

201 93GU



201-9364-12388

Cover Photo:

*"NAWRA" Wheel for Lifting Water from Al-Aasi River, Hama, Syria.  
By Dr H. Rathor (VBC), WHO/ EMRO.*

**Guidelines  
on  
Technologies for  
Water Supply Systems in  
Small Communities**

**Guidelines  
on  
Technologies for  
Water Supply Systems in  
Small Communities**

ish 12388

201 9364



**World Health Organization  
Eastern Mediterranean Regional Office  
Centre for Environmental Health Activities  
Amman  
1993**

© World Health Organization, 1993

This document is issued by the World Health Organization for general distribution. All rights are reserved. Subject to due acknowledgement to WHO, the document may, however, be reviewed, abstracted, reproduced or translated, in part or in whole, provided that such is not done for or in conjunction with commercial purposes, and provided that if it is intended to translate or reproduce the entire work or substantial portions thereof, prior application is made to the World Health Organization, Regional Office of the Eastern Mediterranean, P.O. Box 1517, Alexandria, Egypt.

*In the name of God, the Compassionate, the Merciful*

## **FOREWORD**

by

**Hussein A. Gezalry, MD, FRCS**

**Regional Director for the  
Eastern Mediterranean Region  
of the World Health Organization**

*A constant, adequate supply of good quality water is essential for public health. In small communities the health hazards caused by polluted and inadequate water supplies are often aggravated by shortage of skilled staff and resources. Amongst the many factors limiting the expansion of adequate water supply services in the rural sector are the lack of technical skills and shortage of information regarding construction, operation and maintenance of appropriate installations.*

*In the countries of the WHO Eastern Mediterranean Region, the development of water supplies accelerated during the International Drinking Water and Sanitation Decade. Although much was achieved there is still a great deal of work remaining, especially in rural areas. Most governments in the Region are committed to improving public health conditions in poorer communities in order to better social conditions and increase economic productivity.*

*The purpose of these guidelines is to compile, in a simple form, information regarding various aspects of water supply which may be considered when planning the development of water supply systems.*

*Information concerning planning, design, construction, operation and maintenance of small water supply systems described in these guidelines is based on standard practices used in developed countries. It is, however adapted to suit rural conditions. Material has been included from WHO Monograph 42 **Water Supply of Rural Areas and Small Communities**, (E.G. Wagner and J.N. Lanoix) and from a variety of other sources.*

*The WHO Regional Office for the Eastern Mediterranean enlisted the assistance of Dr B.B. Sundaresan and Mr J.N. Lanoix, WHO Sanitary Engineering Consultants, to draw up guidelines on technologies for water supply systems for small communities. The original manuscript of guidelines was prepared and has been summarised, abridged and reviewed by Dr M.I. Sheikh, Director of Environmental Health, Mr M.A. Mullick, Regional Adviser, Community Water Supply and Mr T.L. Videnov, WHO Sanitary Engineering Consultant, in the WHO Eastern Mediterranean Regional Office in order to produce a document for use by field workers.*

*Both this document and the **Guidelines on Sanitation for Small Communities** were edited by Katherine Wedgwood, Jamie Bartram and Andy Rickards of the Robens Institute, University of Surrey, U.K.*

*It is hoped that these Guidelines will prove useful for all categories of field staff concerned with small water supply systems, by providing the information needed to plan and construct, with limited resources, small systems which are easy to operate and maintain with minimal skills and running costs.*



## ACKNOWLEDGMENTS

The World Health Organization's Regional Office for the Eastern Mediterranean acknowledges with gratitude the work undertaken by Dr B.B. Sundaresan and Mr J.N. Lanoix who prepared the original manuscript of the manual. Later, the first draft was summarized, abridged and reviewed by Dr M.I. Sheikh, Director, Environmental Health, Mr M.A. Mullick, Regional Adviser, Community Water Supply and Mr T.L. Videnov, WHO Sanitary Engineering Consultant in the Regional Office. The names of the experts who reviewed the second draft are listed below and their support is also gratefully acknowledged.

Special thanks are due to Ms Katherine Wedgewood, Messers Jamie Bartram and Andy Rickards from Robens Institute, University of Surrey, United Kingdom, who reviewed subsequent draft and edited it and also provided useful assistance in the preparation of drawings and in the finalization of the guidelines.

### REVIEWERS OF THE SECOND DRAFT

1. Dr B.B. Sundaresan  
Former Vice Chancellor,  
University of Madras, and  
Ex Director, National  
Environmental Engineering  
Institute (NEERI),  
Nagpur, India
2. Dr Bashir M. El Hassan  
Associate Professor in  
Environmental Engineering,  
University of Khartoum,  
Sudan
3. Mr Odyor A. Sperandio  
Formerly Manager,  
(Community Water Supply)  
World Health Organization,  
Geneva, Switzerland
4. Mr Joseph Lanoix  
Formerly Sanitary Engineer,  
World Health Organization,  
Geneva, Switzerland
5. Dr Fahmy M. El-Sharkawi  
Professor of Sanitary  
Engineering, High Institute  
of Public Health,  
Alexandria, Egypt
6. Mr S.M. Rafi Ahmad  
Formerly Managing Director,  
Pakistan Environmental  
Planning and Architectural  
Consultants Ltd.,  
Lahore, Pakistan
7. Eng. Obaidullah Siddiqi  
Sanitary Engineer,  
Saudi Consulting House,  
Riyadh, Saudi Arabia

# Water Supply Guidelines

<b>Table of Contents</b>	<b>Page</b>
<b>1. INTRODUCTION</b>	<b>1</b>
<b>2. WATER QUANTITY AND QUALITY</b>	<b>3</b>
2.1. Water Use and Consumption	3
2.2. Per Capita Supply	3
2.3. Population	7
2.4. Water Quality	7
2.4.1. Bacteriological quality	8
2.4.2. Chemical and physical quality	11
2.5. Sanitary Inspections	13
2.6. Remedial and Preventive Measures	15
<b>3. WATER SUPPLY SYSTEMS</b>	<b>18</b>
3.1. Types of Water Supply Systems	18
3.2. Simple Water Supply Systems Without Treatment	18
3.2.1. Gravity schemes	18
3.2.2. Pumped schemes	19
3.3. Systems with Simple Treatment	20
3.3.1. System with treatment for carbon dioxide removal	20
3.3.2. System with treatment for iron removal from groundwater	20
3.3.3. System with impounding reservoir/Pond water as source	21
3.4. Conventional Water Treatment Systems	21
3.5. Design Guidelines	21
3.5.1. Daily consumption	21
3.5.2. Guidelines for designing of rural water supply systems	22
<b>4. WATER SOURCE SELECTION</b>	<b>24</b>
4.1. Water Cycle Hydrology	24
4.2. Water Source Selection	24
4.2.1. Rain Water	24
4.2.2. Ground Water	26



## Water Supply Guidelines

<b>Table of Contents</b>	<b>Page</b>
4.2.3. Surface Water	26
<b>5. GROUNDWATER SOURCES</b>	27
5.1. Engineering and Geological Considerations	27
5.2. Wells	28
5.3. Dug Wells	30
5.3.1. Diameter	30
5.3.2. Lining	31
5.3.3. Construction	33
5.3.4. Large diameter dug wells	34
5.4. Driven Wells	39
5.4.1. Equipment	40
5.4.2. Technique	40
5.5. Jetted Wells	43
5.5.1. Small-diameter wells	43
5.6. Bored Wells	46
5.7. Drilled Wells	49
5.8. Infiltration Galleries	49
5.9. Improvement of Existing Wells	53
5.10. Springs	59
5.11. Location and Protection of Ground Water Supplies	63
5.11.1. Wells and latrine pollution	63
5.11.2. Sanitary measures	65
5.12. Testing of Wells for Drawdown and Yield	67
<b>6. SURFACE WATER SOURCES</b>	68
6.1. Rainwater Harvesting Systems	68
6.1.1. Design considerations in roof collection	69
6.1.2. Design considerations in storage	71
6.1.3. Design considerations in delivery	75
6.1.4. Maintenance for quality control	76
6.1.5. Water treatment	76
6.2. Drainage Basins and Catchment Areas	77
6.2.1. Rock and soil catchment areas	77
6.2.2. Reduction of rain-water infiltration into the soil	77
6.2.3. Haffirs	78
6.2.4. Ponds and reservoirs	79
6.2.5. Evaporation Collection	80
6.3. Small Dams	80
6.4. Rivers	82

## Water Supply Guidelines

<b>Table of Contents</b>	<b>Page</b>
<b>7. WATER TREATMENT PROCESSES</b>	<b>87</b>
7.1. Purpose and Scope	87
7.2. Treatment Systems	89
7.3. Treatment Processes	89
7.3.1. Storage	89
7.3.2. Sedimentation	91
7.3.3. Pre-filtration	94
7.3.4. Slow sand filtration	94
7.4. Other Treatment Processes Generally Considered Inappropriate for Small Community Water Supplies	100
7.4.1. Pre-chlorination	100
7.4.2. Aeration	101
7.4.3. Chemical dosing	104
7.4.4. Coagulation and flocculation	104
7.4.5. Sedimentation	110
7.4.6. Rapid sand filtration	111
7.5. Post-chlorination	112
7.6. Effectiveness of Treatment	113
7.7. Modular Water Treatment Plants	113
7.7.1. Packaged plants	113
7.8. Operation and Maintenance of Water Treatment Plants	116
7.8.1. Flow measuring devices	117
7.8.2. Chemical feeding unit	118
7.8.3. Rapid mixer	118
7.8.4. Slow mixer	118
7.8.5. Sedimentation tank or clarifier	118
<b>8. DISINFECTION</b>	<b>119</b>
8.1. Need	119
8.2. Methods of Disinfection	119
8.3. Chlorination	119
8.3.1. Chemicals for chlorination	120
8.3.2. Chlorine stock solution	121
8.3.3. Criteria and considerations for the design and development of a chlorination system	122

## Water Supply Guidelines

<b>Table of Contents</b>	<b>Page</b>
8.3.4. Design calculations	136
<b>9. DISTRIBUTION</b>	<b>138</b>
9.1. Small Community Distribution Systems	138
9.1.1. Distribution reservoir	138
9.1.2. Design of pipes	148
9.1.3. Distribution systems	149
9.1.4. Pipelines	151
9.2. Public Standpipes	153
9.3. Water Losses	154
9.4. Laundries and Baths	154
9.5. Protective Measures	156
<b>10. PUMPS FOR COMMUNITY WATER SUPPLIES</b>	<b>158</b>
10.1. Introduction	158
10.2. Classification of Pumps	158
10.3. Selection of Pumps	158
10.4. Hand Pumps	163
10.4.1. Types and uses	163
10.4.2. Shallow well handpumps	163
10.4.3. Deep well handpumps	164
10.5. Centrifugal Pumps	168
10.6. Turbine Pumps	168
10.7. Submersible Pumps	169
10.8. Jet (Ejector) Pumps	169
10.9. Impulse Pumps (Hydraulic Rams)	170
10.10. Selection of Pumps and Pumping Equipment	172
10.11. Design of Pumps	173
10.12. General Precautions for Installation of Pumping Equipment	173
10.13. Sanitary Protection of Pumping Facilities	176
10.14. Power Driven Pumps	177
10.15. Prime Movers	177
10.16. Standby Arrangements	178
10.17. Directly Coupled Motors	178
10.18. Squirrel cage motors	178
10.19. Wound Rotor Motors	179

## Water Supply Guidelines

<b>Table of Contents</b>	<b>Page</b>
10.20. Pumphouse	179
<b>11. PIPES AND FITTINGS</b>	<b>181</b>
11.1. Introduction	181
11.2. Types of Pipe	181
11.3. Design Criteria for the Piping System	181
11.3.1. Design life	181
11.3.2. Design flow rate	182
11.3.3. Pressure in distribution system	183
11.3.4. Types of pipeline	183
11.3.5. Diameter of pipes	185
11.3.6. Velocity of flow	185
11.3.7. Route location	186
11.3.8. Junction wells	186
11.3.9. Valves	186
11.3.10. Air release valves	186
11.3.11. Pressure release and outfall valves	187
11.3.12. River crossings	187
11.3.13. Railway crossings	187
11.3.14. Anchorage for pipes and fittings	189
11.3.15. Location and depth of pipeline	189
11.4. Economic Size of Transmission Mains	189
<b>12. SELECTED BIBLIOGRAPHY</b>	<b>190</b>
<b>13. GLOSSARY</b>	<b>193</b>

### 1. INTRODUCTION

Water is essential to man, animals and plants. Without water, life on earth would not exist. From the beginning of human civilisation, people have settled close to water sources, along rivers, beside lakes or near natural springs.

Safe drinking water is important in the control of many diseases, eg. diarrhoea, cholera, typhoid and paratyphoid fever, infectious hepatitis, amoebic and bacillary dysentery. It has been estimated that as many as 80 per cent of all diseases in the world are associated with unsafe water. These diseases are not only associated with water quality. Many diseases are due to insufficient quantity of water. The basic aim in planning and designing water supplies is to continuously provide adequate quantities of affordable, good quality drinking water.

Depending on climate and life-style, the daily requirement for drinking and food preparation is only a few litres of water per person. Much larger quantities are necessary for other purposes such as personal hygiene, cleaning cooking utensils, laundry and house cleaning. Safe, adequate and accessible supplies of water, combined with proper sanitation, are essential components of primary health care.

The water supply technologies developed and applied in industrialised countries generally require trained operators. However, rural water supply systems should require minimal operation and maintenance skills. Small community water supply systems should not be thought of as "scaled down" versions of urban installations requiring less engineering skill or ingenuity. It may be exactly the opposite. Simplicity and smallness need not be backward or second-rate.

In designing a water supply system the choice of technology should be made taking into account local requirements and limitations, socio-cultural aspects, economic viability and public health considerations. In order to choose the most appropriate water supply technology for a small community, planners must consider both design and required operating skills.

Improvements and substantial savings can be made by standardising designs so that only minor modifications are necessary for individual rural community water supply systems. This is particularly true for repetitive elements such as wells, intake structures, water tanks and pump houses. Standardisation of designs can also lead to technicians replacing more expensive engineers at the design stage. There are simple and rapid investigation methods which can be carried out by technicians or sanitarians to collect sufficient information for designing a small water supply system.

## Water Supply Guidelines

Local materials should be used wherever possible, and local people trained to carry out operation and maintenance.

Piped water supplies with domestic connections are often not economically feasible for small communities. A more realistic option may be to provide a number of individual or "point" sources such as:

- a protected well with a hand pump;
- a spring tapping structure;
- a rainwater catchment and storage system;
- a public stand-pipe.

Small community water supply systems have been built for a long time. During the International Water Supply and Sanitation Decade they were constructed in increased numbers. Some have been successful but many are not suited to the conditions under which they have to operate. Several schemes have been abandoned within a few years of construction and frequent breakdowns are not uncommon. It is necessary to recognise the causes of failure and learn from past mistakes. Guidelines may then be developed for the planning, construction, operation and maintenance of appropriate small water supply systems.

## 2. WATER QUANTITY AND QUALITY

### 2.1. Water Use and Consumption

Community water supply is a capital intensive utility. The "Decade" goal, set to provide 100 per cent of the population with safe drinking water by 1990 was not fulfilled, largely due to the enormous investment it would have required. An important factor influencing the cost of a water supply system is the intended level of service, which is, in turn, related to per capita consumption. Per capita domestic water consumption is influenced by a number of factors such as availability and convenience of supply, socio-economic conditions of the community, cultural and hygiene habits, climatic conditions and whether water is charged for. These aspects have been receiving the attention of water supply system designers in several countries. However, relevant data from field observations are scarce, and for preliminary planning and design purposes per capita values are generally based on local experience.

### 2.2. Per Capita Supply

Water for domestic purposes is needed for:

- drinking
- food preparation and cooking
- ablution
- bathing
- washing cooking utensils
- washing clothes
- flushing
- animals
- house cleaning

Water use and consumption are frequently expressed in litres per capita (head) per day (lcd). Such data neglect the fact that a considerable part of the water is shared by all members of a family (e.g., cooking, cleaning). Nonetheless, per capita daily water consumption data are useful for making estimates of a community's water demand.

## Water Supply Guidelines

Table 1. shows recommended daily per capita supply volumes for domestic connections and for public standpost or hand pump supply. These values have been calculated using information from various climatic and socio-cultural conditions.

**TABLE 1. RECOMMENDED PER CAPITA SUPPLY**

<b>Description</b>	<b>House connections</b>	<b>Public standpost/ hand pump</b>
Drinking	5	5
Cooking	3	3
Ablution	10	6
Bathing	20	15
Washing utensils & housecleaning	15	10
Clothes washing	20	15
Flushing	8	6
Irrigation and Cattle Needs	20	20
<b>Sub-total</b>	<b>101</b>	<b>80</b>
Leakage/wastage at 20%	20	16
<b>Total</b>	<b>121</b>	<b>96</b>
Say ....	125	100

Water distribution through public standposts is often preferred in order to reduce the cost of a water supply system and to minimise the problem of wastewater collection and disposal. A 12 mm diameter tap when fully open (with 1.5 m of



## Water Supply Guidelines

residual head at the tap) can deliver about 15 litres per minute. Thus one such tap can serve, in one hour, up to 9 people at the rate of 100 lcd. If it is assumed that water will be collected for no more than six hours per day, the number of persons that can be served by a tap will be about 50. At some times of the year only a part of the total per capita requirement is actually collected by the consumer from the tap. However, during summer which is the most critical period, consumers may have to depend solely on water available from the public standposts. These should, therefore, provide an adequate supply of water.

**TABLE 2. TYPICAL DOMESTIC WATER USAGE**

Type of water supply	Typical water consumption (liters/capita/day)	Range (liters/capita/day)
<b>Communal water point</b> (e.g. village well, public standpost)		
at considerable distance (> 1000 m)	7	5 - 10
at medium distance (500 - 1000 m)	12	10 - 15
<b>Village well</b>		
walking distance < 250 m	20	15 - 25
<b>Communal standpipe</b>		
walking distance < 250 m	30	20 - 50
<b>Yard connection</b> (tap placed in house-yard)		
	40	20 - 80
<b>House connection</b>		
single tap	50	30 - 60
multiple tap	150	70 - 250

If queuing at standposts, street quarrels and vandalism are to be minimised it is recommended that one standpost, equipped with a minimum of two taps, should be provided for every 150 persons.

The water requirements mentioned above may serve for rough guidance for

## Water Supply Guidelines

preliminary planning and design purposes only. For the final design, criteria are needed that are specific for the country or area concerned.

**TABLE 3. TYPICAL WATER REQUIREMENTS FOR NON-DOMESTIC PURPOSES**

<b>Category</b>	<b>Typical Water Use</b>
<b>Schools</b>	
- Day schools	15 - 30 l/day per pupil
- Boarding schools	90 - 140 l/day per pupil
<b>Hospitals (with laundry facilities)</b>	220 - 300 l/day per bed
<b>Hotels</b>	80 - 120 l/day per resident
<b>Restaurants</b>	65 - 90 l/day per seat
<b>Mosques</b>	25 - 40 l/day per visitor
<b>Cinemas</b>	10 - 15 l/day per seat
<b>Offices</b>	25 - 40 l/day per person
<b>Railway and bus stations</b>	15 - 20 l/day per user
<b>Livestock</b>	
- Cattle	25 - 35 l/day per head
- Horses and mules	20 - 25 l/day per head
- Sheep	15 - 25 l/day per head
- Pigs	10 - 15 l/day per head
- Poultry Hens	15 - 25 l/day per 100

Studies of existing small community water supply systems in the same area can provide very useful water usage data. Field measurements should be taken whenever possible. Table 2. (above) lists typical domestic water usage for different types of water supply systems.

Often water from the community supply is used for other than domestic pur-

## Water Supply Guidelines

poses, and additional water should be provided. Table 3. ( above) summarises typical water requirements for non-domestic purposes.

**TABLE 4. POPULATION GROWTH FACTOR**

Design Period (years)	Yearly Growth Rate			
	2%	3%	4%	5%
10	1.22	1.34	1.48	1.63
15	1.35	1.56	1.80	2.08
20	1.49	1.81	2.19	2.65

### 2.3. Population

A community water supply should have available surplus capacity to account for future population growth and an improved level of service. The estimation of the surplus should take into account:

The daily water demand estimated for the end of a specific period (design period), e.g. 20 years; or

the present water demand plus 50 per cent; or

the demand computed on the basis of the population growth estimate.

However, for smaller communities, it is recommended for design purposes that a minimum of 50 per cent increase in population is assumed.

One possible method is to use a "population growth factor" as shown in Table 4. (above). Ideally, a community water supply system should be able to cater for the maximum hourly or peak water demand during the day.

### 2.4. Water Quality

The relationship between water quality and health has been extensively studied. Drinking water should:

be free from pathogenic (disease-causing) organisms;

fairly clear (i.e., low turbidity, little colour);

not be saline (salty);

## Water Supply Guidelines

not contain compounds that cause an offensive taste or smell;

not contain chemicals, metals or radioactive compounds in concentrations that may have an adverse effect on human health; and

not cause corrosion or encrustation of the water supply system, nor stain clothes washed in it.

### 2.4.1. Microbiological Quality

The most important aspect of drinking water quality is its microbiological quality. It is not practicable to test the water for all organisms which may cause disease (pathogens). So water is examined for a specific type of bacteria which originate in large numbers from human and animal excreta and whose presence indicates of faecal contamination.

Faecal pollution of drinking water may introduce a variety of intestinal pathogens (bacteria, viruses and parasites), their presence being related to microbial diseases and carriers present at that moment in the community. Intestinal bacterial pathogens are widely distributed throughout the world. Those known to have occurred in contaminated drinking-water include *Salmonella*, *Shigella*, enterotoxigenic *Escherichia coli*, *Vibrio cholerae* and *Yersinia enterocolitica*. These organisms may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal dysentery, cholera, or typhoid. Non-bacterial pathogens may also be present in drinking water, eg. rotavirus, hepatitis A, *Giardia lamblia* and *Cryptosporidium*.

Suitable indicator bacteria of faecal contamination are thermotolerant (faecal) coliforms (predominantly *Escherichia coli* or *E.coli*), and faecal streptococci. When these bacteria are present in water, faecal contamination is indicated, and there is therefore a possibility that pathogenic bacteria and viruses are also present. Either one or both of these thermotolerant (faecal) coliform and streptococci bacteria may be used as indicator organisms. However, the second edition of the World Health Organisation *Guidelines for Drinking Water Quality Volume III* to be published in 1993 strongly recommends the use of *E.coli* as the preferred faecal indicator. Confirmatory testing for indole production is necessary to identify thermotolerant (faecal) coliforms as *E. coli*. However, where this cannot be undertaken, thermotolerant (faecal) coliforms will be recommended as the preferred indicators of drinking water quality.

Where samples are to be transported prior to analysis, adequate storage conditions are required. For this reason, maximum storage times and conditions must be specified which are known to be achievable under prevailing conditions. Typically, samples will be taken in sterile glass bottles reserved specifically for the purpose, rapidly cooled and transported in a cool, dark environment. Analysis is best under-

## Water Supply Guidelines

taken within six hours.

The two main techniques for the isolation of indicator organisms are:

- (a) Multiple Tube or Most Probable Number (MPN) technique
- (b) Membrane Filtration

The multiple tube method depends on the separate analysis of a number of volumes of the same sample. Each volume is mixed with culture medium and incubated. The density of microorganisms in the original sample is then obtained by comparing the pattern of positive results (number of tubes showing growth) with statistical tables. The tables provide a 'most probable number' of bacteria per 100ml of sample.

In the membrane filtration method, a specific volume of water is filtered through a sterile membrane filter which retains the bacteria. The membrane is then placed on a selective nutrient medium and incubated. The bacteria multiply forming visible colonies which can be counted and results expressed in numbers of 'colony forming units (cfu) per 100 ml of water sample.

Guidelines values for bacteriologically safe supplies of drinking water are provided in WHO *Guidelines for Drinking-Water Quality* Volume 1 and are shown in Table 5. (overleaf).

## Water Supply Guidelines

**TABLE 5. GUIDELINE VALUES FOR BACTERIOLOGICAL QUALITY**

Organism	Unit	Guideline value	Remarks
<b>A. Piped water supplies</b>			
<b>A.1. Treated water entering the distribution system</b>			
faecal coliforms	number/100 ml	0	turbidity < 1 NTU; for dis-infection with chlorine, pH preferably < 9.0, free chlorine residual 0.2-0.5 mg/litre following (minimum) contact time of 30 minutes.
coliform organisms	number/100 ml	0	
<b>A.2. Untreated water entering the distribution system</b>			
faecal coliforms	number/100 ml	0	in an occasional sample but not in consecutive samples.
coliform organisms	number/100 ml	3	
<b>A.3. Water in the distribution system</b>			
faecal coliforms	number/100 ml	0	in an occasional sample but not in consecutive samples.
coliform organisms	number/100ml	3	
<b>B. Unpiped water supplies</b>			
faecal coliforms	number/100 ml	0	should not occur repeatedly; if occurrence is frequent and sanitary protection cannot be improved, an alternative source must be found if possible.
coliform organisms	number/100 ml	10	

## Water Supply Guidelines

### 2.4.2. Chemical and Physical Quality

Water of good chemical and physical quality is necessary from the point of view of its acceptability to the consumer, protection of consumer health, and conservation of the water system. Situations are encountered in which offending chemical substances have made a water source unacceptable to the public even though its bacteriological quality was excellent.

WHO (1984) has developed guideline values for a number of organic contaminants of drinking-water, including certain commonly used pesticides. In local situations, it may be necessary to control the concentrations of such contaminants in order to protect public health. Such decisions must be made by the health authorities following chemical examination of the water source, and from a knowledge of the local potential for contamination by industrial effluents, agricultural run-off, and other similar factors.

WHO guideline values for chemical constituents and physical characteristics of drinking water are given in Table 6.

**TABLE 6. GUIDELINE VALUES FOR CHEMICAL CONSTITUENTS AND PHYSICAL CHARACTERISTICS OF DRINKING WATER**

Constituent or characteristic	Unit	Guideline Value	Remarks
Turbidity	Nephelometric turbidity units (NTU)	value set 5	Preferably <1 for disinfection efficiency
Colour	True colour units (TCU)	15	
Copper	mg/l	1.0	
Hardness	mg/l (as CaCO <sub>3</sub> )	500	
Hydrogen sulphide	--	Not detectable by consumers	
Iron	mg/l	0.3	
Manganese	mg/l	0.1	

## Water Supply Guidelines

<b>Constituent or Characteristic</b>	<b>Unit</b>	<b>Guideline Value</b>	<b>Remarks</b>
pH	--	6.5 to 8.5	
Sodium	mg/l	200	
Total dissolved Solids	mg/l	1000	
Sulphate	mg/l	400	
Taste and odour	--	Inoffensive to most consumers	
Temperature	--	No guideline value set	
Zinc	mg/l	5.0	
Aluminium	mg/l	0.2	
Chloride	mg/l	250	
Nitrate (as N)	mg/l	10	
Fluoride	mg/l	1.5	
Arsenic	mg/l	0.05	
Cadmium	mg/l	0.005	
Chromium	mg/l	0.05	
Cyanide	mg/l	0.1	
Lead	mg/l	0.05	
Mercury	mg/l	0.001	
Selenium	mg/l	0.01	



### 2.5. Sanitary Inspections

Besides water quality sampling and analyses, sanitary inspections are an essential part of a water quality control programme for small community water supplies.

Variations in the quality of water supplies can help in detecting contamination problems, and in determining whether these have arisen at the source, during water treatment or in the distribution system. Moreover, such an appraisal may later be verified and confirmed by microbiological analyses, which will help assess the severity of the defects.

However, microbiological water quality may vary rapidly and widely; sampling and analysis may miss some point of contamination. Sanitary inspection can help detection of sources of contamination which may not be identified by analysis alone. Sanitary inspections thus provide a direct method of pinpointing possible problems and sources of contamination. They are also important in the prevention and control of potentially hazardous conditions, including epidemics of water-borne diseases.

Sanitary inspections are intended to provide a range of information and to locate potential problems. The data obtained may identify failures, anomalies, operator errors and any deviations from normal that may affect the production and distribution of safe drinking water. When the inspections are properly carried out at appropriate regular intervals, and where the inspector has the knowledge necessary to detect problems and suggest technical solutions, sanitary inspection is a low cost method of helping maintain a high level of service of water supplies.

Sanitary inspection requires a thorough examination of the water supply system, or at least its key points, in order to check whether the installations are satisfactory and whether the various operations are being carried out properly. With small community water supplies, especially those which are not subject to adequate and thorough operation and maintenance, it is recommended that sanitary inspection (and sampling) is not undertaken starting from the source water and intake structure, rather that work should begin at the point of supply. This is because contamination may be introduced during the inspection procedure. Therefore, the recommended sequence would be to start with distribution, going on to storage, disinfection, treatment and finishing at the intake and the source water. At each point it is essential to record what has been observed on appropriate forms.

A form or table should be designed for the rapid assessment of systems and include a summary of the findings. Such a form should be filled in on the occasion of the first visit, and then the results of this and all subsequent visits recorded. Different forms may be required, for example, according to type of treatment, sources of water supply, arrangements for operation and maintenance and in cases of emergency.

The form should include certain checks common to all systems, as well as those which apply specifically to the system inspected (see Figure 1.). Most of the checks

## Figure 1. SANITARY INSPECTION FORMS

### Sanitary Survey of Source: Spring

	Risk	
	Yes	No
1. Is the spring open to surface contamination? If there is not a <b>spring box</b> or equivalent protection then answer YES to boxed questions (2-6).		

2. If there is a spring box, is the masonry protecting the spring source faulty?		
3. If there is a spring box, is the inspection cover insanitary?		
4. Does the spring box contain silt or animals?		
5. If there is an airvent, is it insanitary?		
6. If there is an overflow pipe, is it insanitary?		
Totals 'Yes' score =		
'No' score =		

Check total 'Yes' + total 'No' = 10

**Contamination hazard grade** = total 'Yes' score (ring grade)  
 9-10 = V. High; 6-8 = High; 3 - 5 = Intermediate; 0 - 2 = Low

#### Water Quality Results

Sample	Taste/Odour	Turbidity (TU)	Bacteriology			
			Vol. filt.	No. Colonies	F.C.	Count /100ml
1.						
2.						
3.						
4.						

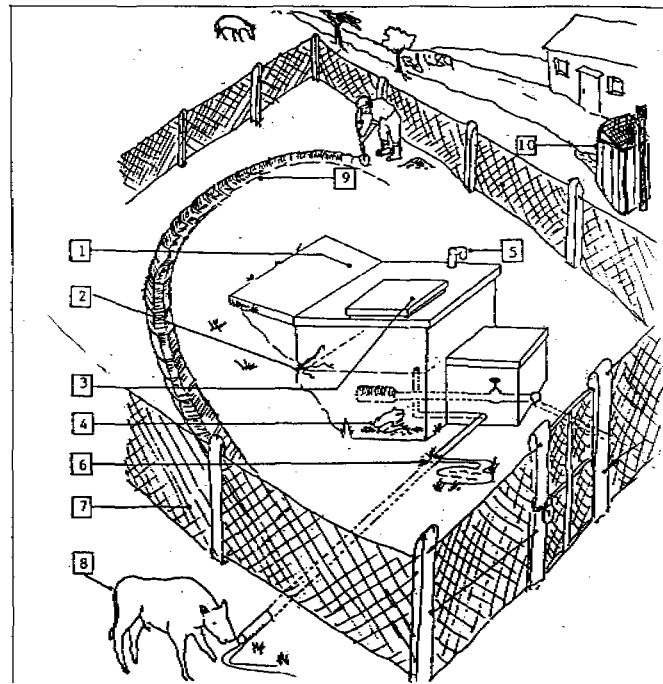
#### Repair Actions on Source

- 1) Done by Monitor \_\_\_\_\_
- 2) Advised Community \_\_\_\_\_
- 3) Actions for Coordinator/repairer \_\_\_\_\_

### Water Supply Evaluation Report For Community

Project Code: \_\_\_\_\_ Village: \_\_\_\_\_

#### Spring Water Source



Circle on diagram those components which require attention

Recommended community actions:

---



---



---



---

## Water Supply Guidelines

should be of the YES/NO type, and be drafted in such a way that the answer suggests potential problems and these can be identified by checking through the completed sanitary inspection record form. It is suggested that individual record forms be based on the layout and principles illustrated below and be completed by the sanitary inspector during a visit.

### **2.6. Remedial and Preventive Measures**

The general objective of drinking water surveillance is to contribute to the improvement of public health by promoting the improvement of water supply services with respect to quality, quantity, coverage, cost and continuity. If the sanitary deficiencies identified by surveillance are not remedied, the effort put into the programme has been wasted. What is then worse, perhaps, is that the situation may become dangerous, because the community will be aware that a surveillance programme has been carried out, and this may lull them into a false sense of security.

Any remedial measures that may be necessary are a direct consequence of the evaluation of bacteriological tests and sanitary inspection. Remedial measures, carried out either by the water-supply agency or the surveillance agency, are essential where problems have been identified. Examples of such measures are the selection of safe and adequate sources; constant vigilance; checking of disinfection through chlorine residual tests; community education and primary health care programmes; bacteriological analysis after remedial measures have been implemented; warnings to the community to boil the water or add disinfectant whenever a serious problem occurs; and sanitary checks to ensure that remedial measures have been carried out properly.

Some sanitary deficiencies may be easy to remedy and unquestionably within the capability of the community; others may be costly or difficult for the community to execute without external financial or technical support. It is up to the sanitary inspector to correctly identify the most appropriate body to take remedial action and the urgency with which it should be undertaken. The relative urgency of some typical preventive and remedial measures is shown in Table 7.

**TABLE 7. REMEDIAL AND PREVENTATIVE MEASURES FOR PROTECTION OF WATER SUPPLIES**

N.B. In accordance with recommended guidelines, the quality of water is regarded as "unsatisfactory" if a positive result obtained on a sample is confirmed on repetition.

Source and mode of supply	Evidence or Information Available	Immediate Remedial Measures	Preventative Action for Avoiding Recurrence
1. Open dug wells	Pollution usually expected to occur	(a) Clean well if necessary and shock-chlorinate followed by continuous chlorination. (b) Recommend boiling of drinking water, use of disinfectants and/or filters in the home.	Convert to a protected, covered well with hand pump or device for raising water isolated from the user; discourage construction of new open-dug wells; promote community education and participation.
2. Unpiped supplies from covered wells or shallow or deep tube-wells with hand pumps or motorised pumps	Findings of Sanitary Inspection unsatisfactory	Confirm bacteriological quality and if necessary recommend boiling or use of disinfectant and/or filters in the home.	Eliminate pollution sources and/or repair well if necessary to remedy shortcomings found in Sanitary Inspection.
	Localised epidemic of enteric infection	(a) If an alternative safe supply is not available, recommend boiling or use of disinfectants in the home. (b) Confirm bacterial quality. (c) Conduct a detailed sanitary inspection and remedy shortcomings found.	(a) Take opportunity to promote community education and participation. (b) Feed information on the episode and sanitary survey results back to the water supply agencies to help in deciding whether the technologies used and the codes of practice followed are appropriate.
3. Untreated piped supplies	Findings of Sanitary Inspection unsatisfactory	Confirm bacteriological quality and if necessary recommend boiling or use of disinfectant and/or filters in the home.	Eliminate pollution sources and/or repair system, if necessary, to remedy shortcomings found in Sanitary Inspection.
	Unsatisfactory bacteriological quality of water at source.	(a) Chlorinate supply if feasible or recommend boiling or disinfection in the home. (b) Conduct a detailed Sanitary Inspection and remedy shortcomings found.	Protect the source and its catchment (this is very important).
	Unsatisfactory bacteriological quality of water in the distribution system.	(a) If source is unsatisfactory, proceed as above (b) If source is satisfactory, but distribution system is suspected, chlorinate supply or recommend boiling in the home. (c) Conduct a detailed sanitary inspection of distribution system and remedy shortcomings found.	Frequent and improved supervision of the distribution system and prompt repair and maintenance are essential, especially for intermittently operated systems.

Source and Mode of Supply	Evidence or Information Available	Immediate Remedial Measures	Preventative Action for Avoiding Recurrence
	Localised epidemic of enteric infection.	<p>(a) Take sample for bacteriological quality determination; without waiting for this result, chlorinate general supply or recommend boiling or disinfection in the home.</p> <p>(b) Conduct a detailed sanitary inspection of source and distribution systems and remedy shortcomings found.</p>	Frequent and improved supervision of the source and distribution system is necessary; careful operation and maintenance of such systems is essential, especially for intermittent systems.
4. Treated piped supplies.	Findings of sanitary inspection of source, treatment plant and/or distribution system unsatisfactory.	Confirm bacteriological quality and if necessary recommend boiling or use of disinfectant and/or filters in the home.	<p>(a) Frequent and improved supervision of the whole system is necessary; careful operation and maintenance are essential for intermittent systems.</p> <p>(b) Ensure that routine Sanitary Inspections are carried out.</p> <p>(c) Feed information back to the water supply agencies.</p>
	Unsatisfactory bacteriological quality of water after treatment or in the distribution system.	<p>(a) Ensure adequate chlorination of general supply or recommend boiling or disinfection in the home.</p> <p>(b) Conduct a detailed sanitary inspection of the whole system and remedy shortcomings found.</p>	<p>(a) Frequent and improved supervision of the whole system is necessary; careful operation and maintenance are essential, especially for intermittent systems.</p> <p>(b) Ensure that routine Sanitary Inspections are carried out.</p> <p>(c) Feed information back to the water supply agencies.</p>
	Localised epidemic of enteric infection.	<p>(a) Take sample for bacteriological quality determination; without waiting for this result, chlorinate general supply or recommend boiling or disinfection in the home.</p> <p>(b) Conduct a detailed Sanitary Inspection of source and distribution system and remedy shortcomings found.</p>	<p>(a) Frequent and improved supervision of the source and distribution system is necessary, careful operation and maintenance are essential, especially for intermittent systems.</p> <p>(b) Ensure that routine Sanitary Inspections are carried out.</p> <p>(c) Feed information back to the water supply agencies.</p>
5. Untreated community rainwater collection systems	Localised epidemic of enteric infection	Chlorinate water in collection reservoir (tank, container, etc) or recommend boiling or disinfection in the home.	<p>(a) Ensure that collection surfaces are in a sanitary condition and that by-pass for initial collected water is properly operated.</p> <p>(b) Promote community education and participation.</p>

## **3. WATER SUPPLY SYSTEMS**

### **3.1. Types of Water Supply Systems**

Depending upon the type of the source and its yield, treatment requirements and storage, rural piped water supply systems can be broadly grouped into three major categories:

- (i) **Simple Water Supply Systems Without Treatment:** these would generally be limited to systems where springs and tube wells are available as supply sources. They may be gravity-fed or purified.
- (ii) **Water Supply Systems With Simple Treatment:** in general, this category would include infiltration galleries abstracting from moderate quality surface sources, systems with carbon dioxide removal as in spring water, the treatment for iron removal as in ground water, and the system in which protected impounding reservoir water is drawn as a source of supply without treatment.
- (iii) **Conventional Water Treatment Systems:** These systems usually involve the use of surface water sources which may present, even only occasionally elevated turbidities, such as rivers, streams, canals, irrigation channels, ponds and lakes.

### **3.2. Simple Water Supply Systems Without Treatment**

This category is limited to water supply systems with a spring source which may be either a gravity or a pumped scheme. Wherever possible, gravity-fed systems are preferred. This is because of their simpler operation and maintenance and much reduced operating costs.

#### **3.2.1. Gravity Systems**

This could be a system for:

1. Community located near the spring;
2. Community located at a lower elevation, several kilometres downstream; or
3. Several communities located at descending elevations in a ribbon pattern.

Components comprising each system are as follows:

##### **3.2.1.1. Community located near the spring source**

- (a) sanitary protection works at the source;
- (b) spring capture works: the capture could be a collecting chamber, an infiltration

## Water Supply Guidelines

- gallery, a percolation chamber or a well;
- (c) storage at the source if the rate of spring flow is less than 2.4 times the average demand. However, no storage is necessary if the source is capable of supplying water to meet the peak demand rate;
- (d) disinfection unit; and
- (e) a distribution system, directly from spring box or storage at source; or with public standposts (storage or pillar type); or with domestic connections.

### 3.2.1.2. Community far from source

- (a) sanitary protection works at the source;
- (b) spring capture works;
- (c) economic-size transmission piped to storage system, preferably with storage near the community. Storage in this case could be a central reservoir or an elevated one, depending on topography. Alternatively, it could include storage-type public standposts;
- (d) disinfection system; and
- (e) a distribution system with public standposts, with or without domestic connections.

### 3.2.1.3. Several communities located at descending elevations in a ribbon pattern

- (a) sanitary protection works at the spring;
- (b) spring capture works;
- (c) transmission mains together with ground or elevated reservoirs located within a few communities in the system, or public storage-type standposts;
- (d) disinfection system; and
- (e) distribution system.

### 3.2.2. Pumped Schemes

In areas where spring elevations are insufficient to permit a gravity supply system, transmission of water by pumping is inevitable. Components of such a system would include:

- (a) spring protection and spring capture works;
- (b) water storage reservoir(s), if required;
- (c) pumping station or hydraulic ram if topography and yield are suitable, especially for small communities where fuel costs or availability limit the applicability of alternative options;
- (d) transmission mains along with an elevated reservoir;
- (e) disinfection system; and
- (f) distribution system.

## Water Supply Guidelines

### **3.2.2.1. Tube well system**

Components of a tube well system for an individual village or for a group of villages could be:

- (a) tube well;
- (b) pump house;
- (c) storage; this could be a central, elevated reservoir, or a combination of an elevated reservoir and storage-type public standposts;
- (d) disinfection system; and
- (e) distribution system.

## **3.3. Systems With Simple Treatment**

### **3.3.1. System with Treatment for Carbon Dioxide Removal**

Spring water from limestone strata often contains excessive amounts of carbon dioxide which must be expelled. Tube well water from these strata may also be rich in carbon dioxide. A removal system may consist of the following components:

- (a) spring capture/tube-well;
- (b) pump house and pumping plant (may not be required if adequate elevation difference exists);
- (c) transmission and rising mains;
- (d) aeration tower;
- (e) disinfection system;
- (f) clear water storage; and
- (g) distribution system.

### **3.3.2. System with Treatment for Iron and Manganese Removal from Ground water**

Components of this system are:

- (a) tube well;
- (b) pump house and pumping station;
- (c) transmission main;
- (d) aeration tower with or without sedimentation tank;
- (e) clear water reservoir;
- (f) disinfection system;
- (g) clear water pumping plant/station;
- (h) elevated storage; and
- (i) distribution system.



## Water Supply Guidelines

### 3.3.3. System with Impounding Reservoir/Pond Water as Source

Components comprising the system are in principle, similar to those of the system for iron removal outlined above, except that the aeration tower with sedimentation units can be eliminated.

### 3.4. Conventional Water Treatment Systems

In some areas it is necessary to develop surface water as a source for the water supply system. This normally requires a treatment plant and subsequently, trained treatment plant operators. As with systems from groundwater sources, gravity-fed systems are preferable wherever possible because of their simpler operation and maintenance and much-reduced operating costs.

Such a system may be comprised of the following components:

- (a) low lift pumping station (if gravity feed is not possible);
- (b) treatment units, including gravel pre-filtration and slow sand filtration; (coagulation, sedimentation and rapid sand filtration are highly unsuitable for small community supplies except under extreme circumstances because of their reliance on skilled and continuous operation.
- (c) disinfection system;
- (d) clear water storage;
- (e) high lift pumping facilities (of gravity feed is not possible);
- (f) storage tank (elevated if necessary); and
- (g) distribution system.

### 3.5. Design Guidelines

The general principles applicable to most village water supply programmes are:  
the system must be designed for simple, cheap and trouble-free operation and maintenance;  
there should be standard designs, which can be modified to meet local conditions and field experience;  
the technology should be kept as simple as possible.

Wide variations between systems and among countries make it difficult to make general recommendations regarding design, quantity of water to be provided, and system components.

#### 3.5.1. Daily Consumption

The water consumption pattern of towns and villages varies from place to place due to socio-cultural and geographical conditions. Calculation of the consumption of water should be made on the basis of either future demand, i.e. twenty years design life or the capacity of the water source.

## Water Supply Guidelines

However, for most rural areas of developing countries, it is reasonable to assume that the provision of between 40-80 lcd will be sufficient to satisfy peoples basic needs.

According to various surveys, the consumption pattern of water in villages lasts for almost twelve hours including intensive water use for a total duration of eight hours in a day.

Peak periods of water consumption occur, for example, in the late morning, at lunch and supper time.

The maximum hourly demand is estimated at 1.5 times the average hourly demand, which is almost 1.4 times the average daily demand.

### 3.5.2. Guidelines for Design of Rural Water Supply Systems

Each system has its specific characteristics requiring detailed engineering considerations. No design standards can be rigidly and universally applied. In India, for example, the following guidelines are recommended:

#### A. Design period

Source (intake)	30 yrs
Treatment units	10-15 yrs
Distribution system	25 yrs

#### B. Per capita supply \*

Distribution through public standposts	70 lcd (litres per capita per day)
Distribution through house connections	90 lcd

#### C. Treatment

When the source is a spring or a dug well	Chlorination using bleaching powder.
When the turbidity is less than 30 NTU and never exceeds 50NTU	Slow sand filtration (SSF) and chlorination.
When water is polluted and turbidity is high	Infiltration gallery, wherever feasible, and chlorination or Roughing prefiltration, slow sand filtration and chlorination or Plain sedimentation/storage, SSF and chlorination or Complete conventional treatment.

\*Add 20 lpcd. for livestock demand.

## Water Supply Guidelines

### 4. Distribution system

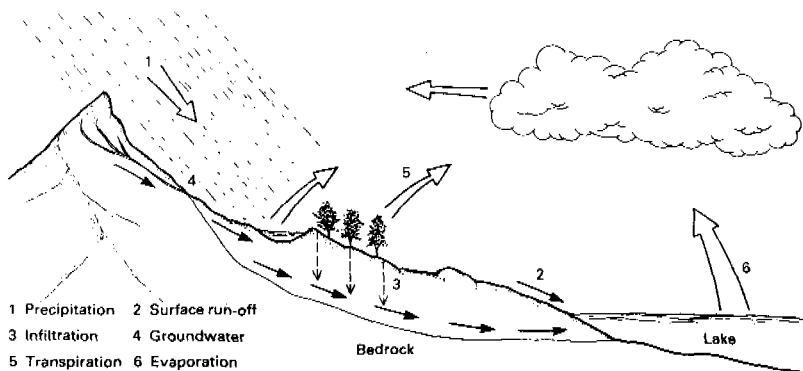
Type of net-work	tree system/dead-end system
Minimum size of distribution pipe	50 mm
Material of pipe	Cast iron, fibre-cement, polyvinyl chloride (PVC) galvanised iron
Minimum terminal pressure	5 m when distribution is through PSPs.
Service reservoir (capacity)	50% of daily requirement, as a minimum.
Number of PSPs (public standposts with 2 taps)	One for every 150-200 persons. At least one PSP for end sections.
Spacing of PSPs	Not to exceed 200 m.

## 4. WATER SOURCE SELECTION

### 4.1. Water Cycle Hydrology

The water on earth, whether as water vapour in the atmosphere, as surface water in rivers, streams, lakes, seas and oceans, or as groundwater in the sub-surface ground strata, is for the most part not at rest but in a state of continuous cyclical movement. This complex process - forming a natural equilibrium of evaporation, transpiration, precipitation, surface runoff, percolation into, and emergence from, the ground, is called the hydrological cycle (see Figure 2.).

Fig.2. HYDROLOGICAL CYCLE



### 4.2. Water Source Selection

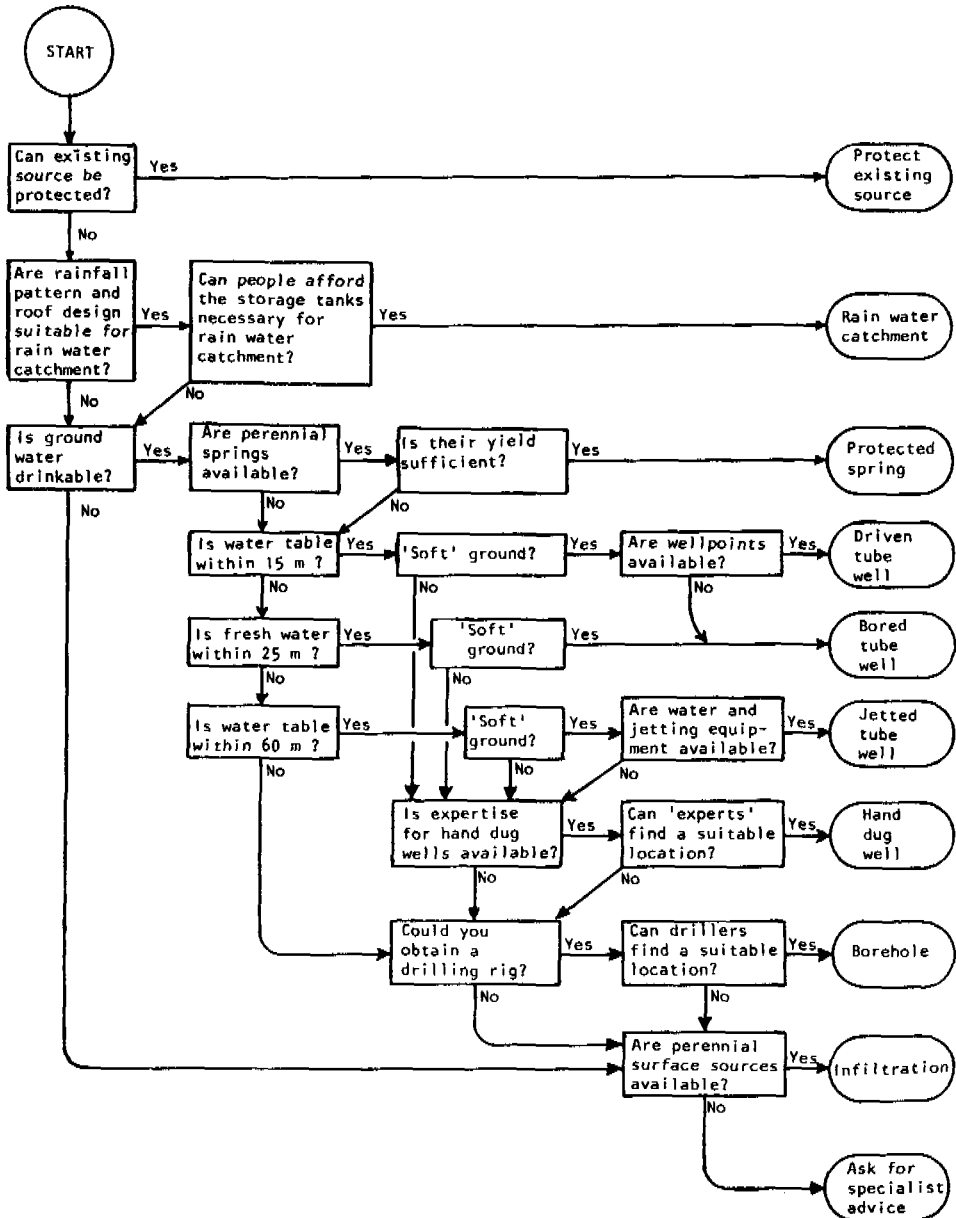
The first step in designing a water supply system is to select a suitable source or combination of sources. The source must be capable of supplying enough water for the community. The process of choosing the suitable source depends on local conditions (see Figure 3.).

