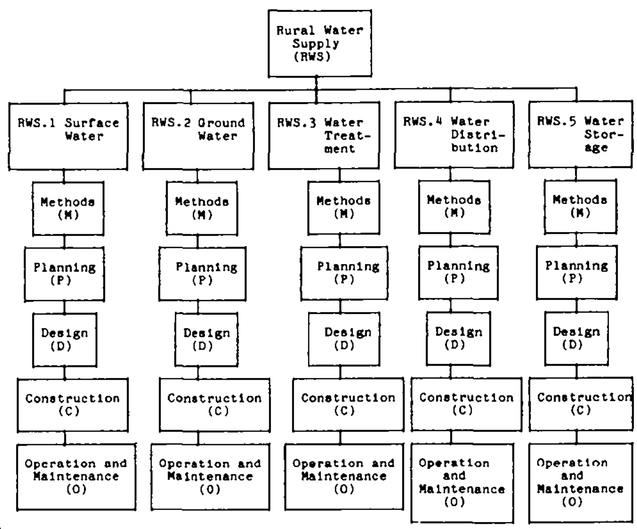
Water for the World

Overview of Rural Water Supply
Technical Note No. RWS. G

The technical notes on rural water supply are divided into five series as shown in Table 1: RWS.1 - Surface Water; RWS.2 - Ground Water; RWS.3 - Water Treatment; RWS.4 - Water Distribution; and RWS.5 - Water Storage. Within each series, the technical notes are organized according to methods (M), planning (P), design (D), construction (C) and operation and maintenance (O). All technical notes have both a title and a number within each category indicating where they fit on Table 1. For example, RWS.3.P.3, "Analyzing a Water Sample," is part of the Water Treatment series (3), discusses planning (P), and is the third technical note in the 3P series (3). See "Overview of Water and Sanitation System Development," HR.G, for a full discussion of the organization of the technical notes and a list of all of them. The rural water supply technical notes are listed at the end of this note.

If possible, the technical notes should be read and used in order of methods, planning, design, construction, and operation and maintenance. This will give the reader a thorough understanding of the subject covered and allow him or her to proceed with the activity in an orderly manner. The methods, planning and design technical notes were written for people with some experience with water supply systems who are responsible for project design and decision-making. The construction and operation and maintenance technical notes, in most cases, may be used by people with less experience since these activities involve little or no decision-making. Thus, the construction and operation and maintenance technical notes may be used by someone who is carrying out their tasks, but is working under another person who has consulted the methods, planning and design notes for that particular project.

Table 1. Organization of Rural Water Supply Technical Notes



Sources of Further Information

The books listed below will be useful to those interested in further reading on the subjects covered by the technical notes on rural water supply.

Appropriate Technology for Water Supply and Sanitation, Richard Feachem, et al., 1981. The World Bank, 1818 H Street, N.W., Washington, D.C. 20433 U.S.A.

Ferrocement Water Tanks and Their Construction, S.B. Watt, 1978. Intermediate Technology Publications Ltd., 9 King Street, London WC2E 8HN United Kingdom.

Ground Water and Wells, 1975. Johnson Division, UOP Inc., Saint Paul, Minnesota 55165 U.S.A.

Manual for Rural Water Supply, 1980. Helvetas, Swiss Association for Technical Assistance, St. Moritzstrasse 15, 8042 Zurich, Switzerland.

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Planning for an Individual Water System, 1973. American Association for Vocational Instructional Materials, Engineering Center, Athens, Georgia 30602 U.S.A.

Slow Sand Filtration, L. Huisman and W.E. Wood, 1974. World Health Organization, Av. Appia, 1211 Geneva 27 Switzerland.

Slow Sand Filtration for Community Water Supply in Developing Countries: A Design and Construction Manual, J.C. Van Dijk and J.H.C. Oomen, December 1978. WHO International Reference Centre for Community Water Supply and Sanitation, P.O. Box 5500, 2280 HM Rijswijk, the Netherlands.

Small Community Water Supplies: Technology of Small Water Supply Systems in Developing Countries, edited by E.H. Hofkes, 1981. WHO International Reference Centre for Community Water Supply and Sanitation, P.O. Box 5500, 2280 HM Rijswijk, The Netherlands.

Small Water Supplies, Sandy Cairncross and Richard Feachem, 1978. The Ross Institute of Tropical Hygiene, London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London WC1E 7HT United Kingdom.

UNICEF Guide List OLGA Rural Water Supply and Sanitation in the Developing Countries, 1975. UNICEF, United Nations, New York, New York 10017 U.S.A.

Using Water Resources, 1977. Volunteers in Technical Assistance, 3706 Rhode Island Avenue, N.W., Mount Ranier, Maryland 20822 U.S.A.

Village Technology Handbook, 1978. Volunteers in Technical Assistance, 3706 Rhode Island Avenue, N.W., Mount Ranier, Maryland 20822 U.S.A.

Water Supply for Rural Areas and Small Communities, E.G. Wagner and J.N. Lanoix, 1959. World Health Organization, Av. Appia, 1211 Geneva 27, Switzerland.

Water Treatment and Sanitation: A Handbook of Simple Methods for Rural Areas in Developing Countries, H.T. Mann and D. Williamson, 1974. Intermediate Technology Publications, Ltd., 9 King Street, London WC2E 8HN United Kingdom.

Wells Construction: Hand Dug and Hand Drilled, Richard E. Brush, 1979. Peace Corps, Information Collection and Exchange, 806 Connecticut Avenue, N.W., Washington, D.C. 20525 U.S.A.

List of Technical Notes

The following is a list of all the technical notes on rural water supply.

RURAL WATER SUPPLY

RWS.2 Ground Water

RWS.3 Water Treatment

RWS.4.D.4	Designing Community Distribution Systems
RWS.4.D.5	Designing a Hydraulic Ram Pump

<u>Construction</u>

RWS.4.C.1	Installing Pipes
RWS.4.C.2	Installing Mechanical Pumps
RWS.4.C.3	Installing Hand Pumps
RWS.4.C.4	Constructing Community Distribution Systems
RWS.4.C.5	Constructing a Distribution System with Household Connections

<u>Operation and Maintenance</u>

RWS.4.O.1	Detecting and Correcting Leaking Pipes
RWS.4.O.2	Operating and Maintaining Mechanical Pumps
RWS.4.O.3	Operating and Maintaining Hand Pumps
RWS.4.O.5	Operating and Maintaining Household Water Connections

RWS.5 Water Storage

<u>Methods</u>

RWS.5.M	Methods of Storing Water

<u>Planning</u>

RWS.5.P.1	Determining the Need for Water Storage

<u>Design</u>

RWS.5.D.1	Designing a Household Cistern
RWS.5.D.2	Designing a Ground Level Storage Tank
RWS.5.D.3	Designing an Elevated Storage Tank

<u>Construction</u>

RWS.5.C.1	Constructing a Household Cistern
RWS.5.C.2	Constructing a Ground Level Storage Tank
RWS.5.C.3	Constructing an Elevated Storage Tank

<u>Operation and Maintenance</u>

RWS.5.O.1	Maintaining Water Storage Tanks

Notes

Notes

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

1982

Water for the World

How to Use Technical Notes

Technical Note No. HR. G

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

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

Other "Water for the World" Materials

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

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

Organization of Technical Notes

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

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

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

List of Technical Notes

HUMAN RESOURCES

RURAL WATER SUPPLY

RWS. 1 Surface Water

RWS 2. Ground Water

Methods

RWS.2.M	Methods of Developing Sources of Ground Water

Planning

RWS.2.P.1	Planning How to Use Sources of Ground Water
RWS.2.P.2	Selecting a Method of Well Construction
RWS.2.P.3	Selecting a Well Site

Design

RWS.2.D.1	Designing Dug Wells
RWS.2.D.2	Designing Driven Wells
RWS.2.D.3	Designing Jetted Wells
RWS.2.D.4	Designing Bored or Augered Wells
RWS.2.D.5	Designing Cable Tool Wells

Construction

RWS.2.C.1	Constructing Dug Wells
RWS.2.C.2	Constructing Driven Wells
RWS.2.C.3	Constructing Jetted Wells
RWS.2.C.4	Constructing Bored or Augered Wells
RWS.2.C.5	Constructing Cable Tool Wells
RWS.2.C.6	Maintaining Well Logs
RWS.2.C.7	Testing the Yield of Wells
RWS.2.C.8	Finishing Wells
RWS.2.C.9	Disinfecting Wells

RWS. 3 Water Treatment

Methods

RWS.3.M	Methods of Water Treatment

Planning

RWS.3.P.1	Determining the Need for Water Treatment
RWS.3.P.2	Taking a Water Sample
RWS.3.P.3	Analyzing a Water Sample
RWS.3.P.4	Planning a Water Treatment System

RWS.4.D.4 Designing Community Distribution Systems

RWS.4.D.5 Designing a Hydraulic Ram Pump

Construction

RWS.4.C.1 Installing Pipes

RWS.4.C.2 Installing Mechanical Pumps

RWS.4.C.3 Installing Hand Pumps

RWS.4.C.4 Constructing Community Distribution Systems

RWS.4.C.5 Constructing a Distribution System with Household Connections

Operation and Maintenance

RWS.4.O.1 Detecting and Correcting Leaking Pipes

RWS.4.O.2 Operating and Maintaining Mechanical Pumps

RWS.4.O.3 Operating and Maintaining Hand Pumps

RWS.4.O.5 Operating and Maintaining Household Water Connections

RWS. 5 Water Storage

Methods

RWS.5.M Methods of Storing Water

Planning

RWS.5.P.1 Determining the Need for Water Storage

Design

RWS.5.D.1 Designing a Household Cistern

RWS.5.D.2 Designing a Ground Level Storage Tank

RWS.5.D.3 Designing an Elevated Storage Tank

Construction

RWS.5.C.1 Constructing a Household Cistern

RWS.5.C.2 Constructing a Ground Level Storage Tank

RWS.5.C.3 Constructing an Elevated Storage Tank

Operation and Maintenance

RWS.5.O.1 Maintaining Water Storage Tanks

SANITATION

SAN. 1 Simple Excreta and Washwater Disposal

SAN. 2 Combined Excreta and Washwater Disposal

SAN. 3 Solid Waste Disposal

Methods

SAN.3.M Methods of Solid Waste Management

Planning

SAN.3.P Planning Solid Waste Management Systems

Design

SAN.3.D.1 Designing a Landfill

SAN.3.D.2 Designing à Composting System

SAN.3.D.3 Designing a Solid Waste Collection System

SAN.3.D.4 Designing a Biogas System

Construction

SAN.3.C.4 Constructing a Biogas System

Operation and Maintenance

SAN.3.O.1 Operating and Maintaining a Landfill

SAN.3.O.2 Operating and Maintaining a Composting System

SAN.3.O.3 Operating a Solid Waste Collection System

SAN.3.O.4 Operating and Maintaining a Biogas System

DISEASE

DIS.G Overview of Diseases

DIS. 1 Water Supply, Sanitation and Disease

Methods

DIS.1.M.1 Means of Disease Transmission

DIS.1.M.2 Methods of Improving Environmental Health Conditions

Planning

DIS.1.P Planning Disease Control Programs

DIS. 2 Specific Diseases

Methods

DIS.2.M.1 Methods of Controlling Schistosomiasis

DIS.2.M.2 Methods of Controlling African Trypanosomiasis

DIS.2.M.3 Methods of Controlling South American Trypanosomiasis

DIS.2.M.4 Methods of Controlling Enteric Diseases

DIS.2.M.5 Methods of Controlling Onchocerciasis

Table 1. Organization of Technical Notes

- Human Resources (HR)
  - HR.1 Overview of Water and Sanitation System Development
  - HR.2 Community Participation
    - Methods (M)
    - Planning (P)
    - Implementation (I)
  - HR.3 Operation and Maintenance Training
    - Methods (M)
    - Planning (P)
    - Implementation (I)
- Rural Water Supply (RWS)
  - RWS.1 Surface Water
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
  - RWS.2 Ground Water
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
  - RWS.3 Water Treatment
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
  - RWS.4 Water Distribution
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
  - RWS.5 Water Storage
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
- Sanitation (SAN)
  - SAN.1. Simple Excreta and Washwater Disposal
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
  - SAN.2 Combined Excreta and Washwater Disposal
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
  - SAN.3 Solid Waste Disposal
    - Methods (M)
    - Planning (P)
    - Design (D)
    - Construction (C)
    - Operation and Maintenance (O)
- Disease (DIS)
  - DIS.1 Water Supply, Sanitation and Disease
    - Methods (M)
    - Planning (P)
  - DIS.2 Specific Diseases
    - Methods (M)

Notes

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1982

Water for the World

Overview of Water and Sanitation System Development

Technical Note No. HR. 1

A large percentage of people in rural areas of the developing world do not have access to safe and convenient water supplies for drinking, personal hygiene and domestic purposes. Even fewer people have adequate waste disposal facilities. The high incidence of water- and excreta-related diseases in rural areas results from unsatisfactory water supplies and poor waste disposal systems. Infections are contracted when people drink or use water contaminated with excreta or when they come in contact with disease-causing agents in soil. The disease cycle continues when people recontaminate water supplies by improperly disposing of their own wastes in or near a water source or the area in which they live. Proper use of water and sanitation systems can eliminate such disease cycles. Water supply and sanitation facilities are complementary in promoting communal and personal hygiene and are essential to improved health conditions.

Water and sanitation system development in rural areas can further the economic, social and educational development of a community. From a villager's point of view, the advantages of improved water and sanitation usually are convenience and prestige rather than health. A water supply project offers immediate and demonstrable results. Those who carry water long distances, especially women and children, have more time for other activities when a water supply is convenient to their houses. Village agriculture, livestock production and small industry will frequently expand with better access to greater quantities of water. Both individual and community productivity can rise because of the better health people enjoy as a result of access to and use of effective water and sanitation facilities.

Useful Definitions

ACTION AGENCY - A group of technical and economic advisors and educators responsible for guiding and training a rural community in water supply and sanitation system development. This may be a regional office of a governmental agency or an independent development group. The action agency is the liaison between the local water and sanitation committee and the national government. The project planner or project designer works out of the regional office of the action agency.

VILLAGE WATER AND SANITATION COMMITTEE - A local community organization which represents the village to the action agency and through which the action agency can reach the community.

Community Participation

The economic, social, environmental and technical aspects of water and sanitation projects must be well coordinated if the projects are to succeed. A very important contribution to balancing these factors is the participation of the community involved in the project. Without the interest and support of the people using the system, no project will succeed, however well planned it is technically. The success of a project depends on people understanding, accepting and using systems they have chosen themselves. See Figure 1.

An educational campaign to develop community awareness of water and sanitation problems will increase local participation in developing a project to satisfy the needs of the community. Continuing health education is required to help villagers understand

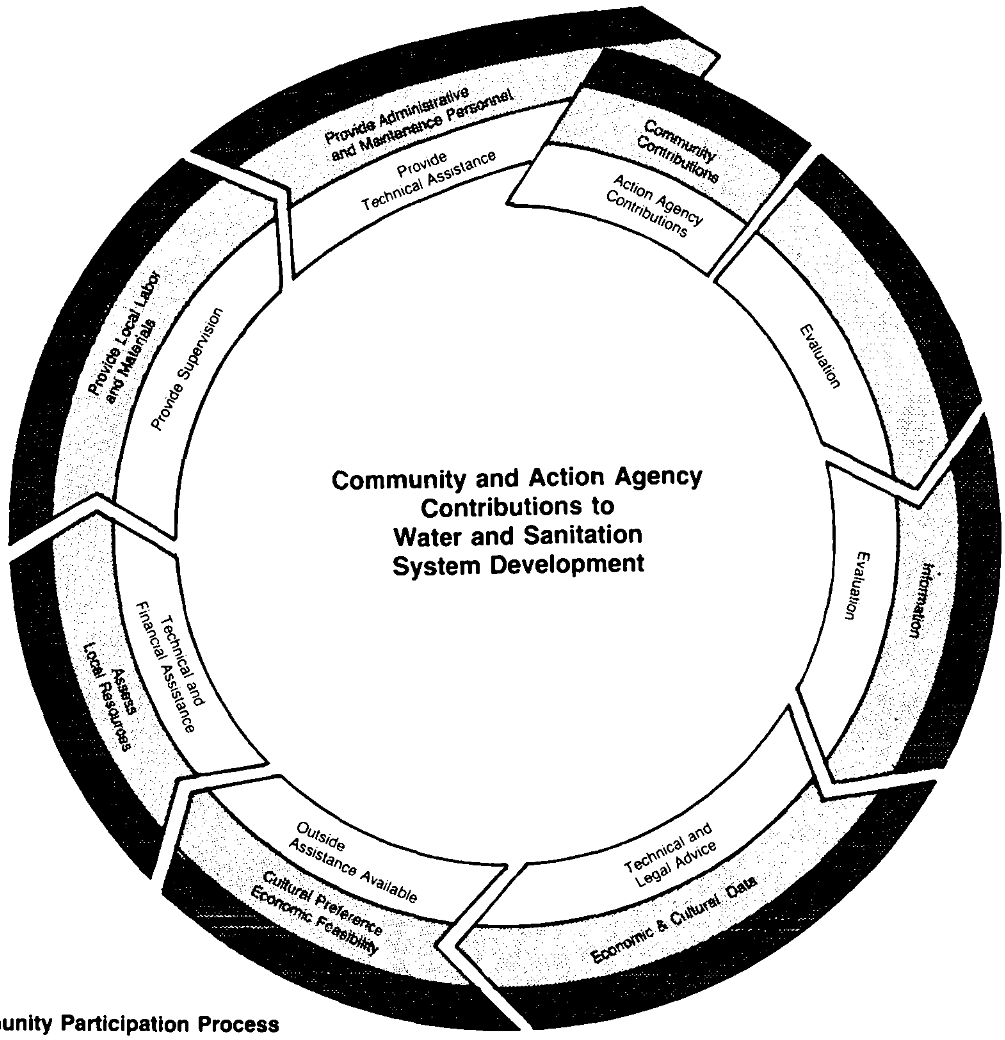

Figure 1. Community Participation Process

the behavioral changes they must make to receive health benefits from improved water and sanitation systems. Technical training in construction, operation and maintenance will teach selected individuals practical skills and may create an understanding of and respect for the facilities among the rest of the villagers.

Developing Water and Sanitation Systems

The development of water and sanitation systems and community involvement in projects will vary according to local circumstances. Several principles apply to most project situations, however. This series of technical notes is written with the following policies and planning guidelines in mind:

1. The community must identify its own water and sanitation problems. A strong interest in improving existing water supply and sanitation systems must be present in the village.

2. An "action" agency should provide the community with technical expertise, economic advice and assistance in developing water and sanitation systems. The action agency should assist the village water and sanitation committee to gain legal powers. Governmental support is necessary for legal clearances but the action agency need not be a government agency, though in most situations it is.

3. The community must be willing to accept, to the extent it is able, the

responsibilities for funding, developing, operating and maintaining local systems. With the assistance of technical advisors, the community must set its own goals for improvement and select its own system. When community members play a major role in developing a project, they view it as their own instead of one that has been imposed on them.

4. The action agency should be decentralized so that the responsibility for activity is as close as possible to the community where the activity takes place. The agency should supply one or two representatives to work directly with each community, although one representative may be responsible for several communities. The representative will coordinate project planning and implementation and is referred to in these technical notes as the project planner or project designer. The project planner and designer should be well acquainted with the problems and needs of the local people, the community's political order, its decision-making process, its sanitation practices, and its attitudes toward excreta disposal, established water sources and water use.

5. If no appropriate local organization exists already, the village should form a water and sanitation committee to represent local interests and work directly with the action agency's project planner and designer. The project planner should provide any organizational assistance requested. The village committee should include members who represent the various family or geographic groups in the village as well as the existing leaders, health workers, extension agents, teachers and agriculturalists. The committee should receive some basic training in water and sanitation from the project planner so it can help educate the rest of the community. It is very important that committee members be both men and women so that water use and sanitation information is distributed through existing cultural channels. The village committee will be responsible for promoting the water and sanitation projects in the community so that local educational needs and economic capabilities can be determined and specific goals can be set.

6. The action agency must understand and respect the economic and cultural setting of the community so that an appropriate technical system can be developed. The agency should be able to provide materials and funding assistance to communities when necessary.

7. The agency should teach the village committee the benefits of water supply and sanitation improvements and explain the technical alternatives available. It must provide supervision during all phases of the project and train community members in construction.

8. The action agency must provide back-up support for water and sanitation systems in the form of continuing education and operation and maintenance training.

9. The community and the agency must collaborate on all decisions and activities throughout the project.

Summary

Water and sanitation systems installed by a community under the expert advice of the action agency have many advantages. The improvement of the local economy and of health conditions are the most obvious. These benefits may also help a community realize the potential it has to develop in other areas.

For example, some villages can learn new technical trades while constructing, operating and maintaining water and sanitation systems. The introduction of bookkeeping procedures required by the project may be extended to other businesses. Improvement in living conditions may keep villagers from migrating to the city where living conditions may not be as attractive as they appear. The primary goal of water and sanitation projects is to provide an adequate and safe supply of water and effective sanitation systems for the entire community at the least cost and with the most suitable technology.

Notes

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Water for the World

Methods of Initiating Community Participation in Water Supply and Sanitation Programs

Technical Note No. HR. 2.M

The development of good water and sanitation systems involves many factors. The technical, environmental, economic and cultural aspects of such projects must be well-coordinated if the projects are to succeed. Such a balance depends on the interest and participation of the people who will be using the water or sanitation facilities. No system, however well designed and constructed, will benefit its users if it will not last, cannot be paid for, is improperly operated and maintained, or is socially unacceptable and so is not used. A full exchange of information between the action agency and the community during all project phases is very important for successful water and sanitation system development.

This technical note reviews the roles and responsibilities of the action agency and the community in preparing to select solutions to local water supply and sanitation problems. Refer to "Overview of Water and Sanitation Systems Development," HR.1, for background information on community participation in water and sanitation projects.

Starting a Project

The initial contact between the action agency and the community may be made by either group. The contact may be a request from the community to the action agency for assistance, based on local concern for better health, desire for convenience, or awareness of alternatives to the current water system. Or, the initial contact may be an invitation from the action agency to the community to work together to improve the community water and sanitation system as part of a regional or national campaign. If the community does not have a water and sanitation committee, the project planner should help form one to represent the village and work directly with the action agency.

The action agency's project planner and project designer should act as a liaison between the village committee and the agency. Initial discussions between the village committee and the project planner should clarify the priorities of each group. In the early meetings try to:

1. Specifically identify the water and sanitation problems. Is the current water supply reliable, accessible, of good quality, of sufficient quantity? Are sanitation conditions likely to cause health problems?

2. Identify community priorities and goals for water and sanitation improvement and community willingness and capability to participate in the project.

3. Identify action agency priorities and goals for water improvement and its willingness and capability to participate.

4. Compare the current water supply with community water needs, including future needs. Refer to "Determining the Need for Water Storage," RWS.5.P.1, for information on how to specify community water needs. Relate this information to water use patterns for drinking, bathing, laundry, agriculture, and livestock.

5. Consider current excreta disposal practices.

6. Organize local feasibility studies to identify technical and economic resources specifically for water and sanitation projects.

The Village Water and Sanitation Committee

The community committee represents the village and works directly with the project planner and project designer. Often an existing local organization, such as a rural development committee or village council, can best act as the village water and sanitation committee. If no appropriate local ogranization exists, the project planner should assist the community in organizing a locally selected committee to oversee the community's contributions to the project.

The project planner should gather the support of community leaders in organizing a committee that will operate according to the community's own customs. Ideally, members of the committee should come from all the groups in the village so that the committee is representative of the entire village's needs. Committee members should be interested in community development, health, and water and sanitation improvements, should be well respected by the community, and should have special knowledge, experience, or resources to offer the committee.

Committee members should be able to work with community leaders, health workers, teachers, extension agents, those familiar with local economic conditions, and the various ethnic and age groups in the community. It is very important that members of the committee be both men and women, so that information on improved hygiene practices related to sanitation and water supply can be effectively communicated through traditional cultural channels. Women usually teach other family members these practices, so they play an especially important role in water and sanitation education and practice.

The committee should be set up legally so that it can sign contracts for village participation, collect funds, arrange for local material and labor for a special project, and be responsible for the operation and maintenance of the systems. Duties of the community water and sanitation committee include:

- presenting the community's view of its own needs and priorities to the agency,
- assisting in feasibility studies and gathering field data with technicians from the action agency,
- reporting to the community at public meetings and explaining the current status of the project, technical alternatives and decision-making factors,
- organizing community education on the benefits of water supply and sanitation systems, especially health education,
- organizing support for the project from individuals in the community, and generating the active community involvement in the project that is essential for its success,
- presenting outside project personnel to the community and explaining their activities and responsibilities,
- explaining system options to the community, including community responsibilities associated with each alternative,
- establishing and enforcing sanctions for any misuse of the water supply and sanitation system.

Action Agency Responsibilities

The action agency is responsible for using its technical expertise and economic advice to guide and train the community. The agency should appoint one or more representatives to coordinate community and agency efforts on the project. These representatives may be project planners, project designers, or field workers who will oversee or assist in the construction of the project. Ideally, these representatives will have training or experience in community organization and public health, as well as a technical background in water supply and sanitation. The project planners, designers, and field workers should be sensitive to the community's political structure decision-making process, sanitary practices and attitudes toward the existing water source. They should be familiar with the community's water and sanitation priorities and goals and should work closely with the village water and sanitation committee. Many village committee members will not be familiar with program administration. The project planner should consider providing special training for them.

The agency representatives' duties include:

- helping to organize a village committee if none exists,

- explaining the action agency's priorities and goals in water supply and sanitation improvements,

- explaining what the action agency expects of the community in the project,

- explaining community benefits of water and sanitation improvement,

- helping the village committee organize a local health education program,

- stressing the importance of community participation in the water and sanitation projects, especially to community leaders, the village committee and health workers,

- leading the local water and sanitation committee in performing local feasibility studies and gathering field data,

- coordinating water supply and sanitation with other agencies' local development programs by contacting those agencies for data and support,

- arranging training for system construction, operation, maintenance and health education for other community members.

Preliminary Studies

A field investigation gathers local technical, socio-cultural and economic information to help determine what kind of water supply and sanitation systems are appropriate for the community. It is an important educational process both for the community and the action agency. Community members learn data-gathering techniques and become more aware of water and sanitation problems. Action agency personnel become oriented to the community and community attitudes toward technical alternatives. A thorough field investigation is a very effective way to establish a good working relationship between community members and action agency personnel. It stimulates community involvement in the project and diminishes future problems in the design, construction, operation and maintenance phases.

Field data can be gathered from existing records, surveys, and special field testing. See the technical notes on planning in the sanitation and rural water supply series for further suggestions.

Data should be collected in the following areas:

1. Existing water supply and sanitation situation. Include:

- comparison of water needs and supply,

- type, number and location of all drinking water sources and sanitation facilities,

- quality, quantity, accessibility and reliability of water sources,

- water collection information (who, when, how, how much, how transported, time spent per day),

• present methods of washwater, excreta and refuse disposal,

• various uses for water (drinking, bathing, laundering, agriculture and livestock).

2. Social and cultural aspects of the community. Include:

• map of community showing households, roads, schools, markets,

• attitude of community members to health education, preferences for water supplies, beliefs, and taboos on sanitation and drinking water and water sources,

• community members' perceptions of benefits of improved systems,

• past development project "histories" involving community participation projects and self-help projects,

• community's willingness to pay or contribute in kind for improvements,

• community's willingness to continue to maintain a facility.

3. Resources. Include:

• sources of funding, including government grants or loans, aid from international organizations, local taxes and community cash contributions,

• amounts of money available from above sources,

• community incomes, willingness and ability to pay, preference for payment methods, and seasonal distribution of incomes,

• affiliations with extension workers in other fields,

• types and quantities of available tools and equipment,

• types and quantities of available local building materials (sand, gravel, stone and wood),

• names and special skills of available workers (both men and women, including masons, carpenters, well-diggers and accountants),

• people who will be available for training for construction, operation and maintenance of water systems,

• when labor will be available,

• whether laborers will contribute their time or whether an incentive will be necessary.

4. Environmental and geological data. Include:

• records of soil conditions for excreta disposal suitability, pipe routes or well suitability,

• groundwater levels:
-- in the wettest season (necessary for excreta and washwater disposal)

-- in the dryest season (necessary for wells),

• topographic information and maps,

• physical size of village,

• population, estimate of future growth rates and water demands,

• rainfall information, including drought and flood periods,

• temperature ranges,

• stream and river flow rates and spring yields,

• data on evaporation and run-off.

5. Health statistics. Include:

• water-related diseases,

• sanitation-related diseases,

• disease patterns,

• primary health care facilities,

• health education in area.

Summary

Community involvement in a water project is an important way for people to become aware of and select solutions to their own water and sanitation problems. It is essential that a community itself believes in the importance of improved water supply and sanitation systems. It is equally important that the governing agency recognizes the importance of community involvement so that effective cooperation is developed.

Initiating community participation in a water or sanitation project is the collective responsibility of the community leaders, the village water and sanitation committee, and the action agency representative. There is no one model for successful community participation in developing water and sanitation system improvements because each community situation is unique. Once the roles and responsibilities of the action agency and community are established and basic data is gathered, selecting and planning a specific system can begin.

Notes

Notes

Notes

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1982

Water for the World

Community Participation in Planning Water Supply and Sanitation Programs
Technical Note No. HR. 2.P

Community participation in planning a water and sanitation system is one of the most important contributions to a project's success. For local participation to be productive, both the community and the action agency must be committed to it from the start. See "Overview of Water and Sanitation System Development," HR.1. Educational campaigns on the options for improvements in water and sanitation on the local level are essential to develop the community awareness that leads to responsible participation in developing a system. The community and the action agency must jointly develop a water and sanitation system that can be locally operated and maintained with a minimum of advice and assistance from outsiders. Community involvement in project planning is essential to the later phases of design, construction, and operation and maintenance. Community involvement is especially important in the areas of financial arrangements, in-kind contributions, labor schedules, legal clearances, selection of acceptable technology, and training in operation and maintenance.

Community Education

Local awareness and understanding of the advantages of water supply and sanitation improvements increase the probability of community participation in developing appropriate water and sanitation facilities. The success of a water and sanitation project depends on users wanting, understanding, and accepting the system.

Community education serves several purposes. One is to explain to villagers the economic advantages of improved water and sanitation systems. Another purpose is to familiarize the community with the technologies available so that they will select one they can operate and maintain with a minimum of outside involvement. A third purpose is to teach villagers which personal and communal water and sanitation practices are harmful to good health so behavioral changes can take place.

Education programs should be arranged through the action agency. The action agency and the village water and sanitation committee should organize the community education campaign using all appropriate cultural channels and reaching all social levels. The educational effort can be coordinated with other development projects, such as hospital construction or primary health care, as well as with local institutions such as schools, and organizations such as mothers' clubs.

Both hygiene and technical education should be integrated into all stages of the planning phase. This is best accomplished if local water and sanitation practices are throughly understood. Local water and sanitation beliefs, legends and patterns of water use and excreta disposal should be identified and understood by the health or technical educator.

Some suggested components to use in health and hygiene education are:

- rules of personal hygiene,
- rules of communal hygiene and environmental sanitation,
- methods of water source protection,
- rules of water supply protection in the household,
- health reasons for a safe water supply,

• health reasons for sanitary excreta and refuse disposal.

Convenience and privacy are the most likely reasons people will accept and use new facilities. Even so, local disease statistics and projected economic consequences are good tools for explaining the need for good health. Examples set by role models such as teachers, engineers, community leaders and even school children can change behavioral patterns in a community. Visual aids and the mass media are effective supplements to an educational campaign.

Local programs might be organized as:

• hygiene explanations of water and sanitation systems integrated into construction schedules for laborers,

• family, mother and child education programs in personal and communal hygiene,

• school programs on health and hygiene, including demonstrations and supervised good use of new facilities at school,

• manuals for facilities use for operation and maintenance personnel,

• environmental sanitation and village clean-up campaigns.

It is difficult to persuade people to change old habits but the difficulty can be lessened by the manner in which change is introduced. Community leaders should understand problems and solutions early so they can help explain the coming changes. Leaders can motivate villagers through their own actions and through community approved sanctions for misuse of facilities. When community leaders, the village committee, the action agency and the villagers all have similar understandings, they can work toward a common goal.

The action agency must explain and evaluate technical options with the community to determine their social acceptability. Throughout the project, the action agency and the village water and sanitation committee should explain each project activity and the reason for its sequence to the rest of the village. This can be accomplished at public meetings or in informal discussions. Refer to "Methods of Operation and Maintenance Training," HR.3.M for more information on technical education.

Community education, or even data collection done with local participation, begun in the early planning stages of a project will stimulate interest and can help start active community involvement in the project. Public awareness of technical alternatives and personal and public practices related to hygiene and sanitation can provide health benefits that the provision of a water or sanitation system alone cannot affect.

Formulate Alternatives

The collection and evaluation of field data will often continue throughout the entire project as new options and information are presented. The action agency will be responsible for appraising the technical field data and identifying the technical options it believes are practically and economically feasible. The community will be responsible for evaluating its social, cultural and economic situation and identifying options which it perfers.

Before final steps are taken in formulating water supply and sanitation alternatives, the community, with technical assistance from the agency, should clarify its priorities and needs. It must identify its expectations and capabilities for technical involvement in system operation and maintenance, its own reliable resources (cash, labor, materials, equipment, services), and the support services it will need for education and training in health, construction, operation, maintenance and facility use.

The action agency should identify the technically feasible alternatives which meet local needs. Each option the agency presents to the community should include:

• a technical description and explanation,

• estimated installation costs,

• installation needs such as construction time, labor, material and equipment,

• operation and maintenance costs,

• community's operation and maintenance responsibilities,

• estimated total costs,

• funding requirements, sources and availability.

The agency must fully explain the community responsibilities for each option and the support services the agency can provide. The action agency must keep in mind that the village will be managing its own system in the operation and maintenance stages. Efficient operation and maintenance of water and sanitation systems in isolated and rural areas requires simple equipment and procedures and as little water treatment as possible.

Both the agency and the village must weigh the following factors for each alternative considered:

1. Technical feasibility, based on data collected in preliminary studies (refer to "Methods of Initiating Community Participation in Water and Sanitation Programs," HR.2.M).

2. Construction needs:

a. Is site (land) available?
b. Can water and sanitation facilities be made available at convenient places for everyone in the village? Can facilities be extended to new residences?
c. What materials, tools, and equipment are necessary?
d. Which are available locally?
e. How can non-local materials and supplies be obtained?
f. What kind of and how much labor is necessary?
g. Is it available?
h. How much will materials, equipment, and labor cost?
i. When are laborers free for construction?
j. When and how will funding be available?
k. What season is best for construction?

3. Operation and maintenance needs:

a. Will an operating budget be required?
b. Is local personnel available for operation of systems?
c. Are trained personnel for operation and maintenance necessary? How many?
d. Can water agency provide training for operation and maintenance?
e. How much will operation and maintenance cost daily, weekly, and monthly?
f. What minimum costs will be necessary to keep the system going? How will funds be provided?

4. Community needs and preferences.

5. Social, cultural, religious acceptability.

Select a Method

After evaluating all alternatives presented, the most appropriate system for the village must be chosen. There is often wide variation between the most desirable alternatives and the most workable solutions. The water committee and the action agency must be careful not to choose either a sophisticated but unrealistic system or a system that is realistic but inadequate for meeting the community's needs. Often, established standards of quantity and quality will have to be balanced off against community preferences.

No system should be selected that involves complicated or expensive designs or equipment. Systems must be technically sound, economically feasible and acceptable to all segments of the community. Systems should be chosen for suitability and not prestige, but convenience and aesthetics should not be overlooked. Any features that exhaust the technical, economic or social resources of the community invite system failure and should not be selected. Systems using local resources are more likely to succeed than those dependent on outside resources.

It is not always necessary to develop an entirely new system. Small projects and improvements on existing systems may meet current urgent needs and promote village participation. The project planner should provide information for the village on the costs and efforts involved in minimal level service improvements which can be expanded over time.

The best water supply alternatives are those that provide the community with safe and abundant water from a reliable, accessible and socially acceptable source at the lowest cost. The best sanitation system alternatives are those which provide the most socially and environmentally acceptable level of effective service at the lowest cost.

Financial Arrangements

Special meetings should be held between the community and the agency to analyze finances and sources of support. The community should be instrumental in establishing financial arrangements for the project. Fund-raising instituted by the villagers to help pay part of the capital costs of the water and sanitation system may help pay for recurrent expenses or raise money for other village projects. Care must be taken to ensure there is equity in contributions and payments. The financial value of local labor, materials and services can constitute a considerable proportion of total costs. When the community has contributed to the cost of the system, and has also participated in planning and constructing it, local residents may develop a stronger sense of responsibility for the system. If the community cannot pay for the project itself, it should arrange for in-kind support. For example, the community can identify sources for items on the materials list and arrange donations, trades or other in-kind commitments.

The community should also be instrumental in developing a financing schedule. If at all possible, the action agency should teach elementary accounting to villagers. The community can:

- price materials and identify the best price alternatives,
- calculate project costs per family, cost per capita, and total cost,
- decide how the community will pay for construction,
- determine any repayment schedules for loans,
- decide how the community will pay for operation and maintenance,
- decide how and when any fees will be collected,
- determine wages for construction workers and operation and maintenance personnel.

Set Specific Goals and Write a Project Plan

After the appropriate technology is selected, goals for developing and completing the system should be set. Set specific goals that can be measured so people can tell when they have reached them. Be sure any necessary legal arrangements are made.

Project goals must clearly state:

- What the project is.
- What the project will accomplish in terms of effort and benefits.
- What methods will be used to complete the project.
- When work will be done.

Write a project plan that incorporates these goals into a specific time frame.

The village committee should help choose personnel for construction, operation and maintenance. Specify:

- How a construction supervisor will be chosen.
- Who will be supervisor.
- Who will be construction workers.
- How the operation and maintenance managers will be selected.
- Who the operation and maintenance managers will be.
- Who will keep books and file monthly maintenance and accounting reports.

The construction supervisor, the village committee, and the action agency should:

- Make a list of

-- the materials which must be procurred outside of the community and their costs, and

-- the materials which can be gathered locally.

- Make an equipment list, including tools and vehicles, and all costs.

- Make a list of where to procure all materials and equipment and set up a schedule for delivery.

The village committee should be instrumental in scheduling labor with the constuction supervisor. Identify and specify in the project schedule:

- Tasks for completeing construction.

- Which parts of the system can be locally constructed.

- Which parts of the system will have to be constructed outside community.

- Which jobs the community will perform.

- Which jobs the agency will perform.

- Which jobs will require both community and agency work.

- Sequence of tasks.

- When work must be done (according to migration patterns, planting, harvesting, climatic cycles and holidays).

- Schedule of completion dates for construction activities.

The action agency usually arranges for equipment and materials to be delivered to the village. Delivery needs to be budgeted into project costs. Tools and equipment are generally furnished for project use by the agency. The community usually pays for construction materials, so it is best to use local materials such as sand, gravel and stones whenever possible.

The community should provide facilities for storing materials, tools and equipment at the project site. This will include an area for storing large equipment and a building for storing smaller items. Transportation within the village should also be provided by the villagers.

The community must help decide where the water and sanitation facilities will be located. Possibilities for extending the system to individual households or new residents should be explained. The community must be responsible for establishing an authority to enforce rules about late fee payments and negligent use of the system.

Adequate provision must be made for proper operation and maintenance of a system, at both the local level and through a backup resource arranged through the action agency and located convenient to the village. The community and the agency should work together to designate a health education staff and plan a health education program schedule. The two groups should set up an evaluation schedule for the system. Specify evaluation criteria, when the system will be evaluated and by whom.

Community Approval

A written or otherwise acceptable project plan may have to be approved by local, regional or national leaders, by water agency officials, or by funding agencies' officials. It must also be officially approved by the community. A project plan should include:

1. A description of the water and sanitation problem in the community.

2. An explanation of the proposed technical system and its expected benefits including the number of facilities.

3. An explanation of the method of construction to be used.

4. Design drawings (these can be simple at first, but dates for final

design drawings must be included in the project timetable).

5. Community and topographic map showing placement of facilities and location of construction. Show placement of facilities within houseplots and relationships of water supply facilities to sanitation facilities.

6. Costs of constructing system including labor (wages, number of workers, time), tools, equipment, materials, services and land that must be purchased.

7. Costs of operating and maintaining project for a specified period of time (per year or per month).

8. Schedule for implementation, including seasonal considerations, timetables for each phase of the project, and total time necessary.

If the community accepts the proposal and the responsibilities involved, a formal agreement should be made. Designing and building the system should begin according to the work schedule proposed.

Notes

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Water for the World

Community Participation in Implementing Water Supply and Sanitation Programs
Technical Note No. HR. 2.I

The community plays very important roles in the implementation of its water and sanitation system. Once a project plan has been agreed upon by the community and the action agency, preparation for constructing the system should begin according to the work schedule proposed. The community, probably through its village committee, will work with the construction supervisor in organizing labor, keeping track of local contributions, arranging the procurement and storage of materials and equipment, and learning technical skills. The community will work with health workers in community health education and project promotion. The village water committee plays an important organizational role during the construction period.

There are many advantages to community members constructing their own water and sanitation system under expert guidance. Individual members of the community, both women and men, will learn trades or technical skills which will benefit the community in future projects. Project costs will be considerably lower if local labor, especially local volunteer labor, is used in place of paying skilled workers from outside the community. The community, especially the construction workers, will gain an understanding of the system as they put it together. Future operation and maintenance personnel can be chosen from those who understand the system best. In addition, a sense of ownership and pride is likely to be created in a community that has helped develop its own system. Such feelings will help the system be accepted and properly used and maintained by the community as a whole.

Before construction begins, it is very important that the action agency, the community water and sanitation committee, community leaders and the community as a whole understand the division of responsibilities, the supervisors' roles, the workers' roles, the list of tasks to be done, the timetable, and the line of communication for problems and progress reports. This should have been determined during the project planning stages and should be part of the official agreement. Refer to "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.P.

A meeting before construction begins can serve as a review of agreements made earlier, especially if very much time has elapsed between phases. All this information should be made available to the whole community at public meetings and through traditional public announcements. Be careful that local involvement in construction is understood so that no overburdening of available resources, labor and time develops, resulting in poor standards of construction, loss of local interest, construction delays or local conflicts. Public gatherings are good opportunities for reviewing the benefits, use and maintenance of a system. Household and community hygiene education combined with technical information will re-establish the importance of a good water and sanitation system.

Role of the Construction Supervisor

The construction supervisor will be in charge of organizing and overseeing the building of the water and sanitation system. He will probably be from outside the village and hired by the agency. This person must have a clearly defined management role so that he or she will have community support in dealing with any organizational problems. The supervisor must be acceptable to both the action agency and the villagers, have proper technical knowledge of water and sanitation systems, and be especially sensitive to the culture and the needs of the community.

Before construction begins, the supervisor must arrange for parts and material which will have to be purchased or constructed outside the community. These should have been determined in the planning phase. The supervisor should be responsible for working with the committee to make warehouse arrangements for tools, small equipment, fittings and other supplies and storage for large materials and equipment. The construction supervisor should work with the water committee to schedule construction. Work must be scheduled according to:

- material delivery (for example, pipe trenches should not be dug and open before pipes arrive),
- seasons and weather,
- harvesting and other community work patterns,
- holidays (religious, national, local),
- technical requirements.

The supervisor should determine the type and amount of training workers will need to complete the tasks listed in the planning phase. Provisions should be made to equalize the value of different tasks such as volunteer labor, cash payments and food contributions. Before each task is begun, or at the start of each day, the construction supervisor should brief workers on the task, the workers' construction duties, and the function of the piece to be constructed.

Role of Village Water and Sanitation Committee During Construction

The village committee can play a very important organizational role during construction. It should work closely with the construction supervisor to organize labor, arrange the storage of equipment, tools, vehicles and materials, and arrange the transportation of supplies within the community. If possible, a committee member who has experience in accounting should keep the financial ledgers during the construction period. Ledgers should be open to public inspection. Committee members should work closely with health educators to explain proper water use, environmental sanitation and personal hygiene so that community understanding of the purpose of a water and sanitation system will develop along with the workers' technical skills. It is very important that the village committee continue project promotion through the construction phase.

Role of Community Bookkeeper

The bookkeeper should maintain careful accounts of all local contributions. Balances for all recognized contributions, including cash, labor, materials, food, shelter, land, and water rights should be established. The agency should help the local bookkeeper set up books and provide instruction in these responsibilities. The local water and sanitation committee treasurer may also be the system bookkeeper.

Cash can be collected by the water committee to offset building costs and any outside labor costs necessary. Simple records should be kept of attendance of workers and construction expenses. Upon completion, the bookkeeper should calculate final project costs, set up financial repayment schedules, and review the terms of any loans or payments necessary with the rest of the water and sanitation committee and with the action agency.

Operation and Maintenance Personnel

One method of choosing operation and maintenance personnel is to use the construction period to select and begin training those who perform well. During the construction phase, the selected personnel will learn what the system is made of, how it is put together, and how it works. With this experience, they can understand and perform the work that will be expected of them later. Operation and maintenance personnel should be from the village. The future of the system will depend on their understanding of their duties and responsibilities and on their dedication to their assignment.

The number of people needed to operate and maintain a water supply or sanitation system depends on the size, complexity and sophistication of the system. One supervisor is usually adequate for small simple systems. More personnel may be needed if distribution systems, pumping stations or water treatment plants are included. Training several operators assures fuller coverage. Refer to "Methods of Operation and Maintenance Training," HR.3.M.

Training in household hygiene and sanitary use of household facilities should continue for household managers and mothers both during system construction and after the system is in use.

Upon Completion

When construction is completed, an inventory should be made of the installation. Detailed plans indicating the various pipelines, valves, equipment and other parts of the system should be recorded. Complete specifications should be included for all equipment, as well as manuals for operation, maintenance and spare parts. The village water committee should maintain a copy of these plans, as should the operation and maintenance personnel and the action agency's regional office.

Spare parts for the system should be carefully labeled, listed and stored. Some will be kept at the village and others at the action agency's office. Both groups should keep a list of materials and equipment stored by the other.

A construction period may be begun or finalized by a traditional ceremony to make it the community's own. Such a ceremony can transfer responsibility for the system from the construction supervisor or action agency to the operation and maintenance personnel, the health education team in the village and the water and sanitation committee. Before a dedication ceremony, a supervising engineer should approve the system. The action agency should explain possibilities for upgrading or extending the system in the future, if this is appropriate.

After the installation of a water supply system or excreta disposal facility is complete, monthly reports on the operation of the system by the operation and maintenance supervisor and periodic inspections by the project promoter from the action agency must be made. Refer to "Implementing Operation and Maintenance Training," HR.3.I.1.

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Water for the World

Methods of Operation and Maintenance Training

Technical Note No. HR. 3.M

One of the most important steps in establishing a water and sanitation system in a rural community is arranging for efficient operation and maintenance of the facilities. Without proper care, a water and sanitation facility will deteriorate and fail to provide the services for which it was designed and built. A malfunctioning system will almost certainly be improperly used and eventually abandoned by the community. Perhaps even more important, a community may develop a false sense of security in a malfunctioning water and sanitation system they do not realize is harmful. It is imperative that the community understand that without proper operation and maintenance by trained system operators, no water and sanitation facility will continue to function properly and safely. Such proper functioning is essential to gain economic benefits, good health, improved hygiene, lower disease rates, and increased convenience in the community.

Improvements in the health conditions and hygiene habits of community members that can result from a good water and sanitation system are lost when a supply breaks down. A community enthusiastic about water and sanitation improvements may view a breakdown as evidence that their contributions to the system were wasted. Their further cooperation may be difficult to obtain. Adequate provision must be made for proper operation and maintenance of the facilities at the local level and through an action agency back-up located conveniently to the village.

A well-maintained water and sanitation system needs well-trained people to operate it. Technical training in operation and maintenance will give selected individuals the practical skills needed to care for community systems and help to instill respect for the people operating the facilities among the rest of the villagers.

Training needs should be defined for operation and maintenance personnel in order to:

- select a training method,
- develop a training method,
- plan a training program,
- conduct a training program, and
- evaluate operator performance after training.

The most appropriate training method is one that meets training needs and makes the best use of local resources.

The initial step in the training process is to decide who is to coordinate the regional training effort and determine where the trainers will come from. Decisions must be made to carry out training at local, regional or national levels. Often the most economical method is to train trainers at the national level so they can train, at a regional center, the people who will work on local water and sanitation systems. Trainers need to learn how to use the technical notes on operation and maintenance that are part of this series. They must learn how to conduct training programs. People trained at the national level for work at the regional level should help the village water and sanitation committee select candidates for the local operation and maintenance positions and coordinate the training for that job.

Selecting Trainees

Since the continual functioning and upkeep of a rural water and sanitation system is primarily the responsibility of the community, the components of the system should have been designed so they can be operated and maintained by personnel available in the village. It is imperative that provisions for training begin at the same time as system design, since the design must fit the local people's capability for operation and maintenance. Refer to "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.P, and to the technical notes on design and on operation and maintenance of the system being constructed in the community.

It is important that the operation and maintenance job tasks be considered when selecting technicians for a project, and it is equally important that the qualifications of the selected system operators be considered when developing a training program. The capabilities of local operation and maintenance personnel can be developed if good training and support are provided by the regional office of the action agency.

The method used for selecting operation and maintenance personnel will depend on local circumstances. Several conditions apply to most situations, however. System operators should live in the village so they are available to work the system regularly. They need to be able to work well with the water committee. They should be accepted by, if not chosen or approved by, the village water and sanitation committee and the community as a whole. They must have an ability to perform technical operations and have an interest in improving the water and sanitation conditions in the village.

The number and qualifications of system operators are determined according to the design of the system, the size of the system, the various components of the system (especially any water treatment facilities) and the number of people who will be using the system. Information on the number and qualifications of system operators needed for the particular facilities constructed at the local level should be obtained from the technical notes that relate to that specific system.

In a typical small water supply and sanitation system, the personnel will probably consist of those needed to administer or manage the system and others who operate it technically. If the village committee acted as an administrative staff during construction of the system, they should continue to do so after the system is in use. The committee can oversee system operators, manage the budget, collect user fees and perform all accounting duties.

System operators' duties will be both technical and non-technical. They will be responsible for operating equipment, performing preventive maintenance, making repairs, reading meters, and cleaning the system. They will also be responsible for ordering supplies, groundskeeping (maintaining fences around facilities, clearing blocked drains, checking pipe coverings), and keeping basic records. System operators must keep the village water and sanitation committee informed on the condition of the water and sanitation system and recognize and report major problems as early as possible to the action agency's regional office.

One method of choosing operation and maintenance personnel is to use the construction period to select and train workers who have shown competency and interest in the system during construction. The system operators chosen from the construction crew learn first how the system is put together and how it works. This facilitates understanding and performing the operation and maintenance work.

Women are the primary water users in villages, so equal access to training in system operations should be ensured for them. If women were involved in construction tasks, they are primary candidates for operation and maintenance tasks. Women are less likely to leave the village than men and have a direct influence on the water and sanitation habits of the children. Their employment as system operators may provide more continuity in operation and maintenance. Since women use water systems more than men, they also detect problems earlier. In addition, the children will soon learn that operation and maintenance are very important aspects of the water and sanitation system and will grow up with a positive attitude toward maintaining a system. Introducing these new attitudes and approaches to children will make introducing ideas and systems in new generations much easier.

Often there is an experienced or skilled mechanic in the village who knows how to use tools similar to those involved in the new system. The village committee should consider hiring such a person for operation and maintenance duties. Other good prospective system operators are water collectors, water vendors, traditional well-diggers, and primary health workers.

Operators who can read and write can make monthly reports and keep other records. However, ability to read and write should not be the deciding factor in chosing system operators. Reports can be made in other ways or special training for writing reports can be incorporated into training.

The village water and sanitation committee should be trained in the needs of operation and maintenance to facilitate good system management and cooperation with system operators. The water committee will be the best liaison between the system operator and the rest of the community. If the committee and the local population develop a sense of pride and ownership in a system, they will demand a smoothly run system which provides the services for which it was designed. In addition, a community which is proud of its system, and understands the importance of its care, is more likely to cooperate with the system operators and properly use their facilities.

In small communities with simple water and sanitation systems, it may be advisable to make one or two people responsible for operation and maintenance tasks. Where systems are larger or more complex, operation and maintenance by a group of system operators may be best. Small water and sanitation systems do not imply small problems or small responsibilities for system operators and the village water and sanitation committee, however. Appropriate training is needed for operation and maintenance of water and sanitation systems of any size.

Methods of Training

There are many ways to conduct training programs. They can be held at national, regional or local levels employing many different teaching styles. The style of the training program will be influenced by the subject matter to be covered, the place the training is conducted, the facilities available, the skills and experience of the trainees, the length of time the trainees can spend at a training site, the length of time trainers can spend with the trainees, the funding that is available, the local conditions under which the operators will have to work, and the back-up support the action agency will provide to local operators. No matter what style of instruction is developed, some principles for training local systems operators should be kept in mind.

1. Training should stress the practical aspects of caring for water and sanitation systems. The trainees should learn the procedures they will need to perform for the community systems by practicing the procedures under the supervision of an experienced trainer. Training cannot be accomplished by lectures, manuals, visual aids and demonstrations alone, although these are acceptable complements to hands-on experience.

2. The training programs must be directly applicable to the facilities the operators will be working on in their own village. If operators are not trained in their villages on the actual equipment to be used, they should practice on identical equipment at the training site. Teach only what is directly useful to the trainees, and limit the amount of extra information.

3. Training programs must be adjusted to fit the individual needs of the people being trained. For example, if the people cannot read and write, their training needs are very different from those who can.

4. The action agency should aid training efforts by arranging refresher courses for systems operators.

5. Resources and dependable back-up support should be available at the action agency's regional office where village system operators can reach them.

6. The success of training will be minimal unless the community and the action agency together create paid positions for operators and are willing to pay a training staff.

7. The training program should

include practical evaluation of system operators to determine if they are able to perform satisfactorily under local conditions.

System operators can be trained in their village or in a training center. On-the-job training in the village under the supervision of an experienced operator may be best for simple systems. No special facilities will be required since system operators can learn tasks using the equipment they will be working on to perform their jobs. On-the-job training is effective with trainees who learn new skills best by doing.

In order to work well, on-the-job programs need skilled and experienced trainers available to travel to job sites. No transportation will be needed to get village trainees to the training site. Trainees are often more likely to attend training sessions in their own villages than in centers to which they must travel. On-the-job training usually costs less than training in a center. It can begin during construction phases and may be supplemented by short courses and refresher courses at the regional training center.

A central training establishment for training can be arranged at the action agency's regional office. Short courses can be based on simulated water and sanitation systems. Trainers would be available to trainees at all times. Other training aids, such as spare parts, printed materials, slides, audio tapes, video and film might be available. Media aids can be adapted to help instruct persons who cannot read. The operation and maintenance technical notes in this series that apply to the system the trainee will operate will be useful training materials.

Self-paced training programs can be developed so that workers at various levels of competence can use materials individually but still have access to trainers when necessary. A trainee can receive one-on-one assistance at a slow or fast pace from the trainer.

Supervised check-ups in the village should follow centralized training. A mobile training unit could come to each village for check-ups and refresher courses.

The disadvantages of centralized training are that transportation must be provided for the trainees from their villages to the training center. Operators are less likely to attend training if they must travel daily. Costs of establishing a central training unit are usually high. Local conditions cannot be taken into account when training takes place in a central spot with a standardized program.

One of the most important aspects of the training process is the attitude of the trainers. Trainers need to be able to encourage operators during training and reward them for performing well. The action agency should develop a basic training course content. A certificate will record the lessons learned and help standardize tasks and training needs between villages.

Efficient operation and maintenance depends on well-trained and paid operators. It is false economy to skimp on either of these items. The absence of a training budget will be as detrimental to operation and maintenance efficiency as the absence of a system for fees collection to cover operation and maintenance costs. Good training needs a good budget.

Summary

If the benefits of water and sanitation programs are to be realized, the systems must operate efficiently and be dependable. Without proper operation and maintenance, systems will fail to operate. Operation and maintenance must be well planned and systems operators must be well trained.

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Water for the World

Planning Operation and Maintenance Training

Technical Note No. HR. 3.P

Planning operation and maintenance training programs for rural village water and sanitation systems requires choosing a training method and arranging a training program schedule. It is imperative that plans for training begin while the system is being designed so that those who will be operating and maintaining it will know how to do so. For more information, refer to the design and the operation and maintenance technical notes for the specific system being constructed.

A good training approach should transmit the practical skills and knowledge a worker needs to operate and maintain a system. Each task should be carefully defined and analyzed so that it is relevant to the system's operation. Extraneous material not directly related to the operation of the system should not be included. All parties concerned with planning, design, construction, management, and operation should help define these tasks. Teaching should always stress the practical aspects of the subjects covered, including more demonstrations and practice than lectures.

Choosing a Training Method

Instructional programs will be influenced by many factors: the subjects to be covered, the place the training can be conducted, the facilities available, the skills and experience of the trainees, the trainers available, the transportation available, the length of time the trainees can spend at a training site, the length of time trainers can spend with the trainees, the funding that is available, the local conditions under which the operators will have to work, and the backup support the action agency will provide to local operators. In order to select the type of training program most appropriate for local circumstances, these aspects of training must be considered:

1. Identify job tasks. These will be the basis of the training program. Fully describe the operation and maintenance job:

- List all tasks (daily, weekly, monthly).

- List schedules and hours needed to perform these tasks.

- List qualifications personnel will need in order to perform each task (any special skills or knowledge will need emphasis in training).

- List the number of operators necessary to perform each task.

- Describe the working environment of the operators. Check to see if the action agency or any other agency has already trained operators to manage similar water and sanitation facilities in the region. If records have been kept of job tasks, they may, with appropriate adaptations, be useful guidelines for the training program.

2. Identify the trainees' understanding of, experience in and abilities to perform the job tasks. Which tasks will need special or intensive training? Identify the number of participants in the training program. How will tasks be divided among local personnel?

3. Identify local constraints for participating in a training program, such as access to transportation, accessibility of training site to trainees, accessibility of trainees to instructor, length of time trainees are able to spend in training, dates for training and places for training. The location and mobility of trainees must be considered when deciding whether to take the trainees to the training or the training to the trainees. At the village level, it usually costs less and is more effective to take the training to the trainees.

4. Identify trainers and their qualifications. In most situations, the people selected to do the training will not be full-time trainers. They will most likely be people with technical experience in the subject area but with little practice in training others. If possible, there should be an efficient and effective training program to prepare trainers for their duties. They should be taught how to use the technical notes on operating and maintaining various systems, to conduct training sessions, and to assist the village water committee in selecting candidates for the operation and maintenance positions. Trainers should be well-versed in the technical aspects of the system, be acceptable to the rest of the group as trainers, and have the potential and personality to become trainers. The following list summarizes some of the attributes that should be considered in selecting trainers:

- communicates at the level of the trainees,
- is technically competent,
- is able to teach all subject matter related to the job tasks,
- is able to use training aids and audio-visual equipment, where more sophisticated training materials are available,
- motivates trainees,
- clarifies points and assists trainees,
- evaluates trainee performance,
- accepts advice from trainees and training staff,
- is supportive of trainees,
- allocates time for preparation of training, training sessions, and follow-up.

5. Identify physical facilities, supplies and equipment available and needed for training:

- regional training center,
- local site,
- specialized equipment,
- safety equipment.

List the training resources available:

- supplies,
- equipment,
- support at village system site,
- audio-visual equipment,
- instructional materials.

6. Identify funds available. List all allocations in cash or in kind from the action agency, the village and any outside resources.

7. Define training objectives and priorities based on conditions identified. Analyze as accurately as possible the training needs of the village operation and maintenance personnel and the capabilities of the action agency to deliver that training.

Choose the training style that best accommodates the objectives and priorities of training, the trainees and the training situation. Refer to "Methods of Operation and Maintenance Training," HR.3.M, for information on training methods. Table 1 suggests a method for choosing a training site.

Arranging a Training Program Schedule

Once a training program coordinator and/or instructors for the program have been selected, they should:

1. Determine how much time is needed to teach the subject matter and decide on the duration of the training program.

2. Schedule use of training facilities or times for training sessions in the village.

Table 1. Choosing a Training Site

IF	AND	AND	AND	AND	THEN
Many trainers are available	→	→	→	→	Train on-site[1]
Few trainers are available	Equipment and supplies are only available on-site	→	→	→	Train on-site[1]
	Equipment and supplies are available at central site	Job tasks are site-specific	→	→	Train on-site[1]
		Job tasks are not site-specific	Trainees can spend time at central site	Transportation for trainees is available	Train at central training site[2]

[1]The advantages of training on-site are:

- trainees have more time for training
- lower costs
- trainees learn on own equipment, no special facilites required
- local conditions can be integrated into training
- entire community realizes importance of training

[2]The advantages of central-site training are:

- trainers available to trainees at all times
- standardization of operation and maintenance practices
- lower costs for trainers
- more teaching aids available

3. Put the information to be presented in sequence. Operation and maintenance personnel should be trained for the specific technical functions they will perform. Design lessons according to the job tasks defined. Training should also extend beyond technical details to explain the basic reasons for maintaining the quality of the water. Operators should be given a sense of pride in their work and of their responsibility for protecting the health of the community.

4. List training equipment, supplies, aids and reference materials needed. Include their costs and where to obtain them.

Trainers should provide system operators with manuals specific to the equipment for which they are responsible. Manuals should be prepared in a form which the trainees can use and understand, whether they can read or not. Local languages and many illustrations should be used. The manuals can serve as textbooks during training and references while on the job.

A supply of spare parts should be maintained at the village level for routine repairs. A similar supply should be fully explained and repair procedures demonstrated during training. Proper storage of spare parts should be covered.

Occasional refresher training sessions should be planned to maintain operators' interest in their duties, to review operators' duties, to teach any new procedures and to introduce any new equipment.

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Water for the World

Implementing Operation and Maintenance Training
Technical Note No. HR. 3.I.1

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

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

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

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

Management of Training Courses

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

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

1. Trainees have more time for training sessions.

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

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

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

Training at a central site has these management advantages:

1. Trainers are available to trainees at all times.

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

3. More teaching aids are available.

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

Roles and Responsibilities of Trainers

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

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

Trainers responsibilities will be:

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

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

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

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

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

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

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

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

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

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

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

Roles and Responsibilities of the Trainees

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

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

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

- Actively participating in all training exercises and drills.

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

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

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

Content of Training Courses

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

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

- job tasks and responsibilities;

- the degree of authority the position holds;

- financial responsibilities;

- support responsibilities.

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

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

- provide system and water quality control checks;

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

- assist in extensions of systems.

The regional office of the action agency should:

- maintain replacement parts to supplement the local supply;

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

- provide transportation of personnel and materials to community.

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

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

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

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

The village water and sanitation committee is generally responsible for:

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

Fix an Implementation Routine

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

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

A basic manual can:

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

- include illustrations for procedures;

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

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

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

Reports

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

Notes

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Water for the World

Evaluating Operation and Maintenance Training

Technical Note No. HR. 3.I.2

Operation and maintenance of water and sanitation systems is necessary to provide continuing water and sanitation services. This requires constant evaluation of operation and maintenance procedures and conditions.

Evaluation is a way for the action agency and the village to review the value of the water and sanitation system to the community. A balanced evaluation by both parties working together can:

- identify the benefits of the system;
- provide encouragement and support for the system operators;
- identify weak spots in procedures and services;
- examine mistakes without emphasizing them;
- provide suggestions for improvement.

One objective of training and evaluation is to make the system operators understand the importance of, their role in and responsibility for providing safe and convenient service to the community. The village as a whole can then develop a sense of pride and ownership in the system. Evaluation can help ensure that the people served by the water and sanitation system, the system operators and the action agency do not develop a complacent attitude toward the system.

Evaluation should be a cooperative effort involving the action agency and the village. All persons involved in the water and sanitation system should contribute to the evaluation. Critical, rule-enforcing inspection should be avoided. The action agency should consider its role as supervisor carefully during the evaluation process, being careful not to treat villagers as subordinates. A full, two-way exchange is very valuable in evaluation.

Evaluations should be as simple and straightforward as possible. It is important, however, to judge the entire water and sanitation system as a whole. All processes, procedures and personnel are interdependent. Isolated criticisms of specific points may not identify an overall problem which may impair smooth operations in general.

Operation and maintenance evaluation includes:

1. Monthly reports on the operation of the system, both mechanically and financially. Reports can be made by the system operators and copies sent to the action agency regional office. See "Implementing Operation and Maintenance Training," HR.3.I.1.

2. Joint analysis of the system by the operator, community leaders, project planners from the action agency and a technical inspector or engineer from the action agency.

3. Evaluation of training programs.

Monthly Reports

No matter how simple a system is, continual follow-up is necessary to ensure that it continues to work properly. Monthly reports, drawn from daily records, should be done by operation and maintenance personnel on the functioning of the water system both physically and financially. Daily or weekly records should be maintained and kept in the village. They should be open to public inspection, and should be read regularly by the water committee. A copy of each monthly report should be sent to the regional office of the action agency.

Joint Analysis of System

A periodic, preferably monthly when the system is new, analysis of the system by members of the village committee, the system operator, the project planner and a technician will be a major aspect of system evaluation. The analysis should cover all facets of the system, including:

- the functioning of the system;
- its acceptance by the villagers;
- any misuse of the system;
- the technical and physical condition of the system;
- the financial status of the system, including a review of fees collection and of the books;
- the supply of spare parts, fuel, equipment, tools and other necessary supplies on site;
- a check on the quality of water being produced;
- an evaluation of the knowledge and skill of the system operator;
- the time needed to perform all operation and maintenance tasks.

Evaluation must first consider whether the total system is effective. When problems are identified, analysis may show whether they are a result of support functions of the action agency, support within the community, poor selection of candidates for system operators, or training failures.

Evaluation of Training

One of the responsibilities of the action agency when examining the village system and analyzing evaluation reports is to determine how training has affected the success of the system. Persons not associated with the development and implementation of the training should evaluate the system if possible.

Two types of evaluation, internal and external, should be carried out to determine if the training program has been effective.

Internal evaluation determines if the training program is providing the trainees with the necessary knowledge and skills to perform their jobs well. This evaluation might consider:

1. The amount of time that was required by trainees to complete the training.

2. The appropriateness of the prerequisites prescribed for the training.

3. The performance of the trainers.

External evaluation determines if the training delivery system is producing trainees who perform well. This evaluation might include:

1. How well do trainees believe they are able to perform on the job?

2. What additional training was required by trainees after arriving on the job?

3. How well did the training program prepare trainees for the job? Do the system operators know how, when, and why to perform tasks?

4. What portions of the training program were most relevant? Have system operators been trained to do the appropriate tasks?

5. What tasks cause the most difficulty?

6. How much improvement do supervisors see in the trainees' performance on the job?

7. How does the project planner evaluate the performance of these trainees compared to previous groups of trainees?

8. In what areas were the trainees inadequate?

9. Was the training adapted to local circumstances or standardized?

The results of the internal and external evaluation are used to improve the training programs. Consideration must be given to making changes based on cost, time available, personnel available, benefits of changes to the program and detriments to the program if changes are not made.

The village and the action agency should be sure to evaluate the system operators on the job to test their skills and knowledge. The following criteria may be used to evaluate a worker's on-the-job performance:

- current water quality,
- change in water-related disease rates,
- maintenance costs,
- supply costs,
- system breakdowns,
- relations with water users, and
- morale of system operators.

Evaluations can contribute information and insights that will help the next training effort be more efficient and effective.

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Water for the World

Methods of Developing Sources of Surface Water

Technical Note No. RWS. 1.M

Water that does not infiltrate the ground is called surface water. Surface water appears either as direct runoff flowing over impermeable or saturated surfaces which then collects in large reservoirs and streams, or as water flowing to the ground from surface openings.

As water flows across surfaces, it picks up contaminants which may be harmful to humans and carries them into surface water sources. In order to use it for drinking, a surface water source must either be well protected or treated.

This technical note discusses four classes of surface water sources: (1) springs and seeps, (2) ponds and lakes, (3) streams and rivers and (4) rainfall catchments. It describes methods typically used to develop each source and discusses their advantages and disadvantages.

Springs and Seeps

A spring or seep is water that reaches the surface from some underground supply, appearing as small water holes or wet spots on hillsides or along river banks. The flow of water from springs and seeps may come from small openings in porous ground or from joints or fissures in solid rock.

There are two categories of springs: gravity and artesian. Within the gravity category, there are three principal types of springs: depression springs; contact springs; and fracture or tubular springs.

- Depression springs are formed when the land surface dips and makes contact with the water table in permeable material. Yield will be good if the water table is high, but the amount of available water may fluctuate seasonally. A gravity depression spring may not be suitable for a drinking water source since it may dry up.

Useful Definitions

ANNULAR SPACE - Small, ring-shaped space between pipe and ground, formed when a pipe is placed in the ground.

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

CONTAMINANT - An impurity which makes water unfit for human consumption or domestic use.

ESTUARIES - Lowland areas where river waters meet tidal waters.

GRAVITY FLOW - Flow of water from high level to low by natural forces.

GROUNDWATER - Water stored below the ground's surface.

IMPERVIOUS - Not allowing liquid to pass through.

INFILTRATION - The process of water passing from the surface, through the soil, and into the ground.

INTAKE - The point where water enters a supply system.

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

WATER TREATMENT - A process in which impurities such as dirt and harmful materials are removed from water.

- Gravity contact springs are formed when downward movement of underground water is restricted by an impervious underground layer and the water is pushed to the surface. This type of spring usually has a very good flow throughout the year and is a good water source.

• Fracture and tubular springs are formed when water comes from the ground through fractures or joints in rocks. Often the discharge is at one point and protection is relatively easy. Fracture and tubular springs also offer a good source of water for a community supply.

Springs in the artesian category occur when water is trapped between impervious layers and is under pressure. There are two types of artesian springs: fissure and artesian flow.

• Artesian fissure springs result from water under pressure reaching the ground through a fissure or joint. Yield will be very good and this source is excellent for a community supply.

• Artesian flow springs occur when confined water flows underground and emerges at a lower elevation. This type of spring occurs on hillsides and will also offer an excellent supply of water.

Before reaching the surface, spring water is generally free from harmful contaminants. To avoid contamination, the spring should be protected at the point where the water leaves the ground. There are three methods of developing springs as drinking water sources: spring boxes; horizontal wells; and seep development.

Spring Boxes. Figure 1 illustrates a spring box. A small area is dug out around the spring and lined with gravel. A concrete box with a removable cover is placed over the spring to collect and store the water. The cover prevents outside contamination and should be heavy enough to keep people from removing it to dip buckets and cups into the collection box. A tap and an overflow to prevent a back up in the aquifer should be installed.

The cost of developing a spring box is minimal and the system is relatively maintenance free. Disinfection is seldom required. Since springs are generally located on hills, a simple gravity flow delivery system can be installed.

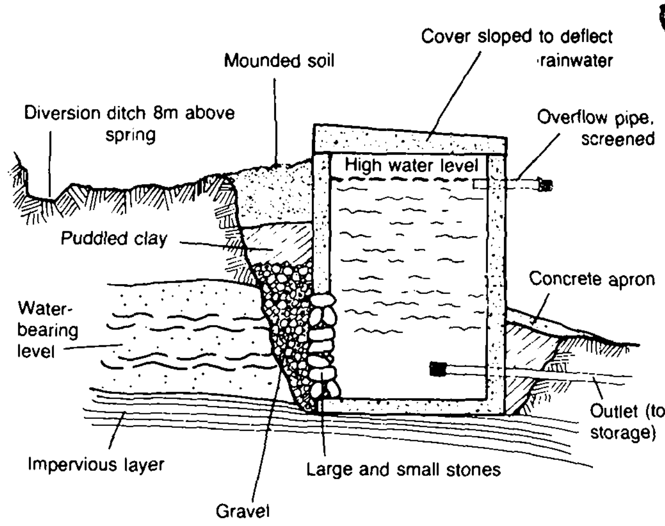

Figure 1. Spring Box with Pervious Side

A disadvantage of using spring water is that the quantity of available water may change seasonally. Local community members should be consulted as to the reliability of the source.

Horizontal Wells. Where a spring has a steeply sloping water table (steep hydraulic gradient), horizontal wells may be developed. Pipes with open ends or with perforated drive points or well screens can be driven into an aquifer horizontally or at a shallow slope to tap it at a point higher than the natural discharge. Figure 2 shows horizontal wells. Horizontal wells are installed in a manner similar to driven and jetted wells (see "Methods of Developing Sources of Groundwater," RWS.2.M) except that care must be taken to prevent flow through the annular space outside the pipe. Any flow can be stopped by grouting or by constructing a concrete cut-off wall packed with clay backfill.

The advantages and disadvantages of this method are similar to those of the spring box. Springs with flat water tables are not suitable for the use of horizontal wells.

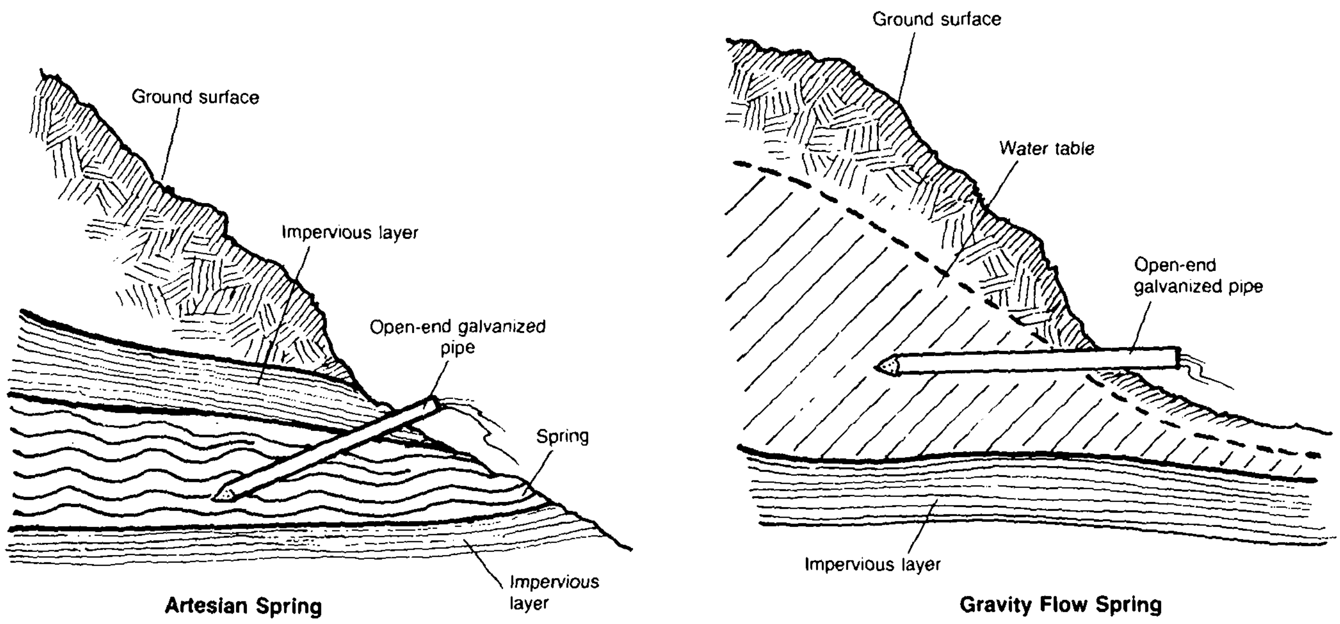

Figure 2. Horizontal Wells

Seep Development. If water seeps from the ground and covers an area of several square meters, a third method may be used. Pipes are laid to collect the underground water and transport it to a collection box as shown in Figure 3. A poured concrete wall just down-slope of the pipes traps the water for more efficient collection.

With this method, maintenance costs are higher as pipes often clog with soil or rocks. Also, the expense and difficulty of construction may prohibit its use. Unless the seep supplies abundant quantities of water, this method should not be considered.

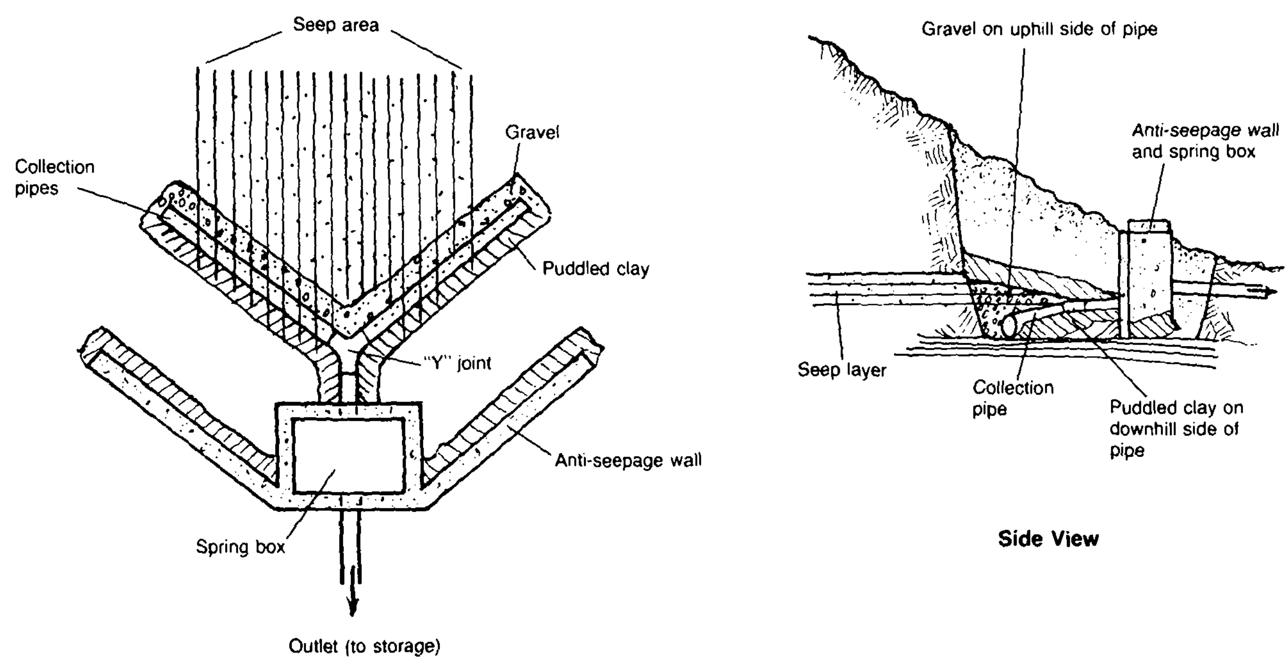

Figure 3. Seep Collection System

Ponds and Lakes

Ponds and lakes exist where surface run-off has accumulated in depressions or where a dam has been built to form a reservoir. Ponds and lakes, with proper watershed management for quality control, can be good sources of drinking water for a community. With good planning, adequate supplies will be available for community consumption throughout the year. Furthermore, the amount of available water is readily apparent and access to it is easier than to groundwater.

Because ponds and lakes are fed by surface run-off, treatment may be necessary. This is especially likely in smaller community ponds. In large bodies of water, a process of self-purification may occur that allows water to be used without treatment.

Another requirement of ponds and lakes is that water usually must be pumped through a distribution system to the point of use. Pumping machinery is expensive and requires a well-organized operation and maintenance program, and an energy source to operate the pump.

Intakes. To use water from ponds an intake is needed. Water flows by gravity or is pumped from the intake to treatment and then into storage. There are three methods typically used. Figure 4 shows a flexible plastic pipe intake. It is attached to a float and anchored so that it rests between 0.3m and 0.5m from the surface of the water. The intake is placed far enough below the water's surface to prohibit the entrance of any organic matter floating near the surface. A lower intake also takes advantage of somewhat cooler water below the surface. Water from the intake is either pumped directly into the distribution system or to treatment and then into the distribution system.

Where a dam has been built, the flexible plastic pipe is attached to a rigid conduit with anti-seepage collars. The conduit passes through the pond embankment to the treatment and storage tanks. If the water is very silty, treatment may consist of (a) a settling basin, which allows large particles to settle out of the water, and (b) a filtration unit where water must pass through a filter bed of sand and gravel before entering storage. For most pond waters, it should be sufficient to pump the water to a small holding tank and then allow it to flow onto a filter bed.

A variation of the above method can also be considered. A galvanized steel intake pipe is connected to a screened concrete storage box located on the reservoir floor near a dam's embankment, as shown in Figure 5. This system functions in the same manner

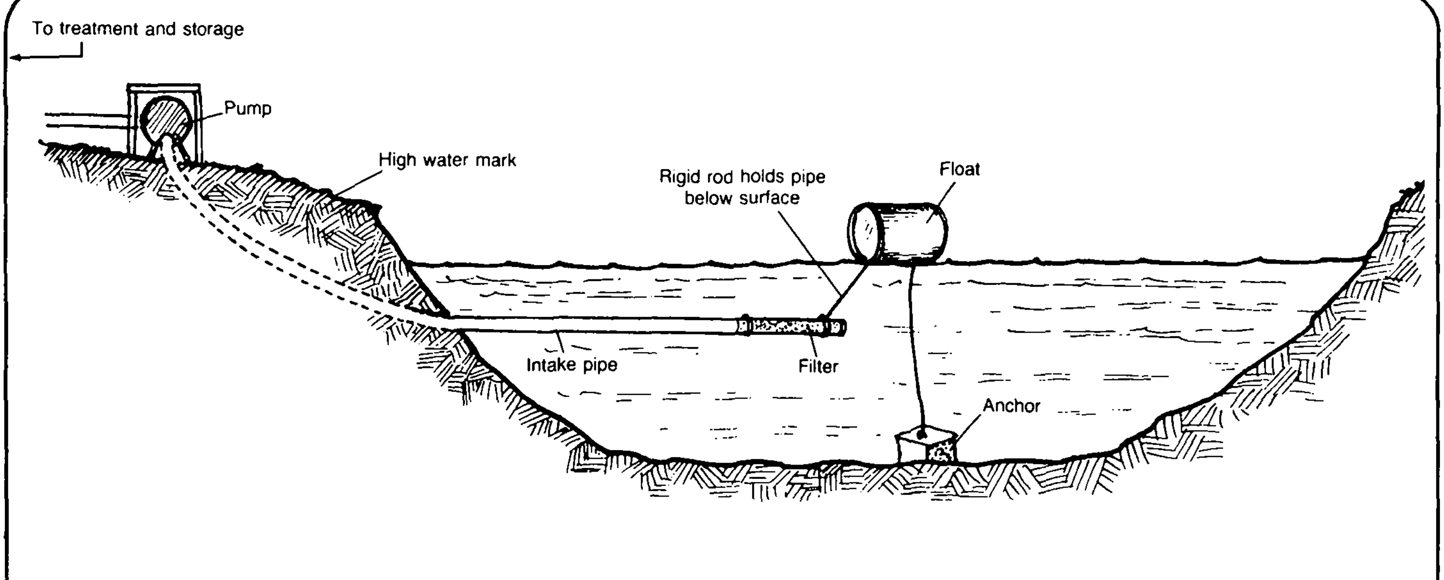

Figure 4. Flexible Plastic Pipe Intake with Float

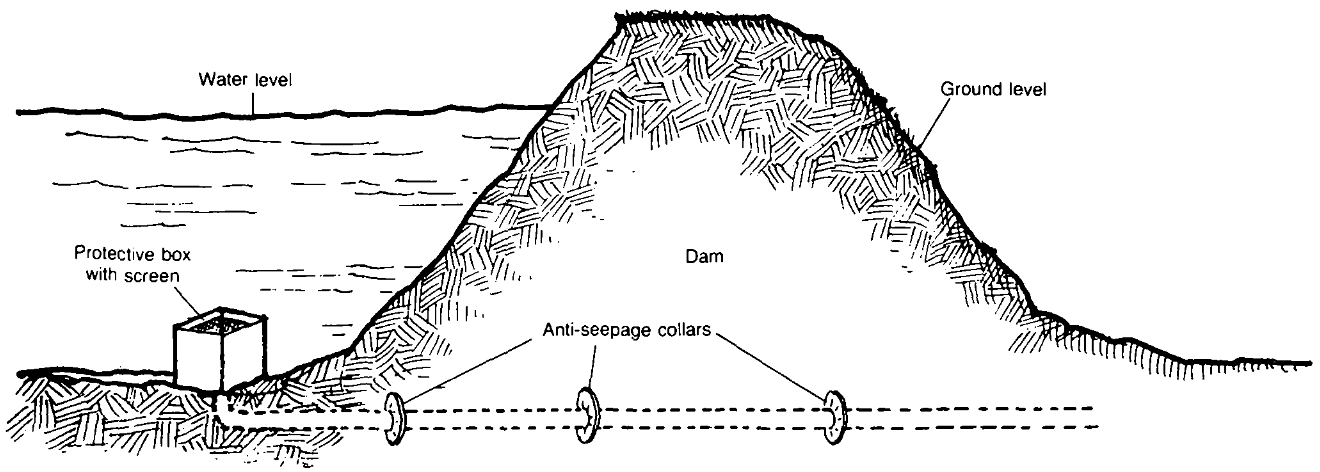

Figure 5. Rigid Pipe Intake at Dam

as the previous one, except that the intake is nearer the bottom of the reservoir. The water generally will be cooler and may be free of vegetation which often floats near the surface. In addition, the system will need less maintenance. The decision to adopt this method should be made before the dam is constructed since it is less easily installed in existing reservoirs. The expertise needed for construction and high cost make this method a less attractive choice.

The quantity of water available from ponds and lakes may not be a problem but quality will be a question. Generally, water from ponds and lakes must receive some treatment, whether at a central facility or in the household. Also, algae and decaying plants may give the water a taste unacceptable to the user, causing him to seek other water sources. Because of these variables and the cost of treatment, the use of water from ponds and streams should be carefully evaluated.

Streams and Rivers

Streams and rivers are formed by surface run-off from rainfall or from snow and ice melting in colder regions. Also, some rivers and streams have springs as their sources.

Streams and rivers have variable yield and water quality. Some streams and rivers dry up during the dry season and have no water for several months. People who depend on the river are left with little or no water. Rivers and streams are also exposed to contamination by waste disposal, laundry, bathing, and animals, and may prove unsuitable for drinking unless treated.

In mountainous areas or in places with few inhabitants, the quality of stream water can be very good, requiring little or no treatment. Streams in such areas offer a good source of water for a community. There are three methods of developing streams and rivers: infiltration wells and galleries; intakes connected to mechanical pumps; and gravity flow intakes.

Infiltration Wells. Digging or drilling a well near the banks of a stream or river is the cheapest and simplest method of development. The well should be close enough to the river channel to collect both water flowing underground and water seeping in through the channel, as shown in Figure 6. Generally, this will provide a very good supply of water throughout the year. Even if the river dries up during times of little rain, water will be available from the ground.

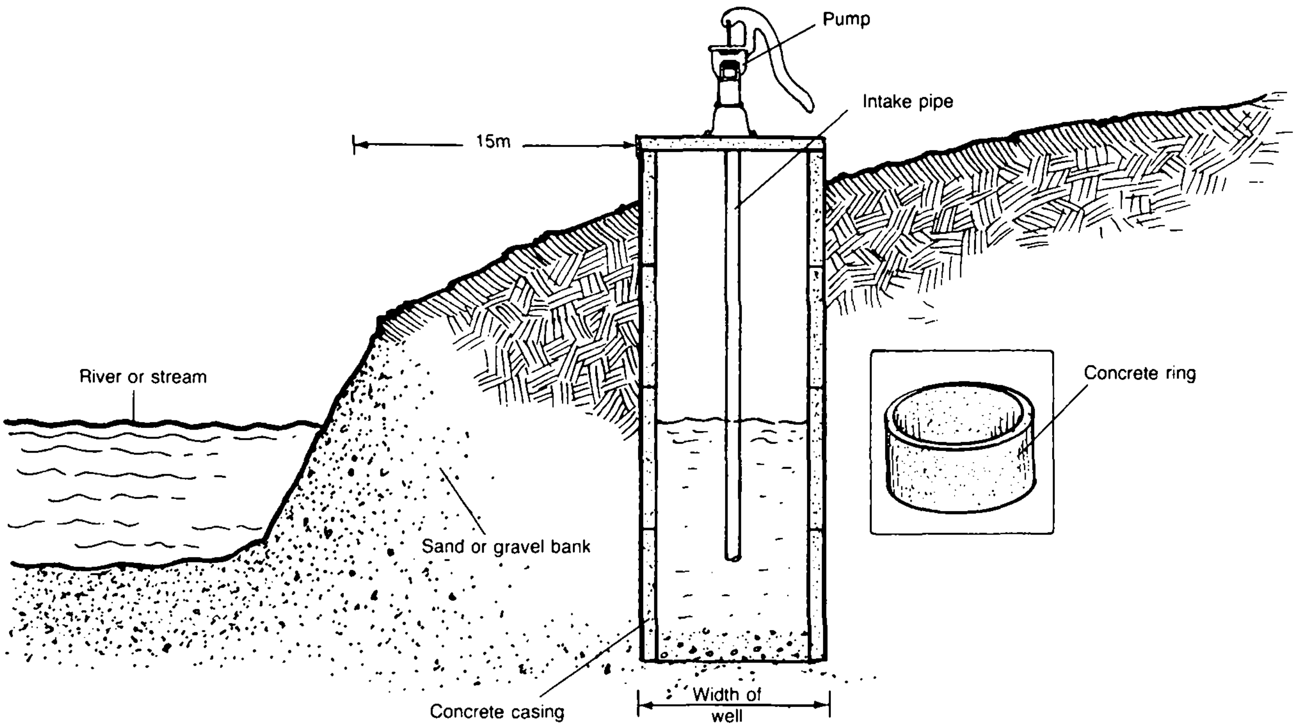

Figure 6. Riverside Well Intake

The water will also be filtered naturally. Water from the stream passes through the sand and silt in the river bank and impurities are removed. The degree of purification will depend on the extent of contamination of the stream and on the soil type. In many cases, the purification process will be sufficient to make treatment unnecessary.

A handpump, windmill or power pump can be installed to extract the water and pump it through the system. The pumping method chosen depends on the distribution system see "Methods of Delivering Water," RWS.4.M. If water will not be delivered further than the source, a handpump should be adequate. If water will be pumped to houses or a public standpipe, some type of power, such as diesel or wind, should be used. If a pump is installed, villagers must be trained in its operation and maintenance.

Infiltration Galleries. To increase the amount of water that can be collected by an infiltration well, infiltration galleries can be constructed. These trenches are dug in the bank parallel to the stream, below groundwater level, or below the stream bed itself. Tile, concrete or perforated plastic collecting pipes are placed in the gravel-lined trenches and connected to a storage well. The gravel in the trench filters out sediment and prevents clogging of the pipes. The water is pumped from the storage well into the distribution system in the same way as described for infiltration wells. See Figure 7.

Intakes with Mechanical Pumps. A surface intake pipe in the channel is another way of drawing the water from a stream or river. An intake pipe should be attached to a concrete well ring on the stream bed. A catwalk supports the pipe between the ring and the bank. Water is pumped from the stream to treatment. This method is shown in Figure 8.

To use this method, a stream with stable banks and a firm bed is needed. Skilled construction workers must also be available as the structure must be sound enough to withstand the stream's current. This method is more costly than riverside wells and requires more expertise.

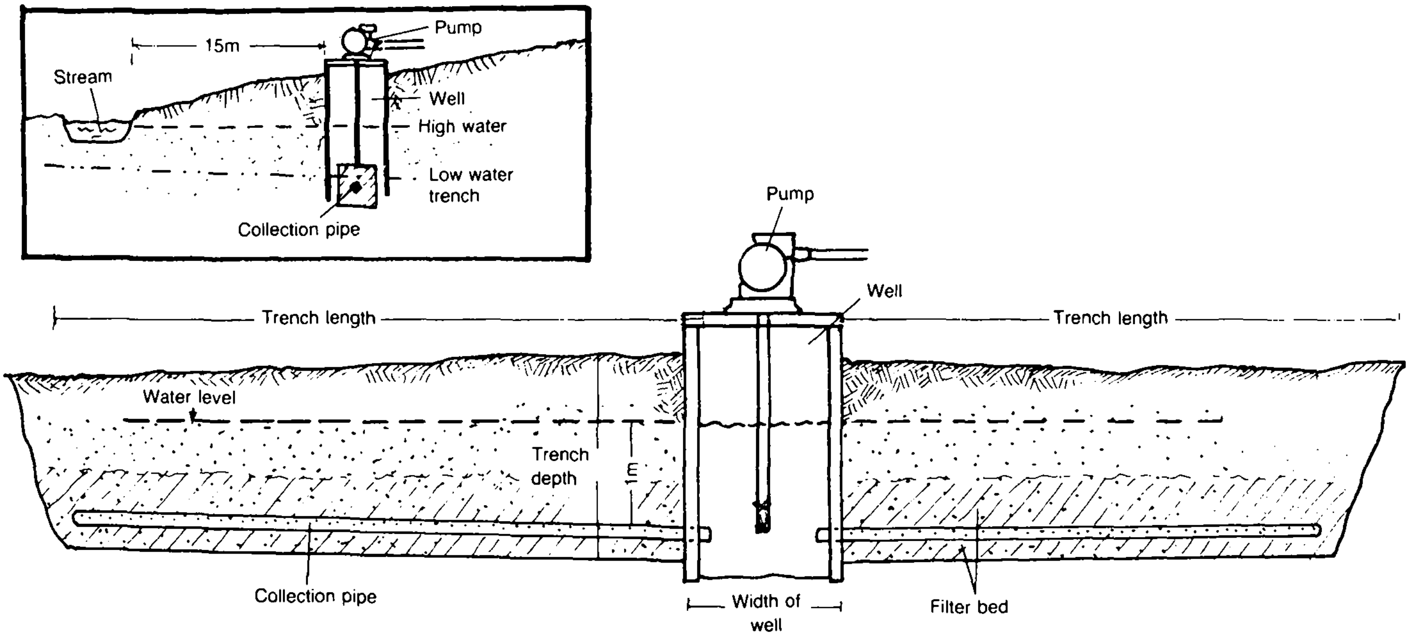

Figure 7. Infiltration Gallery

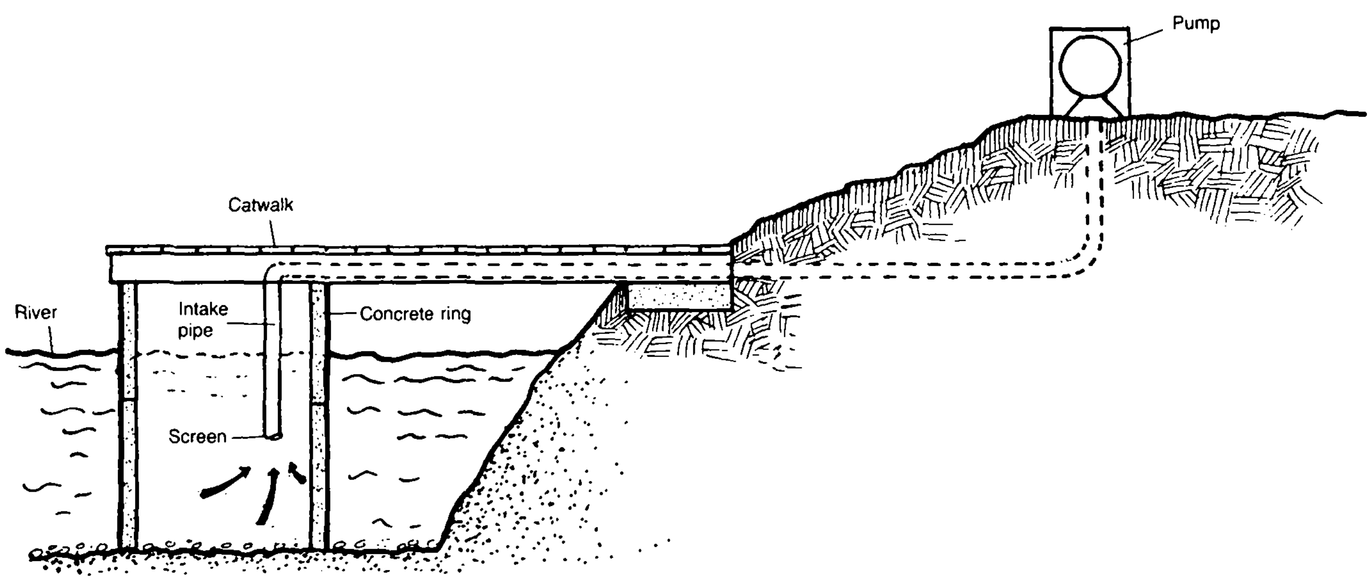

Figure 8. Protected Pipe Intake

Gravity Flow Intakes. Water from a stream can be carried to the user through a gravity flow system. This method is suitable for streams and rivers with enough changes in elevation to allow gravity to move the water from the intake to the storage tank. A concrete collection box with winged sides is constructed to catch water and direct it into a screened intake. The intake should be placed on the stream bed and anchored to the bank, as shown in Figure 9.

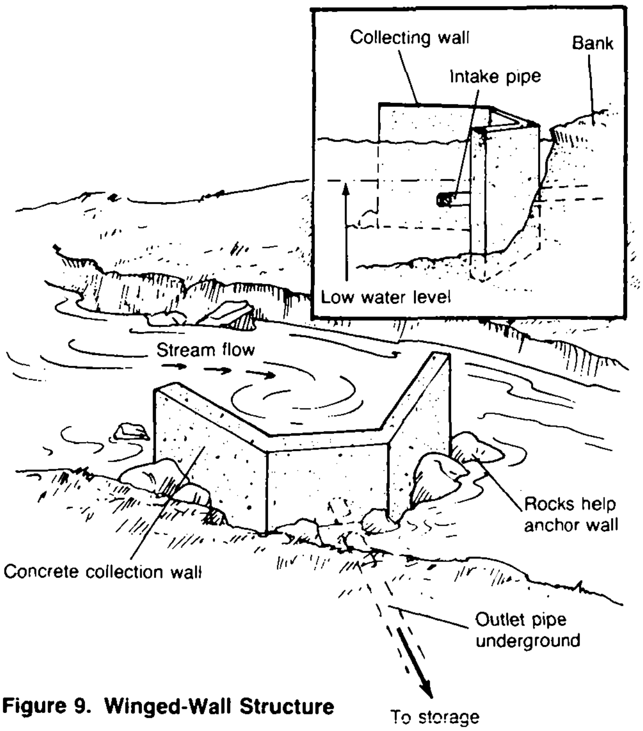

Figure 9. Winged-Wall Structure

Water will then pass from the intake into storage. No pumping will be necessary to supply a community with water, so little maintenance will be required. However, highly skilled technicians are needed to design and construct the system. As with the other methods, treatment will be necessary unless the area above the collection point is uninhabited.

In streams with sufficient fall, a hydraulic ram may be used to pump water to storage. The ram is an inexpensive and easily-maintained pump and can be constructed in the community. The ram is able to lift water from a stream into a storage tank without using an outside source of power see "Selecting Pumps," RWS.4.P.5.

Highly-skilled labor is usually needed for construction involved in developing rivers and streams. This will add to the cost of the project. As a general rule, stream water in low areas and estuaries is contaminated and will need some degree of treatment. Streams that are not exposed to human and animal wastes, and those at higher elevations with little population, will provide good water without treatment. Special care must be taken to choose a source located above inhabited areas if treatment is not available.

Rainfall Catchments

Rainfall catchments collect water from precipitation. They can be installed anywhere a suitable area is available. In areas of little rain or at times of drought, catchments can be used in combination with other surface sources. For example, water from catchments could be used for drinking and cooking while other sources met cleaning needs. There are two types of catchment systems: roof catchments and ground catchments.

Roof catchments. Roof catchment systems offer a simple and fairly inexpensive method of providing water to individual homes. Tile and sheet metal roofs can be adapted with pipes and gutters to trap water and transport it through a filter into a waterproof cistern. The cistern must be closed to avoid surface contaminants and must be disinfected periodically. Thatched or pitch roofs do not make suitable catchment areas due to seepage and potential contamination.

Rain catchments are as reliable as the weather and water may not always be available. Cisterns can be designed for large capacity storage at times when water is scarce. The system is basically maintenance free, except that gutters and pipes must be cleaned often to prevent clogging and contamination. Water quality may be fairly good to poor, depending on the amount of contaminants that settle on the roof between rainfalls, and water should be treated. An example of a roof catchment system appears in Figure 10.

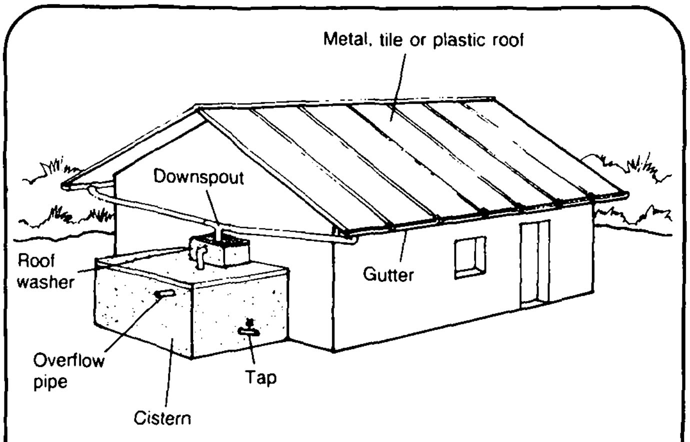

Figure 10. Roof Catchment

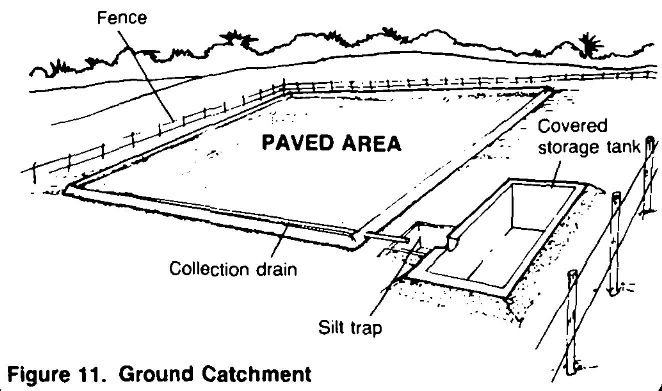

Figure 11. Ground Catchment

Ground catchments. Figure 11 shows a ground catchment system. An area of sloping ground several hundred meters square must be cleared, graded and preferably paved to form a catchment for precipitation. A paved area is desirable to reduce losses due to evaporation and infiltration, and to reduce erosion. A drain should be placed at the downward end of the slope to collect the water and deliver it to a sedimentation basin and into a storage tank.

Ground catchments are costly to install and must be carefully maintained. They also require large tracts of land that may not be available in a community.

Summary

Surface water sources can be developed for drinking water but special care must be taken to ensure the quality of the water. Springs generally offer the best alternative in terms of cost, water quality and maintenance. Spring water also is cool and fresh-tasting and very acceptable to the users.

Ponds and lakes offer good, accessible quantities of water. Water from ponds and lakes is easily delivered to users by installing intakes. Ponds, lakes, and especially small commnuity ponds are often exposed to contamination. Generally, water from them should not be used unless adequate treatment is available.

Streams and rivers also provide good sources of water if developed properly. Stream and river water that is naturally filtered into wells offers a good, low-cost method for using surface water. Untreated stream water from higher elevations is also available at low cost to the user. Near estuaries and at low elevations, contamination is likely and care must be taken before water is used.

Roof catchments offer the advantage that they can be constructed in the yard of the user if the house has a suitable roof. Each individual is responsible for his own system. Water quality is variable with rain catchments and will depend on the users' willingness to clean the roof often and disinfect the cistern occasionally.

Ground catchments provide a fairly good quantity of water and, with storage, a ground catchment system can meet the needs of a community. Ground catchments are expensive to install and use large areas of land which is scarce in many regions.

The choice of a method depends on many factors including the source and resources available and community preferences. These factors are further discussed in the technical notes on planning. Table 1 compares the various methods of developing surface water discussed in this technical note.

Table 1. Summary of Methods of Developing Sources of Surface Water

Method	Quality	Quantity	Accessibility	Reliability	Cost
Springs and Seeps	Good quality; disinfection recommended after installation of spring protection.	Good with little variation for artesian flow springs; variable with seasonal fluctuations likely for gravity flow springs.	Storage necessary for community water supply; gravity flow delivery for easy community access.	Good for artesian flow and gravity overflow; fair for gravity depression; little maintenance needed after installation.	Fairly low cost; with piped system costs will rise.
Ponds and Lakes	Fair to good in large ponds and lakes; poor to fair in smaller water bodies; treatment generally necessary.	Good available quantity; decreases during dry season.	Very accessible using intakes; pumping required for delivery system; storage required.	Fair to good; need for a good program of operation and maintenance for pumping and treatment systems.	Moderate to high because of need to pump and treat water.
Streams and Rivers	Good for mountain streams; poor for streams in lowland regions; treatment necessary.	Moderate: seasonal variation likely; some rivers and streams will dry up in dry season.	Generally good; need intake for both gravity flow and piped delivery.	Maintenance required for both type systems; much higher for pumped system; riverside well is a good reliable source.	Moderate to high depending on method; treatment and pumping expensive.
Rain Catchments	Fair to poor; disinfection necessary	Moderate and variable; supplies unavailable during dry season; storage necessary.	Good; cisterns located in yards of users; fair for ground catchments.	Must be rain; some maintenance required.	Low-moderate for roof catchments; high for ground catchments.

Notes

Notes

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

1982

Water for the World

Planning How to Use Sources of Surface Water

Technical Note No. RSW. 1.P.1

Surface water includes water from ponds, lakes, streams, rivers and springs. Surface water sources can be important for community water supplies. Surface water is available without major digging or use of expensive machinery and sometimes can be delivered to users without pumping. The quantity of water available is easy to determine by simple measurements. The development of surface water sources is not simple and careful planning is necessary. Surface water is subject to run-off and human and animal contact and may be contaminated with feces or other wastes. Before a surface source can be used it should be well protected, and, in most cases, connected to a distribution system. Most water from surface sources should be treated.

This technical note describes the planning needed to use surface water sources in terms of eight important planning steps: (1) recognize the problem, (2) organize community support and set objectives, (3) collect data, (4) formulate alternatives, (5) choose the best method, (6) establish the system, (7) operate and maintain the system and (8) evaluate the system. Worksheet A may be adapted for use in cataloging information gathered during the planning process.

Useful Definitions

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

WATER-RELATED DISEASES - Diseases caused by a lack of safe water and poor sanitation.

Recognize the Problem

Before planning to use any source of water, the community's water supply problem must be defined. The current water source is unacceptable if (a) the water is of poor quality, (b) the water is not available in sufficient quantities to meet the needs of the users, (c) the source is not accessible to the users and (d) the source is not reliable.

Water quality is generally measured by laboratory testing. In many areas, testing will be impossible because of lack of equipment and the distances from the source to testing facilities. Water quality must then be judged through observation of local conditions and through a sanitary survey. (See "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2). If a water source is exposed to contamination from human and animal wastes, aquatic growths in the water, and surface run-off, it must be protected, treated or abandoned for a more suitable source. If there is a high rate of water-related disease among users of a certain water source, suspect that the source is contaminated and take measures to improve the water supply. Table 1 shows examples of diseases caused by lack of safe water. Where such diseases exist, water supply improvements will reduce the number of cases. Water improvements will not eliminate these diseases.

Water quantity is measured by the number of liters per day people use. Table 2 shows typical water consumption rates for rural areas. A water source should provide an average of 15 liters

Worksheet A. Planning the Development of a Surface Water Source

1. Name of community ______
2. Number of people to be served by water source ______
3. Type and number of water-related diseases in the community per year ______
4. Significant beliefs and taboos about water ______
5. Present source(s) of water and form of distribution ______

   Determine:

   water quality (see RWS.1.P.2) ______

   water quantity (see RWS.1.P.3) ______

   accessibility ______

   reliability ______

   form of and location of distribution system ______

6. Potential source(s) of water ______

   Determine:

   water quality (see RWS.1.P.2) ______

   water quantity (see RWS.1.P.3) ______

   accessibility ______

   reliability ______

7. Commmunity resources and organization

   Determine:

   a) sources of income ______

   b) seasonal distribution of income ______

   c) labor and materials available ______

   d) infrastructure in existence ______

   e) concerned community leaders and groups ______

8. Project costs

   Estimate total costs for:

   a) equipment ______

   b) materials ______

   c) labor ______

   d) maintenance ______

   e) other costs (transportation, etc.) ______

9. Sources of finance

   Determine:

   a) local funding capability ______

   b) external funding possibilities ______

Table 1. Diseases Related to Deficiencies in Water Supply and/or Sanitation

Group	Diseases
Diseases transmitted by water (Water Borne)	Cholera Typhoid Bacillary Dysentery Infectious Hepatitis Amebic Dysentery Giardiasis Gastroenteritis
Diseases caused by lack of water and poor sanitation (Water Washed)	Scabies Skin Ulcers Lice and Typhus Trachoma Conjuctivitis Bacillary Dysentery Amoebic Dysentery Salmonellosis Diarrheas Ascariasis Whip Worm or Trichuriasis Hook Worm
Diseases caused by infecting agents spread by contact with or ingestion of water and of animals living in water (Water Based)	Schistosomiasis (Blood fluke) Guinea Worm Thread Worm Lung Worm Human Liver Fluke

per person per day for non-piped systems, 40 liters per person per day for one tap piped systems and 70-100 liters per person for multi-tap piped systems. If the water is to be brought near or into the houses, the amount used will increase greatly. A source producing insufficient quantities is unacceptable. Determine the amount of water a community will need by multiplying the population by the estimated amount of water used per person per day.

Water supplies must be accessible. If a great distance separates the supply from the user, a decrease in the amount of water used and a reduction in standards of hygiene is likely. People who must carry water may even choose a nearby contaminated supply over a distant protected one. The water supply should not be located more than 250m from the users.

Table 2. Domestic Water Use

Type of Supply	Typical Consumption (liters per capita per day)	Range (liters per capita per day)
Communal water point (village well, standpost) located at: - distance greater than 1000m from house - distance between 500-1000m from house	7 12	5-10 10-15
Village well less than 250m from house	20	15-25
Public standposts less than 250m from house	30	20-50
Yard connection (tap in yard)	40	20-80
House connection - single tap in house - multiple taps	50 150	30-60 70-250

The reliability of a source ensures its continued use. A water supply that dries up, provides insufficient water, or is tapped by a system that breaks down often may force people to use a less desirable source. A source must provide water year-round. Local technicians must be able to operate and maintain the treatment delivery system to ensure that water is always available to the community.

Organize Community Support and Set Objectives

The main objective is to provide a community with an adequate quantity of safe water from a convenient and reliable system. A good water system will reduce the incidence of water-related diseases and improve the overall health of the community. An accessible supply will increase water use for hygiene-related purposes and reduce the time spent in carrying water. More time will be available for productive activities. An abundant source can provide water for home vegetable gardens.

A successful project must include a plan for community support. Support is gained through three methods: (1) promotion, (2) community involvement and (3) training for operation and maintenance.

Promote the project in the community to create an awareness of the water supply problem. Organize meetings and educational programs, show pictures or films, and make home visits to explain the connection between a good water supply and good health. Once the community is aware of the problem, it will be more willing to work toward a solution by contributing time, effort and resources.

Involve the community in the project. Enlist the support of local political, religious and community leaders and include them in decision-making. Ask the potential users of the water system for advice. They will be good sources of information. They will express their preferences and be good sources of information on such matters as the resources available for the project. Discuss the cost of the project and emphasize the need to finance not only its construction but also its long-term operation and maintenance.

Training local people to operate and maintain the system is essential. Plan a training program for people active in the project so the water supply system can be developed and maintained by the community. The goal is that the community contribute to, participate in, and maintain the water supply system.

Collect Data

In order to understand the water supply problems of a community, information must be collected about local environmental, social and economic conditions. Appropriate solutions to problems will be suggested by this information. Data should be gathered on the following items: (a) local development history, (b) current community conditions, (c) environmental and geographic factors, (d) available resources and (e) local customs.

Obtain information about the community's development history. The success or failure of a past development project, especially in water supply, can guide decision-making. If a development project has failed, similar mistakes must be avoided. Information about past projects and traditional water sources should be available from village elders or local government agencies.

Study the present situation. Determine the community's current population and estimate likely growth rates and demand for water. Check the present water sources for their suitability and figure out possibilities for improvement. To plan efficiently, you need to collect information about incomes, resources and community needs.

Collect environmental and geographic data. Information should be collected on: (1) total annual precipitation, (2) seasonal distribution of precipitation, (3) annual or monthly variations of rainfall from normal levels, (4) stream and river flow rates and (5) spring yield. Some of this data may be obtained from local or national government agencies. Airports are likely to have useful statistics on rainfall and the stream and river flow rates and spring yield can be measured in the field using simple techniques. These are discussed in "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2. A great deal of useful information can be collected through interviews with local people and observation of local conditions.

Data on run-off and evaporation rates would aid planning greatly. This data is very difficult to obtain, but will prove useful if available.

Know what material and human resources the community can provide to the water project. The community should make contributions of labor, materials and money for the water system. Limit the amount of outside material or assistance whenever possible. Where outside technical assistance or material is needed, try to obtain it from the national or regional government, or from private donors. Determine what percentage of the project can be financed through local funds and use a combination of the local and outside resources to complete the project.

Know the customs of the community. Village preferences and desires may be determined by religious and cultural beliefs or taboos. Certain members of the community, such as water vendors, may depend on the present water system for their economic well-being and be opposed to a change. Know the community well before proposing a water project. Never promote or insist on a method that continues to meet with local resistance after it has been fully explained to the community.

Formulate Alternatives

Once all available data are collected, formulate possible solutions to the problem. The best alternatives will provide the community with safe and abundant water from a reliable and accessible source at the lowest cost. When considering alternatives, determine which method of surface water development will best solve the water supply problem (see "Methods of Developing Sources of Surface Water," RWS.1.M). Evaluate each method by determining its acceptability and suitability to the community. Determine the type of system most appropriate to the community's needs. Decide whether people will obtain their water directly from the source, from a standpipe or from household taps.

Discuss the cost and resource requirements of each alternative with community leaders and local groups to determine community preferences. In some cases, there will be only one acceptable alternative and no choice will be necessary. In other cases, there may be several acceptable alternatives, or there may be a combination of methods that could meet the community's needs. The decision about which to use will depend on the many factors discussed in this technical note.

Select a Method

Where there are several alternatives for a surface water source, it will be necessary to choose the best, most appropriate method. In making this decision consider the following:

Community needs. Determine whether the source can meet the needs of the community adequately now and in the near future. Do not choose a sophisticated method if it is not really necessary. Avoid selecting methods for prestige rather than suitability and maintainability.

Social acceptability. Determine whether the water source is acceptable to all the users. If the water has an odd taste or smell or is turbid, people will be against drinking it. Avoid having the supply a long way from the users since people will not walk long distances to fetch water. The greater the community acceptance of the system, the more willing people will be to pay for building and maintaining it.

Economic factors. Determine whether the community can afford the construction and maintenance of the system. Do not over-tax the resources of the community. A successful project will involve community labor and participation in fund-raising and other activities. A project partially paid for with community resources will be a source of pride. When selecting a method do not overlook the possibility of improving the current water source. It may not need much improvement and will probably meet with little local resistance. Improvement of the current source may be the best and least expensive alternative. Use "Selecting a Source of Surface Water," RWS.1.P.3, in deciding on the best water source for the community.

Establish the System

Once the best method is chosen, develop a project plan. The plan will serve as a guide throughout the project and ensure that labor and materials are available when needed. In many cases a plan must be submitted to a government agency or donor organization for approval. The plan should state a goal, provide population information, indicate the number of people affected by the project, and demonstrate how the project will aid the community. This is especially important when money is sought from international donors. Determine their requirements as early as possible. In such cases the plan should be quite detailed and include information on: (a) proposed system, (b) costs, (c) sources of finance, (d) implementation schedule, (e) plans for construction and sources of materials and (f) operation and maintenance requirements.

Proposed system. Design drawings for the project should be submitted with the plan. The drawings should include all measurements and capacities. Photographs of the work site and a topographic map showing houses, buildings, and water sources should accompany the plan.

Costs. The plan must include a list of all estimated costs, including materials, tools, equipment and labor for both construction and maintenance. If land must be purchased, that cost should be included in the total. Local materials probably will be less expensive and should be used whenever available. Labor costs will depend on the local pay rate and the time and skills required. Any labor or materials which are donated should be included in total costs.

Sources of funding. If at all possible, local funds should be used to finance some portion (at least 10-15 percent) of the project. This money can come from contributions, fund-raising activities such as dances, user fees, and various other sources. Money for the development of larger scale, or more expensive, water systems may be available from government organizations, international groups or private donors. Donor agencies generally require that the community cover a percentage of the construction costs and all of the operation and maintenance costs.

Implementation schedule. Determine the amount of time necessary to complete the project. Attempt to schedule the project at a time when volunteer labor and money are available to the community. Generally, this will be after harvest time or just before planting season. Fund-raising activities should take place during times of increased community income. In scheduling work, take into account wet and dry seasons.

Plan for construction. Develop a plan for constructing the system including both the labor and supplies needed. A complete materials list for the project will help ensure that tools, equipment and materials are at the site when people come to work. If tools and materials are stored at the site, provide a well-protected, secure place to store them. There should be a supervisor at the site so that workers will know what to do at all times. If the system is very complex, a contractor may be hired to do the construction.

Operation and maintenance. Plan for the continued operation of the system. This may include a training program for local villagers. No matter how simple the system, there will always be a need for maintenance. People trained in basic construction, pipe-laying, pump repair and simple water treatment are needed in the community. The people in charge of maintenance must know where to obtain spare parts, extra chlorine and other resources important to the system. A local storehouse can easily be established. Permanent arrangements for operation and maintenance must be made. More systems fail because of improper operation and maintenance than for any other reason.

In a community where water is piped into households, an administrative system for collection of fees and continued operation and maintenance must be established. Community members with managerial skills and community leaders should be involved in the system administration.

Evaluate the System

After completion, evaluate the system by determining if it is achieving the goals set at the beginning of the project. To measure the system's success, use the four characteristics of a suitable water supply: quality, quantity, accessibility and reliability.

Quality. Is the water provided of acceptable quality? Have the water tested, if possible, and determine if there has been a decline in water-related illnesses since the completion or improvement of the system. Fewer cases would indicate that quality has improved. Make sure the source is protected from sources of contamination, and that treatment is adequate.

Quantity. Is the quantity of water produced adequate? Determine if the system is meeting the daily needs of the users and if it supplies adequate quantities for potential additional users.

Accessibility. Is the system accessible to all intended users? Determine if the community is satisfied with the supply's location and has any problem getting water. Also, find out if water consumption has increased since the system was developed. An increase in consumption may indicate that water is more easily available to the users. If traditional family water carriers have increased time for other activities, try to estimate the benefits gained from this extra time.

Reliability. Is the system proving reliable? There should be no design flaws or breakdowns. Water should be reaching the users without interruption. If technicians have been trained, evaluate their performance in operating and maintaining the system. Be sure that they know where parts and materials can be obtained and that they can handle specific maintenance problems. Provide for a modest store of replacements and a means to make added house connections.

The evaluation of the system will provide important information for the development of future projects. Compare the success of this project to projects in other communities to gain valuable lessons in the development of surface water supply systems.

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Water for the World

Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources

Technical Note No. RWS. 1.P.2

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

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

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

Useful Definitions

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

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

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

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

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

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

FISSURE - A narrow, deep crack in rock.

LIMESTONE - A white rock consisting of mostly calcium carbonate.

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

Worksheet A. Questions to be Answered by a Sanitary Survey

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

If yes, determine these sources and

a) remove sources of contamination, and/or

b) protect the water supply, or

c) find a more acceptable water supply.

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

If yes, determine these sources and

a) analyze the water, or

b) remove sources of contamination.

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

a) water must be treated or

b) alternative source must be found.

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

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

Physical Characteristics of the Location

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

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

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

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

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

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

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

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

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

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

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

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

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

Bacteriological Quality of Water

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

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

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

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

Physical and Chemical Quality of Water

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

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

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

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

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

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

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

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

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

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

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

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

Notes

Notes

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Water for the World

Selecting a Source of Surface Water
Technical Note No. RWS. 1.P.3

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

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

Determining Quantity of Water Available

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

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

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

Useful Definitions

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

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

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

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

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

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

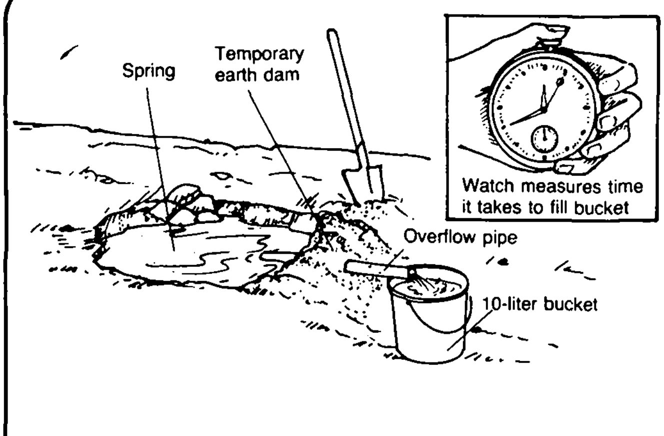

Figure 1. Measuring Spring Flow

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

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

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

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

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

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

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

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

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

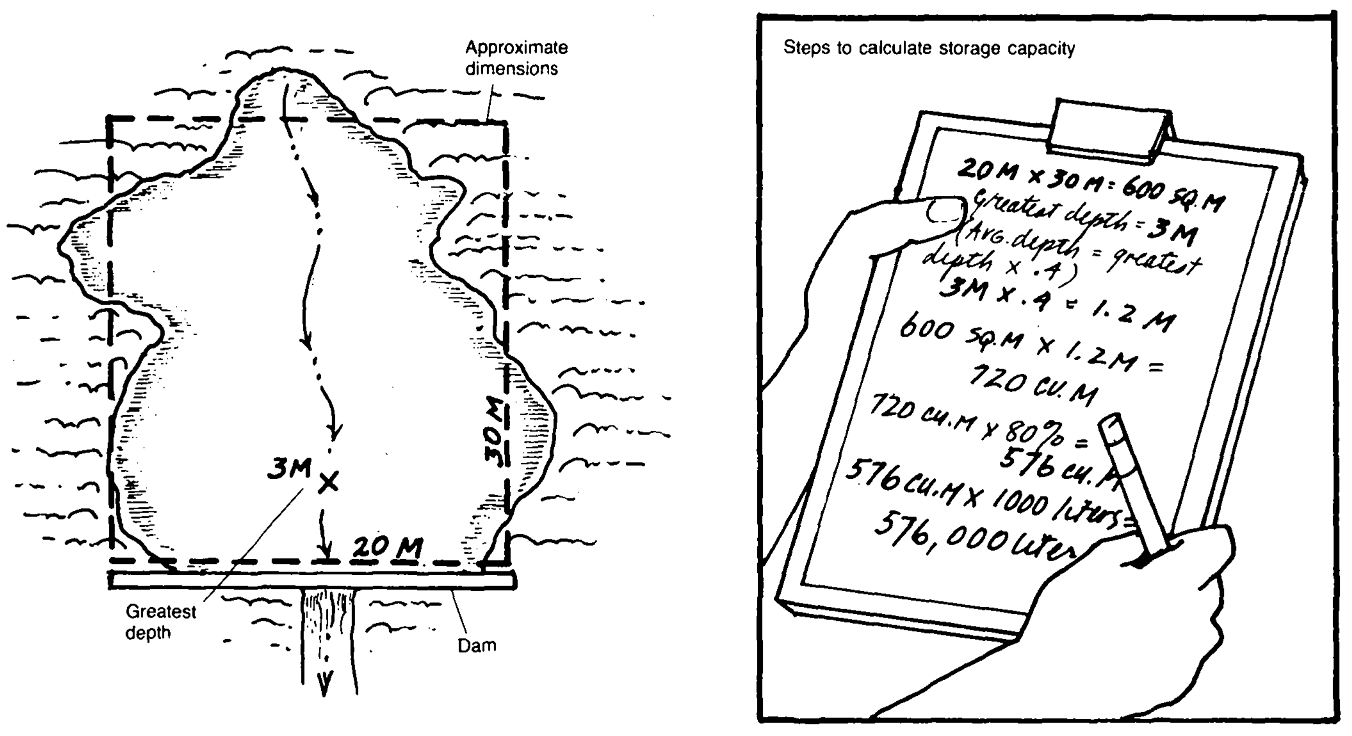

Figure 2. Estimating Storage Capacity of Small Lake or Pond

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

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

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

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

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

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

$576m^3 \times 1000 = 576000$ liters.

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

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

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

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

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

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

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

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

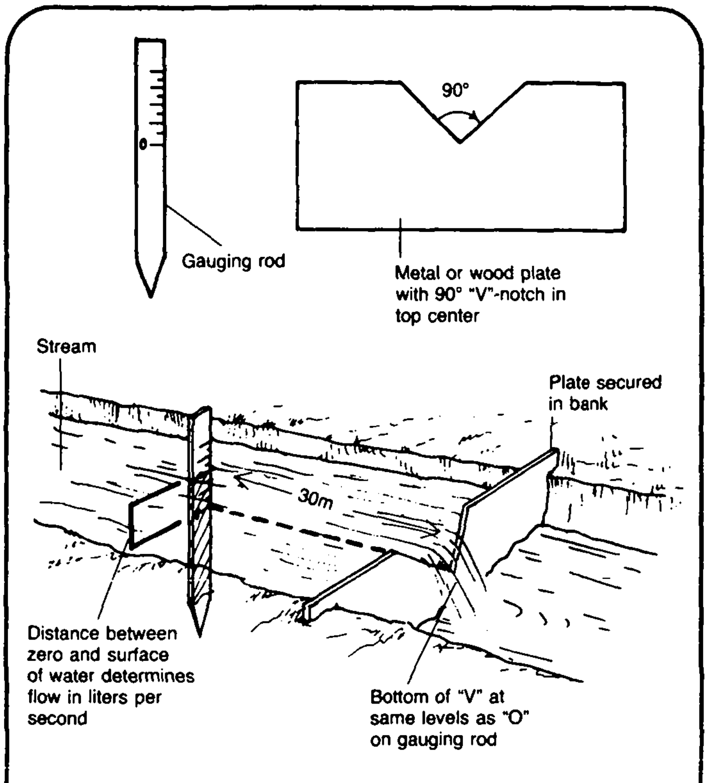

Figure 3. Measuring Stream Flow

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

Table 1. Flow Over a 90° V-Notch

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

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

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

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

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

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

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

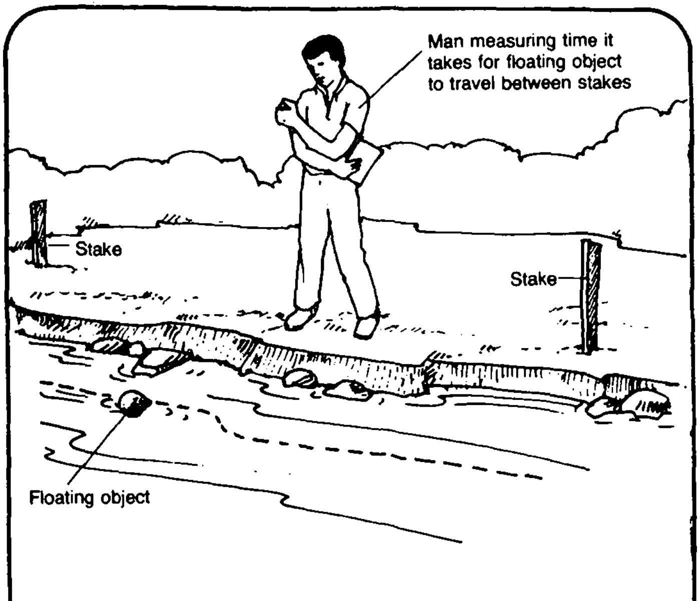

Figure 4. Measuring Large Stream Flow

Rain Catchments

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

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

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

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

36 x 1000 = 36000 liters/year.

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

36000 liters x .80 = 28800 liters.

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

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

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

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

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

Priorities for Source Selection

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

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

Table 2. Priorities for Surface Water Source Selection

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Water for the World

Choosing Where to Place Intakes

Technical Note No. RWS. 1.P.4

Intakes are pipes, canals, wells, collection boxes or other openings through which water from springs, streams and ponds enters a water supply system. From the intake, water goes either to storage, treatment, or, in some cases, directly to the user. Intakes are necessary for the development of most surface water sources. This technical note describes the general characteristics of intakes and discusses important considerations for their placement in surface sources.

Useful Definitions

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

CONVEX - Curving outward like the surface of a sphere.

PUDDLED CLAY - A mixture of clay and water used to make a watertight seal.

RESERVOIR - A natural or artificial lake where water is stored for use.

SPRING EFFLUENCE - The point or opening where spring water flows from the ground.

Purpose of Intakes

Intakes serve as an entrance for water into community water supplies. They make water available and more accessible to the users. For example, the installation of an intake in a source such as a pond or lake located far from a community gives the users access to the water supply without having to walk long distances and carry heavy loads. If water is delivered close to the community, or if house connections are made available, people will use more water than they did when water had to be carried. Increased water availability should result in improved hygienic conditions and practices.

Water quality is affected by the installation of intakes. Structures built to collect water from springs protect the source from contamination by surface run-off and from contact with animals and people. Infiltration galleries and collecting pipes installed in filter beds improve water quality by filtering out sediment and debris. In many cases, harmful bacteria are also filtered from the water as it passes from the source through the soil and into the galleries or collection pipes.

The type of source and the conditions found determine the type of intake that can be installed. Intakes should provide the maximum amount of good quality water at a cost affordable to the community.

Intakes for Springs and Seeps

There are two basic types of intakes for collecting water from springs and seeps. The first, and easiest to install, is the spring box. For springs that flow from a spot on level ground, an open-bottomed spring box should be placed over the opening to capture all available flow. For springs on a hillside, a box with an open back should be placed against the hillside and the water should be channeled into the collection boxes. See Figures 1 and 2 for examples of these types of spring collection.

Intakes for seeps and some springs are perforated plastic or concrete pipe placed in trenches or collection ditches. The trenches are deep enough so that the saturated ground above them acts as a storage reservoir during times of dry weather. Generally, the trenches should be 1m below the water level. Collection pipes are placed in the trenches which are lined with gravel and fine sand so that sediment is filtered out of the water as it flows into the pipes. Clean, clear water flows from the collection pipes to the storage or collection box. See Figure 3 for an example of a spring box with collection pipes. For spring flows that cover a wide area, a concrete wall should be installed to collect all flow.

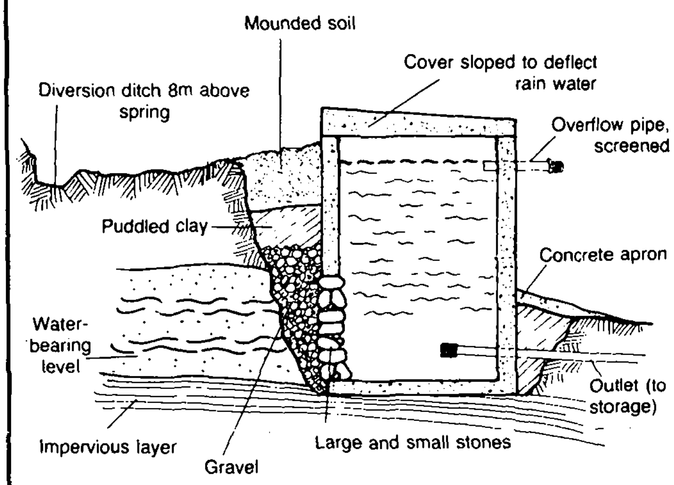

Figure 1. Spring Box with Pervious Side

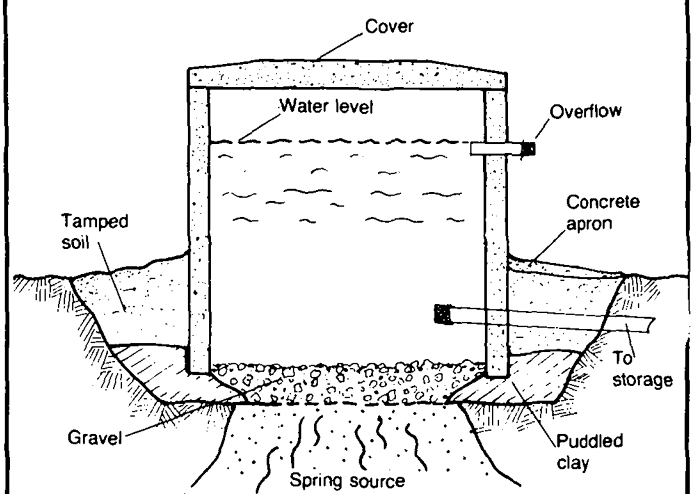

Figure 2. Spring Box for Single Source

In horizontal wells, the intake is a pipe which has been driven, jetted or augured and driven through the ground above a spring effluence. The water reaches the surface by flowing from the tapped aquifer through the installed pipe. Horizontal well intakes must be located in an area with a sloping water table in order to have adequate discharge. The pipe must also enter the aquifer far enough to ensure the required minimum flow throughout the year. See Figure 4 for an example of intake placement for horizontal wells.

Intakes for Ponds and Lakes

The location of intakes for ponds and lakes depends on the size and depth of the source, the quality and condition of the water, and the cost of delivering water to the community. An intake should be placed near or in the deepest part of the pond or lake. At this point, the intake will make maximum use of stored water and will generally be far enough away from the shore to prevent contamination by people and animals. In larger water bodies, the quality of water should improve greatly as distance from the shore to the intake increases.

The depth of the intake in the water is another important consideration. For ponds and medium-sized lakes, a general rule is that the intake should be 0.30-0.50m below the surface. If the intake is placed closer than 0.30m to the surface, floating debris, algae and aquatic plants may clog the intake screen and pipe. Constant maintenance would be required to keep the intake in operation. Another problem is that water containing plant life and organic matter may have an unacceptable taste and odor.

An intake placed too near the bottom of a pond or lake may draw in very turbid water or water containing a large quantity of suspended solids. Sediment and solids will clog the system and increase maintenance costs. Turbid water, if not treated, will be unacceptable to the users.

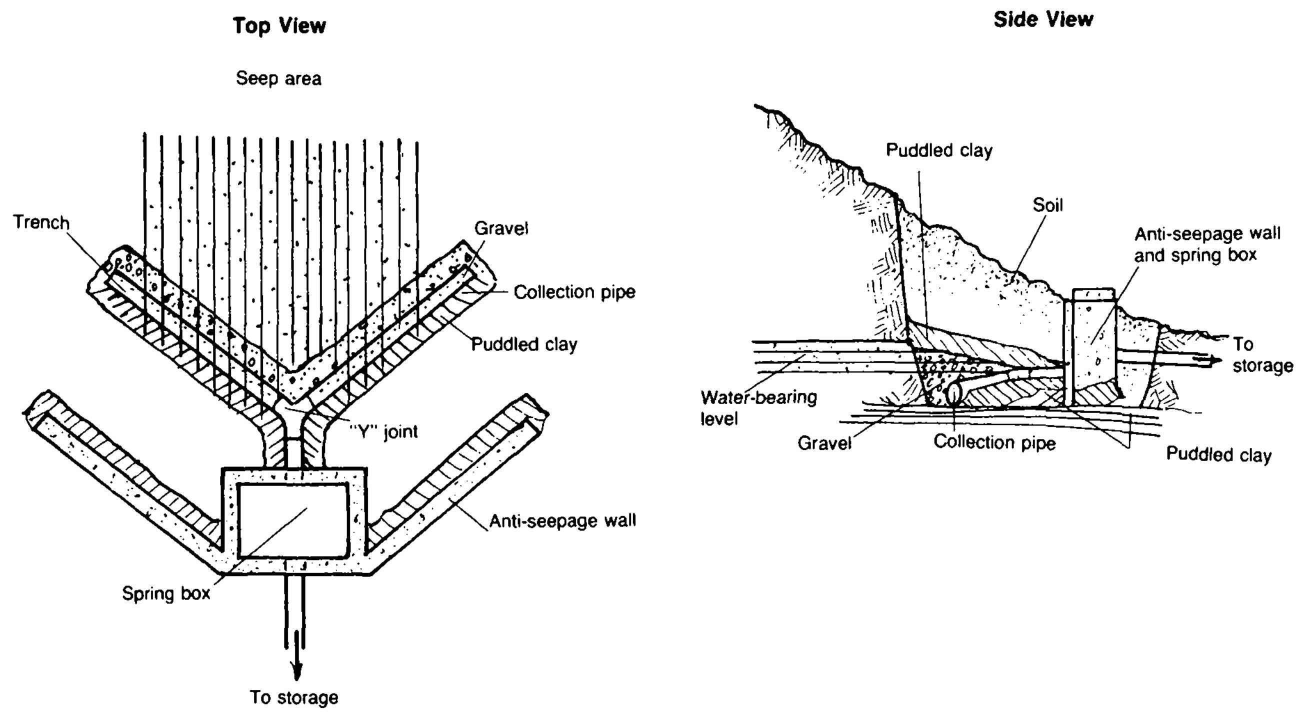

Figure 3. Seep Collection System

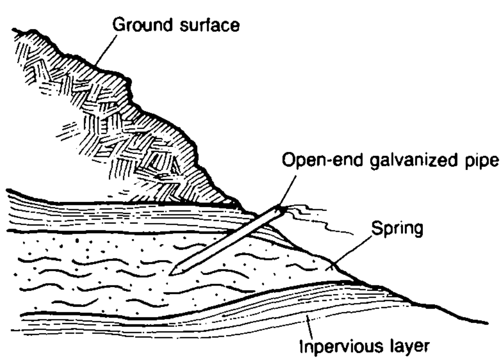

Figure 4. Horizontal Well Driven into Artesian Spring

A floating intake of flexible pipe can be installed to ensure that water is drawn from the same level regardless of changes in the water level. The intake is secured to a float so that it is suspended 0.30-0.50m below it. The float rises and falls with the water level but the intake position remains the same. The floating intake will supply water of uniform quality throughout the year. Figure 5 shows how a floating intake works.

In a newly dug reservoir or in a pond where a dam is to be built, a screened concrete intake box can be located on the floor of the reservoir next to the dam embankment. The water is deepest near the embankment and thus will be free from organic material as it enters the intake. A 10mm screen on

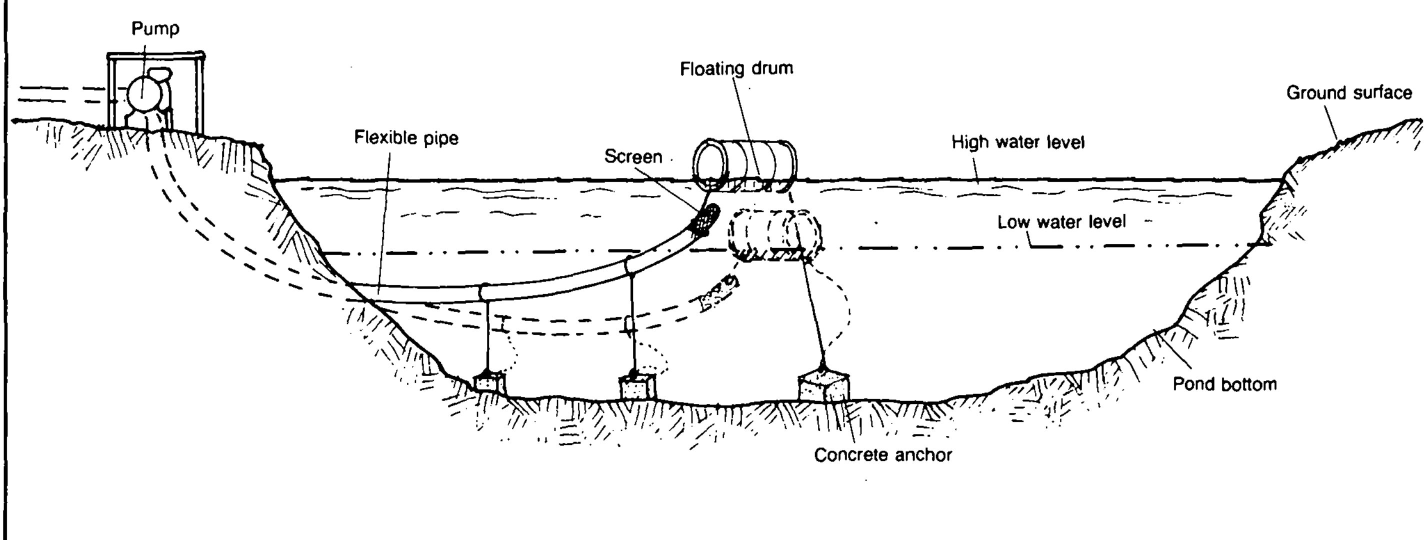

Figure 5. Floating Intake in Pond or Lake

the top of the box filters out any suspended matter or debris drawn to the intake. This type of intake is permanent, quite expensive, and can only be constructed in a newly-excavated reservoir. Floating intakes, which are usually cheaper to build, should be installed under most conditions.

Pond and lake intakes should be located so that the best quality water enters the system. Their location must prevent the drawing of water contaminated by contact with humans and animals, or by organic material and suspended matter. Proper location of the intake will help ensure that suitable water is available to the community.

Generally, developing intakes for ponds and lakes is expensive. The further away the users are from the source, the more expensive the system. Where possible, the source and intake should be located near the community.

Intakes for Rivers and Streams

Intakes will be needed if rivers and streams are to be used for water supply. They can provide sufficient water to a water supply system but there are special considerations which must be recognized for effective planning. Rivers and streams generally have a wide seasonal variation that will affect the location of intakes and the quality of water drawn by them. During the wet season, water is abundant. However, flooding may occur which could destroy the intake and measures must be taken to protect it in this case. In the dry season, water flow will lessen and may even disappear completely. In this case, a community dependent on a river as a water source would have to find an alternative. In faster flowing streams and rivers, erosion along the riverbanks can be a problem. To prevent erosion, a flat stable section of the stream rather than a windy section should be chosen for the intake site. Efficient planning is necessary to ensure a year-round supply of water from a river or stream. There are two types of intakes for rivers and streams: infiltration systems and direct intakes.

Infiltration Systems. A well near a riverbank can be an excellent intake for a stream or river. An infiltration well can provide potable water from a surface source during the entire year if it is excavated below the stream bed level.

Water quality is good because as water is pumped from the well, the stream water is drawn through the ground into the well. As the water passes through the ground, suspended particles and bacteria are removed and the stream water is considerably purified.

The purification process depends on the makeup of the soil in the river bank and the distance of the well from the stream or river. If the soil is made up of large particles, the water will pass through it quickly. Soil containing finer particles of sand and silty clay slows the movement of water. The slower the water moves, the less distance it must travel for filtration to take place. In fine or compacted soils, the well could be placed as close to the river as 2 or 3m. In coarser soils, the well may have to be 20 or 25m from the stream so that the water will flow underground long enough to be purified. In semicoarse soils, a distance of 10-15m from the stream should be sufficient. Be sure that the soil is not a highly compacted clay. Water movement through compacted clay is very slow and the replenishment of the well could also be very slow.

Another advantage of an infiltration well is that water is usually available even in seasons when the river dries up. Water is stored in the soil and in the well. If the river is likely to dry up and no other suitable source is available, be sure to dig lower than the bed of the stream and plan a well with a large storage capacity. Figure 6 shows the process of infiltration at a riverside well.

Infiltration galleries are developed in basically the same way as infiltration wells, except that collecting pipes are installed. Riverbanks with firm soil that does not contain a lot of clay are good for infiltration galleries. Some infiltration galleries are built in the bank parallel to the stream. Trenches are dug to a depth below the water level and collecting pipes are installed as shown in Figure 7. The pipes run into a clear water well which provides some storage and settling. Their distance from the river or stream depends on the soil makeup. Filtration is usually very good because each collection pipe

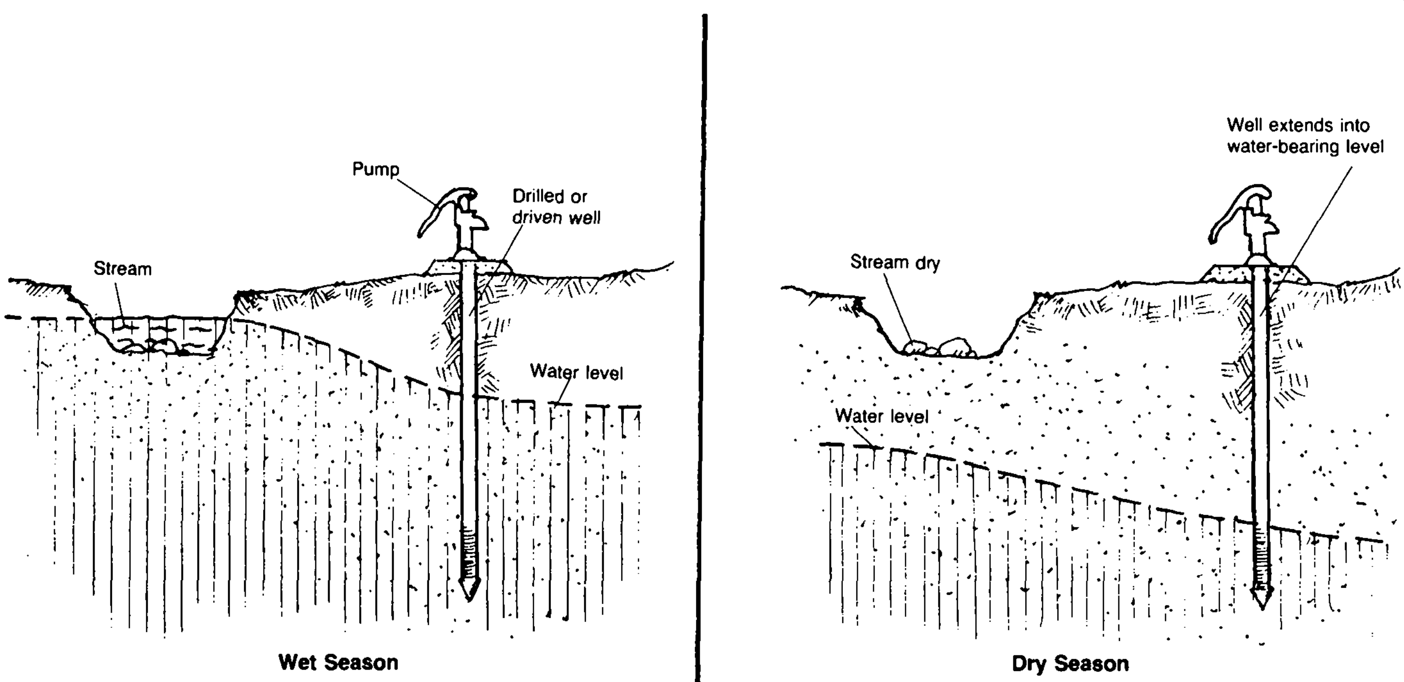

Figure 6. Water Availability in a River Bank

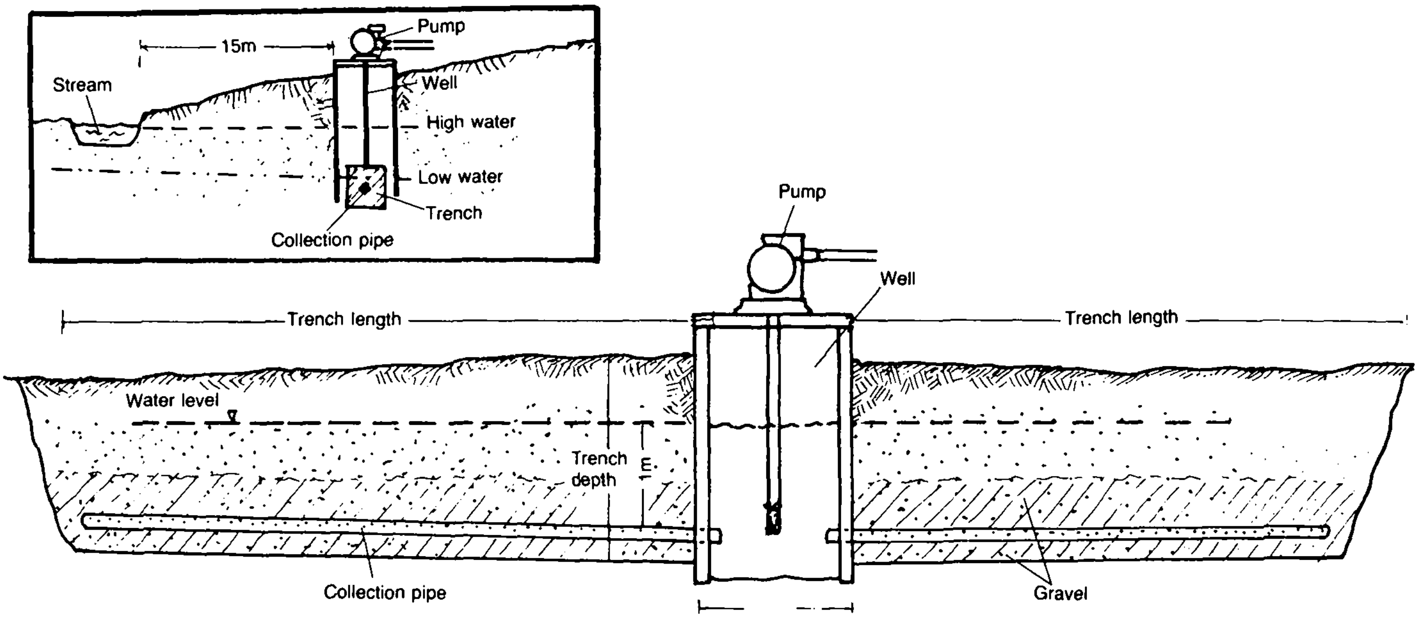

Figure 7. Infiltration Gallery

is protected by a layer of sand and gravel which filters out sediment. As the water moves from the stream to the trenches, bacteria are filtered from it. If soil is sandy this type of infiltration gallery may not work. The sand may clog the collection pipes and cut off the flow of water. Sandy soil is not firm which makes deep excavation dangerous due to cave-ins. Where there are sandy river banks, another alternative should be found.

In some streams, the collection pipes can be laid directly in the stream bed as shown in Figure 8. The stream can be bailed out or have its flow diverted and a trench 0.5-0.7m deep dug out. A collection pipe surrounded by gravel can be placed in the trench and connected by another pipe to a clear well on the shore. This type of infiltration gallery is best installed during the dry season.

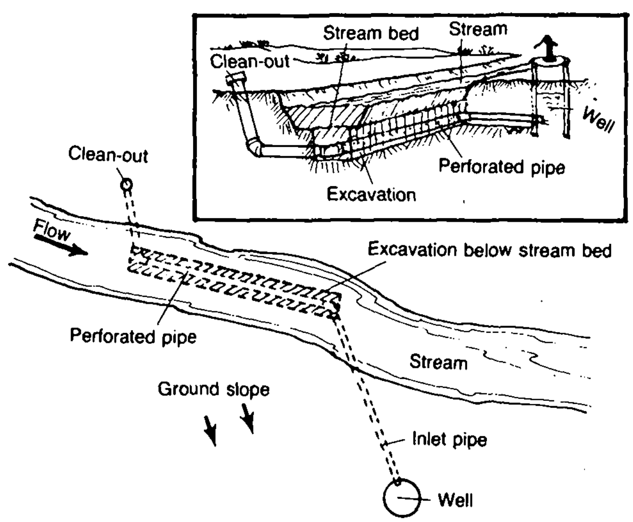

Figure 8. Infiltration Gallery in Stream Bed

Another possibility is to place the pipes under the stream bed, perpendicular to the stream as shown in Figure 9. This technique requires that the pipes be driven into the stream bed. This type of infiltration gallery is much more difficult to build, but is useful when the other two methods cannot be used. With infiltration galleries, often times it is best to use fine filtering materials to slow the velocity of water entering the system. Lower velocity provides clearer water, but less quantity. To maintain the quantity desired, infiltration galleries can be made longer in order to collect water over a larger area.

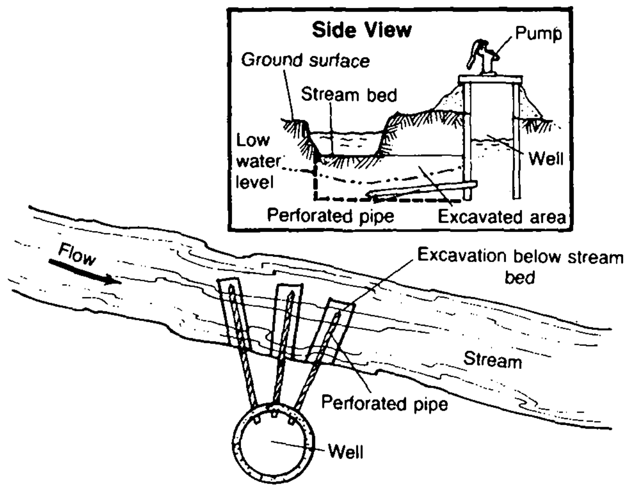

Figure 9. Multiple Pipe Infiltration System

Infiltration galleries can provide large quantities of good quality water because water is collected over a large area. Infiltration wells generally serve only a few users, while infiltration galleries can serve entire communities.

Direct River Intakes. River water quality can be assured by locating the intake above inhabited areas and sources of contamination. There is little chance of fecal contamination by people or animals in areas where few people live.

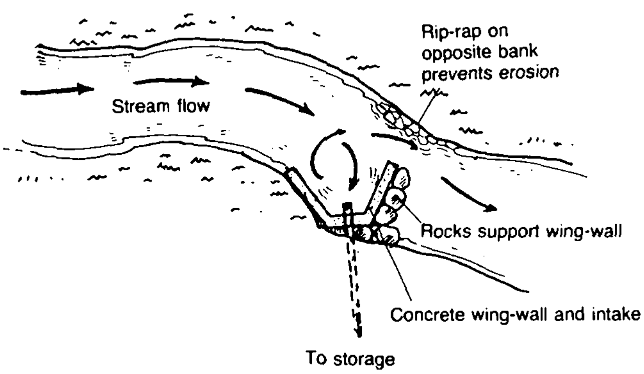

Figure 10. Direct Intake for River or Stream

Direct intake structures should be located either on a straight, stable section of a river bank or else near the convex side of the bank as shown in Figure 10. Be sure that the bank is stable when choosing the location. The intake should be located so that it is submerged all year long. Before attempting to install an intake in a specific location, determine the low water level during the dry season. The intake should be low enough to collect water all year but not too close to the bottom where sediment or rock could enter and clog it.

Many times streams are not very deep and, especially for gravity flow intakes, it will be necessary to introduce techniques which ensure a constant flow through the intake. A weir or submerged dam can be built across the river to raise the water level enough to provide the necessary flow. The intake must be submerged at all times.

In a deeper and faster stream, the intake can be located in a concrete ring attached to the shore by a catwalk. The ring is placed in the stream and protects the intake from damage from debris and the force of the water.

The catwalk is attached to the ring from the shore to provide access for maintenance. The intake is connected to a mechanical pump. This type of intake is generally expensive to construct, operate and maintain, and skilled people must be available for its construction.

Intakes for rivers and streams should be located as close as possible to the users. The expense of piping water over long distances must always be considered when planning to use a source. Where possible, a river intake should take advantage of the purification process that accompanies an infiltration system so treatment can be avoided. If the installation of a gravity system is possible, the costs of pumping water to the users will not be a burden.

Summary

The choice of location for an intake depends upon the type of source to be developed and the conditions present at the potential source. Intakes should be placed so they collect the maximum amount of water available. Their placement should ensure that the best possible quality of water enters the system. Intakes installed in ponds, lakes and rivers should be located so that sediment and organic material do not enter them. Another important consideration is that the intake be located so that the required minimum supply of water is available to the users during the entire year. Finally, if possible, the source should be located close to the community to avoid the cost of installing expensive pipe for a distribution system.

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Water for the World

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

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

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

Useful Definitions

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

CISTERN - A covered tank in which water is stored.

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

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

IMPERVIOUS - Not allowing liquid to pass through.

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

PERVIOUS - Allowing liquid to pass through.

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

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

Roof Catchments

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

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

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

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

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

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

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

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

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

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

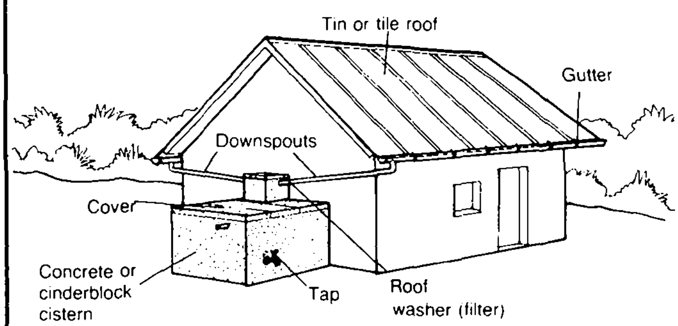

Figure 1. Rainfall Catchment with Cistern

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

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

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

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

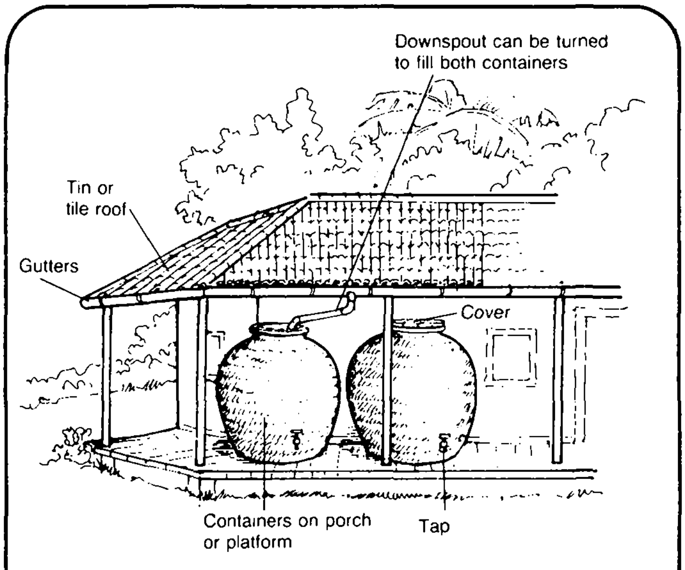

Figure 2. Large Water Storage Containers

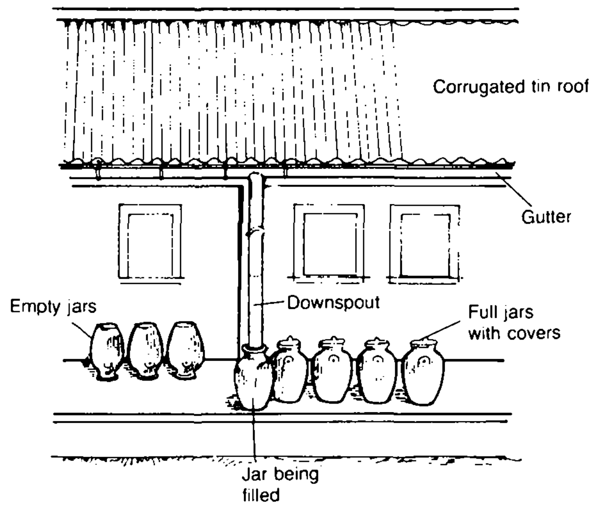

Figure 3. Small Clay Jars for Rainwater Collection

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

Ground Catchments

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

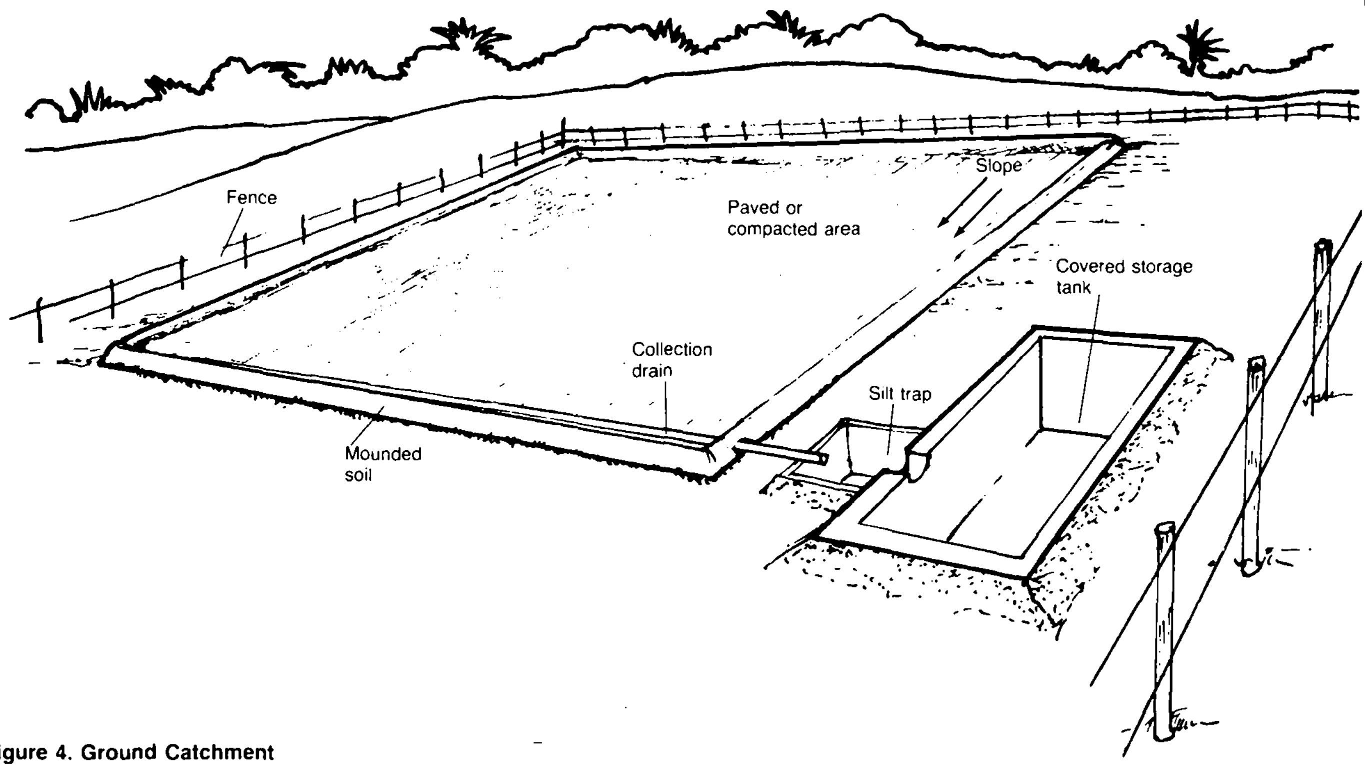

Figure 4. Ground Catchment

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

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

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

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

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

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

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

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

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

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

Summary

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

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

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

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

Notes

Notes

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

Water for the World

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

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

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

Useful Definitions

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

CISTERN - A covered tank in which water is stored.

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

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

IMPERVIOUS - Not allowing liquid to pass through.

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

PERVIOUS - Allowing liquid to pass through.

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

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

Roof Catchments

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

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

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

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

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

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

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

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

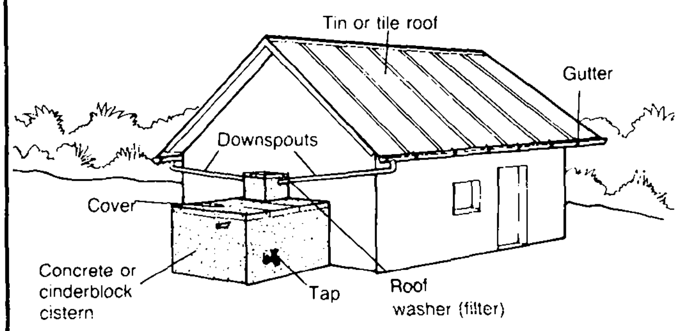

Figure 1. Rainfall Catchment with Cistern

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

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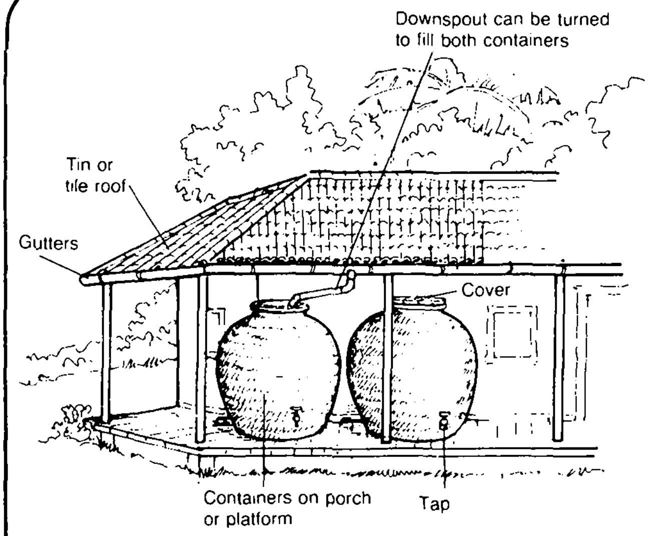

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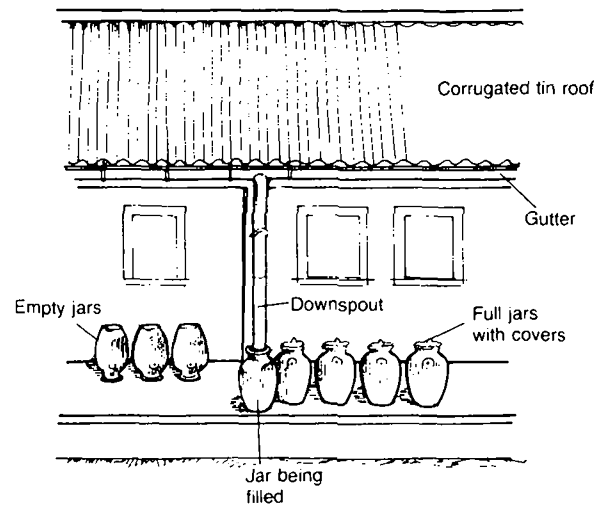

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A similar technique is to use smaller, portable clay jars that can easily be moved under the downspout during a rainstorm. A family could have several 25-liter jars which can be filled during rainfalls. This system will work efficiently, but there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

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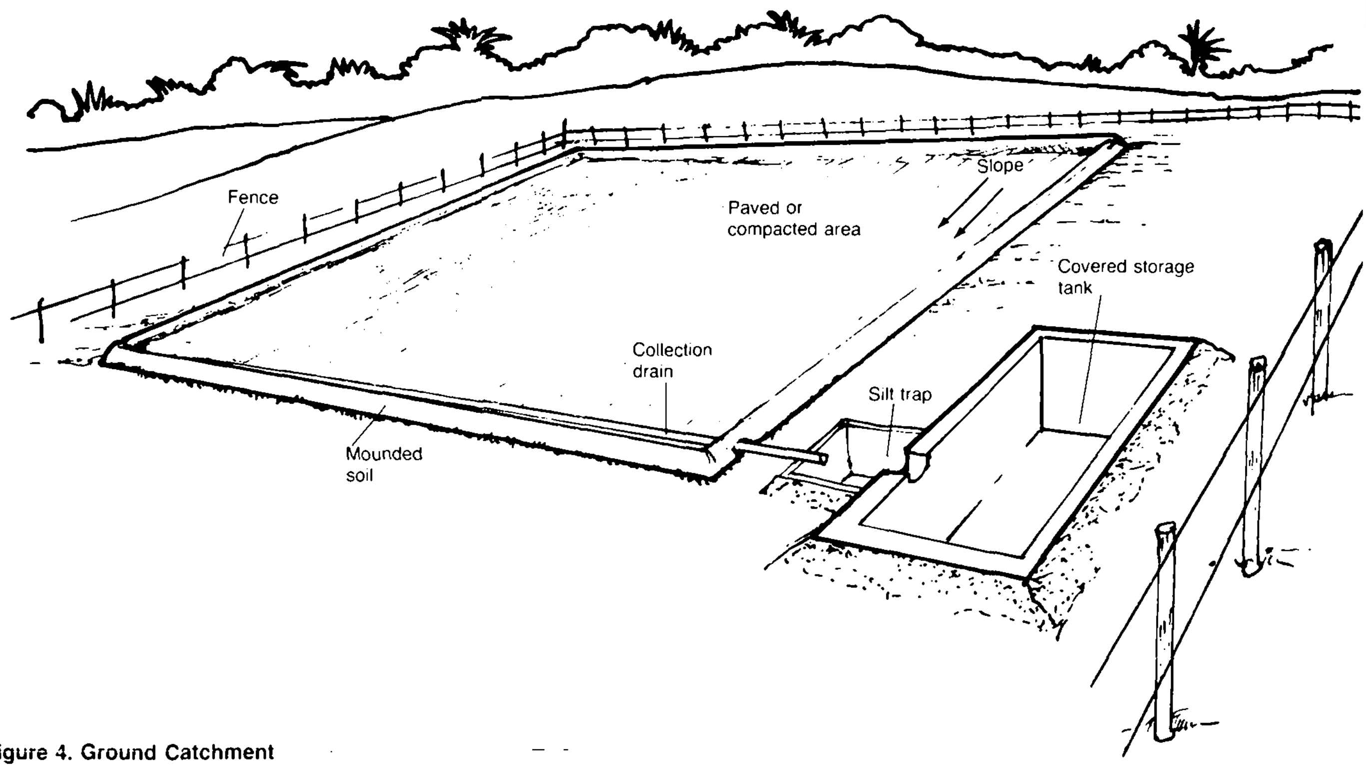

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Water for the World

Designing Structures for Springs

Technical Note No. RWS. 1.D.1

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

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

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

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

Useful Definitions

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

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

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

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

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

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

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

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

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

UNDERFLOW - Flow of water under a structure.

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

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

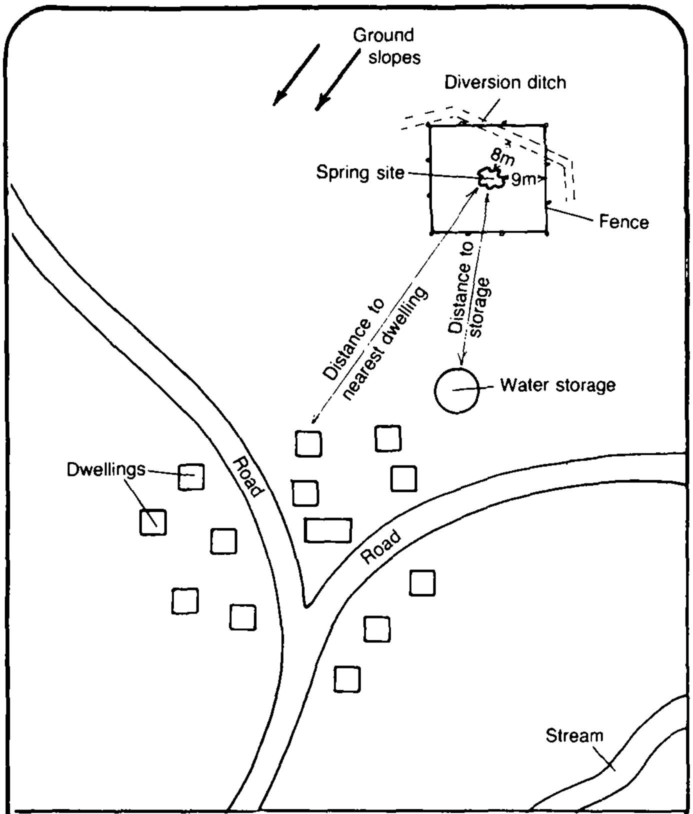

Figure 1. Location Map

Spring Box Design

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

Table 1. Sample Materials List

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

Total Estimated Cost ___

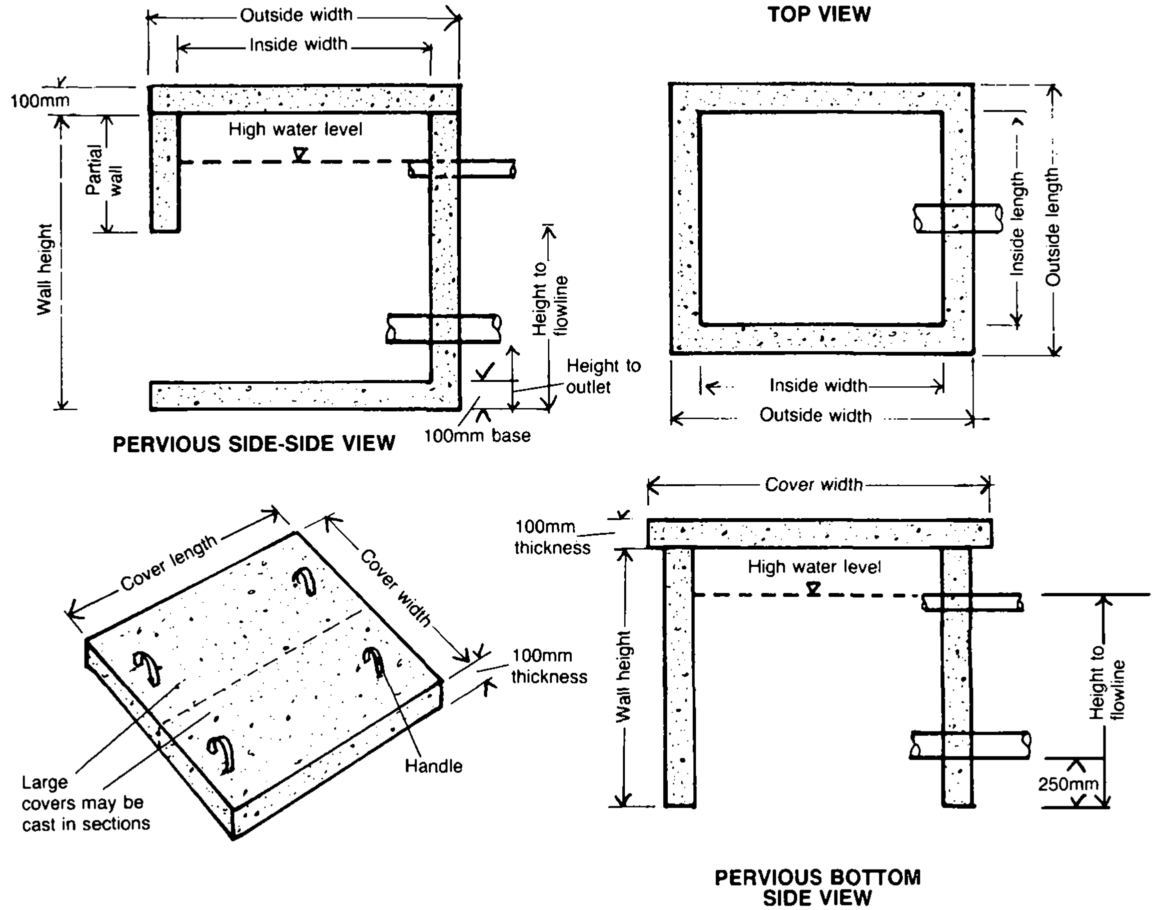

Figure 2. Spring Box Design

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

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

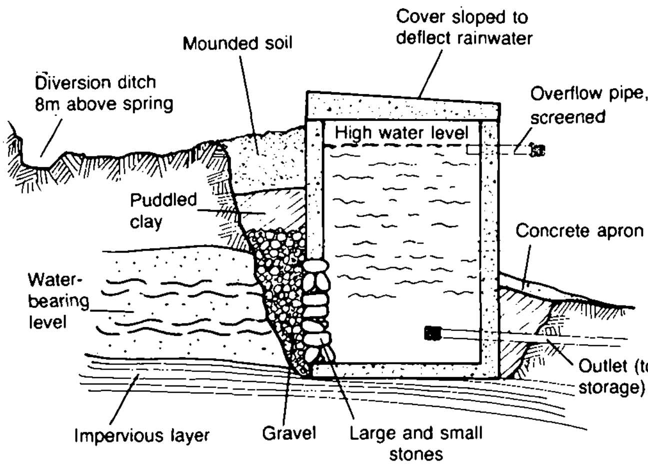

Figure 3. Spring Box with Open Side

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

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

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

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

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

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

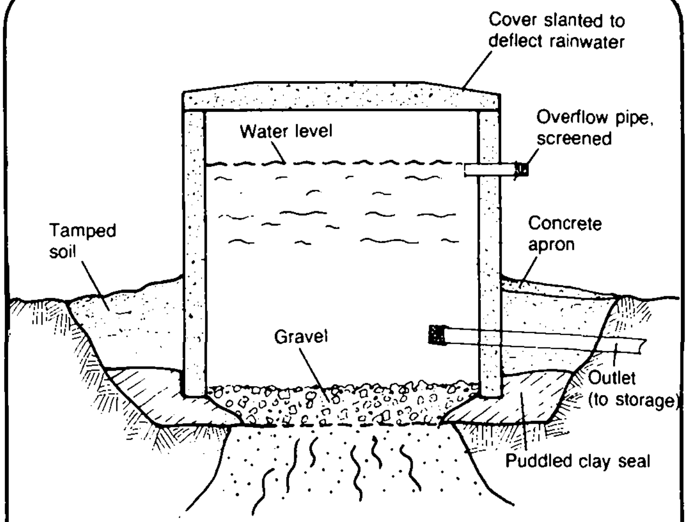

Figure 4. Spring Box with Open Bottom

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

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

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

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

Thickness of walls = 0.10m

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

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

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

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

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

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

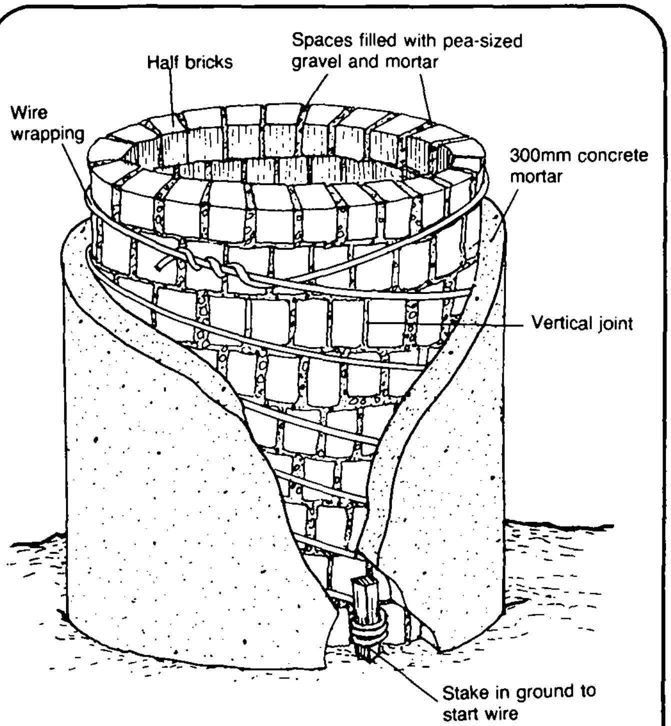

Figure 5. Brick Spring Box

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

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

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

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

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

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

Seep Design

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

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

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

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

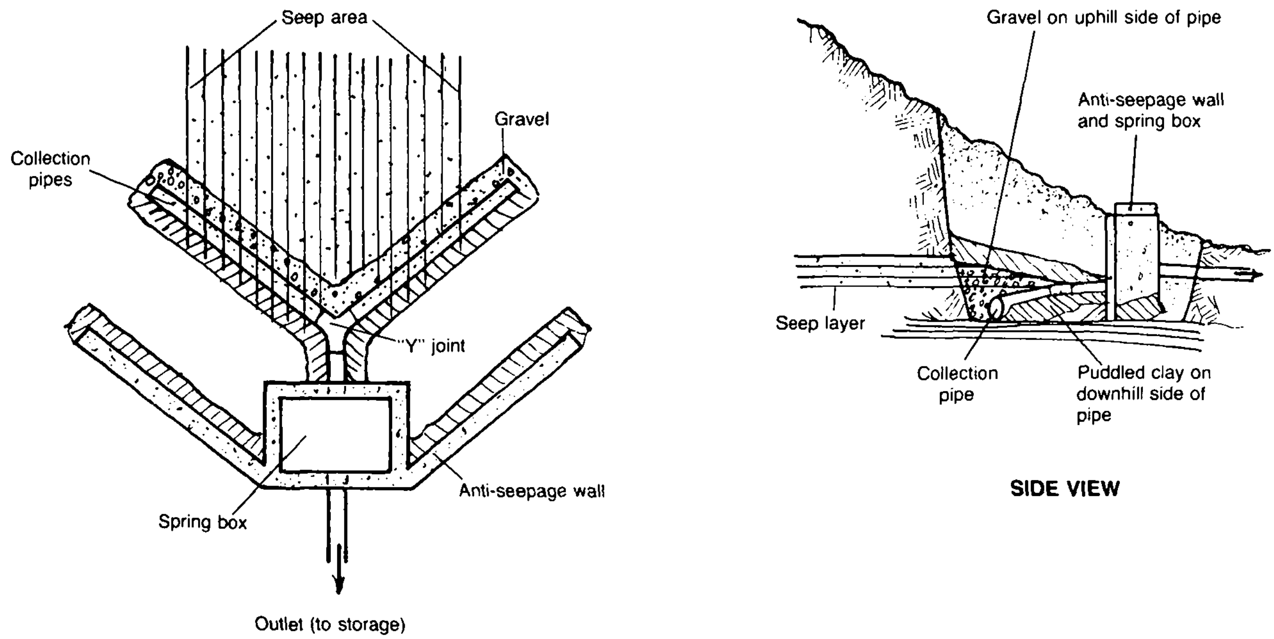

Figure 6. Seepage Collection System

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

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

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

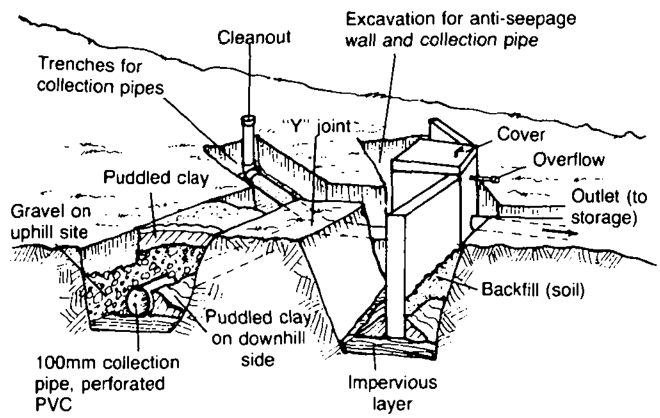

Figure 7. Basic Design Feature of a Seep Collection System

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

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

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

Horizontal Well Design

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

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

"Designing Driven Wells," RWS.2.D.2, outlines the steps in designing a driven well. These same steps should be followed in designing horizontal wells. One design difference is that extra care must be taken to avoid leakage between the driven pipe and the ground. If exterior flow occurs, it can be stopped by forcing clay or grout into the space, or by digging by hand 1m back along the pipe and installing a concrete cutoff wall. The wall should have a diameter of $0.6m^2$ and no more than 0.05m thick. After the concrete slab hardens, the dug-out area should be packed and backfilled with clay.

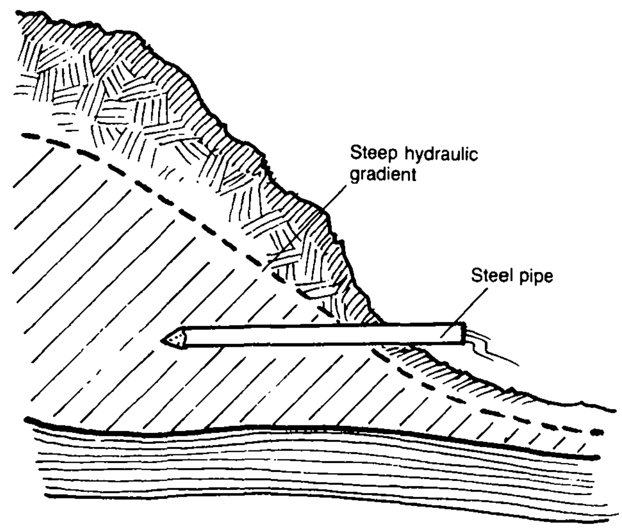

Figure 8. Horizontal Well

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

Materials List

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

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

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

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

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

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

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

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

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

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

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

The reinforcing rod should be located as follows:

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

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

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

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

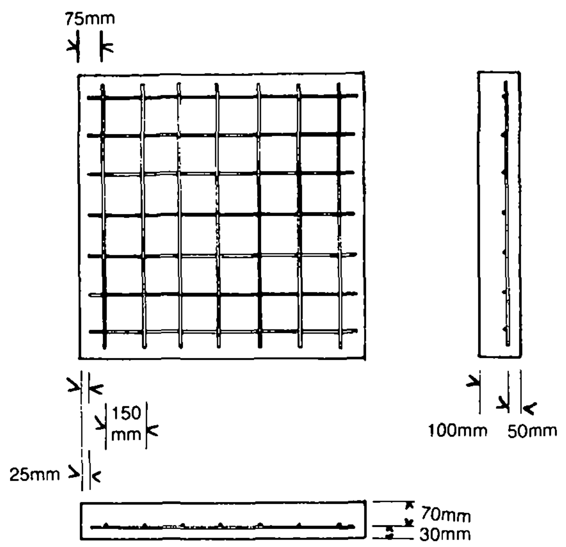

Figure 9. Placement of Rebar in Concrete Slab

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

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

Important Considerations

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

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

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

Notes

Notes

1982

Water for the World

Designing Intakes for Ponds, Lakes and Reservoirs

Technical Note No. RWS. 1.D.2

Intakes make water from ponds, lakes, and reservoirs more accessible. Water can easily be pumped from an intake to a community distribution system. Long walks to fetch water are not necessary. The installation of an intake should lead to increased water consumption. This, in turn, should mean improved health for the community.

