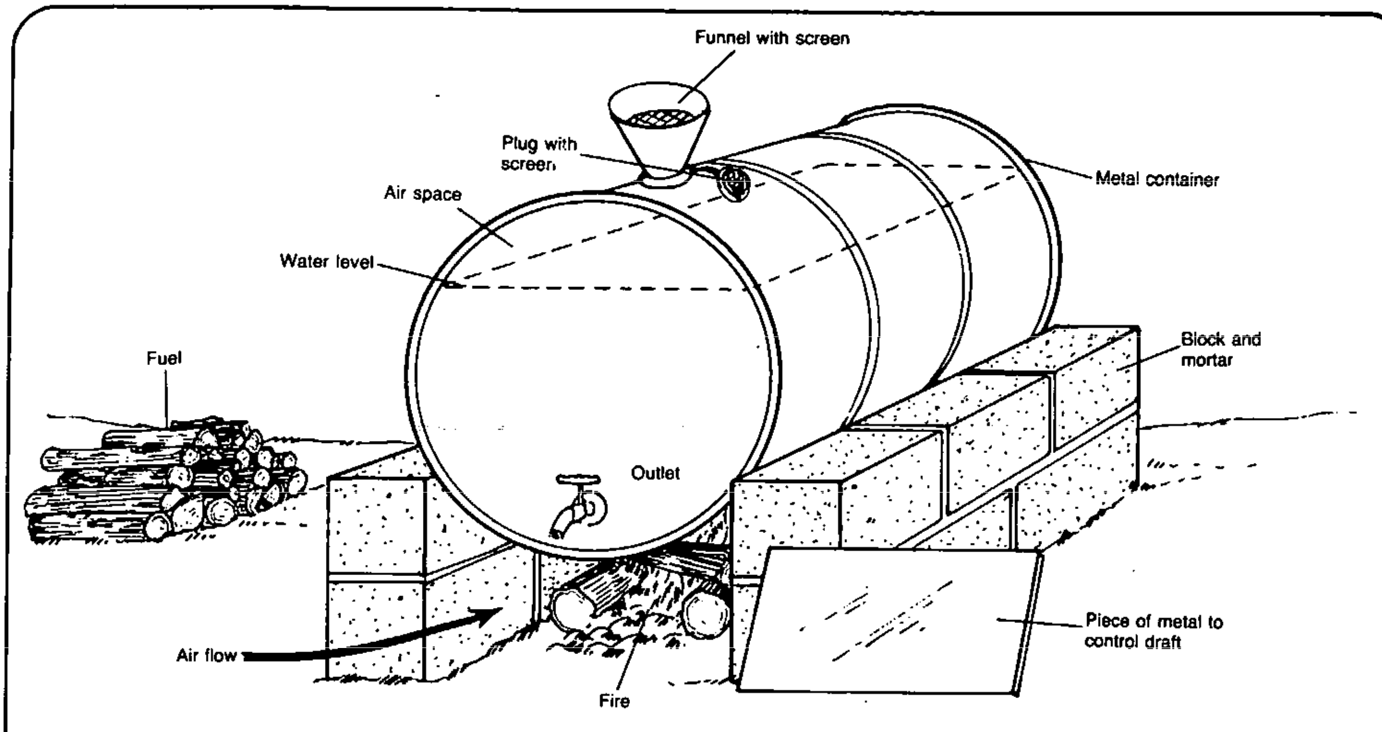


Figure 1. Boiler For Drinking Water

water in small containers. Water should be stored in the same container in which it is boiled to prevent any contamination that could occur from pouring water into a different container.

To boil a large quantity of water that can serve a large group of people, a boiler similar to that shown in Figure 1 can be built. For the boiler, build a simple brick or concrete block fireplace and position it so that the prevailing wind goes between the bricks from the front to the back of the tank. Then, place a 200-liter steel drum or another suitable tank over the fireplace. Laying the tank on its side, make a hole approximately 20mm in diameter on the top side close to the outlet edge as shown. This hole will serve as the inlet. Use a funnel with a small filter screen placed in the hole to fill the tank with water.