#### 4.2.1. Rain Water

In some areas groundwater is inaccessible or highly mineralised such that it is not acceptable for domestic use. In these cases, and when rainfall is sufficient, the use of controlled catchments and cisterns may be necessary. Safe water will be

# Water Supply Guidelines

## Fig. 3. WATER SOURCE SELECTION



## Water Supply Guidelines

provided by a controlled catchment and cistern. Care should be taken to ensure that they are properly located and constructed. Wherever possible, rainwater should be treated by a satisfactory filtration unit and adequate disinfection.

A controlled catchment area is a defined surface area from which rainfall is collected. It may be, for example, a roof or a paved ground surface. The collected water is stored in a covered tank called a cistern or reservoir. Catchments at ground level should be fenced to prevent unauthorised entrance by people or animals. There should be no possibility of surface drainage mixing with the water collected from the catchment area. A drainage ditch, around the upper edge of the area, and raised curb around the surface will prevent the entry of surface drainage.

### 4.2.2. Ground water

Where it can be extracted with reasonable ease, groundwater is normally preferable to surface water because it is purified by the filtering action of the soil through which it flows. Springs, where they exist and have a reliable flow, can make ideal sources of water for a community water supply. Where springs are unavailable or unsuitable, the next best option is to extract the groundwater from a well of some kind. For small supplies simple prospecting methods should be adequate. For larger supplies, more extensive hydrogeological investigations using special methods and techniques are likely to be needed.

Infiltration drains may be considered for shallow ground water sources. Dug wells can be appropriate for reaching ground water at medium depth. Tube wells are suitable for drawing water from deeper water-bearing ground strata.

Dug wells are usually within local construction capabilities; whereas the drilling of tube wells will require more sophisticated equipment and considerable expertise. In some cases, drilling may be the only choice. If groundwater is not available, or where the costs of digging a well or drilling a tube well would be too high, it will be necessary to consider surface water.

### 4.2.3. Surface Water

Surface water sources such as rivers, streams, lakes and reservoirs are usually contaminated and unsuitable for human consumption unless properly treated. The costs and difficulties associated with surface water treatment, particularly the day-to-day problems of operation and maintenance of water treatment plants, need to be carefully considered before surface water sources are exploited.

## 5. GROUND WATER SOURCES

### 5.1. Engineering and geological considerations

Groundwater sources are amongst the most commonly exploited for rural water supplies. The reason being that amongst the various source options, ground water is by far the most practical and safe in nature.

The advantages of groundwater are:

1. it is likely to be free of pathogenic bacteria;
2. often it may be used without further treatment;
3. in many instances it can be found close to rural communities;
4. it is often most practical and economical to obtain and distribute;
5. the water-bearing stratum from which it is drawn usually provides a natural storage at the point of intake.

The disadvantages are:

1. ground water is often high in mineral content;
2. it usually requires pumping.

In groundwater supply investigations and design, the sanitarian and engineer are concerned with the following steps:

1. to locate a source with the required quantity and quality as near as possible to the centre of consumption, in order to reduce transport costs;
2. to extract the water by means of a system which produces the quantity required, safeguards the quality, and, at the same time, involves the least capital outlay;
3. to transport the water to the consumer in a way which requires the least amount of operational and maintenance skill and cost.

In prospecting for groundwater, the first step is to review reports (if any) of relevant geological studies for the particular area involved which indicate the nature and perhaps the characteristics of the underlying formations. Depending on the purpose for which these studies were made, they may be very useful in orientating the initial stage of investigation. Secondly, the examination of existing springs and wells, their profiles, production, water quality, and location, will also give valuable information. Thirdly, the sinking of test holes provides invaluable information. It

## Water Supply Guidelines

entails more work and expense than the previous steps. However, experience shows that test holes are usually indispensable and, in the long run, economical. Samples and profiles of the ground formations can be obtained from test holes providing information as to the nature of the aquifer, depth of the water table, and quality of the groundwater.

Another means of obtaining information about groundwater is through the use of an electric-resistance system. By measurement of the resistance of the earth at desirable well locations and application of formulae developed by the manufacturers of the equipment, reasonably accurate ground data can be obtained. However, interpretation of the results of such tests requires considerable experience. This method is most useful to supplement and extend information obtained from actual well profiles.

### 5.2. Wells

There are three principal methods of well construction that are used under different circumstances: dug wells, drilled wells and tube wells. Each of these is discussed in more detail below.

#### A. Dug wells

The hand-dug well is the most widely used type. Employing traditional methods, often identical with those used hundreds of years ago, people throughout the world rely on open, hand-dug wells as their principal water source.

The use of modern materials, tools and equipment has transformed the hand-dug well. An open, unprotected hole in the ground, a focus of parasitic and bacterial diseases, can be made into a sanitary source providing a hygienic and reliable source of water. The hand-dug well is still one of the cheapest possible types of village water supply, but it is relatively expensive for the individual family.

Construction equipment is simple and light, enabling sites remote from a road to be served. The construction process is easily taught to unskilled workers, and the materials used are usually obtainable locally. Traditional methods of construction may be improved upon, thus increasing the skills of the people trained in well-sinking. The well provides a source of water not unlike a reservoir which enables the water which percolates into it at night to be drawn off during the day. Where demand is low, this property is of particular value, since weak aquifers with a low rate of flow into the well can be utilised.

Hand-dug wells have certain limitations. Successful wells have been sunk in certain circumstances to depths of over 120 m. However, half this depth is usually considered the limit of practical sinking.

#### B. Drilled wells

Drilled wells are usually referred to as boreholes. Large volumes of water can be extracted from a single borehole, often making it the only practical method of supplying urban communities.



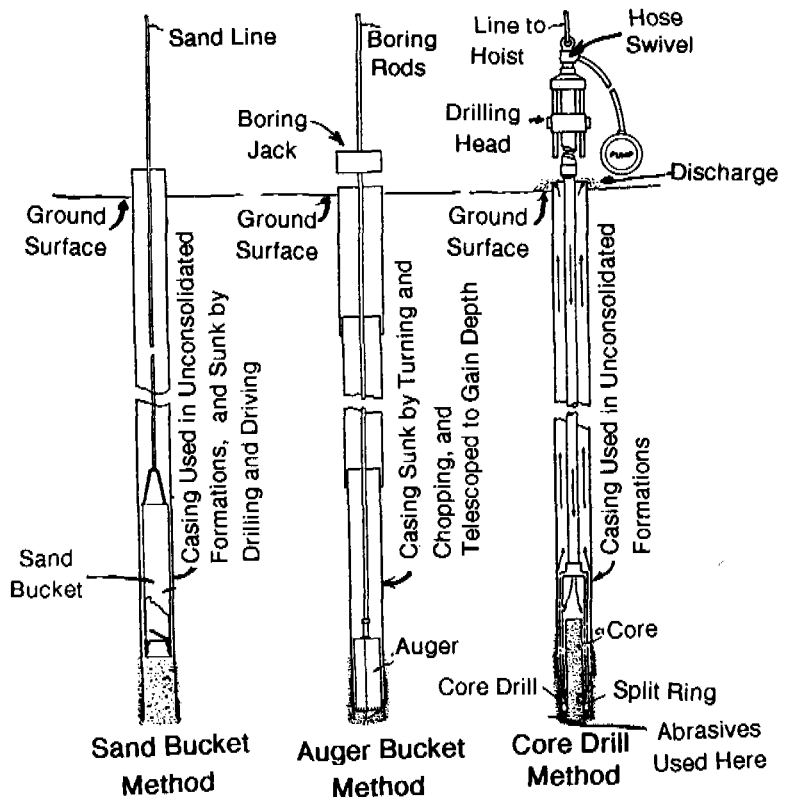
## Water Supply Guidelines

Hard rocks can be penetrated to a considerable depth, although drilling in hard formations is slow. The most important advantage is the depth and rapidity with which a borehole can be drilled, the practical limit being governed solely by the size of the drilling rig being used (see Figure 3).

For depths of more than 60 m, particularly where large quantities of water are required, the borehole is the method usually selected.

Boreholes, of sufficient diameter to take pumps are generally uneconomical for small community water supplies. However, if a hand-dug well is sunk a small diameter (e.g. 8 cm to 10 cm) borehole may be drilled through the bottom of the well to a sub-artesian aquifer. Water will rise into the well throughout the day. The well will act as a reservoir from which water can be drawn during peak periods.

**Figure 4. DRILLING AND BORING METHODS OF EXPLORATION**



## Water Supply Guidelines

### C. Tube wells

The tube well is a perforated or screened pipe which is jetted, (jetted well) or driven (driven well) into a shallow aquifer. This may be a small-diameter casing fitted with a hand pump, or a large-diameter casing fitted with a mechanical pump. Properly constructed and under suitable circumstances, tube wells can yield surprisingly large quantities of water. However, there is a limit to their depth and not all ground formations are suitable.

The most common application of tube wells is for the extraction of water from water-bearing sands, especially those underlying the beds of temporary streams. Here, the natural filtering properties of sandy beds of perennial rivers are exploited by taking water from below the beds instead of from the rivers themselves and thus obtaining water of improved quality.

### 5.3. Dug Wells

When a large scale, well construction programme is to be carried out within a large rural area or country, equipment and methods should be standardised as far as possible. Initial training of the crews will enable them to build similar wells in different areas and under different circumstances without constant supervision. Certain features of the work must be adapted to different conditions, e.g. the thickness and reinforcement of the linings must vary according to the type of ground encountered, and the well intake, (the part of the well through which the water enters) must suit local conditions. However, in general, the basic methods, materials and dimensions should remain as constant as possible. Different types of dug well are shown in Figures 5 to 8.

#### 5.3.1. Diameter

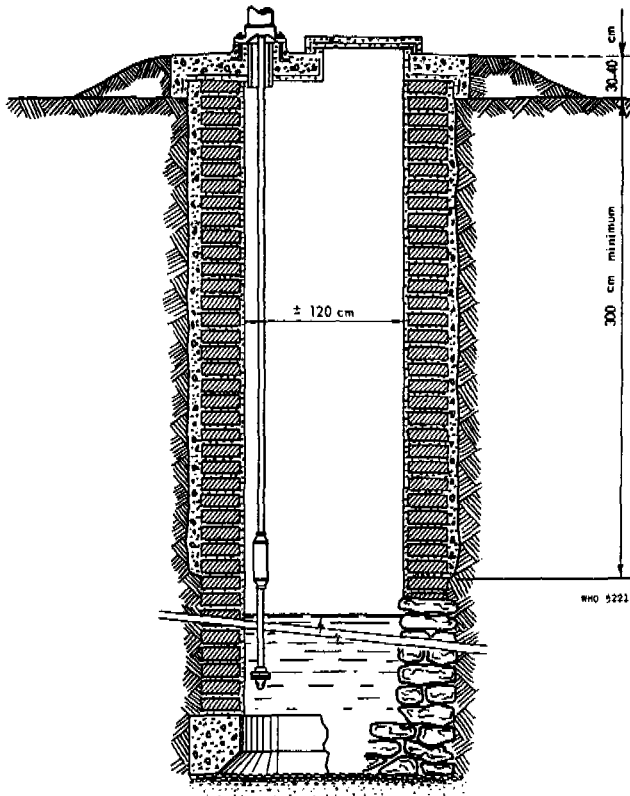
The first consideration in designing a well is its diameter. Neglecting for the moment large-diameter wells built for special purposes, the size of a completed well represents a compromise between economic and practical considerations. Experiments show that a diameter of about 1 m is the minimum space necessary for one person to work in and about 1.3 m is needed for two people. It has been found that the efficiency of two people excavating together is more than twice that of a single person, and consequently a 1.3 m diameter is a convenient standard size. Other considerations affecting this decision are the greater natural ventilation of the larger hole and the more efficient size of the kibles (hoisting buckets) and other equipment used. An increase in diameter beyond 1.3 m does not appear to give any great advantage in construction.



## Water Supply Guidelines

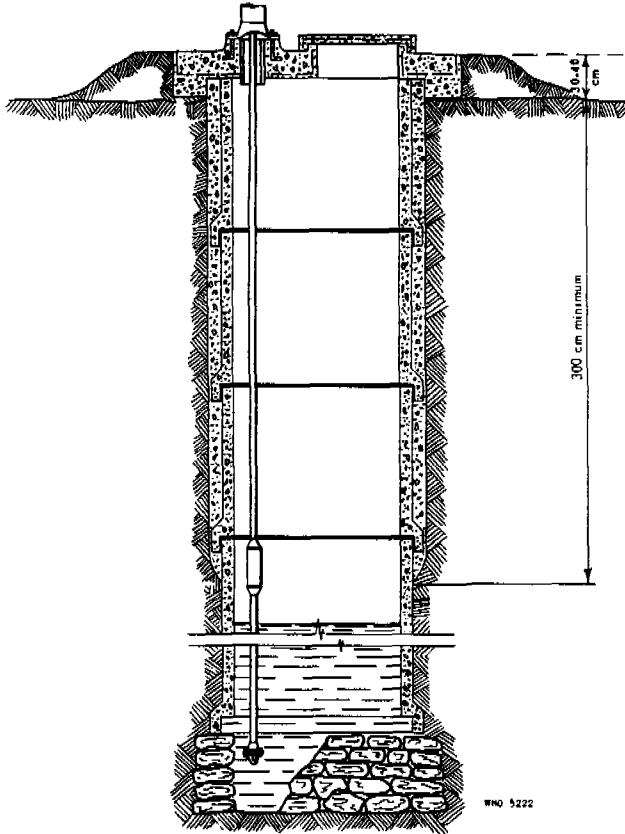
strength. Skilled masons and suitable stone and/or well-fired bricks may not be readily available. However, it is relatively easy to train unskilled workers to construct concrete linings. Sand and gravel to make the cement mix may often be found within reasonable distance of a well site.

**Figure 6. DUG WELL WITH PROTECTIVE CASING AND PLATFORM**



Concrete can be placed quickly by unskilled labourers, provided that they are adequately supervised. It requires only a small thickness (8cm, in good soil conditions to a maximum of 12 cm in poor soils). Concrete can be pre-cast on site into caisson rings using simple moulds. It makes a continuous, impervious lining, strong enough to support itself and any superstructure required. It adapts itself to the face of the excavation and can be made porous opposite the point where water enters the well to act as an entrance screen.

**Figure 7. DUG WELL LINED WITH CONCRETE OR CLAY TILES**



### **5.3.3. Construction**

The procedure which is commonly used in many parts of the world for the construction of shallow wells in firm ground formations may be briefly described as follows:

1. The hole is excavated to the desired diameter and depth, or to a point where the ground appears unstable and "cribbing" (lining with a framework of timber), becomes necessary in the hole to support the walls. In loose soils, dug wells must be cribbed in order to protect the men who are working inside the well. Cribbing material can be rough lumber and logs cut from any wooded area. Tight cribbing helps to keep out the ground water, allowing the well to be dug deep into the water-bearing formation.

## Water Supply Guidelines

2. The material excavated is placed in boxes or buckets and pulled out with ropes from above. Usually one box or bucket is being emptied while another is being filled.
3. When water is reached, it will be necessary to bail the water out of the well along with material excavated. The more efficiently the well is kept dry, the deeper it can be excavated into the groundwater and the greater will be the yield.
4. When the deepest possible point of excavation is reached, round stones should be laid around the wall (see Figure 6) to form the first 0.5 to 1 m of well lining. Brickwork is built up to the top of the well, with an extra heavy wall for the top 3 m, well grouted to provide a waterproof casing. This helps to stop runoff water entering the well and contaminating the water inside.
5. To finish the well, either a bailing apparatus or a hand-pump and platform is installed, as shown in Figures 6 to 8.

Deep-dug wells are associated with the additional complications of cribbing and the danger of caving. The masonry casing is usually started after the excavation is about 5 to 6 m deep. It is built up to ground level and maintained there. It subsequently descends under its own weight as excavation continues (see Figure 9.). This system gives protection to those working in the well.

### 5.3.4. Large-diameter dug wells

Large-diameter dug wells are usually very shallow, between 15 to 20 m in depth and built to provide large water storage capacity. This is necessary when water is drawn by mechanical means and the water-bearing formation is not sufficiently porous to avoid excessive draw-down. The construction of such wells often present problems of caving and heaving of side walls.

These wells are dug by hand, utilising divers with home-made helmets to whom air is pumped by hand and motor pumps. This method of construction is slow because digging under water is not very efficient. The tremendous resistance between the soil and the casing keeps the latter always above the excavation causing a great deal of sand to run into the well. Overall, several times the volume of the well is excavated. Jetting around the bottom of the well appears to facilitate the sinking of the casing. Mechanical excavating equipment would also speed up the excavating process. This well is relatively cheap where cement, reinforcing steel, and bricks are available and, of course, where a water-bearing sand is relatively close to the surface.

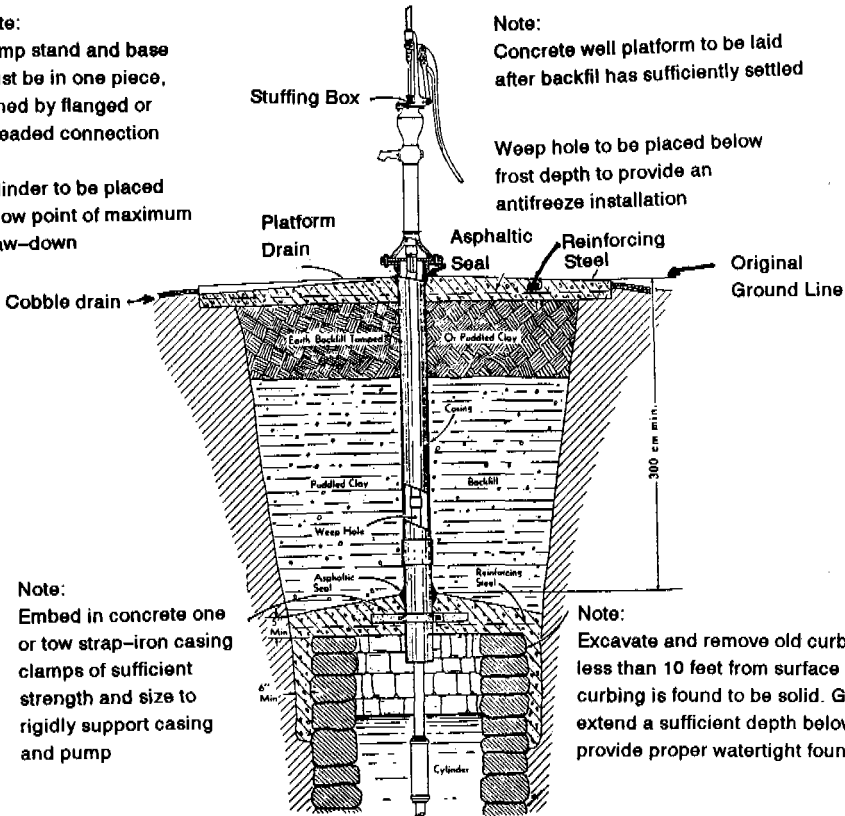
The yield of the large-diameter dug well can be considerably increased by developing a gravel pocket around the bottom filter section and by constructing laterals out from the well. This is accomplished by pumping large quantities of water into the well. It will soon begin to bubble up around the outside walls, and then graded gravel and coarse sand can be introduced all around the well. The surface must be capped so as to prevent entry of pollution. Large quantities of material are needed.

## Water Supply Guidelines

**Figure 8. RECONSTRUCTED DUG WELL WITH BURIED SLAB**

Note:  
Pump stand and base must be in one piece, joined by flanged or threaded connection

Cylinder to be placed below point of maximum draw-down



Note:  
Concrete well platform to be laid after backfill has sufficiently settled

Weep hole to be placed below frost depth to provide an antifreeze installation

Note:  
Embed in concrete one or two strap-iron casing clamps of sufficient strength and size to rigidly support casing and pump

Note:  
Excavate and remove old curbing to point not less than 10 feet from surface where existing curbing is found to be solid. Grouting should extend a sufficient depth below this point to provide proper watertight foundation for cap

This is sometimes a laborious process but is usually cost effective.

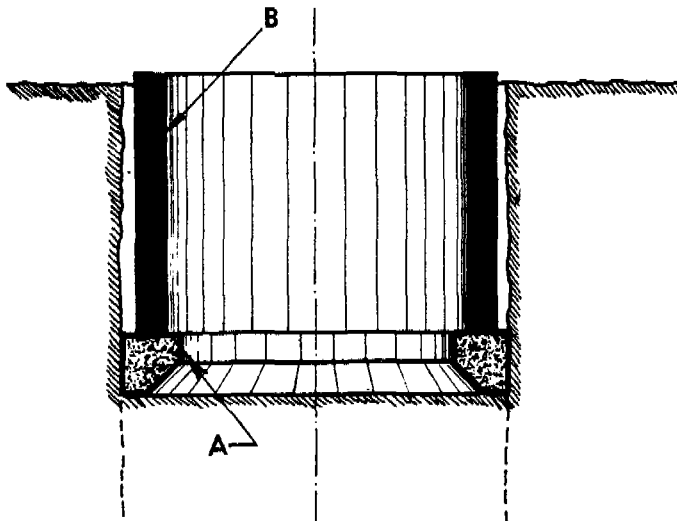
Extending laterals out from the well into the water-bearing strata is an excellent method of increasing its yield (see Figure 11). For small works a heavy automobile jack can be used, but purpose built machines are available. These machines are also used for putting pipes under roads, buildings, etc. without disturbing the surface.

Figure 6. shows a dug well with an outside protective cover of concrete. At the well bottom are two different types of construction; one is of built up, round stones comprising a filter wall. The other is a concrete shoe. The option of a stone filter wall is only practical in areas of coarse sand or gravel. The stones must be laid after the well is completely excavated. The concrete shoe is used where the well casing is sunk as the excavation progresses, and is usually more practical in fine sand. A protective, graded sand filter should be built up in the bottom of this well.

## Water Supply Guidelines

Concrete or clay tiles make excellent well casing and can be placed quickly and easily into the well by the use of a simple A-frame or other temporary structure. Note in Figure 7 the outside, protective layer of concrete which extends down to 3 m minimum to ensure water-tight upper walls. This minimises the risk of infiltration of contamination.

**Figure 9. DUG WELL: CASING DESCENDING WITH EXCAVATION**



**A** = Reinforced-concrete shoe

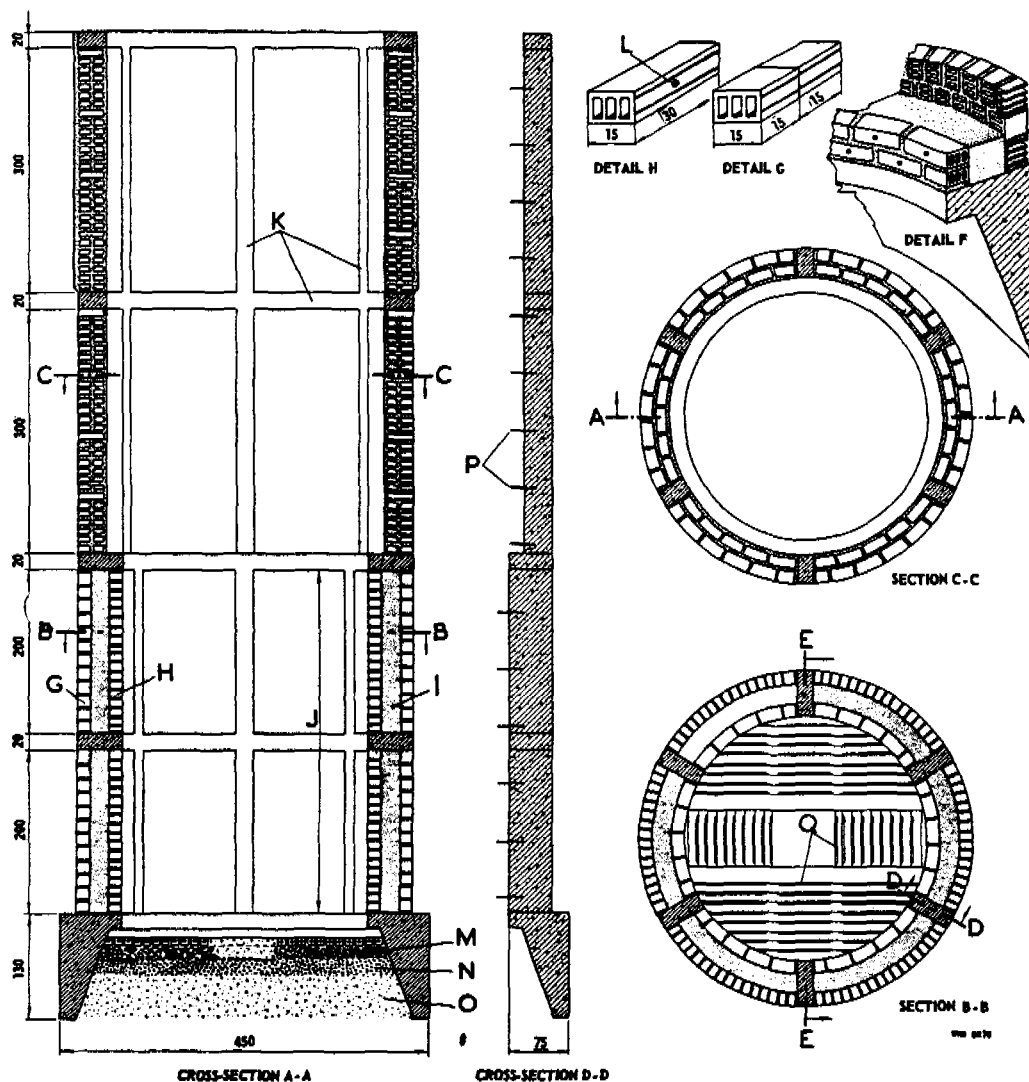
**B** = Concrete or masonry casing

Perforated pipes up to 15 cm in diameter, preceded by a drive point, and by a screen if desired, may be installed in this manner. Once the lateral is in place, provision should be made for developing the aquifer in its vicinity, and for periodic backwashing of these pipes. Laterals can be placed at various levels depending upon the water-bearing characteristics encountered. The construction of large installations of this type requires considerable judgment and engineering experience, and should not be attempted without consultation with competent hydraulic (water) engineers.



# Water Supply Guidelines

## Figure 10. AMAZON WELL



The scale used is in cm.

**A — E** = Cross sections

**F** = Reinforced-concrete shoe

**G** = Hollow bricks laid sideways. Water enters the filter section I through the holes in the brick.

**H** = Hollow bricks laid flat. Water enters the well through small holes designated by L. See detail H and F.

**I** = Sand filter section between brick walls

**J** = Height of filter section, varies with depth penetration into ground water

**K** = Reinforced-concrete beams

**L** = Small perforations through bricks H. See detail H

**M** = Layer of round stones

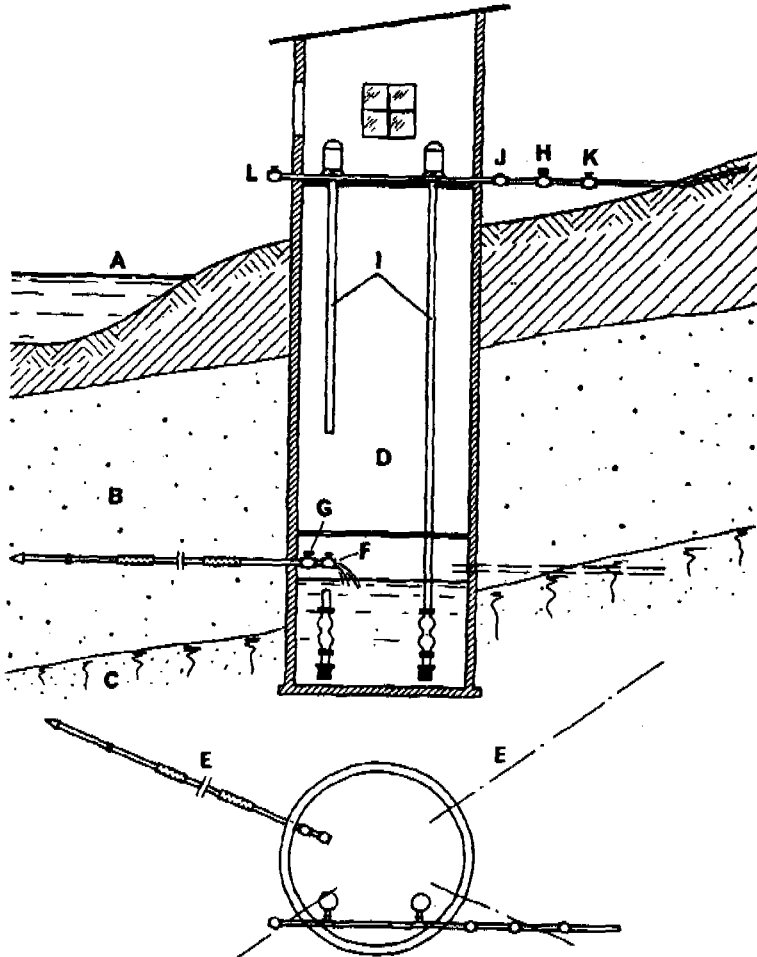
**N** = Layer of gravel

**O** = Layer of coarse sand

**P** = Iron steps, 50 cm (20 in.) apart

**Q** = Grate made of concrete beams

Figure 11. LARGE WELL WITH HORIZONTAL PERFORATED PIPES



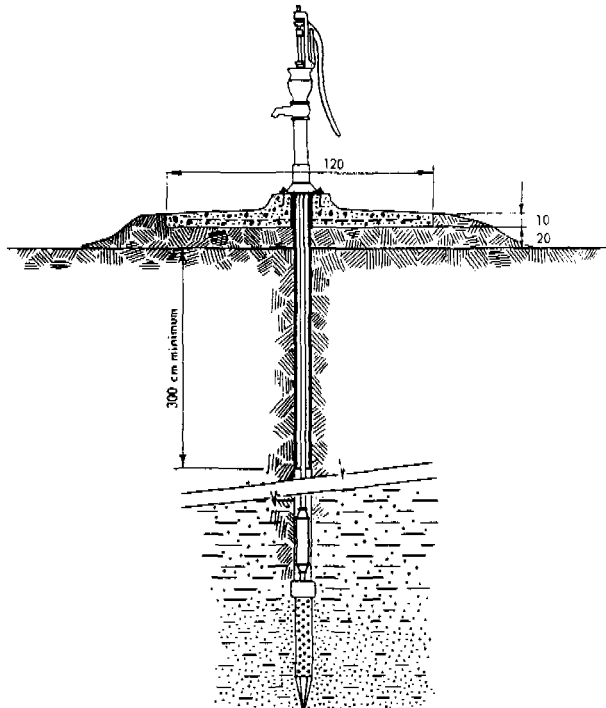
- A = Stream or pond
- B = Water-bearing formation, gravel or sand bank
- C = Impervious stratum
- D = Large-diameter well
- E = Collection pipes (horizontal wells) headed by drive heads and provided with sections of perforated pipes. Lengths of these pipes to be decided after trial holes to see how far the gravel bank extends

- F = Control valve
- G, H = Connexions to receive hose from outlet H for backwashing collection pipes and for development purposes
- I = Rising mains, pumps and motors
- J = Check (non-return) valve
- K = Valve controlling discharge of pipe leading to reservoir
- L = Washout valve

#### 5.4. Driven Wells

Driven wells are constructed by driving a pipe into the ground with a hammer. A drive-well point is attached to the lower end of the pipe (see Figure 12). These wells are usually between 2.5 cm to 10 cm (most commonly 3 cm) in diameter. Owing to the ease with which these wells can be driven, pulled out, and put down again elsewhere, they are very popular in many parts of the world. Some typical well points are shown in Figure 13.

**Figure 12. DRIVEN WELL WITH DROP-PIPE AND CYLINDER AND PROTECTIVE PLATFORM (for driven pump wind mill)**



#### Check list

1. Is the surrounding area free from sources of pollution?
2. Is there a watertight concrete apron and is drainage provided?
3. Is there watertight tubing for 3.00 m below ground level?
4. Is the adduction pipe to pump sealed in apron at exit?

## Water Supply Guidelines

In areas of relatively coarse sand, driven wells can be an excellent and very cheap means of obtaining water. They can be driven rapidly and put into operation quickly. Using the correct techniques, the well can be developed to increase its capacity. Note the water-tight casing, shown in Figure 12, which extends down to a minimum of 3 m below ground surface.

Wells can be successfully driven through compact soils and even through chalk. As in the case of bored wells when solid rock or boulders are encountered it is best to pull up the pipes and try a new spot a small distance away.

The depth of groundwater is an important consideration in the selection of driven wells. In individual installations where the groundwater is very shallow, eg. within 7 m of the ground surface, the pump cylinder is usually attached directly to the top of the rising pipe. The total depth of such wells seldom exceeds 10 to 15 m. For larger installations and under similar circumstances, a well-point system, designed as shown diagrammatically in Figure 14, can deliver relatively large quantities of water from a shallow aquifer.

### 5.4.1. Equipment

Driving equipment and tools are simple and easy to operate. A typical set for driving 3 cm pipe includes:

- (i) 15m of 3cm wrought-iron pipe, extra heavy, with couplings provided
- (ii) 1 pitcher-spout pump, tapped for 3-cm pipe
- (iii) 1 drive-well point, 3cm, with jacket length 1.2m, with openings smaller than 0.4mm
- (iv) 1 pulley bar approximately 3cm x 1.4m
- (v) 1 driving monkey, 35-45kg
- (vi) 15m of cleaning-out tubes, 1.3cm diameter, in assorted lengths
- (vii) 1 pair of driving clamps, 3cm
- (viii) 9m of 2cm manila or cotton rope
- (ix) 1 plumb bob, line and winder, 15m

### 5.4.2. Technique

A typical installation technique is as follows:

A driving clamp is fastened to the drive point or perforated pipe. The monkey or hammer is slipped onto the pipe above the clamp, and the pulley bar is inserted in the pipe. A rig made of local wooden or bamboo poles may be set up for holding the pipes in a vertical position. A small hole 50 to 80 cm deep is dug in the ground by means of a crowbar at the selected spot.

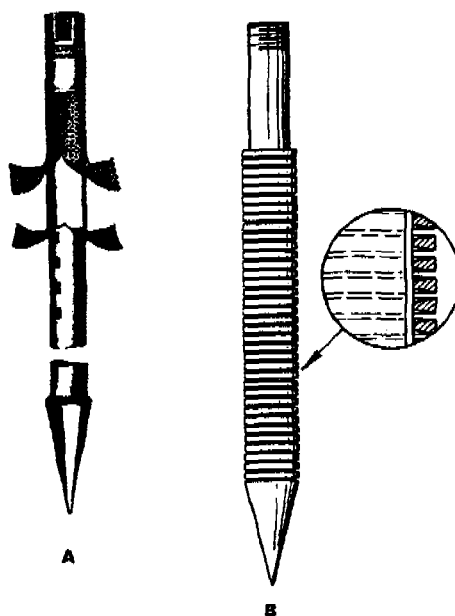
Driving begins by pulling on the ropes, raising the hammer and then letting it fall on the clamp. Care must be taken at all times to keep the pipe vertical. This may be checked by means of a plumb line. When the clamp reaches ground level, driving

## Water Supply Guidelines

is stopped. The clamp is loosened and raised about 30 cm if the soil is hard, or 50 to 60 cm if driving is easy through soft soil. Operations are resumed. When the first pipe has penetrated the ground to such a depth that there is no more head-way for the hammer to work, a new length of pipe is added. To ascertain whether water has been reached, the plumb line is frequently lowered in the pipe. This also helps to determine whether earth or sand has penetrated the pipe through the screen or perforations. When this happens, the dirt may be removed by means of small cleaning-out tubes and a hand-pump.

After the water-bearing stratum has been reached, it is advisable to continue driving operations to such a depth that the well will never dry up, even in dry seasons. The pump may then be installed and the well completed.

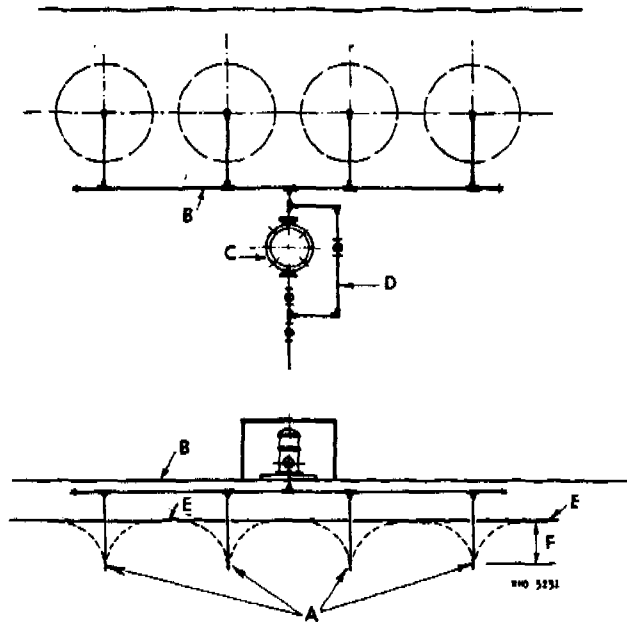
Figure 13. TYPICAL WELL POINTS



- A** = Common type of screen for well point. It is reasonable in cost and, in a good water-bearing formation, it can give good results. Over-pumping is apt to plug up the screen.
- B** = An effective type of well point. It will not plug easily but is more expensive than common screens. With proper development, large quantities of water can be obtained through such well points.

## Water Supply Guidelines

**Figure 14. WELL-POINT SYSTEM**



- A** = Well points properly spaced so that there is no interference between their circles of influence
- B** = Pumping header with allowance for future expansion in both directions
- C** = Pump
- D** = Priming line
- E** = Water table
- F** = Draw-down

To start the pump, it is necessary to fill the suction column with clean water and to exhaust the air which is in it. The water coming out of the well will be muddy at first, but will clear up after an hour or so of vigorous pumping.

In order to ensure a steady flow of water in the future, it is necessary to "open" the water-bearing formation in the vicinity of the drive point by removing its content of fine earth or sand particles. When the ordinary pitcher pump is used, this may be achieved by raising the handle high for a brief moment, thus allowing the water in the suction column to drop suddenly, and then resuming the pumping immediately and vigorously. With this sudden drop, the water in the pipe rushes out of the screen at the bottom of the well and shakes and disturbs the fine particles surrounding the

## Water Supply Guidelines

pipe. Such action facilitates the removal of the fine particles when pumping is resumed and the well water will remain muddy for some time. This process should be repeated several times before the well is considered to have been completed.

Various other methods may be used for developing or finishing wells in sand and gravel formations. One of the simplest and most common methods is over-pumping, i.e., creating a draw-down much in excess of that which will be maintained in future operation. This method, while not fully effective as a development procedure, has the advantage of clearing fine particles from the well and its immediate surroundings and it provides useful data concerning the capacity of the well. It may be used only on small, low-capacity wells driven into fairly well-graded formations. Over-pumping should not be done and may even be detrimental when the formation is uniformly fine and made of silt or clay, because it may result in considerable caving of the ground surrounding the well. Other methods of development, using compressed air, a surge plunger, or back-washing, require skill and experience on the part of the driller or engineer.

### 5.5. Jetted Wells

With a small amount of pumping equipment, it is possible to sink wells to considerable depths very rapidly by the jetting method. Depending on the soil and the amount of water that can be pumped, a fairly large-diameter casing of 25-38 cm can be sunk 50 to 100 m, thereby making it possible to install larger screens and pumps. Jetting is highly recommended for exploration and for small tube-wells, provided that plenty of water is available for sinking.

#### 5.5.1. Small-diameter wells

A system of jetting for small-diameter wells, which has given excellent results, is summarised below.

##### *Equipment*

1. Tripod of bamboo with 8 m of clearance
2. Hand-operated lift and force pump (double-acting, with plunger 10 cm in diameter)
3. 4 chain-type wrenches for gripping pipes
4. 12 m of high quality hose, 38 mm diameter
5. Casing pipe, boring pipe, a swivel joint, steel cutter, pulley ropes, small hand tools.

##### *Technique*

1. Dig a hole 1.5 m deep over which the tripod is mounted; this gives a reasonable starting depth.

## Water Supply Guidelines

2. Attach the cutter to one end of a 38 mm diameter boring pipe, usually about 6 m in length; swivel to other end and place cutter end of pipe into the hole. Suspend the pipe and swivel with pulleys from the tripod as shown in Figure 14. The swivel joint allows water to enter the boring pipe from the hole while, at the same time, permitting the boring pipe to revolve without leaking.
3. The hose is attached to the force pump which pumps water from a sump excavated in the ground near the well. (The pump suction pipe must be held clear of the bottom and sides to avoid sucking up mud and sand.)
4. Jet-boring starts as the pumpers begin to force water into the boring pipe, at which point people with the chain wrenches begin to turn the pipe.
5. With the pressure of the water and the twisting action, the bore pipe begins to descend, and the jetted water begins to boil up around the sides of the bore pipe. This water is full of suspended matter and is really a light mud. (The more water that can be pumped through the pipe, the faster it will descend and the more and larger will be the suspended matter being washed out of the hole.) In a short time the first 6 m length of pipe will be at ground level. The swivel is removed and a second length of bore pipe is screwed on. The swivel is attached to this new length of pipe and the pumping, jet-boring process begins again.
6. One after another, the bore pipes are sunk until the desired depth is reached. This can be ascertained by examining the borings that are coming out of the well. When a stratum of fine sand is reached, boring is stopped; but pumping continues at that level for some time to clean the whole well.
7. Jetting water is re-used by letting the dirt and sand settle out in the sump.

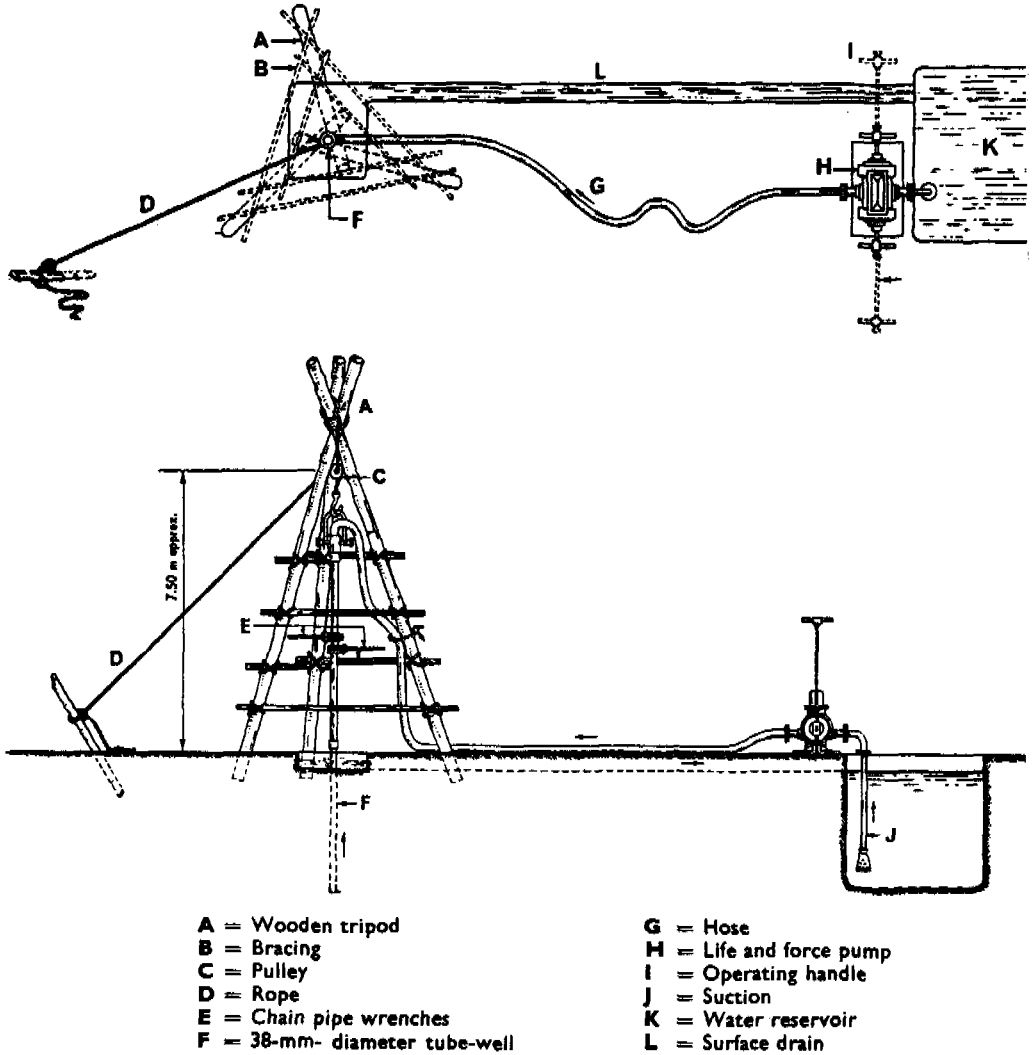
### *Placing the screen:*

1. The entire column of jet-boring pipe is now removed and the cutter is taken from the end of the bottom pipe.
2. The well screen is now attached to the first length of well pipe, and the process of lowering the pipe is repeated with pumping, but through the screen. (Naturally there is little resistance in the recently jetted hole.) The screen is open at the bottom and when it is in the desired position, a pre-seated plug made of lead is dropped into the pipe and closes the hole at the bottom of the well screen, sealing the bottom of the well. A well point with a closed end may also be used, although sometimes a few feet of hole may be lost while raising the jet and lowering the well point.

At this stage, when water is being pumped down through the well pipe and screen, washed pebbles can be dropped into the hole around the outside of the well pipe. These are heavy enough to settle even against the upward stream of water, and the stream can be regulated to allow settlement.



**Figure 15. TUBE WELL BORING BY WATER-JET SYSTEM**



These pebbles of round, washed gravel, from 1 mm to 4 mm in size, help to form a gravel pack around the well, thus reducing the possibility that fine sand may get packed up around the screen and enter the well, with a consequent cutting-down of

## Water Supply Guidelines

capacity. Where sufficient sand-free water is being obtained without gravel packing, methods that have proved successful should be followed. Where trouble is encountered in getting water from fine-sand strata, it will be worth while to experiment with gravel packing. It is highly important that round, selected, washed material be used.

3. A 2 cm dia. pipe is now lowered into the well pipe to the bottom, and a strong jet is pumped. This is done to clean the inside of the well pipe and screen off any possible sediment, sand, or dirt.

### *Finishing the well:*

1. The space between the well pipe and the earth hole should be back-filled with compacted clay or concrete to prevent contamination from reaching the water table through this space.
2. The well is now complete, and the hand-pump is installed and operated continuously for (at least) eight hours per day for three days to clean out the jetting water.
3. A little hypochlorite should be introduced into the well, allowed to stand for 24 hours, and then pumped out again.
4. A watertight platform should be constructed to complete the well.

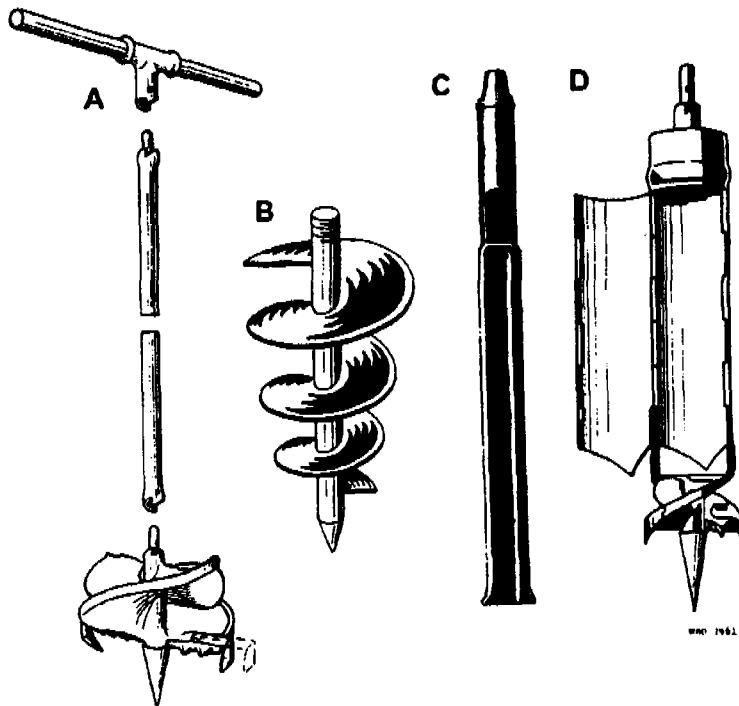
## 5.6. Bored Wells

A simple method of construction of small-diameter wells of shallow depths is the use of an earth auger (see Figure 16). First, a small hole 30 to 50 cm deep, and of sufficient diameter to allow the introduction of the borer, is dug in the ground with an ordinary pick or crowbar. The spiral shape of the borer allows the loosened soil or gravel to rise upwards.

This method is especially adapted to soft soil, chalk, limestone, and alluvial formations which are free of large gravel and stones and can be easily penetrated. Where soil is sandy or clay with no large boulders or hard rock formations, wells may be bored to considerable depths. Bored wells are reasonable in cost and produce good results. When hard underground formations, such as rock or stone, are encountered, boring is stopped and a new spot selected several metres away.

Several accessories to the earth borer have been designed by manufacturers to facilitate boring, especially in soils containing either wet sand or loose gravel. Some of them are shown in Figure 16.

Figure 16. TYPICAL BORING TOOLS



**A** = Tool for boring in top soil, clay, sandy clay, or formations that are not too hard or caving. Cutter (a) may be added to permit boring up to 8 cm (3 in.) wider than standard size

**B** = Spiral auger

**C** = Regular club bit for breaking through hard formations, loosening rock, and breaking soft rock

**D** = Tool for boring in soft, wet, sandy soils

A typical set of boring tools for wells of 10 cm diameter or less includes:

- (i) 1 drill, 10 cm diameter
- (ii) 1 one-piece 10 cm drill and deep-boring attachment
- (iii) 1 T-handle
- (iv) 15 m of steel rods for 10 cm drill
- (v) 1 sand borer, 10 cm diameter
- (vi) 1 spiral point
- (vii) 1 chisel, 9 cm
- (viii) 1 twist drill
- (ix) 2 extension cutters, for 10 cm drill

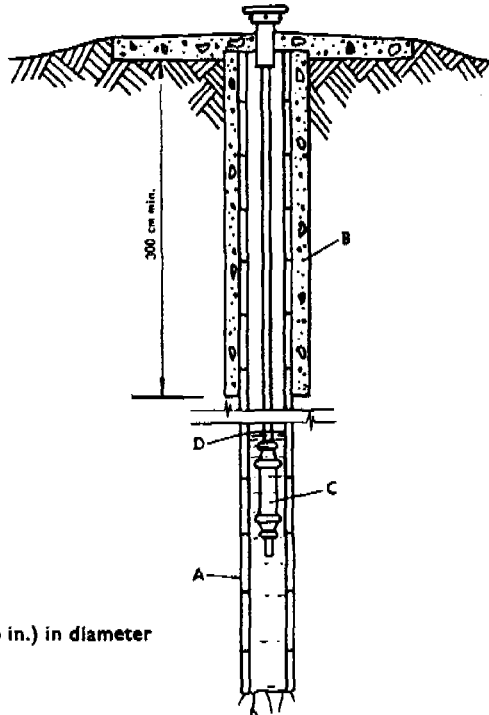
## Water Supply Guidelines

Once a hole is completed which deeply penetrates the water-bearing stratum, small-size pipes with screen or strainer attached are lowered into the hole. The pump is installed, and the well is completed by the construction of an adequate platform and the provision of surface water drainage.