The design of intakes is very important if they are to function properly. A well-designed intake should provide good quality water in abundant quantities. An intake should be designed for cheap installation and operation and as little skilled supervision of construction and maintenance as possible. This technical note describes the design of intakes and should be used with "Choosing Where to Place Intakes," RWS.1.P.4, which discusses site selection for intakes.

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

1. A map of the body of water marked with the location of the intakes, distances and construction areas as shown in Figure 1.

2. A list of all labor and materials needed for the project similar to the sample list in Tables 2 or 3. For information on the design of a clear water well see "Designing Dug Wells," RWS.2.D.1.

3. A detailed plan of the intake structure with all dimensions.

Useful Definitions

CLEAR WATER WELL - A sedimentation area or sump into which an inlet discharges water and from which water is pumped to distribution for community use.

GALVANIZED IRON PIPE - Zinc-coated iron pipe similar in size to rigid plastic, but heavier.

GLOBE OR GATE VALVE - Types of cutoff devices used in pipelines to control the flow of water in a system. The globe valve causes a high resistance to water flow because of small passageways. The gate valve when fully open allows straight-line water flow with very low resistance.

INLET STRAINER - Material, usually wire screen, that is put over an intake pipe to remove sediment and plants from the flowing water.

PEAK DEMAND - The amount of water a pump must deliver in liters per minute to meet the greatest need at whatever time it occurs.

POLYETHYLENE PIPE - Black, light-weight, flexible pipe used in water systems.

POLYVINYL CHLORIDE (PVC) - A white, rigid, plastic pipe used in water systems.

$Q = AV$ - Quantity of water available is equal to the velocity (V) of the water multiplied by the area (A) of the pipe opening, known as the "Equation of Continuity."

SILT - Sediment made up of fine particles carried or laid down by moving water.

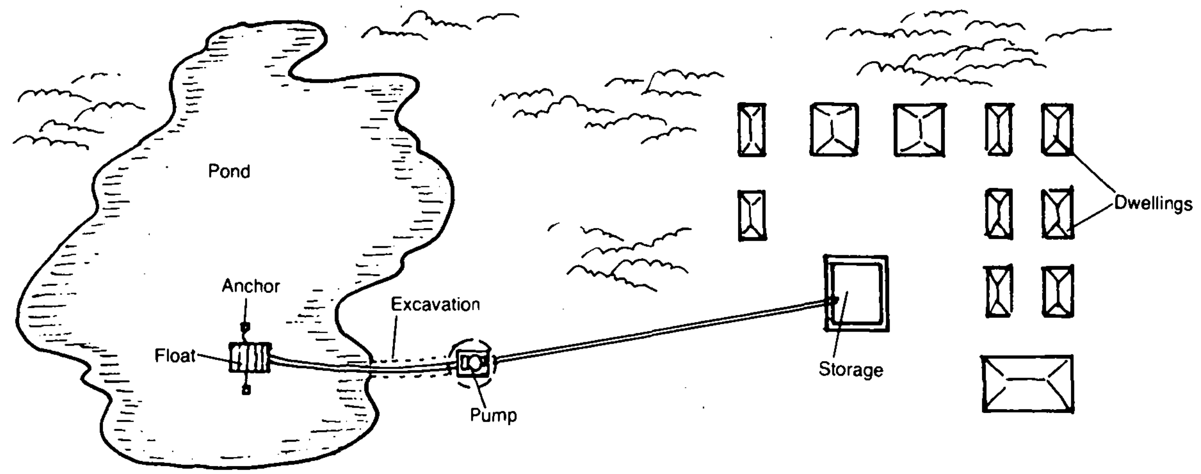

Figure 1. Location Map

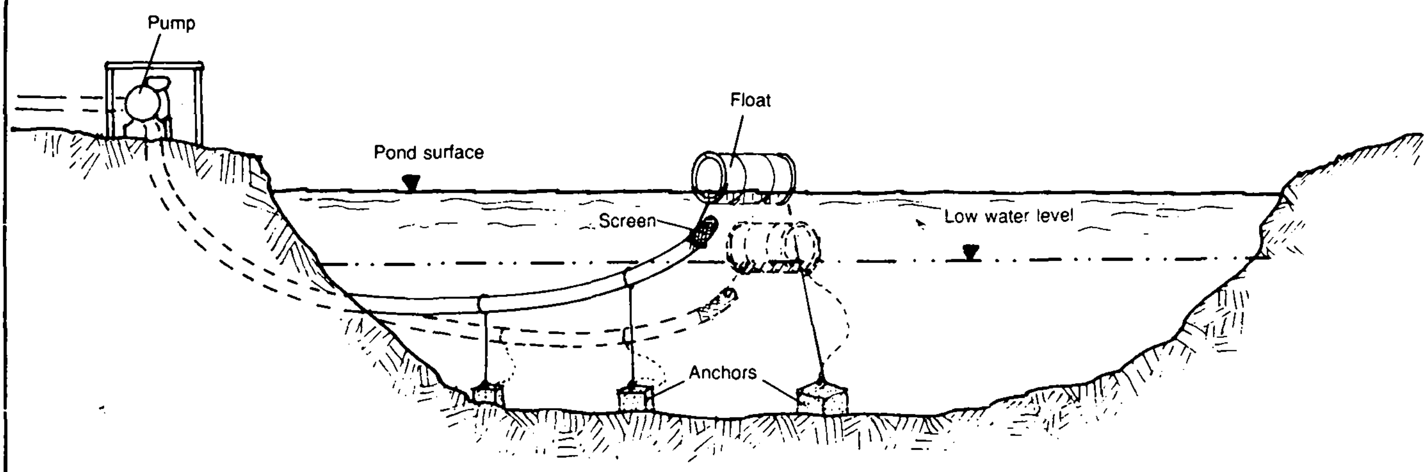

Figure 2. Flexible Plastic Intake with Direct Connection to Pump and Storage

Design Information

In order to design an intake for a pond, lake, or reservoir, it is necessary to (1) select the location for the intake, (2) decide on the diameter, length and type of pipe required, (3) design an inlet strainer, (4) design floats and fixed intake supports, and (5) choose the appropriate installation. Figure 2 shows a typical design for a floating intake. The pipe is plastic and the intake is positioned so it is always 0.3-0.5m below the surface to keep out plants from the surface and sediment from the bottom. If water is silty, it enters a clear well for sedimentation. Otherwise, it is pumped directly to treatment and/or storage. Refer to Figure 2 while reading the remainder of the section on the basic design of intakes.

Location for Intake. Survey the area and attempt to find the best location on the shore for a pump installation and the site for treatment or storage facilities where construction will be easiest. The best location will be on level ground and as close to the users as possible.

Find the deepest point in the body of water. If it is shallow, wade out into the water with a stick marked at 0.25m intervals. Measure the depth at various locations and find the deepest point as shown in Figure 3. Anchor a float at this spot or place a stick at the location. If the body of water is too deep for wading, go out in a boat and measure depths at various locations with a small rope knotted every 0.5m and weighted down with a heavy object as shown in Figure 4. Drop the weight into the water and take a depth reading on the rope. Mark the deepest spot with a float and an anchor, or use a long stake to mark the center point. Whenever possible, locate the intake at the maximum water depth. The depth should be at least 1m.

Diameter and Length of Inlet Pipe. The diameter and length of the pipe chosen depends on the daily volume of water needed to supply the users, the estimated pumping rate, and the distance between the inlet and the clear water well. For piped systems, water use is normally 40 liters per capita. The pump should be used a maximum of eight hours per day to allow sufficient time for operation and maintenance. If possible, the pump should operate fewer hours (perhaps six) in order to save energy. Pumping usually takes place in the morning and evening to meet peak demand during these times.

If pumping time is reduced from eight hours to six hours, the rate that water is pumped into the system must increase. The higher the pumping rate, the larger diameter pipe must be used. Worksheet A shows how to find the necessary pumping rate for a water system.

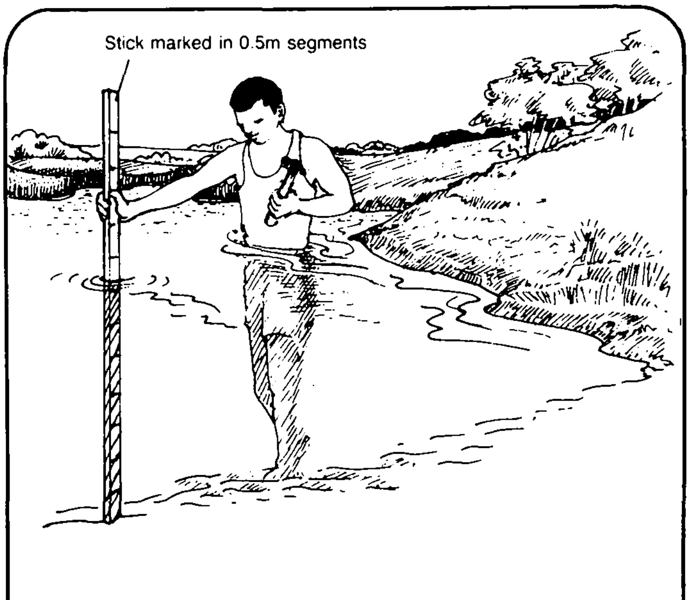

Figure 3. Measuring Pond Depth

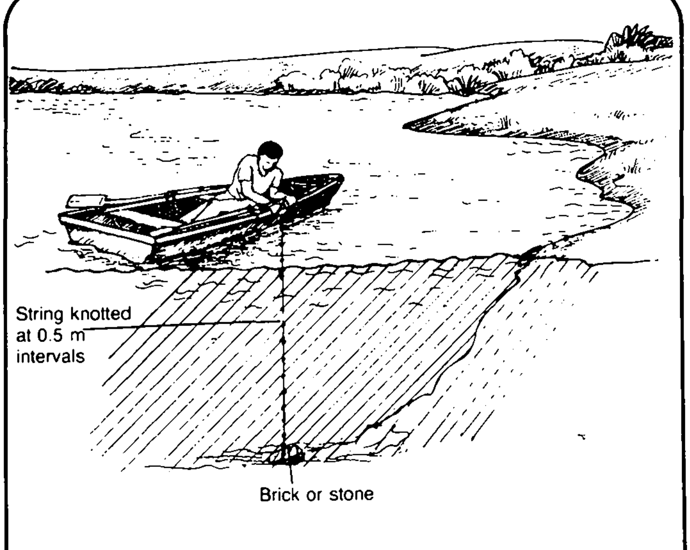

Figure 4. Measuring Depth of Large Pond

The diameter of the inlet pipe must be large enough to maintain a discharge into the clear water well or storage tank greater than the rate at which water is pumped out of it. However, the diameter should not be larger than required since smaller diameter pipe is much less expensive. A general rule is that intake pipes usually have a diameter of 50mm. This diameter should allow an adequate flow rate when pumps with maximum capacity from 1.2 to 1.8 liters per second are used. A low velocity is best since at faster velocities, water may pick up sediment from the bottom and draw it into the intake. Large particles or plants may be held against the intake screen by fast-flowing water, clogging the intake and reducing flow. In contrast, a velocity that is too low requires the use of larger diameter pipe which is more expensive. For rural water supplies, a practical velocity is between 1.2 and 1.8m per second. Use Table 1 to determine pipe diameter. Locate the daily pumping rate in the left-hand column labeled "Q Flow liters per second". Then look under the column that approximately corresponds to the velocity for the water system. The numbers in the columns under the velocities are pipe diameters expressed in millimeters.

Next, the length of pipe must be determined. The length is found by adding together (a) the distance from the intake to the shoreline, (b) the vertical distance between the high and low water levels, and (c) the distance between the clear water well and the shoreline at the high water level. This last distance is usually 2m to provide protection from possible flooding. Add 10 percent to the sum to cover possible error. Figure 5 shows the following example:

Distance from intake to shoreline	5m
Distance between high and low water levels	1m
Distance from shoreline to storage well	2m
	8m
10 percent error	0.8m
Total length of pipe:	8.8m

Worksheet A. Determining Pumping Rate

Step 1. Determine the daily per capita volume of water needed by the community. For example assume a population of 600 people each using 40 liters/day. Number of users x 40 liters/person/day = total daily demand for water, so 600 people x 40 liters/person/day = 24000 liters/day.

Step 2. Determine the pumping rate necessary to supply this amount of water. Divide the total daily demand for water by the hours of pump operation per day.

$$\frac{24000 \text{ liters/day}}{8 \text{ hours/day}} = 3000 \text{ liters/hours or}$$

$$\frac{24000 \text{ liters/day}}{8 \text{ hours} \times 3600 \text{ seconds per hour}} = \frac{24000 \text{ liters/day}}{28800 \text{ seconds/day}} = 0.85 \text{ liters/second.}$$

Step 3. Reduce the pumping time to 6 hours to save energy.

$$\frac{24000 \text{ liters/day}}{6 \text{ hours/day}} = \frac{24000 \text{ liters/day}}{6 \text{ hours} \times 3600 \text{ seconds per hour}} =$$

$$\frac{24000 \text{ liters/day}}{21600 \text{ second}} = 1.1 \text{ liters/second.}$$

Choice of Inlet Pipes. The types of pipe commonly used are plastic and galvanized iron. Plastic pipe is better because it does not rust, is cheaper and easier to work with, and offers less friction to water flowing through it. If both polyethylene, which is black flexible pipe, and polyvinyl chloride (PVC), which is rigid pipe, are available, the former should be used because it is cheaper, easier to use and requires less maintenance. Flexible plastic pipe may cost as much as one-third less than rigid plastic pipe. It comes in 2.5m diameter coils of 30m or more, is light in weight, and is easily transported and installed. Normally, no couplings are necessary when intakes are made from flexible plastic pipe. In contrast, rigid plastic pipe (PVC) comes in 6m lengths and is heavy and more difficult to move around. Couplings and pipe joint glue are necessary with PVC pipe.

Flexible pipe can be attached to stationary floats so that the intake remains 0.3-0.5m below the water surface no matter what the water level is. This allows water to enter the intake all year around. Maintenance is easy because flexible pipe can be lifted from the water to be inspected or serviced.

Table 1. Determining Pipe Diameter

Q Flow liters/sec.	V (Velocity) = 1m/sec. to 1.5m/sec.	V = 1.5m/sec. to 2m/sec.
	Pipe Diameter (mm)	Pipe Diameter (mm)
0.63	250mm	250mm
0.83	300mm	300mm
1.0	300mm	300mm
1.3	400mm	300mm
1.6	500mm	400mm
2.0	500mm	500mm
2.3	500mm	500mm
2.6	600mm	500mm
3.0	600mm	500mm

PVC pipe is usually held up by stationary supports as shown in Figure 5. Because its position does not change with the water level, it may draw in water containing bottom sediments or even stagnant water. Maintenance is more difficult because it must be done underwater.

Inlet Strainer. An inlet strainer allows the required water to enter the system while keeping out unwanted material such as sediment, plants, and small fish or animals. One technique is to plug the end of the inlet pipe and let water flow into the pipe through holes drilled into it. The

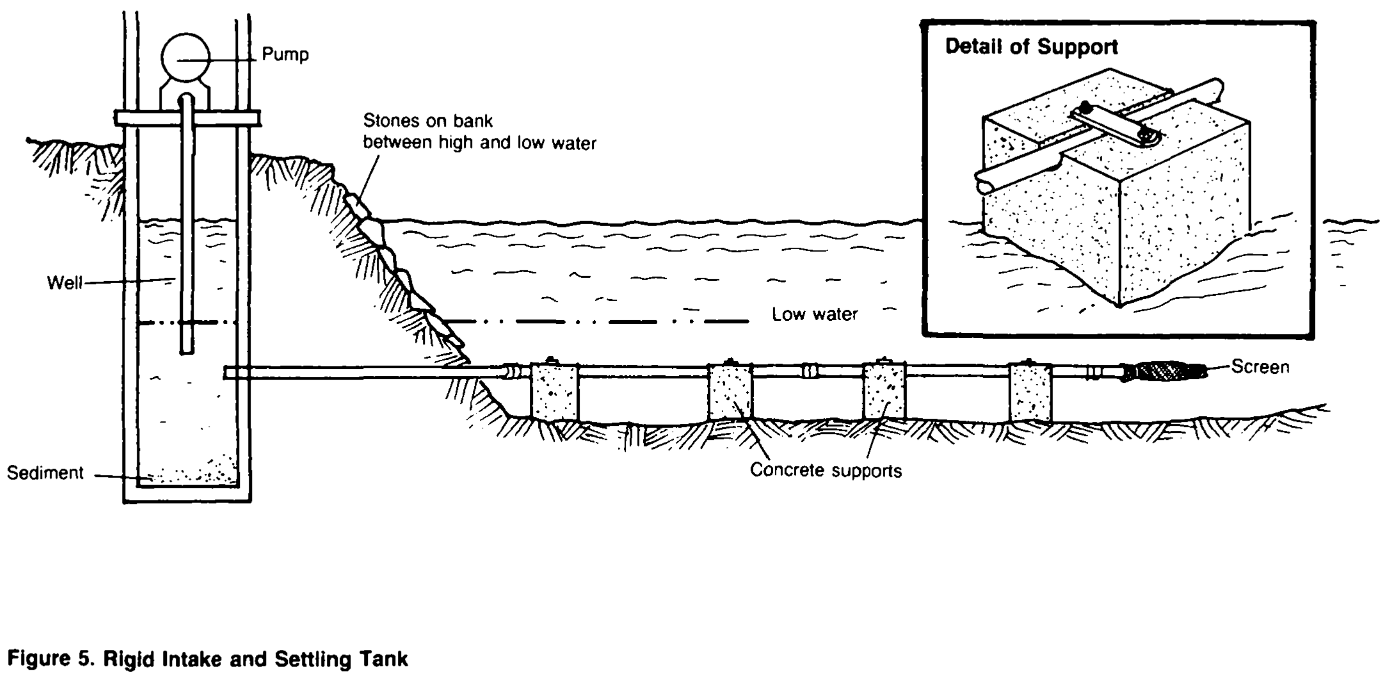

Figure 5. Rigid Intake and Settling Tank

holes are covered with wire mesh to filter out debris. The type of wire mesh will depend on available materials but the mesh should have 10mm squares. Figure 6 shows a perforated inlet pipe. The length of the pipe to be perforated and the size of each hole will depend on the amount of flow needed. A 0.20-0.50cm length of pipe with 15 holes 10mm in diameter would be sufficient for most flows. The distance between the center of each hole should be 25mm. The amount of flow from a perforated pipe can be determined by the following formula:

Q = AV, where Q is the amount of flow, V the velocity (1.2m/second), and A is the area of the holes in the perforated pipe.

Worksheet B shows how to calculate the rate of flow when there are a known number of inlet holes of a specific diameter. The worksheet also explains how to determine the number of holes which should be drilled in an inlet to obtain a desired rate of flow. Use this worksheet and "Determining Pumping Requirements," RWS.4.D.2, in designing the inlet.

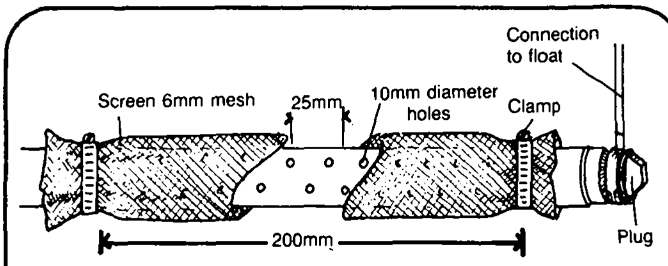

Figure 6. Plastic Pipe Intake

Design of Floats and Fixed Supports

Flexible pipe can be suspended from floats. The construction of floats requires some floatable material, suspension lines, and anchors.

There are many types of floating material available. Bamboo or trees can be used to make very good floats. By tying together logs or bamboo stalks, a floating raft can be constructed. Figure 7 shows a raft float made from nine logs 1.2m long and six cross-members of 0.9m. Bamboo can be used in the same way. The cross-members are nailed into the logs. If bamboo is used, the stalks can be lashed together with rope or twine.

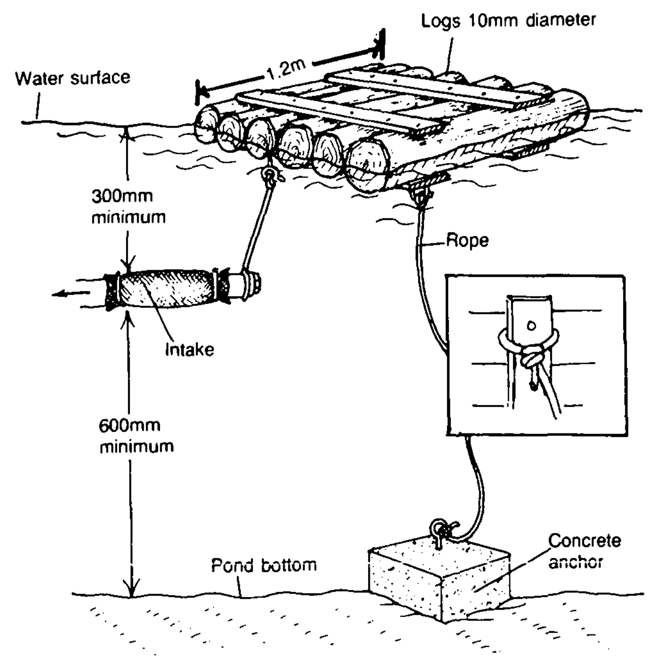

Figure 7. Raft Float and Intake

Instead of a raft, a barrel or other floating container can be used. Figure 2 shows an intake suspended from an empty barrel. If a barrel or other container is available, the cost of installation may be less than for a raft. Both methods are equally acceptable and efficient, however, special care should be taken in choosing and maintaining floats. If barrels rust or if holes are made in them, they will sink taking the intake pipe with them. Wooden floats also sink when they become water logged. Floats should be well maintained and checked often to ensure efficient operation of the intake system.

Worksheet B. Determining the Rate of Water Flow*

Step 1. Determine the total area of the holes drilled in the inlet pipe. Use the formula for the area of a circle:

Area = π (diameter ^{2}) where π = 3.1. For example, assume there are 15 holes, each with a diameter of 0.01m (10mm).

Area of a drilled hole = π (d^2)

Area = $\frac{3.1}{4}$ ($.01m^2$)

Area = $.00008m^2$

Total area of drilled holes = Number of holes x area of one hole:

15 x .00008m = $.0012m^2$
Total area = $.0012m^2$

Step 2. Find the rate of flow of the water entering the system using the formula Q = AV where Q = rate of flow, A = area of the holes and V = velocity of flow. Assume that V = 1.2m/sec. for this example.

Rate of flow (Q) = Total Area (A) x Velocity (V)
Q = $.0012m^2$ x 1.2m/sec.
Q = $.0014m^3$/sec.
Since $1m^3$ = 1000 liters, $.0014m^3$/sec. x 1000 liters = 1.44 liters/sec.
Q = 1.44 liters/sec.

To determine the number of 10mm holes that must be drilled to have a specific flow, follow the above steps in reverse. For example, assume a rate of flow (Q) of 1.4 liters/sec. is desired, and the velocity is 1.2m/sec. To obtain a 1.4 liter/sec. flow:

Step 1. Divide the rate of flow by the number of liters in a cubic meter:

$$\frac{1.4 \text{ liters/sec.}}{1000} = .0014m^3/\text{sec.}$$

Step 2. Divide the volume (m^3) by the velocity ($\frac{Q}{V}$ = A) to find the total area (A).

$$\frac{.00014}{1.2} = .0012m^2$$

A = $.0012m^2$

Step 3. Divide the total area by the area of each hole to find the number of holes needed.

$$\frac{\text{Total Area}}{\text{Area of one hole}} = \text{Number of holes}$$

$$\frac{.0012m^2}{.00008m^2} = 15$$

Number of holes = 15

*Friction and head loss must be considered in the calculations when a water distribution system is developed. For specific details, see "Determining Pumping Requirements," RWS.4.D.2.

With both types of floats, the intake is suspended 0.30-0.50m below the float by lines made from hemp, sisal, nylon or plastic cord. The only requirements are that the line be long enough to allow for changes in water level and strong enough to withstand the velocity of the water.

An anchor should be tied to the float to prevent it from drifting. An anchor made from concrete, a large rock or a bundle of bricks can be used to secure the float. It is best to use two anchors to prevent a floating intake from drifting when winds are high. Double anchors also act as security in case one of the lines should break or an anchor becomes unattached. If polyethylene pipe is used, anchors may also need to be added along the length of the pipe to prevent it from floating. Without anchors, the pipe may bend.

Stationary supports can be made from concrete or wood. The choice of material depends on which one is least costly and most easily available. Stationary supports are used for PVC pipe. They hold the pipe a minimum of 0.6m off the bottom of the basin and help keep the pipe from bending due to gravity and current. These supports should be placed so that each length of pipe has at least two supports under it. Figure 5 shows a PVC intake system with fixed supports.

In reservoirs formed by dams, several types of intakes can be used. Both floating and fixed intakes will function effectively, but floating intakes are easier to install and should prove more practical. A permanent intake can be constructed in the reservoir when a dam is being built. This type of intake consists of a concrete box with an inlet pipe built next to the embankment. A box structure for a PVC inlet at a dam is shown in Figure 8. This intake consists of a vertical pipe in a square concrete box 1m x 1m with an intake opening 0.60m by 0.60m. The box can be cast in place or built of concrete blocks. The top of the box is covered with 10mm wire mesh. Rocks can be used to hold the screen in place. The intake comes up from the bottom of the box and is protected by it. This type of intake cannot be installed in existing reservoirs; it must be put in place when a new dam is being built.

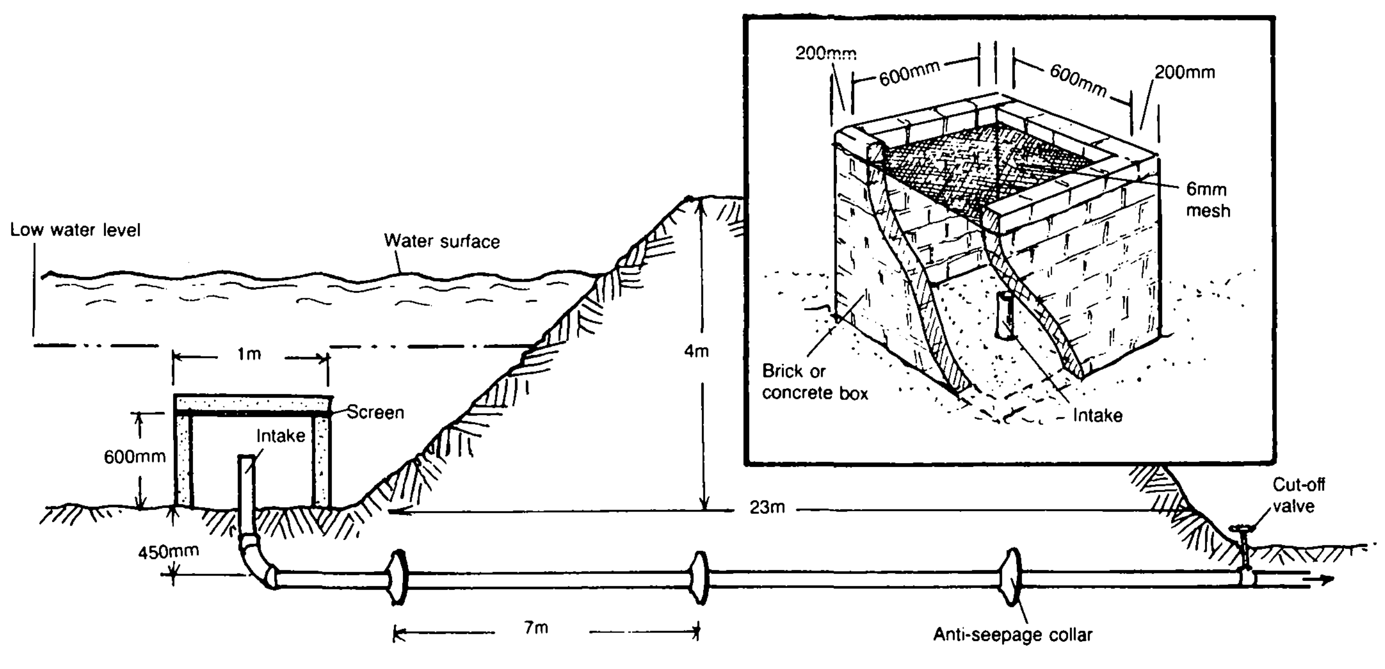

Figure 8. Intake Structure for Dams

Figure 9 shows another typical design for an intake for ponds and reservoirs. A length of pipe is inserted into a concrete form and the cement is poured to form a block containing the pipe. The block should be approximately 0.6m x 0.6m and be tall enough to completely enclose the intake pipe. An elbow joint and a screened vertical length of pipe is connected to one end while the other end is connected to pipe leading to a pump. The intake is installed at the bottom of a pond or reservoir. Floats should be attached so that the intake can be easily located and so it can easily be lifted from the water when maintenance must be done.

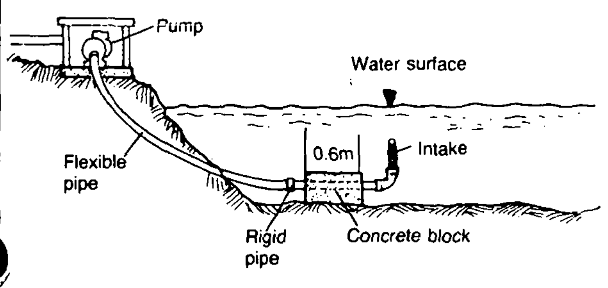

Figure 9. Rigid Intake in Concrete Block

Installation

Water can be pumped directly from the intake into storage or through treatment if necessary. Figure 10 shows an intake system for a dam. The pipe passes 0.45m underneath the embankment into storage. A globe or gate valve placed where the pipe leaves the embankment allows water flow to be turned on or off.

If the water is silty or muddy, it must flow from the intake into a clear water well for sedimentation. The well should be designed to provide 30-minute storage to permit settling of suspended matter.

The well should be approximately 1.5m in diameter to provide sufficient storage. The depth depends on the lowest water level in the pond. The well must be at least far enough below the lowest water level to permit gravity flow from the intake. The bottom of the well should be an additional 1m below the intake entry point to permit settling and to prevent the intake from clogging. There should be a valve on the intake pipe to cut off water flow for maintenance.

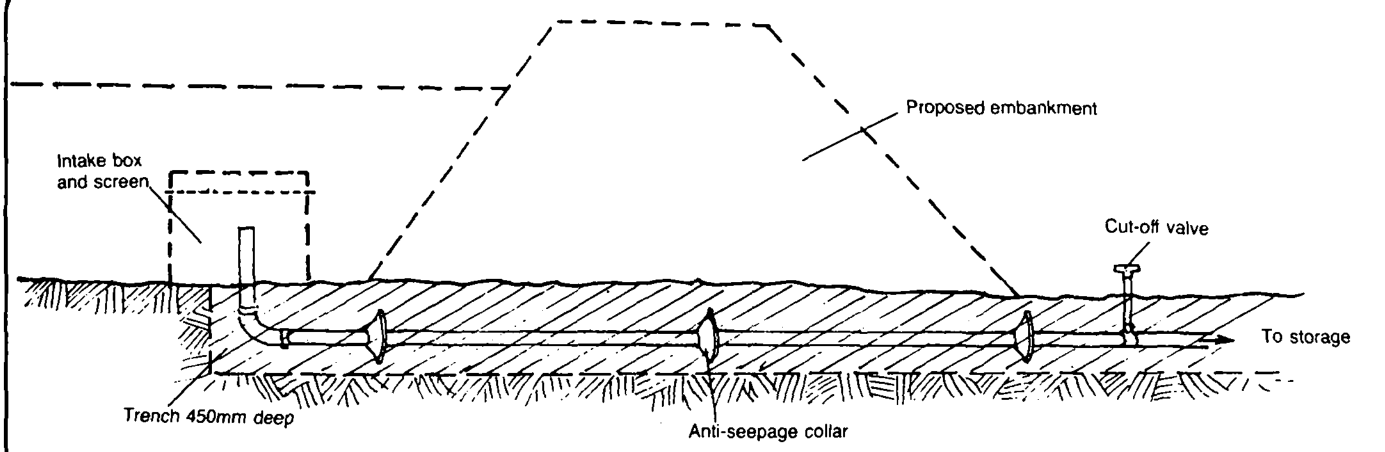

Figure 10. Installing Intake for Reservoir

The well should be lined with concrete or with brick, stones and mortar. The walls should be between 10-15cm thick and covered with mortar to waterproof them. The well should be covered for sanitary protection. The cover can be made either of concrete or metal sheeting. Complete design information for dug wells is available in "Designing Dug Wells," RWS.2.D.1.

Water is taken from the well by either a mechanical or hand pump depending on the type of distribution system. The pump intake should be about 0.50m above the bottom of the well. For information on pumping see "Selecting Pumps," RWS.4.P.5.

Water can be disinfected in the storage well or after it is pumped out. Use "Methods of Water Treatment," RWS.3.M, to decide what type of treatment is most appropriate to the system.

Table 2. Sample Materials List for Floating Intakes

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Laborers	____	____
Supplies	Flexible plastic pipe	____	____
	10mm wire mesh screen (for strainer)	____	____
	Plug (for end of pipe)	____	____
	Floats (wood, bamboo, barrels or plastic containers)	____	____
	Anchors (rocks or cement)	____	____
	Rope	____	____
	Tie wire	____	____
	Wooden stakes	____	____
	Knotted rope with weight	____	____
	Clamps	____	____
Tools	Digging tools	____	____
	Small drill	____	____
	Nails	____	____
	Hammer	____	____
	Bucket	____	____
	Measuring tape	____	____
	Small boat or raft	____	____
	Saw	____	____
	Knife	____	____

Total Estimated Cost = ____

Table 3. Sample Materials List for Rigid Plastic Intakes

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	_____ _____	_____ _____
Supplies	PVC pipe Couplings and pipe glue 10mm wire mesh screen Plug (for end of pipe) Clamps Wood for pipe supports (or cement, sand, gravel, for concrete and wood for forms) Globe valves String Wooden stakes	_____ _____ _____ _____ _____ _____ _____ _____ _____	_____ _____ _____ _____ _____ _____ _____ _____ _____
Tools	Digging tools Hack saw Wood saw Sledge hammer Nails Bucket Measuring tape Small drill	_____ _____ _____ _____ _____ _____ _____ _____	_____ _____ _____ _____ _____ _____ _____ _____

Total Estimated Cost = _____

Notes

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

1982

Water for the World

Designing Intakes for Rivers and Streams
Technical Note No. RWS. 1.D.3

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

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

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

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

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

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

Useful Definitions

ABUTMENT - A structure supporting a bridge or walkway.

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

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

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

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

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

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

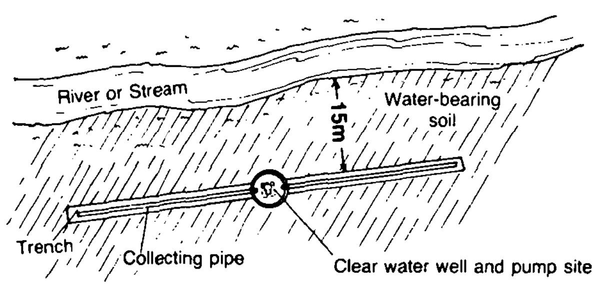

Figure 1. Location Map for Infiltration System

Table 1. Sample Materials List for Infiltration Systems

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

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

Table 2. Sample Materials List for Gravity Flow System

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

Table 3. Sample Materials List for Permanent Direct Pumping System

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

Design of Infiltration Intakes

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

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

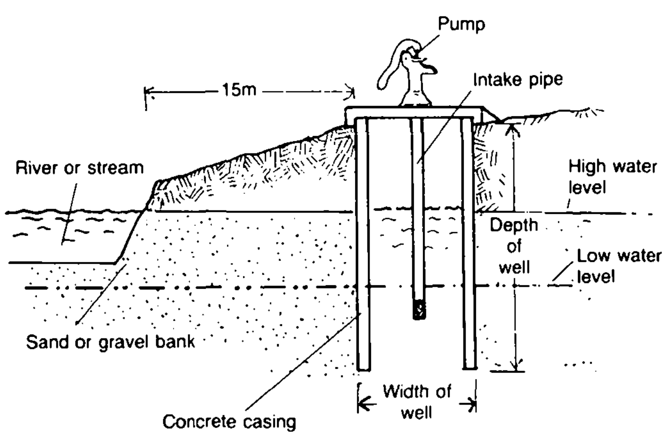

Figure 2. Riverside Well Intake

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

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

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

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

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

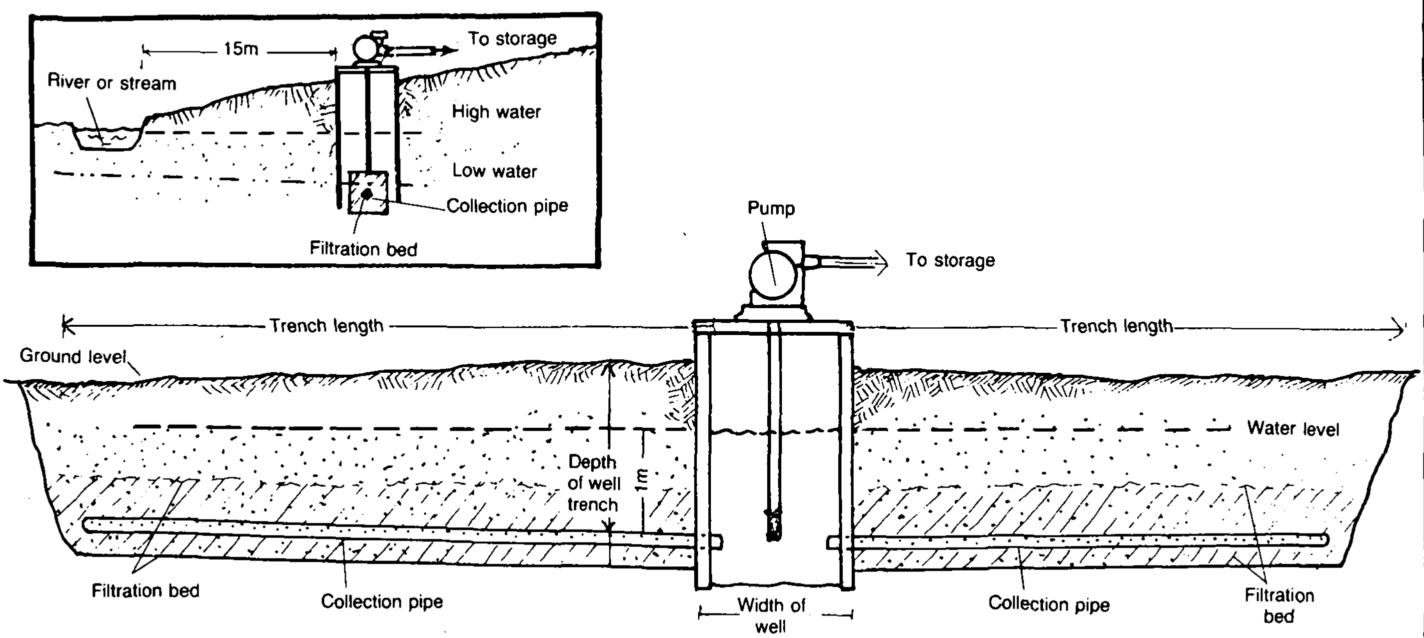

Figure 3. Riverside Infiltration Intake

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

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

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

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

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

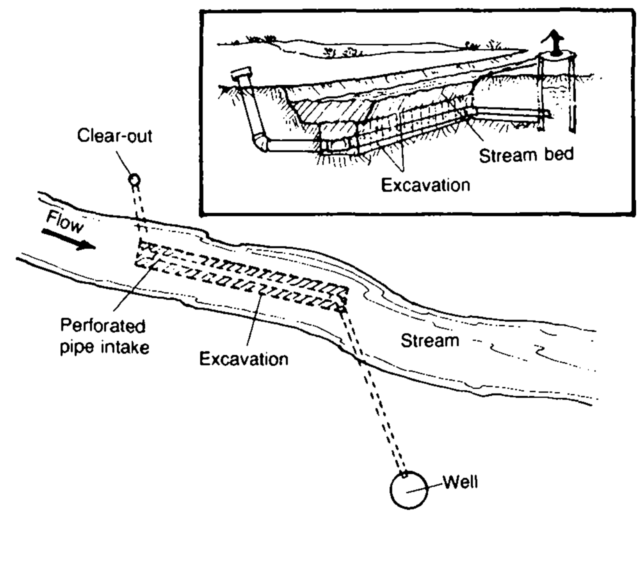

Figure 4. Infiltration System Below Stream Bed

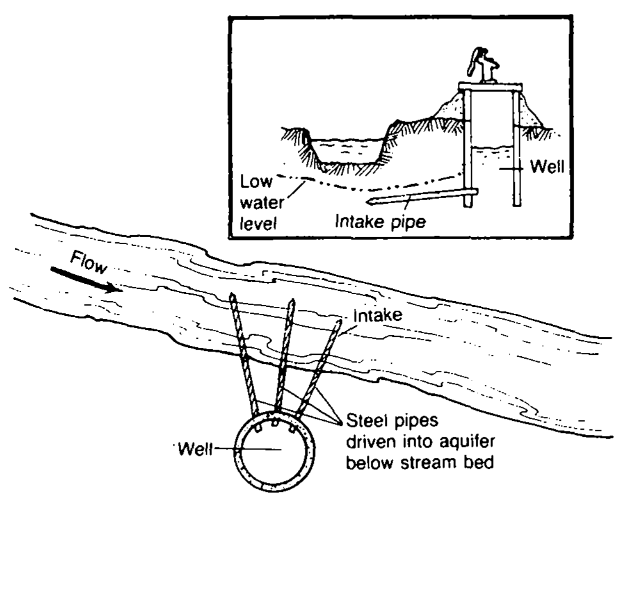

Figure 5. Multiple Pipe Infiltration System

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

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

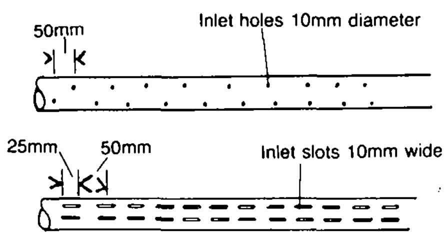

Figure 6a. Collection Pipe for Filtration System

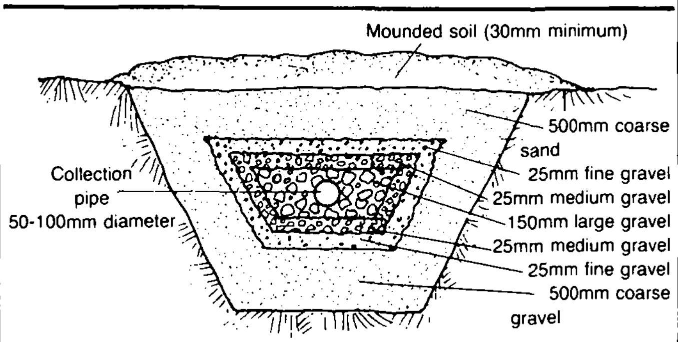

Figure 6b. Filtration Bed

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

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

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

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

Design of Gravity Flow Intakes

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

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

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

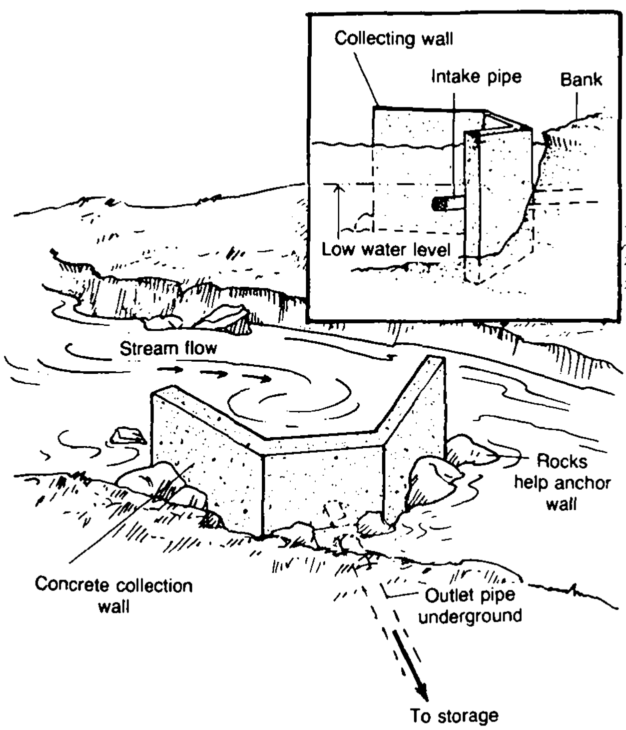

Figure 7. Gravity Flow Intake

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

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

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

Table 4. Determining Pipe Diameter

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

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

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

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

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

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

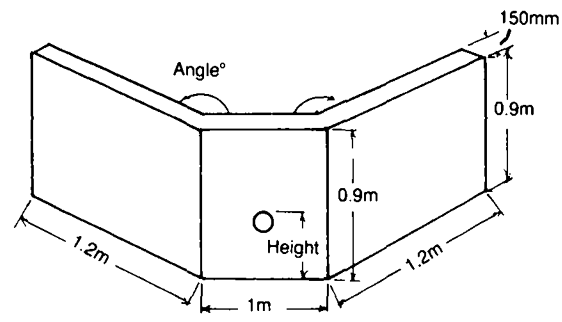

Figure 8. Design of Infiltration Wing-Wall Collector

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

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

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

Design of Permanent Intakes for Direct Pumping

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

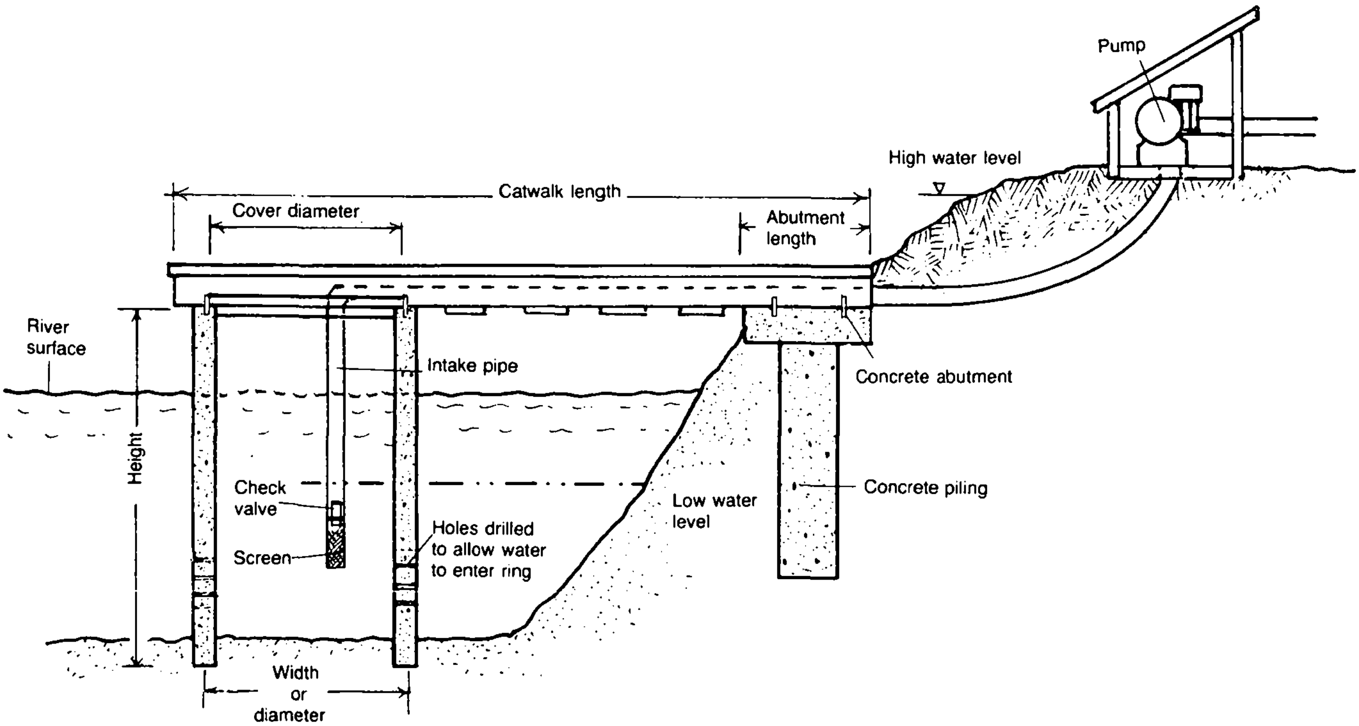

Figure 9. Direct Intake

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

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

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

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

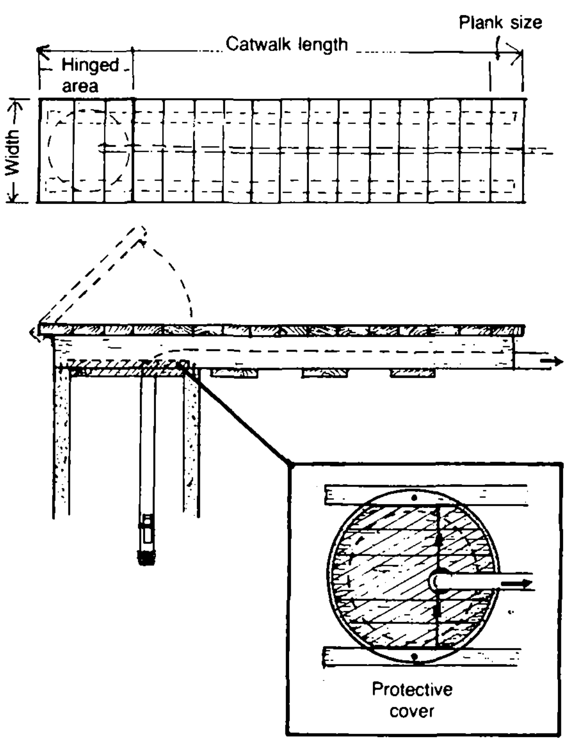

Figure 10. Catwalk and Cover Design

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Worksheet B. Volume of a Concrete Ring

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

a) Area = diameter^2

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

$$A = .785 \times 2.25$$

$$A = 1.76m^2$$

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

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

$$V = 0.176cm^3$$

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

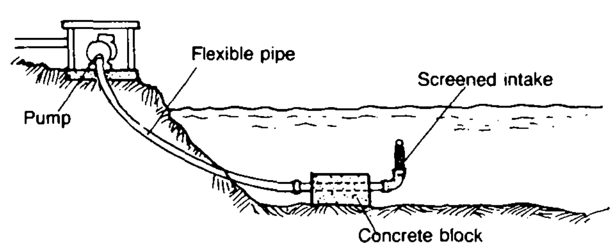

Figure 11. Simple Permanent Intake

Notes

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Water for the World

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

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

Useful Definition

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

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

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

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

Annual Rainfall

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

Table 1. Sample Materials List

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

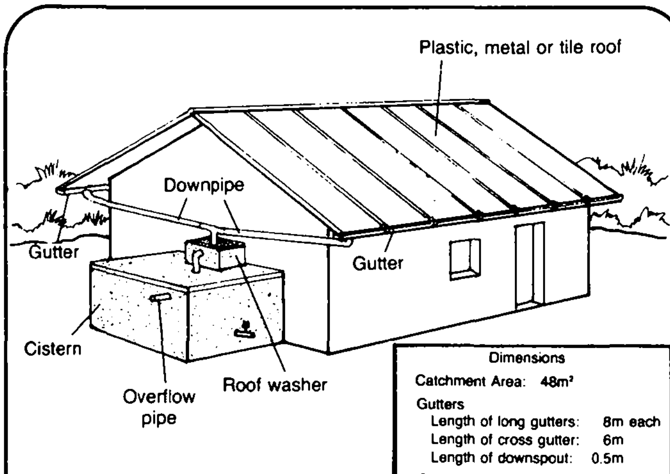

Figure 1. Roof Catchment

Catchment Areas

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

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

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

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

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

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

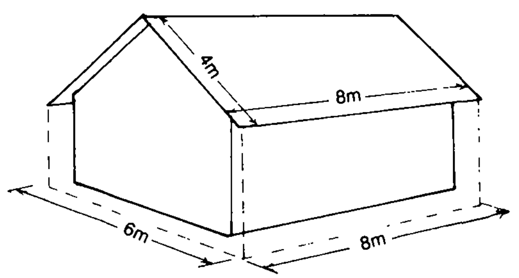

Figure 2. Roof Catchment Area

Worksheet A. Volume of Water Available from a Roof Catchment

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

1. Multiply annual rainfall by the catchment area.

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

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

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

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

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

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

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

Gutters

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

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

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

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

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

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

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

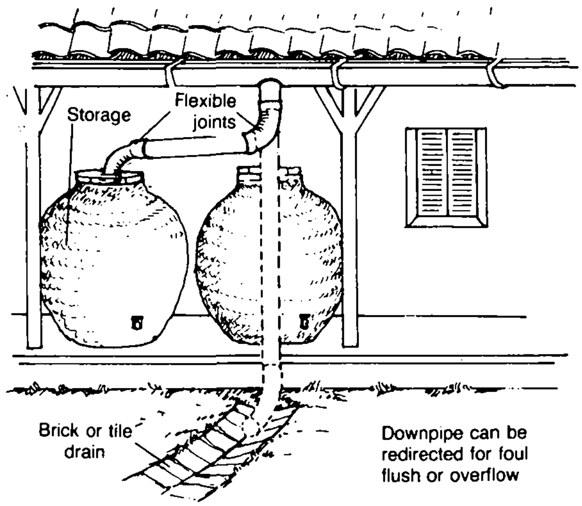

Figure 3. Flexible Downpipe

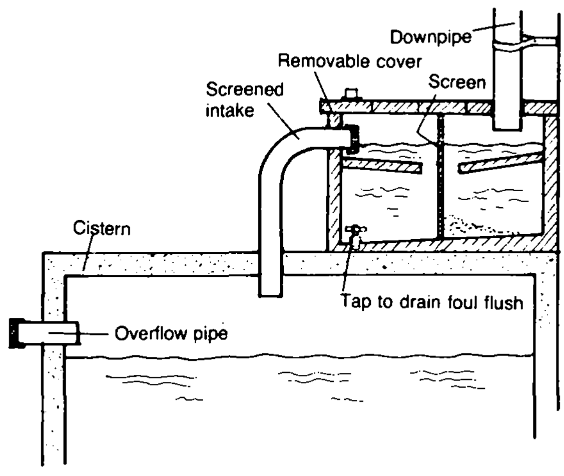

Figure 4. Foul Flush Box

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

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

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

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

Cisterns

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

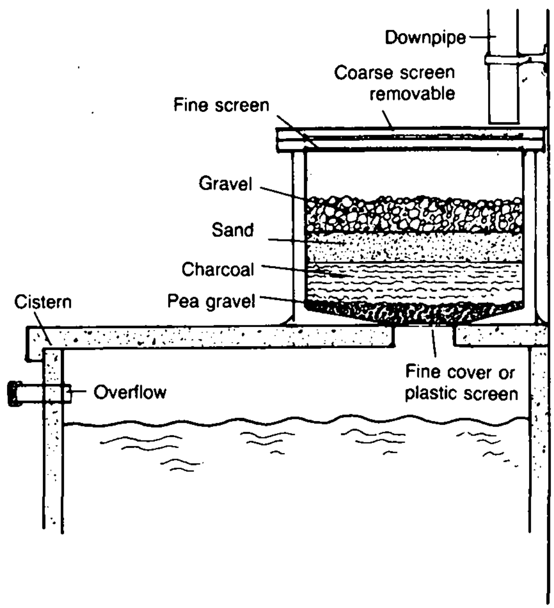

Figure 5. Filter System

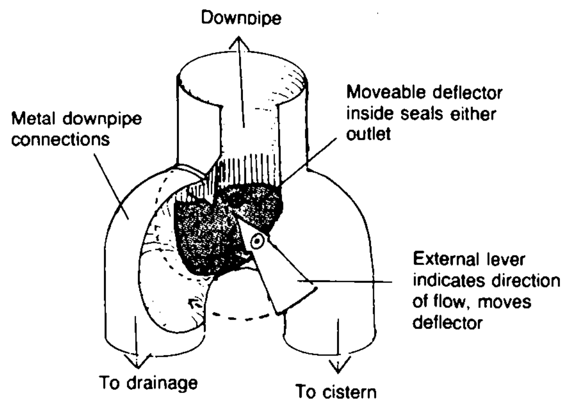

Figure 6. Roof Washer Device in Downpipe

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	Wire screen	___	___
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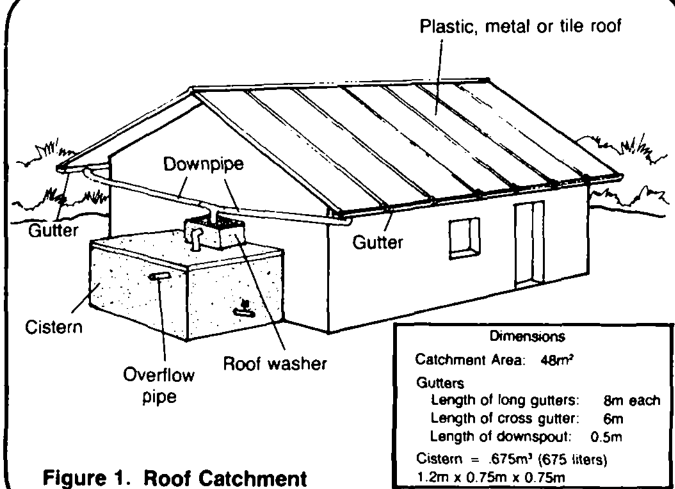
	Machete (to split bamboo)	___	___
	Wire cutters	___	___
	Saw	___	___
	Chisel	___	___



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

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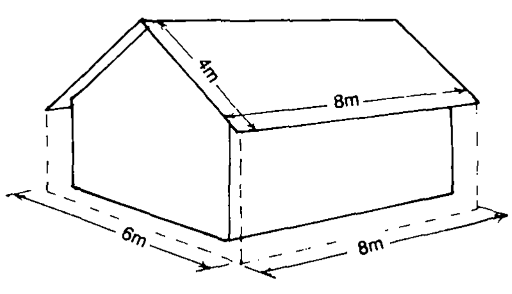

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$\frac{\text{2560 liters/month}}{\text{30 days/month}} = \underline{85}$ liters/day.

Gutters

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

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

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

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

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

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

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

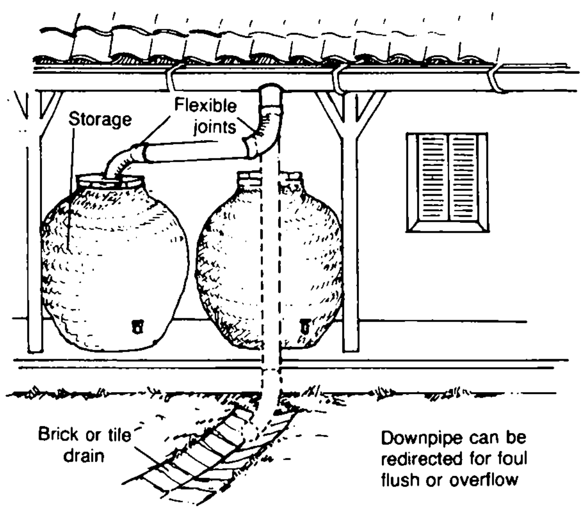

Figure 3. Flexible Downpipe

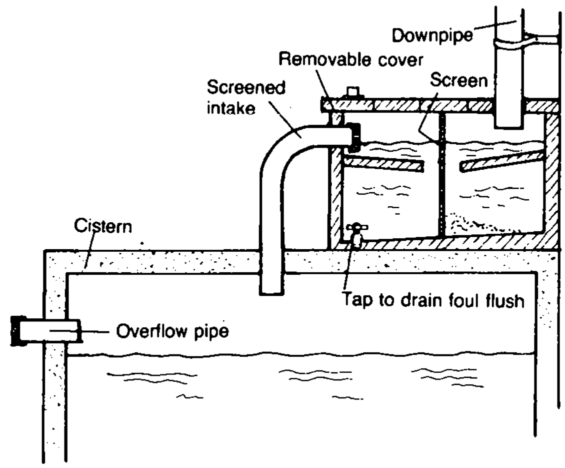

Figure 4. Foul Flush Box

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

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

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

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

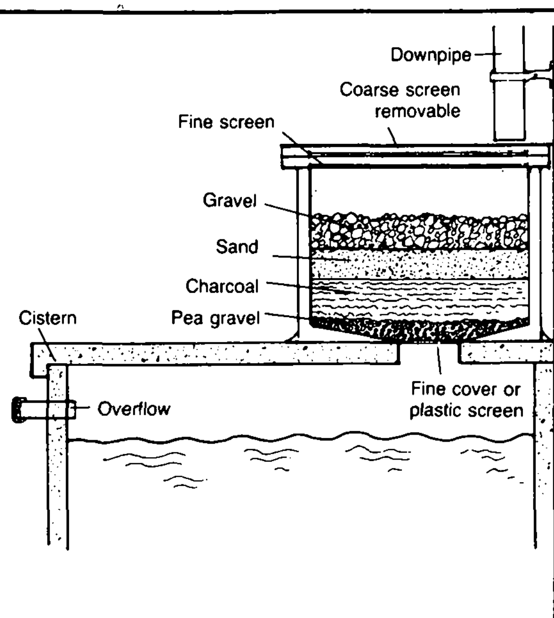

Figure 5. Filter System

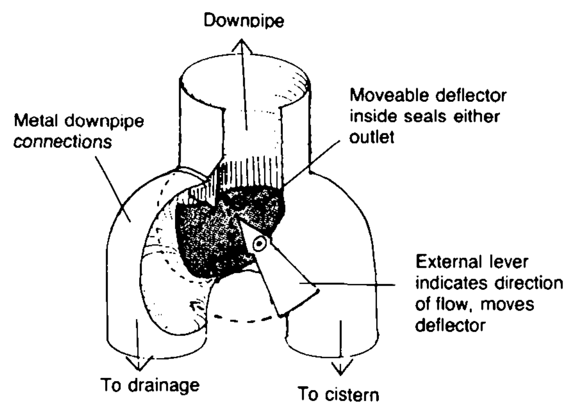

Figure 6. Roof Washer Device in Downpipe

Cisterns

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

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

1982

Water for the World

Designing Small Dams
Technical Note No. RWS. 1.D.5

Dams can be built across small streams and rivers to back up the flow of water and create a reservoir for a community water supply. Water from a reservoir is used by installing intakes and pumping the water to the community. (See "Designing Intakes for Ponds, Lakes and Reservoirs," RWS.1.D.2). Dams are generally made from concrete, reinforced concrete, masonry or earth.

The design of concrete and masonry dams is complex and should only be attempted by an engineering expert with experience in the design of dams. The design of small earthen dams is simpler and their construction is much easier. This technical note outlines the steps that must be taken to design small earth dams: (a) location of a suitable site, (b) design of the dam embankment and (c) design of the spillway.

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

1. A survey map of the area including the exact location of the dam. Figure 1 shows the type of location map that should be prepared.

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

3. A detailed plan of the dam and related structures with all dimensions similar to that shown in Figure 2.

Useful Definitions

BASALT - A dark heavy volcanic rock.

CREST - The highest point or level top of a dam.

EROSION - The wearing away of soil, rock or other material by the flow of water.

EVAPORATION - Loss of water to the air as heat changes it from liquid form to vapor.

FREEBOARD - The height added to a dam as a safety factor to prevent waves or run-off caused by storms from overtopping the embankment.

OVERTOPPING - Water flowing over the crest of a dam due to inadequate spillways.

PERCOLATION - Movement of water downward through the pores of the soil.

RIP-RAP - Blanket foundation or wall made of large stones thrown together irregularly or loosely.

SEEPAGE - Water leaking from the ground or a dam embankment.

SILT - Sediment made up of fine particles carried or laid down by moving water.

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

Location of a Site

The first step in designing a dam is choosing an appropriate site. See Figure 3. The choice of a site depends on six factors:

1. There must be enough water to fill the reservoir.

2. The reservoir must store the maximum amount of water behind the smallest feasible dam.

3. A sound foundation for the dam and an impervious reservoir must be available.

4. The stored water must be as free from sources of contamination as possible.

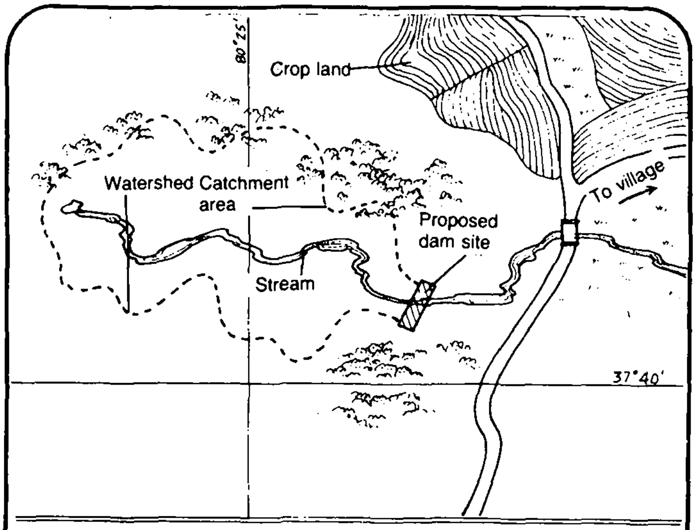

Figure 1. Dam Location Map

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	___ ___	___ ___
Supplies	Clay soil Flat rocks Grass seed Stakes Rope	___ ___ ___ ___ ___	___ ___ ___ ___ ___
Tools	Surveying equipment Digging tools A small tractor or backhoe (if possible) Soil compaction device Levels Earth moving equipment	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___

Total Estimated Cost = ____

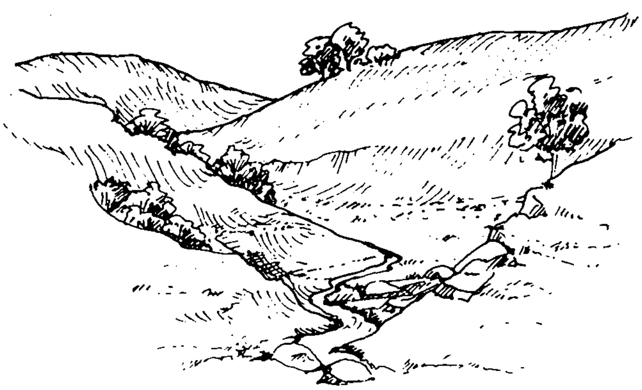

Figure 3. Appropriate Dam Site

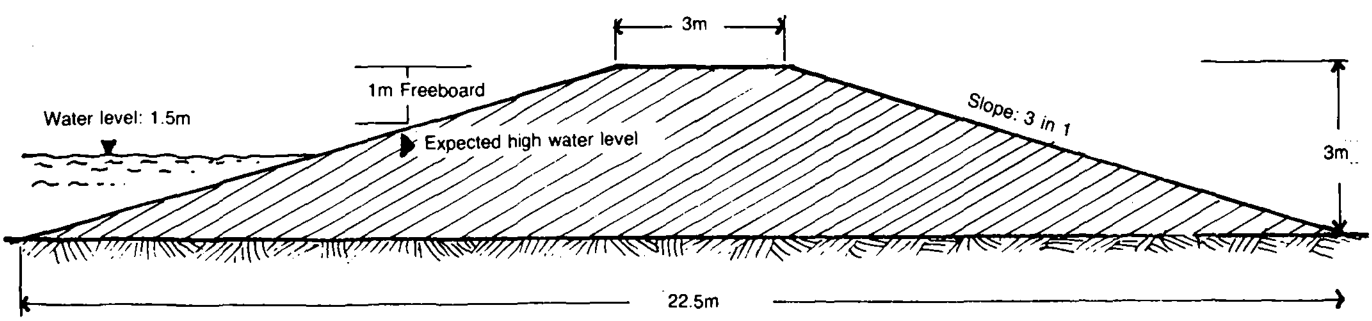

Figure 2. Clay Dam Embankment

Caution!

The proper design and construction of a dam requires some engineering and geological knowledge. No dam holding more than about a 3.0m depth of water should be attempted by anyone without qualified advice, and even smaller dams should be constructed only with technical advice.

Failure of a dam can cause tremendous damage. The most common causes of failure are:

Overtopping or the flowing of water over the top of the dam due to inadequate spillways.

Undermining, the flowing of water below the embankment.

Fissures and cracks caused by the use of poorly compacted material.

Percolation along tree roots that have not been properly removed.

Erosion which is caused by heavy rains.

A dam may not wash away but there are other factors which contribute to the failure of a dam. If the catchment area above the dam is inadequate, it will not fill. If the soil in the catchment area is porous, water will soak into the ground. A stream that contains suspended matter may silt up the dam unless silt traps are built. Further, if allowance for evaporation is not made, the reservoir may dry up during the dry season.

Be sure to consider all these factors when attempting to design a dam. Failure to do so may cause failure of the project, loss of money and possibly even destruction of surrounding areas.

5. The reservoir must be easily accessible to the users.

6. Needed construction materials must be close to the site.

The amount of water available to the reservoir depends on the amount of rainfall, the size of the catchment area or watershed, and the soil conditions. The best catchment area is one with steep, rocky slopes where the rain runs down to the reservoir quickly. In this type of watershed, water is not lost through seepage or evaporation. Special attention must be given to the danger of flooding, however. Another excellent catchment area is one where a thin layer of pervious soil overlays impervious rock. The rainfall seeps through the pervious layer and flows downhill over the rock to form springs lower in the valley. The springs then feed the reservoir. The advantage of this type of catchment is that water flowing underground does not evaporate, is not easily contaminated, and flows out slowly. The amount of water available can be increased by planting trees. Trees slow down run-off but allow water to percolate downwards. Trees planted on steep, rocky hillsides will help prevent possible flooding.

Determining the amount of run-off available from a catchment area requires very specific information about soil types, rainfall, land slopes and other factors. Very complicated mathematical formulas must be used. Worksheet A shows how to determine the quantity of water from a catchment area. The size of the catchment area is best estimated by using a map of the area. A general rule for estimation is that the catchment area is at least 15 times the area of the reservoir formed by the dam. The average catchment area drains about 1000 liters of water for every millimeter of rainfall on a hectare. This figure represents 10 percent of the total rainfall.

Worksheet A. Quantity of Water Available from a Catchment Area	
Area of watershed in hectares	5
Area in meters (5 hectares x 100m x 100m)	50000 m^2
Amount of annual rainfall	700 mm
Volume of rainfall (area in m^2 x rainfall = 50000 m^2 x 700 mm)	35000000 liters
Volume of available water = 10% x total volume of rainfall (0.10 x 35000000 liters)	3500000 liters

The volume of water to be stored can be determined by finding the area of the reservoir and multiplying it first by the average depth of water in the reservoir and then by 80 percent to take into account losses due to evaporation, percolation and transpiration. The area of the reservoir is found by multiplying the length of the reservoir (length of the dam) by the upstream distance. The upstream distance is found by using a hand level and finding a point upstream that is level with the top of the dam. The distance from that point to the top of the dam is the upstream distance. Use the formula Volume = upstream distance x length x average depth x 80 percent to find the volume of stored water. The reservoir should be at least 2m deep at the deepest point. To get the average depth, multiply the greatest depth by 0.4. Figure 4 shows the sample dimensions.

The total volume is multiplied by 80 percent to allow for evaporation and percolation. Evaporation rates vary with climate and wind conditions. In very hot climates and where ponds are unprotected from the wind, evaporation rates are high. Percolation rates depend on the type of soil forming the reservoir floor. These soils should be as impervious as possible.

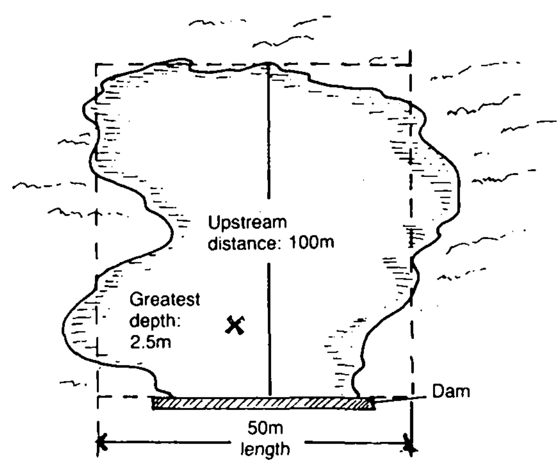

Figure 4. Determining Water Volume

Generally, losses from percolation decrease in time as the reservoir floor is sealed with sediment settling out of the water.

If the reservoir and catchment areas provide sufficient water, then the best location for the dam must be determined. The most economical site is a steep-sided valley where the dam will be shorter and easier to build. The storage capacity is good in this type of location because the water backs up a long way behind the dam. A very good site is where a broad valley suddenly narrows. The dam will not be too long and the valley will provide good storage.

Other geological conditions are important. The site must have a solid foundation. The foundation must provide stable support for the embankment and sufficient resistance to seepage. Granite or basalt beds extending across a valley and thick layers of silty or sandy clay make good dam foundations. The best foundation is a thick layer of impervious material.

The suitability of a reservoir site depends on the ability of the soil to hold water. Soil must be impervious enough to prevent high seepage losses. Clays and silty clays generally are the best soils for a reservoir.

When choosing the most appropriate site, keep in mind the need to avoid contamination. By building the dam above inhabitated areas, the problem of contamination by people is reduced.

Design of the Dam Embankment

Once a suitable site is located, design of the dam embankment can proceed. The major design considerations are the foundation and foundation cut-offs, the embankment side slopes, the top and bottom widths, the freeboard, and the quantity and quality of material to be used in construction.

The best foundation is a thick layer of stable, impervious material. If a suitable layer is found at the surface, no special measures are required. Top soil should be removed and the foundation surface loosened to improve the bond between the foundation and the embankment. If a foundation is pervious material at or near the surface with rock or impervious material at a greater depth, seepage through the pervious layer may occur and must be controlled. For large dams a cut-off joining the impervious layer in the foundation to the base of the dam is needed. Figure 5 shows one example of a typical cut-off trench. A trench is dug parallel to the centerline of the dam into the impervious layer. The trench should have a bottom width of at least 1.2m. The sides should be no steeper than 1:1. The trench should be filled with thin layers of clay soil and compacted.

The slope of the sides of the dam depends on the stability of the material in the embankment. If the fill material is stable, the side can have steeper slopes. Table 2 shows maximum slopes for upstream and downstream faces of a dam built from different fill materials. For safety's sake, especially when dams are being built by people with little experience, the slopes should be at least 3:1 and possibly even 4:1.

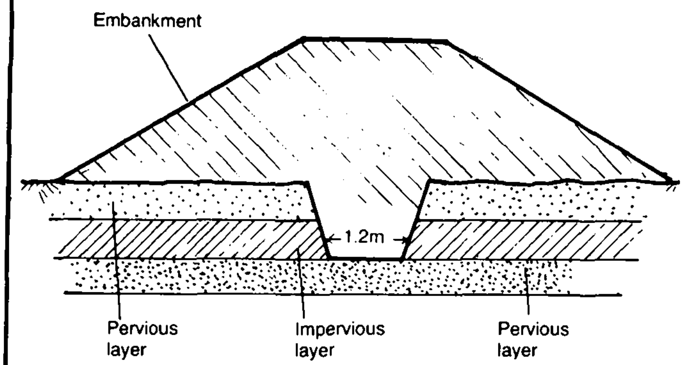

Figure 5. Cut-off Trench in Dam Embankment

Table 2. Side Slopes for Earth Embankments

Fill Material	Side Slopes* Horizontal to Vertical Upstream	Downstream
Clay, Clayey sand, Sandy clay, Silty sand	3:1-3.5:1	2.5:1-3:1
Silty clay, Clayey gravel, Silty gravel	3:1-3.5:1	2.5:1-3:1
Silt or Clayey silt	3.5:1-4:1	3:1-3.5:1

* A 3:1 slope means 3m horizontal distance for every 1m in height.

Each dam has a flat section at the top. The width of this top section depends on the height of the dam. Table 3 shows the relationship between the height of the dam and the width of the top section.

Table 3. Top Widths for Earth Embankments

Height of Dam	Top Width
Under 3m	2.5m
3-4.5m	3.0m
4.5-6m	3.5m
6-7.5m	4.0m

The height of the dam depends on the freeboard. Freeboard is the height added to the dam to prevent waves or heavy run-off from flowing over it. Freeboard is the vertical distance between the top of the dam and the water surface in the reservoir at flood level. Generally, the freeboard height should be at least 0.9m above the flood level of the water. For added safety, the freeboard should be at least 1.5m above the flood level.

The dimensions of the entire dam embankment can be determined by using the following formulas:

Height of the dam = Depth of water at deepest point + maximum depth at flood level + height of freeboard.

Width of the base = (Height of the dam x downstream slope) + (height of dam x upstream slope) + (width of the top). For example, consider a clay dam with a reservoir with the dimensions shown in Worksheet B. Assume a depth for flood channels of 0.5m, a freeboard of 1m, and a top width of 3m. Worksheet B shows how to determine the dimensions of the embankment. Figure 2 shows a dam embankment with the dimensions from Worksheet B.

Worksheet B. Determining Embankment Dimensions

1. Maximum depth of reservoir	1.5 m
2. Maximum depth of flood channels	0.5 m
3. Height of freeboard	1.0 m
4. Total height of dam (sum of 1, 2, 3)	3.0 m
5. Width of top (See Table 3)	3 m
6. Upstream slope	3.5:1
7. Downstream slope	3:1
8. Width of base = 3.0 (height) x 3.5 (upstream slope) + 3.0 (height x 3 (downstream slope) + 3m (width of top) =	22.5m

Knowing the embankment slopes, the width of the top, and the height of the dam, it is possible to determine the volume of fill needed for the embankment by using the sum of the areas method shown in Table 4. Determine the height of fill at any level along the dam and find this number in the left hand column. Then, find the side slope column with the slopes corresponding to the dam. Move down the column until you are across from the fill height you are using. This number is the area that corresponds to the fill height at slope sides are 3.5:1, 3:1 and fill height is 3.0m, the area is 32m^2. Add to this the number in the column under the appropriate top width for the fill height you are using. If the dam has a top width of 3m, the number corresponding to a 3.0m fill is 9.0m^2. The total end area is 32m^2 + 9.0m^2 = 41.0m^2.

The volume of earth fill is the sum of volumes for several cross-sectional areas. Figure 6 and Table 5 should be used for reference. Figure 6 is a profile of a dam embankment 22.5m long with a 3m top width. Eight stations or cross-sectional areas are shown. Each is located at a different distance from the other and each has a different fill height. To find the fill height at each station, look to the scale at the right. Then locate the end area of the cross-section by using Table 4 and adding together the area under the slope column and the area under the width column. Add all the cross-sectional areas together to get the total area. The volume of each cross-section is determined by multiplying the area of the cross-section by the length of each section (the distance between each station). For total volume, add all the volumes together and divide by two. This process is shown in Table 5. The total is divided by two because the calculated volume is twice as big as the volume desired.

Table 4. End Area Table for Embankment Sections for Various Side Slopes and Top Widths

Fill Height (m)	Side Slopes (Upstream Slope / Downstream Slope)					Top Width				
	2.5:1 / 2.5:1	2.5:1 / 3:1	3:1 / 3:1	3.5:1 / 3.5:1	4:1 / 4:1	2m	2.5m	3m	3.5m	4m
	2:1 / 3:1	2:1 / 3.5:1	2.5:1 / 3.5:1	3:1 / 4:1	3:1 / 5:1					
1.0	$3m^2$	$3m^2$	$3m^2$	$4m^2$	$4m^2$	$2m^2$	$2.5m^2$	$3m^2$	$3.5m^2$	$4m^2$
1.2	4	4	4	5	6	2.4	3.0	3.6	4.2	4.8
1.4	5	5	6	7	8	2.8	3.5	4.2	4.9	5.6
1.6	6	7	8	9	10	3.2	4.0	4.8	5.6	6.4
1.8	8	9	10	11	13	3.6	4.5	5.4	6.3	7.2
2.0	10	11	12	14	16	4.0	5.0	6.0	7.0	8.0
2.2	12	13	15	17	19	4.4	5.5	6.6	7.7	8.8
2.4	14	16	17	20	23	4.8	6.0	7.2	8.4	9.6
2.6	17	19	20	24	27	5.2	6.5	7.8	9.1	10.4
2.8	20	22	23	27	31	5.6	7.0	8.4	9.8	11.2
3.0	22	25	27	32	36	6.0	7.5	9.0	10.5	12.0
3.2	26	28	31	36	41	6.4	8.0	9.6	11.2	12.8
3.4	29	32	35	40	46	6.8	8.5	10.2	11.9	13.6
3.6	32	36	39	45	52	7.2	9.0	10.8	12.6	14.1
3.8	36	40	43	50	58	7.6	9.5	11.4	13.3	15.2
4.0	40	44	48	56	64	8.0	10.0	12.0	14.0	16.0

(NOTE: To find the end area for any fill height, add square meter found under "side slopes" column to that under "top width" column. Example: If a dam at a fill height of 3.0m has a 3.5:1 upstream slope, 3:1 downstream slope and a top width of 3m, the end area is: $32m^2 + 9m^2 = 41.0m^2$.)

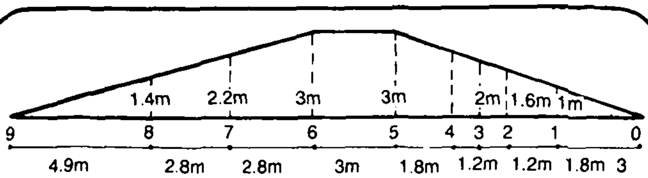

Figure 6. Determining Volume of Fill in Dam Embankment

In the example shown in Table 5, a dam with a base 22.5m long, a top width of 3m, a height of 30m, and 3.5:1 and 3:1 slopes requires $426.4m^3$ of earth backfill. To allow for a 5 percent loss from settlement, add $21.32m^3$ to the total. The final total volume is $447.72m^3$.

When backfilling the dam, keep in mind that the material used should be of uniform quality. If there are

Table 5. Sample Volume of Embankment in Figure 6 Using Sum of Area Method

Station	Fill Height	End Area (from Table 4)	Sum of Areas	Distance	Double Volume = Distance x Sum of Areas
0	0m	0m	---	---	---
1	1.0m	$7m^2$	$7m^2$ (STA 0 + 1)	3m	$21m^3$
2	1.6m	$12.8m^2$	$19.8m^2$ (STA 1 + 2)	1.8m	$35.64m^3$
3	2.0m	$20m^2$	$32.8m^2$ (STA 2 + 3)	1.2m	$39.36m^3$
4	2.4m	$27.2m^2$	$47.2m^2$ (STA 3 + 4)	1.2m	$56.64m^3$
5	3.0m	$41.0m^2$	$67.2m^2$ (STA 4 + 5)	1.8m	$120.96m^3$
6	3.0m	$41.0m^2$	$82.0m^2$ (STA 5 + 6)	3.0m	$246m^3$
7	2.2m	$23.6m^2$	$64.6m^2$ (STA 6 + 7)	2.8m	$180.88m^3$
8	1.4m	$11.2m^2$	$34.8m^2$ (STA 7 + 8)	2.8m	$97.44m^3$
9	0m	0	$11.2m^2$	4.9m	$54.88m^3$
				Total Volume	$852.8m^3$

(NOTE: Divide double volume by two to get volume of fill in embankment.)

$$\frac{852.8m^3}{2} = 426.4m^3$$

Allowance of 5 percent for settlement + 21.32

Total 447.72m3

doubts about the porosity of any of the soil, it should be placed on the downslope side. The best type of soil is clay material containing some silt or sand. If only clay is used, it may crack when dry or slip when wet. Be careful that there is not too much sand in the material. If too much sand is present, water may percolate through. To ensure the strength of the dam, the earth fill must be well compacted. If not, leakage is likely to occur and failure of the dam is possible. Figure 7 shows a way that the earth can be compacted manually. The log must be raised up and down to pound the soil. Compaction done this way is a very slow process but must be done in the absence of other methods.

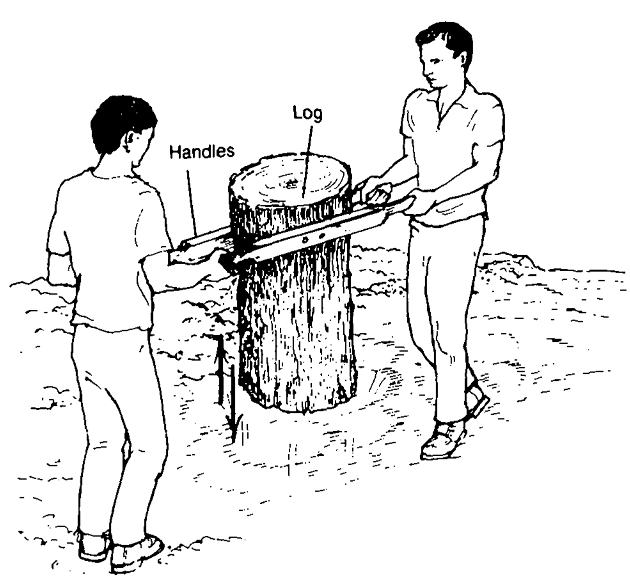

Figure 7. Manually Compacting Soil

Design of a Drain

Before the construction of the dam begins, a large diameter pipe should be placed in the stream bed as shown in Figure 8. The water flow is channeled into this pipe and carried further downstream. In this way, the construction area stays dry without the need for digging a long diversion ditch.

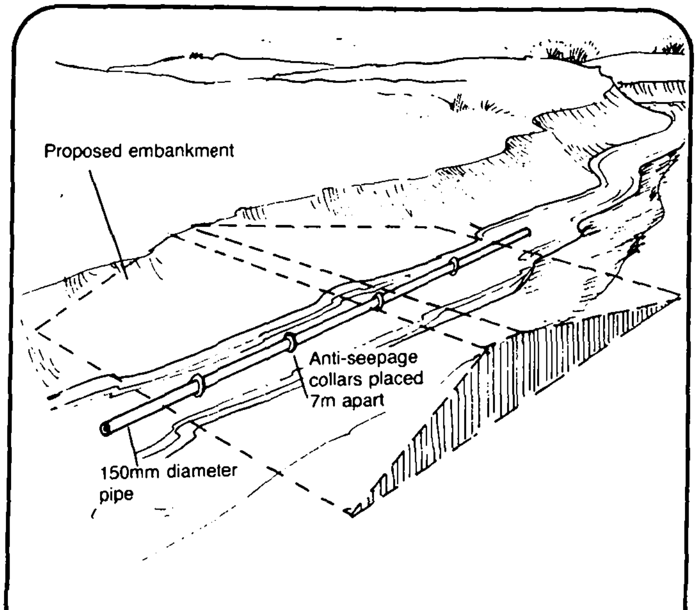

Figure 8. Installation of Drain Pipe in Stream Bed

The pipe serves a further purpose. The pipe, with anti-seepage collars attached, remains in place during the construction of the embankment. Therefore, once the embankment is completed, a drain pipe passing from the reservoir through the dam to the downstream side of the dam is in place. On the downstream side, a cut-off valve is placed on the pipe. In times of heavy rain or flooding, the valve can be opened to drain the reservoir and prevent overtopping. The drain pipe is very important in preventing dam failure.

Design of the Spillway

Water must never be allowed to spill over the top of an earth dam. To prevent overtopping, spillways are built to channel the flood water away. They must be built clear of the dam in solid ground. Often, two spillways are built. One is located lower for regular overflow, the other higher for safety during times of abnormal flooding. Spillway channels should be continued downstream away from the downstream edge of the base in order to prevent erosion of the dam by flood water. Figure 9 shows an example of a dam and spillway design.

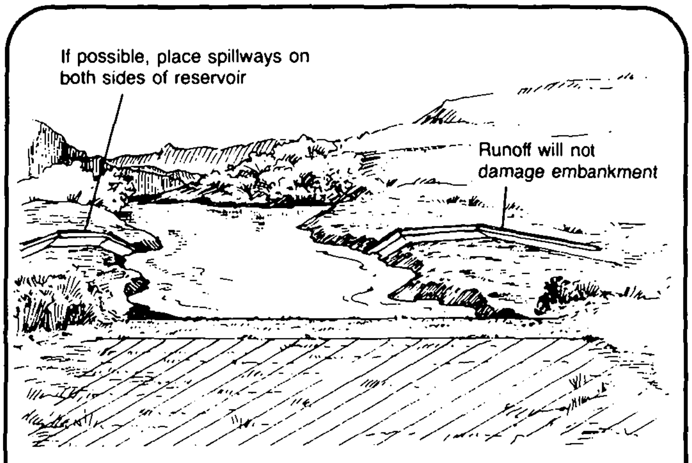

Figure 9. Locating Spillways

Calculate the spillway size by obtaining local information and making a good guess. Find out how high the stream rises at the wettest time of the year and estimate the width of a similar stream running 60cm deep. Allow for extra width according to whether last year was dry, wet or average and then double the amount to allow for a heavy storm. This is the minimum size of the spillway. If there are doubts, widen the spillway.

There are three sections to the spillway as shown in Figure 10. These are the approach channel, control section, and exit channel. The flow enters the spillway through the approach channel. It should be short with smooth easy curves. It should have a slope toward the reservoir of not less than two percent to ensure drainage. The width of the spillway is the same as the width of the channel in the control section (the high, flat section in line with the crest of the dam). This section should be lined with stone or concrete to prevent erosion. The channel should widen a little below the crest to prevent flood water from backing up.

The first part of the exit channel should have a fairly steep slope to move water away from the crest rapidly. It may be necessary to line this section with rough stone. Further downstream, the channel should flatten and move the overflow far away from the dam.

Other Design Considerations

Rainfall and waves in the reservoir cause dam erosion. Rain that falls on

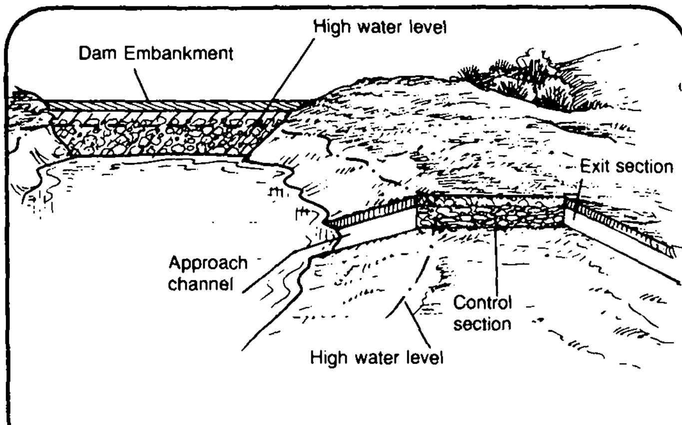

Figure 10. Design of Spillway

the dam crest, on the entire downstream slope, or on the upstream slope above water level will cause damage to the dam. The best way to prevent erosion is to plant a suitable type of creeping grass. The grass should be planted in horizontal rows in top soil mixed with manure.

On the upstream side, the dam should be paved or lined with stone to a height of 0.6m above water level. Riprap walls will help prevent erosion from waves in the reservoir.

Summary

The design of a dam is not easy and generally requires engineering skill. A poorly designed dam may break down or wash away and cause great damage to property and lives. The most common causes of failure are overtopping, undermining caused by water flowing below the embankment, fissures caused by shrinkage or badly compacted materials, percolation along tree roots that have not been cleared from the site, and weaknesses from erosion of the dam by rainfall and wave action. To avoid all these problems, much care and effort must go into the design of the dam.

A well-designed dam will provide a good source of water for a small community. Before deciding to build a dam, however, always be sure that a suitable site exists, that construction materials are available, and that the water can reach the users easily and less expensively than through another method. If these criteria are met, a successful dam project can be developed.

Notes

Notes

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

1982

Water for the World

Designing Small Dams
Technical Note No. RWS. 1.D.5

Dams can be built across small streams and rivers to back up the flow of water and create a reservoir for a community water supply. Water from a reservoir is used by installing intakes and pumping the water to the community. (See "Designing Intakes for Ponds, Lakes and Reservoirs," RWS.1.D.2). Dams are generally made from concrete, reinforced concrete, masonry or earth.

The design of concrete and masonry dams is complex and should only be attempted by an engineering expert with experience in the design of dams. The design of small earthen dams is simpler and their construction is much easier. This technical note outlines the steps that must be taken to design small earth dams: (a) location of a suitable site, (b) design of the dam embankment and (c) design of the spillway.

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

1. A survey map of the area including the exact location of the dam. Figure 1 shows the type of location map that should be prepared.

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

3. A detailed plan of the dam and related structures with all dimensions similar to that shown in Figure 2.

Useful Definitions

BASALT - A dark heavy volcanic rock.

CREST - The highest point or level top of a dam.

EROSION - The wearing away of soil, rock or other material by the flow of water.

EVAPORATION - Loss of water to the air as heat changes it from liquid form to vapor.

FREEBOARD - The height added to a dam as a safety factor to prevent waves or run-off caused by storms from overtopping the embankment.

OVERTOPPING - Water flowing over the crest of a dam due to inadequate spillways.

PERCOLATION - Movement of water downward through the pores of the soil.

RIP-RAP - Blanket foundation or wall made of large stones thrown together irregularly or loosely.

SEEPAGE - Water leaking from the ground or a dam embankment.

SILT - Sediment made up of fine particles carried or laid down by moving water.

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

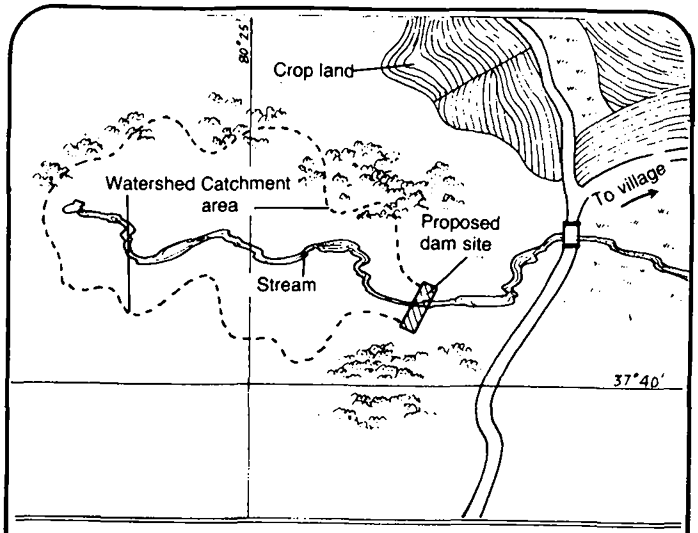

Figure 1. Dam Location Map

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Clay soil Flat rocks Grass seed Stakes Rope	____ ____ ____ ____ ____	____ ____ ____ ____ ____
Tools	Surveying equipment Digging tools A small tractor or backhoe (if possible) Soil compaction device Levels Earth moving equipment	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____

Total Estimated Cost = ____

Location of a Site

The first step in designing a dam is choosing an appropriate site. See Figure 3. The choice of a site depends on six factors:

1. There must be enough water to fill the reservoir.

2. The reservoir must store the maximum amount of water behind the smallest feasible dam.

3. A sound foundation for the dam and an impervious reservoir must be available.

4. The stored water must be as free from sources of contamination as possible.

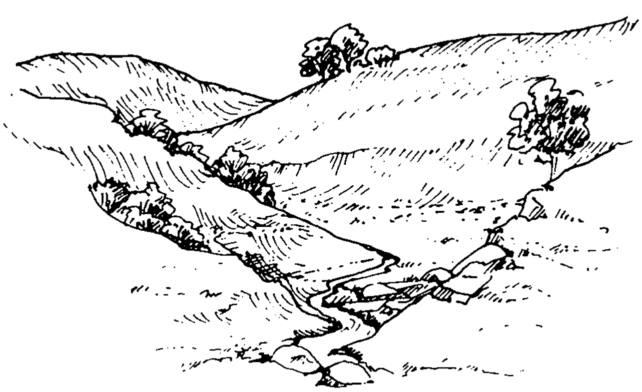

Figure 3. Appropriate Dam Site

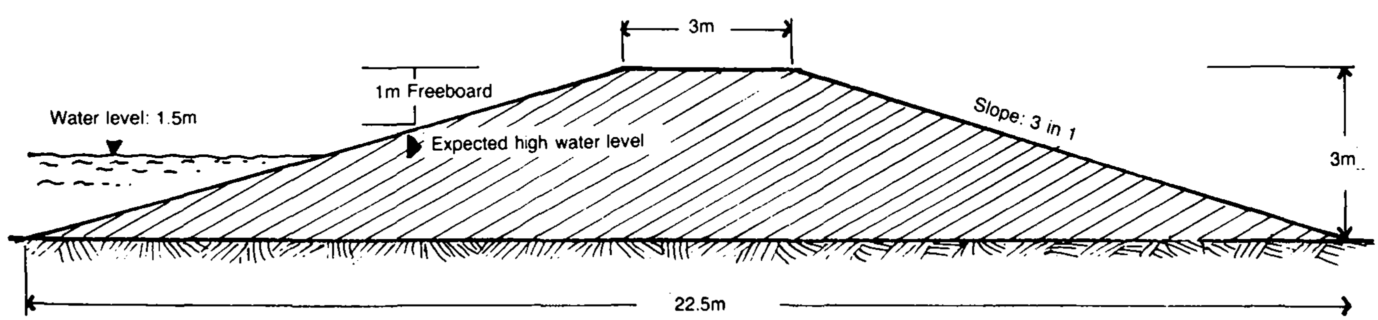

Figure 2. Clay Dam Embankment

Caution!

The proper design and construction of a dam requires some engineering and geological knowledge. No dam holding more than about a 3.0m depth of water should be attempted by anyone without qualified advice, and even smaller dams should be constructed only with technical advice.

Failure of a dam can cause tremendous damage. The most common causes of failure are:

Overtopping or the flowing of water over the top of the dam due to inadequate spillways.

Undermining, the flowing of water below the embankment.

Fissures and cracks caused by the use of poorly compacted material.

Percolation along tree roots that have not been properly removed.

Erosion which is caused by heavy rains.

A dam may not wash away but there are other factors which contribute to the failure of a dam. If the catchment area above the dam is inadequate, it will not fill. If the soil in the catchment area is porous, water will soak into the ground. A stream that contains suspended matter may silt up the dam unless silt traps are built. Further, if allowance for evaporation is not made, the reservoir may dry up during the dry season.

Be sure to consider all these factors when attempting to design a dam. Failure to do so may cause failure of the project, loss of money and possibly even destruction of surrounding areas.

5. The reservoir must be easily accessible to the users.

6. Needed construction materials must be close to the site.

The amount of water available to the reservoir depends on the amount of rainfall, the size of the catchment area or watershed, and the soil conditions. The best catchment area is one with steep, rocky slopes where the rain runs down to the reservoir quickly. In this type of watershed, water is not lost through seepage or evaporation. Special attention must be given to the danger of flooding, however. Another excellent catchment area is one where a thin layer of pervious soil overlays impervious rock. The rainfall seeps through the pervious layer and flows downhill over the rock to form springs lower in the valley. The springs then feed the reservoir. The advantage of this type of catchment is that water flowing underground does not evaporate, is not easily contaminated, and flows out slowly. The amount of water available can be increased by planting trees. Trees slow down run-off but allow water to percolate downwards. Trees planted on steep, rocky hillsides will help prevent possible flooding.

Determining the amount of run-off available from a catchment area requires very specific information about soil types, rainfall, land slopes and other factors. Very complicated mathematical formulas must be used. Worksheet A shows how to determine the quantity of water from a catchment area. The size of the catchment area is best estimated by using a map of the area. A general rule for estimation is that the catchment area is at least 15 times the area of the reservoir formed by the dam. The average catchment area drains about 1000 liters of water for every millimeter of rainfall on a hectare. This figure represents 10 percent of the total rainfall.

Worksheet A. Quantity of Water Available from a Catchment Area

Area of watershed in hectares	5
Area in meters (5 hectares x 100m x 100m)	50000 m^2
Amount of annual rainfall	700 mm
Volume of rainfall (area in m^2 x rainfall = 50000 m^2 x 700 mm)	35000000 liters
Volume of available water = 10% x total volume of rainfall (0.10 x 35000000 liters)	3500000 liters

The volume of water to be stored can be determined by finding the area of the reservoir and multiplying it first by the average depth of water in the reservoir and then by 80 percent to take into account losses due to evaporation, percolation and transpiration. The area of the reservoir is found by multiplying the length of the reservoir (length of the dam) by the upstream distance. The upstream distance is found by using a hand level and finding a point upstream that is level with the top of the dam. The distance from that point to the top of the dam is the upstream distance. Use the formula Volume = upstream distance x length x average depth x 80 percent to find the volume of stored water. The reservoir should be at least 2m deep at the deepest point. To get the average depth, multiply the greatest depth by 0.4. Figure 4 shows the sample dimensions.

The total volume is multiplied by 80 percent to allow for evaporation and percolation. Evaporation rates vary with climate and wind conditions. In very hot climates and where ponds are unprotected from the wind, evaporation rates are high. Percolation rates depend on the type of soil forming the reservoir floor. These soils should be as impervious as possible.

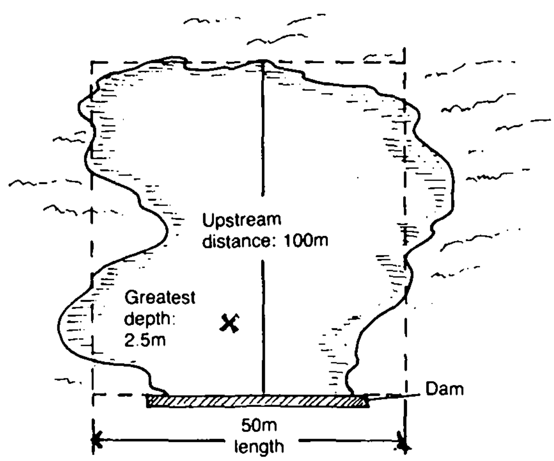

Figure 4. Determining Water Volume

Generally, losses from percolation decrease in time as the reservoir floor is sealed with sediment settling out of the water.

If the reservoir and catchment areas provide sufficient water, then the best location for the dam must be determined. The most economical site is a steep-sided valley where the dam will be shorter and easier to build. The storage capacity is good in this type of location because the water backs up a long way behind the dam. A very good site is where a broad valley suddenly narrows. The dam will not be too long and the valley will provide good storage.

Other geological conditions are important. The site must have a solid foundation. The foundation must provide stable support for the embankment and sufficient resistance to seepage. Granite or basalt beds extending across a valley and thick layers of silty or sandy clay make good dam foundations. The best foundation is a thick layer of impervious material.

The suitability of a reservoir site depends on the ability of the soil to hold water. Soil must be impervious enough to prevent high seepage losses. Clays and silty clays generally are the best soils for a reservoir.

When choosing the most appropriate site, keep in mind the need to avoid contamination. By building the dam above inhabitated areas, the problem of contamination by people is reduced.

Design of the Dam Embankment

Once a suitable site is located, design of the dam embankment can proceed. The major design considerations are the foundation and foundation cut-offs, the embankment side slopes, the top and bottom widths, the freeboard, and the quantity and quality of material to be used in construction.

The best foundation is a thick layer of stable, impervious material. If a suitable layer is found at the surface, no special measures are required. Top soil should be removed and the foundation surface loosened to improve the bond between the foundation and the embankment. If a foundation is pervious material at or near the surface with rock or impervious material at a greater depth, seepage through the pervious layer may occur and must be controlled. For large dams a cut-off joining the impervious layer in the foundation to the base of the dam is needed. Figure 5 shows one example of a typical cut-off trench. A trench is dug parallel to the centerline of the dam into the impervious layer. The trench should have a bottom width of at least 1.2m. The sides should be no steeper than 1:1. The trench should be filled with thin layers of clay soil and compacted.

The slope of the sides of the dam depends on the stability of the material in the embankment. If the fill material is stable, the side can have steeper slopes. Table 2 shows maximum slopes for upstream and downstream faces of a dam built from different fill materials. For safety's sake, especially when dams are being built by people with little experience, the slopes should be at least 3:1 and possibly even 4:1.

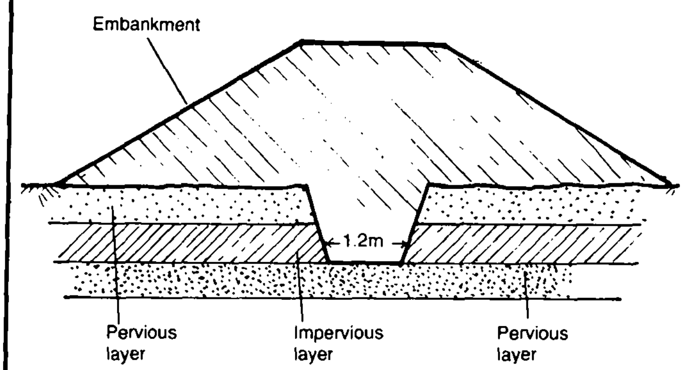

Figure 5. Cut-off Trench in Dam Embankment

Table 2. Side Slopes for Earth Embankments

Fill Material	Side Slopes* Horizontal to Vertical Upstream	Downstream
Clay, Clayey sand, Sandy clay, Silty sand	3:1-3.5:1	2.5:1-3:1
Silty clay, Clayey gravel, Silty gravel	3:1-3.5:1	2.5:1-3:1
Silt or Clayey silt	3.5:1-4:1	3:1-3.5:1

* A 3:1 slope means 3m horizontal distance for every 1m in height.

Each dam has a flat section at the top. The width of this top section depends on the height of the dam. Table 3 shows the relationship between the height of the dam and the width of the top section.

Table 3. Top Widths for Earth Embankments

Height of Dam	Top Width
Under 3m	2.5m
3-4.5m	3.0m
4.5-6m	3.5m
6-7.5m	4.0m

The height of the dam depends on the freeboard. Freeboard is the height added to the dam to prevent waves or heavy run-off from flowing over it. Freeboard is the vertical distance between the top of the dam and the water surface in the reservoir at flood level. Generally, the freeboard height should be at least 0.9m above the flood level of the water. For added safety, the freeboard should be at least 1.5m above the flood level.

The dimensions of the entire dam embankment can be determined by using the following formulas:

Height of the dam = Depth of water at deepest point + maximum depth at flood level + height of freeboard.

Width of the base = (Height of the dam x downstream slope) + (height of dam x upstream slope) + (width of the top). For example, consider a clay dam with a reservoir with the dimensions shown in Worksheet B. Assume a depth for flood channels of 0.5m, a freeboard of 1m, and a top width of 3m. Worksheet B shows how to determine the dimensions of the embankment. Figure 2 shows a dam embankment with the dimensions from Worksheet B.

Worksheet B. Determining Embankment Dimensions

1. Maximum depth of reservoir — 1.5 m
2. Maximum depth of flood channels — 0.5 m
3. Height of freeboard — 1.0 m
4. Total height of dam (sum of 1, 2, 3) — 3.0 m
5. Width of top (See Table 3) — 3 m
6. Upstream slope — 3.5:1
7. Downstream slope — 3:1
8. Width of base = 3.0 (height) x 3.5 (upstream slope) + 3.0 (height x 3 (downstream slope) + 3m (width of top) = 22.5m

Knowing the embankment slopes, the width of the top, and the height of the dam, it is possible to determine the volume of fill needed for the embankment by using the sum of the areas method shown in Table 4. Determine the height of fill at any level along the dam and find this number in the left hand column. Then, find the side slope column with the slopes corresponding to the dam. Move down the column until you are across from the fill height you are using. This number is the area that corresponds to the fill height at slope sides are 3.5:1, 3:1 and fill height is 3.0m, the area is $32m^2$. Add to this the number in the column under the appropriate top width for the fill height you are using. If the dam has a top width of 3m, the number corresponding to a 3.0m fill is $9.0m^2$. The total end area is $32m^2 + 9.0m^2 = 41.0m^2$.

The volume of earth fill is the sum of volumes for several cross-sectional areas. Figure 6 and Table 5 should be used for reference. Figure 6 is a profile of a dam embankment 22.5m long with a 3m top width. Eight stations or cross-sectional areas are shown. Each is located at a different distance from the other and each has a different fill height. To find the fill height at each station, look to the scale at the right. Then locate the end area of the cross-section by using Table 4 and adding together the area under the slope column and the area under the width column. Add all the cross-sectional areas together to get the total area. The volume of each cross-section is determined by multiplying the area of the cross-section by the length of each section (the distance between each station). For total volume, add all the volumes together and divide by two. This process is shown in Table 5. The total is divided by two because the calculated volume is twice as big as the volume desired.

Table 4. End Area Table for Embankment Sections for Various Side Slopes and Top Widths

Fill Height (m)	Side Slopes					Top Width				
	Upstream Slope									
	2.5:1 2.5:1	2.5:1 3:1	3:1 3:1	3.5:1 3.5:1	4:1 4:1	2m	2.5m	3m	3.5m	4m
	Downstream Slope									
	2:1 3:1	2:1 3.5:1	2.5:1 3.5:1	3:1 4:1	3:1 5:1					
1.0	$3m^2$	$3m^2$	$3m^2$	$4m^2$	$4m^2$	$2m^2$	$2.5m^2$	$3m^2$	$3.5m^2$	$4m^2$
1.2	4	4	4	5	6	2.4	3.0	3.6	4.2	4.8
1.4	5	5	6	7	8	2.8	3.5	4.2	4.9	5.6
1.6	6	7	8	9	10	3.2	4.0	4.8	5.6	6.4
1.8	8	9	10	11	13	3.6	4.5	5.4	6.3	7.2
2.0	10	11	12	14	16	4.0	5.0	6.0	7.0	8.0
2.2	12	13	15	17	19	4.4	5.5	6.6	7.7	8.8
2.4	14	16	17	20	23	4.8	6.0	7.2	8.4	9.6
2.6	17	19	20	24	27	5.2	6.5	7.8	9.1	10.4
2.8	20	22	23	27	31	5.6	7.0	8.4	9.8	11.2
3.0	22	25	27	32	36	6.0	7.5	9.0	10.5	12.0
3.2	26	28	31	36	41	6.4	8.0	9.6	11.2	12.8
3.4	29	32	35	40	46	6.8	8.5	10.2	11.9	13.6
3.6	32	36	39	45	52	7.2	9.0	10.8	12.6	14.1
3.8	36	40	43	50	58	7.6	9.5	11.4	13.3	15.2
4.0	40	44	48	56	64	8.0	10.0	12.0	14.0	16.0

(NOTE: To find the end area for any fill height, add square meter found under "side slopes" column to that under "top width" column. Example: If a dam at a fill height of 3.0m has a 3.5:1 upstream slope, 3:1 downstream slope and a top width of 3m, the end area is: $32m^2 + 9m^2 = 41.0m^2$.)

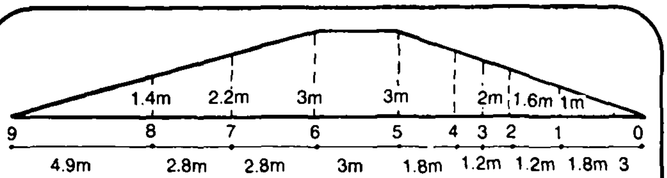

Figure 6. Determining Volume of Fill in Dam Embankment

In the example shown in Table 5, a dam with a base 22.5m long, a top width of 3m, a height of 30m, and 3.5:1 and 3:1 slopes requires $426.4m^3$ of earth backfill. To allow for a 5 percent loss from settlement, add $21.32m^3$ to the total. The final total volume is $447.72m^3$.

When backfilling the dam, keep in mind that the material used should be of uniform quality. If there are

Table 5. Sample Volume of Embankment in Figure 6 Using Sum of Area Method

Station	Fill Height	End Area (from Table 4)	Sum of Areas	Distance	Double Volume = Distance x Sum of Areas
0	0m	0m	---	---	---
1	1.0m	$7m^2$	$7m^2$ (STA 0 + 1)	3m	$21m^3$
2	1.6m	$12.8m^2$	$19.8m^2$ (STA 1 + 2)	1.8m	$35.64m^3$
3	2.0m	$20m^2$	$32.8m^2$ (STA 2 + 3)	1.2m	$39.36m^3$
4	2.4m	$27.2m^2$	$47.2m^2$ (STA 3 + 4)	1.2m	$56.64m^3$
5	3.0m	$41.0m^2$	$67.2m^2$ (STA 4 + 5)	1.8m	$120.96m^3$
6	3.0m	$41.0m^2$	$82.0m^2$ (STA 5 + 6)	3.0m	$246m^3$
7	2.2m	$23.6m^2$	$64.6m^2$ (STA 6 + 7)	2.8m	$180.88m^3$
8	1.4m	$11.2m^2$	$34.8m^2$ (STA 7 + 8)	2.8m	$97.44m^3$
9	0m	0	$11.2m^2$	4.9m	$54.88m^3$
				Total Volume	$852.8m^3$

(NOTE: Divide double volume by two to get volume of fill in embankment.)

$$\frac{852.8m^3}{2} = 426.4m^3$$

Allowance of 5 percent for settlement + 21.32

Total 447.72m3

doubts about the porosity of any of the soil, it should be placed on the downslope side. The best type of soil is clay material containing some silt or sand. If only clay is used, it may crack when dry or slip when wet. Be careful that there is not too much sand in the material. If too much sand is present, water may percolate through. To ensure the strength of the dam, the earth fill must be well compacted. If not, leakage is likely to occur and failure of the dam is possible. Figure 7 shows a way that the earth can be compacted manually. The log must be raised up and down to pound the soil. Compaction done this way is a very slow process but must be done in the absence of other methods.

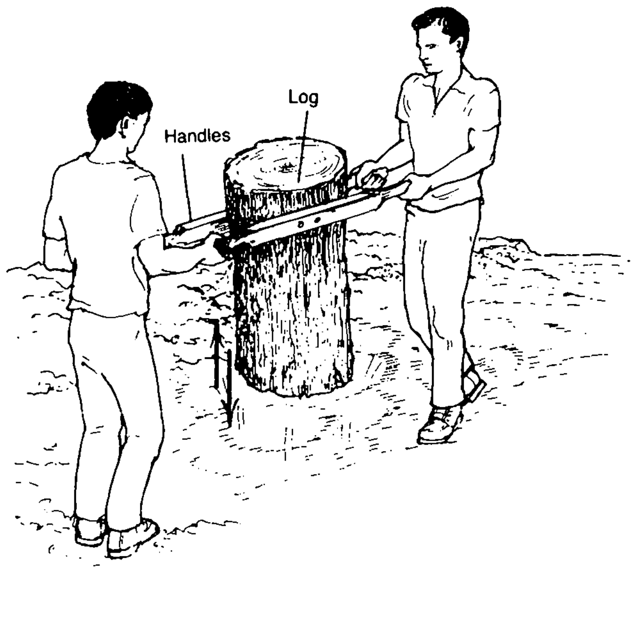

Figure 7. Manually Compacting Soil

Design of a Drain

Before the construction of the dam begins, a large diameter pipe should be placed in the stream bed as shown in Figure 8. The water flow is channeled into this pipe and carried further downstream. In this way, the construction area stays dry without the need for digging a long diversion ditch.

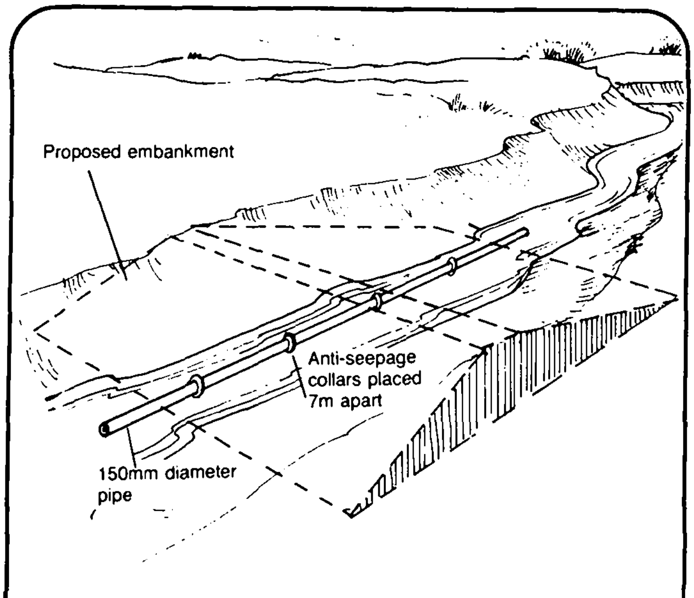

Figure 8. Installation of Drain Pipe in Stream Bed

The pipe serves a further purpose. The pipe, with anti-seepage collars attached, remains in place during the construction of the embankment. Therefore, once the embankment is completed, a drain pipe passing from the reservoir through the dam to the downstream side of the dam is in place. On the downstream side, a cut-off valve is placed on the pipe. In times of heavy rain or flooding, the valve can be opened to drain the reservoir and prevent overtopping. The drain pipe is very important in preventing dam failure.

Design of the Spillway

Water must never be allowed to spill over the top of an earth dam. To prevent overtopping, spillways are built to channel the flood water away. They must be built clear of the dam in solid ground. Often, two spillways are built. One is located lower for regular overflow, the other higher for safety during times of abnormal flooding. Spillway channels should be continued downstream away from the downstream edge of the base in order to prevent erosion of the dam by flood water. Figure 9 shows an example of a dam and spillway design.

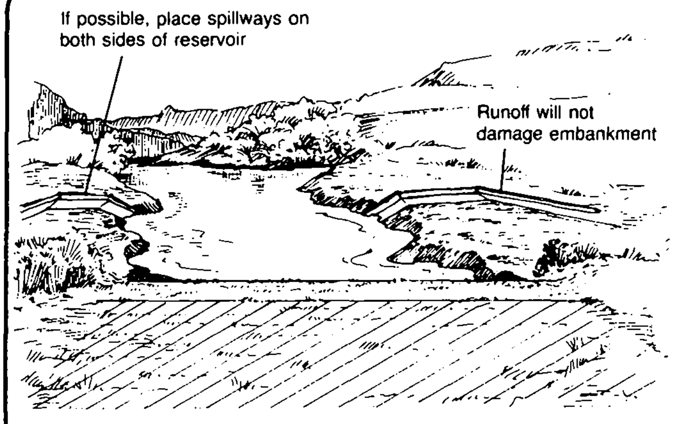

Figure 9. Locating Spillways

Calculate the spillway size by obtaining local information and making a good guess. Find out how high the stream rises at the wettest time of the year and estimate the width of a similar stream running 60cm deep. Allow for extra width according to whether last year was dry, wet or average and then double the amount to allow for a heavy storm. This is the minimum size of the spillway. If there are doubts, widen the spillway.

There are three sections to the spillway as shown in Figure 10. These are the approach channel, control section, and exit channel. The flow enters the spillway through the approach channel. It should be short with smooth easy curves. It should have a slope toward the reservoir of not less than two percent to ensure drainage. The width of the spillway is the same as the width of the channel in the control section (the high, flat section in line with the crest of the dam). This section should be lined with stone or concrete to prevent erosion. The channel should widen a little below the crest to prevent flood water from backing up.

The first part of the exit channel should have a fairly steep slope to move water away from the crest rapidly. It may be necessary to line this section with rough stone. Further downstream, the channel should flatten and move the overflow far away from the dam.

Other Design Considerations

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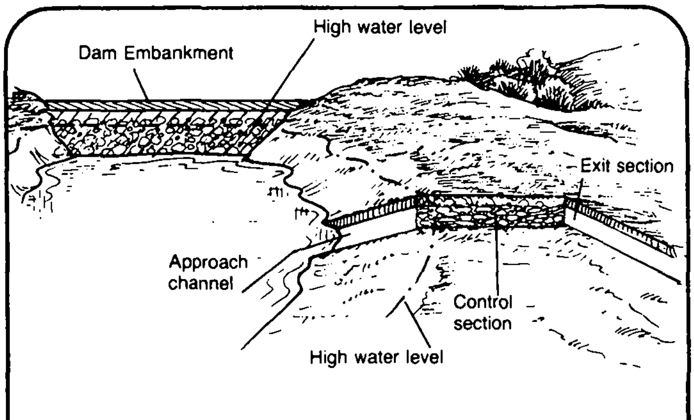

Figure 10. Design of Spillway

the dam crest, on the entire downstream slope, or on the upstream slope above water level will cause damage to the dam. The best way to prevent erosion is to plant a suitable type of creeping grass. The grass should be planted in horizontal rows in top soil mixed with manure.

On the upstream side, the dam should be paved or lined with stone to a height of 0.6m above water level. Riprap walls will help prevent erosion from waves in the reservoir.

Summary

The design of a dam is not easy and generally requires engineering skill. A poorly designed dam may break down or wash away and cause great damage to property and lives. The most common causes of failure are overtopping, undermining caused by water flowing below the embankment, fissures caused by shrinkage or badly compacted materials, percolation along tree roots that have not been cleared from the site, and weaknesses from erosion of the dam by rainfall and wave action. To avoid all these problems, much care and effort must go into the design of the dam.

A well-designed dam will provide a good source of water for a small community. Before deciding to build a dam, however, always be sure that a suitable site exists, that construction materials are available, and that the water can reach the users easily and less expensively than through another method. If these criteria are met, a successful dam project can be developed.

Notes

Notes

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

1982

Water for the World

Constructing Structures for Springs
Technical Note No. RWS. 1.C.1

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

Useful Definitions

CONVEX - Curving outward like the surface of a sphere.

DISINFECTION - The process of destroying harmful bacteria.

EFFLUENCE - An opening from which water flows.

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

UNDERFLOW - Flow of water under a structure.

VOIDS - Open spaces in a material.

Materials Needed

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

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

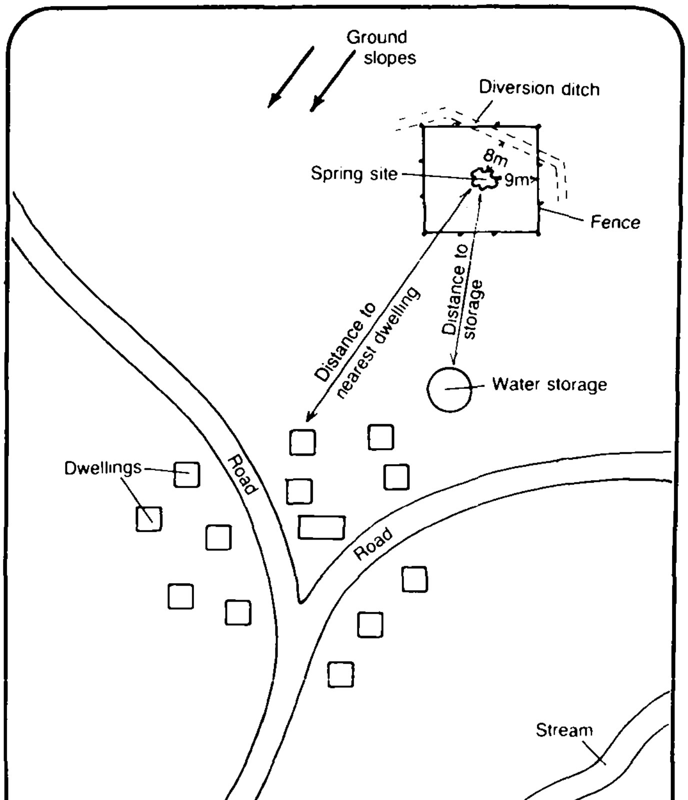

Figure 1. Location Map

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

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

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

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
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	Laborers	____	____
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	Measuring tape or rods	____	____
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	Saw	____	____
	Buckets	____	____
	Carpenter's square or equivalent (to make square edge)	____	____
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	Crowbar	____	____
	Pliers	____	____
	Pipe wrench	____	____
	Wheelbarrow	____	____
	Adjustable wrench	____	____
	Screwdriver	____	____
	Trowel	____	____

Total Estimated Cost ____

General Construction Steps

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

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

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

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

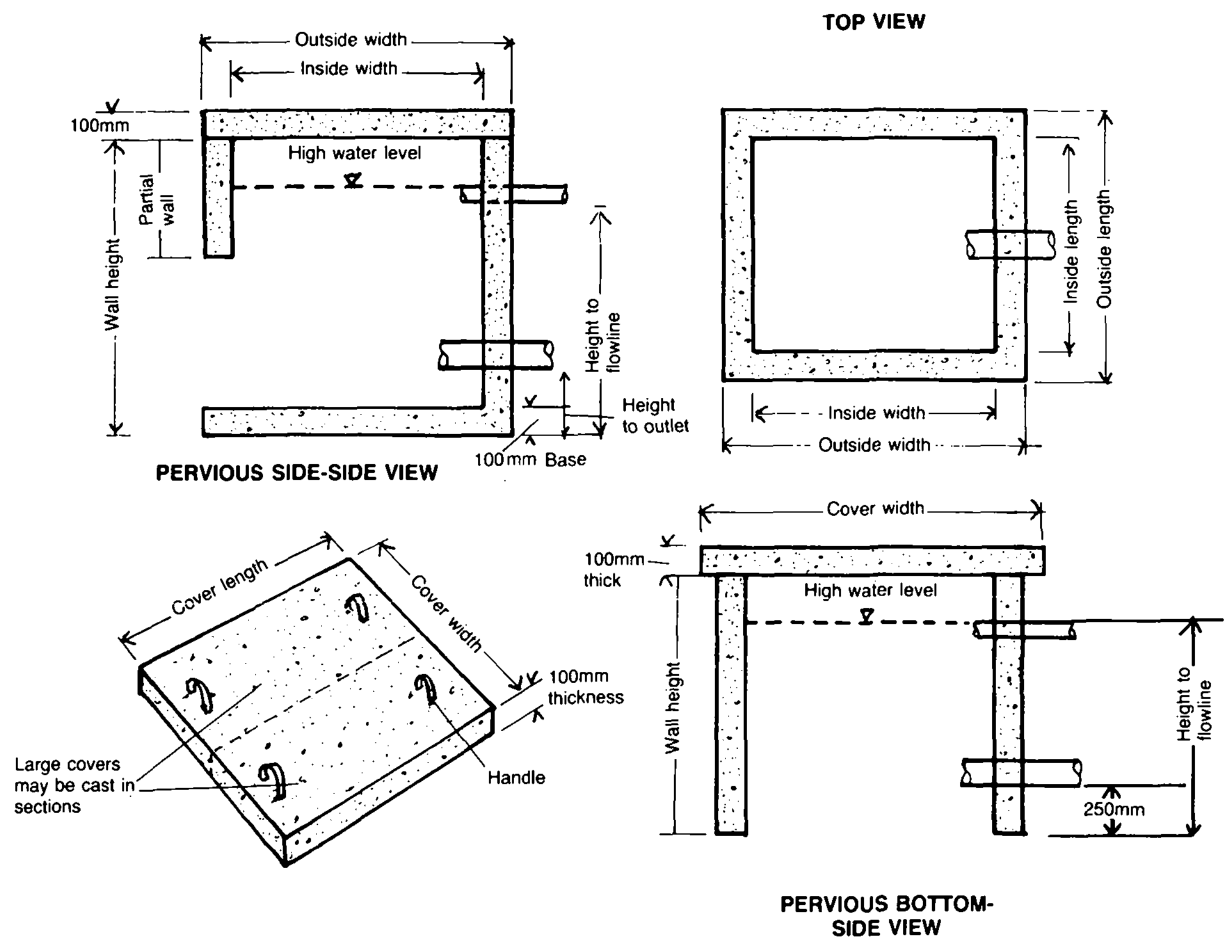

Figure 2. Spring Box Design

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

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

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

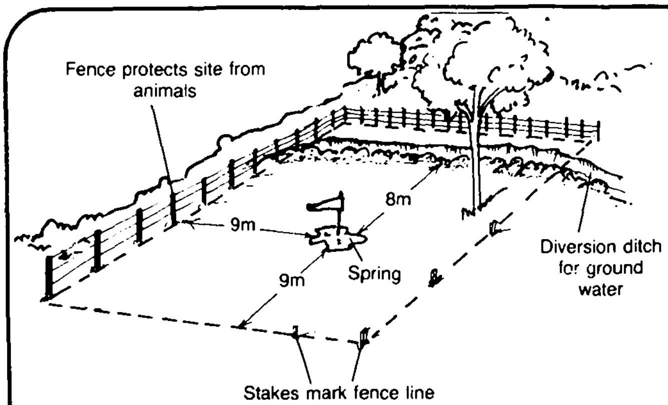

Figure 3. Preparation of Spring Box Site

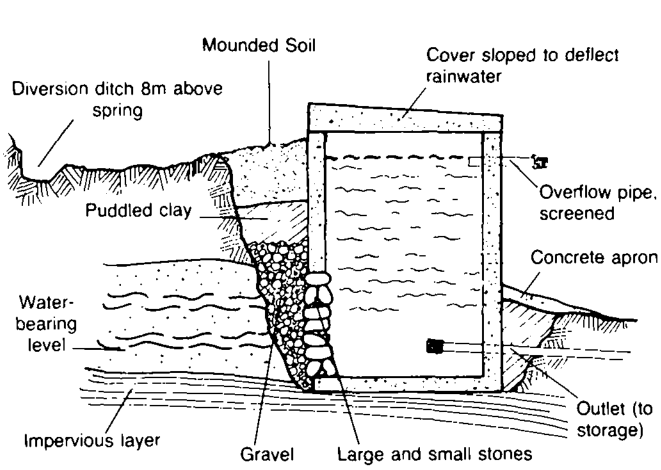

Figure 4. Spring Box with Open Side

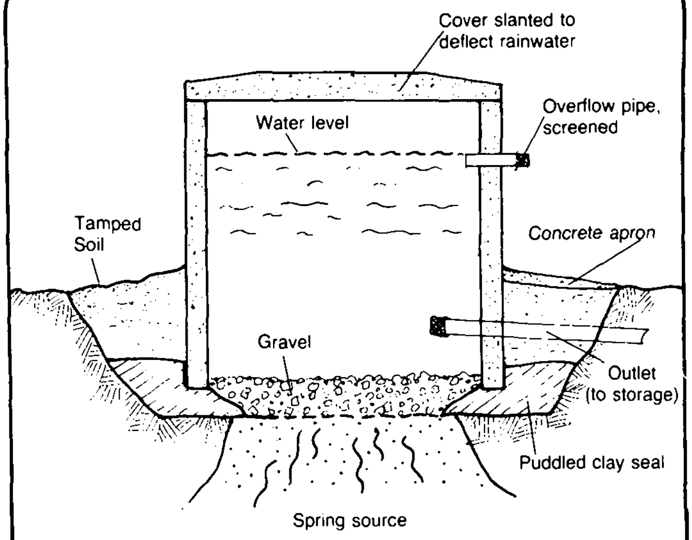

Figure 5. Spring Box with Open Bottom

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

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

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

Concrete Construction Steps

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

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

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

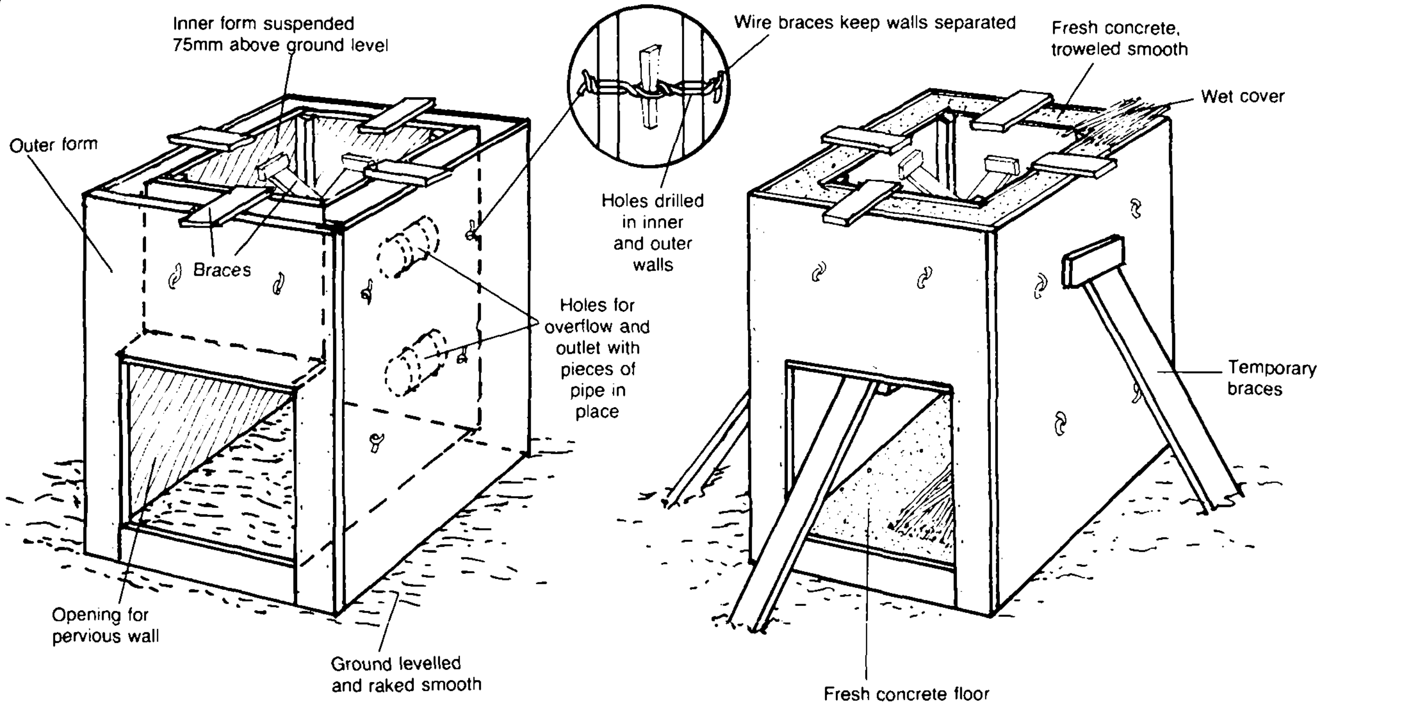

Figure 6. Forms for Spring Box with Open Side

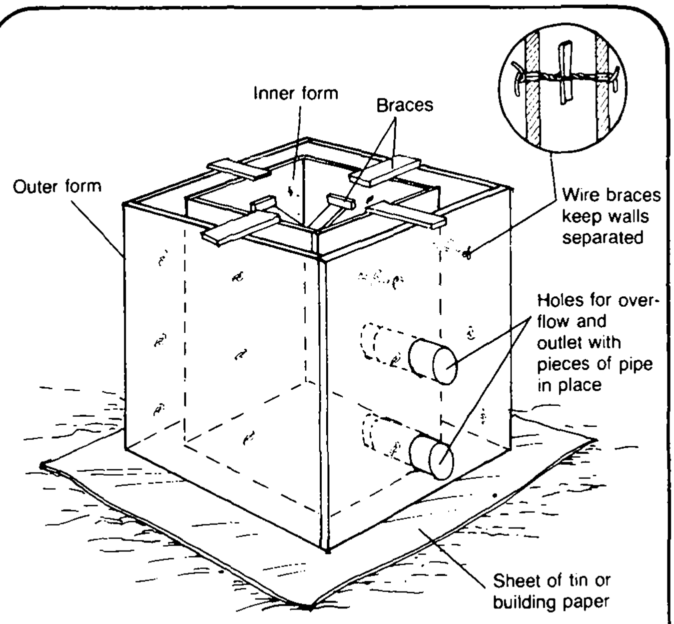

Figure 7. Forms for Spring Box with Open Bottom

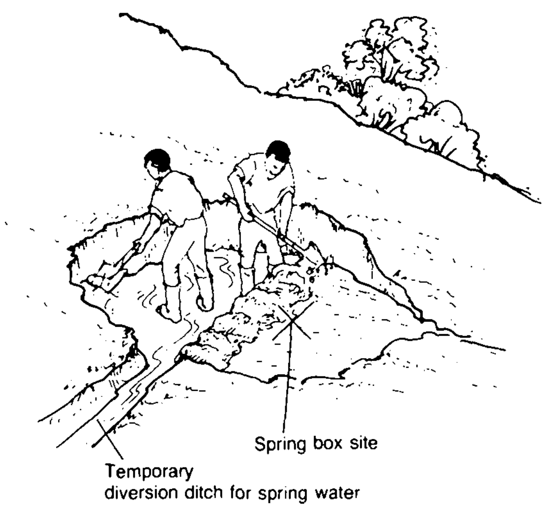

Figure 8. Excavating Spring Site

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

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

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

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

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

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

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

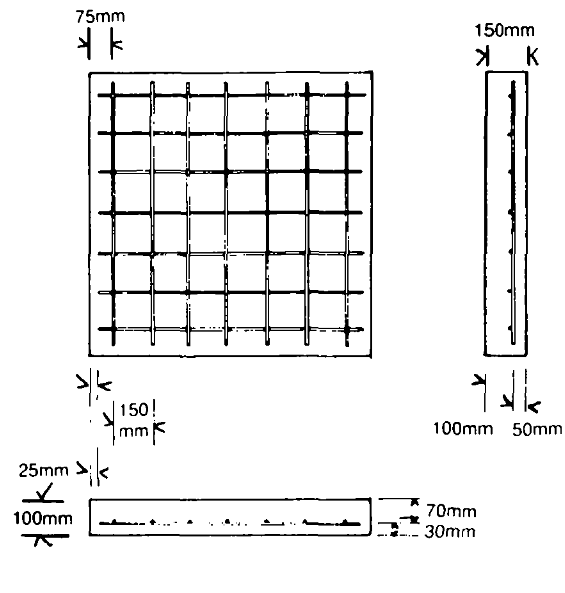

Figure 9. Placement of Rebar in Concrete Slab

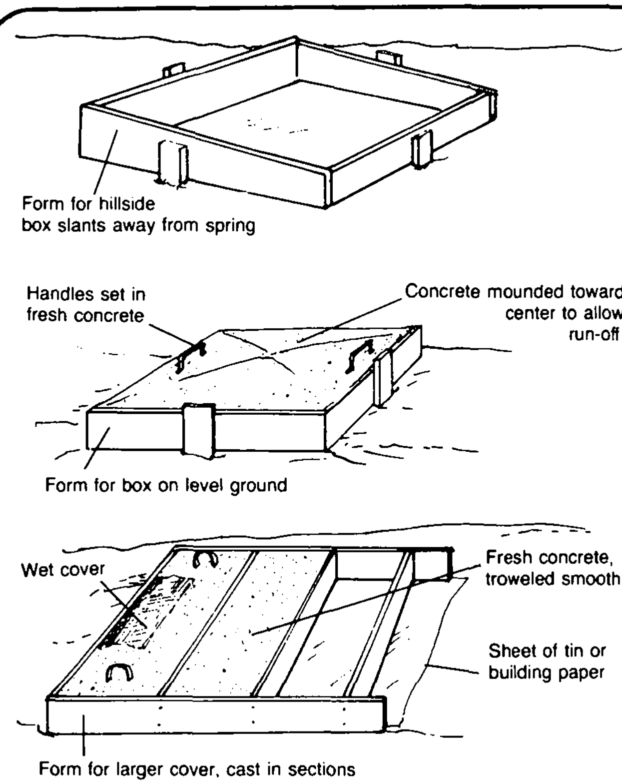

Figure 10. Forms for Spring Box Cover

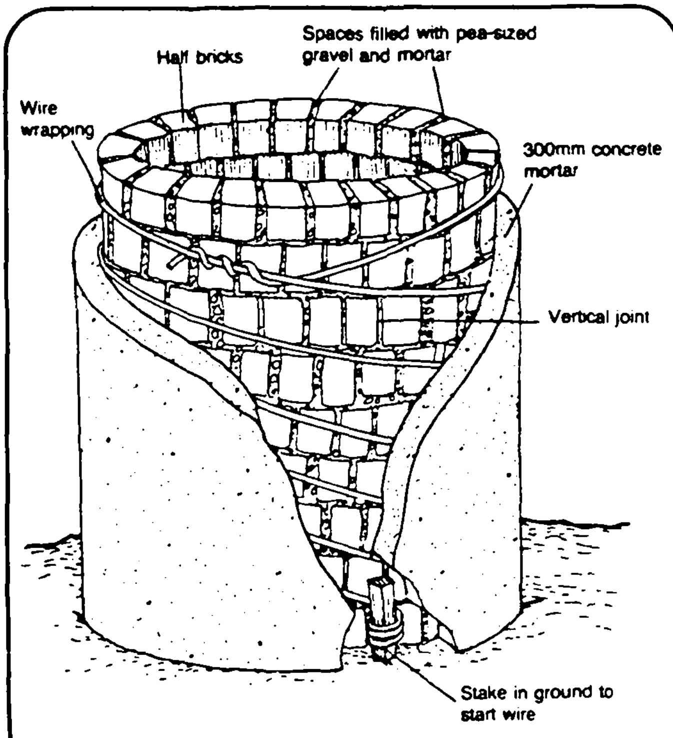

Figure 11. Brick Spring Box

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

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

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

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

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

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

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

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

Installing a Spring Box

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

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

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

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

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

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

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

6. Place the cover on the spring box.

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

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

Constructing Seep Collection System

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

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

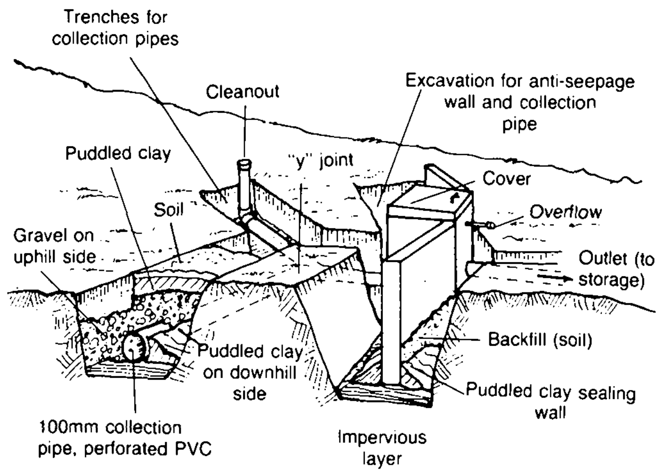

Figure 12. Seep Collection System

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

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

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

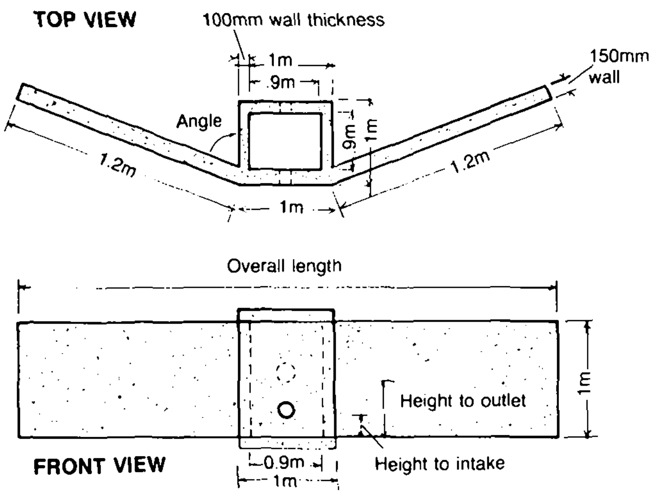

Figure 13. Anti-Seepage Wall and Collection Box

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

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

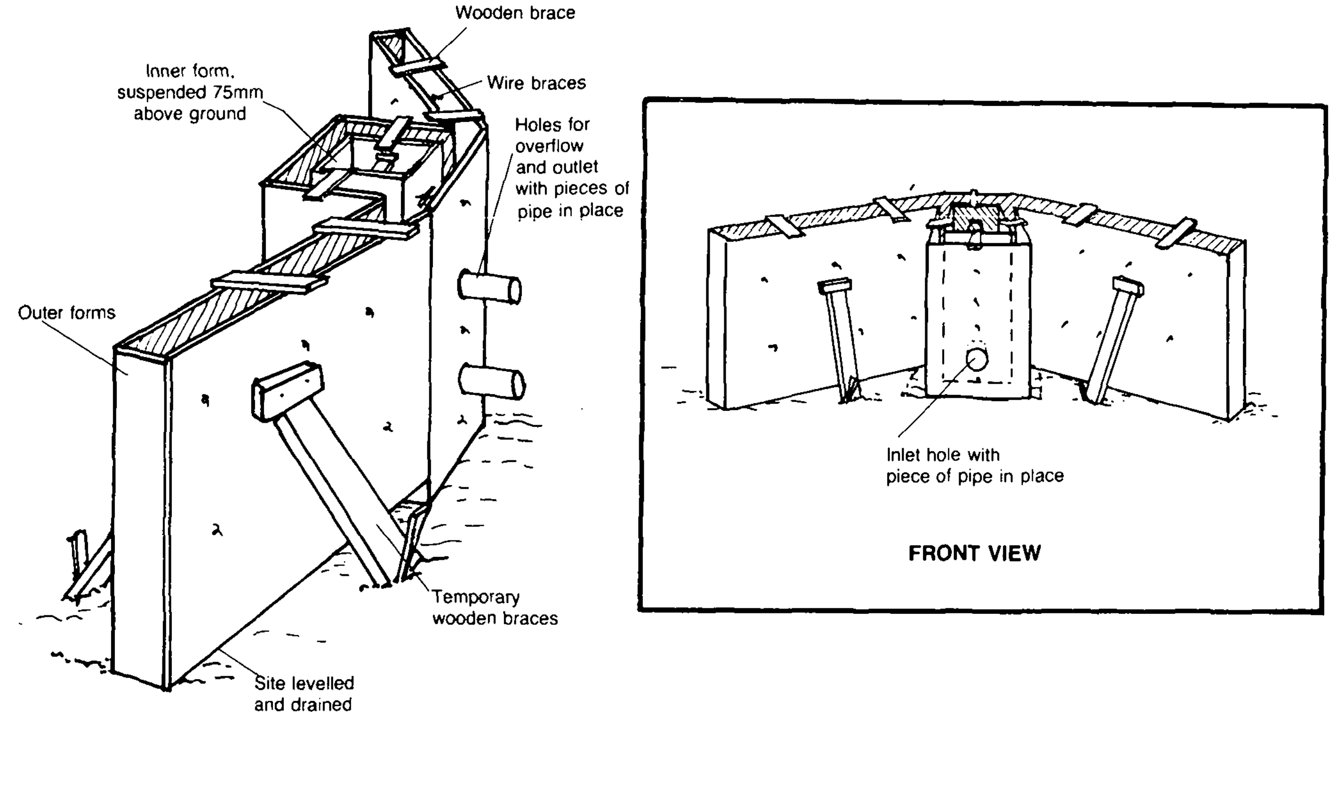

Figure 14. Forms for Anti-Seepage Wall and Collection Box

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

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

Notes

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Water for the World

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Technical Note No. RWS. 1.C.1

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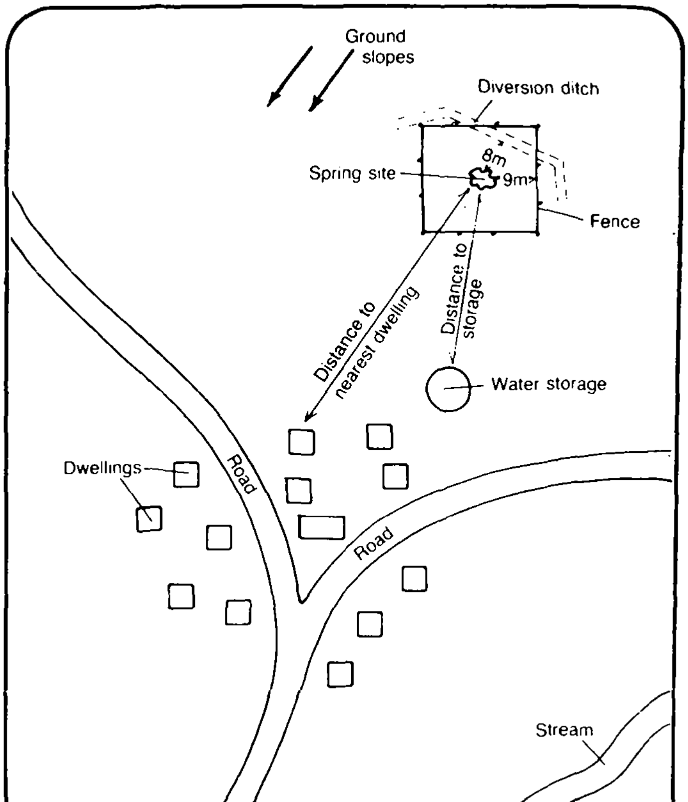

Figure 1. Location Map

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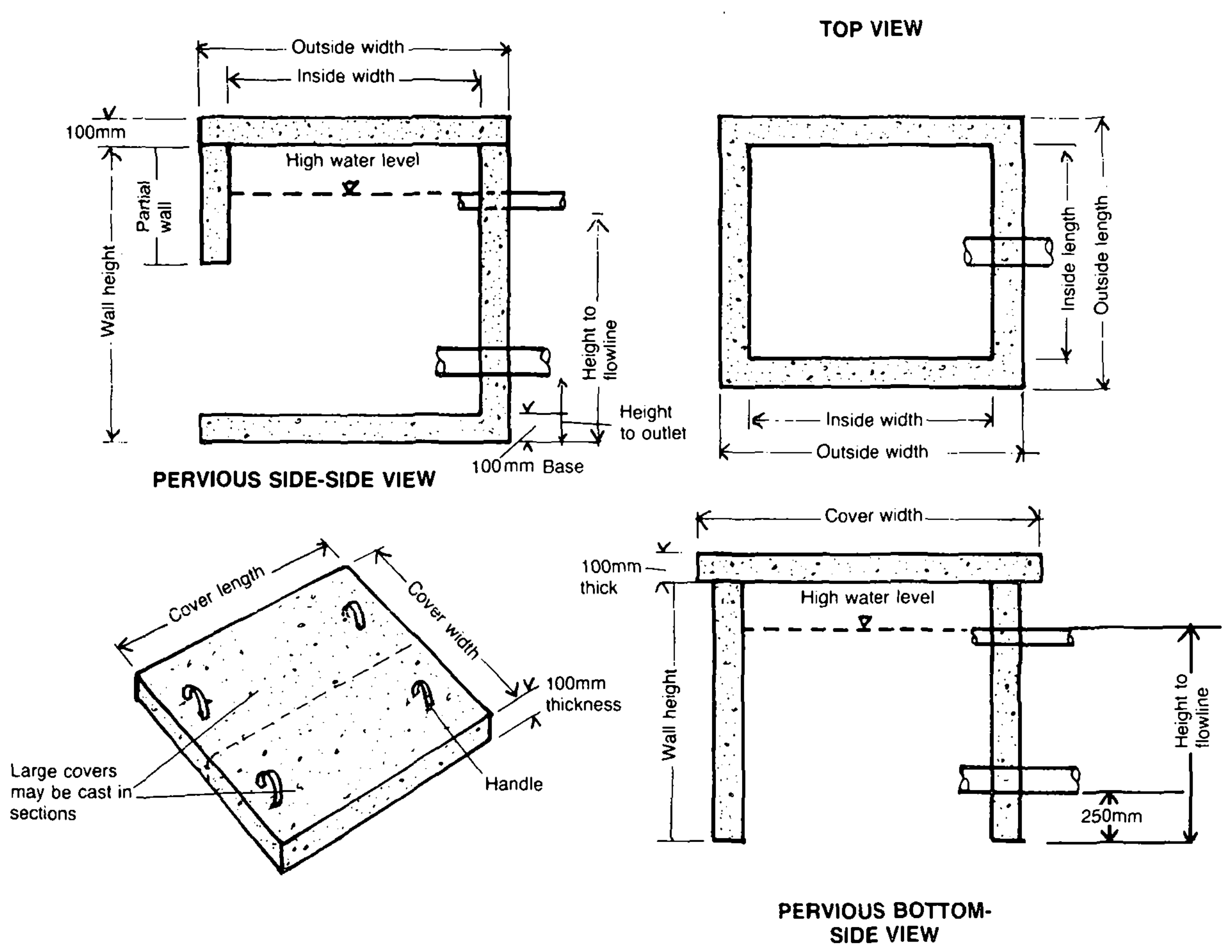

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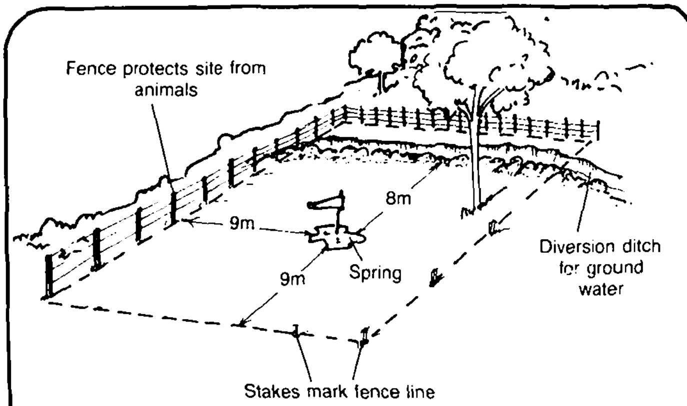

Figure 3. Preparation of Spring Box Site

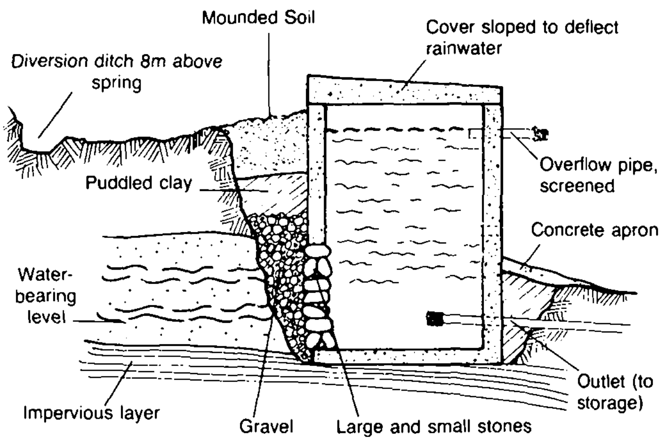

Figure 4. Spring Box with Open Side

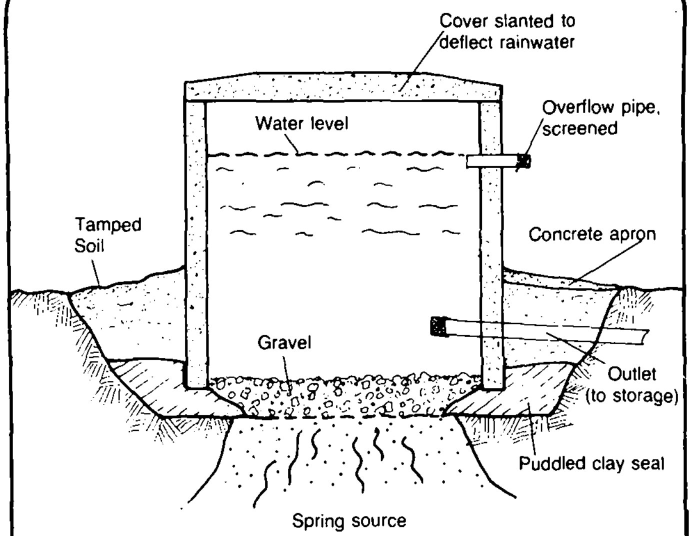

Figure 5. Spring Box with Open Bottom

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

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

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

Concrete Construction Steps

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

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

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

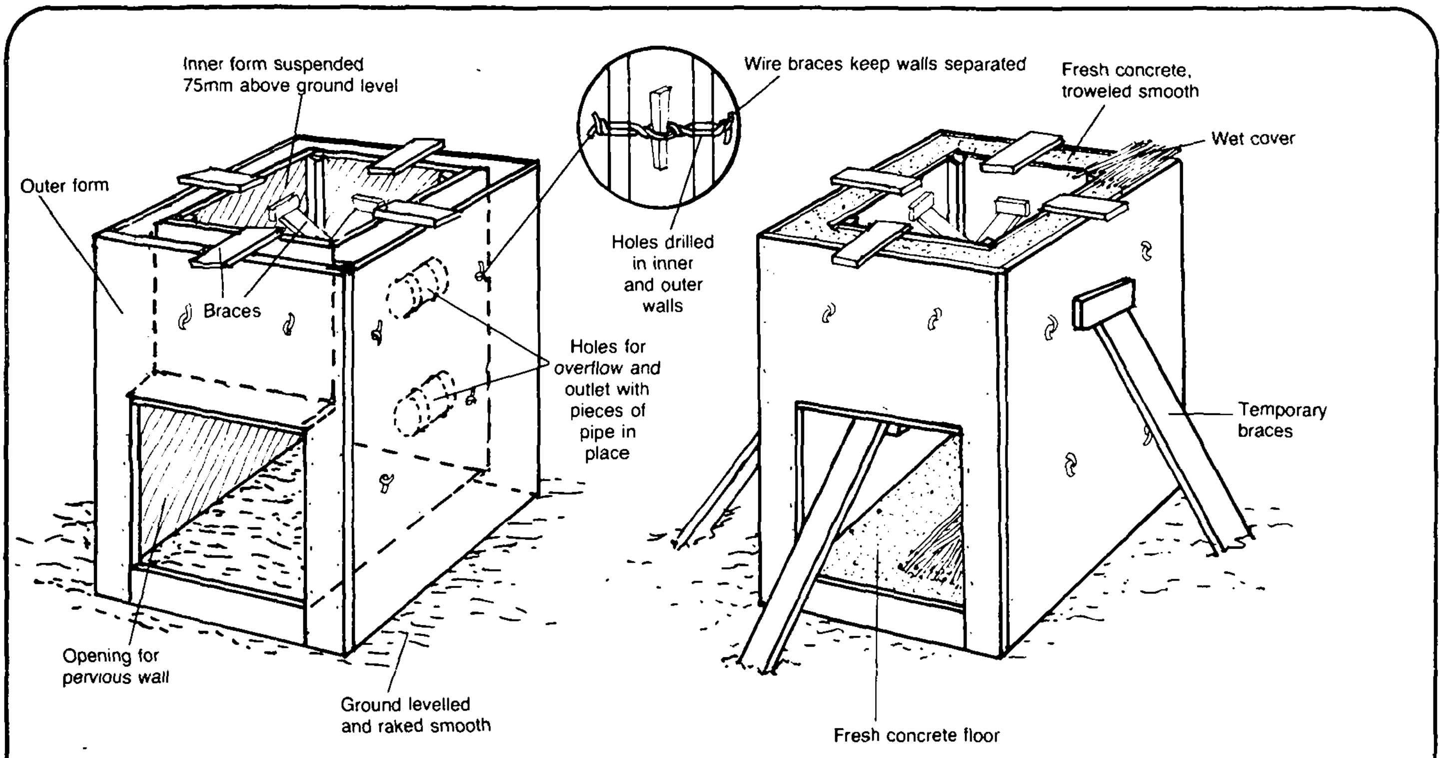

Figure 6. Forms for Spring Box with Open Side

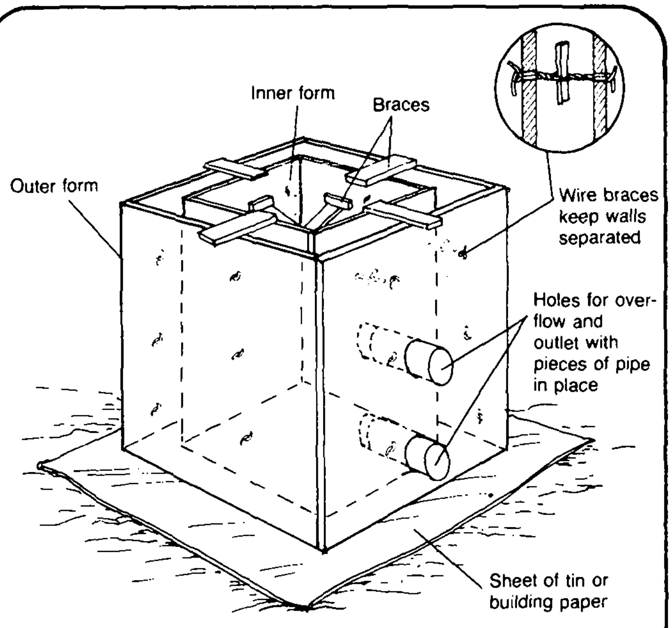

Figure 7. Forms for Spring Box with Open Bottom

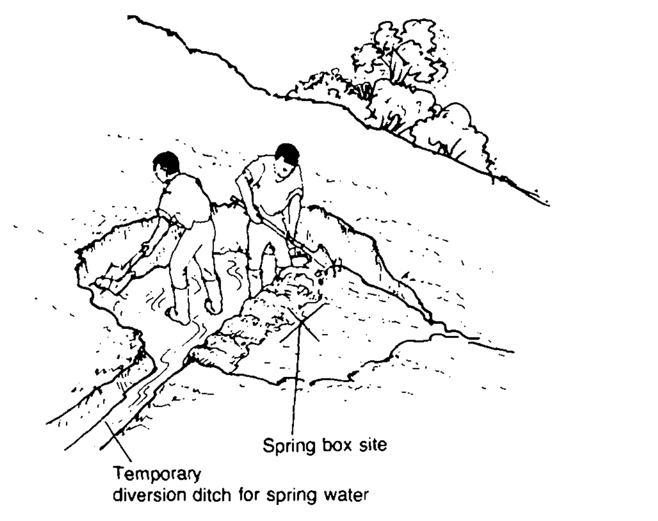

Figure 8. Excavating Spring Site

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

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

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

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

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

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

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

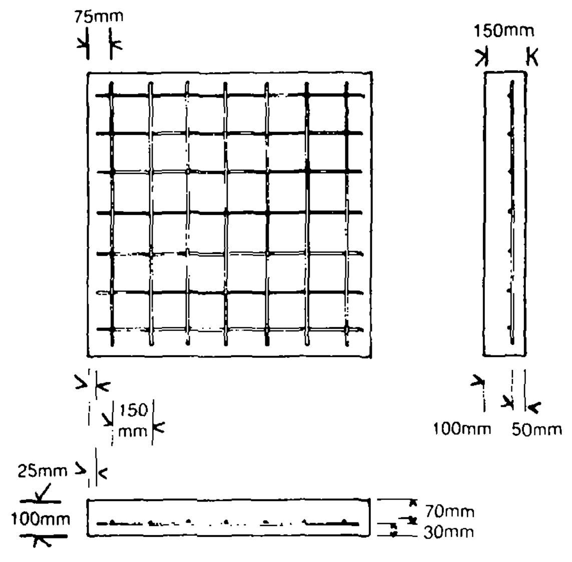

Figure 9. Placement of Rebar in Concrete Slab

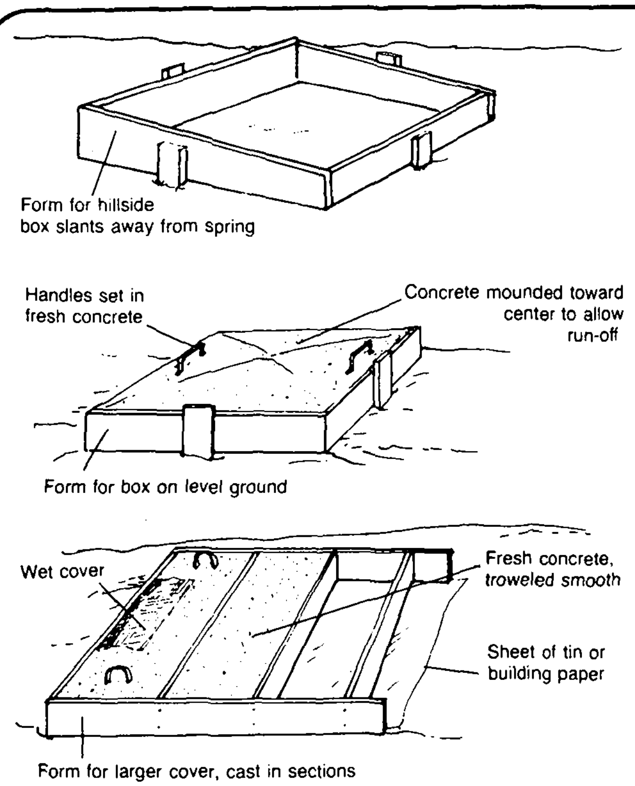

Figure 10. Forms for Spring Box Cover

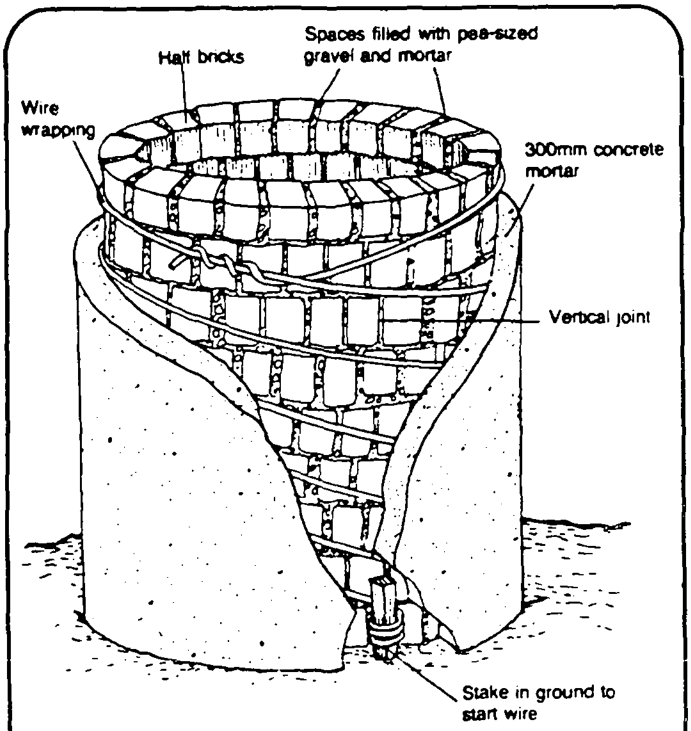

Figure 11. Brick Spring Box

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

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

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

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

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

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

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

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

Installing a Spring Box

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

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

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

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

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

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

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

6. Place the cover on the spring box.

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

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

Constructing Seep Collection System

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

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

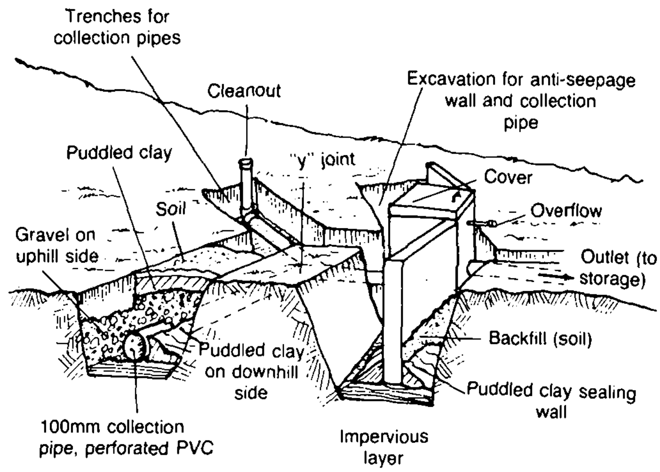

Figure 12. Seep Collection System

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

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

The next step is to build a concrete or impervious clay cutoff or anti-seepage wall. Dig down to an impervious layer for a good foundation. Make the forms for the cutoff wall 0.15m thick. Figure 13 shows a concrete cutoff wall 1.2m long and 0.9m high. Follow the same procedures for constructing the cutoff wall as for the spring box. There must be a good seal between the wall and the ground so that no water seeps underneath. Water must be directed into the trenches and collectors. A small spring box can be built at the inside angle of the winged-wall with the wall forming two sides. If a spring box is built, the forms must be set at the same time as the cutoff wall. Water must be diverted from the construction area by small ditches for the seven days needed for the concrete to dry. Forms must be well braced and have holes for the inflow and outflow pipes as shown in Figure 14. Always pour the seep collection wall and spring box in place. The structure will be much too heavy to move after casting.

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

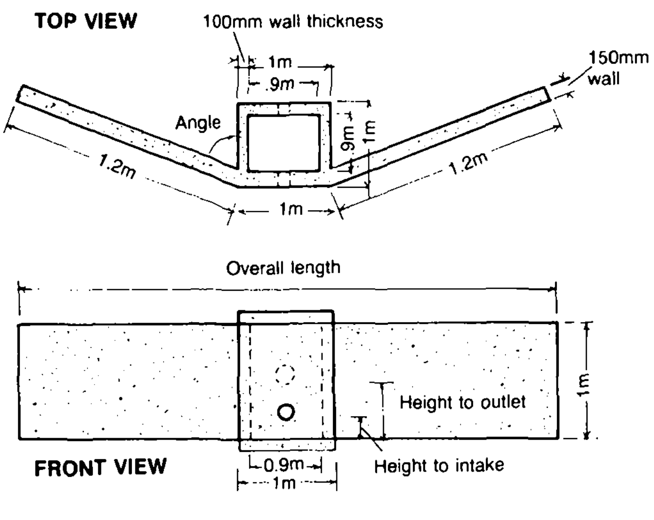

Figure 13. Anti-Seepage Wall and Collection Box

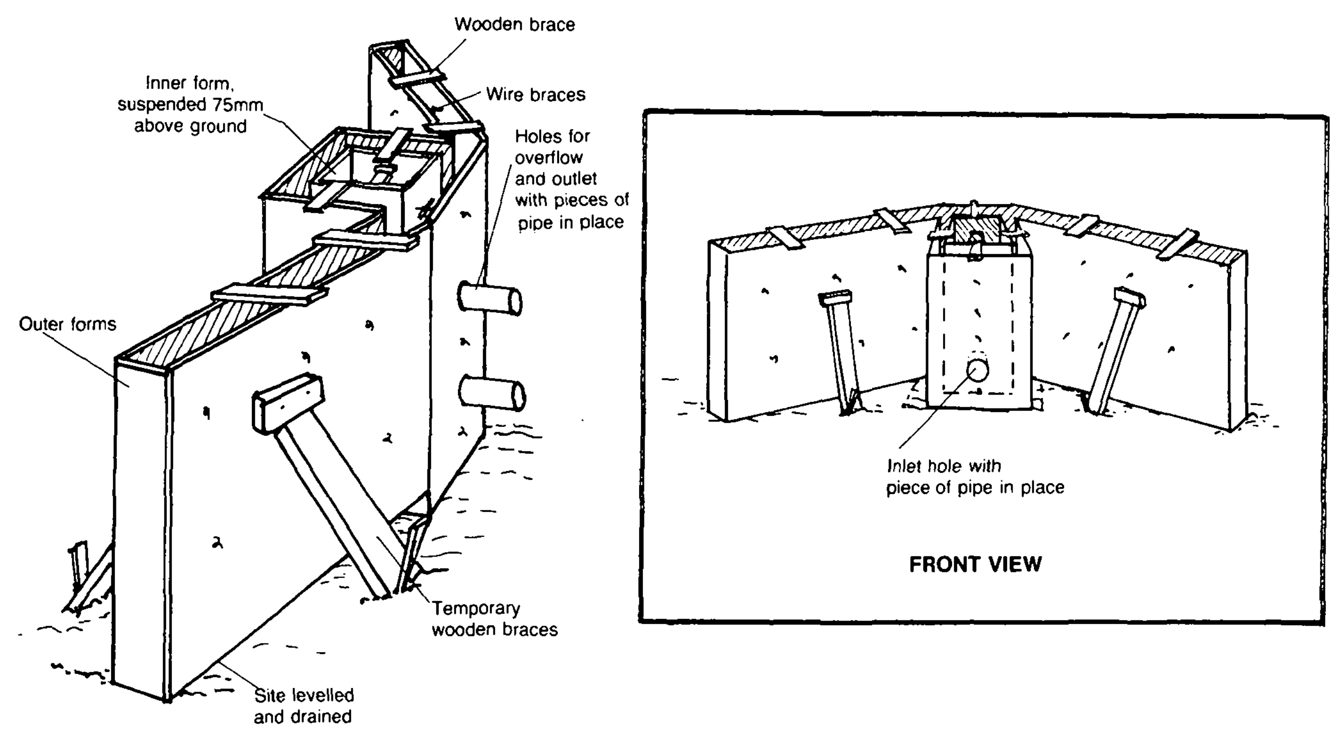

Figure 14. Forms for Anti-Seepage Wall and Collection Box

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

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

Notes

Notes

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

1982

Water for the World

Constructing Intakes for Ponds, Lakes and Reservoirs

Technical Note No. RWS. 1.C.2

The installation of intakes makes water more easily available for community water supplies. Not only does water become more accessible, but chances for human contamination of the water are reduced. Water is pumped through the intake into storage and is made available to the community from community standpipes or house connections.

This technical note describes the construction of three types of intakes for ponds, lakes and reservoirs, and outlines the construction steps that must be followed. For information on small earth dams and reservoirs see "Designing Small Dams," RWS.1.D.5.

Materials Needed

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

1. A map of the body of water marked with the location of the intake, distances and construction areas as shown in Figure 1.

2. A list of all labor and materials needed for the project similar to the sample list in Tables 1, 2, or 3.

3. A detailed plan of the intake structure with all dimensions.

Construction Steps for a Floating Intake

1. Stake out the construction sites with rope and pointed sticks or wooden stakes. The areas which should be marked are the trench line for the pipe, the pump location, and the site for the storage well if there is to be one. The pipeline trench should be about 0.5m wide and should follow a direct line from the intake to the pump.

2. Prepare the intake pipe. Drill 8-10mm inlet holes or cut slots in the pipe and wrap the perforated section in 10mm wire mesh as shown in Figure 2. These holes should be about 25mm apart and cover a length on the end of the pipe of between 0.2m and 0.5m. Do not wind the mesh too tightly. Attach it to the pipe with a clamp. Be sure to plug the end of the pipe so that water only enters by the inlet holes through the mesh.

Useful Definitions

ANTI-SEEPAGE COLLAR - A circular device made from concrete or metal, welded or bonded to pipe, that prevents water from flowing along a pipe installed in a dam embankment.

CLEAR WATER WELL - A sedimentation area or sump into which an inlet discharges water and from which water is pumped to distribution for community use.

GALVANIZED IRON PIPE - Zinc-coated iron pipe similar in size to rigid plastic, but heavier.

GLOBE OR GATE VALVE - Types of cutoff devices used in pipelines to control the flow of water in a system. The globe valve causes a high resistance to water flow because of small passageways. The gate valve when fully open allows straight-line water flow with very low resistance.

INLET STRAINER - Material, usually wire screen, that is put over an inlet pipe to remove sediment and plants from the flowing water.

POLYETHYLENE PIPE - Black, lightweight, flexible pipe used in water systems.

POLYVINYL CHLORIDE PIPE (PVC) - A white, rigid, plastic pipe used in water systems.

WHAT IS PURPA?

The passage of the Public Utility Regulatory Policies Act (PURPA) of 1978 ended utilities' exclusive right to generate and sell electricity. Now, individuals and companies can own their own wind, solar, hydroelectric, and cogeneration facilities and sell power to electric utilities on favorable terms.

WHAT PARTS OF PURPA RELATE TO SMALL POWER PRODUCTION?

Title II, Section 210, defines in general terms what facilities qualify for the new PURPA rules and establishes directions for utilities. The Federal Energy Regulatory Commission (FERC) developed specific regulations to implement the general intent of PURPA.

The essential provisions of PURPA are interconnection, a fair price, and restriction of utility ownership. Each of these is critical to the survival of small power producers in the United States. Section 210 of PURPA is intended to displace the use of scarce and expensive fossil fuels for electric power generation and substitute power from renewable energy sources. Congress decided to achieve this end by unleashing the innovative spirit of small entrepreneurs. PURPA's supporters in Congress argued that utilities were not taking full advantage of solar energy and that competition from independent power producers might spur renewable energy development. Many utilities are using solar technologies only because they were required to do so by these provisions of PURPA.

Interconnection

Small power facilities need to interconnect with a utility to sell excess power and purchase backup power. Small power facilities should not be subject to the same complex regulations governing giant power plants. We must ensure that utilities do not restrict competition and that existing burdensome regulations are eliminated. There is little opposition among elected officials to this provision.

Rates for Sales to Utilities

A small power producer must have a guarnateed rate for the power to be produced in order to secure financing for the facility. PURPA requires a "just and reasonable" rate, which FERC has determined to be the "full avoided cost" (what the utility would pay if they generated the electricity themselves). Each state utility commission determines the full avoided cost in its jurisdiction. The commissions base their figures on the reliability of the small power source, the cost of new plants, and other relevant considerations.

This provision is being contested in court and is discussed below.

Ownership

PURPA limits the utility share of small power facilities to less than 50-percent ownership so that utilities can invest in but not control these operations. This limit was set to ensure that innovative businesspeople would become involved in electric power production.

Solar Lobby
1001 connecticut avenue, nw suite 510 washington, dc 20036 (202) 466-6350

MAY 20, 1982

LEGISLATIVE ALERT

Congress will act next week on a bill that is essential to the individuals and small businesses that own wind generators, small-scale hydroelectric facilities, cogeneration plants, and solar photovoltaics. Your immediate help is crucial to make sure these renewable energy electric power producers can generate electric power for you.

Throughout 1978, the Solar Lobby worked hard to pass the Public Utility Regulatory Policy Act (PURPA). This law is now under attack. With your help, we can preserve it.

PURPA is perhaps the most important law that encourages small businesses to develop solar energy projects. By paving the way for entrepreneurs to produce electricity, PURPA encourages competition and weakens the utility companies' monopoly on power production:

- It guarantees the right of a renewable energy electricity generator to "interconnect" with the utility grid.

- It requires utilities to buy power generated by small power producers at a "just and reasonable" rate.

- It prevents utilities from owning a controlling interest in these facilities.

Since the establishment of PURPA, the interest in hydro, wind, biomass, and photovoltaics has skyrocketed. But the giant American Electric Power Service Corporation and several large utilities are challenging the law and regulations. They have filed lawsuits and complained to the Federal Energy Regulatory Commission (FERC). Resolving the issue through the courts or the standard regulatory procedures could take many months and bankrupt many small solar companies.

The Solar Lobby and pro-solar senators and representatives want to resolve the conflicts through legislative action. With your help, we can win.

WRITE OR SEND A TELEGRAM ("PERSONAL OPINION MESSAGE") TODAY.

The Senate Energy Committee will act on Tuesday, May 25. The House will act during the first week of June. Encourage your representative and/or senator to maintain PURPA's original intention.

Thanks for your help.

8. Install the pump. For information on pump installations, see "Installing Mechanical Pumps," RWS.4.C.2, or "Installing Hand Pumps," RWS.4.C.3. Use "Constructing Dug Wells," RWS.2.C.1, in constructing a storage well. Figure 6 shows the connection of an intake pipe to a pump.

Construction Steps for an Intake on Fixed Supports

1. When staking out the area, connect a line from the clear water well or pump to the intake site. The string marks the path that the pipe and pipe supports must follow.

2. Prepare the intake pipe. Drill 8-10mm holes or cut slots in the plastic pipe and cover the perforated sections with 10mm wire mesh. The holes should be 25mm apart. Clamp the mesh into place.

3. Assemble the supports. If concrete supports are used, build the forms, oil them and pour a concrete mixture of one part cement, two parts sand, and three or four parts gravel into them. See "Constructing Structures for Springs," RWS.1.C.1 for details on using concrete. Allow seven days for curing before removing the forms. If wooden supports are used, installation can begin immediately.

4. Connect the intake pipe with other pipe lengths so that there is a length of pipe that reaches from the intake point to the shore.

5. Place the supports on the pond or lake bed along the line of the string. Leave at least 1.5m between each support. A general rule to follow is to use two supports for each length of pipe in order to provide sufficient support. Fix the supports in place by driving them into the bottom with a sledge hammer or by anchoring them with large rocks. If the clear water well is fed by gravity flow, the installed pipe should slope at a one percent grade toward the well. See Figure 7.

6. Dig a trench at least 2m long and 0.5m deep. Begin digging from the shore toward the water to prevent water from entering the trench. If the water will flow into a clear water well, be sure the trench slopes toward it at a one percent grade.

7. Place the pipe on the supports. To do this, fill the pipe with water so that it sinks. When lowering the pipe, position a person at each support to guide the pipe onto the supports and fix it there while backfilling begins on the shore.

8. Fit the pipe into the trench and backfill to within 0.6m of the end. Insert a new section of pipe into the trench and couple it with the pipe already there. Be sure no water is in the trench when the coupling is done. Lay enough pipe to reach the pump or storage well and backfill to within 0.6m of the end of the pipe.

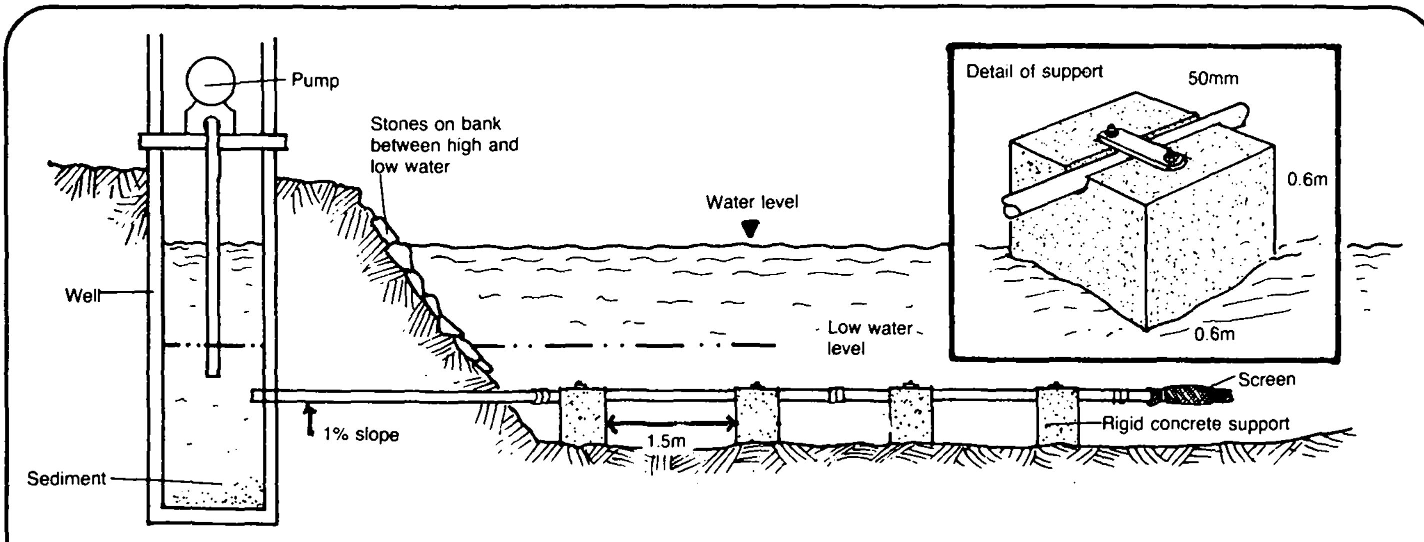

Figure 7. Rigid Intake and Settling Tank

9. Install the pump or dig the clear water well using the technical notes referred to in Step 8 of the section on floating intakes.

Follow the same steps mentioned above for installing an intake as shown in Figure 8. In addition follow these steps:

1. Build the forms for a cement base. A square base 0.6m x 0.6m should be large and heavy enough. The height should be sufficient so that the pipe used for the intake is contained in the block. A space should be made in the forms so that the pipe can be put in place before the concrete is poured.

2. Place the pipe in the forms and brace the forms before pouring the concrete. After pouring, allow the cement to cure for seven days.

3. After the concrete is cured, installation should be easy. An elbow joint and a screened vertical intake pipe should be connected to one end. The other end of the pipe is connected to the pipeline leading to the pump.

4. To install the intake, lower it into the water with rope. Attach floats to the rope to mark the location of the intake so it can be found easily when maintenance is necessary.

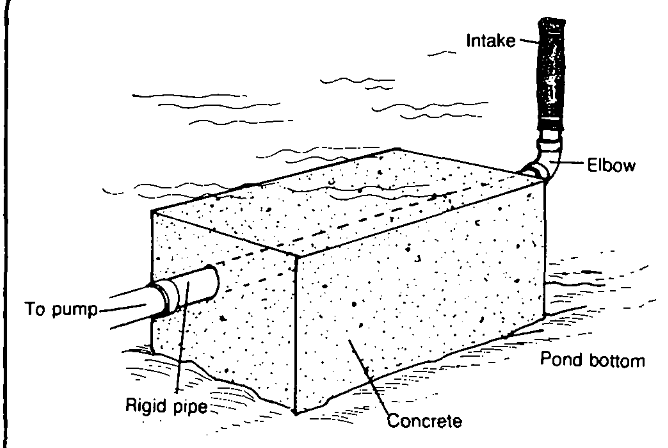

Figure 8. Rigid Pipe in Concrete

Construction Steps for a Concrete Box Intake for Dam Reservoirs

This intake system can only be constructed at newly proposed dam sites. It cannot be installed in existing dam reservoirs.