Place a valve on the front of the tank. Use a metal valve that can withstand the heat of the boiling water. A small plug should be placed in the inlet hole when the funnel is removed. The plug should fit loosely so that steam can escape during boiling.

The boiler system is good not only for boiling but also for storage. A large amount of fuel is needed, however, to boil the large quantities of water in the tank. Where fuel is abundant, this method is a very good form of disinfection for two or three days. Where fuel is in short supply, another method must be chosen.

Chemical Disinfection

Chlorination of water is one of the most widely accepted methods of chemically disinfecting water under emergency situations. Before chlorinating water from an emergency supply, water may need to be filtered. Chlorine is ineffective against organisms embedded in solid particles. Before turbid water is chlorinated, it should either be poured through a clean cloth or stored to permit the settling of particles. The clarified water can then be disinfected. In some cases, a small temporary dam can be built across a small stream. The reservoir formed can provide adequate settling. The reservoir will provide easy access to the water either manually or through installation of an intake and a pump. Whenever possible, choose an emergency source that is not subject to high levels of contamination. Water collected from an emergency source should be stored in clean containers after clarification. Small storage tanks, cisterns or barrels are appropriate for this. Chlorine is then added to the stored water.

Chlorine is available in liquid, powdered and tablet form. For emergency situations, especially when water is highly contaminated, use a dosage of about 50 parts per million (ppm), sometimes called 50 milligrams per liter (mg/l). To determine the amount of chlorine to add to a given quantity of water to make a 50ppm dosage use the following formula:

$$\text{Amount of chlorine} = \frac{\text{Dosage (ppm)} \times \text{Quantity of water}}{\text{Percent available chlorine}}$$

For example, the amount of chlorinated lime, 35 percent available chlorine, that must be added to 100 liters of water to provide a dosage of 50ppm is:

$$\text{Amount of chlorine} = \frac{\text{50ppm (0.05)} \times \text{100 liters}}{0.35}$$

Amount of chlorine = 14 grams

In this example, 14 grams of chlorinated lime must be added to 100 liters of water to make a 50ppm dosage. Dosage can be reduced for cleaner waters to avoid high residuals and strong taste and odors. Table 2 lists various types of chlorine and their percentage available chlorine.

After dosing, let the chlorine stay in the water for 30 minutes. After that time, a check for chlorine residual should be done if equipment is available. There should be a residual of approximately 1.0ppm. Where no testing equipment is available, make sure that the treated water has a slight chlorine odor and taste. If the test shows no chlorine residual, or if there is no chlorine taste or odor, repeat the dosage and wait 15 minutes.

Table 2. Chlorine Strengths

	Percent Available Chlorine
Calcium Hypochlorites	
High Test Hypochlorite	70%
Percloron Powder	70%
B-K Powder	50%
Chlorinated Lime	35%
Sodium Hypochlorites (Liquid)	
Chlorox	5%
Purex	3%
Zonite	1%

If the treated water has too strong a chlorine taste, allow it to stand for a few hours. Contact with the air offsets the taste and smell of the chlorine.

Chlorine is available in tablet form and can easily be applied to contaminated water. Chlorine tablets are available in many areas. To use them, follow the instructions on the package. If no instructions are listed, use one tablet for each liter of water to be treated.

Iodine is another chemical which can be used for disinfection in an emergency situation. Iodine is available in liquid form from pharmacies or small stores, and is used generally for first aid purposes. Most liquids contain two percent iodine. To disinfect clear water, add about five drops of iodine to each liter of water. When treating turbid water, add 10 drops per liter and allow the water to stand for 30 minutes. Reduce the dose if the iodine taste is strong.

Iodine tablets are made commercially and may be available in many areas. For water disinfection, follow the instructions on the packets. If instructions do not come with the iodine, a general rule to follow is to add one tablet to each liter of water.