When the soil is so soft that it frequently caves in, pipes of a diameter equal to - or 1.3 cm larger than - the borer's nominal size are lowered as boring proceeds. The borer is passed inside the pipe and is provided with movable side (or extension) cutters (see Figure 17) capable of cutting a hole 3.8 cm wider in diameter than the borer, to allow the pipes to follow the borer as it descends.

In some parts of the world it is not uncommon to bore wells to 90 cm diameter, using a team of horses and augering equipment designed for such purposes.

**Figure 17. BORED WELL WITH PROTECTIVE CONCRETE CASING AND PLATFORM**



- A** = Clay tile lining, 10-15 cm (4-6 in.) in diameter
- B** = Protective concrete lining
- C** = Pump cylinder
- D** = Standing water level in well

## Water Supply Guidelines

### 5.7. Drilled Wells

The term "drilled well" implies construction with machines designed and manufactured for the purpose of drilling water wells. These machines can be described as being of two general types: (1) percussion, and (2) rotary.

The percussion drilling rig, also known as the "cable tool" rig, is simpler and more commonly used (see Figure 18). It consists of a derrick and hoisting and control equipment, skid-trailer or truck mounted. The derrick serves as the elevated structure from which the drilling tools, well casing, screens and all other materials and equipment are suspended and manipulated. These rigs vary from very small sizes to those which drill to more than 1000 m.

Percussion rigs work on basically the same principle, i.e. the chiselling action of a tool alternately raised and dropped in a borehole. Rotary rigs are much more varied in construction and operation, though all have the common feature that the bit is revolved in the hole.

Drilling wells is very specialised work, requiring considerable experience. This type of well construction should not be attempted without careful consultation with competent well-drilling firms or consulting engineers.

Before any kind of recommendation is made concerning the possibility and practicability of drilling, a thorough study with reference to local conditions must be carried out. It should be remembered that, without previous drilling history in the area, any attempt is a gamble, even if geological studies give positive indications. In rural areas not easily accessible for drilling equipment, this method should be employed after others have failed, and then only when careful investigation indicates a good possibility of success.

Such drills can be transported on 1.5 tonne trucks and may be used for holes from 7.5 cm to 15 cm in diameter and up to 115 m in depth.

### 5.8. Infiltration Galleries

Infiltration galleries are horizontal wells which collect water over practically their entire lengths (see Figures 19 and 20). Where the construction of such galleries is feasible, a good and wholesome supply of water may be obtained.

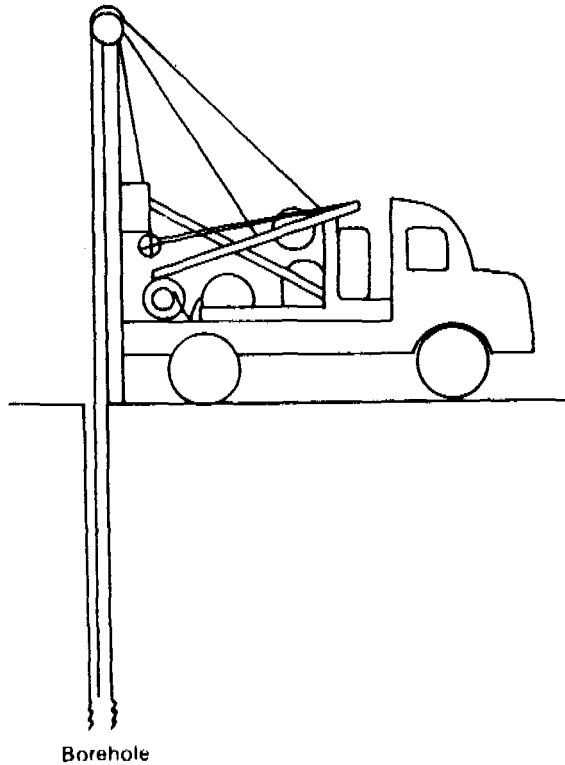
Many towns and villages are located close to or on the banks of rivers or lakes. When the river beds or lake shores are sandy or gravelly, the possibilities of finding a gravel pocket along a bank are excellent. These may sometimes be seen from the stream or lake bed during low water, but are more often found by systematic exploratory borings along the banks.

The gallery is a simple means of obtaining naturally filtered water. It should be located 15 m or more from the bank of the river or lake. It is constructed by digging a trench into the water-bearing sand, then collecting the water in a perforated pipe or gallery (masonry-lined or unlined) which leads to a central casing from which the

## Water Supply Guidelines

water is pumped out. The walls of infiltration galleries may also be built of porous concrete. The length of the trench depends upon the amount of water desired and the size of the water-bearing pocket.

**Fig. 17. PORTABLE WELL-DRILLING RIG**



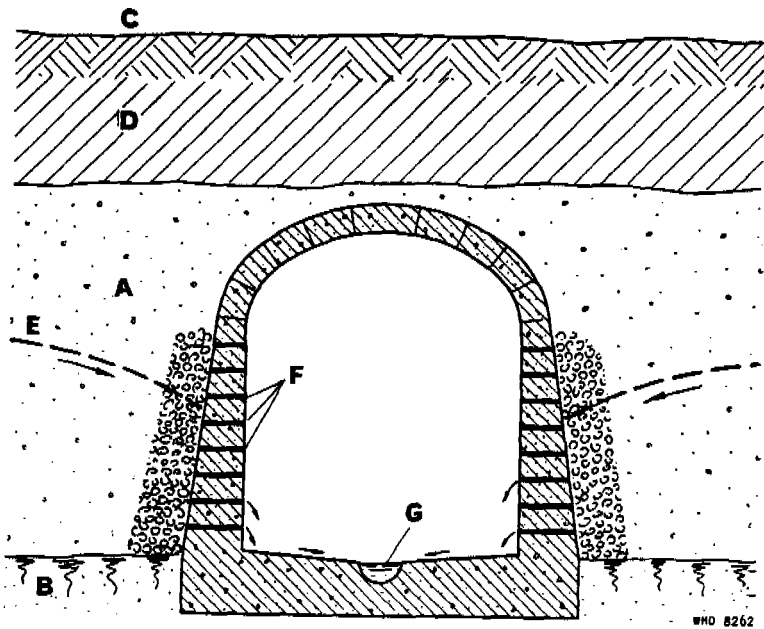
Careful tests to measure capacity should be made before constructing a complete gallery. The best galleries collect water well below groundwater level, thus making it necessary to de-water the working trench. This usually requires cribbing and de-watering pumps and is therefore more expensive than a simple bored or driven well. This system, however, offers better possibilities of obtaining large quantities of water if a suitable formation, such as a reasonably coarse sand, can be found.

## Water Supply Guidelines

An infiltration gallery may also consist of a tunnel driven into a water-bearing stratum. The tunnel may be so built as to lead the collected water out by gravity. This system, which is slow and expensive to build, is common in many countries of the Eastern Mediterranean area and North Africa (e.g., "karez" or "khanat", a gallery of a type used in Iraq and Iran), and is reported to yield substantial amounts of water for irrigation and town water-supply purposes (see Figure 21).

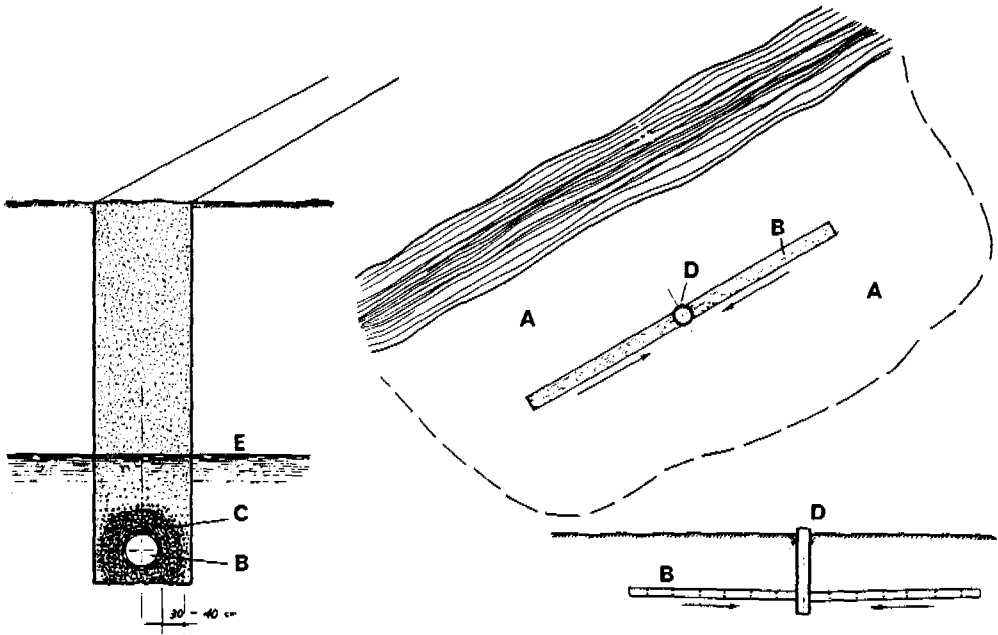
Infiltration galleries alongside rivers can be sited upstream of the community to be supplied such as to enable water to be transported by gravity; otherwise pumping will be necessary.

Figure 19. INFILTRATION GALLERY



- A = Water-bearing sand or gravel
- B = Impervious formation
- C = Surface of the ground
- D = Top soil
- E = Ground-water table
- F = Staggered openings through walls
- G = Collecting-trough conveying water to collection chamber or reservoir

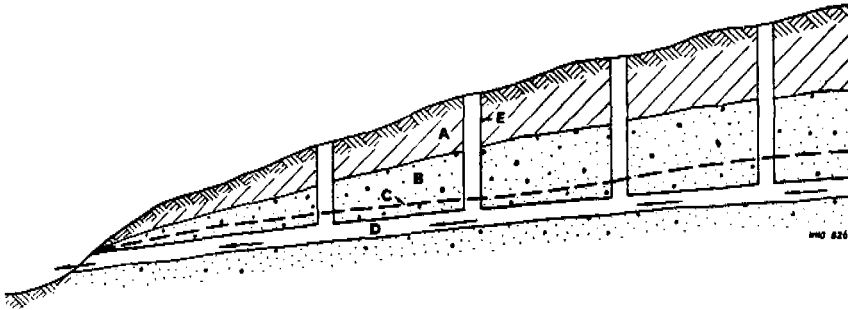
**Figure 20. INFILTRATION GALLERY BESIDE STREAM**



- A** = Sand banks beside streams offer excellent opportunities for infiltration galleries or shallow dug wells.
- B** = Perforated pipe should be laid on a prepared filter bed and more filter bed should be constructed over it.
- C** = Round, 12- to 25- mm stones should be laid around the pipe, and the filter should be built out away from the pipe with graded sand and gravel. Filter should be 30-40 cm in thickness from pipe to extreme edge.
- D** = Well in middle of gallery for mounting pump and collecting water
- E** = Water table



**Figure 21. TYPE OF INFILTRATION GALLERY USED IN EASTERN MEDITERRANEAN AREA AND NORTH AFRICA**



- A = Ground surface (undulating country or foot of hills)
- B = Water-bearing formations
- C = Ground-water table
- D = Small tunnel (approximately 70 × 90 cm.), the sides of which may be supported by rubble masonry or brick walls
- E = Aeration wells

### 5.9. Improvement of Existing Wells

One of the problems that must be faced in water supply work in rural areas is the existence of private and public wells which are open, unprotected, poorly located and constructed, and providing unsafe water. There are both economic and social problems involved in the improvement of these wells. Simply informing the local population that the water is unsafe will achieve little. People are likely to keep using the source, particularly if it is their own well.

The difficult task of education and direct assistance in upgrading wells is often the responsibility of the health authority. Considerable care must be taken over the decision to close a contaminated well. The well should only be closed if a more convenient, reliable and safe source is readily available. If no such alternative source is made available then the condemning and closing of a contaminated well is an utterly pointless action.

A scheme for improving (upgrading/rehabilitating) existing wells should be a part of any water supply programme. In general, the health authority is involved and will have to help finance the work. The building of sanitarily protected wells can be expensive. It is best to try to recover at least a part of the cost of a rehabilitation programme both for this reason and because the system is more likely to be valued by the beneficiaries. All kinds of financing schemes have been tried with varying degrees of success. Those most likely to succeed involve the beneficiaries contribut-

## Water Supply Guidelines

ing at least part of the cost. If they do not contribute, for example with providing labour, materials, or cash, it is likely that the upgraded well will soon degenerate to its original state. Experience has demonstrated conclusively that the permanent improvement of wells is a slow process involving education and direct technical and financial assistance.

Once the programme has developed to the extent that there is a genuine interest in improving the wells, the health authority must assign trained personnel, e.g. sanitary inspectors, to work with families or villages and supervise the work. The rehabilitation itself need not be technically demanding. Generally, a more demanding aspect of the work is keeping the community/individual motivated and committed to caring for the upgraded well. It is recommended that the health (or water) authority continue to provide assistance for some time after the improvement has been made, in order to ensure adequate operation and maintenance. The owner or, in the case of a community upgraded well, a group of interested volunteers should be trained by the sanitary inspector in the operation and maintenance of the supply.

On locating an insanitary well, the sanitary inspector should carry out a sanitary survey of the well and its surroundings in order to determine the most appropriate remedial action. Particular attention should be given to:

1. the location of the well with respect to nearby buildings and possible sources of contamination;
2. the slope of the ground surface;
3. the surface drainage around the well;
4. the condition of the platform and cover of the well (if any);
5. the condition of the lining or curbing;
6. the condition of the pump or other means of raising water out of the well;
7. any other factor allowing contamination of the groundwater.

The sanitary inspector should also measure the capacity of the well before deciding whether it will be necessary to deepen it in order to increase its yield. If there is considerable sediment in the bottom of the well, it should be cleaned before tests are made. Finally, the physical, chemical, and bacteriological quality of the water should be determined.

In a few instances, such as close proximity of a latrine to the well, it may be necessary to condemn the use of an insanitary well. In the great majority of cases, however, a well may be improved and rendered safe by taking the following simple steps:

1. Clean out the well and deepen it to increase capacity.
2. Construct a lining using the best possible materials available. If a stone or brick lining already exists, it may be improved by the methods illustrated in Figure 21, or the well may be reconstructed by using the methods shown in Figures 22

## Water Supply Guidelines

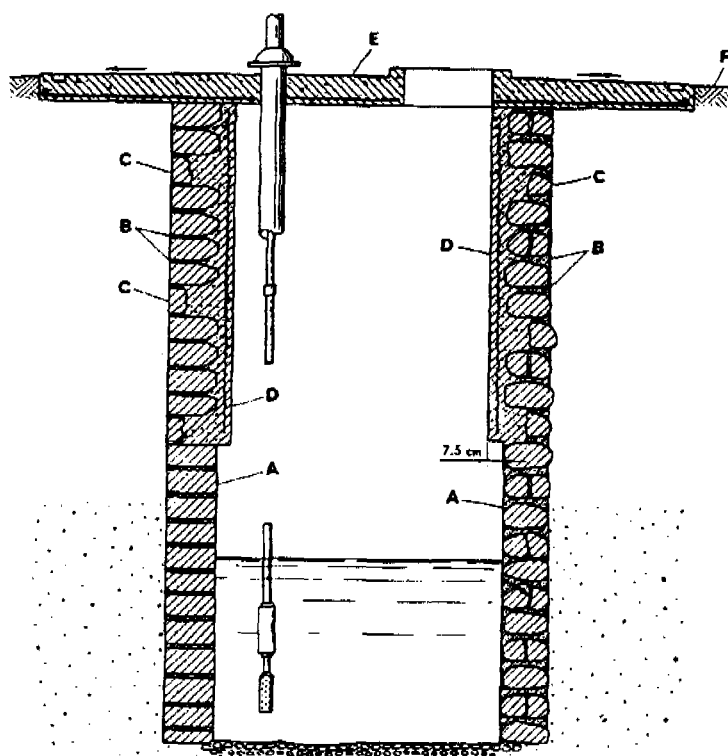
to 24.

3. Build a strong and impervious platform or apron, if possible of concrete, around the well. If this cannot be done, build a tamped earth mound 30 cm high around the well. In both cases the platform or the mound should extend at least 1 m from the well in all directions. The platform should slope away from the well and be edged with a small wall or parapet to prevent surface water draining into the well. In addition, it should have a drainage channel to carry spilt water away from the well.
4. The lining should extend at least 70 cm above ground.
5. Cover the well and install a pump or any other suitable device for drawing water from the well in a sanitary manner.
6. Make provision, wherever possible, for an inspection cover.
7. Build a protective fence around the well to prevent access of animals.

Examples of operation and maintenance problems which may occur with upgraded wells include the following:

1. Depletion of the aquifer. This may be related to either drought, over-pumping, or both. It may be necessary to deepen the well, depending upon its actual penetration into the aquifer. Alternatively, the rate of pumping should be reduced until an equilibrium is reached with the amount of water which the aquifer can yield under the given set of conditions. This requires a close study of the variations in draw-down. One simple way of reducing pumping with a hand pump is to raise the suction pipe. The depletion of the aquifer may be due to recent construction of new wells within the circle of influence of the existing well. Such a situation may be avoided by the enforcement of strict regulations on the part of the control agency.
2. Damage to casing or screen. This may be due to the collapse of the existing masonry or steel casing, the corrosion of the casing or screen, or the incrustation of the screen. The collapse or the corrosion of a small casing necessitates its replacement. Trouble due to incrustation can be alleviated by the introduction into the well of weak hydrochloric acid, which will dissolve the incrustant salts (most likely calcium carbonate). When a screen is obstructed by heavy growth of *Crenothrix*, the iron bacteria, a 50 mg/l chlorine solution will clear the difficulty. After such treatment, wells should be pumped before normal operation is resumed until all traces of the chemicals have disappeared.

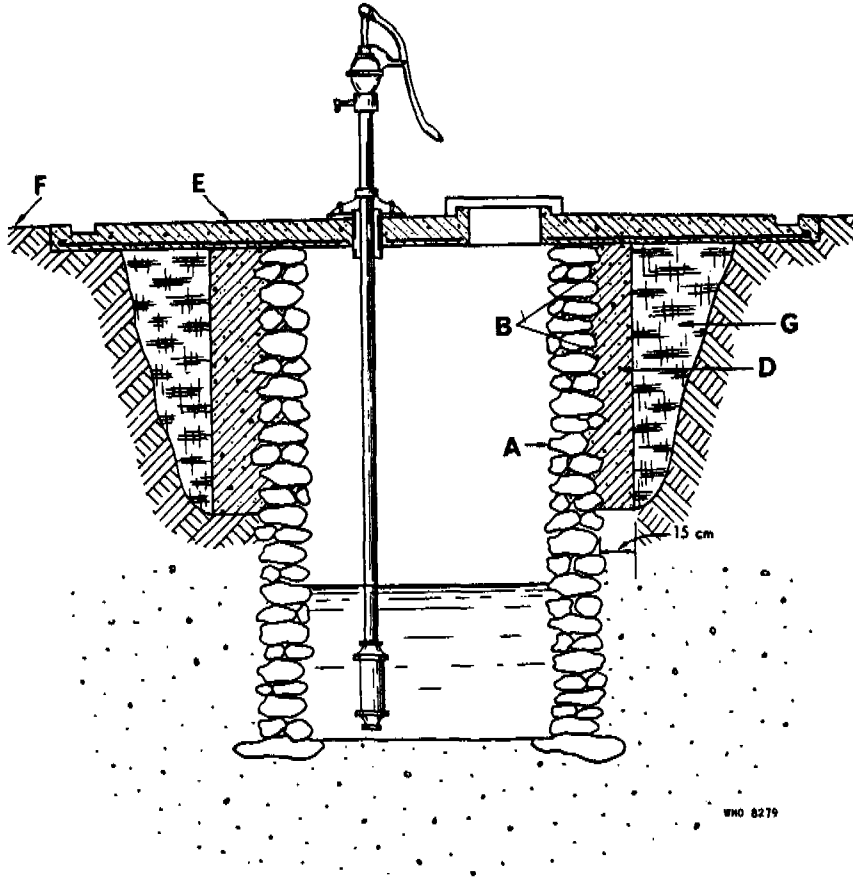
Figure 22. IMPROVEMENT OF EXISTING WELLS



- A** = Existing masonry or brick walls with cracked mortar joints
- B** = Old mortar removed with chisel as far back as possible
- C** = Stone or bricks dug out to provide key for new concrete lining
- D** = New concrete lining, built to a depth of at least 3 m below outside ground level, or to low water level in well. For concrete, use pea-sized gravel and wire-mesh for temperature reinforcement.
- E** = New concrete well top, incorporating sanitary features (manhole with raised edges, slope for proper drainage, proper pump installation, etc.).
- F** = Outside ground level (adequate drainage being provided for excess water or surface run-off)

## Water Supply Guidelines

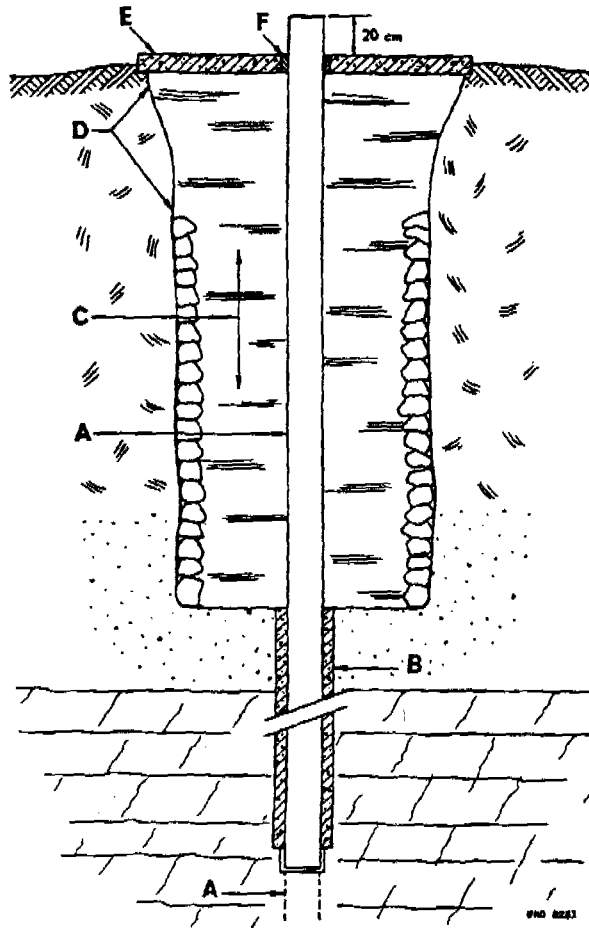
**Figure 23. IMPROVEMENT OF EXISTING WELLS**



WHO 8279

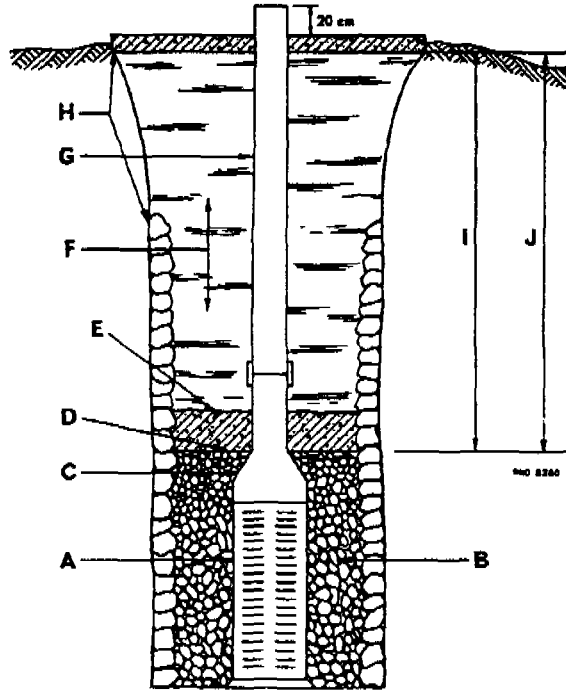
- A = Existing masonry or brick walls with cracked mortar joints
- B = Old mortar removed with chisel as far back as possible
- C = Stone or bricks dug out to provide key for new concrete lining
- D = New concrete lining, built to a depth of at least 3 m below outside ground level, or to low water level in well. For concrete, use pea-sized gravel and wire-mesh for temperature reinforcement.
- E = New concrete well top, incorporating sanitary features (manhole with raised edges, slope for proper drainage, proper pump installation, etc.).
- F = Outside ground level (adequate drainage being provided for excess water or surface run-off)
- G = Backfill with clay, well tamped in layers 15 cm (6 in.) thick

Figure 24. IMPROVEMENT OF EXISTING WELLS



- A = Drill hole and casing
- B = Standard-weight casing
- C = Puddled clay or equivalent
- D = Curbing removed
- E = New platform
- F = Plastic compound

Figure 25. IMPROVEMENT OF EXISTING WELLS



- A = Metal or concrete screen
- B = Washed, round gravel
- C = Reducer
- D = Metal plate
- E = Poured concrete
- F = Puddled clay or equivalent
- G = Standard-weight casing
- H = Curbing removed
- I = 3.6 m in clay
- J = 6.0 m in sand or gravel

### 5.10. Springs

Springs are found mainly in mountainous or hilly areas and occur in specific sites where the groundwater is not permitted to remain underground and comes to the surface. The point at which the water emerges is known as the 'eye' and the water has generally been forced to the surface by an impervious layer of soil or rock; a layer through which water cannot pass. Spring water may emerge directly in the open as in a gravity-fed spring on a mountain side or may be less apparent as in the

## Water Supply Guidelines

case of an overflow trickling almost out of sight into a stream or lake.

Generally, springs are of the gravity or artesian type. In the first instance, the "gravity spring", the ground water flows over an impervious stratum onto the ground surface. The yield of a gravity spring will vary with the position of the water table which, in turn, fluctuates with the rainfall. Such a spring may even dry up during, or immediately after, a dry season. In the other case, the "artesian spring", the water from a permeable formation or a fissure, rises under pressure to the surface of the ground after confinement between two impermeable beds. The yield of an artesian spring is likely to be almost constant throughout the seasons of the year.

The quantity of water from a spring may be substantially increased by digging out the area around the spring down to an impervious layer to remove silt, decomposed rock, and other rock fragments and mineral matter (usually calcium carbonate) sometimes deposited by the emerging groundwater. In doing this, particular care should be taken, especially in fissured limestone areas, to avoid disturbing underground formations to the extent that the spring is deflected in another direction or into other fissures.

Springs which have a reliable flow can make ideal sources of water for a community water supply. No pumping is required to extract water from them, and all that is usually necessary to obtain water of good quality is to collect it and protect it from pollution. This is usually done by building a protective box around the spring so that water flows directly out of the box into a pipe without ever being exposed to pollution from outside (see Figures 26, 27 and 28).

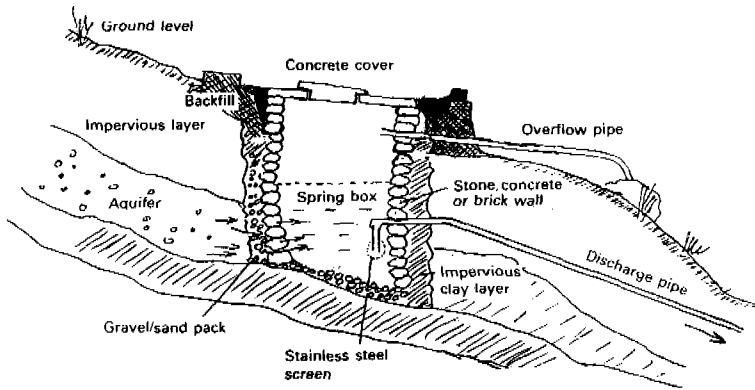
In general, springs are subject to contamination in the area close to the point of emergence. A thorough sanitary survey should be conducted before development work is initiated. Such a survey should yield information on the origin of the groundwater, the nature of the water-bearing strata, the quality of the water, its yield in different seasons, the topography and vegetation of the surrounding area, and the presence of possible sources of contamination. To protect the spring, the collection structures should be so located and built as to force surface water to pass through at least 3 m of soil before reaching the groundwater.

It is also customary to exclude all animals and people from a substantial area (30 to 90 m) around the collection chamber, and to dig a diversion ditch above and around this to interrupt surface run-off and divert it away from the groundwater collection zone. Springs emerging from solution channels in limestone formations should be carefully investigated and observed, since under such conditions very little, if any, natural filtration takes place in the ground. Such springs are likely to yield grossly polluted and turbid water soon after heavy rains, and should not be used as a source of domestic supply without a thorough study, including frequent bacteriological examination. In addition they may require treatment such as filtration and/or disinfection. Other protective measures are discussed below.

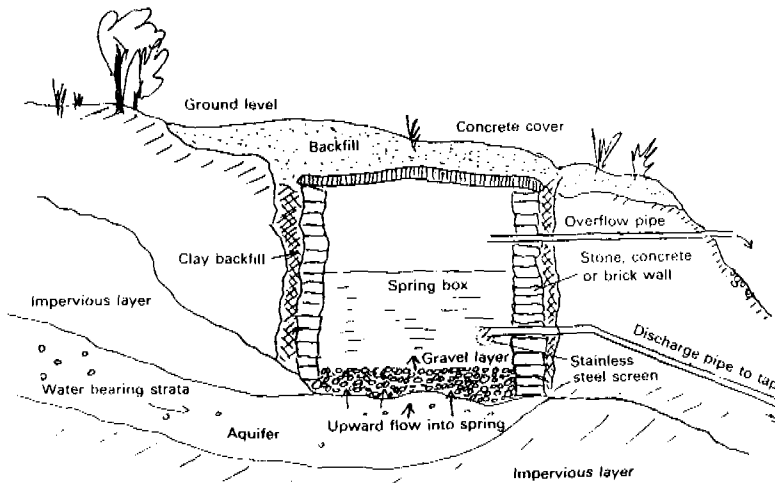


## Water Supply Guidelines

**Figure 26.A. OVERFLOW SPRING**



**Figure 26.B. ARTESIAN SPRING**

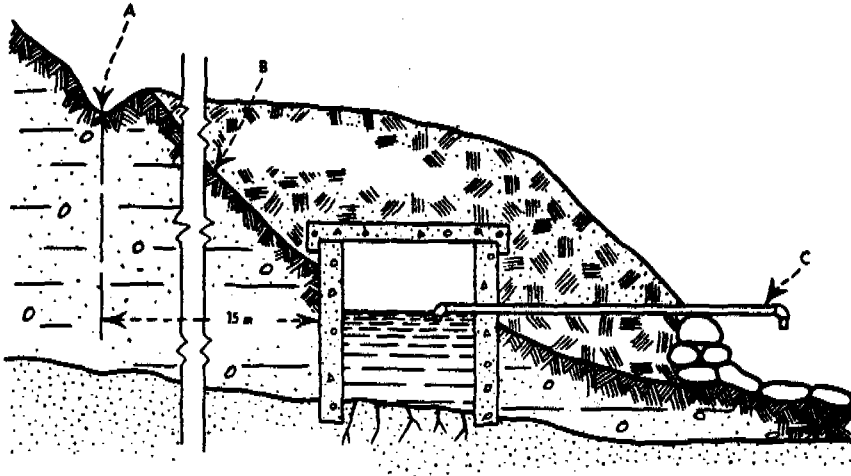


### Check list

1. Is there a diversion ditch?
2. Is the spring inaccessible to users?
3. Is drainage provided below outlet pipes?
4. Are animals excluded by fencing?

## Water Supply Guidelines

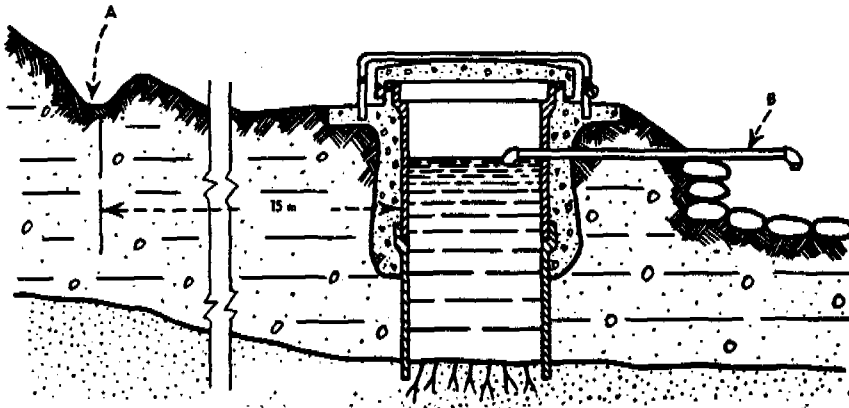
**Figure 27. PROPERLY PROTECTED SPRING**



- A = Protective drainage ditch to keep drainage water a safe distance from spring
- B = Original slope and ground line
- C = Screened outlet pipe : can discharge freely or be piped to village or residence

MO 5213

**Figure 28. PROPERLY PROTECTED SPRING**



- A = Protective drainage ditch to keep drainage water a safe distance from spring
- B = Screened outlet pipe : to discharge freely or be piped to village or residence

### 5.11. Location and Protection of Groundwater Supplies

Numerous possibilities exist for bacterial or chemical contamination of groundwater in rural areas and villages. Shallow groundwater is commonly tapped and used as a source of domestic supply. Pollution from latrines, cesspools and seepage pits, septic tanks, and barnyard manure may easily reach the groundwater source. It is therefore desirable to locate wells as far away as possible from likely sources of pollution.

#### 5.11.1. Wells and latrine pollution

The effects of proximity of wells to latrines and the travel of pollution through groundwater have been widely investigated. Studies indicate that the travel of bacteria in soil depends upon several factors, the most important of which are the porosity and permeability of the soil. Faecal bacteria, assisted by leaching liquids from pit latrines, may be carried up to 90 cm horizontally. They may, however, travel up to 3 m downward from latrine pits open to heavy rains. Unless accompanied by a considerable amount of water, bacterial contamination appears not to travel more than 7.5 m through fine wet sand.

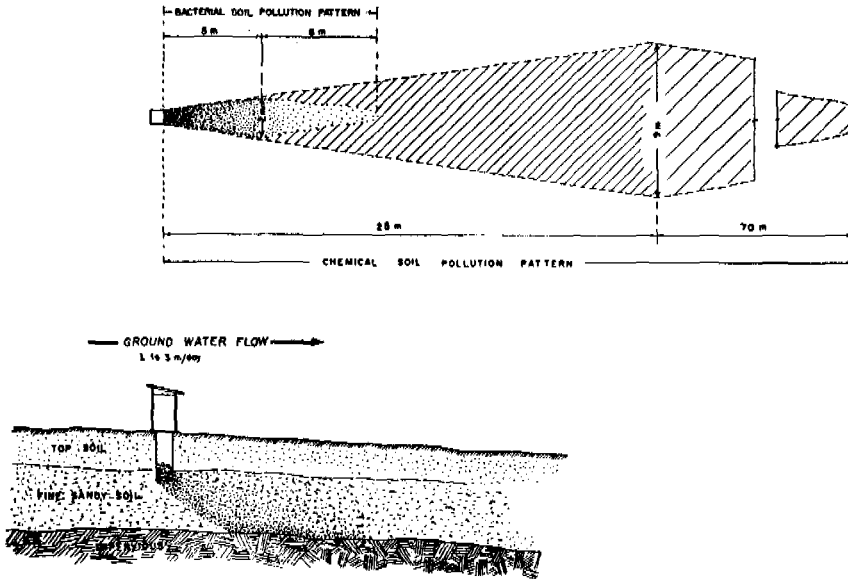
In a study on the artificial recharge of aquifers with reclaimed sewage and other wastewater in the State of California, USA, it was found that bacteria were transported up to 30 m from the recharge well in 33 hours. There was a rapid regression of bacterial numbers over this distance due to effective filtration and to bacterial die-off. It was also found that chemical pollution travelled twice as fast.

Other studies on groundwater pollution noted that bacteria were traced to a distance of 15 m from the dosing well in which test bacteria were introduced. The width of the path of bacterial travel varied between 45 cm and 120 cm. Regression then took place; and, after a year, only the dosing well remained positive for the test organism. These investigations confirmed that the contamination from excreta disposal systems tends to travel downward until it reaches the water table, then moves along with the groundwater flow across a path which increases in width to a limited extent before gradually disappearing (see Figure 29). These studies emphasise the importance of proper location of wells with respect to sources of pollution, if bacterial contamination is to be avoided.

The problem is, however, more complicated in the case of wells from which water is drawn by powerful pumps. In this case, the normal groundwater flow may be reversed within the cone of depression around the well by the draw-down, and pollution may be drawn from a source actually situated downstream from the well.

The source of contamination in these studies was human excreta placed in a hole which penetrated the groundwater table. Samples positive for coliform organisms were picked up quite soon between 4 m and 6 m from the source of contamination. The area of contamination widened out to a width of approximately 2 m at a

**Figure 29. BACTERIAL AND CHEMICAL SOIL POLLUTION PATTERNS AND MAXIMUM MIGRATIONS**



point about 5 m from the privy and tapered off at about 11 m. Contamination did not move "upstream" or against the direction of flow of the ground water. After a few months the soil around the privy became clogged, and positive samples could be picked up at only 2 m to 3 m from the pit. In other words, the area of soil contamination had shrunk.

The chemical pollution pattern is similar in shape to that of bacterial pollution, but extends to much greater distances.

From the point of view of sanitation, the interest is in the maximum migrations and the fact that the direction of migration is always that of the flow of groundwater. In locating wells, it must be remembered that the water within the circle of influence of the well flows towards the well. No part of the area of chemical or bacterial contamination may be within reach of the circle of influence of the well.

The distance of the well from users houses is also an important consideration. If the well is situated too far away, it will not be used and will not fulfil its real purpose: the provision of safe water in adequate quantity for health and domestic needs. It is recommended that there should be at least one well for every 200 inhabitants in rural communities and that no user should have to carry water more than 100 m. Care must be taken to avoid locating a well too close to barns, manure piles, etc., to

## Water Supply Guidelines

avoid excessive chemical pollution in the form of nitrates. A high nitrate content in drinking water is known to produce methaemoglobinaemia or "blue baby syndrome" in infants.

### 5.11.2. Sanitary measures

Other sanitary measures which should be taken in order to exclude the entry of surface water are the following:

1. The ground surface in the immediate vicinity of the well should slope away from it and should be adequately drained.
2. In the case of communal wells, a special drainage system should be provided for wastewater.
3. The pump platform or well cover should be at least 60 cm above the highest flood level of nearby rivers, and should be well-protected against flood waters and surface run-off generally. It should be watertight, preferably of concrete 10 cm thick, and should extend a minimum of 1 metre beyond the well lining. Its surface should slope from the centre towards a drain built along its edges (see Figure 7). The waste water should then be collected by a lined ditch leading to a suitable drainage area or soakage pit, in order to avoid muddy ground and stagnant pools of water collecting in the immediate vicinity of the well.
4. In the case of driven, jetted, and drilled wells, an annular space at least 4 cm wide on the outside of the well casing may be grouted with cement in order to prevent surface water from reaching the casing and running down along it to the groundwater. The cement grout mixture can be made by mixing a 50 kg bag of cement with 20 litres of clean water and adding hydrated lime equivalent to 10 per cent of the cement volume. The depth of the seal should be at least 3 m below ground surface.
5. When inspection covers are provided for dug wells, the rims should project at least 8 cm beyond the well cover, and the inspection cover should overlap the rim, as shown in Figure 23.

When more than one well must be built and pumped simultaneously an undue amount of interference between them should be avoided. For this reason, wells should not be too close to each other. When penetrating the same aquifer they should be located on a line transverse to the direction of groundwater flow. Usually spacings for deep wells vary from between 150 m to 300 m.

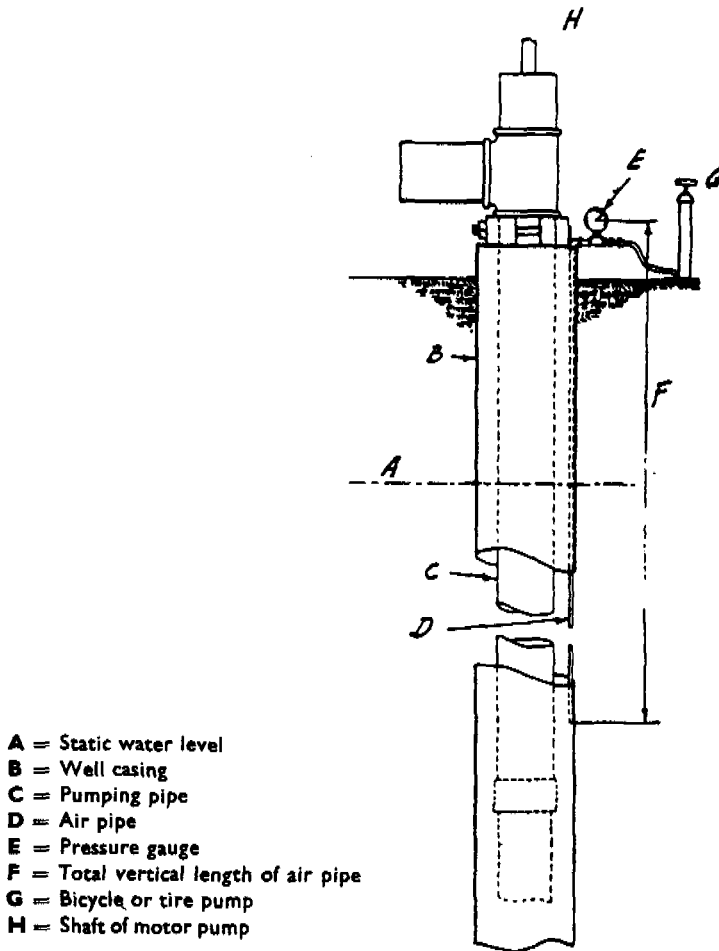
Before being put into operation, or immediately after repairs, a well should be disinfected to neutralise the bacterial contamination which may have been introduced by workers, equipment, or surface water. First, the casing or lining should be washed and scrubbed with a strong solution containing 100 mg/l of available chlorine. Such a solution is obtained by dissolving 50 g of chlorinated lime in 100 litres of water.

## Water Supply Guidelines

The volume of water in the well is measured and the chlorine solution is added so that the effective chlorine dose is between 50 mg/l and 100 mg/l. The well water should be agitated to ensure even distribution of the solution. The chlorinated water is allowed to stand for at least 12 hours, after which it is pumped out.

As a measure of protection of groundwater, abandoned wells should be permanently sealed with puddled clay after as much as possible of the existing lining has been removed. This measure is necessary in order to ensure the protection of nearby domestic wells.

Figure 30. SET-UP FOR DETERMINING DRAW-DOWN



### **5.12. Testing of Wells for Draw-down and Yield**

After a well is completed, its yield often needs to be determined, i.e. the amount of water which can be steadily withdrawn by pumping when the draw-down has reached an equilibrium and remains constant. The pumping tests to do this should not be made immediately following completion of the well but after several weeks, and preferably after one month, of routine pumping. The yield of a new well tested soon after completion is invariably 10 to 30 per cent greater than the yield at the same rate of pumping a month later.

When these tests are made, it is necessary to take frequent measurements of the draw-down, i.e. the distance between the static water level and the pumping level in the well. A convenient method of measuring the depth of water in small well installations involves the use of an air-line or tube and a manometer installed as shown in Figure 30. When air is pumped into the tube, the reading on the manometer increases until the water in the tube has been expelled. At this point the manometer will indicate the amount of pressure required to balance the depth of water outside and above the lower end of the air-line in the casing. This pressure is converted into metres of water and is subtracted from the vertical distance between the manometer and the end of the air-line. The figure obtained is the depth of water in the well. By repeating this measurement during pumping operations, it is possible to determine the depths of water and the draw-down levels for each rate of pumping. The corresponding pump discharges will be determined by means of a weir or an orifice. With the data obtained, it is then possible to establish a capacity curve for the well.

## 6. SURFACE WATER SOURCES

Surface water originates mostly from run-off and rainfall water. It includes large rivers, ponds, lakes and small upland streams which may originate from springs and collect run-off from watersheds. The quantity of run-off depends upon a large number of factors, the most important of which are the amount and intensity of rainfall, climate, vegetation and, the geological, geographical, and topographical features of the area under consideration. It varies widely, from about 20 per cent in arid and sandy areas where the rainfall is scarce to more than 50 per cent in rocky regions in which the annual rainfall is heavy. Of the remaining portion of the rainfall some of the water percolates into the ground, and the rest is lost by evaporation, transpiration and absorption.

The quality of surface water is governed by its content of living organisms and by the amount of mineral and organic matter which it has picked up in the course of its formation. As rain falls through the atmosphere, it collects dust and absorbs oxygen and carbon dioxide from the air. While flowing over the ground, surface water collects silt and particles of organic matter, some of which will ultimately go into solution. It also picks up more carbon dioxide from vegetation, and microorganisms and bacteria from topsoil and decaying matter. In inhabited watersheds, pollution may include faecal material and pathogenic organisms, as well as other human and industrial wastes which have not been properly disposed of. Water from small streams draining isolated or uninhabited watersheds will rarely be of adequate bacteriological and chemical quality for human consumption in its natural state. In most instances surface water is subject to pollution by pathogenic organisms and cannot be considered safe without treatment. It should be remembered that clear water is not necessarily fit for human consumption and even water containing 10,000,000 bacteria per 100ml may appear perfectly clear.

### 6.1. Rainwater Harvesting Systems

Rainwater may be collected from the roofs of buildings, courtyards, or large ground catchments. Rooftop catchments are usually best for satisfying domestic water requirements because they are close to the dwelling and isolated from many sources of contamination. Rainwater may be utilised for drinking and cooking, for which high water quality is required, or for other domestic purposes, such as washing and bathing.



## Water Supply Guidelines

There is little chance that faecal organisms from humans or domestic animals may contaminate roof catchment rain water. Other foreign material that could enter the collected rain water is less important than faecal contamination for human health but may affect the acceptability of the supply.

Where water quality problems have been encountered, they have been related to system defects or failure to adequately maintain the system. When properly collected and stored and standard precautions taken, the quality of rainwater may compare very favourably with that of the water obtained from other good quality sources. Good quality rainwater may be collected and stored by considering the following points:

1. Technical considerations and provisions in design and construction;
2. Ensuring diversion of the 'foul flush' (the first volume of water to leave the collection surface when rainfall begins)
3. Water treatment.
4. Maintenance and cleaning of the whole system;

### 6.1.1. Design considerations in roof collection

#### 1. Roofing materials

It is important to remember that:

Run-off from the structure must be non-toxic and therefore lead roofs are unsuitable because of health hazards.

The surface should be of a smooth, dense material (hard inorganic) since this is less likely to catch and hold wind-blown dust and debris, which is later collected by the rainwater. Rough types of roof include; thatched (straw, reed) and wooden ones. Even if thatched roofs are improved by a surface of plastic sheeting, this sheeting would soon be covered by algal growth.

#### 2. Paint

Painting roofs is to be discouraged. If used, local authorities should develop a list of appropriate paints that may be used.

Paint used for rooftop collection systems should have as low a level as possible of heavy metals, such as mercury and lead. White latex, if controlled to assure it is free from metals and aluminium paint may be used.

Newly painted roofs should be allowed to dry, and harden completely before the first rainfall. Tar based paints may cause taste problems and at least the first 3 run-offs from acrylic painted roofs should be discarded.

#### 3. Other precautions

There should be no overhanging trees adjacent to the roof. The aim is to reduce

## Water Supply Guidelines

the probability of accumulation of vegetation and bird droppings.

The location and design of the roof in conjunction with the wind can keep it clear of leaves and debris.

A roof which birds regularly use for shelter is not suitable for rainwater catchment. A scare-crow may be used.

Aerial spraying of chemicals in the area is to be discouraged.

The catchment should be given an even slope to prevent the formation of pools.

Problems are created by defective plumbing when drains installed over roof surfaces leak onto roofs.

### 4. Inflow system

Rain water is conducted to storage facilities by means of gutters and downpipes. The downpipe is the pipe leading from the gutter to the reservoir.

Gutters should connect to the downpipe with a small, uniform slope without sagging, and should be installed in such a way that pools of stagnant water are avoided, which could provide a breeding site for vectors of disease. The required slope is 8 to 10 cm per metre of gutter.

To prevent leaves and other debris from entering and clogging the downpipe, a 1 cm galvanised course mesh screen should be placed over the opening.

The downpipe should be raised about 1 cm above the bottom of the gutter. Gutter and downpipes should be free of rust.

### 5. Separation

Roofs accumulate dirt and debris during dry periods between rains. The longer the dry spell the greater the amount of debris collected. Therefore, when rain falls, the initial runoff from a collecting surface should be diverted so as not to enter the storage facility. Recommendations appear to vary from between 5 - 20 minutes, for the amount of time for which this 'foul flush' should be diverted.

There are several techniques, manual and automatic, which are used for separation. Simple techniques include the following:

- (i) a movable downpipe so that it can be propped in the "waste" position, then propped in the tank inlet;
- (ii) moving the tank into position in the case of small containers; and
- (iii) in the case of tanks with a small cover, uncovering it only after the roof is clean.

Less simple methods include the diversion valve, the foul flush box, and the tipping twin funnel.

A diversion valve inside the downpipe is normally left in the waste position until sufficient rain has fallen to wash the roof. The valve is then changed by hand and the water diverted to storage.

A foul flush box or a sediment trap works on the same principle. After the container for foul flush fills up, water automatically overflows and enters the storage

## Water Supply Guidelines

tank. A drain is provided at the bottom. A modification is a baffle tank which, by incorporating a baffle crossway and/or a vertical screen, inhibits the stirring action in the case of torrential rain.

The swing or tipping funnel arrangement is a hinged, twin funnel. The first flush of rain water falls into the first compartment causing an increase in weight and, as this funnel fills, the second compartment is tilted into place above the downpipe and the remainder of the rainwater is directed into storage. Whilst both this device and the baffle tank reduce undesirable flows of suspended sediments, this one also enables rejection of an initial flush of soluble pollutants.

Other techniques include pivoting and the use of a filter box. (See Figures 31, 32 and 33).

The small investment required for diversion of the 'foul flush' will markedly improve the quality of the stored rainwater.

### 6.1.2. Design Considerations in Storage

The amount of rainwater which can be collected depends upon the average annual rainfall and the available collecting area.