1. Stake out the proposed site for the dam and the location of the concrete box within the reservoir. Mark out the proposed walls and determine the approximate location of the intake. It should be near the foot of the upstream wall at a deep spot behind the dam. Use the information on dam design in "Designing Small Dams and Water Impoundments," RWS.1.D.5, to stake out the area. See Figure 9.

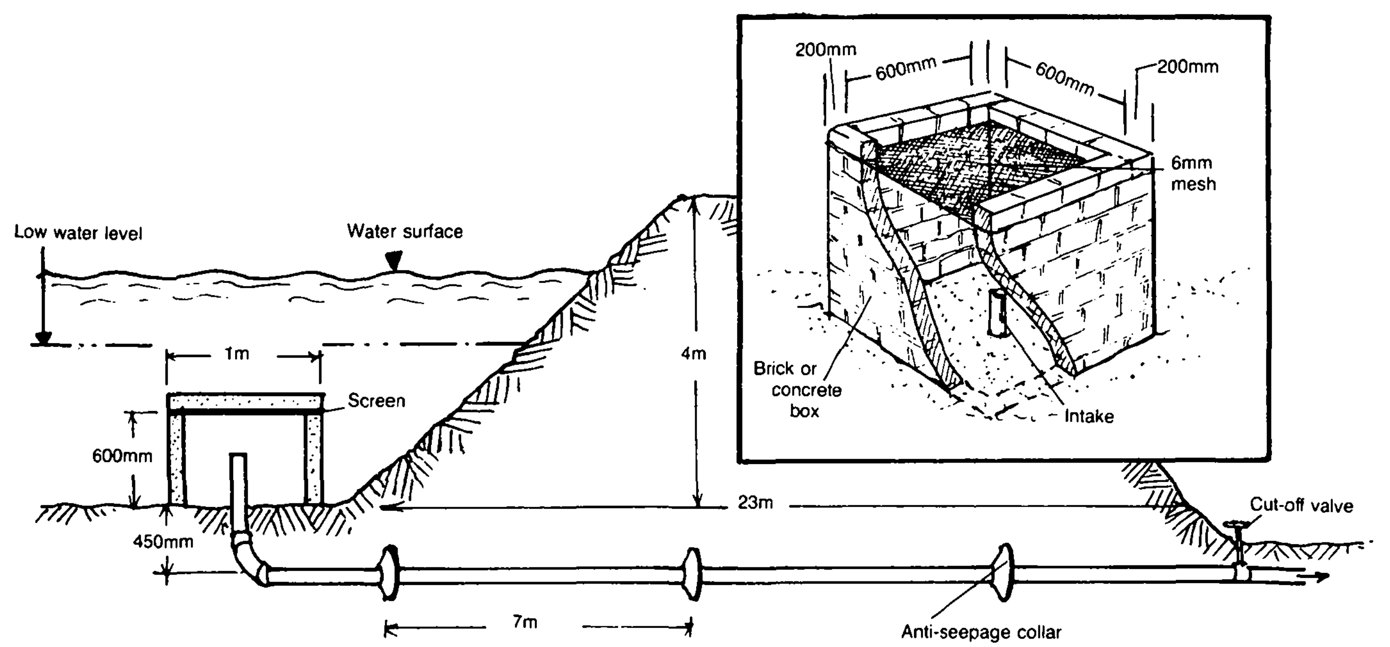

Figure 9. Intake Structure for Dams

YOUR LETTER TO CONGRESS

The Honorable ______________
U.S. House of Representatives
Washington, DC 20515

The Honorable ________________
U.S. Senate
Washington, DC 20510

Be sure your letter is readable whether handwritten or typed.

Be sure that your return address is on your letter. Use printed personal or business stationary OR include your address under your signature.

You can also call Western Union to send a Personal Opinion Message. Your message (20 words cost $4.25) arrives immediately.

Clearly identify the issue in the first sentence of your letter. For example, "A mark-up will occur in your committee in the next few weeks regarding the Public Utility Regulatory Policies Act, and I would like you to support the following issues ..."

Speak in your own words (form letters have less impact) and include any personal or specific experience you may have. For example, "My business will fail."

Do not threaten. Unreasoned letters have less impact. Present your reasons briefly.

Ask your representative or senator for a reply. If you are unhappy with the reply, write again. If you are satisfied with the reply, send a thankyou note. If you think Solar Lobby should see the reply, send it to us.

LETTERS TO MEMBERS OF CONGRESS ARE YOUR PRIMARY MEANS OF CONTACT WITH LEGISLATORS. LEGISLATORS DO PAY ATTENTION TO LETTERS FROM CONSTITUENTS.

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URGENT: Legislative Alert

Some utilities now demand the right to completely own the qualifying plants, though they have shown little interest in partial ownership. Solar Lobby opposes this suggestion for three reasons: The ownership restriction has not been in effect long enough to evaluate its impact. Independent entrepreneurs would have a difficult time competing with utilities for project financing. And utilities would restrict competition by dealing exclusively with their unregulated subsidiaries, thus avoiding regulatory oversight.

WHAT IS THE PROBLEM?

Two lawsuits are holding up implementation of PURPA and have led some utilities to postpone negotiations and cancel agreements with small power producers. The Supreme Court is deciding if the federal government can force state utility commissions to conform to PURPA. The Federal Court of Appeals has suggested that Congress must clarify its intent on interconnection and rates.

Senator Gordon Humphrey (R-NH), chair of the Energy and Natural Resources Subcommittee on Energy Regulation, will hold hearings on interconnection and avoided costs on May 24. Senator Humphrey will be adding amendments on these issues to his bill (S. 1885), which deals with utility ownership of small power facilities. Representative Richard Ottinger's (D-NY) House Energy and Commerce Subcommittee on Energy Conservation and Power will hold hearings on interconnection and avoided cost during the first week of June.

WHAT YOU SHOULD DO

Write a letter or send a telegram ("Personal Opinion Message") to your representative and/or senator to urge him or her to maintain the original intent of the Public Utility Regulatory Policies Act by:

- protecting the right of small power producers to interconnect with a utility without burdensome regulations
- limiting utility ownership of small power facilities to less than 50 percent
- guaranteeing small power producers full avoided cost for their electricity unless the state public utility commission decides on a case-by-case basis that the price should be lower in the ratepayers' interest.

Write immediately and send a copy to Barrett Stambler at Solar Lobby.
Please call if you have questions or want more information.
Thanks very much for your help.

CONTACT THESE MEMBERS OF CONGRESS

Senate Energy Committee

James McClure (R-ID), chair
Gordon Humphrey (R-NH)
Malcolm Wallop (R-WY)
J. Bennett Johnston (D-LA)

House Energy and Commerce (Energy Conservation and Power Subcommittee)

Toby Moffet (D-CT)
Phil Gramm (D-TX)
Mickey Leland (D-TX)
Ralph Hall (D-TX)
Doug Walgren (D-PA)
Cardiss Collins (D-IL)
Carlos Moorehead (R-CA)
Matthew Rinaldo (R-NJ)
James Collins (R-TX)
Tom Corcoran (R-IL)
Don Ritter (D-PA)
Harold Rogers (R-KY)
James Broyhill (R-NC)

Table 3. Sample Materials List for Concrete Box Intakes

Item	Description	Quantity	Estimated Cost
Labor	Foreman	_____	_____
	Laborers	_____	_____
Supplies	PVC or galvanized pipe	_____	_____
	Elbow joint	_____	_____
	Cement	_____	_____
	Sand	_____	_____
	Gravel	_____	_____
	Wire mesh screen	_____	_____
	Concrete blocks	_____	_____
	Globe valve	_____	_____
	Wood for forms	_____	_____
	Anti-seepage collars	_____	_____
	Pipe glue	_____	_____
	Couplings	_____	_____
	String	_____	_____
	Wooden stakes	_____	_____
Tools	Digging tools	_____	_____
	Mortar box	_____	_____
	Hammer	_____	_____
	Nails	_____	_____
	Bucket	_____	_____
	Hack saw	_____	_____
	Measuring tape	_____	_____

Total Estimated Cost = _____

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

1982

Water for the World

Constructing Intakes for Streams and Rivers
Technical Note No. RWS. 1.C.3

Several types of intakes can be constructed to give communities access to water from streams and rivers for their water supply needs. A well-designed and constructed intake provides a community with good quality water in abundant quantities and eliminates the chore of carrying water long distances.

This technical note discusses the construction of three basic intake systems for rivers and streams. The three systems are infiltration systems, gravity flow systems, and permanent direct pumping systems. Read this entire technical note before beginning construction.

Useful Definitions

ABUTMENT - A structure supporting a bridge or walkway.

CATWALK - A narrow walkway that passes over water or spaces that cannot be crossed by foot.

LEVER - A device consisting of a bar turning on a fixed point using force at a second point to lift a weight.

VOIDS - Open spaces in a material.

Materials Needed

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

(1) A map of the area, including the location of the intake system and related items similar to Figure 1 which shows the location of an infiltration gallery.

(2) A list of all labor, materials and tools needed as shown in Tables 1, 2, or 3.

(3) A detailed plan of the intake system with all dimensions similar to Figure 10.

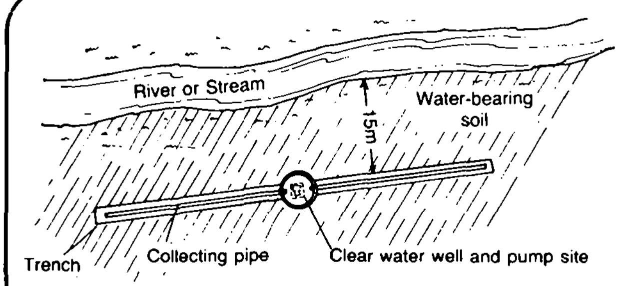

Figure 1. Location Map for Infiltration System

Table 1. Sample Materials List for Infiltration Systems

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

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

Table 2. Sample Materials List for Gravity Flow System

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

Table 3. Sample Materials List for Permanent Direct Pumping System

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

Infiltration Systems

The construction of infiltration system requires a great deal of physical labor and expertise. The construction of two types of infiltration systems is discussed in this section. These are (a) riverside wells and (b) infiltration galleries.

Before beginning construction, stake out the area where construction will take place with string and wooden sticks or stakes. Follow exactly the location map the project designer gives you.

Construction. Figure 2 shows a well with a hand pump built on a riverbank. Construction steps for this well do not differ from any other dug well although cave-ins are more likely due to the sandy soil found in stream banks. The construction steps to follow are available in "Constructing Dug Wells," RWS.2.C.1.

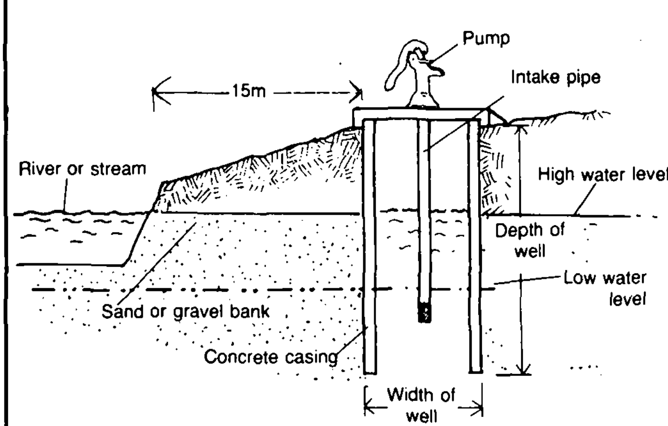

Figure 2. Riverside Well Intake

There are three basic construction components for infiltration galleries: the collecting pipes, the trenches, and the clear well.

1. Dig the clear well. For well construction guidelines, see "Constructing Dug Wells," RWS.2.C.1.

2. Dig the trenches for the collecting pipes. The best time to dig is during the dry season when the water table is low. Dig about 1m below the water table level to collect the maximum amount of water. Extend the trench through the water-bearing layers of soil until the layers end or sufficient quantities of water are being collected. Be sure not to dig deeper than the height of the workers. To avoid accidents from cave-ins, slant the trench walls.

Water will seep into the trenches during excavation. This water must be removed for work to continue. If the flow is slow, water can be bailed out of the trenches during construction.

If a great deal of water enters the trench, a pump is needed to remove it. The trenches should have a one percent slope toward the clear well (0.1m/m) and should connect to it below water level.

3. Prepare the pipe for installation. If clay tile or concrete pipe is used, little must be done because water enters the joints between the pipe sections. Plastic pipe must be perforated with inlet holes or slots. Hole sizes should range between 5-10mm in diameter and should be drilled approximately 25mm apart as shown in Figure 3a. As many holes as possible should be drilled into the pipe to ensure sufficient flow into the collection pipes. Flexible plastic tubing, 100mm in diameter can also be used to collect water, however it is more difficult to lay this pipe to grade. This pipe is made with slots already formed. It is light and can be cut to any length by a saw. Use it if it is available.

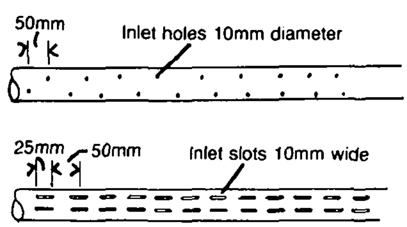

Figure 3a. Collection Pipe for Filtration System

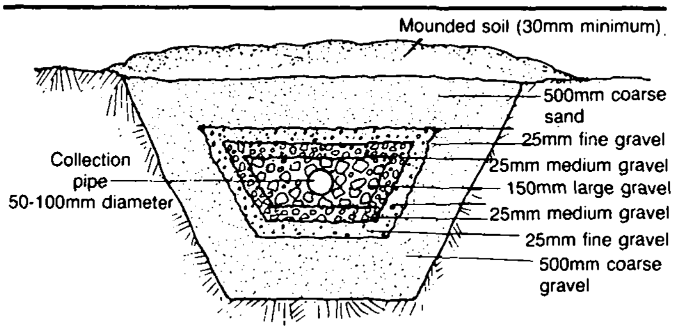

Figure 3b. Filtration Bed

4. Prepare a filter bed in the trench. Line the trench with sand as shown in Figure 3b. Then add layers of gravel or small stone to provide a bed for the pipe. The filter bed and side walls should be constructed very carefully to ensure that grading is good and that filtration is adequate. Place boards vertically in the trench as shown in Figure 4. Then, pour in the first layer of filter material to the desired height. Be sure to pour it in behind the board to build up the side walls. When nearing the desired height, place boards to the inside of the first boards then pour in the next layer. Before putting in the next layer, remove the first boards by slowly sliding them out.

Be sure to build the side walls so that the finest filtering material makes up the layer furthest from the pipe. Once the pipe is placed in the bed, repeat the layering process in reverse, starting with the coarsest materials and building up to the finest.

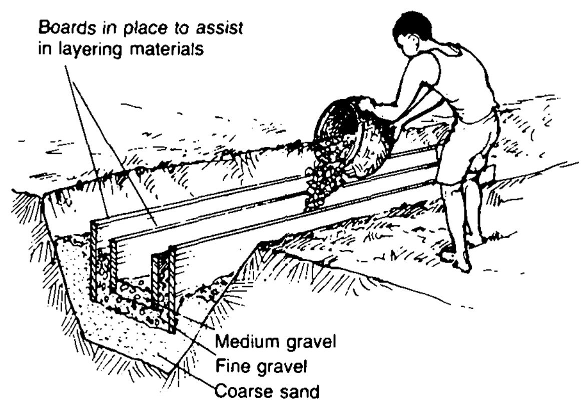

Figure 4. Constructing a Filtration Bed

5. Install the pipe in the trench. Begin at the end of the trench furthest from the well and lay the necessary lengths of pipe to connect it to the clear well. See Figure 5.

6. Backfill the trenches. Cover the pipe with layers of gravel and sand. Then place a layer of impermeable soil about 0.5m thick over the gravel and sand layers.

7. Install the pump in the clear well. Refer to "Installing Mechanical Pumps," RWS.4.C.2, for installation

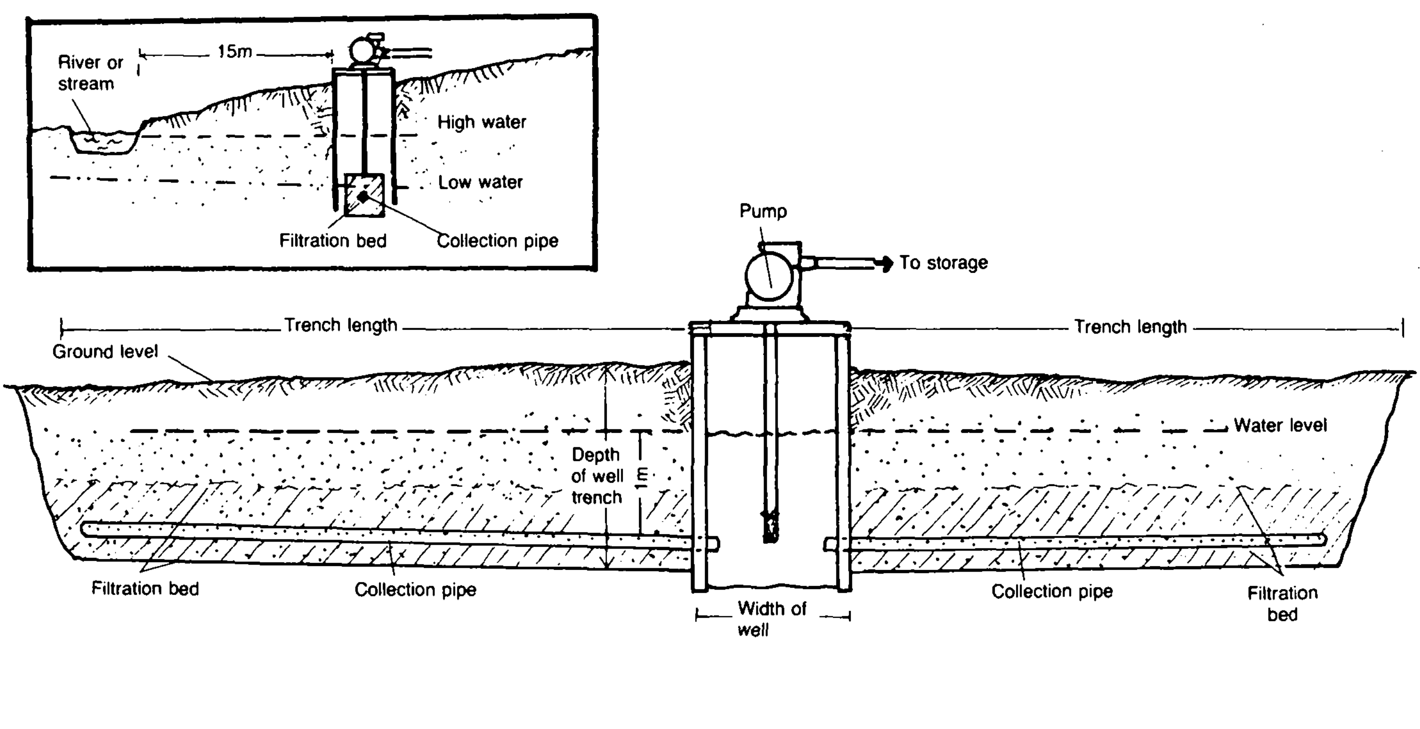

Figure 5. Riverside Infiltration Intake

guidelines. If the location is convenient and the community population using the well is 200 or less, a hand pump can be used.

Where construction of collecting trenches in stream banks is not possible, an alternative method can be used. An infiltration gallery as shown in Figure 6 can be constructed. If the stream flow is relatively slow and soil is not very sandy, a trench in the middle of the stream can easily be constructed by bailing. Generally, the stream should be diverted.

1. Build a small dam and diversion ditch and lead water away from the construction area.

2. Dig a collecting trench approximately 0.5-1.0m deep and line it as described for filter beds. Dig trenches from each end of the filter pipe to each bank. Lay the pipe as shown in the figure. All pipe should be laid so water will flow toward the clear well. The length of the collection pipe chosen depends on the amount of water needed. Several meters of pipe should be installed in the bed to ensure adequate flow.

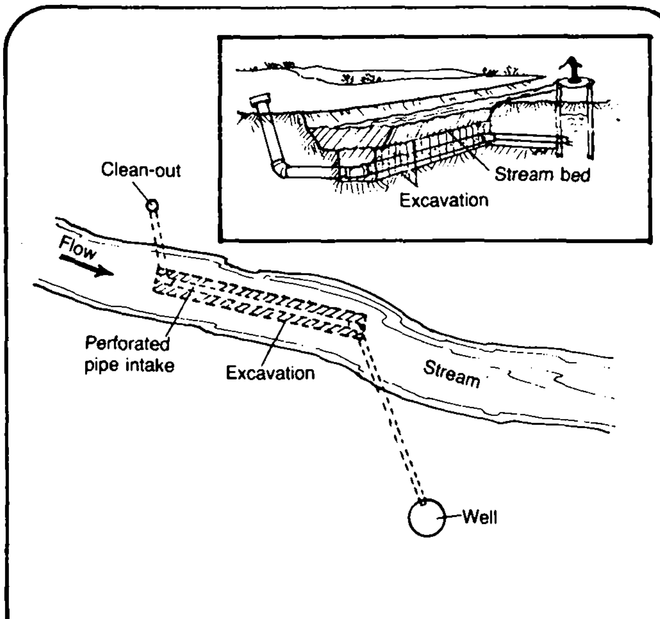

Figure 6. Infiltration System Below Stream Bed

3. On the shore opposite the clear well, install a vertical pipe connected to the main collection system. This pipe acts as the clean-out pipe and should be capped.

4. Connect the other pipe to the clear well. Install a valve in the pipe just above the well so that water flow can be stopped for any needed operation and maintenance.

If appropriate equipment is available an infiltration gallery with collection pipes driven into the stream bed can be constructed. See Figure 7. Follow the construction steps below.

1. Dig a clear well in the stream bank. Make the well about 1.5m in diameter to permit people to work inside.

2. Line the well with concrete rings or bricks and mortar as described in "Constructing Dug Wells," RWS.2.C.1. Leave a section unlined so that the pipes can be driven into the ground. If water enters the well quickly, drain the well using a motorized pump. The well should be kept as dry as possible for work to take place.

3. Lower the necessary tools and equipment into the well. In some cases, the pipe can be driven by hand but generally a pneumatic hammer is necessary.

4. Begin to auger a hole into the side of the well. Once the hole has entered the side of the well about 0.5m, place the drive pipe in place.

5. Drive the pipe into the stream bed so that the pipes slope toward the well. If a sledge hammer can be used, the process should be simple. If a pneumatic hammer is used, brace it against the opposite wall for support and drive the pipes into the stream bed. To prevent destruction of the well casing, extra reinforcement should be added to the side of the well.

6. Drive in the number of pipes desired. If plastic pipe is more easily available than steel, drive in large diameter steel pipe. Once the driving process is complete, slide smaller diameter perforated plastic pipe into the steel pipe and slide the steel pipe out. For more specific information on the process of driving, see "Constructing Driven Wells," RWS.2.C.2.

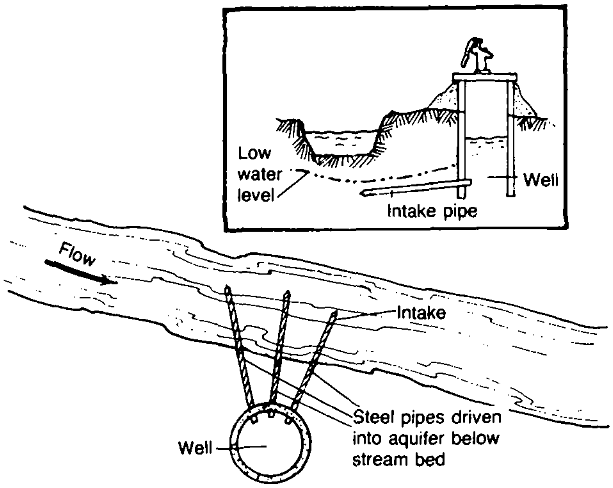

Figure 7. Multiple Pipe Infiltration System

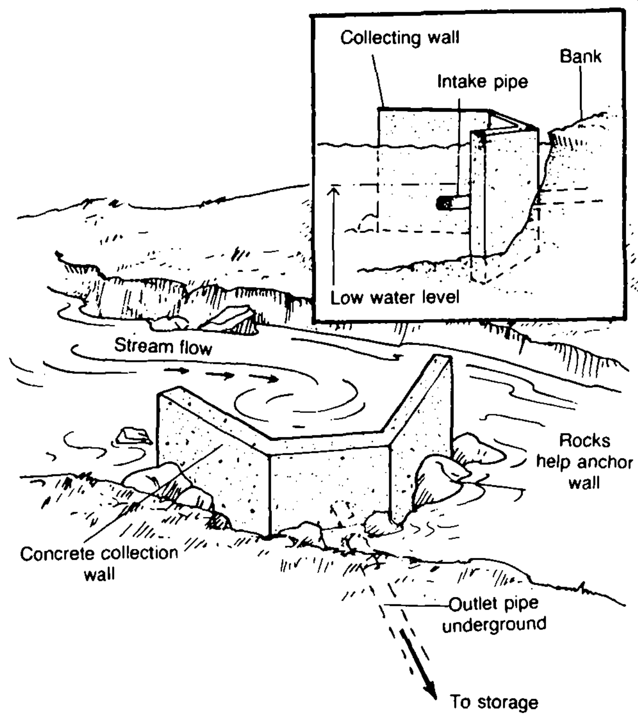

Figure 8. Gravity Flow Intake

Gravity Flow System

In mountains and hilly regions, water from streams and rivers can be collected as shown in Figure 8. This section outlines the construction steps to follow for a concrete intake with winged-walls.

Construction. Move all construction materials to the work site. The winged-wall intake should be built at the site, following exactly the location map and detailed drawings the project designer has given you. See Figures 9 and 10.

1. Build the forms for the structure. For strength, the thickness of the wall should be 15cm. Be sure to oil and brace all forms before pouring the concrete.

2. Cut a 50mm hole in the forms for the intake pipe. Place a small piece of steel pipe in position before pouring the cement.

3. Mix the concrete in a proportion of one part cement, two parts sand and three parts gravel. Add water to make a thick paste.

4. Place reinforcing rod in the forms as shown in Figure 11. The rod should be placed two-thirds the distance from the side receiving the weight of the water.

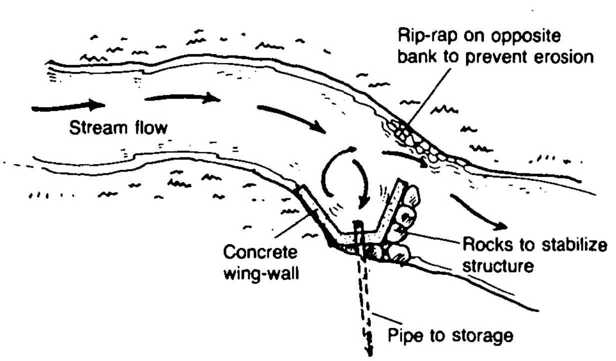

Figure 9. Location Map for Gravity Flow Intake

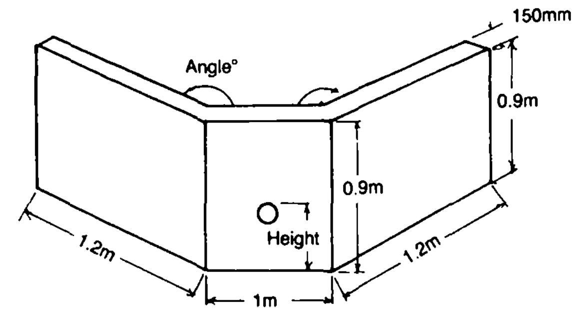

Figure 10. Design of Typical Wing-Wall Collector

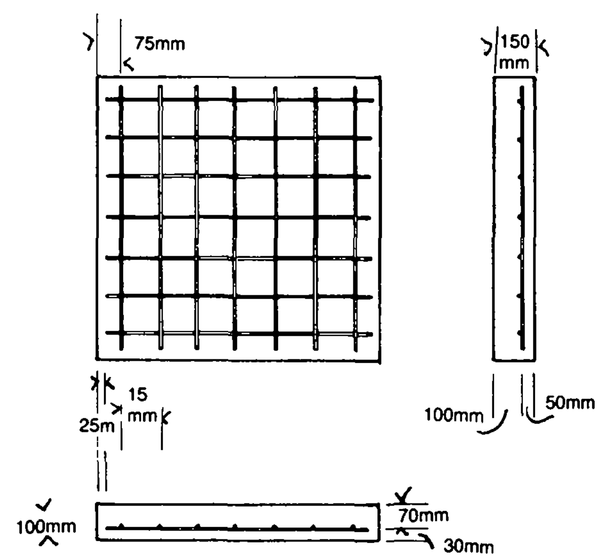

Figure 11. Placement of Rebar in Concrete Slab

5. Pour concrete into the forms making sure to tamp it down to fill any voids or air pockets. After pouring, smooth the top of the walls and cover with canvas, a plastic sheet, or straw to protect it. Wet the structures at least once a day for good curing. Curing produces strong concrete.

6. Allow the concrete to cure for seven days and then remove the forms.

Installation. The placement of the winged-wall structure must be done carefully. Because the structure is heavy, it is difficult to move. If it falls against the rocks in the stream it could break apart. Follow these basic steps when installing the structure.

1. Take out the pipe left in the structure to form the inlet hole and put in a new length of either galvanized or plastic pipe which can be attached to the distribution system. Seal around the pipe and wall with mortar. The pipe length should not be any longer than about 0.5m so that it does not interfere with the installation.

2. Place a piece of 10mm wire mesh over the intake pipe and clamp or tie it in place.

3. Determine where the pipe meets the bank and dig out a trench so that the pipe rests securely in the bank.

4. With logs or heavy duty metal poles, build a tripod on the bank of the stream. Bury a 0.30m length of each pole in the ground to make it secure. Tie the poles together with heavy rope.

5. Install a pulley at the top of the tripod. If the structure is very heavy, a double pulley or two pulleys may have to be installed.

6. Tie the rope around the structure to secure it well and to let it swing freely in the air. Place two or three men at the rope to lift the structure and two others to guide it into place in the stream. See Figure 12.

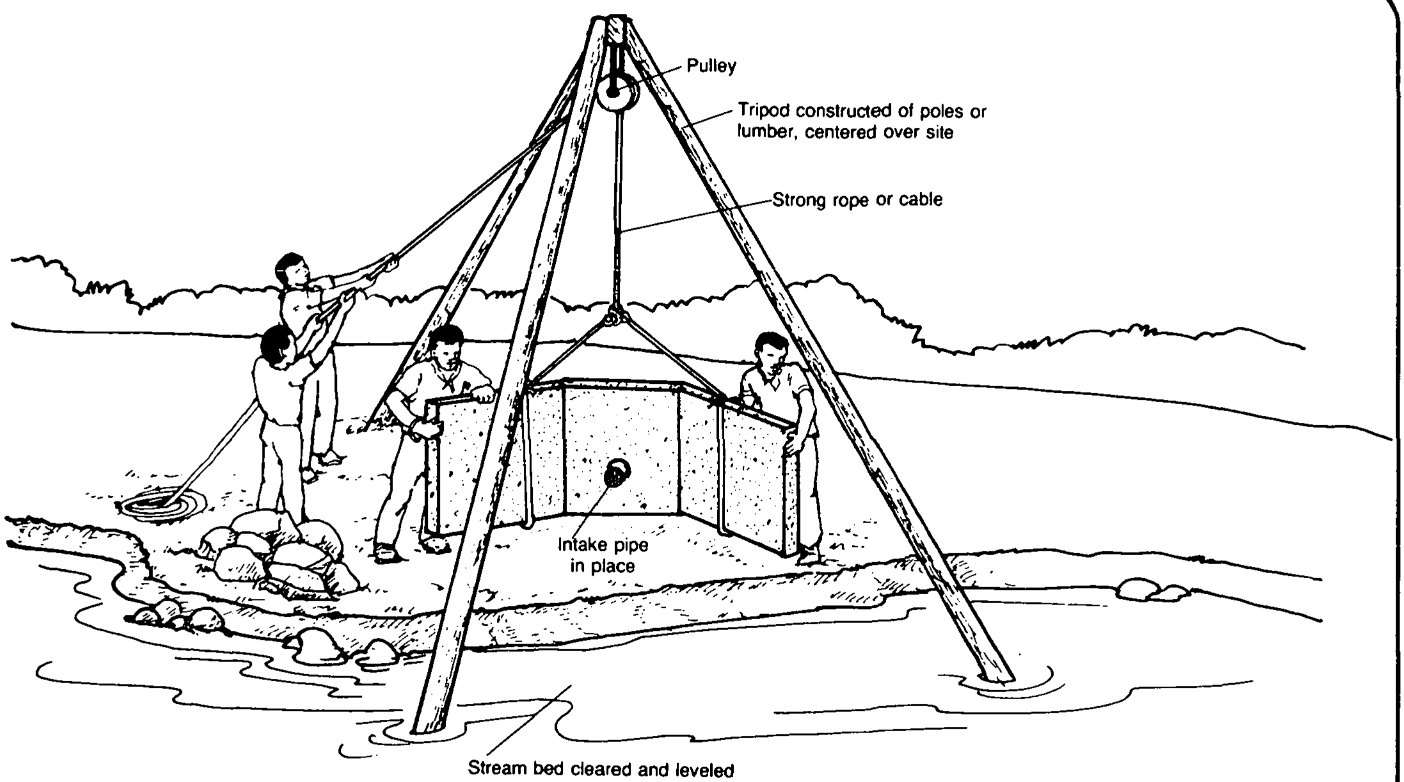

Figure 12. Installing Wing-Wall for Gravity Flow Intake

7. Before placing the structure in the stream, dig out about 10mm on the stream bed to place the structure. Flatten a spot on the shore where the front of the structure can fit tightly. It may be necessary to dig deep and add rip-rap if there is evidence of erosion.

8. Lower the structure into the stream so that the front is flat against the bank. Pile large rocks against the downstream side so that a fast flow does not wash it away. Be sure that the water completely covers the intake pipe.

9. Dig a trench to bury the outlet pipe. The trench should be at least 200mm deep to adequately secure the pipe.

10. Place rip-rap on the shore opposite the structure in order to prevent erosion of the bank.

If the concrete structure is large, it may be too heavy to easily lower into the stream. In such cases, and if the stream flow is not very strong, the forms can be built and the structure cast directly in the water. This technique should only be attempted by someone with a great deal of experience in working with concrete.

Permanent Direct Pumping System

This system is the most difficult to build and requires a construction team of skilled workers. Figure 13 shows an example of an intake for direct pumping. It is a well standing in the stream.

Select a firm area on a river bank about 2-3m from the stream and stake it out for a work area. The site should be in a straight stretch of the bank. Using the location map, find a firm, flat section of the stream or river bed where water is at least 1m deep during the dry season.

Also, stake out the pipeline trench and a foundation for the catwalk support on the river bank. Follow carefully the detailed drawings the project designer has given you.

Construction. Construct or purchase a reinforced concrete ring 1.5m in diameter and 1m in height. Concrete rings are more difficult to cast and it might be easier to buy a concrete ring. Rings, however, can be built using bricks and mortar.

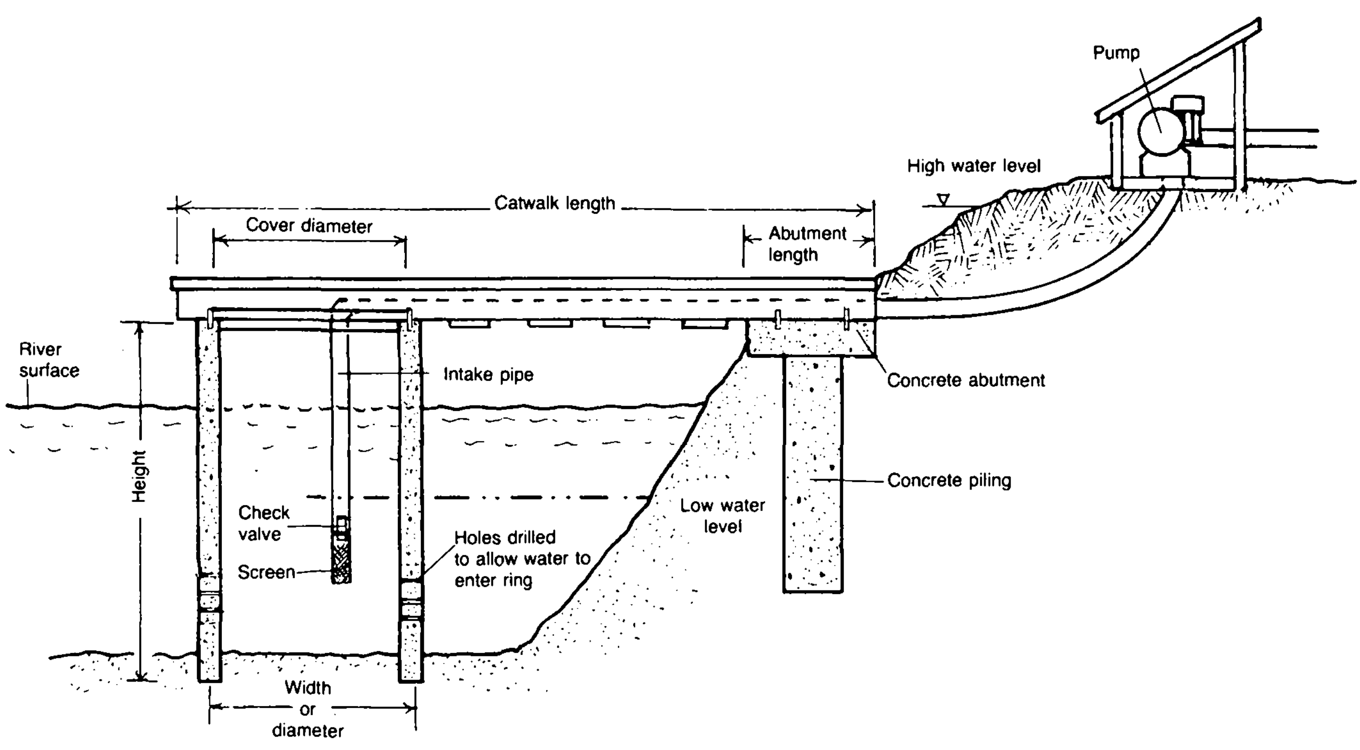

Figure 13. Direct Intake

To make a ring from half bricks and mortar follow these steps:

• Trace the diameter of the ring on the surface where the ring will be constructed.

• Lay the half-bricks around the outside diameter of the traced ring. Fill in the cracks with small loose gravel and mortar, mixed with four parts sand and one part cement.

• Build the ring to the desired height using normal brick-laying techniques.

• Wrap the finished ring with wire. Old barbed wire is useful.

• Cover the wire-wrapped ring with mortar and let it cure for 10 days before installation.

Place two bolts on the top edge of the concrete ring so that they face upwards. One bolt should be located on each side of the ring and should be at least 15cm long in order to anchor the catwalk. To permit the flow of water into the ring, place 5-7mm diameter holes around the side of the ring below the expected low water level. See Figure 14.

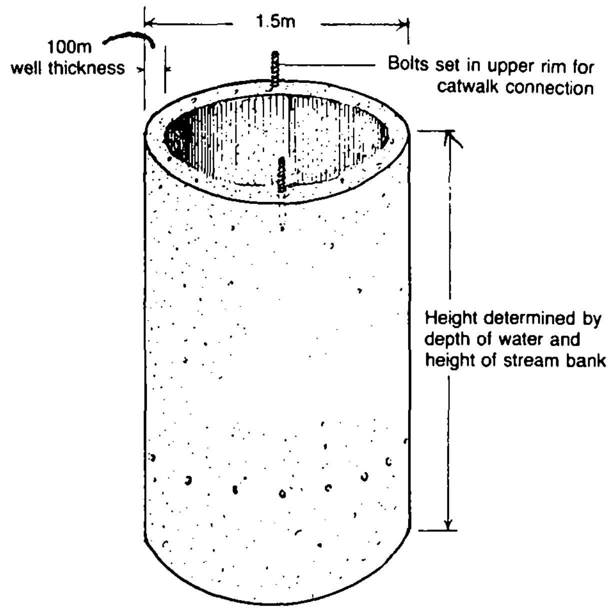

Figure 14. Concrete Ring for Protected Intake

Installation. The first step is the placement of the ring in the stream.

1. Build a skid to help lower the ring into the river. An example of a skid which can be used is shown in Figure 15.

2. Lay the skid on the bank and secure it on the stream bed. Then, place a log or other suitable bracing device on the skid and loop rope around each end.

3. Place the concrete ring on the skid as shown and lower it into the stream by sliding the log down the skid and guiding the ring.

4. To stand the ring upright, use tripod with a pulley placed in the stream bed. Tie a rope around the ring and lift it into place. A long strong piece of wood can be used as a lever to lift the ring. Place the lever inside the ring and with several workers lift it into place. It may be necessary to tie a rope to the top of the lever so that people standing on the bank can pull the ring into an upright position. See Figure 16. Be sure to dig down at least 0.5m to sink and anchor the ring. Level the ring in the stream bed by removing debris below it. The bolt in the ring must be in line at a right angle to the bank.

5. Once the ring is in place, dig the pipe trench in the bank. To support the catwalk build a concrete abutment attached to a concrete piling as shown in Figure 17.

6. Attach catwalk beams with attached lower planks to the top of the concrete ring and abutments by tightening nuts on the pre-placed bolts.

7. Lay the pipe into the trench and under the catwalk. Backfill the trench up to the last 0.60m of the connection to the pump as shown in Figure 18.

8. Connect a union joint to the end of the pipe so that a straight piece of pipe extends down from the catwalk into the water in the concrete ring. See Figure 19. Place a check valve at the end of the intake pipe. Be sure that the end of the pipe rests below the water level, but not close to the flow of the stream.

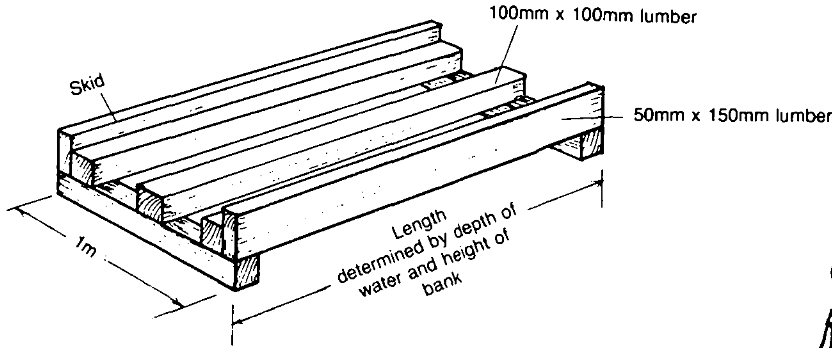

Figure 15a. Design of Skid

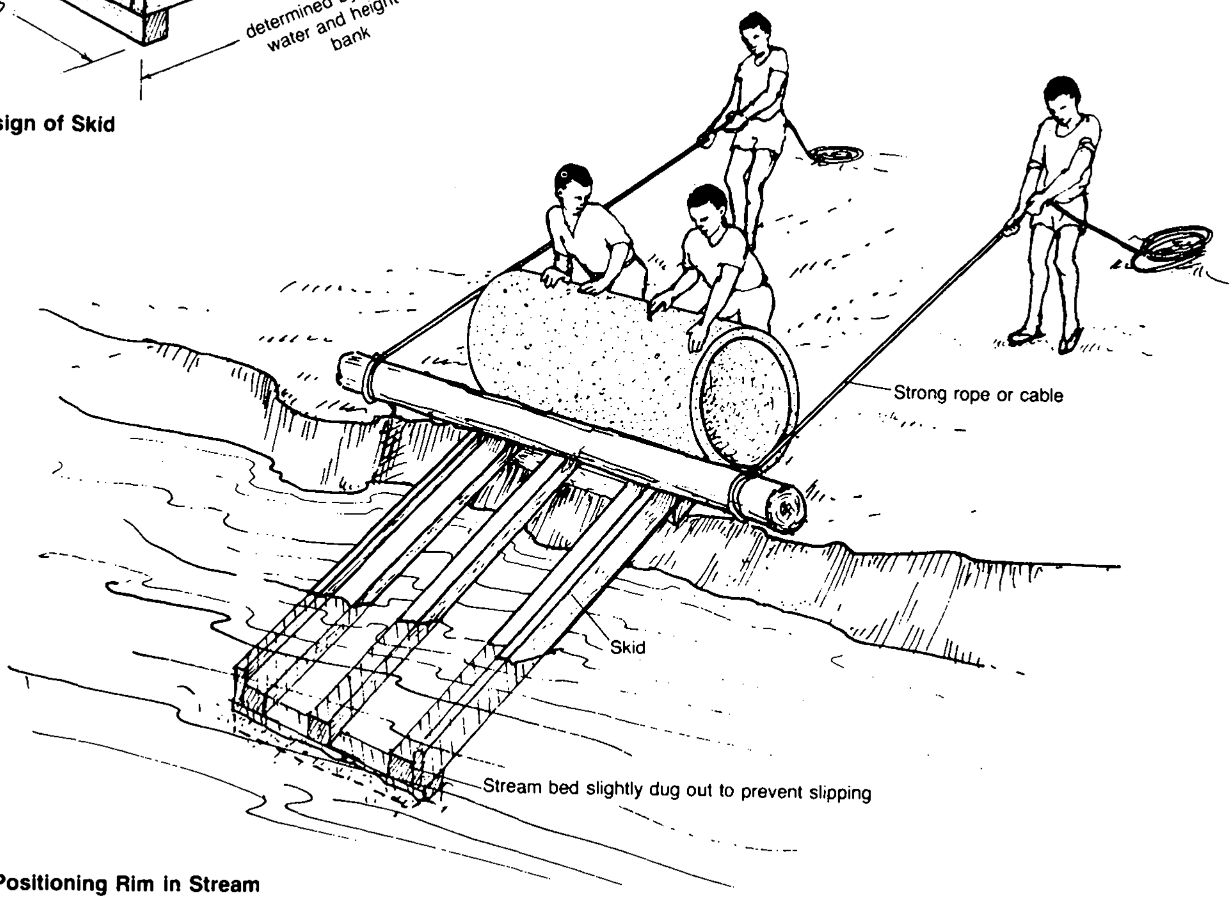

Figure 15b. Positioning Rim in Stream

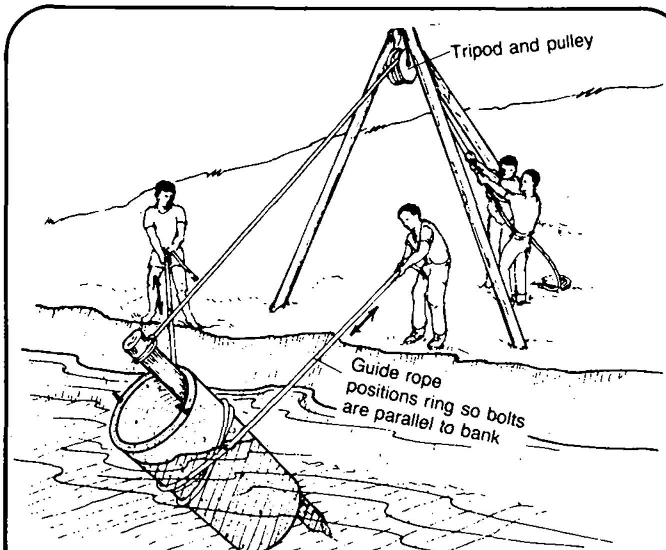

Figure 16. Raising Ring to Vertical Position

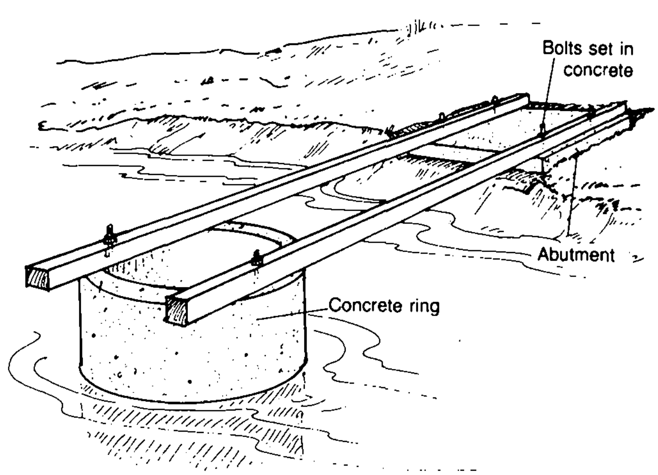

Figure 17. Catwalk and Abutment

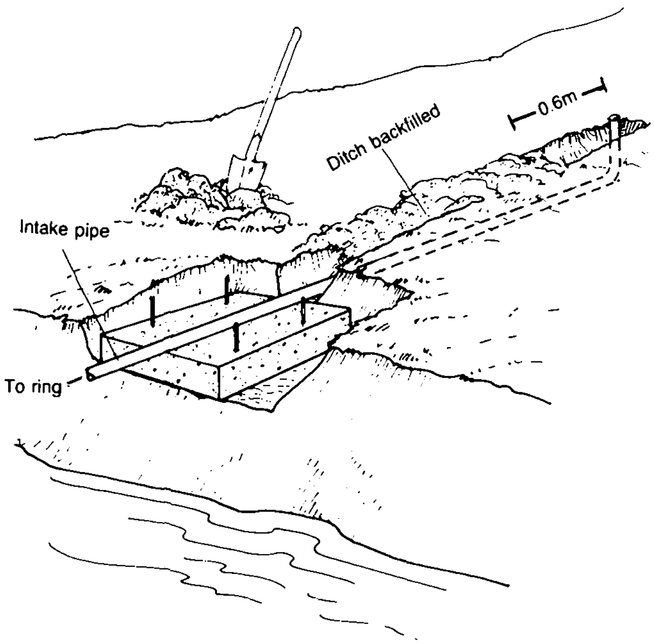

Figure 18. Installing Pipe

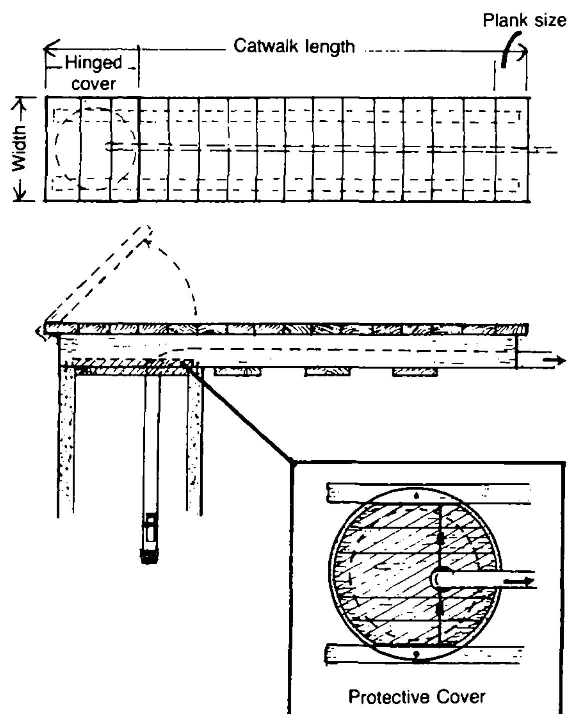

Figure 19. Catwalk and Cover Design

9. To complete the installation, attach the pipe to a mechanical pump as detailed in "Installing Mechanical Pumps," RWS.4.C.2.

Another simpler direct intake design is shown in Figure 20. To construct this intake follow these steps:

1. First, build forms for the intake base. A square base 0.6m x 0.6m should be large and heavy enough. The height should be sufficient to enclose a length of pipe to which the vertical intake can be attached.

2. Place a length of steel pipe in the forms. Make sure that the pipe is in place and that the forms are oiled and braced before pouring the cement. Mix and pour the cement and allow it to cure for at least seven days.

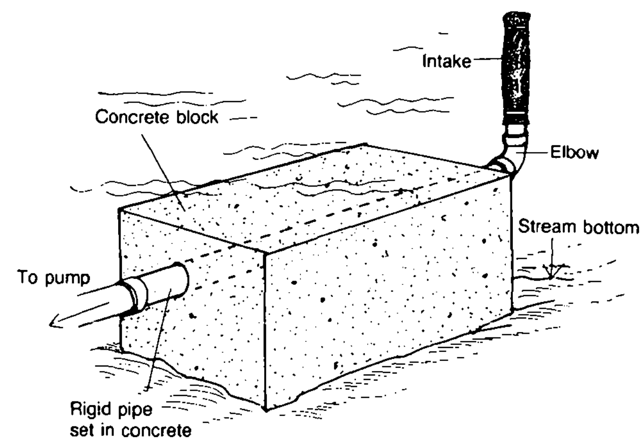

Figure 20. Rigid Pipe Intake

- Once the cement is dry, the intake can be installed. Attach an elbow joint and a length of screened vertical pipe to one end of the base. Attach the pipe leading to the pump to the other.

- Lower the intake into the stream. Mark its location by attaching ropes with floats to its base. The intake can be lifted from the water for maintenance by these ropes.

Notes

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

1982

Water for the World

Constructing, Operating and Maintaining Roof Catchments

Technical Note No. RWS. 1.C.4

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

Useful Definitions

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

CISTERN - A storage tank for water.

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

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

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

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

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

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

Table 1. Sample Materials List

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

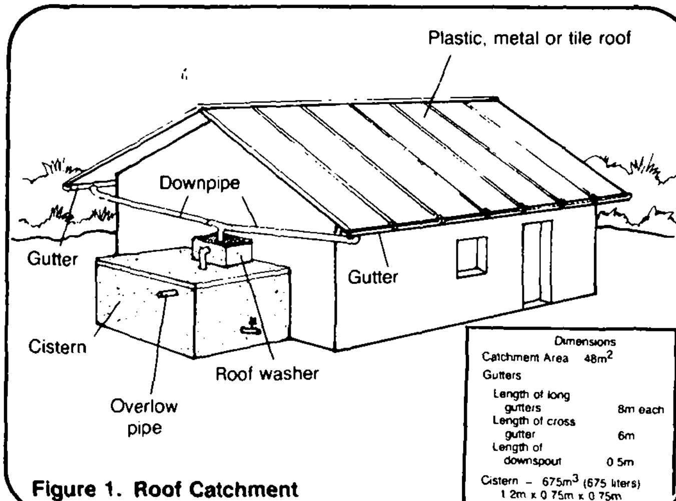

Figure 1. Roof Catchment

Installation

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

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

Table 2. Roofing Material Sizes

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

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

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

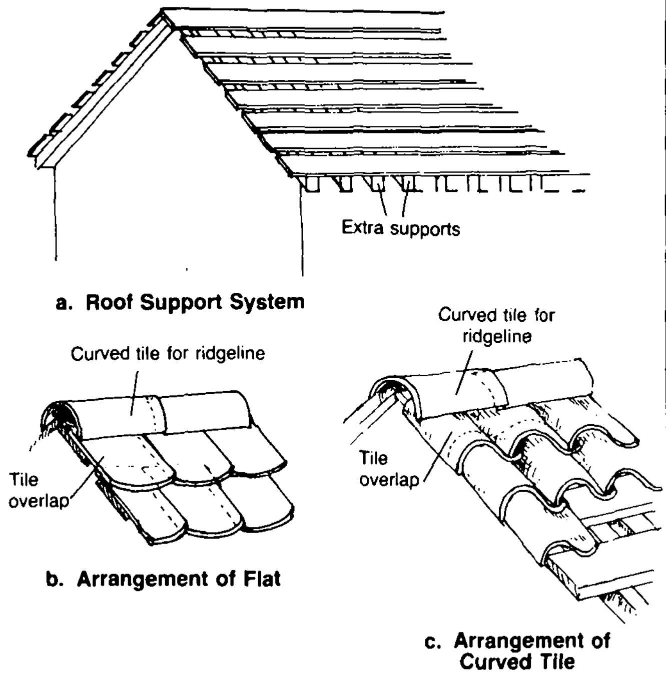

Figure 2. Tile Roofing for Catchment

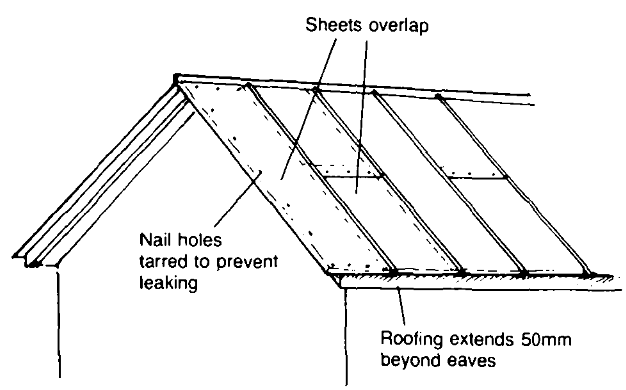

Figure 3. Metal Sheeting for Roof Catchment

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

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

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

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

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

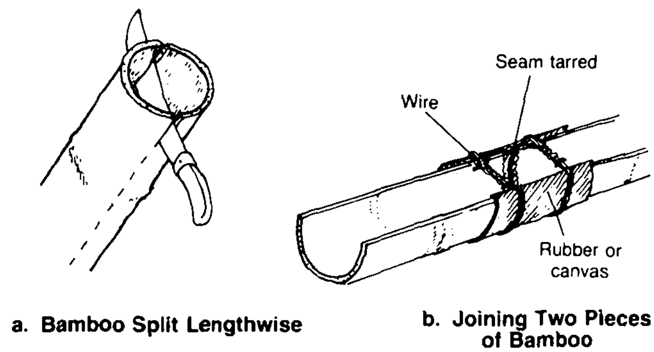

Figure 4. Making Gutters from Bamboo

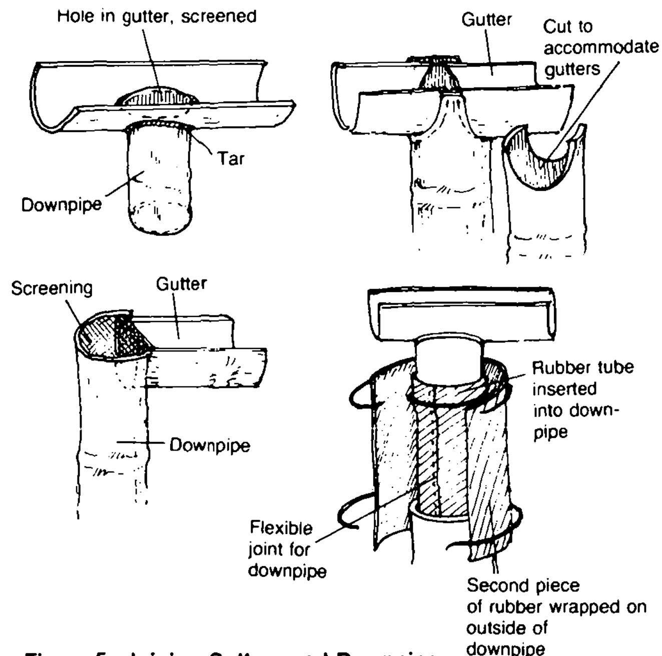

Figure 5. Joining Gutters and Downpipes

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

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

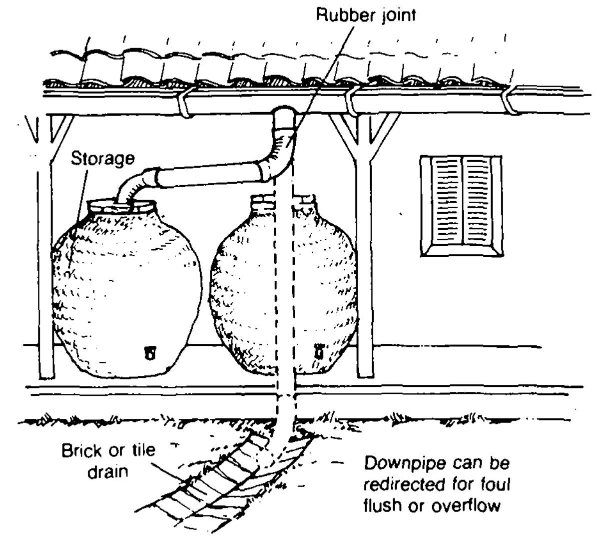

Figure 6. Flexible Joint in Downpipe

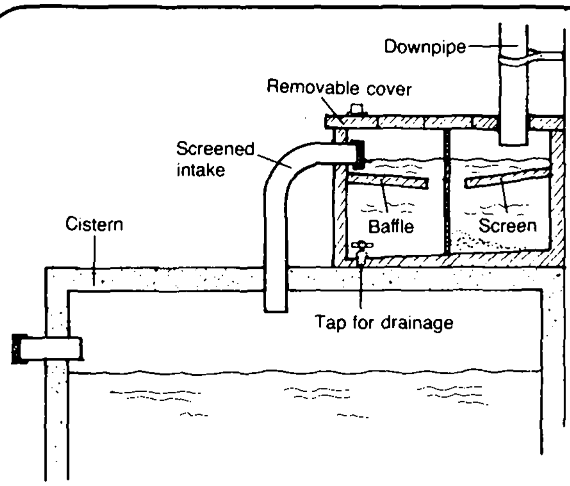

Figure 7. Collection Box for Foul Flush

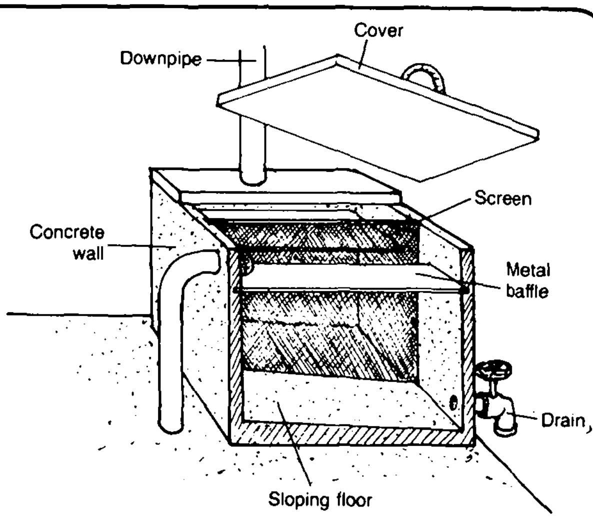

Figure 8. Detail of Collection Box for Foul Flush

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

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

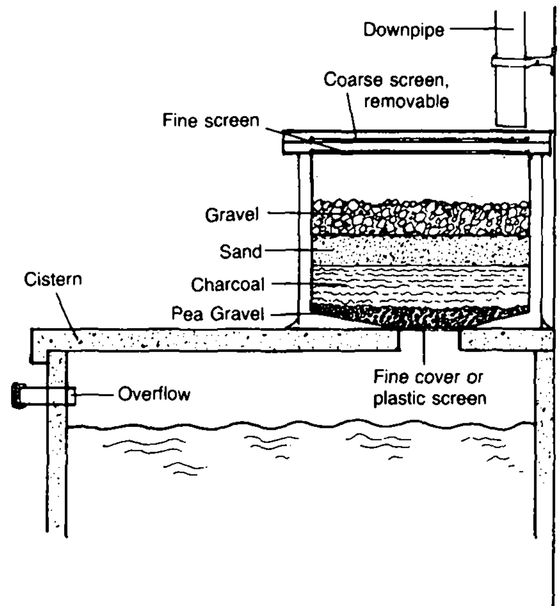

Figure 9. Filter System

Maintenance

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

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

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

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

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

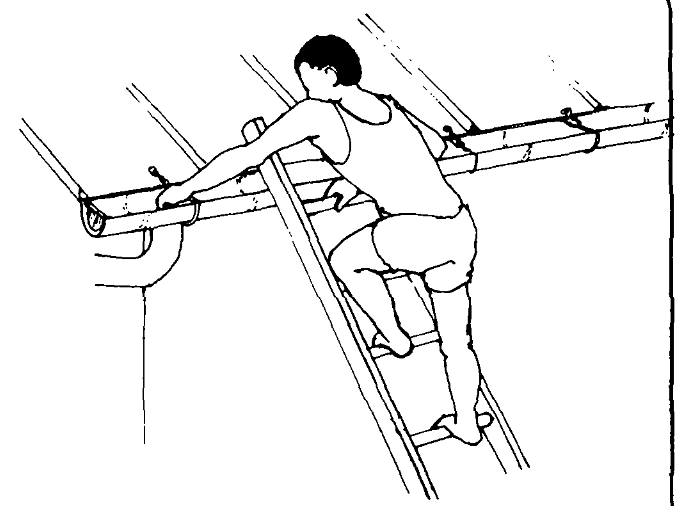

Figure 10. Cleaning Gutter and Screen

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

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

Notes

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

Water for the World

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

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

Useful Definitions

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

CISTERN - A storage tank for water.

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

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

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

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

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

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

Table 1. Sample Materials List

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

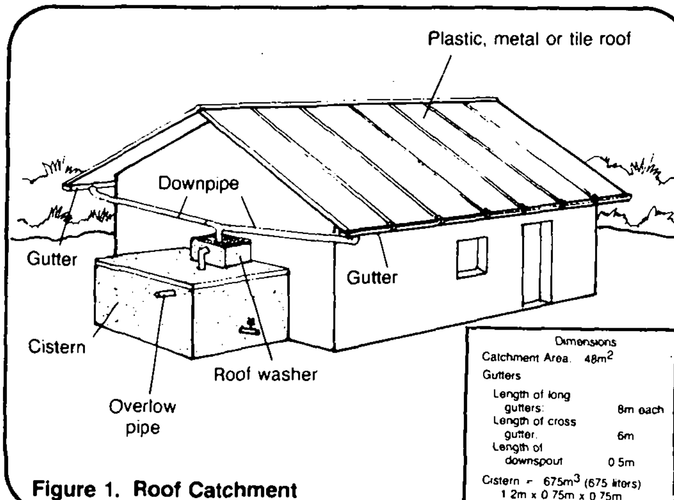

Figure 1. Roof Catchment

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

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

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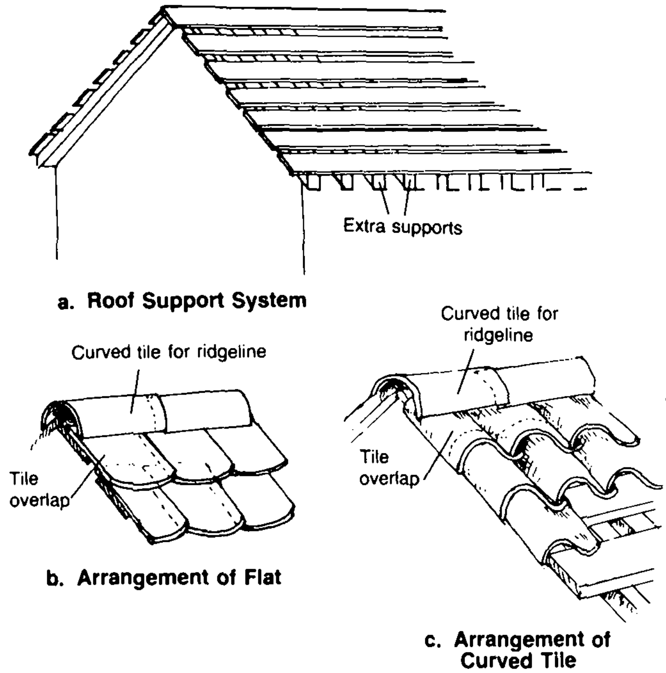
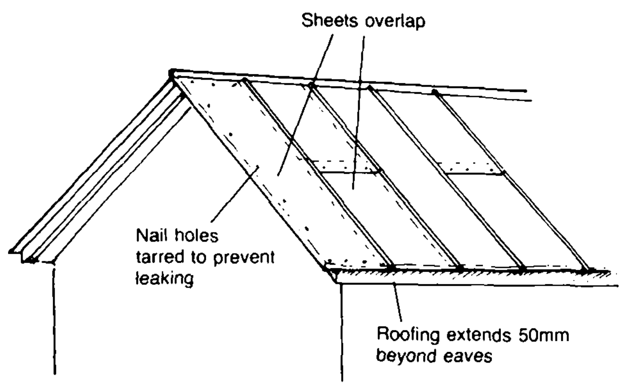


Figure 2. Tile Roofing for Catchment



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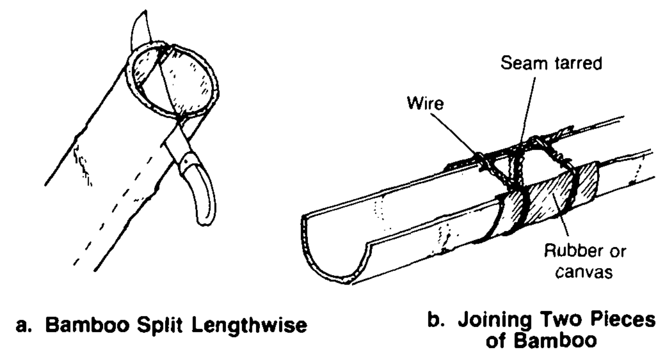

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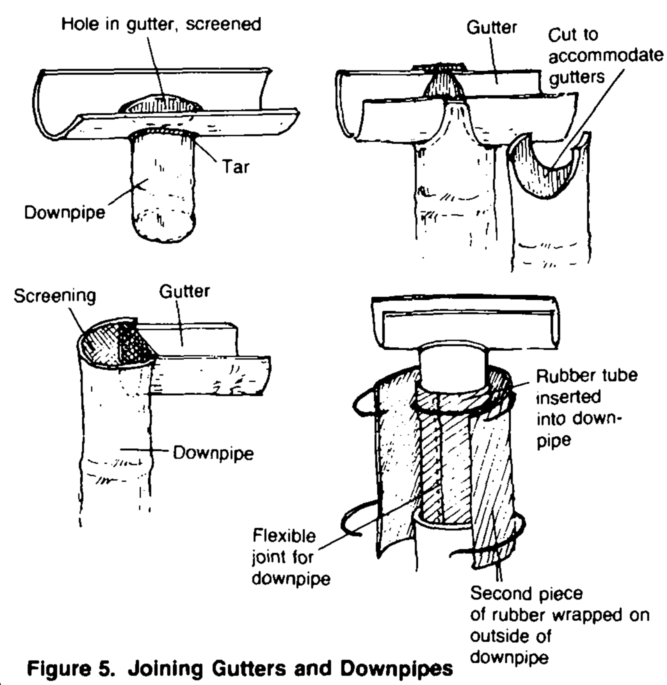

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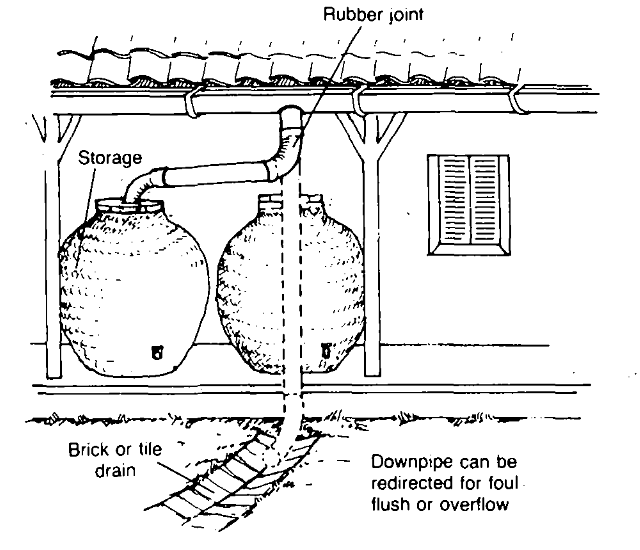


Figure 6. Flexible Joint in Downpipe

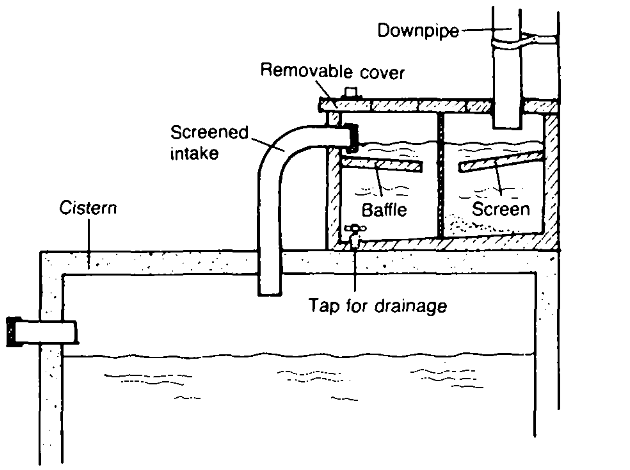
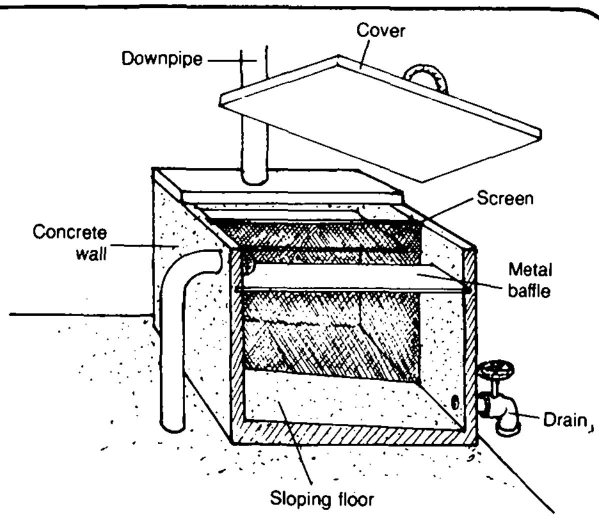


Figure 7. Collection Box for Foul Flush



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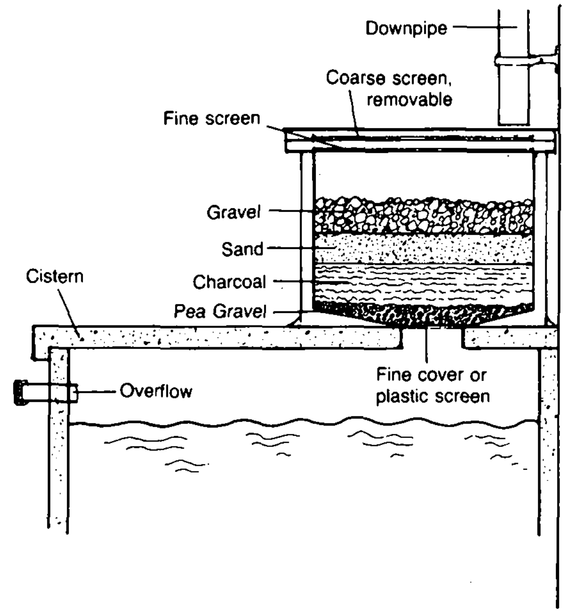

Figure 9. Filter System

Maintenance

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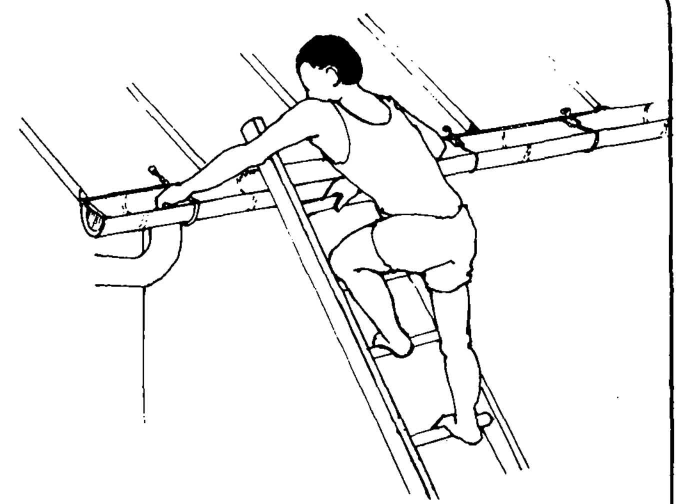

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1982

Water for the World

Constructing Small Dams
Technical Note No. RWS. 1.C.5

The construction of small earth dams and water impoundments requires great care and skill. Poorly constructed dams are dangerous because they may break and cause flooding. A dam construction project should never be attempted without expert technical advice and some skilled labor. In attempting to build a dam, be sure to follow carefully the design prepared by the project designer (see "Designing Small Dams," RWS.1.D.5).

This technical note discusses the construction of small earth dams and outlines the construction steps to follow. Follow each step carefully to ensure that the dam is well built and strong.

Useful Definitions

ANTI-SEEPAGE COLLAR - Metal disks attached to steel pipe installed in a dam embankment. They prevent any flow of water in the space between the outside of the pipe and the embankment and thus prevent erosion and dam failure.

EROSION - The wearing away of soil, rock or other material by the flow of water.

PERCOLATION - Movement of water downward through the pores of the soil.

RESERVOIR - A natural or artificial lake where water is stored for use.

RIP-RAP - A covering of large stones or rock on the water side of a dam or on the banks to prevent erosion by waves or currents.

SILT - Sediment made up of fine particles carried or laid down by moving water.

SPILLWAY - A channel built to control flood water in a reservoir; it causes flood water to spill around the ends of a dam rather than over its top.

WATERSHED - The area of ground over which rainfall flows into bodies of surface water.

Materials Needed

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

1. A map of the area, including the location of the dam, access roads, the watershed area and nearby communities and houses. Figure 1 gives an example of the type of location map needed.

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

3. A cross-section of the dam to be built with slope and sample dimensions as shown in Figure 2. Dimensions other than the sample shown should be in line ratios.

Table 1. Sample Materials List for a Small Dam

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Clay soil Flat rocks Grass seed Stakes Rope Steel pipe	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____
Tools	Surveying equipment Digging tools A small tractor or backhoe (if possible) Soil compaction device Levels Earth moving equipment	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____

Total Estimated Cost = ____

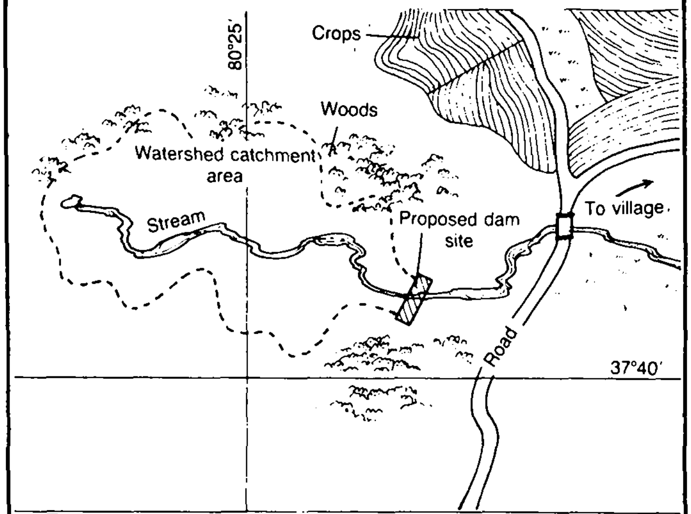

Figure 1. Location Map

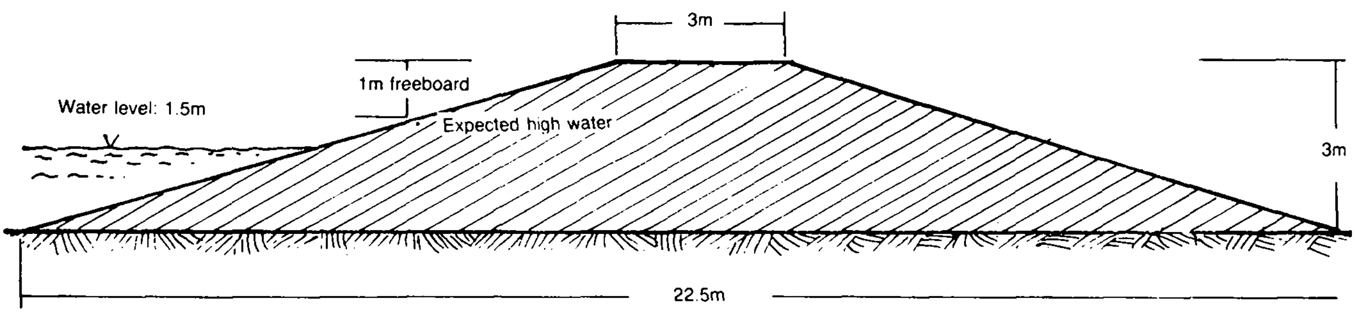

Figure 2. Clay Dam Cross-Section

General Construction Steps

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

1. Divert the flow of water away from the dam construction site. Two methods are available. The first and best method is to install a large diameter steel pipe in the stream as shown in Figure 3. Place the opening of the pipe beyond the furthest extension upstream of the dam embankment. Lay enough pipe so that the entire length extends past the furthest downstream extension of the embankment. Channel all flow into this pipe, if possible.

Before laying the pipe, attach anti-seepage collars to it. Each collar should be welded to the pipe and separated by a distance of 7m. The entire length of the installed pipe for the sample dam described in this technical note should be approximately 25 or 26m in order to extend beyond both sides of the embankment.

If the volume of stream flow is great, difficulties may arise in channeling all water flow into the pipe. A diversion ditch that leads water around the dam may have to be built. The construction of the ditch is very tedious and time-consuming if work is done by hand. In fast flowing streams, a combination of both methods can be used since the pipe should be installed to drain water from the reservoir during times of flooding.

No matter how the water is diverted, the job may be easier if the dam can be built during the dry season since less water will need to be diverted.

2. Mark out the dam site with stakes and rope as shown in Figure 4. Mark the proposed water lines using a hand level. The string across the valley should mark the high point of the dam. Be sure that the line is level before starting the other construction steps.

3. Clear all trees, dead leaves, branches, logs, stumps, roots and other debris from the area that will be covered by water. Special care must be taken to clear out all roots and debris at the site of the dam itself so that percolation and possible embankment leakage and failure do not occur. Before proceeding with further constuction steps, check the area well to be sure that no debris is left in the area.

Embankment

The first step in the construction of the dam is to determine the width of the embankment. First, find the width of the embankment at its widest point. The widest point is also the lowest point of the reservoir. Refer to "Designing Small Dams," RWS.1.D.5, when determining the base width.

Dam width is equal to the height of the dam times the upstream slope added to the height of the dam times the downstream slope (a typical earth dam has a 3.5:1 upstream slope and a 3:1 downstream slope) added to the top width. For example, for a dam 3.0m in height with a 3.0m top width and 3.5:1 and 3:1 bank slopes, the width of the base is:

(height x upstream slope) + (height x downstream slope) + top width

(3.0m x 3.5m) + (3.0m x 3m) + 3.0m = 10.5m + 9.0m + 3.0m = 22.5m

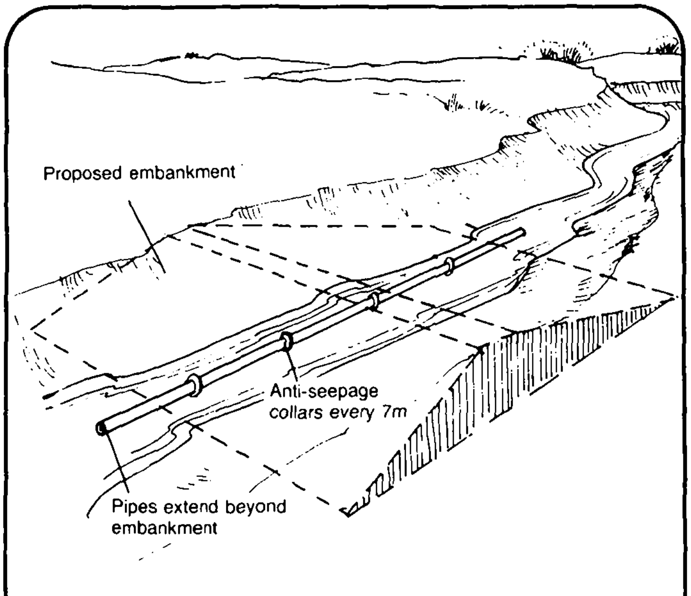

Figure 3. Drain Pipe

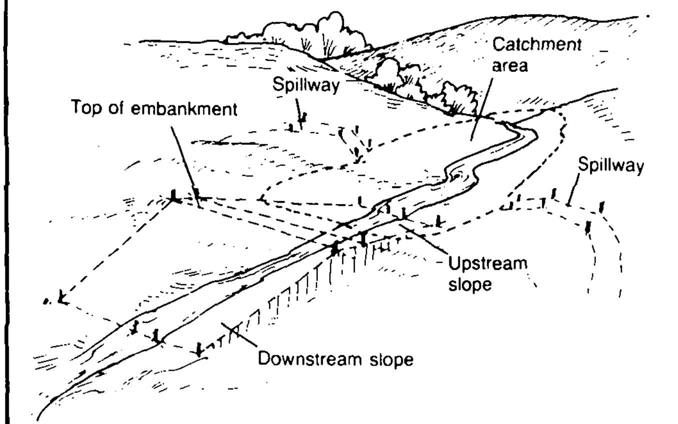

Figure 4. Staking Dam Site and Spillways

The width of the dam should be checked continually to ensure proper slopes and width. For example, if 0.5m of the dam is completed, a new calculation can be done. This time, instead of using the number 3.0m as the height, use only 2.5m. The width of the dam after 0.5m of the fill height is completed should be 19.25m. See Table 2 for the proper widths of dam embankments at various fill levels.

Before beginning to build the embankment with soil, mark its width with rope and pegs to ensure accuracy.

Table 2. Widths of Dam Embankments at Different Fill Heights

Fill Height Above Ground	Embankment Width
Base	22.5m
0.5	19.25m
1.0	16.0m
1.5	12.75m
2.0	9.5m
2.5	6.25m
3.0 (top width)	3.0m

Dig out the pegged area until solid ground is reached. Then dig out another 0.3m of earth to ensure that the structure is well bonded to the ground surface. If the bottom is rough and irregular, the bond to the ground will be better but there should not be any stumps, roots or other debris around the bottom or ends of the dam.

To begin embankment constuction, be sure that adequate quantities of soil are at hand. Try to obtain good soil from the nearest possible site. Soil from spillway and reservoir excavation should meet most needs. Use a clay soil containing some silt and sand. If only clay is used, the embankment may crack. If too much sand is used, water may percolate through. In the construction process, use uniform material. If the quality of any of the material is questionable, use it only on the downstream side of the embankment. If there is any doubt about the suitability of embankment material, consult a soils expert or geologist, or send soil samples to the nearest soils laboratory for analysis.

To ensure the strength of the dam, the following guidelines should be followed in constructing the embankment. First, the fill material should be spread in continuous layers across the entire length of the dam. See Figure 5. Each layer should be between 100-150mm thick. Compact each layer carefully and thoroughly before adding the next layer. If the dam is being constructed without machinery, have the laborers dump their baskets of earth in lines from one end of the dam to the other. The workers should walk over the deposited soil to compact it well. Another method that can be used to compact the soil is to drive cattle from one end of the dam to the other after each day's work.

If the soil contains the correct level of moisture, sufficient compaction occurs from having the laborers tread on the fill and from using a simple pounding device as shown in Figure 6. The soil should be moist enough so that a foot mark will show. Dry soil should be wetted to reach the correct level of moisture. These steps are very important since the water tightness and strength of the dam depends on compaction.

If construction takes place in the wet season, precautions should be taken to ensure that water does not stay on the surface of the fill material. To allow water to drain, build up the center line of the dam and keep it a little higher than the sides so that rain runs off both the upstream and downstream sides. No part of the dam should be more than about 0.9m above any other part.

Continue to build the dam up layer by layer until the desired height and dimensions are reached. No dam holding more than 2.5m of water should be

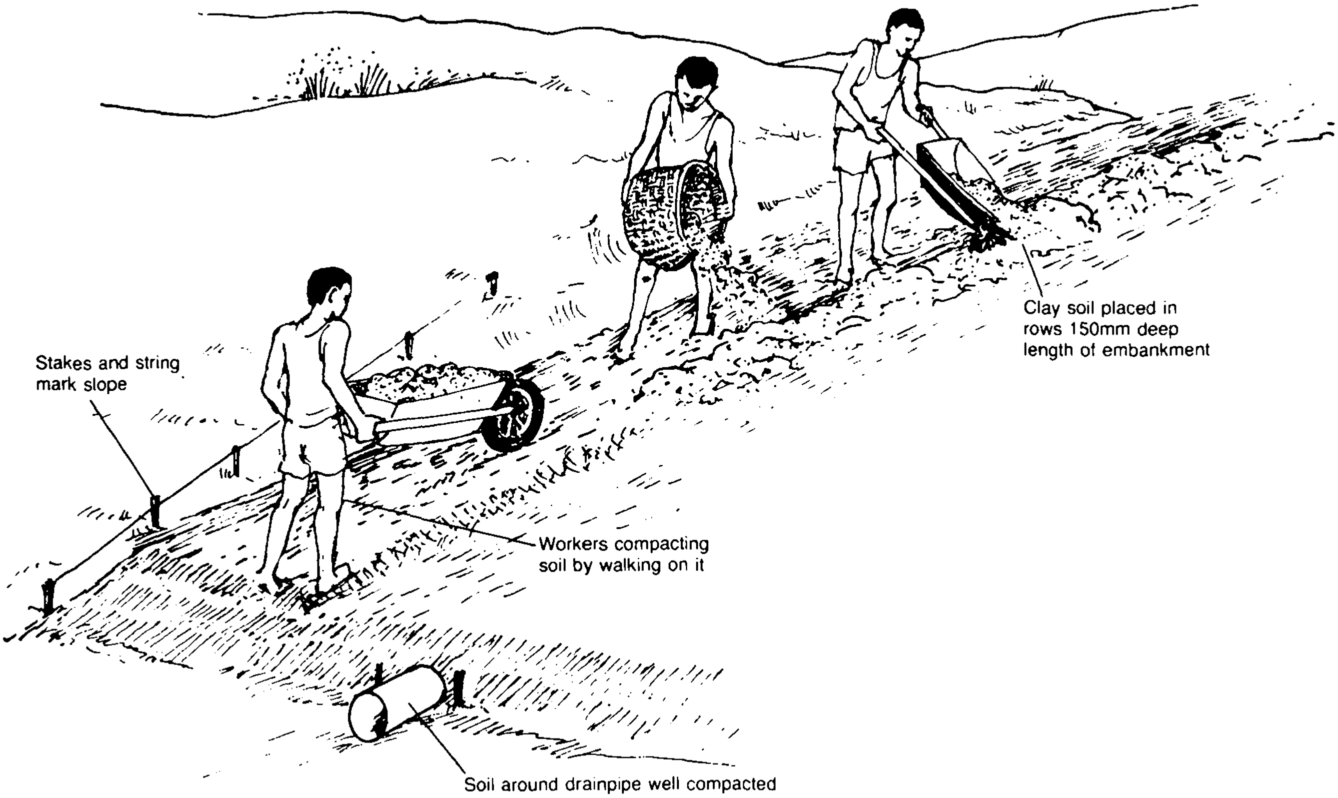

Figure 5. Constructing Embankment

attempted without expert advice. Usually, a small dam should not be more than 3m high. The design dimensions for dams are easily calculated. See "Designing Small Dams," RWS.1.D.5 for specific design information.

When building the embankment, make sure that the soil is well-compacted around the drain pipe. The soil should be as well bonded to the pipe as possible to prevent any flow of water along the pipe. The anti-seepage collars are installed specifically to prevent the wearing away of soil from around the pipe.

Once the embankment is completed, precautions against erosion should be taken. Rainfall may wash away soil from the exposed parts of the embankment. To prevent this, grass--preferably a creeping grass--should be planted on the downstream slope, the crest and the upper part of the upstream slope not covered by water.

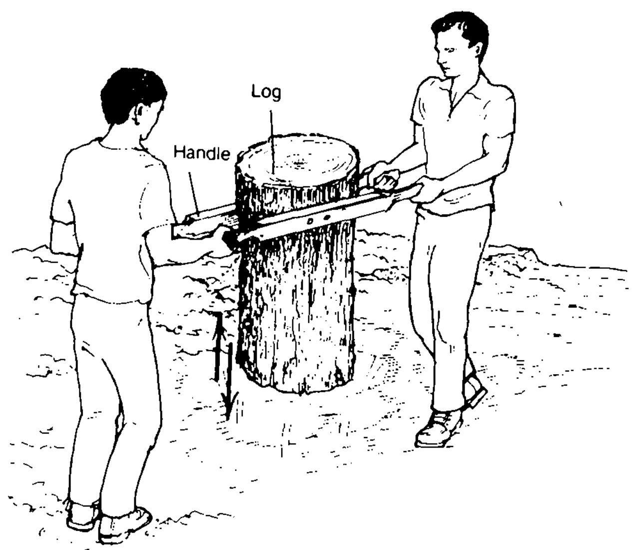

Figure 6. Manually Compacting Soil

Before planting, cover the embankment surface with a mixture of top soil and fertilizer, compost or animal manure. Plant the grass in horizontal rows for best results.

On the upstream side, erosion may be caused by the wave action of the water in the reservoir. To prevent this, pave the upstream slope with large rough stones to a point about 0.6m above the top water level as shown in Figure 7. Fill in the spaces between the large rocks with smaller flint-stones so that few spaces are exposed to the water. This protective covering is called "rip-rap." Once the embankment is completed, install a cut-off valve at the downstream side of the drainage pipe. The valve can be used if there is a need to drain the reservoir or if there is flooding and danger of overtopping. An elbow joint and short vertical extension can be installed at the upstream side of the pipe. This is useful but not essential.

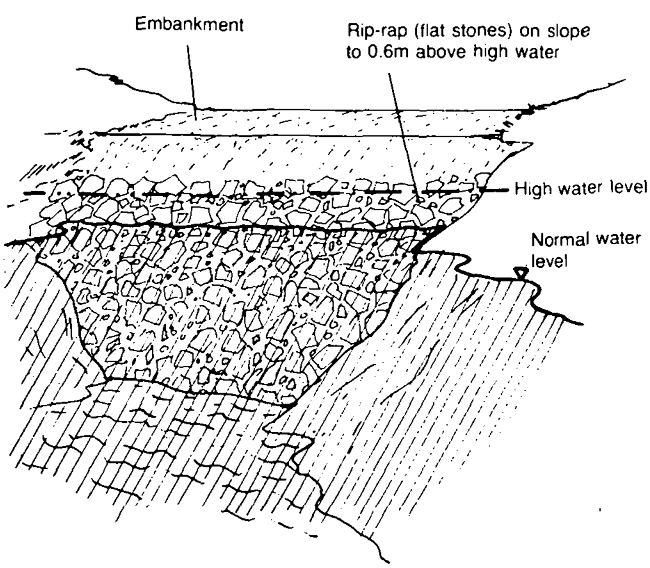

Figure 7. Placement of Rip-rap on Upstream Slope of Dam

Spillways

Spillways are one of the most important parts of the dam structure. They channel water away from the dam during periods of high water and protect the dam from overtopping. For extra safety, two spillways are recommended. Generally, one is placed higher than the other to act as a back-up and extra precaution.

Dig the spillways in solid ground, clear of the ends of the dam. They should be continued past the downstream edge of the base to prevent erosion. The earth excavated from the spillway channels provides fill materials for the embankment, and should be used in construction.

To detemine the dimensions of the spillway, use local information and field observation to make good estimates. From evidence of debris on banks, water marks on rocks and the knowledge of local people, the level to which water rises during typical flood times can be determined.

Find out how high the stream rises during the wettest season of the year. Estimate the width of the stream if it were running with a depth of 0.6m and then double the number to allow for any heavy flooding. This figure should be the minimum width of the spillway.

The calculated width is the width of the spillway at the highest point or crest, which is generally in line with the dam. Line the spillway crest with stone to prevent erosion. There is no need to line the channels leading in and out of the spillway crest. For best results, the channel below the crest should be widened a little and the first part of the channel made steep but smooth. Downstream, the channel should flatten out and lead into the stream below the dam. See Figure 8 for details.

Reservoir

Deepen all edges of the reservoir by approximately 0.6m to prevent the growth of vegetation and weeds and the breeding of mosquitoes and snails. The soil excavated from the edge of the reservoir may also be suitable as fill material for the dam embankment.

Summary

The construction of a small dam must be done carefully to ensure that the dam does not fail. Whenever possible, an expert should be consulted before and during the construction process. Poor construction can cause dam leakage and breakage, resulting in physical and economic loss. Careful construction using the advice of experts will ensure that the dam lasts for many years.

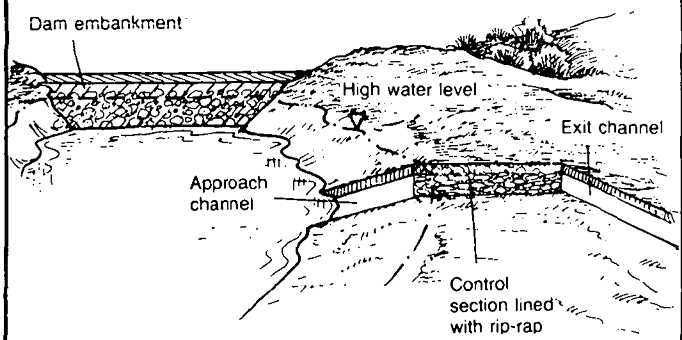

Figure 8. Spillway Design

Notes

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

1982

Water for the World

Constructing Small Dams

Technical Note No. RWS. 1.C.5

The construction of small earth dams and water impoundments requires great care and skill. Poorly constructed dams are dangerous because they may break and cause flooding. A dam construction project should never be attempted without expert technical advice and some skilled labor. In attempting to build a dam, be sure to follow carefully the design prepared by the project designer (see "Designing Small Dams," RWS.1.D.5).

This technical note discusses the construction of small earth dams and outlines the construction steps to follow. Follow each step carefully to ensure that the dam is well built and strong.

Materials Needed

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

1. A map of the area, including the location of the dam, access roads, the watershed area and nearby communities and houses. Figure 1 gives an example of the type of location map needed.

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

3. A cross-section of the dam to be built with slope and sample dimensions as shown in Figure 2. Dimensions other than the sample shown should be in line ratios.

Useful Definitions

ANTI-SEEPAGE COLLAR - Metal disks attached to steel pipe installed in a dam embankment. They prevent any flow of water in the space between the outside of the pipe and the embankment and thus prevent erosion and dam failure.

EROSION - The wearing away of soil, rock or other material by the flow of water.

PERCOLATION - Movement of water downward through the pores of the soil.

RESERVOIR - A natural or artificial lake where water is stored for use.

RIP-RAP - A covering of large stones or rock on the water side of a dam or on the banks to prevent erosion by waves or currents.

SILT - Sediment made up of fine particles carried or laid down by moving water.

SPILLWAY - A channel built to control flood water in a reservoir; it causes flood water to spill around the ends of a dam rather than over its top.

WATERSHED - The area of ground over which rainfall flows into bodies of surface water.

Table 1. Sample Materials List for a Small Dam

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Clay soil Flat rocks Grass seed Stakes Rope Steel pipe	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____
Tools	Surveying equipment Digging tools A small tractor or backhoe (if possible) Soil compaction device Levels Earth moving equipment	____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____

Total Estimated Cost = ____

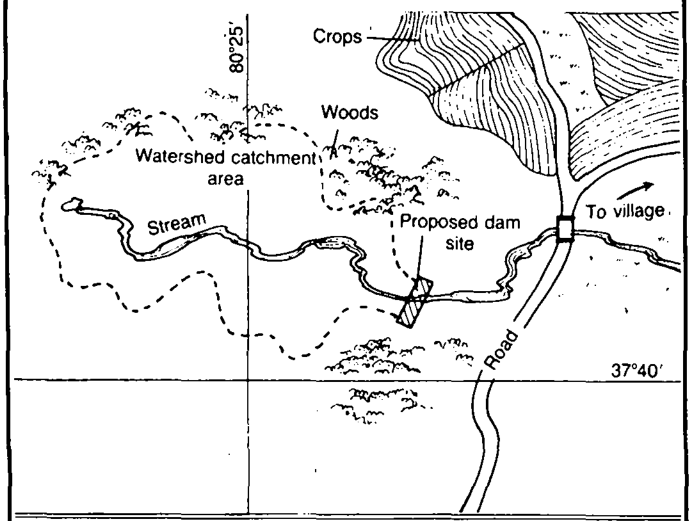

Figure 1. Location Map

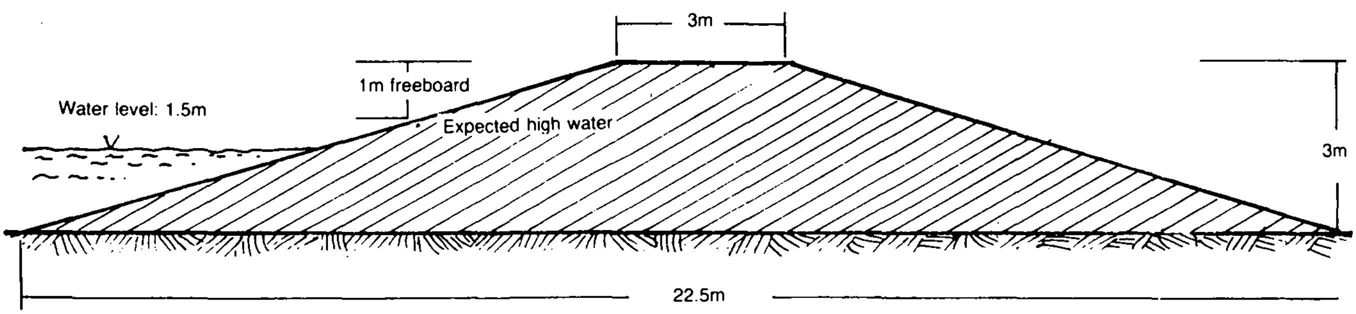

Figure 2. Clay Dam Cross-Section

General Construction Steps

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

1. Divert the flow of water away from the dam construction site. Two methods are available. The first and best method is to install a large diameter steel pipe in the stream as shown in Figure 3. Place the opening of the pipe beyond the furthest extension upstream of the dam embankment. Lay enough pipe so that the entire length extends past the furthest downstream extension of the embankment. Channel all flow into this pipe, if possible.

Before laying the pipe, attach anti-seepage collars to it. Each collar should be welded to the pipe and separated by a distance of 7m. The entire length of the installed pipe for the sample dam described in this technical note should be approximately 25 or 26m in order to extend beyond both sides of the embankment.

If the volume of stream flow is great, difficulties may arise in channeling all water flow into the pipe. A diversion ditch that leads water around the dam may have to be built. The construction of the ditch is very tedious and time-consuming if work is done by hand. In fast flowing streams, a combination of both methods can be used since the pipe should be installed to drain water from the reservoir during times of flooding.

No matter how the water is diverted, the job may be easier if the dam can be built during the dry season since less water will need to be diverted.

2. Mark out the dam site with stakes and rope as shown in Figure 4. Mark the proposed water lines using a hand level. The string across the valley should mark the high point of the dam. Be sure that the line is level before starting the other construction steps.

3. Clear all trees, dead leaves, branches, logs, stumps, roots and other debris from the area that will be covered by water. Special care must be taken to clear out all roots and debris at the site of the dam itself so that percolation and possible embankment leakage and failure do not occur. Before proceeding with further constuction steps, check the area well to be sure that no debris is left in the area.

Embankment

The first step in the construction of the dam is to determine the width of the embankment. First, find the width of the embankment at its widest point. The widest point is also the lowest point of the reservoir. Refer to "Designing Small Dams," RWS.1.D.5, when determining the base width.

Dam width is equal to the height of the dam times the upstream slope added to the height of the dam times the downstream slope (a typical earth dam has a 3.5:1 upstream slope and a 3:1 downstream slope) added to the top width. For example, for a dam 3.0m in height with a 3.0m top width and 3.5:1 and 3:1 bank slopes, the width of the base is:

(height x upstream slope) + (height x downstream slope) + top width

(3.0m x 3.5m) + (3.0m x 3m) + 3.0m = 10.5m + 9.0m + 3.0m = 22.5m

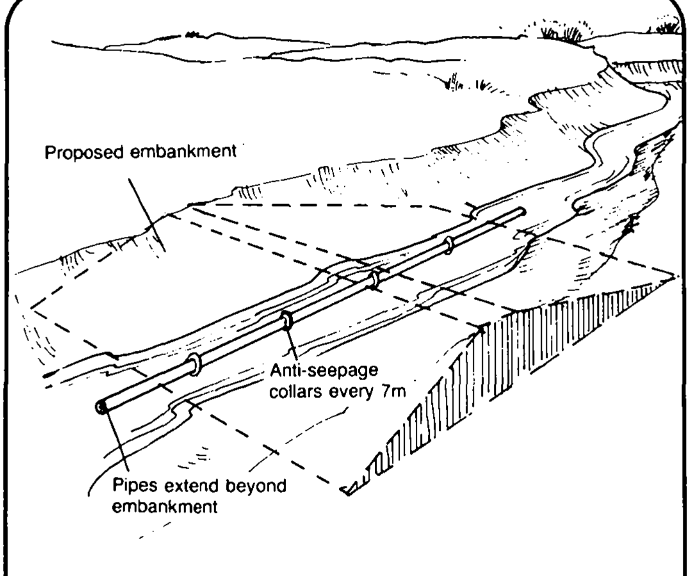

Figure 3. Drain Pipe

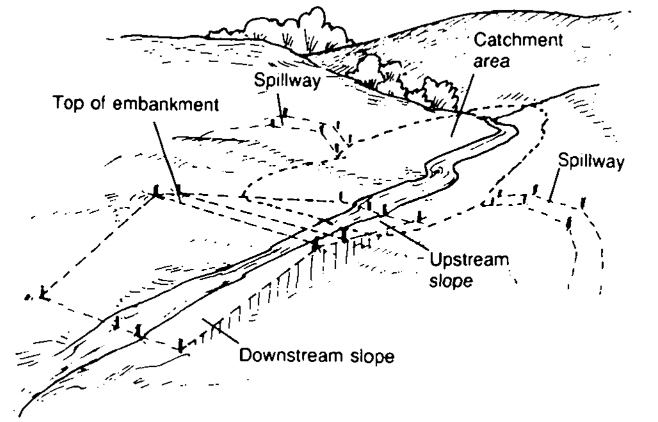

Figure 4. Staking Dam Site and Spillways

The width of the dam should be checked continually to ensure proper slopes and width. For example, if 0.5m of the dam is completed, a new calculation can be done. This time, instead of using the number 3.0m as the height, use only 2.5m. The width of the dam after 0.5m of the fill height is completed should be 19.25m. See Table 2 for the proper widths of dam embankments at various fill levels.

Before beginning to build the embankment with soil, mark its width with rope and pegs to ensure accuracy.

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Fill Height Above Ground	Embankment Width
Base	22.5m
0.5	19.25m
1.0	16.0m
1.5	12.75m
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2.5	6.25m
3.0 (top width)	3.0m

Dig out the pegged area until solid ground is reached. Then dig out another 0.3m of earth to ensure that the structure is well bonded to the ground surface. If the bottom is rough and irregular, the bond to the ground will be better but there should not be any stumps, roots or other debris around the bottom or ends of the dam.

To begin embankment constuction, be sure that adequate quantities of soil are at hand. Try to obtain good soil from the nearest possible site. Soil from spillway and reservoir excavation should meet most needs. Use a clay soil containing some silt and sand. If only clay is used, the embankment may crack. If too much sand is used, water may percolate through. In the construction process, use uniform material. If the quality of any of the material is questionable, use it only on the downstream side of the embankment. If there is any doubt about the suitability of embankment material, consult a soils expert or geologist, or send soil samples to the nearest soils laboratory for analysis.

To ensure the strength of the dam, the following guidelines should be followed in constructing the embankment. First, the fill material should be spread in continuous layers across the entire length of the dam. See Figure 5. Each layer should be between 100-150mm thick. Compact each layer carefully and thoroughly before adding the next layer. If the dam is being constructed without machinery, have the laborers dump their baskets of earth in lines from one end of the dam to the other. The workers should walk over the deposited soil to compact it well. Another method that can be used to compact the soil is to drive cattle from one end of the dam to the other after each day's work.

If the soil contains the correct level of moisture, sufficient compaction occurs from having the laborers tread on the fill and from using a simple pounding device as shown in Figure 6. The soil should be moist enough so that a foot mark will show. Dry soil should be wetted to reach the correct level of moisture. These steps are very important since the water tightness and strength of the dam depends on compaction.

If construction takes place in the wet season, precautions should be taken to ensure that water does not stay on the surface of the fill material. To allow water to drain, build up the center line of the dam and keep it a little higher than the sides so that rain runs off both the upstream and downstream sides. No part of the dam should be more than about 0.9m above any other part.

Continue to build the dam up layer by layer until the desired height and dimensions are reached. No dam holding more than 2.5m of water should be

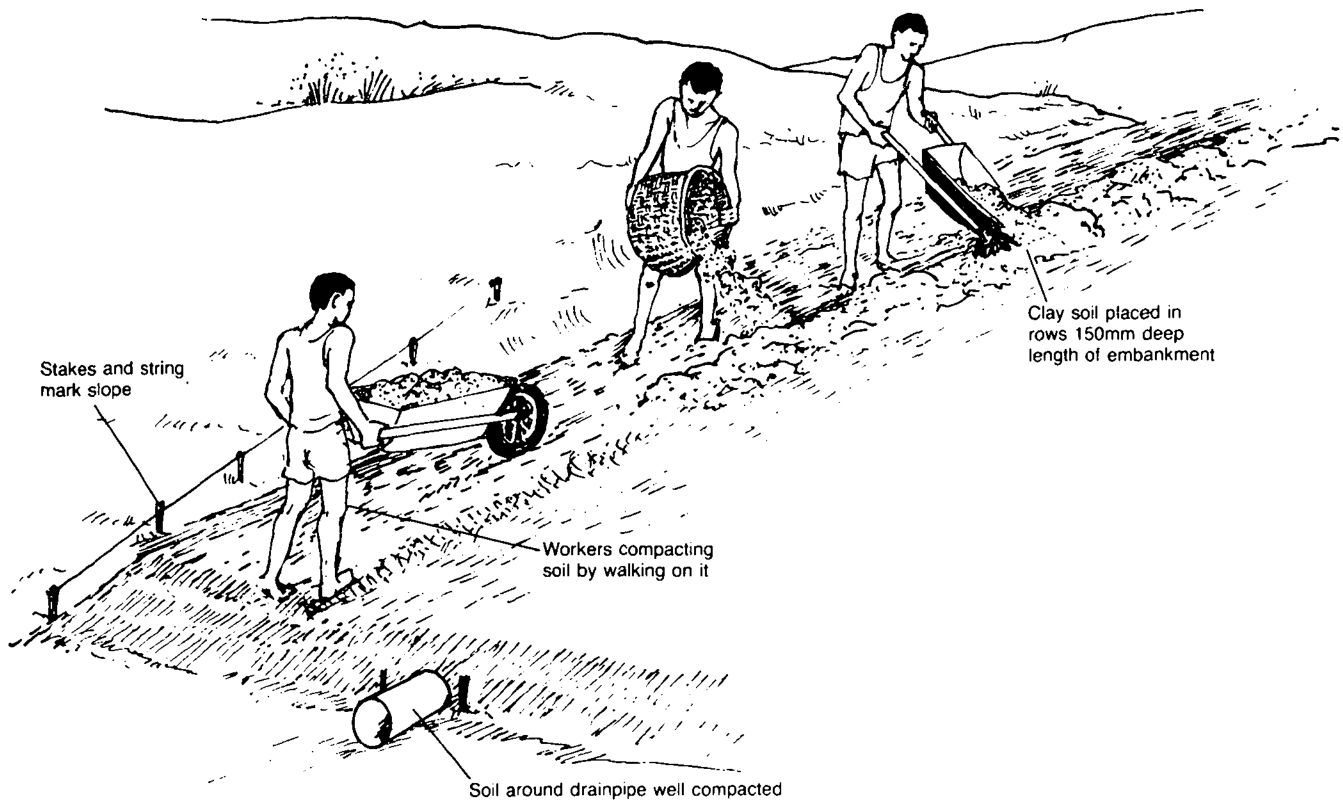

Figure 5. Constructing Embankment

attempted without expert advice. Usually, a small dam should not be more than 3m high. The design dimensions for dams are easily calculated. See "Designing Small Dams," RWS.1.D.5 for specific design information.

When building the embankment, make sure that the soil is well-compacted around the drain pipe. The soil should be as well bonded to the pipe as possible to prevent any flow of water along the pipe. The anti-seepage collars are installed specifically to prevent the wearing away of soil from around the pipe.

Once the embankment is completed, precautions against erosion should be taken. Rainfall may wash away soil from the exposed parts of the embankment. To prevent this, grass--preferably a creeping grass--should be planted on the downstream slope, the crest and the upper part of the upstream slope not covered by water.

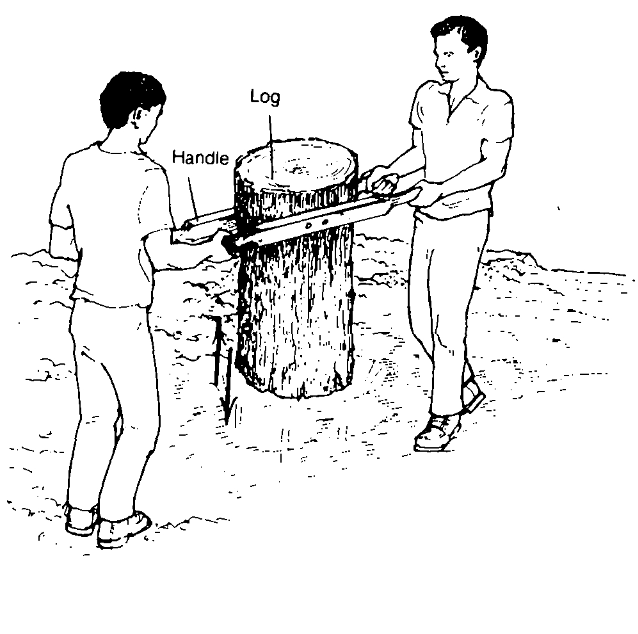

Figure 6. Manually Compacting Soil

Before planting, cover the embankment surface with a mixture of top soil and fertilizer, compost or animal manure. Plant the grass in horizontal rows for best results.

On the upstream side, erosion may be caused by the wave action of the water in the reservoir. To prevent this, pave the upstream slope with large rough stones to a point about 0.6m above the top water level as shown in Figure 7. Fill in the spaces between the large rocks with smaller flint-stones so that few spaces are exposed to the water. This protective covering is called "rip-rap." Once the embankment is completed, install a cut-off valve at the downstream side of the drainage pipe. The valve can be used if there is a need to drain the reservoir or if there is flooding and danger of overtopping. An elbow joint and short vertical extension can be installed at the upstream side of the pipe. This is useful but not essential.

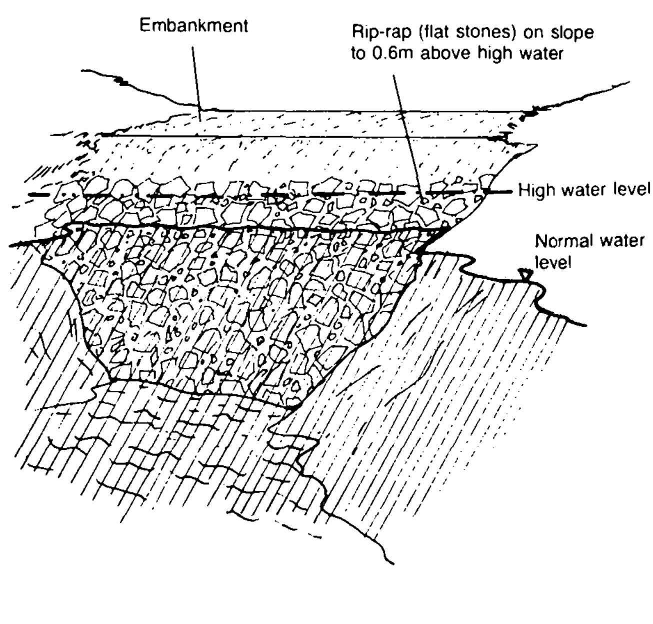

Figure 7. Placement of Rip-rap on Upstream Slope of Dam

Spillways

Spillways are one of the most important parts of the dam structure. They channel water away from the dam during periods of high water and protect the dam from overtopping. For extra safety, two spillways are recommended. Generally, one is placed higher than the other to act as a back-up and extra precaution.

Dig the spillways in solid ground, clear of the ends of the dam. They should be continued past the downstream edge of the base to prevent erosion. The earth excavated from the spillway channels provides fill materials for the embankment, and should be used in construction.

To detemine the dimensions of the spillway, use local information and field observation to make good estimates. From evidence of debris on banks, water marks on rocks and the knowledge of local people, the level to which water rises during typical flood times can be determined.

Find out how high the stream rises during the wettest season of the year. Estimate the width of the stream if it were running with a depth of 0.6m and then double the number to allow for any heavy flooding. This figure should be the minimum width of the spillway.

The calculated width is the width of the spillway at the highest point or crest, which is generally in line with the dam. Line the spillway crest with stone to prevent erosion. There is no need to line the channels leading in and out of the spillway crest. For best results, the channel below the crest should be widened a little and the first part of the channel made steep but smooth. Downstream, the channel should flatten out and lead into the stream below the dam. See Figure 8 for details.

Reservoir

Deepen all edges of the reservoir by approximately 0.6m to prevent the growth of vegetation and weeds and the breeding of mosquitoes and snails. The soil excavated from the edge of the reservoir may also be suitable as fill material for the dam embankment.

Summary

The construction of a small dam must be done carefully to ensure that the dam does not fail. Whenever possible, an expert should be consulted before and during the construction process. Poor construction can cause dam leakage and breakage, resulting in physical and economic loss. Careful construction using the advice of experts will ensure that the dam lasts for many years.

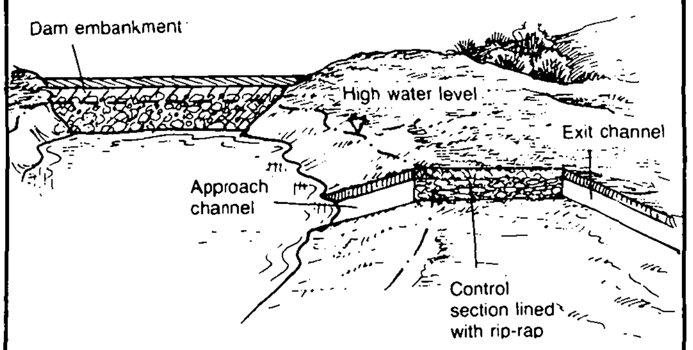

Figure 8. Spillway Design

Notes

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1982

Water for the World

Designing Structures for Springs

Technical Note No. RWS. 1.D.1

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

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

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

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

Useful Definitions

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

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

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

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

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

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

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

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

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

UNDERFLOW - Flow of water under a structure.

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

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

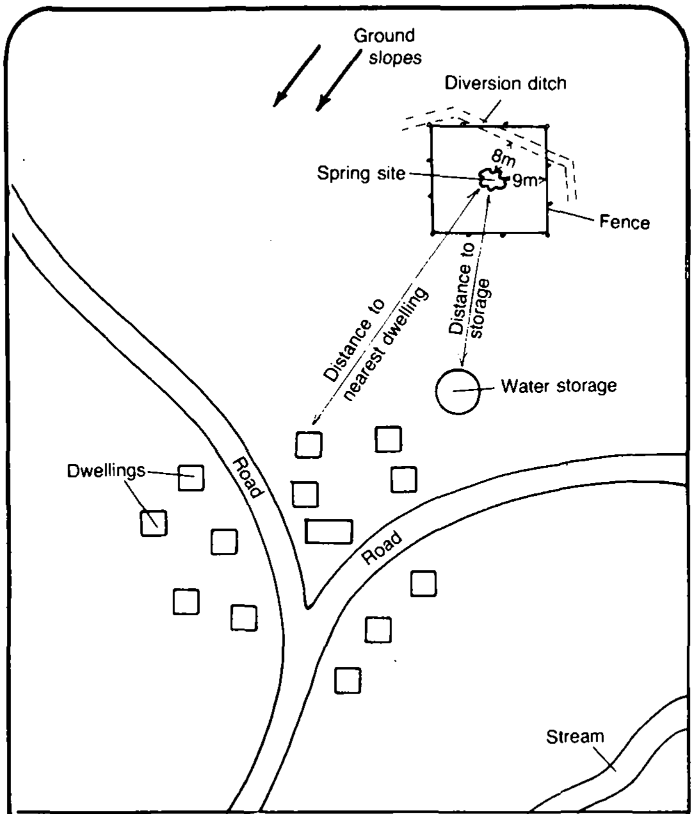

Figure 1. Location Map

Spring Box Design

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

Table 1. Sample Materials List

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

Total Estimated Cost ____

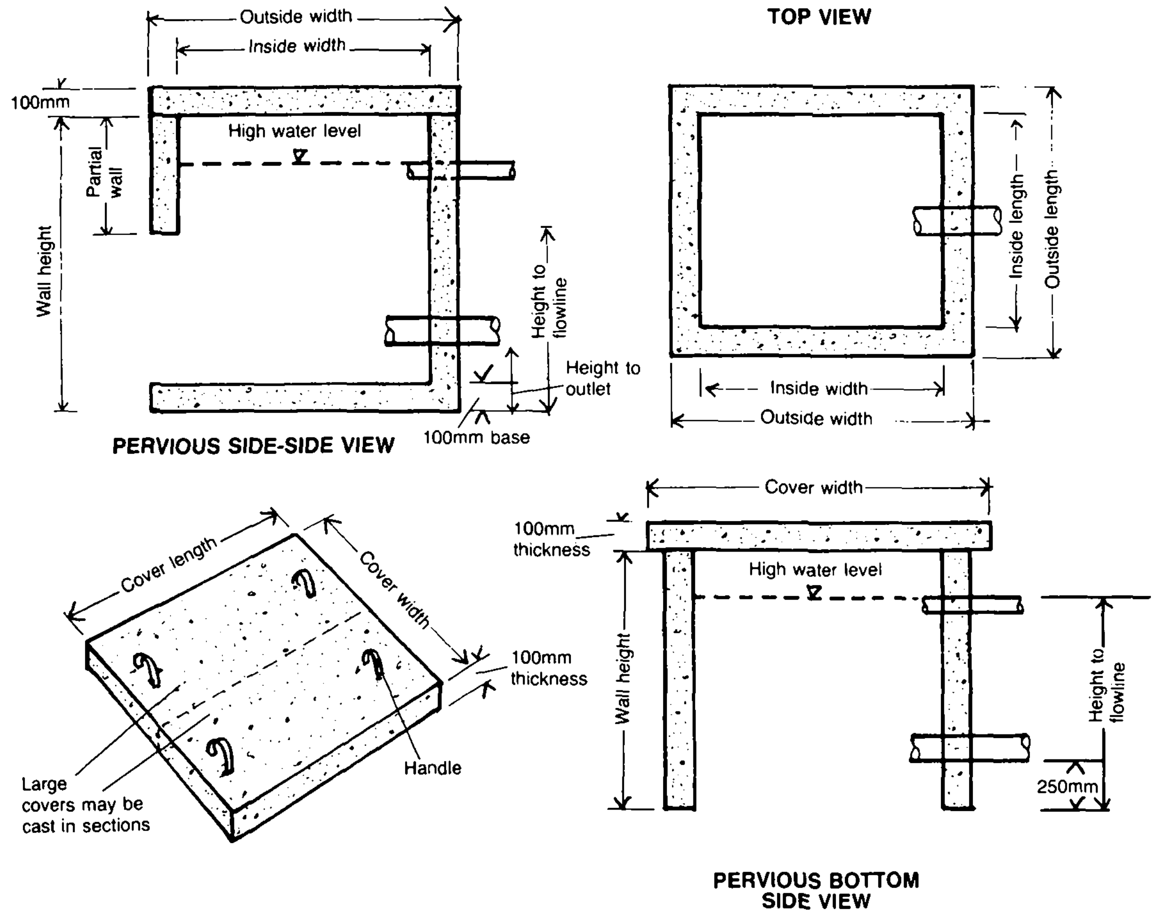

Figure 2. Spring Box Design

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

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

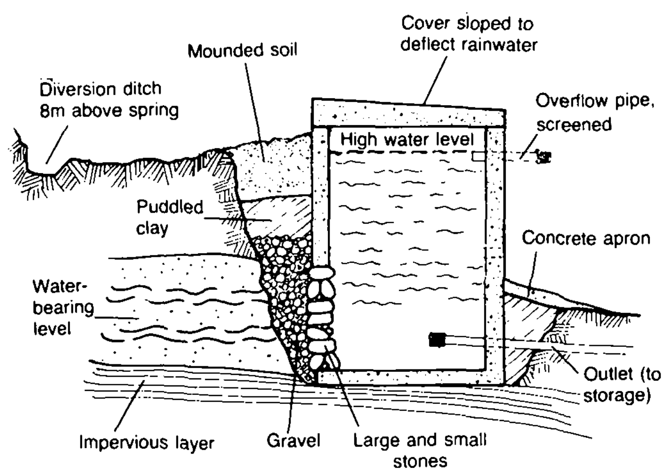

Figure 3. Spring Box with Open Side

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

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

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

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

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

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

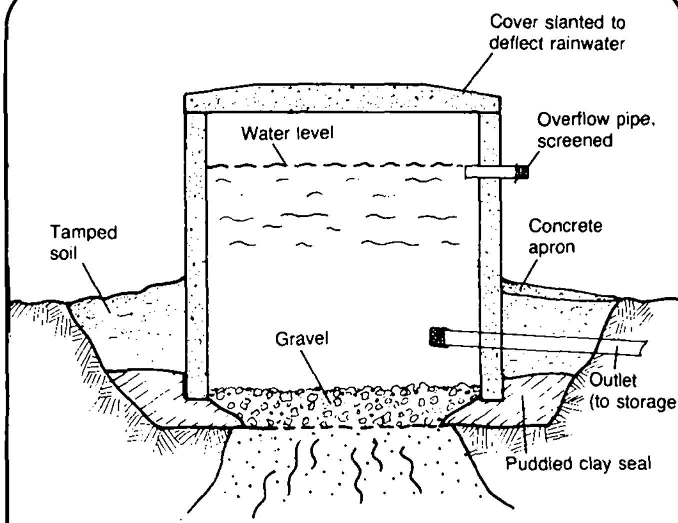

Figure 4. Spring Box with Open Bottom

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

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

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

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

Thickness of walls = 0.10m

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

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

8. Number of 50kg bags of cement = volume of cement / volume per bag
   volume of cement 0.13m^3 - .033m^3/bag = 4 bags.

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

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

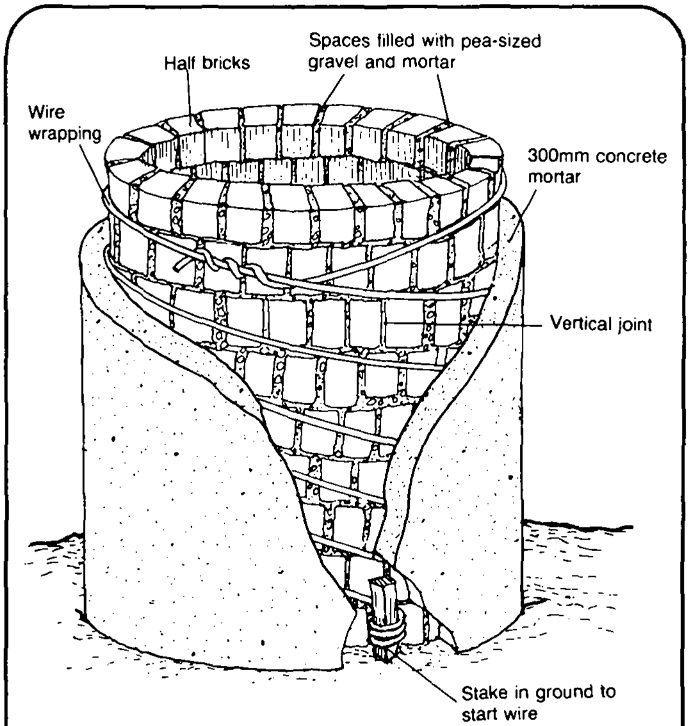

Figure 5. Brick Spring Box

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

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

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

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

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

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

Seep Design

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

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

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

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

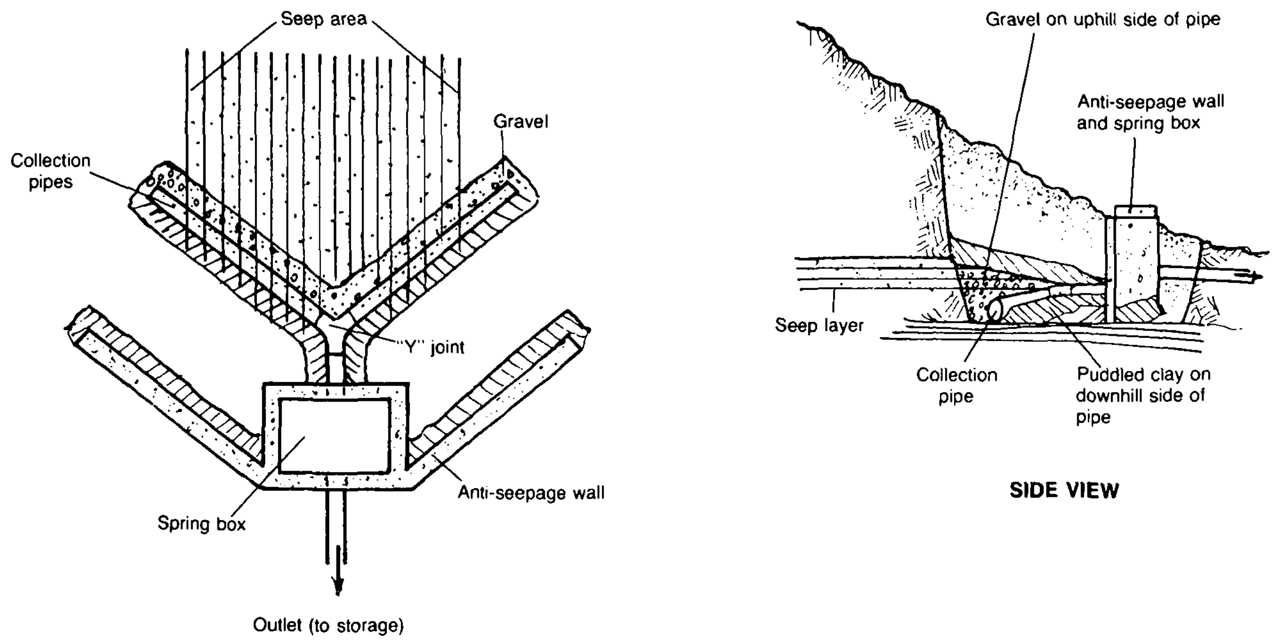

Figure 6. Seepage Collection System

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

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

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

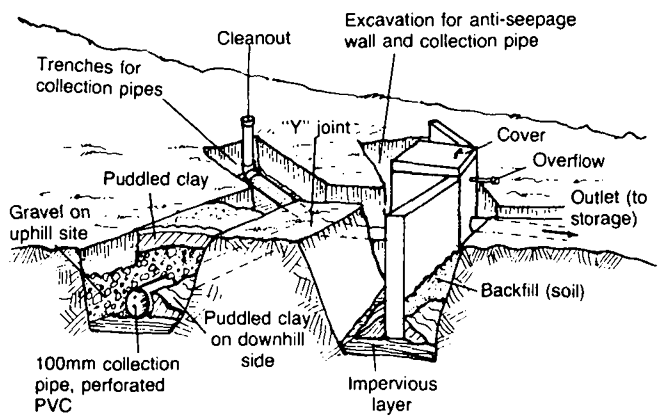

Figure 7. Basic Design Feature of a Seep Collection System

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

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

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

Horizontal Well Design

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

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

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

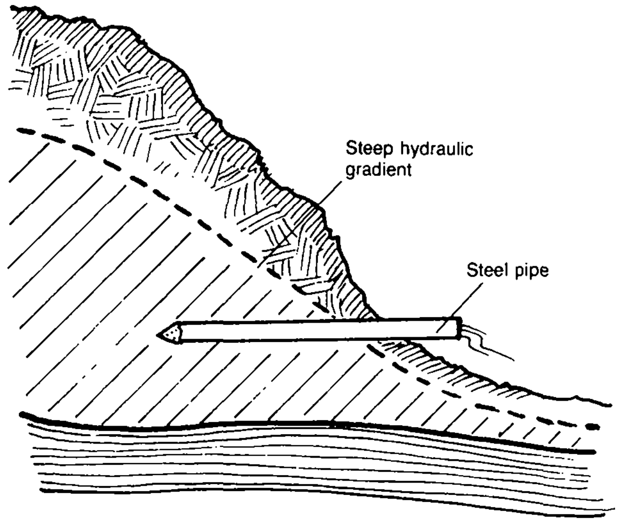

Figure 8. Horizontal Well

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

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

Materials List

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

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

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

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

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

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

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

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

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

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

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

The reinforcing rod should be located as follows:

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

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

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

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

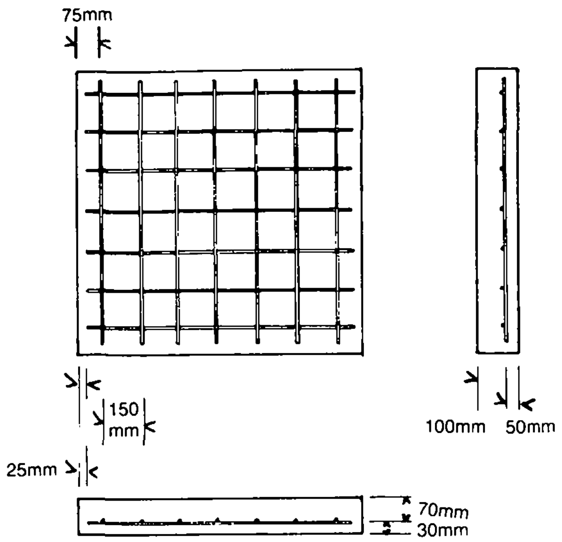

Figure 9. Placement of Rebar in Concrete Slab

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

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

Important Considerations

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

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

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

Notes

Notes

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

1982

Water for the World

Methods of Developing Sources of Surface Water

Technical Note No. RWS. 1.M

Water that does not infiltrate the ground is called surface water. Surface water appears either as direct runoff flowing over impermeable or saturated surfaces which then collects in large reservoirs and streams, or as water flowing to the ground from surface openings.

As water flows across surfaces, it picks up contaminants which may be harmful to humans and carries them into surface water sources. In order to use it for drinking, a surface water source must either be well protected or treated.

This technical note discusses four classes of surface water sources: (1) springs and seeps, (2) ponds and lakes, (3) streams and rivers and (4) rainfall catchments. It describes methods typically used to develop each source and discusses their advantages and disadvantages.

Useful Definitions

ANNULAR SPACE - Small, ring-shaped space between pipe and ground, formed when a pipe is placed in the ground.

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

CONTAMINANT - An impurity which makes water unfit for human consumption or domestic use.

ESTUARIES - Lowland areas where river waters meet tidal waters.

GRAVITY FLOW - Flow of water from high level to low by natural forces.

GROUNDWATER - Water stored below the ground's surface.

IMPERVIOUS - Not allowing liquid to pass through.

INFILTRATION - The process of water passing from the surface, through the soil, and into the ground.

INTAKE - The point where water enters a supply system.

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

WATER TREATMENT - A process in which impurities such as dirt and harmful materials are removed from water.

Springs and Seeps

A spring or seep is water that reaches the surface from some underground supply, appearing as small water holes or wet spots on hillsides or along river banks. The flow of water from springs and seeps may come from small openings in porous ground or from joints or fissures in solid rock.

There are two categories of springs: gravity and artesian. Within the gravity category, there are three principal types of springs: depression springs; contact springs; and fracture or tubular springs.

• Depression springs are formed when the land surface dips and makes contact with the water table in permeable material. Yield will be good if the water table is high, but the amount of available water may fluctuate seasonally. A gravity depression spring may not be suitable for a drinking water source since it may dry up.

• Gravity contact springs are formed when downward movement of underground water is restricted by an impervious underground layer and the water is pushed to the surface. This type of spring usually has a very good flow throughout the year and is a good water source.

• Fracture and tubular springs are formed when water comes from the ground through fractures or joints in rocks. Often the discharge is at one point and protection is relatively easy. Fracture and tubular springs also offer a good source of water for a community supply.

Springs in the artesian category occur when water is trapped between impervious layers and is under pressure. There are two types of artesian springs: fissure and artesian flow.

• Artesian fissure springs result from water under pressure reaching the ground through a fissure or joint. Yield will be very good and this source is excellent for a community supply.

• Artesian flow springs occur when confined water flows underground and emerges at a lower elevation. This type of spring occurs on hillsides and will also offer an excellent supply of water.

Before reaching the surface, spring water is generally free from harmful contaminants. To avoid contamination, the spring should be protected at the point where the water leaves the ground. There are three methods of developing springs as drinking water sources: spring boxes; horizontal wells; and seep development.

Spring Boxes. Figure 1 illustrates a spring box. A small area is dug out around the spring and lined with gravel. A concrete box with a removable cover is placed over the spring to collect and store the water. The cover prevents outside contamination and should be heavy enough to keep people from removing it to dip buckets and cups into the collection box. A tap and an overflow to prevent a back up in the aquifer should be installed.

The cost of developing a spring box is minimal and the system is relatively maintenance free. Disinfection is seldom required. Since springs are generally located on hills, a simple gravity flow delivery system can be installed.

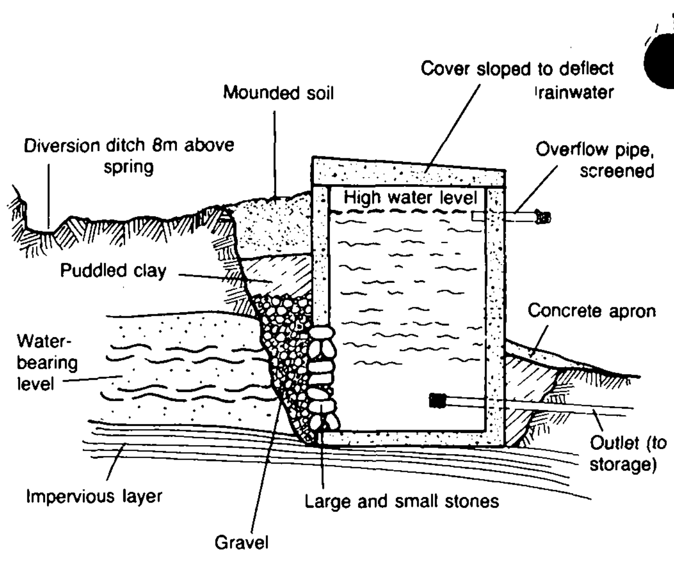

Figure 1. Spring Box with Pervious Side

A disadvantage of using spring water is that the quantity of available water may change seasonally. Local community members should be consulted as to the reliability of the source.

Horizontal Wells. Where a spring has a steeply sloping water table (steep hydraulic gradient), horizontal wells may be developed. Pipes with open ends or with perforated drive points or well screens can be driven into an aquifer horizontally or at a shallow slope to tap it at a point higher than the natural discharge. Figure 2 shows horizontal wells. Horizontal wells are installed in a manner similar to driven and jetted wells (see "Methods of Developing Sources of Groundwater," RWS.2.M) except that care must be taken to prevent flow through the annular space outside the pipe. Any flow can be stopped by grouting or by constructing a concrete cut-off wall packed with clay backfill.

The advantages and disadvantages of this method are similar to those of the spring box. Springs with flat water tables are not suitable for the use of horizontal wells.

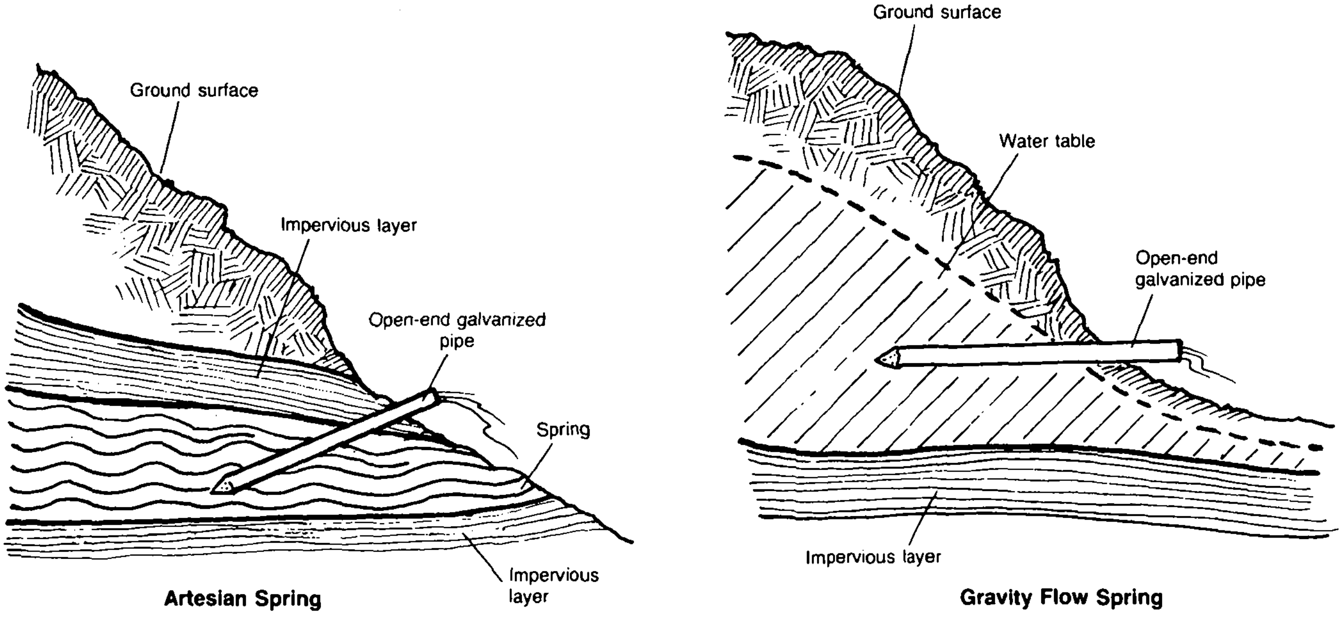

Figure 2. Horizontal Wells

Seep Development. If water seeps from the ground and covers an area of several square meters, a third method may be used. Pipes are laid to collect the underground water and transport it to a collection box as shown in Figure 3. A poured concrete wall just downslope of the pipes traps the water for more efficient collection.

With this method, maintenance costs are higher as pipes often clog with soil or rocks. Also, the expense and difficulty of construction may prohibit its use. Unless the seep supplies abundant quantities of water, this method should not be considered.

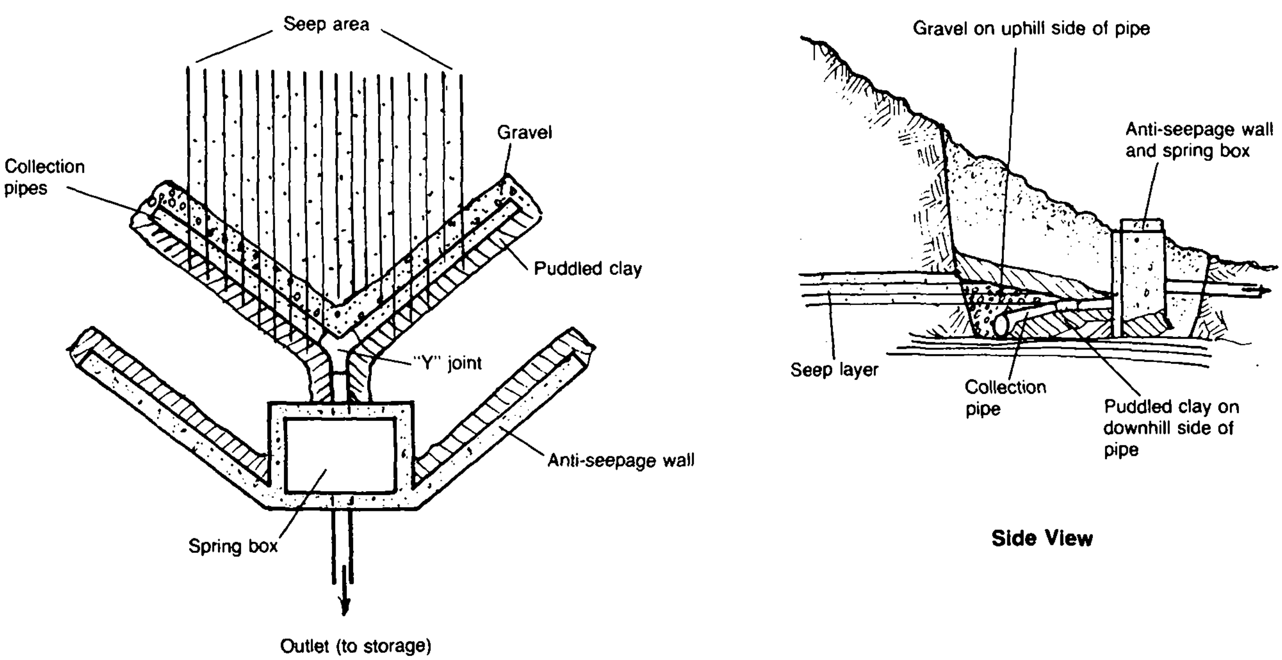

Figure 3. Seep Collection System

Ponds and Lakes

Ponds and lakes exist where surface run-off has accumulated in depressions or where a dam has been built to form a reservoir. Ponds and lakes, with proper watershed management for quality control, can be good sources of drinking water for a community. With good planning, adequate supplies will be available for community consumption throughout the year. Furthermore, the amount of available water is readily apparent and access to it is easier than to groundwater.

Because ponds and lakes are fed by surface run-off, treatment may be necessary. This is especially likely in smaller community ponds. In large bodies of water, a process of self-purification may occur that allows water to be used without treatment.

Another requirement of ponds and lakes is that water usually must be pumped through a distribution system to the point of use. Pumping machinery is expensive and requires a well-organized operation and maintenance program, and an energy source to operate the pump.

Intakes. To use water from ponds an intake is needed. Water flows by gravity or is pumped from the intake to treatment and then into storage. There are three methods typically used. Figure 4 shows a flexible plastic pipe intake. It is attached to a float and anchored so that it rests between 0.3m and 0.5m from the surface of the water. The intake is placed far enough below the water's surface to prohibit the entrance of any organic matter floating near the surface. A lower intake also takes advantage of somewhat cooler water below the surface. Water from the intake is either pumped directly into the distribution system or to treatment and then into the distribution system.

Where a dam has been built, the flexible plastic pipe is attached to a rigid conduit with anti-seepage collars. The conduit passes through the pond embankment to the treatment and storage tanks. If the water is very silty, treatment may consist of (a) a settling basin, which allows large particles to settle out of the water, and (b) a filtration unit where water must pass through a filter bed of sand and gravel before entering storage. For most pond waters, it should be sufficient to pump the water to a small holding tank and then allow it to flow onto a filter bed.

A variation of the above method can also be considered. A galvanized steel intake pipe is connected to a screened concrete storage box located on the reservoir floor near a dam's embankment, as shown in Figure 5. This system functions in the same manner

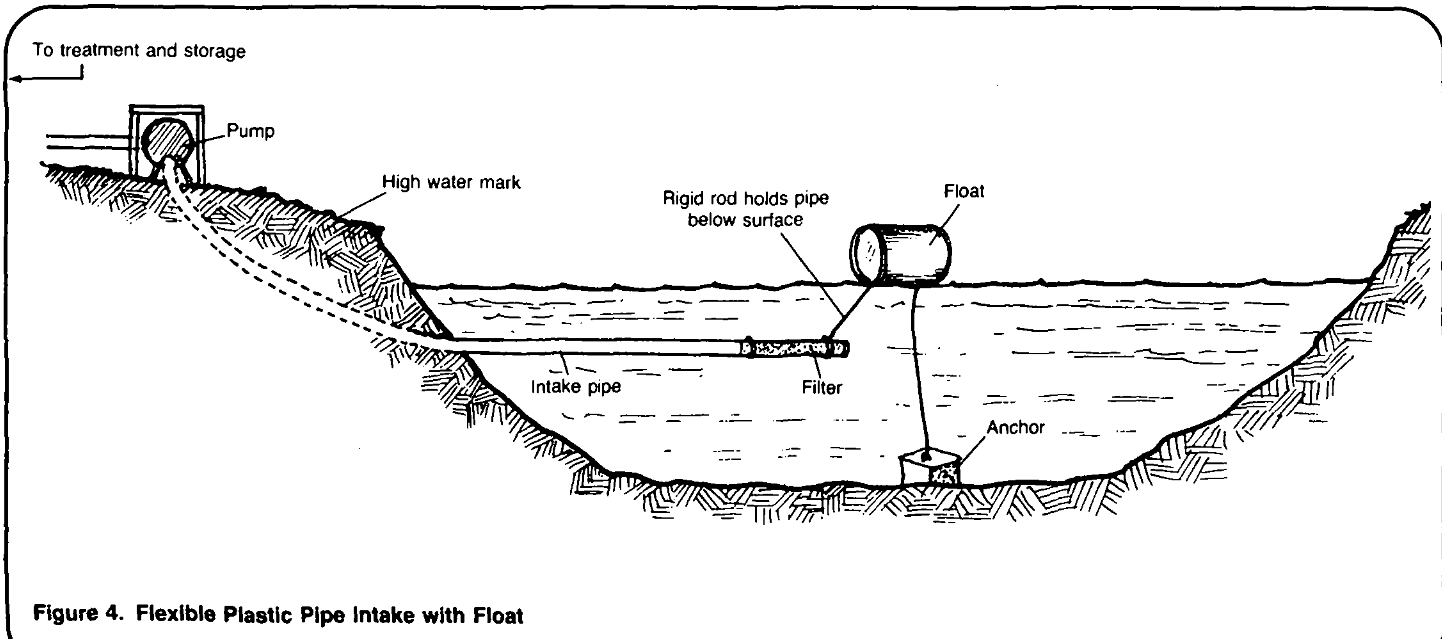

Figure 4. Flexible Plastic Pipe Intake with Float

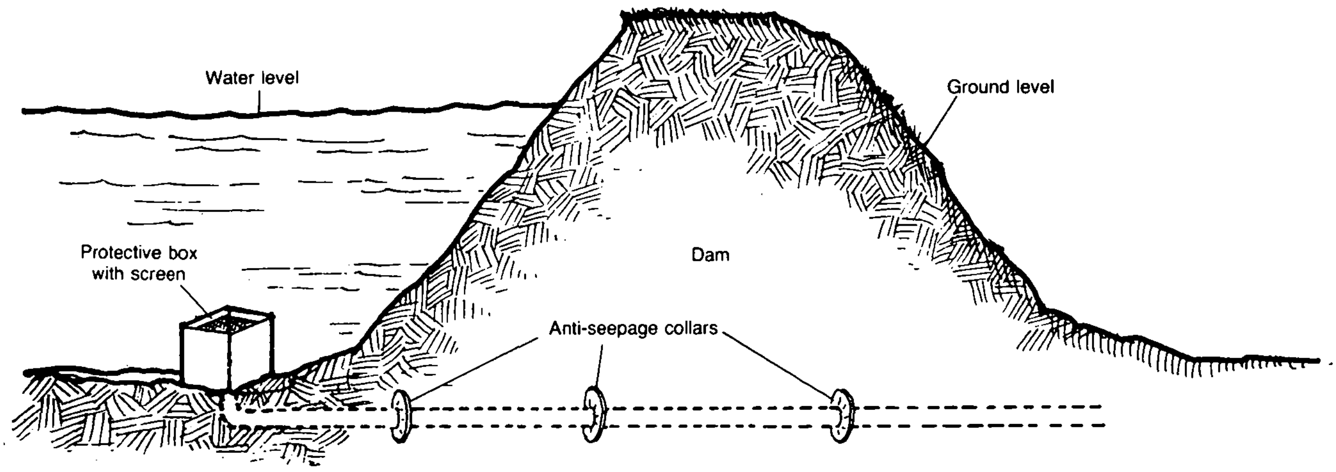

Figure 5. Rigid Pipe Intake at Dam

as the previous one, except that the intake is nearer the bottom of the reservoir. The water generally will be cooler and may be free of vegetation which often floats near the surface. In addition, the system will need less maintenance. The decision to adopt this method should be made before the dam is constructed since it is less easily installed in existing reservoirs. The expertise needed for construction and high cost make this method a less attractive choice.

The quantity of water available from ponds and lakes may not be a problem but quality will be a question. Generally, water from ponds and lakes must receive some treatment, whether at a central facility or in the household. Also, algae and decaying plants may give the water a taste unacceptable to the user, causing him to seek other water sources. Because of these variables and the cost of treatment, the use of water from ponds and streams should be carefully evaluated.

Streams and Rivers

Streams and rivers are formed by surface run-off from rainfall or from snow and ice melting in colder regions. Also, some rivers and streams have springs as their sources.

Streams and rivers have variable yield and water quality. Some streams and rivers dry up during the dry season and have no water for several months. People who depend on the river are left with little or no water. Rivers and streams are also exposed to contamination by waste disposal, laundry, bathing, and animals, and may prove unsuitable for drinking unless treated.

In mountainous areas or in places with few inhabitants, the quality of stream water can be very good, requiring little or no treatment. Streams in such areas offer a good source of water for a community. There are three methods of developing streams and rivers: infiltration wells and galleries; intakes connected to mechanical pumps; and gravity flow intakes.

Infiltration Wells. Digging or drilling a well near the banks of a stream or river is the cheapest and simplest method of development. The well should be close enough to the river channel to collect both water flowing underground and water seeping in through the channel, as shown in Figure 6. Generally, this will provide a very good supply of water throughout the year. Even if the river dries up during times of little rain, water will be available from the ground.

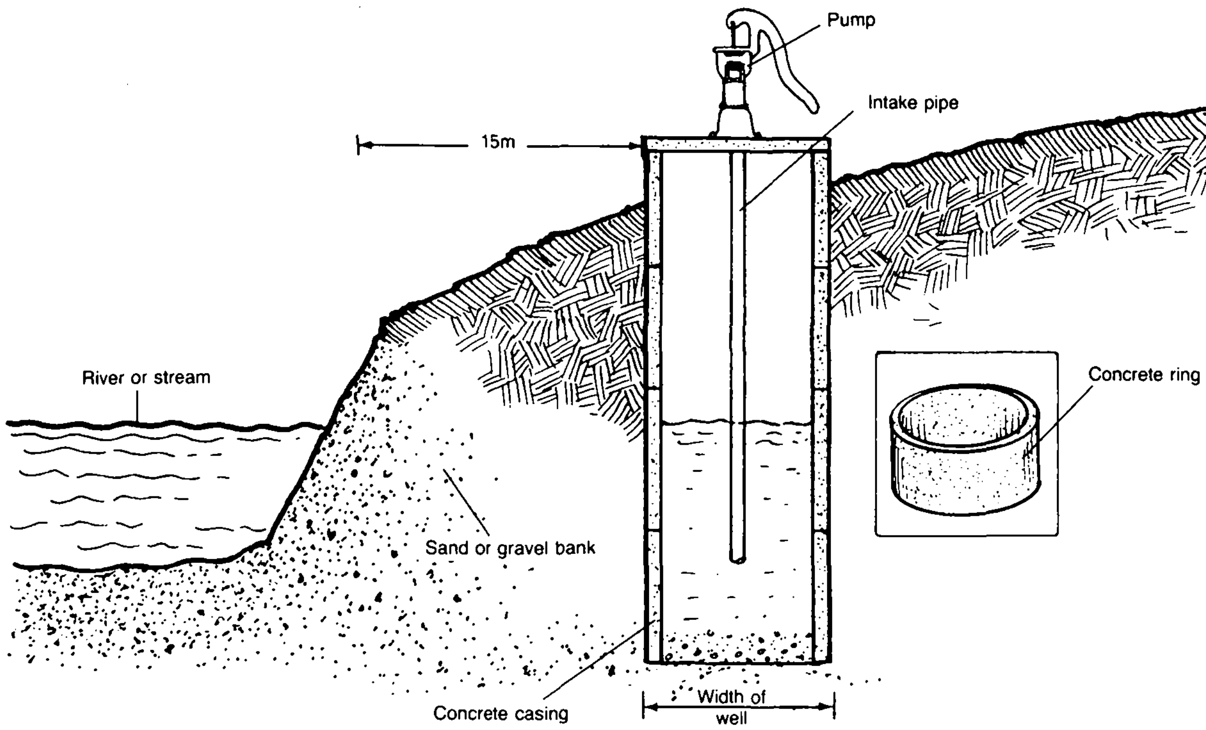

Figure 6. Riverside Well Intake

The water will also be filtered naturally. Water from the stream passes through the sand and silt in the river bank and impurities are removed. The degree of purification will depend on the extent of contamination of the stream and on the soil type. In many cases, the purification process will be sufficient to make treatment unnecessary.

A handpump, windmill or power pump can be installed to extract the water and pump it through the system. The pumping method chosen depends on the distribution system see "Methods of Delivering Water," RWS.4.M. If water will not be delivered further than the source, a handpump should be adequate. If water will be pumped to houses or a public standpipe, some type of power, such as diesel or wind, should be used. If a pump is installed, villagers must be trained in its operation and maintenance.

Infiltration Galleries. To increase the amount of water that can be collected by an infiltration well, infiltration galleries can be constructed. These trenches are dug in the bank parallel to the stream, below groundwater level, or below the stream bed itself. Tile, concrete or perforated plastic collecting pipes are placed in the gravel-lined trenches and connected to a storage well. The gravel in the trench filters out sediment and prevents clogging of the pipes. The water is pumped from the storage well into the distribution system in the same way as described for infiltration wells. See Figure 7.

Intakes with Mechanical Pumps. A surface intake pipe in the channel is another way of drawing the water from a stream or river. An intake pipe should be attached to a concrete well ring on the stream bed. A catwalk supports the pipe between the ring and the bank. Water is pumped from the stream to treatment. This method is shown in Figure 8.

To use this method, a stream with stable banks and a firm bed is needed. Skilled construction workers must also be available as the structure must be sound enough to withstand the stream's current. This method is more costly than riverside wells and requires more expertise.

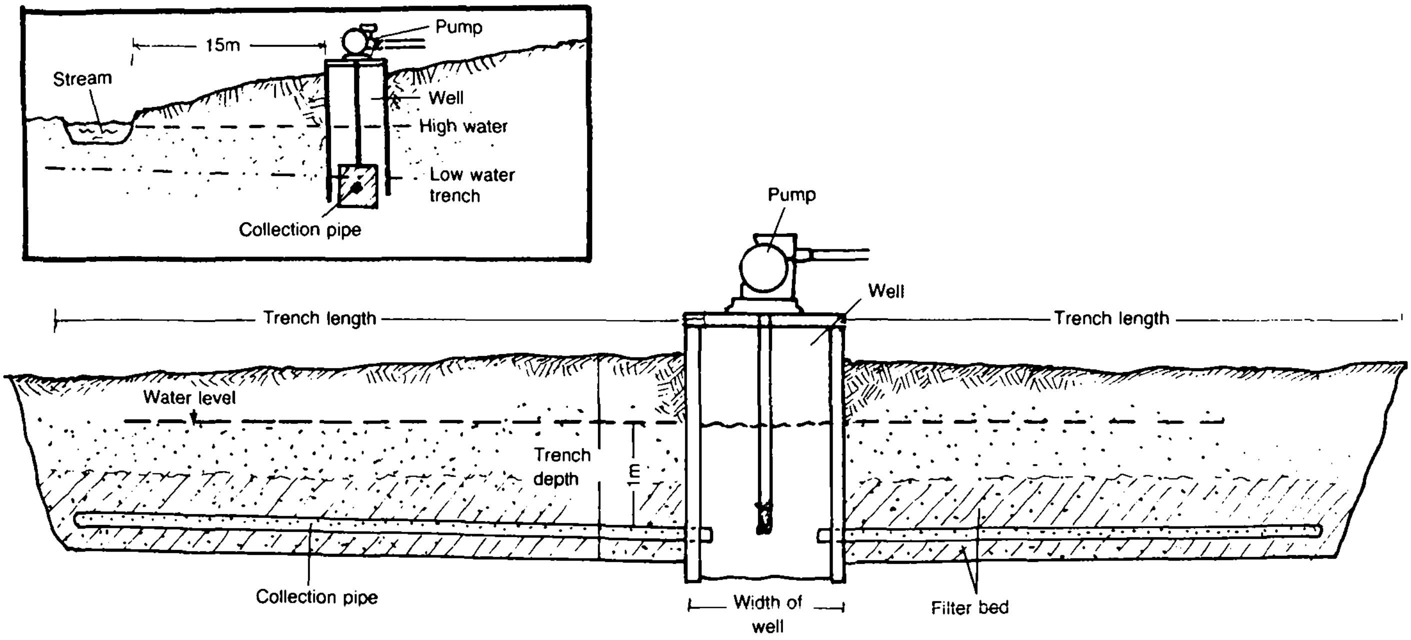

Figure 7. Infiltration Gallery

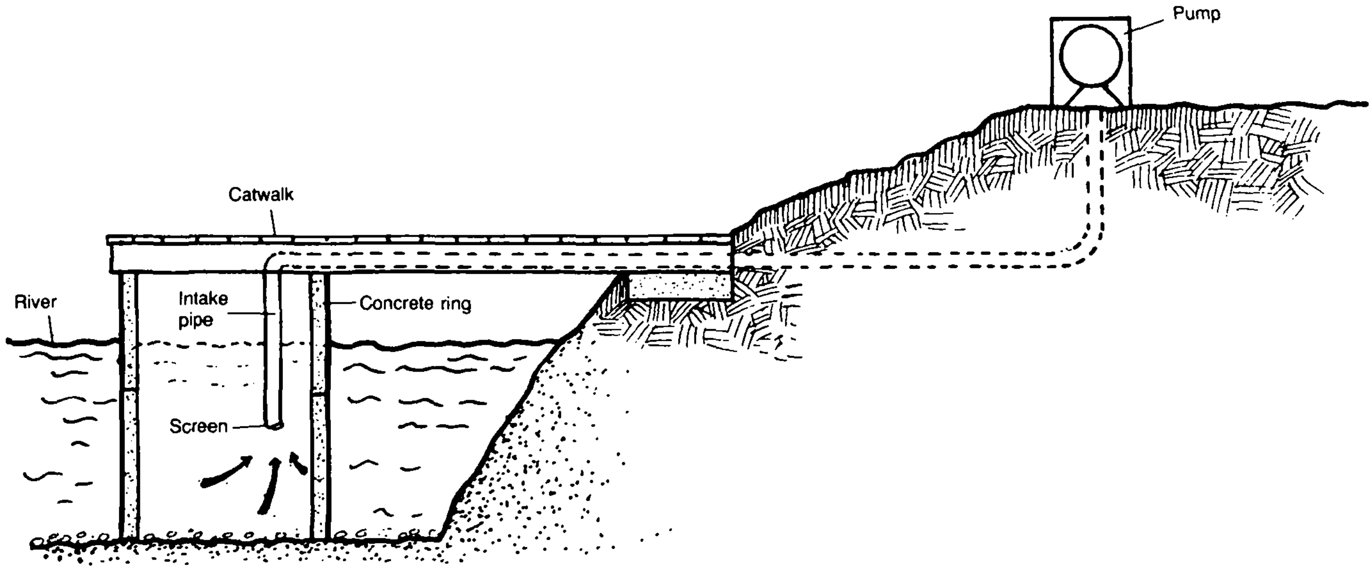

Figure 8. Protected Pipe Intake

Gravity Flow Intakes. Water from a stream can be carried to the user through a gravity flow system. This method is suitable for streams and rivers with enough changes in elevation to allow gravity to move the water from the intake to the storage tank. A concrete collection box with winged sides is constructed to catch water and direct it into a screened intake. The intake should be placed on the stream bed and anchored to the bank, as shown in Figure 9.

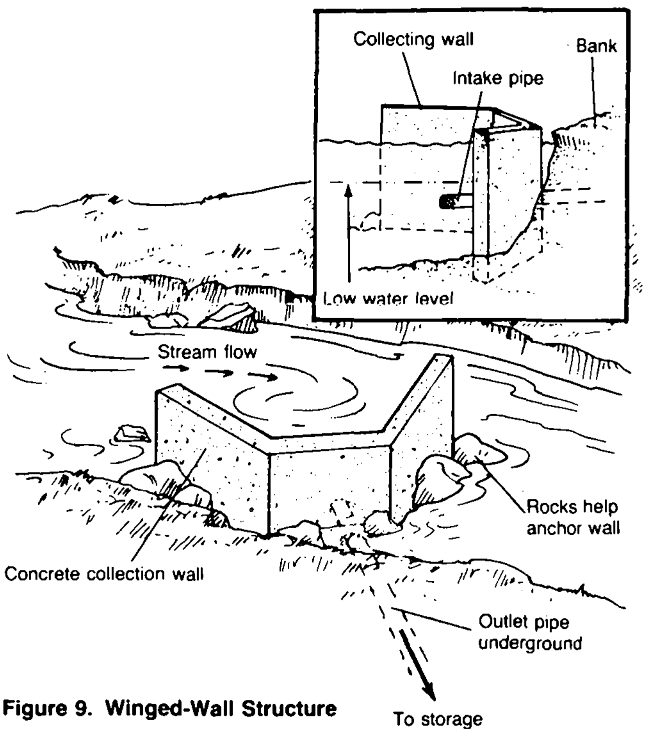

Figure 9. Winged-Wall Structure

Water will then pass from the intake into storage. No pumping will be necessary to supply a community with water, so little maintenance will be required. However, highly skilled technicians are needed to design and construct the system. As with the other methods, treatment will be necessary unless the area above the collection point is uninhabited.

In streams with sufficient fall, a hydraulic ram may be used to pump water to storage. The ram is an inexpensive and easily-maintained pump and can be constructed in the community. The ram is able to lift water from a stream into a storage tank without using an outside source of power see "Selecting Pumps," RWS.4.P.5.

Highly-skilled labor is usually needed for construction involved in developing rivers and streams. This will add to the cost of the project. As a general rule, stream water in low areas and estuaries is contaminated and will need some degree of treatment. Streams that are not exposed to human and animal wastes, and those at higher elevations with little population, will provide good water without treatment. Special care must be taken to choose a source located above inhabited areas if treatment is not available.

Rainfall Catchments

Rainfall catchments collect water from precipitation. They can be installed anywhere a suitable area is available. In areas of little rain or at times of drought, catchments can be used in combination with other surface sources. For example, water from catchments could be used for drinking and cooking while other sources met cleaning needs. There are two types of catchment systems: roof catchments and ground catchments.

Roof catchments. Roof catchment systems offer a simple and fairly inexpensive method of providing water to individual homes. Tile and sheet metal roofs can be adapted with pipes and gutters to trap water and transport it through a filter into a waterproof cistern. The cistern must be closed to avoid surface contaminants and must be disinfected periodically. Thatched or pitch roofs do not make suitable catchment areas due to seepage and potential contamination.

Rain catchments are as reliable as the weather and water may not always be available. Cisterns can be designed for large capacity storage at times when water is scarce. The system is basically maintenance free, except that gutters and pipes must be cleaned often to prevent clogging and contamination. Water quality may be fairly good to poor, depending on the amount of contaminants that settle on the roof between rainfalls, and water should be treated. An example of a roof catchment system appears in Figure 10.

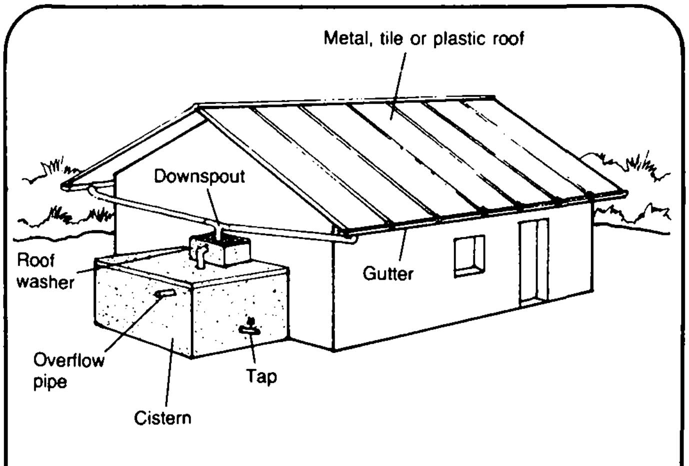

Figure 10. Roof Catchment

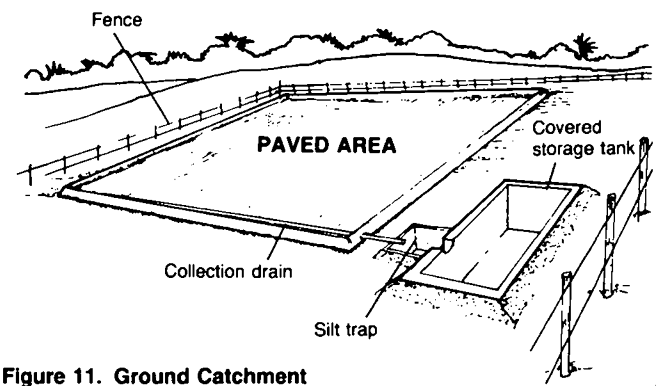

Figure 11. Ground Catchment

Ground catchments. Figure 11 shows a ground catchment system. An area of sloping ground several hundred meters square must be cleared, graded and preferably paved to form a catchment for precipitation. A paved area is desirable to reduce losses due to evaporation and infiltration, and to reduce erosion. A drain should be placed at the downward end of the slope to collect the water and deliver it to a sedimentation basin and into a storage tank.

Ground catchments are costly to install and must be carefully maintained. They also require large tracts of land that may not be available in a community.

Summary

Surface water sources can be developed for drinking water but special care must be taken to ensure the quality of the water. Springs generally offer the best alternative in terms of cost, water quality and maintenance. Spring water also is cool and fresh-tasting and very acceptable to the users.

Ponds and lakes offer good, accessible quantities of water. Water from ponds and lakes is easily delivered to users by installing intakes. Ponds, lakes, and especially small commnuity ponds are often exposed to contamination. Generally, water from them should not be used unless adequate treatment is available.

Streams and rivers also provide good sources of water if developed properly. Stream and river water that is naturally filtered into wells offers a good, low-cost method for using surface water. Untreated stream water from higher elevations is also available at low cost to the user. Near estuaries and at low elevations, contamination is likely and care must be taken before water is used.

Roof catchments offer the advantage that they can be constructed in the yard of the user if the house has a suitable roof. Each individual is responsible for his own system. Water quality is variable with rain catchments and will depend on the users' willingness to clean the roof often and disinfect the cistern occasionally.

Ground catchments provide a fairly good quantity of water and, with storage, a ground catchment system can meet the needs of a community. Ground catchments are expensive to install and use large areas of land which is scarce in many regions.

The choice of a method depends on many factors including the source and resources available and community preferences. These factors are further discussed in the technical notes on planning. Table 1 compares the various methods of developing surface water discussed in this technical note.

Table 1. Summary of Methods of Developing Sources of Surface Water

Method	Quality	Quantity	Accessibility	Reliability	Cost
Springs and Seeps	Good quality; disinfection recommended after installation of spring protection.	Good with little variation for artesian flow springs; variable with seasonal fluctuations likely for gravity flow springs.	Storage necessary for community water supply; gravity flow delivery for easy community access.	Good for artesian flow and gravity overflow; fair for gravity depression; little maintenance needed after installation.	Fairly low cost; with piped system costs will rise.
Ponds and Lakes	Fair to good in large ponds and lakes; poor to fair in smaller water bodies; treatment generally necessary.	Good available quantity; decreases during dry season.	Very accessible using intakes; pumping required for delivery system; storage required.	Fair to good; need for a good program of operation and maintenance for pumping and treatment systems.	Moderate to high because of need to pump and treat water.
Streams and Rivers	Good for mountain streams; poor for streams in lowland regions; treatment necessary.	Moderate: seasonal variation likely; some rivers and streams will dry up in dry season.	Generally good; need intake for both gravity flow and piped delivery.	Maintenance required for both type systems; much higher for pumped system; riverside well is a good reliable source.	Moderate to high depending on method; treatment and pumping expensive.
Rain Catchments	Fair to poor; disinfection necessary	Moderate and variable; supplies unavailable during dry season; storage necessary.	Good; cisterns located in yards of users; fair for ground catchments.	Must be rain; some maintenance required.	Low-moderate for roof catchments; high for ground catchments.

Notes

Notes

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

1982

Water for the World

Methods of Developing Sources of Ground Water
Technical Note No. RWS. 2.M

Ground water is water that is stored underground in porous layers called aquifers. It is found in most parts of the world and can be a reliable source of drinking water. Sources of ground water are usually free from disease-causing bacteria. There is usually less seasonal variation in groundwater quantities than in surface water.

Wells are used to develop or extract ground water. A well is simply a hole that pierces an aquifer so that water may be pumped or lifted out. Wells can be classified according to their method of construction. Five types of wells are: hand-dug, driven, jetted, bored, and cable tool. This technical note describes each of these methods.

Useful Definitions

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

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

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

GROUT - A fluid mixture of cement and sand.

IMPERMEABLE - Not allowing liquid to pass through.

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

Wells have five basic parts as shown in Figure 1: shaft, casing, intake, wellhead, and water-lifting device. The shaft is the hole that is sunk from the surface of the ground down into, and sometimes through, the aquifer. The purpose of the shaft is to provide access to ground water. The method of sinking the shaft differs with each type of well.

The casing lines the sides of the shaft. The purpose of the casing is to prevent the shaft from collapsing, to provide an impermeable barrier to store ground water in, and to keep polluted surface water out. For dug wells, the casing supports the wellhead. Casings are usually made from concrete or metal. For dug wells, they may be brick or masonry. Casings are installed either after the shaft is sunk, or as it is sunk.

The intake is either the lower portion of the casing which is perforated or made from porous material or the open bottom end of the casing. In either case, the intake is within the aquifer, and its purpose is to allow ground water to flow into the casing.

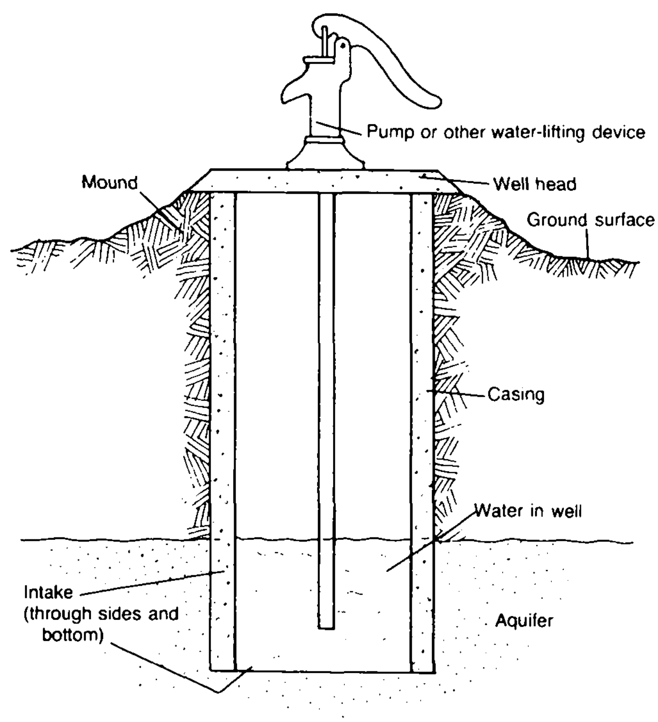

Figure 1. Parts of a Well

The wellhead is a structure built on and around the casing at ground level. It is usually made of concrete. The purpose of the wellhead is to provide a base for a water-lifting device, to prevent contaminants from entering, to keep people and animals from falling in the well, and to drain away surface water. The wellhead should be built on an earthen mound 15-20cm above the original surface so water will drain away from the well.

The water-lifting device can be a pump (see "Selecting Pumps," RWS.4.P.5), windlass, windmill or other method of extraction. The purpose of the device is to get water out of the well.

Hand-Dug Wells

Hand-dug wells are usually 1.0-1.3m in diameter and rarely more than 10m deep. They are dug with pick and shovel by one or two men working in the bottom of the shaft. Excavated soil can be lifted out with a bucket and rope as shown in Figure 2.

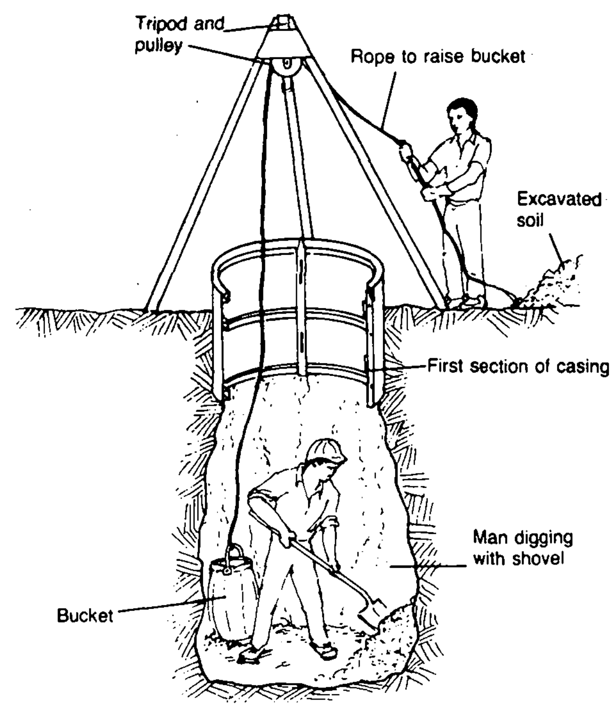

Figure 2. Hand-Dug Well

The casing or lining of a hand-dug well should be concrete. The casing can be installed in two ways. The shaft may be sunk and the casing built in place or sections of casing may be pre-formed above ground, soil excavated from within one section and, as the casing moves down, more sections added on top. Often, both methods are used to line a well. The first method is used until the water table is reached; then the second method, called caissoning, is used to sink the well into the aquifer. Masonry lining can be used but it is hard to make joints watertight with masonry.

The intake of a hand-dug well is designed to fit the nature of the aquifer. Usually the lower sections of casing that are within the aquifer are made of porous concrete to allow ground water to seep through. However, if the aquifer is made of fine sand, which would clog the porous concrete, the lower sections should be standard concrete and the bottom of the shaft should be left open and lined with layers of carefully selected gravel. Ground water then seeps up through the gravel.

After the casing is in place, the wellhead is constructed on the mound around the top of the well. It usually has a concrete apron to drain away surface water. If the well is to be equipped with a pump, the wellhead is fitted with a concrete cover that has an opening for the pump and an inspection port or manhole.

Because of the simple tools and materials needed, and the common construction method, hand-dug wells are the most common type.

Driven Wells

These wells are the simplest to construct. A pointed strainer, called a well point, is connected to sections of pipe and driven into the ground until the aquifer is reached as shown in Figure 3. The well point and pipes are 30-50mm in diameter, and the well is generally driven no more than about 8m deep. The well point serves as the intake for the well and the pipe is the casing.

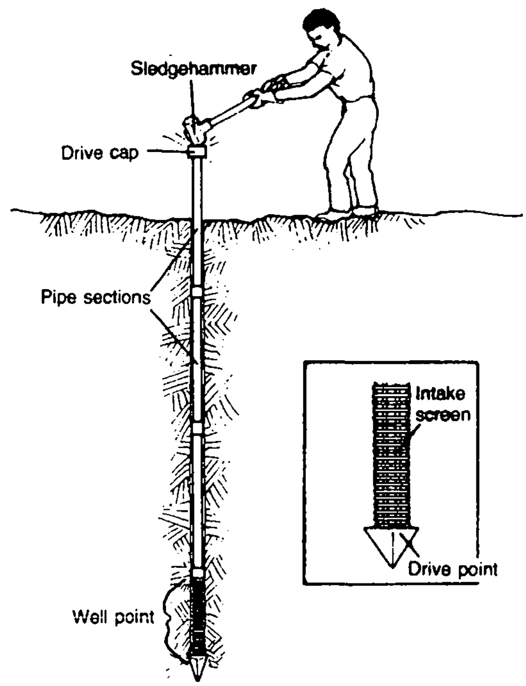

Figure 3. Driven Well

Jetted Wells

Jetted wells are built by pumping water through a boring pipe equipped with a special cutting bit. The boring pipe is held upright by a tower or tripod, and it is attached by a hose to a pump and a supply of water. The pipe is manually rotated. This chopping action, coupled with the jetting action of the water, causes the pipe to sink into the ground. When the first section of 6m pipe is nearly sunk, another section is attached to the top and the pumping and rotating continue. This goes on until the aquifer is reached. See Figure 4.

A 38mm diameter boring pipe can be sunk 60m deep. Larger diameter casings (250-380mm) can be sunk as deep as 100m. However, these larger pipes require pumps of much greater size and a large source of available water, such as a nearby river or lake.

There are a number of ways to drive the well: a drive cap is threaded on top of the pipe, and then is struck repeatedly with a sledgehammer or a drive pipe that fits over the well pipe; a driving bar that fits inside the well pipe is raised and dropped to strike the well point itself; a drive head and guide rod are coupled to the top of the well pipe and a weight is raised on the rod and allowed to drop on the drive head.

The most common types of well points are either a pipe with holes covered by a screen and a brass jacket with holes, or a slotted steel pipe with no covering. Both types have a hard steel point.

After the well point is driven into the aquifer, earth is removed from around the pipe to a depth of at least 2.5m. Grout is tamped into the space around the pipe. When this hardens, it seals out surface contamination and holds the pipe firmly in place. A mound and concrete platform are then built and a pump is attached to the top of the pipe.

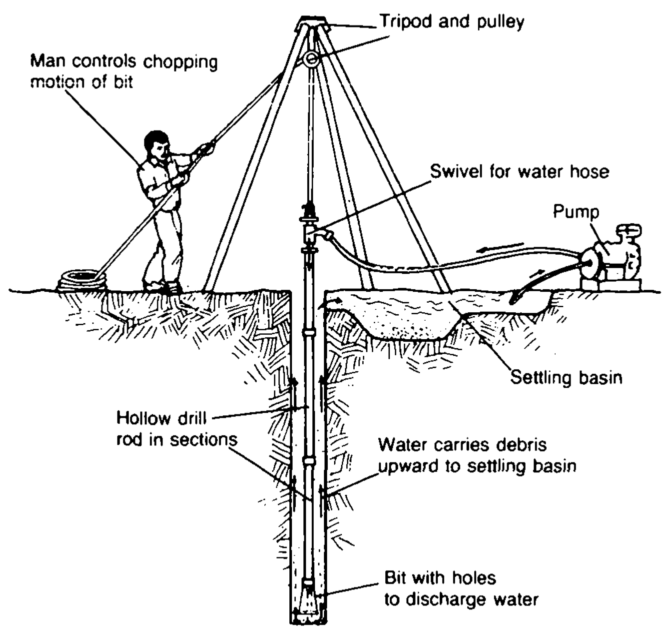

Figure 4. Jetted Well

When the aquifer is reached, the boring pipe is lifted from the hole. If the boring pipe is to be used as the casing, the cutting bit is removed from the first section of pipe and replaced with a well screen. If a different pipe is to be used for casing, the well screen is attached to the first section of casing. See Figure 3. The well screen and the first section of pipe are lowered into the hole. Pumping continues, but now through the screen. When the screen has been lowered to the position desired, a pre-seated plug is dropped into the pipe to seal the bottom of the well.

To finish the well, the space between the well pipe and the earth shaft is compacted with clay or concrete. A mound is built with a concrete platform or apron for drainage. Then a pump is installed.

Jetting can be used in loose soils that can be brought into suspension and moved with a stream of water. Jetting is not suitable for hard rock or tight clays.

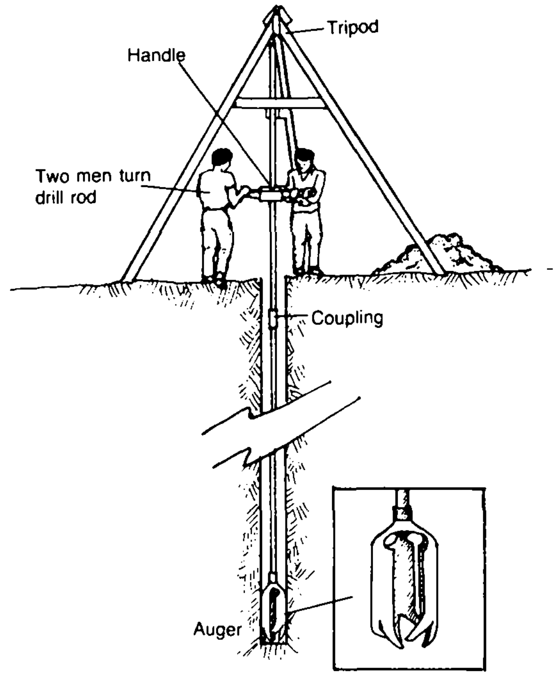

Figure 5. Bored Well

Bored Wells

Bored wells are also called augered or tube wells. They are dug by manually rotating an earth auger which penetrates the ground and fills with soil. The full auger is pulled out of the ground and emptied. As the hole gets deeper, additional sections of drilling line are added. To facilitate operating and emptying the auger, an elevated platform or tripod is constructed over the well site. See Figure 5.