Summary

Water which is used for drinking, cooking or brushing teeth should be properly disinfected to prevent sickness. Therefore, adequate planning is necessary to ensure that sufficient quantities of potable water are available for all who need it. The guidelines below should be followed when attempting to provide water for people in emergency situations.

1. Restrict the use of the available potable water to basic needs. People may have to bathe less often and ration the amount of water used for cooking and drinking. Never let supplies fall to a dangerously low level if possible.

2. Attempt to either put the old system into operation quickly or else search for a new source. If a new source is chosen, make sure that it is either well-protected from contamination or can be protected, and that water can effectively be delivered to those who need it.

3. If a protected source is not available, dig a temporary well or choose a source which is accessible and can be easily treated. Before choosing a source, make sure that there is a way to disinfect it. Water must either be boiled or chemically disinfected before it can be drunk.

FACT SHEET LISTING

RURAL WATER SUPPLY

RWS. 1 Surface Water Systems
RWS. 2 Groundwater Systems
RWS. 3 Water Treatment
RWS. 4 Water Distribution
RWS. 5 Water Storage

SANITATION

SAN. 1 Simple Excreta Disposal
SAN. 2 Combined Washwater and Excreta Disposal
SAN. 3 Solid Waste Management

TROPICAL DISEASES

DIS. 1 Improving Environmental Health
DIS. 2 Controlling Schistosomiasis
DIS. 3 Controlling Trypanosomiasis
DIS. 4 Controlling Enteric Viruses
DIS. 5 Controlling Onchocerciasis
DIS. 6 Controlling Leptospirosis

HUMAN RESOURCE DEVELOPMENT

HR. 1 Community Participation
HR. 2 Training Personnel

June 24, 1981

TECHNICAL NOTES

		User	Priority
Methods			
RWS.1.M	Methods of developing sources of surface water	PD	1
Planning			
RWS.1.P.1	Planning how to use sources of surface water	PD	1
RWS.1.P.2	Locating sources of acceptable surface water and conducting a sanitary survey	PD/TFW	1
RWS.1.P.3	Selecting a source of surface water	PD	1
RWS.1.P.4	Choosing where to place intakes	PD	1
RWS.1.P.5	Evaluating artificial catchments	PD	2
Design			
RWS.1.D.1	Designing structures for springs	PD	1
RWS.1.D.2	Designing intakes for ponds, lakes and reservoirs	PD	1
RWS.1.D.3	Designing intakes for streams and rivers	PD	1
RWS.1.D.4	Designing roof catchments	PD	2
RWS.1.D.5	Designing small dams and water impoundments	PD	2
RWS.1.D.6	Designing improved rainfall catchments	PD	3
Construction			
RWS.1.C.1	Construction structures for springs	TFW	1
RWS.1.C.2	Constructing intakes for ponds, lakes and reservoirs	TFW	1
RWS.1.C.3	Constructing intakes for streams and rivers	TFW	1
RWS.1.C.4	Constructing roof catchments	TFW	2
RWS.1.C.5	Constructing small dams and water impoundments	TFW	3
RWS.1.C.6	Constructing improved rainfall catchments	TFW	3
Operation and Maintenance			
RWS.1.O.1	Maintaining structures for springs	TFW	1
RWS.1.O.2	Maintaining intakes	TFW	1
RWS.1.O.3	Maintaining roof catchments	TFW	2
RWS.1.O.4	Maintaining small dams and water impoundments	TFW	2
RWS.1.O.5	Maintaining improved rainfall catchments	TFW	3
Methods			
RWS.2.M	Methods of developing sources of ground water	PD	1