One millimetre of rainfall on one square metre of roof surface will yield about 0.8 litres of water, allowing for losses due to evaporation or other causes. If, for example, the available roof area is 42 square metres and the average annual rainfall is 710 mm; the amount of rainwater which can be collected annually is equal to:

$$42 \times 710 \times 0.8 = 23856 \text{ litres}$$

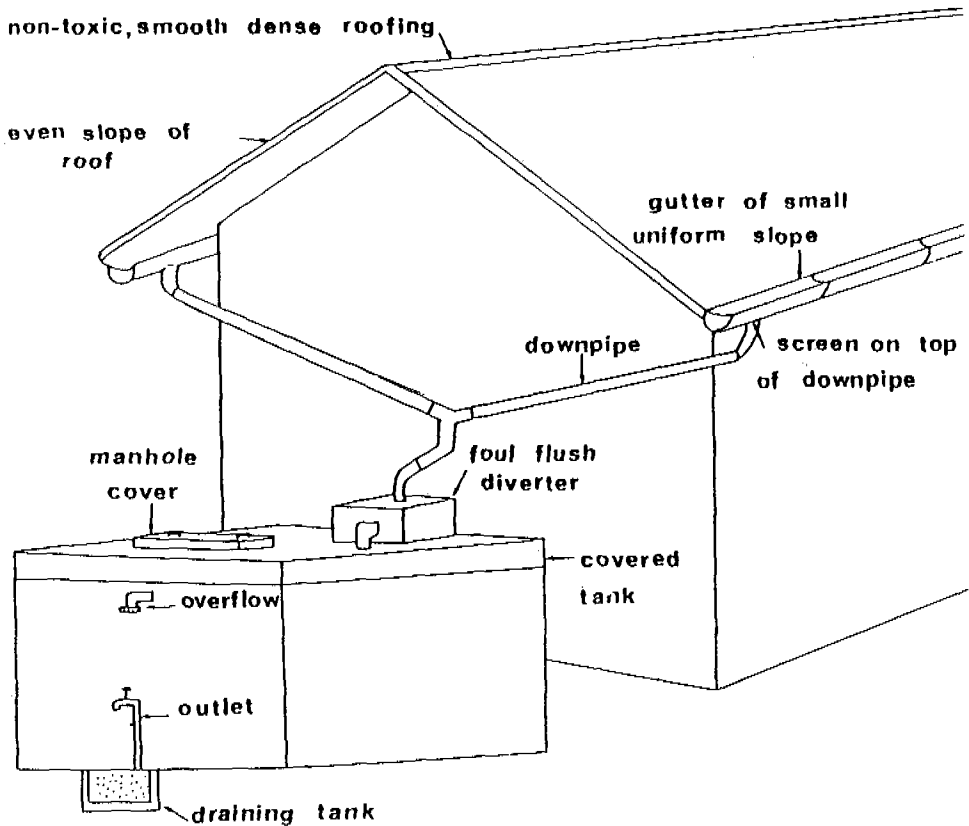
The size of cistern to be built will depend on the amount of water needed, the amount of rainfall and its distribution throughout the year, and the size of the collecting surface. Capacity in excess of that normally required (as much as 50 per cent) must be provided as a safety factor for an abnormally dry year.

The bacteriological and chemical quality of the water stored in the tank depends initially on the quality of water entering it. The water in the tank must be protected from any further possibility of contamination.

#### 1. Location and construction of storage tanks

Quality control is easier to achieve if small capacity, above-ground reservoirs are used. Construction of above-ground reservoirs prevents entry of groundwater and surface water. There is greater risk of contamination in underground tanks. These should be watertight, to eliminate possible entry of groundwater. They should extend about 200 mm to 300 mm above the ground surface since most cracks occur near the top. A watertight top (and inspection covers) prevent surface water entering the cistern.

**Figure 31. TYPICAL ROOF CATCHMENT SYSTEM**



Tanks should be watertight and located on higher ground than the surrounding area and than excreta disposal installations. They should be at least 15 m away from such installations.

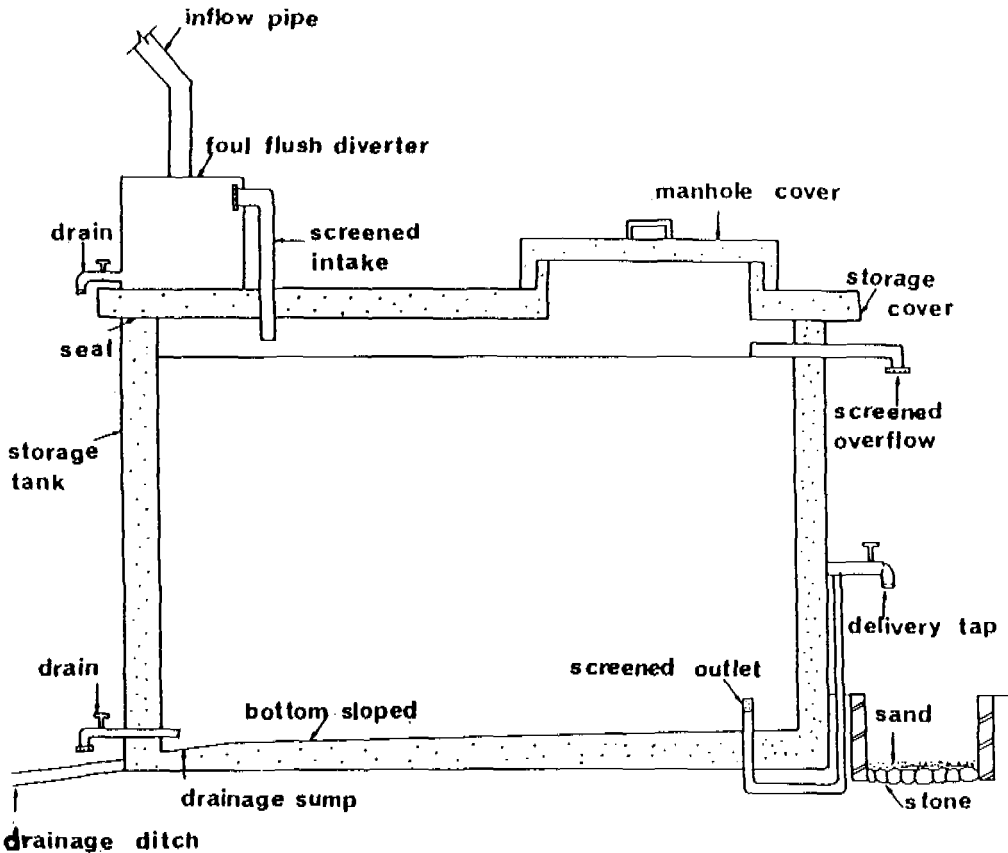
## 2. Screening and covering

The provision of a reservoir cover and screens aims at preventing the breeding of mosquitoes and other possible disease vectors, entry of polluting matter and living organisms, and algal growth induced by sunlight. One of the important factors in tank maintenance is the quality of the tank cover and screening.

## Water Supply Guidelines

The inlet and outlet openings, overflow pipe, drain pipe and any air vent of a tank should be effectively screened. A fine mesh screen strains the inflow. The overflow is fitted with a fine wire mesh or a flap-valve. The mesh should be non-corrosive.

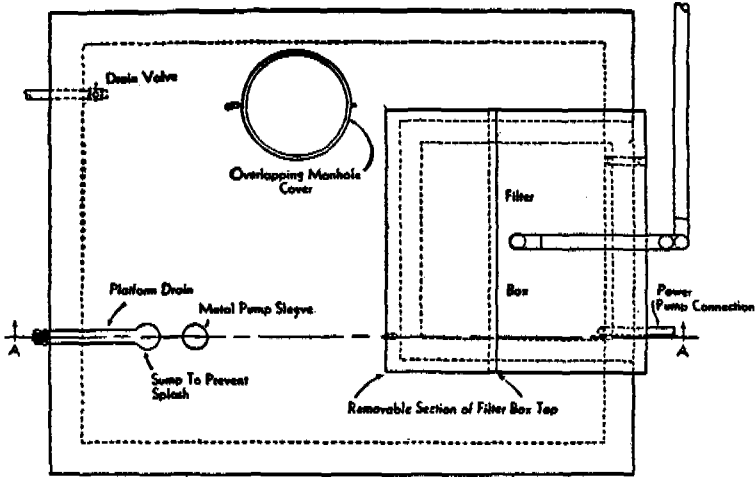
**Figure 32. SIDE-VIEW OF TYPICAL RAINWATER RESERVOIR**



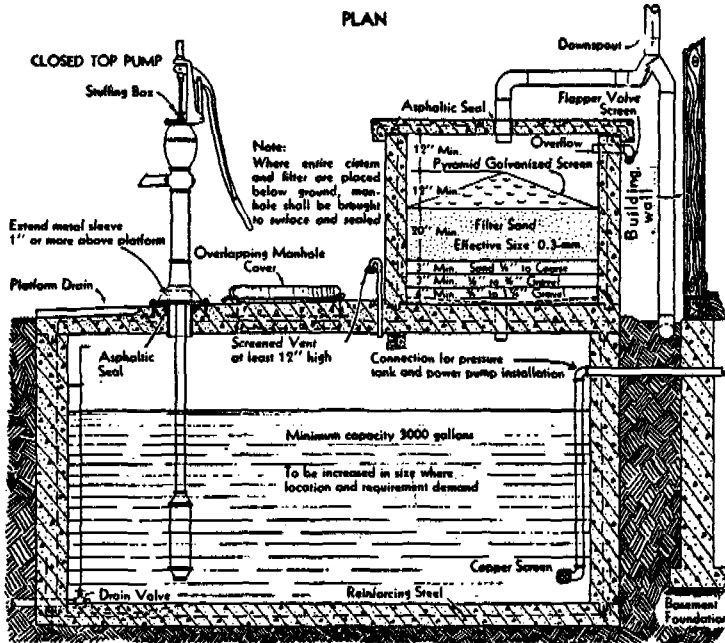
Covering a storage tank is essential for reduction of seepage and evaporation losses as well as for maintaining a high quality of water. The tank should have a tight-fitting, well-secured inspection cover. The inspection cover should be provided with a 5 cm raised concrete lip and its cover should have overhanging edges giving a "shoe box" effect. Inspection covers should be provided with locks.

# Water Supply Guidelines

## Figure 33. CISTERN WITH SAND FILTER (OPTIONAL PUMP INSTALLATION)



PLAN



SECTION A-A

## Water Supply Guidelines

Floating covers must cover the whole of the water surface and have no holes. Pollution is possible if rain can flow off the cover into the reservoir.

### 3. Retaining settled particles

A storage system should be designed to prevent settled particles from being drawn off in normal use. This may be achieved by sloping the floor slightly upwards from the inlet to the outlet which are on opposite sides of the tank and correctly positioning the outlet pipe some 5 cm above the inside tank floor. Alternative methods involve the use of a sump in the floor that captures sediment or incorporating a downward sloping overflow pipe having a free fall discharge to the ground. The inlet and outlet should be far apart in order to guarantee renewal of water.

### 4. Cool storage conditions

In tropical climates rainwater should be kept as cool as possible. Cool storage conditions can be provided by using the following methods; underground tanks because of insulation provided by the ground, although this may not be advisable for the reasons stated in 1. above; clay containers because of their porosity; tanks shaded by trees, and thickened or white painted storage tank covers.

### 5. Other requirements

No connection should be made between storage tank drains and waste, or sewer drains (lines). A drainage line is required for the disposal of overflow or wash water. Any opening or cracks around the drain should be sealed to keep out sunlight.

An overflow and/or air vent should be incorporated. If the tank is buried, a fence will be needed. Structural integrity of the tank and smooth interior surfaces are required. Water from other sources should not be mixed with the rainwater supply.

### 6.1.3. Design Considerations in Delivery

Hygienic disposal of waste water is achieved by constructing a drainage box or soakaway under the outlet tap. In addition drainage channels should be constructed under the overflow pipe, the drain and the waste pipe of the "foul flush" device. The delivery (drainage) box should remain clean and dry. It is normally provided with a drainage pipe. Plastic taps fitted into water jars help to prevent waste and are a more hygienic way of dispensing water.

Water should be pumped (manually) from underground storage. Potentially contaminating receptacles should not be introduced into the reservoir. Badly mounted and poorly designed pumps frequently permit entry of contamination. The pump intake should be located 20 to 30 cm above the reservoir floor in order to avoid disturbing the sediment.

There should be no inter-connections between the water pipes of the rainwater

## Water Supply Guidelines

storage tank and any other drinking water source, regardless of valves. As with all water which is transported into the home, however short the distance, there remains a risk of recontamination in the household.

### 6.1.4. Maintenance for Quality Control

In addition to preventive measures in construction, the system requires regular inspection and maintenance. The whole system (catchments, gutters, tanks, pipes, screens and vents) should be cleaned and kept in good repair especially at the end of the dry season. Gutters and pipes, especially, must be frequently cleaned to prevent clogging and contamination. A possibility is to use water from the first rain to clean roofs and flush the piping.

A newly-built or repaired cistern should always be disinfected with a 50 mg/l chlorine solution. The cistern walls (and filter) should be thoroughly washed with this strong solution and then rinsed.

### 6.1.5. Water Treatment

Some treatment of collected rainwater may be needed. Water treatment methods may include sedimentation (in storage), filtration, disinfection, coagulation using local plants and natural products. These methods may be used singly or in combination.

The sedimentation process in storage is inherent to the system. The settling of particles from the stored water will be more effective the longer that water is kept in the storage tank.

Filtration techniques, which should never be depended upon to produce bacteriologically safe water, include the following:

1. household filters;
2. pre-filtration (i.e. between catchment and storage);
3. a filtering chamber as part of the storage tank which is either pre-filtration or filtration during the withdrawal of water from storage;
4. a continuous slow sand filter between the storage reservoir and a small clear-water reservoir which is used for consumption for one or two days.

For ground catchments (using storage tanks of polythene layers or sand-cement polythene bags) a filter bed may be incorporated before storage and before withdrawal of water.

Disinfection techniques that may be used in rainwater harvesting schemes are:

1. pot chlorination;
2. disinfectant tablets;
3. application of dosage of chlorine or iodine; and



## Water Supply Guidelines

4. boiling which, often, is not a viable alternative due to the scarcity and expense of fuel.

Rainwater harvested through adequate catchment provisions and stored under safe conditions often does not require any treatment to be suitable for domestic water supply. Simple disinfection can be used as a safety precaution. When pollution has occurred under exceptional circumstances, filtration may be used followed by disinfection.

## 6.2. Drainage Basins and Catchment Areas

### 6.2.1. Rock and Soil Catchment Areas

Rock and soil catchment areas are sometimes used like roofs to collect rain-water which is led into storage tanks by means of trenches or drainage pipes. Water gathered in this manner serves mainly for irrigation and stock-watering. However, if given adequate treatment and disinfection, it may be suitable for domestic consumption. In the latter case, the quality of the water should be protected by taking measures to prevent pollution, such as fencing the area. In the case of soil catchment surfaces, measures such as vegetative covering, should be taken against erosion to reduce the turbidity of the water.

### 6.2.2. Reduction of Rain-water Infiltration into the Soil

In arid climates it is often desirable to maximize the amount of surface runoff in order to collect it for human or animal use.

An important way of reducing infiltration is to reduce the amount of time which water needs to flow on the soil surface to a stream, tank, or reservoir, by providing steep slopes and adequate collection channels.

This system has been used effectively for a long time in many countries on all continents. In Malta for example, many houses and storage reservoirs are supplied by surface runoff collected from roofs, roads, streets, and other built up areas. Some form of vegetation must be maintained on the sloped collection surface or it must be hardened by some other means in order to avoid erosion. Runoff from land covered by grass is greater than that from forest or brush covered land. The grass creates a thinner humus layer so water is less likely to infiltrate. The grass also intercepts less water before it reaches the soil.

Infiltration can also be reduced by application of chemicals to seal the surface. Petroleum products may be applied to a surface to bind particles of soil together and render the surface impermeable to water. Petroleum oils have been tried as surface sealants but tend to wash away. They are not recommended as soil treatments. Paraffin wax gives good results.

## Water Supply Guidelines

Flexible sheets of non-porous material may be used to cover the ground to prevent infiltration. Sheets of plastic such as polyethylene have been tried, but they quickly deteriorate as a result of sun and wind effects. Aluminium foil pressed onto an asphalt base has been successful in some cases. The asphalt provides physical support to the foil, which protects the asphalt from weathering deterioration.

The best flexible surface covering appears to be butyl rubber made into a sheet of about 1.5 mm thickness, usually with a nylon mesh reinforcement laminated inside to provide additional strength. The rubber sheet may be laid over soil without much surface preparation. The rubber forms a smooth surface over which water flows freely, resulting in nearly 100 per cent rain recovery.

The most durable surface treatments are hard coatings. Concrete may be poured to form an optimally shaped rainwater collection surface whose lifetime is virtually unlimited. The initial cost is the highest of all surface coatings making it impractical for most applications. It is important to consider the value of existing hard surfaces such as highways and rooftops, and incorporate water recovery features into their design.

### 6.2.3. Haffirs

Haffirs are reservoirs which are formed in the basin of a natural catchment at the lowest ground level. Some of them can be dug out into the ground to expand their volume. Whilst a valley needs a dam to be able to hold a water reservoir, a haffir may create a reservoir in any place where the catchment is sloping towards it. When bunds, a type of large earthen wall, and earth dams are built, digging is done only to provide dirt for the dam and to prevent swamps from forming at shallow edges of the reservoir. For improvement of storage, the whole centre of a haffir can be dug out.

Haffirs are commonly used in the Middle East. They have also been constructed for rainwater harvesting in Ethiopia and Sudan. In southern Sudan, the vast southern plains are poorly drained, as the ground has only a slight gradient. This results in over land flooding during the rainy season with a "creeping flow" of water across the region. Water flows into the haffirs from the creeping flow and provides a supply of water throughout the dry season.

These haffirs are built by digging out a low area and heaping the dug out dirt on the down slope to form a large bund, as shown in Figure 34. The dirt piled up along the sides serves as a three sided bund to hold the water, and the shaded, excavated area provides an additional sink basin for water volume. Reservoirs which are built like this with elevated earthen banks are also used in India and are called "ahars", as shown in Figure 35.

Ahars are constructed by extending a narrow haffir for a long distance across contour lines. Since the ground on which they are built may have a very mild gradient, e.g. a 10 cm fall in 1 km, the bunds sometime have to be built with turns, to

## Water Supply Guidelines

cross contour lines and increase the volume. During heavy rains, rainwater flowing from above the structure is channelled into the ahar, and vast areas of land can be flooded in the structure. This water can then be stored for use during the dry season.

Ahars are often built in series, with drainage pipes between them. If water in one ahar is too high, it can be released directly to another. In addition, the sediments deposited in an ahar are very fertile. Thus, the first one can be drained into the second, and the land in the first used for agriculture while the second stores the water.

When the water in a haffir or ahar is to be used by both livestock and humans, special precautions are recommended. The water which is to be used by humans should be treated and cleaned first, especially if the animals drink directly from the reservoir. Some improvement in getting clean water may be done by filling a part of the haffir with a sand wall to create a storage tank, into which a well for drawing off drinking water can be installed.

Haffirs and ahars must not be used for washing and bathing or they will become polluted, and potential spreaders of epidemics. If they are so used they may harbour pathogenic bacteria, viruses and parasites which account for illnesses and deaths, particularly amongst children.

### 6.2.4. Ponds and Reservoirs

Ponds and reservoirs may provide an abundant supply of water for use in rural and urban areas. This is particularly the case when they are designed for this purpose. Surface water from a small upland stream or spring can sometimes be accumulated in a location which is topographically and geologically suitable. Such an area should be a saucer shape, and the soil should be able to hold water. The nature of the soil can be determined by means of borings or test holes. Heavy clay soils, silt clays, and clay loams are among the best formations for holding water. The presence of porous layers near the ground surface or of faulty rocks should be carefully investigated by a competent geologist.

The quality of water from ponds and reservoirs may be such as to require little treatment, provided certain sanitary precautions are carefully observed. These include strict measures to protect the watershed of inflowing streams from human and animal pollution and from erosion, and to exclude livestock, campers and swimmers from the watershed and reservoir area by fencing it. Measures should also be taken at the time of construction to clear the submerged area of all vegetation and decaying matter and to provide ample storage capacity and area for self-purification processes to occur.

Care should be taken to avoid creating suitable breeding places in ponds and open reservoirs for both nuisance and disease-carrying mosquitoes and for bilharziasis-carrying snails. Schemes of this sort should not be undertaken without

## Water Supply Guidelines

previous clearance with local health authorities.

In designing the capacity of such reservoirs, ample provision should be made for losses of water by evaporation and by leakage. Depending upon the air temperature, humidity and wind velocity in the area concerned, annual losses by evaporation alone may be as high as 178 cm. Provision should also be made for de-silting facilities through periodic flushing of the reservoirs. It is recommended that the depth of water in a small reservoir at the deeper end should be not less than 1.8 m.

The water may be full of silt or colloidal matter, especially immediately after the rains. Some village ponds have been in existence for centuries; they may be full of aquatic vegetation. Some have all sorts of waste dumped in them. Others are well kept, beautiful in appearance, and a distinctive feature of the landscape.

In practice, it is impossible to prevent the pollution of these small reservoirs and village ponds. By their very nature they are at the lowest point of the surrounding area and all the village drainage finds its way into them. Consumers should be advised to boil or filter and disinfect the water for drinking.

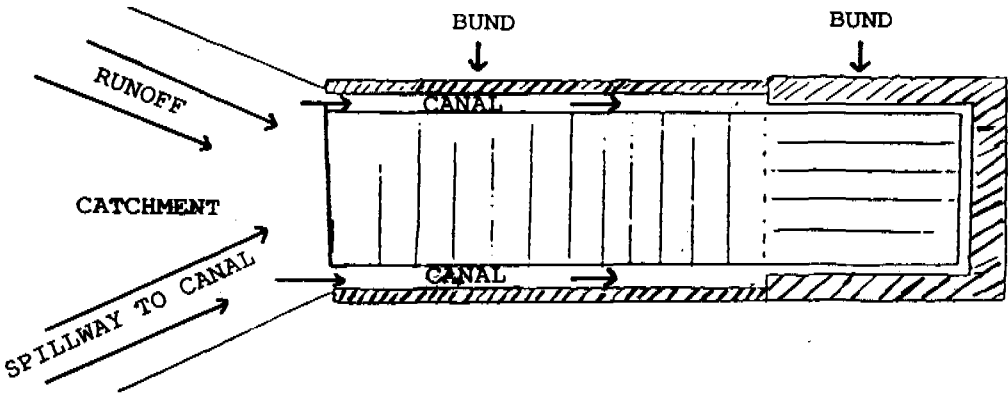
### 6.2.5. Evaporation Collection

Evaporation collection of water is an innovative way of catching water. A hole, as shown in Figure 36, is dug into the ground and covered with plastic sheeting. The plastic is weighted down so that it has a low point in the middle. During the day the sun will cause evaporated moisture to condense on the plastic, trickle down and drip into a collection pot. This water, though limited in volume, is very pure.

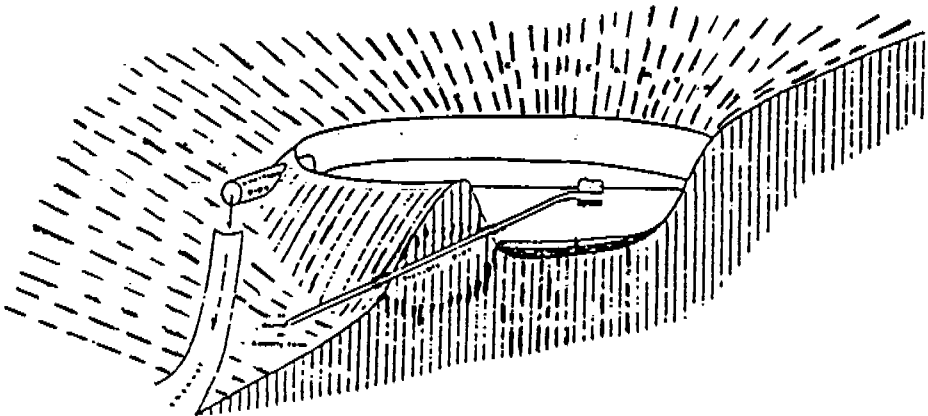
### 6.3. Small Dams

When a dam is required to impound water, the most suitable location for such a reservoir will be one that will hold the maximum amount of water with the smallest dam. Sometimes the construction of a low dam, i.e. a dam whose spillway crest is less than 9 m above the natural stream channel, is sufficient to provide enough water-storage capacity for all uses, agricultural as well as domestic, and to permit delivery of water by gravity at the same time. However, determination of the dam site requires considerable topographical and geological studies even for a small earth structure if failures are to be avoided. One of the most common failures is the inability of the dam or the reservoir site to hold the water, which escapes through porous or fissured formations and/or through the dam itself. Overtopping of earth dams due to unexpected and heavy run-off is also a frequent cause of failure of small water storage projects.

**Figure 34. A HAFFIR WITH BUND WALLS**



**Figure 35. A HILL SIDE AHAR**

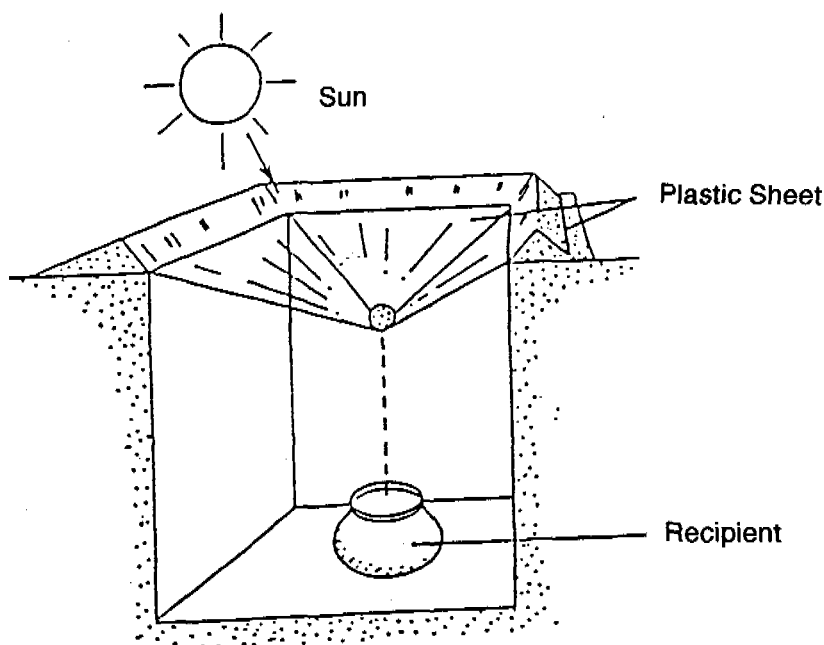


The average sanitarian or engineer rarely has sufficient knowledge or experience to undertake singlehandedly the investigations needed before the design of such projects. The collaboration of an engineer competent in this field is required for examining the porosity, texture and composition of the rock formations for assisting

## Water Supply Guidelines

in the determination of the best location and the most suitable type of dam for the foundations available and finally, for selecting the materials which will be used to construct the earth dam if it is decided to build this particular type of structure. The design and construction of dams, large or small, is a highly specialised task which should not be undertaken by unqualified personnel.

**Figure 36. EVAPORATIVE COLLECTION OF WATER**



### 6.4. Rivers

For small water supply systems, the use of river water should be avoided where possible, because of the necessity for thorough treatment and disinfection to make such water fit for human consumption. River water may be easily contaminated by disease-carriers and by human and animal wastes. Its quality should always be questioned since it is virtually impossible to observe complete sanitary control over the entire watershed. Furthermore, self-purification processes cannot be depended upon to make river water bacteriologically safe. Whenever possible, river intakes should be built upstream of inhabited communities.

## Water Supply Guidelines

The intake may consist of a submerged pipeline used with a submerged crib or a screened bellmouth at the open end. It should be placed well below the water surface since the water is cooler at a greater depth and, also, because of ice formation in cold climates. Sub-surface abstraction also restricts ingress of floating materials. The intake should not be close to the river bottom, in order to avoid disturbing sediment and suspended matter. The intake should also be located some distance from the shore and should be large enough for entrance velocities to be kept to a minimum, preferably less than 15 cm per second. Figure 37 shows a simple intake structure for small water supply systems from rivers or lakes.

Intakes from small streams frequently require the construction of small diversion dams. In this manner, provision can be made for a sufficient depth of water at all times above the intake pipe; for the settling of suspended matter, thereby reducing the turbidity of the water; and for keeping floating leaves and other debris from obstructing the intake structures. Depending upon circumstances such as the depth of water in the river, location and degree of permanency of the structure, a floating intake made of empty oil drums held in place by a suitable frame and supporting a flexible inlet hose may be used. Intakes should always be designed to function with a minimum of attendance. Figures 38 to 42 show different types of intake structures.

The amount of water which can be obtained from a small stream without the construction of a storage reservoir is governed by the rate of minimum flow both per day and per year. The flow of a small stream, i.e. a stream less than 61 cm deep and not more than 15 m wide, may be measured by means of the rectangular weir. With such a device, daily or weekly observations may be made of the flow throughout the year. These data may be correlated with the records of rainfall collected simultaneously. It may be difficult to set a dam across a larger stream and to prevent leakage around its edges. But, in many instances, great accuracy is not required. The following formula may be used for computing the discharge:

$$Q = 3.33 b H^{3/2} \text{ where}$$

Q = discharge, in cubic feet per second (see conversion table)

b = length of weir, in feet, and

H = head over crest of weir, in feet.

For smaller streams, the flow may be measured by means of a V-notch weir. Daily or weekly measurements should be made over at least one year in order to gather a fair knowledge of the variations of flow in the stream.

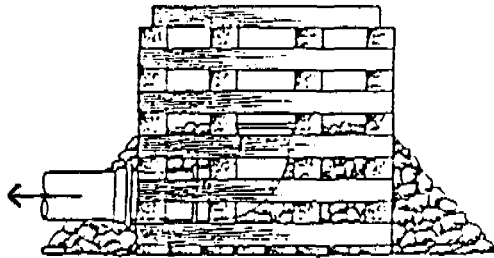
For large rivers, it is necessary to measure the cross-section of the stream at a fixed station and its mean velocity using floats or current meters in order to calculate

## Water Supply Guidelines

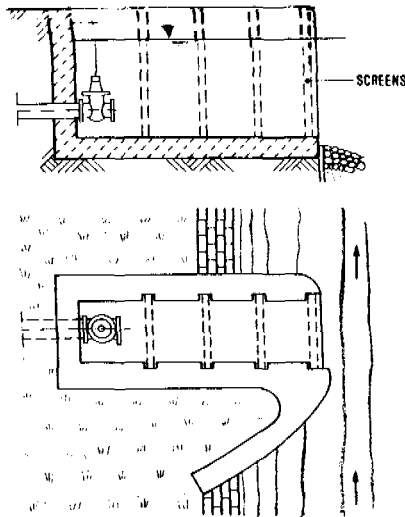
the discharge. These measurements are beyond the scope of this manual, being generally used for large hydraulic projects.

There have been a number of very successful applications of a gravel bed filter as a combined abstraction/preliminary treatment. In essence, water flows across the surface of a shallow, e.g. 40 cm bed of gravel.

**Figure 37. SMALL INTAKE STRUCTURE**

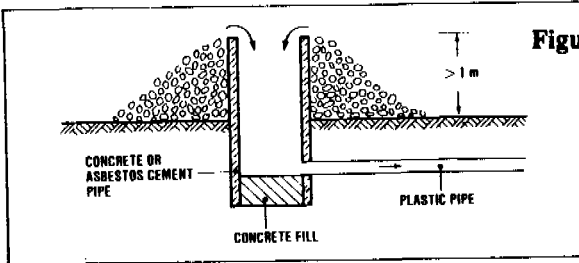
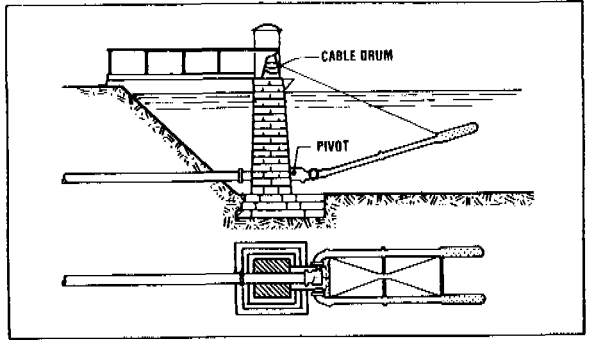


**Figure 38. RIVER INTAKE STRUCTURE**



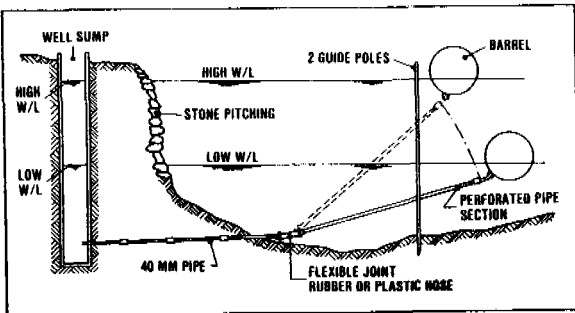
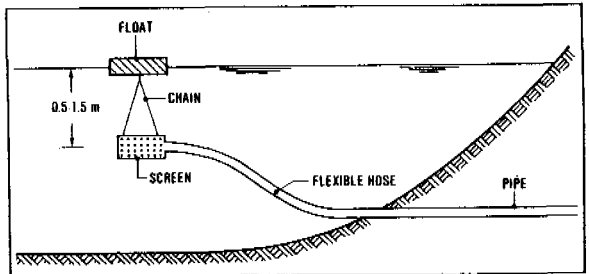


**Figure 39. VARIABLE DEPTH LAKE WATER INTAKE**



**Figure 40. INTAKE STRUCTURE AT BOTTOM OF SHALLOW LAKE**

**Figure 41. SIMPLE WATER INTAKE STRUCTURE**



**Figure 42. FLOAT INTAKE**

## Water Supply Guidelines

Below the gravel bed a network of perforated collection pipes abstracts some of the water which has been filtered down through the gravel pack. Vertical (down-flow) rates may be quite high (such as up to 1.0 metre/hour).

This system is particularly useful for reducing peaks of turbidity. Because of the shallow gravel pack and high flow rates, construction costs are low. Cleaning is straightforward and is undertaken by closing the outlet, raking the gravel bed so as to dislodge accumulated solids (which are washed away in the cross-surface flow) and finally reinstating abstraction.

## 7. WATER TREATMENT PROCESSES

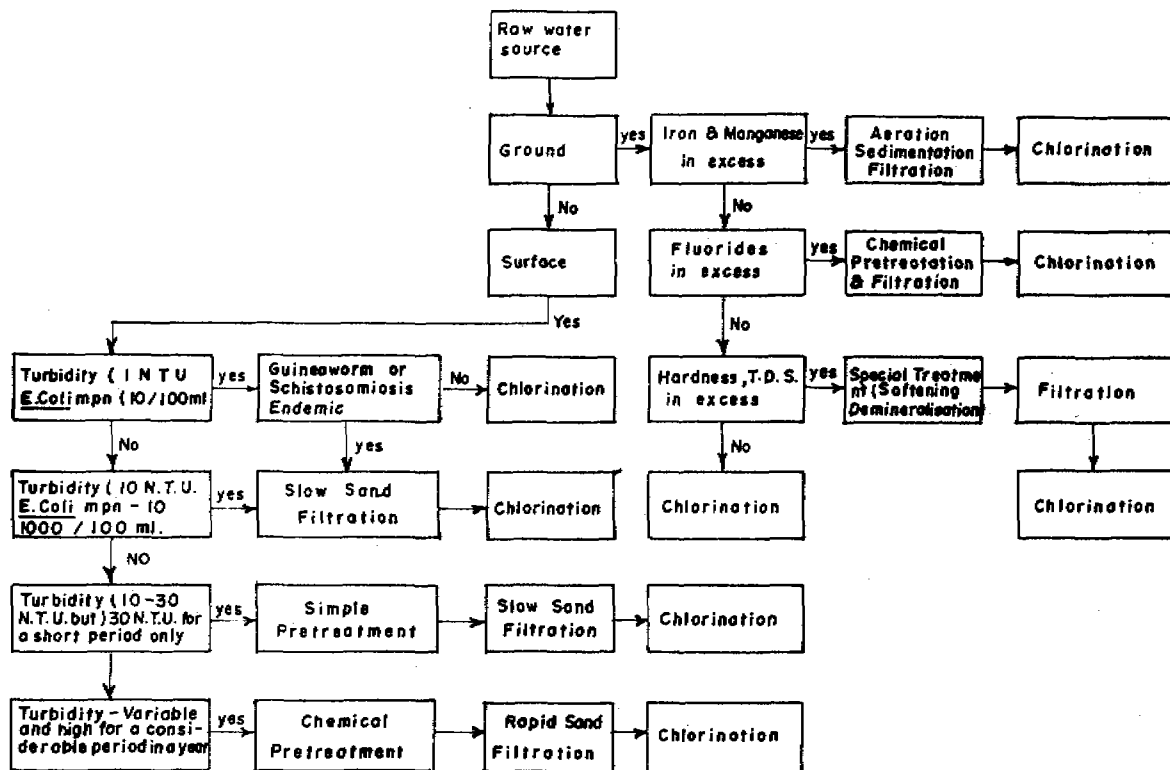
### 7.1. Purpose and Scope

Surface water may contain pathogenic (disease-producing) organisms, suspended matter, or organic substances. Except in limestone areas, groundwater is much less likely to have pathogenic organisms than surface water, but it may contain iron and manganese which impart undesirable tastes and odours, or other mineral impurities limiting its acceptability. Spring water from limestone strata often contains an excessive amount of carbon dioxide which may corrode concrete and metal pipes. In addition, the source itself may be subject to outside contamination. Other characteristics, such as hardness and total dissolved solids, are less important in small community water supplies. They may be reduced to acceptable levels when economic and technical considerations permit. In brief, appropriate treatment may be necessary to render the water supply bacteriologically safe and chemically acceptable.

Modern technology provides a choice of treatment methods to produce water of desired quality from any given source (see Figure 43), the limiting factor being cost. Ideally, the quality of water supplied to small or rural communities should not be inferior to that of water supplied to large or urban communities. However, in rural areas of developing countries, it may be necessary to accept a water quality somewhat lower than the standards, provided the bacteriological quality is safe.

As pointed out above, water systems for small communities should be designed around the need for safeguarding the quality of the natural water selected. It should be the policy of the responsible control agency to restrict the use of water treatment under rural conditions to those cases where such treatment is essential and where proper plant operation and maintenance can be secured and supervised. Experience in many parts of the world has shown that, once a water-treatment plant is constructed, there is need for constant vigilance on the part of the plant operators and control agencies if the plant is to routinely produce water suitable for human consumption. Both present and past literature abounds with the history of water-borne outbreaks of typhoid fevers, cholera, and epidemic jaundice caused by a breakdown of treatment processes (chlorination, for example) for which inexperienced or unqualified operators were responsible.

Figure 43. SELECTION OF A WATER TREATMENT SYSTEM



### 7.2. Treatment Systems

1. When ground and surface water sources are well protected, where faecal contamination is known to be low-level or zero, where turbidity is less than 5 NTU, and water is free from taste, odour and colour problems, plain chlorination alone should be adequate before supply (see Figure 44.a).
2. When groundwater contains excess iron and manganese, dissolved carbon-dioxide and odorous gases, aeration followed by slow sand filtration and chlorination should be sufficient (see Figure 44.b). Alternatively, a more expensive option requiring considerable operation and maintenance skills on the part of the operators would be aeration, followed by flocculation (rapid and slow mixing), sedimentation and rapid sand filtration.
3. When groundwater is very hard and contains high levels of total dissolved solids (TDS) such that consumers will reject the water, special treatment such as softening or demineralisation may be necessary (see Figure 44.c). This should only be considered in extreme cases, as it is expensive.
4. In areas where surface waters have low turbidity (1 NTU), but where there is a prevalence of guinea worms and schistosomiasis, or when turbidity is raised, but normally below 30 NTU, slow sand filtration and chlorination will generally be adequate (see Figure 44.d).
5. When surface waters have a turbidity which fluctuates considerably or exceeds 30 NTU even for short periods during the year, simple pre-treatment, such as plain sedimentation, pre-filtration or storage followed by slow sand filtration and chlorination will generally be adequate (see Figure 44.e).

Conventional treatment including pre-chlorination (optional), aeration, chemical coagulation-flocculation, sedimentation, followed by rapid sand filtration and post chlorination, could also be employed for water of poor quality. However, it is not generally recommendable for small community water supplies and should only be used in special circumstances; for example it may be considered appropriate for certain peri-urban fringe settlements (see Figure 44.f).

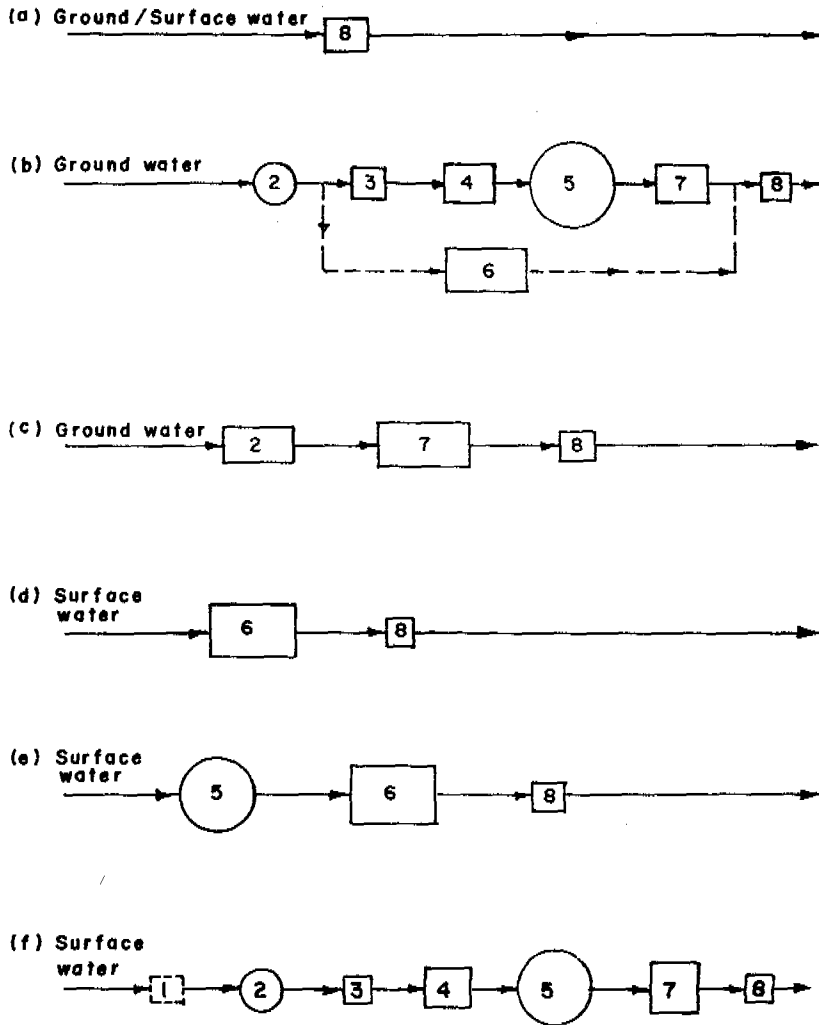
### 7.3. Appropriate Treatment Processes

#### 7.3.1. Storage

Preliminary storage in a reservoir helps to guarantee a continuous supply of water and provides an economical means of sedimenting out some of the suspended particulate material. In areas affected by schistosomiasis, protected storage for a minimum period of 48 hours provides a degree of safety since the cercariae are unable to infect a host and will die. Other organisms may be reduced in numbers by the same method, though storage times in excess of a week are necessary to produce significant reductions of many microorganisms.

## Water Supply Guidelines

**Figure 44. WATER TREATMENT SYSTEMS**



1. Pre-chlorination
3. Rapid Mixing
5. Sedimentation
7. Rapid Sand Filtration
9. Softening

2. Aeration
4. Flocculation
6. Slow Sand Filtration
8. Post-chlorination

## Water Supply Guidelines

Simple holding of water in a reservoir will reduce the total number of bacteria originally present, because they die off faster than they reproduce. This is especially true of pathogens which do not usually find a suitable environment for growth in water. The more adverse the conditions are for bacterial growth, the more rapid will be the reduction in bacterial numbers, e.g. in waters with low pH. The following data are examples of bacterial reduction by means of plain sedimentation alone:

Holding time (days)	Bacterial reduction (%)
3.3-15	49-97
30	93
6	87

Prolonged storage in uncovered reservoirs can, however, encourage algal growths and/or mosquito breeding. Open storage of water provides an opportunity for algae to grow and develop. This may become a serious problem. Algae grow on nutrients such as soluble nitrogen, phosphorus, potash, and some other compounds found in surface water. The greater the quantity of these materials, the larger will be the growth of algae. However, a small amount of nutrient is enough to support growth.

A holding reservoir which stores enough water for several days or weeks can be a highly economical and advantageous means of providing both preliminary treatment and storage. It should be carefully considered wherever it can be used. In many rural areas simple holding of water will be sufficient treatment to provide a reasonably safe supply. Instead of adding more treatment facilities, the engineer and technician should aim at achieving greater public health benefit by using available funds to effect a wider distribution of reservoir water.

### 7.3.2. Sedimentation

Surface water such as that of rivers and streams contains sand, grit, silt and other suspended solids which can damage pumps, clog filters and pipes and reduce the effectiveness of disinfection. Sedimentation is the settling and removal of these suspended solids which takes place when water flows slowly through a large tank. Due to the velocity of flow, particles having a mass density (specific weight) higher than that of the water will settle at the bottom of the tank forming a sludge layer. The water reaching the tank outlet will be clarified.

The efficiency of sedimentation in the reduction of turbidity is dependent on the nature of the suspended material and the settling time allowed. Before a decision is reached regarding the use of this treatment process, it is necessary to study the nature and characteristics of the suspended matter in the raw water. Reduction of turbidities

## Water Supply Guidelines

caused by fine clay or colloidal matter may be impractical because of the considerable time required, unless a chemical coagulant, such as aluminium sulphate, is used. Coarse material and silt are often present in surface water, for example, as a result of watershed erosion after heavy rainfalls or floods. The turbidity caused by such materials may often be quickly and efficiently removed by plain sedimentation in a sedimentor of suitable capacity.

It is therefore necessary, at the time of field investigations and sanitary surveys, to collect as much information as possible on this aspect of surface water sources. Turbidity measurements at various seasons of the year and under different conditions of stream flow are very useful.

Efficiency is enhanced if the arrangement of inlet and outlet structures maximise the retention time of the water in the tank. Depending on local situations, plain holding and sedimentation may accomplish considerable bacterial reduction. It is important, however, to locate, through a sanitary survey, the possible sources of contamination on the drainage area. When such contamination is not of human origin, the health hazards are considerably reduced.

Any reservoir or tank constructed for the primary purpose of accomplishing sedimentation provides at the same time for storage. This is an important consideration. Ample storage helps to guarantee a continuous supply of water. Thus, for example, a substantial reservoir can serve a double purpose. Short periods of plain sedimentation are not very effective in reducing colour.

Where sedimentation without subsequent filtration is practised, the basins are ordinarily constructed as large storage reservoirs which provide from one to several days of sedimentation before the water is drawn out for use.

Where sedimentation tanks are employed in conjunction with slow sand filters, their purpose is to remove turbidity to the point where the water can be handled satisfactorily by the filters. The present trend is to provide a retention period of not less than 4 hours. When sedimentation basins are designed for clarification of river water (plain sedimentation), the design surface loading rates generally adopted are:

For gritty particles of specific gravity 2.65:-

12 to 160 m<sup>3</sup>/day/m<sup>2</sup> (depending on size of particles).

For amorphous slow settling solids:-

32 to 80 m<sup>3</sup>/day/m<sup>2</sup>.

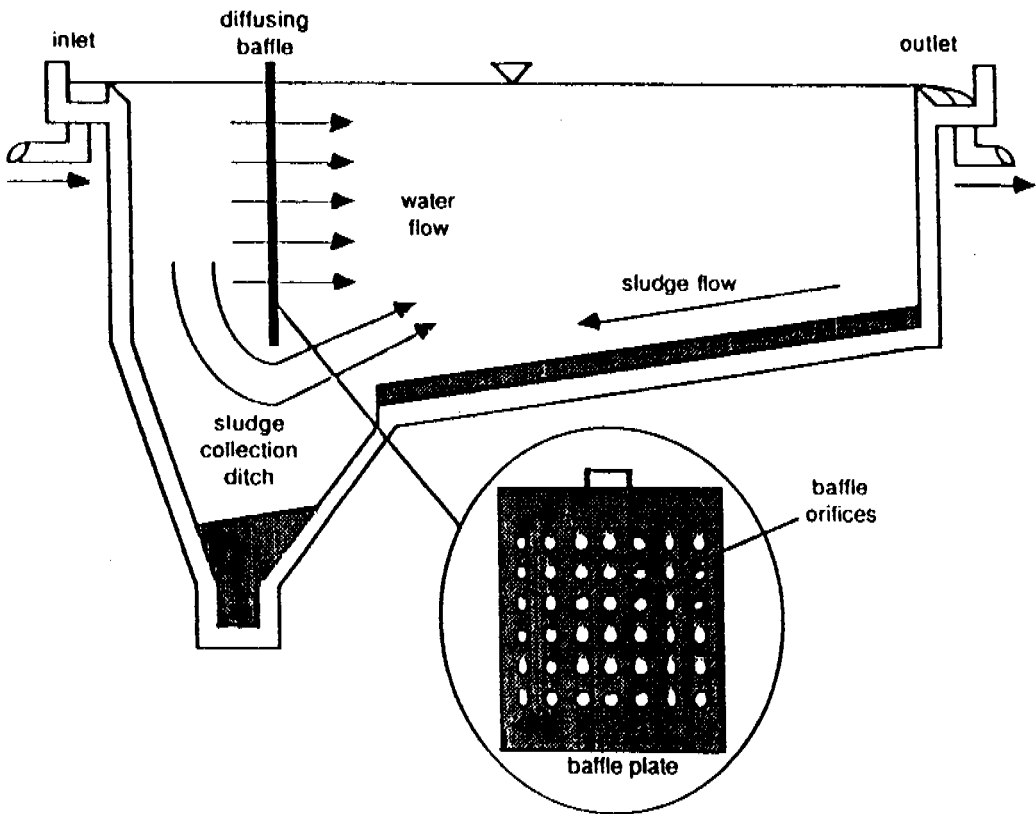
Flow is usually horizontal, where water moves from one end to the other, but many clarifiers are square or circular tanks incorporating upward flow with decreas-



ing velocity, where water enters at the bottom and flows over a weir at the tank edge (see Figure 45).

In horizontal-flow sedimentation tanks the inlet should be arranged so that the incoming water containing suspended matter flows to the outlet uniformly across the entire width of the tank and ensure that there are no dead areas in the depth of the tank.

**Figure 45. RECTANGULAR HORIZONTAL FLOW SEDIMENTATION TANK**



**Improved Sedimentation Tank**

## Water Supply Guidelines

Baffles are usually constructed to reduce high incoming velocities and to prevent short-circuiting of the water. The cleaning and repair of the tank can be facilitated if the tank is designed with two parallel separated sections, each of which may be operated independently. In small water works, the units may be of the hopper bottom, pyramidal type, since they do not require sludge scrapers, and sludge can be disposed off manually.

### 7.3.3. Pre-filtration

In small treatment plants where the turbidity of source waters is high, i.e. exceeds 30 NTU, or subject to fluctuations, pre-filtration with gravel or other coarse material before sand filtration provides an effective means of preventing rapid blocking of the sand filters. A typical pre-filter comprises a box divided into several compartments filled sequentially with material of sizes graded from very coarse, e.g. 50mm pebbles, down to fine gravel of 6 - 10 mm diameter.

Raw water is passed vertically or horizontally through the different compartments and is then collected in an outlet chamber (see Figure 46). Recent experience indicates that vertical, upflow filters are the most efficient means of pre-filtration.

Gravel pre-filters require a moderate area, but clogging will take place only slowly. In well operated pre-filters significant reductions are obtained in both suspended solids and microorganisms.