When the shaft has sufficiently penetrated the aquifer, the auger is removed and the casing and well screen are lowered into the shaft. If the soil is so soft that it frequently caves in, the casing is lowered as the shaft is dug. To do that, a special borer is used that fits through the casing and has a moveable extension cutter. If a water-bearing sand layer is to be penetrated, a special auger or "sand bucket" is used to dig the shaft from inside the casing, allowing the casing to sink with the shaft.

To finish the well, the space between the casing and the earth shaft is filled with concrete grout to a depth of about 3m. An earthen mound and a concrete wellhead or apron are built for drainage. Then a pump is installed.

In general, bored wells are 50-200mm in diameter and no deeper than about 15m. Larger and deeper wells have been bored using a power source and specialized augering equipment.

Cable Tool Wells

The equipment needed for cable tool wells, also called percussion drilled wells, is usually sophisticated and expensive. A simpler version of this method consists of a tripod, pulleys, strong rope, motorized vehicle, heavy drill bits, suction pump, and a 3-6m long pipe called a bailer.

The vehicle is parked at the well site, the rear end is jacked up, and the rear wheel is removed and replaced with a small drum as shown in Figure 6. A rope is wrapped loosely around the drum, threaded through the pulleys, and attached to the drill bit. By setting the drum in motion, and alternately pulling the rope taut and letting it go slack, the drill bit is raised and allowed to fall. The impact of the bit breaks up pieces of ground. The debris is mixed with water and is periodically brought to the surface with either the suction pump or the bailer. When the aquifer is reached, it is generally drilled completely through before the casing and well screen are installed. In sandy soil, the shaft is sunk from the inside of the casing and the shaft and casing descend together.

To finish the well, an earthen mound and a concrete wellhead or apron are built for drainage. Then a pump is installed.

These wells can be 50-100mm in diameter and as deep as 75m.

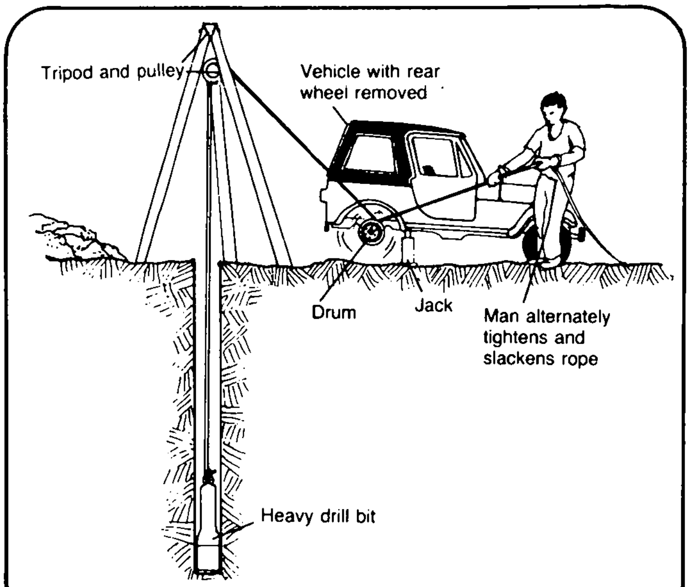

Figure 6. Cable Tool Well

Table 1 summarizes the five types of wells. This table can be used as an aid in selecting a method of well construction. Also see "Selecting a Method of Well Construction," RWS.2.P.2.

Table 1. Comparison of Types of Wells

FACTOR	WELL TYPE				
	Hand-Dug	Driven	Jetted	Bored	Cable Tool
Method of sinking shaft	Soil excavated by pick and shovel and lifted out by rope and bucket	Well point and steel pipe driven into ground	Jet of water and rotating action of bit force pipe into ground	Auger is rotated and fills with soil; lifted out of hole and emptied	Bit raised and dropped to pulverize soil and rock; debris is mixed with water and lifted out with a bailing bucket or pump
Average diameter	1.0-1.3m	30-50mm	40mm	50-200mm	50-100mm
Maximum practical depth	10m	8.0m	60m	15m	75m
Principal tools and equipment	Pick, shovel, rope and bucket; steel forms for concrete; hoist for lowering casing	Sledge, drive pipe, or drive weight; raised platform	Boring pipe; raised platform or tripod; pump and hoses; jetting bits	Augers; drill line; raised platform	Motorized vehicle; tripod, pulleys, rope; heavy drill bits; suction pump; bailer
Casing materials	Cement, sand, gravel, and water (for concrete)	Steel pipe	Steel pipe	Steel or concrete pipe	Steel pipe
Intake	Porous concrete sections, or gravel-lined bottom	Specially-made well point	Well screen	Well screen or perforated pipe	Well screen
Skill of workers	Minimal	Minimal	Moderate	Moderate	Experienced
Outside water needed for construction	No	No	Yes	No	Yes

Notes

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1982

Water for the World

Maintaining Structures for Springs
Technical Note No. RWS. 1.0.1

Spring structures are easy to operate and maintain. One of the main advantages of springs as water sources is that they are inexpensive to develop. The structures needed to protect them require little attention after installation. No structure, however, is completely maintenance free. Even the most simply designed spring structure needs periodic maintenance to ensure that it provides good quality water in sufficient quantities. This technical note describes the periodic maintenance needed for spring boxes and seep collection systems so that they operate effectively for many years.

Useful Definitions

EROSION - The wearing away of soil, rock or other material by the flow of water.

PERVIOUS - Allowing liquid to pass through.

SEDIMENT - Small particles of dirt and other matter that settle to the bottom of water.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

Maintenance of Spring Boxes

The maintenance of spring boxes requires that a check be made to ensure that the structure adequately protects the water source and that all available water is being collected. Examine the spring box periodically to ensure that there is no silt build-up and that water quality is good. Study the following conditions at the site to ensure that the spring is well-protected and free from any operating problems.

Determine whether the diversion drainage ditch above the spring is doing an adequate job of removing surface water from the area. If not, the trench should be improved. The diversion ditch should be lined with gravel or stones to increase flow and to prevent erosion of the sides. Grass can be planted in the trench to prevent erosion, but heavy growth will block flow. Be sure to check the diversion ditch periodically to make sure that grass is not too high and that no other obstructions will block water flow.

If there is a fence above the spring, make sure it is in good repair and is effectively keeping animals away from the spring.

Check the upslope wall to be sure it is solid and erosion is not wearing it away. If there are signs of heavy erosion or settling, add additional backfill of top soil, clay or gravel. Build up the hill with stones and plant grass to help control erosion around the spring box.

Check the water. If there is an increase in turbidity or flow after a rainstorm, surface run-off is reaching the source and contaminating it. Identify the source of the run-off and improve the protection of the spring.

Take periodic samples of the water and have them analyzed to check for evidence of fecal contamination. Information on taking a water sample and analyzing it can be found in "Taking a Water Sample," RWS.3.P.2 and "Analyzing a Water Sample," RWS.3.P.3.

Check the cover to be sure the box is watertight. Make sure that the cover is not removed by the users and that contamination is not being introduced by people dipping buckets and other utensils into the spring box.

Determine that all available water is being collected by the system. Watch out for water seeping from the sides or from underneath the spring box. If water seeps out, seal the leak with clay or concrete so that all flow is diverted into the spring box.

Ensure that the system is cleaned adequately. Once a year disinfect the system and clean the sediment out of the spring box. To clean the system, remove the cover. Allow the water to drain from the spring box by opening the valve on the outlet pipe. If the box has only one pipe for outlet and overflow, use a bucket to empty the spring box as shown in Figure 1. Then use a small shovel to clean out the sediment collected on the bottom of the tank. Sediment removal will prevent clogging and build-up which causes the tank to fill up more quickly.

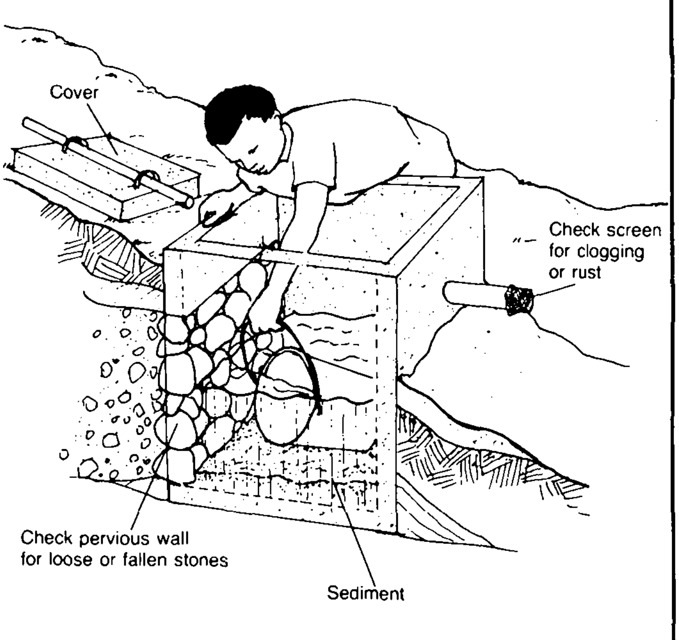

Figure 1. Emptying Spring Box

If a pump is built into the spring box to collect sediment, a drain pipe can be installed to carry sediment away. The drain pipe should have a valve. This type of installation is especially useful when tapping a fast flowing spring.

After cleaning the tank, follow the procedures for disinfection explained in "Disinfecting Wells," RWS.2.C.9. All walls of the spring box should be washed with a chlorine solution and chlorine should be put directly into the water. If possible, the chlorine should be allowed to stand for 24 hours. If the chlorine cannot stand that long, apply two doses of chlorine twelve hours apart to ensure complete disinfection. Figures 1, 2, and 3 show the cleaning and disinfection of a spring box.

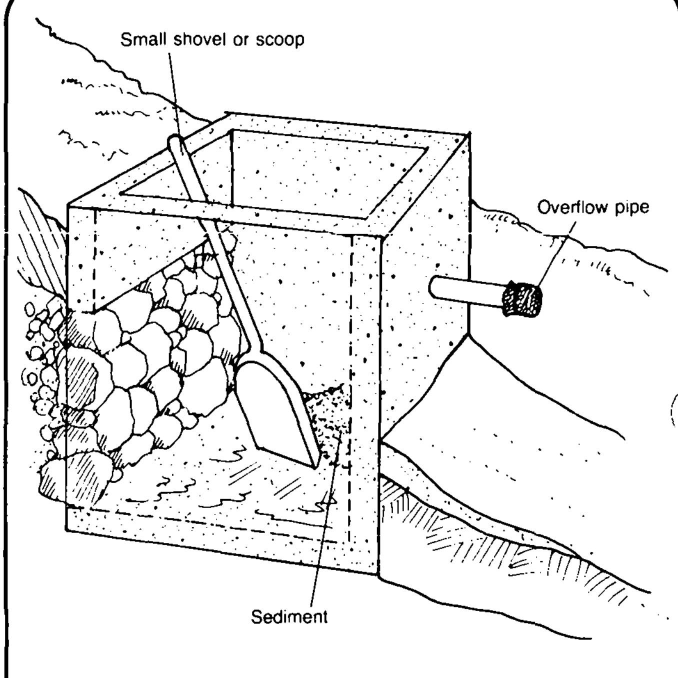

Figure 2. Removing Sediment

Check the screening on the pipes to see if cleaning is necessary. If screens are clogged or very dirty, they should be either cleaned or changed. Always use copper or plastic screening to prevent rust.

Maintenance of Seep Collection Systems

Operating and maintaining seep collection systems is similar to spring boxes except that extra care must be taken in the maintenance of the collection pipes. Although collection pipes are lined with gravel to filter out sediment, the pipes can still clog.

If clogging occurs, substantially less water will reach the collection box. If water flow decreases, suspect that the collection system is clogged.

To clean the clogged pipes, remove the cap from the clean-out pipe and pour water into it. Use either a hose or a bucket so that sufficient force is available to break up the sediment. See Figure 4.

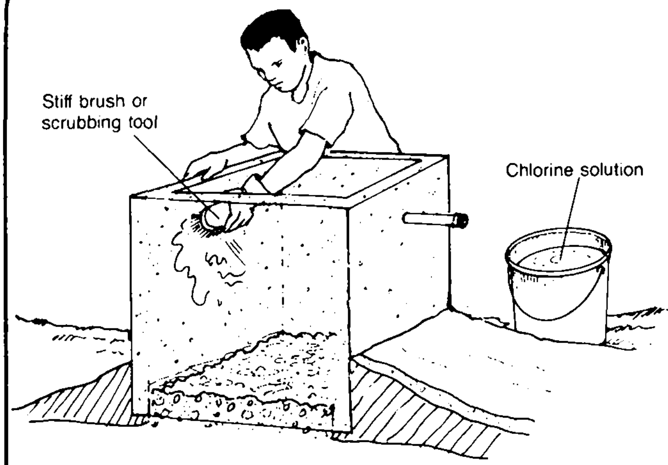

Figure 3. Scrubbing Walls with Chlorine Solution

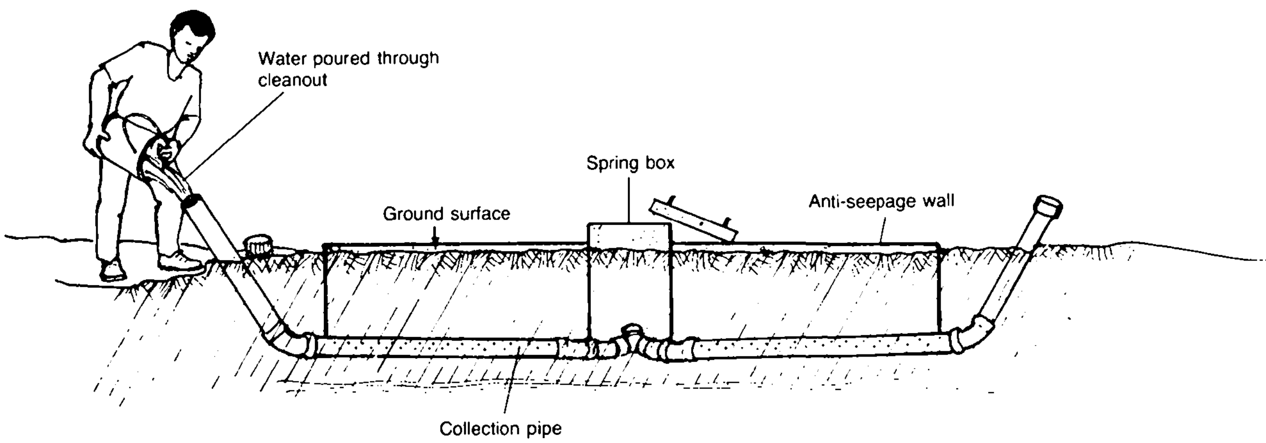

Figure 4. Flushing Out Seep Collection System

Notes

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Water for the World

Maintaining Intakes
Technical Note No. RWS. 1.O.2

Intakes must be well maintained to ensure that there is sufficient water flow from the source to the users. If intakes do not function properly, the flow of water could decrease or even stop completely. This would cause people to look for another water source, possibly a less suitable one. This technical note discusses maintenance of the types of intakes described in "Constructing Intakes for Ponds, Lakes and Reservoirs," RWS.1.C.2, and "Constructing Intakes for Streams and Rivers," RWS.1.C.3.

Useful Definitions

FIXED INTAKE - An intake that does not float or move but is stationary.

PERFORATED PIPE - Pipe that has small holes in it.

SEDIMENT - Small particles of dirt and other matter that settle to the bottom of water.

SUSPENDED MATTER - Visible material in the water that does not settle.

Maintenance of Intakes for Ponds and Lakes

The most important part of the intake is the screened section of perforated pipe which is in the water. All water that enters the system must come through this perforated section. The smaller the openings in the screen, the more unwanted material is kept out of the system. However, smaller openings will cause the screen to clog more quickly. A screen with small openings needs to be cleaned more frequently but yields better quality water. Maintenance of the perforated pipe involves the steps listed below.

1. At least once every three months, check the intake screen as shown in Figure 1 to be sure it is not clogged with suspended matter or plant life. For floating intakes, lift the screened section of the pipe from the water and decide if cleaning is necessary. If the screen is dirty, scrub it clean with a brush. If damaged, replace it with a new one. Be sure to shut off the pump before beginning maintenance.

2. Follow the same steps for a rigid plastic pipe intake on fixed supports. For this kind of intake, the screened section of the pipe cannot be lifted from the water because the pipe does not bend. Wait until the water is low enough that wading into the water is possible. Then, remove the screen from the pipe to check its condition. Be sure to shut the gate or globe valve before removing the screen from the pipe. All pumping equipment should be shut off during intake maintenance.

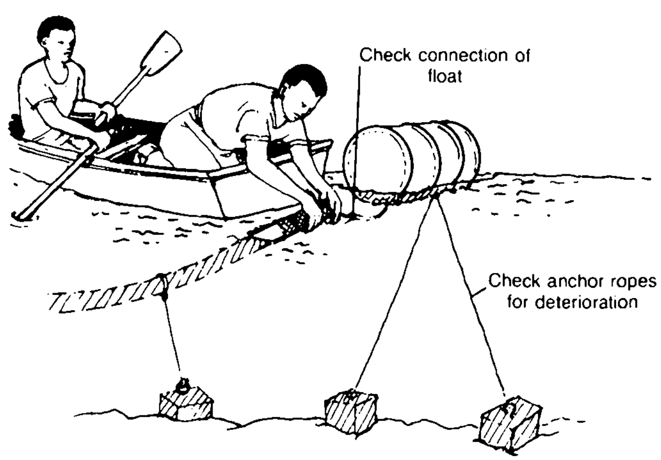

Figure 1. Cleaning Intake Screen on Floating Intake

Where the water is too deep for wading, a system like the one shown in Figure 2 can be installed. Attach an elbow joint to the end of the pipe and connect to it a length of pipe that extends to the surface of the pond or lake. The pipe should contain perforations at the desired water intake level. To screen the perforations allow accessibility for maintenance, attach pieces of rubber tubing to the screen. The rubber tubing should fit over the intake pipe. The screen can be lowered on the pipe to cover the perforations in the pipe. For maintenance, the screen is simply lifted from the pipe by someone in a boat, cleaned and slid onto the pipe once again.

3. During long periods of dry weather, check the water level of the pond or lake to ensure that it is not lower than expected. If a floating intake drifts too close to the bottom of the pond or lake, clogging is likely. Suspended materials may enter the system causing sediment build-up in storage tanks.

For fixed intakes, be sure that the intake is always below water level. If the water level falls a great deal, the intake pipe may have to be lowered. Do not lower it so much that sediment from the bottom can be picked up. If the water level falls during a long drought, the amount of water used by the community must be decreased so the water source will not dry up.

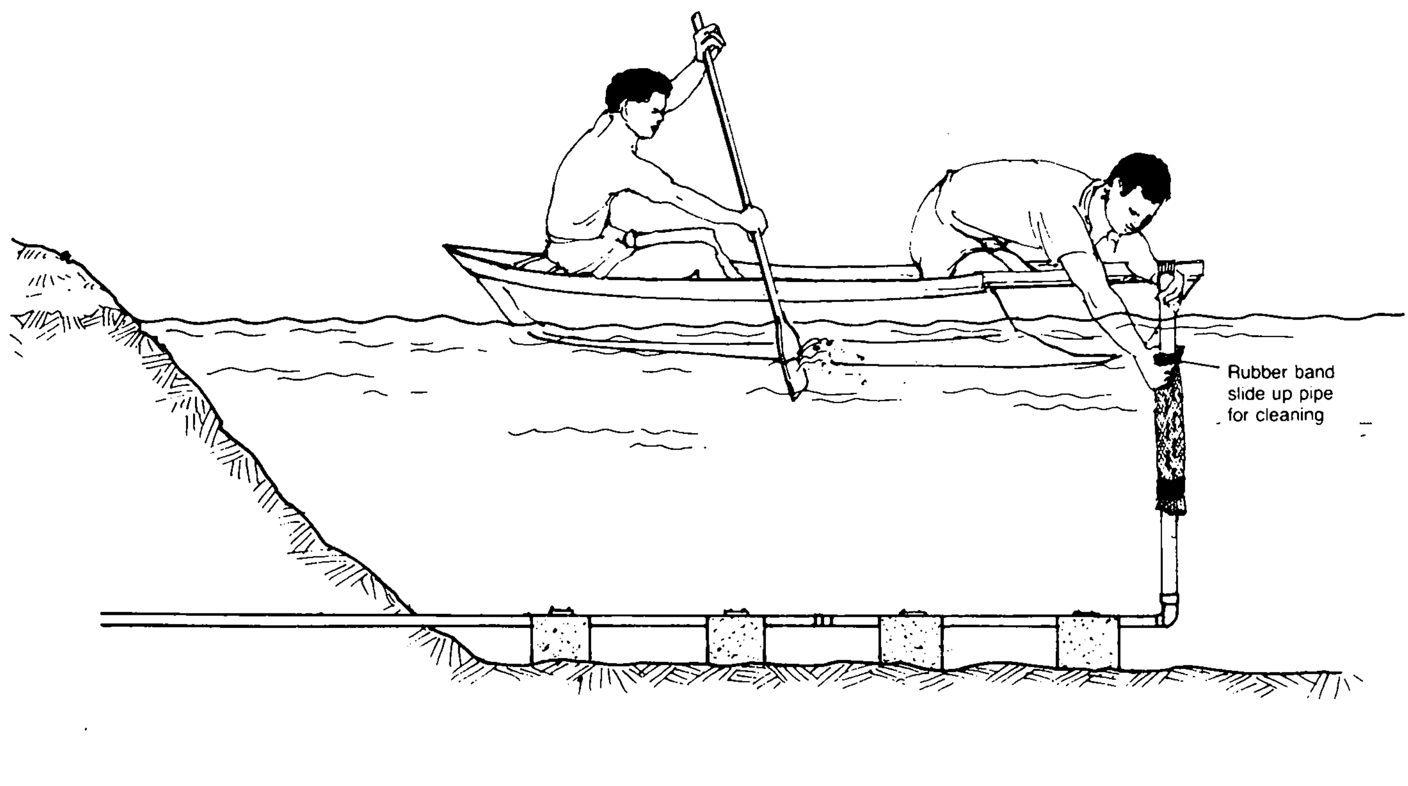

Figure 2. Cleaning Intake Screen on Rigid Intake

4. Check the float, rope, and anchors of the floating intakes to ensure that everything is in good condition. All parts should be securely tied to the float. If rope shows wear or rot, replace it.

5. Check points where PVC or galvanized pipe is coupled and make sure there is no leakage. On the shore, check the ground above the installed pipe to see if there are any wet spots. If the ground is wet, check to see if water is leaking from the pipe. More detailed information may be found in "Detecting and Correcting Leaking Pipes," RWS.4.O.1.

Maintenance of Intakes for Rivers and Streams

Intakes for rivers and streams consist of infiltration systems, gravity flow systems, and permanent direct pumping systems. Follow the steps outlined below for an effective maintenance program.

Infiltration Systems. The maintenance of riverside wells and clear water wells is not difficult. The water in them should be analyzed every six months to ensure that the quality is acceptable. This analysis must be done carefully to detect any contamination. For information on sampling and analyzing water in the field, see "Taking a Water Sample," RWS.3.P.2, and "Analyzing a Water Sample," RWS.3.P.3.

The biggest maintenance problem is the pump. Pumps must be maintained properly if they are to provide good service. See "Operating and Maintaining Mechanical Pumps," RWS.4.O.2, and "Operating and Maintaining Hand Pumps," RWS.4.O.3, for information about pumps.

Collection pipes for infiltration galleries may need maintenance to ensure adequate flow into the water system. Follow the steps below for maintaining collection pipes.

1. Check the flow of water into the clear water well. Be sure that the flow from each side is good. If the water flow is low on either or both sides, suspect that the collection system is clogged.

2. Remove the obstruction from the pipe. The simplest way to unclog the pipes is to pour water into the cleanout system. Uncap the installed cleanout pipe and pour water into the system to break up any sediment. If a hose and water pressure are available, they should be used to thoroughly flush out the collection system. See Figure 3.

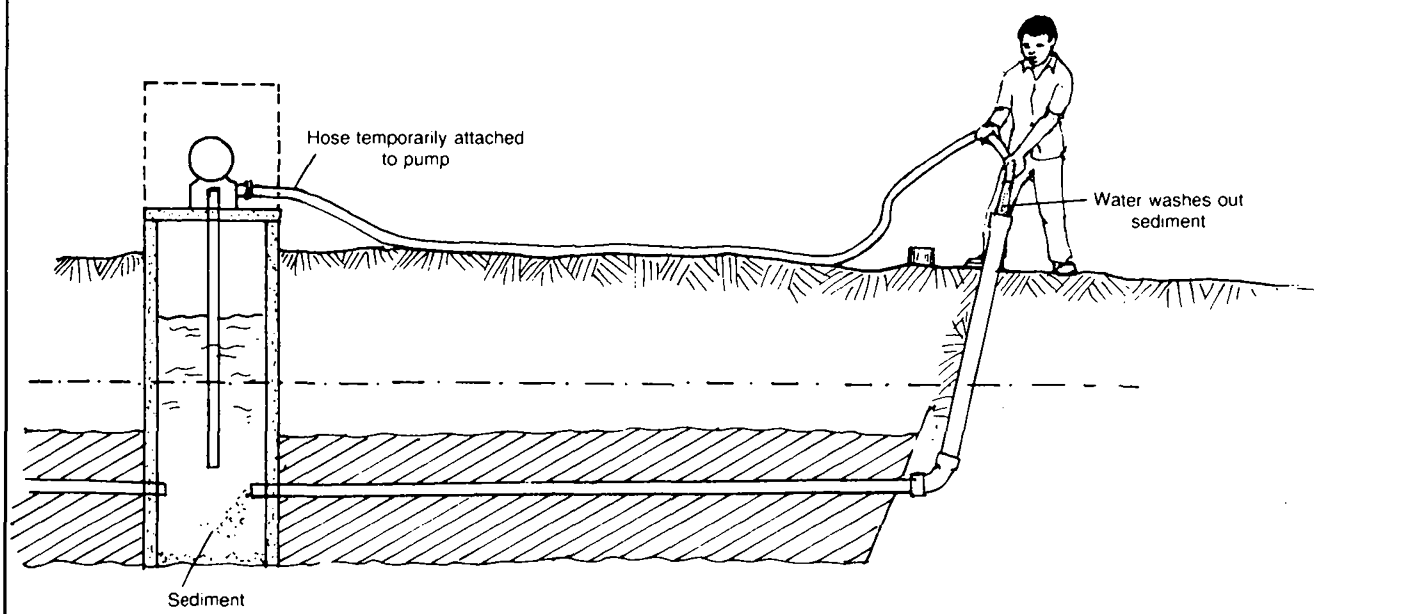

Figure 3. Cleaning Out Infiltration Gallery Pipes

3. If the pipes remains clogged, it may be necessary to locate the clogging by digging out around the collection pipe. Begin digging at the point furthest from the well and dig toward the well. Uncover the entire collection pipe and locate where the clogging is occurring. Clean those areas. Use buckets of water from the well and flush out the sediment from the system. Lay fresh sand and gravel in the filter bed before backfilling the trench.

Gravity Flow and Direct Pumping. For the winged-wall gravity flow system shown in Figure 4 and the permanent intake connected to a mechanical pump shown in Figure 5, maintenance involves the prevention of clogging around the intake.

1. Periodically clean the screen that covers the intake pipe so that water flows freely through the wire mesh. If, the screen is dirty, brush it clean. If it is damaged or in very bad condition, replace it.

2. Clear out any debris that may block the intake in the winged-wall collection box. Tree limbs, leaves, and any other objects should be removed from within the collection area.

3. Check the structure to see if it is securely anchored in the stream. If any movement is suspected, weight the structure with large rocks.

4. Look for any sign of leaking around the pipe and the wall. If the seal is not watertight, mix some mortar and put it around the pipe.

Direct pumping systems require little maintenance of the intake itself. The screens must be cleaned periodically as with other intakes. Be sure that the pipe is always submerged by checking the water level during dry periods. If the river dries up, an alternative source must be found.

The greatest maintenance problems are likely to occur from leaking pipes or mechanical failure of the pump. For information on maintaining pipes and pumps, see "Detecting and Correcting Leaking Pipes," RWS.4.0.1, and "Operating and Maintaining Mechanical Pumps," RWS.4.0.2.

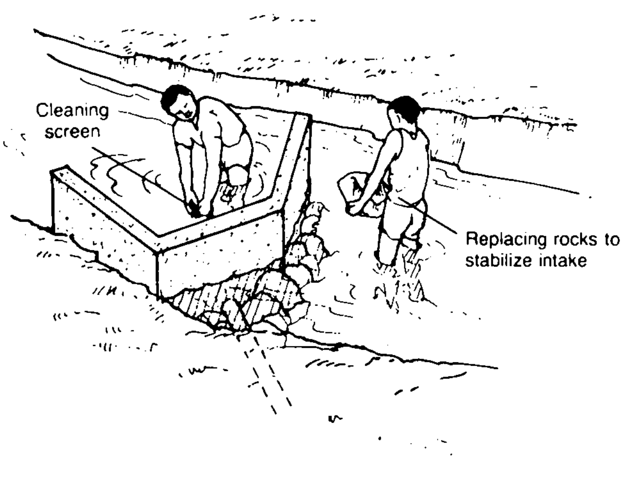

Figure 4. Maintaining Direct Intake in Stream

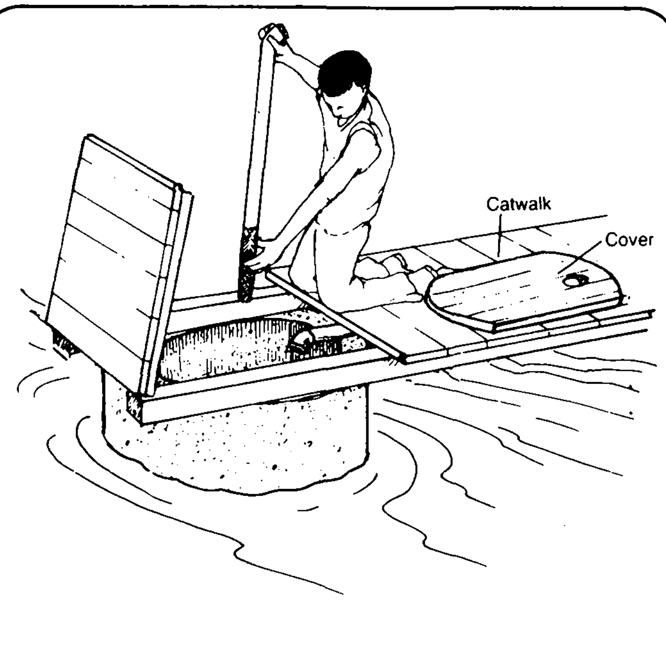

Figure 5. Cleaning Intake Screen in Protected Intake

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Water for the World

Maintaining Structures for Springs

Technical Note No. RWS. 1.0.1

Spring structures are easy to operate and maintain. One of the main advantages of springs as water sources is that they are inexpensive to develop. The structures needed to protect them require little attention after installation. No structure, however, is completely maintenance free. Even the most simply designed spring structure needs periodic maintenance to ensure that it provides good quality water in sufficient quantities. This technical note describes the periodic maintenance needed for spring boxes and seep collection systems so that they operate effectively for many years.

Useful Definitions

EROSION - The wearing away of soil, rock or other material by the flow of water.

PERVIOUS - Allowing liquid to pass through.

SEDIMENT - Small particles of dirt and other matter that settle to the bottom of water.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

Maintenance of Spring Boxes

The maintenance of spring boxes requires that a check be made to ensure that the structure adequately protects the water source and that all available water is being collected. Examine the spring box periodically to ensure that there is no silt build-up and that water quality is good. Study the following conditions at the site to ensure that the spring is well-protected and free from any operating problems.

Determine whether the diversion drainage ditch above the spring is doing an adequate job of removing surface water from the area. If not, the trench should be improved. The diversion ditch should be lined with gravel or stones to increase flow and to prevent erosion of the sides. Grass can be planted in the trench to prevent erosion, but heavy growth will block flow. Be sure to check the diversion ditch periodically to make sure that grass is not too high and that no other obstructions will block water flow.

If there is a fence above the spring, make sure it is in good repair and is effectively keeping animals away from the spring.

Check the upslope wall to be sure it is solid and erosion is not wearing it away. If there are signs of heavy erosion or settling, add additional backfill of top soil, clay or gravel. Build up the hill with stones and plant grass to help control erosion around the spring box.

Check the water. If there is an increase in turbidity or flow after a rainstorm, surface run-off is reaching the source and contaminating it. Identify the source of the run-off and improve the protection of the spring.

Take periodic samples of the water and have them analyzed to check for evidence of fecal contamination. Information on taking a water sample and analyzing it can be found in "Taking a Water Sample," RWS.3.P.2 and "Analyzing a Water Sample," RWS.3.P.3.

Check the cover to be sure the box is watertight. Make sure that the cover is not removed by the users and that contamination is not being introduced by people dipping buckets and other utensils into the spring box.

Determine that all available water is being collected by the system. Watch out for water seeping from the sides or from underneath the spring box. If water seeps out, seal the leak with clay or concrete so that all flow is diverted into the spring box.

Ensure that the system is cleaned adequately. Once a year disinfect the system and clean the sediment out of the spring box. To clean the system, remove the cover. Allow the water to drain from the spring box by opening the valve on the outlet pipe. If the box has only one pipe for outlet and overflow, use a bucket to empty the spring box as shown in Figure 1. Then use a small shovel to clean out the sediment collected on the bottom of the tank. Sediment removal will prevent clogging and build-up which causes the tank to fill up more quickly.

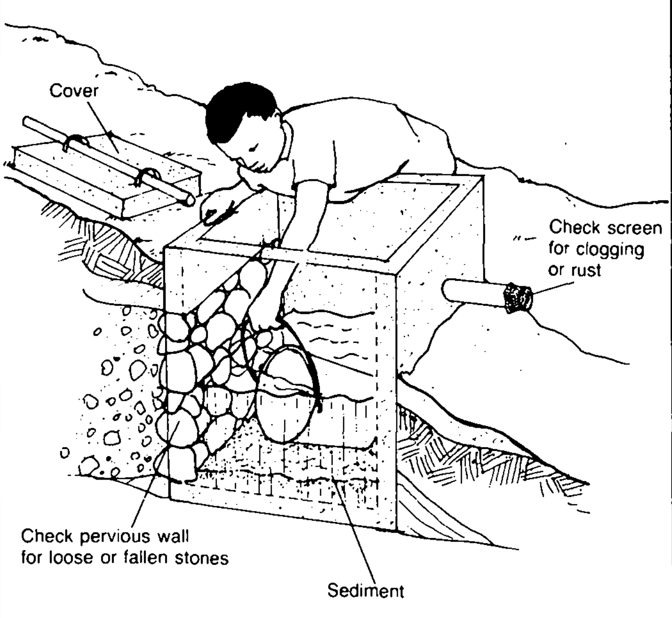

Figure 1. Emptying Spring Box

If a pump is built into the spring box to collect sediment, a drain pipe can be installed to carry sediment away. The drain pipe should have a valve. This type of installation is especially useful when tapping a fast flowing spring.

After cleaning the tank, follow the procedures for disinfection explained in "Disinfecting Wells," RWS.2.C.9. All walls of the spring box should be washed with a chlorine solution and chlorine should be put directly into the water. If possible, the chlorine should be allowed to stand for 24 hours. If the chlorine cannot stand that long, apply two doses of chlorine twelve hours apart to ensure complete disinfection. Figures 1, 2, and 3 show the cleaning and disinfection of a spring box.

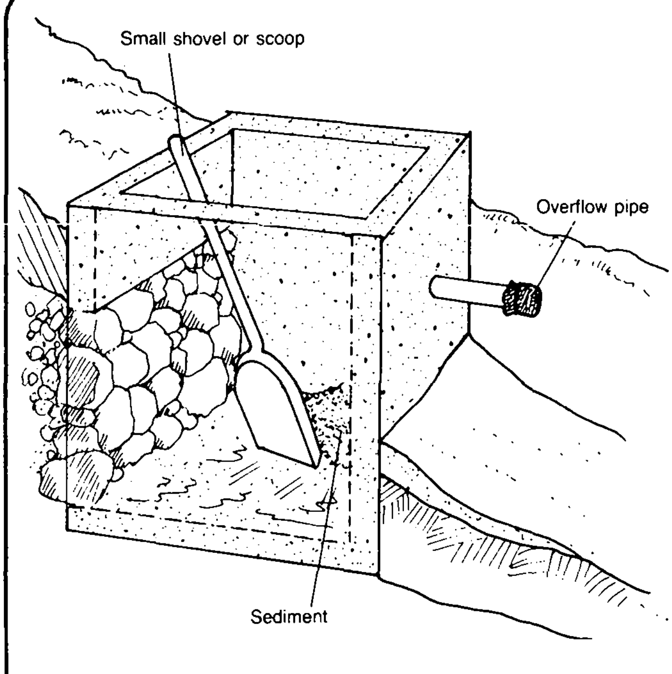

Figure 2. Removing Sediment

Check the screening on the pipes to see if cleaning is necessary. If screens are clogged or very dirty, they should be either cleaned or changed. Always use copper or plastic screening to prevent rust.

Maintenance of Seep Collection Systems

Operating and maintaining seep collection systems is similar to spring boxes except that extra care must be taken in the maintenance of the collection pipes. Although collection pipes are lined with gravel to filter out sediment, the pipes can still clog.

If clogging occurs, substantially less water will reach the collection box. If water flow decreases, suspect that the collection system is clogged.

To clean the clogged pipes, remove the cap from the clean-out pipe and pour water into it. Use either a hose or a bucket so that sufficient force is available to break up the sediment. See Figure 4.

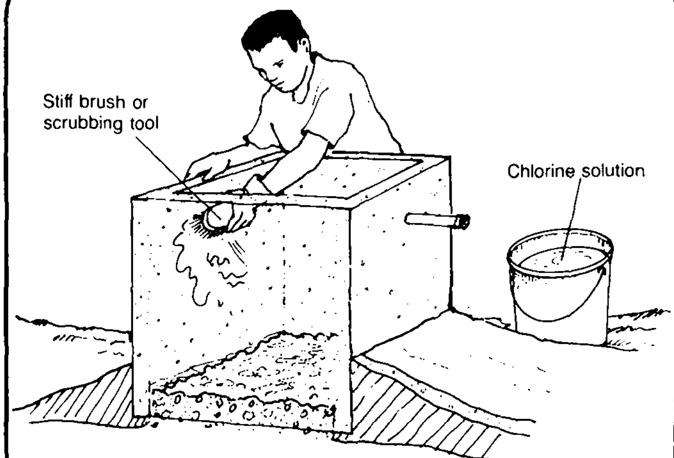

Figure 3. Scrubbing Walls with Chlorine Solution

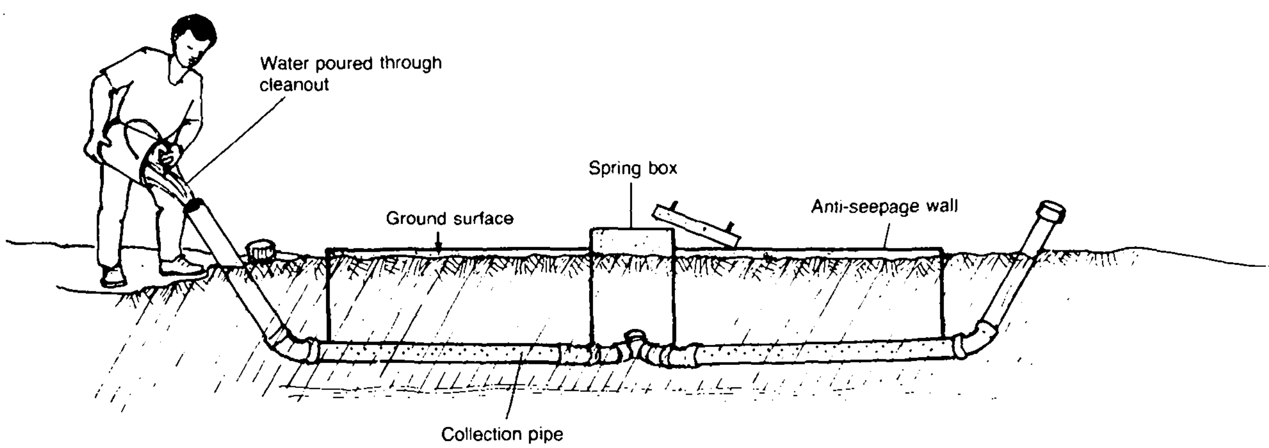

Figure 4. Flushing Out Seep Collection System

Notes

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Water for the World

Maintaining Intakes
Technical Note No. RWS. 1.O.2

Intakes must be well maintained to ensure that there is sufficient water flow from the source to the users. If intakes do not function properly, the flow of water could decrease or even stop completely. This would cause people to look for another water source, possibly a less suitable one. This technical note discusses maintenance of the types of intakes described in "Constructing Intakes for Ponds, Lakes and Reservoirs," RWS.1.C.2, and "Constructing Intakes for Streams and Rivers," RWS.1.C.3.

Useful Definitions

FIXED INTAKE - An intake that does not float or move but is stationary.

PERFORATED PIPE - Pipe that has small holes in it.

SEDIMENT - Small particles of dirt and other matter that settle to the bottom of water.

SUSPENDED MATTER - Visible material in the water that does not settle.

Maintenance of Intakes for Ponds and Lakes

The most important part of the intake is the screened section of perforated pipe which is in the water. All water that enters the system must come through this perforated section. The smaller the openings in the screen, the more unwanted material is kept out of the system. However, smaller openings will cause the screen to clog more quickly. A screen with small openings needs to be cleaned more frequently but yields better quality water. Maintenance of the perforated pipe involves the steps listed below.

1. At least once every three months, check the intake screen as shown in Figure 1 to be sure it is not clogged with suspended matter or plant life. For floating intakes, lift the screened section of the pipe from the water and decide if cleaning is necessary. If the screen is dirty, scrub it clean with a brush. If damaged, replace it with a new one. Be sure to shut off the pump before beginning maintenance.

2. Follow the same steps for a rigid plastic pipe intake on fixed supports. For this kind of intake, the screened section of the pipe cannot be lifted from the water because the pipe does not bend. Wait until the water is low enough that wading into the water is possible. Then, remove the screen from the pipe to check its condition. Be sure to shut the gate or globe valve before removing the screen from the pipe. All pumping equipment should be shut off during intake maintenance.

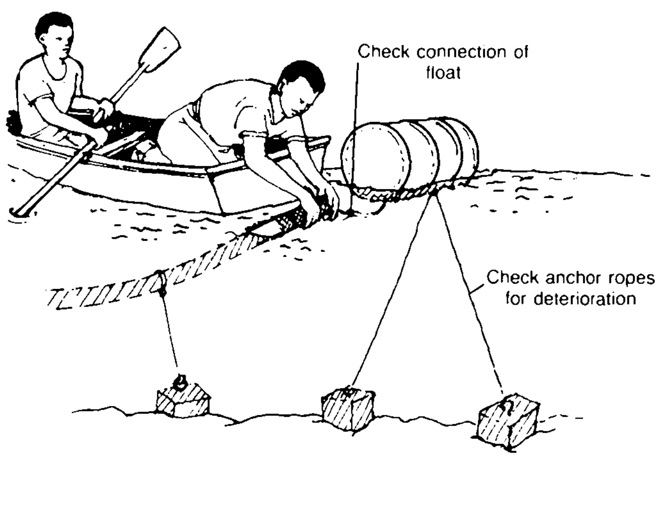

Figure 1. Cleaning Intake Screen on Floating Intake

Where the water is too deep for wading, a system like the one shown in Figure 2 can be installed. Attach an elbow joint to the end of the pipe and connect to it a length of pipe that extends to the surface of the pond or lake. The pipe should contain perforations at the desired water intake level. To screen the perforations allow accessibility for maintenance, attach pieces of rubber tubing to the screen. The rubber tubing should fit over the intake pipe. The screen can be lowered on the pipe to cover the perforations in the pipe. For maintenance, the screen is simply lifted from the pipe by someone in a boat, cleaned and slid onto the pipe once again.

3. During long periods of dry weather, check the water level of the pond or lake to ensure that it is not lower than expected. If a floating intake drifts too close to the bottom of the pond or lake, clogging is likely. Suspended materials may enter the system causing sediment build-up in storage tanks.

For fixed intakes, be sure that the intake is always below water level. If the water level falls a great deal, the intake pipe may have to be lowered. Do not lower it so much that sediment from the bottom can be picked up. If the water level falls during a long drought, the amount of water used by the community must be decreased so the water source will not dry up.

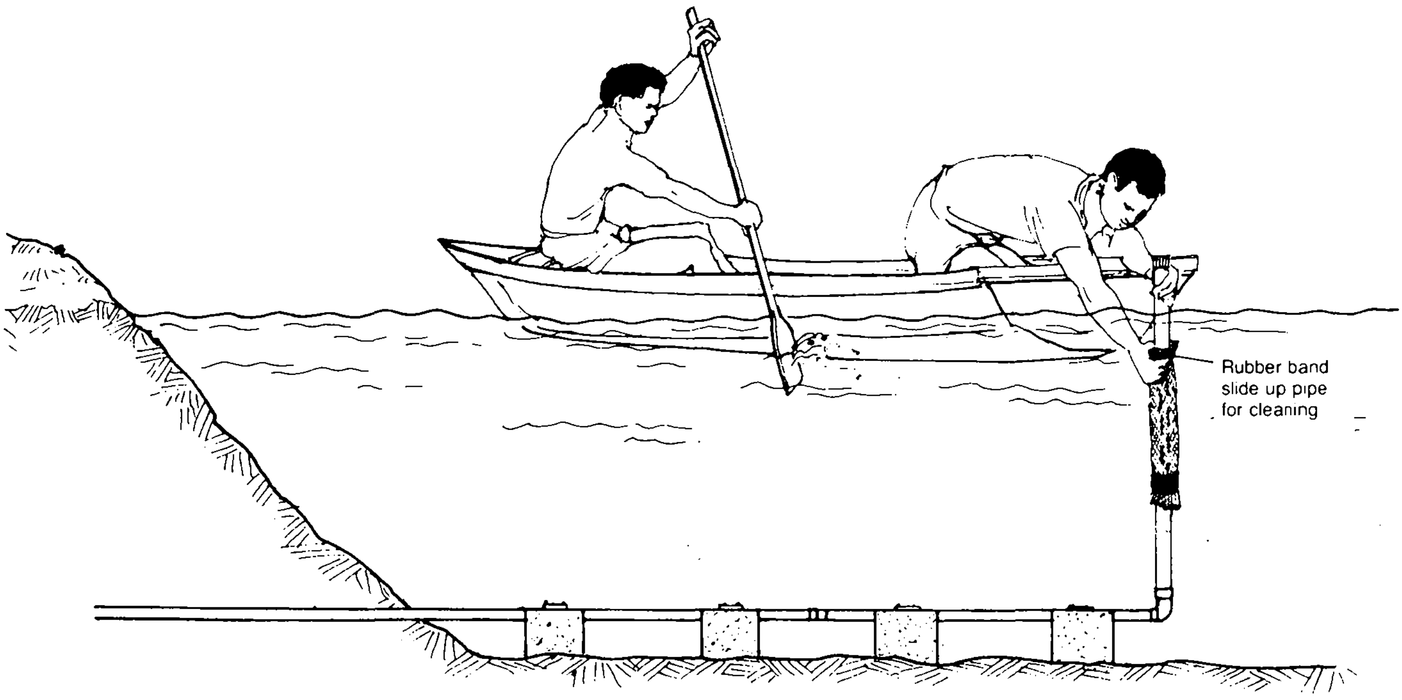

Figure 2. Cleaning Intake Screen on Rigid Intake

4. Check the float, rope, and anchors of the floating intakes to ensure that everything is in good condition. All parts should be securely tied to the float. If rope shows wear or rot, replace it.

5. Check points where PVC or galvanized pipe is coupled and make sure there is no leakage. On the shore, check the ground above the installed pipe to see if there are any wet spots. If the ground is wet, check to see if water is leaking from the pipe. More detailed information may be found in "Detecting and Correcting Leaking Pipes," RWS.4.O.1.

Maintenance of Intakes for Rivers and Streams

Intakes for rivers and streams consist of infiltration systems, gravity flow systems, and permanent direct pumping systems. Follow the steps outlined below for an effective maintenance program.

Infiltration Systems. The maintenance of riverside wells and clear water wells is not difficult. The water in them should be analyzed every six months to ensure that the quality is acceptable. This analysis must be done carefully to detect any contamination. For information on sampling and analyzing water in the field, see "Taking a Water Sample," RWS.3.P.2, and "Analyzing a Water Sample," RWS.3.P.3.

The biggest maintenance problem is the pump. Pumps must be maintained properly if they are to provide good service. See "Operating and Maintaining Mechanical Pumps," RWS.4.O.2, and "Operating and Maintaining Hand Pumps," RWS.4.O.3, for information about pumps.

Collection pipes for infiltration galleries may need maintenance to ensure adequate flow into the water system. Follow the steps below for maintaining collection pipes.

1. Check the flow of water into the clear water well. Be sure that the flow from each side is good. If the water flow is low on either or both sides, suspect that the collection system is clogged.

2. Remove the obstruction from the pipe. The simplest way to unclog the pipes is to pour water into the cleanout system. Uncap the installed cleanout pipe and pour water into the system to break up any sediment. If a hose and water pressure are available, they should be used to thoroughly flush out the collection system. See Figure 3.

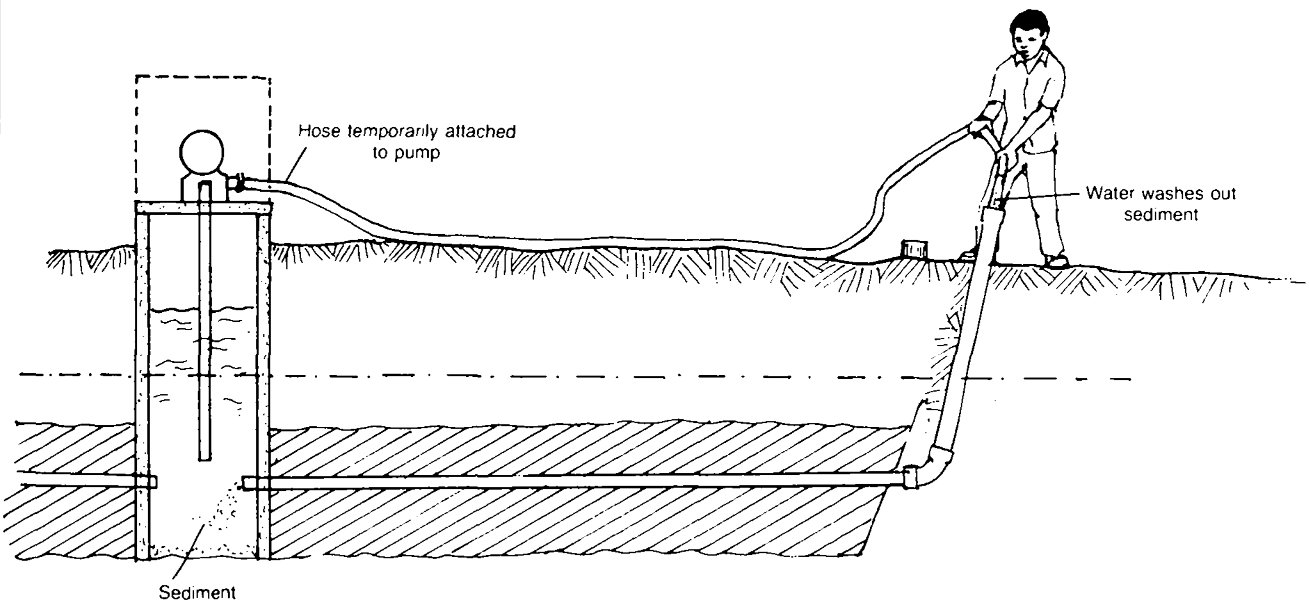

Figure 3. Cleaning Out Infiltration Gallery Pipes

3. If the pipes remains clogged, it may be necessary to locate the clogging by digging out around the collection pipe. Begin digging at the point furthest from the well and dig toward the well. Uncover the entire collection pipe and locate where the clogging is occurring. Clean those areas. Use buckets of water from the well and flush out the sediment from the system. Lay fresh sand and gravel in the filter bed before backfilling the trench.

Gravity Flow and Direct Pumping. For the winged-wall gravity flow system shown in Figure 4 and the permanent intake connected to a mechanical pump shown in Figure 5, maintenance involves the prevention of clogging around the intake.

1. Periodically clean the screen that covers the intake pipe so that water flows freely through the wire mesh. If, the screen is dirty, brush it clean. If it is damaged or in very bad condition, replace it.

2. Clear out any debris that may block the intake in the winged-wall collection box. Tree limbs, leaves, and any other objects should be removed from within the collection area.

3. Check the structure to see if it is securely anchored in the stream. If any movement is suspected, weight the structure with large rocks.

4. Look for any sign of leaking around the pipe and the wall. If the seal is not watertight, mix some mortar and put it around the pipe.

Direct pumping systems require little maintenance of the intake itself. The screens must be cleaned periodically as with other intakes. Be sure that the pipe is always submerged by checking the water level during dry periods. If the river dries up, an alternative source must be found.

The greatest maintenance problems are likely to occur from leaking pipes or mechanical failure of the pump. For information on maintaining pipes and pumps, see "Detecting and Correcting Leaking Pipes," RWS.4.0.1, and "Operating and Maintaining Mechanical Pumps," RWS.4.0.2.

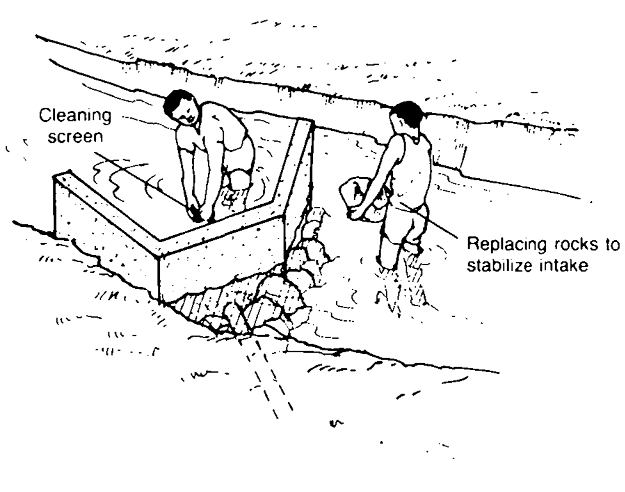

Figure 4. Maintaining Direct Intake in Stream

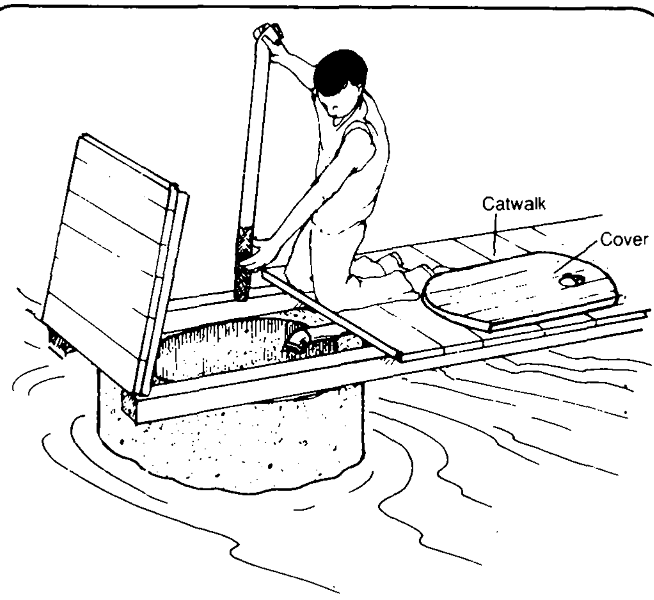

Figure 5. Cleaning Intake Screen in Protected Intake

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Water for the World

Maintaining Small Dams

Technical Note No. RWS. 1.O.5

Proper dam maintenance is very important. It ensures that abundant, good quality water is available for a community supply. Maintenance is essential to protect people near a dam site. If a dam breaks, flooding occurs that may cause destruction of life, homes and crops over a large area. This technical note describes measures which should be taken to maintain a dam effectively. Use the suggestions for preventive dam maintenance.

Useful Definitions

BOOM - A barrier of floating logs that prevents waves from wearing away the embankment of a reservoir.

EROSION - The wearing away of soil, rock or other material by water or wind.

MALARIA - A disease transmitted to humans by the female anopheles mosquito.

RIP-RAP - Blanket foundation or wall made of large stones thrown together irregularly or loosely.

SCHISTOSOMIASIS - A parasitic disease transmitted from snails to man through contact with water containing infected snails.

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

General Maintenance

Earth dams may fail because of poor site investigation, poor soils, poor design, poor construction and unusually heavy rainfall. The most common problem encountered in small earth dams are leaks in the embankment; overtopping (the flow of water over the top of the dam), undermining (the flow of water under the structure), piping failure, erosion of the embankment, and slope failure. These conditions reduce the strength of the dam.

Other factors can affect the reservoir and the quality of water. Poor watershed management can cause contamination of water in the reservoir. Reservoirs may be breeding places for disease-carrying insects such as snails and mosquitoes which cause great harm to a community. For information on diseases associated with standing water, see "Means of Disease Transmission," DIS.1.M.1.

These problems will become serious without proper maintenance. All dams should be inspected every three months and after every heavy rain to determine if there is a need for repairs.

Check the dam for any seepage or cracks. If there is seepage through or under the dam, consult an engineer for advice on correcting the problem. Solve any seepage problems as quickly as possible to prevent conditions from getting worse.

Burrowing animals can cause great damage to a dam. If burrowing occurs in the embankment, the structure will be weakened and the dam could break. To prevent burrowing, place a thick layer of sand and gravel on the fill. As shown in Figure 1, chicken wire can also be placed on the embankment to stop animals from burrowing, but it will rust and need replacement periodically. If burrowing continues, a program to eliminate pests should be developed. See a local agricultural agent for advice.

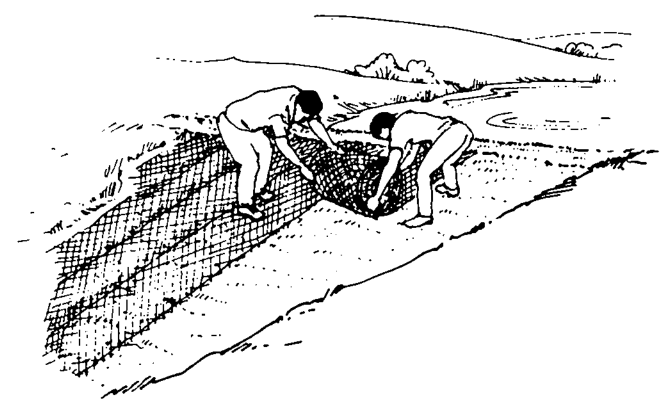

Figure 1. Chicken Wire on Dam Embankment

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If there are any small channels on the embankment, fill them with soil high in clay content and compact it. These areas should be replanted with grasses or other vegetative covering. Maintain the vegetative cover on the downslope side of the embankment by keeping the grass cut and fertilizing if needed. Proper cutting and care of the cover makes it more resistant to run-off. Plant only grass, not trees or bushes. Tree or bush roots will open channels in the embankment through which water can flow.

After any planting, keep people from walking up and down the grass slopes. Rainwater is caught by the footprints and flows down the slopes causing small channels to form. The embankment slowly washes away in these channels.

The top of the embankment should be blocked off so that vehicles do not use it for crossing the stream. Walking across the top of the dam will not cause damage but driving across it should be prohibited.

The upstream embankment must be protected from erosion caused by wave action in the reservoir. It should be paved with rough stone from 0.5m below the low water level to 0.5-1.0m above the high water level as shown in Figure 2. Paving should reach as high as the height reached by waves. Check to be sure that the rip-rap is in place and that erosion is not a problem. If timber is available, a boom can be built to protect the face of the dam. A boom is a single or double line of logs chained together and securely anchored to each end of the dam as shown in Figure 3. The line should have enough slack to fluctuate with the water.

To prevent erosion in dry areas where rock and timber are not available and vegetation is scarce, the front slope of the embankment may have to be flattened or a layer of coarse sand and gravel applied to it at a ten to one (10:1) slope.

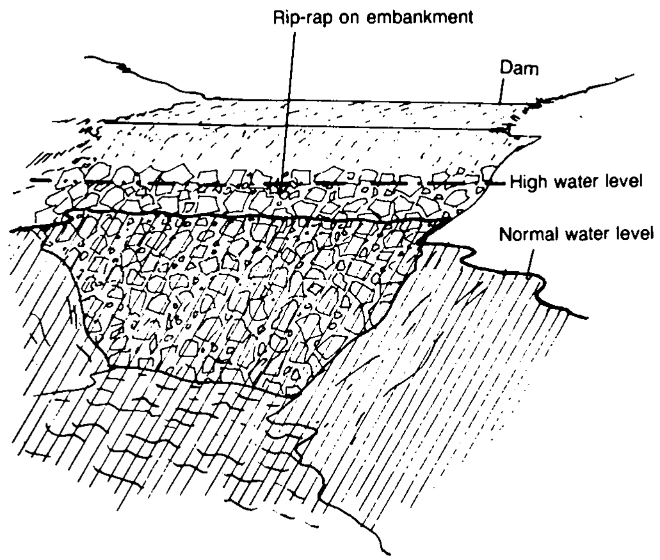

Figure 2. Placement of Rip-rap on Upstream Slope of Dam

Prevention of Overtopping

Water should never be allowed to flow over the top of an earth dam. Overtopping, as this is called, will cause dam failure. Spillways are installed to prevent overtopping and their maintenance is very important. Spillways are installed on either side of the dam to remove water if the reservoir height rises above the normal high water level due to heavy rains or flooding. Spillways move the wastes downstream around the embankment.

Check the condition of the spillways. If there is any sign of erosion, repair the washed out areas with soil and either plant grass or line the spillways with stone. All spillway channels should be lined with either grass or stone.

After heavy rains, make sure that nothing is blocking the channels. Any large debris should be removed from the spillways to prevent water from backing up during a heavy rain and destroying the dam.

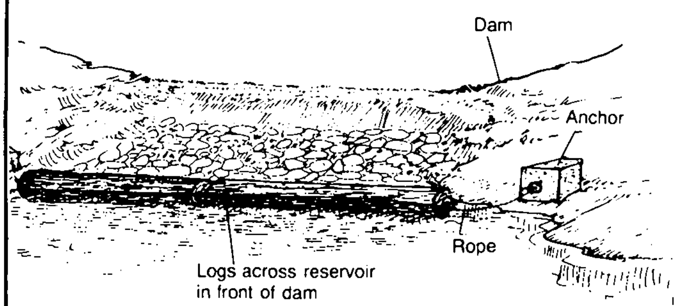

Figure 3. Boom Placed in Reservoir

Watershed Management and Sanitation

The quality of the water in the reservoir is protected by simple watershed management and sanitation practices. Keep livestock and other domestic animals away from both the reservoir and the watershed. Wherever possible, fence the watershed area and keep the fence well repaired.

Prevent erosion on the slopes of the watershed by preserving existing vegetation. If erosion is already occurring, plant trees or grass or take other measures such as terracing to prevent large quantities of sediment from flowing into the reservoir. Sediment colors the water, fills the reservoir basin quickly, and may contaminate the water.

Reservoirs can be breeding places for mosquitoes and snails. Mosquitoes that carry malaria and snails that carry schistosomiasis must not be allowed to breed. To prevent mosquitoes and snails from breeding, steepen the edges of the reservoir about 1m. Breeding of mosquitoes and snails generally takes place in shallow water and deep pond edges should discourage their breeding. The deeper edges will also discourage growth of vegetation in the pond. Where malaria is a problem, aquatic growth and shoreline vegetation should not be permitted. When caring for the reservoir, see a local health official to discuss ways to keep the reservoir from being a source of disease.

NOTES

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Water for the World

Maintaining Small Dams
Technical Note No. RWS. 1.O.5

Proper dam maintenance is very important. It ensures that abundant, good quality water is available for a community supply. Maintenance is essential to protect people near a dam site. If a dam breaks, flooding occurs that may cause destruction of life, homes and crops over a large area. This technical note describes measures which should be taken to maintain a dam effectively. Use the suggestions for preventive dam maintenance.

Useful Definitions

BOOM - A barrier of floating logs that prevents waves from wearing away the embankment of a reservoir.

EROSION - The wearing away of soil, rock or other material by water or wind.

MALARIA - A disease transmitted to humans by the female anopheles mosquito.

RIP-RAP - Blanket foundation or wall made of large stones thrown together irregularly or loosely.

SCHISTOSOMIASIS - A parasitic disease transmitted from snails to man through contact with water containing infected snails.

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

General Maintenance

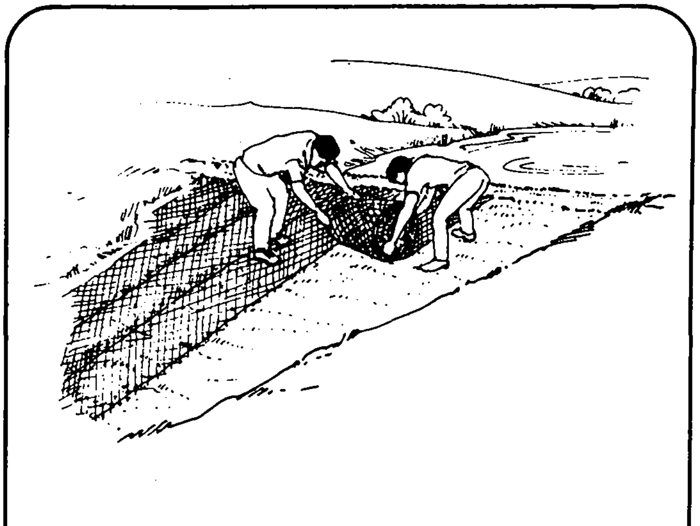
Earth dams may fail because of poor site investigation, poor soils, poor design, poor construction and unusually heavy rainfall. The most common problem encountered in small earth dams are leaks in the embankment; over-topping (the flow of water over the top of the dam), undermining (the flow of water under the structure), piping failure, erosion of the embankment, and slope failure. These conditions reduce the strength of the dam.

Other factors can affect the reservoir and the quality of water. Poor watershed management can cause contamination of water in the reservoir. Reservoirs may be breeding places for disease-carrying insects such as snails and mosquitoes which cause great harm to a community. For information on diseases associated with standing water, see "Means of Disease Transmission," DIS.1.M.1.

These problems will become serious without proper maintenance. All dams should be inspected every three months and after every heavy rain to determine if there is a need for repairs.

Check the dam for any seepage or cracks. If there is seepage through or under the dam, consult an engineer for advice on correcting the problem. Solve any seepage problems as quickly as possible to prevent conditions from getting worse.

Burrowing animals can cause great damage to a dam. If burrowing occurs in the embankment, the structure will be weakened and the dam could break. To prevent burrowing, place a thick layer of sand and gravel on the fill. As shown in Figure 1, chicken wire can also be placed on the embankment to stop animals from burrowing, but it will rust and need replacement periodically. If burrowing continues, a program to eliminate pests should be developed. See a local agricultural agent for advice.



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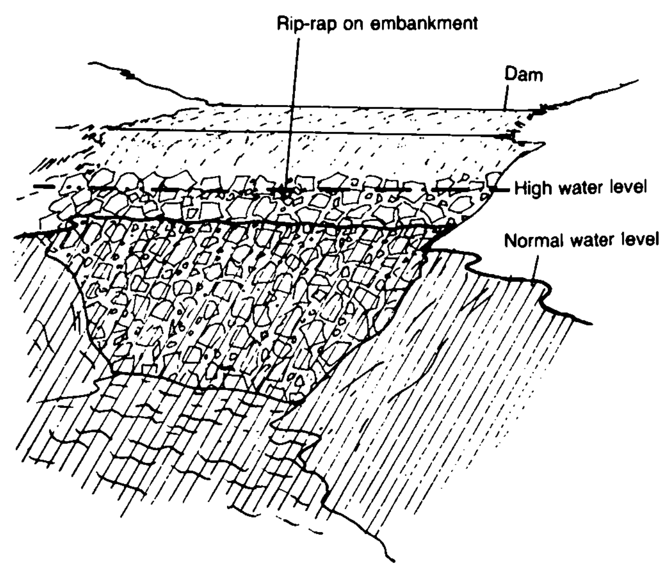

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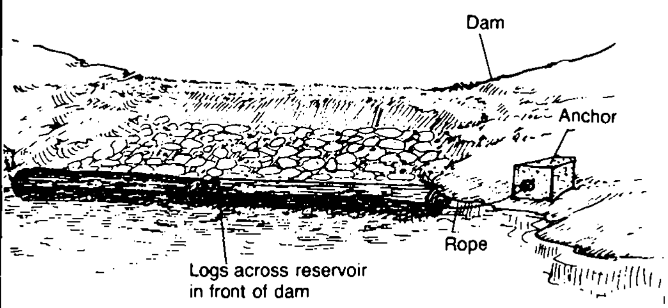

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Water for the World

Planning How to Use Sources of Surface Water

Technical Note No. RSW. 1.P.1

Surface water includes water from ponds, lakes, streams, rivers and springs. Surface water sources can be important for community water supplies. Surface water is available without major digging or use of expensive machinery and sometimes can be delivered to users without pumping. The quantity of water available is easy to determine by simple measurements. The development of surface water sources is not simple and careful planning is necessary. Surface water is subject to run-off and human and animal contact and may be contaminated with feces or other wastes. Before a surface source can be used it should be well protected, and, in most cases, connected to a distribution system. Most water from surface sources should be treated.

This technical note describes the planning needed to use surface water sources in terms of eight important planning steps: (1) recognize the problem, (2) organize community support and set objectives, (3) collect data, (4) formulate alternatives, (5) choose the best method, (6) establish the system, (7) operate and maintain the system and (8) evaluate the system. Worksheet A may be adapted for use in cataloging information gathered during the planning process.

Useful Definitions

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

WATER-RELATED DISEASES - Diseases caused by a lack of safe water and poor sanitation.

Recognize the Problem

Before planning to use any source of water, the community's water supply problem must be defined. The current water source is unacceptable if (a) the water is of poor quality, (b) the water is not available in sufficient quantities to meet the needs of the users, (c) the source is not accessible to the users and (d) the source is not reliable.

Water quality is generally measured by laboratory testing. In many areas, testing will be impossible because of lack of equipment and the distances from the source to testing facilities. Water quality must then be judged through observation of local conditions and through a sanitary survey. (See "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2). If a water source is exposed to contamination from human and animal wastes, aquatic growths in the water, and surface runoff, it must be protected, treated or abandoned for a more suitable source. If there is a high rate of water-related disease among users of a certain water source, suspect that the source is contaminated and take measures to improve the water supply. Table 1 shows examples of diseases caused by lack of safe water. Where such diseases exist, water supply improvements will reduce the number of cases. Water improvements will not eliminate these diseases.

Water quantity is measured by the number of liters per day people use. Table 2 shows typical water consumption rates for rural areas. A water source should provide an average of 15 liters

Worksheet A. Planning the Development of a Surface Water Source

1. Name of community ______________________

2. Number of people to be served by water source ______________________

3. Type and number of water-related diseases in the community per year ______________________

4. Significant beliefs and taboos about water ______________________

5. Present source(s) of water and form of distribution ______________________

   Determine:

   water quality (see RWS.1.P.2) ______________________

   water quantity (see RWS.1.P.3) ______________________

   accessibility ______________________

   reliability ______________________

   form of and location of distribution system ______________________

6. Potential source(s) of water ______________________

   Determine:

   water quality (see RWS.1.P.2) ______________________

   water quantity (see RWS.1.P.3) ______________________

   accessibility ______________________

   reliability ______________________

7. Commmunity resources and organization

   Determine:

   a) sources of income ______________________

   b) seasonal distribution of income ______________________

   c) labor and materials available ______________________

   d) infrastructure in existence ______________________

   e) concerned community leaders and groups ______________________

8. Project costs

   Estimate total costs for:

   a) equipment ______________________

   b) materials ______________________

   c) labor ______________________

   d) maintenance ______________________

   e) other costs (transportation, etc.) ______________________

9. Sources of finance

   Determine:

   a) local funding capability ______________________

   b) external funding possibilities ______________________

Table 1. Diseases Related to Deficiencies in Water Supply and/or Sanitation

Group	Diseases
Diseases transmitted by water (Water Borne)	Cholera Typhoid Bacillary Dysentery Infectious Hepatitis Amebic Dysentery Giardiasis Gastroenteritis
Diseases caused by lack of water and poor sanitation (Water Washed)	Scabies Skin Ulcers Lice and Typhus Trachoma Conjuctivitis Bacillary Dysentery Amoebic Dysentery Salmonellosis Diarrheas Ascariasis Whip Worm or Trichuriasis Hook Worm
Diseases caused by infecting agents spread by contact with or ingestion of water and of animals living in water (Water Based)	Schistosomiasis (Blood fluke) Guinea Worm Thread Worm Lung Worm Human Liver Fluke

per person per day for non-piped systems, 40 liters per person per day for one tap piped systems and 70-100 liters per person for multi-tap piped systems. If the water is to be brought near or into the houses, the amount used will increase greatly. A source producing insufficient quantities is unacceptable. Determine the amount of water a community will need by multiplying the population by the estimated amount of water used per person per day.

Water supplies must be accessible. If a great distance separates the supply from the user, a decrease in the amount of water used and a reduction in standards of hygiene is likely. People who must carry water may even choose a nearby contaminated supply over a distant protected one. The water supply should not be located more than 250m from the users.

Table 2. Domestic Water Use

Type of Supply	Typical Consumption (liters per capita per day)	Range (liters per capita per day)
Communal water point (village well, standpost) located at:		
- distance greater than 1000m from house	7	5-10
- distance between 500-1000m from house	12	10-15
Village well less than 250m from house	20	15-25
Public standposts less than 250m from house	30	20-50
Yard connection (tap in yard)	40	20-80
House connection		
- single tap in house	50	30-60
- multiple taps	150	70-250

The reliability of a source ensures its continued use. A water supply that dries up, provides insufficient water, or is tapped by a system that breaks down often may force people to use a less desirable source. A source must provide water year-round. Local technicians must be able to operate and maintain the treatment delivery system to ensure that water is always available to the community.

Organize Community Support and Set Objectives

The main objective is to provide a community with an adequate quantity of safe water from a convenient and reliable system. A good water system will reduce the incidence of water-related diseases and improve the overall health of the community. An accessible supply will increase water use for hygiene-related purposes and reduce the time spent in carrying water. More time will be available for productive activities. An abundant source can provide water for home vegetable gardens.

A successful project must include a plan for community support. Support is gained through three methods: (1) promotion, (2) community involvement and (3) training for operation and maintenance.

Promote the project in the community to create an awareness of the water supply problem. Organize meetings and educational programs, show pictures or films, and make home visits to explain the connection between a good water supply and good health. Once the community is aware of the problem, it will be more willing to work toward a solution by contributing time, effort and resources.

Involve the community in the project. Enlist the support of local political, religious and community leaders and include them in decision-making. Ask the potential users of the water system for advice. They will be good sources of information. They will express their preferences and be good sources of information on such matters as the resources available for the project. Discuss the cost of the project and emphasize the need to finance not only its construction but also its long-term operation and maintenance.

Training local people to operate and maintain the system is essential. Plan a training program for people active in the project so the water supply system can be developed and maintained by the community. The goal is that the community contribute to, participate in, and maintain the water supply system.

Collect Data

In order to understand the water supply problems of a community, information must be collected about local environmental, social and economic conditions. Appropriate solutions to problems will be suggested by this information. Data should be gathered on the following items: (a) local development history, (b) current community conditions, (c) environmental and geographic factors, (d) available resources and (e) local customs.

Obtain information about the community's development history. The success or failure of a past development project, especially in water supply, can guide decision-making. If a development project has failed, similar mistakes must be avoided. Information about past projects and traditional water sources should be available from village elders or local government agencies.

Study the present situation. Determine the community's current population and estimate likely growth rates and demand for water. Check the present water sources for their suitability and figure out possibilities for improvement. To plan efficiently, you need to collect information about incomes, resources and community needs.

Collect environmental and geographic data. Information should be collected on: (1) total annual precipitation, (2) seasonal distribution of precipitation, (3) annual or monthly variations of rainfall from normal levels, (4) stream and river flow rates and (5) spring yield. Some of this data may be obtained from local or national government agencies. Airports are likely to have useful statistics on rainfall and the stream and river flow rates and spring yield can be measured in the field using simple techniques. These are discussed in "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2. A great deal of useful information can be collected through interviews with local people and observation of local conditions.

Data on run-off and evaporation rates would aid planning greatly. This data is very difficult to obtain, but will prove useful if available.

Know what material and human resources the community can provide to the water project. The community should make contributions of labor, materials and money for the water system. Limit the amount of outside material or assistance whenever possible. Where outside technical assistance or material is needed, try to obtain it from the national or regional government, or from private donors. Determine what percentage of the project can be financed through local funds and use a combination of the local and outside resources to complete the project.

Know the customs of the community. Village preferences and desires may be determined by religious and cultural beliefs or taboos. Certain members of the community, such as water vendors, may depend on the present water system for their economic well-being and be opposed to a change. Know the community well before proposing a water project. Never promote or insist on a method that continues to meet with local resistance after it has been fully explained to the community.

Formulate Alternatives

Once all available data are collected, formulate possible solutions to the problem. The best alternatives will provide the community with safe and abundant water from a reliable and accessible source at the lowest cost. When considering alternatives, determine which method of surface water development will best solve the water supply problem (see "Methods of Developing Sources of Surface Water," RWS.1.M). Evaluate each method by determining its acceptability and suitability to the community. Determine the type of system most appropriate to the community's needs. Decide whether people will obtain their water directly from the source, from a standpipe or from household taps.

Discuss the cost and resource requirements of each alternative with community leaders and local groups to determine community preferences. In some cases, there will be only one acceptable alternative and no choice will be necessary. In other cases, there may be several acceptable alternatives, or there may be a combination of methods that could meet the community's needs. The decision about which to use will depend on the many factors discussed in this technical note.

Select a Method

Where there are several alternatives for a surface water source, it will be necessary to choose the best, most appropriate method. In making this decision consider the following:

Community needs. Determine whether the source can meet the needs of the community adequately now and in the near future. Do not choose a sophisticated method if it is not really necessary. Avoid selecting methods for prestige rather than suitability and maintainability.

Social acceptability. Determine whether the water source is acceptable to all the users. If the water has an odd taste or smell or is turbid, people will be against drinking it. Avoid having the supply a long way from the users since people will not walk long distances to fetch water. The greater the community acceptance of the system, the more willing people will be to pay for building and maintaining it.

Economic factors. Determine whether the community can afford the construction and maintenance of the system. Do not over-tax the resources of the community. A successful project will involve community labor and participation in fund-raising and other activities. A project partially paid for with community resources will be a source of pride. When selecting a method do not overlook the possibility of improving the current water source. It may not need much improvement and will probably meet with little local resistance. Improvement of the current source may be the best and least expensive alternative. Use "Selecting a Source of Surface Water," RWS.1.P.3, in deciding on the best water source for the community.

Establish the System

Once the best method is chosen, develop a project plan. The plan will serve as a guide throughout the project and ensure that labor and materials are available when needed. In many cases a plan must be submitted to a government agency or donor organization for approval. The plan should state a goal, provide population information, indicate the number of people affected by the project, and demonstrate how the project will aid the community. This is especially important when money is sought from international donors. Determine their requirements as early as possible. In such cases the plan should be quite detailed and include information on: (a) proposed system, (b) costs, (c) sources of finance, (d) implementation schedule, (e) plans for construction and sources of materials and (f) operation and maintenance requirements.

Proposed system. Design drawings for the project should be submitted with the plan. The drawings should include all measurements and capacities. Photographs of the work site and a topographic map showing houses, buildings, and water sources should accompany the plan.

Costs. The plan must include a list of all estimated costs, including materials, tools, equipment and labor for both construction and maintenance. If land must be purchased, that cost should be included in the total. Local materials probably will be less expensive and should be used whenever available. Labor costs will depend on the local pay rate and the time and skills required. Any labor or materials which are donated should be included in total costs.

Sources of funding. If at all possible, local funds should be used to finance some portion (at least 10-15 percent) of the project. This money can come from contributions, fund-raising activities such as dances, user fees, and various other sources. Money for the development of larger scale, or more expensive, water systems may be available from government organizations, international groups or private donors. Donor agencies generally require that the community cover a percentage of the construction costs and all of the operation and maintenance costs.

Implementation schedule. Determine the amount of time necessary to complete the project. Attempt to schedule the project at a time when volunteer labor and money are available to the community. Generally, this will be after harvest time or just before planting season. Fund-raising activities should take place during times of increased community income. In scheduling work, take into account wet and dry seasons.

Plan for construction. Develop a plan for constructing the system including both the labor and supplies needed. A complete materials list for the project will help ensure that tools, equipment and materials are at the site when people come to work. If tools and materials are stored at the site, provide a well-protected, secure place to store them. There should be a supervisor at the site so that workers will know what to do at all times. If the system is very complex, a contractor may be hired to do the construction.

Operation and maintenance. Plan for the continued operation of the system. This may include a training program for local villagers. No matter how simple the system, there will always be a need for maintenance. People trained in basic construction, pipe-laying, pump repair and simple water treatment are needed in the community. The people in charge of maintenance must know where to obtain spare parts, extra chlorine and other resources important to the system. A local storehouse can easily be established. Permanent arrangements for operation and maintenance must be made. More systems fail because of improper operation and maintenance than for any other reason.

In a community where water is piped into households, an administrative system for collection of fees and continued operation and maintenance must be established. Community members with managerial skills and community leaders should be involved in the system administration.

Evaluate the System

After completion, evaluate the system by determining if it is achieving the goals set at the beginning of the project. To measure the system's success, use the four characteristics of a suitable water supply: quality, quantity, accessibility and reliability.

Quality. Is the water provided of acceptable quality? Have the water tested, if possible, and determine if there has been a decline in water-related illnesses since the completion or improvement of the system. Fewer cases would indicate that quality has improved. Make sure the source is protected from sources of contamination, and that treatment is adequate.

Quantity. Is the quantity of water produced adequate? Determine if the system is meeting the daily needs of the users and if it supplies adequate quantities for potential additional users.

Accessibility. Is the system accessible to all intended users? Determine if the community is satisfied with the supply's location and has any problem getting water. Also, find out if water consumption has increased since the system was developed. An increase in consumption may indicate that water is more easily available to the users. If traditional family water carriers have increased time for other activities, try to estimate the benefits gained from this extra time.

Reliability. Is the system proving reliable? There should be no design flaws or breakdowns. Water should be reaching the users without interruption. If technicians have been trained, evaluate their performance in operating and maintaining the system. Be sure that they know where parts and materials can be obtained and that they can handle specific maintenance problems. Provide for a modest store of replacements and a means to make added house connections.

The evaluation of the system will provide important information for the development of future projects. Compare the success of this project to projects in other communities to gain valuable lessons in the development of surface water supply systems.

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

1982

Water for the World

Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources

Technical Note No. RWS. 1.P.2

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

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

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

Useful Definitions

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

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

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

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

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

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

FISSURE - A narrow, deep crack in rock.

LIMESTONE - A white rock consisting of mostly calcium carbonate.

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

Worksheet A. Questions to be Answered by a Sanitary Survey

1. Do potential sources of surface contamination exist — Yes / No

    a) above the site or in the watershed? ____ ____

    b) at the site? ____ ____

    If yes, determine these sources and

    a) remove sources of contamination, and/or

    b) protect the water supply, or

    c) find a more acceptable water supply.

2. Do potential sources of fecal contamination exist — Yes / No

    a) above the site or on the watershed? ____ ____

    b) at the site? ____ ____

    If yes, determine these sources and

    a) analyze the water, or

    b) remove sources of contamination.

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

    a) water must be treated or

    b) alternative source must be found.

3. Does the water source have unacceptable chemical or physical qualities such as: — Yes / No

    a) color? ____ ____

    b) turbidity (1) all the time? ____ ____

    (2) after a rainstorm? ____ ____

    c) unpleasant odor? ____ ____

    d) a lot of salt? ____ ____

    e) excessive algae? ____ ____

    f) excessive flourides? ____ ____

    g) hardness? ____ ____

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

Physical Characteristics of the Location

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

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

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

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

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

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

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

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

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

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

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

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

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

Bacteriological Quality of Water

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

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

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

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

Physical and Chemical Quality of Water

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

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

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

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

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

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

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

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

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

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

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

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

Notes

Notes

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Water for the World

Selecting a Source of Surface Water

Technical Note No. RWS. 1.P.3

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

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

Determining Quantity of Water Available

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

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

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

Useful Definitions

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

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

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

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

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

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

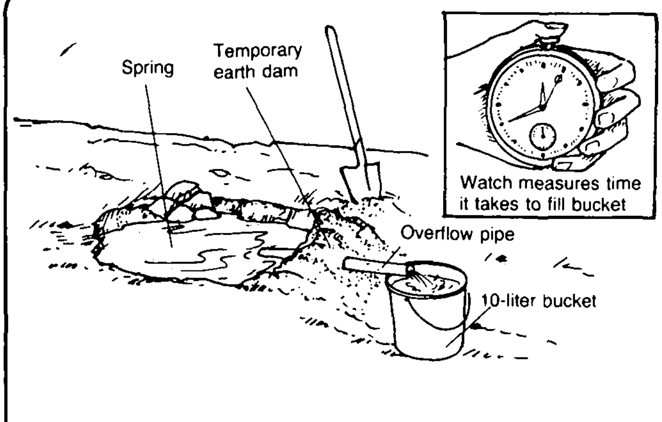

Figure 1. Measuring Spring Flow

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

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

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

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

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

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

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

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

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

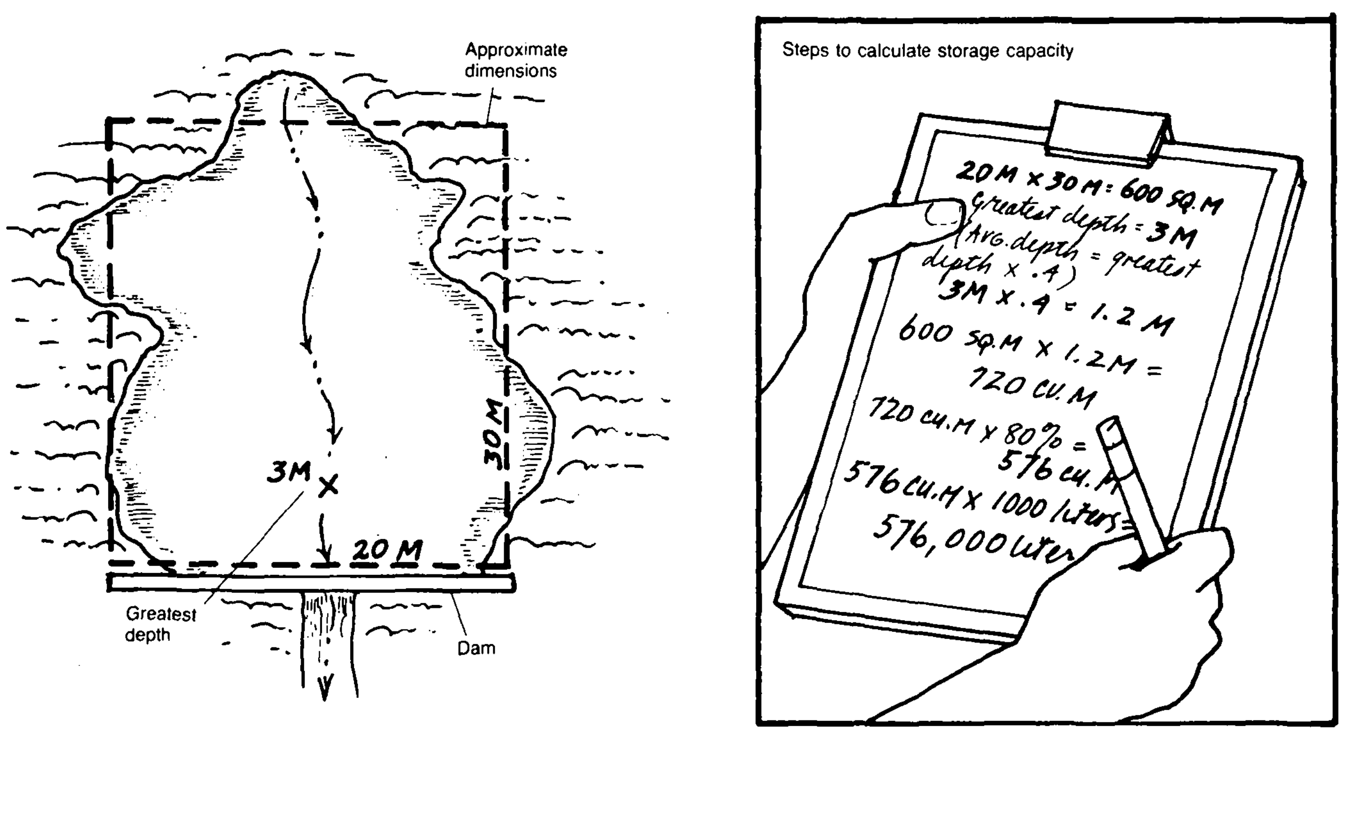

Figure 2. Estimating Storage Capacity of Small Lake or Pond

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

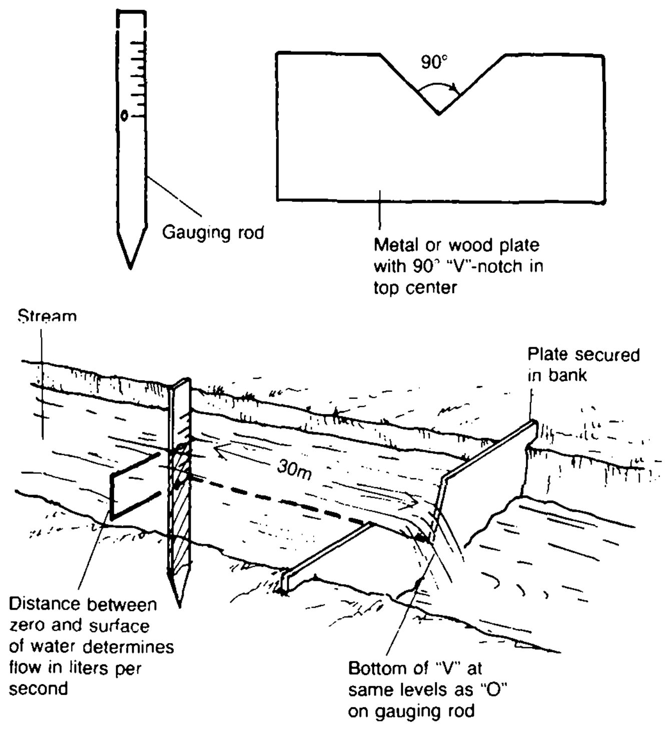

Figure 3. Measuring Stream Flow

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

Table 1. Flow Over a 90° V-Notch

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

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

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

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

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

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

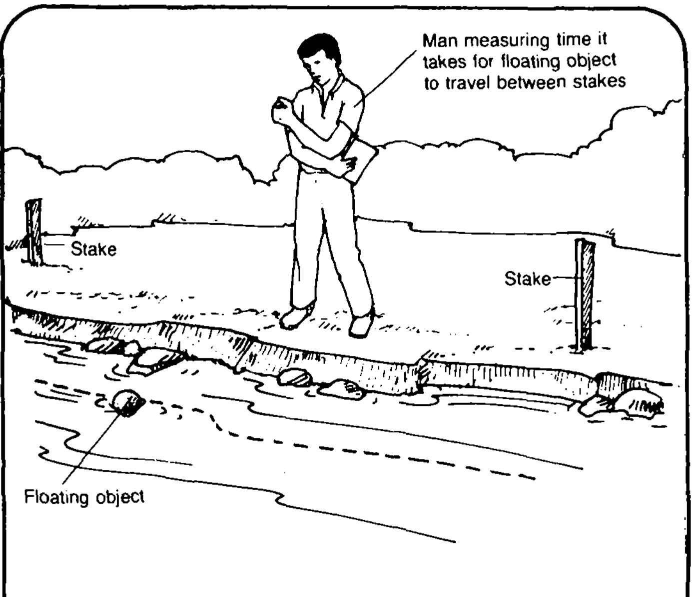

Figure 4. Measuring Large Stream Flow

Rain Catchments

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

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

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

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

36 x 1000 = 36000 liters/year.

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

36000 liters x .80 = 28800 liters.

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

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

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

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

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

Priorities for Source Selection

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

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

Table 2. Priorities for Surface Water Source Selection

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Rain catchments offer a relatively inexpensive method for providing water to individual users. Water from a rain catchment requires treatment because dirt, bird and animal excreta and other contaminants collect on the roofs of houses between rainfalls. During a rainfall, the contaminants are washed into gutters and pipes and then into the water collection cistern. To be safe, this water must be filtered and disinfected (see "Methods of Water Treatment," RWS.3.M). Rain catchments offer a variable yield and should only be considered where rainfall is adequate. Where rainfall is abundant, the system should prove reliable.

A contaminated river or stream in a hilly area is well-suited for a gravity flow system. Where treatment is necessary, water will flow through the intake, through treatment and into storage. This system may be very expensive due to construction and continuing treatment costs.

The source requiring the least treatment will cost less to develop. The amount of treatment a source will need must be determined before a source is selected.

Treatment and Pumping Required. Of all the alternatives mentioned, the most expensive is that which requires both treatment and pumping. Ponds, lakes and most streams fit into this category. Water from ponds and lakes usually must be pumped and usually requires treatment. If a pond is not exposed to fecal contamination, treatment may be a very simple process and not very costly.

A pond or lake can be a very good source of abundant and accessible water and may be the only source available to a community. With proper management of the watershed and with adequate treatment, a pond or lake will be a good source. An efficient system of operation and maintenance must also be established to ensure continued functioning of the system. Costs for this kind of system are likely to be high.

Small community ponds, especially where manmade, usually are highly contaminated from waste and contaminated run-off. Use of a contaminated community pond is risky and treatment must be very good to make the water potable. Water from this type of pond should not be used unless another good alternative does not exist.

Direct use of water from a river or stream usually requires that water be pumped from the source and treated before it is used by the community. Water from rivers and streams in lowland areas is especially likely to be contaminated. Water quality in rivers and streams should always be questioned because there are likely to be sources of contamination upstream. Only in mountain streams or where infiltration galleries are used is stream water likely to be good without treatment.

Direct use of water from a river or stream usually requires that water be pumped from the source and treated before it is used by the community. Water from rivers and streams in lowland areas is especially likely to be contaminated. Water quality in rivers and streams should always be questioned because there are likely to be sources of contamination upstream. Only in mountain streams or where infiltration galleries are used is stream water likely to be good without treatment.

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Water for the World

Methods of Developing Sources of Ground Water

Technical Note No. RWS. 2.M

Ground water is water that is stored underground in porous layers called aquifers. It is found in most parts of the world and can be a reliable source of drinking water. Sources of ground water are usually free from disease-causing bacteria. There is usually less seasonal variation in groundwater quantities than in surface water.

Wells are used to develop or extract ground water. A well is simply a hole that pierces an aquifer so that water may be pumped or lifted out. Wells can be classified according to their method of construction. Five types of wells are: hand-dug, driven, jetted, bored, and cable tool. This technical note describes each of these methods.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

BACTERIA - One-celled microorganisms which multiply by simple division and which can be seen through a microscope.

GROUND WATER - Water stored below the ground's surface.

GROUT - A fluid mixture of cement and sand.

IMPERMEABLE - Not allowing liquid to pass through.

POROUS - Having tiny pores, or holes, which can store water or allow water to pass through.

Wells have five basic parts as shown in Figure 1: shaft, casing, intake, wellhead, and water-lifting device. The shaft is the hole that is sunk from the surface of the ground down into, and sometimes through, the aquifer. The purpose of the shaft is to provide access to ground water. The method of sinking the shaft differs with each type of well.

The casing lines the sides of the shaft. The purpose of the casing is to prevent the shaft from collapsing, to provide an impermeable barrier to store ground water in, and to keep polluted surface water out. For dug wells, the casing supports the wellhead. Casings are usually made from concrete or metal. For dug wells, they may be brick or masonry. Casings are installed either after the shaft is sunk, or as it is sunk.

The intake is either the lower portion of the casing which is perforated or made from porous material or the open bottom end of the casing. In either case, the intake is within the aquifer, and its purpose is to allow ground water to flow into the casing.

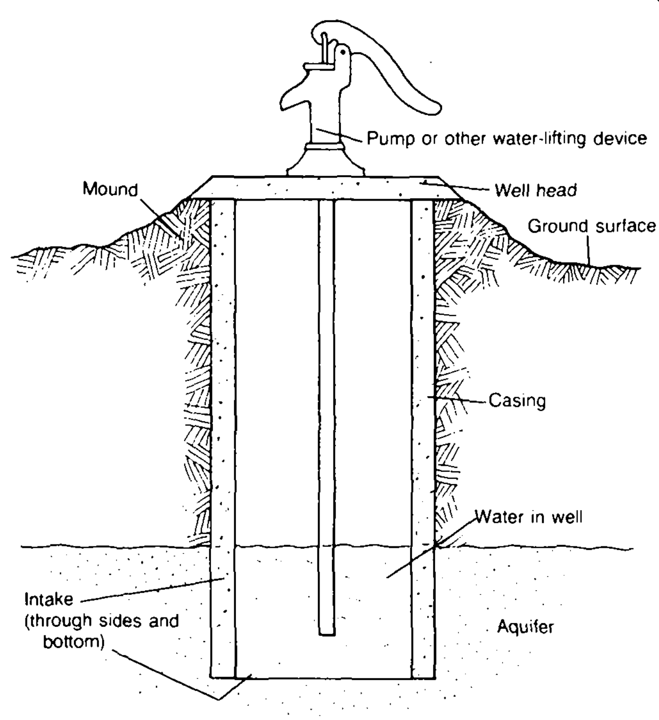

Figure 1. Parts of a Well

The wellhead is a structure built on and around the casing at ground level. It is usually made of concrete. The purpose of the wellhead is to provide a base for a water-lifting device, to prevent contaminants from entering, to keep people and animals from falling in the well, and to drain away surface water. The wellhead should be built on an earthen mound 15-20cm above the original surface so water will drain away from the well.

The water-lifting device can be a pump (see "Selecting Pumps," RWS.4.P.5), windlass, windmill or other method of extraction. The purpose of the device is to get water out of the well.

Hand-Dug Wells

Hand-dug wells are usually 1.0-1.3m in diameter and rarely more than 10m deep. They are dug with pick and shovel by one or two men working in the bottom of the shaft. Excavated soil can be lifted out with a bucket and rope as shown in Figure 2.

The casing or lining of a hand-dug well should be concrete. The casing can be installed in two ways. The shaft may be sunk and the casing built in place or sections of casing may be pre-formed above ground, soil excavated from within one section and, as the casing moves down, more sections added on top. Often, both methods are used to line a well. The first method is used until the water table is reached; then the second method, called caissoning, is used to sink the well into the aquifer. Masonry lining can be used but it is hard to make joints watertight with masonry.

The intake of a hand-dug well is designed to fit the nature of the aquifer. Usually the lower sections of casing that are within the aquifer are made of porous concrete to allow ground water to seep through. However, if the aquifer is made of fine sand, which would clog the porous concrete, the lower sections should be standard concrete and the bottom of the shaft should be left open and lined with layers of carefully selected gravel. Ground water then seeps up through the gravel.

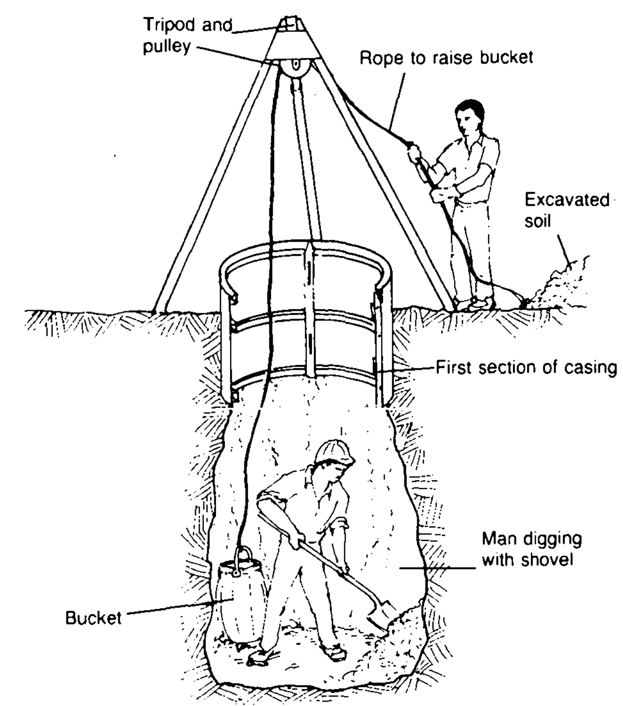

Figure 2. Hand-Dug Well

After the casing is in place, the wellhead is constructed on the mound around the top of the well. It usually has a concrete apron to drain away surface water. If the well is to be equipped with a pump, the wellhead is fitted with a concrete cover that has an opening for the pump and an inspection port or manhole.

Because of the simple tools and materials needed, and the common construction method, hand-dug wells are the most common type.

Driven Wells

These wells are the simplest to construct. A pointed strainer, called a well point, is connected to sections of pipe and driven into the ground until the aquifer is reached as shown in Figure 3. The well point and pipes are 30-50mm in diameter, and the well is generally driven no more than about 8m deep. The well point serves as the intake for the well and the pipe is the casing.

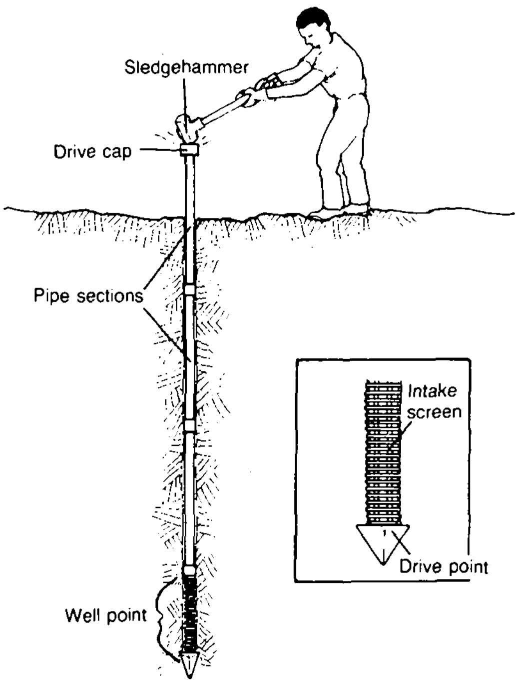

Figure 3. Driven Well

There are a number of ways to drive the well: a drive cap is threaded on top of the pipe, and then is struck repeatedly with a sledgehammer or a drive pipe that fits over the well pipe; a driving bar that fits inside the well pipe is raised and dropped to strike the well point itself; a drive head and guide rod are coupled to the top of the well pipe and a weight is raised on the rod and allowed to drop on the drive head.

The most common types of well points are either a pipe with holes covered by a screen and a brass jacket with holes, or a slotted steel pipe with no covering. Both types have a hard steel point.

After the well point is driven into the aquifer, earth is removed from around the pipe to a depth of at least 2.5m. Grout is tamped into the space around the pipe. When this hardens, it seals out surface contamination and holds the pipe firmly in place. A mound and concrete platform are then built and a pump is attached to the top of the pipe.

Jetted Wells

Jetted wells are built by pumping water through a boring pipe equipped with a special cutting bit. The boring pipe is held upright by a tower or tripod, and it is attached by a hose to a pump and a supply of water. The pipe is manually rotated. This chopping action, coupled with the jetting action of the water, causes the pipe to sink into the ground. When the first section of 6m pipe is nearly sunk, another section is attached to the top and the pumping and rotating continue. This goes on until the aquifer is reached. See Figure 4.

A 38mm diameter boring pipe can be sunk 60m deep. Larger diameter casings (250-380mm) can be sunk as deep as 100m. However, these larger pipes require pumps of much greater size and a large source of available water, such as a nearby river or lake.

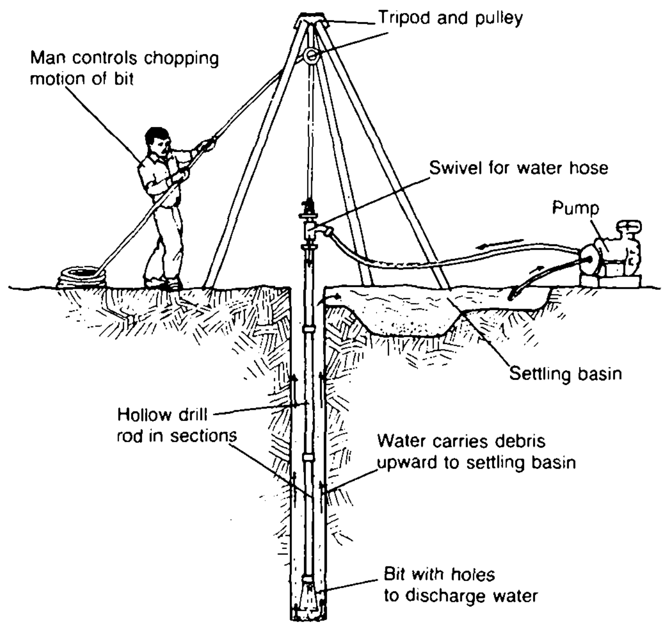

Figure 4. Jetted Well

When the aquifer is reached, the boring pipe is lifted from the hole. If the boring pipe is to be used as the casing, the cutting bit is removed from the first section of pipe and replaced with a well screen. If a different pipe is to be used for casing, the well screen is attached to the first section of casing. See Figure 3. The well screen and the first section of pipe are lowered into the hole. Pumping continues, but now through the screen. When the screen has been lowered to the position desired, a pre-seated plug is dropped into the pipe to seal the bottom of the well.

To finish the well, the space between the well pipe and the earth shaft is compacted with clay or concrete. A mound is built with a concrete platform or apron for drainage. Then a pump is installed.

Jetting can be used in loose soils that can be brought into suspension and moved with a stream of water. Jetting is not suitable for hard rock or tight clays.

Bored Wells

Bored wells are also called augered or tube wells. They are dug by manually rotating an earth auger which penetrates the ground and fills with soil. The full auger is pulled out of the ground and emptied. As the hole gets deeper, additional sections of drilling line are added. To facilitate operating and emptying the auger, an elevated platform or tripod is constructed over the well site. See Figure 5.

When the shaft has sufficiently penetrated the aquifer, the auger is removed and the casing and well screen are lowered into the shaft. If the soil is so soft that it frequently caves in, the casing is lowered as the shaft is dug. To do that, a special borer is used that fits through the casing and has a moveable extension cutter. If a water-bearing sand layer is to be penetrated, a special auger or "sand bucket" is used to dig the shaft from inside the casing, allowing the casing to sink with the shaft.

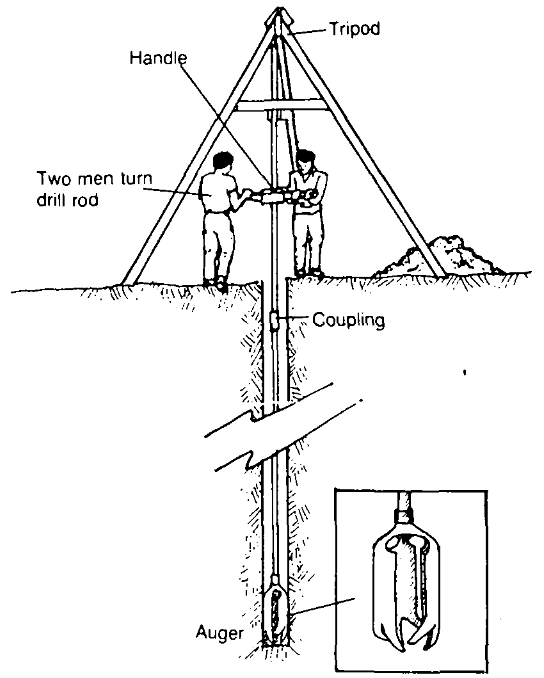

Figure 5. Bored Well

To finish the well, the space between the casing and the earth shaft is filled with concrete grout to a depth of about 3m. An earthen mound and a concrete wellhead or apron are built for drainage. Then a pump is installed.

In general, bored wells are 50-200mm in diameter and no deeper than about 15m. Larger and deeper wells have been bored using a power source and specialized augering equipment.

Cable Tool Wells

The equipment needed for cable tool wells, also called percussion drilled wells, is usually sophisticated and expensive. A simpler version of this method consists of a tripod, pulleys, strong rope, motorized vehicle, heavy drill bits, suction pump, and a 3-6m long pipe called a bailer.

The vehicle is parked at the well site, the rear end is jacked up, and the rear wheel is removed and replaced with a small drum as shown in Figure 6. A rope is wrapped loosely around the drum, threaded through the pulleys, and attached to the drill bit. By setting the drum in motion, and alternately pulling the rope taut and letting it go slack, the drill bit is raised and allowed to fall. The impact of the bit breaks up pieces of ground. The debris is mixed with water and is periodically brought to the surface with either the suction pump or the bailer. When the aquifer is reached, it is generally drilled completely through before the casing and well screen are installed. In sandy soil, the shaft is sunk from the inside of the casing and the shaft and casing descend together.

To finish the well, an earthen mound and a concrete wellhead or apron are built for drainage. Then a pump is installed.

These wells can be 50-100mm in diameter and as deep as 75m.

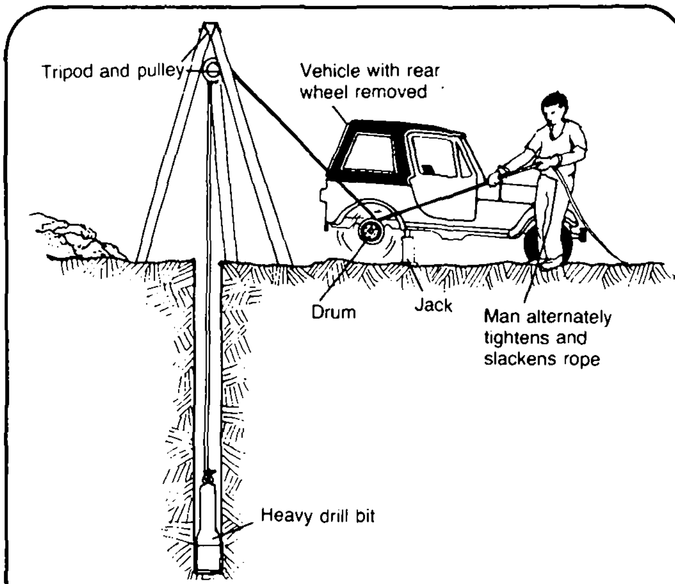

Figure 6. Cable Tool Well

Table 1 summarizes the five types of wells. This table can be used as an aid in selecting a method of well construction. Also see "Selecting a Method of Well Construction," RWS.2.P.2.

Table 1. Comparison of Types of Wells

FACTOR	WELL TYPE				
	Hand-Dug	Driven	Jetted	Bored	Cable Tool
Method of sinking shaft	Soil excavated by pick and shovel and lifted out by rope and bucket	Well point and steel pipe driven into ground	Jet of water and rotating action of bit force pipe into ground	Auger is rotated and fills with soil; lifted out of hole and emptied	Bit raised and dropped to pulverize soil and rock; debris is mixed with water and lifted out with a bailing bucket or pump
Average diameter	1.0-1.3m	30-50mm	40mm	50-200mm	50-100mm
Maximum practical depth	10m	8.0m	60m	15m	75m
Principal tools and equipment	Pick, shovel, rope and bucket; steel forms for concrete; hoist for lowering casing	Sledge, drive pipe, or drive weight; raised platform	Boring pipe; raised platform or tripod; pump and hoses; jetting bits	Augers; drill line; raised platform	Motorized vehicle; tripod, pulleys, rope; heavy drill bits; suction pump; bailer
Casing materials	Cement, sand, gravel, and water (for concrete)	Steel pipe	Steel pipe	Steel or concrete pipe	Steel pipe
Intake	Porous concrete sections, or gravel-lined bottom	Specially-made well point	Well screen	Well screen or perforated pipe	Well screen
Skill of workers	Minimal	Minimal	Moderate	Moderate	Experienced
Outside water needed for construction	No	No	Yes	No	Yes

Notes

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1982

Water for the World

Planning How to Use Sources of Ground Water
Technical Note No. RWS. 2.P.1

Ground water is found in most parts of the world. In rural areas, it may be the safest and most reliable source of water. It is usually free from disease-causing bacteria. Very often it remains available in all seasons. The disadvantage of ground water is that it must be extracted from beneath the ground and sometimes from great depths. Planning how to use sources of ground water is important to ensure that these sources are developed in the most efficient manner possible.

Planning involves setting goals, then establishing step-by-step procedures toward those goals. There are eight major actions involved in project development for which planning is important. It is necessary to (1) recognize the problem, (2) organize community support and set objectives, (3) collect data, (4) formulate alternatives, (5) select the most suitable method, (6) establish the system, (7) operate and maintain the system, and (8) evaluate the system.

This technical note discusses planning and implementation of these eight activities. Read the entire technical note before beginning the planning process. Worksheet A may be adapted for use in cataloging information as planning proceeds.

1. Recognize the Problem

This is done by gathering information from regional and national governments, questioning villagers and village leaders, and observing actual conditions in the field. A problem exists with the community's water supply if it is of poor quality or insufficient quantity, if the source is unreliable, or if it is not easily accessible. Each of these conditions may pose a health hazard to the community. Determine whether people in the community suffer from diseases caused by the lack of a safe water supply. See "Means of Disease Transmission," DIS.1.M.1. Some of these diseases and their relation to water are shown in Table 1.

Table 1. Water and Disease

Role of Water	Disease
Drinking Unsafe Water	Cholera Diarrhea Typhoid Fever
Lack of Safe Water for Personal Hygiene	Ascariasis Scabies Trachoma

In general, water should be clean, clear and good-tasting. It should be available year-round in quantities of at least 15 liters per person per day. If any one of these criteria are not met, a problem exists.

2. Organize Community Support and Set Objectives

The main objective of a groundwater supply is to provide an adequate quantity of safe water from a convenient and reliable system. A good water system will reduce the incidence of water-related diseases and improve the overall health of the community. An accessible supply increases water use for hygiene-related purposes including cleanliness. It will also reduce the time spent carrying water and allow more time for other activities.

A successful project must include a plan for community support. See

"Methods of Initiating Community Participation in Water Supply and Sanitation Programs," HR.2.M, "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.P, and "Community Participation in Implementing Water Supply and Sanitation Programs," HR.2.I. Support is gained through promotion of the project and involving the community in it.

Promote the project in the community by creating an awareness of the water supply problem. Organize meetings and educational programs, show pictures or films, and make home visits to explain the connection between a good water supply and good health. Once the community is aware of the problem, it will be more willing to work toward a solution by contributing time, effort, and resources.

Involve the community in the project. Enlist the support of local political, religious, and community leaders, and include them in decision-making. Ask the potential users of the water system for their opinions and advice. Discuss the cost of the project and emphasize the need to finance not only its construction but also its operation and maintenance.

3. Collect Data

This is an ongoing process that actually begins the problem recognition step. However, the majority of the data is collected after the preliminary investigations carried out under Step 1.

To plan the system, you must have correct and complete infomation about environmental, social, and economic conditions in the community. The data needed can be roughly divided into six categories: (a) past projects, (b) environmental conditions, (c) present water supply, (d) geography, (e) resources, and (f) customs.

(a) Past Projects

The success or failure of a past development project, especially in water supply, can guide decision-making. Mistakes of the past can then be avoided. Information about past projects may be available from village elders or local governmental agencies.

(b) Environmental Conditions

Determine the incidence of water-related diseases by personal observation, questioning villagers and village leaders, and checking health records if available. Local health clinics may have this information. See "Means of Disease Transmission," DIS.1.M.1.

(c) Present Water Supply

Determine if the present water supply is safe. See "Analyzing a Water Sample," RWS.3.P.3. Determine if the present source yields a sufficient quantity of water. At least 15 liters per day for each person in the community is needed. Ask villagers if the supply of water decreases during the dry season or if the quality changes perhaps because of flooding during the wet season. Measure the distance from the source of water to village dwellings and the time it takes to fetch water.

(d) Geography

Draw a map of the village showing the main geographical features and all sources of water: wells, springs, ponds, streams, and rivers. Determine the depth to the water table, particularly during the dry season. Do this either by examining present wells, questioning well owners or well drillers, or by drilling test wells. Note the prevailing soil conditions: sandy, clay, boulders, or hard rock.

(e) Resources

If possible, the community should contribute labor, materials and money to the water system. List the names of skilled and unskilled workers, the available materials, tools, and equipment, and the sources of funds in the community. Try to limit the amount of outside material and assistance.

(f) Customs

Question villagers and village leaders about their attitudes toward water use and their preferences for specific methods of water supply. People may be influenced by their religious or cultural beliefs and taboos. Know the village well before proposing a water project.

4. Formulate Alternatives

Once all available data is collected, use it and the information in "Methods of Developing Sources of Ground Water," RWS.2.M to formulate possible solutions to the problem. The best alternatives will provide the community with safe and abundant water from a reliable and accessible source at the lowest cost. Alternatives may be a single method or several methods of developing sources of ground water. When formulating alternatives, consider only those methods that are appropriate or practical for the community and are basically acceptable to the people. When the most likely alternatives have been formulated, select the best method.

5. Select a Method

When selecting a method of groundwater development, study the features of each alternative carefully and analyze the collected data thoroughly. The decision on which method to select should be based on the information in "Selecting a Method of Well Construction," RWS.2.P.2, and on the following two factors:

Community Needs. Determine whether the source can meet the needs of the community now and in the near future, based on estimates of community growth. Do not choose a sophisticated method if a simpler one will do. Consider improving existing groundwater sources before developing new ones.

Social Acceptability. Determine whether the method selected and the proposed location of the well are acceptable to the community. The greater the community acceptance of the system, the more willing the people will be to use it and pay for building and maintaining it.

6. Establish the System

Once the best method has been chosen, develop a project plan. The plan will serve as a guide throughout the project and ensure that labor and materials are available when needed. In many cases, a plan must be submitted to a government agency or donor organization for approval. The plan should state a goal, provide population information, indicate the number of people affected by the project, and demonstrate how the project will aid the community. This is especially important when money is sought from international donors. Determine their requirements as early as possible. In such cases the plan should be quite detailed and include information on the proposed system, costs, sources of finance, and plans for construction and sources of materials.

Proposed system. Design drawings for the project should be submitted with the plan. The drawings should include all measurements and capacities. Photographs of the work site and a topographic map showing houses, buildings and water sources should accompany the plan.

Costs. The plan must include a list of all estimated costs including materials, tools, equipment and labor. If land must be purchased, this cost should be included in the total. Local materials probably will be less expensive and should be used whenever available. Labor costs will depend on the local pay rate and the time and skills required. Any labor or materials which are donated should be included in total costs.

Sources of funding. If at all possible, local funds should be used to finance some portion of the project. This money can come from such sources as contributions, fund-raising activities or user fees. Money for the development of larger scale, or more expensive, water systems may be available from governmental organizations, international groups or private donors. Donor agencies generally require that the community contribute a percentage of the total cost.

Implementation schedule. Determine the amount of time necessary to complete the project. Attempt to schedule it at a time when volunteer labor and money are available in the community. Generally, this will be after harvest time or just before planting season. Fund-raising activities should take place during times of increased community income.

Plan for construction. Develop a plan for constructing the system including both the labor and supplies needed. A complete materials list for the project will help ensure that tools, equipment and materials are at the site when people come to work. If tools and materials are stored at the site, provide a well-protected, secure place to store them. If possible, there should be a supervisor at the site so that workers will know what to do at all times. If the system is very complex, a contractor may be hired to do the construction.

7. Operate and Maintain the System

Plan for the continued operation of the system. This should include a training program for local villagers. No matter how simple the system, there will always be a need for maintenance. The people in the community should know about basic construction, pump repair, and well disinfection. The people in charge of maintenance must know where to obtain spare parts, extra chlorine, and other resources important to the system. A local storehouse could be established.

8. Evaluate the System

Evaluate the system to determine if it is achieving the goals set at the beginning of the project. To measure the system's success, use the four characteristics of good water supply: quality, quantity, accessibility, and reliability.

Quality. Is the quality of the water acceptable? Test the water, if possible. Determine if there has been a decline in water-related illnesses since the completion or improvement of the system. Fewer cases would indicate that quality has improved. Make sure the source is protected from sources of contamination, and that treatment is adequate.

Quantity. Is the quantity of water produced adequate? Determine if the system is meeting the daily needs of the users, and if it would meet the needs of additional users.

Accessibility. Is the system accessible to all intended users? Determine if the community is satisfied with the supply's location, or if there are problems getting water. Also, find out if water consumption has increased since the system was developed. An increase in consumption may indicate that water is more easily available to the users. If traditional family water carriers have increased time for other activities, try to estimate the benefits gained from this extra time.

Reliability. Is the system reliable? There should be no design flaws or breakdowns. Water should be reaching the users without interruption. If technicians have been trained, evaluate their performance in operating and maintaining the system.

The evaluation of the system will provide important information for the development of future projects. Compare the success of this project to projects in other communities to gain valuable lessons in the development of groundwater supply systems.

Worksheet A. Planning the Development of a Groundwater Source

1. Name of community ______________________

2. Number of people to be served by water source ______________________

3. Type and number of water-related diseases in the community per year ______________________

4. Significant beliefs and taboos about water ______________________

5. Present source(s) of water ______________________

   Determine:

   (a) water quality ______________________

   (b) water quantity ______________________

   (c) accessibility ______________________

   (d) reliability ______________________

6. Potential source(s) of water ______________________

   Determine:

   (a) water quality ______________________

   (b) water quantity ______________________

   (c) accessibility ______________________

   (d) reliability ______________________

7. Community resources and organization

   Determine:

   (a) sources of income ______________________

   (b) seasonal distribution of income ______________________

   (c) labor and materials available ______________________

   (d) infrastructure in existence ______________________

   (e) concerned community leaders and groups ______________________

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Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Selecting a Method of Well Construction
Technical Note No. RWS. 2.P.2

Water wells can be classified by their method of construction: hand dug, driven, jetted, bored, and cable tool. Selecting the most suitable construction method is important to ensure that the family's or the community's water needs are met and to ensure that the method is best in terms of overall cost, available materials, and geological conditions. See "Planning How to Use Sources of Ground Water," RWS.2.P.1.

This technical note compares five methods of well construction and discusses the advantages and disadvantages of each. Read the entire technical note before selecting a method.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

POROSITY - A soil's ability to store water.

WATER TABLE - The top, or upper limit, of an aquifer.

General Information

In many communities, a method of extracting ground water will already exist. If so, the selection of a method should follow these priorities:

(1) improve the present source, such as deepening a hand dug well;
(2) duplicate the present method, such as digging more wells; and
(3) select a new method.

This technical note should be used when the third priority has been reached, or if the community has no present method of extracting ground water.

When selecting a method of well construction, there are non-technical factors that should be considered. These may be called community factors, and they include the social acceptability of the method, the willingness of the community members to assist in construction, and so on. These factors are discussed in "Planning How to Use Sources of Ground Water," RWS.2.P.1, and "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.I. For more information on all the methods of well construction discussed in this technical note, refer to "Methods of Developing Sources of Ground Water," RWS.2.M.

Hand-Dug Wells

The materials used to construct these wells--picks, shovels, concrete, reinforcing material--are available in many villages. The construction methods used are common and no special skills are required. See Figure 1. But constructing a hand dug well is hard work and may take several weeks, compared with the other methods which take only several days. This extra construction time raises the labor cost.

Hand dug wells can be constructed in almost any type of soil, except hard rock or where there are large boulders. Their practical depth is limited to about 10m. Because hand dug wells cannot be sunk far into an aquifer, their yield is affected by changes in the water table. The large diameter, from 1.0-1.5m, of these wells allows them to act as reservoirs for water. This is particularly useful in aquifers with low porosity, since the well can accumulate water for later use. Also, a hand dug well's large diameter can accommodate a variety of water lifting devices.

Advantages:

- readily available materials
- common construction techniques
- can act as a reservoir
- can use a variety of water lifting devices

Disadvantages:

- hard work to construct
- limited depth
- affected by water table changes
- not suitable for formations with hard rock or large boulders

Driven Wells

These wells require a specially built, but inexpensive, well point which must be purchased. The well point is made of hard steel. With the necessary equipment, the construction method is easy and fast and no special skills are required. See Figure 2.

Driven wells are not suitable for hard rock or heavy beds of clay, nor where there are boulders or coarse gravel which can damage the well screen. Their practical depth is limited to about 8m but where driven wells can be sunk fairly deep into the aquifer, they are not affected by fluctuations in the water table.

Advantages

- easy to construct
- not affected by water table fluctuations

Disadvantages

- require special well point
- limited depth
- not suitable for hard rock, heavy clay, boulders, or coarse gravel

Jetted Wells

Constructing these wells requires a water pump and hoses, a raised platform or tripod, and special jetting drill bits--all of which raise the cost. The method is fast, but a certain amount of skill is required. See Figure 3.

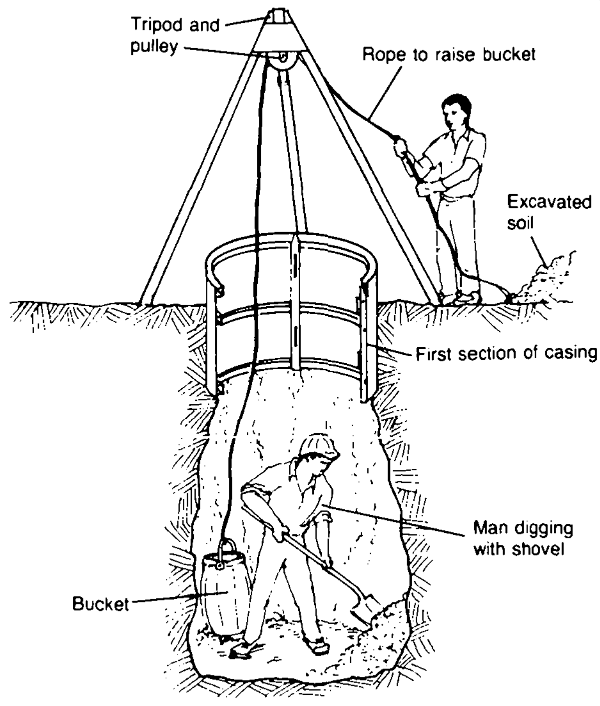

Figure 1. Hand-Dug Well

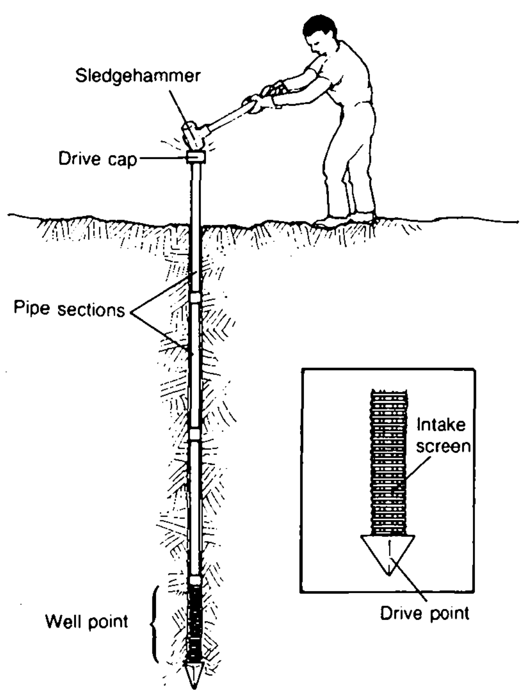

Figure 2. Driven Well

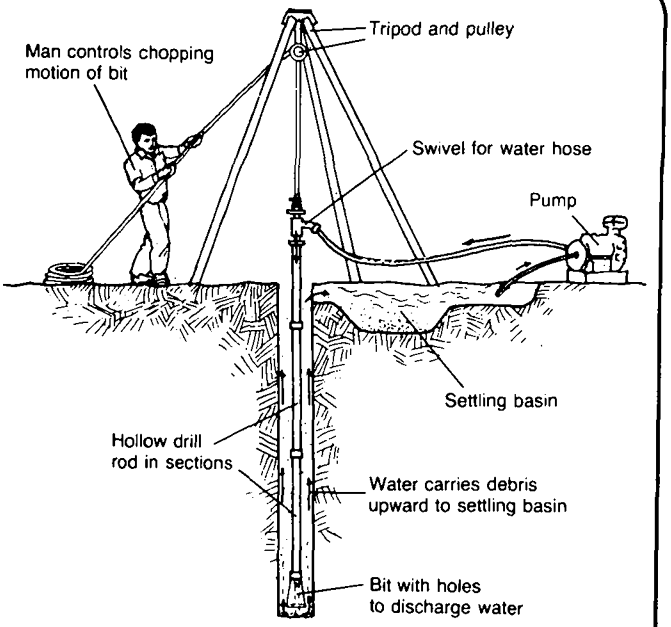

Figure 3. Jetted Well

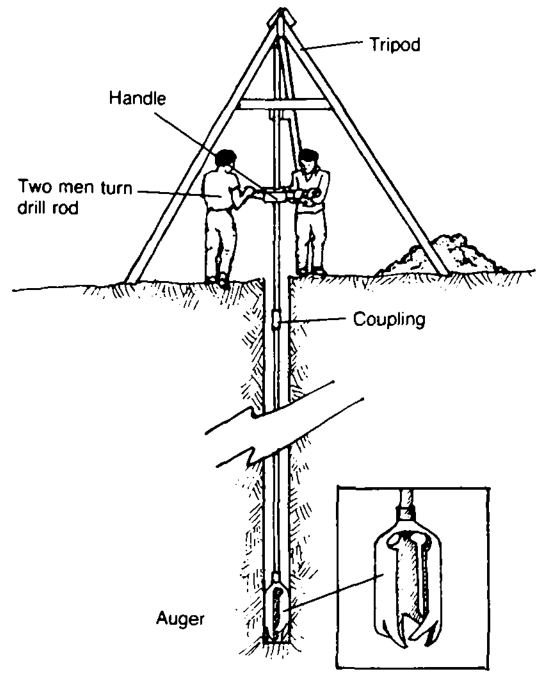

Figure 4. Bored Well

Jetted wells can be carried to depths of 60m, increasing the chances of reaching a groundwater source. They are not seriously affected by water table changes. These wells cannot be constructed in hard rock or where there are large boulders.

Advantages:

- deep construction
- increased chance of finding ground water
- not affected by water table fluctuations

Disadvantages:

- moderate to high cost
- specialized equipment
- special skills
- not suitable for hard rock or boulders

Bored Wells

Constructing these wells requires special augering bits, sections of drill, pipe or rod, and a raised platform. When these are available, bored wells are a good choice. Bored wells are relatively easy to construct, and the techniques used are quickly learned. See Figure 4.

These wells are not suitable for hard rock or where there are boulders larger than the diameter of the augering bit (50-200mm). Their practical depth is limited to about 15m, but they are not affected by changes in the water table.

Advantages:

- easy to construct with the proper equipment and experience
- not affected by water table changes

Disadvantages

- some special tools and skills are required
- not suited for hard rock or boulders larger than auger

Cable Tool Wells

These wells require expensive equipment including a motorized power source, heavy drill bits, a tripod and pulleys, a bailer, and a suction pump. Special skills are required to operate this equipment, and the equipment may be difficult to transport into remote areas. See Figure 5.

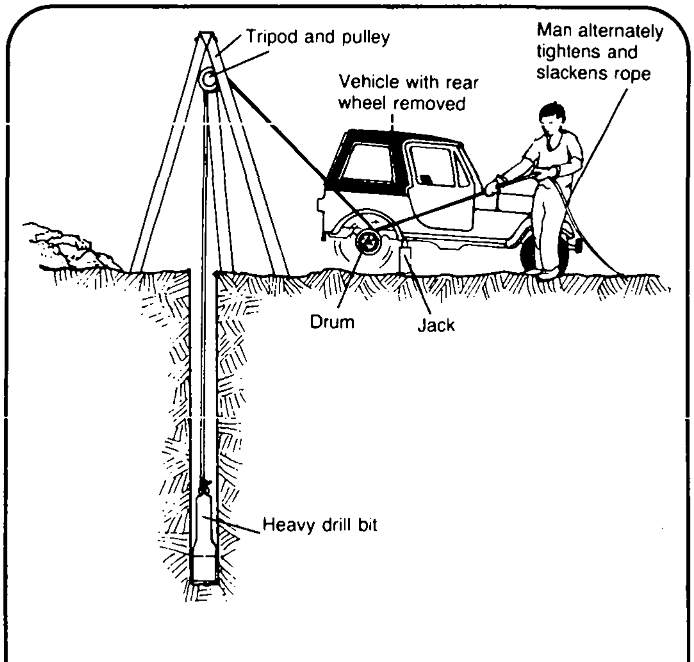

Figure 5. Cable Tool Well

These wells can be sunk in nearly every type of soil, even hard rock. They can be sunk to depths of 75m or more. This increases the chances of finding reliable groundwater sources. They are not affected by changes in the water table.

Advantages:

- suitable for all types of soil
- deep construction
- increased chance of finding ground water
- not affected by water table fluctuations

Disadvantages:

- high cost of equipment
- requires experienced operators
- difficult to carry equipment to remote areas

Comparison of Methods

Table 1 summarizes some of the features of each method of well construction. It can be used as an aid in selecting a method. For further help in making a selection, see "Methods of Developing Sources of Ground Water," RWS.2.M. If more details are needed on any method, consult the "designing" technical note on that method.

Table 1. Comparison of Types of Wells

FACTOR	WELL TYPE				
	Hand Dug	Driven	Jetted	Bored	Cable Tool
Cost	Moderate	Low	Low to moderate	Moderate to high	High
Special Construction Skills	No	No	Yes	No	Yes
Sophisticated Equipment	No	No	Yes	No	Yes
Act as Reservoir	Yes	No	No	No	No
Variety of Water Lifting Devices	Yes	No	No	No	No
Affected by Water Table Fluctuations	Yes	No	No	No	No
Unsuitable Soil Conditions	Hard rock, large boulders	Hard rock, heavy clay, boulders, coarse gravel	Hard rock, boulders	Hard rock, boulders larger than auger	None

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Water for the World

Selecting a Well Site
Technical Note No. RWS. 2.P.3

Selecting a well site properly is important to ensure that the well will tap into a reliable source of good quality ground water, and to ensure that the water will not be contaminated in the future. Selecting a site involves considering existing wells, local geography, quality and quantity of ground water, possible sources of contamination, accessibility to users, and proposed methods of well construction.

This technical note describes the main considerations in selecting a well site. Read the entire technical note before beginning the selection process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria.

DRAWDOWN - The distance between the water table and the water level in a well during continued pumping.

GROUND WATER - Water stored below the ground's surface.

IMPERMEABLE - Not allowing liquid to pass through.

PERMEABILITY - The ability of soil to absorb liquid.

POROSITY - A soil's ability to store water.

WATER TABLE - The top, or upper limit, of an aquifer.

General Information

If possible, the well site should be selected by a qualified engineer who has made a thorough field investigation. This investigation may be expensive and time-consuming, but it is one of the most important steps in developing a source of ground water. The investigation, or part of it, may have been done during the earlier planning stages. See "Planning How to Use Sources of Ground Water," RWS.2.P.1.

Whether an engineer or someone else selects the site, a map of the village and surrounding area should be obtained or produced. Add to the map all relevant features discussed in this technical note. See Figure 1.

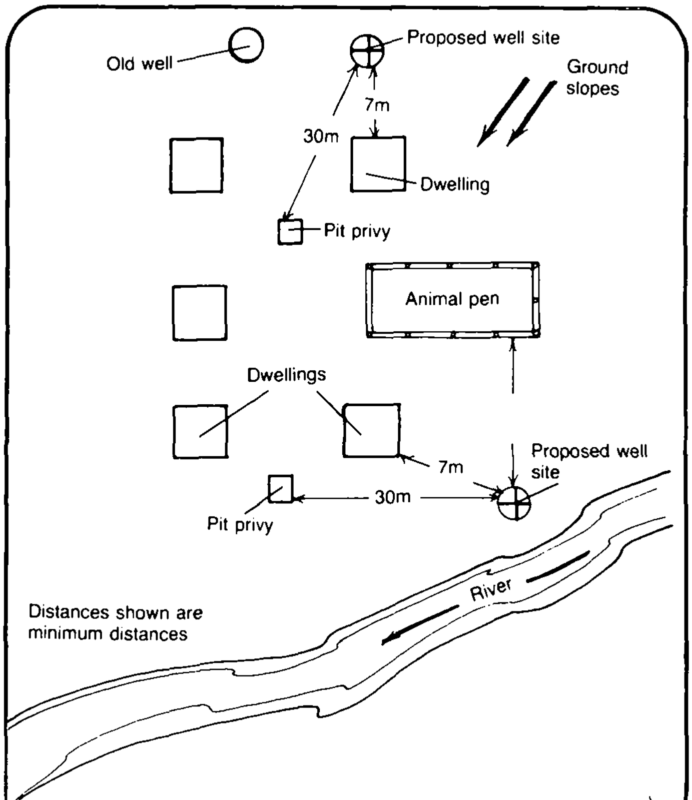

Figure 1. Location Map

Existing Wells

The primary objective when sinking a new well is to sink it where ground water is likely to be found. Existing wells are the best indication of the presence of ground water. Where possible, sink a new well near an old one--ground water will probably be reached at about the same depth. The history of the old well will provide information on seasonal changes in the water table, which may indicate that the new well should be deeper than the old one.

If the new well is to be used in addition to the old one, care must be taken not to sink it too close to the existing well. Otherwise, the yield of one or both wells may be adversely affected. This is due to the effect that a well has on the surrounding water table.

When water is pumped or lifted out of a well, the water level in the well falls below the original level, called the static level, until it stabilizes at a new level, called the pumped level. The distance between the static level and the pumped level is the drawdown. The water table surrounding a well curves down to the pumped level, forming a cone of depression. See Figure 2. If the cones of depression of two wells overlap, the pumped level in one or both wells will be lowered and the yield will be decreased. Draw all existing wells on your map, similar to Figure 1.

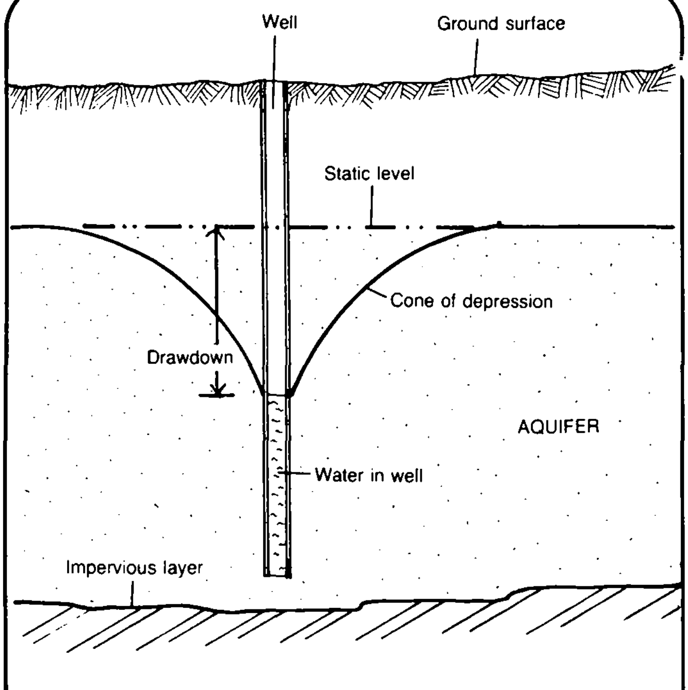

Figure 2. Cone of Depression

Local Geography

If no wells exist, the presence of ground water can be indicated by surface water, topography, and certain types of vegetation.

Surface water. A successful well can generally be sunk near a river because the river will replenish the ground water and reduce changes in the water table. Water taken from such a well is usually cleaner and cooler than water taken from the river. If the well is deep, water may be available even when the river is temporarily dry.

Topography. Ground water gathers in low areas. Therefore, the lowest ground is generally the best place to sink a well. In hilly areas, valley bottoms are the best places for wells. An exception to this could be where there is a spring on the side of a hill. The spring may indicate lateral movement of ground water over a layer of impermeable soil. If so, a successful well could be sunk uphill from the spring. This may have the advantage of bringing the source of water closer to the community or dwelling.

On your map, draw all rivers, springs, and topographical features.

Vegetation. Certain types of vegetation can indicate that ground water lies near the surface. The most useful indicators of ground water are perennial plants (those present year-round), especially trees and shrubs. Annual plants, such as grasses, are not good indicators, because they come and go with the seasons. The dry season is probably the best time to survey vegetation for indications of ground water.

Quality of Ground Water

Once ground water is located, its quality must be tested before constructing permanent wells. The water must be clean, clear, and good-tasting, and be free from disease-causing organisms. For information on testing water, see "Determining the Need for Water Treatment," RWS.3.P.1, and "Analyzing a Water Sample," RWS.3.P.3. If the ground water is contaminated, another source may have to be found.

Quantity of Ground Water

The quantity of a groundwater source is nearly as important as its quality. Unfortunately, the only way to test the yield of an aquifer is to dig a well and pump it. See "Testing the Yield of Wells," RWS.2.C.7. You can, however, make a rough estimate of the yield by identifying the sediment and rock which compose the aquifer.

The two most significant elements of an aquifer are its porosity and permeability. Porosity governs the amount of water that an aquifer can contain. Permeability governs the amount of water that can be brought to the surface. For example, some aquifers may contain large quantities of water, but their rate of yield is too slow to suit the needs of the user. Porosity and permeability depend on a number of factors including particle size, arrangement and distribution.

Table 1 shows the estimated yields of aquifers composed of different types of sediment. The table should not be used for exact calculations but only for indications of yield.

Table 1. Estimated Yields of Aquifers

Sediment Composing the Aquifer	Estimated Yield (liters per minute)
Sand and gravel	11400; could be less based on pump and well design
Sand, gravel, and clay	1900-3800
Sand and clay	1900
Fractured sandstone	1900
Limestone	38-190; more if near stream, or if there are underground caverns
Granite or hard rock	38 or less
Shale	less than 38

If the quantity of ground water is insufficient, another well site will have to be found. The new site may replace or supplement the old site.

Possible Sources of Contamination

A well should not be dug in areas where the ground water is likely to be contaminated. A well site should be uphill and at least:

- 50m from a seepage pit or cesspool;
- 30m from a subsurface absorption system;
- 30m from a pit privy;
- 30m from animal pens, barns, or silos;
- 15m from a septic tank;
- 7m from a drain, ditch, or house foundation.

The well site should not be subject to flooding during the wet season or any other time. This will be of greatest concern where the well is in a low area or near a river that yearly overflows its banks. The site can be protected from flooding by building small dams or ditches to prevent flooding the well. If not, another site should be considered.

Draw all possible sources of contamination on your map, as in Figure 1.

Accessibility to Users

The well site should be as close as possible to the village or dwelling. As the distance between the well and the user increases, the per capita water consumption decreases. This is shown in Table 2. The table should not be used for exact calculations but only for indications of consumption.

Political considerations may influence accessibility. There may be pressure to put the well near the dwelling of the village chief or other influential member of the community. A compromise may be necessary.

Methods of Well Construction

The proposed method of well construction must be suitable to the soil conditions at the well site. If not, another site must be found or another method of construction must be considered. Table 3 shows some of the limitations of well construction methods based on soil conditions. For more information, see "Selecting a Method of Well Construction," RWS.2.P.2.

Table 2. Water Consumption and Distance to Water Source

Distance to Source	Estimated Consumption (liters per person per day)
More than 1000m	7
500-1000m	12
Less than 250m	20-30
In the yard of the dwelling	40

Table 3. Well Construction Methods and Soil Conditions

Construction Method	Unsuitable Soil
Hand Dug	Hard rock, large boulders
Driven	Hard rock, heavy clay, boulders, coarse gravel
Jetted	Hard rock, boulders
Bored	Hard rock, boulders larger than auger
Cable Tool	None

Summary

When all alternative well sites have been determined, draw them on your map, as in Figure 1. Then select the best site. When examining a site, you will no doubt find that even though it may rate well in some ways, it rates poorly in others. Selecting the best site is often a matter of judgment and experience. You must weigh the relative advantages and disadvantages of each site. Figure 3 is a simplified example of four alternative sites from which a village must select one.

Site #1 would allow easy access to ground water because the water table lies close to the surface of the ground. However, limited water would be available because the layer of impermeable rock also lies near the ground surface. Thus, slight fluctuations in the water table would drastically affect the availability of water.

Site #2 is the site closest to the village, and therefore has the greatest accessibility. However, the water table is quite deep and may be difficult to reach. The aquifer cannot be penetrated too deeply, because of the position of the impermeable layer.

At Site #3, the aquifer can be reached without digging very far down. The aquifer can be deeply penetrated. This would ensure a reliable water source. However, the site is some distance from the village, and below the homes.

At Site #4, the most water can be reached with the least difficulty. The site is at the greatest distance from the village. It is in a low spot that may be subject to flooding.

Each site has advantages and disadvantages. The project director, the villagers, and the village leaders must decide which site is best for the community.

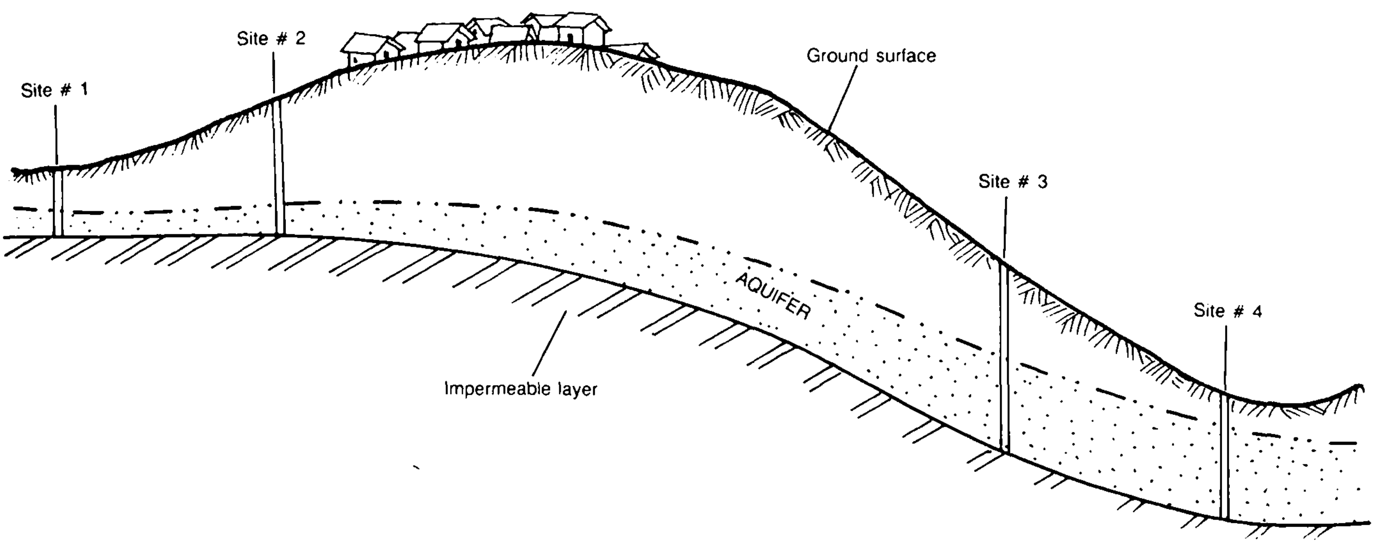

Figure 3. Alternative Well Sites

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Water for the World

Designing Hand Dug Wells
Technical Note No. RWS. 2.D.1

Proper design of hand dug wells is important to asure a year-round supply of water and to assure efficient use of personnel and materials. Designing involves determining the size and shape of the well; the method of lining the shaft; the type of intake; and the necessary personnel, materials, equipment, and tools. The products of the design process are drawings of the shaft and lining and a detailed materials list. These, along with a location map similar to Figure 1 ("Selecting a Well Site," RWS.2.P.3), should be given to the construction foreman before construction begins.

There are several good methods of designing and constructing hand dug wells; if you are familiar with a specific method, use it. This technical note describes one method of designing hand dug wells and arriving at the essential end-products. Read the entire technical note before beginning the design process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

KIBBLE - A large bucket for lifting materials when sinking a shaft; also called a hoppit or sinking bucket.

POROUS - Having tiny pores or spaces which can store water or allow water to pass through.

WATER TABLE - The top, or upper limit, of an aquifer.

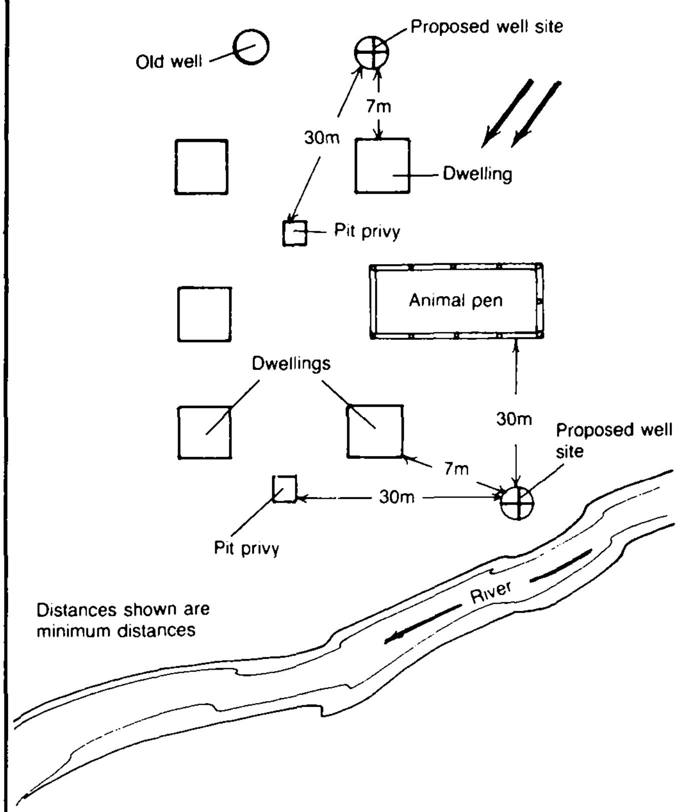

Figure 1. Location Map

Size and Shape

When viewed from the top, wells can be any shape but most of them are round. This is because a round well produces the greatest amount of water for the least amount of excavation, and a round lining is stronger than any other shape.

The size of the well refers to its depth and diameter. Although it is impossible to know the depth of a well before it is dug, an attempt should be made to estimate it. This will allow you to roughly calculate the quantities of materials needed for construction. Use information from test holes or existing wells in the area to estimate the depth of the water table.

For practical and economic reasons, well diameters are between 1.0m and 1.5m. The smaller diameter results in a savings in materials costs, and it requires less soil to be excavated. The larger diameter means a higher materials cost, but a more efficient work output, since two men rather than one can dig the shaft. A larger diameter provides a greater storage capacity and allows more water to enter the well. If pre-made forms or precast concrete rings are used, their size will determine the diameter of the well.

When the depth and diameter of the well shaft have been determined, write the dimensions on a design drawing similar to Figure 2.

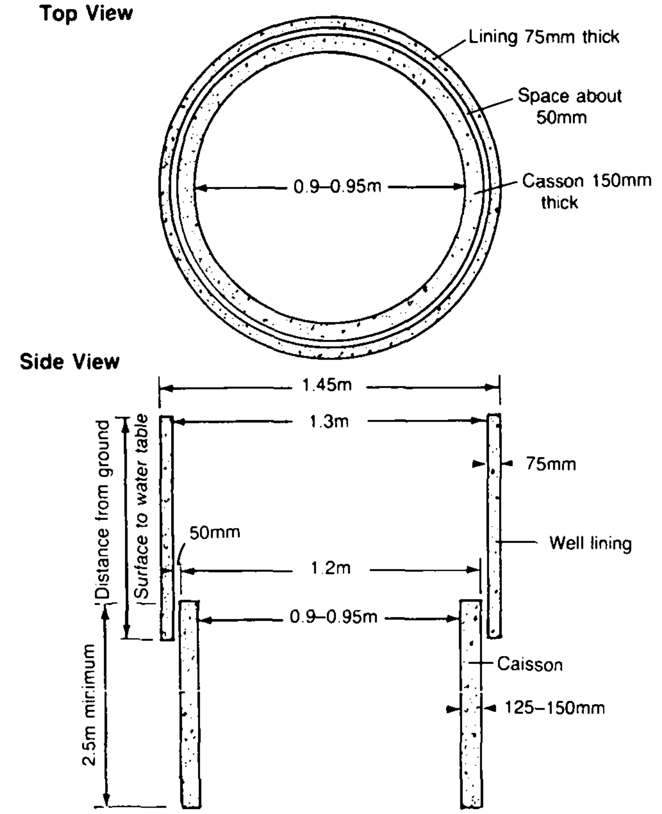

Figure 2. Design of Well Lining and Caisson

Lining the Shaft

Although various materials have been used to line well shafts, concrete is the best and most common lining. It is strong, long-lasting, and widely known.

The two basic methods of lining well shafts are dig-and-line and sink lining or caissoning. In dig-and-line, a portion of the shaft is excavated, shutters are set in place in the shaft, and concrete is poured behind the shutters. When the concrete hardens, the shutters are removed and the next portion of the shaft is excavated.

In sink lining, concrete rings called caissons are cast and cured in special molds at the surface. The rings are stacked on top of each other and attached together with bolts. As soil is excavated from beneath the rings, they sink into the earth and line the shaft.

Often, both methods are employed in a single well: dig-and-line is used until the water table is reached, then caissoning is used to sink the well into the aquifer. The lining is usually 75mm thick and the caisson rings are 125-150mm thick. The outside diameter of the rings is 50-100mm less than the inside diameter of the lining to allow the rings to freely move downward. Table 1 shows common dimensions of shaft, lining, and rings.

Write the dimensions that you determine are best for your well on the design drawing similar to Figure 2.

Intake

The caisson rings are sunk into the aquifer as far as possible; that is, until the water becomes too deep to

Table 1. Dimensions of Shaft, Lining and Caisson Rings	
Feature	Dimension
Shaft diameter	1.45m
Lining, outside diameter	1.45m
Lining, inside diameter	1.30m
Lining, thickness	75mm
Caisson, outside diameter	1.20m
Caisson, inside diameter	0.90-0.95m
Caisson, thickness	125-150mm
Caisson, height	0.50m

continue the excavation. Ground water may then enter the well either (1) through the opening under the lowest caisson ring, or (2) through the rings themselves. In the first case, the rings are made of standard concrete which does not allow entry of water. In the second case, the rings are usually made of porous concrete which allows water to pass through. Another way to allow water to enter through the caisson rings is to build the rings from standard concrete and perforate them with seepage holes. For all types of intakes, the bottom of the shaft should be covered with a porous base plug made from porous concrete or layers of sand and gravel. The plug prevents aquifer material from rising into the well.

The type of caisson ring used depends on the nature of the aquifer. Normally, rings are made of porous concrete. However, if the aquifer is composed of fine sand, which would clog the pores or flow through the seepage holes, the rings should be made of standard concrete without perforations. It may not be possible to know which type of intake is needed until the aquifer is reached. But an attempt should be made to anticipate the necessary intake, based on test holes or other wells in the area.

When the type of intake has been determined, indicate it on the design drawing similar to Figure 2.

Personnel

The most important person involved with well construction is the foreman. He should have some experience. He must oversee all phases of construction, including excavating and lining the shaft, mixing concrete for the lining and caissons, and lowering the caissons into place. It is his responsibility to see that construction proceeds in a safe manner.

At least four workers are needed. One should have some experience with well digging and one should have experience with concrete construction. The workers must be reliable because the construction process may take several weeks or more.

Materials

The materials needed to line a hand dug well are concrete mix and reinforcing steel.

One common mix of concrete is one part cement to two parts sand to four parts gravel by volume and enough water to make a workable mix. The cement should be Portland cement, and it should be dry and free from hard lumps. Sand should be clean, and sized fine to 6mm. If porous concrete is used for the caisson rings, omit the sand. Gravel should be clean and sized 6-36mm (10-20mm for porous concrete). Water should be clean and clear.

Two sizes of reinforcing steel, called re-rods, are generally used: 8mm diameter for the lining and 15mm diameter for the caissons. The quantities of these materials needed can be roughly estimated.

For each meter of depth of the lining:

gravel = $0.5m^3$
sand = $0.25m^3$
cement = $0.125m^3$ (or about 190kg, assuming $0.00066m^3$ = 1.0kg)
8mm re-rod = 33m

For each meter of caisson rings:

gravel = $1.0m^3$ ($1.4m^3$ for porous concrete)
sand = $0.5m^3$ (none for porous concrete)
cement = $0.25m^3$ ($0.35m^3$ for porous concrete)
15mm re-rod = 4m

For example, suppose the estimated depth of the shaft and lining is 15m, the height of the caisson rings is 3m, and the rings are to be made from porous concrete. The quantities would be estimated in the following way.

For the lining:

gravel = $0.5m^3 \times 15 = 7.50m^3$
sand = $0.25m^3 \times 15 = 3.75m^3$
cement = $0.125m^3 \times 15 = 1.88m^3 = \frac{1.88m^3}{0.00066m^3/kg} = 2850kg$
8mm re-rod = 33m x 15 = 495m

For the porous concrete caissons:

gravel = $1.4m^3 \times 3 = 4.20m^3$
sand = none
cement = $0.35m^3 \times 3 = 1.05m^3 = \frac{1.05m^3}{0.00066m^3/kg} = 1590kg$
15mm re-rod = 4m x 3 = 12m

The total quantity of cement needed for the lining and the caisson rings = 2850kg + 1590kg = 4440kg. Cement is often packaged in 50kg sacks, so the number of sacks needed = $\frac{4440}{50}$ = 88.8 or 89 sacks. Worksheet A shows a further example of how to estimate quantities of materials needed for a hand dug well.

Other materials needed are those used to build a storage shed. Use locally available materials and traditional construction methods.

Equipment

The main piece of equipment needed is a headframe capable of lowering workers and caissons into the shaft and hoisting up excavated soil. The headframe must be able to support weights in excess of 350kg, the approximate weight of a concrete caisson. It should have a winch, a main pulley, and an auxiliary pulley.

At least three ropes are needed: one for lowering caissons, tensile strength of rope about $7kg/cm^2$, one for lowering and raising full kibbles and concrete buckets, and one for suspending trimming rods.

A heavy-duty stretcher with a U-bolt in the center is needed to lower caissons.

Steel shutters are needed to form the lining. For caissons, you will need steel molds and templates to position the re-rods.

Two kibbles are needed to hoist up water and excavated soil. The kibbles should be watertight and made of steel, with a safety latch on the handle to prevent them from tipping. They should be wider around the middle than around either end to prevent them from catching on any projections within the shaft.

Other equipment needed includes concrete buckets, a bosun's chair, top plumbing rod, long and short trimming rods, and hard hats.

Tools

The workers need tools for measuring, plumbing, excavating, and trimming the shaft; mixing, pouring, and finishing concrete; and positioning and securing re-rods. When you have determined all necessary personnel, materials, equipment, and tools, prepare a materials list similar to Table 2 and give it to the construction foreman. Give the construction foreman design drawings of the well, a detailed materials list, and a location map.

Worksheet A. Estimating Quantities of Materials for Hand Dug Wells

For the Lining:

1. Estimated depth of shaft = 15 m
2. Gravel = $0.50m^3$ x Line 1 = $0.50m^3$ x 15 = 7.50 m^3
3. Sand = $0.25m^3$ x Line 1 = $0.25m^3$ x 15 = 3.75 m^3
4. Cement (m^3) = $0.125m^3$ x Line 1 = $0.125m^3$ x 15 = 1.88 m^3
5. Cement (kg) = $\frac{\text{Line 4}}{0.00066m^3/kg}$ = $\frac{(1.88\ m^3)}{0.00066m^3/kg}$ = 2850 kg
6. 8mm re-rod = 33m x Line 1 = 33m x 15 = 495 m

For the Caisson Rings:

Type of concrete (check one): ☐ standard ☒ porous

Standard Concrete

7. Height of caisson rings = 3 m
8. Gravel = $1.0m^3$ x Line 7 = $1.0m^3$ x ____ = ____ m^3
9. Sand = $0.50m^3$ x Line 7 = $0.50m^3$ x ____ = ____ m^3
10. Cement (m^3) = $0.25m^3$ x Line 7 = $0.25m^3$ x ____ = ____ m^3
11. Cement (kg) = $\frac{\text{Line 10}}{0.00066m^3/kg}$ = $\frac{(\_\_\_\_\ m^3)}{0.00066m^3/kg}$ = ____ kg
12. 15mm re-rod = 4m x Line 7 = 4m x 3 = 12 m

Porous Concrete

13. Gravel = $1.40m^3$ x Line 7 = $1.40m^3$ x 3 = 4.20 m^3
14. Sand = none
15. Cement (m^3) = $0.35m^3$ x Line 7 = $0.35m^3$ x 3 = 1.05 m^3
16. Cement (kg) = $\frac{\text{Line 15}}{0.00066m^3/kg}$ = $\frac{(1.05\ m)}{0.00066m^3/kg}$ = 1590 kg

Total Amount of Cement for Lining and Caisson =

Line 5 + Line 11 + Line 16 = 2850 kg + – kg + 1590 kg = 4440 kg

Table 2. Sample Materials List

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	____
	Worker, skilled in sinking well	1	____
	Worker, experienced with concrete	1	____
	Workers, unskilled	2-4	____
Supplies	Cement (Portland)	____kg	____
	Sand (clean; fine to 6mm)	____m^3	____
	Gravel (clean; 6-36mm)	____m^3	____
	Water (clean and clear)	____	____
	Re-rod for lining: 8mm diameter	____m	____
	Re-rod for caissons: 15mm diameter	____m	____
	Materials for storage shed	____	____
Equipment	Headframe	____	____
	Rope for caissons; 100m x 12mm diameter, steel wire with fiber core tensil strength $7kg/cm^2$	____	____
	Rope for kibbles: 100 x 6mm diameter	____	____
	Rope for trimming rods: 100m x 3mm diameter	____	____
	Steel shutters (1.30m diameter x 0.5m high) with wedges and bolts	____	____
	Steel shutters (1.30m diameter x 1.0m high) with wedges and bolts	____	____
	Steel molds for caisson rings (1.20m outside diameter, 0.95m inside diameter, 0.5m high)	____	____
	Templates for molds	____	____
	Stretcher for caissons	____	____

Total Estimated Cost = ____

Notes

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Designing Driven Wells
Technical Note No. RWS. 2.D.2

It is important to design driven wells properly to ensure a year-round supply of water and to ensure efficient use of personnel and materials. Designing involves selecting the type of well point; choosing a method of driving; and determining the necessary personnel, materials, tools, and equipment. The products of the design process are: (1) design drawings of the well point and driving equipment and (2) a detailed materials list. These products, along with the location map from "Selecting a Well Site," RWS.2.P.3, should be given to the construction foreman before construction begins.

This technical note describes how to design a driven well and arrive at these end-products. Read the entire technical note before beginning the design process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

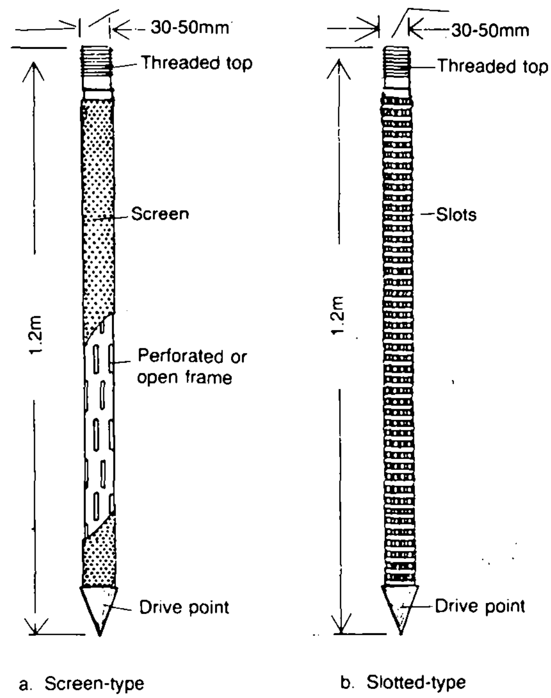

Figure 1. Well Points

Selecting a Well Point

There are a number of types of well points that can be purchased or manufactured. Basically, they can be divided into two categories: screen and slotted. Figure 1a shows a screen-type well point. It consists of an open or perforated frame covered with one or more screens. This type is relatively less expensive than the slotted well points. However, it is less resistant to damage during driving and over-pumping of ground water may plug the screen. Figure 1b shows the slotted-type well point. It is more expensive, but it is sturdier and less likely to become plugged during over-pumping.

When you have determined which type of well point is best for your situation, prepare a design drawing similar to Figure 1a or 1b and give it to the construction foreman.

Determining the Method of Driving

The four basic methods used to drive a well are a sledgehammer, a weighted driver with handles, a driving bar, and a driving weight.

Sledgehammer. This is the simplest and least expensive method. One man strikes the drive cap with a sledgehammer, driving the pipe and well point through the ground and into the aquifer. The depth of the well cannot be very great because of the limited driving force. See Figure 2.

Weighted Driver. This is an inexpensive device consisting of a length of pipe, larger in diameter than the well pipe, with a weight on top and two handles welded to the sides. See Figure 2. The driver is slipped over the well pipe and drive cap. Two men raise the driver and either throw it down or let it drop onto the drive cap, driving the pipe and well point into the ground. This method can be used to reach somewhat greater depths than the sledgehammer method.

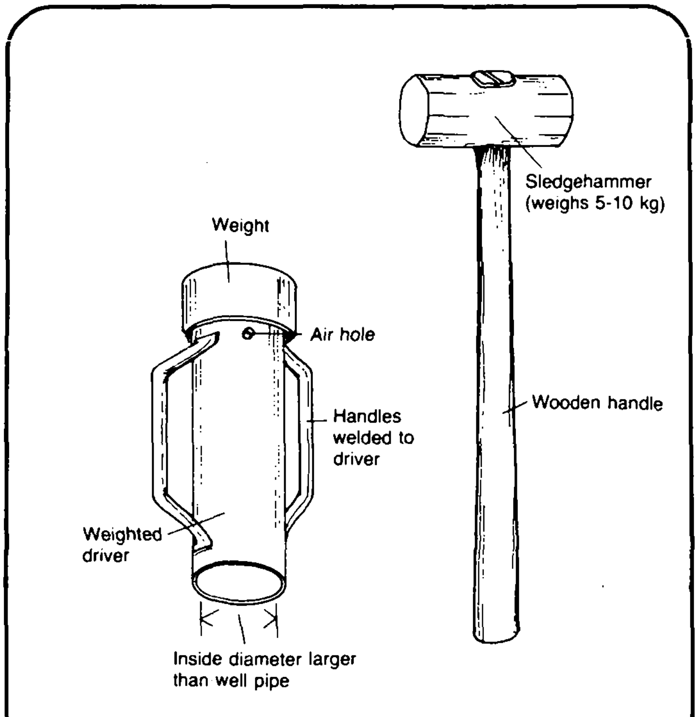

Figure 2. Driving Tools

Driving Bar. In this method, a tripod with a pulley and rope is erected over the site. A heavy drive bar, smaller in diameter than the well pipe, is suspended from the rope and allowed to drop inside the well pipe. See Figure 3. The bar strikes the drive

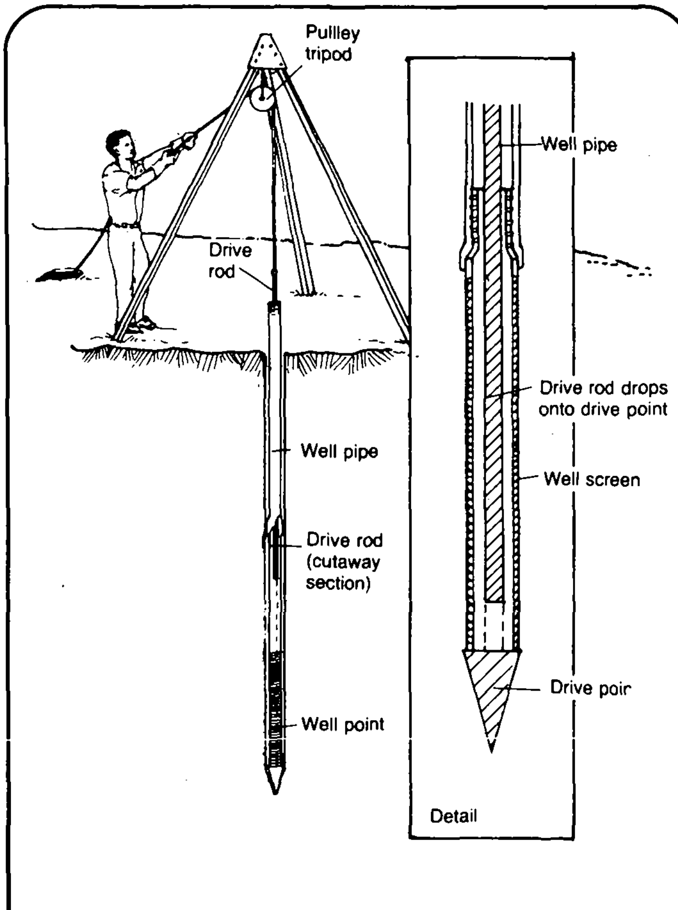

Figure 3. Driving Bar

point, driving the well point and pipe into the ground. This method is more expensive than the sledgehammer and weighted driver methods, but it can sink a well to greater depths.

Driving Weight. This method also requires a tripod with pulley and rope to be erected over the site. A heavy weight is raised with the rope and allowed to fall on the drive cap. The falling weight is directed by a guide rod, which either is attached to the weight and slides into the well pipe, or is attached to the well pipe and slides through the weight, as shown in Figure 4. This method can achieve the greatest depths possible for a driven well.

When you have determined which method of driving the well is best for your situation, prepare a design drawing similar to Figure 2, 3, or 4 and give it to the construction foreman.

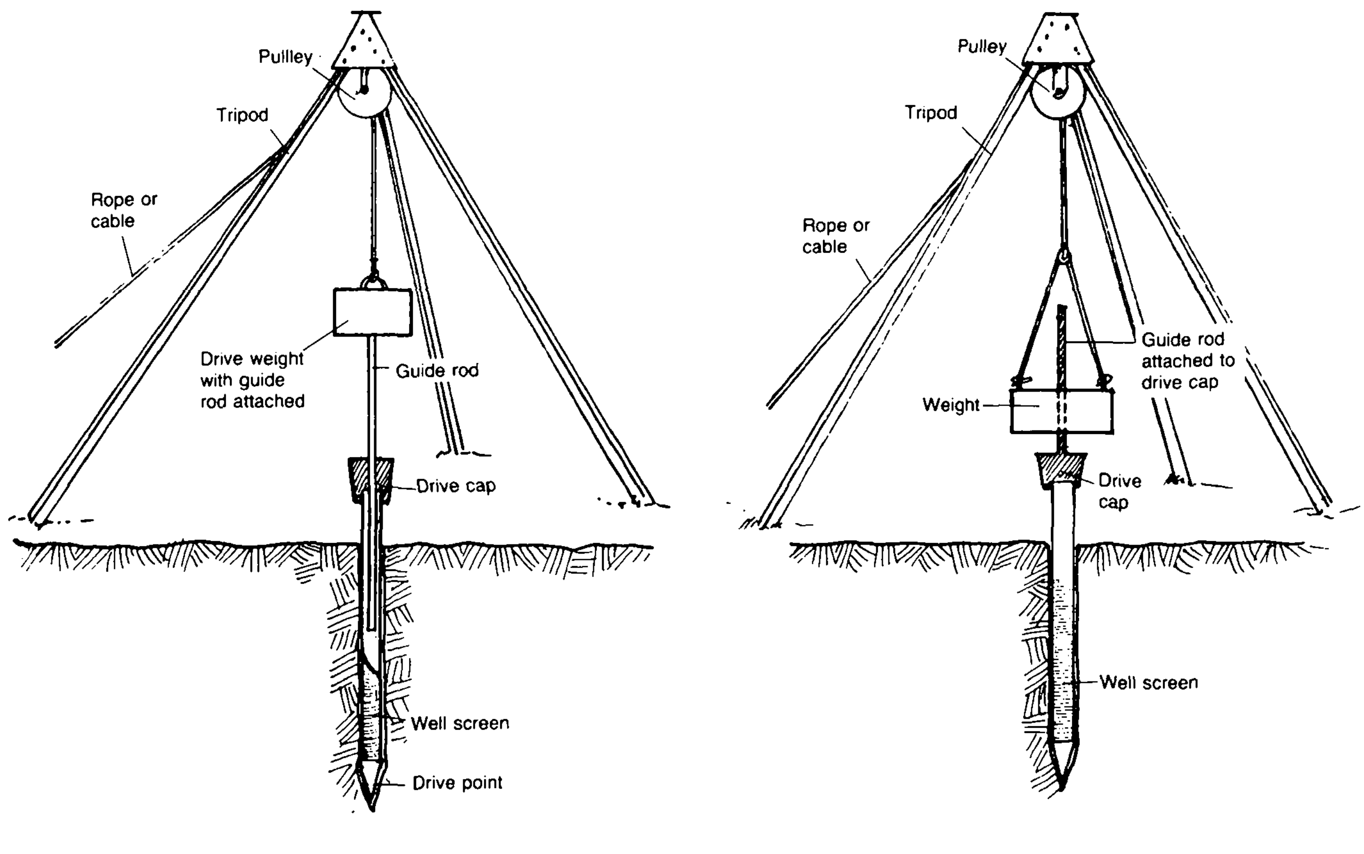

Figure 4. Driving Weights

Determining Personnel, Materials, Tools, and Equipment

The number of workers needed to drive the well depends on the method of driving: one or two for sledgehammer; two for weighted driver; two or three for both driving bar and driving weight. Also, there should be one worker to check the plumb line and to give the pipe a quarter-turn with a pipe wrench after each blow. If the driving equipment is to be fabricated, one worker should have skills as a blacksmith or welder.

The required driving equipment depends on the method of driving the well (see "Determining the Method of Driving"). All driven wells require a well point, sections of well pipe, couplings, and a drive cap (except the driving bar method). Tools needed include a pipe cutter, pipe wrench, file, pipe threader, hammer, crowbar, assorted wrenches and screwdrivers, and a shovel or auger.

When you have determined all necessary personnel, materials, tools, and equipment, prepare a materials list similar to Table 1 and give it to the construction foreman.

Table 1. Sample Materials List for a Driven Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	____
	Worker, skilled in blacksmithing	1	____
	Workers, unskilled	2	____
Supplies	Well point	____	____
	Pipe sections (30mm diameter, 2.0m long)	____	____
	Drive cap	____	____
	Couplings	____	____
Tools and Equipment	Measuring tape	____	____
	Plumb bob and line	____	____
	Shovel	____	____
	Tripod/pulley/rope assembly	____	____
	Drive weight with attached guide rod	____	____
	Pipe cutter	____	____
	Pipe wrench	____	____
	Metal file	____	____
	Pipe threader	____	____
	Hammer	____	____
	Crowbar	____	____
	Wrenches, assorted sizes	____	____
	Screwdrivers, assorted sizes	____	____

Total Estimated Cost = ____

In summary, give the construction foreman a location map similar to Figure 5, described in "Selecting a Well Site," RWS.2.P.3, design drawings of the well point similar to Figure 1 and driving equipment similar to Figure 2, 3 or 4, and a detailed materials list similar to Table 1.

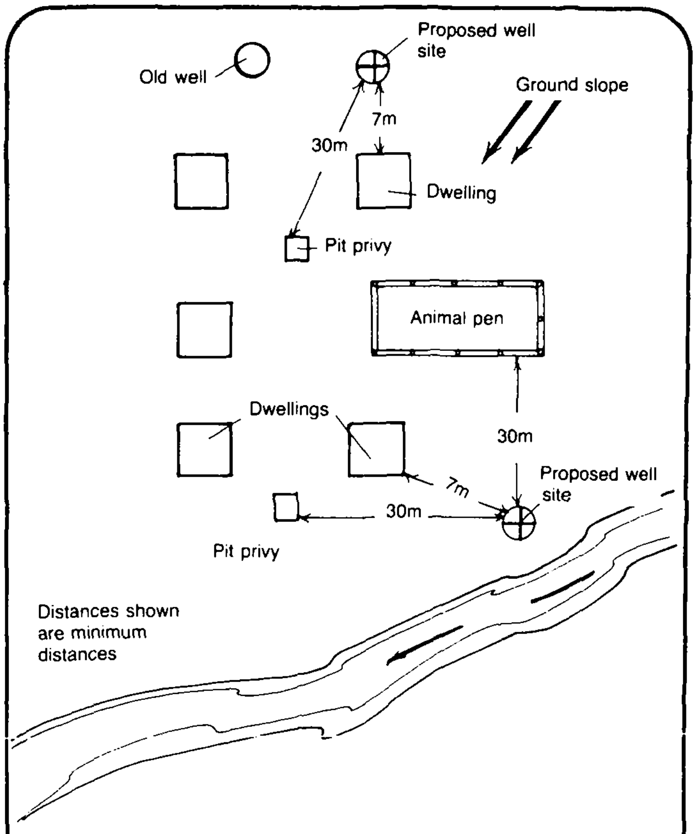

Figure 5. Location Map

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1982

Water for the World

Designing Jetted Wells
Technical Note No. RWS. 2.D.3

Designing jetted wells properly is important to ensure a year-round supply of water, and to ensure efficient use of personnel and materials. Designing involves selecting a screen, and determining all necessary personnel, materials, and equipment. The products of the design process are drawings of the well screen and a detailed materials list. These products, along with a location map similar to Figure 1 from "Selecting a Well Site," RWS.2.P.3, will be given to the construction foreman before construction begins.

This technical note decribes how to design a jetted well and arrive at these two end-products. Read the entire technical note before beginning the design process.

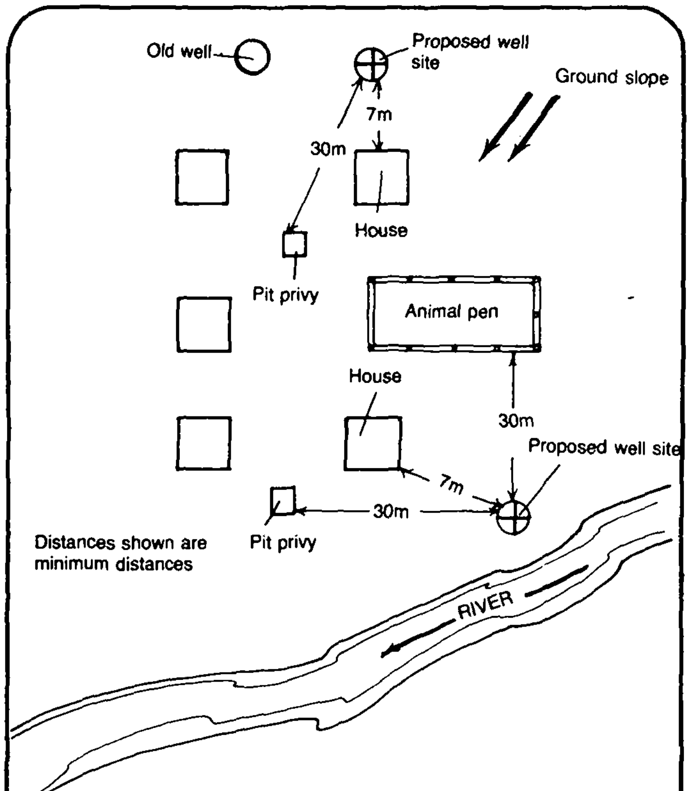


Figure 1. Location Map

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

Selecting a Screen

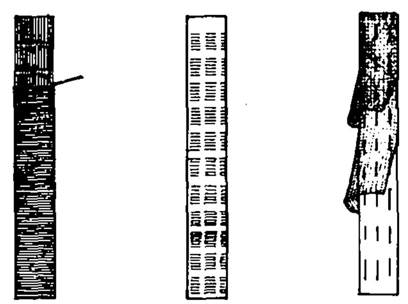
The well screen may be the single most important factor affecting the efficiency of a well. Screens for jetted wells are usually commercially, rather than locally, made.

Probably the best commercial screen is the continuous-slot type, which consists of a triangular-shaped wire wrapped around an array of rods. The screen offers the largest percentage of open area for ground water to enter, while retaining a small slot size to screen out particles in the aquifer. Another advantage is that the triangular-shaped openings prevent particles from sticking in the screen and clogging it during the developing process (see "Finishing Wells," RWS.2.C.8). The size of the slots can be precisely regulated and can be as small as 0.15mm.

Another commercial screen is the shutter or louver type, which is a metal tube with slots stamped out with a metal die. The disadvantages compared to a continuous-slot type are a smaller percentage of open area, a limited number of slot sizes, and a tendency for the screen to clog during the development process if the aquifer contains fine sand.

A wrapped-on-pipe screen is a perforated pipe wrapped by one or more screens. It has the same disadvantages as the shutter type screen.

When the screen has been selected, prepare a drawing similar to Figure 2a, 2b, or 2c, and give it to the construction foreman.



a. Continuous-slot   b. Shutter or louver   c. Wrapped-on-pipe

Figure 2. Well Screens

Determining Personnel, Materials, and Equipment

A foreman is needed to oversee the well construction and one or two workers are needed to operate the jetting equipment. If a manual pump, rather than a mechanical pump is used, an additional worker may be needed to operate it.

Materials needed include a well screen and casing material. Concrete mix will be needed to line the top 3m of the well shaft.

Equipment needed includes a tripod, rope, pulley, hollow drill pipe, jetting bit, pump, flexible hose, swivel joint, pipe couplings, pipe wrenches, crescent wrenches, screwdrivers, pipe cutter, and a shovel.

When all personnel, materials, and equipment have been determined, prepare a materials list similar to Table 1 and give it to the construction foreman.

To summarize, give the construction foreman a drawing of the well screen, a detailed materials list, and a location map (from "Selecting a Well Site," RWS.2.P.3).

Table 1. Sample Materials List for a Jetted Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	____
	Workers	3	____
Supplies	Well screen (continuous-slot)	____	____
	Casing; 50mm diameter	____ m	____
	Plug for screen	____	____
	Concrete mix	____ m^3	____
Equipment	Tripod	____	____
	Pulley	____	____
	Rope	____ m	____
	Drill pipe; 38mm diameter	____ m	____
	Jetting drill bit	____	____
	Pump (hand-operated)	____	____
	Hose	____ m	____
	Swivel hose connection	____	____
	Hose connections (standard)	____	____
	Pipe couplings	____	____
	Pipe wrenches	____	____
	Crescent wrenches	____	____
	Screwdrivers	____	____
	Pipe cutter	____	____
	Shovels	____	____
	Containers (for mixing concrete)	____	____
	Measuring tape	____	____
	Other	____	____

Total Estimated Cost = ____

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1982

Water for the World

Designing Bored or Augered Wells
Technical Note No. RWS. 2.D.4

It is important to design bored or augered wells properly to ensure a year-round supply of water and to ensure efficient use of personnel and materials. Designing involves determining how to install the casing, selecting a screen; and deciding on all necessary personnel, materials, and equipment. The products of the design process are: (1) design drawings of the method of installation and the well screen and (2) a detailed materials list. These products, along with the location map from "Selecting a Well Site," RWS.2.P.3, will be given to the construction foreman before construction begins.

This technical note describes how to design a bored well and arrive at these end-products. Read the entire technical note before beginning the design process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

Installing the Casing

Casing may be made of clay tile, concrete, metal, or plastic. The diameter of the casing determines the diameter of the well. It is usually about 100mm.

There are two basic methods for installing the casing: (1) the well shaft is dug and the casing is lowered into place; and (2) the casing is lowered as the shaft is dug. The method used depends on the soil conditions. If the soil is fairly firm and does not cave in, the first method is used. If the soil tends to cave in, the second method is used. Sometimes both methods are employed: the shaft is dug through firm soil until crumbly soil is reached, casing is lowered into place, and the remainder of the casing is installed as the rest of the shaft is dug.

When the method of installing the casing has been determined, prepare a drawing similar to Figure 1 and give it to the construction foreman.