Planning		User	Priority
RWS.2.P.1	Planning how to use sources of ground water	PD	1
RWS.2.P.2	Selecting a method of well construction	PD	1
RWS.2.P.3	Selecting a well site	PD	1
Design			
RWS.2.D.1	Designing dug wells	PD	1
RWS.2.D.2	Designing a driven well	PD	1
RWS.2.D.3	Designing a jetted well	PD	2
RWS.2.D.4	Designing a bored or augered well	PD	2
RWS.2.D.5	Designing cable tool wells	PD	2
RWS.2.D.6	Designing hydraulic percussion or hydraulic rotary wells	PD	3
Construction			
RWS.2.C.1	Disinfecting wells	TFW	1
RWS.2.C.2	Constructing dug wells	TFW	1
RWS.2.C.3	Constructing jetted or driven wells	TFW	1
RWS.2.C.4	Constructing bored or augered wells	TFW	2
RWS.2.C.5	Constructing cable tool wells	TFW	2
RWS.2.C.6	Constructing hydraulic percussion or hydraulic rotary wells	TFW	3
RWS.2.C.7	Maintaining drilling logs	TFW	2
RWS.2.C.8	Testing the yield of wells	TFW	2
RWS.2.C.9	Installing casing in wells	TFW	2
RWS.2.C.10	Finishing wells	TFW	2
RWS.2.C.11	Providing sanitary protection for wells	TFW	2
Methods			
RWS.3.M	Methods of water treatment	PD	1
Planning			
RWS.3.P.1	Determining the need for water treatment	PD	1
RWS.3.P.2	Taking a water sample	PD/TFW	1
RWS.3.P.3	Analyzing a water sample	PD/TFW	1
RWS.3.P.4	Planning a water treatment system	PD	1

Design		User	Priority
RWS.3.D.1	Designing basic household water treatment systems	PD/TFW	1
RWS.3.D.2	Designing a small community sedimentation basin	PD	1
RWS.3.D.3	Designing a slow sand filter	PD	1
RWS.3.D.4	Designing a small community disinfection unit	PD	1
RWS.3.D.5	Water treatment in emergencies	PD/TFW	1

Construction

RWS.3.C.1	Constructing a household sand filter	TFW	1
RWS.3.C.2	Constructing a sedimentation basin	TFW	2
RWS.3.C.3	Constructing a slow sand filter	TFW	2
RWS.3.C.4	Constructing a disinfection unit	TFW	1

Operation and Maintenance

RWS.3.O.1	Operating and maintaining household treatments	TFW	1
RWS.3.O.2	Maintaining a household sand filter	TFW	1
RWS.3.O.3	Operating and maintaining a sedimentation basin	TFW	2
RWS.3.O.4	Operating and maintaining a slow sand filter	TFW	2
RWS.3.O.5	Operating and maintaining a chemical disinfection unit	TFW	1

Methods

RWS.4.M	Methods of delivering water	PD	1

Planning

RWS.4.P.1	Choosing between gravity flow and pumps	PD	1
RWS.4.P.2	Choosing between communal distribution systems and household water connections	PD	1
RWS.4.P.3	Selecting pipe materials	PD	1
RWS.4.P.4	Selecting a power source for pumps	PD	1
RWS.4.P.5	Selecting pumps	PD	1
RWS.4.P.6	Manufacturing hand pumps locally	PD	2

Design

RWS.4.D.1	Designing a system of gravity flow	PD	1
RWS.4.D.2	Determining pumping requirements	PD	1
RWS.4.D.3	Designing a transmission main	PD	1
RWS.4.D.4	Designing communal distribution systems	PD	1
RWS.4.D.5	Selecting a hydraulic ram pump	PD	3

Construction		User	Priority
RWS.4.C.1	Installing pipes	TFW	1
RWS.4.C.2	Constructing communal distribution systems	TFW	1
RWS.4.C.3	Installing mechanical pumps	TFW	1
RWS.4.C.4	Installing hand pumps	TFW	1
RWS.4.C.5	Constructing a distribution system with household connections	TFW	2

Operation and Maintenance

RWS.4.O.1	Detecting and correcting leaking pipes	TFW	1
RWS.4.O.2	Operating and maintaining mechanical pumps	TFW	1
RWS.4.O.3	Operating and maintaining hand pumps	TFW	1
RWS.4.O.4	Operating and maintaining household water connections	TFW	2