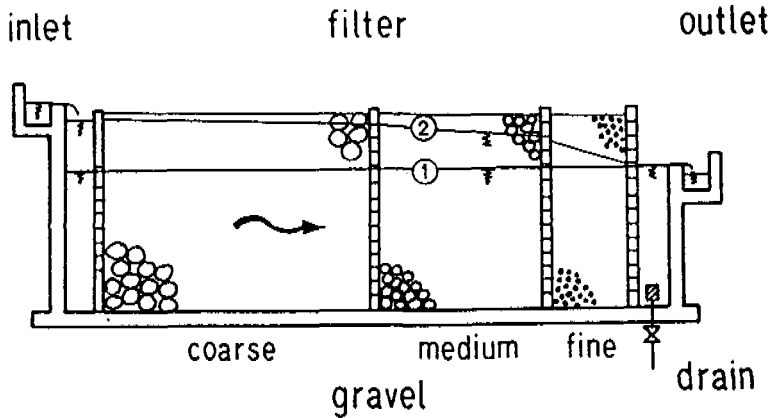
### 7.3.4. Slow Sand filtration

Slow sand filtration significantly improves the physical, chemical and microbiological quality of water.

Slow sand filtration is the process of removing suspended matter from the water as it slowly passes through a bed of sand. The degree of removal depends on the character and size of the filter sand, the thickness of the bed, and the size and quantity of the suspended particles.

The most important processes involved in removing impurities during slow sand filtration are biological. Most particulate matter is retained in the top few centimetres of the sand bed which is termed the "schmutzdecke". Here, scavenging organisms also feed on the microorganisms trapped in the films surrounding the sand grains. Because of the biological nature of slow sand filtration, new filters or recently cleaned filters require a maturation period of several days (or weeks, in cold weather) before full efficiency is obtained.

**Figure 46. TYPICAL PRE-FILTRATION SYSTEM BASED ON THREE STAGE HORIZONTAL FLOW GRAVEL FILTRATION**



**A. Use and limitations:**

Because it is reliable and inexpensive slow sand filtration has particularly useful applications in small community water supplies, and is preferable to rapid sand filtration. Slow sand filters yield water of excellent quality; their operation is very simple and requires a minimum of skills and of maintenance. Moreover, their operating costs are lower than those of rapid sand filters and local material can be used for their construction. A well-designed, well-constructed and well-operated slow sand filter can achieve a reduction of faecal bacteria of 95 to 99 per cent, and of turbidity from 30 NTU down to as low as 1 NTU. The only limiting factor for this system is that the turbidity of the raw water to be treated must not exceed 30 NTU, and should generally be less than 20 NTU. The large space required for the construction of a slow sand filter is regarded as one of its limitations. This could be discounted, as land can usually be obtained at low cost in rural areas.

In some areas, large ponds, lakes, or reservoirs may be used for storage and for preliminary sedimentation purposes, The turbidity of the impounded water may be low, permitting the water to be used as a source of supply after slow sand filtration only.

If turbidity exceeds allowable limits for slow sand filtration then, depending on the usual range of turbidity, plain sedimentation and/or pre-filtration will be necessary as pre-treatment:

Plain sedimentation is necessary if turbidity is in the range of 100 to 200 NTU.

## Water Supply Guidelines

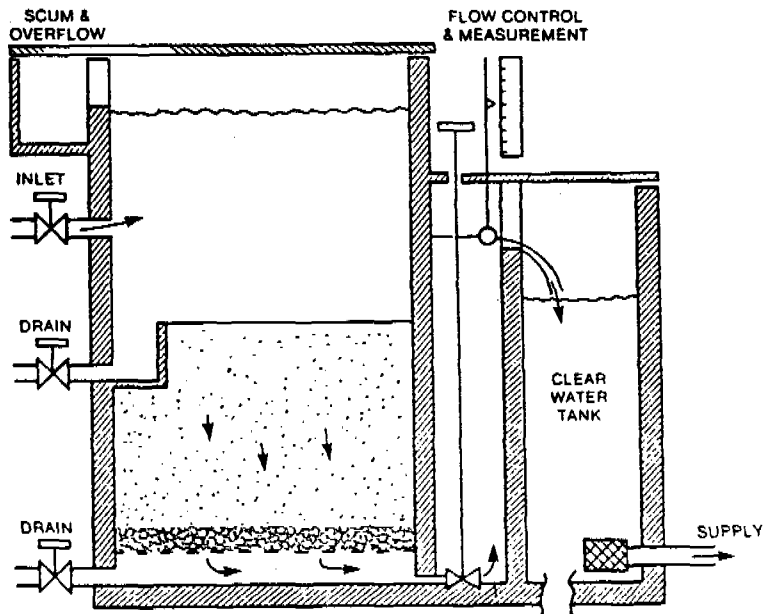
Pre-filtration is needed if turbidity after sedimentation or otherwise is in the range of 30 to 100 NTU.

### B. Components of a slow sand filter:

A slow sand filter, as shown in Figure 47, consists of:

1. An under-drainage system, through which the filtered water is conveyed to a sump or clear water storage tank, ideally for disinfection prior to being piped to the consumers.
2. A bed of filter sand, within and upon which, various purification processes take place.

**Fig. 47 TYPICAL DESIGN OF A SLOW SAND FILTER  
SUITABLE FOR A SMALL COMMUNITY**



## Water Supply Guidelines

3. A minimum head device (as shown in Figure 47) for ensuring that the filter bed never dries out. The head of water above the filter bed will provide pressure for the water to percolate through the filter.
4. A system of control valves to regulate desired velocities and water level, to ensure optimal operating conditions.

### C. Criteria and considerations for the design/development of a slow sand filter.

1. Raw water: turbidity should be less than 30 NTU for the water applied to the filter. Higher turbidities can be filtered for short periods. Average turbidity should be less than 10 NTU for economical and long filter runs.
2. Filter loadings: the design filtration rate should be about  $2.4 \text{ m}^3/\text{m}^2/\text{day}$  (0.1 m/hr), depending on the turbidity, the filter sand, and desired end product. The lower the rate of filtration, the more effective will be the treatment. The maximum allowable rate is  $4.8 \text{ m}^3/\text{m}^2/\text{day}$  (0.2 m/hr).
3. Filter sand: should be uniform, with a uniformity coefficient between 2 and 3, and should be free of organic matter. The effective size should be 0.2-0.3 mm. The finer the filter sand, the more efficient will be its filtering action but the quicker it will clog, thus increasing operational costs. Good results have been obtained with a somewhat coarser sand (0.3 mm) and higher loadings. This reduces the filter size and operational cost. With generally clear water, free of pollution, high filtration rates greater than 0.1 m/hr but less than 0.2 m/hr (maximum loading rate) are well justified.
4. Filter bed: about 1 metre (initial depth) of sand supported on 30 cm of graded, coarse sand and round gravel.

The supporting gravel bed should consist of:

- 6 cm of coarse sand, 0.7-1.4 mm size.
- 6 cm of gravel, 2-4 mm size
- 6 cm of gravel, 6-12 mm size
- 12 cm of gravel or broken stone, 18-36 mm size.

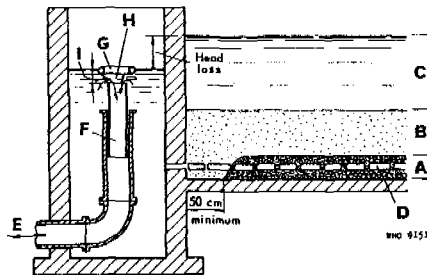
The filter bed depth should never drop below 60 cm of sand.

5. Under-drain system: consists of baked clay or concrete pipe, laid with open joints. Pieces 30-40 cm long are best for this purpose. The spacing of lateral lines depends on the size of the under-drains and the rate of filtration. Maximum spacing of laterals is 2 m. For example, a 5 cm drain tile will drain  $7.4 \text{ m}^2$  at the rate of  $2.8 \text{ m}^3/\text{m}^2/\text{day}$ . At the same rate of filtration, a 7.5 cm tile line will drain  $16.8 \text{ m}^2$  of filter area. Brick under-drains are also quite popular.
6. Filtered water outlet: an important feature of a filter is its outlet. (see Figure

## Water Supply Guidelines

48). The main function of the outlet is to prevent siphonage and to protect the sand filter bed. When head loss becomes too great, due to the filter clogging or the inlet becomes blocked for some reason, the outlet will not allow the level of water to below the sand surface. Obviously, the time to clean the filter is before head loss falls to this level. If, however, routine cleaning is not done, this safety outlet will stop water leaving the sand filter before the filter becomes completely dry. The outlet structure should also permit back-filling via the underdrains after commissioning or re-sanding. This is important to prevent trapping air in the sand bed.

**Figure 48. FILTERED WATER OUTLET**



- |                               |                                    |                      |
|-------------------------------|------------------------------------|----------------------|
| A = Depth of gravel and stone | C = Depth of water over filter bed | F = Telescoping pipe |
| B = Filter sand               | D = Under-drains                   | G = Float            |
| E = Filtered water            | H = Circular weir                  | I = Constant head    |

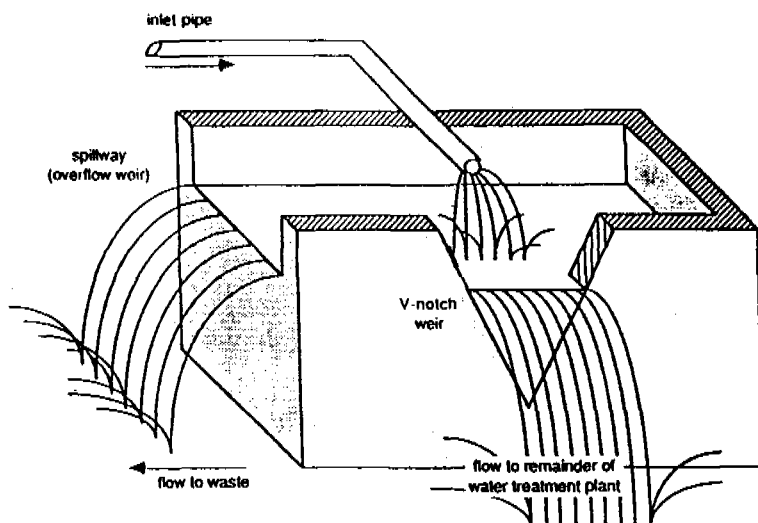
Maximum allowable loss of head equals depth of water on filter.

7. Flow control devices: Maintenance of a constant filtration rate is an important factor in filtration efficiency. Flow control may be practiced at either the inlet or the outlet.

At the outlet, the flow is controlled by a gate valve positioned at the outlet from the under-drainage pipes. The valve is adjusted using a long handle to reach down into the outlet structure. Adjustment usually involves opening the valve slightly more every day, otherwise output will fall. This method has the disadvantage of using a valve which is difficult to reach for repairs. The most efficient method of controlling flow is at the inlet.

At the inlet, flow control is usually achieved by a v-notch and weir, (see Figure 49). As the resistance of the filter bed to the flow of water increases, so the level of water rises. An indicator of the need for cleaning is provided by the level of water reaching the overflow. This type of inlet flow control requires less operator involvement.

**Figure 49. V-NOTCH AND WIER**



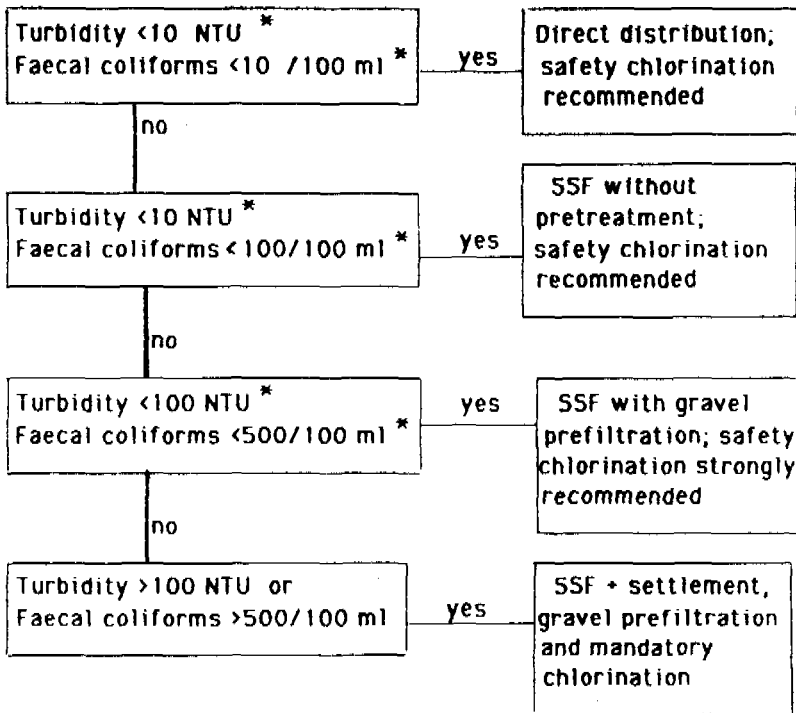
8. **Filter cleaning:** cleaning is accomplished by carefully scraping 5 to 8 cm of sand off the top of the filter. This done, the filter is put back into operation. The dirty sand is placed in a washing box for cleaning and re-use. This process can be repeated until about 40 per cent of the sand is removed. At this time the cleaned sand is returned to the filter to the original elevation. The sand must be carefully levelled with light rakes or similar tools.

9. **Sand washing:** In rural areas this job must generally be done by hand. The sand is agitated in a box with water running through it at a low velocity in order not to wash out the fine particles. The washing-water will clear when the sand is clean. The sand is then stored and is ready for replacement on the filter.

10. It is important that maximum precautions be taken to assure continuous operation and to maintain the water level above the sand. If the filter is not operated properly, it may actually provide a favourable breeding place for bacteria which will contaminate the filtered water, making the sand filter useless.

A guide to the use of slow sand filtration in combination with other treatment processes for various qualities of raw water is shown in Figure 50.

**Figure 50. CHECKLIST FOR THE APPLICATION OF SLOW SAND FILTRATION WITH COMPLEMENTARY TREATMENTS FOR VARIOUS RAW WATER QUALITIES**



\* on 80 per cent of sampling occasions

## 7.4 Other Treatment Processes Generally Considered Inappropriate for Small Community Water Supplies

### 7.4.1. Pre-chlorination

Pre-chlorination is practised:

1. to prevent algal growth in raw water;
2. for destruction of some taste and odour-producing compounds;



## Water Supply Guidelines

3. for oxidation of iron, manganese and hydrogen sulphide;
4. to aid coagulation;

Dosage: 1 to 5 mg/l chlorine depending on the degree of pollution, so as to leave 0.2 to 0.5 mg/l free residual chlorine in the final, delivered water.

### 7.4.2. Aeration

Aeration is necessary to promote exchange of gases between water and the atmosphere. In water treatment plants it is practised for the following reasons:

1. To control tastes and odours: e.g. when tastes and odours are caused by dissolved gases such as hydrogen sulphide. It can also be effective, perhaps to a lesser degree, when they are caused by decomposing organic matter, chemical wastes, or secretions from microorganisms. Aeration also increases the oxygen content of natural waters which are not already saturated with it and, in so doing, helps to remove the flat taste of rain-water and distilled water.

2. To precipitate iron and manganese which are important sources of colour in water: iron is more commonly found in natural waters than is manganese. Fortunately, it is easier to remove. A chemical examination of the raw water will reveal the nature of the iron compound(s) in the water. Usually the iron is in the form of ferrous bicarbonate or ferrous sulphate. Upon contact with free oxygen (0.14 mg/l O<sub>2</sub> for each mg/l of iron oxidised) ferric oxide (Fe<sub>2</sub>O<sub>3</sub>) will be formed. The reaction takes place at pH 7.0 or over. This compound is insoluble and will settle out. For the latter purpose, a short period of storage and sedimentation, followed, if necessary, by filtration, may be desirable to collect the precipitated iron.

When iron is combined with organic matter, separation in the presence of organic acids is much more difficult and requires accurate pH control, special filtering materials and equipment, and sometimes, the addition of other chemicals. Competent advice should be sought if no other water source exists for supplying the area. For large institutions, zeolite equipment specially built for iron removal may be considered.

3. To expel carbon dioxide: excessive amounts of CO<sub>2</sub> make water aggressive and dissolve the exposed iron in the piping system. Aeration can be useful in the removal of CO<sub>2</sub>, which escapes into the air.

Under rural conditions it would normally be uneconomical to provide pumping solely for the purpose of aeration. It might be possible, however, to combine the aeration process with pumping from the source to storage. In a gravity system, ample head may be available to provide for aeration.

In order to effect aeration, the water should come into maximum contact with the air so that it becomes saturated with oxygen. The process can be accomplished by letting the water fall over steps as in cascades, by spraying it from nozzles into the air and draining it back into a tank in thin sheets over a concrete apron, or by letting

Figure 51. CASCADE AERATOR

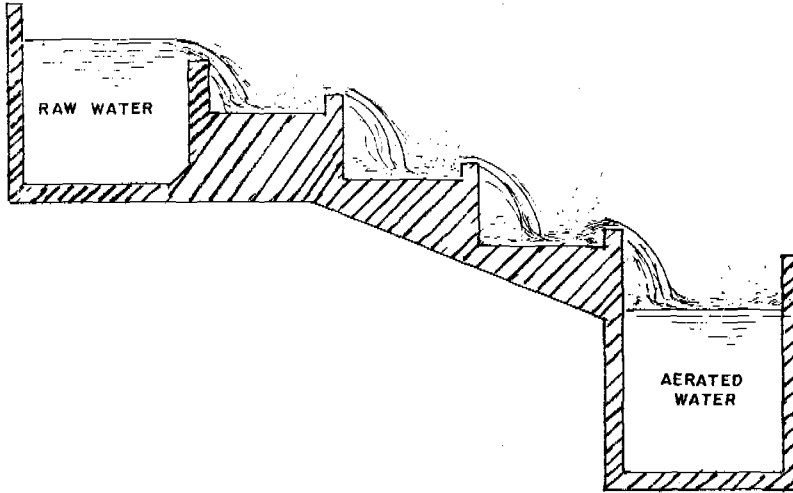


Figure 52. NOZZLED SPRAY AERATOR

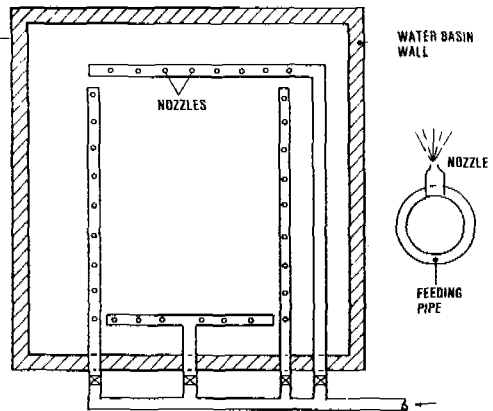
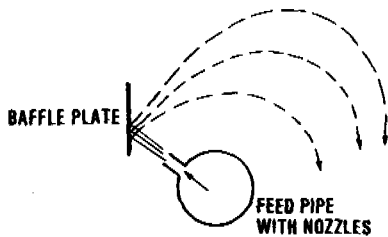
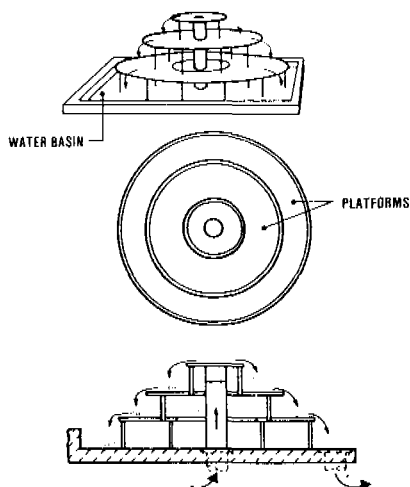


Figure 53. SIMPLE SPRAY AERATOR USING BAFFLE PLATE



**Figure 54. MULTIPLE-PLATFORM AERATOR**



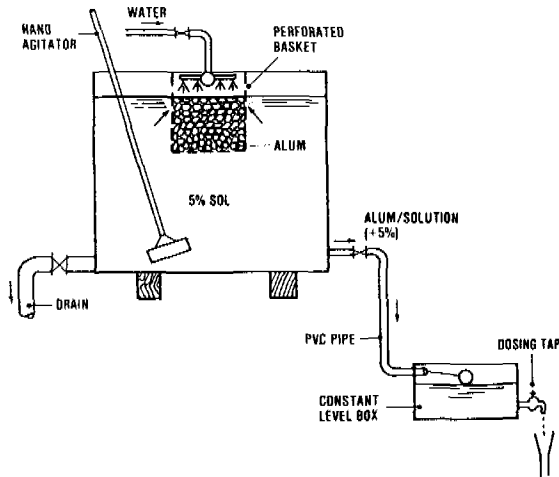
it fall through several perforated trays placed vertically one below the other. Care should be exercised to protect the water against outside contamination in the course of aeration and to prevent the access to the aeration structures of insects which may breed in the slime developing on wet surfaces.

The design details of aeration devices such as cascades, sprays multiple tray or water fall, and mechanical equipment, are given below:

1. Cascade type:  
(see Figure 51)  
Head required: 1 to 3 m  
Space required: 180 to 540 m<sup>2</sup> per mld  
(million of litres per day)
2. Spray type:  
(see Figures 52 and Fig. 53)  
Nozzle diam: 10-40 mm  
Spacing: 0.5 - 1.0 m  
Head required: 2-7 m  
Rating of aerator: 300-600 (lpm) litres per nozzle  
Floor area of aerator: 360 to 1080 m per mld.



Figure 55. CHEMICAL FEED ARRANGEMENT FOR ALUM



Dosage for alum: 20-100 mg/l (1-5 grains/gallon).

Dosage for lime: About one third that of alum.

Dosages of chemicals to be added must be decided on the basis of laboratory experiments, e.g. the Jar test.

Density of alum =  $980 \text{ kg/m}^3$   
Density of lime =  $670 \text{ kg/m}^3$ .

#### 7.4.4.1. Rapid mixing or flash mixing

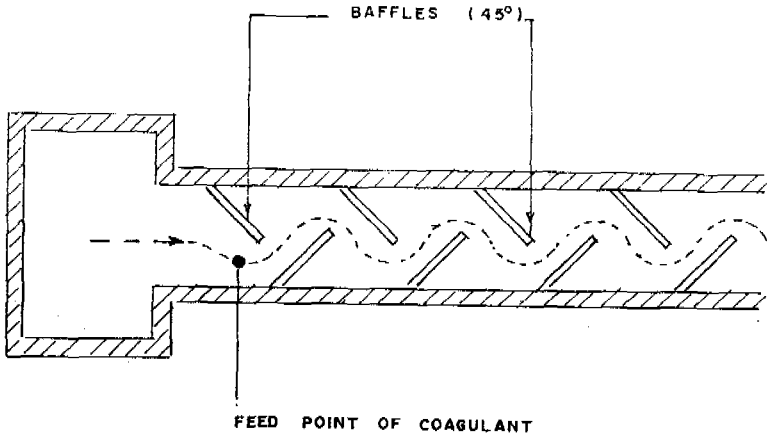
Rapid mixing of the water is needed to uniformly disperse the coagulant throughout the mass of water and to create a homogeneous system. Many devices are used to provide rapid mixing for the dispersal of chemicals in water. Basically there are two groups:

1. Hydraulic devices
2. Mechanical devices

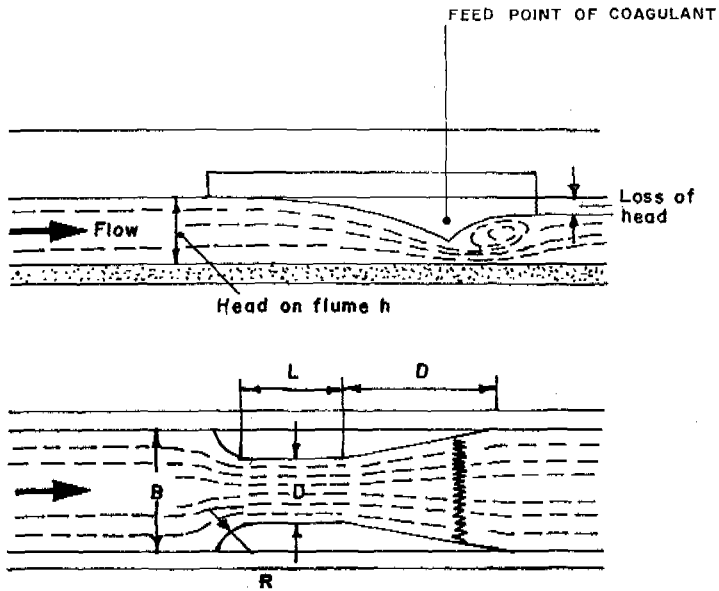
Hydraulic devices (see Figures 56 and 57), such as channels with baffles producing turbulent flow conditions, overflow weirs, and hydraulic jumps, are used for small flows up to  $300 \text{ m}^3/\text{hr}$ . If properly designed a hydraulic mixer can be as effective as a mechanical device.

A simple hydraulic jump for mixing is most common in rural community water supply. The velocity in the flume should be 3 to 4 m/sec, and the water leaving the flume should mix with water moving at 0.5 to 0.8 m/sec. The head loss is likely to be

**Figure 56. BAFFLED CHANNEL MIXING**



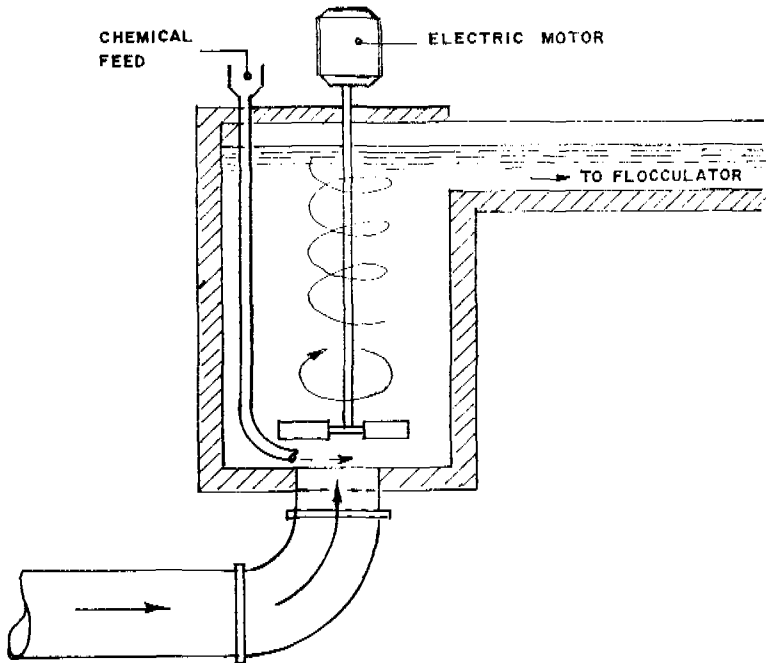
**Figure 57. HYDRAULIC JUMP**



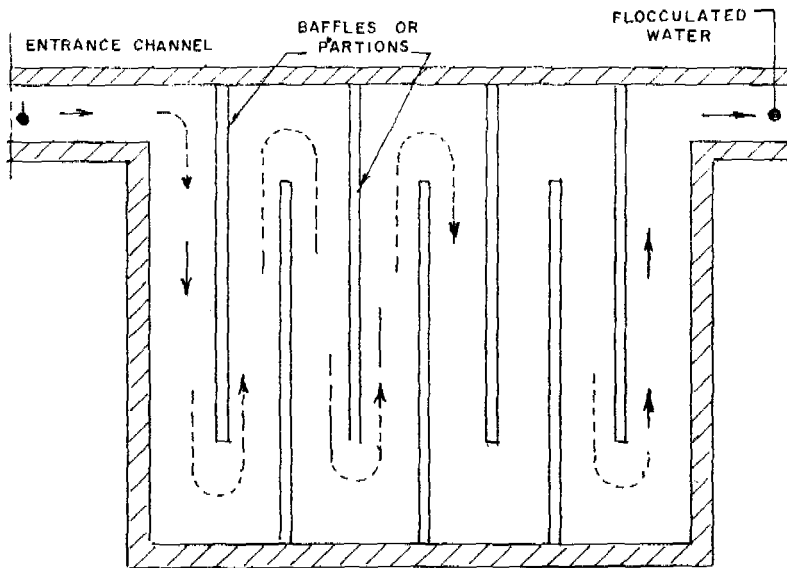
## Water Supply Guidelines

0.25 to 0.50 m. Alternatively, mechanical mixing is achieved using a propeller at 5-15 revolutions per second in a chamber with a retention time of 30 to 60 seconds. In larger systems, power may be used, power utilisation being of the order of 2.5 to 5 KW/m<sup>3</sup>/sec of water. Mechanical mixers (see Figure 58) are preferred when the flow exceeds 300 m<sup>3</sup>/hr.

**Figure 58. MECHANICAL MIXER**



**Figure 59. HORIZONTAL BAFFLED CHANNEL FLOCCULATOR**



PLAN

#### 7.4.4.2. Flocculation

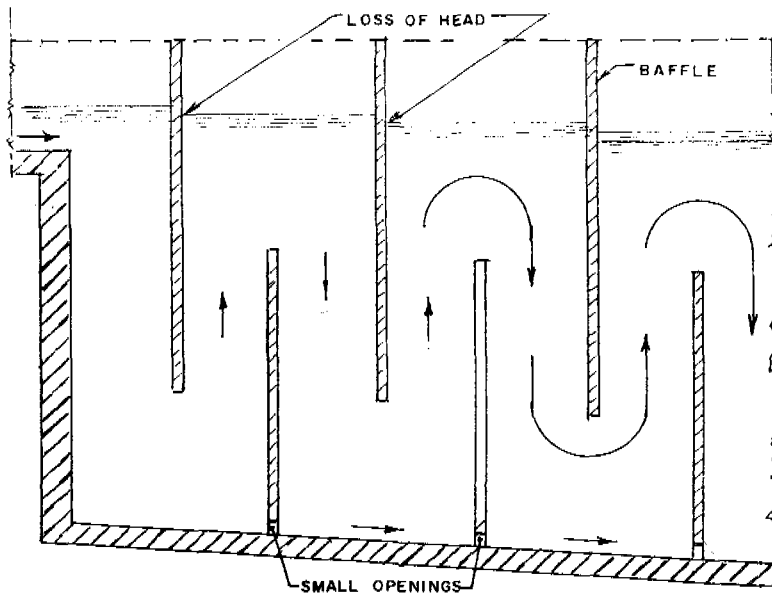
In the flocculation process, the microfloc particles formed during rapid mixing are brought together to aggregate into larger, rapidly settleable flocs by controlled agitation of water. Flocculation can be achieved satisfactorily by use of hydraulic or mechanical devices.

In hydraulic flocculators the flow of water is so influenced that stirring action results due to the creation of turbulence. Typical examples are baffled channel or basins (see Figures 59 and 60) and gravel bed flocculators. These types of flocculators are well suited for small treatment plants (up to 300 m<sup>3</sup>/hr). For a horizontal flow baffled flocculation channel, the designed water velocity is in the range 15 to 45



cm/s, with detention time varying between 10 to 30 minutes. The shortcomings in the hydraulic system are that they are not flexible, and involve much loss of head.

**Figure 60. VERTICAL BAFFLED CHANNEL FLOCCULATOR**



SECTION

Mechanical flocculators consist of revolving paddles with horizontal or vertical shafts, or of paddles suspended from horizontal oscillating beams and moving up and down. Usually they are satisfactory. The design features of the paddle-type mechanical flocculator are:

1. Retention time: 15 to 30 minutes.
2. Average velocity of flow: 0.3 m/min.

## Water Supply Guidelines

3. Paddle area: 10-25% of the area swept.
4. Maximum peripheral velocity: 0.6 m/sec.
5. Speed: 2 revolutions per minute (rpm)
6. Allowable head loss: 0.15 m.
7. Power required: 80-120 kw/mld.

### 7.4.5. Sedimentation

When sedimentation basins are designed for receiving water that has been treated by chemical coagulation - flocculation the following design criteria are generally adopted:

1. Average velocity of flow: 0.5 m/sec.
2. Max. peripheral velocity: 0.5-1.0 cm/sec.
3. Tank dimension:
  - (a) For rectangular tanks:  
Length to width ratio: 2 to 4  
Depth: 2.5 to 4.0 m (and additional 0.15 to 0.30 m if sludge storage is to be provided).
  - (b) For circular tanks:  
Dia: not more than 60 m.  
Depth: 2.5 to 4.0 m, and a space equivalent of 25 per cent of volume for sludge storage.
4. Surface loading:  
For flocculent material: 40-48 m<sup>3</sup>/day/m<sup>2</sup>  
A surface overflow rate of 36 m<sup>3</sup>/m<sup>2</sup>/day is equivalent to a settling velocity of 1.5 m/hour and amounts to a retention period of 2 hours in basins 3 m deep.
5. Weir overflow rate:  
Not to exceed 600 m<sup>3</sup>/day/m, and preferably be held below 300 m<sup>3</sup>/day/m.
6. Sludge removal:  
minimum size to be used:  
for non-mechanised units: 200 mm diameter desludging pipe  
for mechanised units: 100-15 mm diameter desludging pipe
7. Bottom slope:  
for manual scraping: 1 in 10  
for mechanical scraping: 1 in 12
8. Allowable head loss: 0.50 m
9. Power required: 0.15-0.20 kw/mld.

Note: Million litres per day (mld) rating implies 24 hours functioning.

### 7.4.6 Rapid sand filtration

Rapid sand filtration is not recommended for small community water supplies because of the necessary controls and careful attention required to obtain satisfactory results. It is generally preferred, however, when the turbidity of the raw water is highly variable, and remains high for a considerable period in a year. However, it is now accepted that for small communities gravel pre-filtration followed by slow sand filtration and disinfection is preferable.

Chemical pre-treatment of the raw water is necessary prior to rapid sand filtration.

For rapid filtration, sand is commonly used as the filter medium but the process is quite different from slow sand filtration. This is because much coarser sand is used with an effective grain size in the range 0.4-1.2 mm, and the filtration rate is much higher, generally between 5 and 15 m<sup>3</sup>/m<sup>2</sup>/hour (120-360 m<sup>3</sup>/m<sup>2</sup>/day). Due to the coarse sand used, the pores of the filter bed are relatively large and the impurities contained in the raw water penetrate deep into the filter bed. Thus the capacity of the filter bed to store deposited impurities is more effectively utilised and even very turbid river water can be treated with rapid filtration.

For cleaning a rapid filter bed, it is not sufficient to scrape off the top layer. Cleaning of rapid filters is effected by backwashing. This is achieved by directing water at a high rate of flow back up through the filter bed so that it expands and is scoured. The backwash water carries the deposited materials out of the filter. The cleaning of a rapid filter can be carried out quickly; it need not take more than about 30 minutes. It can be done as frequently as required, if necessary every day.

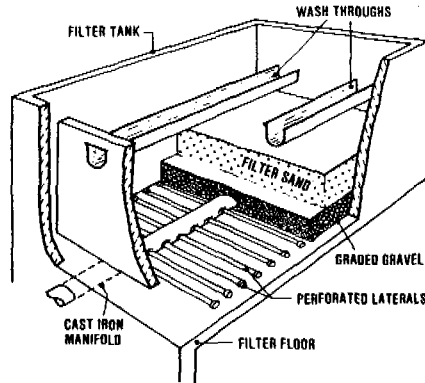
Rapid sand filtration generally implies considerably higher operational costs than slow sand filtration. Operational expenditure involves costs for coagulants, such as lime and alum, for pre-conditioning the raw water before passing it onto the filter. Only when proper adequate operation and supervision are available, can a rapid sand filtration system work successfully.

Components of a conventional rapid sand filtration system (see Figure 61) include:

1. coagulation (by means of hydraulic jump or of mechanically-operated rapid mixing);
2. flocculation (by means of baffled channel or of mechanically-operated slow mixing);
3. supernatant water reservoir;
4. filter sand bed;
5. under-drain system;
6. control valve system, and
7. backwashing facilities.

## Water Supply Guidelines

**Fig. 61. RAPID SAND FILTER (OPEN GRAVITY TYPE)**



In brief, some of the essential design features of a rapid sand filter of the gravity type are:

Influent turbidity	: after pretreatment should not exceed 20 NTU
Pretreatment	: required (chemical dosing: flocculation and clarification)
Length of filter run	: 24 hours, loss of head 2 m.
Minimum number of units	: two
Filtration rate	: 80-160 lpm/m <sup>2</sup> (240 lpm/m <sup>2</sup> can be achieved with improved pretreatment and careful grading)
Headloss allowed	: 1.8 to 2.0 m.
Depth of sand	: 60-75 cm thick, effective size (E.S.) = 0.45-0.70 mm, uniformity coefficient (U.C.) = 1.30-1.75
Depth of gravel	: 30-60 cm thick graded into 4 or more sizes varying from 25-65 mm at bottom and 2 to 5 mm at top
Depth of water over sand	: 1.0-2.0 m

### 7.5. Post-chlorination

Post-chlorination is practised for disinfection of potable water by the use of gaseous chlorine or chlorine compounds to destroy bacteria through the germicidal effects of chlorine. This may be done at the treatment plant and supplemented by additional chlorination in loose pockets of the water distribution system. More details of disinfection and chlorination are given in Chapter 8.

Dosage	: When prechlorination is adopted, relatively small doses will be required, generally 1 to 2 mg/l.
Contact period	: 30 minutes (minimum)

## Water Supply Guidelines

pH value	: 6-7	7-8	8-9	9-10	10-11
Residual or free available chlorine in mg/l at end of contact period	:0.2	0.2	0.4	0.8	0.8
Quantity of chemical required in kg/day	:(Dosage in mg/l) x (Quantity of water to be treated in mld)				

### 7.6 Effectiveness of Treatment

Table 9. (overleaf) indicates the relative degree of effectiveness of each treatment process and helps in the selection of the most suitable unit for water treatment.

### 7.7 Modular Water Treatment Plants

In developing countries, meeting the water quality needs of rural communities is often hampered by scarce technical skills and limited resources. It is too expensive and time consuming to design individual water treatment plants for each situation. In order to simplify the selection and design of a suitable treatment process on the basis of water quality, a modular approach may be used to provide a package of solutions for a range of water treatment problems. Modular designs are applicable to small-scale water treatment processes.

#### 7.7.1. Packaged plants

Packaged treatment plants can provide safe water to small communities not served with piped water supply. They are usually pre-fabricated and pre-assembled and provide various unit processes and operations in a compact system.

##### (a) Household filter

The microbiological effectiveness of household sand filters is questionable so their use should always be followed by disinfection. It is very difficult to operate household sand filters at a continuous flow rate and such that they never dry out, so although they may improve optical clarity they should not be confused with conventional biological slow sand filters. They may reduce the number of larger parasitic organisms provided that the sand grains are fine and flow rates are slow.

A typical household filter unit which can be used in isolated dwellings and farm houses is shown in Figure 62. The unit is essentially a mini-slow sand filter, consisting of a drum 40 cm in diameter and 100 cm deep made of galvanised iron, ferro-cement, or other local material. It is filled with two 5 cm layers, of 3.0 to 6.0 mm gravel and 0.7 to 1.4 mm coarse sand, topped with 40 cm of fine sand of 0.2 to 0.3 mm size. Water to be filtered is allowed to flow into the unit through a distributor placed at the top. The water filters slowly through the sand layer and is collected in a storage vessel. The unit can yield about 100 litres of water per day, which, after disinfection, can satisfy the drinking and cooking needs of a family of 6 to 8 persons.

## Water Supply Guidelines

**TABLE. 9. Relative Effectiveness of Various Water Treatment Processes**

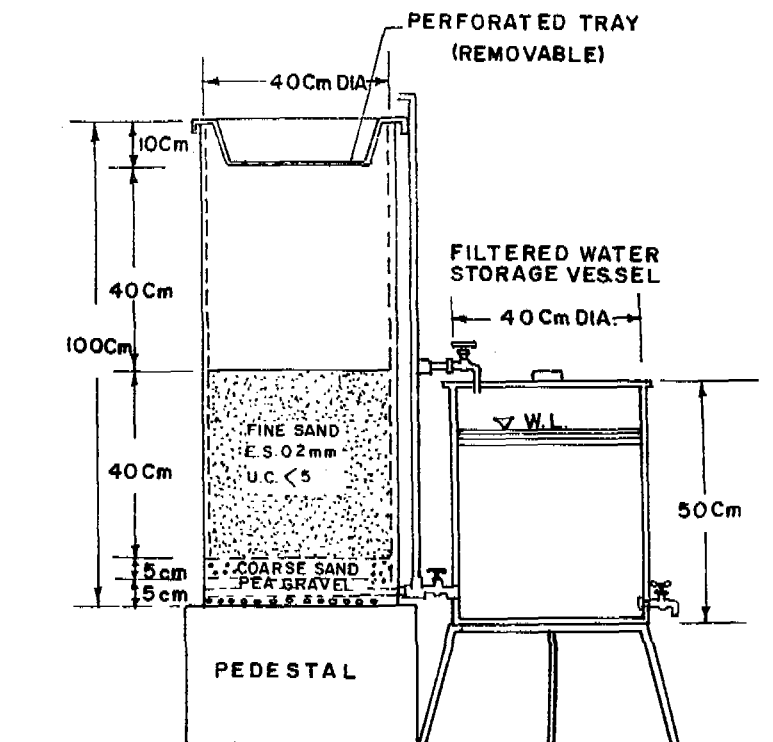
Attributes	Aeration	Plain Sedimentation	Slow Sand Filtration	Coagulation and Rapid Sand Filtration	Softening using Lime Soda Process and Filtration	Disinfection with Chlorine
<b>Bacteria and other Organisms</b>	0	++ <sup>1</sup>	++++	++++	(+++) <sup>2</sup>	++++
<b>Colour</b>	0	0	++	+++	(++)	0
<b>Turbidity</b>	0	+++	++++ <sup>3</sup>	++++	(++)	0
<b>Odour and Taste</b>	++ <sup>4</sup>	(+)	++	(++)	(++)	++++ <sup>5</sup>
<b>Hardness</b>	+	0	0	(-) <sup>7</sup>	++++	0
<b>Corrosiveness</b>	+++ <sup>8</sup>	0	0	(-) <sup>10</sup>	Variable <sup>11</sup>	0
<b>Iron and Manganese</b>	+++	+ <sup>12</sup>	++++ <sup>12</sup>	++++ <sup>12</sup>	(++)	0

**Key for the table**

Favourable	Unfavourable
++++	Very
+++	Considerably
++	Somewhat
+	Slightly
0	None
(+)	Indirectly

1. Somewhat irregular
2. By excess lime treatment only
3. But filters clog too rapidly at high turbidities
4. Except chlor-phenol tastes and odours
5. When break-point chlorination is employed or superchlorination is followed by dechlorination
6. Ordinary chlorination
7. Alum coagulation converts carbonates into sulphates
8. By removing CO<sub>2</sub> (carbon dioxide)
9. By adding oxygen O<sub>2</sub> when it is low
10. Alum coagulation releases CO<sub>2</sub> (carbon dioxide)
11. Some metals are attacked at high p<sup>H</sup> values
12. After aeration.

**Figure 62. HOUSEHOLD FILTER UNIT**



**(b) Packaged unit for iron removal**

In certain areas groundwater is contaminated with iron. The presence of iron in drinking water is often considered a minor problem of aesthetic and technical nature. However, people may resist using a bacteriologically safe groundwater source which has a high iron content, preferring to drink surface water which has a more agreeable taste and colour, but may contain pathogens. Iron removal therefore, can be of major importance. In order to ensure safe potable water free from iron, package plants of different capacities have been developed. Package plants operated by hand pumps and power pumps are shown schematically in Figure 63.

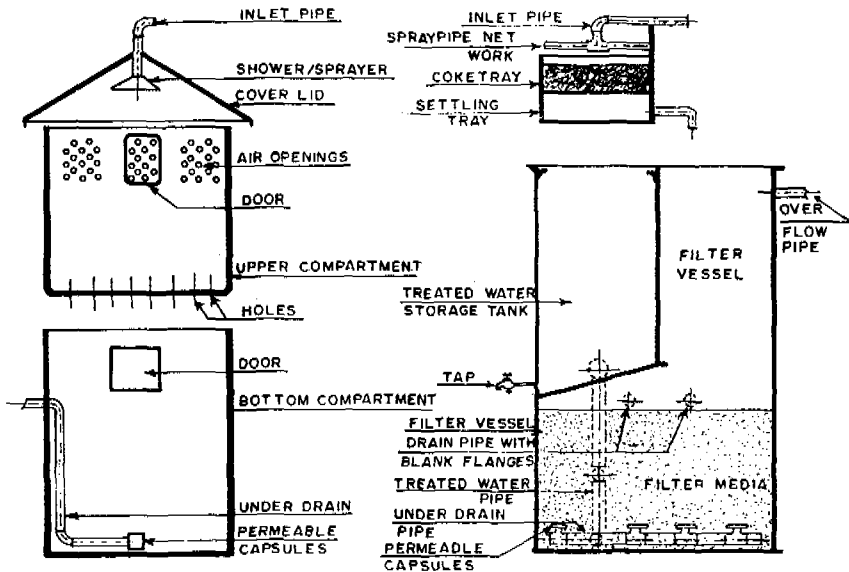
The type I unit is made up of three parts: the bottom compartment, the upper compartment, and the upper compartment cover lid. The bottom compartment is the filter vessel with the sand medium. The upper compartment is provided with coke

## Water Supply Guidelines

medium to support the ferric flocs resulting from the oxidation of soluble iron by spray aeration, which is achieved by means of shower fitted in the inlet feed pipe.

The type II plant consists of the main filter vessel containing the filter medium and PVC underdrain laterals. The plant is provided with an in-built treated water storage tank. The raw water is pumped and sprayed over the coke filter medium through a spray pipe network, and thereafter it is allowed to settle in the lower compartment before filtration takes place in the main filter compartment. The treated water storage tank is provided with taps through which water is withdrawn for use.

**Figure 63. PACKAGED UNITS FOR IRON REMOVAL**



### 7.8. Operation and Maintenance of Water Treatment Plants

The term "maintenance" in an engineering sense may be defined as the art of keeping plant equipment, structures and other related facilities in optimum working order.

The person in charge of maintenance and operation of water treatment plants should have a thorough knowledge of the purpose and functions of the units under their control. The problems that may need to be confronted relate to either;



## Water Supply Guidelines

- (a) poor design,
- (b) faulty construction,
- (c) special situations during operation and
- (d) general wear and tear and reasonable deterioration.

A resourceful operator should be able to identify faults in design and construction which give rise to problems in the course of operation and be able to rectify them.

Additional problems may occur due to:

- (a) fluctuations in the quality of the water;
- (b) fluctuations in quantity and changes in the flow pattern;
- (c) malfunctioning of several units;
- (d) malfunctioning of mechanical and electrical equipment, and
- (e) inadequate or intermittent supply of chemicals, consumables or spare parts.

Maintenance should be carried out in a manner which prevents emergencies and unscheduled shutdowns. Efficient "preventive" maintenance requires considerable skill which can only be acquired by experience, study and practice. Basically, any maintenance programme should observe the following general rules:

- (a) keep a set of plans giving details of the units and indicating the layout and position of all pipelines, fittings and accessories;
- (b) establish a systematic plan of daily operations;
- (c) establish a routine schedule for inspection of machinery and lubrication and keep records of this work. Instructions for lubrication, the type of lubricant suggested and the frequency of lubrication should be written out and clearly illustrated where appropriate, and be easily accessible;
- (d) maintain data and records of each piece of equipment giving details of cleaning and replacement of worn parts and other data of importance such as unusual incidents and faulty operating conditions. Details of any special equipment should be obtained from the manufacturers;
- (e) keep a record of the results of analysis of water collected at various points from the source to the distribution system. Observe and record the effect of such quality on the several units of operation;
- (f) keep records of the water flow at various key points in the plant, and
- (g) make a list of safety measures including good house-keeping practice.

### 7.8.1. Flow measuring devices

Float sumps should be periodically cleaned to see that silt does not accumulate which may affect the proper functioning of the floats. Charts and pen recorders should be stocked adequately. Annual (or more frequent) calibration of these devices is necessary. Annual servicing and checking of all instruments is imperative.

### **7.8.2. Chemical feeding unit**

Alum preparation tanks should be painted annually with anti-corrosive paint. V-notch weirs, floats and floating arrangements should be cleaned daily. Enough spare parts for the technical mixing devices should be kept in stock. Setting of V-notch weirs should be checked periodically.

Sometimes, if the alum dosing equipment is not in running order, alum slabs are simply thrown into the raw water channel. This is bad practice and should not be permitted as it results in incorrect dosage and is a waste of alum. It can also mean high levels of aluminium in the water supply, which may have a long-term effect on the health of those drinking the water.

### **7.8.3. Rapid mixer**

Adequate spares should be kept in stock for replacement when necessary. Life of the equipment can be prolonged by periodic painting with anti-corrosive paints.

### **7.8.4. Slow mixer**

Slow mixers should be operated continuously in order to avoid build-up of sludge. Moving parts should be painted with anti-corrosive paints every year. Electric devices should be properly lubricated and worn parts replaced. In mechanical type flocculators e.g. baffle and tangential flow tanks, it is necessary to desludge at least once every six months.

### **7.8.5. Sedimentation tank or clarifier**

Annual overhauling and repainting of the unit should be done once a year.

Sludge lines should be kept free of blockages. They should be flushed with water under high pressure if blockages are noticed.

The unit should be worked continuously to protect mechanical parts from corroding, and from problems associated with the build-up of sludge. Outlet weirs should be kept cleaned at all times. Bleaching powder may be used for controlling biological growths on weirs.

The important features in the operation of a clarifier are:

- (a) the introduction of water into the tank with a minimum turbulence;
- (b) the prevention of short-circuiting between inlet and outlet; and
- (c) the removal of the effluent with the minimum of disturbance to avoid settled material being carried out of the tank.

Very often, a basin which is not functioning properly can be modified by making changes to the inlet and outlet devices or by installing baffles so as to improve any or all of the important features mentioned above. Algal growth, if present, should be controlled by pre-chlorination

## 8. DISINFECTION

### 8.1. Need

Water sources are often polluted by human carriers of waterborne disease. A water supply may thus spread enteric diseases in the community. Pathogenic organisms in water and more particularly bacteria of intestinal origin, may survive for long periods in the environment.

Much can be done to improve the quality of water by protecting and improving the source. In some cases improvements to wells have reduced the bacterial counts by 60 to 80 per cent. An effective slow sand filter can reduce the total bacterial count by at least 90 per cent. However, to be absolutely sure that waterborne disease organisms are eliminated, disinfection is necessary.

Several disinfection methods are available, but undoubtedly the most common method employed is chlorination. In addition to bacterial pathogens, viruses such as those causing infectious hepatitis and poliomyelitis are also killed by adequate chlorination. Secondary benefits of chlorination include oxidation of iron, manganese, and hydrogen sulphide, the destruction of some taste and odour-producing compounds, and control of algal and slime growth.

### 8.2. Methods of Disinfection

*Disinfection methods can be broadly divided into two groups, as follows:*

- A. Physical methods: boiling water, ultraviolet radiation, filtration.
- B. Chemical methods: chlorine gas and chlorine solution (hypochlorite), ozone gas, potassium permanganate, iodine and metal ions such as copper and silver, alkali and acid.

### 8.3. Chlorination

Chlorine is widely used as a disinfectant. It is commercially available as:

1. solid calcium hypochlorite (bleaching powder);
2. liquid sodium hypochlorite (bleach solution), and
3. chlorine gas.