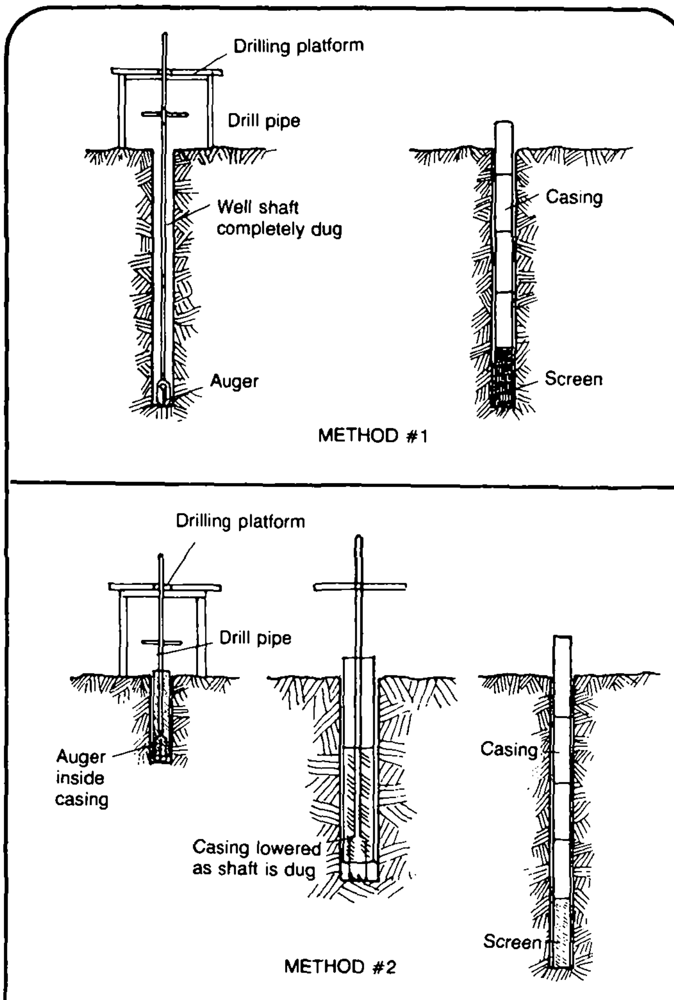

Figure 1. Installing the Casing

Selecting a Screen

The well screen may be the single most important factor affecting the efficiency of the well. Screens can be made either commercially or locally. Commercially-made screens are stronger and allow more ground water to enter, but they may be difficult to obtain. Locally made screens are more readily available, but they are not as strong or as efficient. Figure 2 shows both types of screens.

a metal die. The disadvantages of this type when compared with a continuous-slot type are: (1) smaller precentage of open area; (2) limited number of slot sizes; (3) tendency for the screen to clog during the development process if the aquifer is composed of fine sand.

The wrapped-on-pipe screen is a perforated pipe wrapped with one or more screens. The disadvantages of this type are the same as for the shutter type screen.

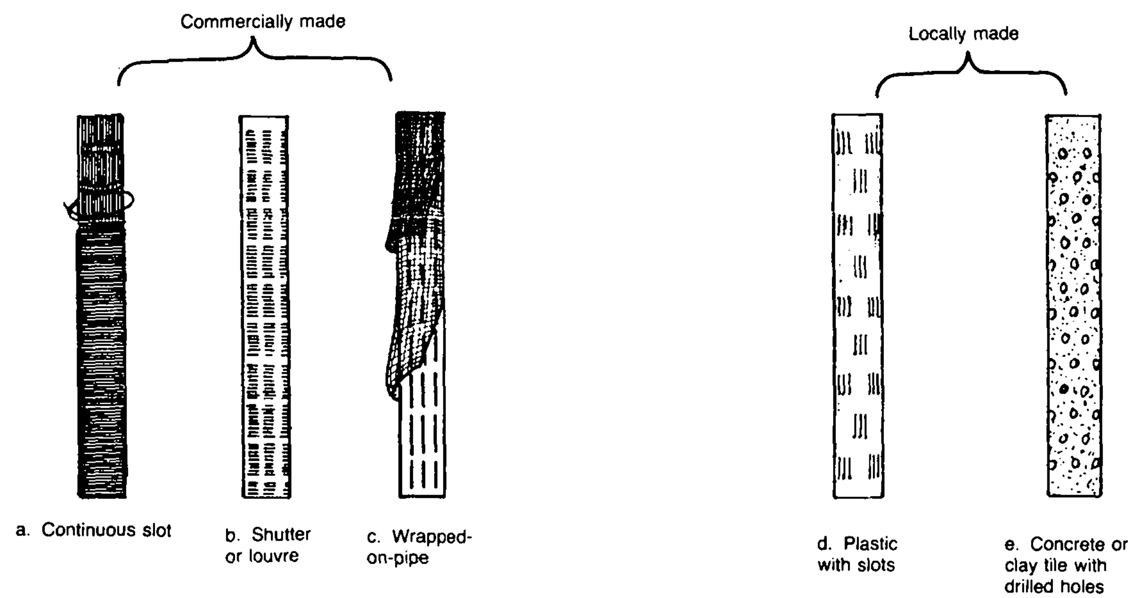

Figure 2. Well Screens

Commercial Screens. Probably the best commercial screen is the continuous-slot type, which consists of a triangular-shaped wire wrapped around an array of rods. The screen offers the largest percentage of open area for water to enter, while retaining a small slot size to screen out particles. Another advantage is that the triangular-shaped openings prevent particles from sticking in the screen and clogging it. The size of the slots can be precisely regulated and can be as small as 0.15mm.

Another commercial screen is the shutter or louver type, which is a metal tube with slots stamped out with

Local Screens. Screens can be made from the same material used for the casing. Holes can be drilled in metal or clay tile casing or slots can be cut in plastic casing. The disadvantages of these screens when compared with commercial screens are: (1) the percentage of open area is lower, thus restricting the entry of water into the well; (2) the size of the holes or slots cannot be made small enough to screen out fine sand.

When the screen has been selected, prepare a drawing similar to Figure 2a, b, c, or d and give it to the construction foreman.

Determining Personnel, Materials and Equipment

A foreman is needed to oversee construction and two workers are necessary to rotate the auger. It may be convenient to have an additional worker to empty the auger and to assist in attaching and removing section of drill pipe. Materials needed include a well screen and casing material. Concrete mix and/or gravel will be needed to line the top 3m of the well shaft.

Equipment needed includes a drilling platform, sections of drill pipe, joints for connecting sections, and an assortment of augers suited for various soil conditions. Hand tools needed include a hammer, hacksaw, and assorted wrenches.

When all personnel, materials, and equipment have been determined, prepare a materials list similar to Table 1 and give it to the construction foreman.

Table 1. Sample Materials List for a Bored Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	____
	Workers	3	____
Supplies	Plastic pipe for casing, 100mm diameter, 2.0m long	____	____
	Plastic pipe with slots for screen	____	____
	Cement mix	____	____
	Sealing material	____	____
	Plug for screen	____	____
Equipment	Wooden platfrom	____	____
	Drill pipe, 25mm diameter, 3.0m long	____	____
	Joints for drill pipe	____	____
	Auger	____	____
	Sand auger	____	____
	Handle, adjustable	____	____
	Shovel	____	____
	Hammer	____	____
	Hacksaw	____	____
	Wrenches	____	____
	Measuring tape	____	____
	Plumb bob and line	____	____

Total Estimated Cost = ____

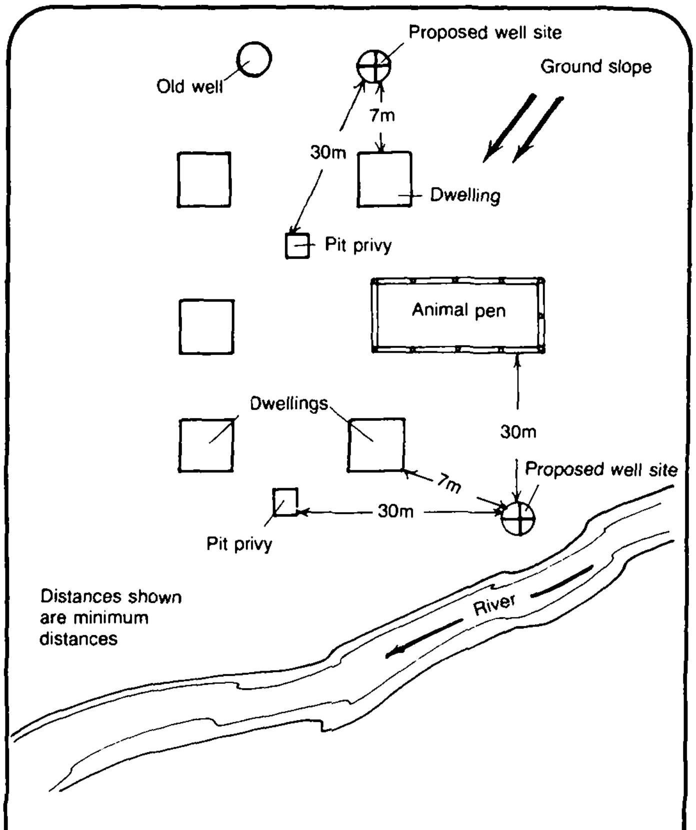

Figure 3. Location Map

To summarize, give the construction foreman a location map similar to Figure 3, described in "Selecting a Well Site," RWS.2.P.3, design drawings of the method of casing installation similar to Figure 1 and the type of screen similar to Figure 2a, b, c, d, or e, and a detailed materials list similar to Table 1.

Notes

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1982

Water for the World

Designing Cable Tool Wells

Technical Note No. RWS. 2.D.5

Properly designing cable tool wells, also called percussion drilled wells, is important to ensure a year-round supply of water and to ensure efficient use of personnel and materials. Design involves determining whether the well will be manually or mechanically drilled; selecting a screen; and determining all necessary personnel, materials and equipment. The products of the design process are design drawings of the method of drilling, drawings of the well screen, and a detailed materials list. These products, along with a location map similar to Figure 1 from "Selecting a Well Site," RWS.2.P.3, will be given to the construction foreman before construction begins.

This technical note describes how to design a cable tool well and arrive at these end-products. Read the entire technical note before beginning the design process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

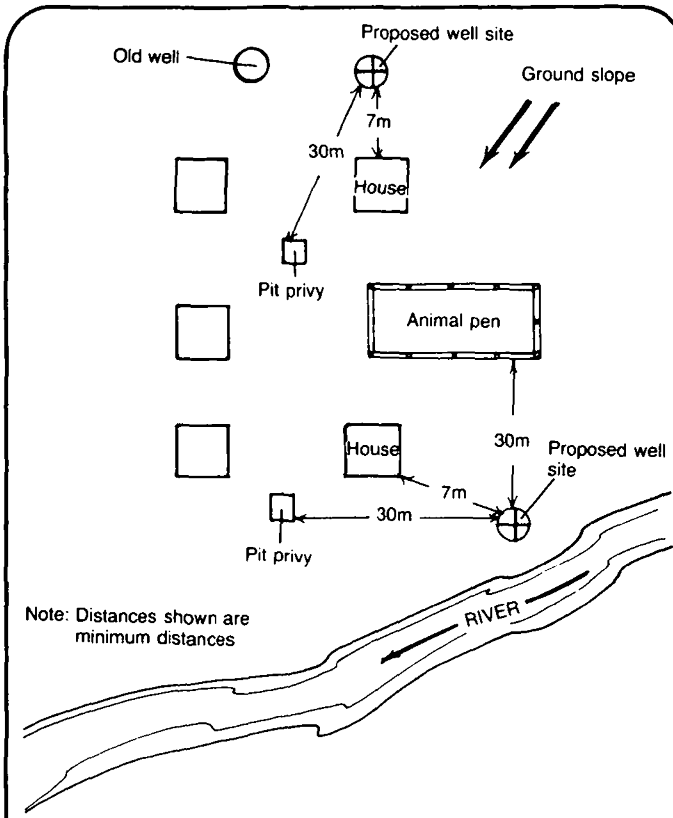


Figure 1. Location Map

Determining the Drilling Method

In the manual method, the rope or cable supporting the drill bit is secured to a tree or a post driven in the ground. Three to five workers push down on the rope to raise the bit, then quickly raise up to allow the bit to fall. This is a relatively inexpensive operation, but it is physically demanding and the workers must be rotated frequently to avoid fatigue.

In the mechanical method, the rope or cable supporting the drill bit is wrapped around a power take-off or a cathead bolted to the rear drum of a truck or jeep. Alternately tightening and loosening the pull on the loose end of the rope will allow the spinning cathead to raise and drop the drill bit. This method takes less physical effort and is faster than the manual method. It requires a vehicle or other power source, and is therefore more expensive.

When the method of drilling has been determined, prepare a drawing similar to Figure 2a or 2b and give it to the construction foreman.

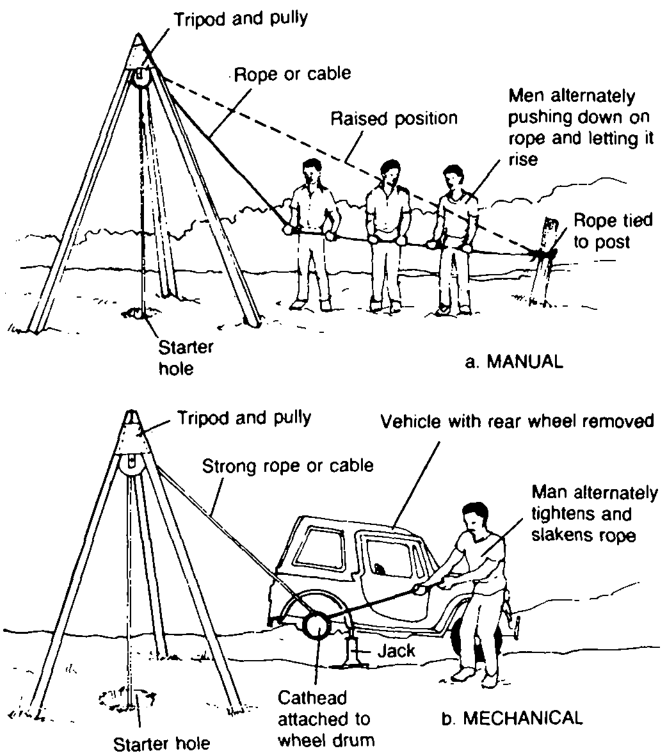


Figure 2. Methods of Drilling

Selecting a Screen

The well screen may be the single most important factor affecting the efficiency of a well. Screens are made either commercially or locally. Commercially made screens are stronger and allow more ground water to enter. In some countries, they may be difficult to obtain. Locally made screens are more readily available, but they are not as strong or as efficient.

Commercial Screens. Probably the best commercial screen is the continuous-slot type, which consists of a triangular-shaped wire wrapped around an array of rods. The screen offers the largest percentage of open area for water to enter, while retaining a small slot size to screen out particles. Another advantage is that the triangular-shaped openings prevent particles from sticking in the screen and clogging it during the developing process, see "Finishing Wells," RWS.2.C.8. The size of the slots can be precisely regulated, and can be as small as 0.15mm. See Figure 3a.

Another commercial screen is the shutter or louver type, which is a metal tube with slots stamped out with a metal die. The disadvantages compared with a continuous-slot type are a smaller percentage of open area; a limited number of slot sizes; and a tendency for the screen to clog during the development process if the aquifer is composed of fine sand. See Figure 3b.

The wrapped-on-pipe screen consists of a perforated pipe wrapped by one or more screens. The disadvantages are the same as for the shutter type screen. See Figure 3c.

Local Screens. Screens can be made from the same materials used for the casing. Since the casings for cable tool wells are generally made from sections of steel pipe, the screen can be a section of pipe with holes drilled in it. The disadvantages of these screens compared with commercial screens are the percentage of open area is lower, thus restricting the entry of groundwater into the well; and the size of the holes cannot be made small enough to screen out fine sand.

When the screen has been selected, prepare a drawing similar to Figures 3a, 3b, 3c, or 4, and give it to the construction foreman.

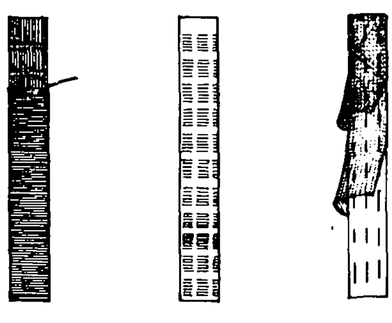


Figure 3. Commercially Made Well Screens

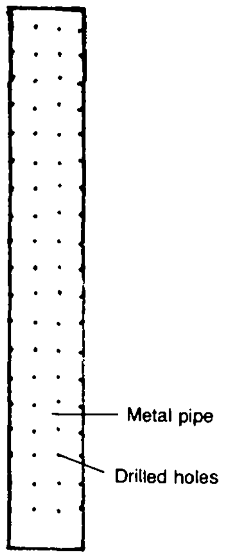


Figure 4. Locally Made Well Screen

Table 1. Sample Materials List for a Cable Tool Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	___
	Blacksmith	1	___
	Workers	10	___
Supplies	Steel pipe section for casing; (75mm diameter, 2.0m long)	___	___
	Pipe couplings	___	___
	Well screen	___	___
	Plug to seal bottom of screen		___
	Cement mix	___ m^3	___
Equipment	Tripod and pulley	___	___
	Heavy-duty ropes; each 50m long	___	___
	Percussion bit; 100mm x 1.5m long; 80kg	___	___
	Hollow rod bit; 100mm diameter; 1.0m long	___	___
	Bailer; 50mm diameter, 1.0m long	___	___
	Fishing tool	___	___
	Anvil	___	___
	Hammers (blacksmith)	___	___
	Hacksaw	___	___
	Metal files	___	___
	Wrenches	___	___
	Screwdrivers	___	___
	Shovels	___	___
	Measuring tape	___	___
	Plumb bob and line	___	___
	Other	___	___

Total Estimated Cost = ___

Determining Personnel, Materials, and Equipment

A foreman is needed to oversee well construction. A blacksmith may be needed to dress or repair the drill bit. Five to ten workers, fewer for the mechanical method, will be needed to raise and lower the drill bit.

Materials needed include a well screen and casing material. Concrete mix and/or gravel will be needed to line the top 3m of the well shaft.

Equipment needed includes a drilling tripod and pulley, heavy-duty rope or cable, percussion bit, hollow rod bit, bailer, and a fishing tool to be used if the rope breaks. Hand tools include metal files, a hacksaw, wrenches, screwdrives, and shovels. If the well is drilled mechanically, equipment needed includes a gasoline- or diesel-powered engine, fuel, oil, grease for the cathead, and maintenance tools.

When all personnel, materials, and equipment have been determined, prepare a materials list similar to Table 1 and give it to the construction foreman.

To summarize, give the construction foreman design drawings of the method of drilling, drawings of the well screen, a detailed materials list similar to Table 1, and a location map similar to Figure 1.

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Constructing Hand Dug Wells
Technical Note No. RWS. 2.C.1

Proper construction of a hand dug well is important to ensure a year-round supply of water and to protect the water from contamination. Construction involves assembling all necessary personnel, materials, and tools; preparing the site; excavating the well shaft; and lining the shaft. Finishing the well is discussed in "Finishing Wells," RWS.2.C.8.

There are several good methods to construct a hand dug well; if you are familiar with a specific method, use it. This technical note describes one method of construction, using locally available materials, that has been employed successfully in a number of countries. Read the entire technical note before beginning construction.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria.

GROUND WATER - Water stored below the ground's surface.

KIBBLE - A large bucket for lifting materials when sinking a shaft; also called a hoppit or sinking bucket.

POROUS - Having tiny pores, or spaces which can store water or allow water to pass through.

WATER TABLE - The top, or upper limit, of an aquifer.

Materials Needed

The project designer must provide three papers before construction can begin:

1. A location map similar to Figure 1.

2. A design drawing similar to Figure 2.

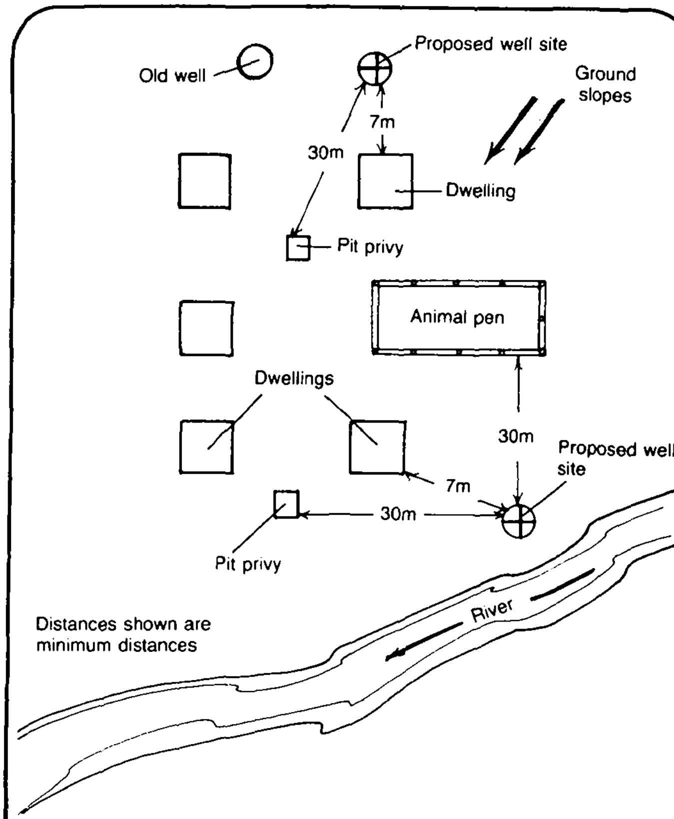


Figure 1. Location Map

3. A materials list similar to Table 1.

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary workers, supplies, and tools.

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when specific workers, materials, and tools must be available during the construction process. Draw up a work plan similar to Table 2 showing construction steps.

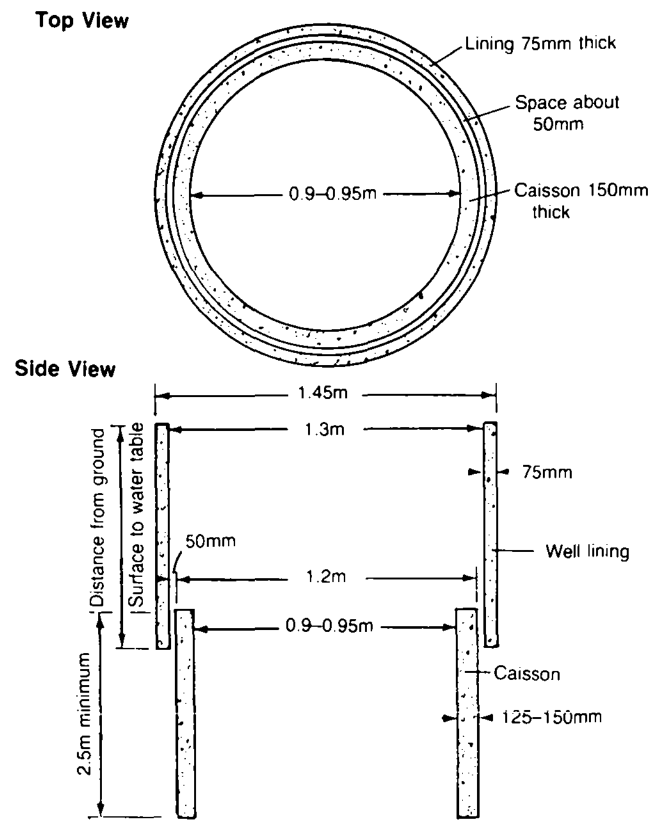


Figure 2. Design of Well Lining and Caisson

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	____
	Worker, skilled in sinking well	1	____
	Worker, experienced with concrete	1	____
	Workers, unskilled	2-4	____
Supplies	Cement (Portland)	____kg	____
	Sand (clean; fine to 6mm)	____m^3	____
	Gravel (clean; 6-36mm)	____m^3	____
	Water (clean and clear)	____	____
	Re-rod for lining: 8mm diameter	____m	____
	Re-rod for caissons: 15mm diameter	____m	____
	Materials for storage shed	____	____
Equipment	Headframe	____	____
	Rope for caissons; 100m x 12mm diameter, steel wire with fiber core, tensil strength $7kg/cm^2$	____	____
	Rope for kibbles: 100 x 6mm diameter	____	____
	Rope for trimming rods: 100m x 3mm diameter	____	____
	Steel shutters (1.3m diameter x 0.5m high) with wedges and bolts	____	____
	Steel shutters (1.3m diameter x 1.0m high) with wedges and bolts	____	____
	Steel molds for caisson rings (1.2m outside diameter, 0.95m inside diameter, 0.5m high)	____	____
	Templates for molds	____	____
	Stretcher for caissons	____	____

Total Estimated Cost = ____

Table 2. Sample Work Plan for a Hand Dug Well

Time Estimate	Day	Task	Personnel	Materials/Tools
1 day	1	Locate and prepare well site; assemble materials	Foreman (present during entire construction); 2-4 workers	Measuring tape; drawings; tools and materials for building shed
1 day	2	Erect headframe; set center point and offset pegs; build mixing slab	2-4 workers	Headframe; plumb bob; re-rod; cement, sand, gravel, water; trowel
4 hours	3	Dig shallow excavation; install temporary lining	2-4 workers	Shovels; shutters (1.3m diameter, 1.0m high) spirit level
7 days	3-9	Excavate and trim first lift	4 workers	Shovels; picks; mattock; kibble; top plumbing rod; trimming rods
2 hours	10	Install first set of shutters	4 workers	Shutters (1.3m diameter, 0.5m high); spirit level; trimming rods; shovel
6 hours	10	Install vertical and horizontal re-rods	4 workers	Lengths of re-rod; binding wire; spacing blocks and holding hooks; wire cutters
1 day	11	Install second set of shutters; pour concrete; build curb	4 workers	Oiled shutters (1.3m diameter, 1.0m high); cement, sand, gravel, water; tamping rod; re-rod; burlap covering; mattock
1 day	12	Install third and fourth sets of shutters; pour concrete	4 workers	Sets of oiled shutters; cement, sand, gravel, water
2 days	13-14	Widen top of well; add re-rods; install fifth and sixth sets of shutters; pour concrete; bend back rods and cover with layer of weak mortar	4 workers	Burlap covering; mattock; re-rod; binding wire; sets of oiled shutters; cement, sand, gravel, water
---	---	Construct second and third lifts and lining as needed	4 workers	Materials and tools as needed
1 day	15	Build caisson rings	4 workers	Molds; re-rods; oiled pipes; templates; cement; sand (none if porous concrete), gravel, water
10 days	16-25	Cure caisson rings	----	Wet burlap or straw
2 days	26-27	Install caisson rings	4 workers	Stretcher; spacers; heavy planks; wrench; mortar; trowel
2 days	28-29	Sink caissons into aquifer	4 workers	Shovels, kibble
2 hours	30	Install base plug	4 workers	Precast base plug

Caution!

1. Workers in the well shaft should wear hard hats for protection.

2. Workers at ground level must be careful not to accidentally drop or kick tools or other materials into the well shaft.

3. A kibble, rather than a bucket or basket, should be used to hoist soil out of the shaft.

4. The well must be dug at the exact location specified by the project designer.

Construction Steps

1. Using the location map and a measuring tape, locate the well site. Clear the area of any vegetation or debris that might interfere with work.

2. Assemble all laborers, materials, and tools needed to begin construction and arrange the materials in a fashion similar to Figure 3. A proper layout will save time and effort during later construction steps. A shelter should be built to protect tools and some materials from the weather, theft, or being misplaced.

Because the caisson rings must be cured for at least 10 days before they can be lowered into the well shaft, build them first even though they will not be needed until later in the construction process. See step #26.

3. Erect the headframe over the site of the well. The headframe must be sturdy enough to support the caisson rings, which may weigh over 350kg. One type of headframe that has been used successfully is shown in Figure 4. It is made of angle iron and equipped with a winch and brake. The four feet of the headframe must rest on solid ground--place stone slabs or pour concrete under them if necessary. It is important that the headframe not be moved once it is in position and the center point of the well has been fixed.

4. Build a slab for mixing concrete by first leveling an area about two meters square. Spread 50mm of well-tamped gravel, cover with a layer of cement mortar (4 parts sand to 1 part cement), and smooth with a trowel. Form a lip around the outer edge, cover the slab with wet burlap or straw, and keep moist for two or three days.

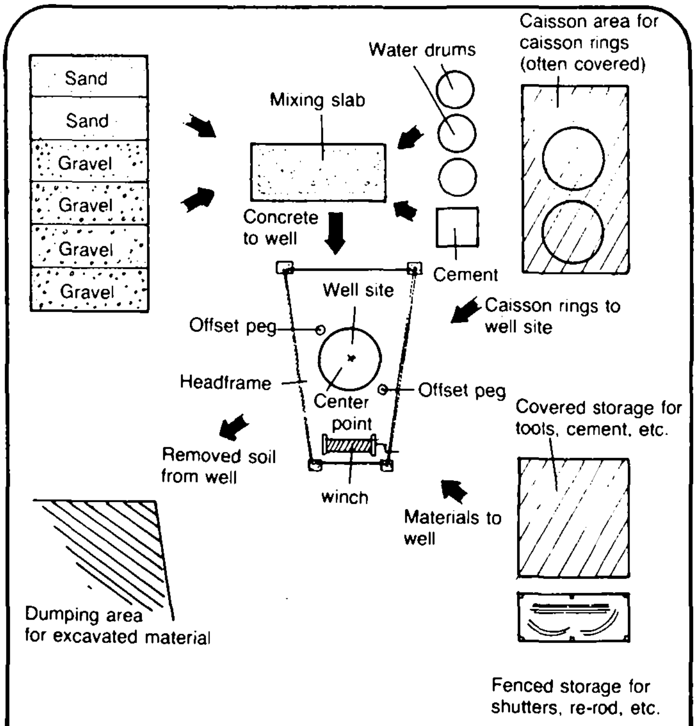


Figure 3. Layout of Well Site

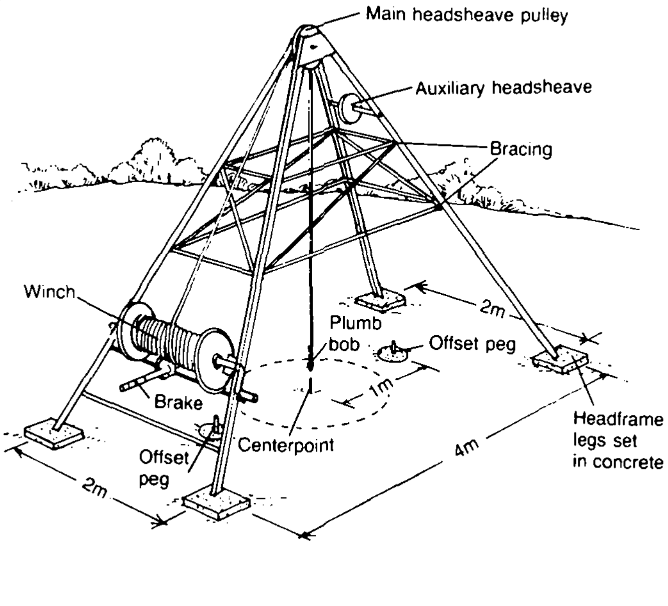


Figure 4. Headframe

5. Establish the center point of the well by lowering a plumb bob from the headsheave pulley on the side opposite the winch; that is, the side from which the main hoisting rope will descend. Mark this point on the ground with a short length of re-rod. Set offset pegs on opposite sides and exactly 1.0m from the center point. Make the top of these pegs at least 150mm above ground level to make allowance for the temporary lining that will be installed. These pegs should be set in concrete and positioned so that the top plumbing rod will fit over them as in Figure 4. Allow the concrete to set for several days before using the pegs.

6. Mark a circle of 650mm radius around the center point. Carefully excavate within this circle to a depth of 0.9m. Position a set of steel shutters 1.3m in diameter and 1.0m high inside this hole with 100mm projecting above ground to act as a temporary lining. See Figure 5. Be certain that the shutters are exactly in place and that the top is level. Firmly tamp soil around the outside. These shutters will prevent the top of the shaft from crumbling, and they will reduce the risk of tools or materials being accidentally kicked into the shaft.

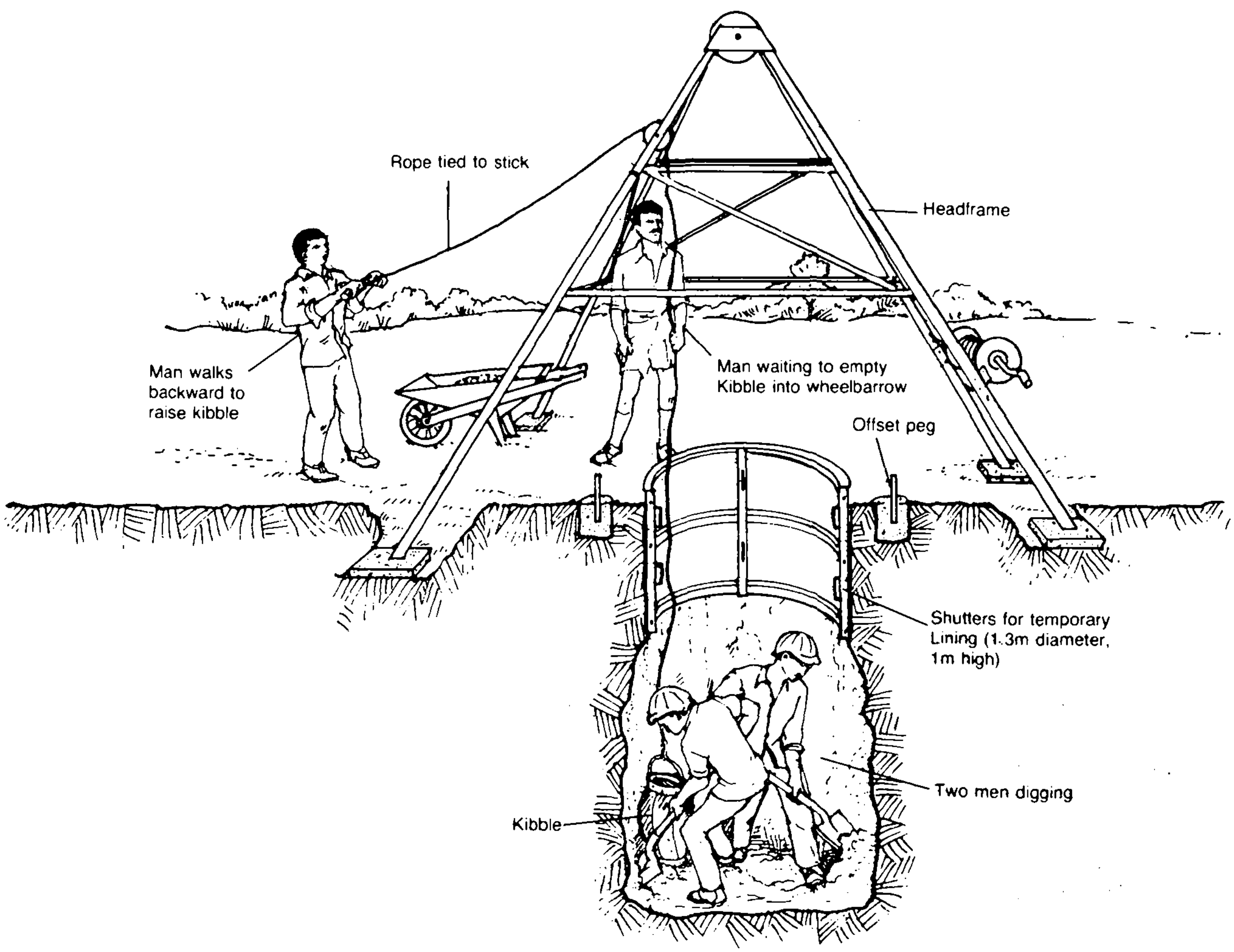


Figure 5. Excavating the Shaft

7. Begin excavating the first lift of the well. Normally, two workers using miner's picks and bars and short-handled shovels excavate the soil in layers about 100mm deep, and they keep the bottom of the excavation fairly level at all times. Soil is removed by hoisting it up in a kibble, as shown in Figure 5. The shaft is dug somewhat less than its finished diameter of 1.45m.

Every meter or so the long trimming rods, 1.45m long, are suspended from the top plumbing rod. The workers carefully trim the walls of the shaft so that the trimming rods can freely turn with their ends just missing the shaft walls, as shown in Figure 6. It is important that the trimming be done with extreme care, for even a small addition to the thickness of the lining will increase the amount of concrete used.

Depending on the condition of the soil, the first lift can be dug as deep as 5.0m, 4.1m below the bottom of the temporary lining. If the soil is crumbly or tends to cave in, the lift must be shallower. If water is struck, stop the excavation and proceed to step 25.

8. A set of shutters, 1.3m in diameter and 0.5m high, is oiled and then lowered to the bottom of the shaft. Set the shutters precisely in place by suspending the short trimming rods 1.3m long and lining up the edges of the shutters directly beneath the ends of the rods. Use a spirit level to be certain that the shutters are level. It is essential that these shutters be exactly in place and perfectly level, or else the entire lining will be out of line. See Figure 7.

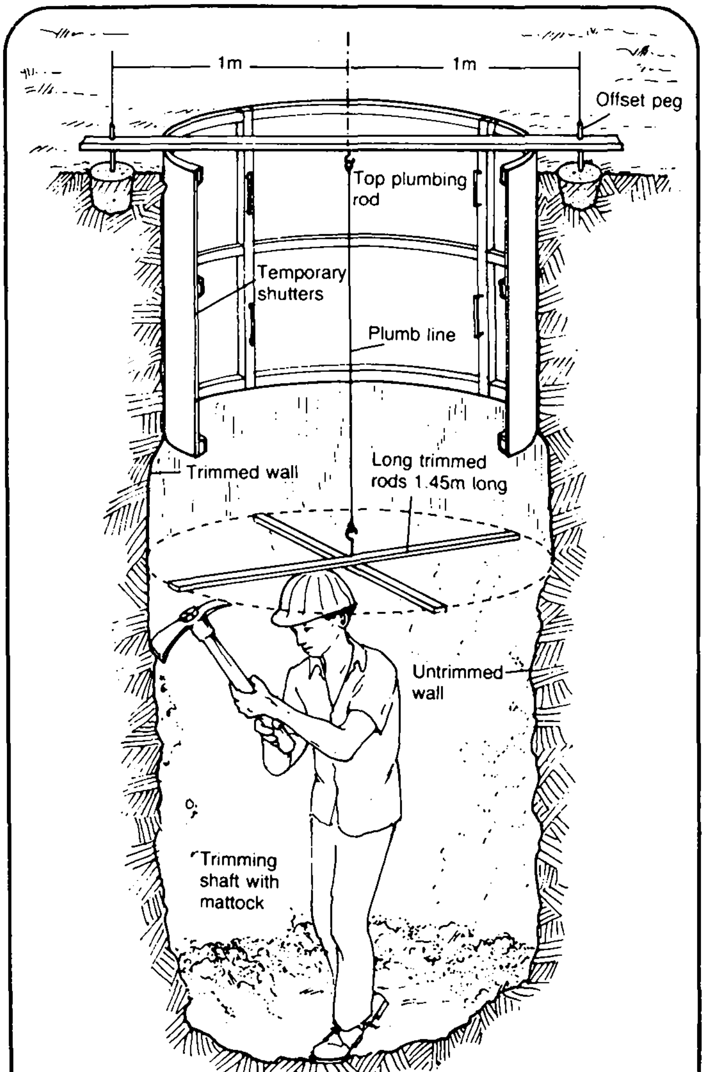


Figure 6. Trimming the Shaft

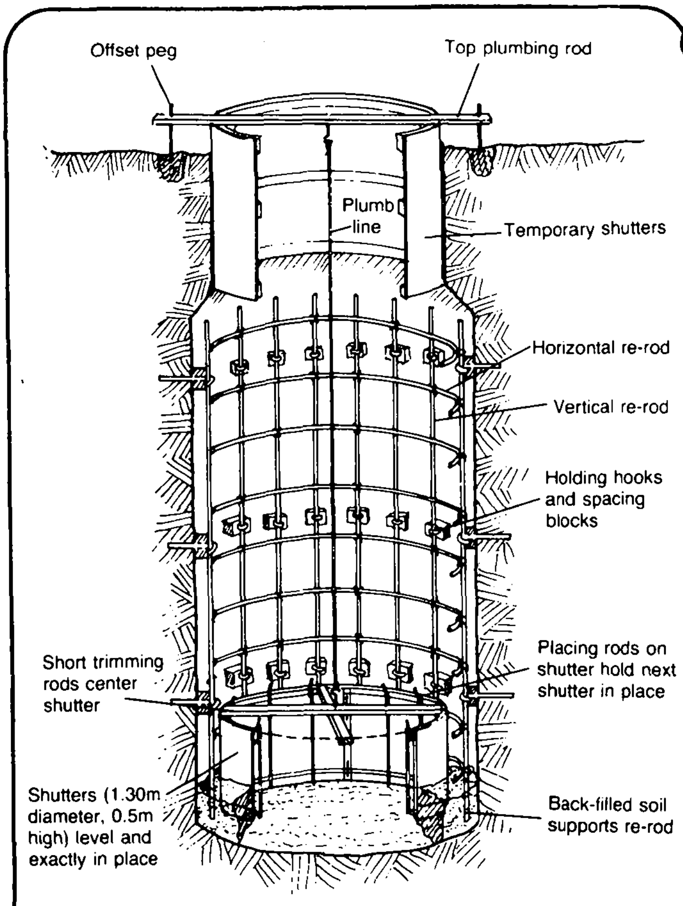


Figure 7. First Set of Shutters and Re-rod

9. Position 20 lengths of vertical re-rod, each length 4.0m long and 8mm in diameter, behind the shutters and around the shaft walls. Fix the rods to the walls about 200mm apart using spacing blocks and holding hooks. Backfill behind the shutters with soil to help hold the rods in place, as shown in Figure 7.

10. On the surface, shape horizontal re-rods into circles 1.38m in diameter. You will need three or four horizontal re-rods for each meter of depth. Lower the re-rods and fasten them to the inside of the vertical re-rods about 250-300mm apart, as shown in Figure 7. They will make the reinforcement cage strong and secure. Use a wire brush to remove all dirt from the re-rods.

11. Oil a set of shutters, 1.3m in diameter and 1.0m high, lower it into the shaft, and position it on top of the first set. Center the shutters with the short trimming rods, 1.3m long, check them with a spirit level, and bolt them in place, as shown in Figure 8.

12. Mix concrete on the mixing slab. Use one part cement, two parts sand, four parts gravel, and enough water to make a workable mix. Lower the concrete in a concrete bucket tied to a rope over the auxiliary headsheave. The main headsheave and a bosun's chair will be used later to raise and lower the workman pouring concrete. When lowering the bucket, be careful that it does not catch on any projection and spill its contents on the workers below.

Pour the concrete behind the shutters as shown in Figure 8. Pour it evenly and in shallow layers to prevent overloading one side. Tamp with a length of re-rod. Fill the space between the shutters and the shaft walls until the concrete is 10-20mm from the top of the shutters, and leave the top of the concrete rough. This will ensure a good bond with the next pour.

13. Temporarily cover the concrete with burlap or other material to keep off soil. Carefully excavate a triangular-shaped groove, 200mm deep and 200mm high at the well face, around the shaft walls just above the shutters. Set re-rod pins into the groove and fasten to the vertical re-rods. Remove the temporary cover. Fill in the groove with concrete as shown in Figure 8. This forms a curb which will help hold the lining in place and prevent it from slipping.

14. Oil the third set of shutters, 1.3m diameter and 1.0m high, lower it into the shaft, and position it on top of the second set. Center the shutters with the short trimming rods, check them with the spirit level, and bolt them in place. Pour concrete as before, and tamp to be certain all voids are filled with concrete.

15. Oil a fourth set of shutters and repeat the process of lowering and positioning them and pouring concrete as shown in Figure 8.

16. The top of the fourth set of shutters will be about 600mm below the bottom of the shutters being used for temporary top lining. Cover the concrete with burlap to keep off soil and remove the temporary lining. Excavate the sides of the well to a diameter of 1.6m from the surface of the ground down to the top of the fourth shutter. Attach lengths of vertical re-rod to the re-rod already in place. Bend the ends of all re-rods into hooks and overlap the lengths by

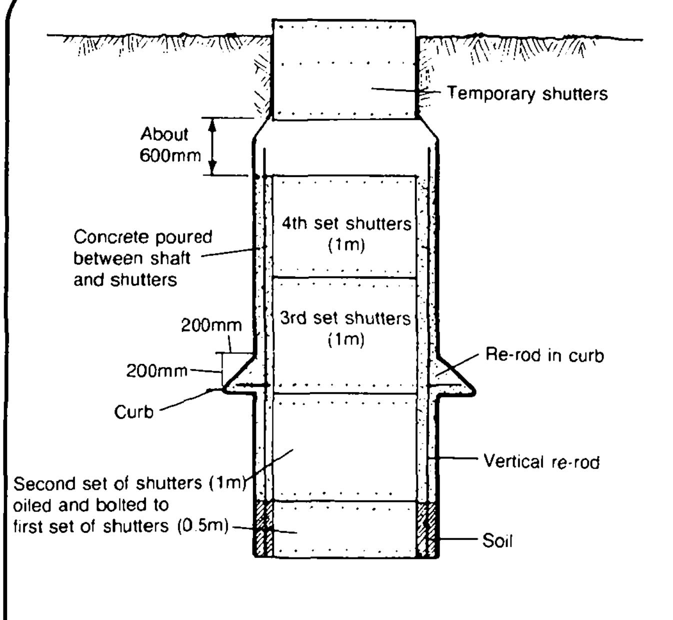


Figure 8. Shutters and Curb

at least 200mm as shown in Figure 9. The new re-rods should protrude above ground about 200mm. Position circles of horizontal re-rods 250-300mm apart and fasten them to the vertical re-rods. Remove the burlap from the concrete.

17. Oil the fifth and sixth sets of shutters in turn, set them in place, check their positioning with trimming rods and a spirit level, and bolt them together. Pour concrete as before, and carefully fill in the space behind the shutters up to ground level as shown in Figure 9. The extra thickness of concrete in the top 1.5m of the lining will provide a solid base for the wellhead. See "Finishing Wells," RWS.2.C.8.

18. Bend back the protruding vertical rods until they are level with the ground. Make a weak mortar mix (1 part cement to 15 parts sand), and use it to cover the re-rods and form a lip around the well as shown in Figure 9. This mortar layer will help keep surface water and debris out of the well, and it can be easily broken away when it is time to build the wellhead.

The first lift is now complete. Leave the shutters in place for about seven days to allow the concrete lining to cure. If you have more shutters, you can begin the second lift at once, leaving the first lift shutters in place. If not, you will have to wait seven days before beginning the second lift.

19. To begin the second lift, remove the earth-filled shutter at the bottom of the first lift, and clean the re-rods with a wire brush.

20. Excavate the second lift to a depth of 4.65m below the bottom of the concrete lining of the first lift. If ground water is encountered before you reach this depth, stop the excavation and proceed to step 25.

21. Position the vertical re-rods in the same manner used in the first lift. Bend the top ends of these re-rods into

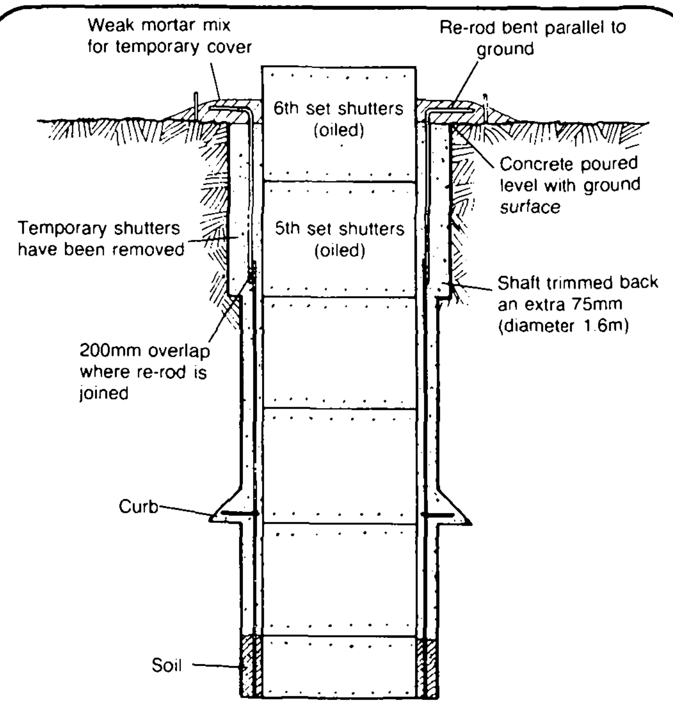


Figure 9. Completing the First Lift

hooks and leave the bottom ends of the re-rods protruding down from the concrete. The lengths should overlap by about 200mm. Fasten them together with wire. Position and fasten circular sections of horizontal re-rods in place.

22. Begin lining the second lift in the same manner as the first. Remember the first set of shutters is 0.5m high and backfilled with soil, and a concrete curb is built just above the second set of shutters.

23. There will be a gap of about 150mm between the top of the fourth set of shutters and the bottom of the concrete lining of the first lift, as shown in Figure 10. To pour concrete into this set of shutters you will need a funnel or scoop made from scrap metal. This will prevent spilling concrete.

24. The gap between lifts should be left open until the entire well is excavated and lined in case there is any movement or shifting of the lining.

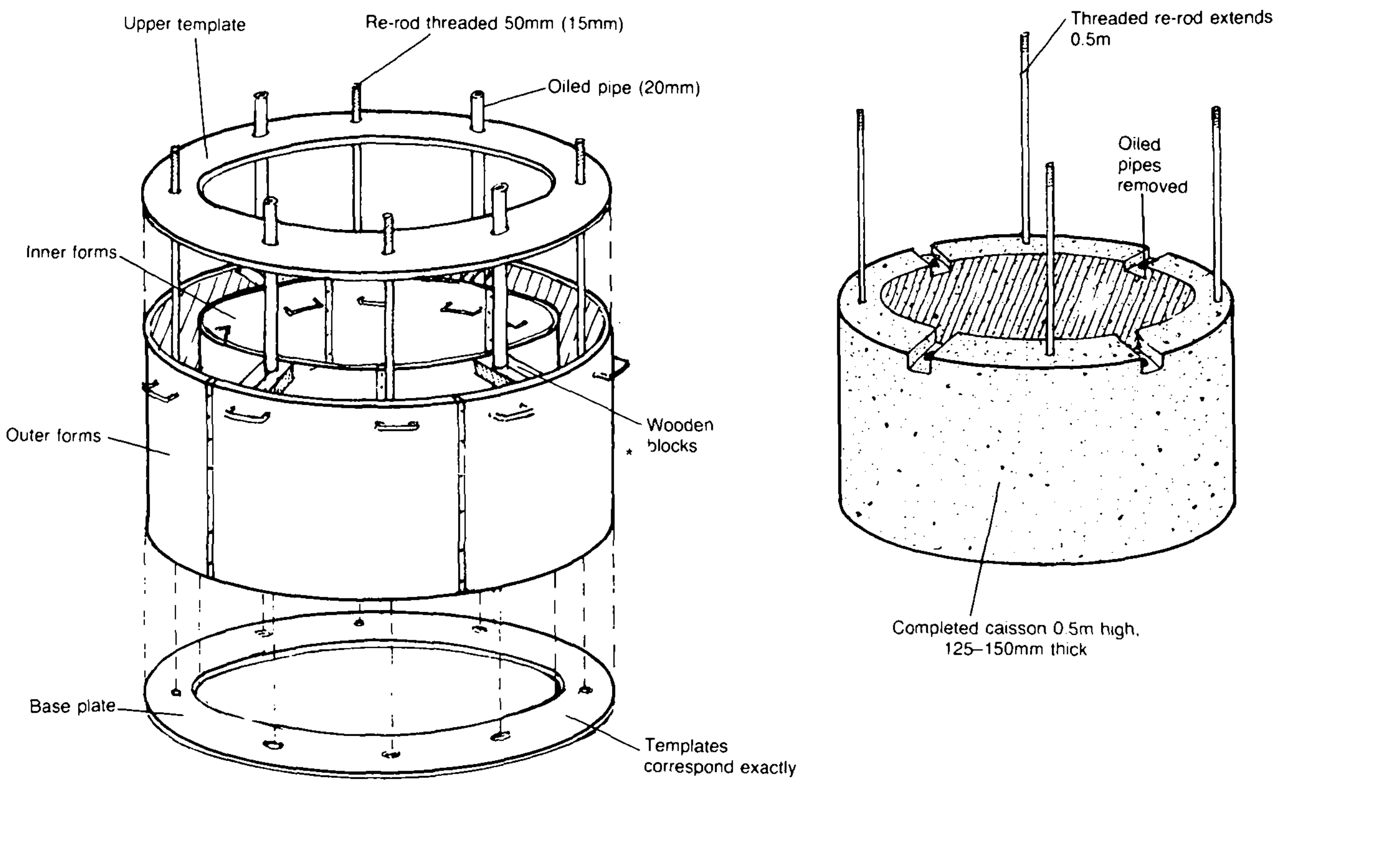


Figure 10. Casting Caissons

These gaps can be used to attach the pipe for a pump or the supports for an access ladder.

When it is time to fill the gaps, use concrete mortar and bricks or stones. Thoroughly seal the entire gap with a coating of plaster to prevent possible contamination by entry of surface water.

25. Continue the process of digging and lining until ground water is reached. If you encounter difficult ground or if the water table is reached before a full lift is excavated, the lift can be made as shallow as 650mm, 500mm for a small set of shutters and 150mm for the gap below the previous lining.

When the aquifer is reached, dig down into it to examine its composition and depth. An auger is a useful tool for this work. If the aquifer is a shallow perched layer, you must sink the well through it to a deeper aquifer. If you have indeed reached a main aquifer, line this last section of the shaft as before and build an extra-deep curb as shown in Figure 10.

26. The remainder of the well will be sunk using the caisson method. Before you can begin, the lining must be given time to harden so that you can remove the shutters. See Figure 2 for the way in which caisson rings fit into the lining.

The caisson rings may already have been cast as described in step 2. The type of rings used depends on the composition of the aquifer. The rings can be made of porous concrete, standard concrete, or standard concrete perforated with seepage holes.

26a. Cast all types of rings in a mold 0.5m high, with an outside diameter of 1.2m and an inside diameter of 0.90-0.95m. See Figure 10. If standard concrete is to be used, it can be the same mix as was used for the lining. If the rings are to have seepage holes, you must use special molds with perforations. If porous concrete is to be used, it should be made by mixing one part cement to four parts washed gravel and no sand. The mix must not be overly wet; use only enough water to make it workable. The gravel must be quite clean and of the correct size. It must all pass through a 20mm screen but none of it must pass through a 10mm screen.

26b. To ensure that the caisson rings will fit together when placed in the well shaft, equip each ring with four evenly-spaced re-rods, 15mm diameter and 1.0m long, and four evenly-spaced holes 20mm in diameter. When the rings are set one on top of the other, the re-rods from one ring will fit into the holes of the other. The holes are made with well-oiled pipes, and the pipes and re-rods are held in position by a template. A small block of wood with a hole for the pipe to pass through is positioned to form a recess in the caisson ring for a bolt which will be secured onto the end of each re-rod. Each re-rod is threaded at the top 50mm and has a hole drilled 25mm from the bottom end through which a nail or piece of thick wire is placed. This will prevent the rod from pulling out when weight is placed on it.

26c. Cast the caisson rings in the shade. Insert the re-rods and the pipes that will form the holes. If the rings are to have seepage holes, place rods or wooden pegs through the holes in the sides of the mold.

26d. When the concrete has been in the mold for 12-24 hours, remove the pipes for the holes and, if necessary, the rods or pegs for the seepage holes.

26e. The molds should not be removed for three days, and the caisson rings should not be moved during this time. If porous concrete is being used, the molds should be left in place for seven days.

26f. Remove the caisson rings from their molds. Cure the rings by keeping them moist and in the shade for seven days. If they are made from porous concrete, the rings should be cured for 14 days.

27. Roll the first caisson ring beside the well shaft and tip it on end so that the re-rods are pointing up. Lower the stretcher over two re-rods on opposite sides of the ring. The stretcher must be made of steel or wood and be capable of supporting the weight of the caisson rings, each of which may weigh over 350kg. Fit lengths of 20mm diameter pipes and washers over the re-rods so that the stretcher can be tightly bolted down as shown in Figure 10.

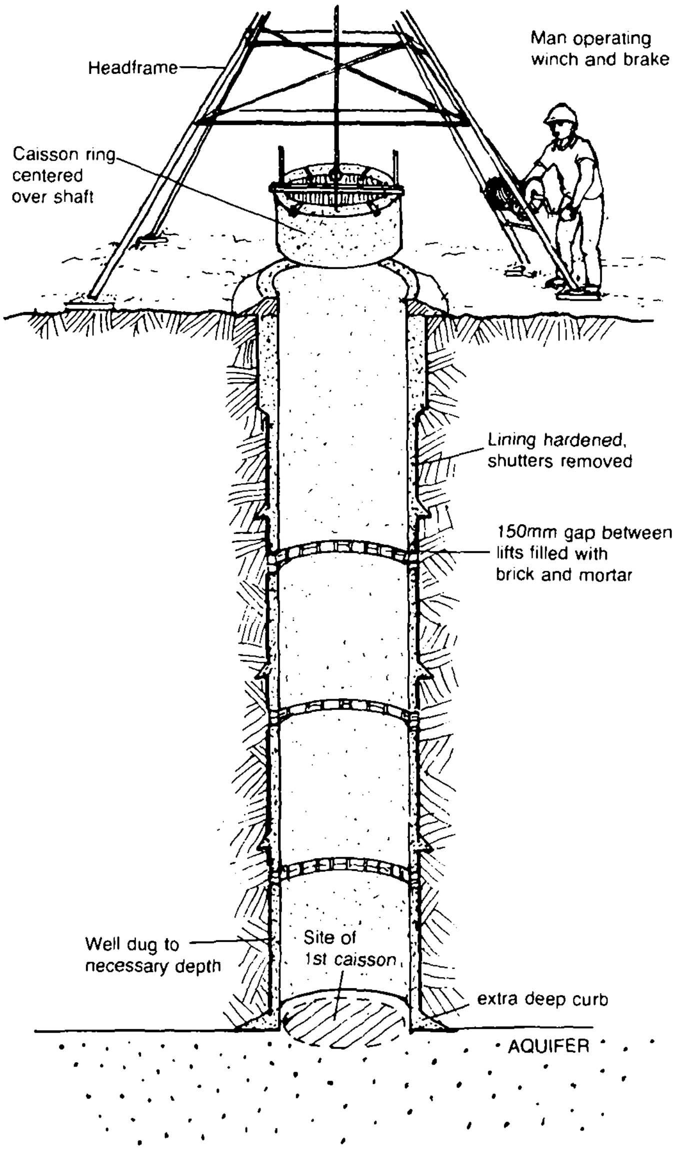
28. Cover the opening of the well shaft with stout logs or planks. Attach the main lowering rope to the U-bolt in the center of the stretcher. Carefully maneuver the caisson ring up onto the logs or planks until it is centered, raise it about 100mm, and remove the planks.

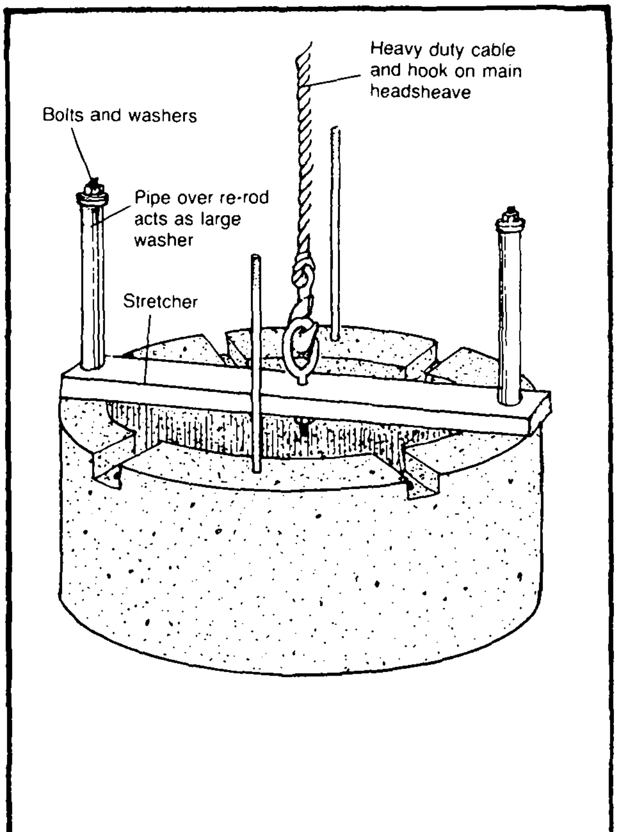
29. Slowly and carefully lower the ring to the bottom of the shaft. The ring must be level and perfectly centered, or you will have difficulty fitting on the other caisson rings. If necessary, raise the ring just off the bottom and wedge pieces of wood underneath until it is level and in position. Only then should you unbolt the stretcher. See Figure 11.

30. Lower the second ring in the same manner as the first. Just before it reaches the projecting re-rods of the first ring, a worker, perhaps sitting on the stretcher, must turn it so that its holes match the projecting re-rods. Partly lower the ring onto the re-rods, then spread a 10mm layer of cement mortar on the top edge of the first ring. Lower the second ring until it rests on the first. The rods of the first ring will project up into the recesses on the top edge of the second ring. Fix bolts on the threaded ends of the re-rods and tighten until the second ring is secure and level. Fill in the recesses and cover the bolt with cement mortar.

31. Continue lowering rings and fitting them together until there are five or six rings in the shaft. See Figure 11.

32. Probe the bottom of the shaft with a pointed length of re-rod to check for hard or soft spots. When excavation starts, there may be a





Method of Lowering Caisson into Well

Figure 11. Installing Caissons in Completed Lining

danger that the ground will suddenly give way and that several caisson rings will drop below the bottom of the lining. This is all right as long as the top ring does not drop below the lining.

33. Begin excavating in shallow layers, first in the center of the shaft and then under the ring. Dig evenly around the ring to prevent it from sinking out of line. As you excavate, the well shaft and the caisson rings will gradually sink into the aquifer and the shaft will begin to fill with water. Dig until the water becomes too deep for working, or until you are satisfied that the well will yield sufficient water. See Figure 11.

If you wish to remove water from the shaft while excavating, bail it out with a kibble. Do not pump out water with a mechanical pump, for that can cause the aquifer to collapse.

34. Set a base plug in the bottom of the shaft as shown in Figure 12. The plug can be made of porous concrete precast at ground level, or it can be made from layers of sand and gravel. If it is precast, it should have handles for lifting and removing it. The purpose of the plug is to prevent aquifer materials from rising into the well.

35. Unless the caisson rings have been sunk during the dry season, you may have to deepen the well during

the dry season. If so, you should add more caisson rings at that time.

36. Fill the space between the caisson rings and the concrete lining with small-sized gravel.

37. To build the wellhead and finish the well, see "Finishing Wells," RWS.2.C.8.

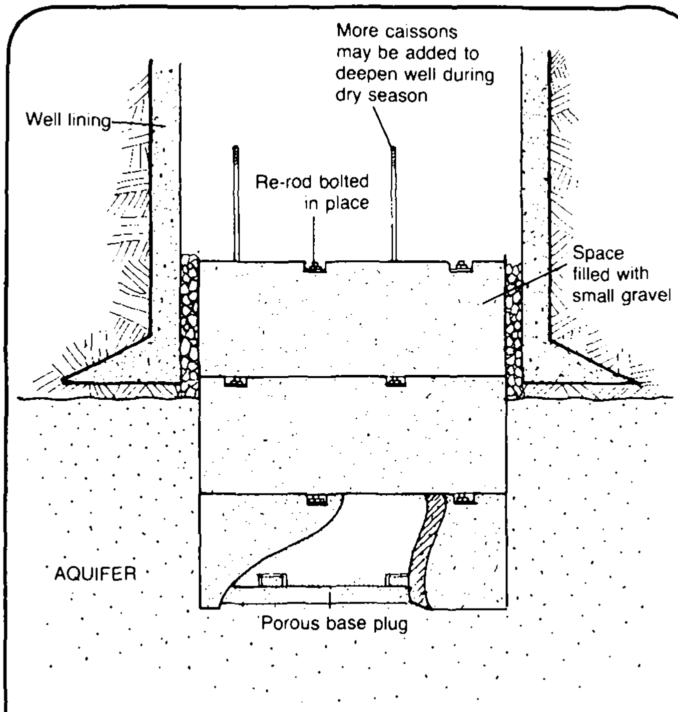


Figure 12. Caissons Sunk into Aquifer

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Water for the World

Constructing Driven Wells
Technical Note No. RWS. 2.C.2

Constructing a driven well properly is important to ensure a year-round supply of water and to protect the water from contamination. Construction involves assembling all necessary personnel, materials, and tools; preparing the site; and driving the well. Finishing the well is discussed in "Finishing Wells," RWS.2.C.8.

This technical note describes how to construct a driven well. Read the entire technical note before beginning construction.

Materials Needed

The project designer must provide four papers before construction can begin:

1. A location map similar to Figure 1.

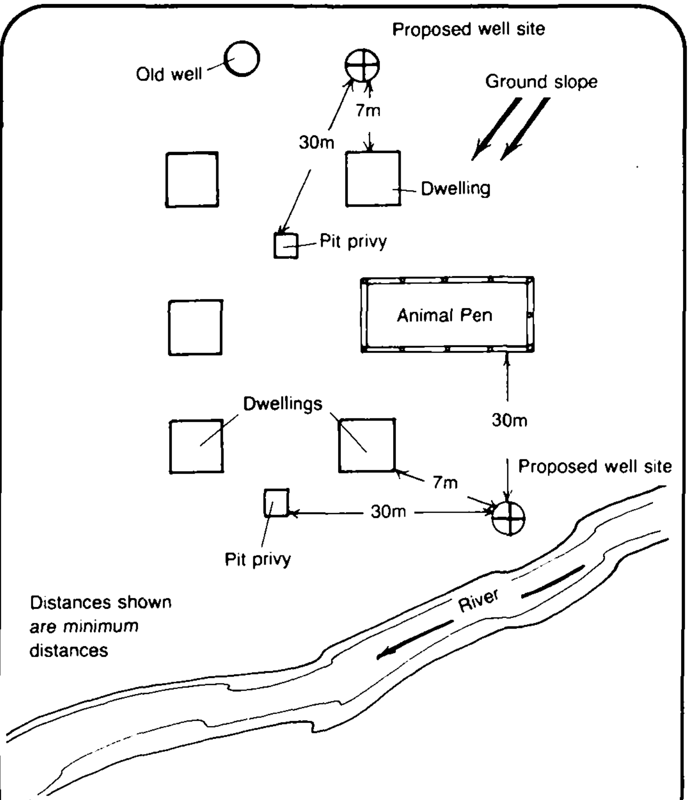

Figure 1. Location Map

2. A design drawing of the well point similar to Figure 2.

3. A design drawing of the driving equipment similar to Figures 3, 4, or 5.

4. A materials list similar to Table 1.

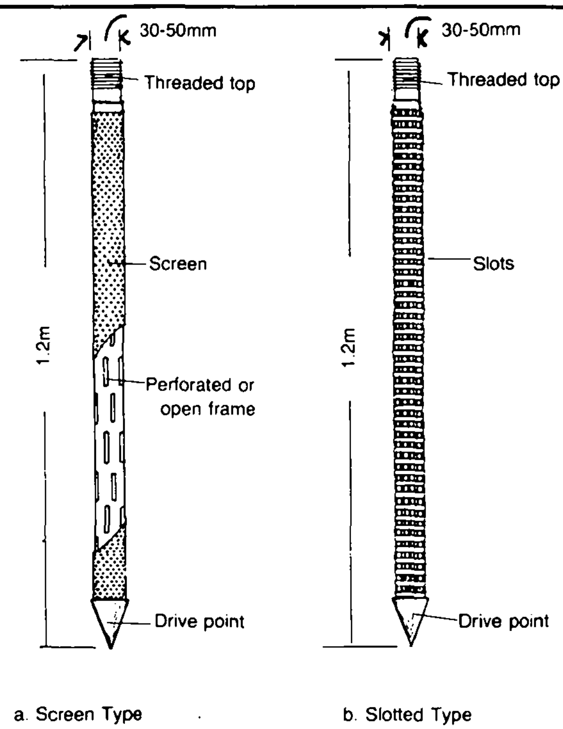

Figure 2. Well Points

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

WATER TABLE - The top, or upper limit of an aquifer.

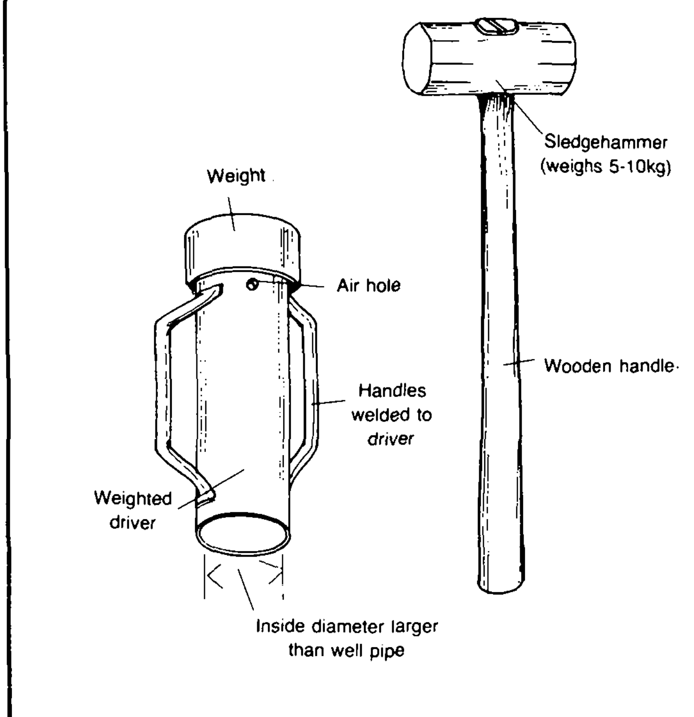

Figure 3. Driving Tools

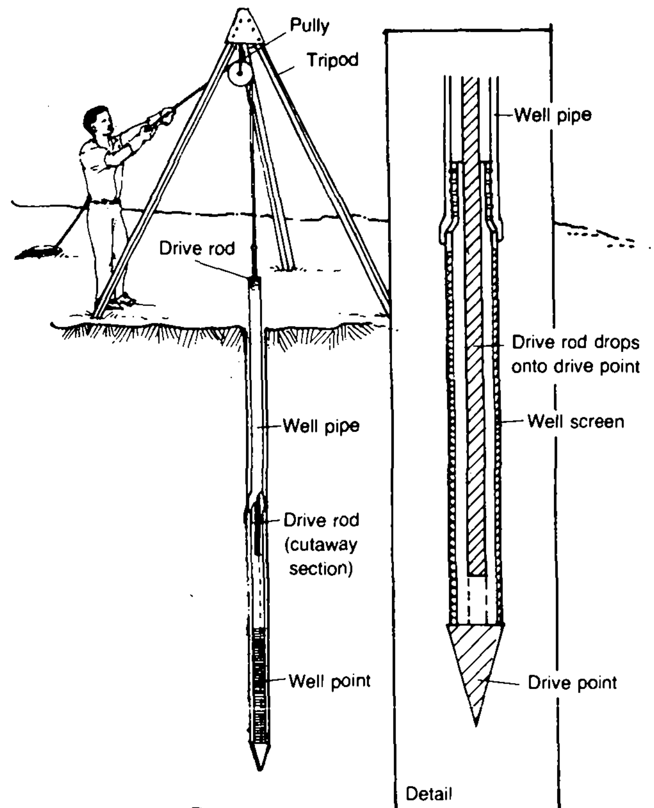

Figure 4. Driving Bar

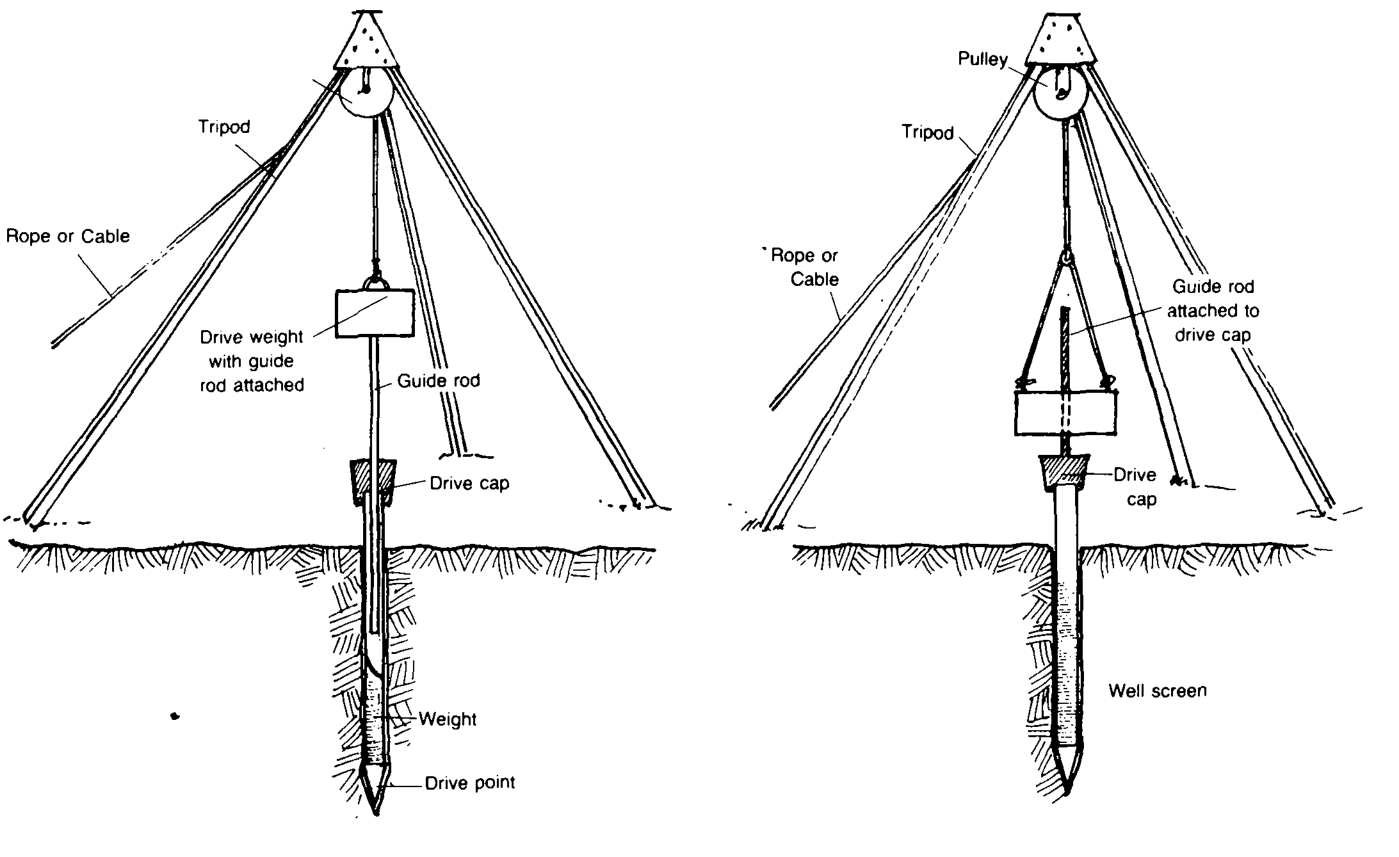

Figure 5. Driving Weights

Table 1. Sample Materials List for a Driven Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	____
	Worker, skilled in blacksmithing	1	____
	Workers, unskilled	2	____
Supplies	Well point	____	____
	Pipe sections (30mm diameter, 2.0m long)	____	____
	Drive cap	____	____
	Couplings	____	____
Tools and Equipment	Measuring tape	____	____
	Plumb bob and line	____	____
	Shovel	____	____
	Tripod/pulley/rope assembly	____	____
	Drive weight with attached guide rod	____	____
	Pipe cutter	____	____
	Pipe wrench	____	____
	Metal file	____	____
	Pipe threader	____	____
	Hammer	____	____
	Crowbar	____	____
	Wrenches, assorted sizes	____	____
	Screwdrivers, assorted sizes	____	____

Total Estimated Cost = ____

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when during the construction process specific workers, materials, and tools must be available. Draw up a work plan similar to Table 2 showing construction steps.

Table 2. Sample Work Plan for a Driven Well

Time Estimate	Day	Task	Personnel	Materials/Tools
1 day	1	Locate and prepare well site; assemble materials	Foreman (present during entire construction); 1-2 workers	Measuring tape; drawings
½ day	2	Erect tripod; dig starter hole	2-3 workers	Tripod/pulley/rope; shovels; plumb bob and line
2 days	2-4	Drive well to aquifer	2-3 workers	Well point; pipe sections; couplings; drive cap; driving weight; wrench
½ day	4	Clean up site; cut pipe to correct height	2-3 workers	Pipe cutter; pipe threader

Caution!

The well must be driven in the exact location specified by the project designer.

Construction Steps

1. Using the location map and a measuring tape, locate the well site. Clear the area of any vegetation or debris that might interfere with work.

2. Assemble all laborers, materials, tools, and equipment needed to begin construction.

2a. For the driving bar or driving weight method, erect the tripod over the site and be certain that its feet are planted firmly in the ground to prevent the tripod from moving during the driving operation.

2b. For the sledgehammer or weighted driver method, set up a temporary platform or sturdy wooden crate for the worker or workers to stand on during driving operations.

3. Mark the exact point where the well will be driven. For the driving bar or driving weight method, this can be done by lowering the plumb bob and line from the tripod's pulley. Dig or auger a small hole about 0.5m deep at this point.

4. Couple the first section of pipe onto the well point, and screw the drive cap onto the pipe section. Set the well point in the hole and hold it perfectly vertical. Check the vertical line with a plumb bob and line.

5. Begin to drive the well.

5a. Sledgehammer. Stand on the temporary platform and strike the drive cap with a sledgehammer as shown in Figure 6. Be certain that the hammer

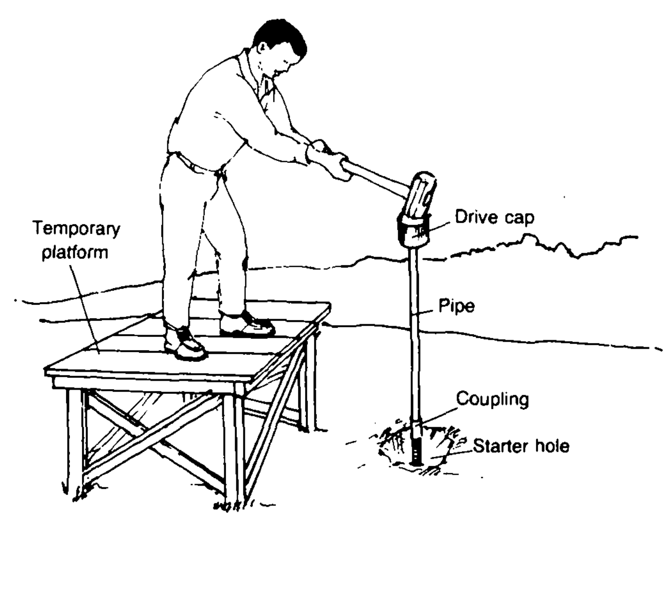

Figure 6. Driving with a Sledgehammer

squarely hits the drive cap. Avoid glancing blows. Use less than full force until the well point has been driven firmly into the ground.

5b. Weighted driver. Two workers must stand on boxes or platforms and face each other over the well pipe, as shown in Figure 7. Together, they raise and drop the driver squarely on the drive cap. Use less than full force until the well point has been driven firmly into the ground.

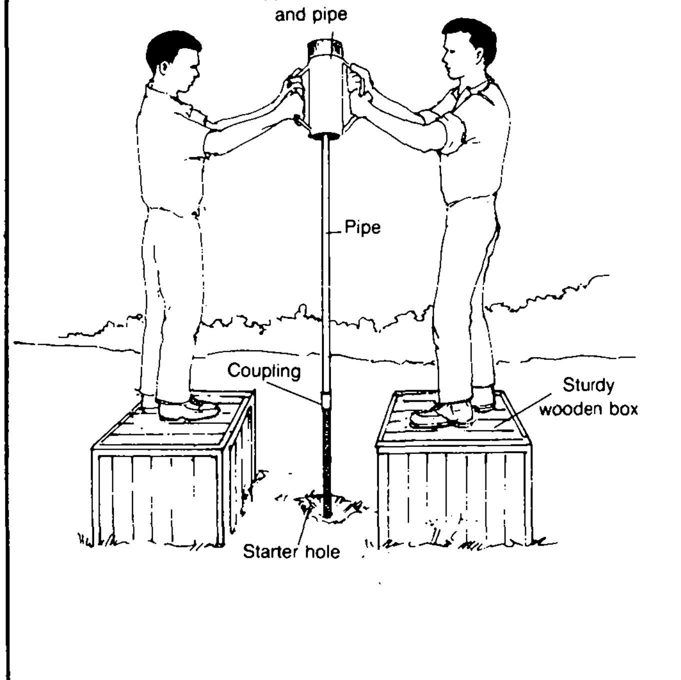

Figure 7. Driving with a Weighted Driver

5c. Driving bar. Slide the driving bar into the well pipe and lower it until it rests on the drive point. Raise the bar and let it fall onto the point. Raise the bar only part way until the well point has been driven firmly in the ground. See Figure 8.

5d. Driving weight. Depending on the equipment, either slide the guide rod into the well pipe, or slide the weight down over the guide rod. Raise the weight and let it fall onto the drive cap. Raise the weight only part way until the well point has been driven firmly in the ground. See Figure 9.

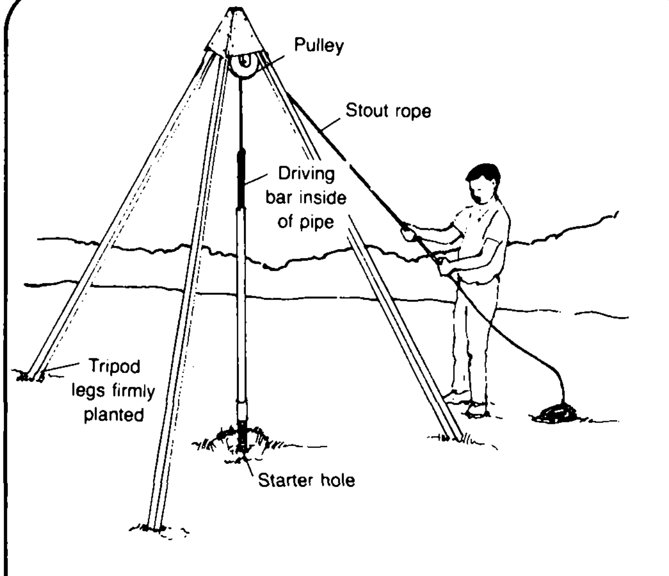

Figure 8. Driving with a Driving Bar

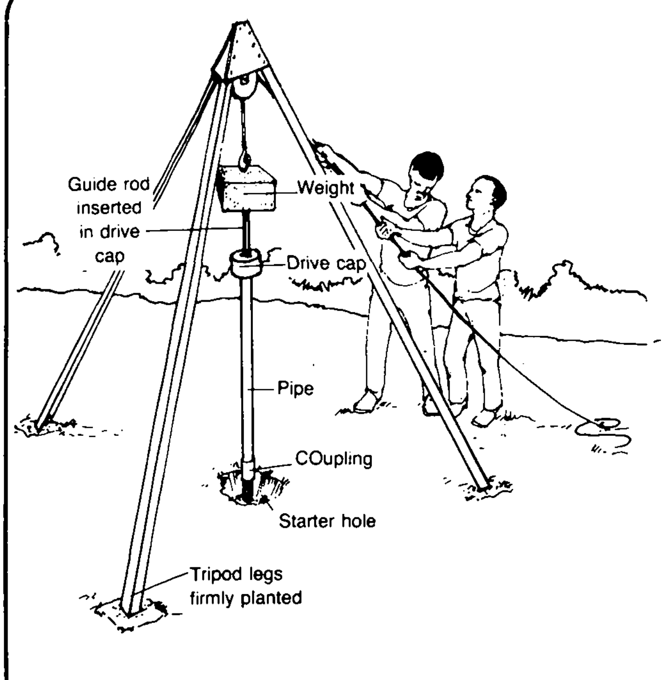

Figure 9. Driving with a Driving Weight

6. After each blow of the driving equipment, use a plumb bob and line to be certain that the well point and pipe are being driven perfectly vertical. Make minor adjustments as necessary. Also after each blow, use a pipe wrench to turn the pipe a fraction of a turn clockwise. This will ensure that the

couplings are well set and watertight. See Figure 10. If the well point and pipe get too far out of vertical to correct with minor adjustments, pull them out of the ground (see step 10) and re-start the driving operation.

7. Continue to drive the pipe. In the sledgehammer and weighted driver methods, the workers will eventually step down off the platform and drive while standing on the ground. When the pipe has been driven so far that further driving is impossible, add another section of pipe. See Figure 11.

7a. Sledgehammer and weighted driver. Unscrew the drive cap. Couple a section of pipe onto the section protruding from the ground. Screw the drive cap on top. Resume driving operations.

7b. Driving bar. Raise the driving bar and lift it out of the well pipe. Couple a section of pipe onto the sec-

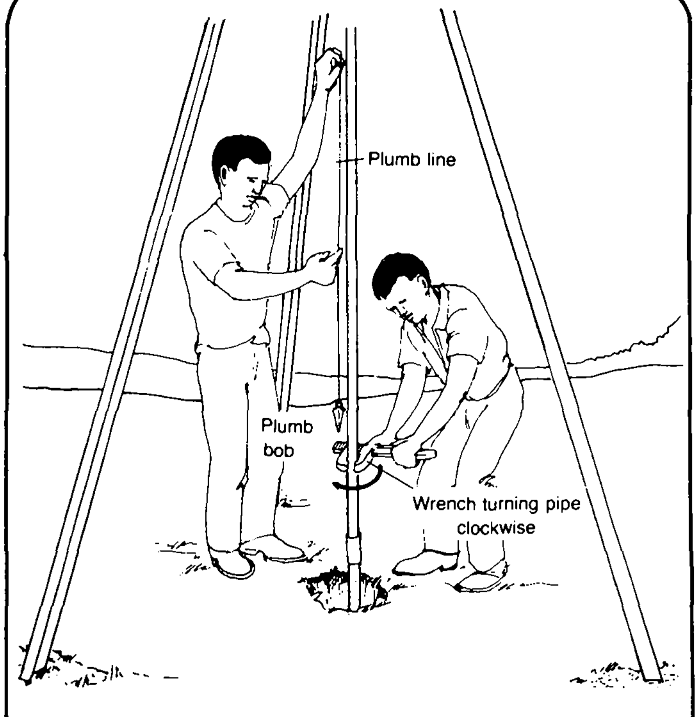

Figure 10. Turning Pipe and Checking for Plumb

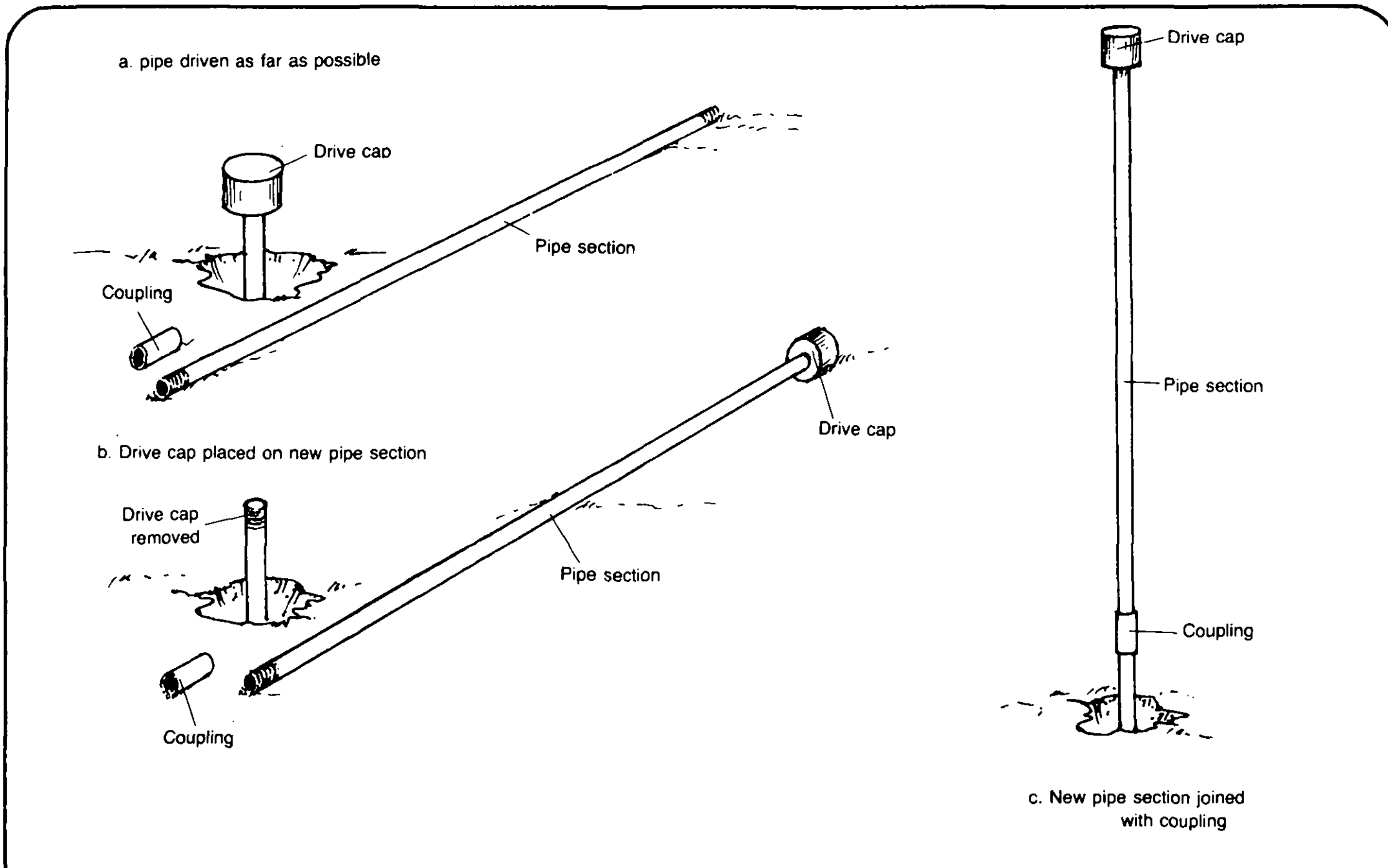

Figure 11. Adding a Pipe Section

tion protruding from the ground. Reinsert the driving bar into well pipe and resume driving operations.

7c. Driving weight (with guide rod attached). Raise the weight and lift guide rod out of pipe. Uncouple the drive cap, couple a section of pipe into the section in the ground, and couple the drive cap on top. Lower the weight and re-insert the guide rod. Resume driving operations.

7d. Driving weight (with hole for guide rod). Raise the weight and lift it off the guide rod. Uncouple the guide rod and drive cap, couple a section of pipe onto the section in the ground, and couple the guide rod and drive cap on top. Lower the weight onto the guide rod and resume driving operations.

8. Occasionally lower the plumb line into the pipe to determine whether the aquifer has been reached and ground water is entering the pipe. The well point should be driven as far below the water table as possible and still remain within the aquifer. The driving conditions will indicate the type of subsurface soil being penetrated as shown in Table 3.

9. When you have driven the well to the desired depth, remove the driving equipment. Use a pipe cutter to cut off the top section of pipe to the desired height. Thread the top end with a pipe threader to receive the base of a pump. To finish the well, see "Finishing Wells," RWS.2.C.8.

10. If you drive beyond the aquifer, you will want to raise the pipe and the well point back into it. If you do not reach water at the limits of your driving capabilities, you will want to raise the pipe and well point completely out of the ground. In either case, attach a pipe clamp to the pipe and use jacks or a lever to raise the pipe as shown in Figure 12. Once the pipe starts to come out of the ground, it can be raised the rest of the way by hand. Turning the pipe clockwise will help to raise it.

Table 3. Driving Conditions and Subsurface Soil

Type of formation	Driving conditions	Rate of descent	Sound of blow	Rebound	Resistance to rotation
Soft moist clay	Easy	Rapid	Dull	None	Slight but continuous
Tough hardened clay	Difficult	Slow but steady	None	Frequent	Considerable
Fine sand	Difficult	Varied	None	Frequent	Slight
Coarse sand	Easy (especially when saturated with water)	Unsteady, irregular penetration for successive blows	Dull	None	Rotation is easy and accompanied by a gritty sound
Gravel	Easy	Unsteady, irregular penetration for successive blows	Dull	None	Rotation is irregular and accompanied by a gritty sound
Boulder and rock	Almost impossible	Little or none	Loud	Sometimes of both hammer and pipe	Depends on type of formation

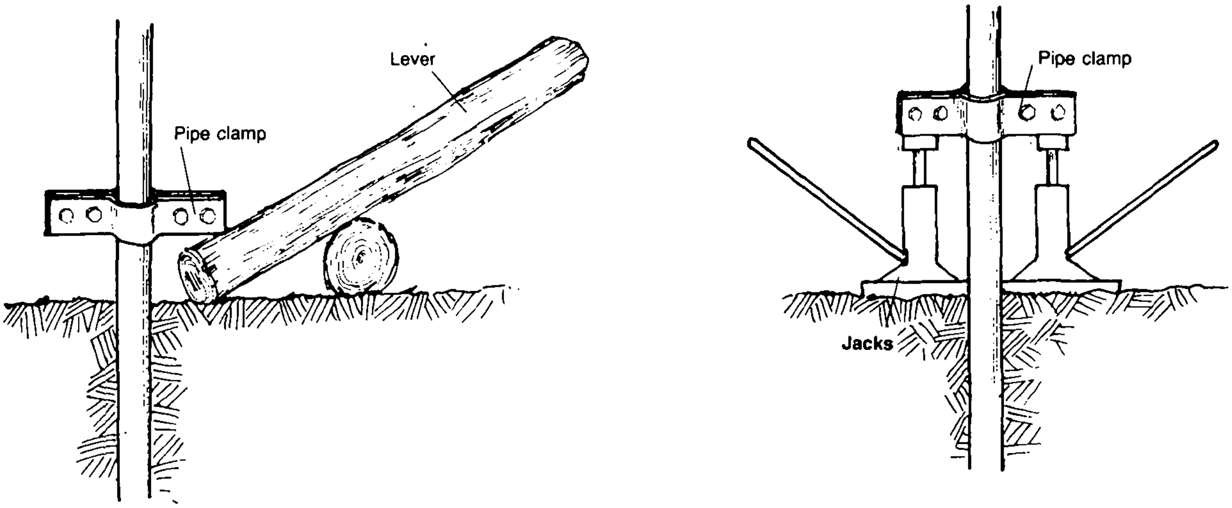

Figure 12. Raising a Pipe

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Constructing Jetted Wells
Technical Note No. RWS. 2.C.3

Constructing a jetted well correctly is important to ensure a year-round supply of water and to protect the water from contamination. Construction involves assembling all necessary personnel, materials, and equipment, preparing the site; jetting the well shaft; and installing the casing and screen. Finishing the well is discussed in "Finishing Wells," RWS.2.C.8.

This technical note discribes how to construct a jetted well. Read the entire technical note before beginning construction.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

WATER TABLE - The top, or upper limit, of an aquifer.

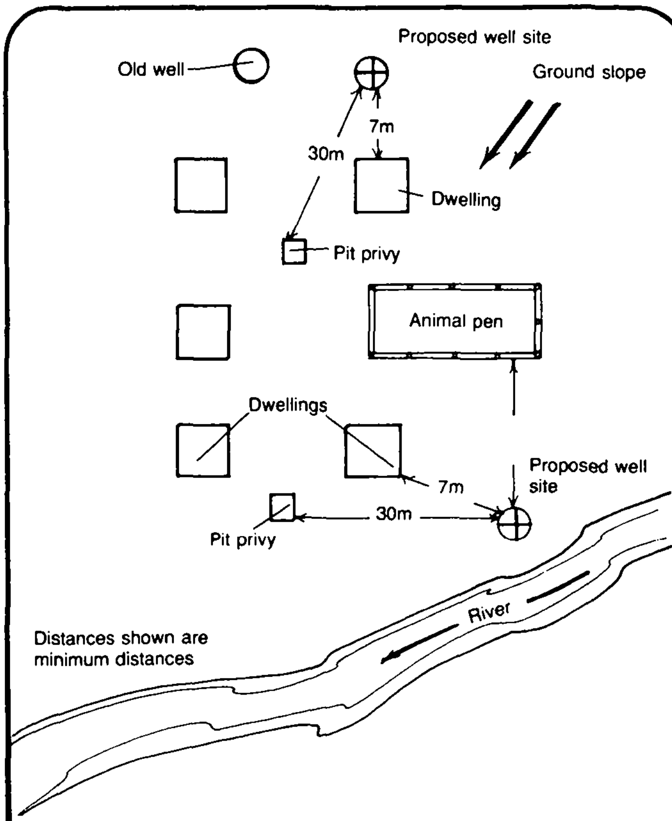

Figure 1. Location Map

Materials Needed

The project designer must provide three papers before construction can begin:

1. A location map similar to Figure 1.

2. A design drawing of the well screen similar to Figure 2.

3. A materials list similar to Table 1.

After the project designer has given you these documents and you have read this technical note carefully, begin assembling the necessary workers, supplies and tools.

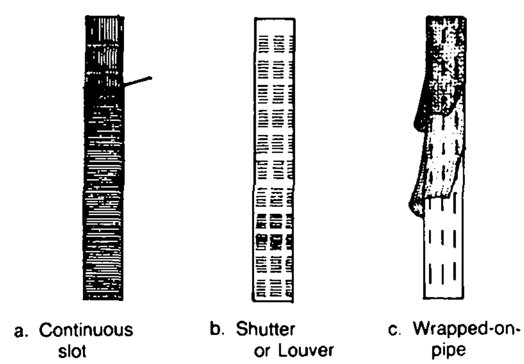

Figure 2. Well Screens

Table 1. Sample Materials List for a Jetted Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman Workers	1 3	___ ___
Supplies	Well screen (continuous-slot) Casing; 50mm diameter Plug for screen Concrete mix	___ ___m ___m3	___ ___ ___ ___
Equipment	Tripod Pulley Rope Drill pipe; 38mm diameter Jetting drill bit Pump (hand-operated) Hose Swivel hose connection Hose connections (standard) Pipe couplings Pipe wrenches Crescent wrenches Screwdrivers Pipe cutter Shovels Containers (for mixing concrete) Measuring tape Other	___ ___ ___ ___m ___m ___ ___ ___m ___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Total Estimated Cost = ___

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when specific workers, materials, and tools must be available during the construction process. Draw up a work plan similar to Table 2 showing construction steps.

Caution!

The well must be jetted at the exact location specified by the project designer.

Construction Steps

1. Using the location map and a measuring tape, locate the well site. Clear the area of any vegetation or debris that might interfere with work.

2. Assemble all laborers, materials, and equipment needed to begin construction.

3. Erect a sturdy tripod over the site. The tripod legs should be planted firmly in the ground, and the tripod should be tall enough to accommodate the sections of drill pipe and casing. Lower a plumb bob from the tripod's pulley to mark the exact point where the well will be jetted, and dig a starter hole about 1m deep.

4. Dig a settling pit to reuse jetted water 6-8m from the well site. The size of the pit depends on the size of the well to be jetted. For most wells, an adequate sized pit would be 1m deep, 1m wide, and 1-2m long. Dig a shallow, narrow trench sloping downward

Table 2. Sample Work Plan for a Jetted Well

Time Estimate	Day	Task	Personnel	Materials/Equipment
1 day	1	Locate and prepare site; assemble materials	Foreman (present during entire construction); 1-2 workers	Measuring tape, drawings
1 day	2	Erect tripod; dig starter hole; dig settling pit and trench	3 workers	Wood, hammer, saw, nails, shovels
1 day	3	Set up pump; attach suction hose; attach hose to drill pipe and bit; excavate shaft by jetting	3 workers	Pump, hoses, drill pipe, bit, couplings, swivel couplings, rope, pipe wrenches, crescent wrenches, screwdrivers
½ day	4	Remove drill pipe; set screen and casing in shaft; install plug	3 workers	Casing sections, couplings, well screen, plug
½ day	4	Pour gravel and concrete mix around outside of casing; fill in settling pit	3 workers	Gravel, concrete mix, containers, shovels

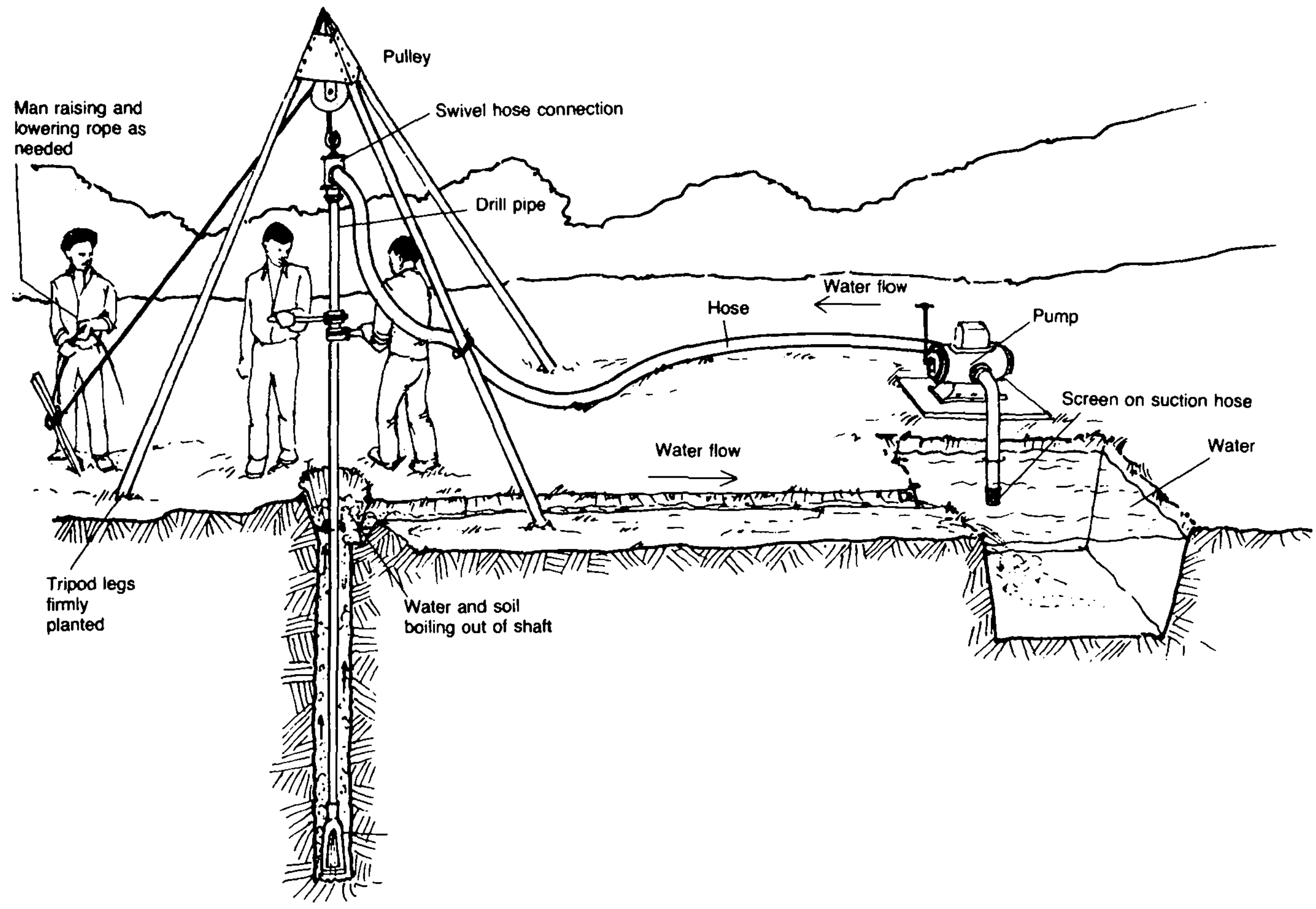

Figure 3. Jetting the Shaft

from the starter hole to the settling pit. Fill the settling pit with water. See Figure 3.

5. Set up the pump near the settling pit. Attach a length of hose with a screen to the suction end of the pump and lower it into the settling pit away from the trench.

6. Attach a length of hose to the outlet end of the pump. Fit a swivel hose connection on the other end of the hose and attach the first section of drill pipe. Attach a jetting bit on the end of the drill pipe. Lower a rope through the tripod's pulley, attach it to the swivel connection, and raise the drill pipe until it hangs vertically.

7. Have one or two workers grip the drill pipe with pipe wrenches. Start the pump.

8. The pump will begin to force water from the settling pit, through the hose, and out through the jetting bit. The workers should turn the drill pipe with the wrenches. The swivel hose connection will allow the pipe to turn without leaking water. The jetting action of the water and the rotating of the drill pipe and bit will cause the pipe to sink into the ground. Water and suspended matter will boil up around the sides of the drill pipe, then flow through the trench into the settling pit. The solid matter will settle and the water will be re-pumped. See Figure 3.

9. When the swivel hose connection nears ground level, that is, when the first section of drill pipe has been almost entirely sunk in the ground, shut off the pump. Disconnect the swivel connection, attach another section of pipe, and connect the swivel connection to the new section of pipe. See Figure 4.

10. Restart the pump and continue the jetting process. Add more sections of drill pipe as needed.

11. Drill through the water table and into the aquifer. You can tell when the aquifer has been reached by examining the suspended matter boiling up out of the well shaft. Compare the suspended matter with material that is known to be in aquifers in your region. Another indication that the aquifer has been reached is a noticeable drop in the level of the jetting water and an increase in the speed with which the shaft is being sunk.

12. When the shaft has been sunk to the desired depth, pull all sections of drill pipe out of the shaft. This may entail stopping and starting the pump. Disconnect the sections of drill pipe from the hose. See Figure 5.

13. Connect the hose to the first section of casing. Attach the well screen to the casing with the bottom end open. Raise the casing over the shaft with the rope and pulley. Lower the casing and screen into the shaft and start the pump. The water will jet out the bottom of the screen and wash out material that has fallen back into the shaft. The casing and screen should sink easily. See Figure 5.

14. When the first section of casing nears ground level, shut off the pump. Disconnect the hose, attach a new section of casing, and reconnect the hose to the new section. Restart the pump and continue to sink the casing. Add more sections of casing as needed.

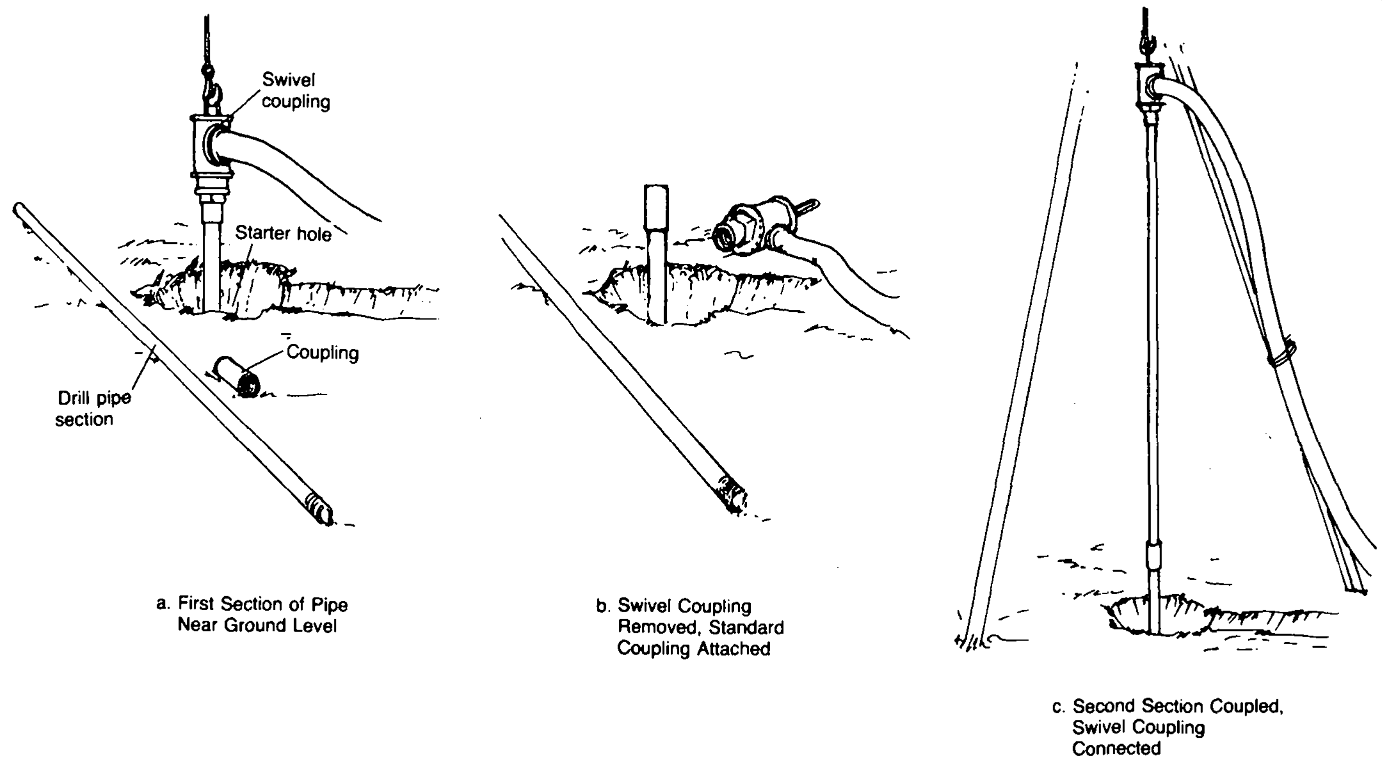

Figure 4. Attaching New Sections of Drill Pipe

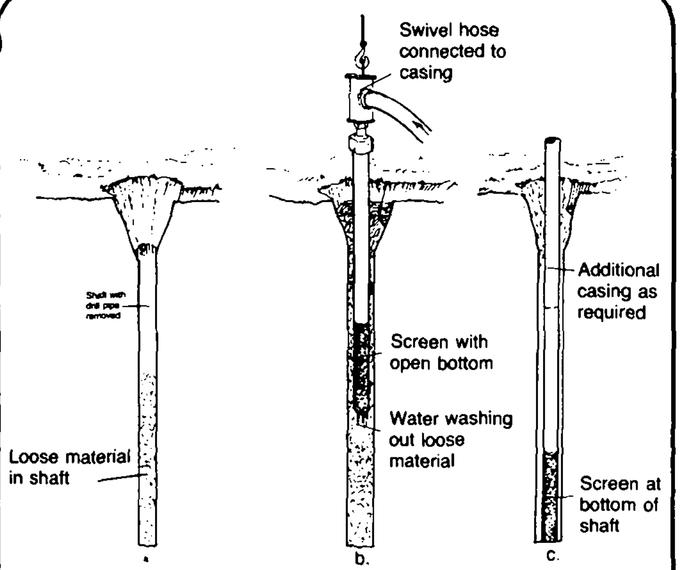

Figure 5. Placing the Screen and Casing

15. When the screen reaches the bottom of the shaft, shut off the pump and disconnect the hose. The casing should protrude about 0.5m above ground level, so part of it may now have to be cut off with a pipe cutter. Drop a pre-seated plug into the casing to seal the bottom of the screen. The plug should be made from concrete or other non-corrosive material. It will prevent aquifer material from entering the screen. See Figure 6.

16. Pour gravel or crushed rock around the outside of the casing and fill the last 3m with concrete mix, pouring it carefully around the outside of the casing.

17. Pump as much water as possible out of the settling pit and let it flow on the ground surface away from the well site. Fill in the settling pit with excavated soil.

18. To finish the well see "Finishing Wells," RWS.2.C.8.

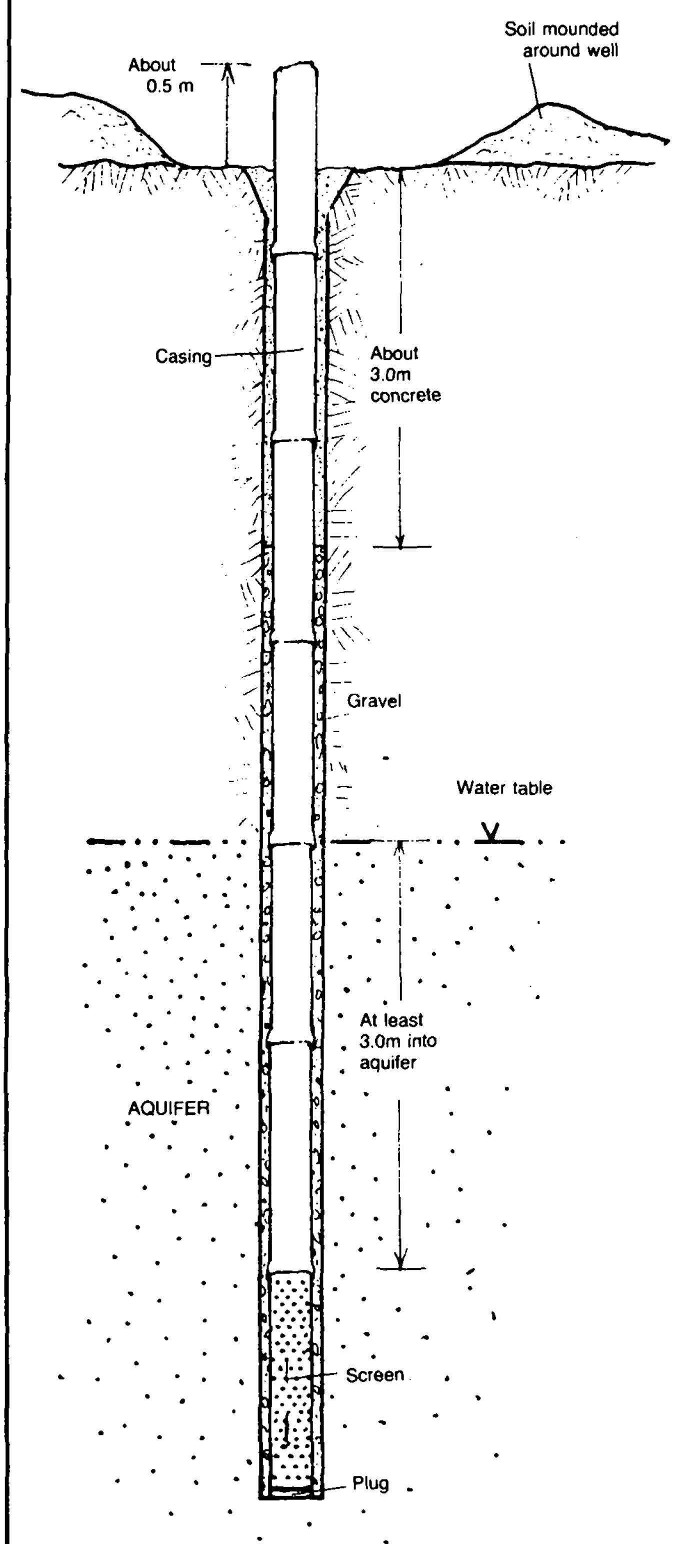

Figure 6. Casing Installed

Notes

Notes

Notes

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1982

Water for the World

Constructing Bored or Augered Wells
Technical Note No. RWS. 2.C.4

Constructing a bored or augered well properly is important to ensure a year-round supply of water and to protect the water from contamination. Construction involves assembling all necessary personnel, materials, and equipment; preparing the site; excavating the well shaft; and installing the casing and screen. Finishing the well is discussed in "Finishing Wells," RWS.2.C.8.

This technical note describes how to construct a bored well. Read the entire technical note before beginning construction.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

GROUND WATER - Water stored below the ground's surface.

WATER TABLE - The top, or upper limit, of an aquifer.

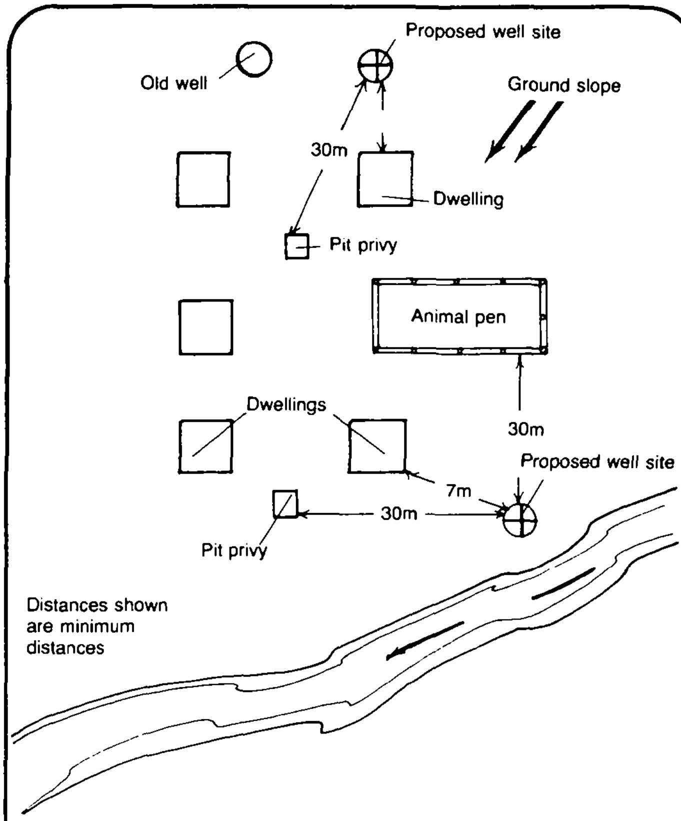

Figure 1. Location Map

Materials Needed

The project designer must provide four papers before construction can begin:

1. Location map similar to Figure 1.

2. Design drawing of the method of installing the casing similar to Figure 2.

3. Design drawing of the well screen similar to Figure 3.

4. Materials list similar to Table 1.

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when during the construction process specific workers, materials, and tools must be available. Draw up a work plan similar to the sample showing construction steps.

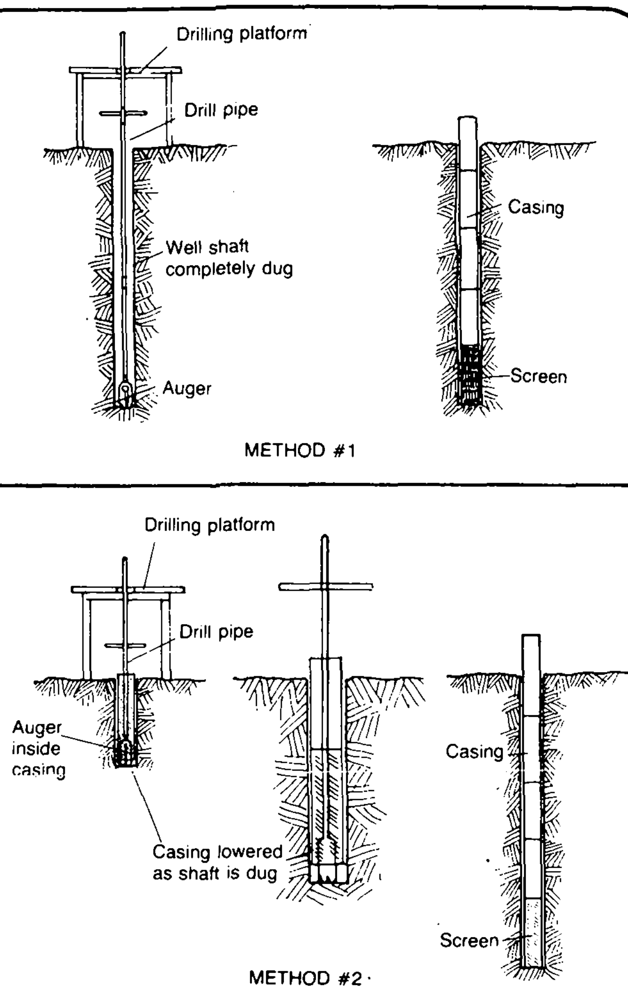

Figure 2. Installing the Casing

Table 1. Sample Materials List for Bored Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman Workers	1 3	____ ____
Supplies	Plastic pipe for casing (100mm diameter, 2.0m long) Plastic pipe with slots for screen Cement mix Sealing material Plug for screen	____ ____ ____ ____ ____	____ ____ ____ ____ ____
Equipment	Wooden platfrom Drill pipe (25mm diameter, 3.0m long) Joints for drill pipe Auger Sand auger Handle (adjustable) Shovel Hammer Hacksaw Wrenches Measuring tape Plumb bob and line	____ (×12)	____ (×12)

Total Estimated Cost = ____

Caution!

The well must be bored at the exact location specified by the project designer.

Construction Steps

1. Using the location map and a measuring tape, locate the well site. Clear the area of any vegetation or debris that might interfere with work.

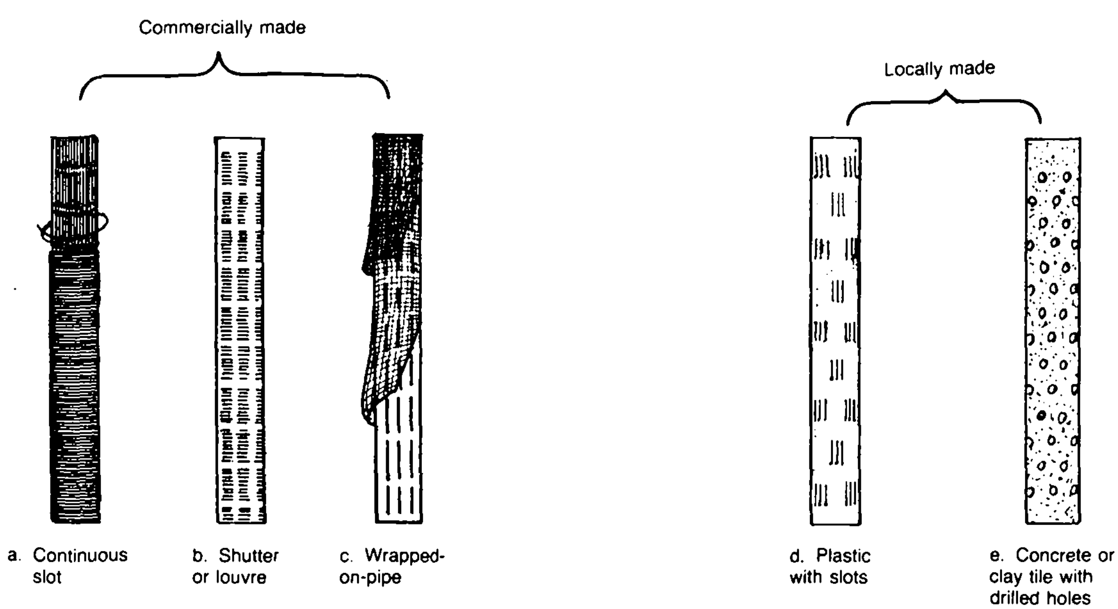

Figure 3. Well Screens

Table 2. Sample Work Plan for a Bored Well

Time Estimate	Day	Task	Personnel	Materials/Equipment
1 day	1	Locate and prepare site; assemble materials	Foreman (present during entire construction); 1-2 workers	Measuring tape; drawings
½ day	2	Erect platform; dig starter hole	3 workers	Wood, hammer, saw, nails, shovel
2½ days	2-4	Bore shaft until sides begin to crumble	3 workers	Auger, drill pipe, handle, pipe joints, wrenches
½ day	5	Remove auger and drill pipe; lower screen and casing; lower drill pipe with sand bailer	3 workers	Screen, casing, casing sealer, sand bailer
2½ days	5-7	Continue sinking shaft, screen, and casing into aquifer	3 workers	Screen, casing, casing sealer, sand bailer
1 day	8	Pour gravel and concrete mix around outside of casing; remove drilling pipe; install plug	3 workers	Gravel, concrete mix, plug

2. Assemble all laborers, materials, and equipment needed to begin construction.

3. Erect a sturdy platform over the site. The platform legs should be planted firmly in the ground. Mark the exact point where the well will be bored. If the drill pipe is to pass through a hole or notch in the platform, this point can be marked by lowering a plumb bob. Dig a starter hole about 0.5m deep and somewhat larger in diameter than the auger.

4. Attach the auger to the first section of drill pipe and set it in the starter hole. Attach the adjustable handle at about shoulder height. See Figure 4. Use a plumb bob and line to be certain that the drill pipe is vertical. Rotate the auger two or three turns or until it is full of soil, then lift it out of the hole and empty the soil. Use the excavated soil to build a mound around the shaft to drain away surface water as shown in Figure 5.

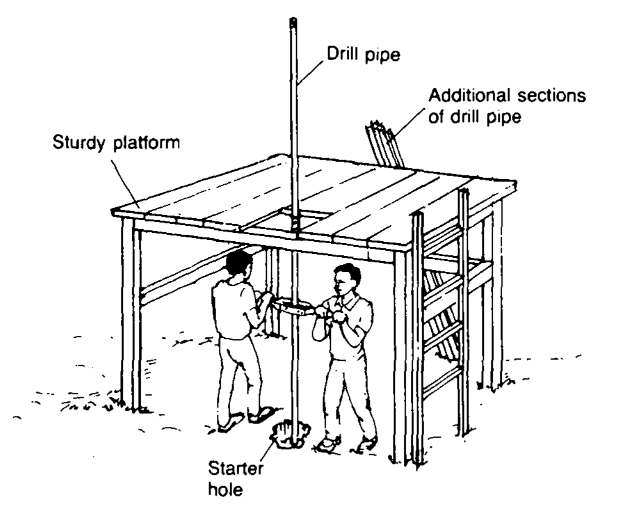

Figure 4. Boring the Shaft

As the shaft is sunk, the handle must be moved up on the drill pipe. When the handle nears the top of the drill pipe, attach another section of pipe using the pipe joint shown in Figure 6a.

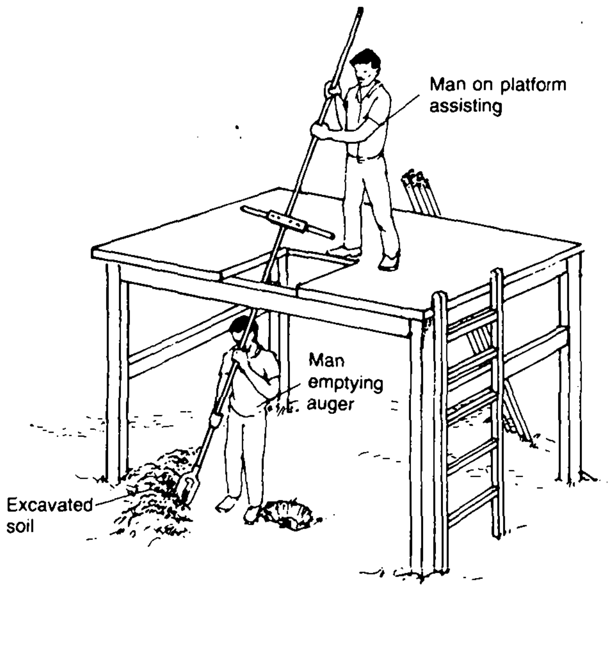

Figure 5. Emptying the Auger

5. When the shaft has been sunk far enough that another pipe section is needed, attach the pipe section with a pipe joint like the one in Figure 6b. Because more than two sections of drill pipe are difficult to handle when raised out of the shaft, continue boring in the following manner:

5a. Rotate the auger until it fills with soil. See Figure 7a.

5b. Raise the drill pipe until joint "B" is at ground level. Slide a support rod through the hole in the joint to prevent the drill pipe from falling into the well shaft. See Figure 7b.

5c. Disconnect the upper section of drill pipe and lean it against the platform. See Figure 7c.

5d. Raise the remaining drill pipe out of the shaft and empty the auger. See Figure 7d.

5e. Lower the drill pipe into the shaft until it is resting on the support rod through joint "B."

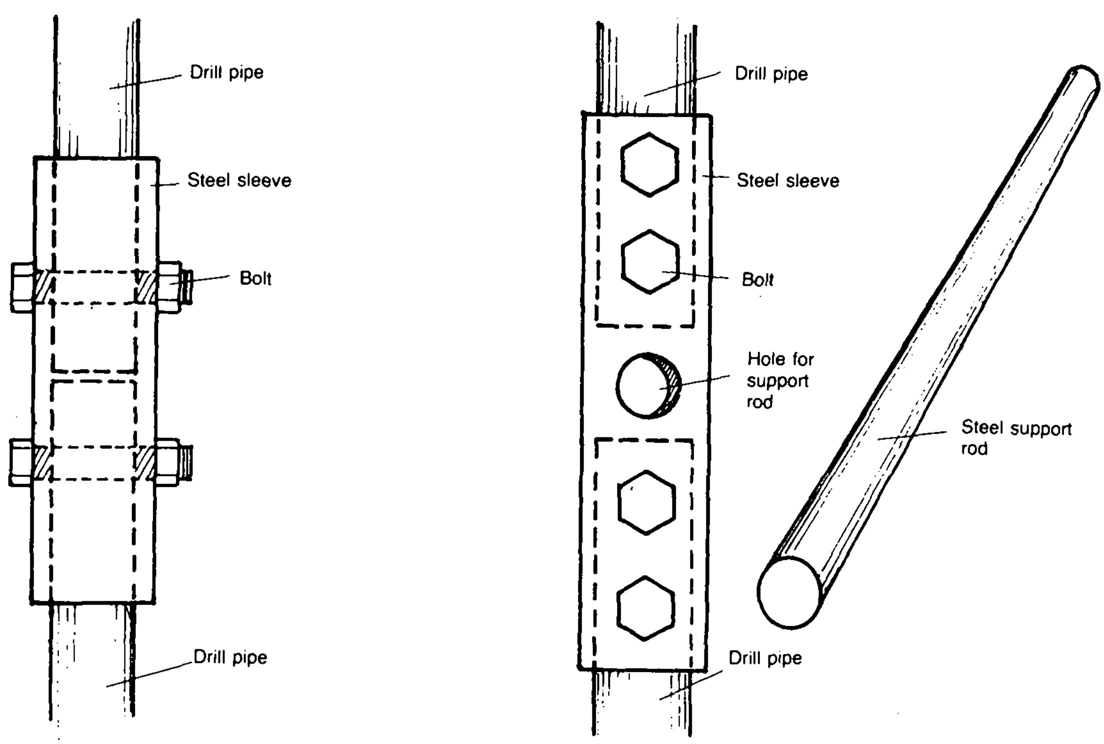

Figure 6. Drill Pipe Joints

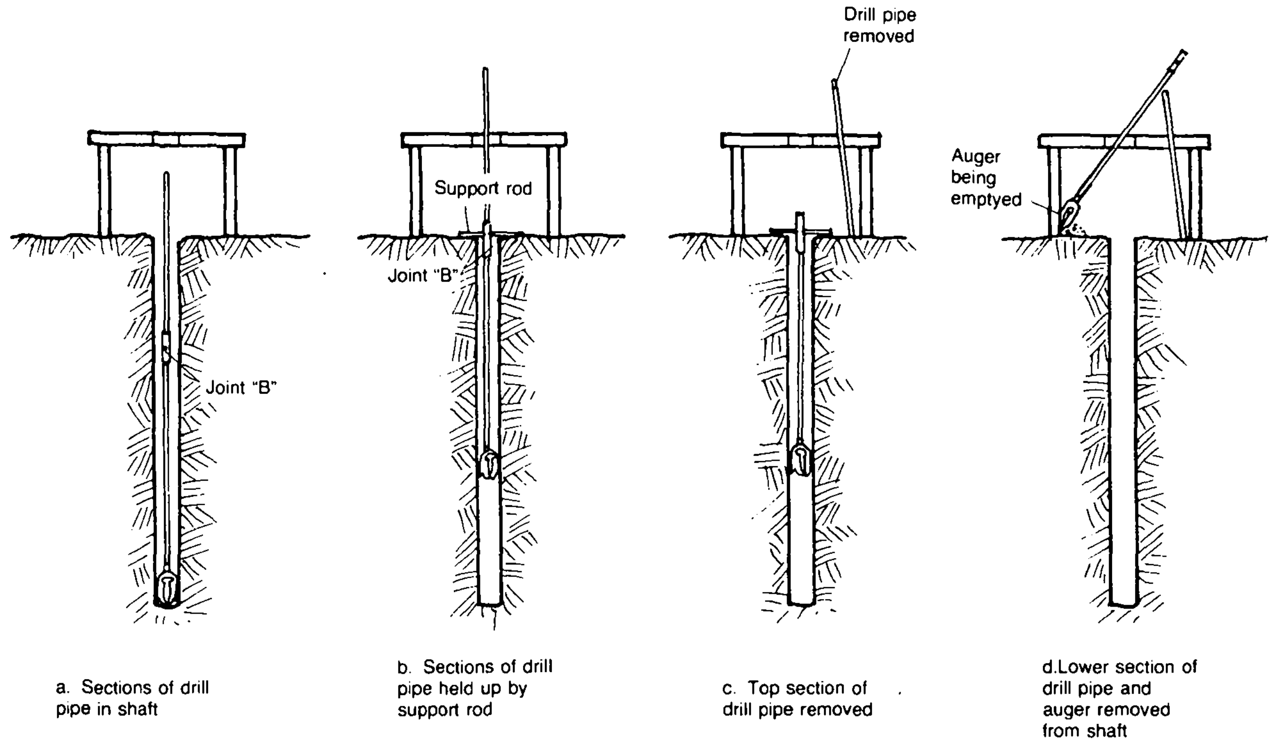

Figure 7. Disconnecting Drill Pipe to Empty Auger

5f. Reconnect the upper section of drill pipe, lower the auger to the bottom of the shaft, and continue boring.

6. If the sides of the shaft tend to cave in or crumble, remove the auger and drill pipe from the shaft. Lower the screen and casing into the shaft. A device for lowering concrete pipe casing is shown in Figure 8. If concrete pipes are used, spread mortar on each pipe section before lowering, and lower the pipe with the bell-end down.

If plastic pipe is used for the casing, the sections are light enough to be joined and bonded together at the surface and lowered into the shaft by hand.

7. Replace the auger with a sand bailer or an auger that fits inside the casing. Lower the bailer or auger and drill pipe into the casing and continue boring. See Figure 9. As the shaft is sunk, the casing will move down and more sections of casing will have to be added on top.

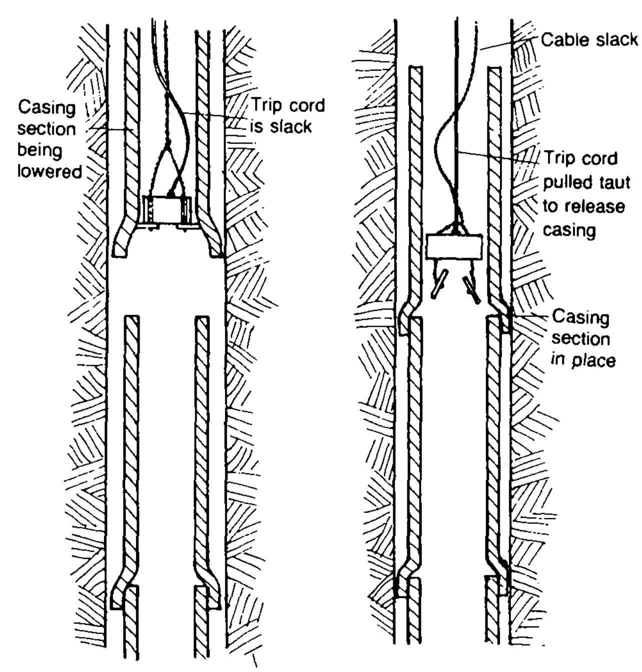

Figure 8. Lowering Casing Sections

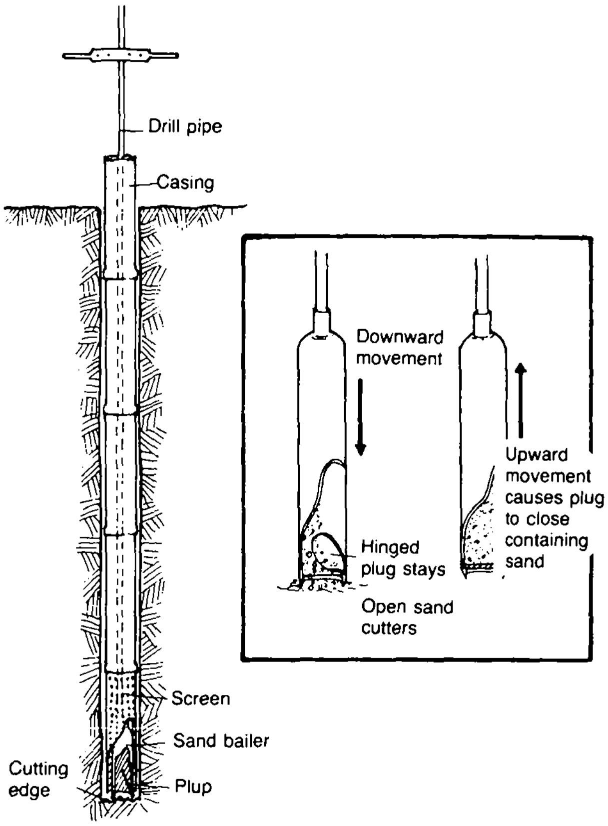

Figure 9. Excavating within Casing with Sand Bailer

8. When the shaft reaches the water table, the soil or sand brought to the surface will show signs of moisture. Continue to sink the shaft into the aquifer until the screen is at least 3.0m below the water table. Allow the top of the casing to protrude about 0.5m above ground.

9. Pour gravel or crushed rock around the outside of the casing to within about 3m from the ground surface. Fill this last 3m with concrete mix, pouring it carefully around the outside of the casing. See Figure 10.

10. Remove the auger and drill pipe from the casing. Lower or drop in a plug to seal the bottom of the screen. The plug will prevent aquifer material from entering the screen. It should be made from concrete or other non-corrosive material.

11. To finish the well see "Finishing Wells," RWS.2.C.8.

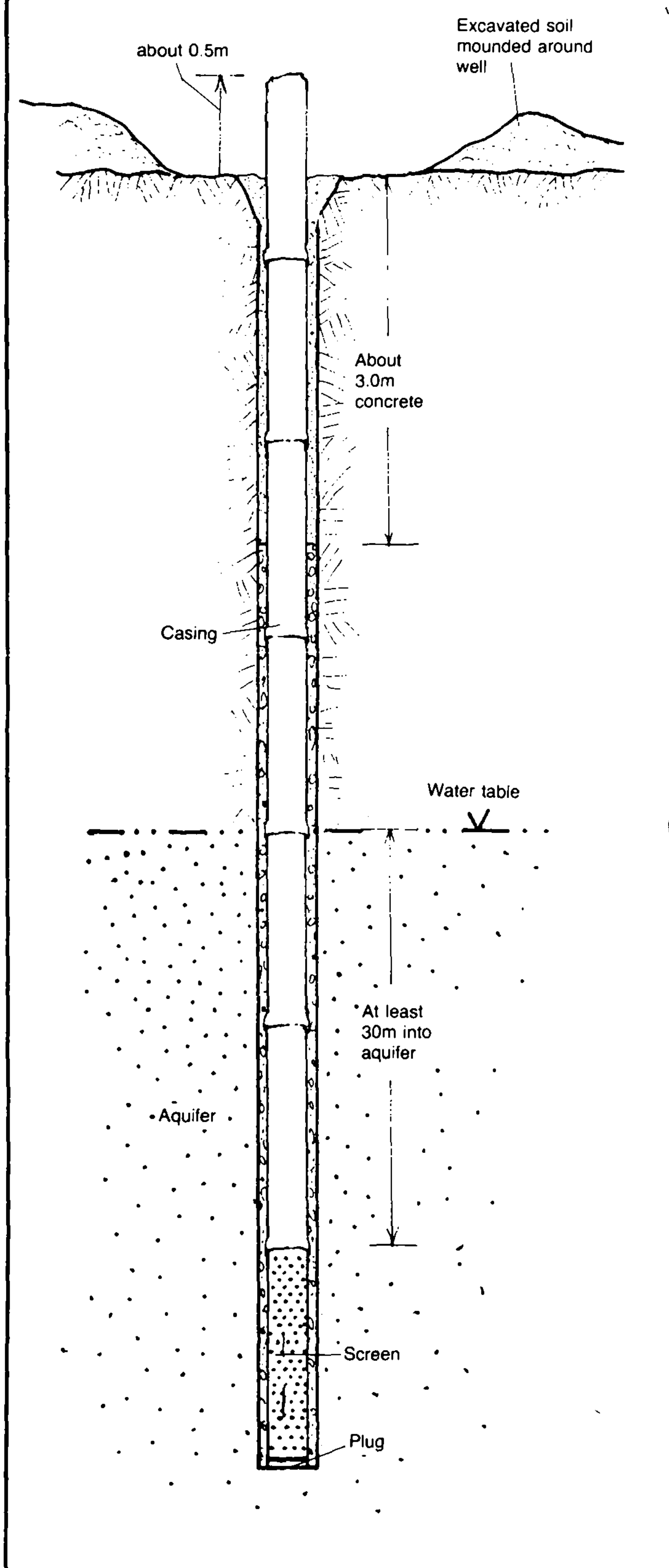

Figure 10. Casing Installed

Notes

Notes

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1982

Water for the World

Constructing Cable Tool Wells
Technical Note No. RWS. 2.C.5

Properly constructing a cable tool well, also called a percussion drilled well, is important to ensure a year-round supply of water and to protect the water from contamination. Constructing involves assembling all necessary personnel, materials, and equipment; preparing the site; drilling the well shaft; and installing the casing and screen. Finishing the well is discussed in "Finishing Wells," RWS.2.C.8.

This technical note describes how to construct a cable tool well. Read the entire technical note before beginning construction.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

CATHEAD - Metal hub bolted to a vehicle brake drum.

WATER TABLE - The top or upper limit, of an aquifer.

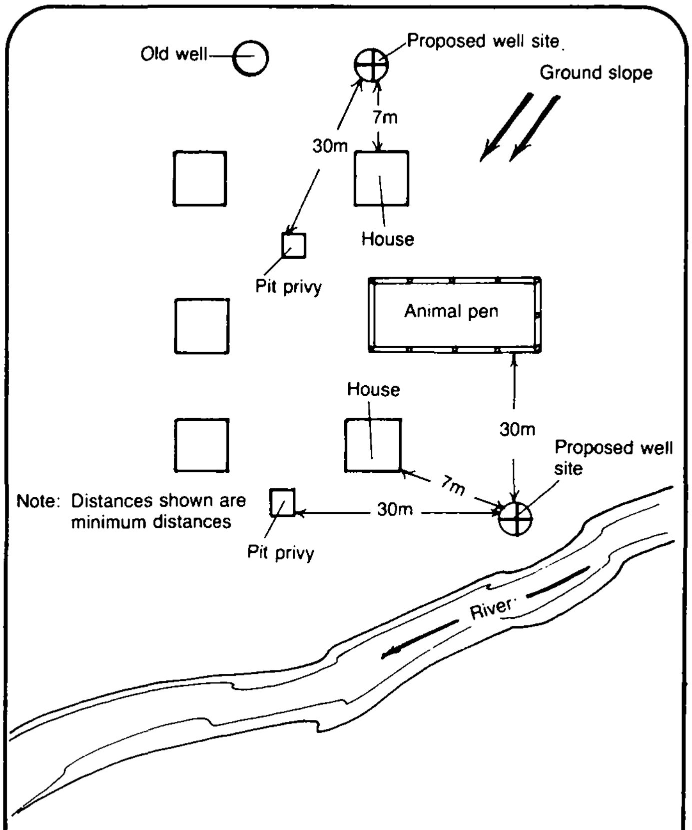

Figure 1. Location Map

Materials Needed

The project designer must provide four papers before construction can begin:

1. A location map similar to Figure 1.

2. A design drawing of the method of drilling similar to Figure 2.

3. A design drawing of the well screen similar to Figure 3.

4. A materials list similar to Table 1.

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when specific workers, materials, and tools must be available during the construction process. Draw up a work plan similar to Table 2 showing construction steps.

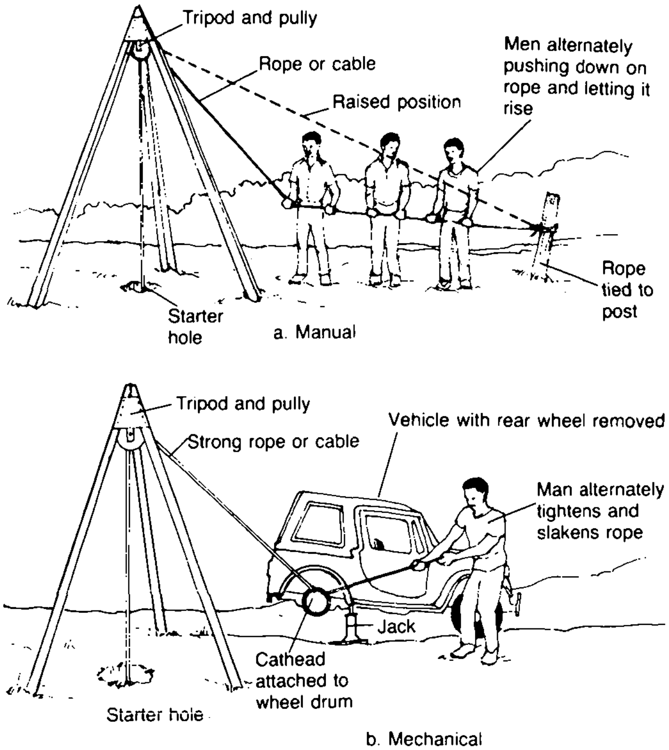

Figure 2. Methods of Drilling

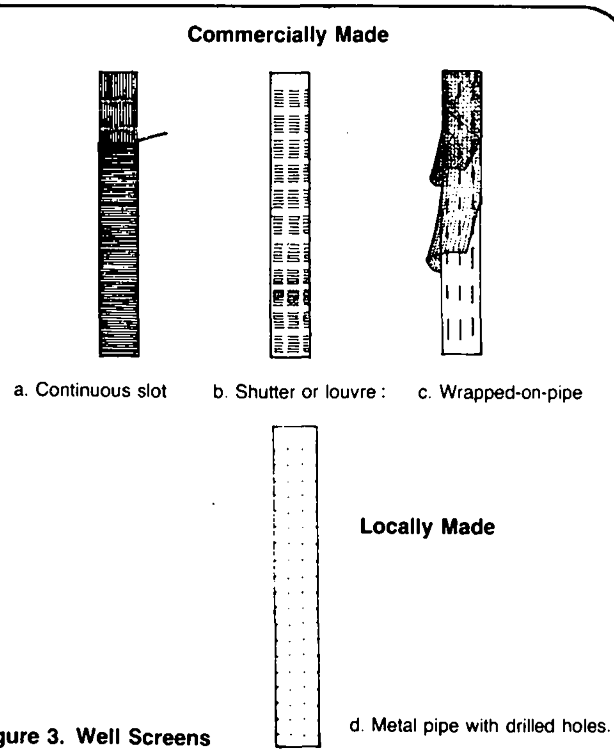

Figure 3. Well Screens

Table 1. Sample Materials List for a Cable Tool Well

Item	Description	Quantity	Estimated Cost
Personnel	Foreman	1	___
	Blacksmith	1	___
	Workers	10	___
Supplies	Steel pipe section for casing; (75mm diameter, 2.0m long)	___	___
	Pipe couplings	___	___
	Well screen	___	___
	Plug to seal bottom of screen	___	___
	Cement mix	___ m^3	___
Equipment	Tripod and pulley	___	___
	Heavy-duty ropes; each 50m long	___	___
	Percussion bit; 100mm x 1.5m long; 80kg	___	___
	Hollow rod bit; 100mm diameter; 1.0m long	___	___
	Bailer; 50mm diameter, 1.0m long	___	___
	Fishing tool	___	___
	Anvil	___	___
	Hammers (blacksmith)	___	___
	Hacksaw	___	___
	Metal files	___	___
	Wrenches	___	___
	Screwdrivers	___	___
	Shovels	___	___
	Measuring tape	___	___
	Plumb bob and line	___	___
	Other	___	___

Total Estimated Cost = ___

Caution!

1. The well must be drilled at the exact location specified by the project designer.

2. If the well is being drilled with a motorized cathead, an experienced worker is needed and care should be taken to avoid injuries.

Construction Steps

1. Using the location map and a measuring tape, locate the well site. Clear the area of any vegetation or debris that might interfere with work.

2. Assemble all laborers, materials, and equipment needed to begin construction.

3. Erect a sturdy tripod over the site and plant the legs firmly in the ground. Mark the exact point where the well will be drilled by lowering a plumb bob from the tripod's pulley. If the ground can be worked with a shovel, dig a starter hole 0.5m deep. See Figure 4.

4. Secure one end of the rope or cable to the percussion bit and run the rope over the pulley.

Table 2. Sample Work Plan for a Cable Tool Well

Time Estimate	Day	Task	Personnel	Materials/Equipment
1 day	1	Locate and prepare site; assemble materials	Foreman (present during entire construction); 3-5 workers	Measuring tape; drawings
½ day	2	Erect tripod; dig starter hole; attach percussion bit; fix rope to tree	3-5 workers	Tripod, pulley, rope, percussion bit, shovels
8 days	2-10	Begin excavating and bailing	10 workers	Bailer
½ day	10	Lower well screen and casing	10 workers	Well screen, casing sections, couplings
1 day	11	Excavate from within casing	10 workers	Bailer
1 day	12	Install plug; pour gravel and concrete mix around outside of casing	10 workers	Plug, concrete mix, containers, shovels

4a. In the manual method, drive a post securely in the ground 8-10m from the well site and find a convenient tree. Tie the rope to the post or tree at about shoulder height or slightly lower. Line up three to five workers along the rope line.

4b. In the mechanical method, park a jeep or truck 4-6m from the well site, jack up the rear end, and put rocks in front of the tires. Remove the rear wheel, bolt a cathead to the brake drum, and grease the cathead. Wrap the rope one turn around the cathead, and pull the loose end away from the well site. See Figure 4.

5. Begin sinking the shaft by raising and dropping the percussion bit. In the manual method, have the workers press down on the rope, then quickly raise up. In the mechanical method, start the engine and engage the cathead to set it spinning; pull taut the loose end of the rope to raise the bit, then let the rope go slack to drop the bit. In both methods, rapid and short strokes of about 0.5m seem to work best. See Figure 4.

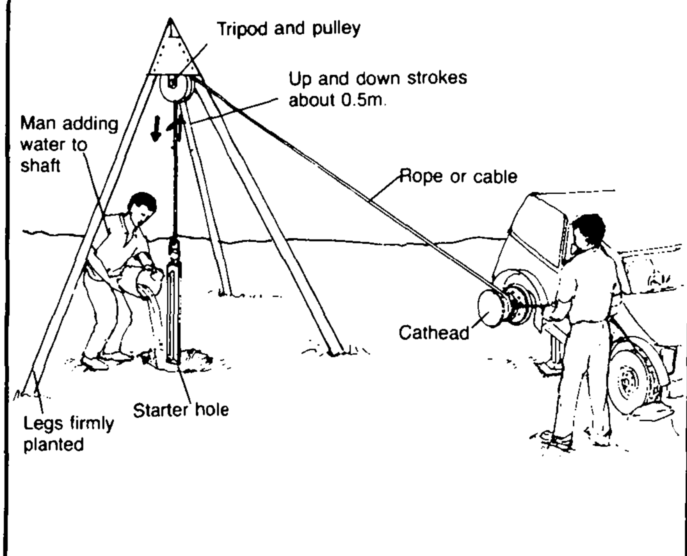

Figure 4. Drilling the Shaft

When the shaft is first being sunk, take extra care to be certain it is vertical. Check the shaft frequently with a plumb bob. As it deepens, the hole will guide the bit.

6. Add a little water to the shaft so that the cuttings will form a paste. This will make bailing operations more efficient.

7. Eventually the paste of cuttings and water will accumulate and prevent the precussion bit from coming in contact with the bottom of the shaft. Exactly when this begins to occur is a matter of experience and judgment. When it does happen, stop drilling and begin bailing. See Figure 5.

8. Remove the percussion bit from the shaft, lay it on the ground, and unfix the rope or cable. Attach the rope to the bailer, lower the bailer in the shaft, and begin raising and dropping it to pick up the debris in the hole. When the bailer is full or is no longer picking up material, remove it from the shaft and empty it. Continue bailing the shaft until little or no material is being picked up.

9. Remove the bailer from the shaft and detach it from the rope. Attach the percussion bit, lower it into the shaft, and continue drilling. Continue the process of alternately drilling or bailing until you reach the aquifer. If at any time the rope breaks, it can be retrieved from the shaft with a fishing tool as shown in Figure 6. Pull up the bit or bailer, repair or replace the rope, and continue drilling.

10. It may be that before you reach the water table, you encounter a loose, non-caving underground formation. If so, a hollow rod bit, as shown in Figure 6, can be used effectively in place of the percussion bit and bailer. Use longer strokes for the hollow rod bit, about 1 or 2m. When the bit fills or partially fills with soil, remove it from the shaft and empty it. Continue using this bit until you encounter harder formations. Then switch back to the percussion bit and bailer until you encounter the aquifer or another loose, caving formation.

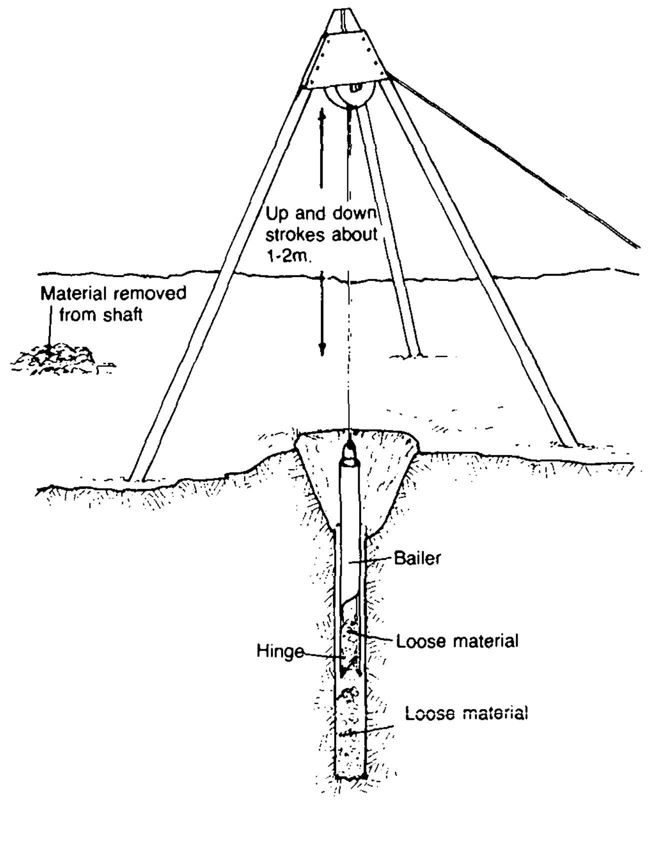

Figure 5. Bailing the Shaft

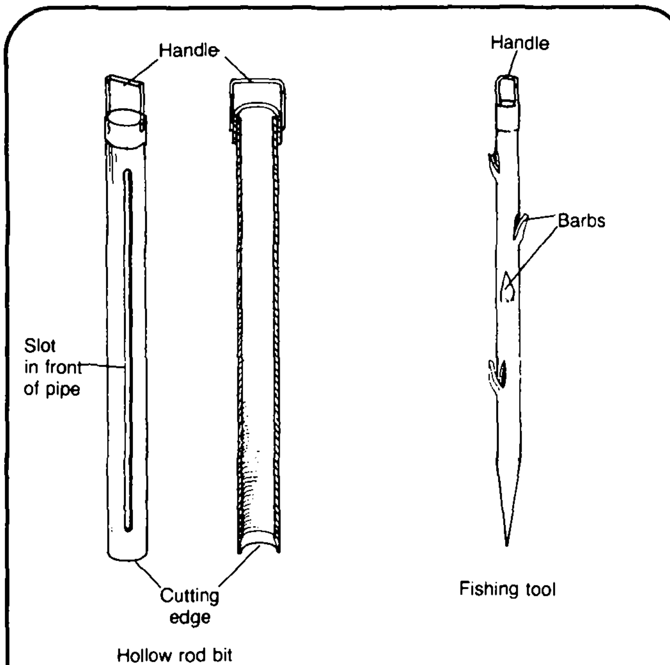

Figure 6. Detail of Hollow Rod Bit and Fishing Tool

11. When you encounter a caving formation, as will be the case with most aquifers, remove the bit or bailer from the shaft. Lower the well screen, with the bottom end open, and sections of casing into the shaft. Attach the bailer to the rope, lower it inside the casing, and continue excavating. The screen and casing should sink as the loose, aquifer material is removed. Add more sections of casing as necessary. See Figure 7.

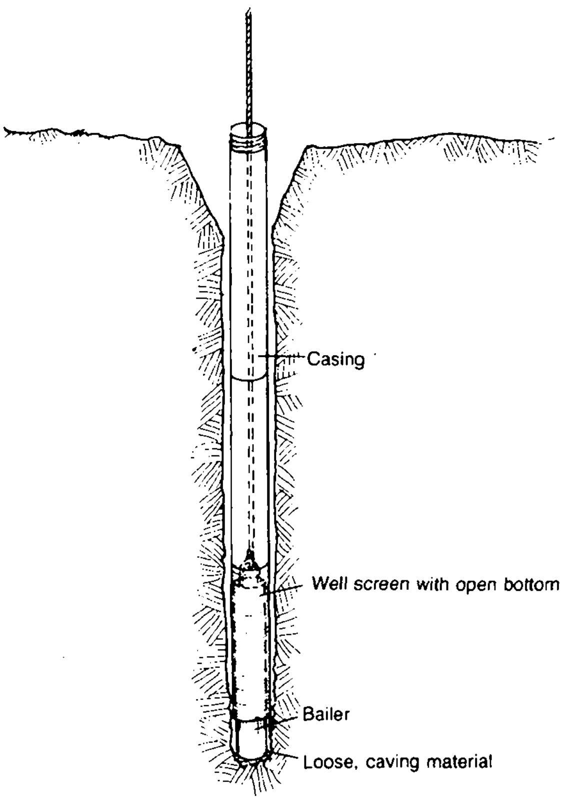

Figure 7. Excavating within the Casing

12. When the well screen and casing have been sunk into the aquifer to the desired depth, remove the bailer from the casing. The casing should protrude about 0.5m above ground level, so part of it may now have to be cut off with a pipe cutter. Drop a pre-seated plug into the casing to seal the bottom of the screen. The plug will prevent aquifer material from entering the screen. The plug should be made from concrete or other non-corrosive material. See Figure 8.

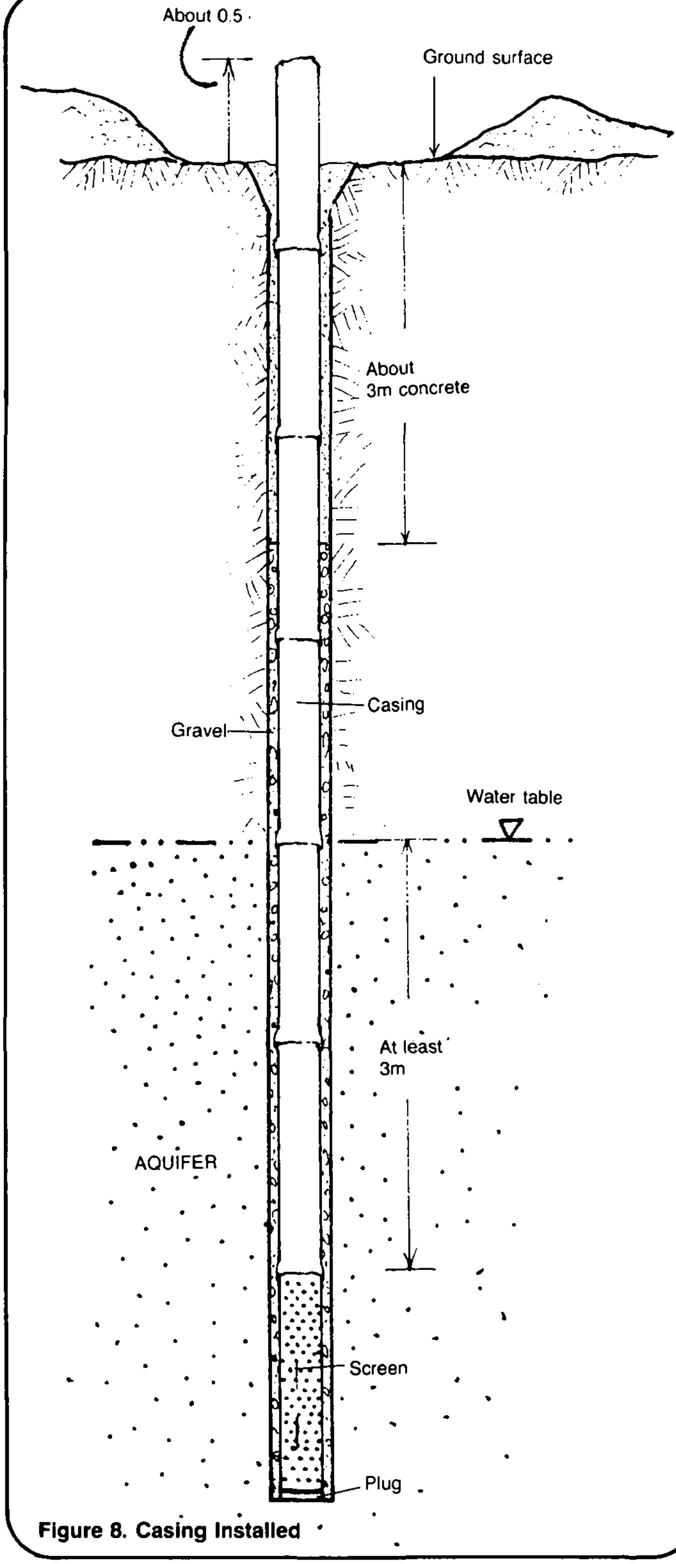

Figure 8. Casing Installed

13. Pour gravel or crushed rock around the outside of the casing and fill the last 3m with concrete mix, pouring it carefully around the outside of the casing.

14. To finish the well see "Finishing Wells," RWS.2.C.8.

Notes

Notes

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1982

Water for the World

Maintaining Well Logs
Technical Note No. RWS. 2.C.6

A well log is a complete record of drilling a well. Maintaining a drilling log is important to record the basic data from a well for future reference and to aid in the designing of new wells. Maintaining a log involves recording information on the physical characteristics of the well, the soil formations encountered during construction, and the yield of the well.

This technical note describes how to maintain a well log. Read the entire technical note before recording information in the log.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

DRAWDOWN - The distance between the water table and the water level in a well during continued pumping.

SPECIFIC CAPACITY - The yield of a well divided by the drawdown.

STATIC LEVEL - Measured distance to the water level in a well before pumping.

WATER TABLE - The top, or upper limit, of an aquifer.

YIELD - The volume of water that can be pumped during a specific period of time.

A well log can be kept on a blank sheet of paper or on a form like the sample shown in Table 1. The following numbered steps correspond to the numbered items in Table 1.

(1) Indicate the location of the well. For example, "southeast corner of Hernandez lot." Draw a location map on the back of the log showing the distances from the well to privies, dwellings, property lines, and other permanent reference markers such as large trees rocks or outcrops. Refer to the location maps shown in the technical notes on construction of wells. If you can use the map provided by the project designer, you need not draw a new one.

(2) Record the owner of the well. For example, "Raoul Hernandez." If it is a community well or if there is more than one owner, write this information on the line after 'owner's name.'

(3) Record the driller's name or the name of the construction foreman or the name of the company that drilled the well. For example, "Yusuf al-Nahis, construction foreman."

(4) Record the date that construction of the well began. For example, "17 June 82."

(5) Record the date that construction was completed, including the installation of the casing and well screen or intake section. For example, "24 June 82."

(6) Record the number of workers that were needed to construct the well. For example, "4."

(7) Indicate whether the well is a hand dug, driven, jetted, bored, or cable tool well. For example, "bored well."

(8) Record the diameter of the well. For example, "100mm."

(9) Record the depth of the well. For example, "27m."

(10) Record the types of soil encountered as the well was dug, the depths at which the soil types were encountered, and the thickness of each soil layer. For example, "topsoil/0-0.5m/0.5m; unconsolidated-small rocks/0.5-12.5m/12.0m; clay/12.5-13.0m/0.5m; coarse gravel/13.0-15.0m/2.0m." If this is a test well, or if you anticipate designing and constructing a number of new wells, it may be useful to collect samples of each type of soil and place them in labeled containers for future reference.

(11) Record the aquifer formation. For example, "coarse sand."

(12) Record the depth to the water table, the top of the aquifer. For example, "15m."

(13) Record the distance that the well was sunk below the water table. For example, "12m."

(14) Record the type of material used for casing. For example, "plastic pipe; sections 2.0m long, 100mm diameter."

(15) Record the type of well screen or intake section. For example, "plastic pipe with slots."

(16) Record the type of pump or water-lifting device. For example, "deep well force pump."

(17) Record the static level of the water in the well. For example, "15.75m." This measurement is made from a fixed reference point, and it is the first step in testing the yield of the well. See "Testing the Yield of Wells," RWS.2.C.7.

(18) Record the data obtained from testing the well yield. Generally, tests are made for yield, drawdown, and specific capacity. These tests are done at one-third, two-thirds, and full capacity of the pump. For example, "one-third capacity: yield = 60 liters/min., drawdown = 2.50m, specific capacity = 24.0 liters/min./m; two-thirds capacity: yield = 120 liters/min., drawdown = 5.50m, specific capacity = 21.8 liters/min./m; full capacity: yield = 180 liters/min., drawdown = 8.75m, specific capacity = 20.6 liters/min./m."

(19) Record the time it takes for the water level to rise completely to the static level after testing the pump at full capacity. For example, "14 hours."

(20) Note and record the quality of the water after the tests; that is, whether it is clear, cloudy, or turbid, heavily clouded with sediment. For example, "clear."

(21) Was the well disinfected? Answer "yes" or "no".

(22) If the well was disinfected, record the type of chlorine compound used. For example, "chlorine bleach with 5 percent available chlorine."

(23) Record the amount of chlorine compound used. For example, "0.2 liters."

When the well log has been completed, file it in a safe place for future reference.

Table 1. Sample Well Log

(1) Location of well (draw map): southeast corner of Hernandez lot

(2) Owner's name: Raoul Hernandez

(3) Driller's name: Yusuf al-Nahis, construction foreman

(4) Date drilling started: 17 June 82

(5) Date completed: 24 June 82

(6) Number of workers: 4

(7) Type of well: bored well (8) Diameter: 100mm (9) Depth: 27m

(10)

Soil formation encountered	Depth encountered	Thickness
a. topsoil	0 - 0.5m	0.5m
b. unconsolidated - small rocks	0.5 - 12.5m	12.0m
c. clay	12.5 - 13.0 m	0.5m
d. coarse gravel	13.0 - 15.0m	2.0 m
e.		

(If more space needed, use back of page.)

(11) Aquifer formation: coarse sand

(12) Depth to water table: 15m (13) Depth of well below water table: 12m

(14) Casing material: plastic pipe; sections 2.0m long, 100mm diam.

(15) Type of screen or intake: plastic pipe with slots

(16) Type of water-lifting device: deep well force pump

(17) Static level (water level before pumping measured for reference point): 15.75m

(18)

	One-third pump capacity	Two-thirds capacity	Full capacity
Yield	60 liters/min.	120 liters/min.	180 liters/min.
Drawdown	2.50 m	5.50 m	8.75m
Specific capacity	24.0 liters/min./m	21.8 liters/min./m	20.6 liters/min./m

(19) Time to fully recover to static level: 14 hours

(20) Water quality after tests: clear

(21) Was well disinfected? yes

(22) If yes, chlorine compound: Chlorine bleach (5% available chlorine)

(23) Amount of compound: 0.2 liters

Notes

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1982

Water for the World

Testing the Yield of Wells

Technical Note No. RWS. 2.C.7

Testing the yield of a well is important to determine its capacity and to obtain information to help aid in selecting a permanent pump. See "Selecting Pumps," RWS.4.P.5. In addition, the yields of several test wells are sometimes compared to determine the best site for a supply well. Testing the yield of a well involves pumping the well at specific rates for specified periods of time, measuring drawdown in the well, and performing calculations. Some of the data obtained when testing the yield will be recorded in the drilling log. See "Maintaining Well Logs," RWS.2.C.6.

This technical note describes how to test the yield of a well. Read the entire technical note before beginning the testing process.

Useful Definitions

DRAWDOWN - The distance between the water table and the water level in a well during continued pumping.

SPECIFIC CAPACITY - The yield of a well divided by the drawdown at a specific pumped level expressed as liters per minute per meter.

STATIC LEVEL - The measured distance to the water level in a well before any pumping has taken place.

YIELD - The volume of water that can be pumped during a specific period of time expressed as liters per minute.

Materials Needed

For a fairly comprehensive test, you will need a pump that can operate continuously for one to four hours at varying pumping rates. You will also need a steel measuring tape, chalk, a large container of known capacity, and some way to record data.

Testing Yield

1. Measure the static level in the well before any pumping has taken place. If the pump is equipped with an air hose and gauge, the water level is measured by pumping air into the hose until all water in the hose has been expelled, then reading the gauge and converting air pressure to meters of water. If the pump does not have an air hose and gauge, the measurements must be made with a steel measuring tape. This technical note describes only the latter method.

Chalk the lower end of a steel measuring tape, fasten a weight to it so that it will hang straight, and lower it into the well about 1m below water level. This may take a few practice tries. Use the top of the well casing, or the base of the pump, or some other convenient mark as a reference point. Make all measurements from this point. Note the reading on the tape and pull the tape out of the well. The water line will be clearly visible on the wet end of the tape. Subtract the wet portion from the total reading to obtain the actual depth from the reference point to the static water level. See Figure 1.

For example, if the total reading, when the tape is in the well, is 17m and the "wet end" reading is 1.25m, then the actual depth equals:
17.00m - 1.25m = 15.75m

The static level is 15.75m. See Worksheet A, Lines 1-3.

2. Operate the pump for about one-third of its capacity for one to four hours. This will produce about one-third of the full drawdown. During the pumping, measure the yield of the pump by filling a container of known volume and recording the length of time it takes to fill it.

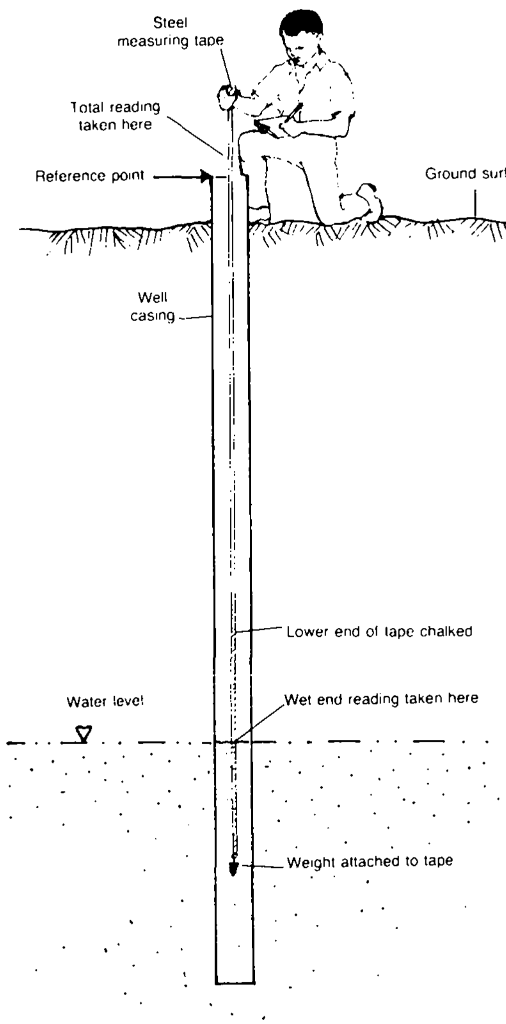

Figure 1. Measuring Water Level in a Well

For example, if the container holds 200 liters, and the pump requires 199 seconds to fill it, then the yield equals:

$\frac{200 \text{ liters}}{199 \text{ seconds}}$ = 1.0 liters/sec. x

60 sec./min. = 60 liters/min.

The yield is 60 liters per minute at one-third the pump's capacity.

3. Measure the water level in the same manner as before, and calculate the drawdown by subtracting the original depth of the static level from the new depth. Do not forget to first subtract the reading on the wet end of the chalked tape.

For example, if the new readings are 19.15m at the reference point and 0.90m at the wet end of the tape, then the new depth equals:

19.15m - 0.90m = 18.25m

The drawdown at this point equals:
18.25m - 15.75m = 2.50m

4. Calculate the specific capacity at this one-third drawdown point by dividing the yield by the drawdown.

$\frac{60 \text{ liters/min.}}{2.50\text{m}}$ = 24.0 liters per minute per meter. See Worksheet A, Lines 4-9.

5. Operate the pump for about two-thirds of its capacity for one to four hours. This will produce about two-thirds of the full drawdown. Measure the yield of the pump by filling a container and timing it as before.

For example, if the pump requires 100 seconds to fill a 200-liter container, the yield equals:

$\frac{200 \text{ liters}}{100 \text{ seconds}}$ = 2.0 liters/sec. x

60 sec./min. = 120 liters/min.

The yield is 120 liters per minute at two-thirds the pump's capacity.

6. Measure the water level in the same manner as before, and calculate the drawdown by subtracting the original depth of the static level from the new depth. Do not forget to first subtract the reading on the wet end of the chalked tape.

For example, if the new readings are 22.30m at the reference point and 1.05m at the wet end of the tape, then the new depth equals:
22.30m - 1.05m = 21.25m

The drawdown at this point equals:
21.25m - 15.75m = 5.50m

7. Calculate the specific capacity at this two-thirds drawdown point by dividing the yield by the drawdown.

$\frac{120 \text{ liters/min.}}{5.50\text{m}}$ = 21.8 liters per minute per meter. See Worksheet A, Lines 10-15.

8. Operate the pump at its full capacity for one to four hours. This will produce the maximum drawdown for the pump. Measure the yield of the pump by filling a container and timing it as before.

For example, if the pump requires 66 seconds to fill a 200-liter container, the yield equals:

$$\frac{200 \text{ liters}}{66 \text{ seconds}} = 3.0 \text{ liters/sec.} \times$$

60 sec./min. = 180 liters/min.

The yield is 180 liters per minute at the pump's full capacity.

9. Measure the water level in the same manner as before, and calculate the drawdown by subtracting the original depth of the static level from the new depth. Do not forget to subtract the reading on the wet end of the chalked tape.

For example, if the new readings are 25.35m at the reference point and 0.85m at the wet end of the tape, then the new depth equals:

25.35m - 0.85m = 24.50m

The drawdown at this point equals:

24.50m - 15.75m = 8.75m

Worksheet A. Calculating Yield, Drawdown, and Specific Capacity

Static Level

1. Total reading = 17.00 m
2. Wet end reading = 1.25 m
3. Static level = Line 1 - Line 2 = 17.00 m - 1.25 m = 15.75 m

Measurements at ONE-THIRD Pump Capacity

4. Yield = (200 liters) / (199 seconds) x 60 sec./min. = 1.0 liters/sec. x 60 sec./min. = 60 liters/min.
5. Total reading = 19.15 m
6. Wet end reading = 0.90 m
7. Water level = Line 5 - Line 6 = 19.15 m - 0.90 m = 18.25 m
8. Drawdown = Line 7 - Line 3 = 18.25 m - 15.75 m = 2.50 m
9. Specific capacity = Line 4 / Line 8 = (60 liters/min.) / (2.50 m) = 24.0 liters/min./m

Measurements at TWO-THIRDS Pump Capacity

10. Yield = (200 liters) / (100 seconds) = 60 sec./min. = 2.0 liters/sec. x 60 sec./min. = 120 liters/min.
11. Total reading = 22.30 m
12. Wet end reading = 1.05 m
13. Water level = Line 11 - Line 12 = 22.30 m - 1.05 m = 21.25 m
14. Drawdown = Line 13 - Line 3 = 21.25 m - 15.75 m = 5.50 m
15. Specific capacity = Line 10 / Line 14 = (120 liters/min.) / (5.50 m) = 21.8 liters/min./m

Measurements at FULL Pump Capacity

16. Yield = (200 liters) / (66 seconds) x 60 sec./min. = 3.0 liters/sec. x 60 sec./min. = 180 liters/min.
17. Total reading = 25.35 m
18. Wet end reading = 0.85 m
19. Water level = Line 17 - Line 18 = 25.35 m - 0.85 m = 24.50 m
20. Drawdown = Line 19 - Line 3 = 24.50 m - 15.75 m = 8.75 m
21. Specific capacity = Line 16 / Line 20 = (180 liters/min.) / (8.75 m) = 20.6 liters/min./m

10. Calculate the specific capacity at the full drawdown point by dividing the yield by the drawdown.

$\frac{180 \text{ liters/min.}}{8.75\text{m}}$ = 20.6 liters per minute per meter. See Worksheet A, Lines 16-21.

11. Measure the recovery time. That is, stop pumping and note the length of time required for the water in the well to rise to its static level. Generally, The shorter the time, the better the aquifer. If the well fails to recover completely to its original static level within 24 hours, question the dependability of the aquifer.

You now have a good indication of the characteristics of the well. However, if your tests were made immediately after the well was constructed and before it was put into full use, the calculated yield will generally be 10-30 percent less than the actual yield of the well after 2-4 weeks of continuous use. In marginal cases, the tests can be repeated after three to four weeks before doing further work on the well or abandoning it.

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1982

Water for the World

Finishing Wells
Technical Note No. RWS. 2.C.8

Finishing a well is important to protect the water from contamination, to prevent people and animals from falling into a hand dug well, and to ensure that water can be drawn from the well with maximum efficiency. How a well is finished depends on whether it is hand dug or drilled. The term "drilled" includes driven, bored, jetted, and cable tool wells. Finishing a hand dug well involves constructing a headwall, an apron, and perhaps a cover; and installing a water-lifting device other than a pump. Finishing a drilled well involves constructing an apron and developing the well.

For drilled wells and for hand dug wells that will have a pump, the pump must be at the well site before the well can be finished. Refer to the following technical notes: "Installing Mechanical Pumps," RWS.4.C.2 and "Installing Hand Pumps," RWS.4.C.3.

This technical note describes how to finish a well. Read the entire technical note before beginning the process.

Useful Definition

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

Materials Needed

For a hand dug well, you will need many of the same tools and materials that were used to construct the well, including cement, sand, gravel, mixing containers, reinforcing steel, wood or metal for forms, and assorted hand tools. See "Constructing Dug Wells," RWS.2.C.1. You will also need a water-lifting device or pump.

For a drilled well, driven, bored, jetted, or cable tool, you will need cement, sand, gravel, mixing containers, reinforcing materials, shovels, and trowels for building the apron. To develop the well you will need a pump and probably a surge plunger and shaft.

Construction Schedule

Depending on local conditions, availability of materials, and skills of workers, some construction steps will require only a few hours, while others may take a day or more. Read the construction steps and make a rough estimate of the time required for each step based on local conditions. You will then have an idea of when specific workers, materials, and tools must be available during the construction process. Draw up a work plan similar to Table 1 showing construction steps.

Caution!

Workers must take care when working around a hand dug well not to fall in or drop tools or materials into the well.

Finishing a Hand Dug Well

1. Break away the weak mortar layer around the top of the well, being careful not to knock debris into the well. Bend the re-rods protruding from the well lining into a vertical position.

2. Scrape smooth a circular area extending 2.0m out from the well. This will form the bottom of the apron. The area should be 25-50mm below the top of the well lining. It should be well-tamped and slope slightly downward away from the well.

Table 1. Sample Work Plan for Finishing a Well

Time Estimate	Day	Task	Personnel	Materials/Equipment
½ day	1	Prepare area for apron	Foreman (present during entire construction); 2 workers	Measuring tape, shovels
½ day	1	Place reinforcing material	Foreman (present during entire construction); 2 workers	Re-rods, wire, wire cutter
1 day	2	Mix and pour concrete; form curb and cut notch; cover with wet burlap	Foreman (present during entire construction); 2 workers	Cement, sand, gravel, containers, shovels, trowels, burlap
7 days	3-9	Keep moist for 7 days	Foreman (present during entire construction); 2 workers	-----
1 day	3-4	Dig trench and soakaway; line trench with mortar; fill soakaway with rocks	Foreman (present during entire construction); 2 workers	Shovels, concrete mix, rocks
1 day	10	Remove cover material; develop well	Foreman (present during entire construction); 2 workers	Surge plunger, shaft, bailer

3. Bend 2.9m-long sections of re-rod into right angles and tie them with wire to the protruding re-rods, so that 0.9m is in the vertical position and 2.0m is in the horizontal position radiating out from the well. Place small wooden spacer blocks under the horizontal portion of the re-rods, as shown in Figure 1.

4. Fashion four circles of re-rod. The diameter depends on the diameter of the circle formed by the vertical sections of re-rod. Fix the circles of re-rod in a horizontal position around the vertical re-rods, and space them about 250mm apart.

5. Make eight circles of re-rod for the apron. Fashion the smallest circle so that there is about 200mm between it and the outside edge of the well lining. Fashion each consecutive circle so that its radius is about 250mm larger than the one before it. The largest circle should fit just inside the ends of the horizontal re-rods. Tie the circles to the horizontal re-rods. Build up a small mound of soil around the ends of the re-rods to contain the concrete when it is poured.

6. Fix a set of steel shutters (1.0m high) around the inside of the well lining. Use metal shims or other means to tightly wedge the shutters in place. They should rise to nearly their full height (1.0m) above the top of the lining.

7. Mix concrete in the proportions of one part cement, two-and-a-half parts sand, five parts gravel, and enough water to make a workable mix. Pour concrete into the apron and make it 75-100mm thick. Trowel smooth the surface of the apron so that it slopes gently downward away from the well. Form a curb of concrete around the outside edge of the apron; make it about 25-50mm high to contain spilled water.

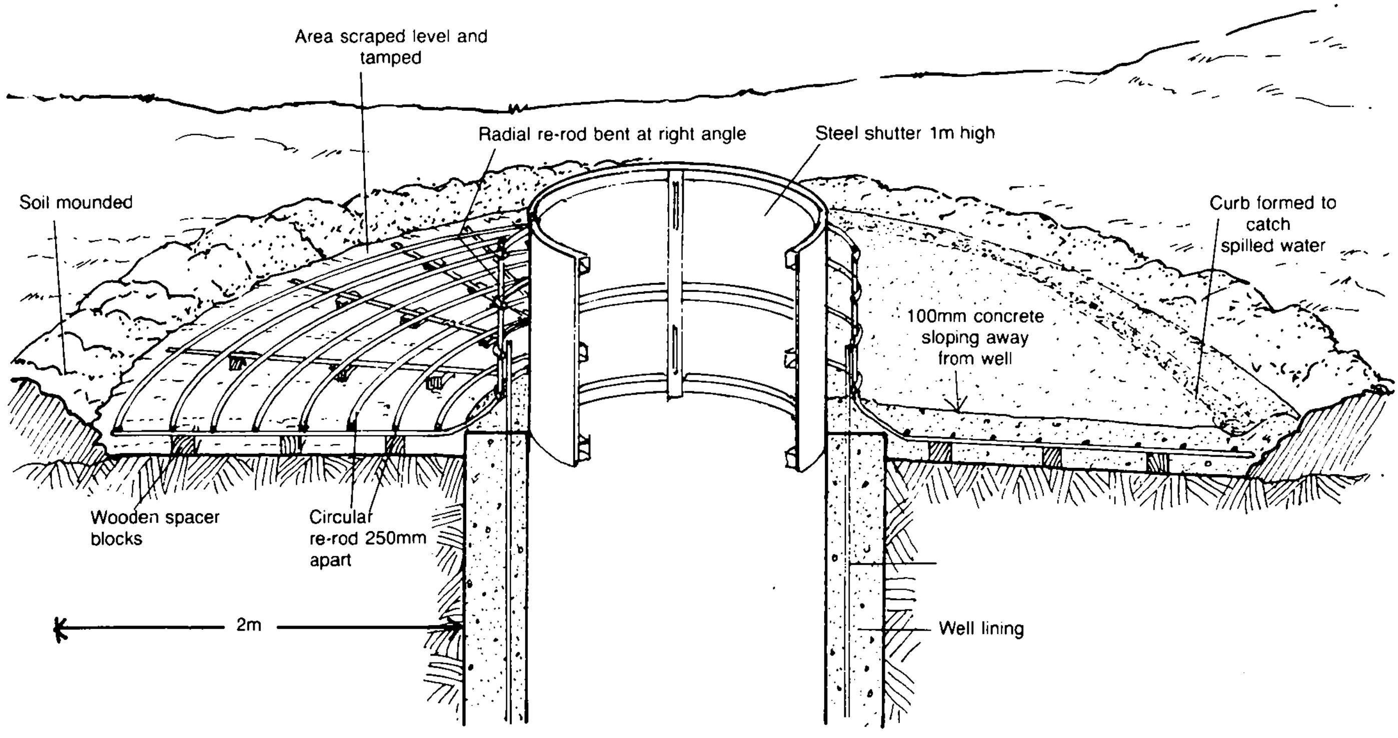

Figure 1. Building the Apron for a Hand Dug Well

8. Cover the concrete with straw or wet burlap and keep it moist for seven days. Before the concrete has fully set, pour water on the apron to determine the low point at the edge. Cut a notch out of the curb at this point to allow water to drain away, as shown in Figure 2.