Methods

RWS.5.M	Methods of storing water	PD	1

Planning

RWS.5.P.1	Determining the need for storage of water	PD	1

Design

RWS.5.D.1	Designing a household cistern	PD	1
RWS.5.D.2	Designing a ground level storage tank	PD	1
RWS.5.D.3	Designing an elevated storage tank	PD	2

Construction

RWS.5.C.1	Constructing a household cistern	TFW	1
RWS.5.C.2	Constructing a ground level storage tank	TFW	1
RWS.5.C.3	Constructing an elevated storage tank	TFW	2

Operation and Maintenance

RWS.5.O.1	Maintaining water storage tanks	TFW	1

SANITATION

SAN.1 SIMPLE EXCRETA DISPOSAL

Methods		Priority	User
SAN.1.M.1	Simple methods of excreta disposal	1	PD
SAN.1.M.2	Simple methods of washwater disposal	1	PD

Planning

SAN.1.P	Planning simple excreta and washwater disposal systems	1	PD

Design, Construction, Operation and Maintenance

SAN.1.D.1	Designing slabs for privies	1	PD
SAN.1.C.1	Constructing slabs for privies	1	TFW
SAN.1.D.2	Designing pits for privies	1	PD
SAN.1.C.2	Constructing pits for privies	1	TFW
SAN.1.D.3	Designing privy shelters	1	PD
SAN.1.C.3	Constructing privy shelters	1	TFW
SAN.1.O.3	Operating and maintaining privies	1	TFW/VW
SAN.1.D.4	Designing aqua privies	2	PD
SAN.1.C.4	Constructing aqua privies	2	VW
SAN.1.O.4	Operating and maintaining aqua privies	2	TFW/VW
SAN.1.D.5	Designing bucket latrines	2	PD
SAN.1.C.5	Constructing bucket latrines	2	TFW
SAN.1.O.5	Operating and maintaining bucket latrines	2	TFW/VW
SAN.1.D.6	Designing compost toilets	3	PD
SAN.1.C.6	Constructing compost toilets	3	TFW
SAN.1.O.6	Operating and maintaining compost toilets	3	TFW/VW
SAN.1.D.7	Designing sumps, soakage pits and trenches	1	PD
SAN.1.C.7	Constructing, operating and maintaining sumps, soakage pits, and trenches	1	PD

SAN.2 COMBINED WASHWATER AND EXCRETA DISPOSAL

Methods

SAN.2.M.	Methods of combined washwater and excreta disposal	1	PD

Planning

SAN.2.P.1	Planning combined washwater and excreta disposal systems	1	PD
SAN.2.P.2	Selecting a combined washwater and excreta disposal system	1	PD
SAN.2.P.3	Estimating sewage or washwater flows	1	PD
SAN.2.P.4	Determining soil suitability	1	TFW

Design, Construction, Operation and Maintenance		Priority	User
SAN.2.D.1	Designing subsurface absorption systems	2	PD
SAN.2.C.1	Constructing, operating and maintaining subsurface absorption systems	2	TFW
SAN.2.D.2	Designing cesspools	2	PD
SAN.2.C.2	Constructing cesspools	2	TFW
SAN.2.O.2	Operating and maintaining cesspools	2	TFW/VW
SAN.2.D.3	Designing septic tanks	1	PD
SAN.2.C.3	Constructing septic tanks	1	TFW
SAN.2.O.3	Operating and maintaining septic tanks	1	TFW/VW
SAN.2.D.4	Designing sewer systems	2	PD
SAN.2.C.4	Constructing sewer systems	2	TFW
SAN.2.O.4	Operating and maintaining sewer systems	2	TFW/VW
SAN.2.D.5	Designing stabilization ponds	2	PD
SAN.2.C.5	Constructing stabilization ponds	2	TFW
SAN.2.O.5	Operating and maintaining stabilization ponds	2	TFW/VW
SAN.2.D.6	Designing lagoon systems	2	PD
SAN.2.D.7	Designing mechanically aerated lagoons and ditches	3	PD
SAN.2.C.7	Constructing mechanically aerated lagoons and ditches	3	TFW
SAN.2.O.7	Operating and maintaining mechanically aerated lagoons and ditches	3	TFW/VW
SAN.2.D.8	Designing non-conventional washwater and excreta disposal systems	3	PD
SAN.2.C.8	Constructing non-conventional washwater and excreta disposal systems	3	TFW