Chlorine dissolves in water to form hypochlorous acid and hydrochloric acid. Hypochlorous acid dissociates to produce hydrogen and hypochlorite ions in a reversible reaction which is pH dependent. Irrespective of the chlorine compound

## Water Supply Guidelines

used, the water will end up containing hypochlorous acid (HOCl), hypochlorite ions (ClO<sup>-</sup>) and some chlorine (Cl<sub>2</sub>), their sum being termed 'free' chlorine.

Chlorine is very active and will react quickly with organic and inorganic matter in water. If disinfection is to be achieved, due allowance must be made for the chlorine consumed in these reactions in addition to the chlorine needed for disinfection purposes. The amount of chlorine required to react with other compounds (mainly ammonia, some metal ions and organic compounds) is termed the 'chlorine demand' of the water. There are three types of chlorine residual which may be measured in water: free, combined and total (the sum of the free and combined residuals).

Chlorine reacts with ammonia in water producing monochloramine (NH<sub>2</sub>Cl), and dichloramine, (NHCl<sub>2</sub>) which have disinfecting properties and are known as combined chlorine.

Where chlorination is practised it is usual to ensure that all the chlorine demand is satisfied and that free chlorine is left in solution. This procedure is known as "breakpoint chlorination".

When one of the chlorine compounds is added to water, a certain amount of time is needed for it to diffuse and to destroy the organic matter. This time is called the "contact time". The chlorine that is added is the "dose" and what remains after a selected contact time (usually 30 minutes) is known as "residual" chlorine. The chlorine dose must be sufficient to satisfy the chlorine demand and produce an excess of unreacted chlorine - the free residual. A minimum free residual of 0.5 mg/l is recommended after a contact time of 30 minutes with a raw water turbidity of less than 1NTU. The chlorine demand of some waters, particularly river waters, can increase dramatically, for example, after heavy rains and the dose will need to be increased. To ensure a free residual chlorine in the water supply the residual should be measured at various points throughout the system.

### 8.3.1. Chemicals for chlorination

Name	% Chlorine	Available state
1. Bleaching powder		
a. Ordinary (powder state) calcium hypochlorite, specific gravity 768 kg/m <sup>3</sup>	Available chlorine by weight, 25, 30, 35%  Losses vary directly with temperature rise	Powder form, size of packing 44 kg and 50kg

continued....

## Water Supply Guidelines

Name	% Chlorine	Available State
<b>b. High test</b> hypochlorite or perchloron or fortified calcium hypochlorite, sp. gr: 840 kg/m	70% available chlorine by weight, more soluble, and deteriorates more slowly	Loose granular form; size of packing 3.3 kg, 44kg and 50kg
<b>2. Sodium hypochlorite</b> (liquid)		
Liquid bleach or sodium hypochlorite (light yellow liquid)	5 to 10% available chlorine, relatively stable, can be stored for 4-5 weeks Max. shelf life 60-90 days	Liquid form; 20 and 60 litre carboys
<b>3. Liquid chlorine</b>		
	100% chlorine	As liquified gas in cylinders of 25 litres and larger

### 8.3.2. Chlorine stock solution

Chlorination is often practised employing concentrated chlorine stock solution in water, usually of 1 per cent available chlorine (10,000 mg/l) strength.

From bleaching powder (25 per cent available chlorine)

Solutions of bleaching powder can be used for chlorination. Stock solution is made up in batches and three important precautions must be taken:

1. Bleaching powder is only poorly soluble and the solution should not be made stronger than 1 per cent by weight available chlorine.
2. Even at this concentration, some part of the powder will remain undissolved. The solution must therefore be left standing overnight to settle and clarify.
3. The solution can lose its chlorine easily unless it is protected from heat, light and exposure to the atmosphere.

To make a litre of 1 per cent solution, the weight of powder to be added to water is given by the expression:

$$W = \frac{\text{percentage strength desired} \times V \times 1000}{S} \text{ grams}$$

where

- W = weight of powder in grams,
- V = volume of water in litres,
- S = strength of powder in percentage chlorine by weight.

## Water Supply Guidelines

For example,  $W = \frac{1\% \times 1 \text{ litre} \times 1000 \text{ grams}}{25} = 40 \text{ grams}$

Dissolve 40 gm of bleaching powder per litre of water. Leave to settle then decant the clear solution. The strength of the solution prepared will be 1 per cent by weight or 10,000 mg/l.

From H.T.H. (70 per cent available chlorine)

To make a 1 per cent solution of HTH [high-test (high strength) hypochlorite] the same calculation is applied.

$$W = \frac{1\% \times 1 \text{ litre} \times 1000 \text{ grams}}{70} = 14.3 \text{ grams}$$

Dissolve 14 gm of granules of HTH in each 1 litre of water to prepare a 1 per cent strength solution.

From sodium hypochlorite (liquid bleach)

Sodium hypochlorite solutions normally contain 10 to 14 per cent by weight of available chlorine. Such solutions are weak and unstable, decomposition being accelerated by heat, exposure to light, exposure to the atmosphere and dilution. In some cases the use of sodium hypochlorite (liquid bleach) may not be practical because of transport difficulties because it is bulky and heavy and highly corrosive.

Chlorine solution concentrate used in practice may vary from 0.1 per cent (1000 mg/l) to 2 per cent (20,000 mg/l). Maximum concentration should not exceed 5 per cent. Only clear chlorine solution should be decanted, to prevent clogging of valves and feed lines. As a proportion of the solution mixture will be lost during decanting, the net volume of solution available will be less than the theoretical calculation.

### 8.3.3. Criteria and considerations for the design and development of a chlorination system

#### 8.3.3.1. Chlorine solution chamber

Enough chlorine solution for one day only, should be prepared, because the solution loses strength during storage. Thus, the chlorine solution chamber should be sized accordingly, allowing it to retain sufficient solution for only one days requirement.

The chlorine solution should not be exposed to sunlight nor open to windy conditions, as a considerable portion of the available chlorine will be lost. Install a

## Water Supply Guidelines

tion of a well covered chlorine solution chamber should be in a shady area. As chlorine solution is very corrosive, it should be stored in a PVC, glass, ceramic, tile-lined, or rubber-lined vessel or chamber.

### 8.3.3.2. Chlorination room

Locate the chlorination room near the point of application such as the inlet of the receiving well, the spring chamber, the inlet of the storage reservoir, the suction pipe of pump, etc. Avoid laying a long length of pipe or hose for carrying the chlorine solution.

The following guidelines should be observed for the construction of a chlorination room.

- (a) Chlorination equipment should be installed in a separate room. Never install such equipment in the pump house or room where other equipment is located.
- (b) The chlorination room should be constructed with a proper roof, side walls and ventilation and sunlight screening. This is necessary to reduce the loss of chlorine due to exposure to high temperatures. A permanent wooden, or masonry structure should have a hard acid-proof flooring and a tiled or mosaic wainscot (skirting board). A framed wooden structure should have corrugated fibre cement roofing and wooden flooring and sides.
- (c) The chlorination room should be of sufficient size to provide space for the preparation of chlorine solution, installation of chlorine equipment, space for handling chemicals, and to permit easy movement.
- (d) A water tap (5 l/min minimum flow) for the preparation of chlorine solution, and a wastewater and wash drain, and space for handling sludge disposal, should be provided.
- (e) As chlorine gas is 2.5 times heavier than air, natural cross-ventilation should be provided at floor level where gas is used. An exhaust fan for forced ventilation is desirable.
- (f) A separate, covered, damp-proof, properly ventilated room with a weighing arrangement should be provided for the storage of chlorine containers or cylinders.

### 8.3.3.3. Chlorination equipment

The solution-feed chlorinator and hypochlorinator are widely used for disinfection of rural water supplies, both for wells and piped water supplies (see Tables 10 and 11). In the hypochlorinator, the chlorine compound is dissolved in water and the resulting solution is then applied under a constant head by gravity, by differential pressure, or by injection into the pump suction or discharge lines.

Gas chlorinators are used only in large water systems in which liquid chlorine, under reduced pressure, is converted into chlorine gas, which in turn, is dissolved in

## Water Supply Guidelines

water. The chlorine solution is then added by gravity or is injected under pressure. Chlorinators may be manual, semi-automatic, or automatic in operation.

The simple solution-feed type chlorinators, readily made from local materials, and utilising bleaching powder for the preparation of hypochlorite solution, are easily adaptable for small rural water works. Figures 64 to 74 show various different types of chlorination equipment.

**TABLE. 10. Chlorination Arrangements for Well Supplies**

Types of well	Capacity of container (litres)	Quantity of bleaching powder	Suitable for supply 1/day	Residual chlorine range mg/L	Interval for refilling approx
1. Dug well					
Pot diffuser	12-15	1.5 kg	900-1300	0.2-0.3	1 week
Double jar type	5-6	1.0 kg	310-450	0.2-0.1	2-3 weeks
Bamboo chlorinator	50 mm bamboo	100 gm	family well	0.2-0.1	1 week
2. Dug or tube wells					
Siphon feed	20	1000 mg/l	1000-2000	0.2-0.1	2 weeks
Gravity feed	20	10 000 mg/l	200 000	0.2	daily

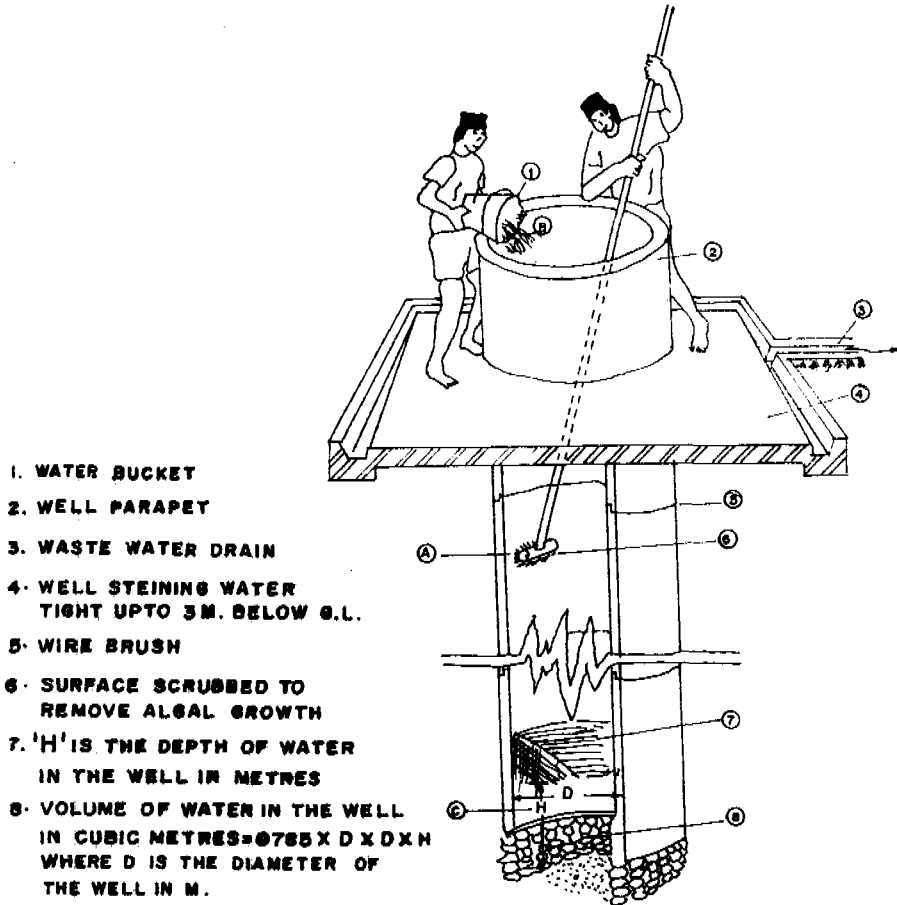
**TABLE 11. Chlorination Arrangements for Piped Water Supplies**

Types of well	Capacity	Quantity of bleaching powder (kg)	Supply m <sup>3</sup> /day	Dosing rate	Frequency of refilling
1. Differential pressure feed	35; 70; 100; 210	1.5; 3; 4.5; 9	360; 720; 1.080; 1.440	1 mg/L	Daily
2. Automatic solution feed	20	800 gm 10.000 mg/l	200.000	1 mg/L	Daily
3. Liquid/gas chlorinators at 1-1.5 kg/cm <sup>2</sup>	Applicable only for large waterworks not for small rural community systems				



## Water Supply Guidelines

**Fig. 64. CHLORINATION OF AN OPEN DUG WELL**

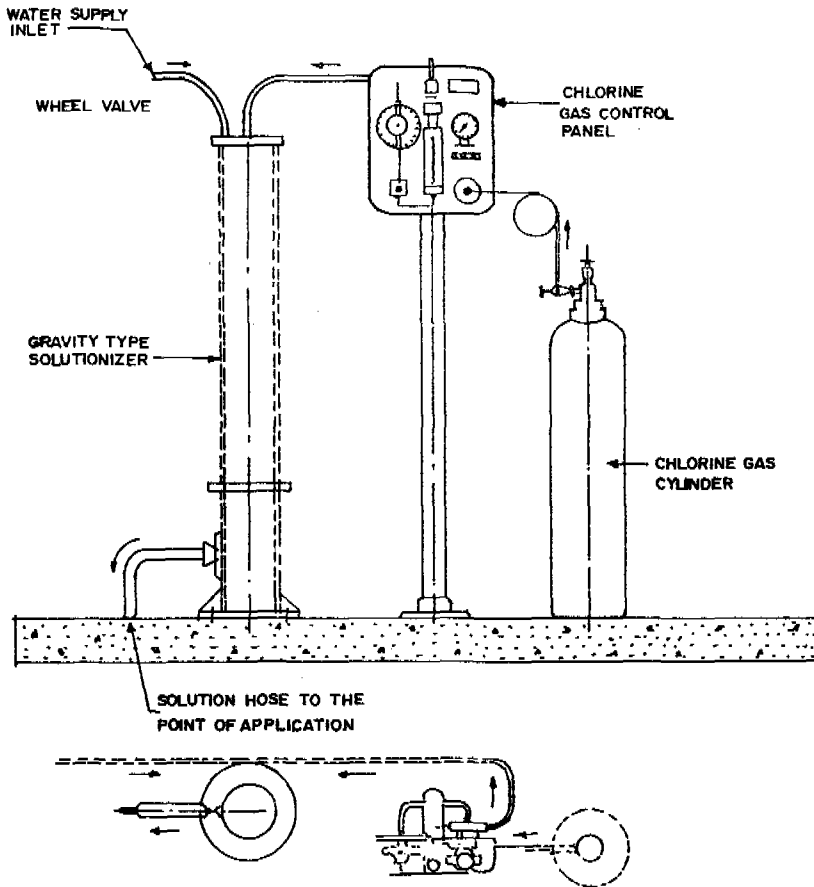


Construction drawings with details of structural and mechanical specifications should be planned and prepared according to the type of equipment selected, local conditions, availability of materials, and operation personnel. All piping and valves should be of corrosion-resistant material such as PVC.

## Water Supply Guidelines

Solution piping should have the minimum number of bends, junctions, and joints, and should be well supported, protected from exposure to high temperature, and adequately sloped for complete drainage of the chlorine solution when the feeding is stopped. For two or more units, valves should be provided for isolation during cleaning and repairs.

**Figure 65. GAS CHLORINATION PLANT, GRAVITY TYPE**



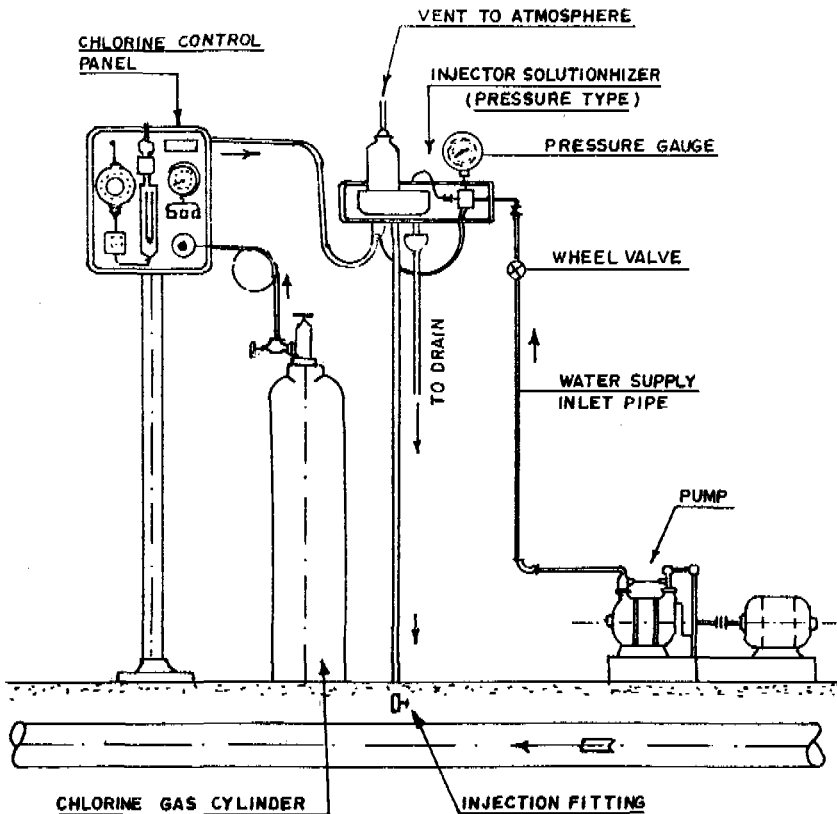
The chlorine solution preparation vessel should be rubber-lined or of glass, ceramic, PVC, fibreglass, or acid-resistant coated concrete.

In the case of calcium hypochlorite solution, some of the calcium in the solution is converted to calcium carbonate when it comes in contact with air. These

## Water Supply Guidelines

calcium carbonate particles can clog the orifice, piping and valves, which should, therefore, be cleaned regularly to ensure proper dosing and working of the equipment.

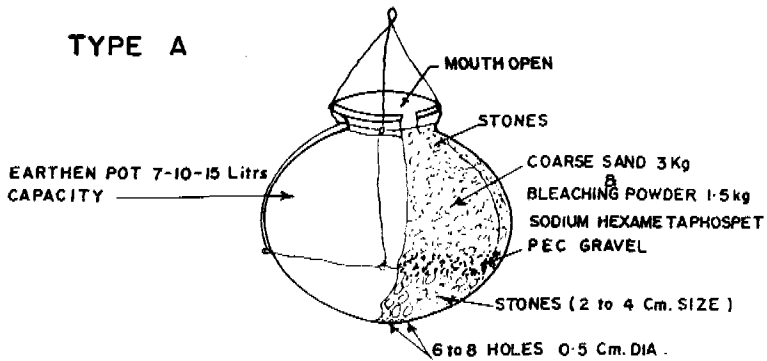
**Figure 66. GAS CHLORINATION PLANT, PRESSURE FEED**



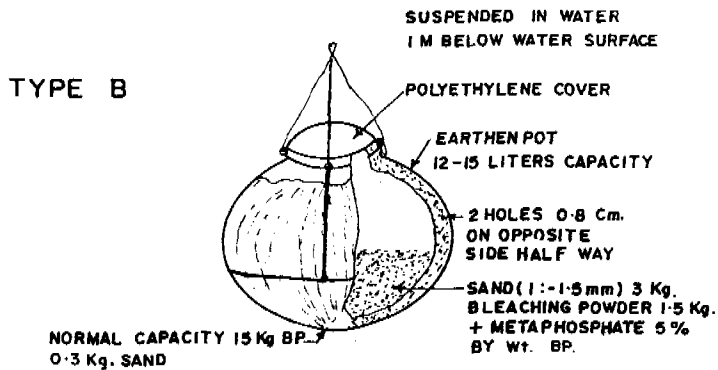
In recent years, some manufacturers have developed small scale chlorinators capable of generating sodium hypochlorite solutions on-site for disinfection of drinking water in small rural communities. This equipment, which requires a small source of electricity (250 to 350W for a supply for 8000 people), uses a sodium chloride solution (brine), or sea water, which is circulated through an electrolytic cell.

## Water Supply Guidelines

**Figure 67. POT CHLORINATOR**



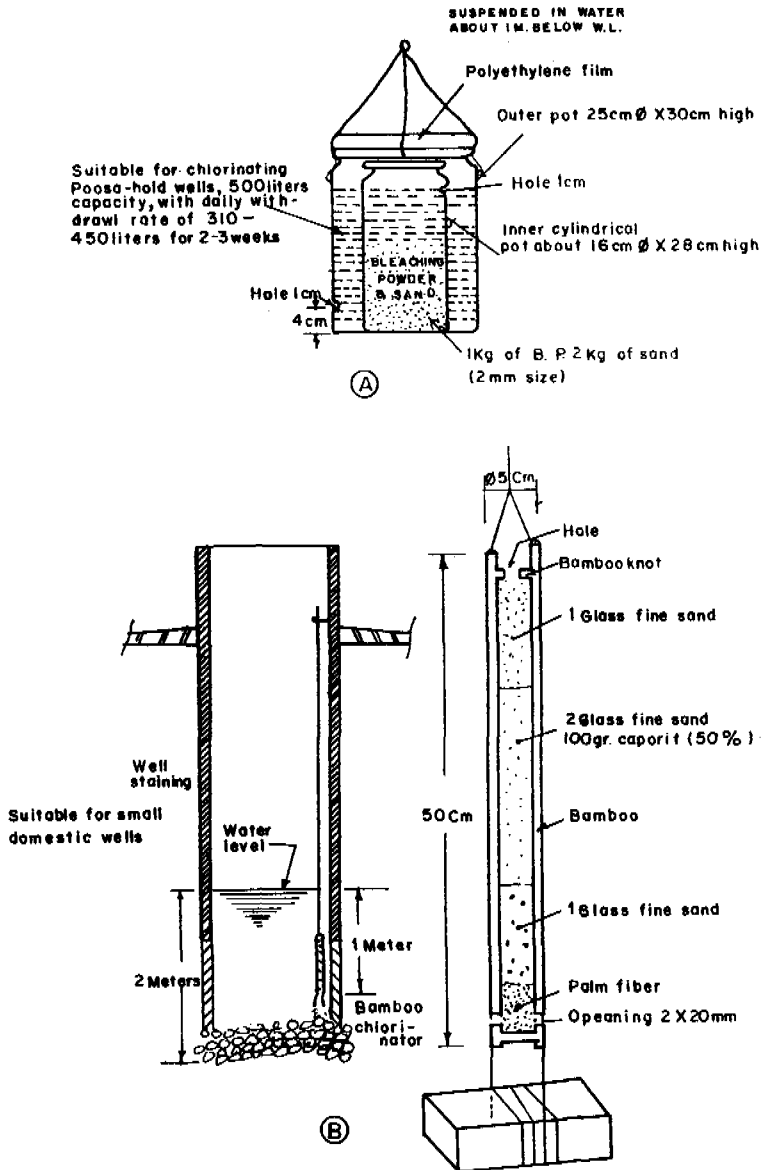
SUITABLE FOR HOUSE-HOLD WELLS HAVING WATER CONTENT OF 9,000-12,000 LITERS WITH DAILY WITHDRAWAL RATE OF 900-1000 LITERS FOR ONE TO TWO WEEKS



SUITABLE FOR HOUSE-HOLD WELLS HAVING WATER CONTENT AS 3000-13000 LIT. & HAVING WITHDRAWAL RATE OF 900-1300 LITERS /DAY FOR A PERIOD OF ONE WEEK.

## Water Supply Guidelines

**Figure 68. (a) DOUBLE POT CHLORINATOR (b) BAMBOO CHLORINATOR**

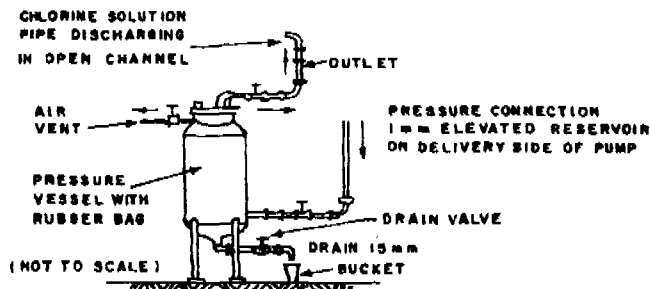


## Water Supply Guidelines

It also includes a dosing mechanism which can be regulated to treat 100 000 or more litres of fresh-water per day at the rate of 2 mg/l of chlorine, or the daily water supply for between 500 and 2000 persons. These devices have the disadvantage of requiring electricity, but the advantage of generating chlorine from readily available substances on-site, thereby obviating the need for chlorine manufacture and distribution.

**Figure 69. HYPOCHLORITE DOSER - INSTALLATION DETAIL**

### GRAVITY FEED SYSTEM



### PRESSURE FEED SYSTEM

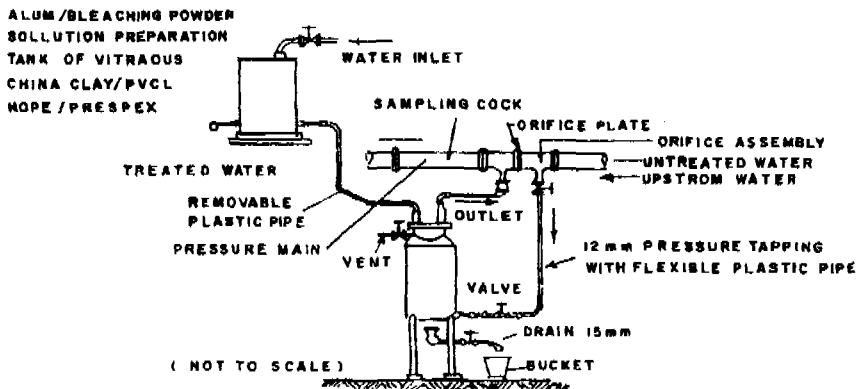


Figure 70. HYPOCHLORITE DOSER

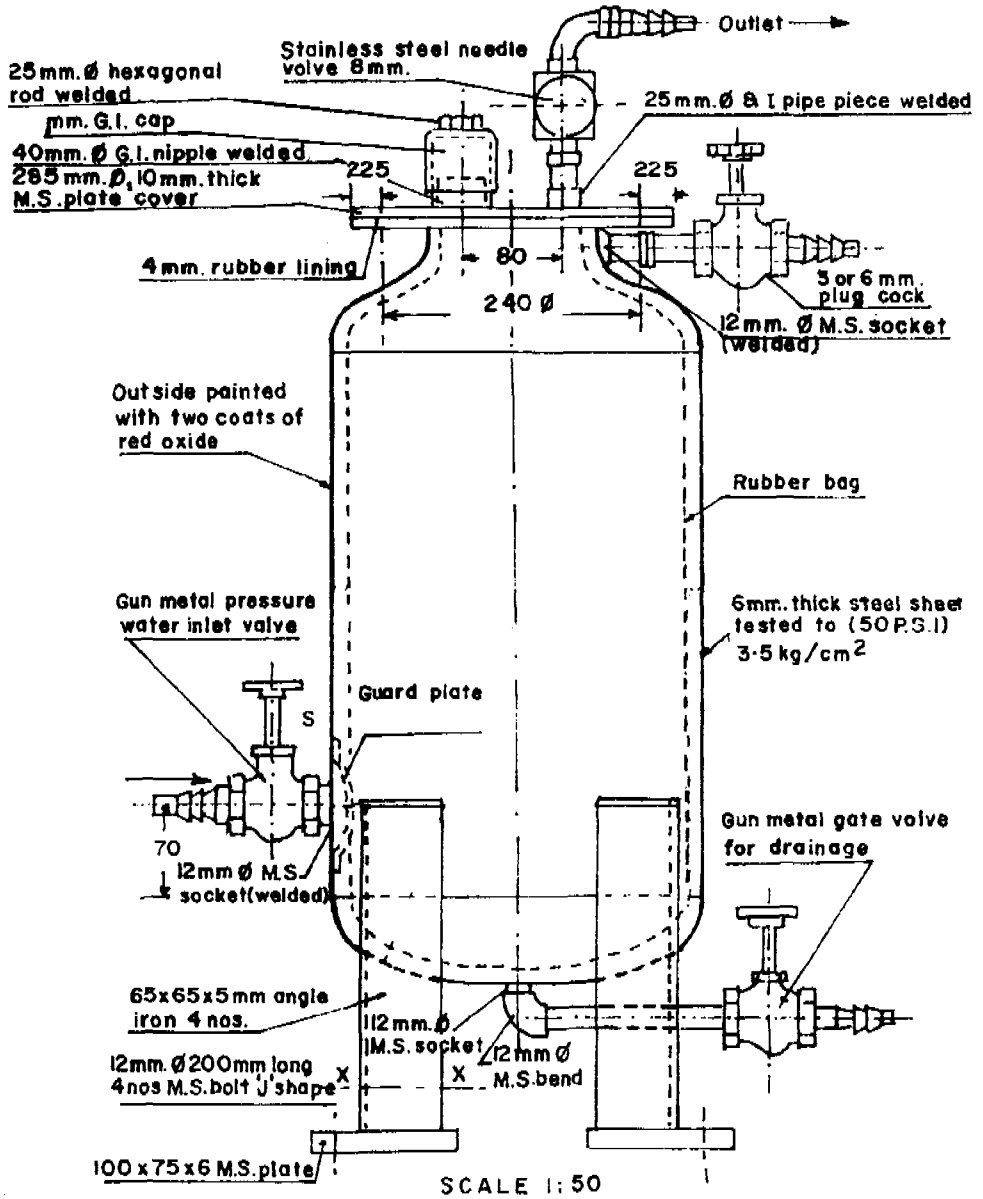
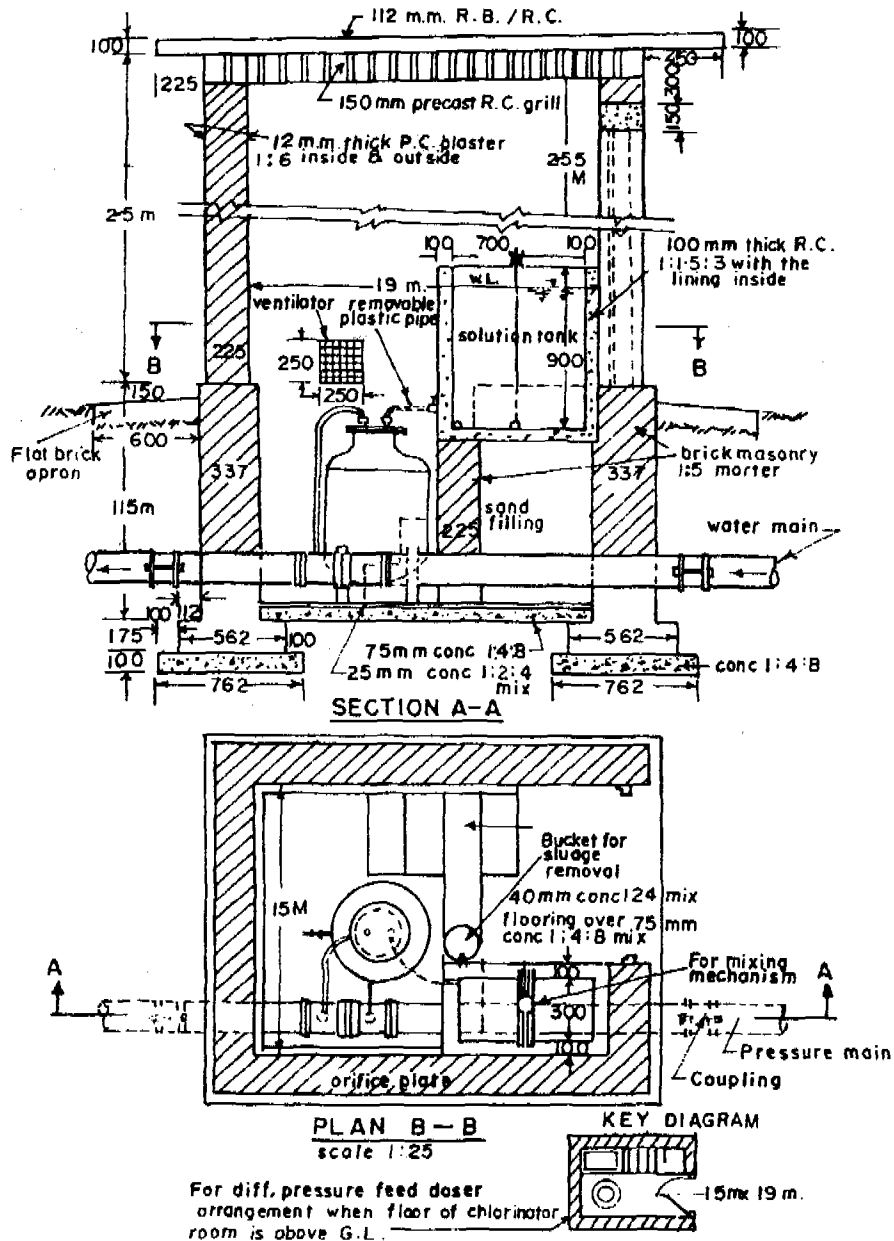


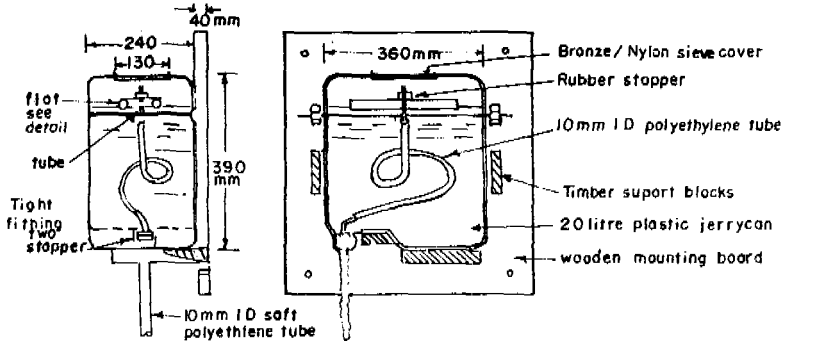
Figure 71. CHLORINATOR ROOM





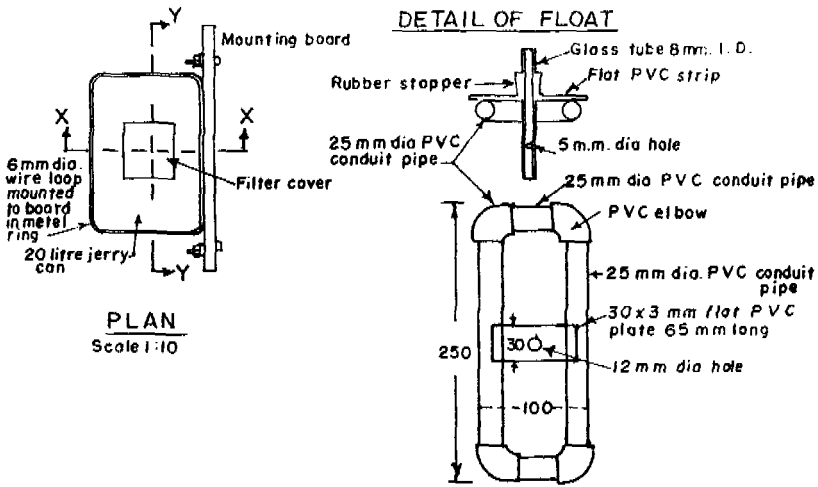
## Water Supply Guidelines

**Figure 72. JERRY-CAN - GRAVITY FEED CHLORINATOR**



SECTION X-X

SECTION Y-Y



PLAN

Scale 1:10

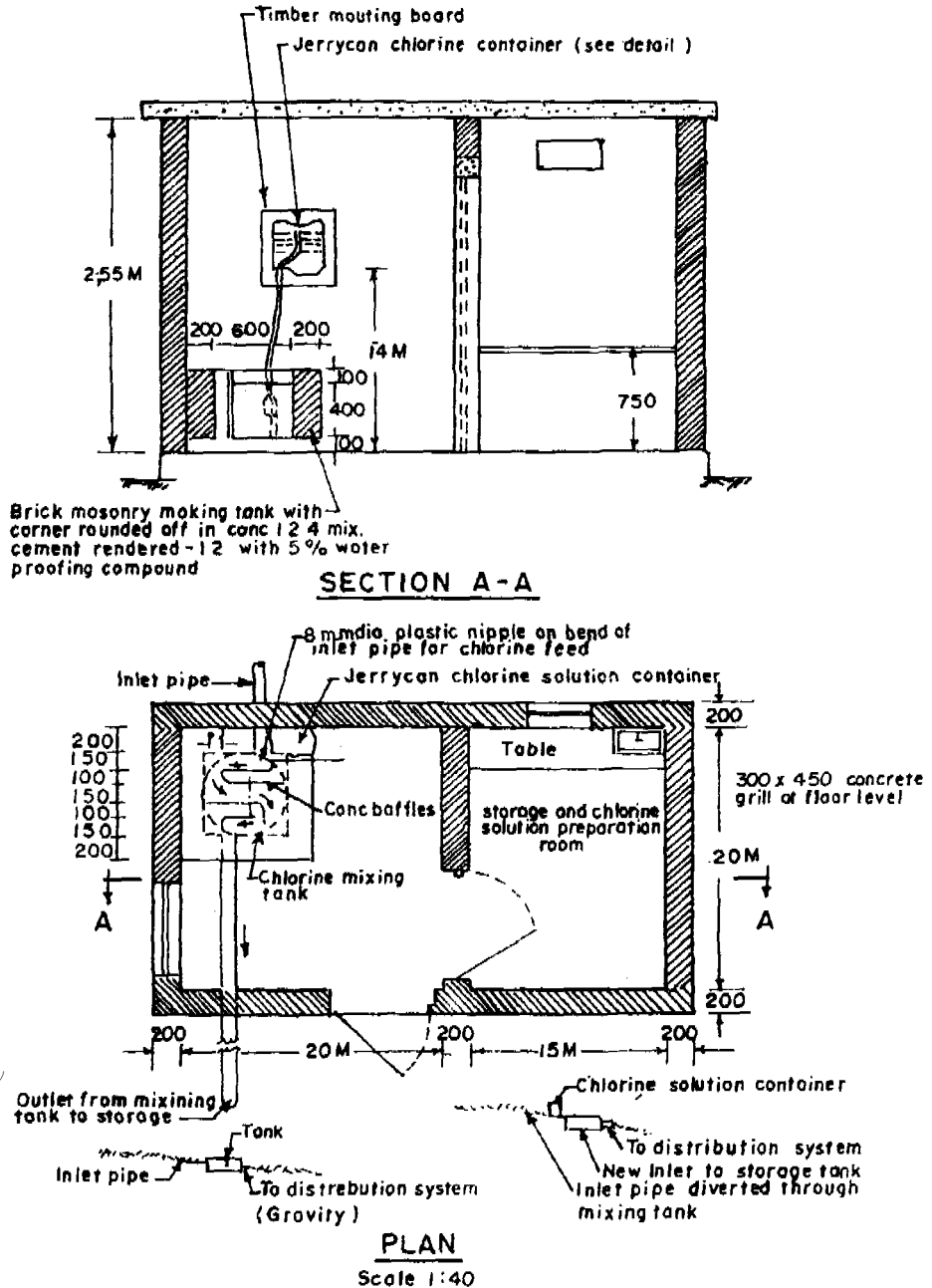
DETAIL OF FLOAT

SCALE 1:4

Although this drawing is to the scale indicated dimension are not given, as these will depend on the jerrycan used

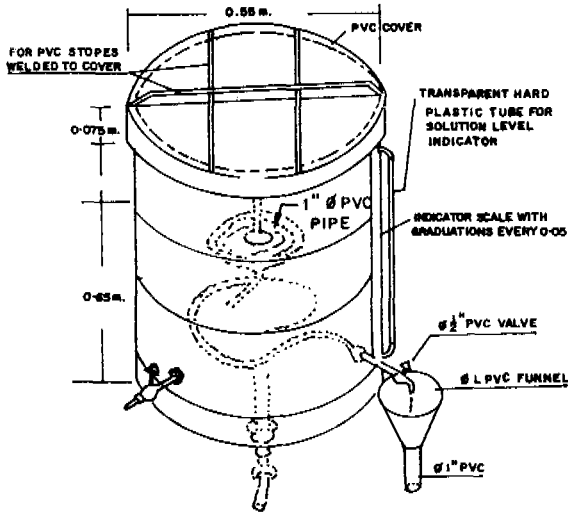
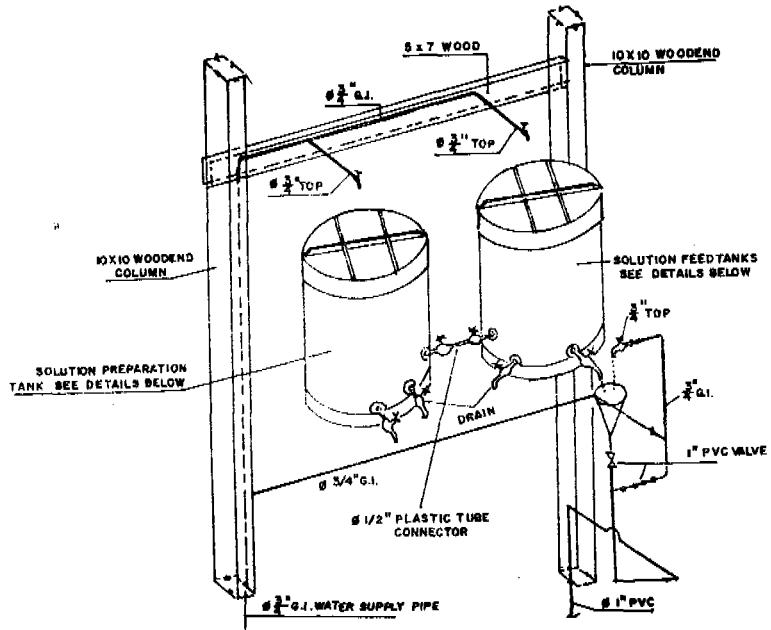
## Water Supply Guidelines

**Figure 73. JERRY-CAN GRAVITY FEED CHLORINATOR - INSTALLATION**



# Water Supply Guidelines

**Figure 74. CONSTANT HEAD ORIFICE - CHLORINATION**



## Water Supply Guidelines

### 8.3.4. Design calculations

Prior to design the most suitable type of chlorination equipment must be selected and sized to suit the quantity of water to be disinfected each day. The "chlorine demand" of the water must be measured and the "residual chlorine" defined after a minimum contact time of 30 minutes. Dosage, volume of solution chamber and feed rate are then calculated.

#### Example

Assuming a rural water supply system with a spring yield of 10 l/sec and 24 hour flow to a reservoir supplying the community by gravity, calculate the weight of bleaching powder required for chlorination, the necessary volume of chlorine solution of 1 per cent strength, and the proper feed rate of the chlorine solution for the system.

Chlorine required per day:

$$\text{Flow per day} = 10 \times 60 \times 60 \times 24 = 144,000 \text{ l}$$

Determine the chlorine demand by laboratory test (assume here, say) = 0.8 mg/l

Assume that a chlorine residual of 0.5 mg/l is required

Therefore, chlorine dosage required

$$(0.8 + 0.5) = 1.3 \text{ mg/l}$$

Chlorine required per day (g) =  $\frac{\text{Chlorine dosage mg/l} \times \text{Flow l/day}}{1000}$

$$= \frac{1.3 \times 144000}{1000} = 187 \text{ grams ... (A)}$$

Bleaching powder required:

Theoretical quantity of bleaching powder of 25 per cent strength required to produce 187 grams of available chlorine per day

$$= \frac{\text{Chlorine required per day} \times \text{strength of chlorine required}}{\text{actual \% strength}}$$

$$= \frac{(A) \times 100\%}{25}$$

continued...

## Water Supply Guidelines

$$= \frac{187 \times 100}{25} = 748 \text{ g/day,}$$

Say 0.75 kg/day

In practice, a laboratory determination of actual strength of bleaching powder should be made.

Dosing solution:

Selected strength of chlorine solution (percentage by weight)

= 1% by weight .....(B)

Volume of solution = (A) x S.G. (Specific gravity)  
(B)

$$= \frac{0.144 \times 100 \times 1}{1}$$

= 14.4 litres .....(C)

Dosing rate:

Dosing rate per minute

$$= \frac{C}{24 \times 60} = \frac{14.4 \text{ litres}}{1440 \text{ min}}$$

$$= \frac{1}{100} \quad \text{l/min, or}$$

$$= 10 \text{ ml/min}$$

Taking the volume of a drop as 0.05 ml, the number of drops of solution to be fed per minute will work out as 200.

(Note: check the volume of a drop by an actual measurement in a graduated cylinder).

### 9. DISTRIBUTION

In many rural areas domestic water for individual houses and communities is supplied from point sources such as wells equipped with hand pumps. Since the water obtained in this way must be carried in containers from the wells to the house, the amount of water actually used is often limited and insufficient for the effective promotion of health and personal hygiene.

Although the use of wells in villages is inevitable and often dictated by economic and engineering considerations, the piped distribution of water from a central source to every house is a goal towards which every community strives. The most important benefits are:

1. the increased quantity of water which will inevitably be used for domestic purposes;
2. the improved quality which may be achieved by treatment and disinfection and removing the necessity of transporting and storing water in containers, which involves further risk of contamination and;
3. the convenience and time saving which may increase economic productivity.

The design of a small community water-distribution system involves:

1. the determination of storage;
2. the location and size of feeders;
3. the location and sizes of distribution pipes, valves and hydrants; and
4. the determination of the pressure required in the system.

#### 9.1. Small Community Distribution Systems

##### 9.1.1. Distribution reservoir

In small distribution systems, whether the water is obtained by gravity or by pumping, it is often desirable to provide a distribution reservoir. The main reasons are:

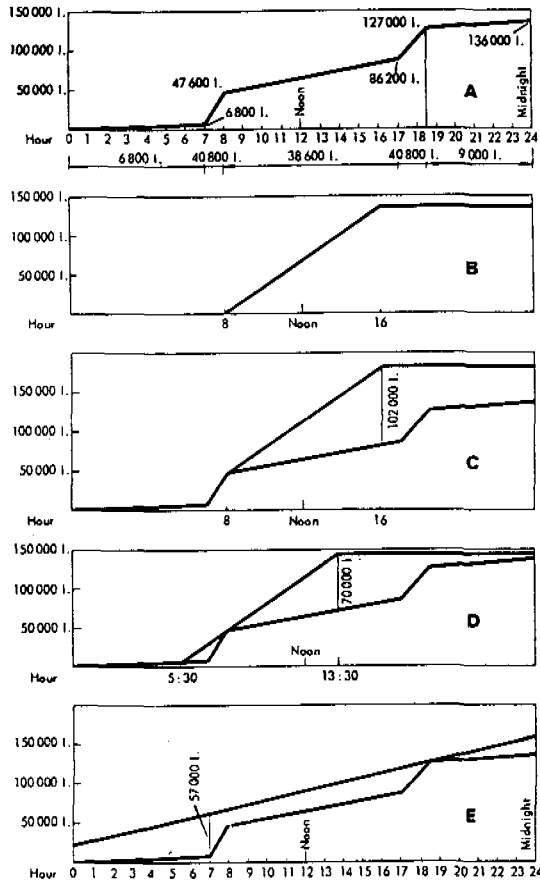
1. to satisfy hourly variations in the rate of consumption, such variations may be three times the average hourly consumption;
2. to maintain adequate pressure throughout the distribution system;
3. to permit the repair of conduction pipes between the source of supply and the reservoir, without interruption of the village water service;

## Water Supply Guidelines

4. to provide for fire protection.

The first consideration when designing storage is to calculate the capacity which will be provided. This depends to a great extent on the type of supply, and is influenced by two main factors: the necessity of catering for peak demand periods, and the provision of reserve to cover breakdown or normal maintenance interruptions.

**Figure 75. DISTRIBUTION RESERVOIRS: THEORETICAL REQUIRED RESERVOIR CAPACITY**



## Water Supply Guidelines

Conditions vary in different parts of the world, but a typical pattern of draw-off in a small community is as follows:

1. 30 per cent of the day's supply between 7 a.m. and 8 a.m.;
2. 30 per cent between 5 p.m. and 6.30 p.m.;
3. 35 per cent during the other hours of daylight; and
4. 5 per cent between sunset and sunrise.

Local customs will produce local variations. These and similar considerations must be taken into account when assessing the extent and duration of peak draw-offs: this must be balanced against the rate and periods of water delivery.

Once the probable distribution of draw-off during 24 hours and the proposed hours of delivery is decided, two graphs can be drawn, similar to diagrams A and B in Figure 75. In this particular case a probable demand of 136 000 litres per day is envisaged, to be provided by pumping for eight hours per day between 8 a.m. and 4 p.m. These graphs are then superimposed, as in diagram C, in such a way that the lowest point on line B touches, but does not come below, line A. This gives a theoretical picture of how much storage will be required, the vertical distance between the two lines representing the amount in the reservoir at any hour of the day.

From this example the reservoir would be empty at 8 a.m., filling to a maximum of 102 000 litres at 4 p.m., after which it will empty at varying rates until 8 a.m. the next day when pumping starts again.

It can be seen that the hours of pumping proposed are uneconomical in this example. Diagram D shows how the storage required may be decreased by arranging the pumping hours between 5.30 a.m. and 1.30 p.m., the maximum difference between supply and demand now being 70 000 litres at 1.30 p.m.

Diagram E assumes that instead of pumping, the water is supplied by a gravity main from source, running through the day and night at 5665 litres per hour. In this case the highest storage demand occurs at 7 a.m., and 57 000 litres reserve is needed, the reservoir emptying at 6.30 p.m.

The figures obtained by the above method show the minimum storage required to satisfy hourly variation in flow; they take no account of break-down, repairs, or maintenance. It is necessary to add to the reservoir capacity for these contingencies. The quantity required for this purpose will depend on the layout of the installation.

If adequate standby pumping plant has been provided and can be brought into use immediately (e.g. if the supply is from duplicate boreholes each capable of supplying full needs) little need be added for repair purposes. However, the possibility of a burst main must always be taken into account. The time taken to repair a main depends on the local facilities available. In a typical rural scheme, it is usual to allow 8 hours at the time of day with the highest flow, and to rely on pumping extra hours to make up those lost.



## Water Supply Guidelines

In the example illustrated in Figure 75 an extra 70 800 litres would be provided, assuming that a burst occurs at 7 a.m.. This, added to the requirements calculated from diagram D, would suggest a storage reservoir capacity of 140 800 litres. If the supply were from a gravity main, as in diagram E, the reservoir storage capacity would be 127 800 litres.

It will be seen that in both these instances the storage volume required is of the order as the daily demand. In cases where insufficient information is available for accurate calculations to be made, it is usual as a rule-of-thumb, to design the reservoir such that its volume is equal to the daily demand. Reservoir capacity should never be less than half the daily demand.

There are conditions under which much larger storage should be provided, e.g. where pumping is by electricity from a supply which is prone to long and/or frequent interruption.

Once the size of the reservoir required has been determined, the next consideration is site selection. One of the most important points influencing site selection is height. Allowing for friction loss in the distribution mains, the bottom water level should be at such a height that there is a minimum residual head of 10 metres for single-storey buildings throughout the system. This can be ensured either by siting the reservoir on high ground or by building an elevated tank. Since the cost of an elevated tank is considerably more than of one built on the ground, the first choice of site will nearly always be high ground if there is any within a suitable distance of the town.

However, if the site is flat and an elevated tank is required, it is usual to construct this tank in a position which is relatively central to the distribution (thus avoiding long, and consequently large-diameter, service mains), and which is near to the pumping station rather than away from it so as to keep the friction in the pumping main to a minimum.