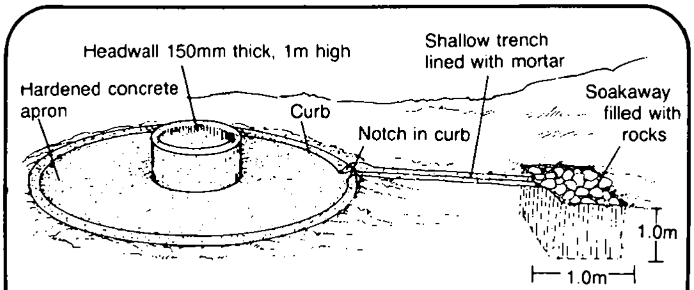

Figure 2. Finishing Headwall and Soakaway

9. Dig a shallow ditch from the notch in the curb to a soakaway pit, a small pit filled with rocks, or other drainage area a few meters or more away from the well. Line the ditch with mortar.

10. When the concrete apron has firmly set, remove the cover material. Position forms for the outside of the headwall. The radius of the forms should be 150mm greater than the radius of the steel shutters already in place. This will make the headwall 150mm thick. Pour concrete into the headwall forms and trowel smooth the top. See Figure 2. If a water-lifting device other than a pump is to be fixed to the headwall, set the base of the device, or the bolts to hold it, into the fresh concrete. Cover the concrete with straw or wet burlap and keep moist for seven days.

11. If the well is to have a pump, build a concrete cover for the well. This can be done while the headwall is curing.

11a. Build a circular form 100mm high and with the same diameter as the outside of the headwall. Place the form on a flat, oiled sheet of tin as shown in Figure 3.

11b. Make a circle of tin about 600mm in diameter and 200mm high. Set it inside the form for the cover at least 200mm from the outside edge. This will form the access hole. Fashion another circle of tin to form a hole large enough for removal of the riser pipe and pumping unit.

11c. Fill the form about one-third full with concrete. Set re-rods in place as shown in Figure 3. Fill the form with concrete and trowel the top smooth. Before the concrete has set up, form a lip around the access hole to prevent spilled water from entering. Set bolts in the fresh concrete for the pump and the access hatch. Cover the concrete with straw or wet burlap and keep moist for seven days.

12. When the concrete headwall has firmly set up, remove the outside form and the steel shutters.

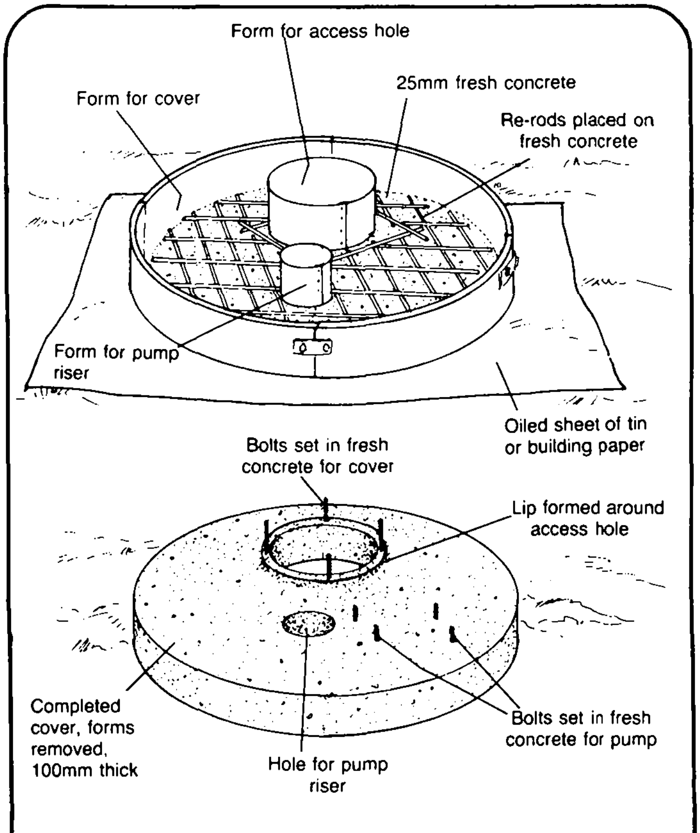

Figure 3. Making the Well Cover

13. If the well is to have a water-lifting device, set the device in place and bolt it to the headwall. See Figures 4a, 4b, 4c, and 4d.

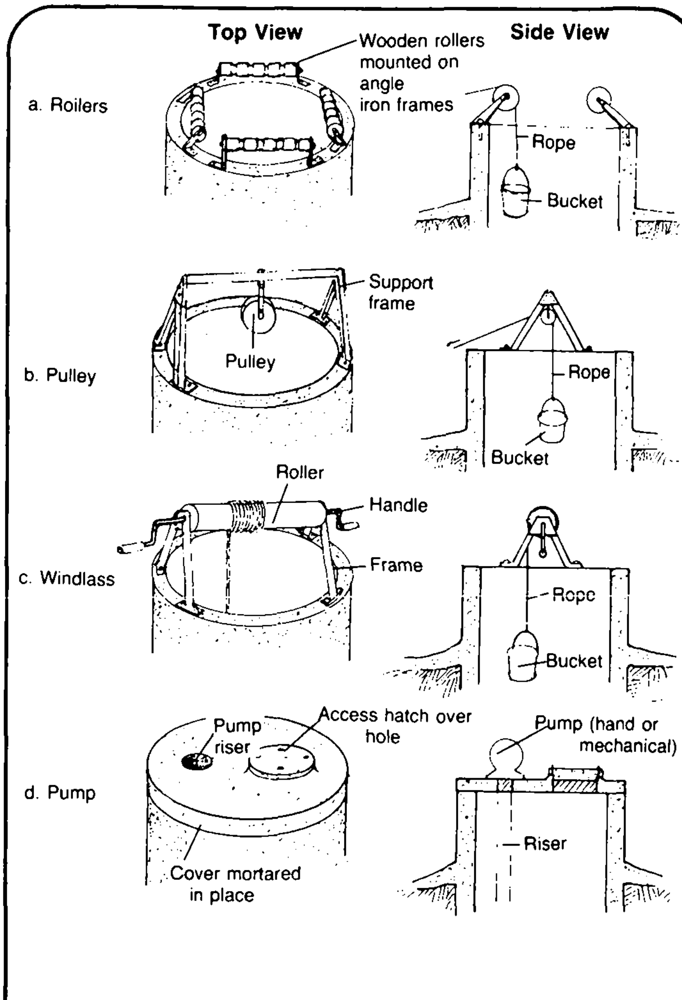

Figure 4. Examples of Finished Hand Dug Wells

14. If the well is to have a pump, remove the forms from the well cover after the concrete has set up and set the cover on the headwall, as shown in Figure 4d. Seal around the edges with concrete mortar. Bolt the access hatch in place. To install the pump, refer to "Installing Mechanical Pumps," RWS.4.C.2, or "Installing Hand Pumps," RWS.4.C.3.

Finishing a Drilled Well

Finishing a drilled well, driven, bored, jetted, or cable tool, involves building an apron or platform and, usually after the pump is installed, developing the well.

To build the apron:

1. Scrape smooth a square area of about 2.0m on each side with the well casing in the center. The area should be well-tamped and slope slightly downward away from the well. Build a small mound of soil around the outside edge.

2. Lay 1.9m-long re-rods in a grid pattern in the area. Space the re-rods about 250mm apart, tie them together with wire, and raise them up on 25mm high wood spacer blocks. See Figure 5.

3. Mix concrete in the proportions of one part cement, two-and-a-half parts sand, five parts gravel, and enough water to make a workable mix. Pour concrete into the apron area. Make it about 100mm thick at the well casing and sloping slightly downward away from the well. Trowel it smooth. If the pump or the base of the pump is to be bolted to the apron, set bolts into the fresh concrete in exactly the required position. Form a curb of concrete around the outside edge of the apron; make it about 25-50mm high to contain spilled water. See Figure 6.

4. Cover the concrete with straw or wet burlap and keep it moist for seven days. Before the concrete has fully set, pour water on the apron to determine the low point at the edge. Cut a notch out of that point to allow water to drain away.

5. Dig a shallow ditch from the notch in the curb to a soakaway pit, a small pit filled with rocks, or other drainage area a few meters or more away from the well. Line the ditch with mortar. See Figure 6.

6. When the concrete apron has firmly set, remove the cover material.

To develop the well:

Developing a well removes the fine particles in the aquifer from around the well screen. This improves the yield of the well, and it may lengthen the operating life of the well and the pump. The three basic methods of developing a well are overpumping, backwashing, and surging.

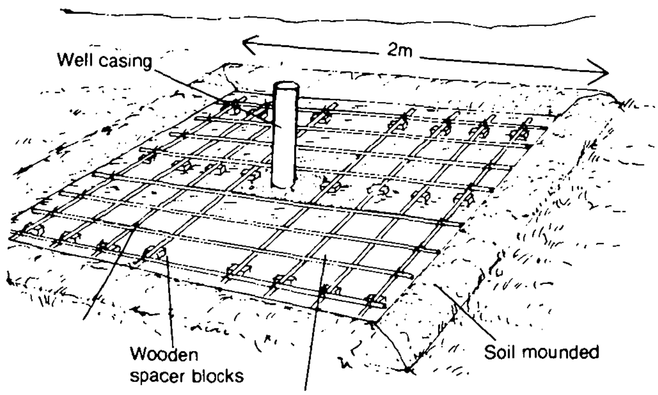

Figure 5. Building the Apron for a Drilled Well

Overpumping. Pump the well at a faster rate than normal, until no more fine aquifer particles are removed with the water. Use a separate pump for this process, because the fine particles will cause excessive wear on the pump and result in early pump failure. Although this is the simplest method, it does not fully develop the well.

Backwashing. Pump water to the surface and let it flow back into the well, and repeat the process many times. Although this method may be more effective than overpumping, in most cases it is difficult to accomplish. The reason is that most pump risers have a foot valve that prevents water from flowing back down; therefore, the pump may have to be completely removed to allow the water to flow down.

Surging. This is the most common and effective method of well development. It involves forcing water back and forth through the well screen. This not only removes small aquifer particles from around the screen, but it also forms a graded filter around the screen. The filter prevents the entry of small particles that would eventually clog the well or damage the pump.

1. Attach a surge plunger, solid or valve type, to a shaft and lower it down the well casing. See Figure 7. The shaft should be longer than the depth of the well so that if it is dropped, part of it will stick up out of the casing and be easy to remove.

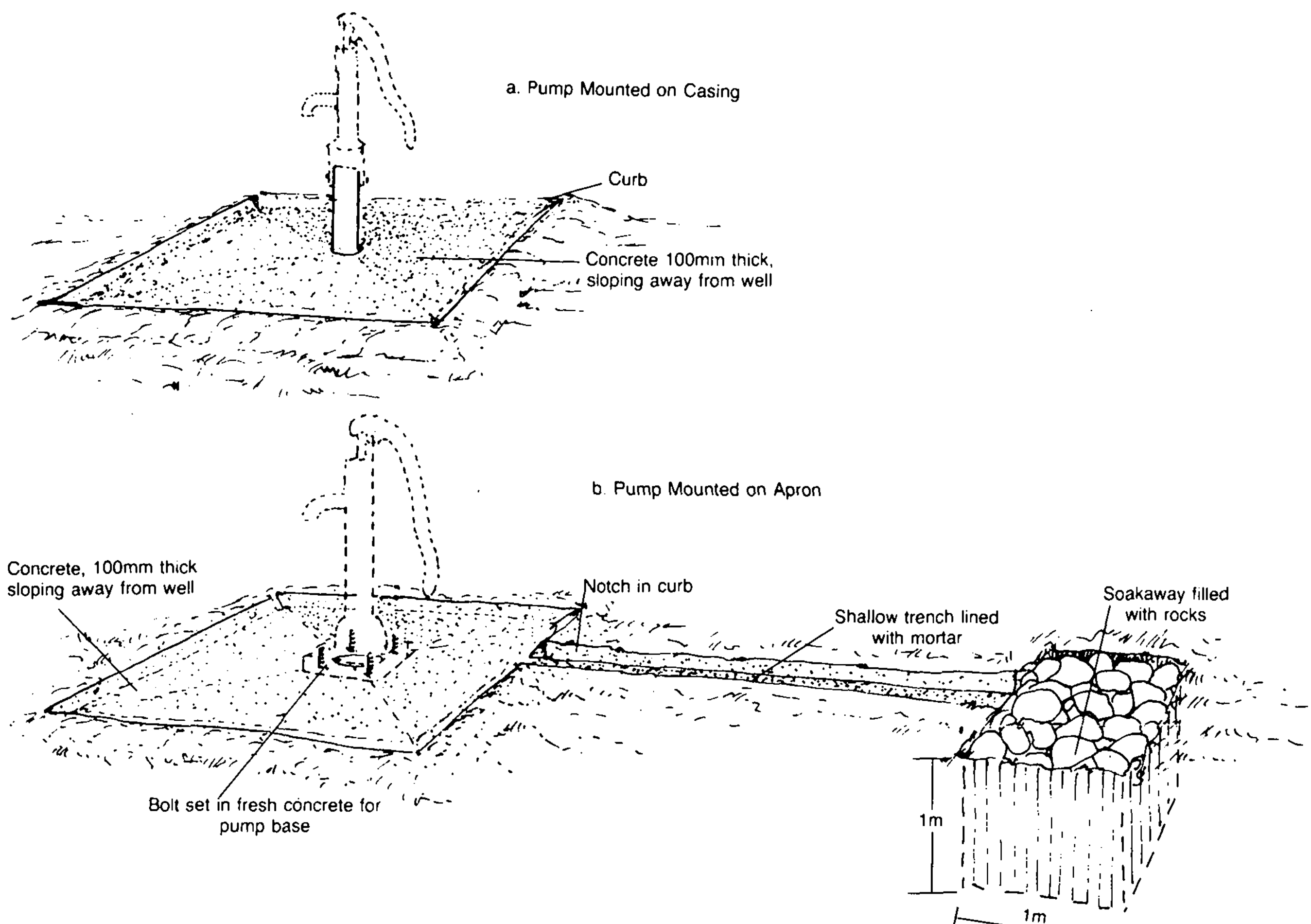

Figure 6. Finished Drilled Well

2. Lower the plunger until it is below the water level. Begin surging by rapidly raising and lowering the plunger for several minutes. Make the strokes about 0.6-1.0m long. See Figure 8.

3. Remove the plunger and shaft from the casing. Disconnect the plunger from the shaft, attach a sand bailer, and lower the bailer into the casing. Use the bailer to pick up fine particles and remove them from the shaft.

4. Disconnect the bailer and attach the plunger to the shaft. Continue surging and bailing until no more fine particles are removed with the water.

5. Remove the shaft and plunger or bailer from the casing and install the pump. See "Installing Mechanical Pumps," RWS.4.C.2, or "Installing Hand Pumps," RWS.4.C.3.

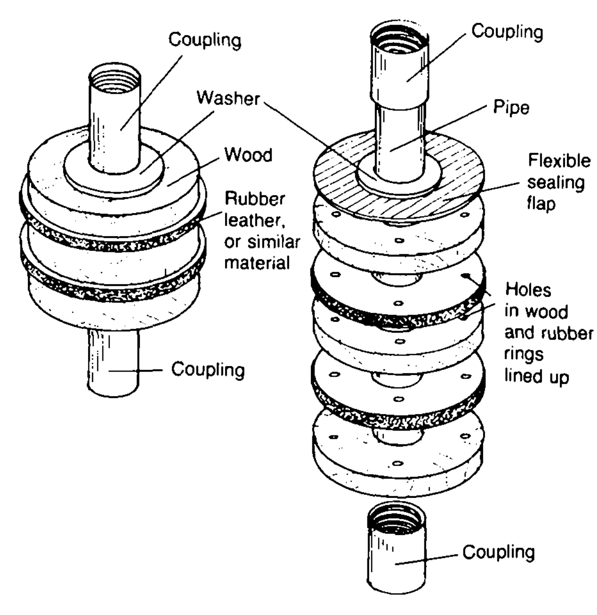

Figure 7. Plungers

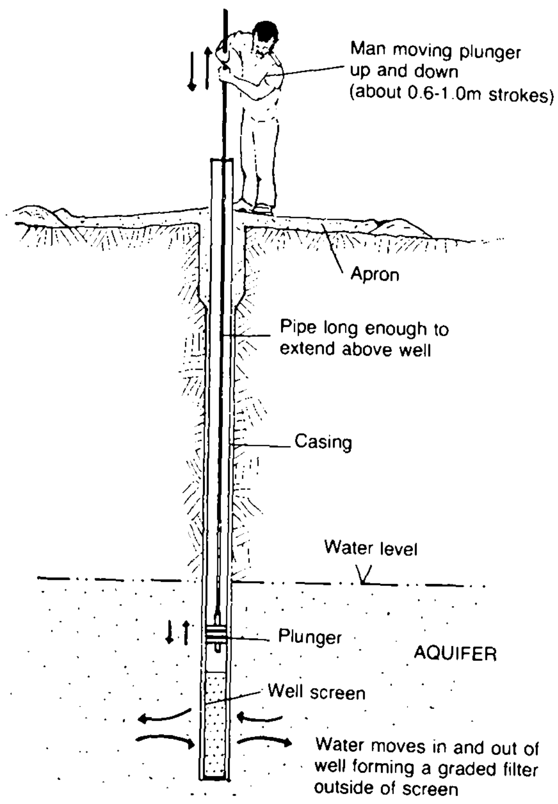

Figure 8. Developing a Drilled Well

Notes

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Water for the World

Disinfecting Wells
Technical Note No. RWS. 2.C.9

Disinfecting a well is necessary to eliminate the contamination that was introduced by equipment, materials, or surface drainage during construction or repairs. A chlorine compound is generally used for the disinfectant. Disinfecting a well involves calculating the required amount of chlorine compound, mixing a chlorine solution, and applying the solution to the well.

This technical note describes how to disinfect a well. Read the entire technical note before beginning the disinfection process.

Useful Definitions

AQUIFER - A water-saturated geologic zone that will yield water to springs and wells.

AVAILABLE CHLORINE - The amount of chlorine present in a chemical compound.

DISINFECTION - Destruction of harmful microorganisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

Materials Needed

To disinfect a well, you will need:

Chlorine compound such as calcium hypochlorite, bleaching powder, or liquid bleach,

Mixing container which should be rubber-lined or made from crockery or glass,

Stiff broom with a long handle, for hand dug wells,

Length of rope,

Length of perforated pipe, 0.5-1.0m long, 50-100mm in diameter, for deep-drilled wells with a high water table.

Caution!

Chlorine compounds or solutions may irritate skin and eyes upon contact. If possible, wear gloves, protective clothing, and glasses when handling chlorine. If you get chlorine on your skin or in your eyes, immediately wash it off with water.

General Information

The most easily obtainable and safest disinfectants are chlorine compounds. These compounds have various amounts of available chlorine, that is, chlorine that can be released to disinfect the water.

Calcium hypochlorite, also knows as high-test hypochlorite or HTH, has 70 percent available chlorine. It is produced as powder, granules, or tablets. Bleaching powders have 25-35 percent available chlorine. Common household laundry bleach, such as Clorox and Purex, has about 5 percent available chlorine.

Chlorine compounds should be stored in their original containers in a cool, dark place.

Calculating the Amount of Compound Needed

To disinfect a well properly, make a mix of available chlorine and water from the well in a ratio of 100 parts per million, ppm. To illustrate: 1 ml per 1000 liters equals 1 ppm; 100ml per 1000 liters equals 100ppm.

Table 1 shows the amounts of HTH, bleaching powder, and chlorine bleach that must be added to various volumes of well water to produce 100ppm of available chlorine. Before you can use the table, you must calculate the volume of water in the well.

The volume of water in a well equals the radius of the well squared times the depth of the water in the well times 3.1416.

$$V = r^2 \times D \times 3.1416$$

The radius, r, equals the diameter, d, of the well divided by two.

$$r = \frac{d}{2}$$

The diameter, d, can be measured directly or read from design drawings or from the driller's log described in "Maintaining Well Logs," RWS.2.C.6.

The depth, d, of the water in the well can be measured directly by lowering a rock tied to a length of twine to the bottom of the well, retrieving the twine, and measuring the wet portion. Or, it can be read from the driller's log.

For example, suppose the diameter of the well is 100mm (0.10m) and the depth of the water in the well is 12m. First, calculate the radius.

$$r = \frac{d}{2} \qquad r = \frac{0.10m}{2} \qquad r = 0.05m$$

Then calculate the volume of water.

$$V = r^2 \times D \times 3.1416$$
$$V = 0.05m \times 0.05m \times 12m \times 3.1416$$
$$V = \text{about } 0.1m^3$$

See Worksheet A Lines 1-4.

From Table 1, you can see that in order to disinfect this well you would need to use 0.2 liters of chlorine bleach, 5 percent available chlorine, or 33 grams of bleaching powder, 30 percent available chlorine, or 14 grams of high-test hypochlorite, 70 percent available chlorine.

For another example, suppose the diameter of the well is 1.2m and the depth of the water in the well is 2.6m. The radius equals the diameter divided by two $= \frac{1.2m}{2} = 0.6m$ Now calculate the volume.

$$V = r^2 \times D \times 3.1416$$
$$V = 0.6 \times 0.6 \times 2.6 \times 3.1416$$
$$V = 2.9m^3$$

See Worksheet A, Lines 5-8.

From Table 1, you can see that the nearest volume to this is $3.0m^3$, so to disinfect this well you would need to mix in 6.0 liters of chlorine bleach, or 1010 grams of bleaching powder, or 433 grams of HTH.

Table 1. Amounts of Chlorine Compounds for Well Disinfection

Water in Well (m^3)	Liquid Bleach 5% available chlorine (liters)	Bleaching Powder 30% available chlorine (grams)	Calcium Hypochlorite (HTH) 70% available chlorine (grams)
0.1	0.2	33	14
0.12	0.24	40	17
0.15	0.3	51	22
0.2	0.4	68	29
0.25	0.5	86	37
0.3	0.6	100	43
0.4	0.8	133	57
0.5	1.0	170	73
0.6	1.2	203	87
0.7	1.4	233	100
0.8	1.6	267	113
1.0	2.0	334	143
1.2	2.4	400	173
1.5	3.0	500	217
2.0	4.0	670	287
2.5	5.0	860	367
3.0	6.0	1010	433
4.0	8.0	1330	567
5	10	1700	730
6	12	2000	870
7	14	2300	1000
8	16	2600	1130
10	20	3300	1430
12	24	4000	1730
15	30	5000	2170
20	40	6700	2870

Worksheet A. Calculating the Volume of Water in a Well

Drilled Wells

1. Diameter of well = $\frac{(\underline{100}\ mm)}{(1000mm/m)}$ = 0.10 m

2. Radius of well = $\frac{\text{Line 1}}{2}$ = $\frac{(0.10\ m)}{2}$ = 0.05 m

3. Depth of water in well = 12 m

4. Volume of water in well = Line 2 x Line 2 x Line 3 x 3.1416 =
0.05 m x 0.05 m x 12 m x 3.14.6 = 0.09 m^3

Hand Dug Wells

5. Diameter of well = 1.2 m

6. Radius of well = $\frac{\text{Line 5}}{2}$ = $\frac{(1.2\ m)}{2}$ = 0.6 m

7. Depth of water in well = 2.6 m

8. Volume of water in well = Line 6 x Line 7 x 3.1416 =
0.6 m x 0.6 m x 2.6 m x 3.1416 = 2.9 m^3

Mixing the Solution

Do not pour the chlorine compound directly into the well. It will not mix properly. First make a chlorine solution.

To make a chlorine solution from chlorine bleach, mix one part of bleach with one part of water, then pour the entire solution into the well. In the second example, this would mean mixing 6.0 liters of chlorine bleach with 6.0 liters of water and pouring 12.0 liters of chlorine solution into the well.

To make a chlorine solution with HTH or bleaching powder, first mix the compound with enough water to form a smooth paste, then mix the paste with water in the ratio of one liter of water per 15 grams of compound. To calculate the amount of water needed to make a chlorine solution, divide the amount of chlorine compound by 15. In the second example,

$\frac{\text{1010 grams of bleaching powder}}{\text{15 grams}}$ =

67 liters of water

$\frac{\text{433 grams of HTH}}{\text{15 grams}}$ = 29 liters of water

Mix the chlorine paste with the water for 10-15 minutes. Allow inert materials to settle and use only the clear chlorine solution. Discard the rest. Pour the clear chlorine solution, about 67 liters in the case of bleaching powder or about 29 liters in the case of HTH, into the well.

Do not mix chlorine solutions in metal containers. Mix them in clean containers that are rubber-lined or made from crockery or glass.

Disinfecting a Hand Dug Well

If the well has no cover, it should be disinfected every day, or as often as possible. If the well is covered it must be disinfected before the first use and every time it is opened for maintenance or repair.

For a dug well with pump and cover:

1. Prepare a chlorine solution to wash the inside of the well casing. Mix 10 liters of water with <u>one</u> of the following: 0.02 liters of chlorine bleach, or 3.3 grams of bleaching powder, or 1.4 grams of HTH.

2. Wash the exterior surface of the pump cylinder and drop pipe with the chlorine solution before they are lowered into the well.

3. Remove all equipment and materials that will not be a permanent part of the well.

4. Wash the inside surface of the well casing with a clean, stiff broom and the 10 liters of chlorine solution. See Figure 1.

5. Install the cover over the well.

6. Calculate the amount of chlorine solution needed to disinfect the well. Prepare the solution and poor it through the access hole in the cover, making sure that the solution covers as much of the surface of the water in the well as possible. See Figure 2.

7. Mix the chlorine solution with the water in the well by using a rope tied to a large, clean rock. Lower the rock into the well and move it up and down in the water.

8. Cover the access hole. Pump water from the well until you can smell chlorine.

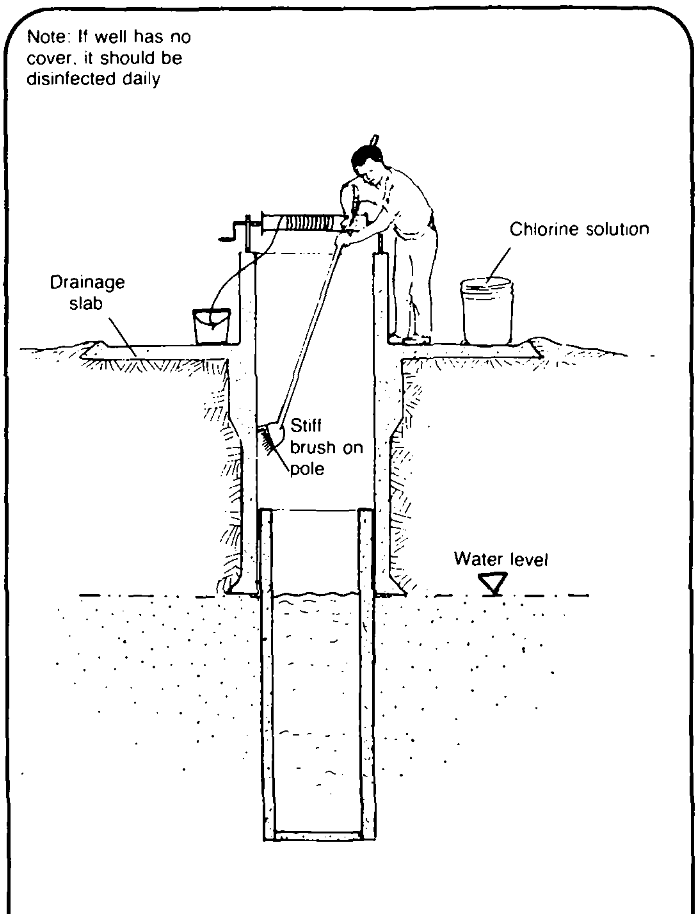

Figure 1. Washing Inside of Casing (Hand-dug well)

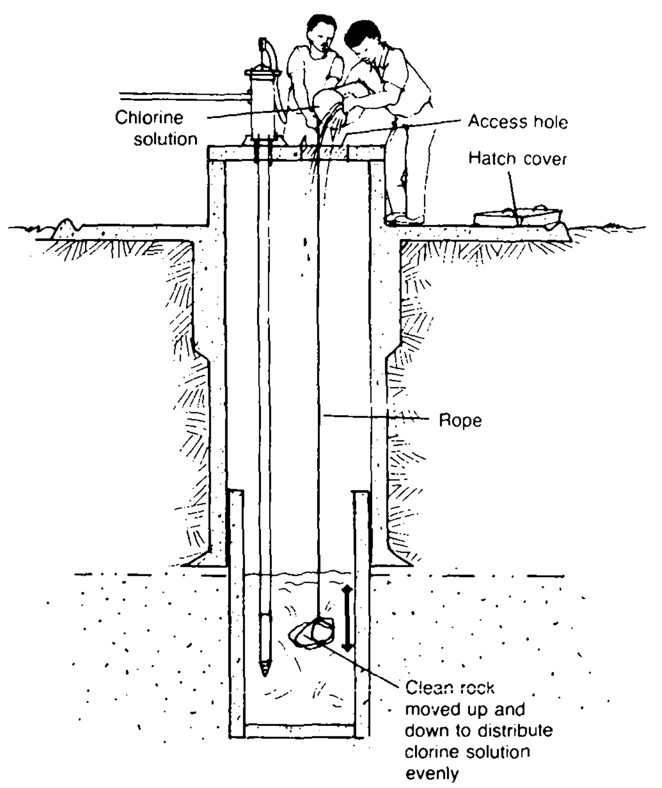

Figure 2. Pouring Chlorine Solution into Well

9. Allow the chlorine solution to remain in the well for 24 hours.

10. Pump water from the well until chlorine can no longer be smelled or tasted. Dispose of this water in a soakaway.

Disinfecting a Driven, Jetted, Bored, or Cable Tool Well

After the well has been tested for yield as described in "Testing the Yield of Wells," RWS.2.C.7, it must be disinfected before its first use and every time it is opened for maintenance or repair.

1. Remove the test pump from the well.

2. Calculate the amount of chlorine solution needed to disinfect the well. Prepare the solution and pour it into the well.

3. Mix the chlorine solution with the water in the well by using a rope tied to a clean rock. Lower the rock into the well and move it up and down in the water.

4. Add 40 liters of clean, chlorinated water to the well to force the solution into the aquifer. This solution can be made by mixing 40 liters of water with either one-half teaspoon of HTH or 20ml of chlorine bleach.

5. Prepare a chlorine solution to wash the pump cylinder and drop pipe. Mix 10 liters of water with one of the following: 0.02 liters of chlorine bleach, or 3.3 grams of bleaching powder, or 1.4 grams of HTH.

6. Wash the exterior surface of the pump cylinder and drop pipe as they are lowered into the well.

7. Pump water from the well until you can smell chlorine.

8. Allow the chlorine solution to remain in the well for 24 hours.

9. Pump water from the well until chlorine can no longer be smelled or tasted. Dispose of this water in a soakaway.

Deep Well with High Water Table

In the case of a deep well with a high water table, you need to take special steps to ensure that the chlorine and well water are properly mixed.

1. Drill a number of small holes through the sides of the pipe that is 0.5-1.0m long and 50-100mm in diameter. Cap one end of the pipe.

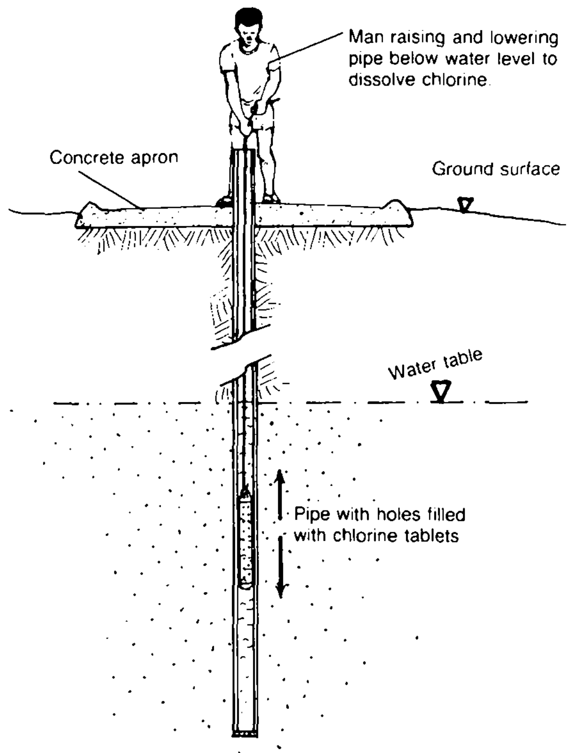

Figure 3. Disinfecting Deep Well with High Water Table

2. Pour the calculated amount of HTH granules or tablets into the pipe. Only HTH can be used in this method.

3. Fit the other end of the pipe with a threaded cap equipped with an eye loop.

4. Tie a rope to the eye loop, lower the pipe into the well, and alternately raise and lower the pipe in the water. Continue until the HTH has dissolved and the chlorine is distributed in the water. See Figure 3.

Notes

Notes

Notes

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1982

Water for the World

Designing a Small Community Sedimentation Basin

Technical Note No. RWS. 3.D.2

Sedimentation is the removal of suspended matter from water through a process of settling. In the process, particles heavier than water settle to the bottom of an especially designed tank.

Sedimentation is a very important process. Particles which enter a water supply through erosion and run-off can be harmful to water distribution and treatment systems. Suspended particles can block pipes, clog filter screens and filter beds, reduce storage tank capacity and affect water quality since pathogens may be trapped in the particles. These particles must be removed or receive further treatment before water can be consumed. Further treatment may be needed to remove fine clay and colloidal matter which have a very slow settling rate and are difficult to remove by plain sedimentation.

This technical note describes the design of a plain sedimentation basin for a rural water supply system. This type of basin should be used where water contains much suspended matter. The basin can be used alone or as a pre-treatment step for a slow sand filter. See "Designing a Slow Sand Filter," RWS.3.D.3. No chemicals or mechanical parts are used with a plain sedimentation basin and maintenance is relatively easy. Sedimentation basins can serve as storage tanks as well as water treatment units.

Useful Definitions

BAFFLE - A wall or other device which holds back or turns aside water flow.

COLLOIDAL MATERIAL - Substances made up of small particles that remain in suspension in water.

FREEBOARD - The height of the sedimentation basin above the water level; it prevents water from overflowing and reduces disturbance by winds.

PERIOD OF DETENTION - The amount of time water is held in a sedimentation basin.

RAW WATER - Untreated water that is to pass through a treatment system.

REINFORCED CONCRETE - Concrete containing steel reinforcing rods for extra strength.

RESERVOIR - A natural or man-made facility to store water.

SETTLING VELOCITY - The rate at which particles settle in still or slowly flowing water.

SHORT-CIRCUITING - The passage of water from a sedimentation basin inlet to an outlet without ample time for sedimentation to occur; the use of straight inlets and outlets cause this to happen.

WEIR - A barrier placed in moving water to stop, control or measure water flow.

The design process should result in the following three items which should be given to the construction supervisor:

1. A map of the area marked with the location of the water supply, the proposed sedimentation basin and other treatment units that may be included. The map must show major landmarks and distances. Figure 1 shows a sample location map.

2. A list of all labor and materials needed for the project similar to Table 1.

3. A detailed plan of the sedimentation basin showing all dimensions as shown in Figure 2.

Table 1. Sample Materials List for a Plain Sedimentation Basin

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Laborers	____	____
Supplies	Bricks	____	____
	Cement	____	____
	Clean sand	____	____
	Water	____	____
	Material for weir	____	____
	PVC pipe	____	____
	Rope	____	____
	Stakes	____	____
Tools	Digging tools	____	____
	Trowels	____	____
	Wheelbarrow	____	____
	Saw	____	____
	Mortar box	____	____
	Hammer	____	____
	Nails	____	____
	Plumb line	____	____
	Measuring tape	____	____
	String	____	____
	Buckets	____	____

Total Estimated Cost = ____

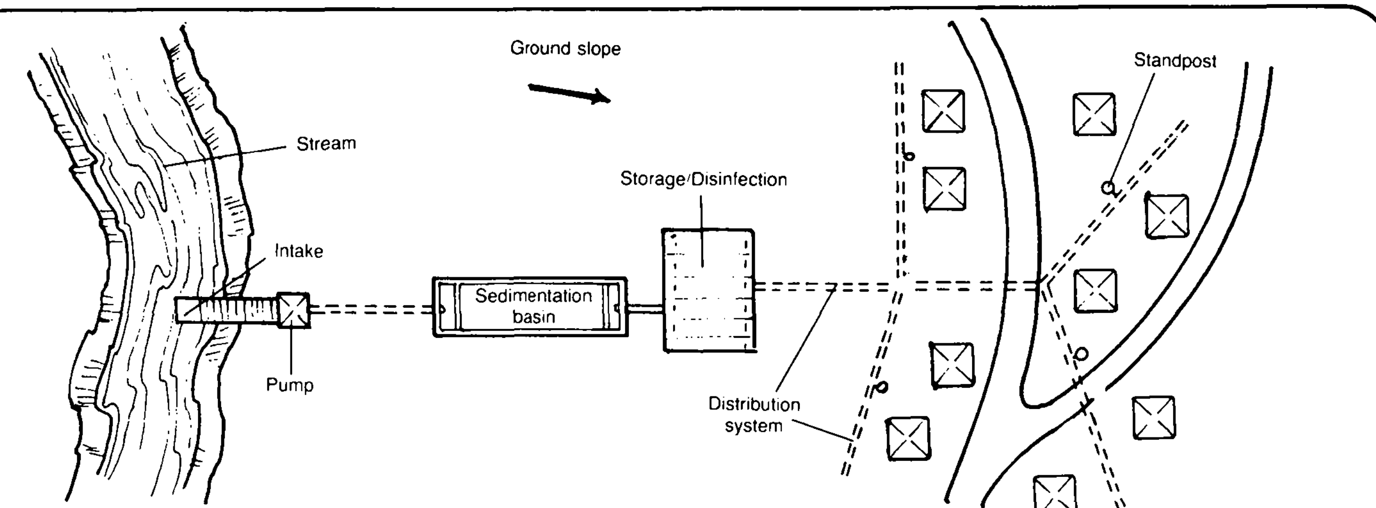

Figure 1. Location Map

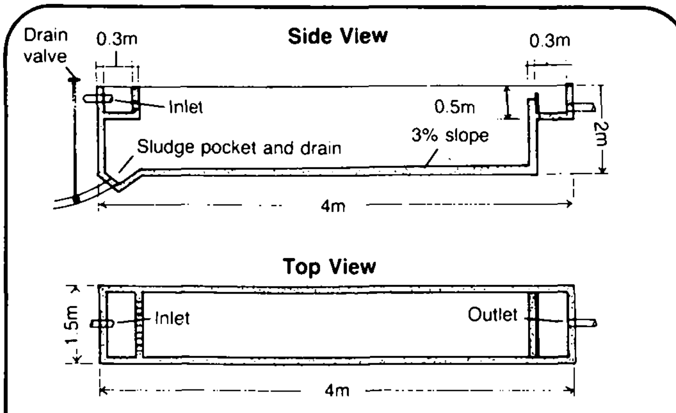

Figure 2. Sedimentation Basin

In order to design an effective sedimentation basin, it is necessary to know the nature and characteristics of the suspended matter in the water, determine the dimensions for the sedimentation basin, and choose the design that best meets local needs. Sedimentation basins are rectangular for easier construction and manufacture and are generally made of masonry, plain concrete or reinforced concrete. They usually do not need covers unless there is a major problem with mosquito breeding.

Raw water, especially river water, may contain many different types of impurities. There may be large particles which can be strained out of the water or which settle out naturally in still or slow moving water because of the force of gravity. These particles are removed by the sedimentation process. Reservoirs, ponds and lakes act as natural sedimentation basins. Tanks are built to provide sedimentation for water from rivers and streams. Water may also contain small microscopic or colloidal particles which do not settle well and can be removed only with chemical coagulation, usually followed by filtration. Finally, there may be material dissolved in water that can only be removed by chemical treatment.

Table 2 gives the sedimentation rates for several types of material. The table provides only a guide for settling rates. Exact determination of settling rates involves complicated calculations and should be done by an engineer.

Table 2. Sedimentation Rates

Material	Partical Diameter (millimeters)	Settling Velocity (meters per hour)
Coarse sand	1.0mm 0.5mm	365m/h 194m/h
Fine sand	0.25mm 0.10mm	97.5m/h 29.0m/h
Silt	0.5mm 0.005mm	10.6m/h 0.14m/h
Fine clay	0.001mm 0.0001mm	0.005m/h (5mm/h) 0.00005m/h (0.005mm/h)

Basic Design Features

Sedimentation basins are designed to reduce the velocity of water entering the tank so that it is retained long enough to permit particles to settle. A sedimentation basin has four sections: the inlet zone, the settling zone, the outlet zone, and the sludge deposit zone. See Figure 3.

The <u>inlet</u> zone is the area where water enters the tank and is distributed evenly throughout its entire area. A baffle or wall separates the inlet zone from the settling zone. The work of the sedimentation basin is done in the <u>settling</u> zone, where the water is held long enough to permit suspended particles to settle.

In the <u>outlet</u> zone, clarified water is collected from the top layer of the basin. This area is separated from the settling zone by a weir which controls water flow out of the basin. Water from the settling basin flows over the weir into the outlet zone.

Finally, the <u>sludge</u> zone collects the material settled from the water. The floor in the sludge zone should have a minimum of 3 percent slope toward the drain.

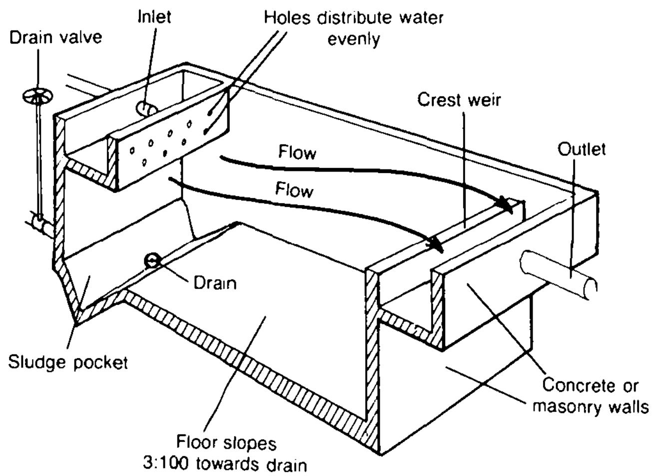

Figure 3. Sedimentation Basin

<u>Dimensions</u>. The first step in determining the proper dimensions of the sedimentation basin is calculating the capacity of the tank. Determine the capacity by the following formula:

$$\text{Flow rate } (m^3/h) = \frac{\text{User population} \times \text{liters/capita/day} \times \text{maximum daily demand}}{1000 \text{ liters}/m^3}$$

For example, assume a population of 1200, average demand of 40 liters/capita/day, and maximum daily demand of 1.2 times the average demand.

$$\text{Flow rate} = 1200 \times \frac{40 \text{ liters}}{1000 \text{ liters/m}^3} \times 1.2$$

$$\text{Flow rate} = 1200 \times .04\text{m}^3 \times 1.2$$

$$\text{Flow rate} = 57.6\text{m}^3\text{/day}$$

$57.6\text{m}^3\text{/day} \div 24$ hours per day = $2.5\text{m}^3\text{/hour}$.

Next, determine the settling velocity of the material. For plain sedimentation, the settling velocity should be in the range of 0.1-1m/hour. For the example above, assume a settling velocity of 0.6m/hour which is the settling velocity of silt grain with a diameter of 0.01mm. All particles with a settling velocity higher than 0.6m/hour and some particles that settle slower will be removed.

Determine the size of the tank by using the settling velocity rate of 0.6m/hour and the following formula:

$$\text{Surface area (length x width of basin)} = \frac{\text{flow rate}}{\text{settling velocity}}$$

$$\text{Area (m}^2) = \frac{2.5\text{m}^3\text{/hour}}{0.6\text{m/hour}}$$

$$\text{Area m}^2 = 4.2\text{m}^2$$

The minimum area of the tank should be 4.2m^2. A somewhat larger tank can be constructed for more capacity, longer detention time and to allow for population growth. In this case, a tank with a 6m^2 area would be appropriate.

To determine the length and width of the tank, keep the following guideline in mind. The ratio between the length and width of the tank should range between two and six. In other words, if you divide the length of the tank by the width, the result will be between two and six. Good design dimensions for the tank would be a length of 4m and a width of 1.5m. This gives an area of 6m^2 and a ratio of 2.7 between length and width ($\frac{6\text{m}}{1.5\text{m}} = 2.7\text{m}$).

The efficiency of the settling process is reduced if there is turbulence or short-circuiting in the tank. This is prevented by ensuring that the correct ratio of length to width exists and by taking other measures. The measures that prevent short-circuiting are the provision of adequate tank depth and a well-designed inlet and outlet. The tank should be between 2-2.5m deep. Because wind may disturb settling, place the inlets and outlets at least 0.5m below the tank edge. This provides a protective freeboard to reduce wind disturbance.

Check the capacity of the tank by finding the volume and determining the retention time of water in the tank. The tank should retain water for at least four hours. Generally, a retention time of between four and six hours is sufficient.

Determine the retention time by first calculating the volume of the tank. The volume of the tank is equal to the length times the width times the height.

$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$

$$\text{volume} = 4\text{m} \times 1.5\text{m} \times 2\text{m}$$

$$\text{volume} = 12\text{m}^3$$

The retention time is calculated by dividing the volume by the rate of flow of the water in the tank.

$$\text{Retention time} = \frac{\text{volume of the tank}}{\text{flow rate}}$$

$$\text{Retention time} = \frac{12\text{m}^3}{2.5\text{m}^3\text{/hour}}$$

$$\text{Retention time} = 4.8 \text{ hours}$$

Water is retained for 4.8 hours in the settling tank. This should be sufficient to allow settling to occur.

Wall Structure. Two types of wall structure designs can be chosen for a sedimentation basin. There are sloping walls and vertical walls.

Sloping wall structures are dug into the ground and the walls are lined with masonry, rip-rap, sand-cement or mortar to protect them and to prevent leaking. A sloping wall structure is a good choice if money is limited and skilled labor is not available. Sloping walls should not be used where the groundwater level is high. Vertical wall structures follow typical masonry or concrete storage tank design and should be designed by someone with construction experience. More detailed information on the construction of wall structures for sedimentation basins is available in "Constructing a Sedimentation Basin," RWS.3.C.2.

Inlet Structure. The settling basin must have a separate inlet structure to ensure an even distribution of the water in the tank. Figure 4 shows one simple design. The inlet structure should extend between 0.5-0.75m from the wall into the basin and across the entire basin width.

Separate the inlet from the settling zone with a wall. Place equally sized, 20mm holes in the wall at equal distances from each other. These holes should be placed in the vertical wall as shown in Figure 4. The velocity of flow into the inlet should be less than 1m per second. To get sufficient flow, a large number of holes are needed spread out across the width of the inlet. Make three rows and three columns of holes in the inlet wall. For the example given, the inlet consists of three rows of 15 holes each with each hole 20mm apart.

In the upper part of the inlet structure, there should be an overflow pipe. Place this pipe above the highest row of holes to prevent any flow over the inlet wall.

Outlet Structure. Place an outlet channel at the far end of the settling tank. The outlet consists of a weir made of wood, metal or concrete extending across the width of the basin. The simplest weir is formed by the top of the basin wall. To work effectively, the weir must be leveled very carefully. The top of the wall can be rounded or a V-notched strip added to ensure even flow on the wall. The outlet structure should form a trough with an outlet hole at the bottom. Make the trough sufficiently deep to avoid spillage. To provide for even flow into the trough, attach a metal strip for the weir crest as shown in Figure 5. Cut triangular sections at even intervals and bolt it to the concrete weir.

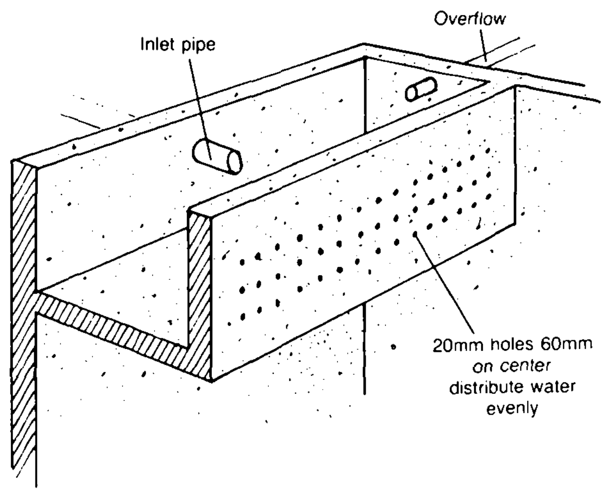

Figure 4. Inlet Structure

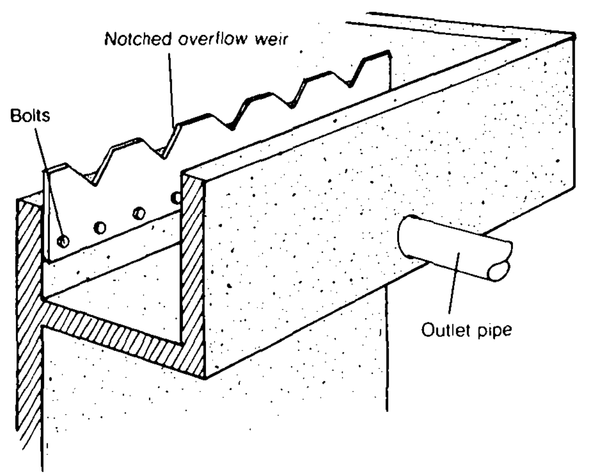

Figure 5. Outlet Structure

Finally, place a drain pipe at the bottom of the tank as shown in Figure 2. The pipe is necessary for draining the water out of the tank when cleaning it. For all pipes, including inlet, outlet, and drain pipes, 40-50mm polyvinyl chloride (PVC) pipe can be used.

The Basin. Sedimentation basins are rectangular structures made of either concrete or masonry. The use of reinforced concrete requires a higher level of skill and costs more money than masonry or plain concrete. Two designs generally used are an above-ground structure with vertical walls or an excavated structure with sloping walls.

A structure with vertical walls should have an excavated foundation of at least 0.3m. A deeper foundation is often preferred so that pressure on the inside and outside of the structure is equalized. Use a raft foundation as shown in Figure 6. The foundation should extend about 0.25m beyond the wall on each side. When determining the depth of the foundation, be sure to take into account that the distance from the ground level to the top of the tank should be at least 0.5m to prevent animals or young children from climbing or falling in. A tank height about 1.0m above ground level is best.

Once the basic design is set, the amount of materials needed should be determined. If bricks are used for construction, determine the dimensions of the tank and the amount of bricks and mortar needed by following the steps in Worksheet A. Add 10 percent for error. Generally, local builders know the number of bricks needed per cubic meter of construction. When using plain concrete, determine the amount of materials needed by doing the calculations shown in Worksheet A. Make all walls 0.2-0.3m thick.

If the excavated sloping wall structure is used, the tank will be completely in the ground. The slope of the walls should be approximately 1:2, 1m of slope for every 2m of height. This slope will increase the length of the tank by 2m, 1m on each end. Suitable lining materials are masonry, concrete, puddled clay and a sand/cement mixture with chicken wire reinforcing. Wall thickness will vary with material used. Make sand/cement and concrete walls 0.8m thick, impervious clay walls 0.05m

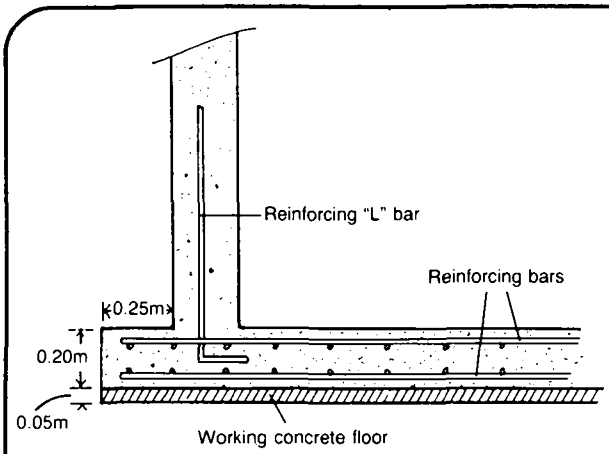

Figure 6. Raft Foundation for Vertical Walls

thick, and brickwork 0.10m. Other design features are similar to basins with vertical walls.

Summary

Sedimentation basins are designed so that turbid water flows through them at a low velocity and suspended particles settle out. For rural areas, rectangular masonry basins are the least expensive and simplest to install and the easiest to maintain. Tanks may also be made of reinforced concrete. Water that passes through a sedimentation basin loses suspended solids but generally must receive further treatment in a slow sand filter. For information on designing slow sand filters see "Designing a Slow Sand Filter," RWS.3.D.3. Where water needs no further treatment, the sedimentation basin can serve as a storage tank for the water supply.

Worksheet A. Calculating Quantities Needed for a Concrete Sedimentation Basin (Dimensions from Figure 2)

Total volume of each rectangle = length (l) x height (h) x width (w)

1. Volume of two sides = 4 m x 2 m x 0.25 m x 2 = 4 m^3
2. Volume of two ends = 1.5 m x 2 m x 0.25 m x 2 = 1.5 m^3
3. Volume of foundation = 4.5 m x 0.25 m x 1.5 m = 1.7 m^3
4. Total volume of structure from steps 1, 2, 3 = 7.2 m^3
5. Add 10 percent to cover extra height due to slope of bottom = .8 m^3
6. Total volume of structure from steps 4, 5 = 8.0 m^3

Volume of inlet structure:

7. Volume of bottom = 0.3 m x 0.25 m x 1.5 m = .11 m^3
8. Volume of side = 1.5 m x .75 m x 0.25 m = 0.28 m^3
9. Total volume of inlet from steps 7, 8 = .4 m^3

Volume of outlet structure:

10. Volume of bottom = 0.3 m x 0.25 m x 1.5 m = .11 m^3
11. Volume of side = 1.5 m x 0.55 m x 0.25 m = 0.20 m^3
12. Total volume of inlet from steps 10, 11 = .31 m^3
13. Total volume from steps 6, 9, 12 = 8.71 m^3
14. Unmixed volume of materials needed = total volume from step 13 x 1.5 = 8.71 m^3 x 1.5 = 13.1 m^3
15. Volume of each material (cement, sand, gravel 1:2:3)

    Cement: 0.167 x volume from line 14 13.1 m^3 = 2.2 m^3

    Sand: 0.33 x volume from line 14 13.1 m^3 = 4.3 m^3

    Gravel: 0.50 x volume from line 14 13.1 m^3 = 6.6 m^3

16. Number of 50kg bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$

    $\frac{\text{Volume of cement} = 2.2 \text{ m}^3}{\text{Volume per bag} = .033\text{m}^3/\text{bag}}$ = 67 bags

17. Use about 28 liters of water for every bag of cement. Amount of water = 67 bags x 28 liters = 1,876 liters

Note: To save cement, a 1:2:4 mixture can be used with no loss of strength.

Notes

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1982

Water for the World

Methods of Operation and Maintenance Training

Technical Note No. HR. 3.M

One of the most important steps in establishing a water and sanitation system in a rural community is arranging for efficient operation and maintenance of the facilities. Without proper care, a water and sanitation facility will deteriorate and fail to provide the services for which it was designed and built. A malfunctioning system will almost certainly be improperly used and eventually abandoned by the community. Perhaps even more important, a community may develop a false sense of security in a malfunctioning water and sanitation system they do not realize is harmful. It is imperative that the community understand that without proper operation and maintenance by trained system operators, no water and sanitation facility will continue to function properly and safely. Such proper functioning is essential to gain economic benefits, good health, improved hygiene, lower disease rates, and increased convenience in the community.

Improvements in the health conditions and hygiene habits of community members that can result from a good water and sanitation system are lost when a supply breaks down. A community enthusiastic about water and sanitation improvements may view a breakdown as evidence that their contributions to the system were wasted. Their further cooperation may be difficult to obtain. Adequate provision must be made for proper operation and maintenance of the facilities at the local level and through an action agency back-up located conveniently to the village.

A well-maintained water and sanitation system needs well-trained people to operate it. Technical training in operation and maintenance will give selected individuals the practical skills needed to care for community systems and help to instill respect for the people operating the facilities among the rest of the villagers.

Training needs should be defined for operation and maintenance personnel in order to:

- select a training method,
- develop a training method,
- plan a training program,
- conduct a training program, and
- evaluate operator performance after training.

The most appropriate training method is one that meets training needs and makes the best use of local resources.

The initial step in the training process is to decide who is to coordinate the regional training effort and determine where the trainers will come from. Decisions must be made to carry out training at local, regional or national levels. Often the most economical method is to train trainers at the national level so they can train, at a regional center, the people who will work on local water and sanitation systems. Trainers need to learn how to use the technical notes on operation and maintenance that are part of this series. They must learn how to conduct training programs. People trained at the national level for work at the regional level should help the village water and sanitation committee select candidates for the local operation and maintenance positions and coordinate the training for that job.

Selecting Trainees

Since the continual functioning and upkeep of a rural water and sanitation system is primarily the responsibility of the community, the components of the system should have been designed so they can be operated and maintained by personnel available in the village. It is imperative that provisions for training begin at the same time as system design, since the design must fit the local people's capability for operation and maintenance. Refer to "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.P, and to the technical notes on design and on operation and maintenance of the system being constructed in the community.

It is important that the operation and maintenance job tasks be considered when selecting technicians for a project, and it is equally important that the qualifications of the selected system operators be considered when developing a training program. The capabilities of local operation and maintenance personnel can be developed if good training and support are provided by the regional office of the action agency.

The method used for selecting operation and maintenance personnel will depend on local circumstances. Several conditions apply to most situations, however. System operators should live in the village so they are available to work the system regularly. They need to be able to work well with the water committee. They should be accepted by, if not chosen or approved by, the village water and sanitation committee and the community as a whole. They must have an ability to perform technical operations and have an interest in improving the water and sanitation conditions in the village.

The number and qualifications of system operators are determined according to the design of the system, the size of the system, the various components of the system (especially any water treatment facilities) and the number of people who will be using the system. Information on the number and qualifications of system operators needed for the particular facilities constructed at the local level should be obtained from the technical notes that relate to that specific system.

In a typical small water supply and sanitation system, the personnel will probably consist of those needed to administer or manage the system and others who operate it technically. If the village committee acted as an administrative staff during construction of the system, they should continue to do so after the system is in use. The committee can oversee system operators, manage the budget, collect user fees and perform all accounting duties.

System operators' duties will be both technical and non-technical. They will be responsible for operating equipment, performing preventive maintenance, making repairs, reading meters, and cleaning the system. They will also be responsible for ordering supplies, groundskeeping (maintaining fences around facilities, clearing blocked drains, checking pipe coverings), and keeping basic records. System operators must keep the village water and sanitation committee informed on the condition of the water and sanitation system and recognize and report major problems as early as possible to the action agency's regional office.

One method of choosing operation and maintenance personnel is to use the construction period to select and train workers who have shown competency and interest in the system during construction. The system operators chosen from the construction crew learn first how the system is put together and how it works. This facilitates understanding and performing the operation and maintenance work.

Women are the primary water users in villages, so equal access to training in system operations should be ensured for them. If women were involved in construction tasks, they are primary candidates for operation and maintenance tasks. Women are less likely to leave the village than men and have a direct influence on the water and sanitation habits of the children. Their employment as system operators may provide more continuity in operation and maintenance. Since women use water systems more than men, they also detect problems earlier. In addition, the children will soon learn that operation and maintenance are very important aspects of the water and sanitation system and will grow up with a positive attitude toward maintaining a system. Introducing these new attitudes and approaches to children will make introducing ideas and systems in new generations much easier.

Often there is an experienced or skilled mechanic in the village who knows how to use tools similar to those involved in the new system. The village committee should consider hiring such a person for operation and maintenance duties. Other good prospective system operators are water collectors, water vendors, traditional well-diggers, and primary health workers.

Operators who can read and write can make monthly reports and keep other records. However, ability to read and write should not be the deciding factor in chosing system operators. Reports can be made in other ways or special training for writing reports can be incorporated into training.

The village water and sanitation committee should be trained in the needs of operation and maintenance to facilitate good system management and cooperation with system operators. The water committee will be the best liaison between the system operator and the rest of the community. If the committee and the local population develop a sense of pride and ownership in a system, they will demand a smoothly run system which provides the services for which it was designed. In addition, a community which is proud of its system, and understands the importance of its care, is more likely to cooperate with the system operators and properly use their facilities.

In small communities with simple water and sanitation systems, it may be advisable to make one or two people responsible for operation and maintenance tasks. Where systems are larger or more complex, operation and maintenance by a group of system operators may be best. Small water and sanitation systems do not imply small problems or small responsibilities for system operators and the village water and sanitation committee, however. Appropriate training is needed for operation and maintenance of water and sanitation systems of any size.

Methods of Training

There are many ways to conduct training programs. They can be held at national, regional or local levels employing many different teaching styles. The style of the training program will be influenced by the subject matter to be covered, the place the training is conducted, the facilities available, the skills and experience of the trainees, the length of time the trainees can spend at a training site, the length of time trainers can spend with the trainees, the funding that is available, the local conditions under which the operators will have to work, and the back-up support the action agency will provide to local operators. No matter what style of instruction is developed, some principles for training local systems operators should be kept in mind.

1. Training should stress the practical aspects of caring for water and sanitation systems. The trainees should learn the procedures they will need to perform for the community systems by practicing the procedures under the supervision of an experienced trainer. Training cannot be accomplished by lectures, manuals, visual aids and demonstrations alone, although these are acceptable complements to hands-on experience.

2. The training programs must be directly applicable to the facilities the operators will be working on in their own village. If operators are not trained in their villages on the actual equipment to be used, they should practice on identical equipment at the training site. Teach only what is directly useful to the trainees, and limit the amount of extra information.

3. Training programs must be adjusted to fit the individual needs of the people being trained. For example, if the people cannot read and write, their training needs are very different from those who can.

4. The action agency should aid training efforts by arranging refresher courses for systems operators.

5. Resources and dependable back-up support should be available at the action agency's regional office where village system operators can reach them.

6. The success of training will be minimal unless the community and the action agency together create paid positions for operators and are willing to pay a training staff.

7. The training program should

include practical evaluation of system operators to determine if they are able to perform satisfactorily under local conditions.

System operators can be trained in their village or in a training center. On-the-job training in the village under the supervision of an experienced operator may be best for simple systems. No special facilities will be required since system operators can learn tasks using the equipment they will be working on to perform their jobs. On-the-job training is effective with trainees who learn new skills best by doing.

In order to work well, on-the-job programs need skilled and experienced trainers available to travel to job sites. No transportation will be needed to get village trainees to the training site. Trainees are often more likely to attend training sessions in their own villages than in centers to which they must travel. On-the-job training usually costs less than training in a center. It can begin during construction phases and may be supplemented by short courses and refresher courses at the regional training center.

A central training establishment for training can be arranged at the action agency's regional office. Short courses can be based on simulated water and sanitation systems. Trainers would be available to trainees at all times. Other training aids, such as spare parts, printed materials, slides, audio tapes, video and film might be available. Media aids can be adapted to help instruct persons who cannot read. The operation and maintenance technical notes in this series that apply to the system the trainee will operate will be useful training materials.

Self-paced training programs can be developed so that workers at various levels of competence can use materials individually but still have access to trainers when necessary. A trainee can receive one-on-one assistance at a slow or fast pace from the trainer.

Supervised check-ups in the village should follow centralized training. A mobile training unit could come to each village for check-ups and refresher courses.

The disadvantages of centralized training are that transportation must be provided for the trainees from their villages to the training center. Operators are less likely to attend training if they must travel daily. Costs of establishing a central training unit are usually high. Local conditions cannot be taken into account when training takes place in a central spot with a standardized program.

One of the most important aspects of the training process is the attitude of the trainers. Trainers need to be able to encourage operators during training and reward them for performing well. The action agency should develop a basic training course content. A certificate will record the lessons learned and help standardize tasks and training needs between villages.

Efficient operation and maintenance depends on well-trained and paid operators. It is false economy to skimp on either of these items. The absence of a training budget will be as detrimental to operation and maintenance efficiency as the absence of a system for fees collection to cover operation and maintenance costs. Good training needs a good budget.

Summary

If the benefits of water and sanitation programs are to be realized, the systems must operate efficiently and be dependable. Without proper operation and maintenance, systems will fail to operate. Operation and maintenance must be well planned and systems operators must be well trained.

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Water for the World

Planning Operation and Maintenance Training

Technical Note No. HR. 3.P

Planning operation and maintenance training programs for rural village water and sanitation systems requires choosing a training method and arranging a training program schedule. It is imperative that plans for training begin while the system is being designed so that those who will be operating and maintaining it will know how to do so. For more information, refer to the design and the operation and maintenance technical notes for the specific system being constructed.

A good training approach should transmit the practical skills and knowledge a worker needs to operate and maintain a system. Each task should be carefully defined and analyzed so that it is relevant to the system's operation. Extraneous material not directly related to the operation of the system should not be included. All parties concerned with planning, design, construction, management, and operation should help define these tasks. Teaching should always stress the practical aspects of the subjects covered, including more demonstrations and practice than lectures.

Choosing a Training Method

Instructional programs will be influenced by many factors: the subjects to be covered, the place the training can be conducted, the facilities available, the skills and experience of the trainees, the trainers available, the transportation available, the length of time the trainees can spend at a training site, the length of time trainers can spend with the trainees, the funding that is available, the local conditions under which the operators will have to work, and the backup support the action agency will provide to local operators. In order to select the type of training program most appropriate for local circumstances, these aspects of training must be considered:

1. Identify job tasks. These will be the basis of the training program. Fully describe the operation and maintenance job:

- List all tasks (daily, weekly, monthly).
- List schedules and hours needed to perform these tasks.
- List qualifications personnel will need in order to perform each task (any special skills or knowledge will need emphasis in training).
- List the number of operators necessary to perform each task.
- Describe the working environment of the operators. Check to see if the action agency or any other agency has already trained operators to manage similar water and sanitation facilities in the region. If records have been kept of job tasks, they may, with appropriate adaptations, be useful guidelines for the training program.

2. Identify the trainees' understanding of, experience in and abilities to perform the job tasks. Which tasks will need special or intensive training? Identify the number of participants in the training program. How will tasks be divided among local personnel?

3. Identify local constraints for participating in a training program, such as access to transportation, accessibility of training site to trainees, accessibility of trainees to instructor, length of time trainees are able to spend in training, dates for training and places for training. The location and mobility of trainees must be considered when deciding whether to take the trainees to the training or the training to the trainees. At the village level, it usually costs less and is more effective to take the training to the trainees.

4. Identify trainers and their qualifications. In most situations, the people selected to do the training will not be full-time trainers. They will most likely be people with technical experience in the subject area but with little practice in training others. If possible, there should be an efficient and effective training program to prepare trainers for their duties. They should be taught how to use the technical notes on operating and maintaining various systems, to conduct training sessions, and to assist the village water committee in selecting candidates for the operation and maintenance positions. Trainers should be well-versed in the technical aspects of the system, be acceptable to the rest of the group as trainers, and have the potential and personality to become trainers. The following list summarizes some of the attributes that should be considered in selecting trainers:

- communicates at the level of the trainees,
- is technically competent,
- is able to teach all subject matter related to the job tasks,
- is able to use training aids and audio-visual equipment, where more sophisticated training materials are available,
- motivates trainees,
- clarifies points and assists trainees,
- evaluates trainee performance,
- accepts advice from trainees and training staff,
- is supportive of trainees,
- allocates time for preparation of training, training sessions, and follow-up.

5. Identify physical facilities, supplies and equipment available and needed for training:

- regional training center,
- local site,
- specialized equipment,
- safety equipment.

List the training resources available:

- supplies,
- equipment,
- support at village system site,
- audio-visual equipment,
- instructional materials.

6. Identify funds available. List all allocations in cash or in kind from the action agency, the village and any outside resources.

7. Define training objectives and priorities based on conditions identified. Analyze as accurately as possible the training needs of the village operation and maintenance personnel and the capabilities of the action agency to deliver that training.

Choose the training style that best accommodates the objectives and priorities of training, the trainees and the training situation. Refer to "Methods of Operation and Maintenance Training," HR.3.M, for information on training methods. Table 1 suggests a method for choosing a training site.

Arranging a Training Program Schedule

Once a training program coordinator and/or instructors for the program have been selected, they should:

1. Determine how much time is needed to teach the subject matter and decide on the duration of the training program.

2. Schedule use of training facilities or times for training sessions in the village.

Table 1. Choosing a Training Site

IF	AND	AND	AND	AND	THEN
Many trainers are available	→	→	→	→	Train on-site[1]
Few trainers are available	Equipment and supplies are only available on-site	→	→	→	Train on-site[1]
	Equipment and supplies are available at central site	Job tasks are site-specific	→	→	Train on-site[1]
		Job tasks are not site-specific	Trainees can spend time at central site	Transportation for trainees is available	Train at central training site[2]

[1]The advantages of training on-site are:

- -trainees have more time for training
- -lower costs
- -trainees learn on own equipment, no special facilites required
- -local conditions can be integrated into training
- -entire community realizes importance of training

[2]The advantages of central-site training are:

- -trainers available to trainees at all times
- -standardization of operation and maintenance practices
- -lower costs for trainers
- -more teaching aids available

3. Put the information to be presented in sequence. Operation and maintenance personnel should be trained for the specific technical functions they will perform. Design lessons according to the job tasks defined. Training should also extend beyond technical details to explain the basic reasons for maintaining the quality of the water. Operators should be given a sense of pride in their work and of their responsibility for protecting the health of the community.

4. List training equipment, supplies, aids and reference materials needed. Include their costs and where to obtain them.

Trainers should provide system operators with manuals specific to the equipment for which they are responsible. Manuals should be prepared in a form which the trainees can use and understand, whether they can read or not. Local languages and many illustrations should be used. The manuals can serve as textbooks during training and references while on the job.

A supply of spare parts should be maintained at the village level for routine repairs. A similar supply should be fully explained and repair procedures demonstrated during training. Proper storage of spare parts should be covered.

Occasional refresher training sessions should be planned to maintain operators' interest in their duties, to review operators' duties, to teach any new procedures and to introduce any new equipment.

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Water for the World

Implementing Operation and Maintenance Training

Technical Note No. HR. 3.I.1

Training is very important to successful water and sanitation system operation. Training is necessary when a new operator begins a job, when an experienced operator needs to perform a new task, or when an operator does not have enough skill or knowledge to perform a job well.

Training must be directly applicable to local circumstances, understandable to local trainees, technically appropriate and technically correct. Training should be practical to the extent that trainees learn operational procedures on equipment identical to that which they will operate, if they are not trained on village equipment itself.

Training should take into account local learning techniques and educational methods so that credibility for teaching authority and prestige for training are created. Training should be conducted in a manner which meets local work standards and ethics, attaching a sense of dignity and pride to both the training process and the operation and maintenance job itself.

Training should be provided at appropriate levels for all personnel involved with the operation and maintenance of the water and sanitation system. This may include system operators, bookkeepers, local health educators and the village committee. Extensive training of this sort will provide a catalyst for wider community education and understanding of the water and sanitation system and will prevent one trained operator from monopolizing proper system operation. In case of the absence of one trained person, several other trained people will be available. There will also be a balance of power. For example, the village committee can select a system operator for training but the committee can also manage the water and sanitation system along with the system operator.

Management of Training Courses

Training programs must be well organized to work effectively. It is extremely important that trainers and trainees communicate well during the training sessions. The roles and responsibilities of both should be understood before training begins.

The roles of trainer and trainee are partially dependent on the location of the training program. See Table 1 in "Planning Operation and Maintenance Training," HR.3.P. Training in the village where the water and sanitation system will be operated has these advantages:

1. Trainees have more time for training sessions.

2. Trainees can learn on equipment they will actually be working on later. Special problems and conditions can be handled during training.

3. Local routines, people and conditions can be integrated into the training program.

4. The entire community can be helped to realize the importance of training.

Training at a central site has these management advantages:

1. Trainers are available to trainees at all times.

2. Operation and maintenance practices are taught in a standard manner to each trainee.

3. More teaching aids are available.

The role of the trainers and trainees may vary somewhat depending on where training takes place.

Roles and Responsibilities of Trainers

Trainers must be technically competent in the technology to be used. They must also be capable of handling administrative duties from both technical and management standpoints.

The training staff is responsible for determining the job tasks of all system personnel, determining the training course content based on those job tasks, organizing the material to be presented, selecting an instructional method and conducting the training programs.

Trainers responsibilities will be:

1. <u>To learn the trainees' needs and adapt the training program to meet those needs</u>.

Trainees may be divided into learning groups. Courses can then be molded to the needs of the individual groups while still covering necessary procedures. Trainers should personally examine local circumstances and determine what job tasks will need to be performed. They should then determine what the trainees already know and what they will need to be taught. Standard procedures for the defined tasks should be established and taught. Tool and equipment supplies should be adequately provided.

Operation and maintenance personnel with little mechanical background and little other education will probably need very structured and practical training programs. This is especially true if the system operators to be trained have not participated in the construction of the water and sanitation system they are being taught to maintain. Trainers must understand the procedures well and be able to explain them clearly to trainees in the trainees' own language.

If the operation and maintenance personnel have some mechanical background or are experienced in operation and maintenance, and have actively participated in the construction of the system and demonstrate a good understanding of its use, training may not need to be as regimented as it is for the inexperienced operation and maintenance trainee. The trainer can demonstrate procedures and have trainees practice them with trainer direction as needed for evaluation. One trainer can manage several trainees at the same time this way.

If trainees have been trained in the operation and maintenence procedures before, and demonstrate a good understanding and skill in their work, they may only need a refresher course. The trainer may only need to explain new types of equipment and procedures and be available to answer questions the trainees have while experimenting on their own.

2. <u>To maintain a positive and helpful attitude toward trainees</u>.

A "reward" may be established by the training co-ordinator as an incentive to create and maintain positive attitudes toward training. "Rewards" should be appropriate to local desires and circumstances. Public recognition, a special privilege, increased responsibility and pay increases are often used as incentives. Job security and official recognition for trainees by the village committee or regional center are usually more effective as incentives than financial benefits.

3. <u>To help install local respect for the proper operation and maintenance of the water and sanitation system</u>.

This may involve working with the entire village to some extent, and especially with community leaders and health educators. If training is taking place in the village, special efforts can be made to integrate local schedules, people and problems into the training program.

4. <u>Creating and maintaining a desire for learning and understanding during training</u>.

It is important that trainees understand that proper operation and maintenance can improve life in the village. It is also very important that trainers conduct training sessions in a manner that attaches a sense of pride and dignity to the training process which will be continued on the job.

Roles and Responsibilities of the Trainees

Trainees' responsibilities may be more circumstantial than trainer responsibilities. Overall, of course, the trainees' greatest responsibility is to learn how to operate and maintain the local water and sanitation system in order to provide good service to the rest of the community. Trainees' specific training duties may include:

- Clearly explaining to the trainer the extent of their experience with and knowledge of the water and sanitation system.

- Co-operating with the trainer's course structures.

- Actively participating in all training exercises and drills.

- Asking questions that are applicable to the trainee's local working situation.

- Maintaining a positive and co-operative attitude throughout training.

It is very important that the roles and responsibilities of all persons involved in the operation of the water and sanitation system be defined. Review those agreed upon during the planning stages of the system. Refer to "Community Participation in Planning Water Supply and Sanitation Programs," HR.2.P. The responsibilities of the project planner, others in the action agency, the system operators, the village water and sanitation committee and the community as a whole should be clearly explained and agreed upon at the outset of the training program.

Content of Training Courses

The content of the training courses will be an explanation of the defined job tasks. See "Planning for Operation and Maintenance Training," HR.3.P.

Generally, the action agency is responsible for providing logistical support and major repair services. The community will be responsible for the administration, operation, preventive maintenance and basic repairs of the system. For each position on the local level, the trainer should identify:

- job tasks and responsibilities;

- the degree of authority the position holds;

- financial responsibilities;

- support responsibilities.

The action agency is responsible for providing training for project planners, trainers and all village personnel. The project planner will be responsible for providing action agency support to the village while the system is in use. Community personnel, especially system operators, will need outside assistance when facing problems they cannot solve themselves. Back-up resources, such as information, skilled assistance, tools and parts should be readily available in the regional office of the action agency. The project planner should be prepared to:

- provide maintenance and repair services which village system operators have not been trained to perform;

- provide system and water quality control checks;

- supervise, assist and instruct local operators in operation and maintenance procedure reviews;

- assist in extensions of systems.

The regional office of the action agency should:

- maintain replacement parts to supplement the local supply;

- provide dependable central services for ordering other materials and spare parts;

- provide transportation of personnel and materials to community.

It may be possible for a supervisor or team from the action agency to visit villages on a regular basis to supervise procedures, answer questions, check the condition of facilities, perform needed repairs and provide other preventive maintenance services. Qualified advisors who provide regular refresher training to local operation and maintenance personnel are useful. This will minimize costly breakdowns and the length of time systems are out of order and increase community satisfaction and use of the system. Action agency support should emphasize that preventive maintenance is essential to the long-term operation and use of the system.

The responsibilities of local personnel will vary with local arrangements and with the design of the local system. System operators should be supervised by the village water and sanitation committee and by the project planner and trainer of the action agency. System operators are generally responsible for:

- basic daily operation of equipment;
- preventive maintenance of water supply equipment and sanitation facilities;
- protection of the water source from pollutants, children, and animals;
- simple repairs;
- reporting to the village committee, requesting new parts and asking for action agency assistance when needed;
- recognizing and reporting major problems.

Operation and maintenance training must prepare system operators to help the village committee create respect for the facilities among the rest of the villagers so that the facilities are properly used. System operators should know where they can obtain help at either the local or the regional level.

The village water and sanitation committee is generally responsible for:

- demonstrating proper use of facilities;
- teaching villagers to understand and appreciate the advantages of safe water supply and sanitation systems;
- assisting individual households to care for individual facilities and installations;
- retaining a bookkeeper to maintain system finances;
- establishing flat or metered rates for water supply and sanitation services;
- collecting and retaining fees;
- paying for operation and maintenance with collected fees;
- ordering and purchasing needed equipment, perhaps at an agreed price from the action agency;
- requesting the services of the action agency, including the purchase and provision of major materials.

Fix an Implementation Routine

Regular methods of operating and maintaining the local water supply and sanitation system should be established as part of a training course. Regular times (daily, weekly, monthly) for the procedures should also be established. Any preventive maintenance or cautionary procedures should be incorporated into the regular operation and maintenance routines.

System operators' performance on the job can often be improved by using job manuals and visual aids such as posters to remind them of the established routine. Manuals and aids can be introduced as part of training, and may even serve as the outline for a training course. They can help trainees avoid having to memorize information they may remember incorrectly.

A basic manual can:

- explain operation and maintenance procedures step by step, as simply as possible;

- include illustrations for procedures;

- list and illustrate tools, supplies and equipment needed to carry out procedures;

- stress the importance of potable water and sanitary waste disposal.

Visual aids, such as posters and picture manuals can replace written instructions for those unable to read well and supplement any manuals on the job. Training, operation and maintenance manuals and visual aids can be developed by the regional office of the action agency. The regional office staff should know better than the national office staff how the tools, equipment, supplies and procedures should be applied to the local situation.

Reports

Monthly reports on the functioning of the system should be made by the system operator. Oral reports can replace written reports for those who do not write well and can be given directly to the action agency maintenance supervisor or inspector. A system opertor who does not read or write well can be taught to check an illustated chart in order to make reports, or another member of the community can write up the system operator's oral report. Periodic inspections of the system should be made by the project promoter from the action agency.

Notes

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Water for the World

Evaluating Operation and Maintenance Training

Technical Note No. HR. 3.I.2

Operation and maintenance of water and sanitation systems is necessary to provide continuing water and sanitation services. This requires constant evaluation of operation and maintenance procedures and conditions.

Evaluation is a way for the action agency and the village to review the value of the water and sanitation system to the community. A balanced evaluation by both parties working together can:

- identify the benefits of the system;
- provide encouragement and support for the system operators;
- identify weak spots in procedures and services;
- examine mistakes without emphasizing them;
- provide suggestions for improvement.

One objective of training and evaluation is to make the system operators understand the importance of, their role in and responsibility for providing safe and convenient service to the community. The village as a whole can then develop a sense of pride and ownership in the system. Evaluation can help ensure that the people served by the water and sanitation system, the system operators and the action agency do not develop a complacent attitude toward the system.

Evaluation should be a cooperative effort involving the action agency and the village. All persons involved in the water and sanitation system should contribute to the evaluation. Critical, rule-enforcing inspection should be avoided. The action agency should consider its role as supervisor carefully during the evaluation process, being careful not to treat villagers as subordinates. A full, two-way exchange is very valuable in evaluation.

Evaluations should be as simple and straightforward as possible. It is important, however, to judge the entire water and sanitation system as a whole. All processes, procedures and personnel are interdependent. Isolated criticisms of specific points may not identify an overall problem which may impair smooth operations in general.

Operation and maintenance evaluation includes:

1. Monthly reports on the operation of the system, both mechanically and financially. Reports can be made by the system operators and copies sent to the action agency regional office. See "Implementing Operation and Maintenance Training," HR.3.I.1.

2. Joint analysis of the system by the operator, community leaders, project planners from the action agency and a technical inspector or engineer from the action agency.

3. Evaluation of training programs.

Monthly Reports

No matter how simple a system is, continual follow-up is necessary to ensure that it continues to work properly. Monthly reports, drawn from daily records, should be done by operation and maintenance personnel on the functioning of the water system both physically and financially. Daily or weekly records should be maintained and kept in the village. They should be open to public inspection, and should be read regularly by the water committee. A copy of each monthly report should be sent to the regional office of the action agency.

Joint Analysis of System

A periodic, preferably monthly when the system is new, analysis of the system by members of the village committee, the system operator, the project planner and a technician will be a major aspect of system evaluation. The analysis should cover all facets of the system, including:

- the functioning of the system;
- its acceptance by the villagers;
- any misuse of the system;
- the technical and physical condition of the system;
- the financial status of the system, including a review of fees collection and of the books;
- the supply of spare parts, fuel, equipment, tools and other necessary supplies on site;
- a check on the quality of water being produced;
- an evaluation of the knowledge and skill of the system operator;
- the time needed to perform all operation and maintenance tasks.

Evaluation must first consider whether the total system is effective. When problems are identified, analysis may show whether they are a result of support functions of the action agency, support within the community, poor selection of candidates for system operators, or training failures.

Evaluation of Training

One of the responsibilities of the action agency when examining the village system and analyzing evaluation reports is to determine how training has affected the success of the system. Persons not associated with the development and implementation of the training should evaluate the system if possible.

Two types of evaluation, internal and external, should be carried out to determine if the training program has been effective.

Internal evaluation determines if the training program is providing the trainees with the necessary knowledge and skills to perform their jobs well. This evaluation might consider:

1. The amount of time that was required by trainees to complete the training.

2. The appropriateness of the prerequisites prescribed for the training.

3. The performance of the trainers.

External evaluation determines if the training delivery system is producing trainees who perform well. This evaluation might include:

1. How well do trainees believe they are able to perform on the job?

2. What additional training was required by trainees after arriving on the job?

3. How well did the training program prepare trainees for the job? Do the system operators know how, when, and why to perform tasks?

4. What portions of the training program were most relevant? Have system operators been trained to do the appropriate tasks?

5. What tasks cause the most difficulty?

6. How much improvement do supervisors see in the trainees' performance on the job?

7. How does the project planner evaluate the performance of these trainees compared to previous groups of trainees?

8. In what areas were the trainees inadequate?

9. Was the training adapted to local circumstances or standardized?

The results of the internal and external evaluation are used to improve the training programs. Consideration must be given to making changes based on cost, time available, personnel available, benefits of changes to the program and detriments to the program if changes are not made.

The village and the action agency should be sure to evaluate the system operators on the job to test their skills and knowledge. The following criteria may be used to evaluate a worker's on-the-job performance:

- current water quality,
- change in water-related disease rates,
- maintenance costs,
- supply costs,
- system breakdowns,
- relations with water users, and
- morale of system operators.

Evaluations can contribute information and insights that will help the next training effort be more efficient and effective.

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Water for the World

Methods of Water Treatment
Technical Note No. RWS. 3.M

A safe and adequate water supply is essential for the prevention of waterborne diseases. Drinking water must be free of organisms and chemical concentrations that are hazardous to human health. It should be free of suspended particles, bad tastes, colors and smells, and should not damage a water supply system. Water treatment is the process of making impure water safe to drink and use. Water that is both safe and acceptable is called "potable." It is best to develop a source that is naturally potable or that needs as little treatment as possible. Treatment processes are often expensive and always require regular attention. Since many water supplies, especially surface supplies, are not naturally potable, water treatment is often necessary.

This technical note describes basic treatment methods for individual household water supplies, simple community water systems, advanced community water systems, and water emergencies. It should be used in conjunction with "Selecting a Source of Surface Water," RWS.1.P.3, and "Selecting a Well Site," RWS.2.P.3, so that a water source needing as little treatment as possible is developed. See Table 1.

Basically, three types of water need treatment. Contaminated water contains disease-causing organisms called pathogens. The process of destroying these organisms is called disinfection. This is the most important type of water treatment in the control of diseases. Turbid water, which is clouded with suspended matter, needs to be settled or filtered to make it clear. This treatment process is called clarification.

Useful Definitions

BACTERIA - One-celled microorganisms which multiply by simple division and which can only be seen through a microscope.

BAFFLE - A wall or screen which redirects water flow in a tank or basin.

PATHOGENIC - Disease-causing.

POROUS MATERIAL - A medium full of tiny openings that water can pass through.

RAW WATER - Untreated water.

SLUDGE - Solids settled from water-carried wastes.

SUSPENDED MATTER - Small particles in water such as soil or plant debris which are light enough to remain suspended and which give water a hazy appearance.

WATERBORNE DISEASES - Diseases caused by drinking water containing pathogenic organisms.

Some well water has a high mineral or salt content or bad taste, color or odor. It needs a treatment process called conditioning. Conditioning makes unpleasant water aesthetically acceptable which may encourage people to use it.

To determine if a potential water source is potable, a sanitary survey and water analysis can be conducted. A sanitary survey is a field evaluation of local health and environmental conditions which helps determine the acceptability of a potential water source. It is an important step in determining the need for water treatment. See "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2. A water analysis measures bacterial, physical and chemical characteristics of water. See "Taking a Water Sample," RWS.3.P.2, and "Analyzing a Water Sample," RWS.3.P.3, for details on water analysis.

Treatment for Individual Household Supplies

Individual household water treatment methods are simple ways of killing some pathogenic organisms in small drinking water supplies. They are appropriate for communities without the resources or finances to construct and operate larger treatment systems. Local materials can be adapted to the design of these methods and the construction and operation skills needed are minimal. This technical note describes four types of individual household water treatment: storage, filtration, boiling, and chemical disinfection. These methods can be used alone or in combination with each other, depending on the quality of the water supply.

Storage. The simplest water treatment is holding water in a container for at least two days before using it. This short-term storage of household water supplies will kill some disease-causing organisms and will settle much of the turbidity. Storing water for two weeks or longer can kill up to 90 percent of the disease-causing bacteria present. Storage containers can be made of metal, glass, plastic, or ceramic material. Earthen pots should not be used if it can be avoided because of the risk of bacterial growth in the porous clay walls. Household containers are normally from 10-30 liters in volume.

Storage containers must be covered to keep dirt and other contaminants

Table 1. Methods of Water Treatment for Small Rural Communities

Method	Type of Treatment	Construction Cost	O & M Cost	Reliability	Construction Skill Required	O & M Skill Required
Storage	Clarification of mild turbidity	Low	Low	Small volumes of water only; used with filter and/or disinfection	Low	Low
Household filter	Clarification of turbid water; removes some pathogens	Low	Low	Up to 2700 liters/ day; used with disinfection	Low	Low
Boiling	Complete disinfection	Low	High	Small volumes	Low	Low
Chemical disinfection by hand	Disinfection of clear water; kills most pathogens	Low	High	Difficult to determine; taste test only	Low	Medium
Plain sedimentation basin	Clarification of very turbid water	Medium	Low	Use with filtration and disinfection	Low	High
Slow sand filter	Clarification and disinfection	High	Low	Kills most pathogens with proper maintenance	High	Medium
Simple disinfection unit	Disinfection of clear water	Low	High	Frequent chlorine checks are necessary	Medium	High

from entering the water supply, to keep algae from growing, and to prevent evaporation. A screen at the inlet will remove large particles (see section on filtration). An outlet for drawing water as shown in Figure 1 can be added to reduce the risk of contamination. The storage container must be cleaned often to prevent organisms from growing in the settled sludge. Storing water will not kill all pathogens and is not effective for fine turbidity. Stored water should be boiled or chemically disinfected to make it completely safe to drink.

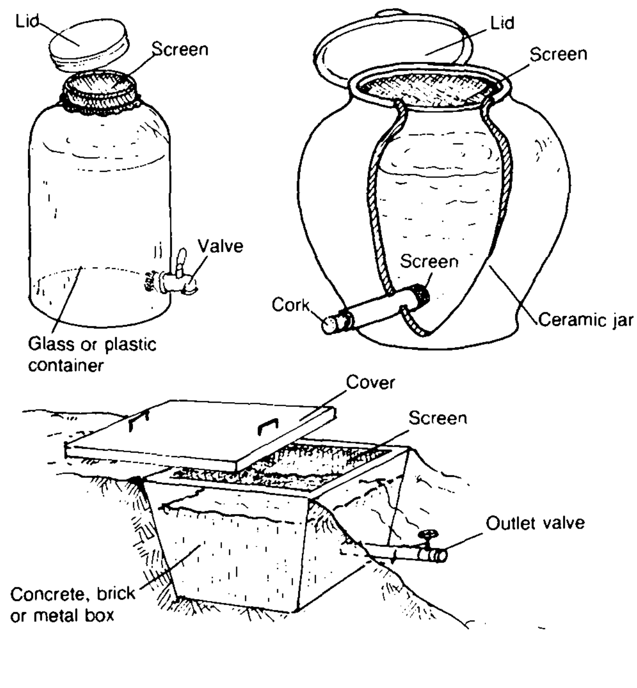

Figure 1. Methods of Household Storage

Filtration. Turbid water supplies can be clarified by filtration. This is the process of passing water through porous material to remove suspended particles. Several types of filters can be used for household water supplies. They are relatively ineffective against bacteria and fine turbidity, but they will strain out coarse materials. The filtering medium can become blocked or contaminated after prolonged contact with turbid water. It must be renewed frequently to avoid adding bacteria to the water supply. Filtered water should be boiled or otherwise disinfected before drinking.

Porcelain or ceramic filters are available commercially in some areas but they are usually expensive. They consist of a filter candle which filters water from one storage vessel to another or from one compartment to another within a single storage unit as shown in Figure 2a. They may also be attached directly to the taps of a water delivery system. Ceramic filters are relatively common in prosperous areas. They are effective for moderate turbidity, but must be cleaned whenever sediment builds up on the candle and reduces filtering efficiency and rate of flow. The candle is cleaned by scraping it with a brush and by occasionally soaking it in a mild chlorine solution.

Charcoal, ricehulls and other local materials are sometimes used as filter mediums for small water supplies. Charcoal improves the taste of some water supplies. These materials must be changed often to prevent recontamination and to maintain the required rate of flow.

A sand filter shown in Figure 2b, is inexpensive and simple to construct and maintain. It is made of a large barrel partially filled with a layer of clean sand on top of a layer of small stones. Turbid water poured into the top of the barrel flows through the sand which traps the sediment. The resulting clear water flows out of a perforated pipe at the bottom of the barrel. A layer of gravel can be placed on top of the sand layer to prevent erosion of the sand where the turbid water is poured in. A continous flow through a 208-liter barrel filter can process approximately 2700 liters of water per day. The sand layers must be changed every two to three weeks to keep up the flow rate and to prevent organisms from growing in the sediment trapped in the sand layers and recontaminating the water. The sand that is removed can be washed, dried and used again. Household sand filters are often used with rainfall catchments or other sources where water may contain small debris. They can filter large quantities of water quickly but do not kill pathogenic organisms. They must be carefully maintained because dirty filters can breed new organisms. A household sand filter only provides clarification of the water and prepares it for boiling or chemical disinfection.

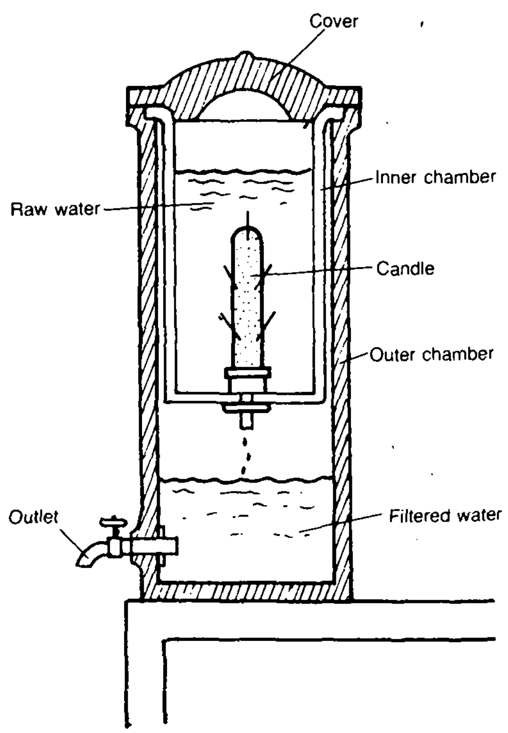

Figure 2a. Porcelain Filter

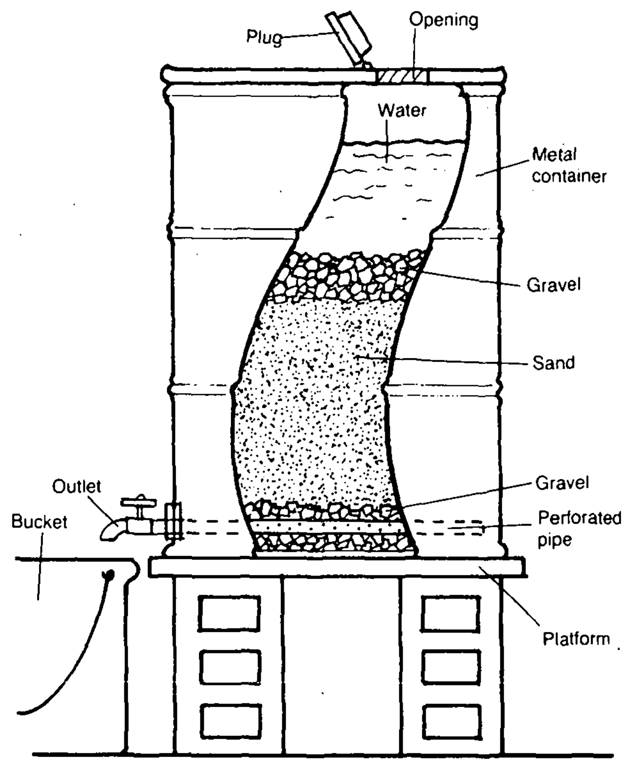

Figure 2b. Sand Filter

<u>Boiling</u>. Boiling water is the most effective way to disinfect relatively small quantities of water. All pathogenic organisms are destroyed in water brought to a rolling boil for two to three minutes. Cooking pots or large steel drums over fireplaces shown in Figure 3, are common vessels for boiling water for groups of less than 20 people. The water must be covered, cooled and stored in the same container it is boiled in to prevent recontamination. Constructing a boiling unit is simple and materials are inexpensive, but fuel required to boil the water (such as firewood, charcoal, kerosene or bottled gas) may be difficult to get and can be very expensive. The boiling method of water treatment is impractical for large quantities of water or large groups of people.

Boiling has been used very successfully as a treatment method in the People's Republic of China where tea is a common beverage and hot drinking water is preferred. The Chinese boil a large kettle of water each morning while they are preparing breakfast,

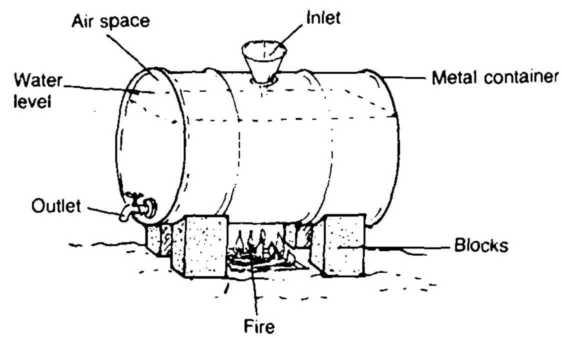

Figure 3. Method of Boiling Water

then pour the water into large thermos jugs and use it throughout the day. Using this method, the Chinese have drastically reduced the incidence of waterborne disease over the past thirty years.

<u>Chemical disinfection by hand</u>. Contaminated water can be disinfected with chemicals. Iodine, bromine, and chlorine can eliminate most disease-causing organisms in water but they do not kill all pathogens and are not

effective against organisms embedded in solid particles. Chemical disinfection is only appropriate for clear water supplies. Turbid water must be settled or filtered first.

Chlorine is the most widely used chemical disinfectant and is marketed in many forms. Directions for use are supplied in the purchased package and should be followed carefully. A small amount of chlorine powder or liquid can be added by hand to a water supply and allowed to set for thirty minutes to react with the contaminants present. Liquid laundry bleach is often the easiest form of chlorine stock to apply in this manner.

Chlorine added to a water supply reacts with soil particles and inorganic materials as well as disease-causing organisms. The amount of chlorine needed to disinfect a water supply is called the "chlorine demand." It changes according to the condition of the water to be treated. Extra chlorine must be added to turbid water, for example, to react with organic and inorganic material present and still kill the bacteria. The amount of chlorine left over in a water supply after disinfection is complete is called the "chlorine residual." This provides some continuing protection of the water supply against subsequent contamination. The level of chlorine residual in a chlorinated supply must be measured regularly to be certain the treatment remains effective.

Manual chemical disinfection is not always reliable. The quality of raw water often changes, and it is difficult to determine how much chemical is needed for proper disinfection. An insufficient amount will not disinfect the supply at all, and an overtreated supply can have such a bad taste or odor that no one will use it. A simple rule is to add a chlorine solution, such as laundry bleach, to a container of water just until a chlorine taste or odor is noticed.

Treatment for Simple Community Systems

Simple community water treatment methods are appropriate for groups larger than a single household. They are best suited for larger volumes of water and require more construction, operation and maintenance skills than simple household methods. This technical note discusses three types of simple community treatment. They are plain sedimentation, slow sand filtration, and chemical disinfection dispensers. Depending on the quality of the water supply, they may be used separately or in combination.

Plain sedimentation. Plain sedimentation is a method of clarifying very turbid water. It involves holding water in or moving it slowly through a large basin until most of the suspended particles have settled to the bottom. Sedimentation is often a preparation for filtration.

A sedimentation basin is usually rectangular and made of concrete, but it may also be made of steel, stone, or local materials. It must be completely leak-proof. If filtration does not follow, it is desirable to cover the sedimentation basin to prevent algae growth or recontamination of the water. Figure 4 shows a typical sedimentation basin. Water enters it through a inlet near the top of one side of the basin, is slowed by a baffle, which is a wall or screen that redirects water flow, near the inlet. The water leaves the basin over a wire and through an outlet at the top of the other side. Valves or gates can be added to control the speed of the water. Floors of sedimentation basins

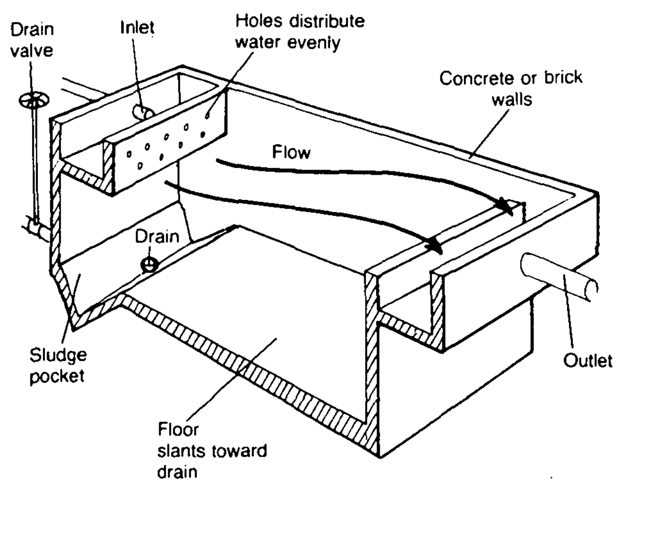

Figure 4. Sedimentation Basin

are often sloped to make removing settled sludge easier. The size of a sedimentation basin depends on the average daily water needs of the community it is serving. The basin can be designed to provide a constant flow or it can be filled and emptied as needed. Building a sedimentation basin requires trained designers and skilled construction workers.

Water is usually held in a retention type of sedimentation basin for at least two days. Very turbid water may need a chemical additive to induce settling (see section on advanced treatments). Water passing out of a sedimentation basin is clear, but needs to be disinfected to be certain it is safe to drink.

Slow sand filter. A slow sand filter shown in Figure 5, removes almost all bacteria from and clarifies large water supplies with low turbidity. It is often used in conjunction with a plain sedimentation basin for highly turbid water. It consists of a steel drum or large concrete tank partially filled with layers of small stones and very fine sand. The filter tank is flooded with water which slowly seeps through the sand. After several days, a thin slime called a schmutzedecke forms on top of the sand. The schmutzedecke filters out bacteria and pathogenic organisms in the water passing through it. The filtered bacteria and pathogens either die or are eaten by the schmutzedecke life. The clean water passes out of the bottom of the slow sand filter through a drainage system of baked clay bricks or concrete pipes. The filtered water is usually stored in an outlet tank. Valves control the rate of draining water so that a constant depth of water remains on top of the sand to preserve the schmutzedecke. If the schmutzedecke dries out the benefits of bacteriological filtration will be lost.

Design of a slow sand filter system requires skill. The inlet and outlet arrangements, flow rates, tank sizes, sand sizes, and sand volumes must be calculated carefully. Construction of the filter tank does not require highly skilled labor, but construction costs are high and a large site is needed. Operation and maintenance skills and costs are low.

The filter should be cleaned every several weeks when the filter rate slows. It must be drained and several centimeters of sand scraped off the top of the sand bed. Raw water is allowed to flow through the sand again until the schmutzedecke has reformed. This

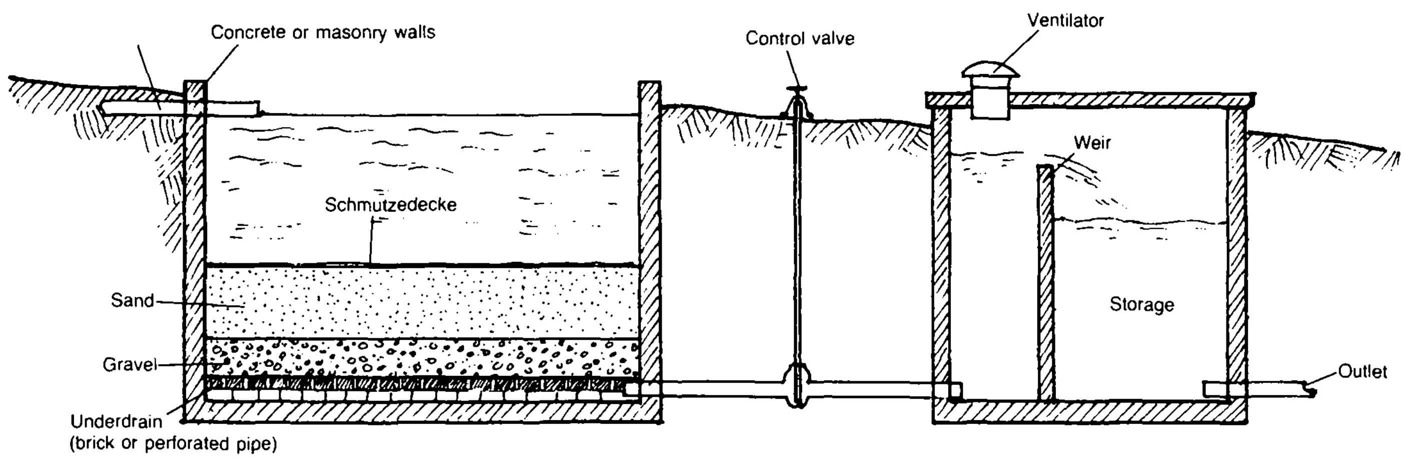

Figure 5. Slow Sand Filter and Storage Tank

usually takes a couple of days. The dirty sand can be cleaned and reused.

A slow sand filter can reduce the bacterial count of raw water by 85 percent. It can reduce turbidity significantly although sedimentation will still be needed for very turbid water. Chlorination often follows slow sand filtration. It further disinfects the supply and carries a chlorine residual into distribution pipes. Because of its capacity to improve the physical and bacteriological characteristics of a water source, the slow sand filter is an excellent means of treatment for rural communities with limited resources.

Chemical disinfectant dispensers. Storage, sedimentation, and filtration reduce the bacterial content of large quantities of water but rarely disinfect a supply entirely. More complete treatment of a clear water supply can be achieved with chemical disinfectants, if regular operation and maintenance are possible. A chemical disinfectant dispenser can be used to add a small amount of chemical to a well or storage tank at a constant rate. Chlorine is the most widely used chemical disinfectant because it is relatively inexpensive and available in many areas. (See section on chemical disinfection by hand.)

Simple chlorinators that dispense chlorine at a constant rate into a water supply can be bought or made with local materials. Design and adjustment of chlorinators require careful attention. Regular testing and maintenance are necessary to ensure their effectiveness.

There are two types of simple chlorinators. A diffuser is used in non-flowing water supplies like wells, cisterns and tanks. It consists of a pot or other container filled with coarse sand and chlorine powder and submerged in a water supply. The chlorine seeps into the water through holes in the container. A single pot diffuser, shown in Figure 6, holding 1.5kg of bleaching powder in 3kg of coarse sand can serve up to 60 people for two weeks. Diffuser chlorinators have slow rates of disinfection and are most effective in wells or tanks that

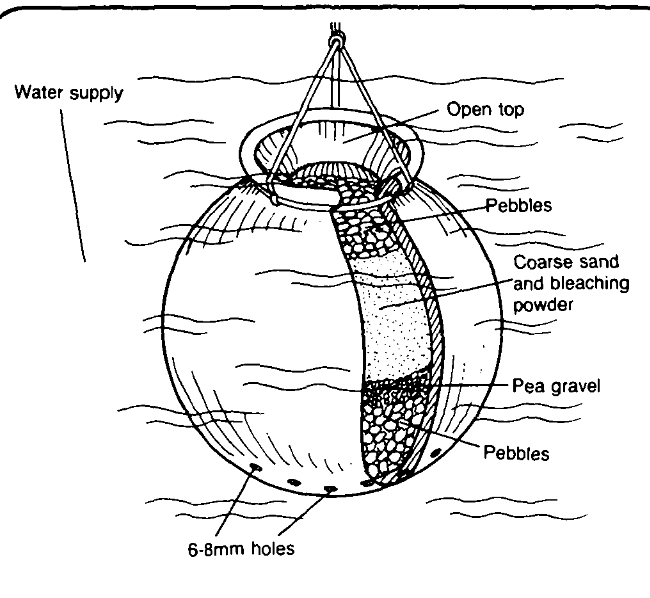

Figure 6. Pot Chlorinator

do not dispense more than 1000 liters of water per day. More pots would be required for larger wells.

A drip-feed chlorinator is a container or tank which feeds chlorine solution at a constant rate into a reservoir of slowly flowing water. Figure 7 shows a drip chlorinator. It consists of a tank, usually a steel drum or concrete container about 200 liters in capacity; a cover; a floating feed valve, which can be in a bowl or a wooden float; and outlet; and a flexible tube leading from the valve to the outlet. The tank is filled with chlorine solution, and the bowl and valve float on top of the solution. A hole in the bottom of the valve is blocked with a stopper which has two holes in it. One hole has a flexible tube passing through it which runs from the bowl to the outlet of the tank. The other hole has a smaller tube passing through it which rises in the bowl to just below the level of the chlorine solution in the tank. This placement causes the chlorine solution to flow up through the small tube, collect in the bowl, drip down the other tube to the outlet, and then into the water supply. The flow into the bowl can be altered by raising or lowering the small tube. Regular attention to the level of the solution and occasional replacement of parts are necessary for drip-feeders.

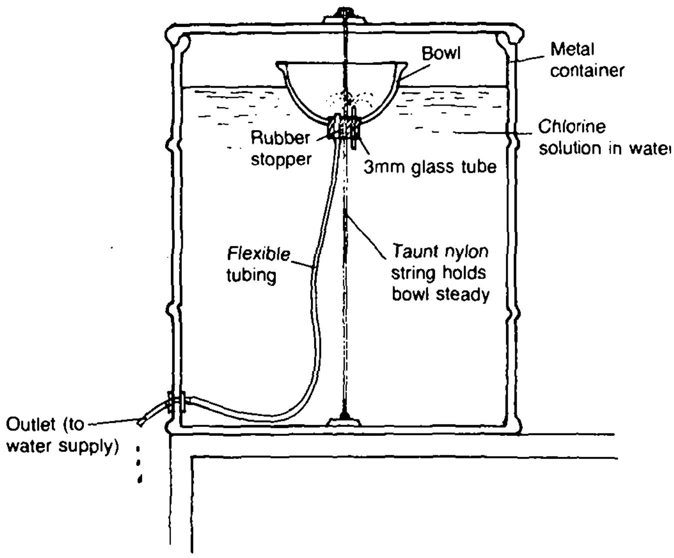

Figure 7. Drip Chlorinator

Treatment for Advanced Community Systems

Advanced treatment processes for community water supplies are those that require highly skilled construction and operation and are usually very expensive. They are rarely appropriate to rural water supply systems, but several are described briefly here.

Conditioning. Conditioning is the elimination of minerals and other substances that give water a bad color, taste or odor. Conditioning water supplies is less important than disinfection, but pleasant water encourages people to use a safe source.

Aeration is a conditioning process that exposes water to oxygen in the air. It changes iron and manganese in water to solid particles so they can be removed. Aeration will also remove gases, bad tastes and odors. Many methods of aeration can be used on small water supplies, but an expert's advice is recommended. All require energy to expose the water to air.

Desalination. Desalination is the process of removing salt from a water supply. It is a highly technical and very expensive process. Solar distallation is the simplest method of desalination, but it is rarely appropriate for small water supplies. Choosing a salt-free water source is recommended.

Clarification. Coagulation and flocculation are chemical processes that speed sedimentation. They prepare water for filtration and can reduce bacteria levels. An alum solution added to turbid water causes suspended matter to form larger particles which settle quickly. Coagulation and flocculation are often used in treatment systems for large towns and cities.

A rapid sand filter is a tank containing sand in selected sizes. It is used for clarification of turbid water. Water is forced quickly through the sand bed. A schmutzedecke has no time to develop in a rapid sand filter as it is backwashed often. A pump is necessary to backwash the filter. Construction and operation costs are high because the system of valves, pumps, and dosing devices require skilled operation and laboratory control. Regular maintenance is required.

Disinfection. Mechanized chlorinator units can be used to feed a chlorine solution into a pumped water supply. The chlorine is in either liquid or tablet form, and several different types of mechanized units are available. They all require a power source, sophisticated maintenance, and laboratory control.

Treatment Plants. A small, prefabricated package treatment plant may be an economically viable alternative for some small communities. Such treatment plants are highly mechanized systems which combine several different processes to clarify, disinfect and condition large volumes of water. They require a reliable source of energy, skilled construction, operation and maintenance personnel, and constant supplies of chemicals. They are expensive to buy, to operate and to maintain. They are rarely appropriate to small rural water supply systems, although they can sometimes be used at hospitals, schools, or other locations where trained operating personnel are available.

Emergency Water Treatment

Methods of emergency water treatment are those which can be used on short notice. Disasters which cause a complete disruption of water supplies demand a fast appraisal of local conditions and available water resources. Emergency water treatment is needed when the current source becomes contaminated, when a treatment facility has been destroyed, or when a change in water source is necessary. A protected water source should be used under emergency conditions if at all possible.

Disinfection is the priority treatment process to prevent outbreaks of waterborne diseases. Boiling water or adding chlorine or iodine tablets to supplies are suitable methods of disinfecting small quantities of drinking water. For large groups, an automatic chlorination unit of some kind is most efficient and effective. Diffusers or drip-feeders are designs most easily improvised from available materials. More sophisticated mechanized chlorination units may be used if a reliable power source is available.

Summary

In any water treatment situation, the priority treatment process is disinfection. The absence of pathogenic organisms in a water supply is essential to good health. Clarification of water supplies is often necessary for efficient disinfection. Conditioning is important to develop an aesthetically pleasing supply. A water treatment system must eliminate any current contamination, be able to reduce any subsequent contamination, and deliver an adequate amount of safe water. A carefully planned water treatment system may be the only way to provide a safe and adequate supply of drinking water to a small rural community.

Notes

Notes

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Taking a Water Sample
Technical Note No. RWS. 3.P.2

Laboratory or field analysis of water is one way of determining its quality. Tests for bacteriological quality and for physical and chemical quality are the two most important types of analysis for small community water supplies. These tests show the types and levels of contaminants present in a water sample. This information is essential in deciding whether a water supply must be treated. It is also important for choosing a specific treatment process.

Accurate analysis of a water sample depends on proper collection of the sample. Samples must be taken from several locations at different times so that they are representative of the entire water supply. Samples for "specific analysis" are those collected when a new water source is being developed, when an outbreak of water-related disease occurs, when there are changes in a water system, or when water pollution is suspected. Samples collected regularly to monitor an existing water system are for "routine analysis."

Methods of sample collection depend on whether the analysis to be made is bacteriological or physical and chemical, and on whether the sampling and analysis are routine or specific. The main considerations in sampling are to collect representative samples of the water supply and transport them quickly to the place where they will be analyzed.

The objective of water analysis is to measure any contamination present in the sample to determine the need for and level of treatment. Water analysis can be conducted in a laboratory or in the field. Field tests eliminate the problem of transporting water samples to laboratories.

Whenever possible, both bacteriological and physical and chemical water analysis should be conducted. Bacteriological sampling and analysis is the most important, however. Bacteriological contamination causes many infectious diseases and is most important to eliminate. Treatment processes for physical and chemical impurities are usually too costly and complex for rural areas.

Useful Definitions

BACTERIOLOGICAL CONTAMINATION - The presence of disease-causing microorganisms in a water supply.

CHLORINE - A chemical which can be added to water to kill disease-causing organisms.

CONTAMINANT - An impurity which makes water unfit for human consumption or domestic use.

PHYSICAL AND CHEMICAL CONTAMINATION - The presence of chemicals, suspended particles, bad taste, color or odor, or other impurities in water that make it offensive or poisonous to users.

STERILE - Free of living organisms.

Collecting Samples for Bacteriological Analysis

Frequency of bacteriological sampling. Bacteriological analysis reveals only the quality of the water at the time of the sampling. It does not necessarily represent the quality of the water at other times. Samples for bacteriological analysis should be collected over all seasons, during dry and wet periods and particularly after heavy rains. Each time, a number of samples should be collected over a period of days. Analysis of a single sample is not reliable.

Exact frequency of sampling depends mainly on the population served by the water supply being tested. Water supplies serving greater populations need to be sampled more often. Frequency of sampling and analysis also depends on the quality of the water source, past contamination, risks of new contamination, and the complexity of the water system. No universal frequencies for sampling and analysis can be set because of all these variables.

For populations under 5000, one sample per month is suggested for routine bacteriological analysis of an existing system. For populations over 5000, one sample per month for each 5000 people is suggested. More frequent sampling and analysis are necessary after repairs are made to a system in areas where water-related diseases are common and in emergency situations (see "Water Treatment in Emergencies," RWS.3.D.5). For very small supplies serving fewer than 500 people, the frequency of sampling and analysis may have to be based entirely on the variables revealed by the sanitary survey. Water that is chlorinated must be tested very often to check the chlorine's effectiveness (see "Operating and Maintaining a Chemical Disinfection Unit," RWS.3.O.4).

Equipment. Samples for bacteriological analysis must be collected in sterile glass bottles with sterile stoppers. A paper or foil hood over the stopper and bottle neck is necessary. Stoppers can be made of ground glass or rubber. Figure 1 shows different types of bottles for samples. Normally, pre-sterilized sample bottles are obtained from a central laboratory. In an emergency, well-washed bottles can be sterilized in the field by boiling them for five minutes. If sample bottles are not sterile, any bacteria present on them will make the analysis useless.

The sample bottle must be kept sealed, and the stoppers and bottle neck should be covered with parchment paper or thin aluminum foil. The covering should be kept in place after sampling. Each sample should be at least 100ml in order to perform all tests required for bacteriological contamination.

Sampling sites. Samples should be collected from the places where people draw water. Samples drawn from a stream or river that is being developed as a new source should not be collected too close to the bank nor too deep under the surface. Areas of stagnation should be avoided. Samples should not be drawn from the same spot every time, but should be taken from different points.

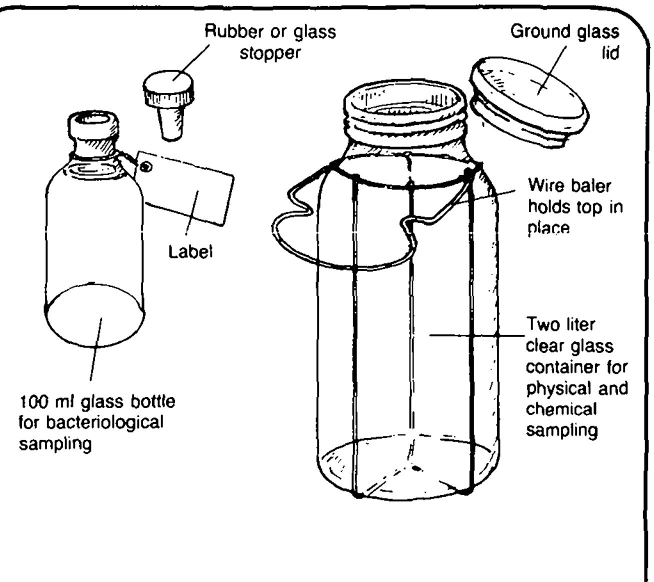

Figure 1. Types of Sample Bottles

In piped water systems, samples should be collected at all points where water enters the distribution system and at representative points where it leaves the distribution system. In addition, samples should be drawn from taps connected directly to the water main, not from the storage tank or a roof catchment. Special samples need to be drawn from known problem areas, such as areas with low pressure, areas with high leakages, and areas far from the treatment system, if one exists.

Procedure. Samples for bacteriological analysis must be very carefully collected to ensure that the sample is representative of the water supply and not contaminated by other sources during collection or by the person taking the sample. Keep the stopper or cover on the bottle until the sample is collected. It is very important not to touch the inner portion of the stopper or the inside of the bottle neck when removing or replacing the stopper. During sampling, the stopper and the neck of the bottle should not be handled, and should be protected from contamination. Labels should be prepared in advance so they can be attached to the bottle immediately after the sample is collected.

Collecting a sample from a stream or river. Samples should be collected from midstream. Face upstream. If the sample is collected from a boat, take the sample from the upstream side of the boat. Figure 2 shows the collection procedure for a stream or river.

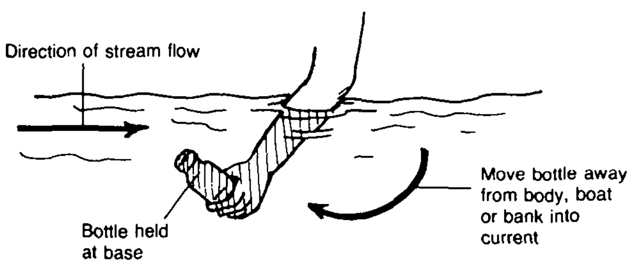

Figure 2. Taking a Sample from Stream or Lake

1. Remove the stopper from the bottle, being careful not to touch the inner portion of the stopper or bottle neck.

2. Hold the lower portion of the bottle. With the mouth of the bottle facing upstream, plunge the bottle, neck downwards, into the stream.

3. Tilt the bottle until the neck points slightly upwards, with the mouth facing the direction of the current. Allow the bottle to fill completely. Do not let any splashing water enter the bottle.

4. Carefully replace the cap and hood.

5. Label the bottle immediately.

Collecting a sample from a lake, pond or reservoir.

1. Remove the stopper from the bottle, being careful not to touch the inner portion of the stopper or bottle neck.

2. Hold the lower portion of the bottle. Plunge the bottle neck downwards, into the water.

3. Tilt the bottle so that the neck points slightly upwards. Move the bottle forward horizontally, away from the hand, body or boat, so that no water enters the bottle that has been in contact with the hand, body or boat. Allow the bottle to fill completely. Do not let any splashing water enter the bottle.

4. Carefully replace the cap and hood.

5. Label the bottle immediately.

Collecting a sample from a well or deep basin. Figure 3 shows the collection procedure for a well or deep basin.

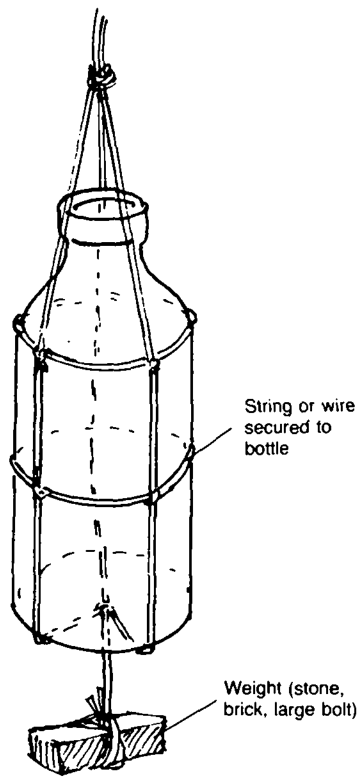

Figure 3. Weighted Bottle for Well Samples

1. With the stopper still in place, tie a length of rope or very strong string to the bottle.

2. Attach a stone or piece of metal to the bottom to weight the bottle down.

3. Carefully remove the cap from the bottle and lower the bottle into the well until it is about 1m below the water surface.

4. When no more air bubbles rise to the surface, raise the bottle out of the well and carefully replace the cap and hood.

5. Label the bottle immediately with date, time, place, receptacle depth and receptacle type.

Collecting a sample from a well with a hand pump.

1. Pump water to waste for at least one minute.

2. Remove the stopper from the bottle being careful not to touch the inner portions of the stopper or bottle neck.

3. Fill the bottle carefully, making sure no water that has touched your hands enters.

4. Carefully replace the stopper and hood.

5. Label the bottle immediately.

Collecting a sample from a tap.

1. Choose a tap that is farthest from the treatment system, if there is one.

2. Turn on the water and let it run fast for at least one minute.

3. Turn the water down so it runs slowly.

4. Remove the stopper from the bottle being careful not to touch the inner portions of the stopper or bottle neck.

5. Fill the bottle carefully, being careful not to let any water enter that has been in contact with your hands.

6. Carefully replace the stopper and hood.

7. Label the bottle immediately.

Labeling samples. All samples must be labeled or tagged immediately upon collection at the sampling site. Figure 4 shows the type of label that is needed. Information on the label should include:

1. Sample number;

2. Reason for sampling: bacteriological or physical and chemical, routine, specific, other;

3. The exact place from where the sample was taken:
a) type of sample source (pond, stream, pump, tap),
b) exact location of site;

4. Temperature of sample source;

5. Date, day, hour of sampling.

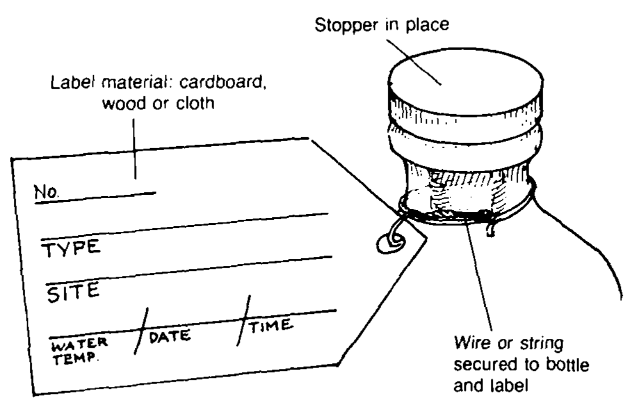

Figure 4. Sample Label

In addition, records similar to Worksheet A should be kept showing the following information:

1. Name and address of person or agency requesting sample;

Worksheet A. Suggested Record Form for Field Data Relevant to Water Samples

Agency or person requesting sample: ______________ Sample No. ______

Reason for sample: ☐ Routine ☐ for bacteriological analysis

☐ Specific (explain) ______ ☐ for physical/chemical analysis

☐ for other analysis ______

Date and hour of sampling ______________

Sample Location:

Town: ______________

Sample Source: ☐ Tap ☐ Cistern ☐ Stream ☐ Pond ☐ Well ☐ Spring ☐ Rain catchment ☐ Other (specify) ______

Exact spot from where sample was drawn: ______________

Raw water source: ______________

Is water treated? ☐ No ☐ Yes (If yes, specify type of treatment) ______

Does water quality change after heavy rains? ☐ No ☐ Yes If yes, explain (odor, color, taste, turbidity) ______________

If sample is drawn from a well, specify:

Depth of well ______________
Distance from water surface to ground level ______________
Whether well is covered or uncovered ______________
Type of cover, materials, condition of cover ______________
Whether well is newly constructed or recently altered or repaired (explain) ______________
Method of raising water (pump, rope and bucket, etc.) ______________
Whether the well has a protective apron ______________
Type, material, size and condition of apron ______________
Well lining material ______________
Possible sources of contamination ______________

If sample is drawn from a spring, specify:

Whether sample is drawn directly from spring or collection box ______________

Construction material and condition of collection box ______________

If sample is drawn from a stream or river, specify:

Depth at which sample was drawn ______________
Whether sample was drawn from boat ______________
Possible sources of contamination ______________

Length of time sample was stored before analysis ______________

Temperature at which sample was stored ______________

2. Identification of any treatment used, including where treatment is applied and in what dose;

3. Whether water is affected in appearance, odor or taste by heavy rains;

4. If sample is taken from a well:
a) depth of well,
b) depth of water surface to ground level,
c) whether covered or uncovered; nature, material and construction of the cover,
d) whether well is newly constructed or has any recent alterations that might affect the condition of the water,
e) type of well,
f) proximity of possible sources of contamination,
g) other visible signs of contamination,
h) nature of soil and water-bearing stratum;

5. If sample is from a spring:
a) type of ground from which it issues,
b) whether sample was drawn directly from spring or from a collection box; if from a collection box, detail construction of box;

6. If sample is collected from a river or stream:
a) depth at which sample was taken,
b) whether sample drawn from boat,
c) proximity and observations of possible sources of contamination.

Storage of samples. Changes occur in the bacteriological content of water when it is stored. To get an accurate analysis of the water supply, bacteriological analysis of the water sample is best begun within one hour of collection. Samples for bacteriological analysis must be tested within 24 hours of collection. When a field kit is used to analyze samples, testing within an hour of collection is possible. If samples must be transported to another site, it is often impossible to analyze them so soon. Therefore, they must be carefully stored and transported so they remain representative of the water supply at the time the sample was collected. Temperature of samples during storage should remain as close as possible to the temperature of the source from which they were drawn. The length and temperature of storage of all samples should be recorded and considered in interpreting the analysis.

Collecting Samples for Physical and Chemical Analysis

Frequency of physical and chemical samples. Sampling for physical and chemical analysis does not need to be done as often as bacteriological sampling. One complete chemical analysis each year should be adequate for most small communities. This should be done in a well-equipped laboratory. If a water supply has a history of containing harmful chemicals, if a new industry develops, if chemical insecticides or fertilizers are used in farming, or if other chemical contamination is suspected, monthly samples may be necessary.

Equipment. Samples of water for physical and chemical analysis must be collected in chemically clean bottles of colorless glass with ground glass stoppers. Bottles and stoppers for collecting water samples for chemical and physical analysis do not need to be sterile, but they need to be very clean. Wash them in a good detergent and rinse them three or four times in distilled water to remove all odors and residues. At least 2 liters of water need to be collected for a complete physical and chemical analysis.

Procedure. Collecting samples for physical and chemical analysis of water follows basically the same procedure as for bacteriological analysis. Rinse the bottle out at least three times with the water to be sampled. Fill the bottle completely and secure the stopper. Label or tag the bottle immediately, with the same information needed for bacteriological samples. Analysis should be done as soon as possible, and should not be delayed over 72 hours. Whenever possible, samples should be kept between 0°C and 10°C during storage and transportation.

Where several samples are being collected from the same source at the same time, samples for bacteriological analysis should be collected first in order to avoid contaminating the sampling point with non-sterilized equipment. In either type of sample collection, the main considerations remain the same: obtain representative samples of water without contaminating them, seal the containers, and transport them quickly to the place of analysis.

Notes

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Water for the World

Analyzing a Water Sample
Technical Note No. RWS. 3.P.3

A water supply for domestic use should be free of disease-causing organisms and substances which make the water unacceptable to its users. There are several ways to find out if a water supply is safe to drink (see "Determining the Need for Water Treatment," RWS.3.P.1). One method is analysis, the measurement of the type and level of contaminants present in a sample of the water supply. The results of water analysis can verify the findings of a sanitary survey and suggest the level of treatment a water supply needs.

There are five kinds of water quality analysis. All of them measure different characteristics of a water sample. The two most important types of analysis for small community water supplies are the bacteriological tests and physical and chemical tests. Bacteriological analysis identifies organisms associated with disease. Physical and chemical analysis identifies elements in a sample that make water turbid, offensive or poisonous to users. Of these two, bacteriological analysis is more important because bacteriological contamination is more likely to occur in small community water supplies than physical or chemical contamination is.

A physical and chemical analysis includes tests for turbidity, color, taste and odor, followed by tests for excess minerals, toxins and elements which may harm the system. Physical and chemical analysis is extensive, and is best carried out in a well-equipped laboratory because of the complexity of the testing. Field kits are available for partial physical and chemical analysis. They require especially prepared materials and equipment. These kits are costly and therefore usually are impractical for analyzing water in isolated rural areas. Physical and chemical analysis requires skill, training and experience. It is best to

Useful Definitions

CONTAMINANT - An impurity which makes water unfit for human consumption or domestic use.

FECAL COLIFORM - Bacteria found in the large intestine; a coliform count is often used as an indicator of fecal contamination in water supplies.

GROWTH MEDIUM - A liquid or gelatin which promotes the development of bacteria into colonies.

INCUBATE - To cause bacteria to develop colonies by keeping them warm.

NUTRIENT BROTH - A liquid which induces the development of bacteria colonies; a growth medium.

PATHOGENS - Disease-causing bacteria.

PETRI DISH - A shallow round transparent glass or plastic dish with an overlapping cover used for developing bacteria colonies in a growth medium.

PIPET - A slender tube into which small amounts of liquid are drawn for measuring or transferring.

POLLUTION - Contamination.

SANITARY SURVEY - An extensive field evaluation of actual and potential conditions affecting the acceptability of all available water sources.

TURBID WATER - Water that is clouded with suspended particles.

VACUUM - A pump used to pull or push water through a filter in the membrane filter technique of bacteriological analysis of water.

WATER TREATMENT - A process in which impurities such as dirt and harmful materials are removed from water.

consult an expert for details and assistance in conducting this kind of analysis. This technical note describes bacteriological analyses of drinking water.

The most serious water pollution is bacteriological contamination which can cause disease. Bacteriological analysis of a water sample finds and counts organisms whose presence indicates that disease-causing pollution has occurred in the water supply. These "indicator" organisms are members of a large group of bacteria called coliform bacteria. Most coliform bacteria do not cause disease themselves but, because they enter water supplies from the excreta of humans and animals, they indicate the possible presence of pathogens, the disease-causing organisms in excreta. Coliform bacteria are easier to identify then pathogens, so coliform levels are used to determine the bacteriological quality of water.

Testing for Bacteria

The simplest and cheapest bacteriological water analysis procedure is the Standard Plate Count (SPC). It is a method of measuring the overall bacterial content in a water sample. In the SPC, small quantities of a properly collected water sample are mixed with a growth medium in a petri dish and incubated. A portion of all the bacteria types present in the water will develop into colonies. Although the SPC does not distinguish coliform from other forms of bacteria, it is a valuable procedure for evaluating the general bacteriological quality of a water supply. It is a good method for measuring basic bacteriological content when no other means of analysis is available.

The equipment and supplies needed for the standard plate count are common to most laboratories. One milliliter of a diluted water sample is put into a sterile petri dish using a sterile pipet. Approximately 10-15ml of sterile growth media, such as glucose agar, are poured over the sample in the dish. The sample and the agar are thoroughly mixed and incubated at 35°C plus or minus (±) 0.5°C for 24 ± 2 hours. The bacteria colonies are counted after incubation using an illuminated colony counter or a reading glass. If less than 500 colonies of bacteria grow, the water is considered relatively good. Most established laboratories will be familiar with the standard plate count.

Examining a water sample specifically for the presence of coliform bacteria is called "coliform detection." A "total coliform detection" will identify many sorts of coliform bacteria in a water sample. The presence of the particular fecal coliform bacteria known as E. coli is strong evidence of the presence of pathogenic organisms. Water that is free of coliform bacteria or has a very low coliform count in a total coliform detection analysis is considered free of disease-producing bacteria. Total coliform detection is the most frequently used bacteriological analysis.

Almost all rural water supplies show coliform bacteria when analyzed. Not all water supplies can be condemned, so it is the level of coliform content in water tested, not simply the presence or absence of coliform bacteria that determines the safety of a drinking supply. The World Health Organization (WHO) International Standards for the bacteriological quality of drinking water vary depending on whether the water supply is unimproved or is disinfected or piped. Much higher standards are expected for improved supplies. Ideally, no E. coli are acceptable in any drinking water sample, and only low levels of other coliform bacteria are tolerated in unimproved supplies. The basic WHO standards are explained in the section on "Interpreting Results of Coliform Bacteria Detection."

Water analysis can be conducted in a laboratory or in the field using special kits. Laboratories provide a controlled environment for analysis and often have extensive facilities for testing. Field kits decrease the problems of storing and transporting samples and are convenient, but field kit equipment is not always as complete as a laboratory. Lack of laboratory facilities is one of the greatest difficulties of conducting bacteriological examinations of water in remote areas. Analysis should be begun as soon as possible after samples are collected to minimize changes in the bacteriological character of the water. Analysis can be done properly in a laboratory when testing can begin within six hours. Field kits start the analysis procedure on the collection site, so they are highly recommended for circumstances where the delay between collection and laboratory analysis will be over six hours. When neither laboratory or field analysis can begin within six hours, the samples must be properly stored and transported to the nearest testing facility (see "Taking a Water Sample," RWS.3.P.2). Some field kits are designed to hold samples under proper conditions until they arrive at a laboratory for analysis. Others contain complete portable analysis facilities.

Testing for Coliform Bacteria

There are two basic methods of detecting coliform bacteria. First, there is the "multiple tube method," in which small measured volumes of sample water are added to a nutrient broth in one or more sets of five test tubes. The sample tubes are incubated and the nutrient broth supports the multiplication of the bacteria. After 48 hours in incubation, the most probable number (MPN) of bacteria in the water sample is estimated based on the number of tubes which produce gas, the sign of baterial growth. Field kits are available for the multiple tube method but this test is most effectively performed in a well-equipped laboratory.

In the second method, the "membrane filter technique," a measured volume of sample water is drawn or pushed through a flat filter which retains any bacteria present in the water. The filter is then placed on a growth medium and incubated. The bacteria multiply, forming visible colonies. The colonies are counted directly by eye or with the aid of a binocular widefield microscope.

The accuracy of both these methods of coliform detection is highly dependent on a water sample that is properly collected from the water source being evaluated. Refer to "Taking a Water Sample," RWS.3.P.2.

<u>Multiple Tube Method of Coliform Bacteria Detection.</u> In the multiple tube method, the number of coliform bacteria in a water sample is calculated based on a statistical estimate of bacteria growing in a set of five test tubes containing a mixture of nutrient broth and water sample. Any coliform bacteria present will ferment lactose in the form of gas when this mixture is incubated. Formation of a gas bubble in the test tube indicates the presence of coliform bacteria. An inverted vial is placed in the test tube to trap any gas bubbles that form. See Figure 1.

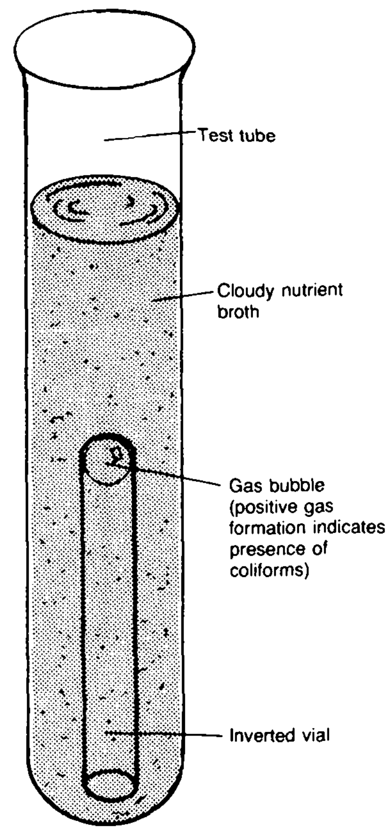

Figure 1. Multiple Tube Method of Coliform Detection

There are three different types of multiple tube tests. They are the Presumptive Test, the Confirmed Test, and the Complete Test. The Presumptive Test is for general coliform bacteria detection. The Confirmed Test is more thorough than the Presumptive Test, and the Complete Test is even more accurate. However, the Confirmed and Complete Tests require more supplies, skills and experience to perform. The Presumptive Test is sufficient for testing most rural water supplies.

In the Presumptive Test, the five test tubes filled with a mixture of nutrient broth and water sample are incubated at 35°C ± 0.5C for 24 ± 2 hours. If gas bubbles have formed in the nutrient broth surrounding the vial and if there is a small gas bubble in the inverted vial after this period of time, the test is considered positive, meaning coliform bacteria are probably present in the water supply. If no gas has formed, the test tubes are incubated for another 24 hours. If gas bubbles form during the second incubation period, the test is also considered positive. Absence of gas at the end of the second incubation period constitutes a negative test, meaning coliform bacteria are definitely not present. Refer to Figure 2.

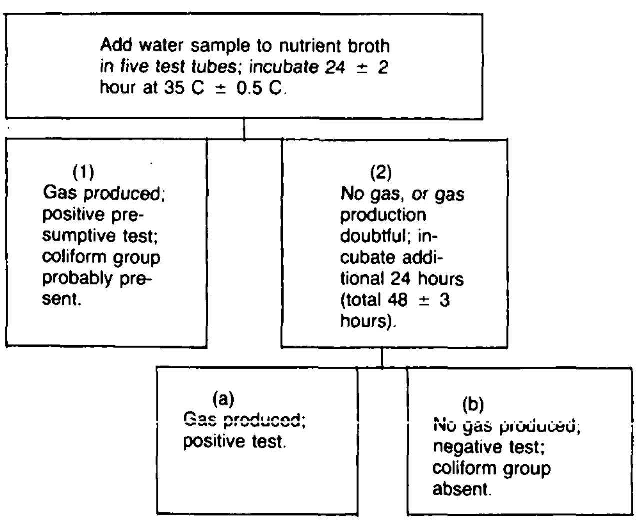

Figure 2. Multiple Tube Method of Coliform Detection, Presumptive Test

A confirmed or Complete Test can be performed on the same water samples following a postive Presumptive Test. However, the most probable number (MPN) of coliform bacteria per 100ml of water can be estimated after a positive Presumptive Test using a standard MPN table. See Table 1. It is important to remember that MPN values are not absolute numbers of coliform bacteria present. They are good estimates for judging water quality.

Table 1. Most Probable Number Index for Coliform Bacteria (When Five 10ml Portions Are Used)

Number of Tubes Giving Positive Reaction Out of Five 10ml Water Samples	Most Probable Number (MPN) of Coliform Bacteria per 100ml of Water
0	2.2
1	2.2
2	5.1
3	9.2
4	16.0
5	16.0

Membrane Filter Technique of Coliform Bacteria Detection. In the membrane filter method, a water sample is drawn from a funnel by a vacuum through a flat filter. The wet filter is removed from the filter holder and placed in a petri dish over a pad saturated with a growth medium. Refer to Figure 3. The petri dish is placed in an incubator. Any coliform bacteria present will grow in distinctly colored colonies on the filter. After the proper incubation period, the filter is examined with the naked eye or under a microscope and the colonies are counted.

Membrane filters must be examined within 30 minutes of their removal from the incubator so that the difference between the colored colonies is easier to see. The colors will stabilize after the filters dry, and the results

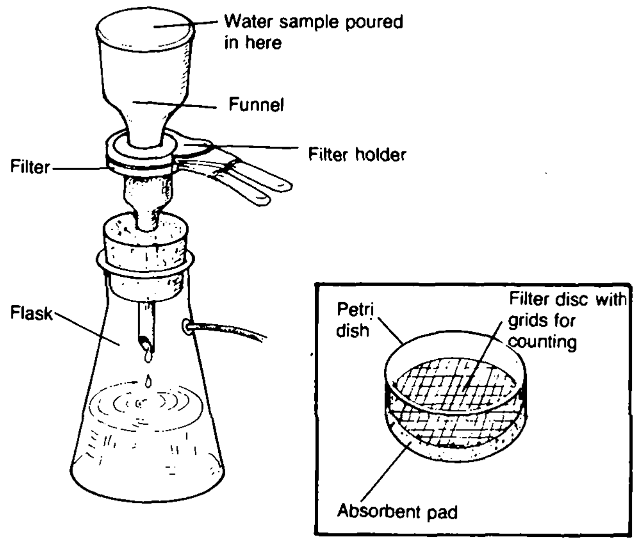

Figure 3. Membrane Filter Method of Coliform Detection

can be preserved for future reference by storing the filter between two layers of plastic film.

Field kits for the membrane filter test are available as units from several manufacturers. Consult the regional or national water authority for information on acquiring kits. If one brand of equipment is already being used by an agency, additional equipment should be from the same manufacturer to assure compatibility. Parts of field kits are usually not interchangable. Be sure a complete instruction manual is included with the kit.

Facilities for incubation are the main constraint for coliform bacteria detection. Temperatures must be controlled very carefully. It is not always possible to maintain the exact temperature ranges in an incubator under field conditions unless portable incubators are used. Portable incubators are relatively expensive and require a power source such as a car battery for operation. If incubation with accurate temperature control is not possible on site, the filter must be transported to an incubator immediately. If no incubator with accurate temperature control is available at all, the incubation temperature for the total coliform test can be provided by the human body. Vests with pockets for membrane filter plates can be made or purchased.

<u>Comparison of the Multiple Tube and Membrane Filter Methods</u>. The advantages of the multiple tube method over the membrane filter method are as follows:

1. The equipment and supplies necessary for the multiple tube test are common to well-equipped laboratories. They are more readily available in most countries than equip ment and supplies for the membrane filter method. Membrane filter portable kits must be imported from the manufacturer which involves high expenditure of foreign exchange for aquisition and replacement parts. Because costs are high, availability and distribution may also be problems.

2. The equipment for the multiple tube method can be re-used. The membrane filter portable kits are disposable and cannot be used more than once.

The multiple tube method of bacteriological analysis is appropriate for established laboratories near the water supply to be tested but not for isolated rural areas without reliable laboratory service.

Advantages of the membrane filter method over the multiple tube method for field analysis are as follows:

1. The number of coliform bacteria colonies grown in a filter can be visually identified and counted. The multiple tube method estimates the number of coliform bacteria statistically. The membrane filter results can be preserved for future reference unlike the multiple tube results.

2. The membrane filter method requires less equipment preparation and clean-up. Disposable equipment and pre-prepared supplies are standard parts of membrane filter field kits. The membrane filter test also takes less time to perform than the multiple tube method. The membrane filter

method requires 24 hours from sample collection to interpretation of results. The multiple tube method requires 48 hours for incubation alone, and can take up to 96 hours for complete procedures. Therefore, where labor costs are high, the membrane filter method may be less expensive to use.

3. The membrane filter technique is better adapted to field work and emergencies than the multiple tube method. Preparation for, performance of, and clean-up after the membrane filter test are less complicated and quicker than for the multiple tube method. Membrane filter test equipment and supplies take up less space than those for multiple tube tests. More equipment especially adapted for field conditions is available for the membrane filter tests than for the multiple tube tests.

The membrane filter method is appropriate when reliable laboratory service is not available within six hours of water sample collection and when the kits are available and not too high priced.

Interpreting Results of Coliform Bacteria Detection. Ideally, all samples should be completely free of coliform bacteria. It is not always possible to attain such a high standard in rural areas. Local standards should be used if they exist. The World Health Organization recommends the following standards:

1. Throughout any year, 95 percent of the drinking water samples should not contain any coliform organisms in 100ml of water.

2. No sample should contain E. coli in 100ml of water.

3. No sample should contain more than 10 coliform organisms of other types per 100ml.

4. Coliform organisms should not be detectable in any two consecutive samples of 100ml of water.

If the supply does not meet these standards or local standards, it should be considered unsuitable for use without treatment. If any coliform organisms are found, further investigation is needed to determine their source. The first step is immediate re-sampling and analysis (see "Taking a Water Sample," RWS.3.P.2). If subsequent water samples do not meet the standards summarized here, refer to "Planning a Water Treatment System," RWS.3.P.4, for recommendations on improving the water quality. Disinfected water supplies should be completely free of any coliforms, however polluted the raw water may have been. See "Operating and Maintaining a Chemical Disinfection Unit," RWS.3.O.4, for information on interpreting results of analysis of disinfected water supplies.

Summary

Water sample collection and analysis should be repeated under varying conditions. A number of samples should be collected over a period of days for each analysis period. Reliance cannot be placed on the results of analysis of a single sample from a water supply.

When an analysis is completed, results need to be very carefully interpreted in conjunction with the observations of a sanitary survey. An analysis determines the type and level of contamination present in a sample of a water supply. A sanitary survey identifies the probable sources of that contamination. Conclusions from both processes need to be balanced to judge the safety of existing water systems and plan appropriate water quality improvements.

Notes

Notes

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1982

Water for the World

Planning a Water Treatment System
Technical Note No. RWS. 3.P.4

Water may need treatment before it can be used for drinking. Water treatment in rural areas stresses bacteriological treatment, the removal of pathogens through filtration, and chemical disinfection. Clarification processes are used to remove suspended matter. To remove certain dissolved chemicals and minerals, water conditioning is needed. Conditioning requires expensive equipment and chemicals and is usually not practical for rural areas.

Water subject to bacteriological contamination and turbidity must be either protected from the contamination or treated. Ground water is usually naturally protected from contamination. However, if wells are located near latrines or other sources of contamination, or near limestone or other fractured rock, water quality is questionable. If water sample analysis or a sanitary survey shows bacteriological contamination, the water must be treated.

Treatment of surface water is almost always necessary to ensure its quality. Unlike ground water, surface water is not protected from contact with people, animals and surface run-off which can introduce disease-causing organisms. This technical note discusses the basic factors which must be considered when planning a water treatment system and the choice of a treatment process or mix of processes that best meets the needs of the community.

Useful Definitions

CLARIFICATION - The process of removing suspended matter from turbid water to make it clear.

DISINFECTION - Destruction of harmful microorganisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

TURBID WATER - Water which is clouded with particles of suspended matter.

General Considerations

The addition of any type of treatment to a water system increases the cost of developing the system, the amount of maintenance required, and the risk of breakdown.

If water treatment is necessary, the following factors must be considered when choosing which treatment system to use.

1. Amount of funds available for the project. Most rural communities have limited funds and cannot afford expensive treatment methods. The choice between a treated and an untreated source and the choice of a treatment technique depends on the funds available in the community.

2. Cost of construction. The construction of a water treatment facility is expensive. Construction costs must be determined before deciding to use a specific process. Compare the construction costs of the processes that would provide the treatment needed. Also, compare the costs of developing alternative water sources. For example, a water source needing treatment is located near a village and a source needing no treatment is further away. The cost of installing a pipeline and pumping the water from the source needing no treatment to the village may be less than the cost of developing a treatment system for the closer source. If the

pipeline is cheaper or the difference in cost is not great, the development of the longer pipeline may be the better alternative.

3. Availability of trained personnel or the likelihood of establishing the necessary training programs. See "Community Participation in Implementing Water and Sanitation Programs," HR.2.I. Trained personnel are needed to operate and maintain water treatment systems and the success of water treatment depends on their skill. If trained personnel are not available or are poorly trained, the water treatment system will not function properly, water quality will be poor, and the benefits of money spent on construction will be lost.

4. Cost of operation and maintenance. The cost and availabiltiy of chemicals such as chlorine for treatment, energy to run pumps, and salaries for workers must be determined. Their total cost may be beyond the means of the community. Chemicals and spare parts must be readily available to avoid closing down the treatment system or, worse, operating it without the required equipment and materials.

The general policy should be that a water source needing no treatment is preferable in rural areas. By selecting a source of water which needs no treatment, a community can save money and have a supply that is more dependable and a water system that is easier to operate. Table 1 lists some measures to protect water sources to reduce the need for treatment. In cases where water treatment is essential, the most efficient and least expensive method should always be chosen.

The quality of a community water supply must be good. When an entire community is dependent on one or a few sources, the quality of the water is important to the health and well-being of each community member. A failure in a public supply will affect more people than failure in individual family supplies. Depending on the level of water contamination, there are simple community treatment systems that will ensure adequate water quality.

Simple Community Treatments

Simple community water treatment systems should be used under the following conditions:

(a) when a water source serves a larger population than can be served by household or individual treatment systems, especially in rural villages and towns;

(b) when a community water source is contaminated and simple protective measures can neither improve water quality nor stop the contamination;

(c) when resources in the community are adequate to cover the cost of construction, operation, and maintenance.

The best method of water treatment is one that removes the contamination, can be built with local materials at a low cost, uses few mechanical parts, requires little use of chemicals, and is easy to operate and maintain. Table 2 summarizes the different types of water treatment processes.

Slow sand filters. Slow sand filters are excellent choices for treating community supplies. They are especially good for gravity flow systems, particularly with pond or river sources; water of fairly good bacteriological quality but subject to possible contamination; and water low in turbidity.

The advantages of the slow sand filter are that it:

- Removes 90-95 percent of bacteria responsible for water-related disease,
- Removes suspended matter and reduces color,
- Can generally be built with local materials using local skills and labor,
- Needs no complex mechanical or electrical machinery, and
- Requires simple operation and maintenance.

Table 1. Preventive Measures to Protect Water Sources

Ground Water

- Line wells with casing, cover and finish them so that run-off flows away from rather than into the well.
- Locate wells above latrines and other sources of contamination such as manure piles and animal yards. Put individual wells at least 15m and community wells at least 50m from the nearest source of contamination.
- Cover and protect wells and install pumps to lift the water from the well.

Surface Water

Springs

- Protect springs with a covered spring box to seal them off from contamination.
- Remove all sources of contamination above the spring. Do not use water from springs directly below animal yards or latrines. Locate springs above such sources of heavy contamination.
- Install a fence and diversion ditch for run-off above and along side of the spring.

Rivers and Streams

- Install riverside wells or infiltration galleries on stream or river banks so that water from the stream flows underground and loses its impurities.
- Whenever possible, install intakes at a point in the river above all inhabited areas and pipe the good quality water to the community.

Ponds and Lakes

- Practice good watershed management to ensure water quality without treatment. If a watershed is small, fence it and make sure it supports no farming or livestock. Water from ponds and lakes usually needs treatment, as it is difficult to keep out small animals and birds.

Rain Catchments

- Clean roofs and gutters to remove leaves and bird droppings between rainfalls or at least once every one or two weeks.
- Install a device between the catchment troughs and the cistern for directing the first wash (foul flush) to waste.
- Make sure the cistern is watertight and covered to prevent the entrance of contamination.

Sand filters are not the best choice in all situations. There are certain conditions under which a slow sand filter is not very effective. If a source is highly turbid, slow sand filtration is not the best treatment method. Very turbid water clogs the filter in a few weeks and makes the system require frequent maintenance. Pre-treatment of the water by sedimentation is necessary. If large quantities of clean, suitably sized sand are not available or cannot be obtained easily, the slow sand filter is not a good alternative. If land is in short supply, a slow sand filter is not the best choice since it requires large areas of land.

If people dedicated to the maintenance of the filter are not available, an alternative method must be found. Slow sand filters require frequent, though easy, maintenance. Skimming the top 10-25mm of the bed may be needed every two to three months. If workers are not available for the periodic cleanings, slow sand filters should not be used.

Plain sedimentation. Sedimentation is a practical method of water treatment for rural communities. Plain sedimentation is used to remove turbidity, and provide some improvement in bacteriological quality. Plain sedimentation is used as a pre-treatment process and for treatment of sources with good bacteriological quality. Sedimentation occurs in especially constructed storage tanks or in reservoirs formed by dams, large ponds or lakes. If water is stored for long periods of time, and further contamination is not introduced, bacteria die and improvement in bacteriological quality results.

Do not plan to use only plain sedimentation if the bacteriological quality of the water is poor or if possible sources of contamination are located near the supply. Generally, some other type of treatment must be used with plain sedimentation when water contains pathogenic organisms.

Chlorination. Chlorination is another popular form of rural water treatment. Chlorine can be used to disinfect most sources of water. Chlorine is most useful for disinfecting wells, spring boxes and other structures after construction, treating a source that is physically and chemically aceptable but is bacteriologically contaminated, and treating water that already has been through filtration and sedimentation. The advantages of chlorine are that it is inexpensive and easily available in many rural areas. In sufficient doses chlorine effectively destroys disease-causing organisms. Further, it is easy to use and simple chlorination requires no machinery. The skills of dosing and testing can be learned quite readily. Chlorine is a very good disinfectant when there has been accidental contamination of a source during construction and is excellent for disinfecting a well or protective structure. Only a small amount is needed for disinfection.

Under many conditions, chlorine is not acceptable. If water cannot be tested every four to six weeks, chlorine use should be discouraged. For effective treatment, the level of chlorine in the water must be checked to make sure the quantity or chlorine residual is sufficient. Water can be tested either with portable kits or in laboratories. If testing is not possible, the use of chlorine may not be practical. If chlorine is difficult to obtain, discourage chlorination except for small scale disinfection or emergency treatment.

Household Treatment Systems

Basic household treatment systems are designed for relatively small volumes of water used by one or several households. They are most effective in the following situations:

- Where small amounts of water are being supplied from a well, spring, or cistern, particularly if water is collected and transported by hand;

- Where a source is contaminated and simple protective measures can neither improve water quality nor stop contamination;

- Where community resources are inadequate to meet the cost of a simple commmunity treatment system;

- Where a community uses several water sources or homes are widely separated, making it difficult to develop a centralized treatment system;

- Where an emergency situation causes disruption of service and contamination of the water supply so that a rapid, short-term solution is needed.

Storage. Water storage is one of the most practical methods of water treatment available to rural areas because it reduces the amount of turbidity, color and bacteria. Storage can be used for water with mild turbidity and low to moderate levels of bacteriological contamination. Storage in well-protected reservoirs for a two-week period will kill 90 percent of the disease-causing bacteria in water. Storage also has the advantage of creating a reservoir which permits access to water not only of better quality but in greater quantity.

If water is highly turbid or heavily contaminated, simple storage is not adequate. Other treatment processes must be used instead of or in addition to simple storage. Users must be educated about the importance of storage time to the treatment of water, the need for periodic cleaning of the storage tank, and how to use the water so that it is not recontaminated. Unless these measures are taken, water quality may suffer and the purpose of storage will be lost.

Boiling. Boiling water is one of the most effective methods of treatment for individual households. Turbid water should be filtered before boiling. When water is boiled for two or three minutes, all disease-causing organisms are killed. Boiling does not require chemicals or expensive equipment.

Boiling is only practical if fuel is available in large quantities. It requires expensive energy that people may prefer to use for other activities. Boiled water has a "flat" taste since dissolved oxygen and carbon dioxide are boiled off. Some people find the taste disagreeable. For these reasons, boiling may be a better short-term emergency treatment method than a long-term solution to water quality problems. Water used to dissolve powdered milk, infant feeding formulas, or dehydrated foods should always be boiled if the water quality is doubtful.

Filtration. Water filtration is used to remove turbidity from water. It is especially effective when the water is of good bacteriological quality but is moderately turbid. Sand filters can be made from local materials at very low costs and in some areas can be purchased at a reasonable price. A filter provides for some storage and protection of water from outside contamination.

Most filters do not remove all disease-causing organisms. If water passed through a filter is bacteriologically contaminated, it will also need disinfection. All filters require maintenance to operate effectively. If a sand filter is used, the sand must be cleaned every two or three weeks to keep up its filtering capacity. Filter candles in manufactured filters must be scrubbed or changed periodically. Users of filters must be educated about the importance of their maintenance. Unless the users understand the need for a clean filter, this form of water treatment will fail. Some household sand filters can be designed to remove bacteriological contamination. These filters need constant attention and maintenance to be effective. See "Designing Basic Household Water Treatment Systems," RWS.3.D.1.

Chlorination. Chlorine can disinfect most bacteriologically contaminated water effectively. Turbid water should be clarified before it is chlorinated.

The advantages of chlorination are that chlorine is effective, relatively inexpensive, generally available, and easy to apply in liquid, powdered, or tablet form.

Where chlorine is easily available and a water supply needs treatment, chlorination is a good choice. Unfortunately, unless equipment for testing the amount of chlorine needed and the amount of chlorine remaining in a water supply is available, a correct dosage is difficult to determine. A rule of thumb is that enough chlorine should be added to give the water a slight odor or taste. Specific information on chlorine dosage is available in "Designing Basic Household Water Treatment Systems," RWS.3.D.1.

Summary

The type of treatment chosen depends on the conditions at the site, available materials, water quality and the size of the supply to be treated. Choose the form of treatment that ensures good quality water at the least cost. Remember that the best water source is one that needs no treatment. Measures to protect the water source from contamination are generally not expensive and they help ensure good water quality. The following list summarizes the preventive measures that can be taken to preserve water quality.

Table 2 shows possible water treatment methods and indicates the conditions under which each form of treatment is most appropriate. The

Table 2. Water Treatment Processes

	TREATMENT PROCESS				
WATER QUALITY	Sedimentation	Slow Sand Filtration	Chlorination	Protection Against Possible Contamination	Advanced Methods
Clear and uncontaminated				Develop best method to protect water from sources of contamination	
Low level contamination, low or medium turbidity		Use of slow sand filter will remove turbidity and contamination	Chlorination can be used for sources with low turbidity	Source of contamination should be discovered and attempts made to protect water supplies from all contamination	
Low level contamination, medium to high turbidity	Pre-treatment by sedimentation removes most turbidity	After pretreatment, contamination and the rest of turbidity removed	Effluent water should be tested to see if chlorination is necessary		For high turbidity an advanced method may have to be used (see "Methods of Water Treatment," RWS.3.M)
High level contamination with low turbidity		Most bacteria should be removed; test water after treatment	Post-chlorination may be needed to ensure water quality		
High level contamination with high turbidity	Turbidity must be decreased before further treatment	Slow sand filters will remove bacteria once turbidity reduced	Test water to see whether chlorination is needed to improve water quality		Advanced treatment methods necessary

best water treatment method is one that both removes bacteria and clarifies the water. Under most conditions, the slow sand filter is the best form of treatment for a rural community when water is not turbid or when measures are taken to remove turbidity. With the addition of a sedimentation tank or basin, the slow sand filter becomes a very efficient treatment method. Other methods are less effective and require materials or chemicals that must be obtained outside the community. If water treatment needs cannot be met with a slow sand filter, chlorination, or sedimentation, expert advice should be sought about more advanced methods.

Individual treatment requires constant attention by the user. An important incentive for good maintenance is the education of the users to the need for good quality water. If people do not maintain their systems, water quality suffers. Individual treatment fails in most instances because people do not keep up the maintenance needed.

Water treatment adds to the cost of a water system and should be avoided whenever possible. The least costly and most efficient way of ensuring good water quality is to choose a source that requires no treatment and protect it from sources of contamination.

Notes

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1982

Water for the World

Designing Basic Household Water Treatment Systems

Technical Note No. RWS. 3.D.1

Basic household treatment systems are used to ensure the quality of individual water supplies that are subject to possible contamination. They are designed for supplies that cannot be included in a community treatment system due to lack of resources or distance from a central water supply. Basic household treatment systems are simple to use and relatively inexpensive. This technical note discusses the design of several simple household treatment methods useful for most water supplies. Read the entire technical note before deciding on the design that can meet your needs best.

Useful Definition

CHLORINE DOSAGE - The amount of chlorine added to a water supply for disinfection.

Hand or Batch Chlorination

Small amounts of clear, slightly contaminated water can be treated effectively by simple hand chlorination. First, you must know what type of chlorine is available and the amount of chlorine which must be added to treat the water adequately.

Find out what type of chlorine is available locally. In most rural areas, two basic types of chlorine are available for use in treatment: sodium hypochlorite and calcium hypochlorite.

Sodium hypochlorite is the main ingredient in liquid laundry bleaches. It comes in domestic and commercial strengths. The domestic strength is the most common and usually can be bought in local stores. This strength contains about five percent available chlorine but can be purchased with concentrations up to 12-15 percent. Sodium hypochlorite loses its strength gradually in two or three months after containers are opened. Calcium hypochlorite is available in powdered or tablet form and comes in strengths ranging between 30-75 percent available chlorine. A solution of 70 percent is most common. Like sodium hypochlorite, it slowly loses its strength with exposure to air. Calcium hypochlorite dissolves easily in solutions for water treatment.

To treat water prepare a one percent chlorine solution. Remember all chlorine must be stored in sealed containers in a cool dark place to retain its strength. Table 1 shows the availability of chlorine in different compounds of various strengths and the amount of each that must be mixed with one liter of water to make a one percent solution.

Table 1. Chlorine Strengths and Mixtures for a One Percent Solution

Material and Strength (percent available chlorine)	Amount of Material to Dissolve in One Liter of Water to Make a 1% Solution	
	Grams	Tablespoons (level full)
Calcium Hypochlorites		
High-Test Hypochlorite or		
Perchloron Powder (70%)	15	1.0
B - K Powder (50%)	18.6	1.5
Chlorinated Lime (35%)	37.5	2.5
Sodium Hypochlorites		
Liquid (12%)	78.2	5.5 = (1/2 cup or 120ml)
Chlorox (5%)	188.6	12.5 = (1 cup or 240ml)
Purex (3%)	307	20.5 = (2 1/4 cups or 540 ml)

To chlorinate water using a one percent solution, add three drops of the solution per liter of water or 30ml (2 tablespoons) per 145 liters of water. For example, to determine the amount of one percent chlorine solution to add to a cistern with a capacity of 500 liters, follow the steps outlined in Worksheet A.

After adding the correct chlorine dosage, wait 20 minutes or longer for the chlorine to take effect before using the water. If the water is not turbid but is colored or has a noticeable sulfur odor, the dosage should be doubled.

Chlorine is available in tablet form. When using the tablets, carefully follow all directions printed on the package to determine the correct chlorine dosage. When in doubt about the appropriate dosage, add enough chlorine to get a noticeable chlorine taste or odor.

Boiling

Water should be brought to a rolling boil rapidly for two to five minutes to destroy the disease-causing organisms in it. The amount of fuel needed to boil water depends on the type of fire, stove, and container used. An acceptable assumption is that 1kg of wood is needed to boil 1 liter of water. Water should be cooled and stored in the same container in which it is boiled. The boiled water should not be stirred or poured from one container to another in an attempt to add air and regain the taste lost by boiling. Stirring the water or changing containers may recontaminate the water.

Storage

If water is stored for several days, the level of disease causing bacteria in it is reduced. Usually, five or six days' water storage is enough to reduce the level of bacteria enough so

Worksheet A. Amount of One Percent Solution Needed for Disinfection of a Cistern

Example: Assume the cistern is 1m long, 0.8m wide, and 0.6m high.

1. Determine the volume of water that must be treated.

Volume of a rectangular cistern: V = Length x Width x Height

V = 1 m x 0.8 m x 0.6 m

V = 0.48 m^3 ($1m^3$ = 1000 liters)

V = 480 liters

2. Determine the amount of solution to add, using 30ml of 1% solution per 145 liters of water.

Volume of water - 145 liters = Times must add 30ml of solution

480 liters - 145 liters = 3.3
Multiply this figure by 30ml
3.3 x 30ml = 100 ml (0.1 liters)

3. Divide ml by 15 to get the number of tablespoons

100 ml - 15 = 7 tablespoons or
Multiply ml by .0042 to get the number of cups
100 ml x 0.0042 = 0.42 cups, (about one half cup or 120ml)

that people can safely drink the water. However, water quality should be checked. If water quality is poor, the length of storage should be much greater. Furthermore, certain bacteria are not affected by storage (i.e., giardia) and no length of storage will be sufficient to make water quality acceptable.

For basic four or five day storage, use two 200-liter steel barrels with spigots as shown in Figure 1. These two barrels should provide enough storage if the "treated" water is used only for drinking, cooking and minor bathing purposes. These barrels must be cleaned carefully. They may have contained oils, pesticides, chemical liquids or chemical powders. Such remains can be poisonous.

Fill both barrels and empty one completely before using water from the second. When use of water from the second barrel begins, refill the first barrel. Water from one barrel should not be used until the other barrel is empty.

To determine the amount of storage needed, multiply the number of people who will use the stored water by the average daily consumption rate. Assume that the water is used only for drinking, cooking and minor bathing purposes so that each person uses 10 liters per day. A family of six would then use 60 liters per day (6 people x 10 liters per person per day). Each 200-liter barrel would store enough water for just over three days. If less water is used, storage time will increase. Water from the second barrel will only be used on the fourth or fifth day which should be sufficient if water quality is not very bad.

If storage time in the barrels is insufficient, another form of storage must be found. For information on storage, refer to "Methods of Storing Water," RWS.5.M and "Designing a Household Cistern," RWS.5.D.1. If an alternative storage method is not available, chlorinate the water stored in the barrels. All storage containers must be covered to protect the stored water from contamination. Buckets or utensils should never be dipped into

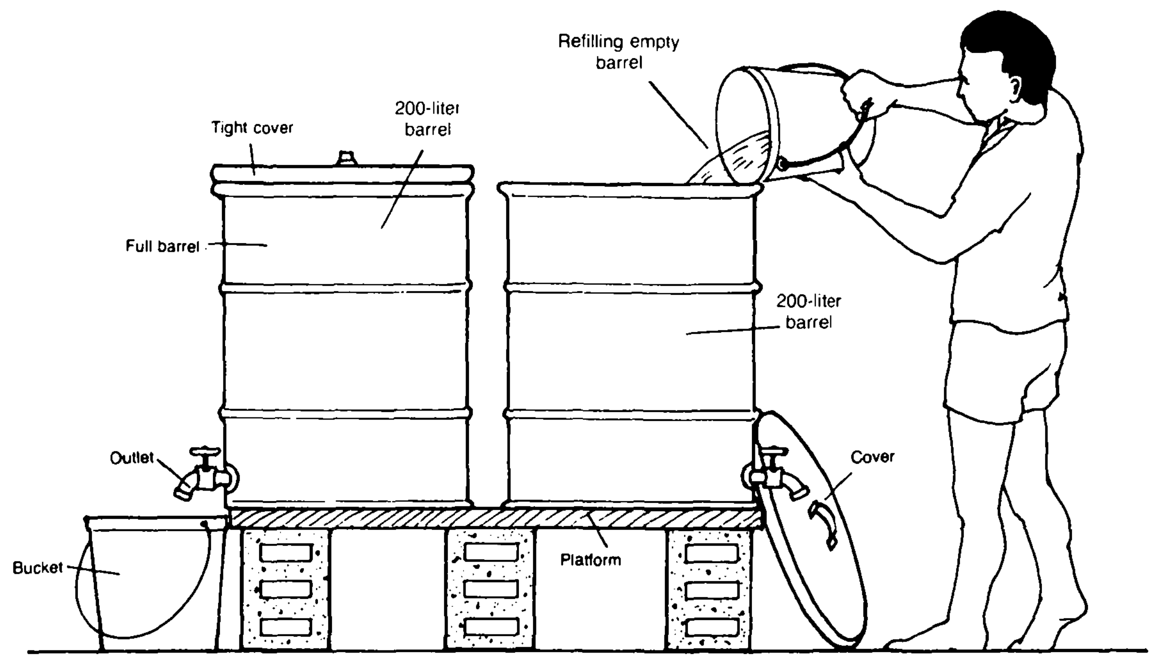

Figure 1. Using Barrels for Water Storage

storage containers. Remember, to be safe, water quality should be checked or water should be boiled or chlorinated.

Filtration

Household sand filters are very useful and popular devices for filtering water and providing basic treatment. They can be built with locally available materials. Household sand filters are relatively effective in removing most bacteria from water if a constant flow of water covers the sand at all times. Otherwise, the household filter will only remove turbidity and the water will need further treatment.

The design of a sand filter can fit local needs. Follow the design steps outlined below and refer to Figure 2. Table 2 is a list of materials needed.

A household sand filter requires a 200-liter steel barrel approximately 600mm in diameter and 750mm tall and enough clean sand to make a layer 600mm deep in the barrel. The sand layer should be about 750mm deep if a taller barrel is used. Sand size between 0.1-1.0mm is acceptable, but sand size from 0.2-0.5mm is preferred.

Determine the volume of sand needed for the filter by using the following formula:

$$V = \frac{\pi}{4} (d^2) (h)$$

where V = volume

π = 3.1

d = diameter of the barrel = (0.6m)

h = the height of the sand layer = (0.6m)

$$V = \frac{3.14}{4} (0.6m^2) (0.6m)$$

$$V = 0.785 (.36m^2) (0.6m)$$

$$V = 0.17m^3 \text{ or } 0.2m^3$$

For the filter, choose a fine grain sand. Generally, the finer the sand, the better the quality of water. Do not use coarse sands in the filter. Coarse sands allow organic matter and bacteria to pass through the filter.

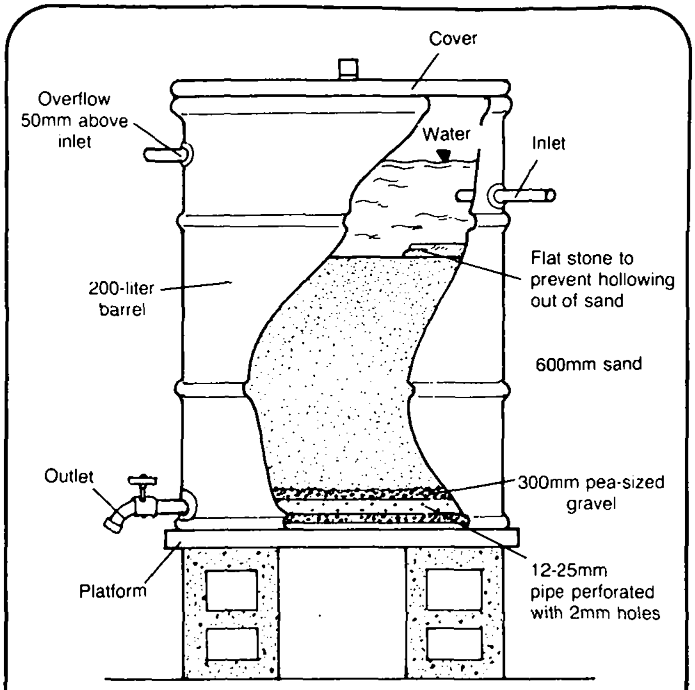

Figure 2. Household Sand Filter

Table 2. Materials List for Slow Sand Filter

Item	Quantity
Steel drum for filter (0.6m x 0.75m)	____
Pre-and post-filtration storage drums (200-liter capacity)	____
Clean sand, sized 0.1-1.0mm	____
Pea gravel	____
Sheet metal and wood, for cover	____
Polyethylene flexible pipe for inlets and outlet pipes	____
Valve to regulate water flow	____

Pea-sized stones should be used to line the bottom of the barrel where the outlet for the filter is located. The gravel layer should be 30-50mm thick. The filter outlet hole should be no more than 2mm in diameter.

If the sand filter is designed to receive a continuous flow of water, there should be an inlet hole and an overflow at the top of the barrel. The overflow should be about 50mm higher than the inlet.

Provide for a continuous flow of water through the filter sufficient to keep the filter full with a slight overflow. The maximum rate of flow through the filter should not be more than about 1 liter/minute. Water should flow from storage into the sand filter by gravity flow through flexible plastic pipe. A valve should be installed to regulate the flow. See Figure 3.

The sand in the filter should never be allowed to dry out. If the sand layer dries, the sand should be wasted or replaced. Dried sand may add bacteria to the water. Flow should be checked occasionally to ensure that the sand layer is always covered. An outlet pipe should be connected to the filter so that the water flows to a storage container.

It is much easier to use the sand filter only as a means of clarifying water rather than removing bacteria. The design of the sand filter is simpler when disinfection is not included. Operation and maintenance requirements are also less demanding.

For simple filtration, design the sand filter in the same way as described except do not include either an inlet or an outlet hole on the upper side of the steel barrel. To filter the water, the cover is removed and the desired quantity of water poured into the filter. Then the cover should be replaced. There is no need to keep the sand layer always submerged. Filtered water is collected in a storage vessel. Water filtered in this manner probably needs further treatment to disinfect it.

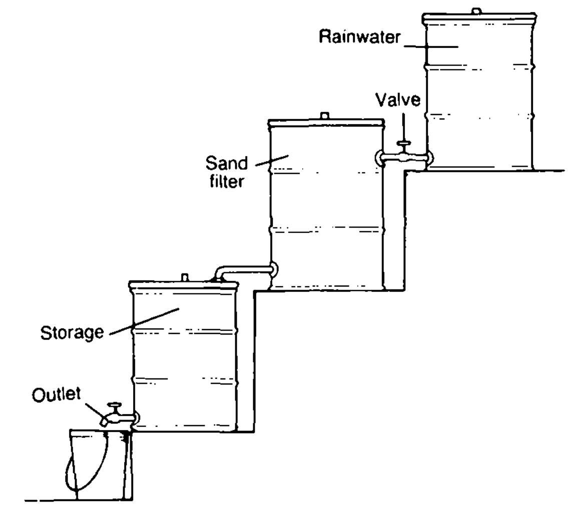

Figure 3. Household Sand Filter System with Gravity Flow and Storage

Summary

The design of most household treatment systems is simple and inexpensive. The choice of treatment method depends on available materials for construction, the users' access to chemicals, and the quality of the water supply. Proper design and proper use of chemicals are very important in ensuring that water quality is suitable. If questions or doubts about the use of a treatment process arise, an expert should be consulted to assist in the development of the most appropriate treatment method. If this is not possible, water should be boiled to disinfect it until a more permanent solution to the problem is found.

Notes

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1982

Water for the World

Designing a Slow Sand Filter
Technical Note No. RWS. 3.D.3

A slow sand filter is a very useful water treatment process. Slow sand filtration effectively removes organic matter, pathogenic organisms, color and mild turbidity to provide clean and safe water. No other single treatment process can improve the physical and biological quality of water as well as sand filtration.

Slow sand filters offer other advantages which make them useful in rural areas. They can be constructed with local materials and labor at a low cost. Operation and maintenance requirements are few and local labor can be trained to carry them out.

Even though sand filters are not difficult to design and operate, special care must be taken to ensure their efficient operation. This technical note describes the basic design features of a slow sand filter. Before attempting to design such a system, consult an engineer whenever possible.

The design process should result in the following three items which should be given to the construction supervisor.

1. A map of the area marked with the locations of the slow sand filter, other treatment systems planned, the water source, and any important landmarks. See Figure 1. Whenever possible, the filter should be located close to the water source.

2. A list of all labor and materials needed for the project. A sample list appears in Table 1.

3. A plan of the slow sand filter showing the design dimensions as shown in Figure 2.

Useful Definitions

BUTTERFLY VALVE - A valve used to accurately regulate the flow of water through a pipeline; a butterfly valve can be opened and closed slightly to regulate flow.

CREST - The top of a weir or spillway to which water must rise before passing over the structure.

DESIGN PERIOD - The length of the useful life of a structure or system during which no extension or expansion is required.

FREEBOARD - The height of the filter box above the water level.

GATE VALVE - A type of cut-off valve in a pipeline; when completely open, it provides a low resistance to straight line water flow.

SCHMUTZDECKE - A layer of biologically active microorganisms that forms on the top of the filter bed; the microorganisms break down organic matter and kill the bacteria in the water.

WEIR - A barrier placed in moving water to either measure, stop or control flow.

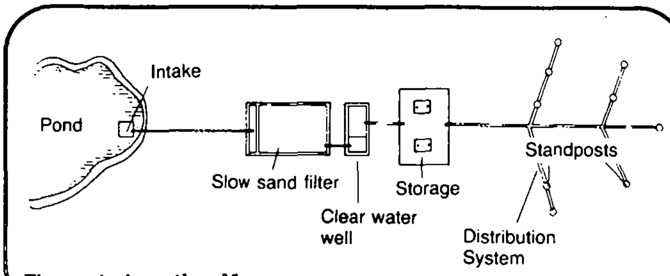

Figure 1. Location Map

Design Information

The basic parts of a slow sand filter are:

- the water reservoir above the layer of filter sand,
- the filter bed,
- the filter bottom and water drainage system,
- the filter box containing the three items above,
- the filter control system,
- the effluent system.

Each part plays an important role in the overall design. Before beginning to design the filter, it is necessary to determine the following:

- the amount of water that must be provided to the community and the capacity of the filter,
- the number of filter beds desired.

Table 1. Materials List for Slow Sand Filters

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	___ ___	___ ___
Supplies	Bricks Cement Gravel, 60-100mm Sand, 0.15-0.35mm Gate valves Butterfly valve PVC pipes Wooden stakes Rope Pipe glue	___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Tools	Digging tools Small saw Sieve Hammers Nails Measuring tape Trowels Wheelbarrow Mortar box	___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___

Total Estimated Cost =

The slow sand filter should be designed to meet a community's needs for about 7-10 years. Some systems can be designed for up to 20 years. In designing for the capacity of a slow

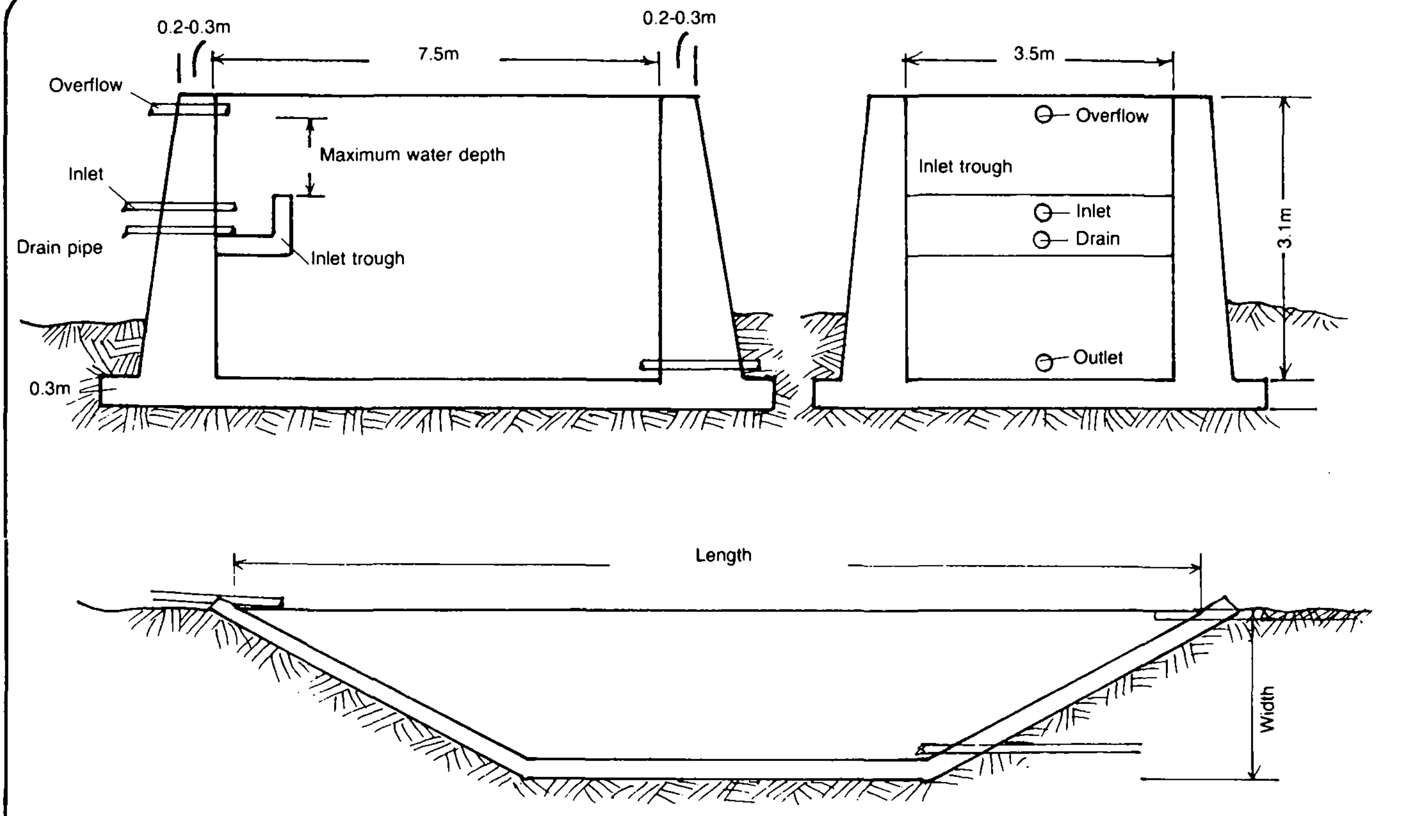

Figure 2. Design of Slow Sand Filter

sand filter, make an estimate of the community's population 10 years in the future. Although accurate information on population growth may not be available, gather any available data from local sources and make an estimate. Table 2 shows the population growth factors that can be used to estimate the future population of a community.

Table 2. Population Growth Factors

Design Period Years	Yearly Growth Rate (%) 1.5	2	2.5	3	3.5	4
7	1.1	1.15	1.19	1.23	1.27	1.32
10	1.16	1.22	1.28	1.34	1.41	1.48
15	1.25	1.35	1.45	1.56	1.68	1.80
20	1.35	1.49	1.64	1.81	1.99	2.19

For example, if the population of a certain town is 1000 and the yearly growth rate is 2.5 percent, the population in 10 years can easily be determined in the following way. First, look in Table 2 under the column 2.5 percent and find the number in the row for a 10-year design period. The number is 1.28. Multiply the present population (1000) by 1.28 to determine the population in 10 years:

1000 people x 1.28 = 1280

Therefore, the sand filter should be designed for a population of 1280 people.

Calculate the daily demand for water. When determining demand, assume a level of consumption of 40 liters per person per day. Total daily demand is:

1280 people x 40 liters/person/day = 51200 liters/day or approximately $52m^3$/day.

For design of the clean water storage tank and the distribution system, the hourly water demand must be calculated. The hourly water demand takes into consideration daily peak flows to ensure that water is provided to the users without interruption. Determine the hourly water demand by taking 20 percent of the daily demand. For example: $52m^3$/day x .20 = $10.4m^3$/h

Next determine the total filter area. The filter bed area can easily be calculatd using the following formula: $A = \frac{Q}{V}$. The area equals the quantity of water per hour divided by the velocity of water through the filter bed. Velocity should range between 0.1m/h and 0.2m/h. In this example, the quantity of water is $10.4m^3$/h. Assume a filtration rate of 0.2m/h. Therefore, the total filter area equation is:

$$\text{Area} = \frac{10.4m^3/h}{0.2m/h} = 52m^2$$

A minimum of two filters should be constructed. Each should have a filtration rate of 0.1m/h if they operate together. If one filter is shut down for cleaning, the other filter can be used. With one filter closed down, the filtration rate for the filter in operation would be no more than 0.2m/h. Since the total area of the filter beds is $52m^2$, two filters of $26m^2$ can be constructed ($52m^2 \div 2 = 26m^2$). Space for a third filter with the same area should be reserved for future expansion. Design the filters so that the ratio of length to width is between one and four. For example, each filter could have a width of 3.5m and a length of 7.5m (7.5 ÷ 3.5 = 2.1).