SAN.3 SOLID WASTE MANAGEMENT

Methods

SAN.3.M	Methods of solid waste management	1	PD

Planning

SAN.3.P	Planning solid waste management systems	1	PD

Design, Construction, Operation and Maintenance

SAN.3.D.1	Designing a landfill	1	PD
SAN.3.O.1	Operating and maintaining a composting system	1	TFW/VW
SAN.3.D.2	Designing a composting system	2	PD
SAN.3.O.2	Operating and maintaining a composting system	2	TFW/VW
SAN.3.D.3	Designing a solid waste collection system	2	PD
SAN.3.O.3	Operating a solid waste collection system	2	TFW/VW
SAN.3.D.4	Designing a biogas system	3	PD
SAN.3.C.4	Constructing a biogas system	3	TFW
SAN.3.O.4	Operating and maintaining a biogas system	3	TFW/VW

HUMAN RESOURCE DEVELOPMENT

HR.1 COMMUNITY PARTICIPATION

Methods		Priority	User
HR.1.M	Methods of community participation in water supply and sanitation programs	1	PP
Implementation			
HR.1.I.1	Organizing community support for water supply and sanitation programs	1	TFW
HR.1.I.2	Setting up a community education program in water supply and sanitation	1	PP
HR.1.I.3	Dealing with community customs in water supply and sanitation	2	PP

HR.2 TRAINING PERSONNEL

Methods			
HR.2.M	Methods of operation and maintenance training programs	1	RP
Planning			
HR.2.P.1	Planning operation and maintenance training programs	2	RP
HR.2.P.2	Evaluating system management, operation, and maintenance	3	PP
Implementation			
HR.2.I.1	Implementing an operation and maintenance training program	2	PP

TROPICAL DISEASES

DIS.1 IMPROVING ENVIRONMENTAL HEALTH

Methods			
DIS.1.M.1	Means of disease transmission	1	RP
DIS.1.M.2	Methods of improving environmental health conditions	1	RP

Planning		Priority	User
DIS.1.P	Planning disease control programs	1	RP

Implementation

DIS.1.I.1	Establishing drinking water standards	2	RP
DIS.1.I.2	Establishing guidelines for wastewater disposal	2	RP
DIS.1.I.3	Establishing guidelines for solid waste management	2	RP

DIS.2 CONTROLLING SCHISTOSOMIASIS

Methods

DIS.2.M	Methods of controlling schistosomiasis	1	PD

Implementation

DIS.2.I.1	Controlling schistosomiasis with environmental means	1	TFW

DIS.3 CONTROLLING TRYPANOSOMIASIS

Methods

DIS.3.M	Methods of controlling trypanosomiasis	2	PD

Implementation

DIS.3.I.1	Controlling trypanosomiasis with environmental means	2	TFW

DIS.4 CONTROLLING ENTERIC VIRUSES

Methods

DIS.4.M	Methods of controlling enteric viruses	2	PD

Implementation

DIS.4.I.1	Controlling enteric viruses with environmental means	2	TFW

TROPICAL DISEASES

DIS.5 CONTROLLING ONCHOCERCIASIS

Methods		Priority	User
DIS.5.M	Methods of controlling onchocerciasis	2	PD
Implementation			
DIS.t.I.1	Controlling onchoceriasis with environmental means	2	TFW

DIS.6 CONTROLLING LEPTOSPIROSIS

Methods			
DIS.6.M	Methods of controlling leptospirosis	3	PD
Implementation			
DIS.6.I.1	Controlling leptospirosis with environmental means	3	TFW

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