Distribution mains or connections should never be taken directly from the rising main, unless absolutely necessary. Water should be pumped, in the first instance, directly to the storage tank. This is particularly important when centrifugal pumps with steep efficiency curves are used as they can pump at all times at a maximum efficiency if the head does not fluctuate with the demand.

Other advantages of direct pumping are:

1. the ability to close down parts of the distribution system without interfering with the rest of the town;
2. the increased contact period when chlorine is used as a sterilising agent;
3. the maintenance of constant pressure in all services;
4. the possibility of checking consumption by observing the draw-off from the tank; and

## Water Supply Guidelines

5. leak detection is simpler when individual parts of the system can be shut off or metered separately which is not possible when pumping is done into the distribution system.

There are however, occasions when a combined rising and distribution main are desirable, particularly when, of necessity, the reservoir is at the opposite end of the town from the pumping plant. In such a case, direct pumping would require a long rising main laid parallel to a service main, with consequent duplication of costs. With a pump of very flexible performance, such as a reciprocating pump, a saving in fuel results if all the water does not have to be pumped to a high-level reservoir, but is drawn off en route at a lower head.

Ground-level reservoirs are usually built of masonry, mass concrete or reinforced concrete depending on locally available skills and materials. Of these alternatives, reinforced concrete requires the least amount of cement which is, in most cases, the most expensive of the materials used, particularly in rural areas where long transport hauls are involved. However, construction requires steel, timber for formwork and skilled supervision.

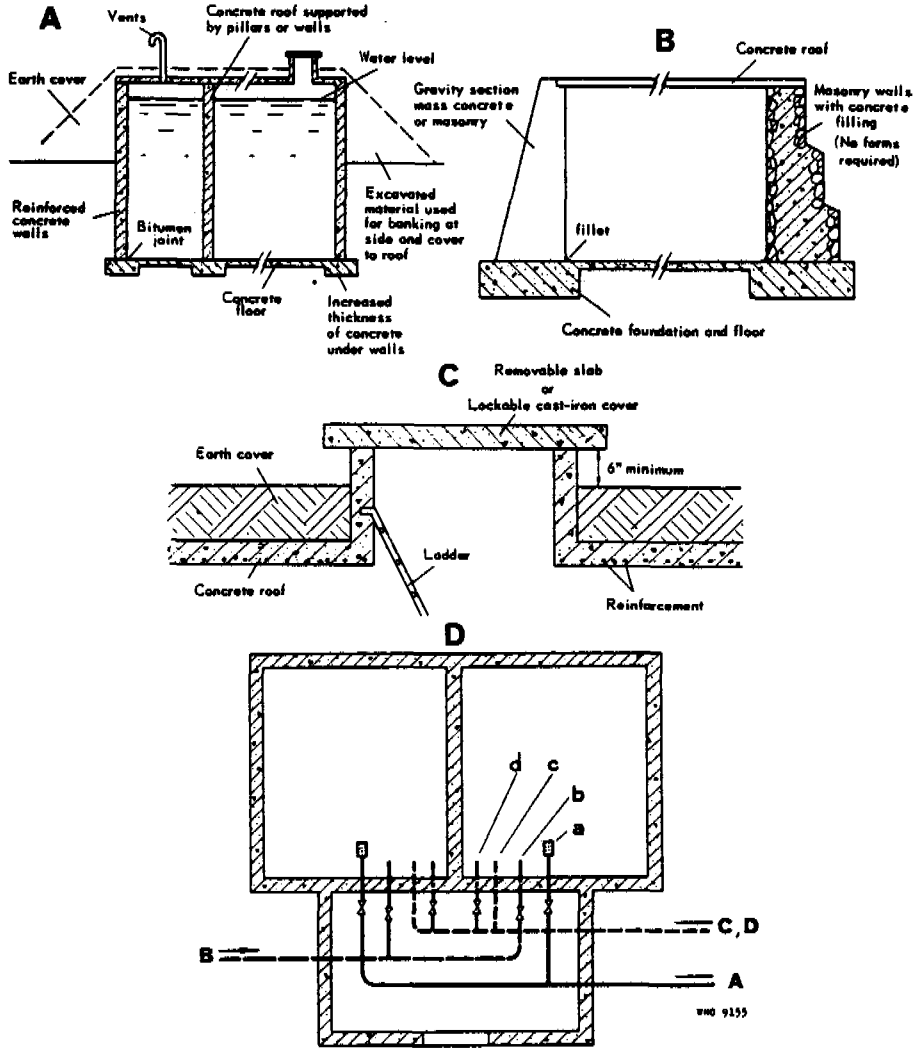
Where suitable stone is available, masonry is usually cheaper than mass concrete as the aggregate does not have to be broken and graded to the same extent, and formwork is not required, but it is more difficult to make watertight. A compromise between masonry and mass concrete is often employed, using thin masonry walls and filling between them with concrete. In this case walls are stepped, not battered (see Figure 76).

Joints in concrete walls should be avoided as far as possible and are the principal cause of leakage from reservoirs. Where possible, vertical joints should always have a copper or polythene strip built in. Where this is impossible, and in all horizontal joints such as occur at the end of a day's construction, the surface should be left rough. When the next layer is added the old surface should be cleaned and covered with cement mortar to ensure a good bond.

To prevent leakage in a concrete reservoir, particularly when constant supervision of the work has not been possible and there is a danger that the material has not been adequately tamped during construction, it is recommended that its interior walls be painted with a solution of sodium silicate (water-glass). A better (but considerably more expensive) method is to render the interior surface with a very thin layer of mortar composed of waterproof cement and sand, after thoroughly roughening the surface to be rendered to ensure a good bond.

Elevated tanks may be made of reinforced concrete or of steel (see Figures 77 and 78). When a number of tanks of similar size are to be built in a series of communities, reinforced concrete can be more economical as formwork can be re-used, machinery such as hoist, concrete mixer, vibrator, etc., can be transported from site to site, and the same workforce may be employed.

**Figure 76. GROUND-LEVEL RESERVOIRS**



**A** = Cross-section of reservoir  
**B** = Types of walls for reservoirs  
**C** = Sketch detail of manhole opening in reservoir cover

**D** = Typical valve arrangement for ground-level reservoir with two compartments

**Aa** = Effluent  
**Bb** = Supply  
**Cc** = Overflow  
**Dd** = Drain

## Water Supply Guidelines

For single small tanks it is usually found that steel is a much simpler, and sometimes cheaper, form of construction. A common form of such a tank is made from pressed, 1.2 metre square steel plates, which can be bolted together on top of a tower which is similarly prefabricated and assembled. These tanks are sent out complete by manufacturers with all bolts, washers, jointing compound, ladders, pipework, valves, depth gauges, etc.. Their assembly is relatively easy, requiring less supervision than other types of construction; the only local material used is the concrete in the tower foundations.

This form of sectional steel construction may also be used for ground-level tanks on difficult sites, such as on rocky hilltops, and in areas where stone suitable for concrete is scarce. In these instances the tanks should be mounted on low walls of concrete or brickwork at such a height above ground level as to allow of access below for inspection and regular painting.

Reservoirs must be covered, access to the interior being through a tightly-fitting inspection cover which is sufficiently raised above the reservoir cover to prevent surface water from entering. Covers are needed to prevent the entrance of contaminants and of sunlight which favours the multiplication of algae and other microorganisms in water. To avoid interference by the public the inspection cover should be lockable.

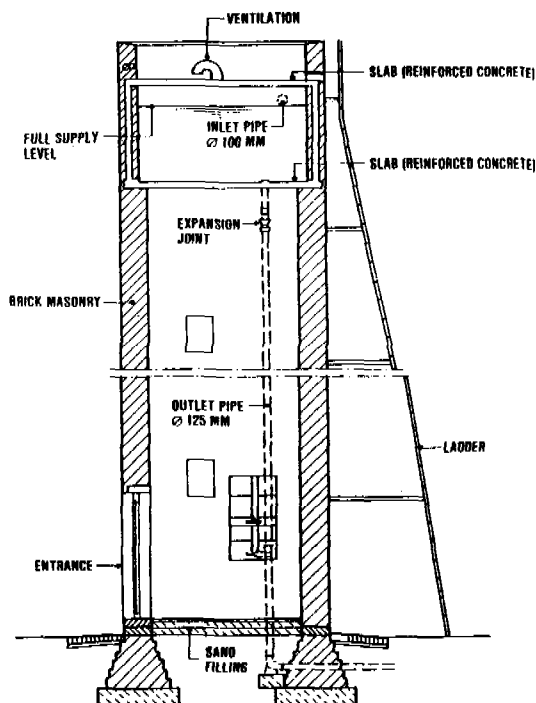
Ventilation must be provided to allow air inside the reservoir to escape when water enters. Ventilators should be designed to prevent entry of surface or rain water and dust. They should be screened with fine mesh wire (not less than 18-mesh) to keep out bats, birds, animals, mosquitoes and other insects. Bats are a particular nuisance in overhead tanks; they will enter through very small openings and love the dark, humid atmosphere in the space between the roof and water level inside the tank.

Small reservoirs and tanks are frequently built as a single unit. However, it is preferable to divide large reservoirs into two sections by means of a vertical wall and to arrange valves and piping in such a way as to allow either section to be used independently. This prevents interruption of the supply during servicing and cleaning. The wall must be designed to stand the thrust in either direction.

When a ground level tank is built to meet an existing demand which is expected to increase in the future, one wall may be designed of sufficient strength to become a partition wall when storage capacity is later increased by building an extension to the reservoir.

Ground level tanks may be built on the ground, wholly underground, or partially buried; the choice depending largely on the level required. If the ground is hard rock and excavation is expensive, a tank with its base built at about ground level will normally be least expensive.

**Figure 77. ELEVATED SERVICE RESERVOIR**



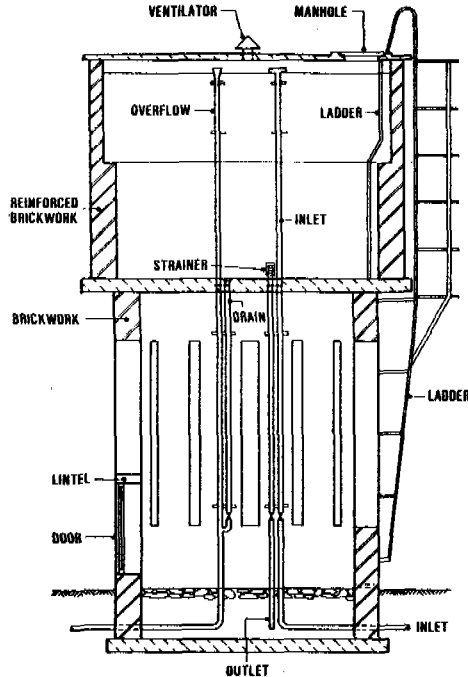
In reasonable ground conditions a common form of construction is to build the tank half below and half above the surface. The excavated material is then used to form sloping banks around, and a 15 cm earth cover over, the reservoir. In this case it is especially important that the tank is properly fenced to exclude animals.

Every reservoir needs an inlet, outlet, overflow and wash-out. In balancing or "floating" tanks, the inlet and outlet may be combined and a single connection may serve the dual purpose. This may be connected through the side of the tank with the inlet of the pipe at least 15 cm from the bottom of the tank. Alternatively, it may be connected up through the tank floor, ending at least 15 cm above the floor. Thus there is a "dead" volume of water 15 cm deep at the bottom of the reservoir which cannot be drawn off through the outlet. This allows for any particles to settle out and to be drawn off at regular intervals through the wash-out pipe, which must be at the lowest point of the tank. In tanks with concrete floors, the floors are generally designed so as to slope to one point where a sump is constructed, which functions as

## Water Supply Guidelines

the wash-out. In this way it is possible to empty the tank completely for cleaning and disinfection.

**Figure 78. ELEVATED SERVICE RESERVOIR**

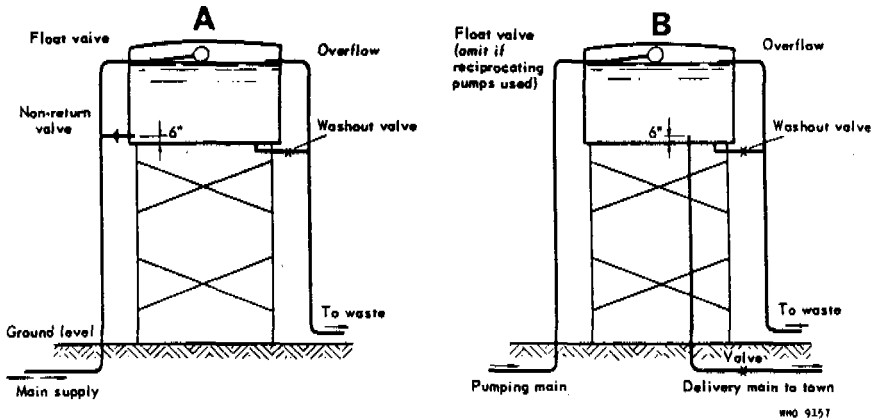


When a float valve is used to control the water level in the tank, the overflow should never need to be used if the valve is working properly. In the case of a "floating" tank it is usual to control the inlet by means of a float valve the outlet joins the delivery pipe through a non-return valve (see Figure 79). A depth gauge operated by a float and wire shows the amount of water within the tank, and is visible from the outside.

When a float valve is not used, there is no control of the water level in the tank except for the overflow. This may be unimportant if water is fed to the tank by gravity. However, if the water is pumped, then the operator of the supply pump needs to be experienced so as to adjust the hours of pumping in order to avoid wastage. The further the tank is from the pump house, the easier it is to overlook such wastage. The simple indicator shown in Figure 80 is one way of minimising wastage as, properly sited, it can be seen for a considerable distance.

## Water Supply Guidelines

**Figure 79. ELEVATED STORAGE TANKS**



Outlet always taken from 15 cm above tank floor; wash-out at extreme bottom of tank

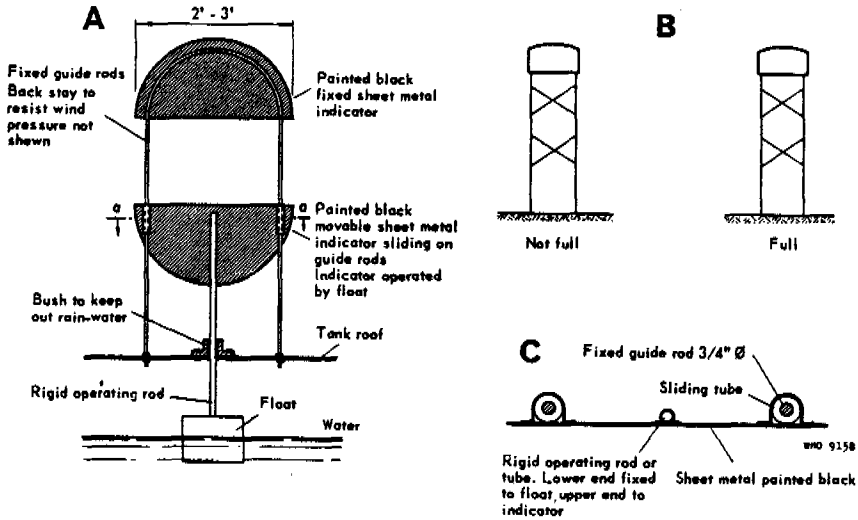
A = Diagrammatic arrangement of pipes when overhead tank acts as balancer (floating tank). Not suitable for use with reciprocating pumps

B = Diagrammatic arrangement of pipes when pumping direct to storage tank

When provision for fire hydrants is made, their requirements must be taken into account when calculating reservoir capacity. Experience shows that for small communities, the amount of water needed for fire-fighting alone may be several times as great as the daily requirement for domestic consumption. In this instance, the design of the distribution system will require the services of a competent engineer.

In many rural areas, no storage provision is made for fire-fighting and in cases of fire, other sources of water are tapped. Under such circumstances there is a danger that the water supply system may receive a considerable amount of pollution through an accidental cross-connection with the emergency fire piping. In some urban communities there is no storage for fire-fighting but the distribution pipes are large enough for water to be pumped directly into them in the event of a fire.

**Figure 80. WATER-LEVEL INDICATOR FOR ELEVATED STORAGE TANKS**



A = Suitable indicator for top two to three feet of water in tank;

B = Appearance of indicator from a distance; it should be oriented so that it appears against the indicator skyline from observation point; it can be seen clearly a mile away.

C = Section showing construction and operation of lower indicator

**9.1.2. Design of pipes**

For detailed methods of design of gravity conduits and pipes, the reader should refer to standard texts on hydraulics.

The design of pipes in a small water supply system is usually confined to two main problems:

1. calculating the size of pipe required to convey a specified amount of water under a given hydraulic gradient; and
2. determining the amount of water which will be delivered by a pipeline of a given size under a known pressure.

These calculations yield only approximate results because they are based on several assumptions, e.g. the water demand 20 years or more in the future, the



## Water Supply Guidelines

roughness of the pipes at that time, etc. It is important however, that basic topographical data from which static heads and pressures are determined should be as accurate as possible.

### 9.1.3. Distribution systems

There are two main systems of distributing water in a community; the dead-end system and the gridiron system. As may be seen in Figure 81, in the gridiron system the extremities of pipes are connected, with the result that dead-ends, and consequent stagnant water, are eliminated. Water circulates continuously throughout the distribution system. Such a distribution system is not often suitable for ribbon developments (communities which are built, for example, along a stream, an irrigation canal, or a main road).

It is desirable wherever possible to compromise between the two types of systems by laying out a gridiron pattern around the main residential or business districts and following the dead-end pattern for the rest of the system.

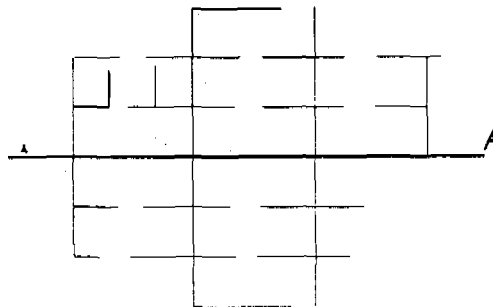
In designing the pipes of a dead-end distribution system, it is assumed that all the water needed in a particular district will be delivered at the end of the pipe serving this particular district and at the minimum pressure selected. A similar assumption may be made for each pipe in a gridiron layout. In this way the calculations result in pipes slightly larger than absolutely necessary. More accurate methods of calculation are available, but are seldom used for the design of small distribution systems. The following design assumptions may be made for the design of small distribution systems:

1. Population: estimates depend on a study of the local situation and available statistics. For economical design, the estimated population in 20 to 30 years time should be selected. However, a minimum increase of 50 per cent should be assumed under most circumstances.
2. Average daily consumption: also depends on local conditions, such as climate, economic status of the population, number of domestic connections compared to public standpipe, the installation of meters, and the amount of waste. The percentage of houses with domestic connections may vary from 20 to 100 per cent. Recommended design figures are:
  - distribution through public standposts ..... 70 lpcd
  - distribution through domestic connections ..... 90 lpcd
3. Maximum hourly demand: may be taken as 1.5 times the average daily demand.
4. Pressure: In order to maintain adequate pressure in the system, the following recommendations are made:
  - 5 m head minimum when distribution is through public stand posts only.
  - 8 m head minimum when house connections are also provided.
  - 50 m head maximum pressure.

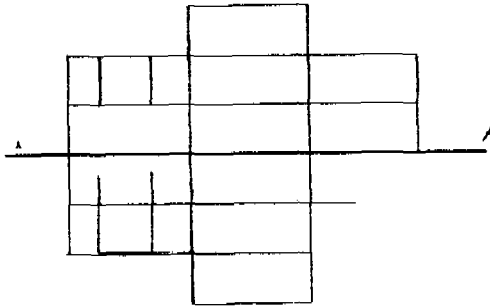
## Water Supply Guidelines

5. Feeder pipe: should be capable of delivering 130 per cent of average daily demand. The diameter should never be less than 5 cm.
6. Velocity of flow: should not be more than 1.8 metres per second in main pipes, and about 0.90 metres per second in distribution pipes.

**Figure 81. SYSTEMS OF DISTRIBUTION**



Dead-end distribution system



Gridiron distribution system

A = Main distribution pipe

7. Distribution pipes: main distribution pipes should have a minimum diameter of 5 cm. When fire protection must be provided, no hydrant should be served by a pipe smaller than 10 cm in diameter.
8. Service connections: not less than 12 mm in diameter. Each connection should be made by means of a corporation cock tapped into the main followed by a short length (about 60 cm) of piping e.g. PVC, galvanised iron, copper. This is continued

## Water Supply Guidelines

by selected pipes 20 mm or more in diameter and a control valve.

9. Number of public standposts (with 2 taps): one for every 150 persons.
10. Spacing of public standposts: not more than 200 metres apart.

### 9.1.4. Pipelines

Water from the selected source needs to be transported to the community, either directly or via a storage reservoir, and/or a treatment plant. Covered aqueducts and pipelines, especially the latter, are used for conveying water for domestic consumption. Pipelines are usually selected because of their efficiency in carrying water and the ease with which they can be transported and laid, even in relatively inaccessible areas. In addition, pipes are unlikely to impart taste, odour, or colour to the water being conveyed, as is sometimes the case with aqueducts.

Small communities usually require small pipe sizes. Wrought iron, black or galvanised cast iron, steel, fibre-cement or PVC are excellent materials for pipes. Galvanised cast iron, fibre-cement or PVC pipes are preferred because they last longer and are not subject to corrosion. In order to adapt wrought-iron pipes to different pressures, they are made available in three categories:

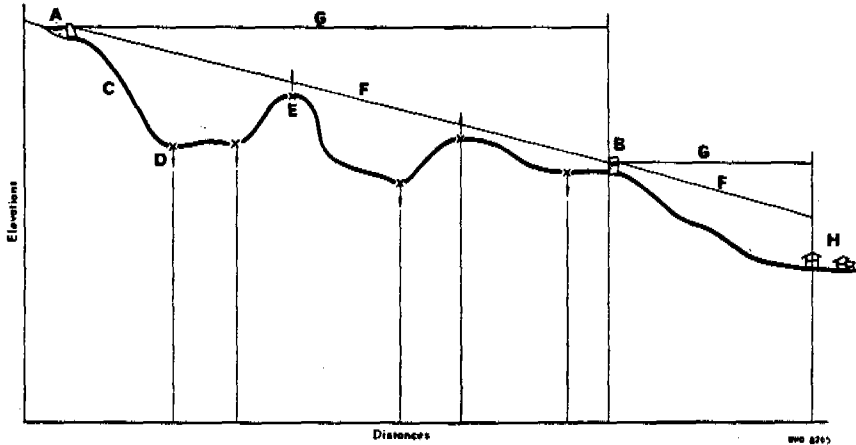
1. standard,
2. extra strong (heavy) and
3. double extra strong (extra heavy)

In all three grades the outside diameters of the pipes remain the same while the thickness is increased, thereby reducing the inside diameter. They have threaded joints.

Certain steps must be observed when designing and constructing pipelines. First, a topographic map should be prepared showing the location of the pipeline and other relevant structures and the profile of the ground along the route to be followed. The map should also show pipe sizes and location of valves and other fittings. A pipe-line usually follows the profile of the ground. However, its location should be such as to reduce construction costs and internal pressures. Water pressure is reduced when the pipeline is close to the hydraulic gradient (see Figure 82.). The pipeline should not rise above the hydraulic gradient at any point since this would create siphonage and a negative pressure in the pipe.

Excessive pressures can be avoided by suitably located pressure break tanks, overflows or auxiliary reservoirs. The pipes should be laid on gradients which are as uniform as possible. When this is not possible, valves should be installed at low points to enable drainage of the line and removal of sediment. Air-relief valves should be placed at summits to allow air to escape when filling the pipe and to prevent interference with the flow of water due to accumulation of air at such points. The velocity of water in the pipe should not be less than 0.60 to 0.75 metres per second in order to prevent the deposition of silt.

**Figure 82. PROFILE OF A PIPELINE FROM SOURCE TO DISTRIBUTION SYSTEM**



Not to scale

- |   |                                 |                        |
|---|---------------------------------|------------------------|
| A = Intake structure<br>(reservoir, pond, etc.) | C = Pipeline                    | F = Hydraulic gradient |
| B = Storage reservoir                           | D = Pressure-<br>release valves | G = Static head        |
|   | E = Air valves                  | H = small community    |

The pipeline should be laid along the shortest possible route and changes of direction should be made, as far as possible, by gradual deflection in the pipes joints. Sharp bends should be avoided, as they cause excessive friction which reduces the carrying capacity of the pipeline.

In the case of surface water sources, the intake should be located some distance from the river bank or lakeside so as to minimise the danger of pollution. A strainer should be fitted at the inlet end of the pipe to prevent the entrance of fish and debris.

Each section of pipe should be inspected for cracks or damage before it is laid. When laying bell-and-spigot cast iron pipes, the bells should always be directed upwards. In order to protect pipe from damage due to traffic or bad weather conditions, it should be buried at a suitable depth. In the tropics an earth cover of at least 50 cm should be provided. The width of excavated trenches varies with the required depth but is usually not less than 45 cm.

The pipes should be laid on firm ground or foundation to prevent them settling unequally which may damage pipe joints. In rocky soils, rocks and stones should be removed from the bottom of the trenches to a depth of at least 15 cm below the pipes

## Water Supply Guidelines

and should be replaced by plain earth, sand, or pea-sized gravel.

Newly-layed pipelines should undergo hydrostatic tests at 1.5 times the normal working pressure for at least 24 hours to determine both the location and the amount of leakage. The pipeline should be filled slowly, after flushing through pressure-release valves and all air should be expelled through air valves. While these tests are carried out, the sections of pipe between joints should be covered, but the joints themselves should remain exposed for inspection. The leakage should not be allowed to be greater than 8 litres per metre of joint per 24 hours under normal operating pressure.

In the course of construction, pipelines become contaminated. For this reason, they should be disinfected before they are put into service for domestic use. Chlorine, calcium hypochlorite (bleaching powder), and high-test hypochlorite may be used for this purpose. The dose should be not less than 50 mg/l of available chlorine and the time of contact not less than 12 hours. This dose may be obtained by dissolving and applying 72 g of high-test calcium hypochlorite, or 240 g of chlorinated lime, to each cubic metre of water used to fill and disinfect the pipeline.

### **9.2. Public Standpipes (public water points)**

Most distribution systems in small communities have some public standposts. When individual domestic connections cannot be afforded, or there is insufficient volume of water available, then public standpipes have to be provided.

There are several factors which must be considered in their design including defining the number required, distribution, adequate location, type of tap or outlet to be used, height of the loading platform, drainage around the standpost, and the charge to be levied. Most of these factors depend almost entirely on local circumstances. However, the experience already acquired in several countries may be useful.

Attention should be paid to local customs of carrying burdens (especially water) and consequently, to the height of the standpost loading platform. Water may be carried in a variety of containers, such as pottery or brass vessels, 20 litre tins, buckets, and assorted cooking utensils. It may be transported on the head, shoulder, or back, or in the hand, or with the help of a yoke.

Ideally the platform on which the container is filled should be only a little lower than the height at which the load is carried, to eliminate unnecessary lifting. It should provide room for more than one container. The spout should project far enough to reach the mouth of the container. Dual platforms may be needed, one a little lower than knee level, the other at about shoulder height. Where jugs with round bottoms are used, a depression may be provided in the loading platform to give firmer support.

## Water Supply Guidelines

Public standpipes are subject to continual use and are often repeatedly broken through rough and heavy usage and vandalism. As a result they are frequently responsible for considerable water losses, especially when pressure is high and the size of the outlet is large. Pressure-reducing valves and a reduction of tap sizes will help to limit these losses. Public standpipes require constant supervision and frequent repairs.

Poor location of standpipes can defeat the public health objectives of the water supply system. An inadequate location may discourage its use by the population in favour of possibly unsafe water sources.

Every public standpipe should be built with provision for the disposal of spilt water and waste water used for washing at the water point. Water standing around public standpipes can create a serious nuisance and discourage their use. The area on which water will spill should be paved, preferably with concrete, and the wastewater drained to a water course or a soakage pit, a pit filled with stones and covered with a layer of soil. Figure 83 shows a typical standpipe and drainage scheme.

Public standpipes should be constructed of the most durable materials possible. No other part of the water system will be required to take so much heavy and frequent use. It is usually possible to construct the platform and tap supports so that only the most excessive abuse will damage it. The weakest part is the tap itself, which should be of the best quality available.

### 9.3. Water Losses

There are leaks in every distribution system, no matter how well it is built. It is important to minimise leakage and waste in small water distribution systems.

The control of water losses usually involves some kind of an inspection system, either personal or mechanical. The mechanical system of inspection implies the use of water meters and gauges which in turn require maintenance and attention and are generally beyond the means of small communities. Since the major losses in most small communities are from domestic connections and public standpipes, it is here that most effort must be concentrated.

A system of private house inspection may be developed which will lead to the discovery and repair of leaky taps and valves and to the elimination of waste in general. The amount of water lost through carelessness of consumers can be very large; it is not uncommon to find towns in which as much as 75 per cent of the water supplied is wasted.

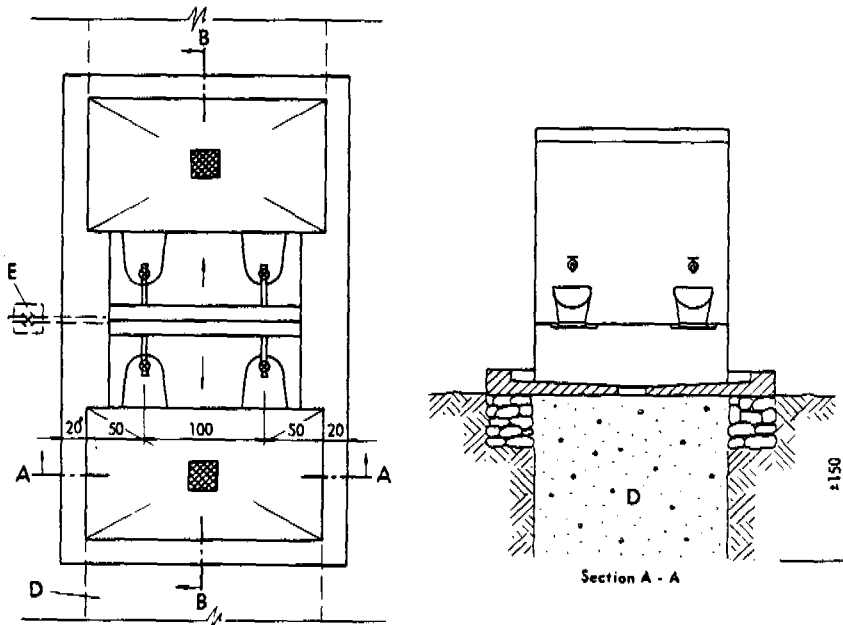
### 9.4. Laundries and Baths

Public laundries and baths are often included as a part of small town water supply systems. These are especially needed in areas where bilharziasis (schistosomiasis) is prevalent. In such areas, disease transmission takes place mostly through

## Water Supply Guidelines

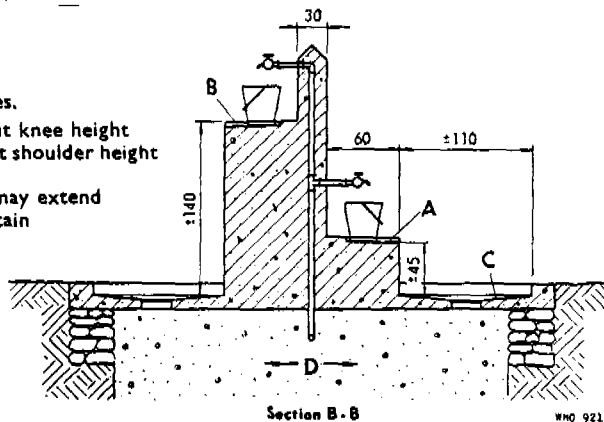
skin contact with river, pool, or canal water which is infested with the parasite. The danger is particularly great for children, who in warm climates of bilharzia-infested countries, spend much of their spare time playing in rivers, water pools, or irrigation canals which are easily infected by the faeces and urine of apparently healthy, but infected individuals. The provision of public laundries, public baths, and swimming pools is a step towards preventing the transmission of this debilitating disease.

**Figure 83. POSSIBLE ARRANGEMENT OF PUBLIC STANDPIPE**



Measures are in centimetres.

- A = Platform level at about knee height
- B = Platform level at about shoulder height
- C = Hard-surface floor
- D = Soakage pit : length may extend beyond limits of fountain
- E = Control valve



WHO 9217

## Water Supply Guidelines

Public laundries and baths are generally well used as long as they are properly maintained. If however, reasonable cleanliness and maintenance cannot be assured, the funds may be better employed elsewhere.

In the design of a public laundry, the following points should be carefully observed;

1. The design should be practical and conform reasonably well to local customs. For this purpose, the designer should make a preliminary study of local laundering methods.
2. The provision of ample drying space unless clothes are taken home for drying. Overhead lines or concrete slabs can be constructed, depending on local customs. In some areas, clothes are lain flat on the ground to dry rather than on lines.
3. The provision of sufficient supply of water. Although this sounds an obvious requirement, it is not uncommon to find public laundries in which the pipes are too small to supply enough water for laundering. The construction of a small storage tank at the side will help during heavy use of the laundry.
4. The chemical examination of the water supply for content of iron and manganese compounds. These substances are capable of staining clothes a reddish-brown or black colour.
5. The drainage of waste water from the public laundry installation.

Similarly, in the case of public baths, the designer should pay particular attention to the physical quality of the water supply (e.g. turbidity, colour and odour), the drainage of waste water, the separation of sexes, etc. In the case of swimming pools in bilharzia-infested areas, it may be necessary (depending upon the source of water supply) to enforce chlorination to destroy bilharzia cercariae in the water.

In filtered water cercariae will be killed in 10 minutes by application of chloramine with a 1 mg/l chlorine residual at 1 minute. In unfiltered water, they will be killed within 10 minutes by chloramine with 1 mg/l chlorine residual at 30 minutes. With calcium hypochlorine solution, cercariae will be destroyed within 20 minutes with a chlorine residual at 30 minutes of 0.75 p.p.m.

### 9.5. Protective Measures

The protective measures needed for water distribution systems aim at conserving the quality of water obtained from the source to consumers taps. At many points in a system the quality of the water may be altered by any of the following factors:

1. ingress of external polluted water through faulty joints or leaks;
2. growth of bacteria and microorganisms in the distribution system itself;
3. solution of chemical substances from metal pipes or from the cement mixtures or other building materials used in the construction of reservoirs or cisterns; and
4. pollution obtained from accidental cross-connections with contaminated water pipes or back-siphonage.



## Water Supply Guidelines

Protective measures need to be designed into the system. They should also be given attention during construction and pipe-laying operations. Disinfection carried out after construction of the system is essential but will not completely sterilise the surfaces with which the distributed water comes into contact. Therefore, good standards of general hygiene should always be maintained.

The principal sanitary measures involve the following:

1. Proper location of reservoirs and distribution pipes.  
Direct contact with, or proximity to, all sources of pollution such as sewage or storm-water ditches, latrines, etc. must be avoided. Distribution pipes should not be submerged in surface water pools and, wherever possible, should be placed above sewers or drain pipes.
2. Watertightness of reservoirs and pipes and the elimination of leaks.
3. Maintenance of continuous pressure in the system (i.e. 24 hours per day in all parts).
4. Planning the distribution system in such a way as to permit effective circulation of water and a reduction in the number of dead ends, which favour the growth of bacteria and micro-organisms and the build-up of sediment.
5. Detection and elimination of cross-connections.
6. Prevention of back-flow and entry of external water or materials through openings such as overflow pipes and inspection covers of reservoirs, etc. through good construction practice.
7. Use of pipe and construction materials which do not easily corrode or dissolve in water.

These sanitary measures are usually specified in detail by government sanitary codes or regulations, which should be complied with by the design and construction engineer.

## **10. PUMPS FOR COMMUNITY WATER SUPPLIES**

### **10.1. Introduction**

Pumps and motors are complex machines and can be dangerous and even fatal when installed or operated incorrectly. It is therefore recommended that any installation, operation or maintenance of pumps and motors should not be undertaken by untrained and inexperienced staff.

### **10.2. Classification of Pumps**

A classification of pumps for use in community water supplies is illustrated in Figure 84.

The most commonly used is the centrifugal pump, which may be of a single-stage or multistage type. The centrifugal pump in its several variations has almost completely displaced all other types of pumping equipment for piped water supplies. The hand pump is a reciprocating (piston/plunger type) pump using human motive power. Other types of pump include rotary, injector or jet, air lift, and hydraulic ram pumps, and are largely used for special applications.

For small communities in developing countries, human and animal power are often the most readily available power for pumping water, particularly in rural areas. Under suitable conditions, wind power is of relevance. Solar energy has potential but has been little used for water pumping to date. Diesel engines and electric motors imply much greater expense, both in capital and recurrent costs and also require skilled operation and maintenance. They should only be used if the necessary fuel or electricity and operating costs are affordable and if adequate trained personnel for maintenance and spare parts are obtainable.

### **10.3. Selection of Pumps**

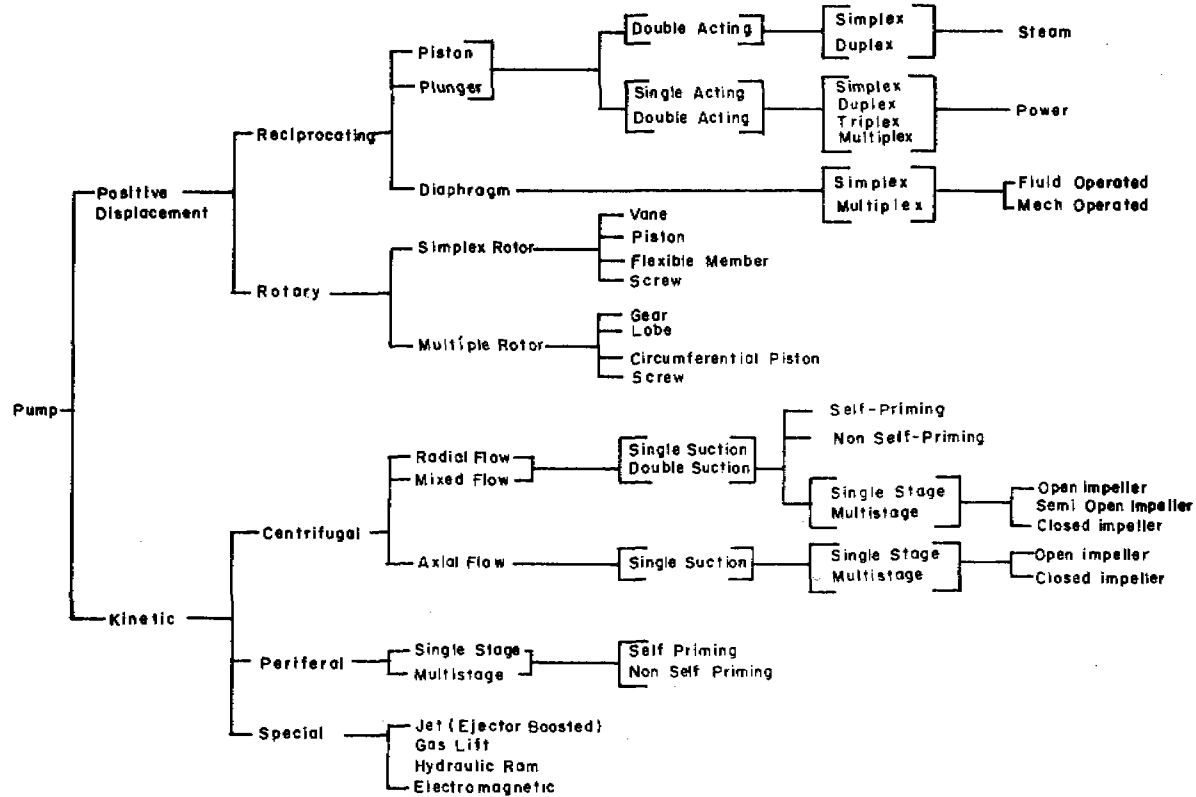
Some important considerations for selection of pumps include:

(a) Nature of the water to be pumped

The nature of the water will determine the type of impeller best suited for the purpose and the material to be used for pump construction. For pumping clear water, pumps with single or double suction and closed-type impellers are recommended. For pumping muddy water, pumps with mixed flow impellers are suitable. For pumping brackish water, corrosion-resistant materials should be used.

(b) Pumping capacity and lifting head

Figure 84. CLASSIFICATION OF PUMPS



## Water Supply Guidelines

For small units, the single suction, closed impeller, type of pump is more practical.

In larger plant, the horizontal shaft, double suction, volute casing centrifugal pump is the most commonly used type and is recommended up to a capacity of 100,000 cubic metres per day with a total head of 75 metres.

In deep wells, vertical turbine or submersible pumps are universally used.

An indication of the pump type to be selected for a particular application can be obtained from Figure 85 and Table 12 gives characteristics of the various types of pumps.

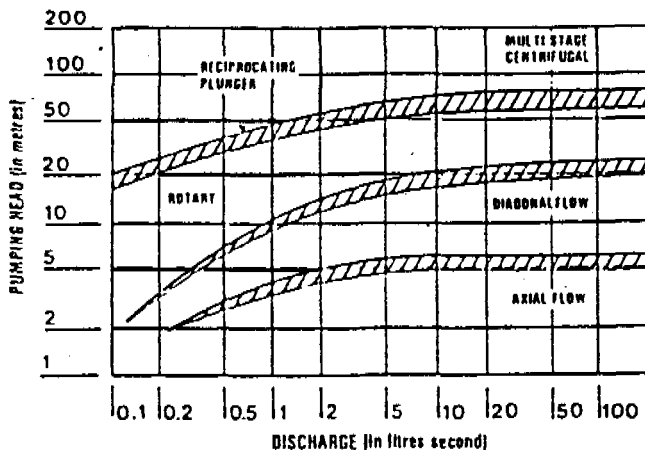
In the case of the turbine and centrifugal pumps, the efficiency and power consumed vary with operating heads. It is therefore advisable to select a pump unit that gives maximum efficiency at the operating point. If there is a chances that the operating point may vary, pumps of the non-over-loading type should be selected with maximum efficiency in the operating range.

Generally, manufacturers of standard pumps supply units which operate continuously unless otherwise specified. Nevertheless, it is desirable to check whether the equipment is likely to become overloaded under operating conditions other than the one specified.

Oil lubricated pumps generally have a longer life and are slightly more efficient than the water lubricated ones.

High temperatures may dictate the use of special materials, water-cooled stuffing boxes or special mechanical arrangements such as centre-line support of the casing.

Figure 85. PUMP TYPE SELECTION CHART



## Water Supply Guidelines

**(c) Initial cost of pump and its driving equipment**

Efficiency is a very important factor where electric motors are used, particularly where power is expensive. In some circumstances, a new pump installed to replace an old, inefficient one would pay for itself within a very short time simply by reducing electricity consumption.

**(d) Extent and reliability of maintenance**

Pumps in which all moving parts are above ground and easily accessible are preferable and will in most instances be easier to maintain. However, if qualified maintenance can be assured, pumps with submerged cylinders should be considered.

**(e) Desirability of standardisation and reduction of spare parts**

When a number of pumps are involved, it is desirable to standardise the units so that parts are easily interchangeable in times of emergency, and to reduce the number and diversity of spare parts to be stocked for repair and maintenance purposes.

**(f) Fluctuations in suction levels**

Suction lift is of great importance when dealing with centrifugal pumps. Normally, the pump should be installed such that the distance of the centre line of its suction opening from the lowest water level obtained in the well when pumping will not exceed 4.5 metres. If the suction lift exceeds the maximum value, serious problems like cavitation may result.

**TABLE 12. INFORMATION ON TYPES OF PUMP**

Type of Pump	Usual Depth Range	Characteristics and Applicability
1. Reciprocating (plunger)		Low speed of operation: hand, wind or motor-powered. Efficiency low (range 25 to 60%)
(a) Suction (shallow well)	Up to 7 m	Capacity range: 10 to 50 L/min,
(b) Lift (deep well)		Suitable to pump against variable heads, valves and cup seals require maintenance attention.
2. Rotary (positive displacement)		Low speed of operation: hand, animal, wind powered.
(a) Chain and bucket pump	Up to 10 m	Capacity range 5 to 30 L/min. discharge constant under variable heads,

## Water Supply Guidelines

<b>Type of Pump</b>	<b>Usual Depth Range</b>	<b>Characteristics and Applicability</b>
(b) Helical rotor	25 to 150 m	Hand, wind or motor powered. Good efficiency, best suited to low capacity, high-lift pumping.
3. Axial flow	5 to 10 m	High capacity, low-lift pumping. Can pump water containing sand or silt.
4. Centrifugal		High speed of operation. Smooth, even discharge. Efficiency (range 50 to 85%) depends on operating speed and pumping head.
(a) Single stage	20 to 35 m	Require skilled maintenance. Not suitable for hand operation. Powered by engine or electric motor.
(b) Multi stage shaft driven	25 to 50 m	As for single stage. Motor accessible, above ground. Alignment and lubrication of shaft critical. Capacity range 25 to 10,000 L/min.
(c) Multi stage submersible	30 to 120 m	As for multi stage shaft driven. Smoother operation. Maintenance difficult. Repair to motor or pump requires pulling unit from well. Wide range of capacities and heads. Subject to rapid wear when sandy water is pumped.
5. Air lift	15 to 50 m	High capacity at low lift. Very low efficiency especially at greater lifts. No moving parts in the well. Well casing straightness not critical.

### (g) Number of units

It is important to determine whether one or more units can be operated in parallel, as the hydraulic performance of individual units may need to be adapted for this purpose. If there is a fluctuating demand, two or more pumps may be operated in parallel.

## 10.4 Handpumps

Handpumps installed on wells and boreholes provide one of the simplest and least costly means of providing small communities with clean water. They have been in use for centuries, made of wood at first and later of metal. Machined mass-produced pumps were being produced by the mid-19th century. Most handpumps in common use today use the same basic operating principles as those designed centuries ago. A handpump may be described as a machine equipped with a cylinder and a piston, used for raising water. Most handpumps use a piston with leather washers which moves up and down inside a cylinder, rather like a bicycle pump. The washers wear out and must be replaced regularly.

A handpump provides some protection of well water against contamination. However, it should be remembered that contamination can still enter the water. Good sanitary finishing, taking into account all the factors outlined in section 5.3 is necessary.

### 10.4.1. Types and uses

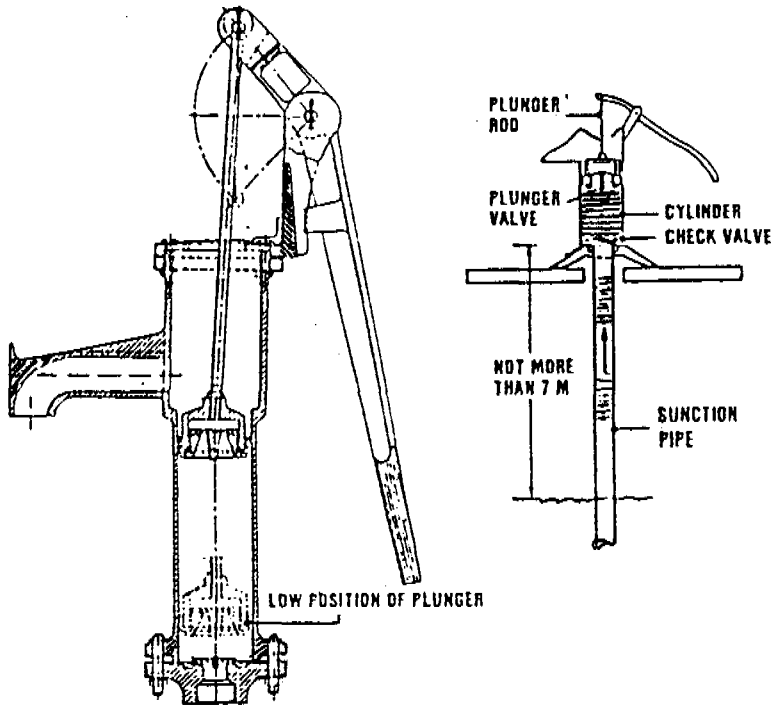
In most developing countries, the largest coverage of the rural population with water is by means of drilled or dug wells equipped with handpumps. The use of a handpump to withdraw water from wells is limited by the capacity of the well, the capacity of the pump itself and the energy input of the user. Handpumps may be classified into "shallow-well handpumps" and "deep-well handpumps".

### 10.4.2. Shallow well handpumps

The term shallow well refers to the depth of water table below the ground level which should not exceed 7 metres. Shallow-well handpumps in common use are shown in Figures 86 and 87.

Shallow-well handpumps are cheaper and easier to maintain because the pumping mechanism is above ground level. However, the suction lift from the spout of the pump to the well water level should not exceed 7.0 metres during the driest period of the year. Theoretically, atmospheric pressure would allow a suction pump to draw water from as deep as 10 metres, but in practice 7 metres is the limit depending on altitude and water temperature where the pump is operated.

**Figure 86. SHALLOW-WELL SUCTION PUMP**

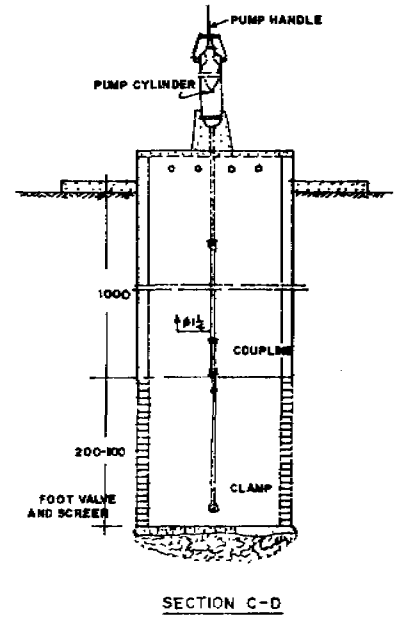
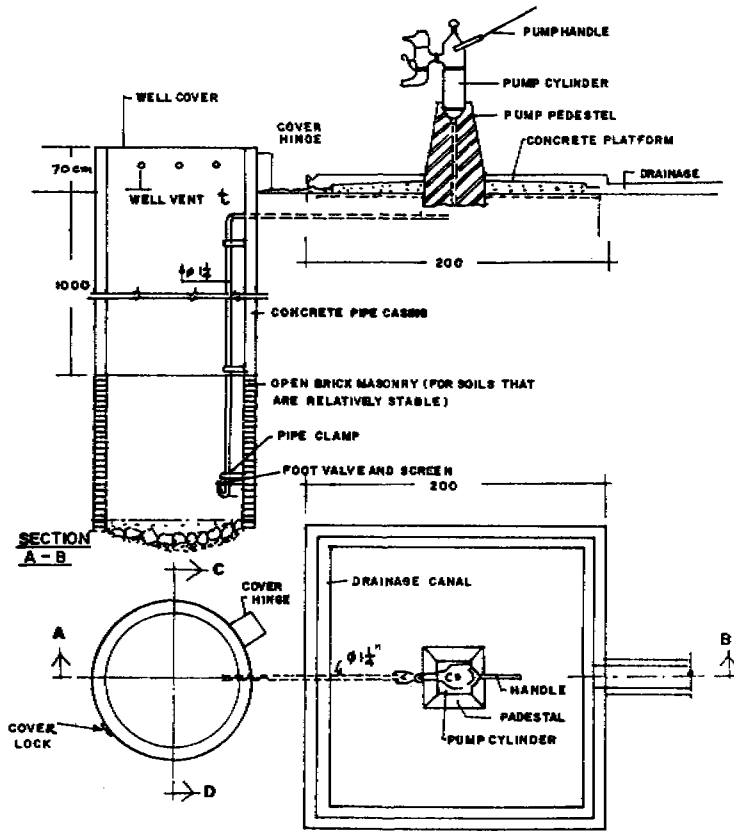


#### **10.4.3. Deep-well handpumps**

In deep-well pumps the pumping mechanism is immersed in the water at the bottom of the well, as shown in Figure 88. A deep-well often consists of a 60 mm galvanised iron pipe driven in (or jetted) to a depth of about 18 m (3 pipe lengths) into the ground. Such wells are normally used in areas of low ground water. In this type of installation, the handpump head is at ground level. The pump body is suspended in the well by a 32 mm or 40 mm diameter riser pipe so that its lower valve is always below the pumping water level. A 1 metre diameter well with casing up to 1 metre below the pumping water level should be provided to lower and house the pump cylinder.