For filters with loads of $6m^3$/h or less, a circular ferrocement filter can be constructed. A circular ferrocement filter is easier and cheaper to build than a rectangular concrete or masonry filter. Ferrocement filters are built using chicken wire, wire strips and a mixture of one part cement and two parts sand. The wire mesh is usually 20mm thick and the walls are between 60 and 120mm thick. See Figure 3 for more detail. Ferrocement filters should not be more than 5m in diameter and should have a filtration rate of 0.1m/h. They are especially useful in small villages.

The greater the capacity needed, the greater the number of filter units which should be built. Filter units should not be too large in order to simplify cleaning. To determine the number of filter units needed for a system, use the following formula:

$n = 1/4\sqrt{Q}$ (the number of filters is equal to one-fourth the square root of the infiltration flow rate) where:

n = number of filters (where n must be 2 or greater)

Q = the water flow rate in m^3/h.

In the above example, the flow rate, Q, is equal to $10.4m^3/h$.

Therefore, $n = 1/4\sqrt{10.4m^3}$
$n = 1/4\ (3.2)$
$n = 0.8$, or approximately one filter. Since two filters should be provided, an adequate supply of water will be available for the community from two small sand filters.

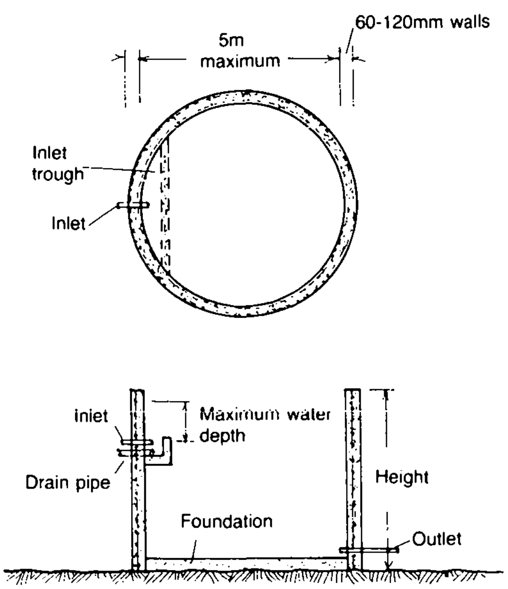

Figure 3. Ferrocement Sand Filter

Filter Box

The filter box consists of four parts:

- the water reservoir above the filter bed,
- the filter bed,
- the underdrain system, and
- the filter control system.

The water reservoir above the sand level provides a waiting period for the water in which sedimentation can take place and produces a head of water greater than the resistance of the filter bed. A head of between 1.0-1.5m above the filter bed is an acceptable water depth. The walls of the reservoir should extend 0.2-0.3m above the water level as shown in Figure 4. This extension is called the freeboard.

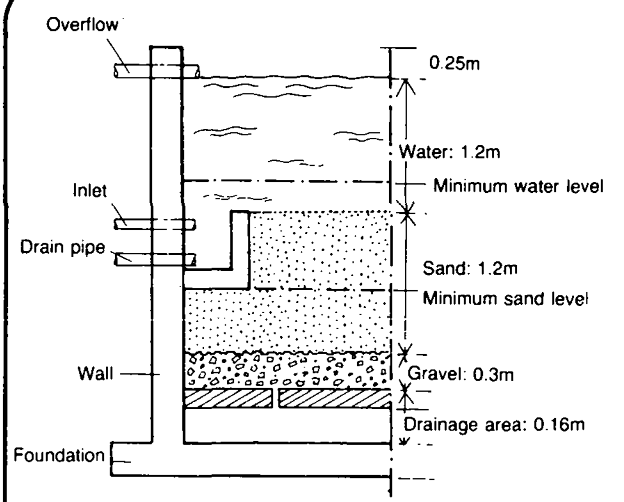

Figure 4. Filter Bed Construction

The filter bed is where the purification process takes place. The filter material is usually a fine grain sand and should be free from clay loam and organic matter. The diameter of the sand should be just small enough to ensure that the filter produces good quality water and to prevent the entry of clogging material into the filter bed.

Sand size is described by two measurements, the effective size and the uniformity coefficient. The effective size of the sand is the size of the sieve opening through which 10 percent of the filter bed material will pass. For the sand filter, use sand with an effective size between 0.15-0.35mm.

The coefficient of uniformity of the sand used in the filter should be less than 3. The coefficient of uniformity is a ratio between the sieve size through which 60 percent of the filter material passes (d_{60}) and the size through which 10 percent of the sand passes (d_{10}). The coefficient of uniformity can be determined as follows:

$$\text{coefficient of uniformity} = \frac{d_{60}}{d_{10}} = \frac{\text{diameter through which 60 percent of material passes}}{\text{diameter through which 10 percent of material passes}}$$

For example, if 60 percent of the material passes through a sieve of 0.61mm and 10 percent through a sieve of 0.21mm, the coefficiency of uniformity is:

$$\frac{d_{60}}{d_{10}} = \frac{0.61\text{mm}}{0.21\text{mm}} = 2.9$$

To determine the effective size and the uniformity coefficient of sand requires a set of standard sieves and good scales. Equipment for making these measurements is used in soil laboratories. Other places that can do sand analyses are public works departments, concrete mixing plants and cement factories. Check with local people to see whether sized sand can be obtained. If sized sand is unavailable, choose coarser sands for the filter bed. Try to avoid using fine sands.

Design the filter box to provide space for a filter bed 1.0-1.4m thick. This thickness permits the filter bed to last several years before new sand must be added. New sand must not be added until the filter bed thickness falls to 0.7m. For information on the care of the filter bed see "Operating and Maintaining a Slow Sand Filter," RWS.3.0.3.

Next, determine the amount of sand needed for the filter. To determine this amount, the volume occupied by the sand must be calculated using the following formula:

Volume of sand = the area of the filter bed times its height

Filter bed area = length x width of filter

Area = 3.5m x 7.5m

Area = 26.25m^2

Volume = area x height

Volume = 26.25m^2 x 1.2m

Volume 31.5m^3

The volume of sand needed for each filter bed is 31.5m^3 or a total of 63m^3 of sand for the two filters.

Below the filter bed is the underdrain system. The purpose of the underdrains is to support the filter bed, ensure a uniform filtration rate and collect the filtered water.

The support for the filter bed consists of several gravel layers of different sizes. Use four layers of gravel sized as shown in Figure 5. Each layer should be between 60mm and 120mm thick.

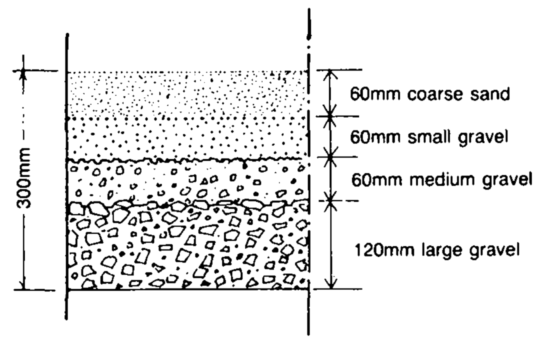

Figure 5. Filter Support System

The collection system is located below the gravel layers. The underdrain system can be built with bricks and porous concrete or prefabricated concrete slabs as shown in Figure 6. The distance between the lateral drains must be between 1-2m, with 2m the maximum allowable distance. Lay the brick drain tile so that the space between the bricks is 2-4mm and the distance between the spaces is approximately 0.15m. See Table 3 for more specific information.

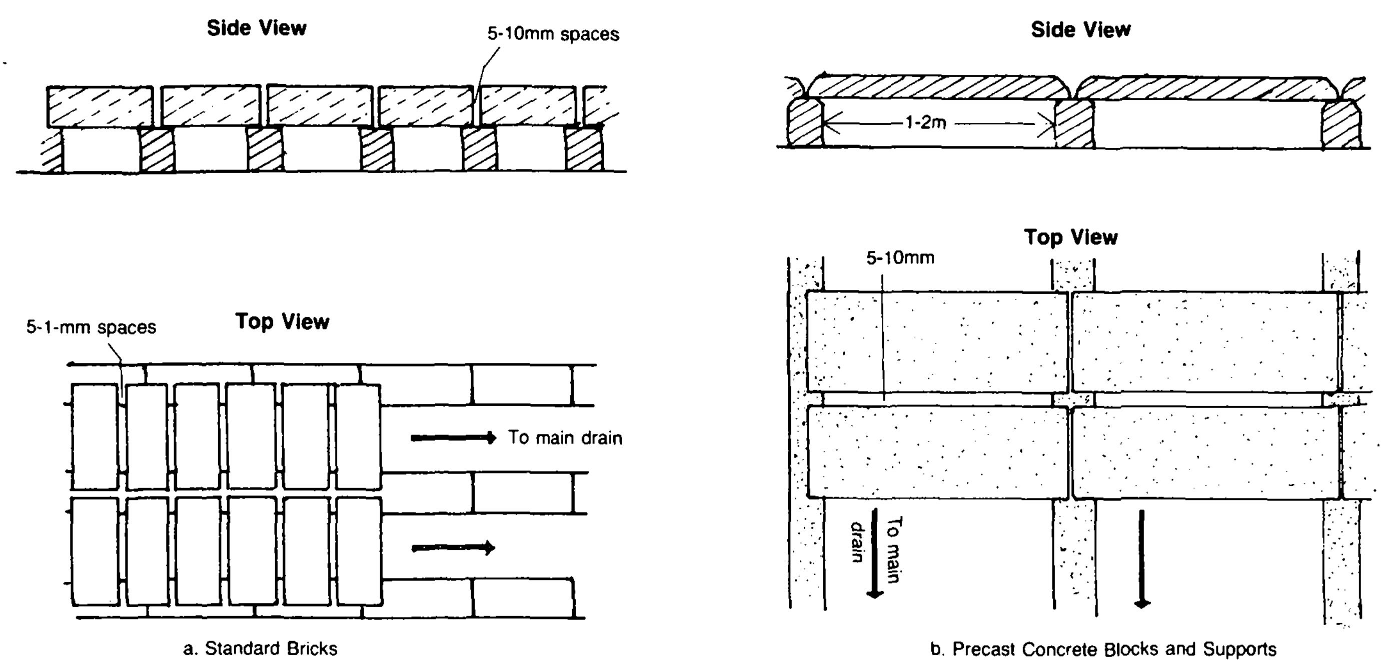

Figure 6. Underdrain System

By adding the dimensions of the filter box parts, it is possible to calculate the total depth of the filter. The dimensions below are averages.

Freeboard above water level in tank	0.25m
Water level	1.20m
Filter bed	1.20m
Four layer gravel support	0.30m
Brick filter bottom	0.16m
Total	3.11m

The total depth is 3.11m.

Table 3 gives a complete list of the design dimensions of a typical slow sand filter.

Table 3. Slow Sand Filter Design

Description	Design Limits	Technical Note Example
Area per filter bed	10-100m^2	26m^2
Number of filter beds	Minimum 2	2
Water level height in filter	1-1.5m	1.2m
Depth of filter bed	1-1.4m	1.2m
Depth of under-drain system	0.3-0.5m	0.46m
Spacing of laterals in drain	1-2m	1.5m
Size of spaces in laterals	2-4mm	3mm
Distance between spaces in laterals	0.1-0.3m	0.15m
Filtration rate	0.1-0.2m/h	0.1m/h
Filter box height	2.5-4m	3.11m

The rate of filtration should be controlled in order to ensure effective operation of the slow sand filter. The control basically consists of an inlet, a drain and an effluent regulation system. Refer to Figure 7 while reading this section.

The inlet structure must ensure an even flow of water onto the filter so that the sand bed is not disturbed by falling water. If falling water displaces or destroys the schmutz-decke, the filtration process will not work properly. For best results, the flow of water into the filter should be low (0.1m/second). A small trough located under the inlet to catch the

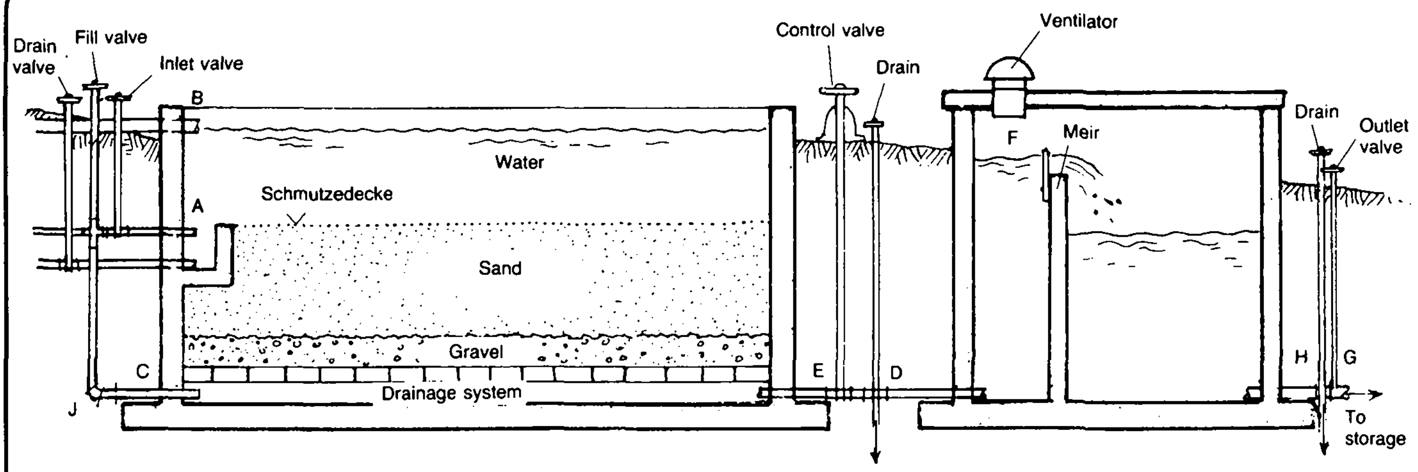

Figure 7. Slow Sand Filter with Valve System and Clear Water Well

inflow can be constructed. This catchment is useful in evenly distributing the incoming water. A control valve should be located at the filter inlet to adjust the water level in the tank. A float controlled butterfly valve or a manually operated gate valve can be used for this purpose. The valve is needed to shut down the system for cleaning. See valve A in Figure 7. An overflow weir should be installed above the water level in the filter box as shown by outlet B in Figure 7.

Install a drain, Figure 7, controlled by valve C, to remove water from the filter when cleaning is necessary. Locate the drain near the bottom of the inlet trough. There should also be a drain to remove the water in the top layers of the filter bed. See the valve marked D in Figure 7.

The most important control in the filter system is the effluent control valve E. This valve can be either a gate or butterfly valve. The butterfly valve provides better control as it can respond to small changes in pressure and adjust the filtration rate by opening more fully as resistance in the filter bed increases. This adjustment allows the total resistance in the bed and valve to remain uniform.

As the filter becomes increasingly loaded, resistance to flow increases. By opening valve E, the total resistance decreases so that the flow in the filter continues over the weir. Open the control valve wide enough to keep an even flow of water over the weir, F. One valve is generally sufficient to provide a uniform flow in the filter. When the flow rate drops below the level of resistance, the sand bed should be cleaned by skimming and raking it. If cleaning does not renew good flow, a sand change may be necessary. This should not be needed for a year or more. Another valve, H, should be installed to run water to waste before the filter bed is ready for operation. Valve G is installed to control the flow from the filter to the clear water well. The clear water well should have a capacity of 30-50 percent of daily water production from the filter.

An overflow weir forms part of the system to control the filtration rate. The crest of the overflow weir should be a little above the top of the sand bed shown by point F in Figure 7.

To refill the filter after cleaning, an inlet for backfilling is installed in the filter as shown by valve J. Refilling the filter from the bottom to the top pushes trapped air upward and out of the filter bed to provide for more efficient filtration.

Construction Materials

Most slow sand filters are rectangular shaped with vertical walls. Various materials can be used in the construction of slow sand filters. Large filters, which generally are built with reinforced concrete, require more advanced construction techniques and skilled labor. Small filters with a maximum length of 20m can be built using mass concrete or masonry. Most filters have concrete floors and vertical walls of concrete, masonry, or stonework. The choice depends upon which materials are available and the skills of the labor force working on the construction. Small rectangular filters with vertical walls can be built above ground for convenience. They should be above ground where the groundwater table is high or where solid rock makes excavation difficult. Larger filters should be built into the ground so that the ground provides support for the walls. When designing a rectangular slow sand filter with vertical walls, always keep in mind the following design criteria:

- Prepare a foundation with a minimum depth of 0.3m to provide support for the walls.

- Plan the depth of the foundation so that there is a minimum distance of 0.5m between the top of the filter and the ground level to prevent the entrance of children or animals. Generally a distance between 0.5-1.0m is adequate.

- Use a raft design for the foundation. See Figure 8. The raft foundation gives the filter structure extra strength and prevents leaking at the joints.

Once the basic design is set, the amount of materials needed should be determined. If bricks are used for construction, determine the volume in cubic meters of the construction and the number of bricks needed per cubic meter. Add a 10 percent error factor to the calculation to prevent falling short of materials. Check with local masons or brick-makers who generally know the number of bricks needed per cubic meter.

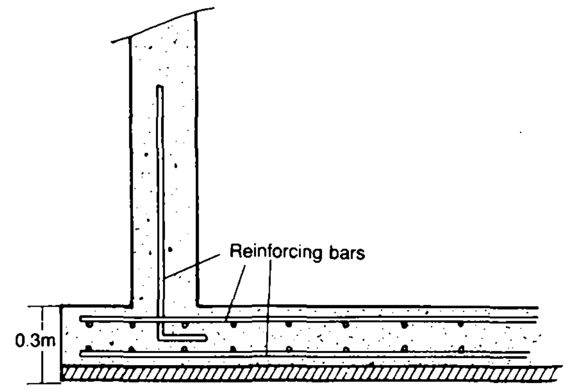

Figure 8. Raft Foundation for Filter Walls

When using mass concrete, determine the amount of materials needed by doing the calculations shown in Worksheet A. Make all walls 0.2-0.3m thick. The dimensions given are those used in the earlier example.

Excavated sloping wall structures can also be designed. They are the simplest and most inexpensive filters to install but they are not as sound structurally as rectangular filters. Do not design a sloping wall structure where the groundwater table is high or where there is doubt about whether the structure will be watertight.

If a sloping wall structure is used, the tank will be completely below ground level. The slope of the walls should be approximately 1:2, 1m of slope for every 2m of height. This slope will increase the length of the filter basin and require that a larger land area be used. Piping and valves to control flow must be carefully worked out beforehand as flow is by gravity.

Suitable lining materials for the walls are masonry, mass concrete, puddled clay or a sand/cement mixture with chicken wire reinforcing. Wall thickness will vary with material used. Make sand/cement and mass concrete walls .08m thick, impervious clay walls .05m and brickwork 0.1m. Other design features are similar to filters with vertical walls. The area around the filter should be fenced to keep animals away.

Worksheet A. Calculating Material Quantities for a Concrete Slow Sand Filter

Total volume of each rectangle = length (l) x width (w) height (h)

1. Volume of two sides = 1.75 m x 0.25 m x 3.1 m x 2 = 11.625 m^3
2. Volume of two ends = 3.5 m x 0.25 m x 3.1 m x 2 = 5.245 m^3
3. Volume of foundation = 8.0 m x 3.5 m x 0.25 m = 7.0 m^3
4. Total volume from steps 1, 2, 3 = 24.0 m^3
5. Add 10% for safety factor = 2.5 m^3
6. Total volume of structure from steps 4 and 5 = 26.56 m^3
7. Unmixed volume of materials needed = total volume, from step 6 x 1.5 = 26.5 x 1.5 = 39.75 m^3
8. Volume of each material (cement, sand, gravel, 1:2:3)

   Cement: 0.167 x volume from line 7 39.75 = 6.7 m^3

   Sand: 0.33 x volume from line 7 39.75 = 13.15 m^3

   Gravel: 0.5 x volume from line 7 39.75 = 19.9 m^3
9. Number of 50kg bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$

   $\frac{\text{volume of cement} = 6.7\ m^3}{\text{volume per bag} = .033\ m^3/\text{bag}}$ = 203 bags
10. Use about 28 liters of water for every bag of cement. Amount of water = 28 liters x 203 bags = 5684 liters

Note: To save cement, a 1:2:4 mixture can be used with no loss of strength.

Summary

A slow sand filter is an effective method of treatment for a rural water supply system. The filter is easy to operate and maintain with local skills and labor. However, a skilled technician should be available to design and construct the filter to ensure that it works correctly. Slow sand filters are useful in most areas where there is sufficient good quality sand and where land is available. The site should provide gravity flow to the users.

The filters mentioned in this technical note are examples of design suggestions. The choice of sand filter design will depend on the site available, materials and local skills. Follow the directions in this technical note as a basic guide.

Notes

Notes

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Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Designing a Small Community Disinfection Unit

Technical Note No. RWS. 3.D.4

Disinfection of ground and surface water is often necessary to ensure that drinking water is free from microorganisms that could cause disease. Usually, drinking water is disinfected by adding chlorine. Chlorine is used because it destroys pathogens quickly and because it is available in most areas at a moderate cost.

This technical note describes the design of three basic methods for chlorinating community water supplies: a pot and a drip feed chlorinator which are used to disinfect water in individual and community wells and cisterns, and a floating bowl chlorinator which feeds chlorine solution into the water supply. These methods are cheap to develop and do not require skilled labor to operate. However, adequate supervision must be available to ensure that the chlorinators work satisfactorily and that sufficient chlorine is added to the water to make it safe.

The design process should result in the following items which should be given to the people making the disinfection units:

1. A list of all materials needed for the chlorinators. A sample materials list appears in Table 2 for a pot chlorinator and in Table 3 for a floating bowl chlorinator.

2. A detailed plan of each type of chlorinator similar to those shown in Figures 1, 2 and 3. Figure 1 shows a typical pot chlorinator, Figure 2 a drip feed chlorinator and Figure 3 a floating bowl chlorinator.

Useful Definitions

AVAILABLE CHLORINE - The amount of chlorine present in a chemical compound.

CHLORINE RESIDUAL - Amount of chlorine left over in water after the chlorine demand has been met; residuals may be as chlorines combined with ammonia nitrogen (CAC) or free available chlorine (FAC). FAC kills bacteria more rapidly than CAC.

Chlorine

Several types of chlorine are available for use in disinfection. The choice of which type to use depends primarily on what is readily available at a low cost. The most common form of chlorine is sodium or calcium hypochlorite which is available in either a powder or liquid form. The available chlorine in these compounds varies from 20 percent to approximately 5 percent. Table 1 lists the various types of chlorine and their strengths.

For chlorination to be effective, a sufficient amount of chlorine must be added to the water to provide a residual. A free available chlorine residual, FAC, of 0.4mg/l after contact of 30 minutes will surely kill bacteria. To test for chlorine residual, a field testing kit is needed. If that is not available, a guess can be made by taste and smell. If the water has a slight chlorine taste and odor, than adequate chlorination can be assumed.

Pot Chlorinators

Pot chlorinators are effective for disinfecting water in contaminated shallow dug wells. The simplest type of chlorinator is an open-mouthed pot containing a mixture of sand and bleaching powder. The pot is simply lowered into the well by a rope and left to hang underwater. See Figure 1.

Table 1. Chlorine Compounds

Compound	Available Chlorine	Basic Characteristics
High Test Hypochlorite (HTH)	70%	Retains strength for over a year under normal storage conditions; less common on the market.
Chlorinated Lime (Bleaching Powder)	33-37%	Very unstable; loses strength quickly with exposure to air, light or moisture; should be stored in a dark, cool, dry place in rust resistant containers; more usually available then HTH.
Sodium Hypochlorite Solutions a. Commercial b. Household (laundry bleach)	 12-15% 3-5%	Like bleaching powder, very unstable and the same precautions must be taken; readily available in most areas.

To make a pot chlorinator, use a plastic or earthen jar with a capacity of 7-10 liters. Seven 6-8mm holes are made in the bottom of the pot, then it is filled half way with pebbles and pea gravel with a diameter of 20-40mm. Next, a mixture of sand and bleaching powder is made. The mixture should contain one part bleaching powder to two parts sand and should fill the pot almost to the neck. A thin layer of pea gravel is placed on top of the chlorine-sand mixture in order to fill the pot almost to the neck.

The pot containing 1.5kg of chlorine will effectively chlorinate for one week a well from which water is taken at a rate of 1000-1500 liters/day. Where volumes are smaller, the chlorination process will last longer. In larger wells, an additional pot or several pots may have to be added to kill pathogenic organisms. Pot chlorinators can be used for disinfecting water in cisterns and other storage units.

Drip Feed Chlorinators

Another method of disinfection of water in wells and small reservoirs or tanks is the drip feed method. A typical drip feed chlorinator is shown in

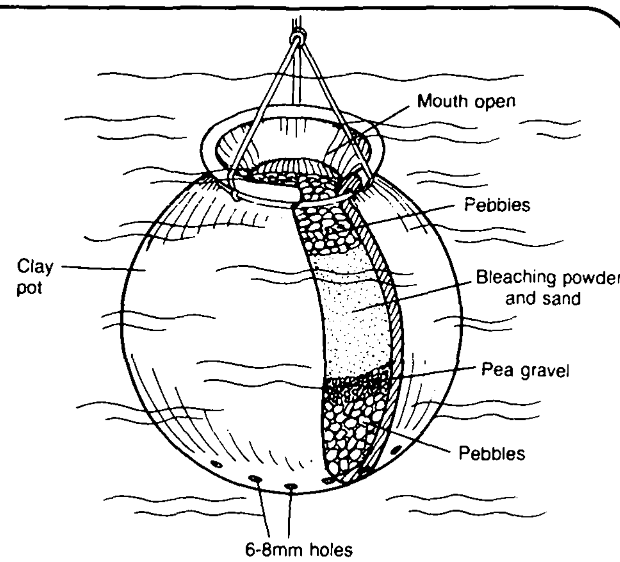

Figure 1. Pot Chlorinator

Figure 2. A small drip feed chlorinator can be made from plastic jars easily available in most areas. The spout of the container serves as the outlet and the bottom of the jar is cut out so that solution can be added.

A drip chlorinator requires a small float, rubber tubing, and stoppers. Choose a material to serve as a float.

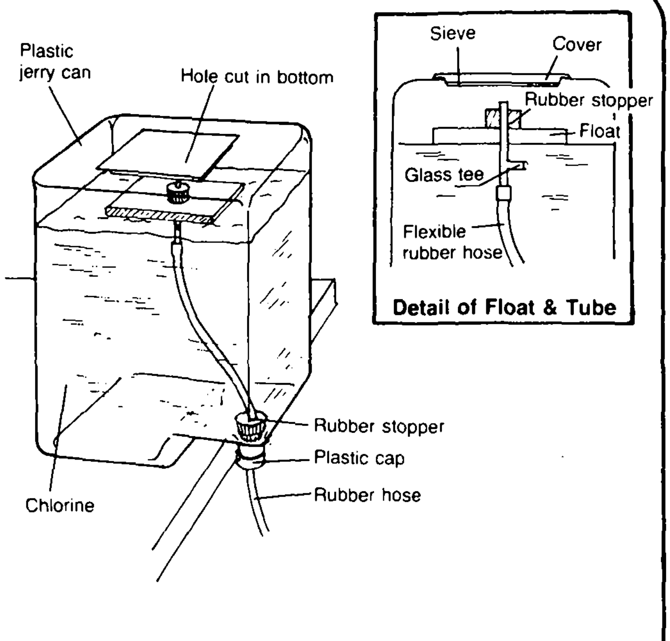

Figure 2. Drip Feed Chlorinator

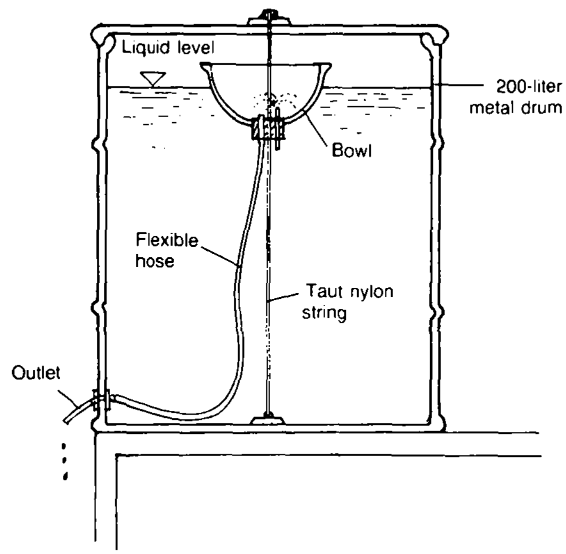

Figure 3. Floating Bowl Chlorinator

A rubber stopper is placed in the middle of the float and a piece of hard tubing is placed through the stopper. Glass, brass, or plastic tubing can be used. The tubing should extend below the float into the solution. A small hole is placed in the tube for the solution to enter.

A small diameter flexible rubber hose is attached to the hard tubing. The hose extends from the hard tube to the outlet. It passes through a rubber or cork stopper placed in the container's neck and a plastic cap that covers the spout. Choose a long rubber hose so that it extends from the chlorinator to the water that is to be disinfected.

Use 2-5 percent chlorine bleach to fill the chlorinator. The chlorine solution can be used directly at full strength. No water must be added. To control the rate of flow, a small clamp is placed on the discharge hose to regulate the flow. Set it at a slow drip. The chlorinator is hung in a well or cistern and the hose extends into the water to be treated. The chlorinator must be refilled with chlorine bleach when it is nearly empty.

Floating Bowl Chlorinators

There are many commercial chlorinators on the market for disinfecting both small and large water supplies. If they are available, their use may be an economical and efficient method of disinfecting piped water supplies. Where such equipment is difficult to obtain and too costly for the community, homemade solution feeders that provide close control of the solution and a low rate of feed can be made locally. One device is the floating bowl chlorinator as shown in Figure 3.

Solution feed, drip chlorinators use the batch method of mixing to disinfect water in storage tanks or reservoirs. The batch method involves mixing a specific volume of water with a certain strength and volume of chlorine and adding it to the water through a gravity flow system. The strength of the batch should be about 1-2 percent.

The floating bowl chlorinator consists of a small tank, generally a 200-liter barrel, fitted with devices for controlling the rate of flow from it to the reservoir. See Figure 3.

The major part of the design is the tank or barrel. Use a 200-liter steel drum for this purpose, although a larger concrete tank can also be used. The drum should be painted inside with a latex or rubber base paint. This will prevent the chorine from rusting the metal and damaging the water quality. The drum should have a drain. A small 10mm hole should be placed at the bottom of the drum for that purpose. The system must be drained periodically for cleaning. A cover over the top of the tank keeps out light. To allow air entry, do not place an airtight cover on the tank.

A floating bowl arrangement should be designed to ensure that the chlorine solution trickles from the outlet at a constant rate. Use a plastic or light metal bowl or cut out the bottom of a plastic bottle to form the floating bowl. Any material that floats should be adequate. A hole must be placed in the bottom of the bowl and stopped with a rubber stopper, or a large piece of cork. The size of the hole will depend on the cork size. The cork should be large enough so that three tubes can pass through. One tube should be 6-9mm in diameter and the other two 3mm. See Figure 4.

Choose either glass, plastic, copper, or brass tubes. The tubes should be pushed through the cork so that one end opens into the bowl. The larger tube, 6-9mm in diameter, should be connected to a flexible hose that runs to the outlet. A smaller tube, 3mm in diameter, should be pushed through the cork until the top of it is slightly below the liquid level in the tank. The other 3mm tube should be higher than the other two tubes as shown in Figure 4.

Finally, a string should run through the third tube which should be placed through the center of the cork. The string is secured to the top and bottom of the barrel as shown in Figure 3. The string keeps the bowl in the center of the tank and prevents it from catching on the sides. An outlet is placed on the lower side of the tank and the flexible hose is stretched out. This type of connection permits the water to drip into a funnel system which leads to the water.

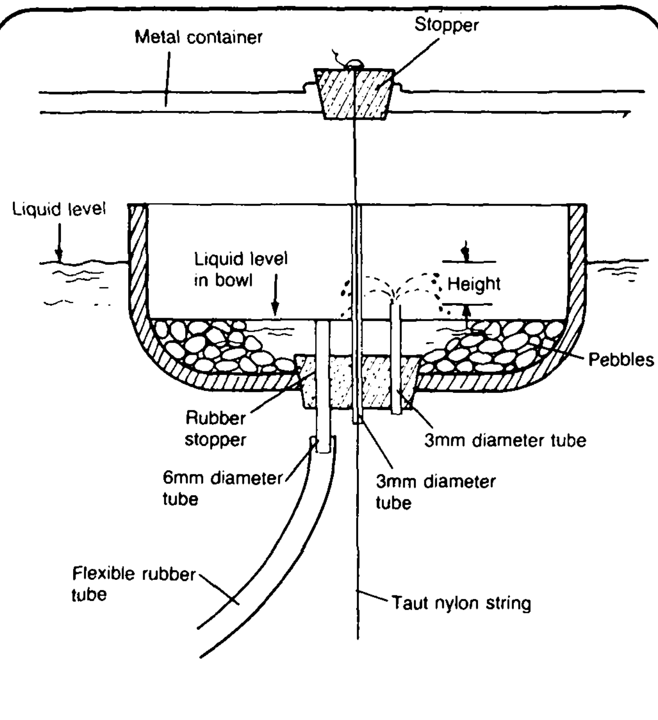

Figure 4. Detail of Floating Bowl Chlorinator

The chlorine solution should then be prepared and the tank filled with a solution of one percent chlorine. To determine the amount of chlorine to add to make a one percent solution, use the following calculation:

Kilograms of chlorine required =

$$\frac{\text{Percent strength of solution desired} \times \text{Liters of solution required}}{\text{Percent available chlorine in compound}}$$

For example, to prepare 200 liters of a one percent solution using hypochlorite powder with 70 percent available chlorine, find the amount of chlorine which must be added as shown below.

$$Q \text{ chlorine} = \frac{1\% \times 200 \text{ liters}}{70\%}$$

$$Q \text{ chlorine} = \frac{.01 \times 200}{.70}$$

$$Q \text{ chlorine} = 3\text{kg}$$

In other words, 3kg of hypochlorite powder would have to be added to 200 liters of water to make a one percent solution.

Add the solution to the tank. Then weight the float using small stones so that it floats steadily and straight. Figure 4 shows this technique. To function properly, the chlorinator must be effectively maintained.

Build a small platform above the reservoir holding the water to be treated. The platform allows the solution to be applied by gravity flow.

Chlorination is only effective if sufficient chlorine is added. Water should be tested after chlorination to ensure that there is a residual of 0.4mg/l after 30 minutes contact time. A color comparator tester is needed to make this test. Several brands of test kits are available on the market. Those using the orthotolidine test are most widely used and cheapest.

Although these kits are available in many areas at a low cost, not everyone has access to one. Therefore, the use of chlorinators may be a guessing game which may give poor results. If water is insufficiently chlorinated, the bacteriological quality will not improve and people may lose faith in chlorine and stop using it altogether. After chlorinating water, make sure that there is a slight chlorine taste and odor in the water. If not, chances are that insufficient quantities of chlorine have been added. The taste of chlorine should not be too strong, however, or it may keep people from using the water.

When chlorine is used in large quantities, the cost of maintaining an effective chlorination system rises. In the long run, the cost of developing a potable well or spring and protecting it from contamination may be lower than depending on chorination.

Table 2. Materials List for Pot Chlorinator

Item	Description	Quantity	Estimated Cost
Labor	Members of household	____	____
Supplies	Earthen jar Gravel Chlorine bleach Clean sand Rope or wire	____ ____ ____ ____ ____	____ ____ ____ ____ ____
Tools	Hammer Wire cutters Pliers Knife	____ ____ ____ ____	____ ____ ____ ____

Total Estimated Cost =

Table 3. Materials List for Floating Bowl Chlorinator

Item	Description	Quantity	Estimated Cost
Labor	Foreman Workers	____ ____	____ ____
Supplies	200-liter steel drum Rubber or cork stopper 3 small tubes 6-9mm and 3mm Flexible hose String Wood or plastic bowl Drain plug Outlet connection Small stones Planks and other wood for platform Paint Latex or rubber base	____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
Tools	Hardware Saw Nails Drill Knife Buckets Paint brush	____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____

Total Estimated Cost = ____

Summary

Simple chlorination can be used to treat small community water supplies. The cost of a chlorination system is relatively low, if very large quantities of chlorine are not required. Simple pot chlorinators and solution feed systems are built with local materials and require little skilled labor. Chlorination systems are best used where water quality and chlorine levels can be tested periodically to ensure good water quality. Where testing is not possible, alternatives to chlorination should be sought.

Notes

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1982

Water for the World

Water Treatment in Emergencies
Technical Note No. RWS. 3.D.5

The treatment of water supplies in emergency situations is important to protect people's health. When natural disasters, drought, or social unrest cause a loss of supply of potable water or when, for any other reason, a water supply is disrupted or a supply change is necessary, measures should be taken quickly to provide for a safe water supply.

This technical note discusses the use of several methods for emergency water treatment. Many are similar to simple household purification methods which are described in "Designing Basic Household Water Treatment Systems," RWS.3.D.1. Community members should be instructed in the best methods to use to make water potable during emergencies. Read the entire technical note to evaluate the type of treatment most appropriate to local circumstances.

The design process for emergency water treatment should result in a list of materials needed to provide the appropriate disinfection of water during the time potable supplies are cut off. A sample list for a water boiler appears in Table 1. A list of sources of chlorine and their strengths is in Table 2.

Table 1. Sample Materials List for Boiler System

Item	Description	Quantity	Estimated Cost
Labor	Emergency workers Unskilled labor	____ ____	____ ____
Supplies	200-liter steel drum 20mm pipe nipple Valve Large funnel Cement blocks or bricks Filler plug Solder	____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____
Tools	Drill or punch	____	____

Total Estimated Cost = ____

Useful Definitions

CLARIFICATION - The process of removing suspended matter and other forms of turbidity from water.

CONTAMINANT - An impurity which makes water unfit for human consumption or domestic use.

DISINFECTION - Destruction of harmful microorganisms present in water through physical (such as boiling) or chemical (such as chlorination) means.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

When dealing with a disruption in the water supply, the major effort should to go toward getting the system back into operation as quickly as possible. Until operation can begin again, emergency treatment measures should be undertaken.

Usually a source of water that must be used in an emergency is contaminated. Therefore, the water should be disinfected before people drink it. Various methods are available for disinfection during emergenices. The choice of methods will depend on the resources available in each community or region.

Boiling

Boiling destroys all forms of disease organisms in water. It can be used whether water is clear or turbid and even if it contains a large amount of organic matter. For boiling to be effective, water must be brought to a rolling boil; that is, the water must be bubbling rapidly. Boiling water to disinfect it is a very good method of disinfection if fuel is available to heat the water. Individuals can boil

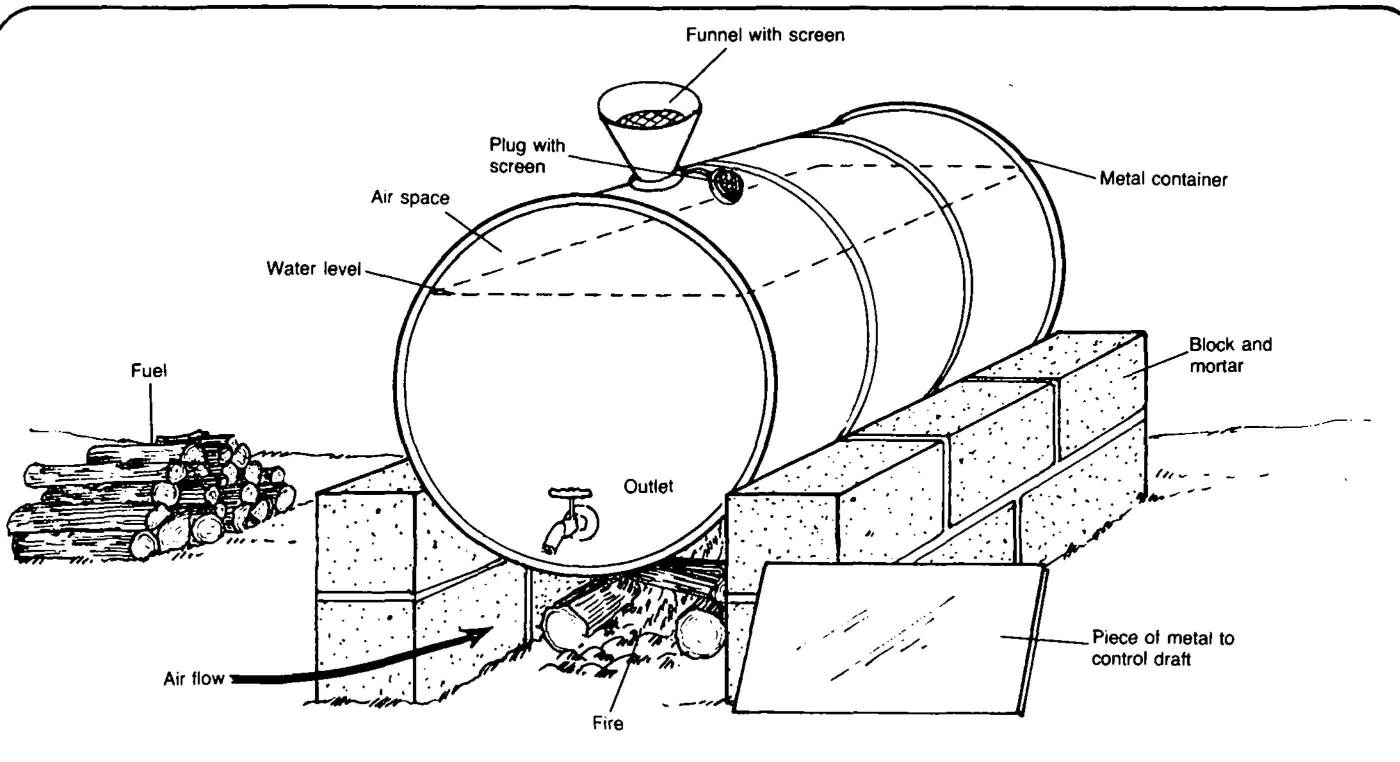

Figure 1. Boiler For Drinking Water

water in small containers. Water should be stored in the same container in which it is boiled to prevent any contamination that could occur from pouring water into a different container.

To boil a large quantity of water that can serve a large group of people, a boiler similar to that shown in Figure 1 can be built. For the boiler, build a simple brick or concrete block fireplace and position it so that the prevailing wind goes between the bricks from the front to the back of the tank. Then, place a 200-liter steel drum or another suitable tank over the fireplace. Laying the tank on its side, make a hole approximately 20mm in diameter on the top side close to the outlet edge as shown. This hole will serve as the inlet. Use a funnel with a small filter screen placed in the hole to fill the tank with water.

Place a valve on the front of the tank. Use a metal valve that can withstand the heat of the boiling water. A small plug should be placed in the inlet hole when the funnel is removed. The plug should fit loosely so that steam can escape during boiling.

The boiler system is good not only for boiling but also for storage. A large amount of fuel is needed, however, to boil the large quantities of water in the tank. Where fuel is abundant, this method is a very good form of disinfection for two or three days. Where fuel is in short supply, another method must be chosen.

Chemical Disinfection

Chlorination of water is one of the most widely accepted methods of chemically disinfecting water under emergency situations. Before chlorinating water from an emergency supply, water may need to be filtered. Chlorine is ineffective against organisms embedded in solid particles. Before turbid water is chlorinated, it should either be poured through a clean cloth or stored to permit the settling of particles. The clarified water can then be disinfected. In some cases, a small temporary dam can be built across a small stream. The reservoir formed can provide adequate settling. The reservoir will provide easy access to the water either manually or through installation of an intake and a pump. Whenever possible, choose an emergency source that is not subject to high levels of contamination. Water collected from an emergency source should be stored in clean containers after clarification. Small storage tanks, cisterns or barrels are appropriate for this. Chlorine is then added to the stored water.

Chlorine is available in liquid, powdered and tablet form. For emergency situations, especially when water is highly contaminated, use a dosage of about 50 parts per million (ppm), sometimes called 50 milligrams per liter (mg/l). To determine the amount of chlorine to add to a given quantity of water to make a 50ppm dosage use the following formula:

$$\text{Amount of chlorine} = \frac{\text{Dosage (ppm)} \times \text{Quantity of water}}{\text{Percent available chlorine}}$$

For example, the amount of chlorinated lime, 35 percent available chlorine, that must be added to 100 liters of water to provide a dosage of 50ppm is:

$$\text{Amount of chlorine} = \frac{50\text{ppm } (0.05) \times 100 \text{ liters}}{0.35}$$

Amount of chlorine = 14 grams

In this example, 14 grams of chlorinated lime must be added to 100 liters of water to make a 50ppm dosage. Dosage can be reduced for cleaner waters to avoid high residuals and strong taste and odors. Table 2 lists various types of chlorine and their percentage available chlorine.

After dosing, let the chlorine stay in the water for 30 minutes. After that time, a check for chlorine residual should be done if equipment is available. There should be a residual of approximately 1.0ppm. Where no testing equipment is available, make sure that the treated water has a slight chlorine odor and taste. If the test shows no chlorine residual, or if there is no chlorine taste or odor, repeat the dosage and wait 15 minutes.

Table 2. Chlorine Strengths

	Percent Available Chlorine
<u>Calcium Hypochlorites</u>	
High Test Hypochlorite	70%
Percloron Powder	70%
B-K Powder	50%
Chlorinated Lime	35%
<u>Sodium Hypochlorites (Liquid)</u>	
Chlorox	5%
Purex	3%
Zonite	1%

If the treated water has too strong a chlorine taste, allow it to stand for a few hours. Contact with the air offsets the taste and smell of the chlorine.

Chlorine is available in tablet form and can easily be applied to contaminated water. Chlorine tablets are available in many areas. To use them, follow the instructions on the package. If no instructions are listed, use one tablet for each liter of water to be treated.

Iodine is another chemical which can be used for disinfection in an emergency situation. Iodine is available in liquid form from pharmacies or small stores, and is used generally for first aid purposes. Most liquids contain two percent iodine. To disinfect clear water, add about five drops of iodine to each liter of water. When treating turbid water, add 10 drops per liter and allow the water to stand for 30 minutes. Reduce the dose if the iodine taste is strong.

Iodine tablets are made commercially and may be available in many areas. For water disinfection, follow the instructions on the packets. If instructions do not come with the iodine, a general rule to follow is to add one tablet to each liter of water.

Summary

Water which is used for drinking, cooking or brushing teeth should be properly disinfected to prevent sickness. Therefore, adequate planning is necessary to ensure that sufficient quantities of potable water are available for all who need it. The guidelines below should be followed when attempting to provide water for people in emergency situations.

1. Restrict the use of the available potable water to basic needs. People may have to bathe less often and ration the amount of water used for cooking and drinking. Never let supplies fall to a dangerously low level if possible.

2. Attempt to either put the old system into operation quickly or else search for a new source. If a new source is chosen, make sure that it is either well-protected from contamination or can be protected, and that water can effectively be delivered to those who need it.

3. If a protected source is not available, dig a temporary well or choose a source which is accessible and can be easily treated. Before choosing a source, make sure that there is a way to disinfect it. Water must either be boiled or chemically disinfected before it can be drunk.

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1982

Water for the World

Constructing a Household Sand Filter
Technical Note No. RWS. 3.C.1

A household sand filter can be used to treat water for individual households. There are two different designs for household sand filters. One design simply is used to filter turbidity from water and does not affect the bacteriological quality of the water. This type of filter is easier and cheaper to construct, operate and maintain. The other sand filter design not only removes turbidity but also removes some of the bacteria. However, further treatment may be necessary. The construction, operation and maintenance required for this filter type is more expensive and more difficult than for the first type mentioned.

This technical note describes the construction of both types of slow sand filters. Construction does not require any special skills.

Useful Definitions

INTAKE - The point where water enters a supply or treatment system.

TURBIDITY - Cloudiness in water caused by particles of suspended matter.

Before beginning construction, be sure that the people building the filter have the following:

1. Detailed plans of the sand filter to be constructed as shown in Figure 1.

2. A complete list of all materials that will be needed. A sample list appears in Table 1.

Table 1. Materials List for Household Sand Filter

Item	Description	Quantity	Estimated Cost
Labor	Household members	____	____
Supplies	Steel drum Sand (0.2-0.5mm diameter) Flexible pipe Gravel Pipe glue Nails Framing wood Sheet metal Blocks	____	____
Tools	Shovel Hammer Saw	____	____

Total Estimated Cost =

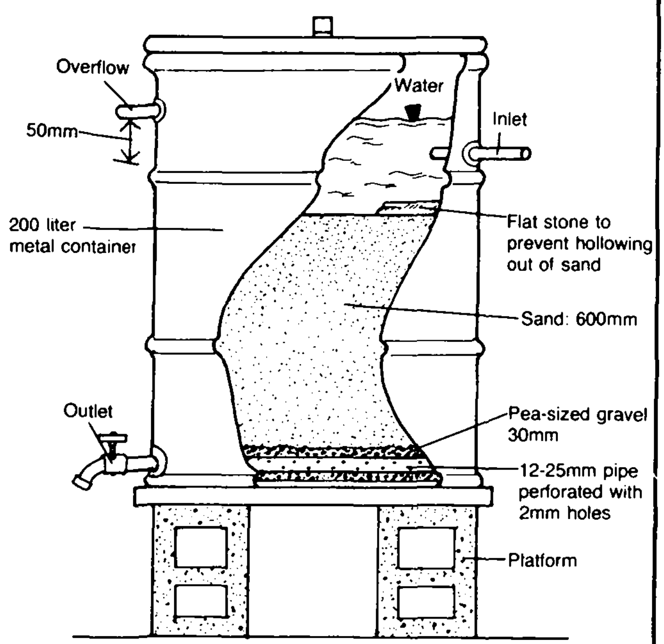

Figure 1. Household Sand Filter

Construction Steps

Follow these steps in building a household sand filter:

1. Prepare a steel barrel approximately 600mm in diameter and 750mm tall to be used for the filter. Remove the top cover and wash the barrel thoroughly and rinse with a one percent chlorine solution to disinfect it. See "Designing Basic Household Treatment Systems," RWS.3.D.1, for information on the preparation of chlorine solutions. Keep the chlorine rinse water in the barrel for at least 30 minutes to ensure proper disinfection.

2. At the bottom of the wall of the barrel drill or cut a 7-10mm hole. This hole will be the outlet for the filtered water. Do not make the hole larger than 7-10mm. Place a pipe joint and pipe in the hole so that water can flow either to storage or further treatment. Seal around the pipe and the barrel with pipe cement if plastic pipe is used. If steel pipe is used and soldering equipment is available, solder the pipe to the barrel. A good seal is needed to prevent leaks.

Another way to make an outlet is to place a perforated pipe in the gravel layer at the bottom of the barrel as shown in Figure 1. Use a small diameter pipe, 12-25mm, and make small holes in it. This method may prove easier because leakage around the pipe is less likely.

3. Line the bottom of the barrel with pea-sized gravel. The gravel layer should be about 30mm thick.

4. Fill the barrel with sand to within approximately 100mm from the top. Approximately $0.2m^3$ of sand is needed for a barrel 600mm in diameter. This will give a sand bed 600mm thick.

To determine the volume of sand needed for a layer of sand 600mm thick in a barrel 600mm in diameter, use the following formula:

Volume of sand = $.785\ (\text{diameter})^2 \times$ height

Volume of sand = $.785\ (0.6m^2) \times (0.6m)$

Volume of sand = $.785\ (.36m) \times (0.6m)$

Volume of sand = $0.2m^3$

Use fine sand for the filter. To size the sand, make a sieve using window screen and small pieces of wood as shown in Figure 2. The window screen is 16-mesh which has openings of 1.6mm. The sand that passes through the window screen will be less than 1.6mm in diameter and generally a satisfactory size. One problem is that all sand grains less than 1.6mm in diameter will pass through the sieve and an attempt to use the coarser sand should be made. If too much very fine sand is used, the filter system may clog quickly.

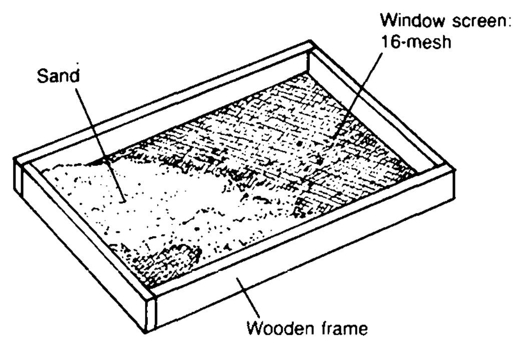

Figure 2. Sand Sieve

Grain sizes larger than 1.6mm should not be used because filtration may not be adequate in coarser sand. When choosing the sand to use in the household sand filter, only use sand that passes through the screen and from this sand, try not to use the finest grains.

To ensure effective operation, be sure that the sand is clean. Washing the sand before placing it in the filter drum is recommended. Wash the sand by placing it in a box and slowly pumping water in at the bottom. Continue this process, raking the sand to distribute it evenly, until water overflowing the box is clean.

5. If water is poured into the filter from a bucket, an overflow is not necessary. However, if water flows into the filter from an intake pipe, an overflow should be installed. For the overflow, make a 50mm hole near the top rim of the barrel and install a pipe. Locate the overflow approximately 50mm above the inlet.

6. Cover the filter. Provide a cover for the intake that adequately protects the filter. The cover should be easy to remove in order to clean the filter.

For the cover, use a piece of sheet metal nailed to a wooden frame. The frame should fit tightly over the barrel and have an overhang of about 20mm to prevent dust and rain from getting into the filter. Make the length and width of the cover frame 20mm greater than the outside diameter of the barrel. Hammer nails into the wooden form as shown in Figure 3 so that some air can circulate under the filter cover.

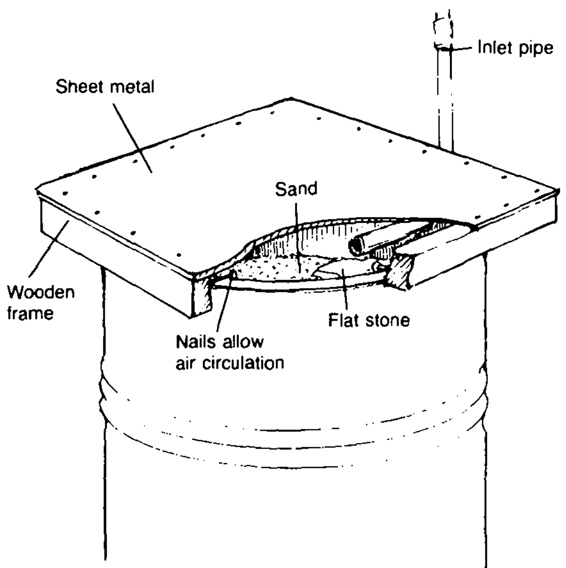

Figure 3. Cover for Sand Filter

7. When water is simply poured into the filter, no inlet other than removing the cover is necessary for filling the filter. However, if water is supplied from a cistern or other type of storage tank, an inlet can be provided. Place the inlet in either the cover or the side near the top of the barrel. Connect flexible pipe from the water source to the filter. Under the inlet pipe, place a small flat stone so that water hits it without disturbing the sand layer.

For easy access to the filtered water, place the sand filter on at least three blocks so that water can be easily collected from the outlet pipe. When constructing a household sand filter in which the sand will always be covered, a gravity flow system like the one in Figure 4 can be installed. Wooden or brick platforms can be constructed so that water flows from the pre-treatment storage to the filter and to the filtered water storage by gravity. This structure is more complicated and expensive to build and the sand layer must constantly be under water. If this system is used, taps should be installed on all outlet pipes so that water flow can be controlled.

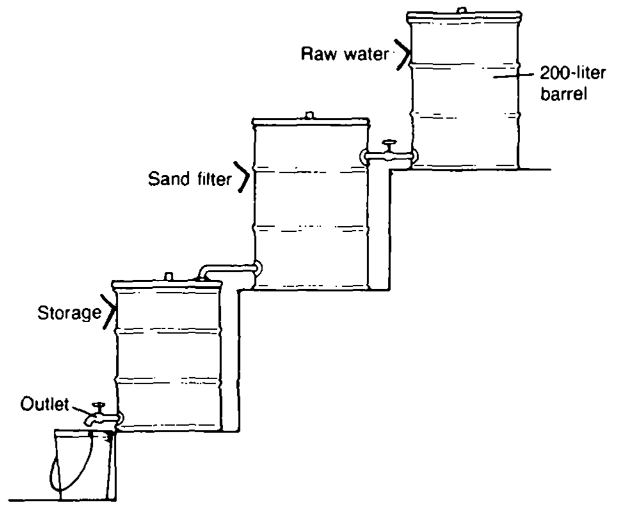

Figure 4. Gravity Flow Filter and Storage System

Caution!

If water is bacteriologically contaminated, further treatment may be necessary. The household sand filter removes bacteria if care is taken to keep the filter bed under water and if sand is fairly uniform in size. However, the sand filter may not remove all bacteria and the quality of the water should be determined before it is used. In some cases, water must be chlorinated after filtration to be of acceptable quality.

Summary

Household sand filters are a good way to remove turbidity and some bacteria from water. They can be constructed at a low cost and with locally available materials and labor. In fact, a household sand filter can be made wherever there is good sand available. Sand filters work very well if they are properly maintained.

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1982

Water for the World

Constructing a Sedimentation Basin
Technical Note No. RWS. 3.C.2

A sedimentation basin provides an effective way to remove turbidity from water before it reaches the users. In some cases, sedimentation basins are the only water treatment system through which water passes and the basin is used both for treatment and storage. Or, a sedimentation basin can provide pre-treatment of water before it enters a slow sand filter. The design and construction of a sedimentation basin should take into account its ultimate use.

This technical note discusses the steps to follow in constructing a plain sedimentation basin. Follow all steps carefully. Construction follows general rules for rectangular tank construction. Whenever possible, an engineer or someone skilled in masonry or reinforced concrete tank construction should be available to participate in the construction process. For smaller systems, 10m diameter circular tanks made from ferrocement can be constructed. For information on constructing tanks using ferrocement, see "Constructing a Ground Level Storage Tank," RWS.5.C.2.

Useful Definitions

CUT-OFF VALVE - Any valve (for example, a gate valve) which is used to shut off the flow of water from one point to another.

FERROCEMENT - An economical and simple-to-use type of reinforced concrete made of wire mesh, sand, water and cement.

MASONRY - Brick or stone work used in construction.

MASS CONCRETE - Concrete that is not reinforced.

WEIR - A barrier placed in moving water to either measure, stop or control flow.

Materials Needed

Before construction begins, the project designer should give you the following items:

1. A map of the area that includes the sedimentation basin, the water sources, other treatment systems planned, and the distribution system. Any major landmarks should also be included on the map. See Figure 1.

2. A list of all labor, materials and tools needed as shown in Table 1. Ensure that all needed materials are available and at the work site before construction begins. To avoid delays, make sure that adequate quantities of material are available.

3. A plan of the sedimentation basin with all dimensions as shown in Figure 2. The design drawing should either show a basin with sloping walls dug into the ground or a rectangular structure with vertical walls. Construction of both types of basins is described in this technical note.

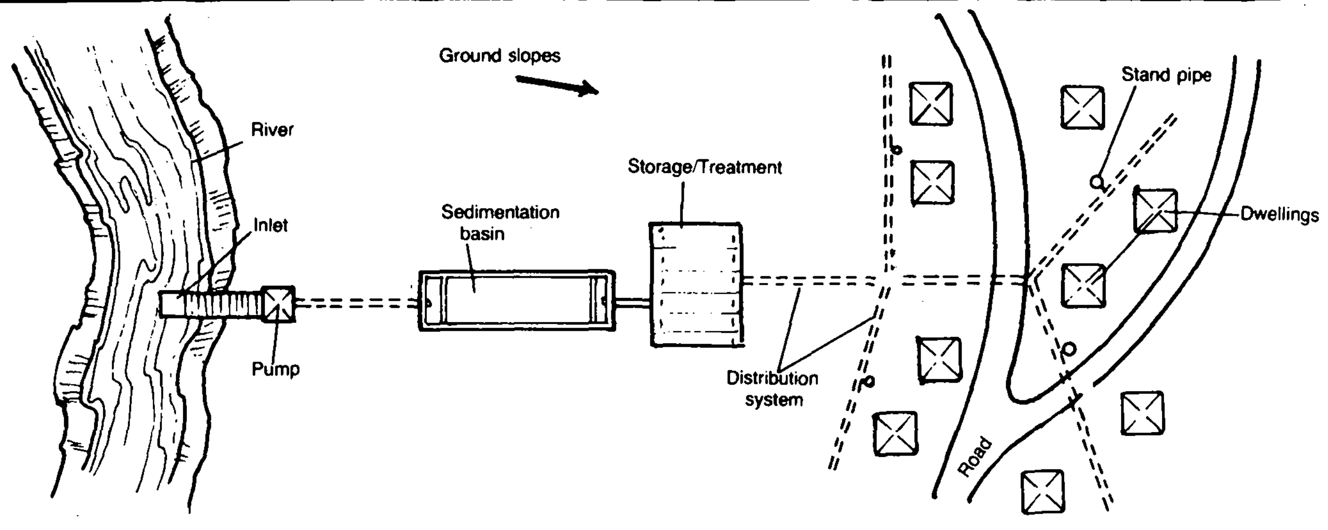

Figure 1. Location Map

Table 1. Sample Materials List for a Plain Sedimentation Basin

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Bricks Cement Clean sand Water Material for weir PVC pipe Rope Stakes	____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____
Tools	Digging tools *Trowels* Wheelbarrow Saw Mortar box Hammer Nails Plumb bob Measuring tape Buckets	____ ____ ____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____ ____ ____

Total Estimated Cost = ____

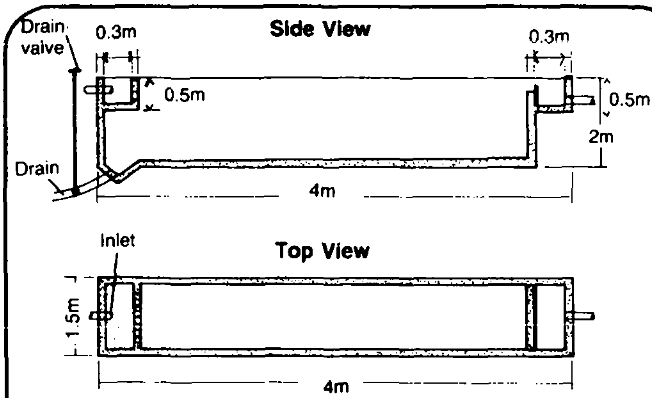

Figure 2. Sedimentation Basin

General Construction Steps

Follow the construction steps below. Refer to all diagrams and follow all directions carefully before attempting to build the sedimentation basin.

1. Locate the site designated for the sedimentation basin. Mark out the dimensions on the ground using a tape measure, string, stakes and a hand level with sighting slope on a pole, or a surveyor's level and a tripod. See Figure 3. If a sloping wall structure

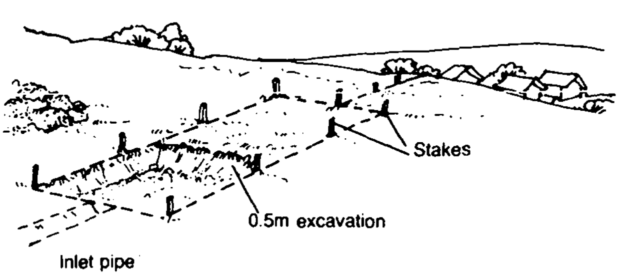

Figure 3. Stakes Marking Site of Sedimentation Basin

is to be built, the basin will be larger. Generally, walls should slope at a 1:2 ratio (1m slope for every 2m height). This slope increases the length of the basin so more ground area is needed for the structure.

2. After the area is completely marked, begin the excavation. If construction is for a vertical wall tank, excavation of the foundation is necessary. Dig down a minimum of 0.3m for the foundation. A deeper foundation will provide greater support for the walls because the outside soil pressure offsets the pressure from within the tank. When choosing a deep foundation, remember that the distance from ground level to the top of the tank should be at least 0.5m to prevent children, animals or debris from getting into the tank. A height of between 0.5-1.0m is best. For example, for a basin 2m in height, the height along ground level would be 1m and the foundation would be 1m deep.

After reaching the desired depth, level the floor of the tank for the foundation. After leveling, slope the bottom downward toward the inlet side at least three percent and not more than five percent to provide for drainage.

When excavating sloping wall structures, it is necessary to dig down to the entire depth of the structure, or 2m in the example. After digging down about 1m, begin to slope the walls. In this way cave-ins are prevented. After reaching floor depth, level the floor and provide a slope for drainage as described for vertical wall structures. Then use stakes and string to mark out the slope of the walls.

Foundations and Walls

For very large tanks, reinforced concrete foundations and walls should be used. The type and quantity of reinforcing rod depends on local conditions and availability of materials. Always consult an engineer before constructing a reinforced concrete tank. An engineer or skilled craftsman should always be on site to ensure proper construction. Foundations and walls for small- and medium-sized rectangular sedimentation basins can be constructed of mass concrete or masonry. When using these materials, construct a raft foundation as shown in Figure 4. This type of foundation is not difficult to construct and prevents loss of water through the joint between the wall and the foundation. When mass cement or masonry are used, the difference between the inside and outside pressures should not be very great. Therefore, the tanks should be built into the ground. For safety and strength, make the walls between 0.2-0.3m thick.

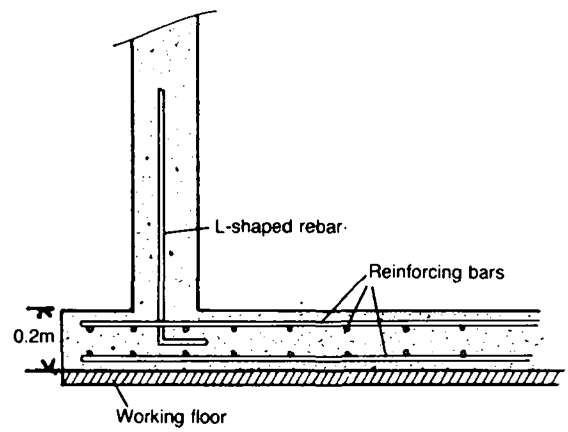

Figure 4. Raft Foundation for Vertical Walls

Prepare wooden forms for the foundation and walls. Walls should be about 0.25m in width. Oil the forms before pouring the cement. When setting the forms for the foundation, place 8mm steel rods near the bottom and top of the form as shown in Figure 5. The steel rods should be placed at least 200mm apart. The reinforcing bars should be placed in both directions to form a grid pattern and bars should be tied together where they cross.

When setting up the forms, be sure to prepare a place for sludge catchment and install a pipe for drainage. A 30-50mm pipe is appropriate for this purpose. Place the drainage pipe toward the inlet side of the basin. The catchment should be carved into the floor to a depth of about 0.2m.

Forms must be prepared for the inlet and outlet structures. Refer to Figure 6 for an indication of the type of forms needed.

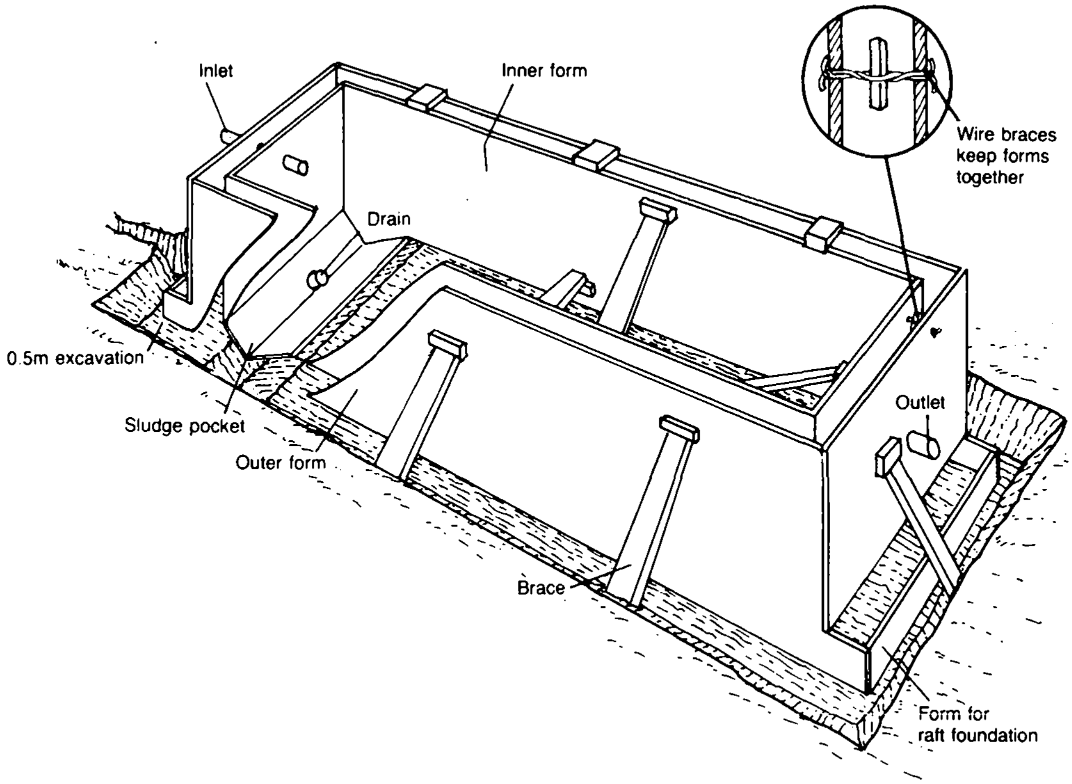

Figure 5. Forms for Vertical Walls

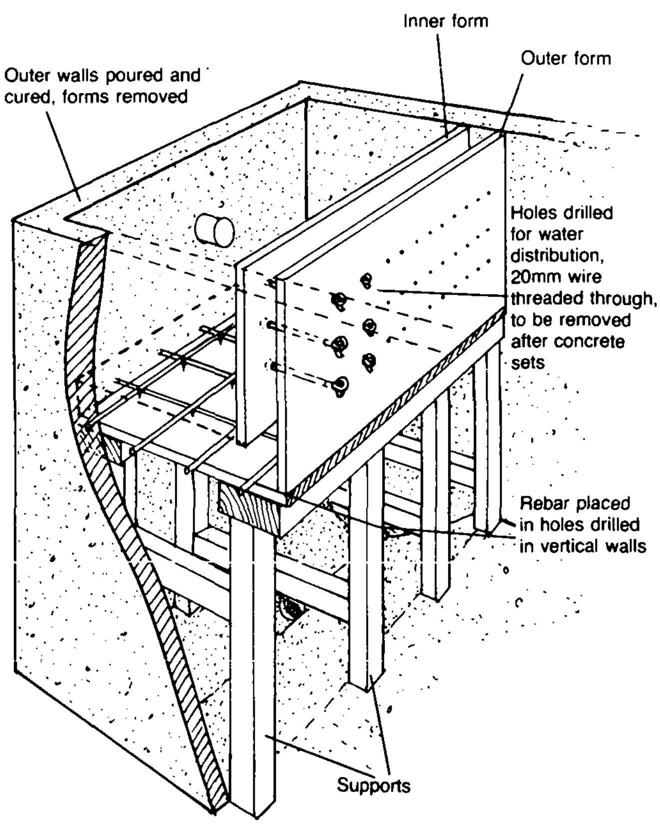

Figure 6. Forms for Inlet Section

Once the forms are set and the structure is completely level, mix the concrete in the following proportion: one part cement to two parts sand to three parts gravel (1:2:3). Try to mix as much concrete in each batch as possible, so that a large amount can be poured at one time. Use a hand or mechanical mixer if available. Once poured, allow the concrete to cure for at least 10 days to two weeks.

For brick sedimentation basins, use workers with good experience in laying brick. Special care must be taken to ensure that the structure is watertight. Masonry tanks, like concrete tanks, should have a foundation of concrete for added strength. To form a good foundation, dig a trench at least 0.6m wide and 0.3m deep. Level the bottom and pour a layer of concrete 0.2m thick. Then begin to lay the bricks for the walls. These walls should be at least 0.3m thick. When laying brick, be sure that vertical joints do not line up. Use a mixture of one part cement and three or four parts sand for the mortar.

When building the inlet and outlet walls, set up the wooden form work as shown in Figure 6. After the entire structure is complete, plaster the inside walls and the floor with two coats of mortar, each 10mm thick. Again, use a mixture of one part cement to three parts sand for the mix. Add just enough water to get a good paste.

A well-constructed intake is important for the efficient operation of the sedimentation basin because it provides for even water flow into the basin. Figure 7 shows an intake structure for a sedimentation basin. To build this type of structure follow these steps:

1. Prepare the forms for the inlet. The bottom of the inlet channel should be located approximately 0.5-0.7m below the top of the tank. The inlet should extend across the entire width of the tank and 0.5m from the end wall. Brace the forms well. Before pouring the concrete, drill an inlet hole and put the pipe in place. The pipe should be located halfway between the bottom of the inlet channel and the top of the tank. Place the overflow pipe at the top of the inlet.

2. Drill 45 holes, 20mm in diameter and 20mm apart, in the wooden forms as shown in Figure 7. Place wooden plugs in the holes. These plugs can be removed after the cement dries.

3. If bricks are used for building the inlet, simply leave bricks or half bricks out of the wall at even intervals so that water flows through evenly.

The outlet is also very important for regulating the water flow in the basin. The outlet structure has a weir and an outlet channel as shown in Figure 8.

1. Use the wall of the tank as the weir. To provide for even flow over the wall, either round the edges or bolt on a V-notched weir. The notches can be cut into a metal strip. Each is cut to form 90° angles and separated by a distance of 150mm. Install the V-notch by bolting it to the wall.

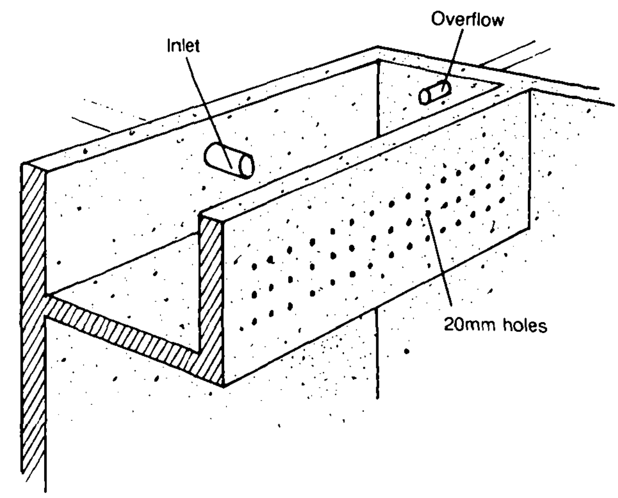

Figure 7. Inlet Structure

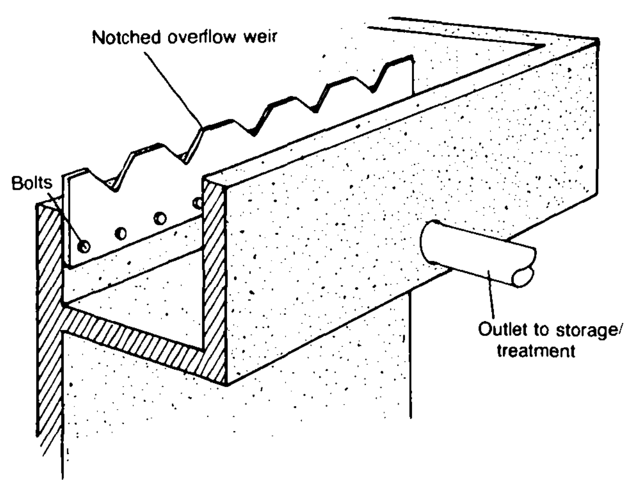

Figure 8. Outlet Structure

2. Prepare forms to build the outlet channel. The outlet channel should follow the same design and construction as the inlet channel. Instead of holes placed in the vertical wall, put the outlet pipe in place and seal around its edges with mortar to prevent leakage. Remember when building the forms to place a pipe in them so that an outlet hole is left in the walls. Connect the outlet pipe to a pipe that either goes to users or to further treatment. Generally, water should

pass to a slow sand filter after sedimentation. Place a cut-off valve between the sedimentation basin and the next part of the system to control water flow from the basin. Figure 9 shows a model of a completed sedimentation basin. It represents only one design. Other designs may be chosen as long as the basin provides for low turbulence and an overflow of water throughout the basin.

Summary

A sedimentation basin can be constructed locally. Various materials can be used in the construction process. For small to medium tanks, mass concrete or masonry is preferred. They require little skilled labor and materials are generally available. Reinforced concrete is used for larger tanks. The use of reinforced concrete requires more skilled laborers than are needed for either masonry or mass concrete basins. Further, the cost of materials is much higher.

Generally, after sedimentation water goes on to further treatment by slow sand filtration. For information on the design and construction of slow sand filters, see "Designing a Slow Sand Filter," RWS.3.D.3 and "Constructing a Slow Sand Filter," RWS.3.C.3.

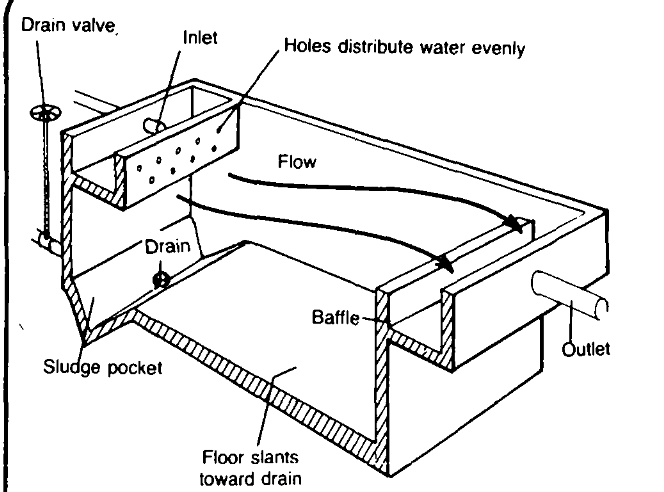

Figure 9. Completed Sedimentation Basin

Notes

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Constructing a Slow Sand Filter
Technical Note No. RWS. 3.C.3

A slow sand filter is a type of water treatment system suitable for use in small, rural communities. A well-designed, well-constructed slow sand filter removes sediment and pathogenic organisms from contaminated water in a single treatment process. Only when very turbid water is treated must another treatment step, for example, plain sedimentation, come before filtration.

Slow sand filters offer other advantages which make them attractive for water treatment in rural areas. They can be built with locally available materials and their construction does not require skilled labor. Most of the work can be done by local people. Operation and maintenance does not require the use of machinery. As long as many people are available to work, slow sand filters can be maintained manually by local workers.

This technical note describes the construction of small slow sand filters made from materials such as bricks, mass concrete and ferrocement. Larger filters, which should be made from reinforced concrete, are not discussed here because their construction requires skilled labor and because they should not be built without technical advice from an engineer.

Useful Definitions

BUTTERFLY VALVE - A valve used to accurately regulate the flow of water through a pipeline; a butterfly valve can be opened and closed slightly to regulate flow.

FERROCEMENT - An economical and simple-to-use type of reinforced concrete made of wire mesh, sand, water and cement.

SCHMUTZDECKE - A layer of biologically active microorganisms that forms on the top of a filter bed; the microorganisms break down organic matter and kill bacteria in water.

WEIR - A barrier placed in moving water to stop, control or measure water flow.

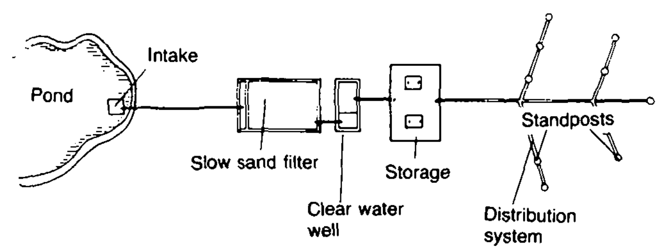

Figure 1. Location Map

Materials Needed

Before construction begins, the project designer should give you the following items:

1. A map of the site where the filter will be constructed similar to Figure 1. The map should include the location of the water source, other parts of the treatment system, and the water distribution system. It should indicate important landmarks, elevations and any other information relevant to the project.

2. A list if all labor, materials, and tools needed as shown in Table 1. Ensure that all needed materials are available and at the work site before work begins. Make sure that adequate quantities of materials are accessible to prevent construction delays.

3. A plan view of the filter with all dimensions. Figure 2 is an example of the type of plan necessary. The dimensions in Figure 2 are average dimensions for a filter with an area of 26m².

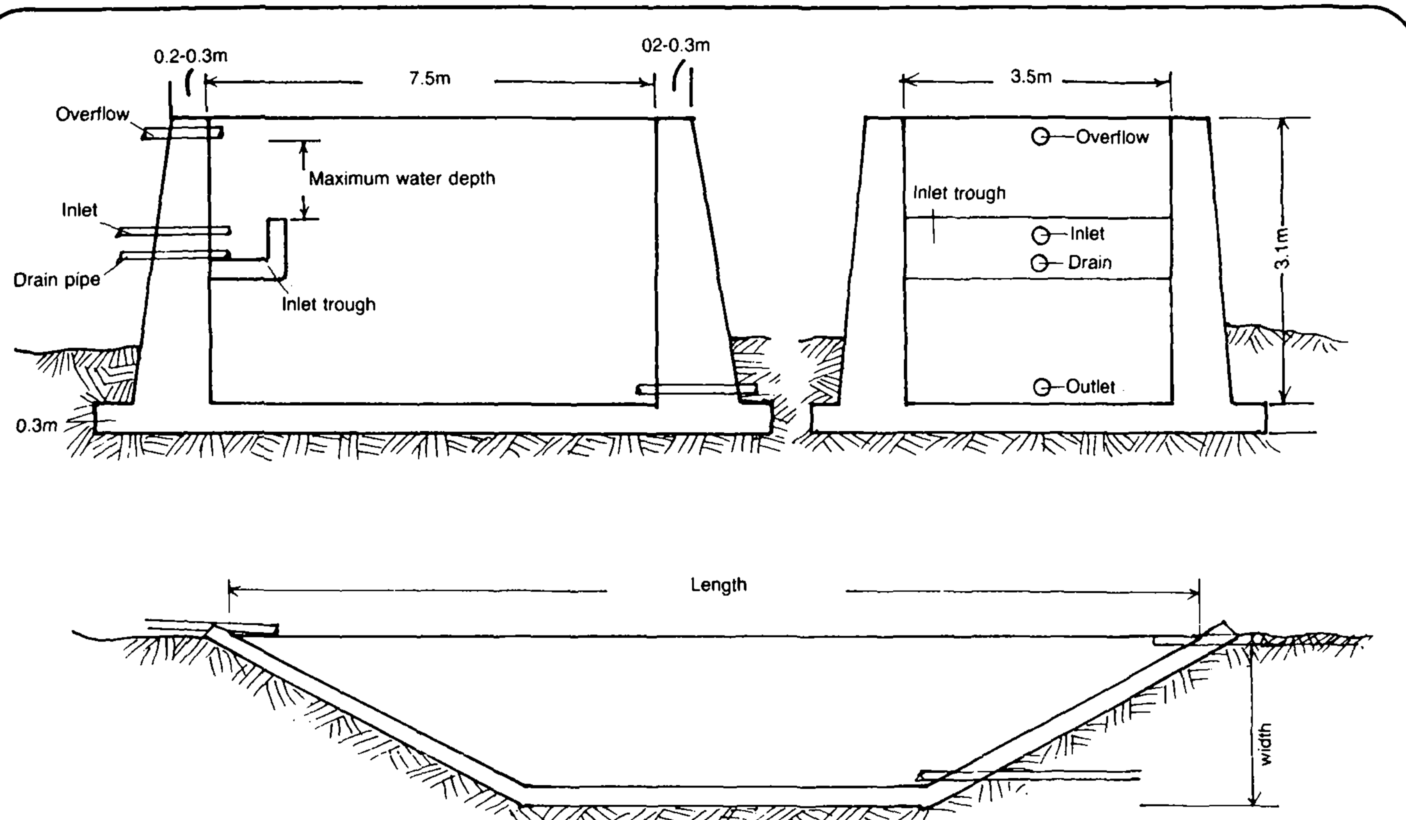

Figure 2. Design of Slow Sand Filter

General Construction Steps

Follow the construction steps below. Refer to the diagrams noted during the entire construction process.

1. Begin marking out the site of the filter with stakes and rope. Mark out the length and width of the filter and the trenches planned for the inlet and outlet pipes. The entire area should be staked as in Figure 3 before constuction begins.

Table 1. Materials List for Slow Sand Filters

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Bricks Cement Gravel, 60-100mm Sand, 0.15-0.35mm Gate valves Butterfly valve PVC pipes Wooden stakes Rope Pipe glue	____ ____ ____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____ ____ ____
Tools	Digging tools Small saw Sieve Hammers Nails Measuring tape Trowels Wheelbarrow Mortar box	____ ____ ____ ____ ____ ____ ____ ____ ____	____ ____ ____ ____ ____ ____ ____ ____ ____

Total Estimated Cost = ____

2. Dig out the base for the foundation. If a vertical wall structure is chosen, the foundation should be at least 0.3m deep. If conditions permit, dig the foundation deeper to provide more support for the walls. The foundation cannot be dug deep if the water table is high or if a subsurface rock layer is located near the ground surface. All parts of the system should

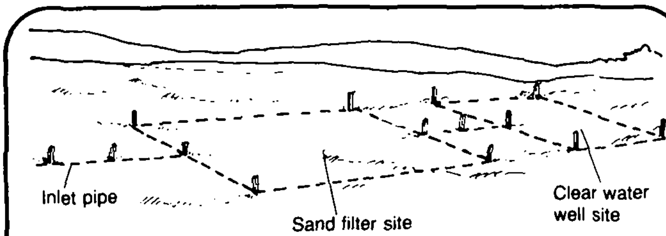

Figure 3. Staking Construction Site

be constructed carefully. Take care to provide for correct elevations so that gravity flow through the filter, valves and piping is maintained.

If a slope wall structure is chosen, excavation should continue down to the full depth of the filter. The walls should be sloped as digging occurs so that the sides do not cave in.

3. Ferrocement filters can be built either above or below ground. The filter base can be built below ground

for added structural support. After reaching the desired depth, level the floor of the excavated area. At this time, begin to excavate a trench for the filter outlet so that installation will be easier as work progresses. Do not make the trench too wide but leave sufficient room for one person to work comfortably. When completing the excavation, begin setting up the form work for the foundation and walls, 0.25m thick. If mass concrete is to be used, use wooden forms and oil them thoroughly before pouring any concrete. For ferrocement structures, the form work will be the wire itself.

When setting up the form work, be sure to leave a place for an inlet pipe and, if you are building a rectangular filter, a small trough for receiving the inflow. See Figure 4. The trough prevents disturbance of the filter bed and schmutzdecke, which can be caused by the jet of water from a pipe.

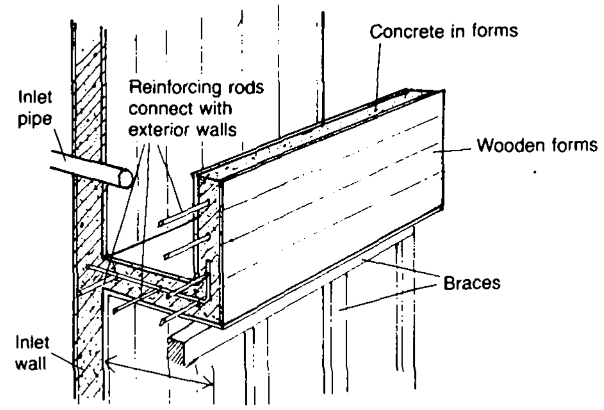

Figure 4. Inlet Trough

For rectangular filters, a concrete raft foundation like that in Figure 5 should be constructed. The raft foundation provides for equal settling of the filter box and prevents water loss through the joint between the wall and the foundation. When laying the foundation, use 8mm diameter reinforcing rods placed 200mm apart. The reinforcing bars should be placed in a grid pattern at the top and bottom of the floor as shown in Figure 5. For all concrete work, mix ingredients in the proportion of 1 part cement to 2 parts sand to 3 parts gravel.

After pouring the foundation, the rest of the filter structure can be built. For mass concrete filters, use the same mixture of ingredients used for the foundation. Fill in the forms completely and let the cement cure for at least 10 days. For increased strength, the concrete should cure at least two weeks. Keep the concrete moist during the curing process to prevent cracks and to allow it to gain full strength.

If bricks are used to build the walls, be sure to keep them vertical. A plumb bob should be used to check the walls after each two lines of bricks are laid. Make sure that vertical joints do not line up. After all bricks are laid, prepare a mixture of mortar using 1 part cement and 3 parts sand. Plaster the walls of the basin with the mortar to form a lining 300mm thick. For a circular ferrocement tank, use mesh to form walls 0.06-0.12m thick. To cover the wire mesh, prepare a mixture of cement using 1 part cement to 2 parts sand. Add water to form a paste-like consistancy, or add approximately 0.4 parts water by weight. Apply the mixture to the mesh with a trowel. Ferrocement should be kept moist during the seven days required for curing.

Sloping wall structures follow similar wall construction techniques. The walls should be excavated for a 1:2 slope and a lining should be applied to the walls. Lining thickness range from between 0.05-0.1m.

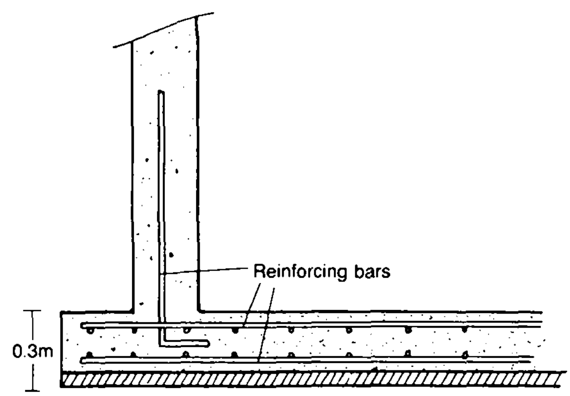

Figure 5. Raft Foundation for Filter Walls

Underdrainage System

Once the basic structure is completed, prepare the system of underdrains for the sand filter as shown in Figure 6. Several different types of materials can be used for the

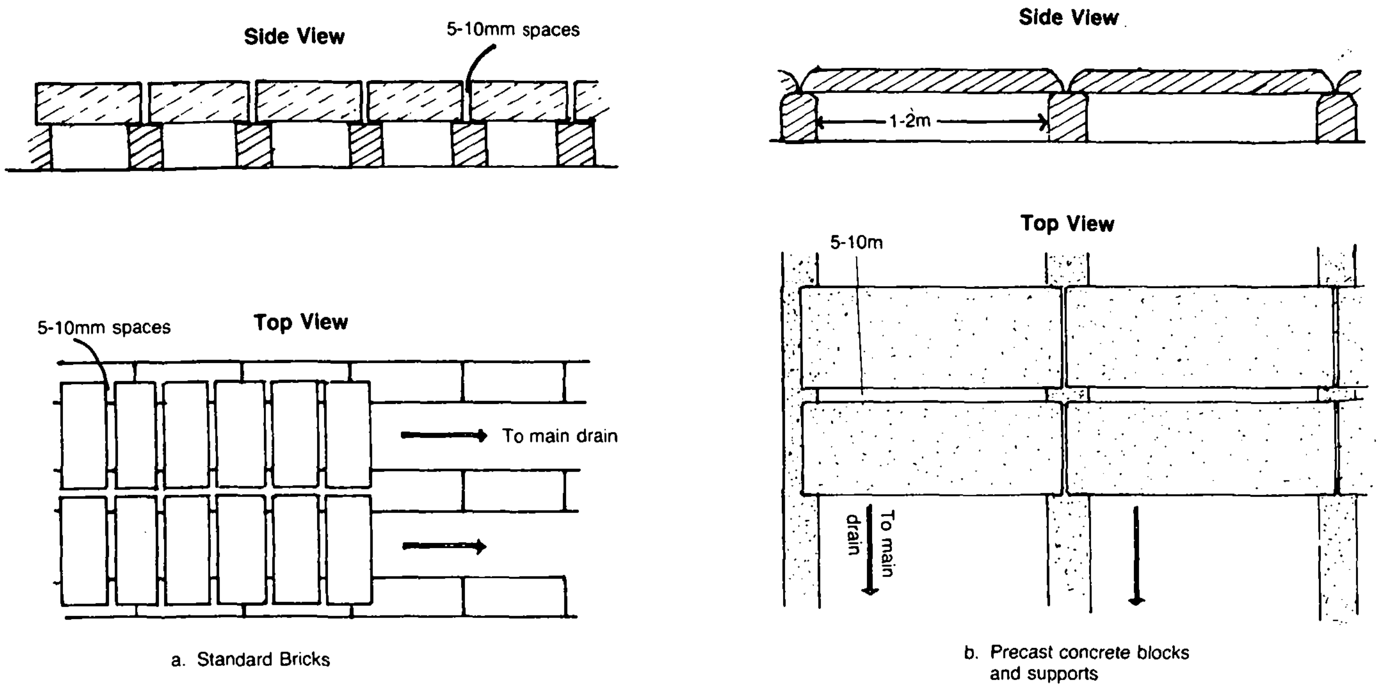

Figure 6. Underdrain System

lateral drains. Porous or perforated drainage tiles, open-joint tile and cement pipe, and perforated concrete or perforated PVC pipe are all acceptable materials. Pipes should have a diameter of 100mm. Bricks may be used for the construction of lateral drains. Drains made with brick should have a width of approximately 230mm.

In small filters and especially in ferrocement filters, perforated pipe can be used for the main drain. In larger filters, use concrete. One of the best methods is to build a concrete drain bedded into the floor of the filter bed.

When placing laterals, space them at 1-2m. The hole sizes in the laterals should be no greater than 2-4mm and have a space between them of 0.1-0.3mm. Figure 7 shows a drainage system using bricks for drains. The velocity of water through the lateral and main drain will be approximately 0.3m/second.

After the drainage system has been put in place put several layers of gravel over the drains. Use stones that are hard and as round as possible. Place a 120mm layer of coarse gravel sized 18-36mm over the top of the drain. Then place three 60mm layers of fine gravel on top of the bottom layer. Use 6-12mm gravel in the second layer, 2-4mm gravel in the third and 0.7-1.4mm gravel in the top layer. Once the gravel is in place, the underdrainage system is complete. Be sure that the drainage system is well-constructed. Once the gravel and sand layer is placed on top, it is difficult to reach the drains for repairs.

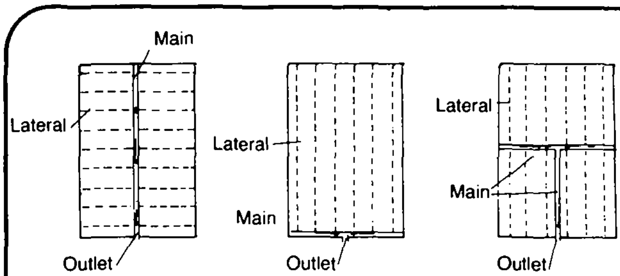

Figure 7. Common Arrangements for the Main Drain of a Slow Sand Filter

The Sand Bed

Construction of the sand bed is one of the most important parts of slow sand filter construction. Correctly sized sand should already be at the site when construction begins so all that should be necessary is to be sure the sand contains no clay, loam or organic matter.

In some cases, it may be necessary to wash the sand to ensure its quality. If so, place the sand to be washed in a box and let water flow through it from the bottom. Rake the sand to distribute it evenly and ensure that all of it is washed. Wash the sand until the water overflowing the box is clear.

Fill the filter box with sand. The depth of the filter bed should range between 1.0-1.4m so that frequent changing of the sand is unnecessary. When the filter bed is thick enough, level the sand.

Filter Control Systems

The filter control system regulates the flow of water into and out of the sand filter and allows effective operation and maintenance. Refer to Figure 8 when reading these directions. Put piping in place as walls are built.

- Install the inlet pipe A. Use a 50-100mm diameter pipe and attach a cut-off valve to it to control the flow of water into the tank.

- Install an overflow pipe B, approximately 1.25m above the filter bed surface. The height ensures that the water in the tank will be 1.2m deep.

- Place a drain pipe C at the bottom of the inlet trough so that the filter can be drained for cleaning. The drain pipe should have a tap that is protected from children.

- At the outlet end of the sedimentation basin, place an outlet pipe of equal diameter to the inlet. The filter outlet structure needs a cut-off or control valve, E. The best choice for a control valve is a butterfly valve as it permits a more precise regulation of flow through the filter. A gate valve can be used. These valves are important in controlling water flow in the filter, especially as resistance builds up in the filtration process.

- Install another valve at point D. This valve permits the drainage of all water in the sand layers before the water goes to storage. This valve is important for cleaning out the filter.

- Construct an overflow weir and clear water well. For small systems, the clear well may serve as storage for the completed system. In larger systems, a storage tank should be constructed. Build the clear well and weir from the same materials as the filter and follow similar construction steps. The tank should be at least 2.5m deep and hold 30-50 percent of daily water production. Ventilation, or preferably an access opening, should be provided as shown in Figure 8.

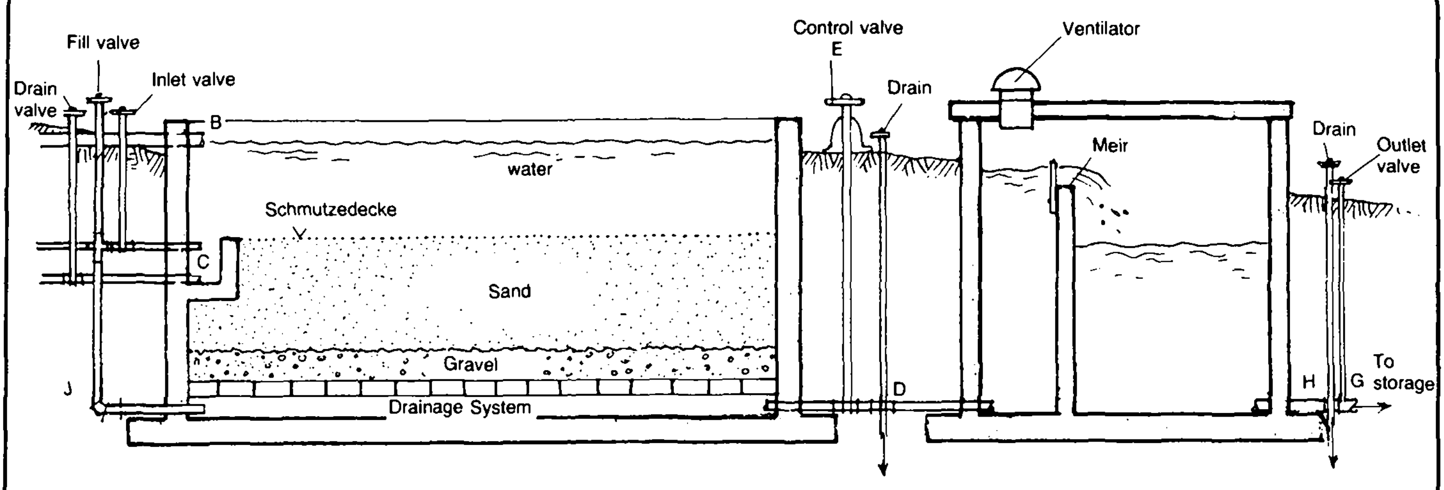

Figure 8. Slow Sand Filter with Valve System and Clear Water Well

The overflow weir should be constructed so that its crest is above the sand layer. This weir serves the purpose of maintaining a certain level of water in the filter and providing for aeration of the water.

Finally, three more valves should be installed in the filter system. Valve G is a cut-off valve which controls water flow from the clear water well to storage and distribution. Valve H allows raw water to run from the filter to waste. A valve for backfilling the filter should be installed at the base of the underdrain system as shown by J. This pipe is used to refill the filter after cleaning. By forcing water up from the bottom, air caught in the filter bed is forced out.

Ferrocement filters are usually of small capacity and they will generally not require as complicated a control system as the larger rectangular filter. General construction steps should be followed, however, for the filter bed, underdrain and outlet structure to storage.

Summary

Most small-to medium-sized slow sand filters can be constructed using local labor and materials as long as good supervision is available. Larger filters should only be built if an engineer or a person experienced with filter construction is available for technical support. A well-designed and well-constructed filter will provide good quality water if properly maintained. For information on the proper care and maintenance of a slow sand filter, see "Operating and Maintaining a Slow Sand Filter," RWS.3.O.3.

Notes

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Constructing a Disinfection Unit
Technical Note No. RWS. 3.C.4

Disinfection units can be constructed for both large and small water supply systems. For most disinfection purposes, chlorine compounds are used as the disinfecting agent. Chlorine is available in most countries and can be obtained in many regions at a relatively low price.

This technical note discusses the construction of simple chlorination units for small water supplies. Each unit can be built using local materials and local labor. Read the entire technical note before beginning construction.

Useful Definition

DISINFECTION - Destruction of harmful microorganisms present in water, through physical (such as boiling) or chemical (such as chlorination) means.

Materials Needed

Before beginning the construction process, the following items should be available:

1. A list of all materials and tools needed as shown in Table 1. All of these materials should be available when construction begins in order to avoid delays in the project.

2. A plan of the disinfection unit similar to Figures 1, 2 or 3 which show a pot chlorinator, a drip feed chlorinator, and a floating bowl chlorinator.

Follow the construction steps described below when building a disinfection unit. Refer to the appropriate diagram throughout the construction process.

Table 1. Materials List for Floating Bowl Chlorinator

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Workers	____	____
Supplies	200-liter steel drum	____	____
	Rubber or cork stopper	____	____
	3 small tubes 6-9mm and 3mm	____	____
	Flexible hose	____	____
	String	____	____
	Wood or plastic bowl	____	____
	Drain plug	____	____
	Outlet connection	____	____
	Small stones	____	____
	Planks and other wood for platform	____	____
	Paint	____	____
	Latex or rubber base	____	____
Tools	Hardware	____	____
	Saw	____	____
	Nails	____	____
	Drill	____	____
	Knife	____	____
	Buckets	____	____
	Paint brush	____	____

Total Estimated Cost = ____

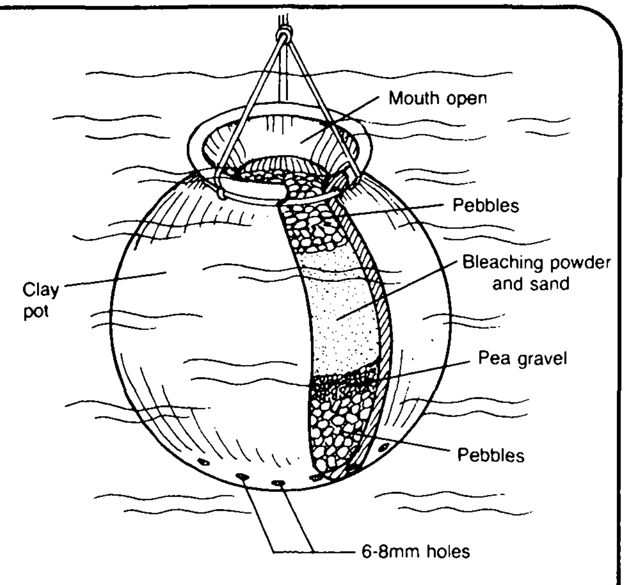

Figure 1. Pot Chlorinator

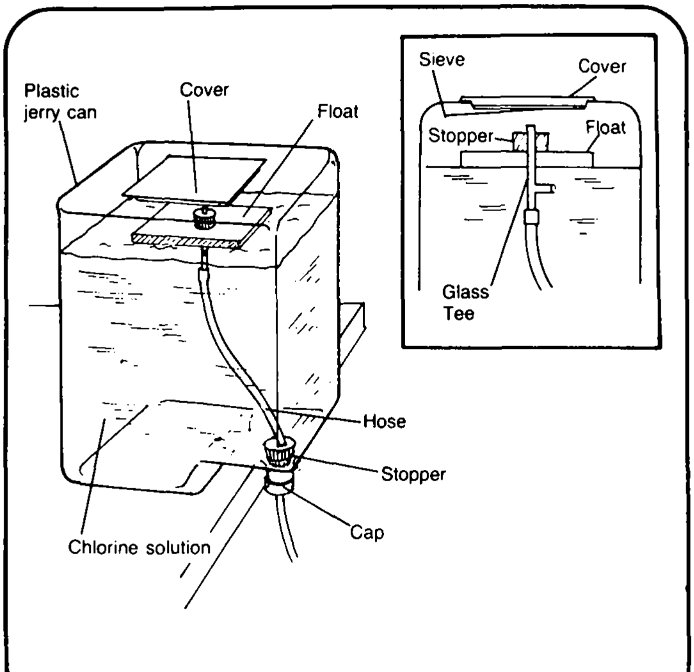

Figure 2. Chlorine Feeder

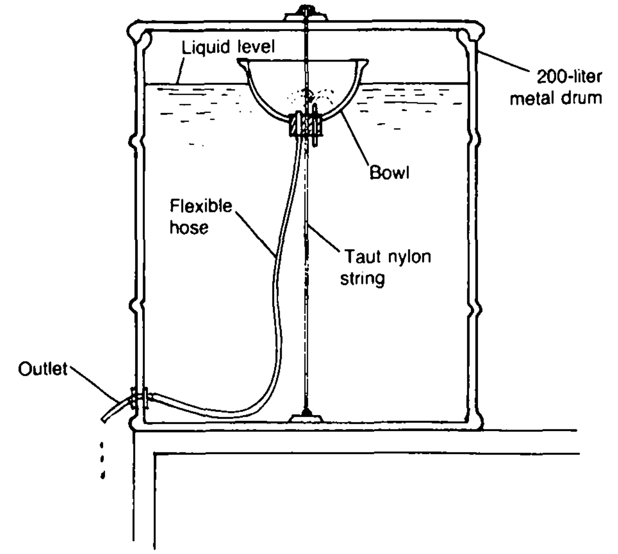

Figure 3. Floating Bowl Chlorinator

Pot Chlorinators

A pot chlorinator, shown in Figure 1, is effective for disinfecting water in shallow dug wells. To make one, follow the steps below and refer to Figure 1.

1. Use a ceramic, plastic or earthen jar or urn with a capacity of 7-10 liters. The jar does not need a cover.

2. With a sharp object, chisel or hand drill, make seven 6-8mm holes along the bottom of the jar.

3. Fill about half the jar with pebbles and pea gravel 20-40mm in size. The gravel should form a level layer in the pot. Then make a mixture of bleaching powder and sand. Add one part bleaching powder to two parts sand. Usually, 1.5kg of bleaching powder is sufficient for making a pot chlorinator.

4. Add the chlorine and sand mixture to the pot. Then use pebbles to fill the space between the layer of bleaching powder and sand and the neck of the jar.

5. Finally, attach wire or rope to the jar as shown so that the pot can be attached to a rope or hook and lowered into the well. Be sure that the pot is firmly secured to prevent it from being lost in the well.

Drip Chlorinators

A drip chlorinator can be used to disinfect water in wells, cisterns and other small reservoirs. To make a drip chlorinator, follow the steps listed below and refer to Figure 2.

1. Use a plastic can or bottle to make the drip chlorinator. The spout of the container will act as the outlet for the chlorine solution.

2. Cut open the bottom of the jar to provide a solution inlet and for access to the inside of the can.

3. Prepare the chlorine feed equipment that will fit in the plastic can. Use a piece of plastic, styrofoam, or wood for a float. In the center of the float, place a rubber stopper or cork and pass a piece of hard tubing through it. Glass, copper, brass or rigid

plastic tubing can be used. The tubing should be long enough to extend a little above the rubber stopper but below the float. In the part of the hard tubing below the float, make a small hole. This hole is the inlet for the chlorine solution which will fill the container. Use a tee, as shown in Figure 2, if one is available.

4. Attach a piece of small diameter rubber hose to the tubing. Connect the tubing below the inlet hole as shown.

5. Prepare the outlet for the drip chlorinator in the spout of the bottle. Make a hole in a plastic cap or the cover of the bottle spout so that the hose can pass through it. Pass the hose through a rubber stopper or cork that securely fits in the spout. Place the stopper in the neck of the container as shown, and put a cap or cover on the container spout.

6. Fill the plastic jar with chlorine bleach. Domestic chlorine beach contains 2-5 percent available chlorine. Fill the container until the float reaches the top. Then cover the top of the jar.

7. To control the flow, use a small clamp or make one from two pieces of aluminum and two aluminum nuts and bolts. Place the clamp around the hose and tighten it to cut off all flow during installation. Loosen the clamp to get the rate of flow desired.

8. Install the plastic can over the well or reservoir using wire. The wire can be attached to the well head or lip of the cistern and the container hung inside. The rubber outlet hose should reach into the water.

Floating Bowl Chlorinators

Floating bowl chlorinators hold a much larger volume of chlorine solution than the drip type used for disinfecting water in wells and small reservoirs. Floating bowl chlorinators are used to add chlorine at a constant rate to water in a tank or in a low pressure pipeline. Floating bowl chlorinators can be constructed with local materials and local labor. Refer to Figure 3 as you read the construction steps.

1. Prepare a 200-liter barrel for storing the chlorine solution. Remove the top cover and clean out the barrel by washing it with a one percent chlorine solution. Let the chlorine stand in the barrel for at least thirty minutes. Empty the barrel and, when it is dry, paint the inside with a latex or rubber base paint. This type of paint is not affected by chlorine.

Once the paint is dry, place a small outlet hole in the side of the barrel as shown in Figure 3. Make the hole 6mm in diameter. Make another hole approximately 10mm in diameter at the bottom of the barrel to serve as the tank's drainage.

2. To feed the chlorine into the water supply, make a floating bowl like that shown in Figures 4 or 5. Use a wooden or plastic bowl or cut the bottom out of a plastic bottle to form a bowl and use it as a float.

3. Using a stopper borer or hand drill, make a hole in the middle of the float to fit a medium-sized rubber or cork stopper. The rubber or cork stopper must be wedged into the opening to fit securely without leaking. Before placing the stopper in the opening, push three short tubes through

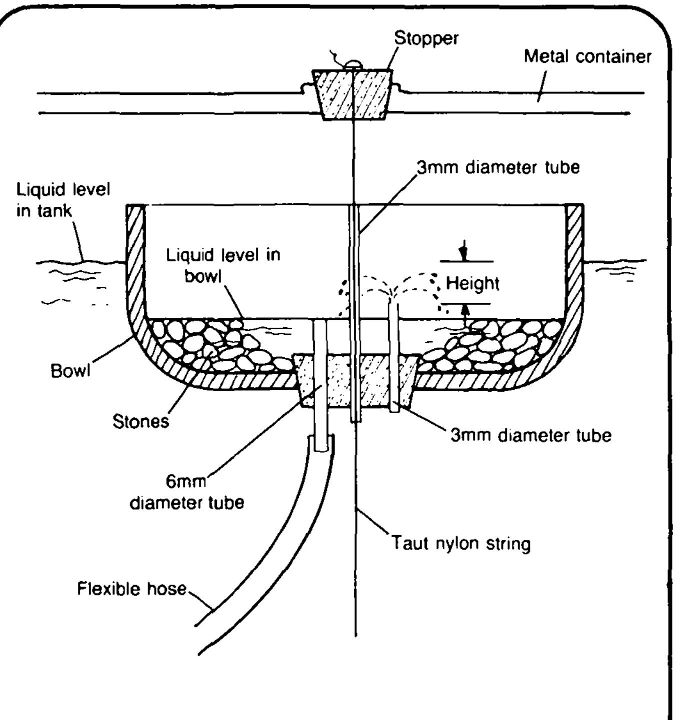

Figure 4. Floating Bowl Chlorinator

the stopper. Use glass, copper, brass or hard plastic tubing. Use two 3mm and one 6-9mm diameter tubes. One 3mm tube should go through the center of the stopper and the other two tubes should be placed to either side of the center. The tube through the center which will carry the guide string shown in Figure 4 should extend to the top of the bowl. The other 3mm tube should reach just below the liquid level in the tank. The 6-9mm diameter tube should reach no higher than the top of the stopper or the layer of small stones used for weights.

4. To install the floating bowl in the tank, first connect one end of the flexible rubber hose to the largest diameter tube. Connect the other end of the hose to a small drip outlet. The drip outlet can be made of plastic or a watertight joint. Or, flow can be controlled by placing a clamp over the flexible tube. Tightening the clamp will slow the flow; loosening it will increase the flow.

5. Secure one end of a nylon string to the bottom of the tank. Take the free end and thread it through the 3mm tube passing through the center of the stopper. Pull the string as tight as possible, and attach it to a wooden cross piece over the top of the barrel. Secure it well so it can be separated from the cover to refill the barrel without disconnecting the bowl. The string serves as a guide for the bowl so that it does not hit the sides of the tank. Figure 5 shows a bowl without a guide string. The chlorinator is easier to make without the guide string, but the bowl may drift to the sides of the barrel. If there are no ridges or plugs in the sides that could keep the bowl from moving downward as the chlorine solution is used, the chlorinator will work.

6. Fill the tank almost to the top with a one percent chlorine solution. To determine the amount of chlorine compound needed to prepare a one percent solution, use the following equation.

Amount of chlorine needed:

$$\frac{\text{Percent strength of solution desired} \times \text{Liters of solution required}}{\text{Percent available in compound}}$$

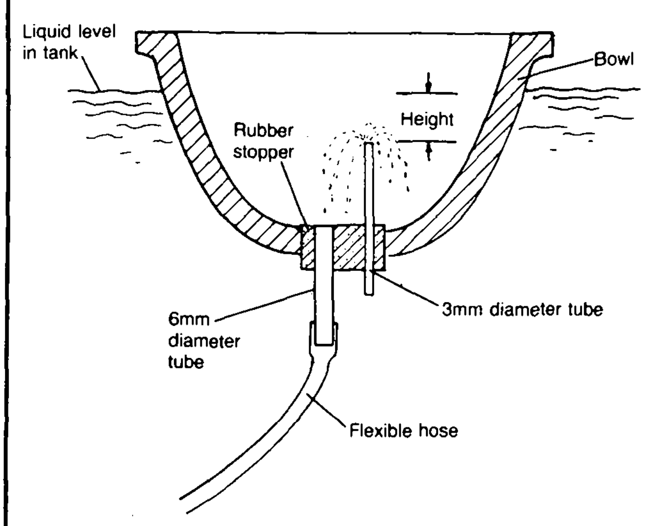

Figure 5. Floating Bowl Chorinator

To prepare 200 liters of a one percent solution using bleaching powder with 35 percent available chlorine, the amount of bleaching powder which should be used is:

$$Q \text{ chlorine} = \frac{1\% \times 200 \text{ liters}}{35\%}$$

$$Q \text{ chlorine} = \frac{.01 \times 200}{.35}$$

$$Q = 5.5\text{kg}.$$

Approximately 5.5kg of bleaching powder should be added to the water in the tank. Stir gently but well for at least five minutes.

7. To control the flow of the solution from the tank, one of three methods can be used. To reduce the flow, raise the tube that lets water into the bowl to the height near the water level in the tank. Lowering the tube increases the flow. The second method is to reduce the size of the opening to the bowl in the top of the inlet tube. A glass tube can be heated and drawn out. A brass or copper tube can be flattened out. Third, small stones or gravel can be placed in the bowl to increase flow. The stones act as weights and force larger amounts of water to flow into the bowl through the tube. Weights may be added or removed to control the rate of flow.

The tank should be checked often to be sure that the tank always contains chlorine solution. The water being treated should be tested periodically to ensure that there is adequate chlorine residual. A color comparator tester is needed to do this. The addition of a reacting agent called orthotolidine produces a yellow color which increases with chlorine content and indicates the amount of chlorine in the water.

Summary

Several simple methods are available for chlorinating small supplies of water. The pot chlorinator, the drip feed chlorinator and the floating bowl chlorinator can all be constructed using locally available supplies and labor. These methods are useful for chlorinating small water supplies but in order to be assured of their effectiveness, water should be tested after chlorination. Where water cannot be tested, make sure that the treated water has a slight chlorine taste and odor. Insufficient chlorination does not provide protection from disease-causing bacteria.

Notes

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1982

Water for the World

Operating and Maintaining Household Treatment Systems

Technical Note No. RWS. 3.O.1

The operation and maintenance of household treatment systems requires the attention of individual families. Proper operation and maintenance will ensure that adequate water treatment is performed and that storage containers are cleaned and protected against the entry of contaminants.

This technical note describes several measures to follow for effective operation and maintenance of household treatment systems. These measures will help maintain good water quality in the household when chlorination, boiling, storage or household sand filtration is used.

Chlorination

For effective chlorination to take place, sufficient stocks of chlorine should be available and correct chlorine dosages should be applied. The best way to ensure that an adequate amount of chlorine is available is to prepare a large quantity of one percent stock solution and store it in jars in a cool dark place for future use. To determine the amount of chlorine to add to a certain volume of water, use the following formula:

Kg of chlorine required =

$$\frac{\text{Percent strength of solution desired} \times \text{Liters of solution desired}}{\text{Percent available chlorine}}$$

For example, to prepare a 50-liter supply of one percent solution using bleaching powder with 35 percent available chlorine, the amount of powder which must be added to the 50 liters of water is:

$$\frac{.01 \times 50 \text{ liters}}{.35} = 1.4\text{kg.}$$

Thus, 1.4kg of bleaching powder should be added to 50 liters of water to make a one percent stock solution. Using this formula, both larger and smaller volumes of one percent solution may be made. As the stock solution becomes low, be sure that more chlorine is available.

Whenever possible, test the water to ensure that chlorination is adequate. Under most conditions, such testing will not be practical. Check with local health officials to see whether testing kits are available or whether someone from a regional or national center tests water in the area periodically. If testing is impossible, the dosage outlined in "Designing Basic Household Water Treatment Systems," RWS.3.D.1, should prove sufficient.

Boiling

To produce good quality water through boiling and ensure that it does not become contaminated, follow these steps:

- Always store the boiled water in the same container in which it is boiled. Changing containers increases the risk of re-contamination. The only exception to this is if a household has a ceramic filter. In that case, pour the water into the filter for storage.

- Use containers that have covers or can be covered adequately. Dust, dirt and other debris can easily get into uncovered containers. Children and animals are more likely to come into contact with water left in uncovered containers.

- If possible, attach a spigot to the container so that there is no need to dip cups or other utensils into the water. If a spigot cannot be attached, always pour the water from the storage container rather than dip utensils into it. Figure 1 shows a sample design for a tap that can help prevent re-contamination of stored water.

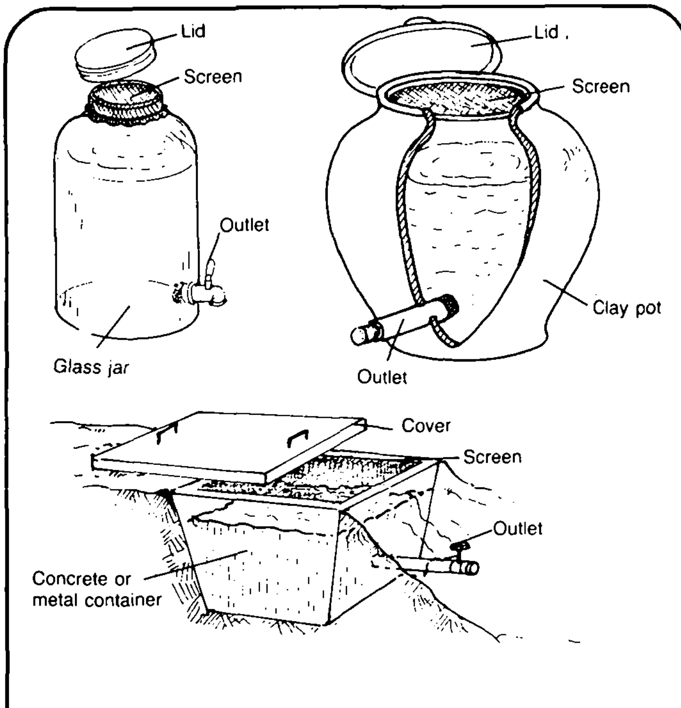

Figure 1. Methods of Storing Water

Storage

To ensure good water quality, clean storage containers after they are emptied each time. Remove the sediment from the bottom and sides of the containers. At least once a month, wash the containers with a chlorine solution. Keep the storage containers covered at all times. Never dip buckets or cups into them.

Household Sand Filter

Operation and maintenance requirements for a household sand filter depend on the type of filtration system constucted. Two designs are available: one that provides a continuous flow of water and keeps the sand layer submerged, and another which does not have a continuous flow of water and does not always keep the sand layer under water.

For filters that are designed for continuous flow, effective operation and maintenance should ensure that there is a continuous flow of water through the filter at all times. To ensure that this occurs, be sure to set up the intake so that there is always a small overflow from the filter. The small overflow indicates that the filter is full and the sand layer completely submerged.

For both continuous flow and non-continuous flow filters:

- Keep household sand filters covered so that it is completely dark inside the filter. Light may cause growths of green algae on the surface of the sand. Place the cover on the filter with a small space left so that some air may circulate. See Figure 2. Air circulation will help the growth of the biological layer on the sand in continuous flow filters.

- Clean the filter when water flow from it slows down greatly. To clean the sand, scrape off a layer approximately 5mm thick and throw it out. See

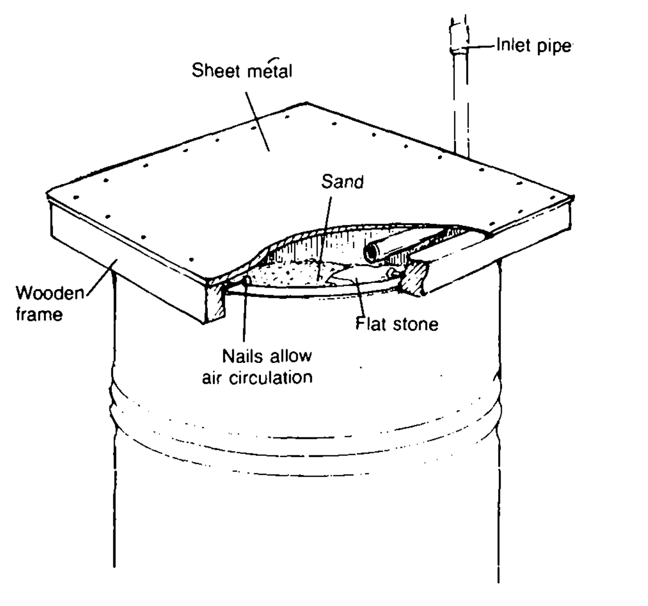

Figure 2. Cover for Sand Filter

Figure 3. Then rake or scratch the surface lightly. Cleaning should only take place once every several weeks so as not to disturb the biological layer on the surface of the sand. After four or five cleanings, clean sand should be added to bring the layer of sand back to its normal height. Before adding new sand, scrape the old sand clean. Then add either new sand or sand from the filter that has been thoroughly washed.

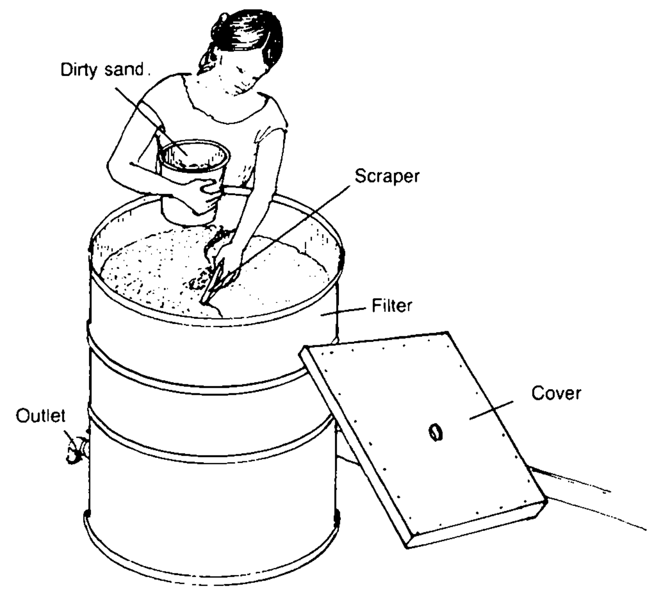

Figure 3. Scraping the Sand Filter

Notes

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Water for the World

Operating and Maintaining a Sedimentation Basin

Technical Note No. RWS. 3.O.2

Proper maintenance of sedimentation basins is necessary to ensure that they work efficiently and effectively. Unless properly cared for, sedimentation basins may not remove suspended matter from the water, causing filter systems or distribution systems to clog. This technical note discusses several measures that can be followed to ensure that the sedimentation basin works effectively and that clear water is provided for either the next treatment process or for storage.

Useful Definition

PEAK DEMAND - The greatest demand or need for water by the users; peak demands usually occur in the morning and late afternoon.

To maintain the sedimentation basin, the solids or sludge which settle to the bottom of the basin must be removed. The frequency of sludge removal depends on the quantities that collect on the bottom. This will usually be six to eight weeks. If the water is very turbid, sludge removal should take place more often. A thick sludge layer interferes with the sedimentation process by increasing the velocity of water in the tank. Furthermore, accumulations of sludge can decompose and cause tastes and odors.

To remove the sludge, the sedimentation basin must be taken out of operation.

• Cut off the flow of water into the sedimentation basin by closing the valve at the inlet to the basin. Before cutting off the water, be sure that the storage tank is filled so that people have access to water during the cleaning process. It is always a good policy to advise users of a shut-down in the water system so that they use less water. It is important to try to cut off the supply only during off-peak demand periods. This will usually be from mid-morning to mid-afternoon.

• Drain all water from the tank through the drain located at the bottom of the tank. Allow all water and sediment to flow out of the tank.

• With shovels, buckets, pusher boards and wheelbarrow, remove the sludge from the tank by pushing it out through the drain and carry it away from the site. Figure 1 shows workers removing the sludge from a basin. If a pump and hose are available, flush the sludge off the bottom. Sludge has a high water content and should flow easily from the tank. A board fasten to a pole is useful for scraping the bottom completely clean. Rinse the tank completely before restarting operation.

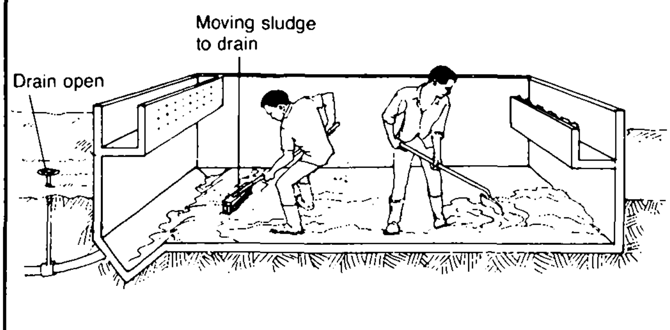

Figure 1. Cleaning Out Sedimentation Basin

• Remove the sludge as quickly as possible so that the basin is not out of operation for a long period of time. The water system should not be disrupted for more than one day. For small basins, this should not be a problem. The most time will be taken up refilling the tank.

In cases where water is low in turbidity, storage and sedimentation take place in the same tank and water is used directly. In these instances, water is generally not highly contaminated and tank cleaning is not necessary very often. When the tank must be cleaned, some provision for household storage or other storage should be made so that supplies to users is not completely cut off.

- Once all sediment is removed, close all drains and open the valve to refill the tank. Once cleaned, the system should return to operation as soon as the tank fills. This will be within four to six hours, depending on the volume of the tank.

Cleaning and repairing a sedimentation basin is easier if the tank is designed with two separate sections which can be used independently. This type of design allows for continuous flow of water into the distribution system since one section can be cleaned while the other operates normally.

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Water for the World

Operating and Maintaining Slow Sand Filters
Technical Note No. RWS. 3.0.3

A well-designed and well-constructed slow sand filter requires a simple but essential program of operation and maintenance. Operation and maintenance of slow sand filters can be done by local workers with little training. Neither expensive machinery nor highly skilled labor is needed. This technical note describes the basic steps in operating and maintaining small slow sand filters in rural areas. Follow the procedures included in this technical note to ensure that sand filters function properly and that good quality water is produced.

Useful Definitions

EFFLUENT - Settled sewage.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

SCHMUTZDECKE - A layer of biologically active microorganisms that forms on the top of a filter bed; the microorganisms break down organic matter and kill bacteria in water.

The procedures for operating and maintaining slow sand filters include: (a) initial start-up of the filter, (b) daily operation and control of water flow, (c) cleaning the filter and (d) replacing the sand. Each procedure is discussed in detail.

Filter Start-up and Operation

Once the filter is constructed, it must be put into operation. Preparation of the filter takes several weeks as the sand bed must be adequately prepared to act as a biological filter.

- Close all outlet valves in the filter system and add potable water to the filter from the bottom as shown in Figure 1. The water that enters from the bottom forces air bubbles out of the filter bed and ensures that all grains of sand are in contact with water. Continue adding water until the water level is approximately 0.1m above the sand bed.

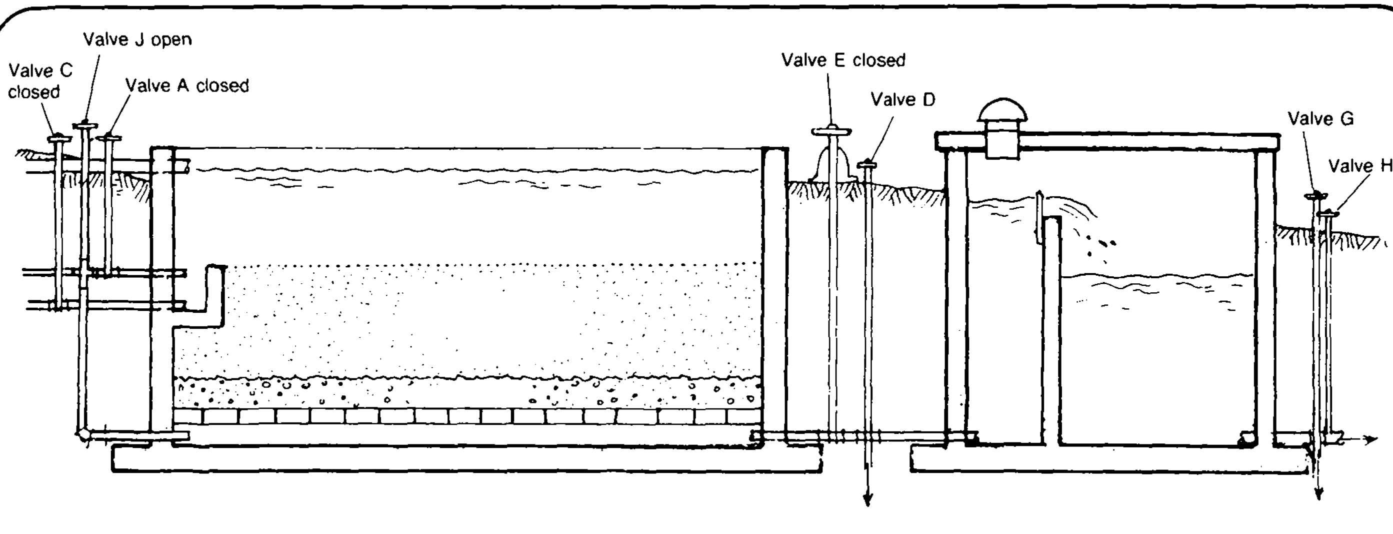

Figure 1. Filling the Slow Sand Filter

• When the water reaches 0.1m above the sand, begin to let water in through the raw water inlet. At first, let the water in very slowly so as not to disturb the sand layer. Once the water deepens, the rate of inlet flow can increase.

• When the water reaches the working level, open valve D as shown in Figure 2 and let the water run to waste at a rate of about one-quarter the normal filtration rate. Control the flow with the filter regulating valve. Run the filter for several weeks to allow the schmutzdecke to form on the sand. This is called the ripening process.

• During the ripening process, gradually increase the filtration rate until it reaches the design rate. Test the effluent water to see that the filter is working properly. Once the filter works, close the drain and open the valve that directs the water to the clear water tank.

• Regulate the flow of water in the filter using valve E. When the filter first begins operation, it will operate with the regulatory valve almost completely closed. As the filter bed becomes partially clogged, the valve is opened a little more each day to keep a constant head in the reservoir and a constant flow rate. Open the valve as needed. Once the valve is completely open and flow begins to decrease, the filter should be cleaned.

Cleaning the Filter

After several months of operation, a filter will need cleaning. For cleaning the filter, follow these steps:

• Close inlet valve A shown in Figure 2 to stop the flow of water to the filter. As the head in the water reservoir drops, the rate of filtration decreases. Let filtration continue for a few hours, usually overnight.

• In the morning, close the valve that controls the effluent flow to the clear water tank and open valve D, which lets the water flow to waste. Run the water to waste until the level of water in the filter bed is 0.1-0.2m below the surface of the filter bed.

• As soon as the top layer of the filter is exposed, begin removing it using flat-nosed shovels. Carefully remove the schmutzdecke and the surface sand sticking to it by stripping it off and piling it into heaps. Remove as little sand as possible, not more than 20 to 30mm. Remove the waste with wheelbarrows or large baskets or buckets. See Figure 3.

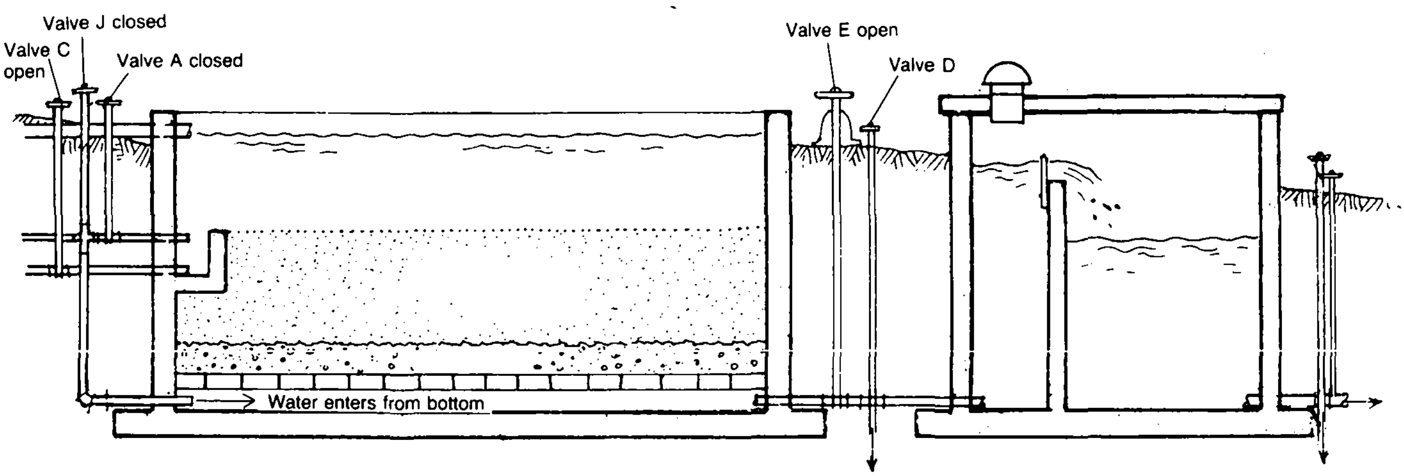

Figure 2. Draining the Filter for Cleaning

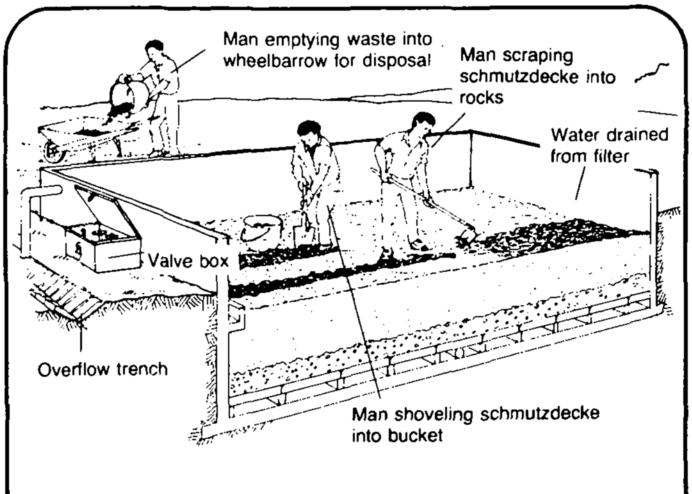

Figure 3. Cleaning the Schmutzdecke Layer

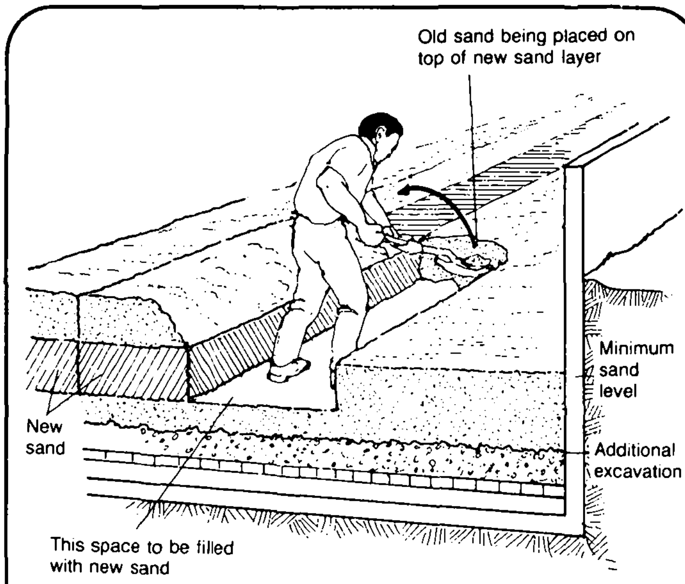

Figure 4. Turning the Filter Layer

• Clean the filter as quickly as possible to prevent deterioration of the bed. The quicker the bed is cleaned, the less bacteria in the lower layers will be disturbed. Re-opening the bed is therefore much quicker. Quick cleaning of the filter prevents damage caused by scavenging birds that may be attracted to the filter bed. These birds contaminate the surface of the bed and disturb the sand at a greater depth than is affected by scraping.

• After scraping and removing the schmutzdecke, level the sand in the filter.

• To restart the filter, follow the same steps as for start-up. The time required for both backfilling and re-ripening is much less than needed for initially putting the filter into operation. Backfilling requires only a few hours and re-ripening a few days.

Replacing the Sand

After 20-30 scrapings, or several years, the filter bed will reach its minimum thickness (0.5-0.8m above the gravel layer) and new or washed filter sand should be added to the filter bed. Sand is replaced through a process called "throwing over" and is done as follows:

• Dig a strip into the remaining sand layer as shown in Figure 4. Dig down a maximum of 0.3-0.5m being sure not to disturb the gravel layer.

• Place the excavated sand to the side and add new filter sand to the trench. Excavate a second strip next to the first. Throw the sand excavated from this second trench on top of the new sand in the first. Follow this process until the whole filter is refilled with new sand, and the upper 0.5m is made up of the old sand taken from the bottom. The last excavated strip is covered with the sand taken out from the excavation of the first strip.

• Once resanding is completed and the filter bed levelled, the re-ripening process can begin. Because a layer of sand containing some bacteria is placed at the top of the filter bed, the re-ripening process should not take as long as for a new filter.

Where sand is difficult to obtain or expensive, the sand taken from the filter can be washed and stored. The scrapings should be washed as soon as they are taken from the filter to prevent taste- and odor-producing substances that are impossible to remove later from developing. Care should be taken not to lose too many small sand particles during the washing.

The manual cleaning and other operation and maintenance work described in this technical note do not require special equipment or skills, especially when small filters are being used. For large filters, many workers are needed and the expense and time required are very demanding for rural communities. Mechanical cleaners are available but are too expensive and difficult to operate and maintain for small treatment systems.

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Water for the World

Operating and Maintaining a Chemical Disinfection Unit

Technical Note No. RWS. 3.O.4

When chlorine compounds are used for disinfecting drinking water, the systems that add chlorine to water must be well maintained to provide the correct dosage and prevent any disruption in the application of chlorine. This technical note discusses the operation and maintenance of simple disinfection units and describes a maintenance program to follow to ensure constant and adequate treatment of water.

Useful Definition

CHLORINE RESIDUAL - Amount of chlorine left over in water after the chlorine demand has been met; only then is disinfection certain.

For all chemical disinfection units--pot chlorinators, drip feed chlorinators and floating bowl chlorinators--the most important task is to make sure that sufficient chlorine is available in the water. For successful operation and maintenance, follow these steps:

- Check each chlorinator periodically. It is very easy to tell when drip and floating bowl chlorinators need additional chlorine. When the solution is low, refill the jar or barrel with a one or two percent chlorine solution. At first, it is more difficult to determine when to change the chlorine in pot chlorinators unless the water can be tested. The volume of water and its quality determines how long the chlorine will last. Generally, chlorine powder should be changed at least every week or ten days. Establish a regular schedule for refilling chlorinators.

- When removing a chlorinator to add additional solution or powder, be sure to check that all parts are in good repair. In drip feed and floating bowl chlorinators, carefully inspect hoses and tubes. Rubber can be damaged by chlorine. Hoses must periodically be changed due to reaction with chlorine.

- Check pipes and tubes for clogging and remove any deposits or sediment that may have built up at the tube openings.

- Determine whether the flow of chlorine solution from the feeders is correct. If not, adjust the tube that lets the solution into the bowl. Raising the tube reduces the flow, while the flow is increased by lowering the tube. See Figure 1. Flow can also be controlled by using a clamp on the rubber hose.

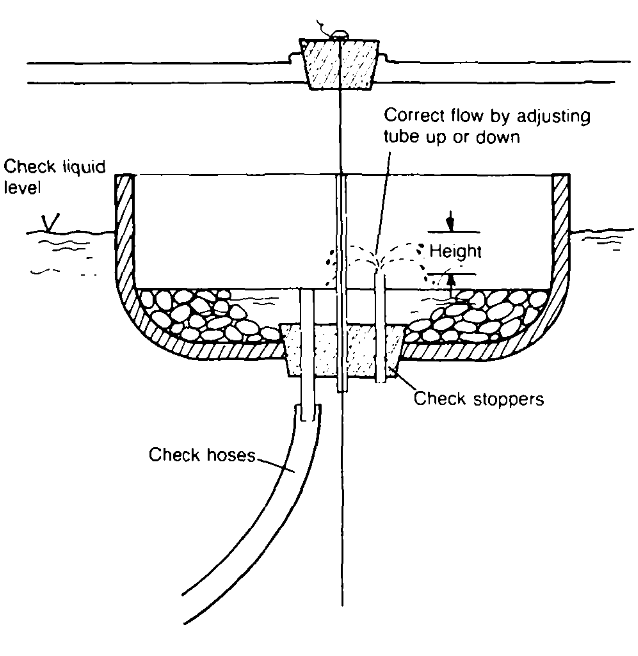

Figure 1. Maintaining Chlorinator

• Make sure that all supports for the chlorinator are strong. If chlorinators are hung by rope, be sure that the rope is not frayed. Change rope as necessary to prevent chlorinators from falling into wells.

• Store chlorine in a cool, dark place and be sure that all containers are well sealed. Improperly stored chlorine quickly loses its strength.

• Whenever possible, test the water before and after treatment to determine how much treatment is necessary and whether there is sufficient chlorine residual. Unless the water is tested, there is no real way to determine if treatment is adequate. Insufficient treatment is no more useful than no treatment at all. If testing is impossible, be sure that chlorine is always changed on schedule. Otherwise, there is no way of ensuring the quality of the water.

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Water for the World

Determining the Need for Water Treatment

Technical Note No. RWS. 3.P.1

A potable water supply is essential for the prevention of waterborne diseases. Water that is contaminated by disease-causing organisms or that is unacceptable aesthetically will need some kind of treatment before being used.

All water from natural sources has some impurities in it. Not all of these impurities are harmful to human health. Some are easily detected by sight, taste or smell. Others can be found only by scientific analysis. To determine if a water supply is potable or will need treatment, the bacteriological, physical and chemical characteristics of the water must be studied.

There are three basic methods of studying water supplies to determine their acceptability. One method is simple observation of a locality, looking for obvious signs of water contamination. Simple observation precedes a second method, the sanitary survey, which is an extensive field evaluation of actual and potential conditions affecting the acceptability of all available water sources. A third method is laboratory or field analysis of a water sample. This analysis measures selected bacteriological and chemical characteristics of the water. Each of these methods of studying water quality collects different kinds of data on a water source. It is best to use all three methods to compile complete information on the quality of a water supply.

A water supply should be treated only when the source cannot be protected from contamination, when there is no other better source available, and when complete operation and maintenance of the treatment system is possible.

Useful Definitions

ALGAE - Tiny green plants usually found floating in surface water.

BACTERIA - One-celled microorganisms which multiply by simple division and can be seen only through a microscope.

COLIFORMS - Bacteria found in the large intestine; a coliform count is often used as an indicator of fecal contamination in water supplies.

CONTAMINATION - Bacteria and physical or chemical concentrations in water that are hazardous to human health.

POTABLE WATER - Water that is both safe and acceptable for drinking.

TURBID WATER - Water that is clouded with suspended particles.

WATER-RELATED DISEASES - Diseases caused by a lack of safe water and poor sanitation.

WATERSHED - The ground area over which rainfall flows into bodies of surface water.

WATER TREATMENT - A process in which impurities such as dirt and harmful materials are removed from water.

Water Quality Problems

The World Health Organization (WHO) has issued standards that define acceptable water quality. The basic requirements for drinking water are that it should:

- be free from disease-causing organisms,

- contain no compounds that harm human health,
- have little turbidity, color, taste or odor, and
- not corrode or encrust piped water supply systems or stain clothing washed in it.

The most important type of contamination to look for and treat is bacteriological contamination which causes many kinds of infectious diseases. Bacteriological contamination is usually caused by fecal organisms from human and animal wastes. Fecal organisms are members of the coliform bacteria group. Not all coliform bacteria cause diseases, but their presence in a water sample indicates that fecal contamination is present. Water that is free of coliform bacteria is free of disease-causing bacteria. A bacteriological water analysis will estimate the coliform level in a water supply. (See "Analyzing a Water Sample," RWS.3.P.3.) A higher standard of quality is expected of sophisticated water systems than of smaller, simpler ones but if coliform bacteria are detected in any kind of water system, a sanitary survey must be conducted to determine their source if it is not known. The source of contamination should be eliminated and the water should be treated to destroy the coliform bacteria already present.

Physical and chemical contaminants are not usually as serious a health hazard as bacteriological contamination. However, physical and chemical impurities often make a water supply so unacceptable aesthetically that people use a non-offensive, but contaminated, supply instead. Physical and chemical impurities can be removed but the treatment processes are usually inappropriate for rural areas because of their cost and complexity.

Improvement of rural water supplies must emphasize elimination of bacteriological contamination. Care must be taken to ensure that water and sanitation facilities and operational procedures do not introduce contaminants to a water supply that is free of disease-causing organisms and is aesthetically acceptable. Water supplies and systems that do not meet these standards should be improved or treated or another source should be developed.

The quality of a water source should be examined when a water supply system is first being developed and periodically after it has been put into use. The quality should be checked when any change occurs that might affect the watershed, such as construction work or use of new farming techniques; when an outbreak of disease occurs in the area of the water supply; when the physical characteristics of the water change; and during all seasonal variations. Records of all examinations should be carefully kept.

Simple Observation of Water Quality

Quality of an existing water source can often be judged by observing the source and local habits of water use. Unprotected water sources such as open wells and ditches, very turbid water, animals or people wading in a supply, people bathing or washing clothes in a supply, and direct waste disposal into a supply are strong signs of bacteriological contamination. Heavily populated areas are more likely to be subject to fecal contamination from these conditions than sparsely populated areas.

Physical characteristics of the water may indicate other contamination. High turbidity may be caused by decomposing organic matter. This may indicate the presence of acids and carbon dioxide which can both damage metal water pipes. Algae growing in a water supply may indicate the presence of sewage and cause bad tastes and odors. Algae may also indicate large amounts of nitrate which can cause blood problems in infants. Rust colored or black water indicates high iron and manganese content. This could leave deposits on pipes and cooking utensils.

If any of these conditions are obvious, a sanitary survey needs to be conducted to determine the source of the contamination. It should be followed by analysis of a water sample if possible.

Sanitary Survey

A sanitary survey is an extensive field inspection and evaluation of local environmental and health conditions. It is an important method of examining a water supply's quality because it assesses current and potential hazards to the water supply or the existing water system, or both. Sanitary surveys are especially important when outbreaks of water-related diseases occur in the area and when changes such as repair work or construction affecting the water system take place. Conducting a sanitary survey requires technical knowledge and good judgment.

Sanitary surveys are equally important as backup inspection when interpreting the results of a laboratory or field analysis of a water sample. If analysis indicates contamination of the water supply, a sanitary survey should be conducted to identify the source of the contamination. A sanitary survey may also indicate that a supply used regularly without incidence of disease should not be condemned when analysis of a single sample shows contamination.

Sanitary surveys should be undertaken when new surface water sources are being developed. See "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2 and "Selecting a Well Site," RWS.2.P.3. In addition, sanitary surveys should be conducted to inspect existing water supply systems. "Simple observation" is the first part of all sanitary surveys. Closer inspection of existing water supply systems involves checking facilities and operational practices for signs of contamination. For example, water from a well should be considered contaminated if the well is uncovered or unprotected. Water drawn from a well should be considered contaminated when the collection vessel is not kept clean, or is in contact with possible ground contaminants. Water stored in uncovered tanks or other containers is subject to contamination from birds, animals and humans. Water stored in tanks with cracked walls or with poorly constructed, broken or loose covers is subject to contamination from leakage, especially during the rainy season. Leaky pipes may draw in sewage or other contamination from the soil. If pipes have been packed or repaired with jute, hemp, cotton or leather, they may provide a wet breeding material for bacteria that will contaminate the water supply.

If a sanitary survey reveals possible bacteriological contamination, the water should be treated until the system can be improved, repaired or replaced. When possible, an analysis of the water should be done to measure the level of contamination and determine the treatment needed.

Sanitary surveys of existing systems can reveal physical and chemical impurities. Water that is turbid may not be safe or aesthetically acceptable. If pipelines, pumps or other system components are corroded, the water supply may be chemically contaminated. Hard, scaly deposits on pipes or pumps indicate water with high mineral content which may be unsuitable for many domestic purposes. Minerals can encrust pipes and pots. If red stains appear on plumbing the water may be high in iron. If the community believes a water source is harmful even though contamination is not evident, the water should be tested for harmful toxic chemicals.

If a sanitary survey reveals possible physical or chemical contamination, a complete laboratory analysis should be done to verify conditions. If analysis reveals that the water system is seriously contaminated either physically or chemically, the problem should be solved immediately or another water source should be developed. Treatment of physical and chemical impurities is complex and often inappropriate for rural communities.

Analysis of Water Sample

An analysis is a laboratory or specific field examination of a sample of water. A sanitary survey identifies probable <u>sources</u> of contamination of a supply. An analysis determines the <u>type</u> and <u>level</u> of contamination present in a sample of the supply. A water analysis can verify a sanitary survey's conclusions and is an important aid in choosing a method of water treatment.

Water analysis is not a replacement for a sanitary survey. Contamination is often intermittent in a water supply and is not always revealed by analysis of a sample. A sample provides information only on conditions of the supply at the time of the sampling and cannot identify potential contamination like a sanitary survey can. For example, a bacteriological analysis of two sources may indicate that both are of the same quality at a given time. A sanitary survey considers potential environmental changes in both supplies which may indicate that one source is safer than another in the long run and is a better choice for a water supply. When an analysis is done it needs to be very carefully interpreted in conjunction with results of the sanitary survey so that a relatively good water source is not abandoned.

A bacteriological analysis examines a water sample for coliform bacteria indicating fecal contamination. Analysis of almost any rural water supply will show some amount of coliform bacteria. It is the level of bacteria that is important in determining the need for water treatment. See "Analyzing a Water Sample," RWS.3.P.3, for details on determining the need for water treatment from bacteriological analysis. Simple field kits for bacteriological analysis of a water sample are available at considerable cost.

A physical and chemical analysis of a water sample would include tests for turbidity, color, taste and odor, followed by tests for elements which may harm a water system, for hardness and for excess minerals. A chemical analysis of a water supply cannot be done with a simple field kit, although some complex field kits are available at a high price. Chemical analysis is best done in a well-equipped laboratory which is rarely available in rural areas. For information on analyzing a water sample for its physical and chemical content, consult an expert.

Water samples should be drawn and analyzed whenever a new source is being developed and periodically after a system has been put into use. See "Taking a Water Sample," RWS.3.P.2, for details on collecting samples for analysis. Water that is already treated should be analyzed routinely to make sure the treatment is effective. Refer to technical notes on the operation and maintenance of specific treatment methods for information on analyzing treated water.

Summary

To determine whether a water supply needs treatment to make it safe for drinking, the supply should be carefully studied. This is done by simple observation of water used in a community, by a sanitary survey of the area and by scientific analysis of a water sample. The WHO standards for drinking water summarized at the beginning of this technical note should be used as quality criteria in observation and sanitary surveys. Standards for levels of bacteriological contamination are explained in "Analyzing a Water Sample," RWS.3.P.3.

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Water for the World

Methods of Delivering Water
Technical Note No. RWS. 4.M

Once a water source has been identified and developed, some means of delivering the water to the users must be found. This is usually called a distribution system or a delivery system. Several factors must be taken into account in deciding on a method of delivering water. These include the desired use of the water, such as drinking, cooking, washing, livestock, gardens and religious and commercial needs, and resources in the community to construct, operate and maintain a distribution or water delivery system.

Individual water systems, communal watering points, or community water distribution systems may be used. The closer to individual homes that water is supplied, the less the chance of contamination and the more water will be used for such purposes as hand-washing and bathing. Water should be provided as close to individual homes as possible.

The type of delivery system chosen depends on the concentration of homes, water availability, resources such as construction materials, labor and funds, and the desire and ability of the users to operate and maintain the system. In any case, a distribution system, whether a communal watering point or one which provides water to each home, will be a wasted investment if it becomes inoperative because of lack of maintenance or of funds to operate it. The distribution system should be designed and constructed with simplicity and cost of operation in mind. Systems should be designed to allow future expansion and upgrading to a higher level of service.

Types of Delivery Systems

In this technical note, the delivery systems normally considered for rural villages are described in terms of three levels of service. As a general rule, the higher the level of service, the more expensive the system will be to construct, operate and maintain. However, the higher level systems provide greater potential for improved health, and reduce or eliminate the need for water hauling so that people have more time for other activities, such as raising vegetables. The levels of service from least to most desirable are as follows:

Level 1. Water source development or improvement with a distribution point at or near the source. At this level, water must be hauled from the source to each house. The distance water must be carried will vary with the location of the source. The primary advantage of Level 1 service is a protected water source.

Level 2. Water source development or improvement with distribution point(s) near population centers. This level of service provides water at one or more points serving several homes. The method of distribution may be by a water pipeline or by a tank truck or trailer. Individuals haul water from the distribution point to their homes.

Level 3. Water source development or improvement with distribution of water to each house by a pipeline.

Whichever system is initially decided on, the eventual goal should be to at least provide water to a sink in each house.

Useful Definitions

COMMUNAL DISTRIBUTION POINT - A place where water is delivered for community use; usually consists of one or more taps.

TRANSMISSION LINE - The pipeline from the water source to the point of storage and/or use.

Level 1 Service

Water source development or improvement with a distribution point at or near the source is normally provided when resources are not available to pipe or haul the water nearer to the point of use and/or it is beyond the capability of the village to operate and maintain a more complicated system. It should also be considered when water sources are scarce and have very low yields. The location of the distribution point should be slightly away from the source to reduce the chance of contamination. Storage at or near the source will often be required if the source has a low yield. Storage for dug wells can be incorporated into the well design. The system should provide at least 15 liters per day for each person using it.

Typical Level 1 service developments include a windmill pumping to an adjacent storage tank with a public distribution point, shown in Figure 1, a hand pump used to pump water away from the source to a distribution point, shown in Figure 2a, a hand pump at the source with the distribution point at the pump, shown in Figure 2b, and a spring development with water piped to a nearby distribution point, shown in Figure 3.

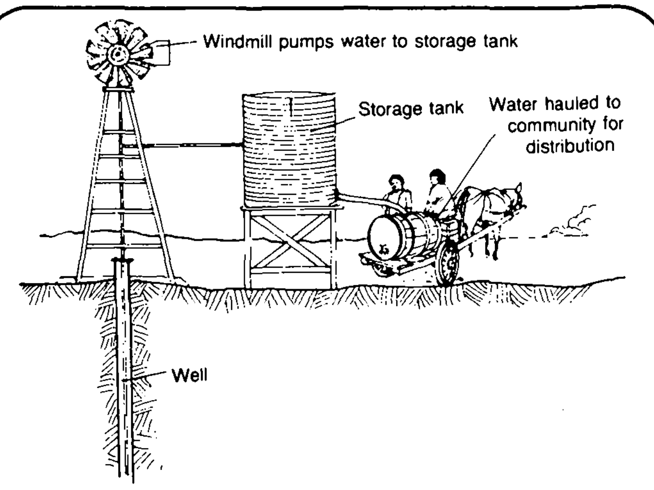


Figure 1. Drilled Well, Windmill and Elevated Storage

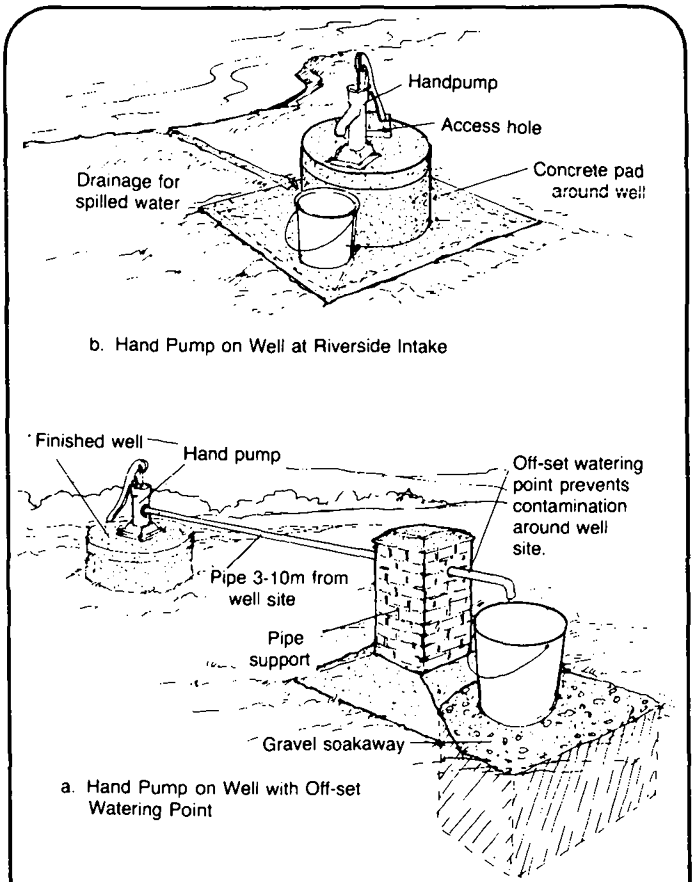


Figure 2. Typical Level 1 Delivery Systems

Level 2 Service

At this service level, the water source is developed or improved with distribution of water to population centers. If the source is near the population center, Level 1 service can be the same as Level 2. See Figures 1, 2 and 3. If the source is remote from the users, a tank, truck or trailer may be used to haul water as shown in Figure 4c or a transmission line can be installed to the distribution point(s). A source of pressure will be required to move the water from the source to the point of use. This can be accomplished by gravity if the source is at a higher elevation than the point of use or by pumping. See Figure 4a.

Level 2 service is more costly and complicated than Level 1 because valves are required so that repairs can be made, so that air trapped in the main line can be released, and so that the main transmission line can be flushed clean. A transmission line may be required and a more sophisticated distribution point may be needed. More storage is also needed since water use will increase when the distribution point is nearer the household. Pump controls may also be required. Storage may be provided at or near the source, the distribution point, or both. Level 2 systems should be designed to provide at least 40 liters of water per day to each person being served. Figure 4b shows a system with several distribution points in a rural community with one storage tank.

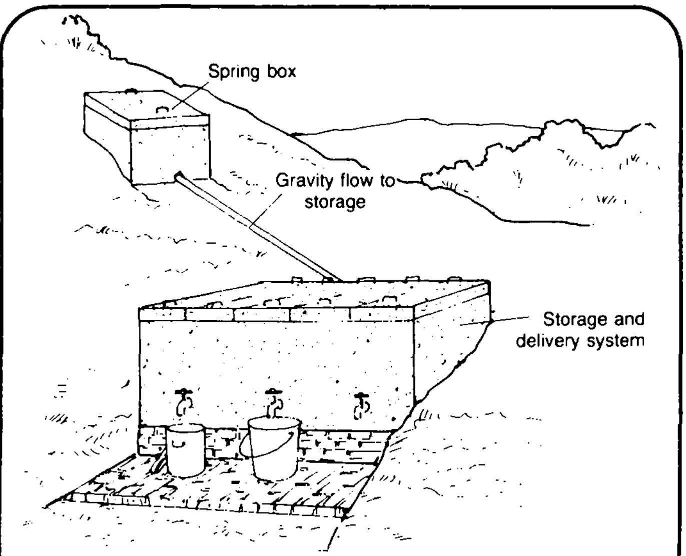


Figure 3. Spring Box and On-Site Storage

Level 3 Service

Level 3 systems have a water source, usually have mechanical pumps, a transmission pipeline, water storage reservoirs and a water distribution system. They are similar to Level 2 systems except that water is delivered to each house rather than to one or more communal distribution points. Water may be supplied to a tap outside the house or to a sink inside the house. In some systems, a water meter may be installed at each home to measure the amount of water used so that each household can be charged for the water it uses. Figure 5a and b

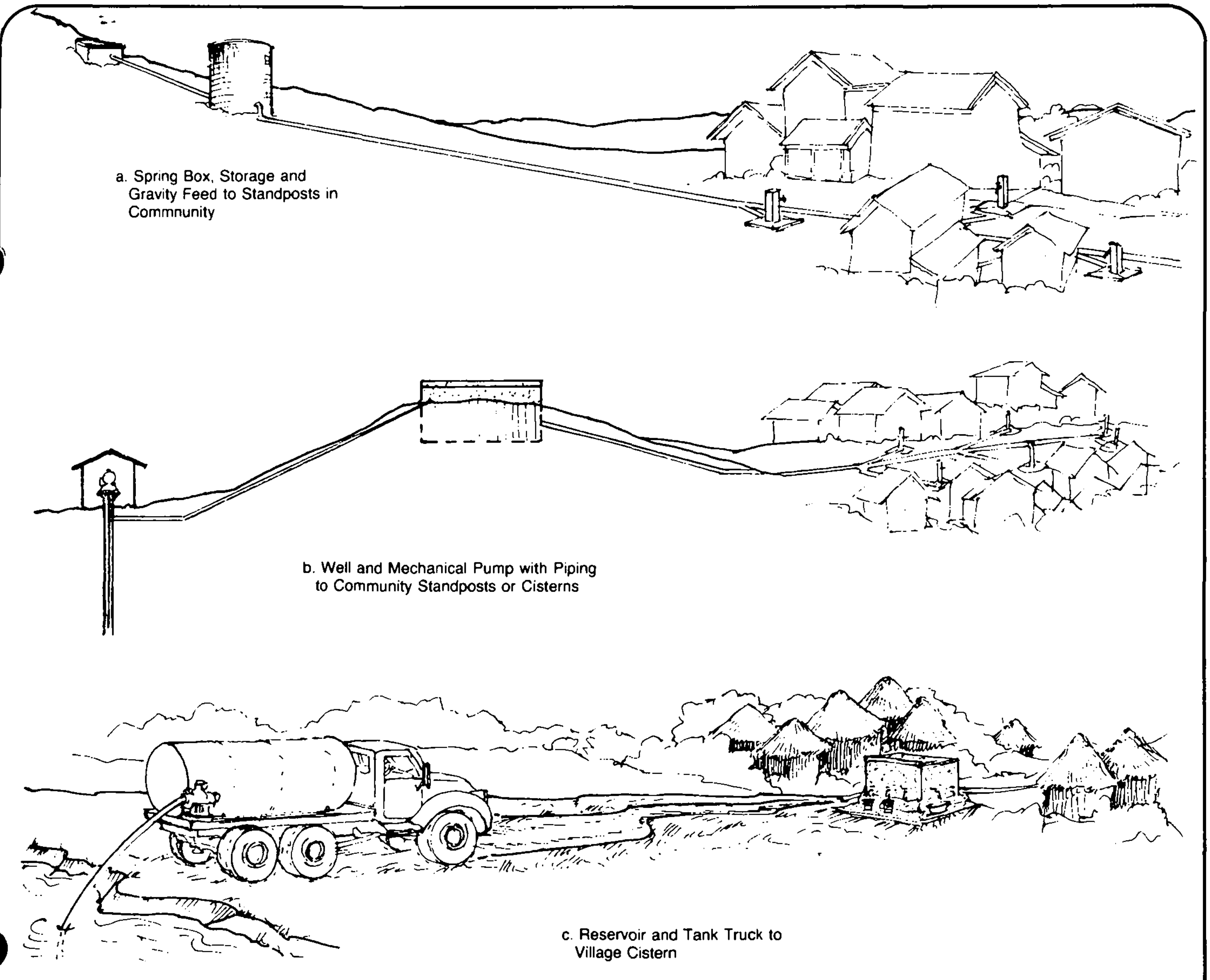
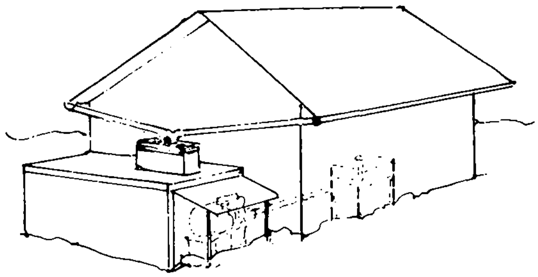
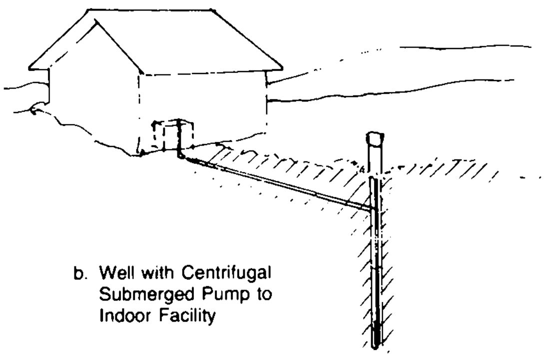


Figure 4. Typical Level 2 Delivery Systems

INDIVIDUAL

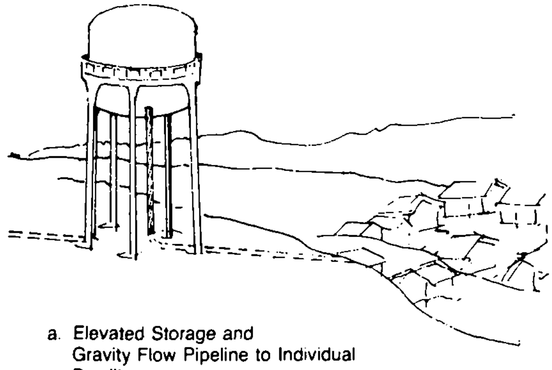


a. Roof Catchment With Pressure Tank and Pump to Indoor Facility

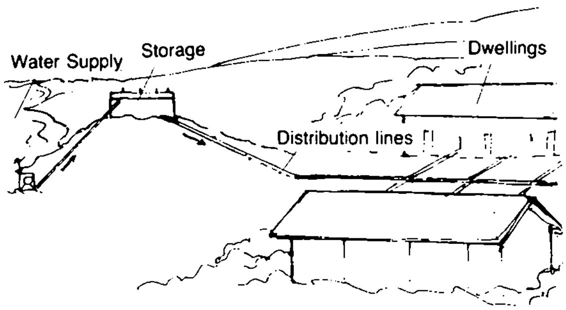


b. Well with Centrifugal Submerged Pump to Indoor Facility

COMMUNITY



a. Elevated Storage and Gravity Flow Pipeline to Individual Dwellings



b. Pond or River Intake to Storage, and Pump to Distribution Lines

Figure 5. Typical Level 3 Delivery Systems

show Level 3 systems using a water source near the house. This would be most likely to occur where water is easy to obtain. Figures 5c and d show water supplied by gravity or by mechanical means to each home through a water distribution system.

Table 1 summarizes the most important considerations in choosing a method of water delivery.

Table 1. Delivery Method Selection Considerations

Level of Service	Suitability for Population Size			Construction Costs			Relative Costs of O&M		
	Small (to 100)	Medium (100-500)	Large (500+)	Low	Moderate	High	Low	Moderate	High
Level 1									
Gravity	x	x	x	x to	x		x to	x	
Handpump	x	x		x			x		
Windmill	x	x			x		x to	x	
Level 2									
Gravity	x	x	x	x to	x		x		
Handpump	x	x		x			x		
Windmill	x	x			x to	x	x to	x	
Electric	x	x	x		x to	x		x to	x
Fuel		x	x			x			x
Level 3									
Gravity	x	x	x	x to	x		x		
Handpump	x	x	x	x			x		
Windmills	x				x to	x	x to	x	
Electric	x	x	x	x to	x		x to	x	
Fuel		x	x			x			x

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Water for the World

Choosing Between Gravity Flow and Pumps
Technical Note No. RWS. 4.P.1

Water can be delivered from one point to another in four basic ways: hauling, pumping, gravity flow or a combination of these methods. Hauling is the least efficient method. It is labor intensive, very costly, and provides only minimal quantities of water. Pumping may require a great deal of energy and usually is more expensive to operate and maintain than gravity flow. Gravity flow is efficient, requires no additional energy and is economical to operate and maintain. It may, however, be expensive to construct initially.

Gravity flow systems usually restrict the source to a specific location. Pump systems provide much more flexibility in locating a source. A source suitable for gravity flow is more likely to require treatment than one using a pump because it is likely to be a spring or a surface source. Because of its dependability and low operation and maintenance costs, if the water is of satisfactory quality gravity flow should always be considered. The final decision to use a particular means of moving water must be based on comparison of costs including operation and maintenance as well as construction costs.

Evaluating Gravity Flow Versus Pumps

To choose between gravity flow and pumps, each type of system should be evaluated. Factors which should be included in this evaluation are:

- The amount of water needed by the village,
- The amount of water the source can produce,
- The water quality,
- The difference in elevation between the source and the highest point in the system, usually the top of the storage tank,
- The distance between the source and the point of storage,
- The obstacles between the source and the village,
- The alternative water sources that are available or could be made available,
- The type of power available and its cost,
- The estimated pumping head.

Worksheet A can be used to tabulate the needed information for all sources. A map should be made of the area identifying the sources in relation to the homes to be served. Any good, clear existing map can be used. The map should show land elevations, existing homes and buildings, roads and streets. Swamps, high groundwater areas, and rock zones should be added to the map. Digging trenches for pipes in such places will be difficult and costly.

Once the necessary information is obtained, gravity flow and pumped transmission lines can be compared and cost estimates, including operation and maintenance costs, can be compared. See "Designing a System of Gravity Flow," RWS.4.D.1, and "Determining Pumping Requirements," RWS.4.D.2, for information about how to size the respective systems.

Worksheet B is a form that can be used to make cost estimates for the transmission line. Prepare an estimate for each possible source. Worksheet C can be used to compare the costs of developing one source among two, three or more possible sources. When a satisfactory source from which water can be moved by gravity is found, every effort should be made to use it. Added pipeline length which may be required will be less costly in the long run than a pumped transmission line.

Worksheet A. Data Required for Choosing Between Gravity Flow and Pumps

1. Estimated present water needs in liters:

	Number of			Unit use		Total
Population	Persons	_____	x	_____	=	_____
School	Students	_____	x	_____	=	_____
Church	Attendees	_____	x	_____	=	_____
Large animals such as cows, oxen		_____	x	_____	=	_____
Small animals such as sheep, goats		_____	x	_____	=	_____
Public watering fountains		_____	x	_____	=	_____

Total present needs = _____

2. Estimated future water use:

Use a 20 year design life. If no better information is available, use a population growth factor of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of water use of 2 times the present use.

Population	Present use _____ x 4 = _____	liters
Institutions & public fountains	Present use _____ x 2 = _____	liters
Animals	Present use _____ x 1.25 = _____	liters

Total future water use = _____ liters/day

3. For each possible water source, determine or judge:

Water quality	______________________
Sustained yield in liters per day	______________________
Difference in elevation between source and highest point in system	______________________
Distance between source and storage	______________________
Obstacles between source and village	______________________
Ease of construction of source protection and pipeline	______________________

Worksheet B. Estimated Cost of Transmission Line Pump/Gravity Flow Delivery System

Item	Quantity	Unit Cost	Total Cost
Transmission Line Materials			
8-inch PVC pipe	_____m	_____	_____
6-inch PVC pipe	_____m	_____	_____
8-inch gate valve & box	_____	_____	_____
6-inch gate valve & box	_____	_____	_____
4-inch flush valve	_____	_____	_____
Pressure reducing valves	_____	_____	_____
Power source (electricity)	_____	_____	_____
(fuel engine)	_____	_____	_____
Pump & Controls	_____		_____
Pumphouse	_____	_____	_____
Storage tank (_____m3)	_____	_____	_____
		Transmission Line Materials	_____
Labor			
Lay water lines	_____	_____	_____
Construct pumphouse	_____	_____	_____
Construct storage tank	_____	_____	_____
Construct water source	_____	_____	_____
(dug well)	_____	_____	_____
(spring)	_____	_____	_____
(surface)	_____	_____	_____
Install pump	_____	_____	_____
Install motor	_____	_____	_____
		Labor	_____
Equipment			
Pickup truck	_____	_____	_____
Dump truck	_____	_____	_____
Front end loader	_____	_____	_____
Trencher	_____	_____	_____
Backhoe	_____	_____	_____
Crawler tractor	_____	_____	_____
Compressor	_____	_____	_____
Other __________	_____	_____	_____
__________	_____	_____	_____
		Equipment	_____
Cost Summary			
Sub-total Materials			_____
Sub-total Labor			_____
Sub-total Equipment			_____
Sub-total project cost			_____
Add contingency 20%			_____
Total Project Cost			_____

Worksheet C. Comparison of Costs for Transmission Lines

	Source	Type System Gravity/Pump/Both	Transmission Line Cost	O&M Cost
A.	________	________	________	________
B.	________	________	________	________
C.	________	________	________	________
D.	________	________	________	________
E.	________	________	________	________
F.	________	________	________	________
G.	________	________	________	________

Source Selected ________________

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1982

Water for the World

Choosing Between Community Distribution Systems and Household Water Connections

Technical Note No. RWS. 4.P.2

A communal distribution system provides water to public watering points in or near the community. Household water connections can be simply an outside faucet at each home or a connection to indoor plumbing. A communal distribution system is Level 2 service while household connections are Level 3 service as described in "Methods of Delivering Water," RWS.4.M.

To determine which type of system is best for a given community, the following considerations should be addressed:

- Project feasibility from a technical standpoint,

- Project feasibility from an economic standpoint,

- Community desire, willingness and ability to operate and maintain a system.

Technical Feasibility

The first step which should be taken is to determine the technical feasibility of the project. This requires estimating the quantities of water needed for each type of system. Potential sources of water can then be identified. This may require drilling or digging a test well if information is not available. Potential sources should be shown on a map. If the potential source produces insufficient water for household water connections, the only option is communal distribution. Once a source or sources is identified, estimates of the cost of delivering water to the community can be developed. A major factor in estimating costs is whether the water is delivered by gravity flow or with a pump. See "Choosing Between Gravity Flow and Pumps," RWS.4.P.1. Worksheet A can be used to estimate water needs for communal distribution points and for household connections.

Economic Feasibility

Once the project has been determined to be technically feasible, an economic analysis should be done comparing the costs of Level 2 and Level 3 service. Worksheet B can be used for cost estimates. The cost of operation and maintenance should also be estimated for each type of system as shown in Worksheet C. These costs play an important role in the final decision on the type of system. The costs of the more economical systems should then be compared using Worksheet D.

Once costs have been determined, available resources must be assessed. there are several methods of obtaining the necessary resources ranging from the community fully paying for, contracting for, and operating and maintaining the system to the government assuming this responsibility. Most projects fall between these extremes with the community providing some funding or in-kind contributions of labor and material and the government providing technical help and funding for materials and equipment that the community cannot contribute. Level 3 systems require additional resources from the homeowner to install plumbing in the house and provide for wastewater disposal.

Community Involvement

The community should be involved in deciding on the type of distribution system. This can be accomplished through community meetings and discussions. Problems concerning crossing privately owned land and providing operation and maintenance can be discussed at these meetings. Responsibilities for providing resources must be clearly understood along with the cost of and responsibility for operation and maintenance.

Worksheet A. Estimating Water Needs for Communal Distribution Systems and Household Water Connections

1. Estimated present water needs in liters:

	Number of		Unit use		Total
Population	Persons ____	x	____	=	____
School	Students ____	x	____	=	____
Church	Attendees ____	x	____	=	____
Large Animals (cows)	____	x	____	=	____
Small Animals (sheep)	____	x	____	=	____
Public Watering Fountains	____	x	____	=	____

Total present water needs = ____

2. Estimated future water use:

Use a 20 year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of water use of 2 times current use.

Population — Present use ____ x 4 = ____ liters

Institutions & Public Fountains — Present use ____ x 2 = ____ liters

Animals — Present use ____ x 1.25 = ____ liters

Total future water use = ____ l/day

3. Sources to be considered (each letter is a different source):

Quantity available (liters per day Gravity-G or Pumped-P)

A. ____ B. ____ C. ____ D. ____ E. ____ F. ____ G. ____ H. ____

Types of source (Spring-Sp, Surface-S, Well-W)

A. ____ B. ____ C. ____ D. ____ E. ____ F. ____ G. ____ H. ____

Height above (+), below (-) point of use

A. ____ B. ____ C. ____ D. ____ E. ____ F. ____ G. ____ H. ____

Distance from source to point of use

A. ____ B. ____ C. ____ D. ____ E. ____ F. ____ G. ____ H. ____

Distance to existing power (Electricity-E, None-N)

A. ____ B. ____ C. ____ D. ____ E. ____ F. ____ G. ____ H. ____

Quality (Taste, odor, clarity -Good-G, Fair-F, Poor-P; Chemical test Yes/No, Y/N; enter for each source)

A. T.____ O.____ C.____ Chem.____ B. T.____ O.____ C.____ Chem.____

C. T.____ O.____ C.____ Chem.____ D. T.____ O.____ C.____ Chem.____

E. T.____ O.____ C.____ Chem.____ F. T.____ O.____ C.____ Chem.____

G. T.____ O.____ C.____ Chem.____ H. T.____ O.____ C.____ Chem.____

Obstacles between source and point of use

A. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Other ____
Right of Way ____

B. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Other ____
Right of Way ____

C. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Right of Way ____

D. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Right of Way ____

E. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Other ____
Right of Way ____

F. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Other ____
Right of Way ____

G. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Other ____
Right of Way ____

H. Rock ____m
Wash/stream ____
Paved road (y/n) ____
Other ____
Right of Way ____

Water rights available?

A. ____ B. ____ C. ____ D. ____ E. ____ F. ____ G. ____ H. ____

Worksheet B. Estimated Cost of Facilities Communal/Household Delivery System

Item	Quantity	Cost	Total
Water System Materials			
4-inch PVC pipe	____	____	____
2-inch PVC pipe	____	____	____
3/4 inch PVC pipe	____	____	____
4-inch gate valve and box	____	____	____
2-inch gate valve and box	____	____	____
4-inch flush valve	____	____	____
2-inch flush valve	____	____	____
House service line	____	____	____
Miscellaneous fittings & valves	____	____	____
Water source (well)	____	____	____
(spring)	____	____	____
(surface)	____	____	____
Power source (electricity)	____	____	____
(fuel engine)	____	____	____
Pump and Controls	____		____
Pumphouse	____	____	____
Water treatment	____	____	____
Storage tank (_____m3)	____	____	____
Communal watering point	____	____	____
	Water System Materials		____
Labor			
Lay water line	____	____	____
Construct pumphouse	____	____	____
Construct storage tank	____	____	____
Construct water source	____	____	____
(dug well)	____	____	____
(spring)	____	____	____
(surface)	____	____	____
Install pump	____	____	____
Install motor	____	____	____
Construct communal watering points	____	____	____
		Labor	____
Equipment			
Pickup truck	____	____	____
Dump truck	____	____	____
Other ____________	____	____	____
____________	____	____	____
	Equipment		____
Cost Summary			
Sub-total Material			______________
Sub-total Labor			______________
Sub-total Equipment			______________
Sub-total project cost			______________
Add contingency 20%			______________
Total project cost			______________

Worksheet C. Operation and Maintenance Costs

Labor

Monthly: _____hrs/mo. x _____/hr. x 12 mo/yr. _____
Annual: _____hrs/yr. x _____/hr. _____
Overhead 1.25 _____ = _____/yr. _____
Total Labor _____

Vehicle

Monthly: _____miles/mo. x _____/mi. x 12 mo/yr. _____
Annual: _____miles/yr. x _____/mi. _____
Total Vehicle _____

Special

1 major repair every two (2) years (time - 12 Hr)
_____men @ _____/hr. x _____hr. _____
_____trucks @ _____/day _____
Total Special _____

Pumps and Controls

Cost of pump and control replacement _____
_____hrs. of crane @ _____/hr. _____
Labor _____ men for _____ hr. @ _____/hr. _____
Total Pumps and Controls _____

Tank

At ten (10) years needs flushing and cleaning
_____ men x _____ days x _____ hr./day x _____/hr. _____
Equipment and Paint _____
Total Tank _____

Chemical

Fluoride: 3gm/1000 liters x _____ liters/day x 365 days/yr. _____
.657 gm/yr. x $0.58/Kg _____
Chlorine: 0.5mg/l/day x 365 day/yr x _____l/day 1000000mg/Kg
_____Kg pure chlorine/year
329 Kg/yr. x $0.90/Kg Chlorine _____
Total Chemical _____

Chemical feeders

Chlorinator: replace every 15 years _____ x 15 _____
Fluoridator: replace every 15 years _____ x 15 _____
Total Chemical Feeders _____

Electrical

_____ hp pump @ 21 hr/day
_____ hp x 0.746 kw/hp x 12 hr/day x $\frac{\text{365 days}}{\text{12 months}}$ = kwh/mo _____

_____ Kwh @ $_____/Kwh $_____
_____ Kwh @ $_____/Kwh $_____
_____ Kwh @ $_____/Kwh $_____
_____/mo.
_____/mo. x 12 mo/yr. _____
Total Electrical _____

Motor

Replace every 10 years: _____ x 10 _____
Cost of fuel _____liters/hr x _____ hrs/day x 365 days x
$_____liter = $_____yr.
Total Motor _____

Summary

Labor $_____
Vehicle _____
Special _____
Pump and Controls _____
Tank _____
Chemical _____
Chemical Feeders _____
Electrical _____
Motor _____
Total Operation and Maintenance Cost _____/yr.

Worksheet D. Comparison of Costs for All Systems

	Type system	System number	Cost
A.			
B.			
C.			
D.			
E.			
F.			
G.			

System selected ________________

Notes

Notes

Notes

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1982

Water for the World

Selecting Pipe Materials
Technical Note No. RWS. 4.P.3

Several factors will influence the type of pipe material chosen for a water distribution system: corrosiveness of the water, water pressure, flow required, soil characteristics and the physical properties of the pipe material. Other considerations are whether the pipe will be used for transmission lines, distribution lines or service lines, the cost and availability of the pipe material and ease of construction and repair.

The materials most often used for water pipes in rural systems include plastic, asbestos cement, steel, and cast iron. Other materials used less often are bamboo, wood, concrete and ductile iron.

Factors in Choosing Pipe Materials

Corrosion. Some water reacts with pipe materials due to an imbalance in the chemical make-up of the water or to minerals in it. The result can be corrosion of metal pipes, leaching of cement in concrete pipes, or deposits of minerals which reduce the water flow in all types of pipe. Most likely, a judgment on the corrosiveness of the pipe will have to be based on experience in the area.

Flow. Pipe materials vary in smoothness which, in turn, affects their resistance to the flow of water. The rougher the surface, the more energy is required to move water from one point to another, thus increasing system costs. These losses are compounded as the rate of flow increases.

Water Pressure. Pipe materials vary greatly in their ability to withstand pressure without bursting so it is important that the pressure at all points in the system be known.

Soil Characteristics. Soils react with pipe materials under some conditions. Again, past experience is the best method of predicting problems. Other problems in the soil include rocks or boulders which might crush or break the pipe, swamps or bogs which do not provide adequate support, and sand which can shift and expose the pipe. Important physical properties of the pipe materials include resistance to crushing, degree of stiffness, and reaction to temperature changes, sun rays, and chemicals.

Physical Characteristics of Pipe. Impact resistance is a material's ability to absorb a blow without damage. Such a blow might occur if a rock fell on the pipe in a trench or if the pipe were dropped. The stiffness or flexibility of material indicates how it will react to impacts. Pipe materials which are inflexible include concrete, asbestos cement and cast iron. Care must be taken to prevent unintentional "bridging" of inflexible materials as shown in Figure 1. Steel pipe is moderately flexible, particularly in smaller diameters. The plastic pipes are usually very flexible.