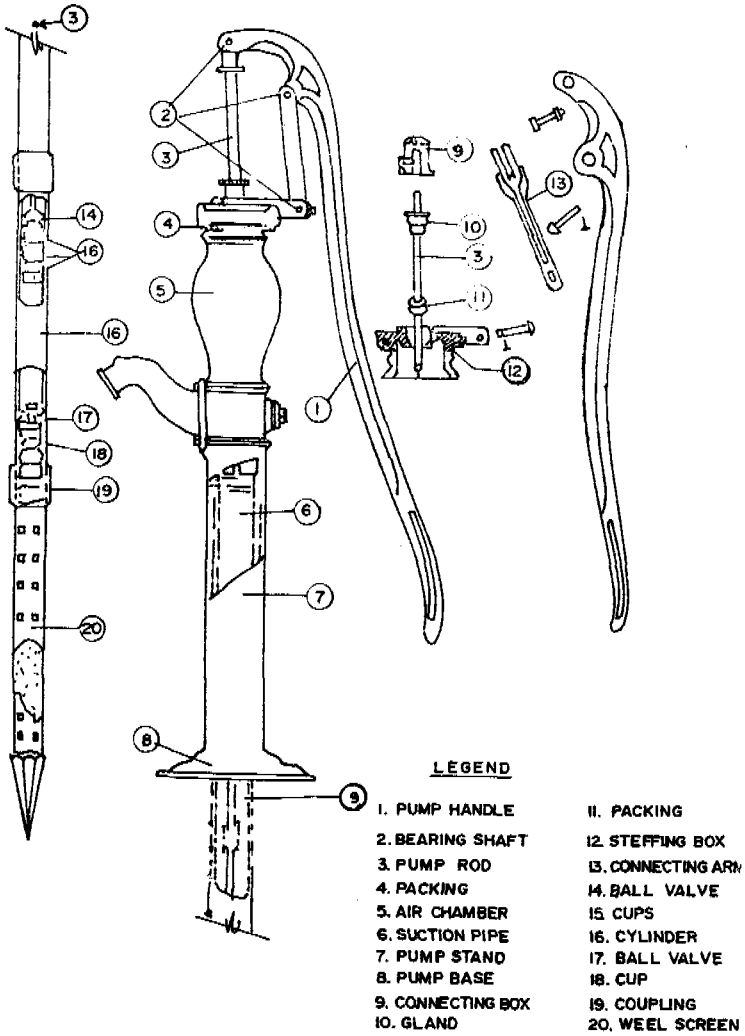


Figure 87. SHALLOW WELL HANDPUMP FOR DUG WELL



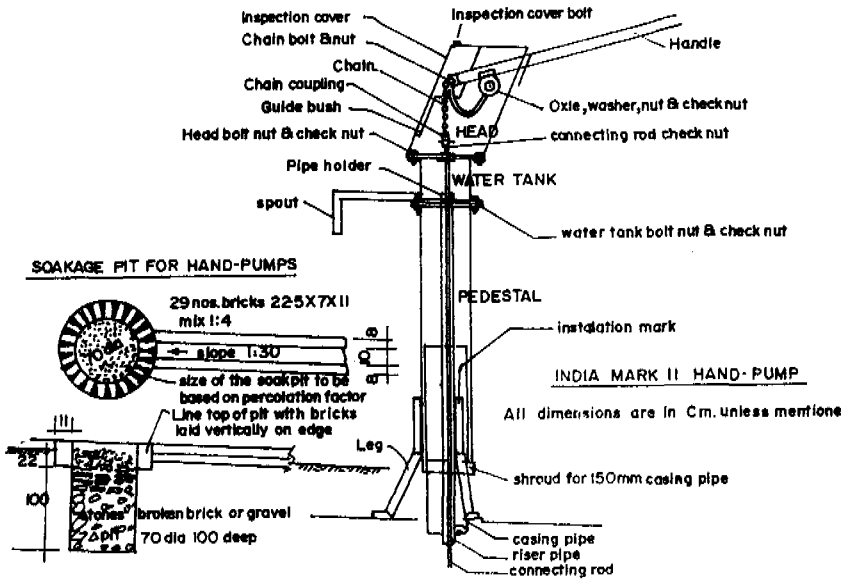
# Water Supply Guidelines

**Figure 88. DEEP-WELL HANDPUMP**

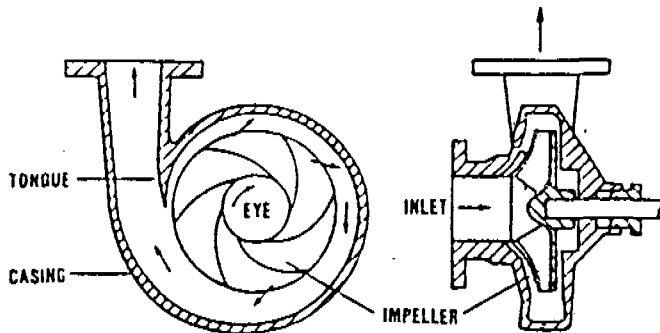


## Water Supply Guidelines

**Figure 89. DEEP-WELL HANDPUMP - India Mark II**



**Figure 90. CENTRIFUGAL PUMP (VOLUTE-TYPE CASING)**



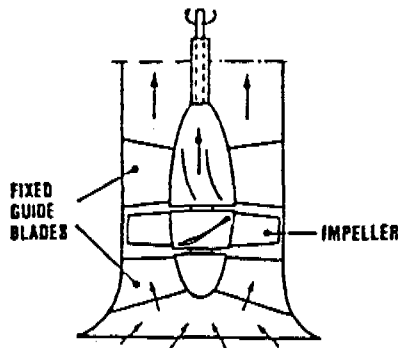
### 10.5. Centrifugal Pumps

Centrifugal pumps contain a rotating impeller mounted on a shaft turned by a power source. The rotating impeller increases the velocity of the water and discharges it into a surrounding volute casing which is shaped to slow down the velocity of the water and convert the velocity to pressure (see Figure 90).

When the pressure is more than can be practically or economically lifted by a single stage pump, additional stages are used. A pump with more than one stage is called a multistage pump. Water passes through each stage in suction side, with an increase in pressure at each stage. Multistage pumps commonly used in individual water systems are of the turbine or submersible types.

Because of the limitation of suction lift, centrifugal pumps with radial flow cannot be used where the groundwater level is below 8 metres.

Figure 91. TURBINE (AXIAL-FLOW) PUMP



### 10.6. Turbine Pumps

Where there are fluctuations in groundwater level, turbine pumps in which water flows in the general direction of the axis of the pump through a number of stages should be used, see Figure 91. Turbine pumps have the advantage of being compact. Powerful pumps can be lowered into small diameter bores (15 cm and above) and are capable of pumping large quantities of water. Turbine pumps work at high speeds and the transmission mechanism is light and compact. These pumps are not suitable for rural water supply schemes because their operating speed is critical. Rural electricity supplies or inadequately maintained diesel engines may cause pumps to operate at greatly reduced efficiency since the rate of rotation falls below that for which these pumps were designed. In addition, turbine pumps cannot be installed in tube wells which are not perfectly vertical, as is often the case in rural

areas.

The vertical drive turbine pump consists of one or more stages with the pumping unit located below the draw-down level of the water source. A vertical shaft connects the pumping assembly to a drive mechanism located above the pumping assembly. The discharge casing, pumphouse and inlet screen are suspended from the pump base at ground level.

The weight of the rotating portion of the pump is usually suspended from a thrust bearing, located in the pump head. The intermediate pump bearings may be lubricated by either oil or water. From a sanitary point of view, lubrication of pump bearings by water is preferable.

### 10.7. Submersible Pumps

The submersible pump, which incorporates the pump and motor in one assembly and remains submerged in water all the time, is the best choice for pumping clear water. When a centrifugal pump is driven by a closely coupled electric motor constructed for submerged operation as a single unit, it is called a submersible pump (see Figure 95). Problems of maintenance are minimised because of the absence of any complex mechanical power transmission system.

The electrical wiring to the submersible motor must be waterproof. The electrical control should be properly grounded to minimise the possibility of shorting and thus damaging the entire unit. The pump and motor assembly are supported by the discharge pipe. The pipe should therefore be of a size that prevents breakage.

### 10.8. Jet (ejector) Pumps

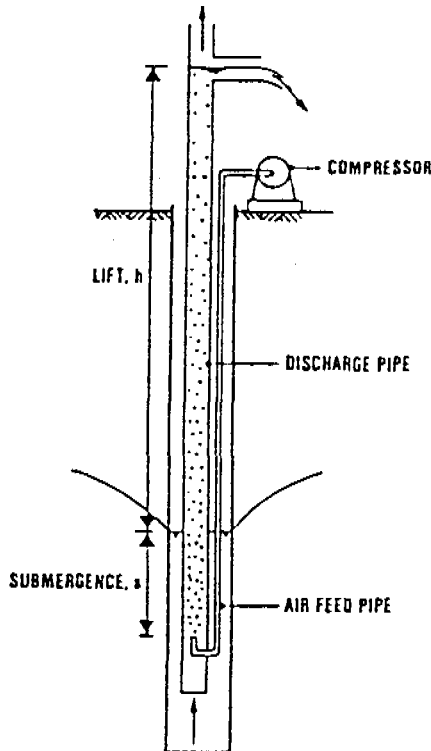
Jet pumps are very suitable for small water supply schemes. They are a combination of centrifugal and ejector pumps. A portion of the discharged water from the centrifugal pump is diverted through a nozzle and venturi tube. An air compressor may be used for injection of small evenly distributed bubbles at the foot of a discharge pipe. A pressure zone lower than that of the surrounding area exists in the venturi tube. Water from the source (well) will therefore flow into this area of reduced pressure (see Figure 92).

The velocity of the water from the nozzle pushes it through the pipe towards the surface where the centrifugal pump can lift it by suction. The centrifugal pump then forces it into the distribution system. Priming is necessary, since if the whole system is not filled, operation will not start. Priming can be done by means of a return feed from the storage tank. The normal operation limits of a small jet pump are:

- (a) Lift below ground level ..... 6-30 meters
- (b) Delivery head ..... 25 meters

The jet must always be covered by at least 1.5 metres of water, so that the well cannot be completely emptied.

Figure 92. JET PUMP



Jet pumps have the following advantages:

1. they are simple, light and compact;
2. all moving parts are on the surface, which facilitates easy maintenance;
3. they can be quickly installed, and
4. they are not affected by sand or silt in the pumped valves.

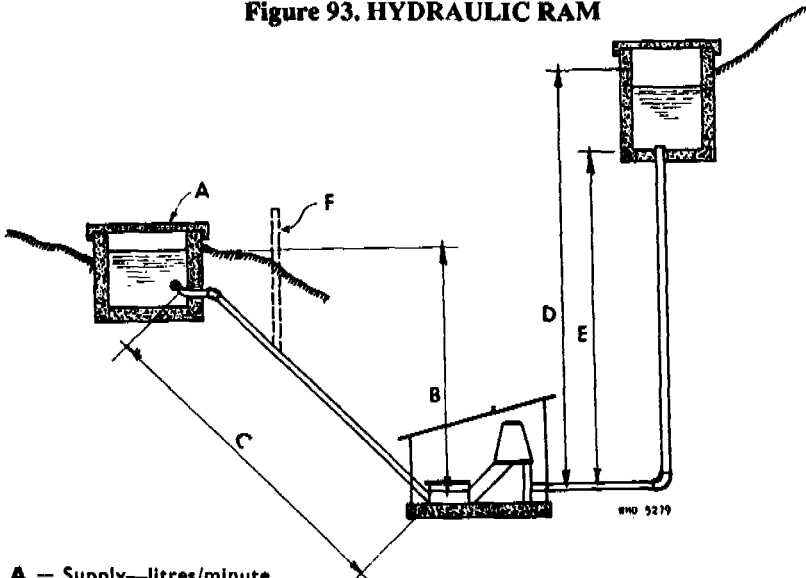
### 10.9. Impulse Pumps (Hydraulic Rams)

In the hydraulic ram, power is derived from water hammer which is intentionally produced (see Figure 93). The force of the water is captured in a chamber where air is compressed. This force is released when the compressed air expands, pushing a small amount of the water to a higher elevation than the source.

The water not raised up to a higher level is wasted. At each compression and decompression of the air in the chamber, a fixed quantity of water is pushed up to the tank or reservoir.

## Water Supply Guidelines

**Figure 93. HYDRAULIC RAM**



- A** = Supply—litres/minute
- B** = Difference in elevation between ram and supply—power head
- C** = Length of drive pipe
- D** = Difference in elevation between ram and highest point to which water is to be elevated—pumping head
- E** = Total length of supply pipe
- F** = Stand-pipe, necessary in case of exceedingly long drive pipe

Where a continuous supply is available, e.g. from a spring, this process can go on continuously and a great deal of water is pumped over a 24 hour period.

Table 13 gives an idea of the amount of water that can be pumped with various heads and amounts of power water:

**Table 13. QUANTITY OF WATER DELIVERED VERSUS RATIO OF PUMPING HEAD AND POWER HEAD**

Ratio of pumping head to power head	2	3	4	5	6	7	8	9	10	12	15	20
Delivery in gallons * per day for each gallon per min. of power water.	540	345	240	192	160	137	120	107	96	80	64	43

\*1 U.S. gallon = 3.785 litres

Suitable topographical conditions for the installation of hydraulic rams are not common, but when they exist it is one of the most useful pumps to be considered, especially for individual water-supply installations. It is durable and inexpensive. It requires practically no maintenance, and will work 24 hours a day with neither attention nor operating costs. However, only a small portion of the available water will be pumped. Unless the remainder of the operating water can be used in other ways (e.g. for irrigation), it is wasted. Where there is a source, ideally a spring which has a good fall and a flow several times greater than required for the water supply, then a hydraulic ram should always be considered.

Under the proper circumstances, as shown in Figure 93, in which the water supply is situated so that the ram can be located well below the supply and is considerably in excess of the needs, the hydraulic ram can be an excellent solution to a pumping problem.

When writing to manufacturers about ram sizes, the information in items A, B, C, D, and E is necessary. With this the factory will be able to recommend the correct size, feasibility, etc.

Other pumps similar to the hydraulic ram but employing differential cylinders as motive power may be found on the market. They have the advantage of being able to pump clean water from a well while using some other water such as that from a contaminated stream, as motive power.

### 10.10. Selection of Pumps and Pumping Equipment

The type of pump selected for a particular installation should be determined on the basis of the following fundamental considerations:

1. yield of the well or water source;
2. daily needs and immediate demand of the users;
3. size of storage tank;
4. size and alignment of the well casing;
5. total operating head pressure of the pump including lift and all frictional losses;
6. difference in groundwater level and water level in the well during pumping;
7. availability of power;
8. ease of maintenance and availability of replacement parts;
9. initial capital cost and operating costs, and
10. reliability of pumping equipment.

In rural water supply, the selection of prime mover and pump has a very important bearing on the success and regular maintenance of the scheme. Several factors influence the selection of a particular type of pump. The following guidelines may be valuable:

- (a) For populations not exceeding 200, the handpump is the most convenient pump



## Water Supply Guidelines

because it has no associated operating costs and generally, has low maintenance costs.

(b) In villages where drinking water demands are beyond the capacity of hand-pumps and where the groundwater table is less than 6 to 8 metres deep, the possibility of installing a centrifugal pump may be investigated. Electric power is always preferable to diesel power.

(c) Where the groundwater table is greater than 6 metres deep, the possibility of installing a jet pump may be investigated.

(d) Where there is a large water demand and groundwater is more than 25 metres deep, the possibility of installing a submersible set or turbine pumps may be examined.

### 10.11. Design of Pumps

In order to design a pump the following data are required:

- pump discharge,
- total dynamic head (TDH).

For pump discharge or capacity the following criteria are used:

If the pump is used directly to supply water, the capacity must be equal to the peak hourly demand.

If the water distribution system has a service reservoir, the pump capacity must be equal to the maximum daily demand.

The power required for driving a pumping unit can be computed with the following formula:

$$\text{Shaft horsepower} = \frac{\text{Total dynamic head (m)} \times \text{discharge (l/s)}}{75 \times \text{Efficiency of pump}}$$

where: total dynamic head = static head + loss of head in pipe

Efficiency of pump: mechanical and electrical efficiency of meter and pump is usually taken as 50%-60%.

### 10.12. General Precautions for Installation of Pumping Equipment

For installation of pumping facilities, it is always desirable to:

1. Investigate the use of storage tanks or reservoirs, to allow uniform rates of pumping for long periods of the day;
2. Provide a stand-by pump in order that each pump can work alternately, thus prolonging the working life of the engine;
3. Design for no suction lift if possible, or minimum suction lift. The lower the suction lift, the more efficient the pump;

## Water Supply Guidelines

4. If possible, provide a separate suction intake for each pump. If not, provide a tapering header with branches;
5. Provide an exactly horizontal suction pipe, or slope down to intake. Avoid high spots in the suction pipe to prevent air pockets;
6. Provide flexible couplings to facilitate placing and replacing the flanged pipe;
7. Provide check (non-return) valves on the discharge side of each pump and a gate valve on both sides of each pump;
8. Provide tie-rods and thrust blocks for pipes;
9. Have all equipment accessible to an overhead crane or arranged so that the pump assembly can be removed and replaced without disturbing other units of equipment, and
10. Provide a well-lighted and ventilated pump house with the floor above the expected flood level.

In addition to the above, the following points should be considered:

### (A) Vertical turbine pump

In the vertical turbine pump installation, the power unit (usually an electric motor) is installed directly over the well casing. The pump portion is submerged within the well, and the two are connected by a shaft enclosed within the pump column (see Figure 94).

Since the long shaft must rotate at high speed (1800 to 3600 rpm), correct alignment of the motor, shaft and pump is vital to good performance and long life of the equipment. The main points to consider in obtaining a proper installation are:

1. correct and stable positioning of the power unit and
2. verticality and straightness of the pump column within the well.

### (B) Submersible pumps

The entire weight of the pump, cable, drop pipe and column of water are located within the well. The reaction load when pumping, must be supported by the drop delivery pipe itself. It is important therefore, that the drop pipe and couplings be of good quality steel, galvanised, and of standard weight. Cast-iron fittings should not be used where they must support pumps and pump columns (see Figure 95).

### (C) Jet pumps

A jet pump may be installed directly over the well, or along side of it. Since there are no moving parts in the well, straightness and plumb do not affect the performance of the jet pump. The weight of equipment in the well is relatively low, being mostly due to the pipe casing (often plastic), so that loads are supported easily by the sanitary well seal.

**Figure 94. VERTICAL TURBINE PUMP**

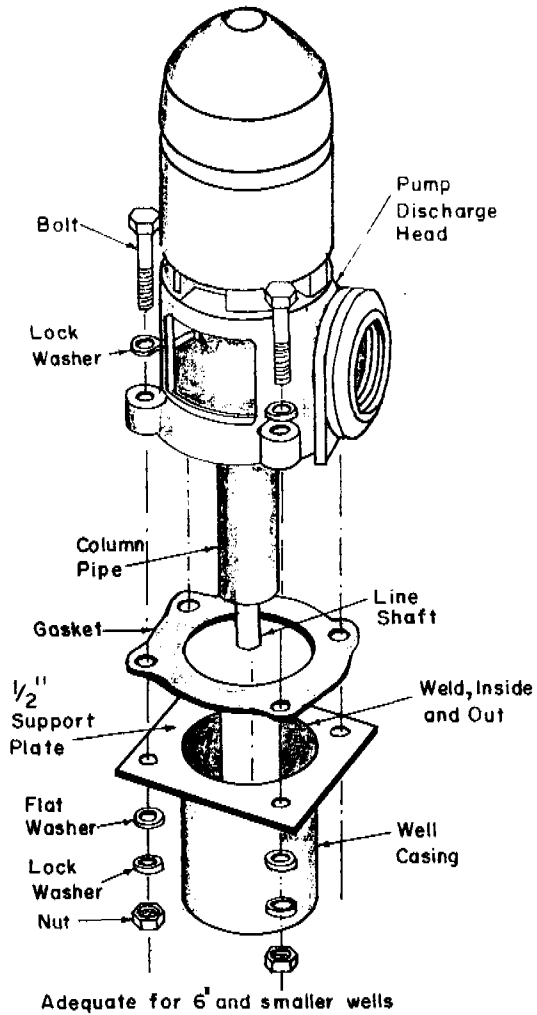
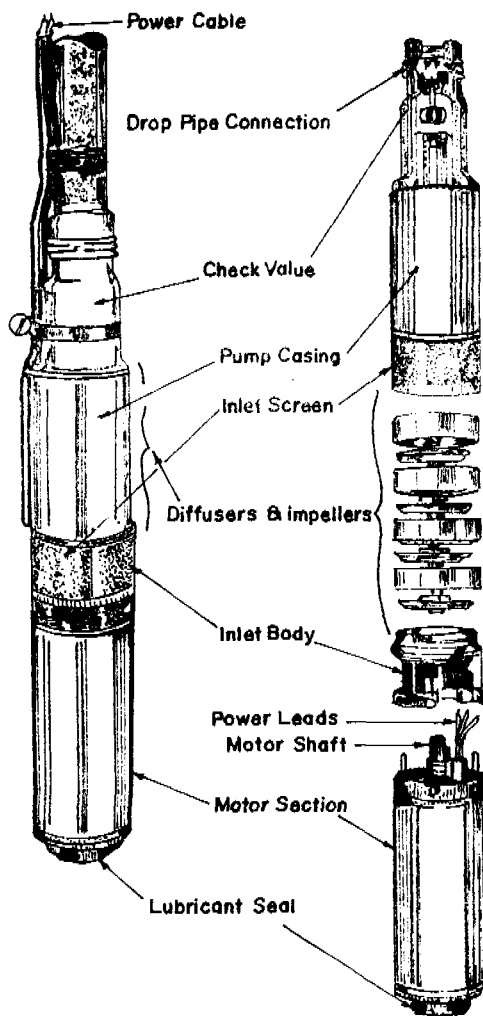


Figure 95. SUBMERSIBLE PUMP



### 10.13. Sanitary Protection of Pumping Facilities

Both power-driven and manual pumping equipment should be constructed and installed so as to prevent the entrance of contamination or objectionable material either into the well or into the water that is being pumped. The following factors

## Water Supply Guidelines

should be considered:

1. Designing the pumphead or enclosure so as to prevent pollution of the water by lubricants or other maintenance materials. Pollution from hand contact, dust, rain, birds, flies, rodents or animals, etc. should be prevented from reaching the water chamber of the pump or the source of supply.
2. Designing the pump base or enclosure so as to facilitate the installation of a sanitary well seal within the well cover or casing.
3. Installation of the pumping portion of the assembly near or below the static water level in the well so that priming will not be necessary.
4. Designing for frost protection (when applicable), including pump drainage within the well when necessary.
5. Designing the pump so as to best facilitate necessary maintenance and repair, including overhead clearance for removing the drop pipe and other accessories.
6. Well vents: a well vent is recommended on all wells not having a packer-type jet pump. The vent prevents a partial vacuum inside the well casing as the pump lowers the water level in the well. (The packer-type jet installation can not have a well vent, since the casing is subjected to positive system pressure). The well vent whether built into the sanitary well cover or conducted to a point remote from the well should be protected from mechanical damage, have watertight connections, and be resistant to corrosion, vermin, and rodents.

The opening of the well vent should be located not less than 60 cm above the highest known flood level. It should be screened with durable and corrosion-resistant mesh (bronze or stainless steel no. 24 mesh) to exclude insects and vermin.

7. The water to be introduced into the pumping system, either to prime the pump or to lubricate rubber bearings that have become dry while the pump was inoperative, should be free from contamination.

### 10.14. Power Driven Pumps

Pumps and pumping machinery in a water supply system serve purposes such as:

- (a) lifting water from the source (surface or ground) to treatment works or to service reservoirs;
- (b) boosting water from source to low service areas and to the upper floor of multi-storey buildings; and
- (c) transporting water through treatment works, draining settling tanks and other treatment units, withdrawing deposited solids, supplying water (especially water under pressure) to operating equipment and pumping chemical solutions to treatment units.

### 10.15. Prime Movers

In general, the engines used with pumps are either steam engines, internal

## Water Supply Guidelines

combustion engines or electric motors. Steam engines are going out of use on account of their large initial cost, the bulky installation represented by the boilers and reciprocating pumps and the scarcity of the fuels used, e.g. furnacite, oil and coal.

Steam turbines are used to generate power for driving pumps and have a low initial cost. Electrical and internal combustion engines are more commonly used, though water power, wind power and combustion turbines also find use in specific circumstances.

All electric motors should have heat sensors giving low voltage and overload protection. The pump can be started and stopped with simple automatic controls actuated by a float in the tank (reservoir) or a pressure device that can be set for the proper pressures.

### 10.16. Standby Arrangements

As water supply, and consequently water pumping, is usually intermittent, it should be free from interruptions due to power failure, at least during the hours of peak supply. The practice in small water supplies is to provide an oil engine as standby. Such alternative provision would be very costly in major water supplies and may be ineffective unless full capacity is provided for.

A common practice is to establish a diesel generator station for producing power for use during power failures. The generators can be kept in working condition by running them during specified hours, or days, and utilising the generated power on the regular electrical motor and pump sets or on lighting.

### 10.17. Directly Coupled Motors

In most waterworks, pumps driven by electric motors are directly coupled. The prime mover should be capable of carrying the load that will be imposed, taking into consideration the various adverse operating conditions under which the pump has to work. If the duty of a centrifugal pump exceeds the safe operating load of the motor it may be damaged or burnt out. Careful attention must be paid to the shape of the speed-torque curve of the motor and the supply voltage. For general guidance, Table 14 (overleaf), gives the standard voltages and the corresponding ranges of motor sizes.

### 10.18. Squirrel Cage Motors

*Squirrel cage motors are most commonly used for driving centrifugal pumps. These are the simplest polyphase electric motors manufactured. Mechanical construction permitting, squirrel-cage motors can be run in either direction.*

Centrifugal pumps generally do not require motors with high starting torque. Vertical turbine pumps require more than the normal starting torque. In such cases, a wound rotor motor with secondary control are recommended.

## Water Supply Guidelines

**Table 14. DETAILS OF MOTOR SIZES**

Supply	Voltage	Reasonable size in kw	
		Minimum	Maximum
Single phase alternating current	220/440 V	0.3	2.5
3 phase alternating current	440-440 V		350
	6.6 KV	300	
	11 KV	350	
Direct current	230 V		150

In cases where normal torque is required, low starting current motors are ideally suited for operating the centrifugal pumps. A reduced voltage starter is necessary to limit the starting current.

### 10.19. Wound Rotor Motors

Wound rotor motors have both primary and secondary windings. The primary or stator winding is the same as that of a squirrel cage motor. The secondary or rotor windings are connected to slip-rings so that external resistance can be introduced in the secondary winding for starting or speed regulation. This reduces the flow of current and also affects the torque speed characteristics of the motor. Thus the wound rotor motor has to be used for low starting current.

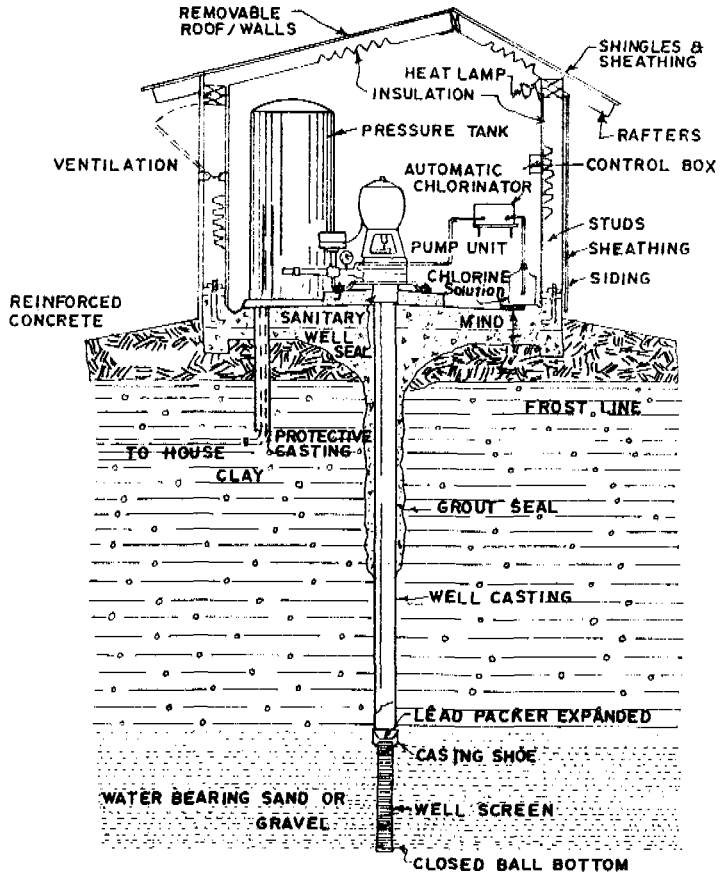
### 10.20. Pump House

A pump house installed above the surface of the ground should be used (Figure 96). The pump room floor should be of watertight construction, preferably concrete, and should slope uniformly away in all directions from the well casing or pipe-sleeve. It should be unnecessary to use an underground discharge connection if an insulated, heated pumphouse is provided. For individual installations in rural areas, two 60 watt light bulbs, a thermostatically controlled electric heater, or a heating cable will generally provide adequate protection when the pumphouse is properly insulated.

In areas where power failures may occur, an emergency, gasoline driven power supply or pump should be considered.

# Water Supply Guidelines

## Figure 96. PUMP HOUSE





## 11. PIPES AND FITTINGS

### 11.1. Introduction

Water transmission and distribution through pipelines account for an appreciable proportion of the capital outlay for a small community water supply system. For this reason, they deserve proper design before decisions are made as regards the type and size of pipe to be selected.

### 11.2. Types of Pipe

Three types of pipe are most commonly used in small community water supplies;

1. fibre cement (FC) pipe;
2. polyvinyl chloride (PVC) pipe;
3. galvanised iron (GI) pipe.

The selection of pipeline material should be based on the following considerations:

1. The initial carrying capacity of the pipe and its reduction with use.
2. The strength of the pipe, as measured by its ability to resist internal pressures and external loads.
3. The life or durability of the pipe. Such factors as the resistance of;
  - (a) steel pipe to corrosion;
  - (b) fibre-cement pipe to erosion and disintegration and
  - (c) of plastic pipe to cracking and disintegration, may have to be taken into account.
4. The ease or difficulty of transporting, handling and laying the pipe under different conditions of topography, geology and communication.
5. The safety, economy and local availability of pipe sizes required.
6. The availability of skilled labour in the construction of pipelines of different types.
7. Maintenance and repair requirements and losses of water by leakage.

### 11.3. Design Criteria for the Piping System

#### 11.3.1. Design life

The design life for various components are shown in Table 15. (overleaf) However, in systems where a large population growth is anticipated, it is good prac-

## Water Supply Guidelines

tice to install

pipe sizes which will meet anticipated future demands. Pumping equipment for this situation however, may be chosen with a shorter design life to meet current demands, with an intended replacement with larger pumps in the future.

**TABLE 15. LIFE OF PIPE SYSTEM COMPONENTS**

<b>Components of system</b>	<b>Life expectancy (years)</b>
1. Transmission and distribution mains	25
2. Pump house	25
3. Pump, motor/engine, control	10
4. Meters	15
5. Valves	15

### 11.3.2. Design flow rate

The design flow rates of transmission mains (raw water), and of distribution mains (treated water) should be based on the following considerations:

1. For the raw water transmission main, the flow rate should be designed in accordance with the maximum treatment capacity of the system, if any. Where treatment is unnecessary, but a balancing storage is provided, then the design flow rate should be capable of meeting the average daily demand depending on the number of pumping hours. A 24 hour supply period is always desirable.

2. The design flow rate of the distribution mains should be based on the following "peak" factors:

(a) Where the supply of water is delivered only through storage-type public standpipes (no house connection or house connections with storage tank):

$$\text{Factor} = 1 \times \text{average daily demand}$$

(b) Where 70% of the population draw water from storage-type public standpipes and 30% from house connections direct from the distribution lines:

$$\text{Factor} = 1.5 \times \text{average hourly demand}$$

## Water Supply Guidelines

- (c) With pillar-type public standpipes and house connections direct to distribution lines:

$$\text{Factor} = 2.4 \times \text{average hourly demand}$$

### 11.3.3. Pressure in distribution system

The desired pressure in the distribution system should be based on the following requirements:

1. If supply is restricted only to either storage-type or pillar public standpipes (no house connections), a minimum of 4 metres residual pressure is desirable; details of water taps are shown in Figure 97. (overleaf).
2. In addition, if house connections are also provided, the minimum pressures at ferrule points should be 6 metres for communities with single-storey houses, and 10 metres for two-storey houses.

### 11.3.4. Types of pipes

Pipes, both for water transmission and distribution, should be selected in accordance with the following guidelines:

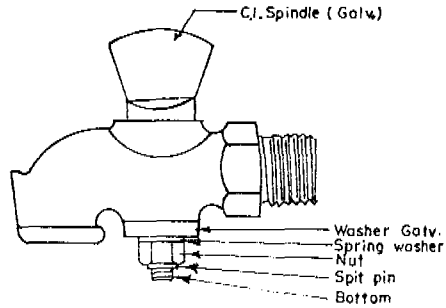
Cast-iron, ductile cast-iron, steel, asbestos cement, pre-stressed concrete, and polyvinyl chloride pipes (PVC) may be used as appropriate. High pressure, ordinary pressure or low pressure pipes may be used, depending on the operating pressure and external load. Asbestos cement pipes are usually classified according to their hydraulic test pressure as shown in Table 16.

**Table 16. CLASSIFICATION OF FIBRE CEMENT PIPES**

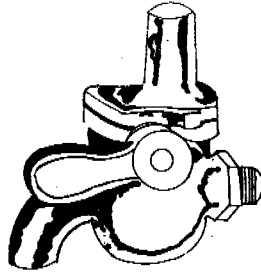
Class	Hydraulic test pressure		Head of water m
	Atmospheres	Kg/cm <sup>2</sup>	
15	1.5	15.3	153
20	2.0	20.4	204
25	2.5	25.5	255
30	3.0	30.6	306

## Water Supply Guidelines

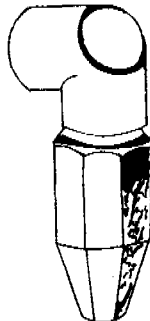
**Figure 97. DETAILS OF WATER TAPS**



C. I. PLUG BIB COCK



C. I. WAST NOT COCK  
(DLULEX) FITTED WITH HANDLE



JAYSON WATER TAP (India)

## Water Supply Guidelines

PVC pipes are normally classified by working pressure as shown in Table 17.

**Table 17. CLASSIFICATION OF PVC PIPES**

Class	Working pressure	
	Kg/cm <sup>2</sup>	Head of water m
6	6	60
9	9	90
12	12	120
15	15	150

### 11.3.5. Diameter of pipes

The diameter of each pipeline will be determined in accordance with the following principles:

1. The difference in hydraulic head between the lowest water level at the upstream end and the highest water level at the downstream end of the pipeline.
2. In the case of cast-iron, ductile cast-iron or steel pipes, a coefficient of  $C = 100$  in the *Hazen and Williams* formula is ordinarily recommended because of the decrease in the conveying capacity of such pipes over long periods of use. For other classes of pipe a higher  $C$  value may be used.

### 11.3.6. Velocity of flow

The mean velocity of flow in transmission and distribution pipelines should be higher than 0.3 m/sec, but it should not exceed the values shown in Table 18.

**Table 18. RECOMMENDED UPPER LIMIT OF VELOCITY IN PIPES**

Upper limit of velocity

Pipe type	Velocity
Concrete	3.0 m/sec.
Steel or cast-iron	5.0 m/sec.

## Water Supply Guidelines

### 11.3.7. Route location

Pipeline routes should be selected in accordance with the following principles:

1. Pipelines should be located in land owned by the Government or in a public right of way.
2. The route of the pipeline should be determined so as to avoid acute bends, either horizontal or vertical, and to avoid siphons in which water flows above the hydraulic grade line.
3. In long pipelines through which water is pumped, relief valves or surge tanks should be provided to prevent water hammer.
4. If necessary, dual pipelines may be required in critical cases, and interconnecting pipes should be provided to ensure uninterrupted service.

### 11.3.8. Junction wells

Junction wells should be designed in accordance with the following rules:

1. they shall be constructed of mass concrete or reinforced concrete, circular or rectangular.
2. If the inlet velocity of the flow is high, a baffle wall may be required to reduce the outlet velocity of flow.
3. The distance between the centre line of the outflow pipe and the low water level shall be not less than two times the diameter of the pipe.
4. A flow meter, drain pipe, and overflow pipe may be required in the junction well. Valves shall be provided in the main pipeline and in the drain pipe.

### 11.3.9. Valves

Valves should be arranged in accordance with the following rules:

1. Pipelines shall be provided with valves at locations of influents, effluent branches, connections, and pressure-release valves. In addition, valves are required upstream of inverted siphons, bridges, highways, and railroad crossings.
2. Sectionalising valves shall be provided and located to a maximum of 3 kilometres apart in long pipelines.

### 11.3.10. Air release valves

Air release valves should be arranged in accordance with the following rules:

1. they shall be located at crest points of the pipeline. However, if there is no crest point between the line valves, the air valve should be located immediately behind the upper valve.
2. An air release valve should be provided with a stop valve between the air valve and the pipeline.
3. they should be installed at a level higher than the ground water level to prevent the possibility of a backward flow of polluted water into the pipeline.

## Water Supply Guidelines

### 11.3.11. Pressure-release and outfall valves

Pressure-release and outfall valves should be designed in accordance with the following rules:

1. they should be placed at the lowest points of the pipeline with suitable gravity drainage to ditch or stream.
2. The diameter of the pressure-release valve should be 1/4 to 1/2 the diameter of the pipe. The bigger size is better if the drainage outfall is large enough to accommodate the drain flow.
3. In case the water level of the drain is above the invert level of the pressure-release valve, a drainage chamber shall be provided between the pressure-release valve and the outfall.
4. The lining of the outfall shall be sufficiently strong so as not to be eroded or destroyed by the drain water flow.

### 11.3.12. River crossings

Submerged pipelines should be designed in accordance with the following rules:

1. Dual submerged pipelines may be laid as far apart as possible.
2. Trench depth, length, method of passing through stream embankment and other pertinent details concerning the method of installing a pipeline shall be approved by the government office concerned.
3. The gradient of the inclined sections of inverted siphon shall not exceed 45 degrees and shall be securely anchored with concrete anchor blocks.
4. When the submerged pipeline is laid in the trench, the trench shall be covered with concrete slabs or other solid materials to prevent damage from obstacles or navigation. Consolidation of the pipe trench may be necessary in the waterway of the river bed.
5. In cases where difficulties are encountered while laying a submerged pipeline by the open cut method, necessary facilities should be provided to permit inspection and repair of the line.
6. Where the pipeline trench is in an unstable stream bottom, a complete foundation or a series of pile bents with caps and pipe straps should be provided to prevent unequal sinking of the pipeline.

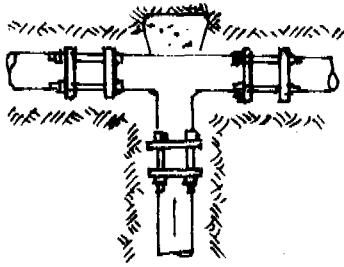
### 11.3.13. Railway crossings

Crossings under a railway shall be designed in accordance with the following rules:

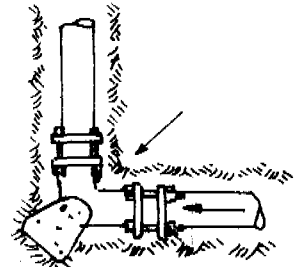
1. To protect the pipe from railway loads and shock, a railway crossing pipeline should be installed in a duct with removable cover plates to allow inspection of the pipe, or in a protective duct of sufficient size to isolate the pipe from duct walls.
2. If the pipeline is subject to electrolytic corrosion, suitable protection should be provided based on studies of the situation.

Water Supply Guidelines

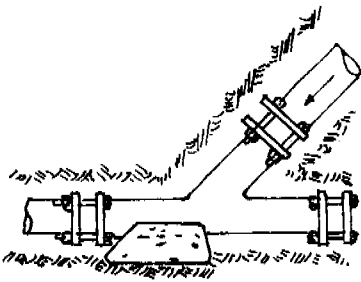
Figure 98. ANCHORAGE FOR THE PIPES



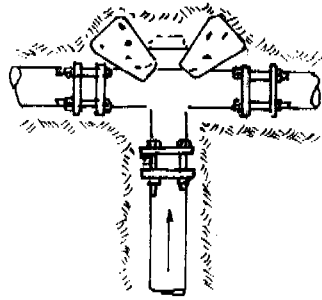
CONDITION I



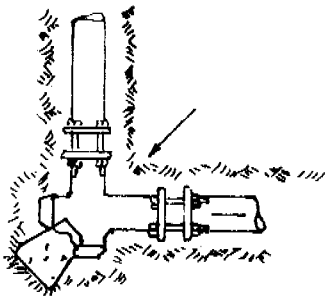
CONDITION II



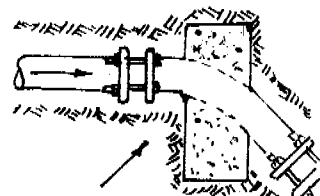
CONDITION III



CONDITION IV



CONDITION V



ANCHOR AT VERTICAL



## Water Supply Guidelines

### 11.3.14. Anchorage for pipe and fittings

Anchor blocks for pipes and fittings (see Figure 98), when required, should be designed in accordance with the following rules:

1. Anchor blocks are required in several situations as follows:
  - (a) bell-and-spigot joints with caulking: at a  $90^{\circ}$  bend with diameter above 200 mm; and tee above 200 mm.
  - (b) mechanical joint:  $90^{\circ}$  bends of all sizes;  $45^{\circ}$  bends between 100 to 300 mm and tee above 100 mm.
  - (c) pipes should be supported with concrete anchors, piles or tie rods. However, this rule may be excepted for a pipe with harnessed joints and/or welded joints.
2. Bends and tees smaller than those mentioned above should also be anchored in case of unstable earth conditions or high operating pressure.

### 11.3.15. Location and depth of pipeline

1. In the case of a pipeline installed under a public road/highway, the depth of line shall be approved by the road/highway office concerned.
2. The depth of earth covering the upper surface of the pipe should not be less than 70 cm for lines with a diameter not greater than 200 mm and not less than 100 mm for lines with a diameter between 200 and 500 mm. However, this rule need not be strictly enforced if traffic and traffic loads are not a consideration. Nevertheless, in no case should the depth of the pipe be less than 50 cm.
3. Where the required depth, due to unavoidable local conditions cannot be provided, and traffic loads are to be considered, the pipe should be protected by reinforced concrete slab insulation.

## 11.4. Economic Size of Transmission Mains

Under certain circumstances, sizes of transmission mains would significantly affect the economy of the water system, and hence need a careful analysis and evaluation. The considerations are:

1. Providing a transmission main to convey water from the source to meet the demand rate of the supply area at any time.
2. Installing a smaller feeder pipe size for a 24 hour water transmission from the source to an additional storage (discussed in Section 9) constructed near the community from which water is supplied to the consumers.

The provision of storage for the system may not be necessary and the transmission could be sized to carry water from the source directly to the consumers, when:

- (a) Relative elevations of source and service area permit gravity feed;
- (b) Safe yield of source exceeds peak demand; and
- (c) Distance from source to supply area is relatively short.

## 15. SELECTED BIBLIOGRAPHY

1. Acra, A.; Raffoul, Z.; and Karahagopian, Y. (1984). *Solar Disinfection of Drinking Water and Oral Rehydration Solutions*. Published for UNICEF by Illustrated Publications S.A.L., Beirut, Lebanon, 56p. (Also available in Arabic language).
2. *All India Seminar on Rural Water Supply*. Souvenir, National, October 8-12, 1975, Nainital, the Institution of Engineers (India), 1975>
3. American Water Works Association. *Water Quality and Treatment*, New York, McGraw Hill, 1971.
4. Babbitt, H.E.; Doland, J.J.; and Cleasby, J.L. *Water Supply Engineering*. McGraw Hill Book, New York, 1962.
5. Cairncross, A. and Feachem, R. *Small Water Supplies*, Bulletin No. 10, London, Ross Institute, 1978.
6. Cox, C.R. *Operation and Control of Water Treatment Processes*, Geneva, WHO, 1964.
7. Environmental Sanitation Information Centre. *Surface Water Filtration for Rural Areas - Guidelines for Design, Construction, Operation and Maintenance*, Bangkok, 1982.
8. Gibson, U.B. and Singer, R.D. *Small Well Manual*, 2nd ed., Washington, Agency for International Development, 1969.
9. Huisman, L. and Wood, W.E. *Slow and filtration*. World Health Organization, Geneva, 1974.
10. India, Ministry of Works and Housing. *Manual on Water Supply and Treatment*, 2nd ed. 1976.

## Water Supply Guidelines

11. Indonesia, Department of Health, East Java. Rural Water Supply Project. *Manual on Planning and Design of Rural Water Supply Schemes*, prepared by WHO for UNEP, WHO/INO/PUP/003-UNDP/INS/73/003, 1980.
12. Majumder, N. and Sengupta, J.N. *Final Report on Study of Hand Pump (Shallow Tube Well)*, for WHO/UNICEF Assisted Projects and other Rural Water Supplies.
13. Mann H.T. *Water Treatment and Sanitation, Simple Methods for Rural Areas*, London, Intermediate Technology Pub. Ltd., 1979.
14. Michaelides, G. and Young, R. (1985). *Design and Maintenance of Rainwater Harvesting Systems*. Water Resources Journal, Dec. 1985, pp. 35-41. Published by U.N. Economic and Social Commission for Asia and the Pacific.
15. Pacey, A. *Hand Pump Maintenance and the Objective of Community Well Projects*, OXFAM International Document, Oxford, 1976.
16. Pacey, A. *Water for the thousand millions*, Oxford, Pergamon Press, 1977.
17. Phillips, R. *Bangladesh Rural Water Supply Programme, Hand Pumps in Bangladesh, 1972-1976*, UNICEF Rural Water Supply Workshop, Dacca, 1976.
18. *Rural Water Supply in Developing Countries*, Proc. of a Workshop 5-12 August 1980, Ottawa, IDRC, 1981.
19. Saunders, R.J. and Warford, J.J. *Village Water Supply, Economic and Policy in the Developing World*, Baltimore, World Bank Research Publication, 1976.
20. Shawcross, J.F. *Hand Pump Maintenance, Organisational consideration for Water Supply Projects in Developing Countries*, Voorburg, Netherlands, WHO IRC for Community Water Supply, 1979.
21. Sundaresan, B.B.; Kshirsagar, S.R. and Paramasivam, R. *Evaluating of Rural Water Supply Schemes in India, Nagpur*, NEERI, 1982.
22. *Symposium on Community Water Supply in Development Cooperation*, Report, Amsterdam, Netherlands, WHO IRC for Community Water Supply, 1977.
23. U.S. Environmental Protection Agency. *Manual of Individual Water Supply Systems*, 1973.

## Water Supply Guidelines

24. Wagner, E.G. and Lanoix, J.N. *Water Supplies for Rural Areas and Small Communities*, Geneva, WHO, 1959.
25. *Water for the World*. Technical Notes Series, Washington, USAID.
26. *Water Supply and Sanitation in Rural Development*, Proceedings of Conference held at Pump American Health Organization, Washington, Dec. 1-4, 1981, Washington, The Water and Sanitation for Health, 1981.
27. *Water Supply and Waste Disposal, Poverty and Basic Needs Series*, Washington, World Bank, 1980.
28. Watt, J.B. and Wood, W.D. *Hand-dug Wells and their Construction*. London, Intermediate Technology Development Group, 1977.
29. WHO International Reference Centre for Community Water Supply and Sanitation. *Small Community Water Supplies, Technology of Small Water Supply System in Developing Countries*. Technical Paper Series 18, The Hague, The Netherlands, 1981.
30. WHO International Reference Centre for Community Water Supply, *Evaluation for Village Water Supply Planning*. Technical Paper Series 15, Chichester, John Wiley & Sons, 1980.
31. WHO International Reference Centre for Community Water Supply. *Hand Pumps for use in Drinking Water Supplies in Developing Countries*, Technical Paper Series 10, The Hague, The Netherlands, 1977.
32. WHO International Reference Centre for Community Water Supply. *Slow Sand Filtration for Community Water Supply in Developing Countries. A Design and Construction Manual*. Technical Paper Series 11, The Hague, The Netherlands, 1978.
33. World Health Organization. *Typical Designs for Engineering Components in Rural Water Supply*. WHO Regional Publications, S.E. Asia Series No. 2, New Delhi, 1976.
34. World Health Organization. *Guidelines for Drinking-Water Quality*, Geneva:  
Vol. 1. Recommendations, 1984.  
Vol. 2. Health Criteria and Other Supporting Information, 1984.  
Vol. 3. Guidelines for Drinking-Water Quality Control for Small Community Supplies, 1985.

## 16. GLOSSARY

**Aggregate**

Rock or gravel used for mixing cement

**Arid**

Excessively dry

**Bell-and-Spigot**

Type of joint used to connect lengths of pipe

**Bellmouth**

Widened end of pipe

**Break-point Chlorination**

Addition of chlorine to water until all chlorine demand is satisfied

**Caisson**

Barrel shaped cement casting used to support the walls of wells

**Caving**

Collapse of walls from above

**Caulking**

To make watertight

**Cercariae**

Larvae of parasitic flatworm

**Chlorine demand**

Ability of water to absorb chlorine

**Colloidal**

Small particles in water which do not settle out

**Corporation cock**

Type of valve used to control flow of water

**Cribbing**

To line or support with a framework of timber

**De-chlorination**

To remove chlorine residuals from water

**Derrick**

Vertical support for drill in a drilling rig

**Floc**

Fluffy or foamy mass formed by clumping together of small particles

## Water Supply Guidelines

**Germicidal**

Something that kills germs

**Galvanised**

Metal coated with zinc to prevent rusting

**Head**

Height difference between the two ends of a closed pipe filled with water

**Methaemoglobulinaemia**

Disease in infants caused by high levels of nitrates in drinking water

**Retention time**

Time for which water must be retained in a tank for a process to be effective

**Shmutzdeke**

Layer of protozoa and other organisms which eat harmful bacteria in a slow sand filter

**Super chlorination**

Addition of large amounts of chlorine to water

**Torque**

Force that produces rotation

**Turbid**

Cloudy

**Topography**

The art of making maps or charts of a region. May be used to plan a water supply