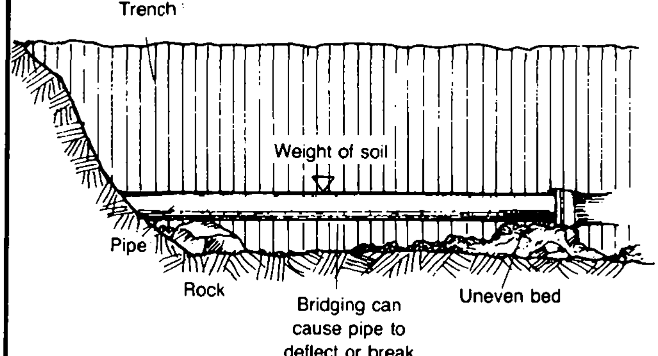


Figure 1. Bridging (Incorrect Installation)

Heat and sunlight usually affect only plastic pipe. Plastic has a relative high expansion/contraction factor when exposed to variations in temperature. For this reason, plastic pipe, particularly polyethylene, should be "snaked" in the trench. The ultraviolet rays in sunlight can cause deterioration in plastic pipe so it should not be exposed for long periods of time. The weight of the pipe is an important consideration due to the need to transport and handle the pipe. Toxicity is a potential problem if recycled plastic products are used in pipe manufacture, if toxic materials such as lead are used, or if pipe is contaminated by prior use or improper storage.

Pipes vary in length from 3-6m and longer by special order. Polyethylene coils are an exception. They come in lengths of 30 and 150m with longer lengths available. Methods used to join pipes include threaded, glued, clamped, welded, mechanical joint, rubber ring couplings and integral bell couplings. These are shown in Figures 2, 3, 4, 5, and 6. Glued joints are used for some plastics but are difficult to make properly and are not recommended for most water systems. Threaded joints are mostly used for steel pipe but occasionally are used with plastic.

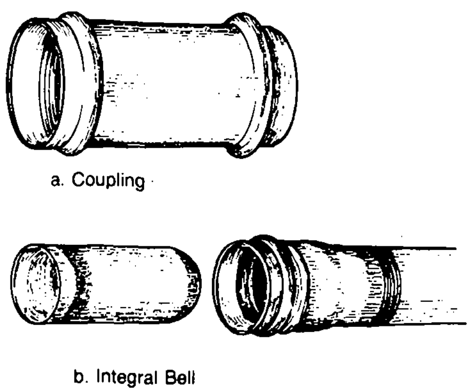


Figure 2. Gasket Joints for PVC Pipe

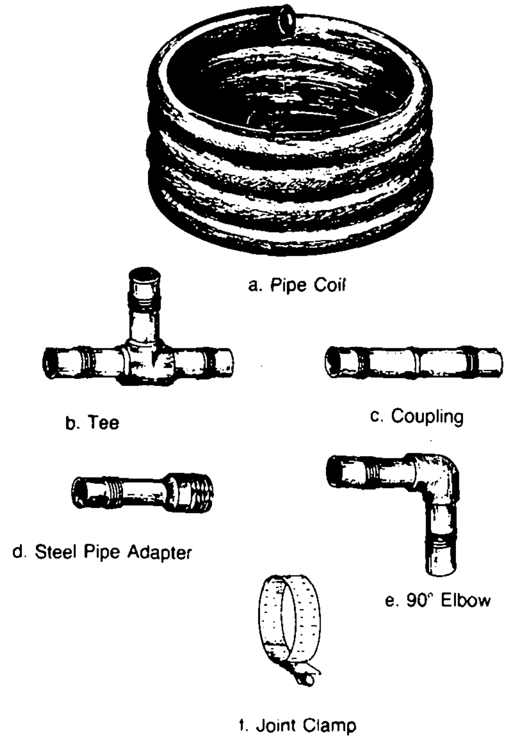


Figure 3. Polyethelene Plastic Pipe and Fittings

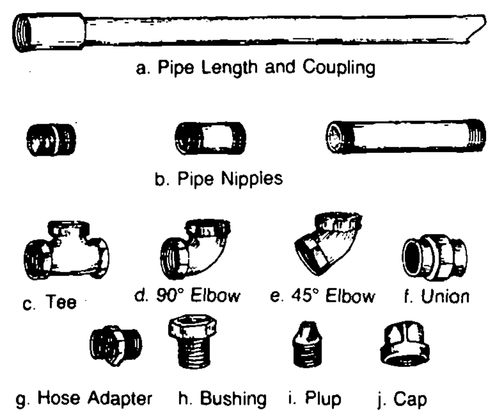


Figure 4. Galvanized Steel Pipe and Fittings

Pipe Materials

Table 1 compares common pipe materials according to several factors. While no pipe is best in all regards, plastic pipe rates high in most characteristics and is the material of choice in many small rural systems.

Bamboo is lightweight and strong. It is very inexpensive in areas where

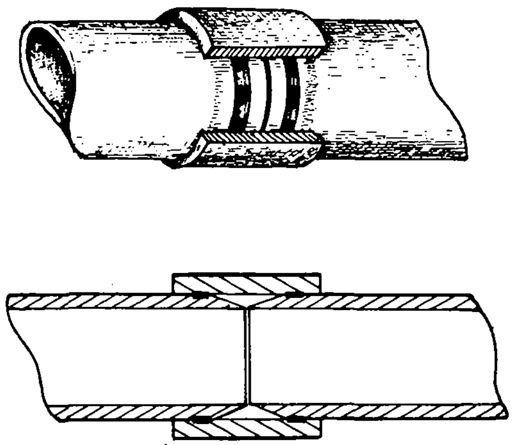
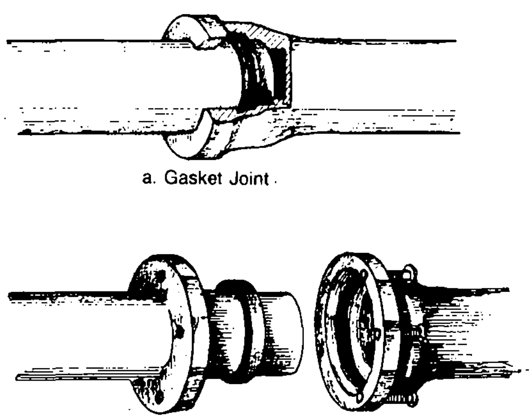


Figure 5. Typical Asbestos-Cement Pipe Joint



a. Gasket Joint

b. Mechanical (Bolted) Joint

Figure 6. Cast Iron Pipe Joints

it grows. Its primary advantages are its availability and suitability for low technology construction. Its drawbacks include a short useful life and inability to withstand pressure. Bamboo is not normally used for water systems because of the constant maintenance required and the fact that most water systems must operate under pressure.

The plastics commonly used in water systems are poly-vinyl-chloride, PVC, and high and low molecular weight polyethylene. PVC is usually available in 3 or 6m lengths and in diameters of 13-300mm. Common pressure ranges are 11 and 14 kilograms per square centimeter (kg/cm^2). While the small diameters (13-50mm) may be joined by gluing or by screwed joints, pipe diameters of 50mm and up are commonly joined by integral bell or rubber ring coupling. PVC is lightweight, flexible, resistant to breakage, highly resistant to chemicals, and easy to install. PVC is simple to repair and to tap for services and is one of the smoothest materials, which reduces friction due to flow. Its useful life should exceed 20 years.

Polyethylene is manufactured in lengths of 30 and 150m. Common diameters range from 13-50mm. It, too, is lightweight and very easy to install

Table 1. Common Pipe Materials

Material	Relative Cost	Range of Size (mm)	Common Length (m)	Pressure Rating (kg/cm^2)	Ease of Installation and Repair	Common Uses
Bamboo	Very low	Varies	Varies	Very low	Easy	Low pressure transmission
Plastic PVC	Low	13-150	6	11, 14	Very easy	All parts system
Polyethylene Low molecular High molecular	 Very low Low-moderate	 13-50 13-50	 30 & 150 30 & 150	 6 11	 Very easy Very easy	Service lines and wells
Asbestos Cement	Moderate	50-900	3 & 4	7, 11, 14	Moderately difficult	Transmission and distribution
Steel (GIP)	Moderate	13-150	6	7, 11	Moderately difficult	Wells, pump houses, tanks, wash, and stream crossing
Cast Iron	High	75-1220	3.6 & 6	4 to 25	Difficult	Large transmission mains

and repair. Service taps are simple and do not require special tools. Low molecular weight polyethylene can withstand pressures of 6 kg/cm^2 and high molecular weight, 11 kg/cm^2. Low molecular weight polyethylene is usually one of the least expensive pipe materials to purchase and install. Its useful life is over 15 years. The primary disadvantages to any type of plastic pipe are poor quality control for some locally manufactured pipe and potential damage if stored in direct sunlight.

Asbestos cement pipe is made of asbestos fibers mixed with cement and silica. The pipe is available in 3 and 4m lengths and in diameters of 50-900mm. Common pressure ratings are 7, 11, and 14 kg/cm^2 depending on wall thickness. Asbestos cement is commonly available and moderately easy to install, tap and repair in diameters of 150mm or less. The pipe walls are smooth and resistant to corrosion.

The principal disadvantage of asbestos cement is its stiffness. It must be handled with care or it will break. It also must be installed with care, often with a select backfill and bedding material as shown in Figure 7. Bridging, shown in Figure 1, must not be allowed to occur. Although asbestos cement is resistant to corrosion, highly aggressive water can leach out the cement and expose and release asbestos fibers which may then be ingested.

Steel pipe coated with zinc is known as galvanized iron pipe (GIP). It usually is manufactured in 6m lengths and in diameters of 13-150mm. Uncoated steel pipe can be obtained in longer lengths and in diameters up to 2400mm. GIP is very impact resistant and can withstand unintentional bridging. In fact, it is used when bridging is desired, such as in crossing a ravine or wash. It is moderately easy to install although special tools, including pipe wrenches and pipe threading equipment, are needed.

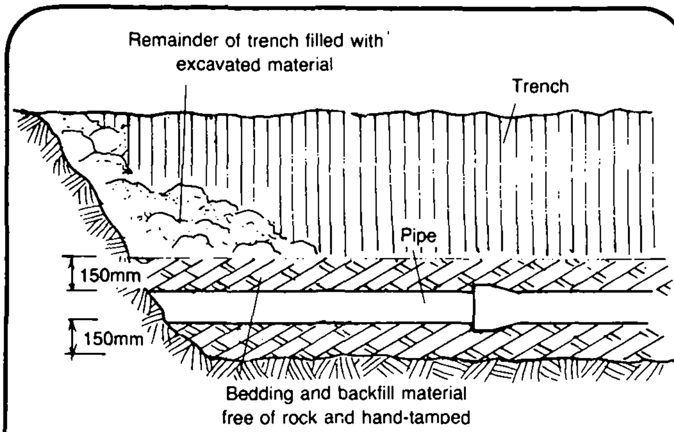


Figure 7. Installing Pipe with Select Material for Bedding

Shortcomings of GIP include its tendency to corrode in aggressive waters and soils. Repair is difficult, as is providing service taps or extensions. GIP is most commonly used for well and pump installations, for stream and wash crossings and at storage reservoirs.

Cast iron is an alloy of pig iron, carbon, manganese, phosphorous, silicon, sulphur and other materials. It is available in lengths of 3.6 and 6m. Diameters range from 75-1220mm. Pressure ratings vary between 4-25kg/cm^2. Cast iron is known for long life in water systems, often exceeding 50 years. It is expensive, moderately difficult to install due to its weight, difficult to tap or repair and is not readily available. Its primary use is for large transmission mains.

Table 1 compares the various pipe materials most often used in small rural systems. Not shown are lead, which should never be used, or copper, which is expensive and primarily used in house plumbing.

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1982

Water for the World

Selecting a Power Source for Pumps
Technical Note No. RWS .4.P.4

There are many sources of energy which can be used to move water. These include people and animals, gravity flow, wind, steam, sun, and fossil fuels. These are converted to useful power through hand pumps, windmills, hydro projects, electricity production and fossil fuel engines.

The specific method chosen depends on the quantity of water required, the type of water supply and the availability and cost of a specific energy source. In fact, availability and cost are usually the controlling factors in selecting a power source in rural villages. If relatively large quantities of water are required, the options are limited since human, animal or wind power are not sufficient to produce more than a few liters of water per minute.

Useful Definitions

FURLING - The action of a windmill in high winds; the wheel swings away from the direction of the wind.

GRAVITY FLOW - Flow of water from high ground to low by natural forces.

POTABLE WATER - Water that is free from harmful contaminants, is aesthetically appealing, and is good for drinking.

Human and Animal Power

Water moved by manpower, while limited in quantity, is used in many villages. It requires carrying, hand bailing and hand pumping which take many hours of work. In most places, these hours could be used to grow more food, gather fuel and keep houses clean and in good repair.

Animal power is used extensively in villages in some countries to pump and/or haul water. This may be an efficient use of an animal if it is not needed for other tasks. Since animals can haul much more water than humans, they should not be underestimated as a method of moving water. On the negative side, the animal needs food grown on land that could be used for growing food for the family.

If water is located at a higher elevation than the users, it can be piped to the lower elevation by gravity flow. This requires no other source of energy, is very economical and is simple to operate and maintain. If the water is potable, it can be consumed at the point of delivery without any further energy being needed. Water from a source that is not potable can be used to generate power either mechanically or by producing electricity, which in turn can be used to produce potable water. With an abundant water source, gravity flow can be used to pump from a lower elevation to a higher one by means of a hydraulic ram. Gravity flow should be used wherever feasible. When deciding between gravity flow and other sources of energy, comparisons should take into account the cost of operation and maintenance as well as capital costs.

Wind Power

Wind is a very attractive energy source for pumping water. Wind is free, available everywhere and a windmill is simple to operate and maintain. Its drawbacks include moderate production of water and the need for constant, year-round wind. Wind must be blowing at 12-20km per hour to start pumping and a suitable site is needed. Many of these conditions can be met along large bodies of water, in mountain passes, on the crest of hills, on open plains and, seasonally, in many parts of the world.

Prior to selecting a site for a windmill, information on wind is necessary. If it is not available, whether through other windmill performance or by measurement, then measurements should be taken over one year's time. The site should be such that the windmill can be placed at least 5m above any surrounding wind obstructions within 120m.

Although the higher the wind speed, the greater the water production, the practical maximum usable wind speeds are 25-32km per hour. This is because the windmill is designed to "furl" or swing out of the wind at wind speeds higher than 40 km/hr to protect the mill from damage. See Figure 1. Figure 2 shows how wind speed affects water production.

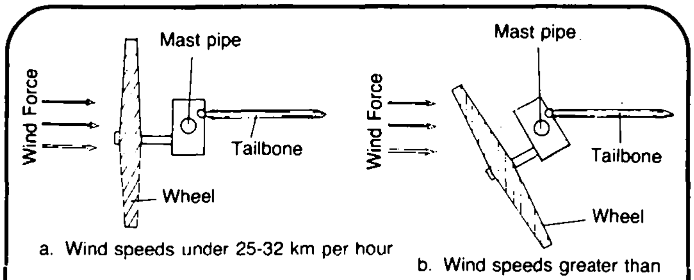

Figure 1. Furling of Windmill Wheel

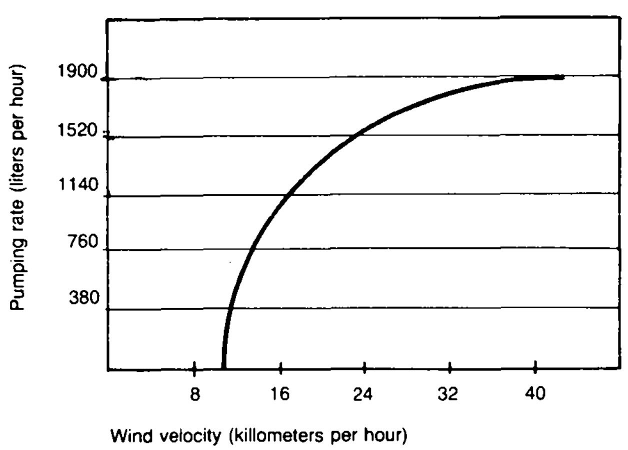

Figure 2. Windmill Output Versus Wind Velocity

Electric Power

Electricity is the most flexible means of moving water. Electric motors are available from a fraction of a horsepower to many horsepower (HP) to meet a variety of pumping needs. Most pump systems can be powered by electric motors. Electric motors are relatively economical to operate, are simple to maintain and have long useful lives. They are the most efficient motor-driven pump for producing water. If electricity has to be generated just for powering a motor, the cost can be much higher than for other energy sources since operation and maintenance of the power-generating equipment is costly and complicated. As a general rule, if a diesel oil or gasoline engine must be used to generate electricity, it is probably more efficient and less complicated to use the engine to drive the pump directly. If the electricity is to be used for other purposes, however, a generator can usually be sized for power pumps with very little additional cost. In considering power generation, Table 1 shows the minimum kilowatt rating required for specific HP pumps.

Table 1. Minimum Generator Requirements for Electric Motors

Motor Horsepower (HP) Size (single or three phase)	Minimum Kilowatt (KW) Rating of Generator
1/4	1.0
1/3	1.2
1/2	1.5
3/4	2.0
1	2.5
1 1/2	3.5
2	4.0
3	6.0
5	9.0
7 1/2	12.5
10	15.0

The ratings in Table 1 take into account the need for power to start the motor under a load which is much higher than the power needed to run contin*o*usly. An estimation of the horsepower required to pump water can be calculated for any flow by using the following formula:

$$HP = \frac{\text{Liters per second (Q)} \times \text{head in meters (H)}}{76 \times \text{pump efficiency (E)}} = \frac{Q \times H}{76\ E}$$

As an example, the HP required to pump 1.5 liters per second to a height of 50m, assuming a pump efficiency of 60 percent, would be:

$$HP = \frac{1.5 \times 50}{76 \times .6} = 1.6$$

In this case, a 2 HP electric motor would be the nearest available size motor that would accomplish the requirements.

The approximate cost of electricity for different sizes of electric motors is shown in Table 2. If there are electric power lines in the community, an estimate of the power available can be made by observation as shown in Table 3.

Table 2. Estimating Pumpint Costs

Motor Horsepower	Average Kilowatt Input or Cost per Hour Based on 1 U.S. Cent per Kilowatt Hour	
	1-Phase	3-Phase
1/4	.305	---
1/3	.408	---
1/2	.535	.520
3/4	.760	.768
1	1.00	.960
1 1/2	1.50	1.41
2	2.00	1.82
3	2.95	2.70
5	4.35	4.50
7 1/2	6.90	6.75
10	9.30	9.00

Note: To find the cost for any other rate, multiply by the rate. For example, if electricity costs 5 cents U.S. currency per Kilowatt hour, for a 3/4 HP single phase motor, the electricity cost would be .760 x 5c = 3.8c per hour.

Table 3. Identification of Available Power by Field Inspection

Type of Power: Phase	Type of Power: Volts	Number of Transformers	Number of Leads from Transformer	Voltage Rating of Power Meter
1	115	1	2	120 2 wire
1	230	1	2	230 2 wire
1	115/230	1	3	230 3 wire
3	220	2 or 3*	3	220 or 240#
3	440	2 or 3*	3	440 or 480#
1 & 3	120/240	3	4	120/240##
1 & 3	120/208	3	4	120/208###

*Some power companies may only use one transformer.
#-3 phase
##-3 phase, 4 wire Delta
###-3 phase, 4 wire Wye

Conversion of sunlight to electricity through a process called photovoltaics is an alternative to using a fossil fuel engine to generate electricity., While the technology is well known and is currently being used to power pumps, the costs are quite high and it will be years before it will be economical for many applications. Photo-voltaics is an attractive alternative, though, because operation and maintenance are minimized and fuel is not required. If water is pumped to storage only when the sun shines, the need for batteries to store electricity is eliminated, thus substantially reducing initial costs and simplifying operation and maintenance.

Although fossil fuel powered motors are costly to operate and maintain, and fuel may be difficult to obtain and expensive, there often is no other choice if water is to be moved in sufficient quantities to be beneficial. When fossil fuel engines must be used, it is better to use diesel fuel than gasoline. The initial cost of the engine is generally more, but the cost of fuel is less as are the costs of maintenance and repair. The diesel engine does not require spark plugs or points and operates at a low rotating speed, thus prolonging its life. Natural or bottled gas engines are low in operating cost and have a longer life because they are very clean burning. Although natural and bottled gas are not widely available, in petroleum-producing countries gas is increasingly being bottled and piped for wide use.

Table 4 summarizes the whole range of energy sources for moving water.

Table 4. Characteristics of Energy Sources to Move Water

Consideration	Human & Animal	Gravity	Wind	From Central Station	Electricity Generated On-site Fossil	Electricity Generated On-site Voltaic	Fossil Fuel Engines
Quantity of H2O produced	Low to moderate	Varies with source	Moderate	High	High	Moderately high	High
Availability	Readily	Varies	Varies with site	Highly variable	Low	Low, experimental	Readily
Captial Cost	Low	Low to moderate	Moderate	Low to high	Moderate to high	Moderate to high	Moderate
Operation and Maintenance	Low	Low	Low	Low	High	Low to moderate	High
Positive Factors	Accepted, in place, understood	Low operating cost, long life	No fuel cost, simple technology	No maintenance, relatively inexpensive	Easily obtained	Very low maintenance, low operational cost	Easily available in wide range of powers
Negative Factors	Inefficient, hidden costs	None	Wind may not blow certain times	Expensive to extend lines	Expensive to operate and maintain	Still being developed, high first cost	Very high operation and maintenance costs

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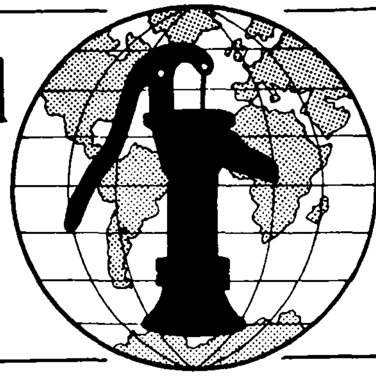
Water for the World



Selecting Pumps
Technical Note No. RWS. 4.P.5

The preferred method of delivering water from the source to the point of use is by gravity flow because no external power source or mechanized apparatus is required. Very often, however, a water source is at a lower elevation than the point of storage or use, the rate of flow must be increased, or the water must be boosted due to friction losses in the pipe. When any of these conditions occur, some method of pumping must be used. See Figure 1.

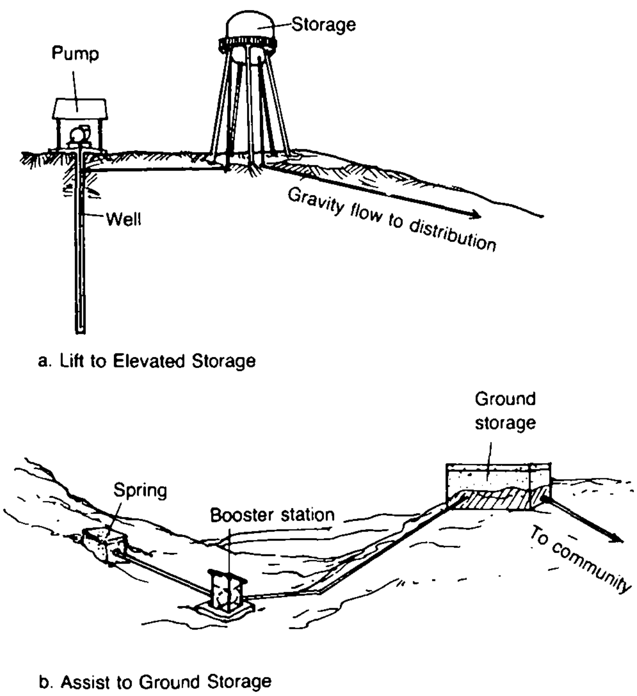


Figure 1. Situations Requiring Pumps

Useful Definitions

DEEP WELL PUMP - Any pump capable of pumping water from wells where the water is more than 10m below the ground surface.

FRICTION LOSSES - The energy required to overcome friction caused by pipe roughness, restrictions and changes in direction; usually expressed in meters of water or "head".

GRAVITY FLOW - Flow of water from high ground to low by natural forces.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

PRIME - To put water in a pump to start it pumping.

PUMPING HEAD - The height of water a pump produces when pumping; it includes the height of the highest point in the system plus the equivalent height to overcome friction; expressed as meters of water.

SHALLOW WELL PUMPS - Any pump which cannot pump from depths of over 10m below the level of the pump.

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

SUCTION LIFT - The difference in elevation between the inlet (suction) side of a pump and the water level in the well when the pump is pumping plus friction losses; expressed in meters of water.

Types of Pumps

Pumps commonly used in domestic water systems can be classified as centrifugal, shown in Figure 2, positive displacement (piston), shown in Figure 3, or impluse (ram), shown in Figure 4. The type of pump chosen depends on the volume of water required, pumping head and type of power available.

In general, where only animal, human or wind power is available, positive displacement pumps are the best choice. These normally deliver low quantities of water and would probably be the choice for Level 1 systems described in "Methods of Delivering Water," RWS.4.M.

Impulse pumps, also known as hydraulic rams, are water driven. They are simple and economical to operate and maintain and are the pump of choice when the right conditions exist.

Centrifugal pumps include single stage suction, jet, submersible and line shaft turbines. These classes of pumps require electric motors or internal combustion engines for power and one would normally be selected for Level 2 or 3 systems as described in "Methods of Delivering Water," RWS.4.M.

Pumps can be divided into two categories based on their power source.

Category 1. Pumps which can be powered by animals, humans, wind or water. These pumps usually produce low volumes of water at or near the source. They include bucket, positive displacement and impulse pumps.

Category 2. Pumps which are usually powered by electric motors or external combustion motors. These pumps include single stage suction, jet, submersible and line shaft turbines. They produce medium to high quantities of water compared to Category 1 pumps. The positive displacement pump mentioned in Category 1 can be power driven to produce relatively high quantities of water.

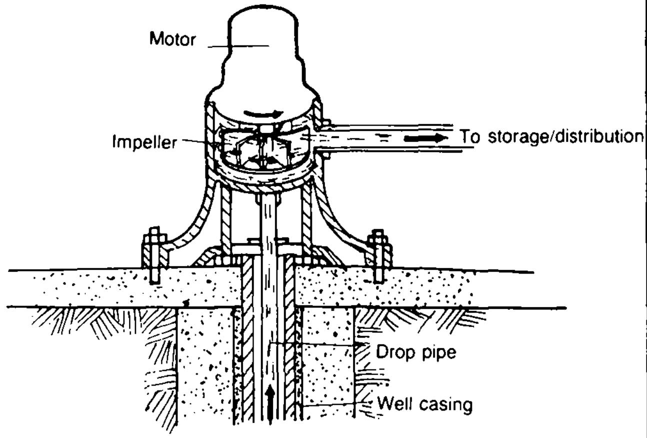


Figure 2. Centrifugal Pump

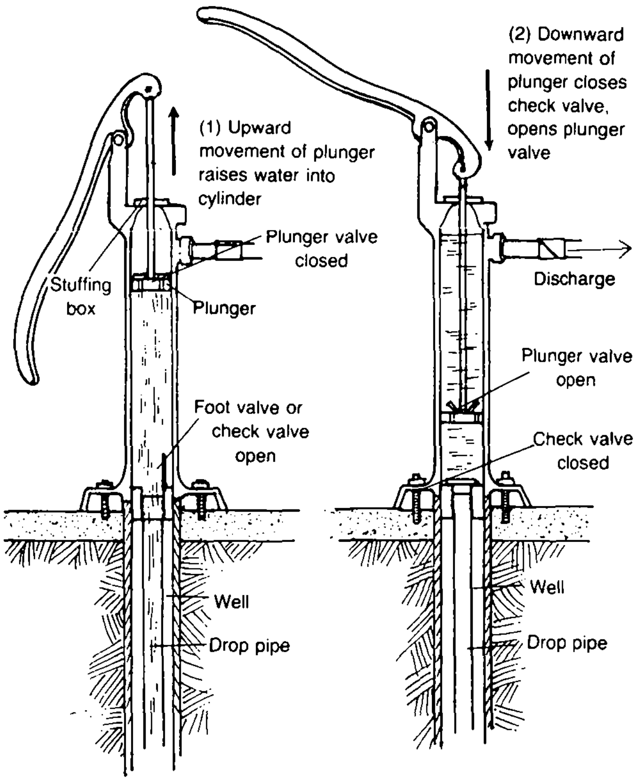


Figure 3. Positive Displacement Pump

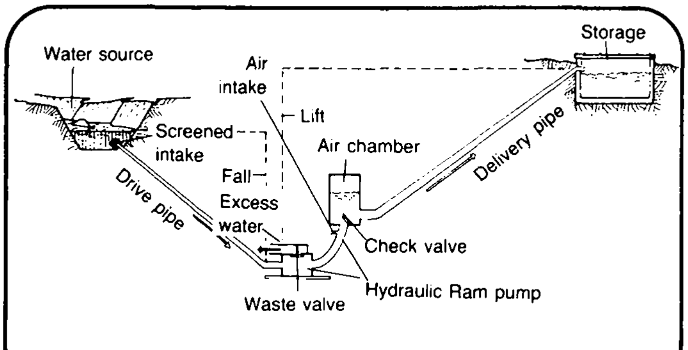


Figure 4. Impulse Pump (Hydraulic Ram)

Within categories, there is a distinction between shallow and deep well pumps. See Figure 5. Shallow well pumps are those which can pump from a depth of 7m or less, which is the maximum practical suction lift at sea level. Deep well pumps can pump from deeper depths depending on pump design.

Category 1 Pumps

Bucket. This type of pump may be considered where relatively large diameter dug wells are used, there is a relatively short distance to water and low quantities of water are needed or available. Several variations exist including:

- Rope and Bucket. In shallow wells, it is common to throw a bucket tied to a rope directly into the well. In deeper wells, leverage is required or an animal is used to raise the water. This is undesirable from a public health viewpoint as contamination can be and usually is introduced into the well by careless placement of the rope and/or bucket. For this reason, rope and bucket should not be considered unless other alternatives are not available. See Figure 6a.

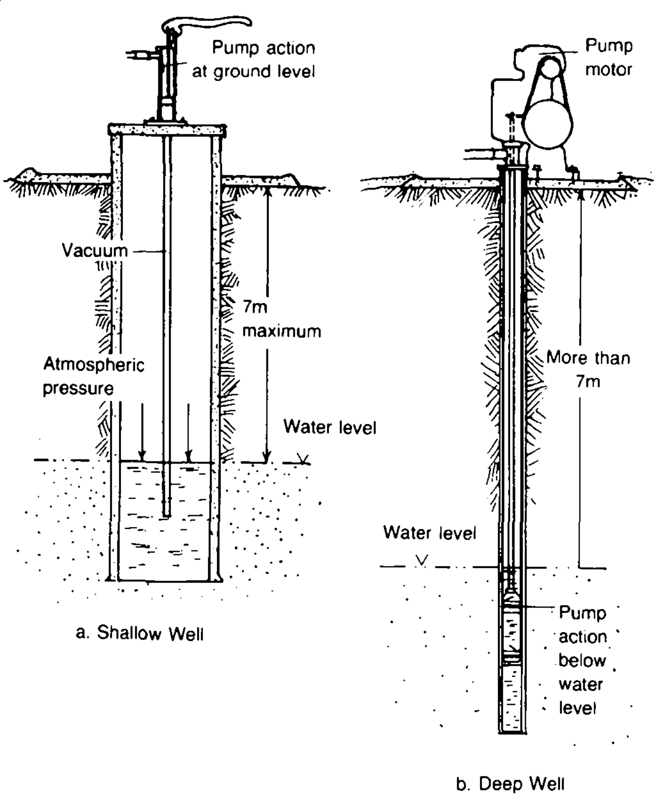


Figure 5. Shallow and Deep Well Pumps

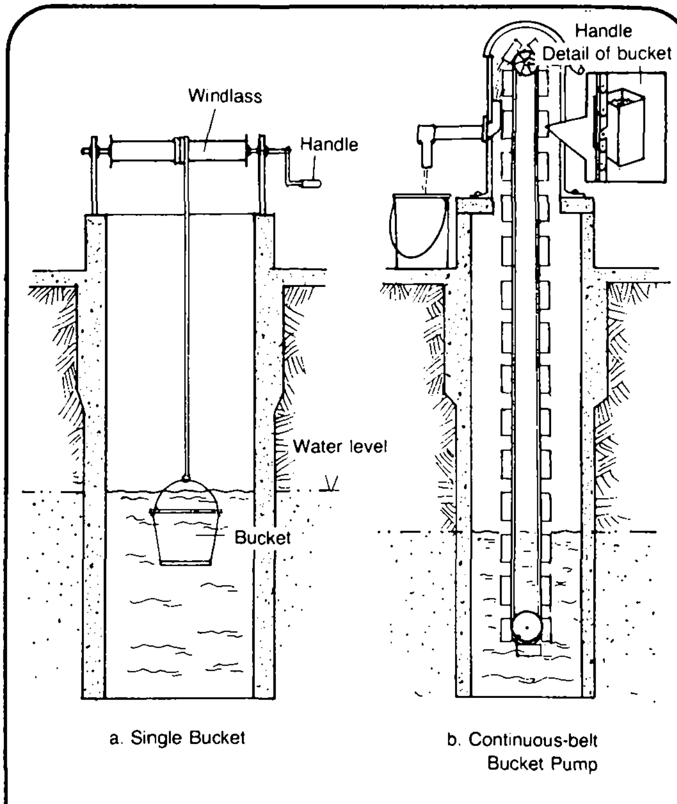


Figure 6. Bucket Systems in Shallow Wells

• Continuous-belt Bucket Pump. This can be made much more sanitary than a rope and bucket but is much more expensive to install. Essentially, this method involves attaching small buckets to a continuous loop as shown in Figure 6b.

Impulse (Hydraulic Ram). A hydraulic ram has very few moving parts and is very economical to operate and maintain. Hydraulic rams may be used singly or in tandem depending on the amount of water available and required. The water is raised to a higher elevation by the force of falling water which creates a drive force within the ram by compressing air. This in turn pushes a small amount of the falling water to a higher elevation. See Figure 4.

In order to work, most rams require a flow of at least 12 liters per minute and a fall of 50cm. The essential elements of the system include a source at a higher elevation than the ram, a drive pipe, ram, delivery pipe and storage. Water used to drive the ram may be different than that to be pumped. However, there is a potential for cross-contamination when this is done. Since only a portion of the water delivered to a ram is pumped to a higher elevation, the source must produce several times as much water as is needed. The water must be free of trash and sand since these can plug the pump. If these conditions exist, along with a good head, then a hydraulic ram is a good choice. It requires no external power source other than water and pumps 24 hours per day with very little maintenance.

Positive Displacement. This pump consists of a cylinder containing a piston and is called a positive displacement pump because it displaces an amount of water equal to the distance the piston travels. See Figure 7. Double acting pumps are available. They pump on the upward and downward or forward/backward stroke of the piston and thus tend to be more efficient. The cylinder may be located above or in the water. When the cylinder is above water, suction is required to lift the water to the piston. This type of pump

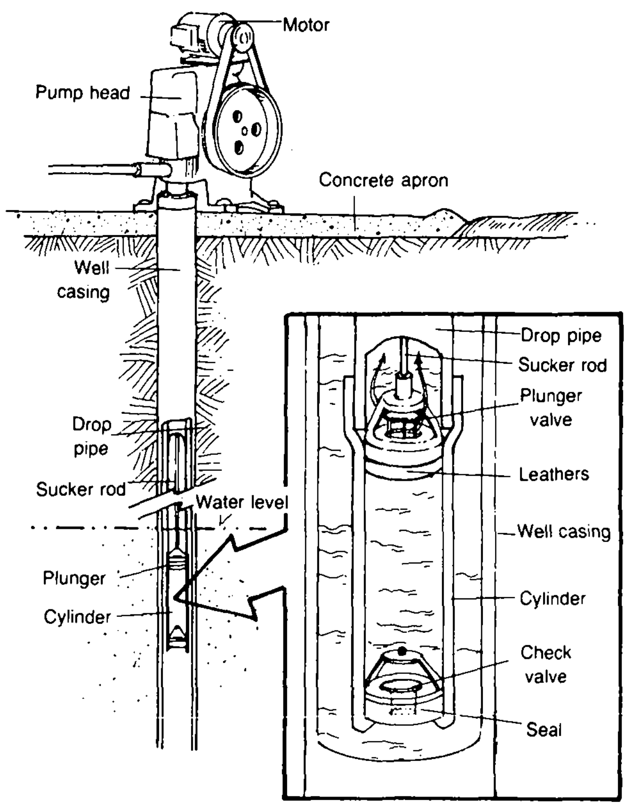


Figure 7. Motor Driven Positive Displacement Pump (Submerged Piston)

usually requires "priming" and is less desirable than a pump with the cylinder in the water. Priming a pump is a possible cause of contamination and a source of priming water is needed.

The cylinder can be driven by a variety of power sources including a hand pump, windmill or motor. The amount of water which can be produced is limited by the suction lift, if the cylinder is above water level; the diameter of the piston; the length the piston travels; and the number of times the piston is moved in a given time period. When the cylinder is located in the water, a sucker rod is required. This rod connects the drive mechanism to the cylinder and is usually made of steel. Due to the weight of the steel sucker rod, a pumping depth of 60-80m for a hand pump should be considered maximum. If motor-driven, positive displacement pumps can pump from depths exceeding 300m if sufficient power is available. These pumps can be used in small diameter wells by selecting a small diameter cylinder or by using the well casing itself for the drop pipe when the cylinder is built into the pump.

Positive displacement pumps are the pump of choice, if only hand or wind energy is available or if motors are available and great pumping depths and low flow requirements are encountered.

Category 2 Pumps Motor-driven pumps may be divided into shallow well pumps and deep well pumps.

Shallow Well Pumps. These must be located within at least 7m vertically of the water surface when at sea level and closer at higher elevations. For every 300m of elevation above sea level, the pump will need to be 25cm closer to the water. This is because they rely on a vacuum in the suction side of the pump to get water to the pumping mechanism. The actual suction capability varies with the pump being considered.

Shallow well pumps include surface-mounted positive displacement piston pumps and centrifugal pumps, which in turn include shallow well jets, turbines and straight centrifugal pumps. The positive displacement pump might be chosen for relatively high heads and low flows. Centrifugal pumps would be used for higher volume and lower pumping heads. Centrifugal pumps are more readily available.

Deep Well Pumps. These can pump water from over 7m deep. Types of deep well pumps include a submerged piston pump shown in Figure 7, a submersible pump shown in Figure 8a, a line shaft turbine shown in Figure 8b, and a jet action pump, shown in Figure 8c. While piston pumps can theoretically pump from very great depths, there are practical limitations because of the weight of the sucker rod. This, combined with other limitations, indicates that 300m would be an upper limit.

- Line Shaft Turbines. Like the positive displacement pumps, the line shaft turbines have the motor at the surface. However, a drive shaft connects the motor to the pump. The deeper the well, the more shaft guides required along the drive shaft and the greater the possibility of guide failure. In addition, the shaft needs to be relatively straight and plumb which requires a very straight bore hole for the well. Since it is extremely difficult to keep deep wells plumb, the pumping depth is often limited. For this reason, practical pumping depths in small diameter wells, 12-24mm, are usually limited to 12 to 35m. Large diameter wells, 30mm and greater in diameter, can be pumped at much greater depths. Failing guides are still a problem as is the possibility of breaking a shaft. These pumps can pump against relatively high heads and at high volume by adding to the pump bowls.

- Submersible pumps. These have the advantage of being usable in less plumb wells and they can usually be set at greater depths. Since the sealed electric motor is below the pump, the whole unit must be pulled for repairs. Because there are no moving parts connecting a motor at the surface to the pump, installation is not complicated. Operation and maintenance problems are reduced since there are fewer moving parts. These pumps can produce water from great depths, but the greater the depth, the larger the motor and the electric cable to the motor. This can be very expensive as special electric cable, capable of being operated in water, is required. Also, 240 volts and/or three-phase power may be necessary. For these reasons, 150m should be considered an upper limit. At this depth, special pump pulling equipment would be required. If electrical service is intermittent, or only available during evening hours, no electrically powered pump can be used.

Table 1 compares different types of pumps according to a number of different factors.

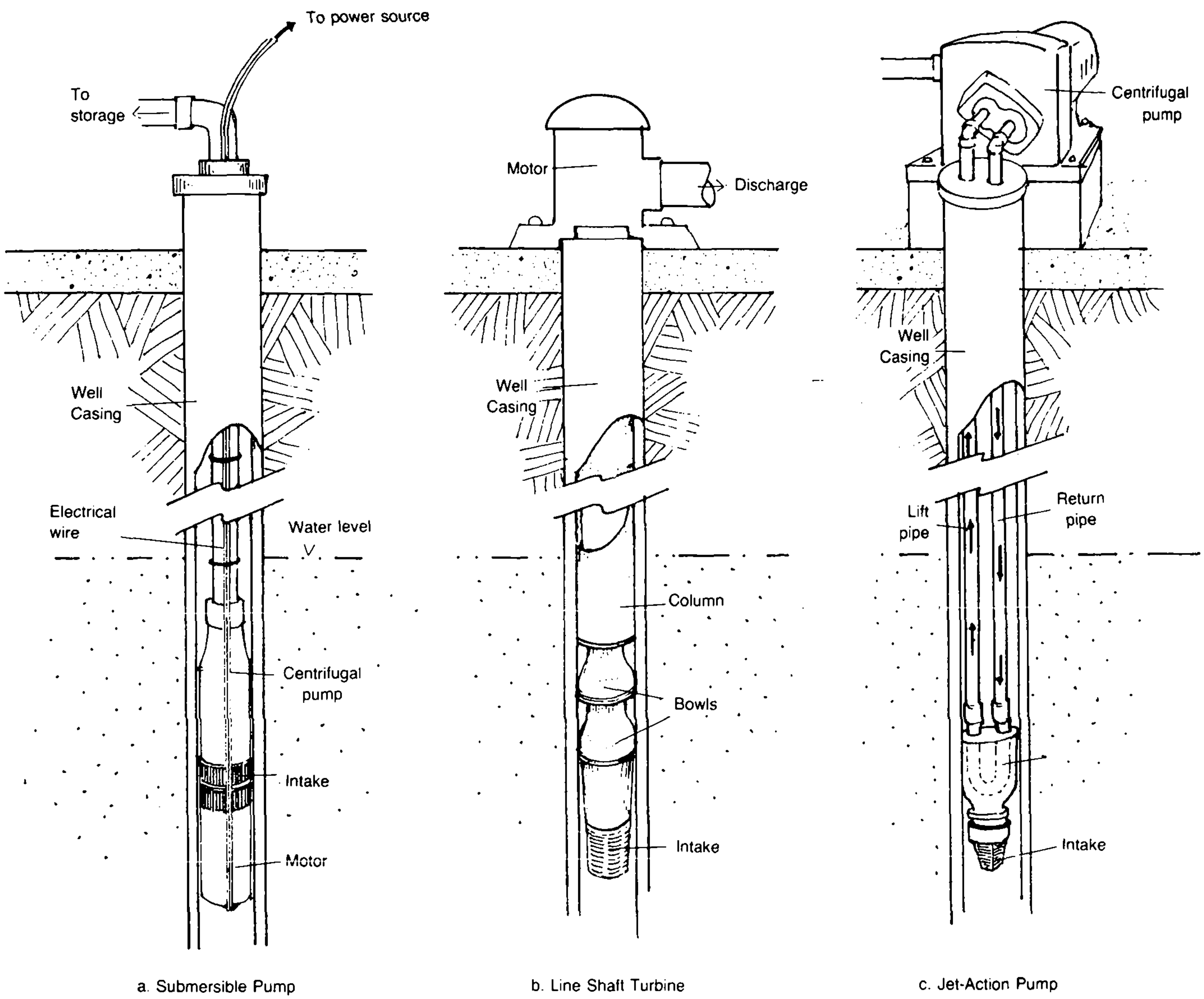


Figure 8. Examples of Deep Well Pumps

Table 1. Comparison of Different Types of Pumps

	Wind, Water, Animal Powered					Electric, Fossil Fuel Powered			
	Rope and Continuous Bucket	Impulse Hydraulic Ram	Positive Displacement			Straight Centrifugal	Centrifugal Jet	Submersible	Line Shaft Turbines
			Hand	Wind	Motor				
Capacity liters/minutes	15 to 70	—	10 to 50	0 to 100	12 to 150	Very wide range, almost unlimited	18 to 300	40 to 240 and higher	120 to 360 and much higher
Lift from water to pump (m)	1 to 30	—	—	Medium to high 8 to 250	Low to high 8 to 500	Low, less than 8	Low to medium 8 to 25	—	Medium
Lift from pump to higher level	Normally none	—	0 to 3 Normal	0 to 3 Normal	Limited by strength of pipe	Wide range 6 to 500	Usually 6 to 100	30 to 400 and higher	5 to 500
Diameter well required (cm)	Large 100	Not used with wells	6	6	6	6	12 with jet in well	12	12
Efficiency	Low	Low	Low 25 to 60%	Low 25 to 60%	40 to 60%	50 to 85%	40 to 60%	65 to 85%	65 to 80%
Relative cost	Low to reasonable	Reasonable	Reasonable	Reasonable to high	Reasonable	Reasonable	Reasonable	Reasonable but high at greater depth	Higher
Operation and Maintenance	Very simple	Simple	Simple, needs occasional maintenance	Simple, needs occasional maintenance	Simple, needs attention	Simple, needs attention	Simple, needs attention	Simple, needs attention	More difficult, needs constant skilled attention
Advantages	Easily understood, very simple	Simple, few moving parts	Easy to understand, low cost	—	Easy to repair or replace	Easy to repair or replace	Easy to repair or replace	Pump and motor in well less subject to vandalism	Can be operated by alternate power sources, high volume
Disavantages	Limited use, low efficienty	Needs constant flow of water	Low efficiency, required some maintenance	Dependent on wind	Needs attention	Requires attention for bearing lubrication	Requires attention	Difficult to pull, needs special electrical cable for wells	Difficult to repair if bearings fail

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1982

Water for the World

Manufacturing Hand Pumps Locally

Technical Note No. RWS. 4.P.6

Many villages need hand pumps but have limited local resources to purchase them. Even when hand pumps are obtained, repair parts may not be readily available. Many communities which have had hand pumps in the past have experienced failure due to the lack of repair parts.

Because of this, there are compelling reasons for local manufacture of hand pumps so that both repair parts and skills are readily available. The alternatives to be considered are village manufacture of pumps which may be inefficient and have a short lifetime but are within the villagers' capability to understand and construct and the construction of long-lasting and relatively maintenance free pumps which require skilled workers and sophisticated equipment and must be built in a central location within a country. Another alternative is to have those parts of a pump which require accurate machining or casting made at a central location in-country and to construct the balance of the parts and assemble the pumps at the village level. These methods have been applied with success. The choice of options depend on the specific country and village.

Types of Hand Pumps

To evaluate alternatives, it is necessary to know what a hand pump is and what its component parts are. The most common hand pump is one which uses leverage to enable a person to lift water either by developing a vacuum or by positive displacement or a combination of both. These pumps are classified as shallow well pumps with a maximum pumping depth of 7m, or deep well pumps which can pump from depths over 7m. Shallow well pumps have the pump cylinder built into the pump stand as shown in Figure 1a. Deep well pumps have the pump cylinder located in the well, below water level. This requires a pump rod in the well. See Figure 1b.

The component parts of a hand pump are a pump cylinder, a drop pipe, a pump rod and pump stand, and a handle.

Pump Cylinder. Pump cylinders may be open or closed as shown in Figure 2. The advantage to an open cylinder is that the plunger can be removed without removing the drop pipe. The pump cylinder must be accurately machined. For this reason, it cannot readily be

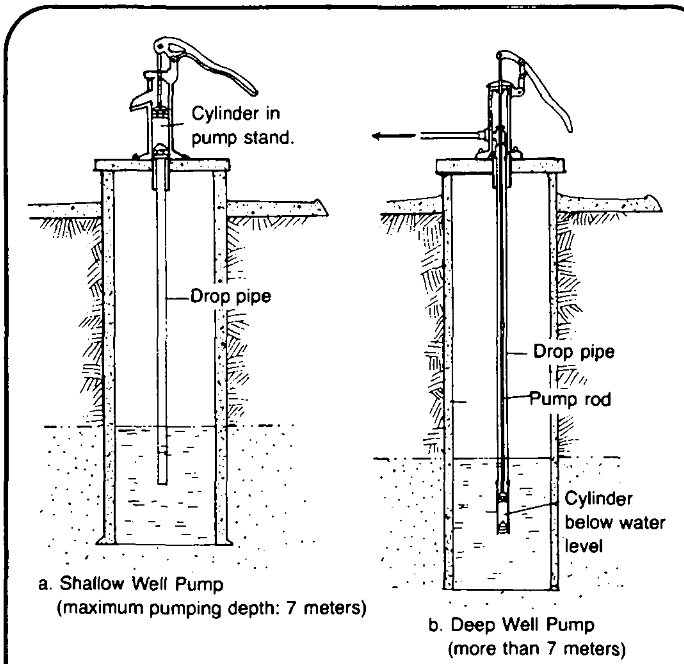

Figure 1. Types of Hand Pumps

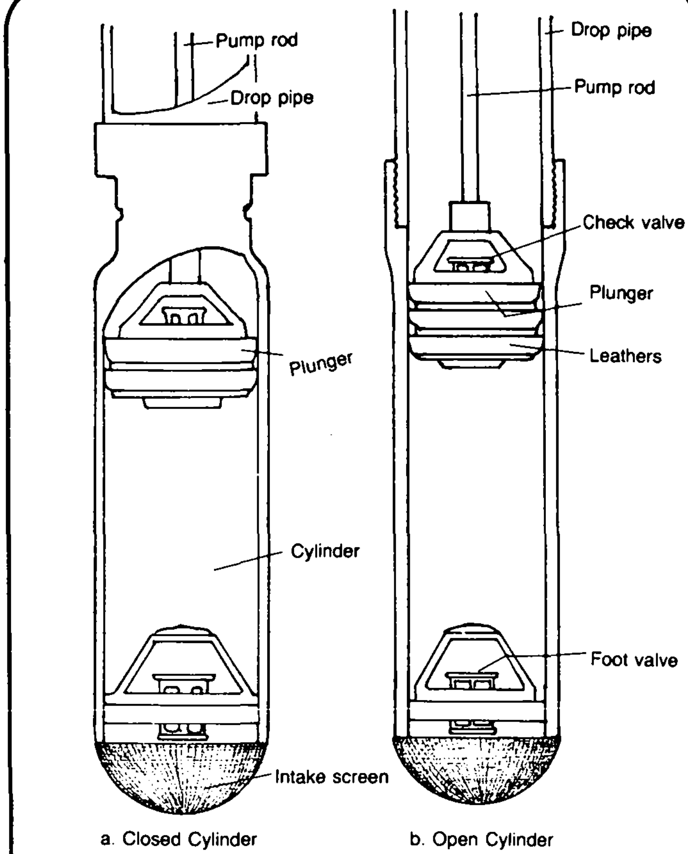

Figure 2. Pump Cylinders

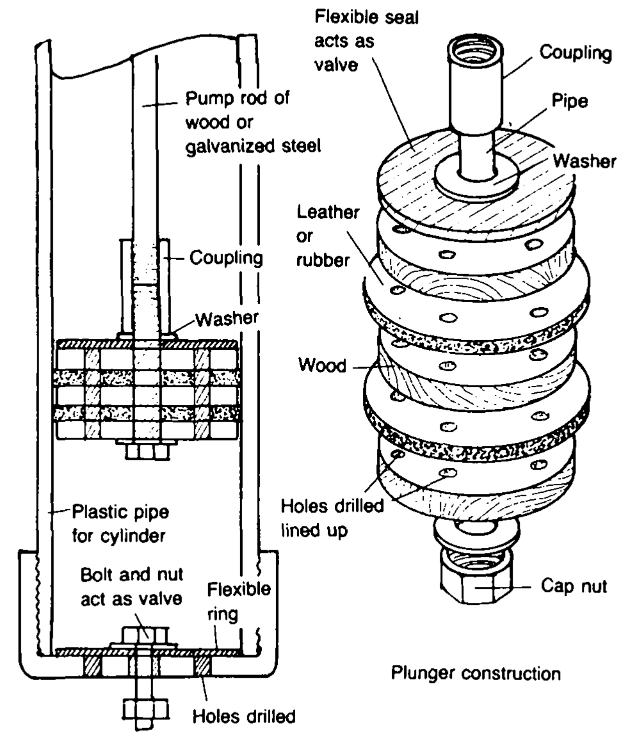

Figure 3. Locally Manufactured Cylinder and Plunger

constructed at the village level. Some development is underway using plastic pipe for the cylinder but the results are not yet complete. Pump cylinders are available in cast iron and brass. Both have long expected lives. The primary reason for failure is in the "leathers," which are easily replaced and can be made locally. Figure 3 shows a locally made pump cylinder.

Drop Pipe. The drop pipe is usually made of galvanized iron or rigid plastic for shallow depths. Galvanized iron pipe is much more commonly used. Neither can be manufactured at the local level.

Pump Rod. This is necessary for connecting to pump cylinders located in a well. Galvanized iron rod is common for wells up to 30m deep and wood rod for greater depths. These must be obtained from outside the immediate village area in most cases. Wood rod may be used if locally available. Reinforcing steel can be used as a pump rod but it is likely to rust.

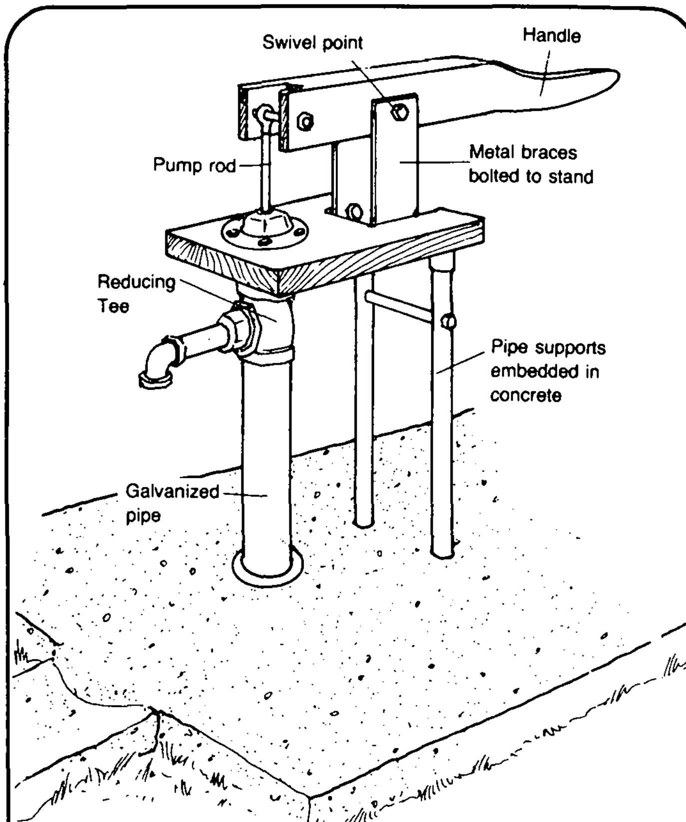

Figure 4. Pump Stand

Pump Stand. Pump stands may be cast, welded or fabricated from pipe or wood. Since the main points of wear are in the bearing areas, they should be made to close tolerances and of durable material to increase the life of the stand. This primarily involves the pump handle and the pivot point on the stand which supports the pump handle. The pump stand and handle usually are the first to wear out and are also relatively easy to build. For this reason, they should be considered the principle elements for local manufacture. Figure 4 shows one type of locally manufactured pump stand and handle.

Notes

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1982

Water for the World

Designing a System of Gravity Flow

Technical Note No. RWS. 4.D.1

This technical note provides information on designing a simple, gravity flow piping system from a water source to a point of use, such as a water storage tank serving an adjacent community distribution point. The design of a distribution system to multiple points or to homes throughout a village is covered in "Designing Community Distribution Systems," RWS.4.D.4.

Whenever the water source is at a higher level than the point of water use, it may be possible to avoid mechanical pumps and allow the force of gravity to deliver the water. This is the preferred method for water delivery since the cost of operating and maintaining pumps is avoided. To design a gravity system, it is first necessary to accurately determine the height of the source above the point of use. The source must be higher for a gravity system to work. The difference in elevation between the source and point of storage is called the system head. This is one of the controlling factors in determining the amount of water that can be delivered. Other factors are the pipe diameter, pipe length, pipe material and rate of flow in the pipe.

Preliminary Design Considerations

The first step in designing the system is to draw a map showing the location of the source in relation to the point of use and the distances in between. Obstacles should be shown, as should the elevations of land along the proposed conduit, particularly at the source, storage site, point of use and hills and washes in between. Figure 1 shows a map similar to that needed for a small project. Figure 2 is a profile showing elevations along the proposed conduit route.

There are two ways to conduct the water from the source to the point of use. These are open channel or piping under pressure. An open channel conduit is essentially a man-made stream. It should be carefully shaped and lined with concrete, bricks or indigenous material to make it more durable and enable the water to flow easily. This type of conduit can often be constructed using hand labor and indigenous materials. On the negative side, it must be built at a fairly uniform downhill slope. This condition may not exist due to barriers between the source and the point of use. More importantly, the water in an open conduit is open to contamination. For these reasons, a closed conduit or pressure pipeline is preferred.

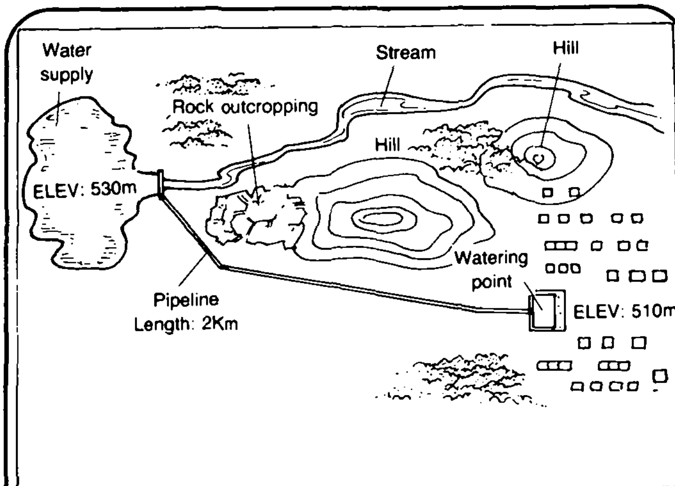

Figure 1. Location Map

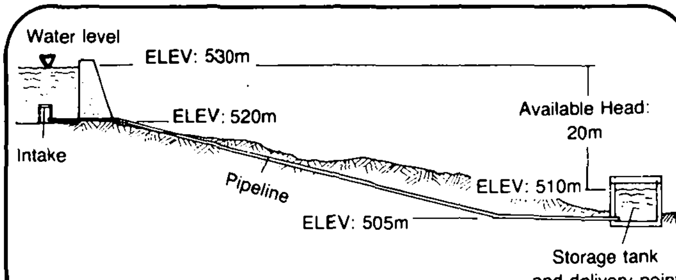

Figure 2. Profile of Pipeline

A fundamental understanding of hydraulics is necessary to design a pressure pipeline. The force which pushes the water through a pipeline is known as "head" and is the height of water expressed as meters of water above any point being considered in the system. See Figure 2.

As water flows through the pipe, there is a small resistance to the flow caused by the roughness of the pipe material. This is known as "friction". Friction is also caused by sharp bends and constrictions in the pipeline. The energy required to overcome this friction is known as head loss. These losses increase as the amount of flow or the length of pipe is increased or as the diameter of pipe is decreased. This is shown in Figure 3.

A Design Example

As an example, suppose a rural community of 500 people is located as shown on the map in Figure 1 with the profile as shown in Figure 2. The small stream shown has an available flow of 10 liters per second as measured during the lowest flow. For the present, it has been decided to provide a public distribution point in conjunction with a storage tank. As soon as the community can find the resources, it plans to expand the system to serve individual homes. There are no buildings to be served other than private homes and water for animals will not be provided by the system. Based on this, it has been decided to size the transmission line and storage as if the system were to serve the individual homes right away. Water usage of 100 liters person/day is expected.

Using Worksheet A as a guide, follow these steps:

1. The estimated current daily water needed is 50000 liters/day.

2. Future use is estimated to be 200000 liters/day. This will be the volume of water used to size the tansmission line.

3. The storage reservoir is sized for future use at 200m^3. If this system were not to be expanded for a period of time, consideration would be given to providing less storage now with increased capacity to be added later.

4. The water supply has a continuous source and, because storage is being provided to meet peak demands, the transmission line can be sized to supply water over a 24-hour period.

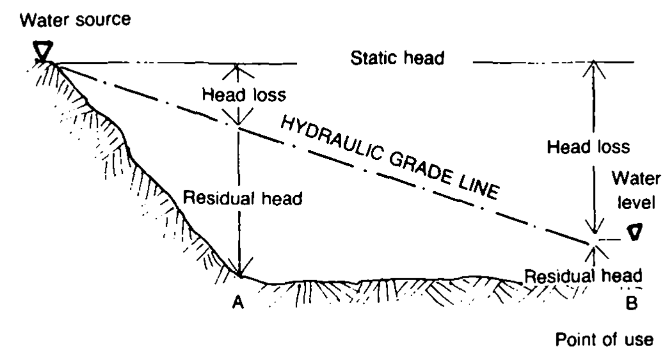

Figure 3. Available System Head

This allows for the minimum pipe size to be selected. In this case, a flow of 2.3 liters/second is needed. Since 10 liters/second is available, the source can provide the necessary flow.

5. Pipe size can now be determined based on the available head to drive the water to the point of use on the required flow and on the total length of pipe in the system.

a. The total length of pipe is determined by adding the measured length to the equivalent length including valves and fittings, shown in Table 2. The number of valves and fittings was estimated for this example. The total pipe length is 2038m.

b. The static head is the difference between the elevation of the source and the water level in the storage tank. In this case, it is 20m.

c. The head available to drive the water through the pipeline is the static head less a small amount of head held in reserve to help prevent a vacuum from occurring in the transmission line. It is recommended that at least 5m be available. This amount is used for this example so that available head is 9.8m.

d. Now use Table 1 to choose a pipe size. Read down the flow column to the flow required (2.3 liters/second). If the desired flow is listed, read across to the right as far as the first column which shows a lower head loss for that flow than is available from step 5c above. If the flow is not shown in the table, then follow the above steps for the next lower flow and the next higher flow. In this case, either flow

Table 1. Head Loss Table in Meters per 1000 Meters
Pipe Diameter in mm

Flow liters/ second	30		40		50		80		100	
	GI	AC/P	GI	AC/P	GI	AC/P	GI	AC/P	GI	AC/P
0.1	3.4	2.2	1.5	0.9	.34	0.22				
0.2	5.8	3.5	2.5	1.5	.59	.36	.12			
0.3	13	5.6	4.0	2.4	.9	.55	.12			
0.3	21	8	9	3	1.25	.75	.18	.1		
0.4	23	14	14	5.7	2.2	1.4	.3	.2		
0.5	34	21	19	8.6	3.4	2.1	.45	.3	.12	
0.6	48	30	20	12.5	4.6	3	.61	.4	.15	
0.7	61	39	27	16	6	3.9	.8	.51	.2	
0.8	80	50	35	22	8	5	1.2	7.0	.26	.17
0.9	100	61	42	27	9.9	6.1	1.4	0.9	.32	.2
1.0		75	51	32	13	7.5	1.7	1.1	.39	.4
1.1		90	62	38	15	9.4	2.0	1.3	.47	.3
1.2			73	45	18	11.0	2.5	1.5	.55	.35
1.3			83	54	20	13.5	2.75	1.75	.6[illegible]	.4
1.4			100	60	24	15	3.2	2.1	.75	.48
1.5				68	28	17	3.7	2.4	.88	.55
1.6				75	30	19	4	2.6	.95	.60
1.7				88	34	22	4.6	2.9	1.1	.68
1.8				95	37	25	5.0	3.2	1.25	.72
1.9					40	27	5.6	3.5	1.3	.8
2.0					46	30	6.1	4.0	1.5	.90
2.5						44	8.7	6.0	2.2	1.35
3.0						60	14	8.4	3.0	1.9
3.5						75	18	11.5	6.2	2.5
4.0						105	23	15	8.3	3.3
5.0							37	26	12	5.0
6.0							50	3[illegible]	16	7
7.0							67	42	20	9.5
10							130	80	30	18.5
15									70	45
20									125	70

[Note: Based on Hazen-Williams C of 130 for asbestos cement (AC) and plastic (P) and for a C of 100 for galvanized iron (GI).]

If the desired flow rate is not shown, then use an average of the actual flow rate to the next low and next high flow rate. EXAMPLE: For a flow rate of 4.6 liters/second and a 100mm pipe:

1. $\frac{4.0 \times 3.3}{4.6} = 2.9$

2. $\frac{5.0 \times 5.0}{4.6} = 5.4$

3. $\frac{2.9 + 5.4}{2} = 4.2$m head loss

Table 2. Friction Losses in Fittings Equivalent Length of Straight Pipe Meters

Size mm	30	40	50	80	100
Gate valve-open	1.2	1.3	1.6	2.0	2.7
Elbow, 90 degree	6.7	7.5	8.6	11.1	13.1
Elbow, 45 degree	1.8	2.2	2.8	4.1	5.6
Tee, straight	4.7	5.7	7.8	12.1	17.1
Tee, through side	8.8	10.0	12.1	17.1	21.2
Check valve	13.1	15.2	19.1	27.1	38.2

requires the same pipe size, 80mm. If the next lower flow had allowed a smaller pipe size, then an interpolation would have been required, taking an average of the ratio of the actual flow to the next highest flow and the next lowest flow as shown in Table 1.

Other Factors in Designs

Factors other than pipe size must be considered when designing a transmission line. These include high and low points along the line and valving to facilitate operation and maintenance.

Even when a positive pressure is maintained by providing for a residual head, it is possible for air to collect at high points in a line. An air release valve should therefore be installed at the top of each rise as shown in Figure 4. Low points in the line should be equipped with a drain valve so that any sediment that collects can be flushed out. This is very important if the source contains sand or fine sediment.

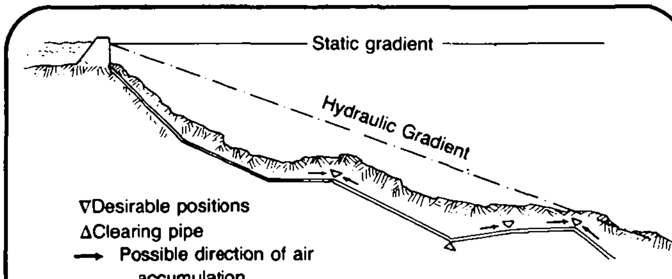

Figure 4. Desirable Positions for Air Valves on Pipeline

Gate valves should be placed in the line to permit system operation and repair. In a piped distribution network, valves are located so portions of the lines can be isolated for repair while the rest of the system is still in operation. With a simple gravity system, a failure anywhere in the line will put the entire system out of operation so a large number of valves are not needed. One valve should be placed at the source and a second near the storage tank or point of use. Additional valves located at intervals of 1000m may be desirable for quicker access to turn the system off should a break occur or to isolate portions of the line for testing purposes.

Worksheet A. Designing a System of Gravity Flow

1. Estimated present water needs in liters:

		Number of:		Unit Use		Total
Population	Persons	500	x	100	=	50,000
School	Students	______	x	______	=	______
Church	Attendees	______	x	______	=	______
Commercial		______	x	______	=	______
Large animals (cows)		______	x	______	=	______
Small animals (sheep)		______	x	______	=	______
Public watering fountains		______	x	______	=	______

Total present water needs = 50000

2. Estimated future water use:

Use a 20-year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of use of 2 times.

Population	Present use	50,000	x 4	=	200,000	liters
Institutions and public fountains	Present use	______	x 2	=	______	liters
Animals	Present use	______	x 1.25	=	______	liters

Total future water use = 200,000 liters/day

3. Storage tank:

Take the future water use and convert it to cubic meters:

Reservoir = $\frac{200{,}000}{1000}$ liters = 200 m^3

4. Source production requirements:

Determine the required production rate in liters/second

Total daily demand = $\frac{200{,}000 \text{ liters}}{86400 \text{ second}}$ = 2.3 liters/second

Assume water production over 24 hours or 86400 seconds

5. Pipe sizing:

a. To calculate the pipe size, first find the total equivalent length of pipe.

Total length = measured length + equivalent length of fittings

Equivalent length of pipe due to fittings (Table 2):

Fitting	Number	x	Equivalent length	=		
Gate valve	1	x	2.7m	=	2.7	m
Elbow, 90 degree	2	x	13.2	=	26.4	m
Elbow, 45 degree	____	x	____	=	____	m
Tee (straight)	____	x	____	=	____	m
Tee (through side)	____	x	____	=	____	m
Swing check valve	1	x	38.2	=	38.2	m

Total equivalent length = 67.3 m

Length of pipe from source to storage = 1971.0 m

Total pipe length = 2038 m

b. Determine static head:

Static head = elevation at source - elevation at top of storage

= 530 m - 510 m = 20 m

c. Find head available per 1000m to overcome friction:

Head available = $\frac{\text{static head - 5m residual head}}{\text{Total pipe length in km}}$

= $\frac{20 \text{ m} - 5\text{m}}{2.038 \text{ km}}$ = 9.8 m/1000m

d. Select a pipe size from Table 1 using the 24-hour flow in liters/second and the available head loss found in c. above.

	Flow liters per second	Head loss per 1000m	Pipe size	Type material	Select yes/no
Required	2.3	Available 9.8	____ mm		____
Next low	2.0	6.1, 4.0	80 mm	GI P/AC	____
Next high	2.5	8.7, 6.0	80 mm	GI P/AC	____

From d. a pipe size of 80 mm is recommended for the transmission line as the head loss is too great for the next smaller pipe size.

Notes

Notes

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1982

Water for the World

Determining Pumping Requirements
Technical Note No. RWS. 4.D.2

Before pumping requirements can be determined, a water source must be identified, water use must be estimated based on the population to be served and the type of system must be chosen. If a Level 1 or 2 system, described in "Methods of Delivering Water," RWS.4.M, is selected, then much less water is required and pumping costs will be lower.

The World Health Organization recommends that provision be made for a minimum of forty (40) liters of water per person per day if a communal distribution point is used. Where water must be hauled, fifteen (15) liters per person per day should be provided. For water piped to the home, one hundred (100) liters or more per person per day is desirable.

The next most important factor in determining pumping requirements is the *pumping head. This head includes the* difference in height between the pump and the highest point in the system, usually the storage tank, and the head needed to overcome friction. See Figure 1. Part of the head may be fixed, as in the case of the location of the pump and the storage tank, and part may vary depending on the difference in flow or pipe size. Since pipe size can be changed, as can flow by using longer or shorter pumping times, these are the primary variables in designing a pumping system. Provision must be made for friction requirements of valves, bends and meters, if used.

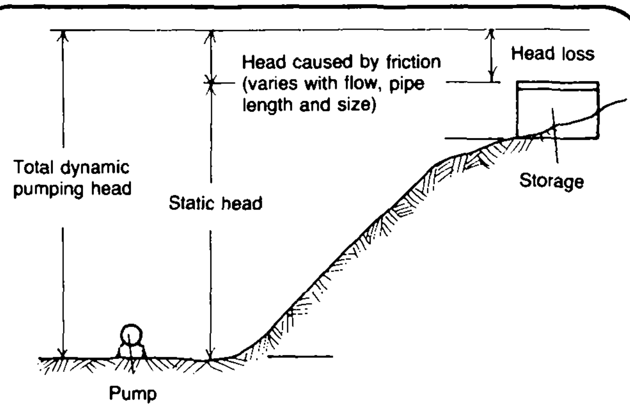

Figure 1. Total Dynamic Pumping Head

Useful Definitions

DRAWDOWN - The distance between the water table and the water level in a well during continued pumping.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

HEAD LOSS - The head required to overcome friction.

PUMPING HEAD - The height to which a pump must raise water including the height of the highest point in the system plus the equivalent height to overcome friction; expressed as meters of water.

STATIC HEAD - The difference in meters between the elevation of the pump and the highest point in the system, usually the top of a storage tank, to which the pump must raise water.

STATIC WATER LEVEL - The water level in a well when the pump is not operating.

TOTAL DYNAMIC HEAD (TDH) - The total energy which the pump must provide to lift water to the pump, to raise water to the maximum elevation, and to meet all friction requirements; expressed in meters of water.

When a water source has been selected and the type of system chosen, then quantity, pumping distance and elevation of storage can be measured or calculated. Once these are known and flow is estimated, a pipe diameter can be selected. This information is then used to determine pump size.

Windmill Pumping Systems

Windmills can be used to pump water in quantities ranging from 380-12000 liters per hour depending on wind speed, windmill diameter, pump size and pumping head or lift. Wind speed determines pumping capacity. Although windmills are under development which can pump at much lower windspeeds, the most widely available windmill pumps at its maximum rate at wind speeds of 25-32km per hour. At 16km per hour, the capacity is reduced 37 percent and at 20km per hour it is reduced 22 percent. The wind normally blows at the most usable speeds for only a few hours per day and this must be taken into consideration. If the wind blew strong enough to pump water for six hours per day, then the quantity of water produced would be 2400-73000 liters per day.

Since wind speeds vary over the course of a year, this must be taken into account. It is advisable to provide for a storage tank near the windmill to provide for times when the wind does not blow.

To design a windmill system, the quantity of water needed must be determined, the total dynamic head (TDH) found and the expected wind speed predicted. These data can then be used to size the system.

Example: A village of 150 people have decided to develop a Level 2 water system with several distribution points near the population center. Water is available in a well 30m deep. Wind energy measurements have been taken and it has been determined that the wind speed is between 25 and 32km per hour an average of three hours per day; 16km per hour for six hours per day; and 20km per hour for four hours per day. What size windmill and pump cylinder would be required?

1. Calculate the amount of water needed: 150 people x 50 liters per day = 7500 liters. Next, convert average wind speed to effective wind speed. This is done by multiplying the number of hours the wind blows times the percentage of the windmill pump's full power.

Wind speed	Percent of full power	Hours/ day	Equivalent hours
25-32 km/hr	100%	3	3.0
20 km/hr	78%	4	3.1
12 km/hr	63%	6	3.8
		Total	9.9 hours

The wind will have optimum power 9.9 hours per day.

2. Then find the liters of water per hour required to meet the community's needs.

$$\frac{\text{Water required}}{\text{Pumping time in hours}} = \frac{7500 \text{ liters}}{9.9 \text{ hrs}} =$$

758 liters/hour

Once the quantity of water required per hour and the elevation to which the water must be lifted are known, the windmill can be sized using Table 1.

Table 1. Windmill Data

Pump cylinder size in mm	Capacity in liters/hour		Elevation to which water can be raised SIZE OF FAN					
	2m	2.4-4.8m	2m	2.4m	3m	3.6m	4.2m	4.8m
44	397	568	40	56	85	128	183	305
48	473	681	37	53	79	119	171	280
50	492	719	29	43	66	98	140	229
57	681	984	23	34	52	76	110	180
64	852	1230	20	29	43	64	91	149
70	1003	1457	17	24	37	55	79	130
80	1211	1779	14	21	30	47	67	110
83	-	2082	-	-	27	40	56	93
89	1666	2438	11	15	23	35	49	81
95	-	2763	-	-	20	30	44	70
100	2158	3142	8	12	18	26	38	61
108	-	3558	-	-	16	23	34	55
114	2744	3975	6	9	14	21	30	49
121	-	4429	-	-	-	19	27	43
127	3407	4921	5	8	11	17	24	40
146	-	6435	-	-	-	12	18	30
152	-	7098	-	5	8	12	17	26
178	-	9653	-	-	6	9	12	20
203	-	12492	-	-	4	7	9	15

In the example, the pumping rate of 758 liters/hour and the pumping head of 30m can almost be met by a windmill with a 2.4m diameter fan and a 50mm cylinder. To determine that this is true, look down column 3 in Table 1 to the number 719 liters/hour. The number is in the column under 2.4-4.8m. Looking to the left under column 1, pump cylinder size, the capacity corresponds to a cylinder size of 50mm. However, 719 liters/hour is somewhat below the needed capacity. Therefore, looking down column 3 the next greatest capacity is 984 liters/hour which is sufficient to supply community needs. A pipe cylinder of 57mm would be needed for this windmill as shown in column 1.

Now the exact size of the windmill fan can be determined. Columns 4-9 represent the height which water can be raised by a certain sized fan. In our example, water needs to be raised 30m. Look across the fourth row where the figure 984 liters/hour is located until a figure of 30 or greater is found. In column 5, the number 34m is found under a fan size of 2.4m. Therefore, a 2.4m diameter fan is needed. If a relatively high storage tank and friction requirements mean the water must be raised over 34m, the next largest diameter fan should be chosen.

Electric Pumping Systems

There are many combinations of electric pumps available and often the pump and motor come as a unit. There are two main methods of selecting electric pumps. One is to design the system and select the pump from manufacturers' catalogs. The other is to give the supplier complete details of the pumping conditions and have him determine the pump needed. The information needed to select an electric pump includes:

1. Quantity of water required.
2. Pumping head.
3. Type of power available, number of phases, and voltage type (AC or DC).
4. Size of well. If applicable, depth to water, drawdown, and production capability.
5. Special considerations such as limited pumping times and elevation above sea level.

Quantity of water required. Identify the number of people to be served and the type of system to be used. From this, estimate the total quantity of water needed.

Pumping head. Provide the elevation difference between the pump and the high point in the system and the head losses due to friction.

Type of power available. Determine what is available from the electric utility organization and any restrictions that may be placed on the use of the electricity. This is important because restrictions may limit the amount of power available and in some locations electricity may not be available 24 hours per day.

Size of well. If a well is to be used, its diameter, the depth to water, and the drawdown at the rate it is pumped are required.

Special considerations. These include such items as any operation limitations, pump controls desired, elevation of the water source above sea level, and other considerations which might influence pump size.

For flows in the range of .3-13 liters per second, pumps are readily available and can be selected directly from manufacturers' catalogs. In sizing the pump, an optimum pumping time is 10-12 hours. Pumping can be timed manually, by using a time clock or by using other types of pump controls. If the system is to be manually operated, the pumping rates must be based on the availability of an operator. In any case, the pumps should be sized for population increases expected over the next five years. The pump should meet the maximum daily water requirement supplemented by elevated storage. If no other information is available, use a factor for maximum daily use of twice the average use.

Calculating Pumping Requirements

The following example describes how to determine pumping requirements:

A pump is to be selected for a Level 3 system with distribution to every household in a village with a current population of 500 people. There are no commercial operations or institutions in the village and livestock will obtain water from a nearby stream. No growth is expected in the next five years. There is a dug well 20m deep with the static water level at 10m. Pumping tests show the well can produce 5 liters of water per second with a drawdown of 3m. Single phase, 120/230 volt AC electricity is available. Because of electric line size, the electric utility agency has limited motor size to 5 HP. The site is not favorable for use of a windmill and no water that could be delivered by gravity flow is available. The storage tank will be located on a hill 300m from the well and the top of the tank will be 20m above the top of the well.

It is always a good idea to draw a graphic representation of the information prior to designing a solution. This example is illustrated in Figure 2.

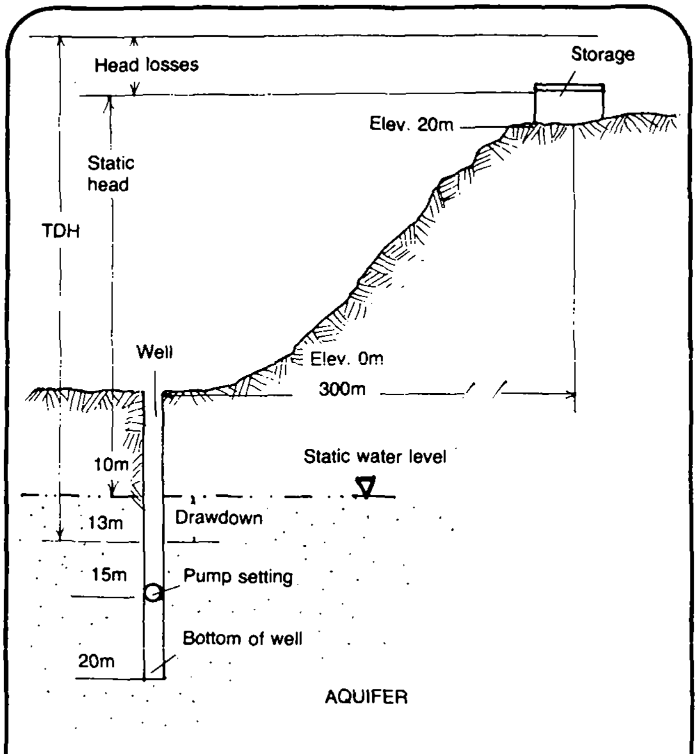

Figure 2. Graphical Representation of Data

Worksheet A shows the steps described below in sizing the system.

Step 1. Estimating present water needs.

Since the system is to serve only the village, the present estimated needs are 50000 liters per day.

Step 2. Estimating future water needs.

Worksheet A provides a way to estimate future water needs if other information is not known. In this case, future needs are 200000 liters of water per day.

Step 3. Estimating storage needs.

Convert liters to cubic meters to find the storage needed. In this example, storage is $200m^3$.

Step 4. Pump production requirements.

Pumps and motors are more efficient and last longer if they have relatively long interrupted pumping cycles. This also permits the use of lower yield wells. In this case, 4.6 liters per second are required for a 12 hour pumping cycle at the design life of 20 years.

In comparing the water available, 5 liters per second, with that required, 4.6 liters per second, the source appears to be sufficient for the design period of 20 years.

Step 5. Determine pipe size.

The selection of a pipe size is influenced by the cost of pumping. The larger the pipe size, the lower the pumping costs so larger pipe sizes should be selected where the cost of energy is high. Since energy requirements are directly related to the velocity of water in the pipe, the costs can be minimized by using a relatively slow velocity. A velocity of 0.75m per second is considered optimal and is used in this formula.

The exact calculated pipe size is 88mm. A pipe could be selected from available sizes of 80mm or 100mm. Friction losses could be calculated for each size and a total dynamic head (TDH) found. If the friction head were approximately 10 percent or less of the TDH for one or both pipes, then either would be suitable. In this case, 100mm pipe was chosen as being more readily available.

Step 6. Motor size.

The horsepower requirements were calculated based on needs for 20 years. It is better to size pumps for a shorter period as they only have an estimated life of five to ten years.

If a ten year design were used and the water required were estimated to be 50 percent of the 20 year use, the pump would be designed for a flow of 2.3 liters/second and the necessary HP would be:

$HP = \frac{2.3 \times 33.5}{76 \times .6}$ (recalculated for lower friction loss) =

$\frac{77.05}{45.6} = 1.68$ HP (use 1 3/4 HP)

Diesel oil or gasoline powered pumps. The information needed for a diesel oil or gasoline powered pump is the same as for an electric pump. The primary difference is in the power required. This will be greater due to inefficiencies in the drive mechanism to the pump. It is best to rely on the pump supplier for this data.

Worksheet A. Designing a Small Water Pumping System

1. Estimated present water needs in liters:

		Number of		Unit use		Total
Population	Persons	500	x	100	=	50,000
School	Students	____	x	____	=	____
Church	Attendees	____	x	____	=	____
Commerical		____	x	____	=	____
Large animals (cows)		____	x	____	=	____
Small animals (sheep)		____	x	____	=	____
Public watering fountains		____	x	____	=	____

Total present water needs = 50,000

2. Estimated future water use:
Use a 20 year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number. In addition, assume an increase in the rate of use of 2 times.

Population — Present use 50,000 x 4 = 200,000 liters

Institutions & public fountains — Present use ____ x 2 = ____ liters

Animals — Present use ____ x 1.25 = ____ liters

Total future water use = 200,000 liters/day

3. Storage reservoir:
Take the future water use and convert it to cubic meters

Reservoir = $\frac{200{,}000 \text{ liters}}{1000}$ = 200 m^3

4. Pump production requirements:
Determine the estimated pumping rate in liters/second

Total daily demand = $\frac{200{,}000 \text{ liters}}{43{,}200 \text{ second}}$ = 4.6 liters/second

If a pumping time is not given use 12 hours or 43200 seconds

5. Determine pipe size from pump to storage:

Pipe diameter d = 1.3 $\sqrt{m^3 \text{ per second}}$

= 1.3 $\sqrt{.0046 \text{ liters/second}}$ = 0.088 m

Convert meters to mm: 1000 x 0.088 m = 88 mm

Round mm calculated to available pipe size: d = 100 mm

(Note: This method of pipe sizing is based on limiting the velocity of water in the pipe to 0.75 m/second).

6. Motor size:
To calculate the pump size, first find the total dynamic head (TDH).

TDH = static head + friction losses

Friction losses
a. Determine head required to overcome friction.

Fitting	Number	x	Equivalent length	=	
Gate valve	1	x	2.7	=	2.7 m
Elbow, 90°	2	x	13.2	=	26.4 m
Elbow, 45°		x		=	m
Tee (straight through)		x		=	m
Tee (through side)		x		=	m
Swing check valve	1	x	38.2	=	38.2 m

Total equivalent length 67.3 m

Length of pipe from pump to storage = 300 m

Total pipe length = 367 m

Friction loss = $\frac{367}{1000}$ m x 4.2 head loss per 1000/m = 1.5 m

b. Determine static head
Static head = elevation at top of storage - pump elevation
= −13 m − 20 m = 33 m

c. TDH = a+b = Friction loss + static head = 1.5 + 33 = 34.5 m

d. Horsepower requirements:

Horsepower = $\frac{Q \times H}{76\ e}$

Q = Flow in liters/second
H = System head in meters
76 = Constant
e = Pump efficiency

Horsepower = $\frac{4.6 \text{ liters/second}}{76 \times e}$ x 34.5 meters = 3.48 HP

Round to nearest available motor size = 3.5 HP

If the efficiency is unknown, assume 60 percent, 0.6.

Notes

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Designing a Transmission Main
Technical Note No. RWS. 4.D.3

A water system has several component parts: a source, a transmission delivery line from the source to a point of use or storage, a transmission main from the point of storage to points of use, and the points of use such as service lines or public/communal watering places. Figure 1 shows the parts of a transmission system. Designing a transmission main requires the assistance of an experienced engineer. This technical note only explains the basic steps involved in design.

The design of a delivery line from source to storage is discussed here, in "Determining Pumping Requirements," RWS.4.D.2, for a source using pumps, and in "Designing a System of Gravity Flow," RWS.4.D.1, for water which can be delivered by gravity. The design of distribution systems is covered in "Designing Community Distribution Systems," RWS.4.D.4.

Useful Definitions

GATE VALVE - The type of cutoff valve in a pipeline; when completely open, it provides a low resistance to straight line water flow.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

HEAD LOSS - The head required to overcome friction.

PLAN VIEW - A drawing of a water system, water line or other part of a system as if one were looking down on it.

PROFILE - A cross-sectional view of the route along a water line or pipe.

RESIDUAL HEAD - The head available after all losses are subtracted; also known as dynamic or working head.

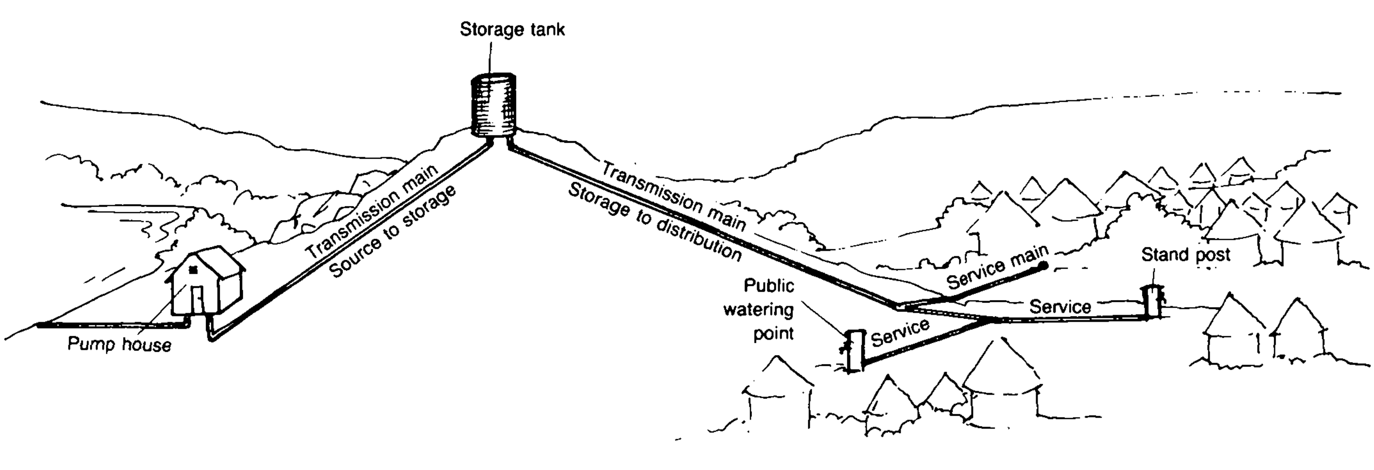

Figure 1. Elements of a Transmission System

There is a different set of factors in the design of a transmission line from the source to storage then from storage to point of use. This difference is in the time in which a quantity of water must be delivered. The transmission line to storage can be designed to provide water for a day's use over a period of several hours to a full 24 hours. This is because the storage tank equalizes the demand for water. The transmission line from the storage tank to the points of use must be sized to carry the instantaneous flow needed at any point in time.

Steps in Design

The first step in designing a transmission main is to obtain a map which shows elevations, obstructions and distances for the area to be served. A typical map is shown in Figure 2. From this, a profile map which identifies the slope of the land should be drawn. Figure 3 is an example of a profile map. This information is identical to that required to design a delivery pipe.

The next step is to estimate the maximum flow demand that the pipe will be expected to carry at any point in time. For transmission from the source to storage, the quantity required over a full day can be figured using Worksheet A. For transmission from storage to distribution, estimate the number of points of use and the expected quantity of water to be used at each point at any given time. This may include a public watering point or points, individual house connections, or both. Table 1 gives estimates of peak demand for individual services. The size of the transmission main usually does not change in a rural distribution system until at least the first point of use. When individual services are taken from a water line, the line then becomes part of the water distribution system rather than a transmission main. A line can serve as a transmission main and a distribution system line when the point of storage is beyond the points of use as shown in Figure 4. Water flows to the tank during low demand periods and flows from the tank to help meet peak demand.

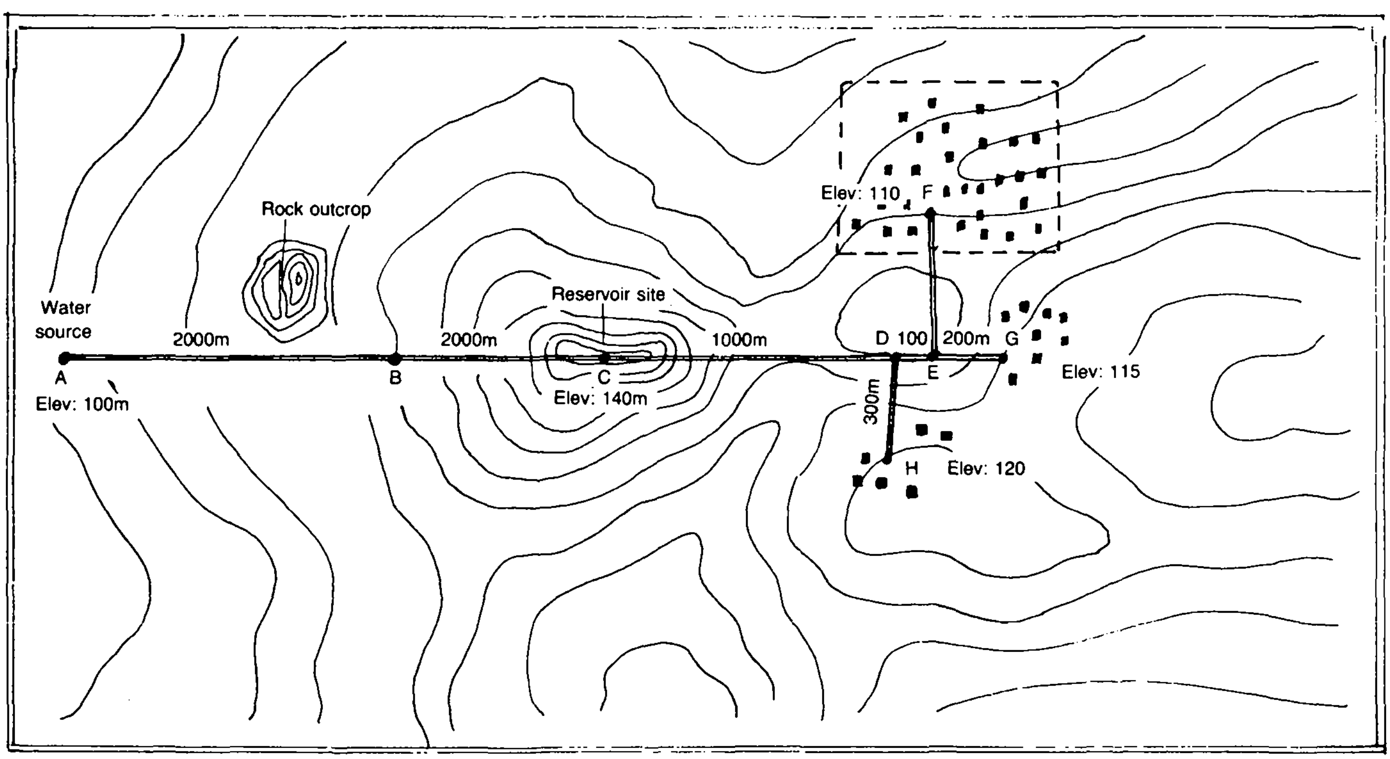

Figure 2. Location Map

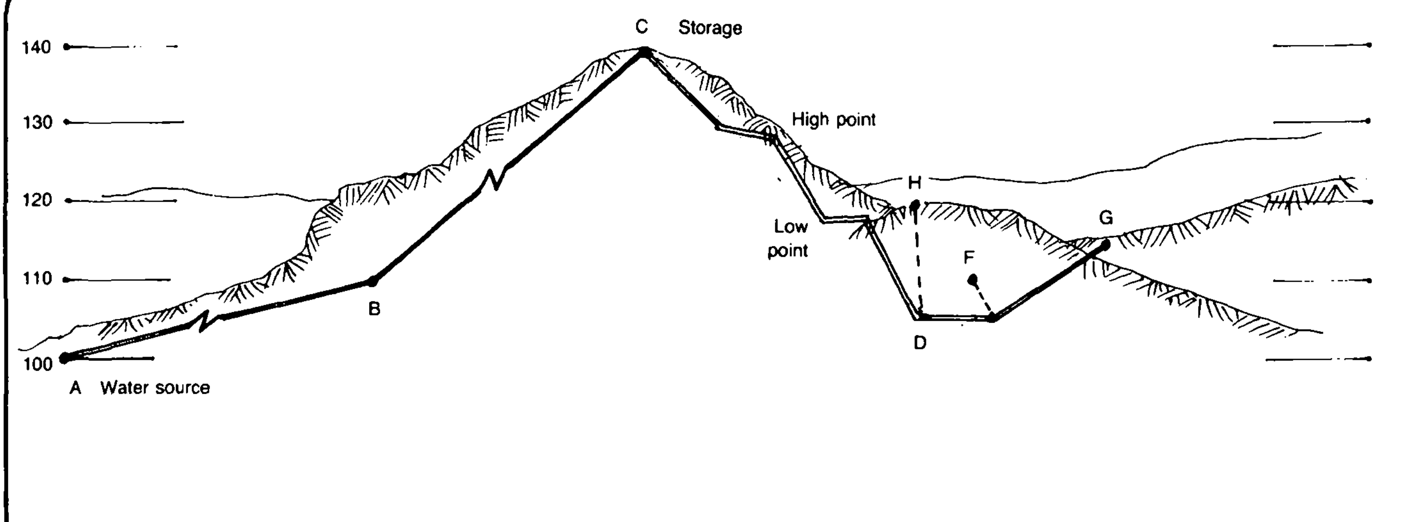

Figure 3. Profile Map

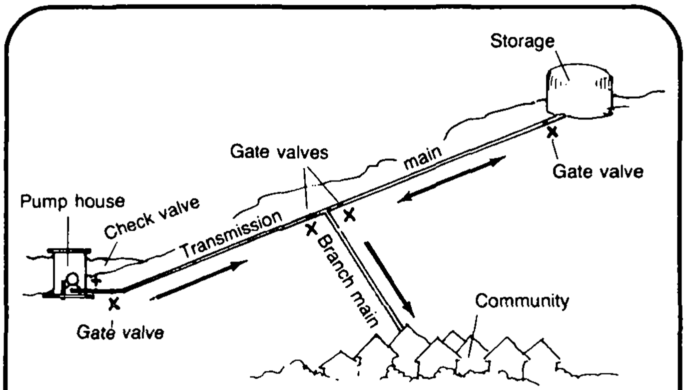

Figure 4. Alternative Piping System

Design Examples

Examples follow for designing a water transmission line from a pump to the storage site and from the storage site to a point of use. For this example, the area to be served includes two small clusters of homes that will be provided public watering points and a group of 30 homes that are to receive individual services. These are located as shown in Figure 2 and the profile is shown in Figure 3. The first cluster of homes has a population of 40 people and the second cluster, a population of 80 people. There are 200 people living in the 30 homes to be provided individual services. These are the only services to be provided.

The transmission line from source to storage is sized as shown in Worksheet A.

First, present and future needs are estimated. Then a flow rate is determined by assuming a pumping time, a pipe size is selected as shown in item 5 on Worksheet A, and the head loss is found as shown in item 6. This will be used later to size a pump. The pipe size needed is 80mm for a flow of 1.9 l/sec.

Next, the size of the transmission line from the storage tank to the point of use is determined. This pipe must be sized, see Table 2, based on the water demand at any point in time rather than on a constant flow as would be found in the line from source to storage. The step by step design is shown in Worksheet B and includes:

1. Estimating the peak flow considering the present population.

2. Estimating future demand. This should be based on reasonable expectations which will vary from area to area.

3. Sizing the transmission line based on limiting the flow in the pipe to 0.75 liters/second. Flows of up to 1.5 liters/second can be used when elevation is not a major requirement.

Worksheet A. Designing Water Transmission Lines from Source to Storage

1. Estimated present water needs in liters

		Number of		Unit use		total
Population	Persons	320	x	50	=	16000
School	Students	____	x	____	=	____
Church	Attendees	____	x	____	=	____
Commercial		____	x	____	=	____
Large animals (cows)		____	x	____	=	____
Small animals (sheep)		____	x	____	=	____
Public watering fountains		____	x	____	=	____

Total present water needs = 16000

2. Estimated future water use:
Use a 20 year design life. If no better inforamtion is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number. In addition assume an increase in the rate of water use of 2 times the current amount.

Population Present use 1600 x 4 = 84,000 liters

Institutions & public fountains Present use ____ x 2 = ____ liters

Animals Present use ____ x 1.25 = ____ liters

Total future water use = 84,000 l/day

3. Storage reservoir:
Use the future use and convert to m^3

Reservoir = $\frac{84,000}{1000}$ liters = 84 m^3

4. Pump production requirements:
Determine the estimated pumping rate in liters/second (l/s). If a pumping time is not given, use 12 hours.

Q l/s = Total daily demand = $\frac{84,000 \text{ liters}}{43200 \text{ sec.}}$ = 1.94 l/sec

5. Determine pipe size from pump to storage:

Pipe diameter d = 1.3 $\sqrt{Q\ m^3}$ per second
= 1.3 $\sqrt{.0019}$ l/sec = .056 m

Convert meters to mm 1000 x .056 m = 56 mm

Round mm calculated to available pipe size d = 80 mm

(Note: this method of pipe sizing is based on limiting the velocity of water in the pipe to 0.75m/sec)

6. System head:
To calculate the head losses through the pipe selected, add the losses due to fittings to friction losses. Add these to find the total dynamic head (TDH). Use Table 2 and determine friction losses.

TDH = static head + friction losses

a. Determine head required to overcome friction. Equivalent length of pipe due to fittings (Table 2).

Fitting	No.	x	Equivalent Length		
Gate valve	____	x	____	=	____ m
Elbow, 90°	____	x	____	=	____ m
Elbow, 45°	____	x	____	=	____ m
Tee (straight through)	____	x	____	=	____ m
Tee (through side)	____	x	____	=	____ m
Swing check valve	____	x	____	=	____ m

Total equivalent length ____ m

Length of pipe from pump to storage = 4,000 m

Total pipe length = 4,000 m

Friction loss = $\frac{4000}{1000}$ m x 3.5 head loss per 1000/m = 14 m

b. Determine static head
Static head = elevation at top of storage - pump elevation
= 100 m - 150* m = 50 m

TDH = a+b = friction loss + static head = 14 + 50 = 64 m

*Assume tank 10m high

Worksheet B. Designing Water Transmission Line from Storage to Distribution

1. Design Flow - Present
   Line C to D

   Peak demand from homes with individual services

   No. of homes served 30

Range	Actual	x Demand in liters/second	Total
First	1	x 0.23	.023
2 to 10	9	x 0.08	.72
11 to 20	10	x 0.06	.60
21 to 30	10	x 0.06	.60
31 to 50		x 0.05	

Total 2.15

Peak demand from public watering fountains

Number of faucets		Demand per faucet in liters/second	Total
1 to 6	3	x 0.23	0.69
7 to 9		x 0.19	
10 to 12		x 0.17	

Total 0.69

Peak demand from other points of use

Facility	Number of fixtures		Demand in liters/second	Total
Schools		x	0.23	
Religious		x	0.23	
Commerical		x	0.23	
Industrial*		x	varies	
Fire*		x	varies	
Animal*		x	varies	

Total 0

*Normally not included in rural system.

Total peak demand 2.84 l/sec.

2. Estimated water use - Future
   Use a 20 year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number.

   Population Present use 2.84 x 2 = 5.78 l/sec.

   Institutions & public fountains Present use ____ x 2 = ____ l/sec.

   Animals Present use ____ x 1.25 = ____ l/sec.

   Total future water use = 5.78 008 l/sec.

3. Determine transmission line diameter for each section of pipe being considered and tabulate in section 5. Table 3 solves this formula for a range of flows.

   Line C to D

   Pipe diameter d = 1.3/Q m^3 per second
   = 1.3/.00___ l/sec. = ____ m

   Convert meters to mm 1000 x ____ m = ____ mm

   Round mm calculated to available pipe size d = 100 mm

   (Note: This method of pipe sizing is based on limiting the velocity of water in the pipe to 0.75m/sec)

4. Head requirements:
   To calculate the head required, first find the total dynamic head (TDH). Use Table 2 to determine friction losses. Do this for each section of pipe being considered.

Worksheet B. Designing Water Transmission Line from Storage to Distribution (continued)

TDH = static head + friction losses

Friction Losses

a. Detemine head require to overcome friction.
Equivalent length of pipe due to fittings* (Table 2)

Fitting	No.	x Equivalent length		
Gate valve	____	x ____	=	____m
Elbow, 90°	____	x ____	=	____m
Elbow, 45°	____	x ____	=	____m
Tee (straight through)	____	x ____	=	____m
Tee (through side)	____	x ____	=	____m
Swing check valve	____	x ____	=	____m

Total equivalent length ____m   92%

b. Length of pipe from C to D = 1000 m

c. Total pipe length = a + b = 100 m

Friction loss = 1000 m / 1000 x 7 head loss pe 1000/m = 7 m

*Note: When pipelines exceed 500m, these losses are relatively small and can usually be ignored.

5. Tabulate results of first 4 steps for each length and branch.

Line	1 & 2 Flow 1/sec	3 Pipe Size	4c Length m (x 1000)	4d Head loss 1000m (HL)	Elevation difference (EL)	Total required (HL-EL)
Branch 1						
C to D	6	100	1	7	-35	
____ to ____						
____ to ____						
____ to ____						
____ to ____						
			Branch Total ---	7	-35	-28 m
Branch ____						
____ to ____						
____ to ____						
____ to ____						
____ to ____						
____ to ____						
			Branch Total ---			
Branch ____						
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____ to ____						
			Banch Total			
Branch ____						
____ to ____						
____ to ____						
____ to ____						
____ to ____						
____ to ____						
			Branch Total			

Table 1. Peak Flows for Single Hydrant and Full Facilities in Liters Per Second

Number of homes	Single Hydrant	Full Facilities	Number of homes	Single Hydrant	Full Facilities
1	0.23	1.0	91-100	.03	.12
2-10	0.08	.32	101-125	.03	.11
11-20	0.06	0.25	126-150	0.03	0.10
21-30	0.06	0.24	151-175	0.02	0.09
31-40	0.05	0.21	176-200	0.02	0.08
41-50	0.05	0.20	201-300	0.02	0.07
51-60	0.05	0.19	301-400	0.02	0.06
61-70	0.04	0.16	401-500	0.01	0.05
71-80	0.04	0.14	501-750	0.01	0.04
81-90	0.03	0.13	751-1000	0.01	0.03

Table 2. Pipe Sizes Based on Limiting Velocities in the Pipe to 0.75 and 1.5 meters/second

Range of Flow (l/sec)	Pipe Sized Based a Velocity of 0.75 m/sec*	Range of Flow (l/sec)	Pipe Size Based on Velocity of 1.5 m/sec*
0.1-0.6	30mm	0.1-1.3	30mm
0.7-1.0	40mm	1.4-2.2	40mm
1.0-1.5	50mm	2.3-3.5	50mm
1.6-3.9	80mm	3.6-8.9	80mm
4.0-6.0	100mm	9.0-13.8	100mm
6.1-14.0	150mm	13.9-31.0	150mm

*Formula for determining pipe size:

Flow of 0.75 m/sec. Diameter = 1.3/Q
Flow of 1.5 m/sec. Diameter = 0.85/Q

Table 3. Friction Losses in Fittings Equivalent Length of Straight Pipe, Meters

Size mm	30	40	50	80	100
Gate valve-open	0.4	0.4	0.5	0.6	0.8
Elbow, 90°	2.0	2.3	2.6	3.4	4.0
Elbow, 45°	0.5	0.7	0.9	1.2	1.7
Tee (straight)	1.4	1.7	2.4	3.7	5.2
Tee (through side)	2.7	3.0	3.7	5.2	6.4
Check valve	4.0	4.6	5.8	8.3	11.6

4. Determining head losses from these flows. This must be done so that the elevation of the storage tank can be calculated or checked.

5. Tabulating and comparing head losses. See Table 3.

Other Design Considerations

Considerations other than pipe size must be taken into account when designing a transmission line. These include high and low points along the line and valving to facilitate operation and maintenance. Even when a positive pressure is maintained by providing for a residual head, it is possible for air to collect at high points in a line. A combination vacuum and air release valve should therefore be installed at the top of each rise as shown in Figures 5 and 6. Low points in the line should be equipped with a drain valve so that any sediment that collects can be flushed out. This is very important if the source contains sand or fine sediment.

Gate valves, shown in Figure 7, should be placed in the line to permit system operation and repair. In a piped distribution network, valves are located so that portions of the system remain in operaton when other parts are shut down. See Figure 8. With a simple gravity flow system, a failure anywhere in the line will put the entire system out of operation so a large number of valves are not needed. One valve should be placed at the source and a second near the storage tank or point of use. Additional valves located at intervals of 1000m may be desirable for quicker access to turn the system off should a break occur or to isolate portions of the line or testing purposes.

Occasionally, the terrain is so steep that the water pressure would be too great for the pipe. In this case, pressure reducing valves may be required at appropriate locations. An alternative is to provide water storage tanks at the appropriate locations to relieve the pressure.

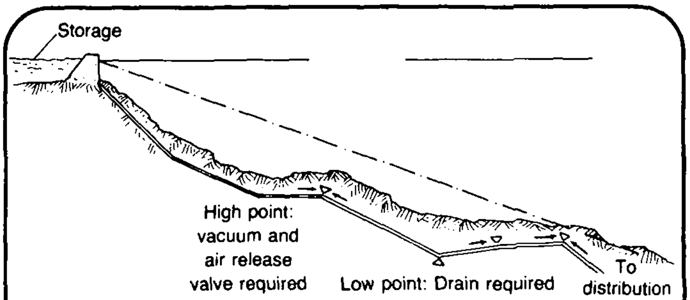

Figure 5. Placement of Vacuum and Air Release and Drain Valves

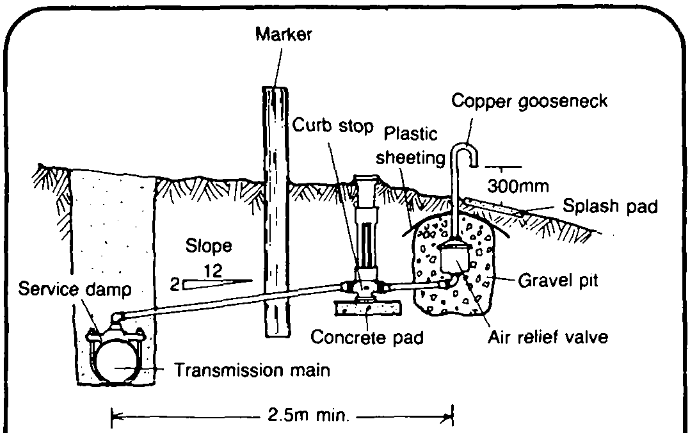

Figure 6. Typical Installation of Vacuum and Air Release Valves

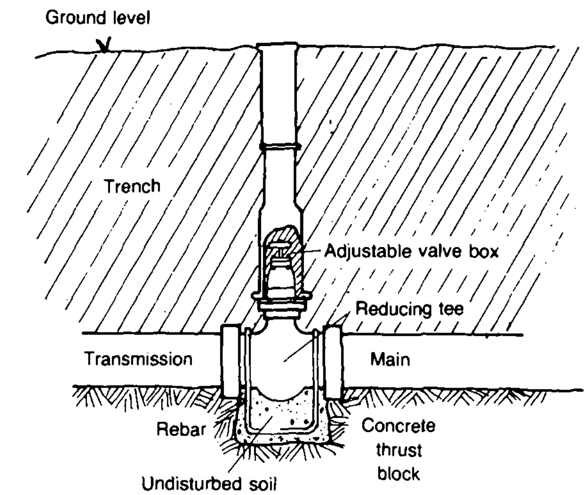

Figure 7. Typical Installation of Gate Valve

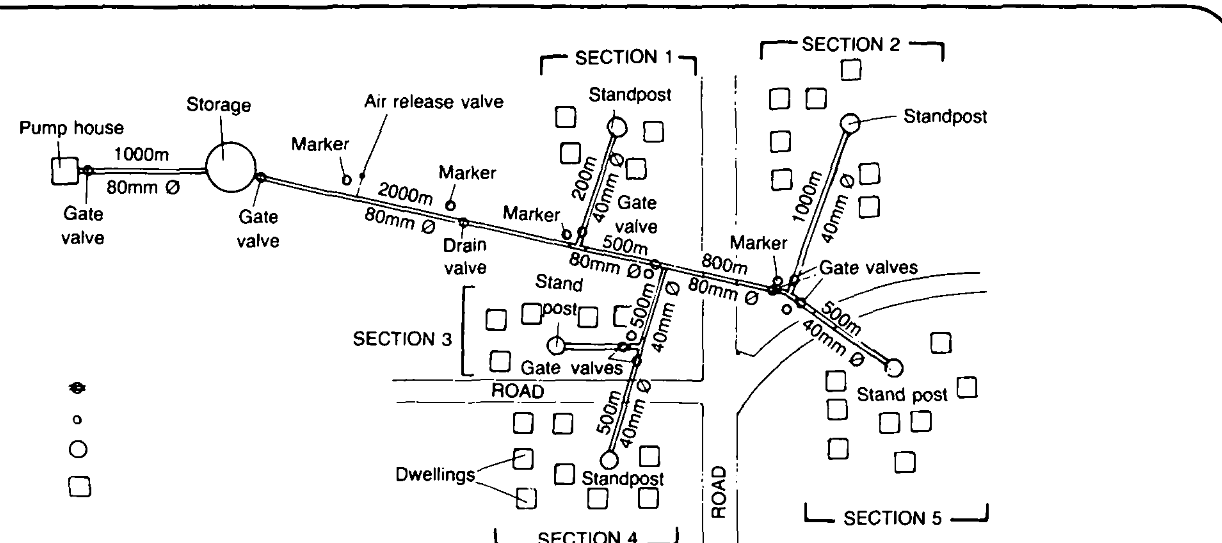

Figure 8. Design Map of Transmission Main and Distribution System

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Designing Community Distribution Systems
Technical Note No. RWS. 4.D.4

A community water distribution system technically begins where the transmission main ends as described in "Designing a Transmission Main," RWS.4.D.3. Basically, this is the point at which water begins to be used either at individual services or public standposts. Designing a distribution system requires the assistance of an experienced engineer. This technical note only explains the basic steps involved in design.

As is true of all aspects of water system design, a map of the area to be served and a profile along the proposed line are necessary. These are illustrated in Figure 1 and 2. Homes to be served and their elevations should be accurately located on the map. This is important in locating public watering points.

Rural water distribution systems generally consist of one or more main lines which do not interconnect at the end. This is because the lines are generally far apart. In larger communities, the ends of the lines are "looped", or connected to one another, to keep the water in the end of the lines from becoming stagnant and to allow it to flow from more than one direction. Looping the lines provides more flexibility in operation and maintenance.

Looping should always be considered if the layout of the community is such that it is feasible.

The design of a community water system serving public standposts should follow certain standards. These include a minimum of one tap for each 50 users. Up to 300 people can be served by each standpost if sufficient taps are added. Figure 3 shows a single tap standpost and Figure 4 shows a standpost with multiple taps. Public watering points should be located within 200m of each household or up to 500m in sparsely populated areas. Each faucet should be designed to provide from 0.23-0.03 liters/second. Static

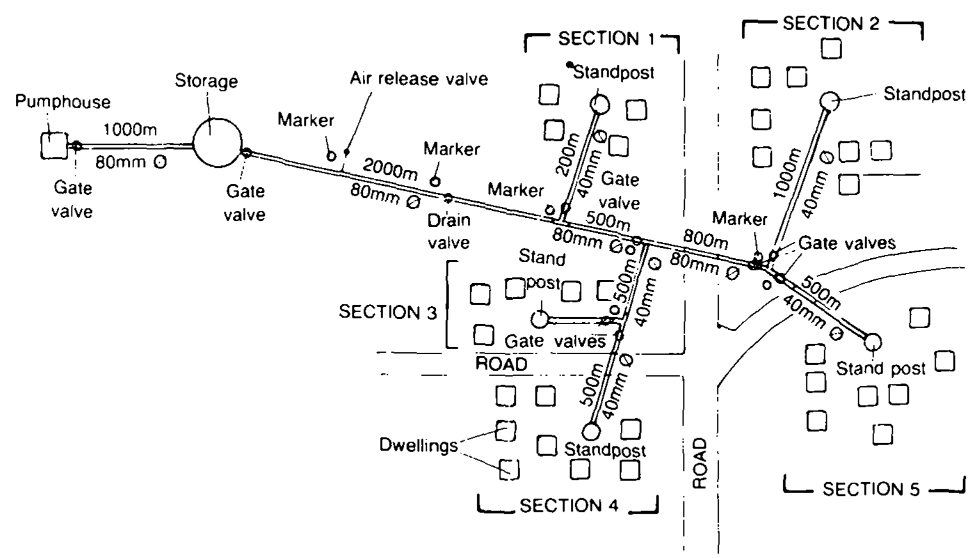

Figure 1. Design Map of Transmission Main and Distribution System

water pressure should be a minimum of 7m. Maximum water pressure should be less than 15-20m due to increased problems of leakage and wastage under higher pressures. Community standposts should be designed so that rain and wastewater drains away from the area and are not allowed to stand. Spigots or faucets are often leaky and easily broken. They should be designed for easy repair and replacement.

Design Example

Assume that a community distribution system using Figure 1 as the layout is being designed. While the population is relatively scattered, there are groupings of homes which can be served with public watering points. As shown on the map, there are five sections of 5, 9, 7, 15 and 12 dwellings. The estimated population is seven people per house. No other services are planned.

Since the map and profile have already been prepared, the next step is to plan the number of faucets for each watering point and calculate the expected peak flow using the information given. This is shown in Table 1.

Table 1. Peak Flows for Public Watering Points

Section	Number of homes	People	Number of Faucets	Peak Flow Per Faucet liters/second	Total liters/second
1	5	35	1	0.23	0.23
2	9	63	2	0.23	0.46
3	7	49	1	0.23	0.23
4	15	105	3	0.23	0.69
5	12	84	2	0.23	0.46
					2.07

The pipelines can now be sized according to flow. Table 2 shows pipe sizes based on limiting the velocity of water in the pipeline to 0.75m per second or 1.5m per second. Each line should be sized individually and the head loss determined. This can be done tabular form as shown for this village in Table 3. Worksheet A shows step-by-step how to design a water transmission line from storage to distribution, including how to arrive at the information presented in Table 3.

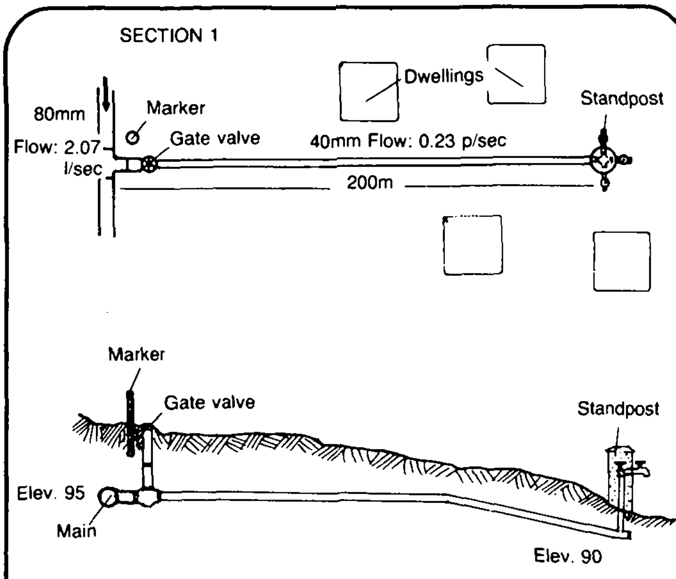

Figure 2. Plan and Profile of Typical Map Section

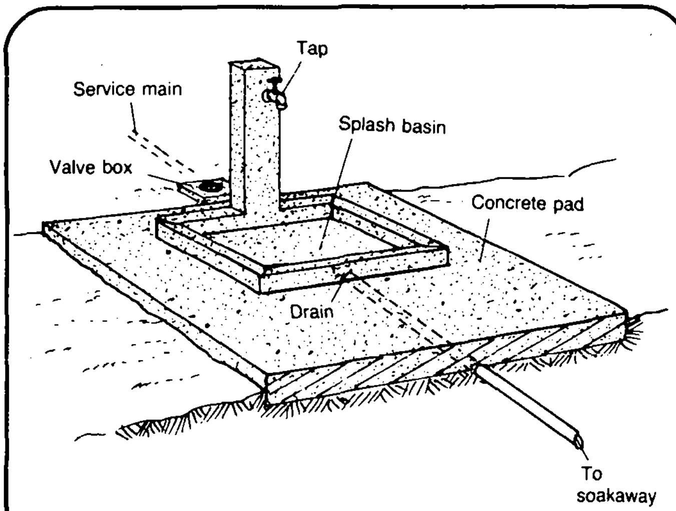

Figure 3. Standpost Design

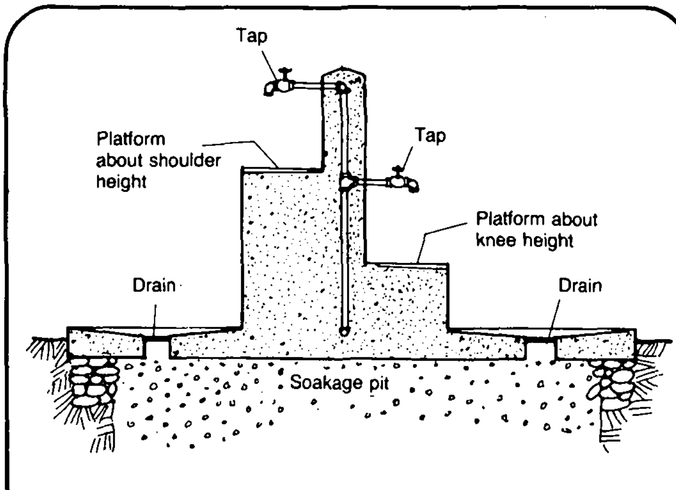

Figure 4. Standpost with Multiple Taps

Table 2. Pipe Sizes Based on Limiting Velocities in the Pipe to 0.75 and 1.5 meters/second

Range of Flow (1/sec)	Pipe Sized Based a Velocity of 0.75 m/sec*	Range of Flow (1/sec)	Pipe Size Based on Velocity of 1.5 m/sec*
0.1-0.6	30mm	0.1-1.3	30mm
0.7-1.0	40mm	1.4-2.2	40mm
1.0-1.5	50mm	2.3-3.5	50mm
1.6-3.9	80mm	3.6-8.9	80mm
4.0-6.0	100mm	9.0-13.8	100mm
6.1-14.0	150mm	13.9-31.0	150mm

*Formula for determining pipe size:

Flow of 0.75 m/sec. Diameter = 1.3/Q
Flow of 1.5 m/sec. Diameter = 0.85/Q

Table 3. Head Loss for Design Example

Section	Line	Flow	Size mm (1)	Head Loss (2)	Length (1000m)	Head Loss	Difference in Elevation	Additional Head Required Head Loss ± Elevation
1	AB BO	2.07 0.23	80mm 30mm	4m 4m	2 0.2	8m 0.8 8.8m	-10m	-1.2
2	AB DC CD DP	2.07 1.8 0.69 0.46	80mm 80mm 40mm 40	4m 3.2 16.0 7.3	2 0.5 0.2 1.0	8.0 1.6 3.2 7.3 20.1	-10	10.1
3	AB BC CD DE	2.07 1.8 0.69 0.23	80mm 80 40 30	4m 3.2 16.0 4	2 0.5 0.2 0.5	8.0 1.6 8.0 2.0 19.6	-15	4.6
4	AB BC CI IH	2.07 1.8 1.15 0.69	80mm 80 50 40	4m 3.2 10 15	2 0.5 0.5 0.5	8.0 1.6 5.0 7.5 22.1	-10	12.1
5	AB BC CI IJ	2.07 1.8 1.15 0.46	80mm 80 50 30	4m 3.2 10 18	2 0.5 0.5 0.5	8.0 1.6 5.0 9.0 23.6	-15	8.6

From Table 3, it can be determined that the bottom of the storage tank will have to be at least 12.1m above ground level in order to provide the design flows to the most critical spot, Section 4. Section 2 would have been critical, but the pipes line from D to F was increased in size to reduce head loss. In addition to the 12.1m elevation to allow flow, an additional 5m should be added to the tank height to maintain a positive head during times of peak flow.

If the bottom of the storage tank had to be located at elevation 100, then friction losses would have to be reduced by increasing pipe sizes, limiting flow with flow controlling devices, or both. A flow controlling device can be a partially closed valve or an orifice design to limit flow to a preset level.

It should be noted that Section 1 shows a negative head (-) needed. This indicates that the head losses are less than the available head.

Worksheet A. Designing Water Transmission Line from Storage to Distribution

1. Design Flow - Present
   Line _____ to _____

   Peak demand from homes with individual services

   No. of homes served _____

Range	Actual	x Demand in liters/second	Total
First	1	x 0.23	_____
2 to 10	_____	x 0.08	_____
11 to 20	_____	x 0.06	_____
21 to 30	_____	x 0.06	_____
31 to 50	_____	x 0.05	_____

Total _____

Peak demand from public watering fountains

Number of faucets			Demand per faucet in liters/second	Total
1 to 6	_____	x	0.23	_____
7 to 9	_____	x	0.19	_____
10 to 12	_____	x	0.17	_____

Total _____

Peak demand from other points of use

Facility	Number of fixtures		Demand in liters/second	Total
Schools	_____	x	0.23	_____
Religious	_____	x	0.23	_____
Commerical	_____	x	0.23	_____
Industrial*	_____	x	varies	_____
Fire*	_____	x	varies	_____
Animal*	_____	x	varies	_____

Total _____

*Normally not included in rural system.

Total instantaneous demand _____l/sec.

2. Estimated water use--Future
Use a 20 year design life. If no better information is available, use a population growth of 2 times the present population and an increase in animals of 1.25 times the present number.

Population Present use _____ x 2 = _____l/sec.

Institutions & public fountains Present use _____ x 2 = _____l/sec.

Animals Present use _____ x 1.25 = _____l/sec.

Total future water use = _____l/sec.

3. Determine transmission line diameter for each section of pipe being considered and tabulate in step 5. Table 3 solves this formula for a range of flows.

Line _____ to _____

Pipe diameter d = 1.3/Q m^3 per second
= 1.3/.00___ l/sec. = _____m

Convert meters to mm 1000 x _____m = _____mm

Round mm calculated to available pipe size d = _____mm

(Note: This method of pipe sizing is based on limiting the velocity of water the pipe to 0.75m/sec)

4. Head requirements:
To calculate the head required, first find the total dynamic head (TDH). Use Table 2 to determine friction losses. Do this for each section of pipe being considered.

TDH = static head + friction losses

Friction Losses,

a. Determine head require to overcome friction.
Equivalent length of pipe due to fittings* (Table 2)

Fitting	No.	x	Equivalent length	=	
Gate valve	_____	x	_____	=	_____m
Elbow, 90°	_____	x	_____	=	_____m
Elbow, 45°	_____	x	_____	=	_____m
Tee (straight through)	_____	x	_____	=	_____m
Tee (through side)	_____	x	_____	=	_____m
Swing check valve	_____	x	_____	=	_____m

Total equivalent length _____m

b. Length of pipe from _____ to _____ = _____m

c. Total pipe length = a + b = _____m

Friction loss = $\frac{\_\_\_\_\_ m}{1000}$ x _____ head loss per 1000/m = _____m

*Note: When pipelines exceed 500m, these losses are relatively small and can usually be ignored.

5. Tabulate results of first 4 steps for each length and branch.

Line	1 & 2 Flow l/sec	3 Pipe Size	4c Length m (x 1000)	4d Head loss 1000m (HL)	Elevation difference (EL)	Total required (HL-EL)
Branch _____						
_____ to _____	_____	_____	_____	_____	_____	
_____ to _____	_____	_____	_____	_____	_____	
_____ to _____	_____	_____	_____	_____	_____	
_____ to _____	_____	_____	_____	_____	_____	
_____ to _____	_____	_____	_____	_____	_____	
		Branch Total ---		_____	_____	_____
Branch _____						
_____ to _____	_____	_____	_____	_____	_____	_____
_____ to _____	_____	_____	_____	_____	_____	_____
_____ to _____	_____	_____	_____	_____	_____	_____
_____ to _____	_____	_____	_____	_____	_____	_____
_____ to _____	_____	_____	_____	_____	_____	_____
		Branch Total ---		_____	_____	_____

Worksheet A. Designing Water Transmission Line from Storage to Distribution (continued)

Branch ______

______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
			Branch Total	______	______	______

Branch ______

______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
			Banch Total	______	______	______

Branch ______

______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
______ to ______	______	______	______	______	______	
			Branch Total	______	______	______

Notes

Notes

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1982

Water for the World

Designing a Hydraulic Ram Pump

Technical Note No. RWS. 4.D.5

A hydraulic ram or impulse pump is a device which uses the energy of falling water to lift a lesser amount of water to a higher elevation than the source. See figure 1. There are only two moving parts, thus there is little to wear out. Hydraulic rams are relatively economical to purchase and install. One can be built with detailed plans and if properly installed, they will give many trouble-free years of service with no pumping costs. For these reasons, the hydraulic ram is an attractive solution where a large gravity flow exists. A ram should be considered when there is a source that can provide at least seven times more water than the ram is to pump and the water is, or can be made, free of trash and sand. There must be a site for the ram at least 0.5m below the water source and water must be needed at a level higher than the source.

Factors in Design

Before a ram can be selected, several design factors must be known. These are shown in Figure 1 and include:

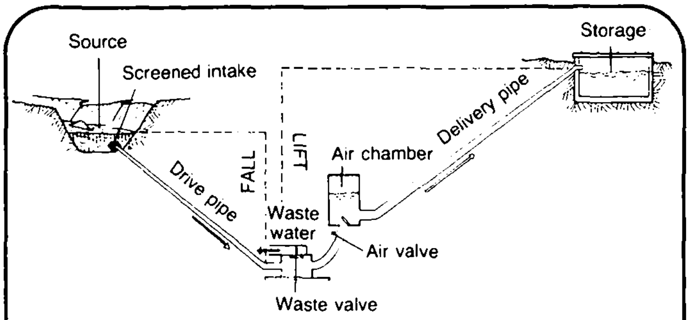

Figure 1. Hydraulic Ram Pump

1. The difference in height between the water source and the pump site (called vertical fall).

2. The difference in height between the pump site and the point of storage or use (lift).

3. The quantity (Q) of flow available from the source.

4. The quantity of water required.

5. The length of pipe from the source to the pump site (called the drive pipe).

6. The length of pipe from the pump to the storage site (called the delivery pipe).

Once this information has been obtained, a calculation can be made to see if the amount of water needed can be supplied by a ram. The formula is:

$$D = \frac{S \times F \times e}{L}$$

Where:

D = amount delivered in liters per 24 hours
S = quantity of water supplied in liters per minute
F = the fall or height of the source above the ram in meters
e = the efficiency of the ram (for commerical models use .66, for home built use .33 unless otherwise indicated)
L = the lift height of the point of use above the ram in meters

Table 1 solves this formula for rams with efficiencies of 66 percent, a supply of 1 liter per minute, and with the working fall and lift shown in the table. For supplies greater than 1 liter/minute, simply multiply by the number of liters supplied.

Components of Hydraulic Ram

A hydraulic ram installation consists of a supply, a drive pipe, the ram, a supply line and usually a storage tank. These are shown in Figure 1. Each of these component parts is discussed below:

Table 1. Ram Performance Data for a Supply of 1 liter/mintue Liters Delivered Over 24 Hours

Working Fall (meters)	Lift - Vertical height to which water is raised above the ram (meters)											
	5	7.5	10	15	20	30	40	50	60	80	100	125
1.0	144	77	65	33	29	19.5	12.5					
1.5		135	96.5	70	54	36	19	15				
2.0		220	156	105	79	53	33	25	19.5	12.5		
2.5		280	200	125	100	66	40.5	32.5	24	15.5	12	
3.0			260	180	130	87	65	51	40	27	17.5	12
3.5				215	150	100	75	60	46	31.5	20	14
4.0				255	173	115	86	69	53	36	23	16
5.0				310	236	155	118	94	71.5	50	36	23
6.0					282	185	140	112	93.5	64.5	47.5	34.5
7.0						216	163	130	109	82	60	48
8.0							187	149	125	94	69	55
9.0							212	168	140	105	84	62
10.0							245	187	156	117	93	69
12.0							295	225	187	140	113	83
14.0								265	218	167	132	97
16.0									250	187	150	110
18.0									280	210	169	124
20.0										237	188	140

Supply. The intake must be designed to keep trash and sand out of the supply since these can plug up the ram. If the water is not naturally free of these materials, the intake should be screened or a settling basin provided. When the source is remote from the ram site, the supply line can be designed to conduct the water to a drive pipe as shown in Figure 2. The supply line, if needed, should be at least one pipe diameter larger than the drive pipe.

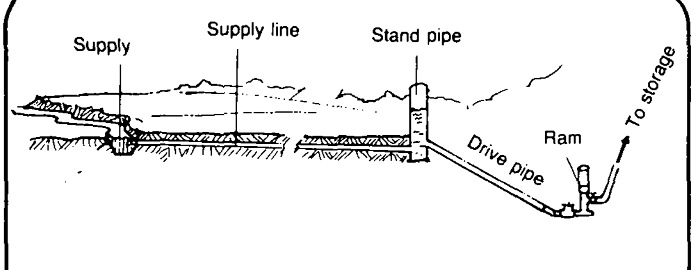

Figure 2. Ram Pump Remote from Source

Drive pipe. The drive pipe must be made of a non-flexible material for maximum efficiency. This is usually galvanized iron pipe, although other materials cased in concrete will work. In order to reduce head loss due to friction, the length of the pipe divided by the diameter of the pipe should be within the range of 150-1000. Table 2 shows the minimum and maximum pipe lengths for various pipe sizes.

Table 2. Range of Drive Pipe Lengths for Various Pipe Diameters

	Length	
Drive Pipe Size (mm)	Minimum (m)	Maximum (m)
13	2	13
20	3	20
25	4	25
30	4.5	30
40	6	40
50	7.5	50
80	12	80
100	15	100

The drive pipe diameter is usually chosen based on the size of the ram and the manufacturer's recommendations as shown in Table 3. The length is four to six times the vertical fall.

Table 3. Drive Pipe Diameters by Hydram Manufacturer's Size Number

Hydram Size	1	2	3	3½	4	5	6
Pipe Size (mm)	32	38	51	63.5	76'	101	127

Ram. Rams can be constructed using commercially available check valves or by fabricating check valves. They are also available as manufactured units in various sizes and pumping capacities. Rams can be used in tandem to pump water if one ram is not large enough to supply the need. Each ram must have its own drive pipe, but all can pump through a common delivery pipe as shown in Figure 3. In installing the ram, it is important that it be level, securely attached to an immovable base, preferably concrete, and that the waste-water be drained away. The pump cannot operate when submerged. Since the ram usually operates on a 24-hour basis the size can be determined for delivery over a 24-hour period. Table 4 shows hydraulic ram capacities for one manufacturer's Hydrams.

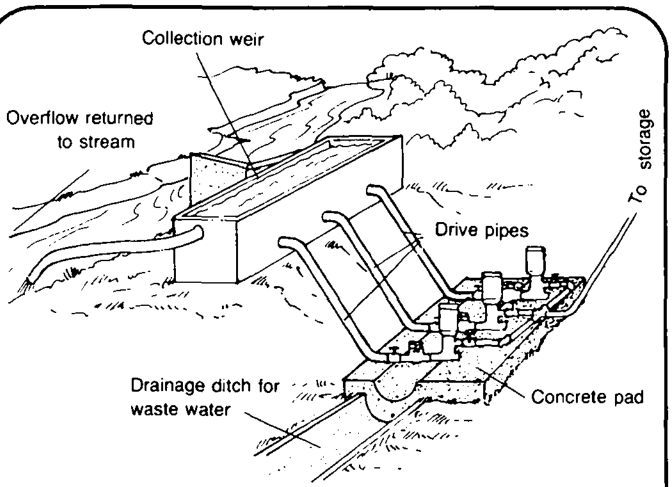

Figure 3. Multiple Rams with Common Delivery Pipe

Table 4. Hydram Capacity by Manufacturer's Size Number

		Size of Hydram								
		1	2	3	3½	4	5X	6X	5Y	6Y
Volume of Driving Water Required (liters per minute)	From	7	12	27	45	68	136	180	136	180
	To	16	25	55	96	137	270	410	270	410
Maximum Height to which Hydram will Pump Water (meters)		150	150	120	120	120	105	105	105	

Delivery Pipe. The delivery pipe can be of any material that can withstand the water pressure. The size of the line can be estimated using Table 5.

Table 5. Sizing the Delivery Pipe

Delivery Pipe size (mm)	Flow (liters/minute)
30	6-36
40	37-60
50	61-90
80	91-234
100	235-360

Storage Tank. This is located at a level to provide water to the point of use. The size is based on the maximum demand per day.

Sizing a Hydraulic Ram

A small community consists of 10 homes with a total of 60 people. There is a spring 10m lower than the village which drains to a wash which is 15m below the spring. The spring produces 30000 liters of water per day. There is a location for a ram on the bank of the wash. This site is 5m higher than the wash and 35m from the spring. A public standpost is planned for the village 200m from the ram site. The lift required to the top of the storage tank is 23m. The following are the steps in design.

Identify the necessary design factors:

1. Vertical fall is 10m.

2. Lift is 23m to top of storage tank.

3. Quantity of flow available equals 30000 liters per day divided by 1440 minutes per day or $\frac{30000}{1440} =$ 20.8 liters per minute.

4. The quantity of water required assuming 40 liters per day per person as maximum use is 60 people x 40 liters per day = 2400 liters per day.

$\frac{2400}{1440}$ = 1.66 liters per minute (use 2 liters per minute)

5. The length of the drive pipe is 35m.

6. The length of the delivery pipe is 200m.

The above data can be used to size the system. Using Table 1, for a fall of 10m and a lift of 80m, 117 liters can be pumped a day for each liter per minute supplied. Since 2400 liters per day is required, the number of liters per minute needed can be found by dividing 2400 by 117:

$\frac{2400}{117}$ = 20.5 liters per minute supply required.

From item 3 above, the supply available is 20.8 liters per minute so the source is sufficient.

Table 3 can now be used to select a ram size. The volume of driving water or supply needed is 20.5 liters per minute. From Table 4, a No. 2 Hydram requires from 12-25 liters per minute. A No. 2 Hydram can lift water to a maximum height of 250m according to Table 4. This will be adequate since the lift to the top of the storage tank is 23m. Thus, a No. 2 Hydram would be selected.

Table 3 shows that for a No. 2 Hydram, the minimum drive pipe diameter is 38mm. Table 2 indicates that the minimum and maximum length for a 40mm pipe the closest size to 38 is 6m-40m. Since the spring is 35m away, the length is all right. Table 5 can be used to select a delivery pipe 30mm in diameter which fits the supply needed, 20.5 liters per minute.

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1982

Water for the World

Installing Pipes

Technical Note No. RWS. 4.C.1

This technical note provides general information on installing water distribution systems using any type of piping material. It contains specific information on installation using the more common piping materials. The full useful life of trouble-free service from properly selected pipe materials can only be obtained if the pipes are installed in accordance with the manufacturer's instructions and standards of good practice.

Useful Definitions

BACKFILL - Material placed in the trench over the pipe.

BEDDING - Material in the trench on which the pipe is placed; it should be carefully selected and free of rocks, pieces of wood, and other debris.

CONTAMINATE - To make unclean by introducing an infectious (disease-causing) impurity such as bacteria.

DISINFECTION - Destruction of harmful microorganisms present in water through physical (such as boiling) or chemical (such as chlorination) means.

SELECT MATERIAL - Material that is free of rocks or organic material.

STRINGING - Placing pipe sections along one side of the route of the trench to be ready for laying.

Pre-Installation

Precautions must be taken in transporting pipe to the construction site and in storing it. Pipe should arrive on-site with parts that are easily damaged protected by the manufacturer. This could be nothing more than protective tape or a cap or threaded pipe ends or it could be paper wrapping to protect sensitive material from sunlight. Separating pipe by specially formed blocks of wood is also common. The protective packaging material should be left in place up to the time the pipe is installed. Manufacturer's instructions about handling and storing of pipe should be followed. This could involve such items as how to lift the pipe, how to protect the ends from damage, or how to store it. For example, most plastic pipe will be damaged if left in direct sunlight for long periods to time. Lengths of stored pipe should be supported at intermediate points so they will not bend, which could cause them to break or warp. Rubber gaskets should be stored in a cool dark place, out of the direct rays of the sun.

Installation

There are seven steps in installing pipe. These are trenching and stringing pipe, bedding, joining, thrust blocking, pressure testing, backfilling and disinfecting the system. Each step is discussed briefly.

<u>Trenching and Stringing Pipe</u>. As a general rule, do not excavate a trench too far ahead of laying the pipe. Stake the pipe lines and grades as shown in Figure 1 but only stake that portion of the pipeline that can be constructed in a few days. Avodiing long stretches of open trench will minimize the risk of flooding and caving and will reduce hazards that might cause accidents. Trenches should be no wider than necessary to permit workmen easy access to install the pipe. Not only do wide trenches require unnecessary digging, they will add more weight to backfill earth on the installed pipe. Figure 2 shows how to excavate a trench. Table 1 shows recommended trench widths at the top of the pipe.

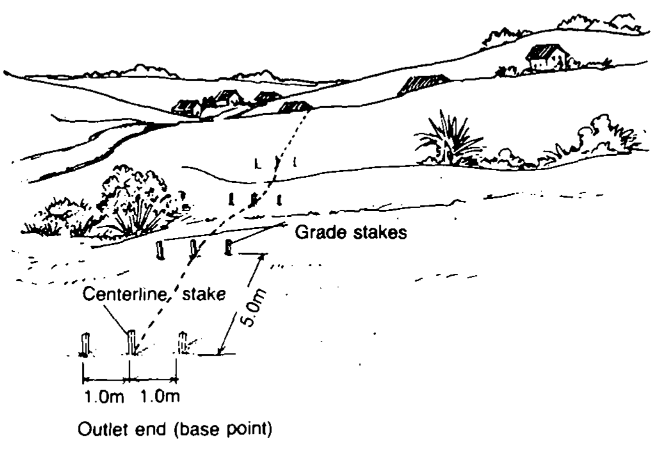

Figure 1. Centerline and Grade Stakes

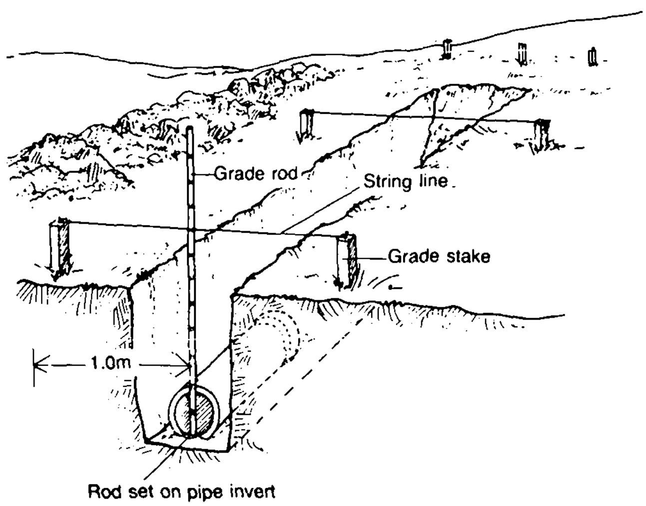

Figure 2. Excavating Trench

Table 1. Trench Width at Top Level of Pipe

Pipe size (mm)	Trench Width (cm)	
	Minimum	Maximum
30-50	15	45
80-100	45	70
150-200	50	80
250-300	60	90
350-400	75	105

Pipe must be buried deep enough to prevent freezing if that ever occurs and to protect it from surface activity, vehicle loads, and high temperatures caused by the sun. Normally a minimum depth cover of 60cm will provide adequate protection. If the trenches are too deep or the soil too unstable, caving may be a problem. If so, some form of sheeting and bracing must be used or the sides of the trench must be sloped. Sloping or widening should be done correctly as shown in Figure 3.

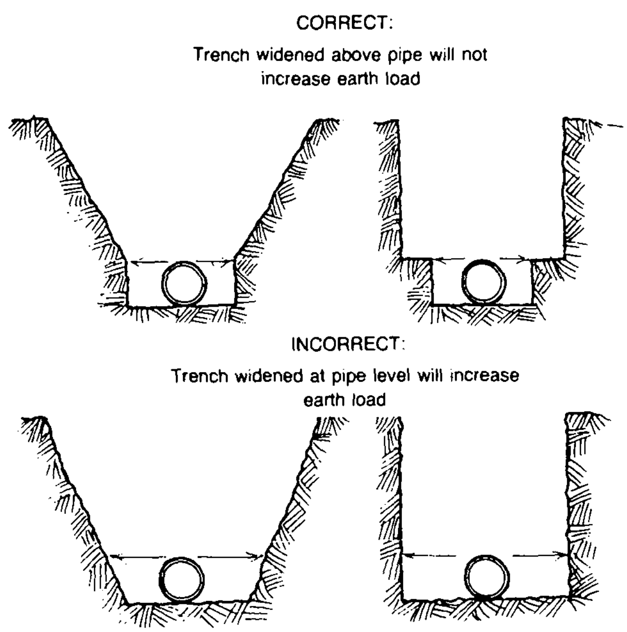

Figure 3. Sloping or Widening Trench

If rock is encountered, the trench will have to be dug deeper than the planned depth of the pipe and brought back to grade using material free from rocks. The pipe must not be laid on rock. Usually, overexcavating 50cm is recommended. Excavated material should be placed to one side of the trench so pipe may be "strung" close to the edge of the opposite side. This makes it easy to lower the pipe from the ground into the trench. Lightweight, small diameter plastic pipe may be assembled on the ground surface next to the trench and then lowered into the trench as a single long length. Heavier pipe should be handed down by two workers to two other workers as shown in Figure 4. Larger slip and mechanical coupled pipe must be assempled in the trench a length at a time. Where separate slip couplings are used, they should be put on one end of each pipe length above ground to reduce the amount of work that must be done in the trench.

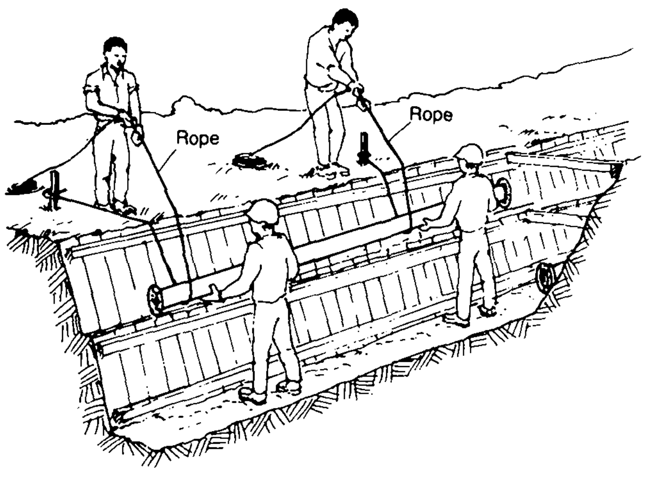

Figure 4. Lowering Heavy Pipe

Bedding. Most pipe materials need to be protected from direct contact with rocks that could be forced against the pipe and cause a facture. Most pipe should be uniformly supported along the underside so it will not have to "bridge" low spots. For these reasons, trench bottoms should be level, free of rocks and preferably of loose material that can easily conform to the shape of the pipe. At couplings and fittings, a small depression in the trench bottom should be made to ensure the pipe will not "bridge" from coupling to coupling. See Figure 5.

If the excavated material has rocks, a "select" material must be used to lay the pipe on a bed of soil and to back-fill the trench. Select material may be obtained by screening out the rocks or by bringing material from another location.

Joining. In joining pipe lengths and fittings, manufacturer's instructions should be followed. While they are no longer commonly used, pay close

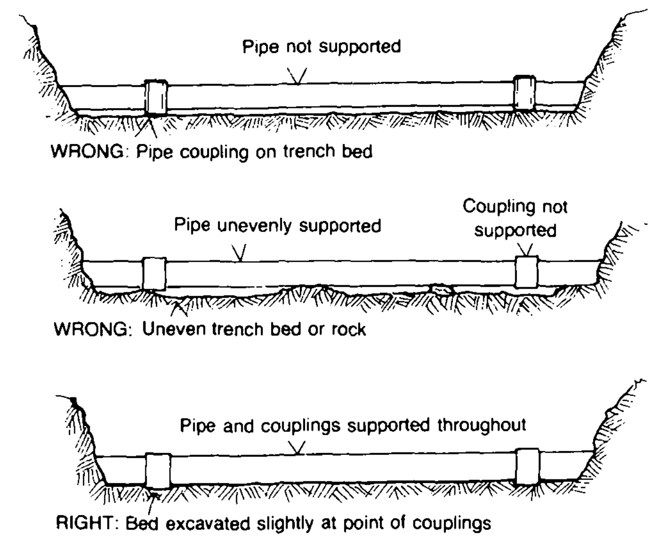

Figure 5. Prevention of Bridging

attention to the types of solvents or "glues" to be used on plastic pipes should you encounter them. They are not all the same. Gaskets used in various slip type couplings and mechanical joints may look similar, but they may not be interchangeable. Use the ones that were furnished with the pipe and fittings. Be sure pipe ends, gaskets, and couplings are clean before assembly. A few grains of sand under a gasket can result in a leak. Grease can prevent a plastic pipe solvent from sealing tightly. Keep the inside of the pipe as clean as possible while assembling. This will shorten the flushing time and lessen the chance of material plugging valves and small diameter water lines.

When assembling asbestos cement pipe, a light coating of special lubricant, supplied by the manufacturer, must be applied to the tapered end of the pipe. Do not use, common grease or other substitutes that could contaminate the water. A gasketed coupling can be pushed onto the pipe, or sections of pre-belled pipe can be pushed together, using a bar and wood block or a special lever type puller. See Figure 6.

Plastic pipe can be assembled using gasketed couplings or integral bell couplings as shown in Figure 7. Again a special lubricant is used, but the coupling can usually be installed by hand without the use of bars or other devices.

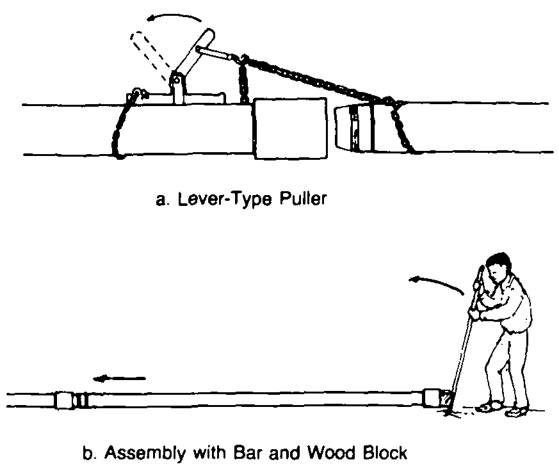

Figure 6. Jointing A/C Pipe

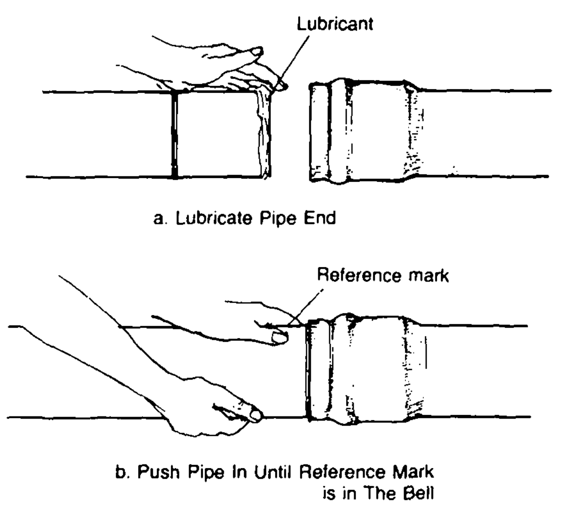

Figure 7. Joining Plastic Pipe

Thrust Blocking. Water under pressure in a pipe will not only exert a force against the sides of the pipe, but along its length as well. For this reason, joints must resist the force of being pulled apart. Thrust blocks are needed for all pipe material and joints, particularly when a slop coupling and gasket is used. Thrust blocks should be used at fittings, bends and pipe ends to prevent pipe movement due to water pressure. A thrust block consists of concrete that is placed between the fitting and the solid, undisturbed face of the trench.

The size of the thrust block is determined by the pipe size, type of fitting, water pressure, and soil stability. Manufacturer's literature should be consulted for design information. For most rural systems, it will be sufficient if a concrete block is poured which provides a full bearing surface to the fitting and extends to undisturbed earth. Typical placement of thrust blocks are shown in Figure 8.

Longitudinal forces can result from thermal expansion or contraction of pipe material. An extreme case may occur when polyethelyene pipe is installed on a very hot day and then filled with cold water. The force of contraction could pull joints apart. It is common, therefore, particularly for polyethelyene pipe, to "snake" the pipe in the trench so the force of contraction will merely straighten the pipe rather than cause joint failure. Lay the pipe in a slight wavy pattern, rather than straight. See Figure 9.

Pressure Testing. After a pipeline has been installed, but before completing of backfilling, the pipe should be tested for leaks. This can be done by filling the section to be tested with water under pressure and, after several hours, looking for a drop in pressure and/or leaks. When filling the lines with water, valves at the far ends should be opened to allow air to escape and then close when water begins to flow. It is desirable to raise the pressure in the pipe to 50 percent above the normal working level, but not above the rated strength of the pipe, by use of an auxiliary pump. This will show leaks that may occur at a later date when there are pressure surges in the line. Prior to pressure testing, it is essential that thrust blocks be installed and allowed to harden. The line should be partially backfilled, leaving the joints exposed. This will prevent the pipeline from moving under the pressure from the water.

Backfilling. Proper backfilling is essential in order to protect the pipe, prevent erosion, and avoid too much settlement of the filled trench. Dry soil, that is free of rocks and organic material should be used. If the excavated materials is not free of rocks, then a "select" material should be

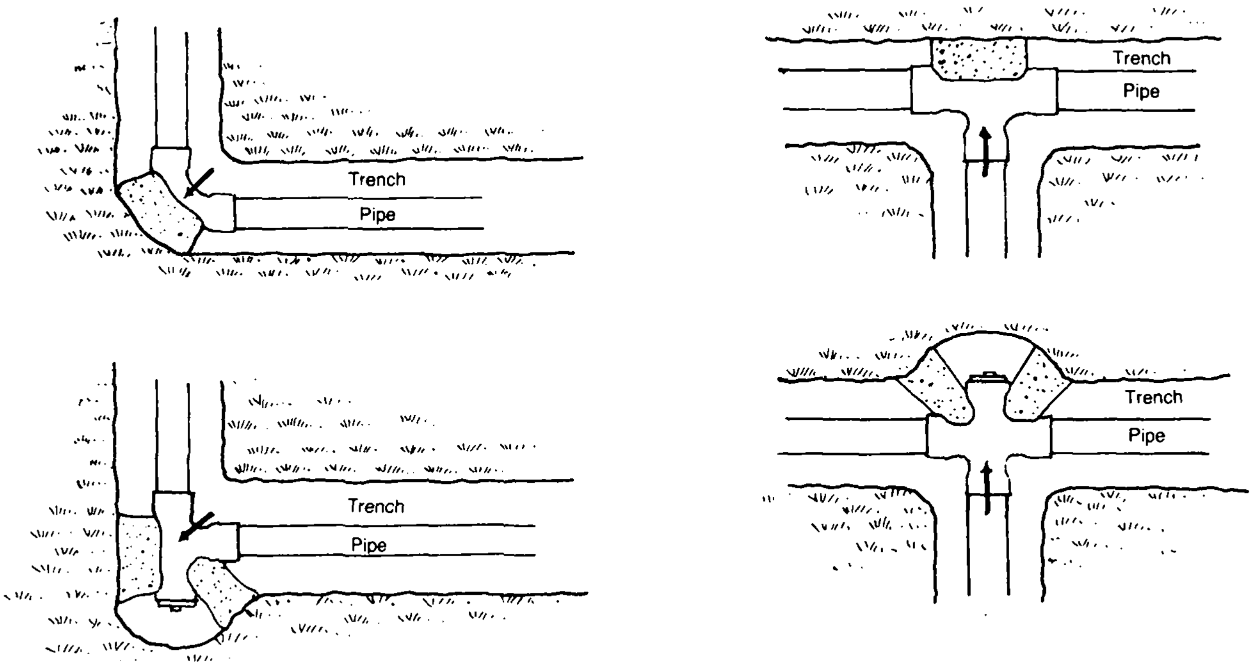

Figure 8. Examples of Thrust Blocking

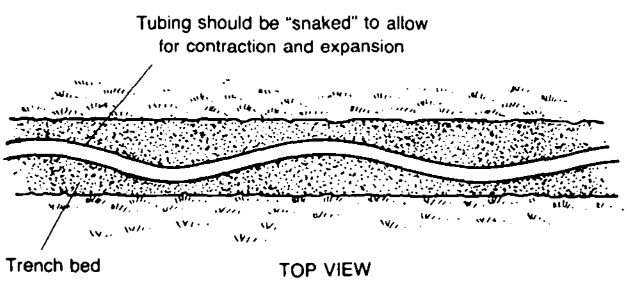

Figure 9. Installing Polyethelene Tubing

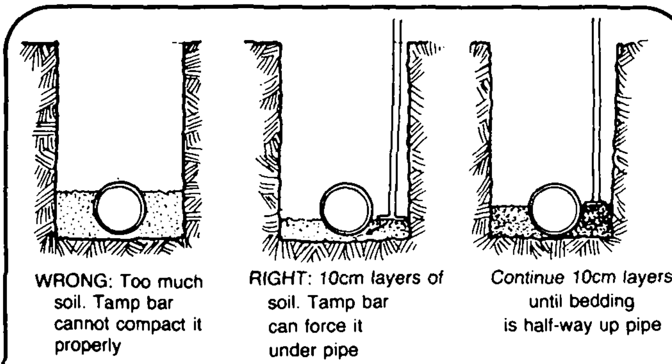

Figure 10. Backfilling the Trench

used. This can be obtained by screening out the rocks before backfilling or by ringing material from a nearby source. Sand or sandy loam is considered excellent for this purpose. A small amount of the backfill material should be placed on both sides of the pipe and tamped into place. This process is continued in layers of about 10-12cm until there is about 30cm of fill over the top of the pipe. Backfilling can then be completed with common excavated material and the surface left mounded to allow for eventual settlement. Figure 10 shows right and wrong ways of backfilling.

Disinfecting the System. When installation has been completed, the entire system should be flushed with clean water to remove dirt and sediment and then disinfected. This can be done by filling the system with water containing at least 50 mg/liter of chlorine and leaving it in the main for 24 hours. A properly adjusted hypochlorite solution can be injected into the main with a hypochlorinator. However, on a small system with a storage tank, add chlorine directly to the tank and then let it flow into the system. Table 2 can be used to calculate the quantity of chlorine compounds to add to yield of 50 mg/liter solution.

Table 2. Amount of Chlorine Needed to Produce a 50 mg/liter Solution

Chlorine Compound	Amount per 1000 liters of water
5% Chlorine bleach	1 liter
12-17% Chlorine solution	.3 liter
25-30% Chlorine powder	200 g
65-75% Chlorine powder	75 g

During the 24 hour period of time, valves and hydrants should be opened to assure the chlorine solution reaches all surfaces. Following this period, no less than 25 mg/liter of chlorine residual should remain. The main should then be flushed and the bacteriological quality of the water checked at several points in the system.

Post Installation

Once a distribution system is installed, it should not be forgotten. Its location should be indentified with markers in the field and on "as-built" maps. This will help to prevent damage to the pipe from subsequent construction activities and to locate the pipe if it is necessary to repair or extend it. Pipelines in open country should be identified by posts or stone markers at bends, intersections, valves, and along the pipeline at 1000m intervals. In populated areas, these points can be identified in relation to their distance to three existing points, such as corners of buildings. An "as-built" drawing should be prepared showing the lines, the markers, the tie points, and the depth of bury. It is important that these be prepared as the pipe is being installed. Remember that a valve in the system is of no use if it cannot be located when needed.

Notes

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Installing Mechanical Pumping
Technical Note No. RWS. 4.C.2

Installing mechanical pumps for community water systems involves several considerations including protecting the pump and motor from vandalism and the weather, ensuring accessibility for operation, maintenance and replacement, minimizing potential contamination of the water supply, proper sizing and protection of electrical components, and providing pump controls and metering.

Both pump and motor should be protected from weather extremes. In areas where freezing occurs, supplemental heat may be needed. Usually this means that a pump house is required. Even if the pump is in the well and an underground discharge is used, pump controls are needed and the water should be metered. This will usually require a pump house or meter vault. Pumps should not be placed in pits due to the risk of flooding. See Figure 1. Earth can be mounded around a pump house for insulation as long as the floor of the pump house can be drained to ground level by gravity flow.

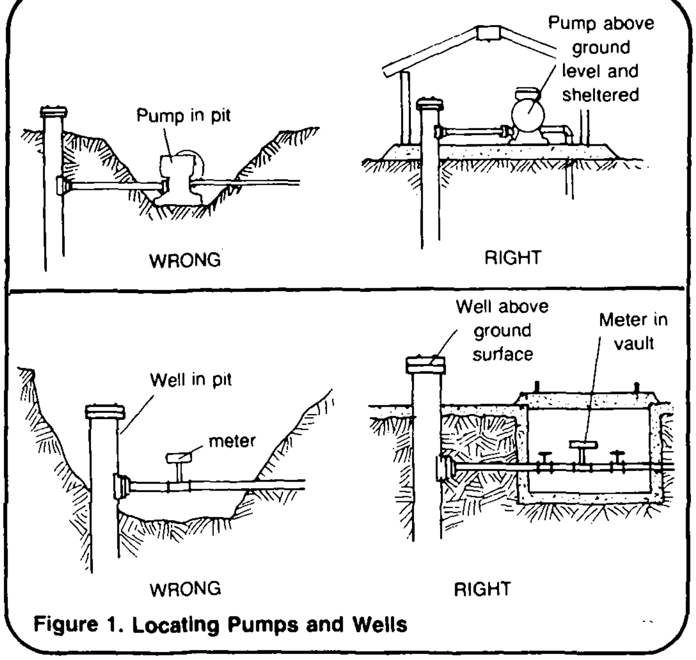

Figure 1. Locating Pumps and Wells

Useful Definitions

ALTERNATE OPERATION - In two-pump systems the pumps alternately operate except that when one pump cannot keep up with demand, both pumps operate at the same time.

CONTAMINATION - Introduction of harmful substances including organisms and chemicals to a water supply; these substances may cause illness or disability.

DROP PIPE - The pipe in the well connecting to the pump.

If the well is located inside the pump house, roof access will be needed so the drop pipe and/or the pump in the well can be removed. See Figure 2. For small units, the entire roof can be removed. Care must be taken to locate and size the doors so the pump and other equipment can be removed for repair or replacement. A vent is required to minimize excess moisture. For deep wells, a method to hoist the pipe and pump may have to be incorporated into the design.

Sizing and Protection of Electrical Components

The electric wire within the pump house should be enclosed in flexible cable or in a conduit. Care must be taken to use the correct size wire and fuses. Table 1 shows the correct sizes for motors of different horsepower. The electric meter should be as close to the pump as possible, preferably along with a main circuit breaker on the outside of the pump house.

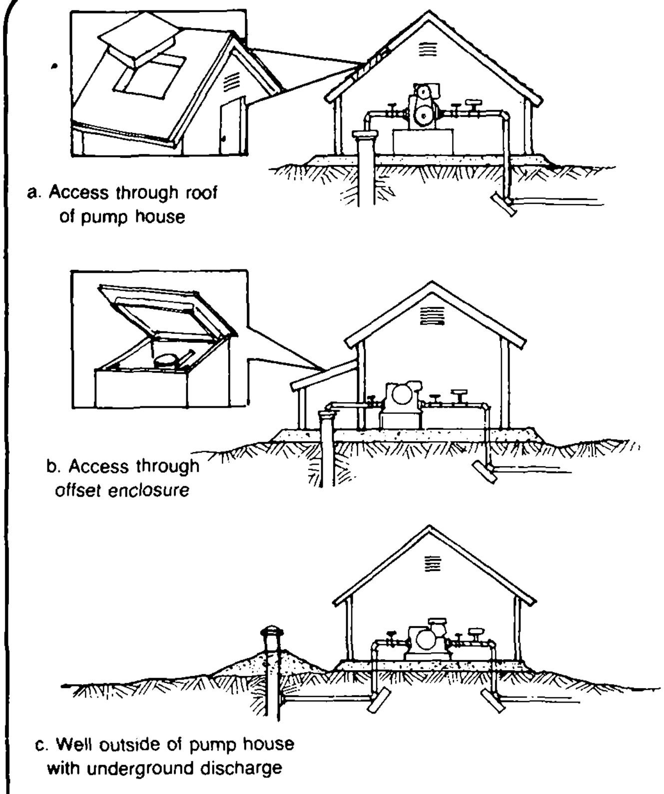

Figure 2. Providing Access to Well for Pump Removal

Although lightning surges are not common, they occasionally cause damage to a motor when thunderstorms are in an area. To protect against these surges, a lightning arrester should be installed either at the service entrance or at the switchbox. Care must be taken to install adequate grounding. This can be done by driving a ground rod into the earth with a copper wire connection at the entrance location.

Pump Controls

Pump motors must be turned on and off in accordance with water needs. This can be accomplished by a person controlling a switch, called manual operation; by a time clock; by pressure differences; or by high/low probes in the water. These controls are used to maintain the water level in a storage tank, the pressure in a system or to protect a pump from low water levels in a well or low flows which can cause a pump to burn out.

Table 1. Wire and Fuse Table
(From Service Entrance to Pump Motor or Control Box)

H.P.	Volts	Full Load Amps.	Max.* Fuse Size Amps.	**Minimum Wire Size of Rubber Insulated Copper Wire-A.W.G. Length Wire from Motor to Meter or Distribution Point-Meters									
				0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150
1/6 1/6	115 230	3.0 1.5	15 15	14 14	14 14	14 14	14 14	14 14	14 14	14 14	12 14	12 14	12 14
1/4 1/4	115 230	4.0 2.0	15 15	14 14	14 14	14 14	14 14	14 14	12 14	12 14	12 14	12 14	10 14
1/3 1/3	115 230	5.0 2.5	15 15	14 14	14 14	14 14	14 14	12 14	12 14	12 14	10 14	10 14	10 14
1/2 1/2	115 230	7.2 3.6	25 15	14 14	14 14	14 14	12 14	12 14	10 14	10 14	10 14	9 14	9 14
2/4 2/4	115 230	9.2 4.6	30 15	14 14	14 14	12 14	12 14	10 14	10 14	9 14	9 14	8 14	8 12
1 1	115 230	12.0 6.0	40 20	14 14	12 14	12 14	10 14	9 14	9 14	8 14	7 12	7 12	6 12
1½ 1½	115 230	16.0 8.0	50 25	14 14	12 14	10 14	9 14	8 14	7 12	7 12	6 12	5 10	5 10
2 2	115 230	20.0 10.0	60 30	14 14	12 14	10 14	8 14	7 12	6 12	6 12	5 10	5 10	4 10
3 3	115 230	29.0 14.5	90 45	12 14	10 14	8 14	7 12	6 12	5 10	4 10	4 9	3 9	3 8
5 5	115 230	46.0 23.0	150 80	10 14	8 14	6 12	5 10	4 10	3 9	2 8	2 7	1 7	1 6

*These fuses are maximum for protection at wiring only and do not give motor overload protection.
**Wire sizes shown permit maximum voltage drop at 5 percent.

Metering

A water meter is a management tool that is desirable for more sophisticated systems. If the amount of water produced is known, excessive use can be identified. This often indicates leakages or unauthorized use. In addition, water use trends can be identified and system design adjusted to these trends.

Accessibility of Equipment

The pump and motor must be easily accessible for repair, replacement, operation and preventive maintenance. This means that the site should be accessible in all weather conditions.

Minimizing Contamination Potential

Water sources must be protected to prevent contamination. This is done by using well slabs set on mounds, well seals, draining wastewater away from the well, extending the casing at least 15cm above the well slab and by using materials that are clean and meant to be used in water systems. See Figure 3.

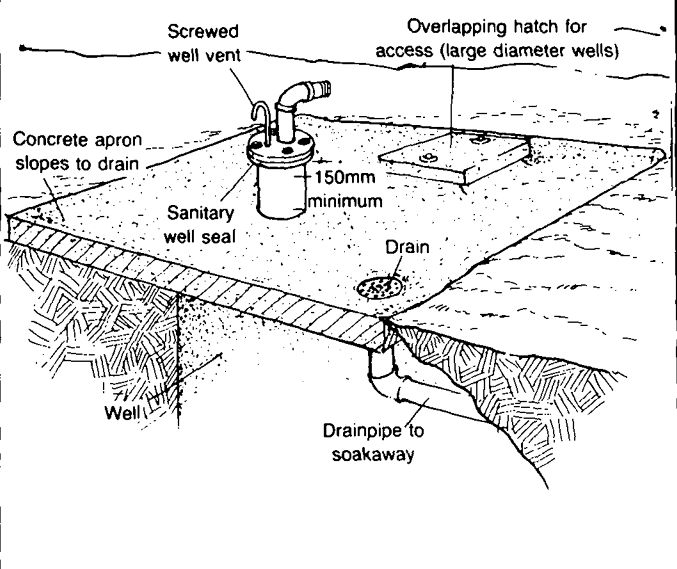

Figure 3. Minimizing Pollution Potential

Typical Pump Installation Techniques

Centrifugal pumps are installed as shown in Figures 4 and 5. They should preferably be installed in tandem with alternate operation. They are relatively simple to install and do not normally require hoists or A-frames.

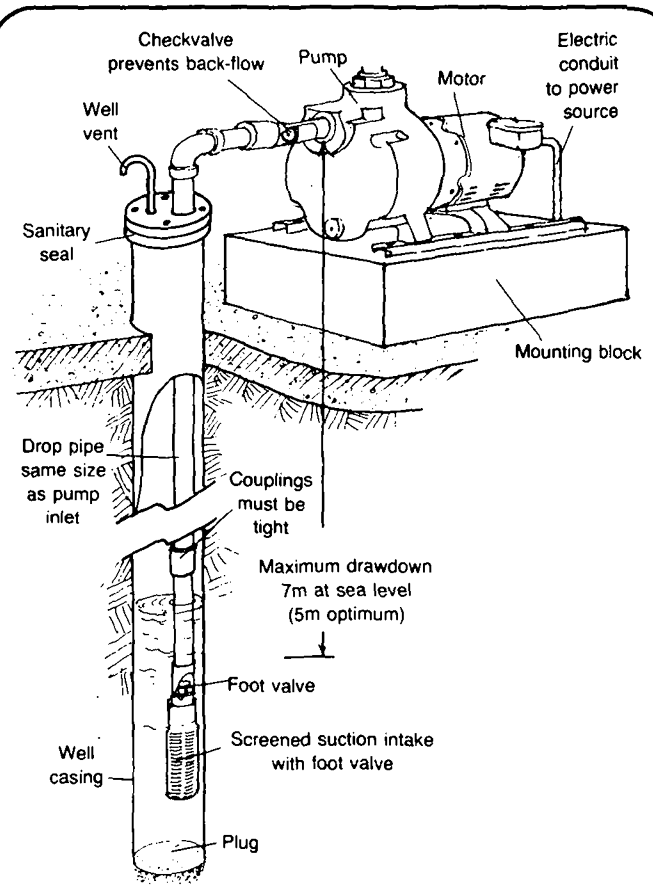

Figure 4. Typical Close-Coupled or Frame-Mounted Centrifugal Pump Installation

Submersible pumps are typically installed as shown in Figure 6. Pump controls are often located outside of the equipment house as shown in Figure 7. Special equipment is usually needed for installation including a tripod, block and tackle, pipe holder, pipe clamps and electric instruments to check for grounding once the pump is in water.

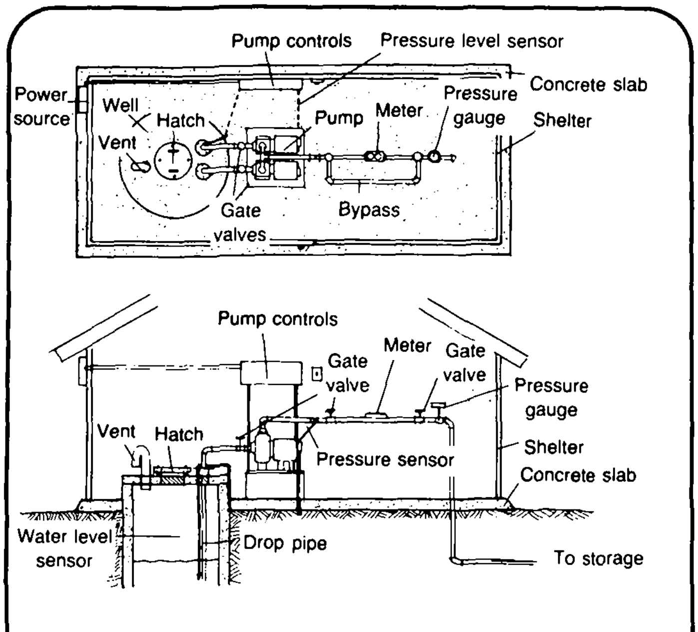

Figure 5. Dual Pump Suction Lift Installation (Well Less than 7m)

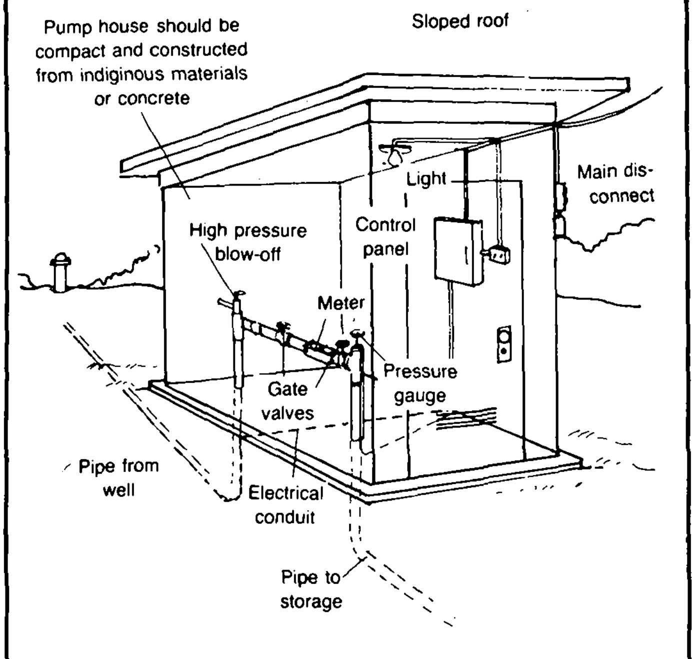

Figure 7. Pump House for Submerged Pump

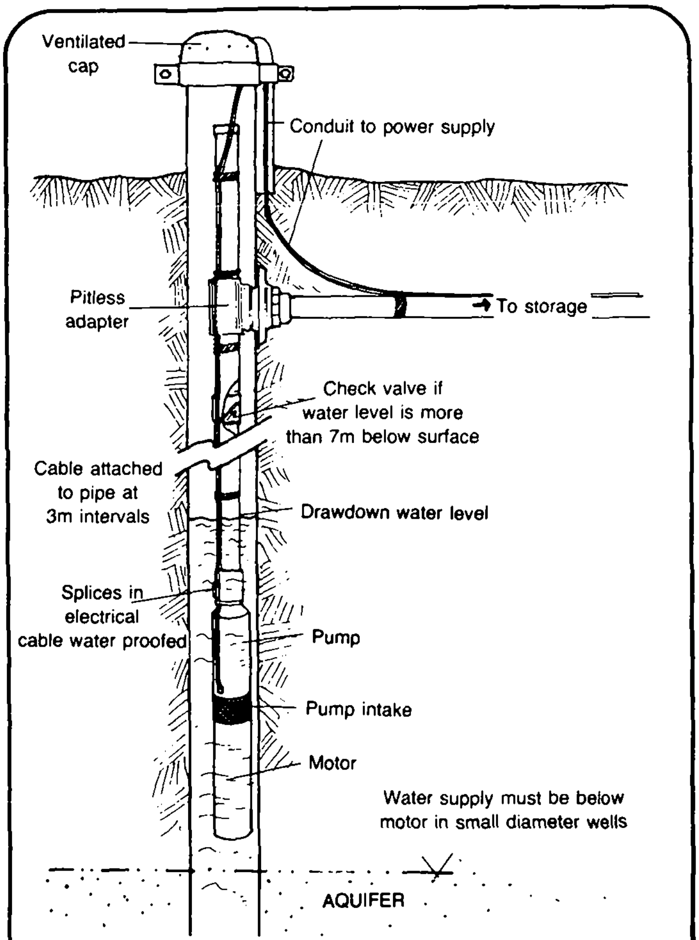

Figure 6. Installation of Submersible Pump with Underground Discharge

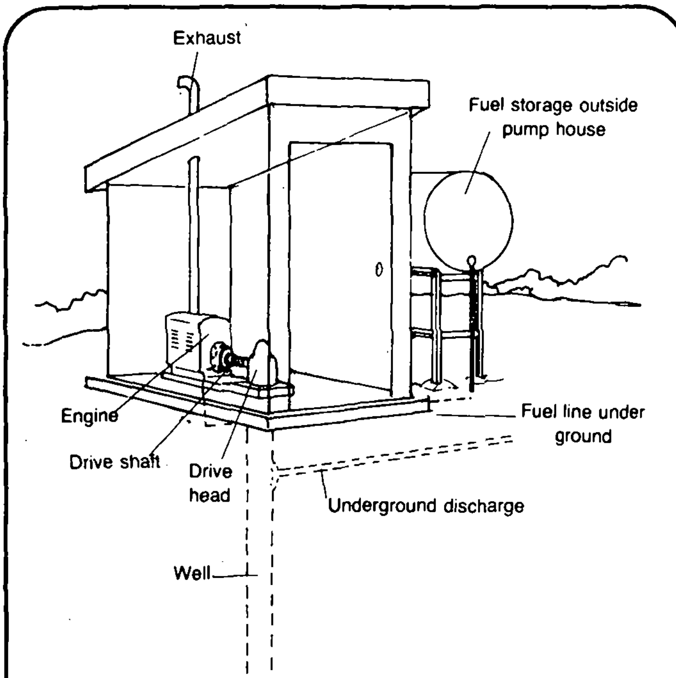

Figure 8. Pump House for Internal Combustion Engine and Vertical Turbine Pump

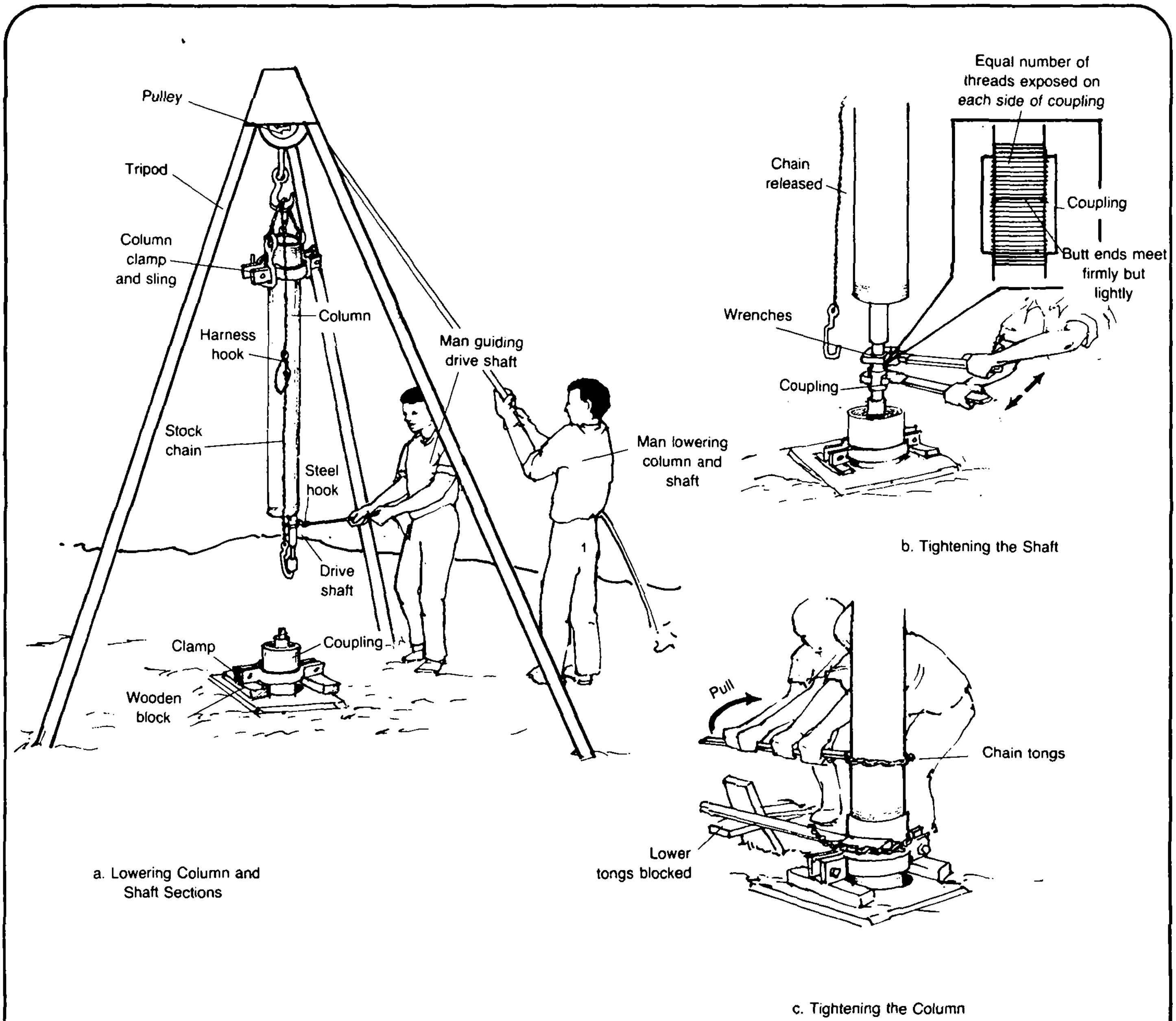

Figure 9. Installing Line Shaft Turbine Pumps

Line shaft turbines, also called deep well and vertical axis turbines, require a tripod, block and tackle, pipe holder and pipe clamps. Since the motor is not in water, shorting it out is not a problem. Because of the shaft which connects the motor to the pump, vertical alignment is much more critical than with a submersible pump. Typical installations are shown in Figure 8. Figure 9 shows how line shaft turbine units are installed or removed.

Windmill installations are similar to vertical axis turbines. A typical installation is shown in Figure 10.

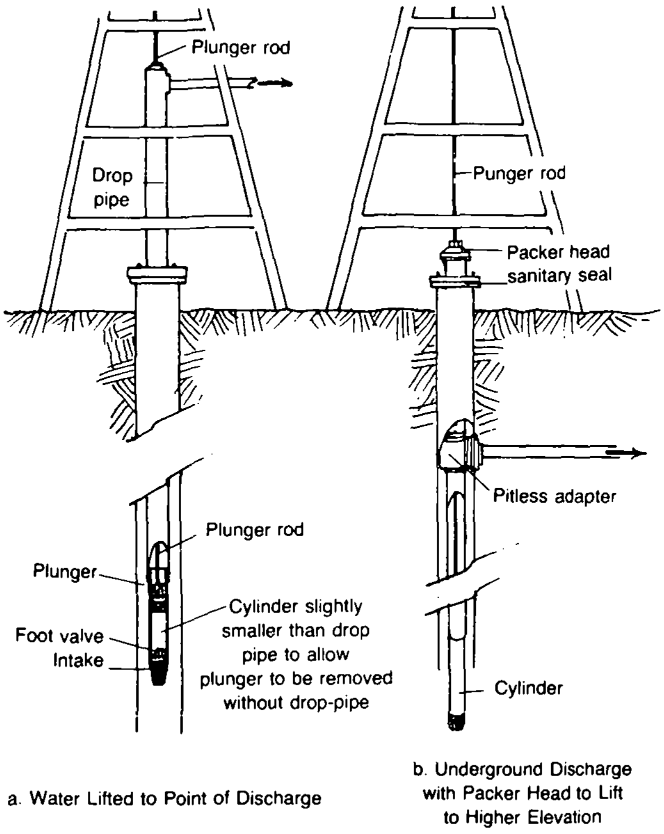

Figure 10. Typical Windmill Installations

Notes

Notes

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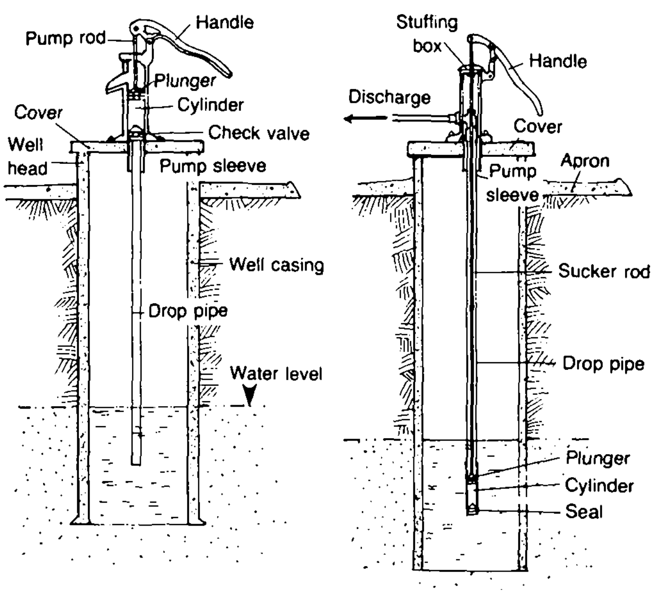
1982

Water for the World

Installing Hand Pumps
Technical Note No. RWS. 4.C.3

Hand pumps may be used for shallow wells, less than 7m to water, or deep wells. Deep well pumps can be used in many shallow wells and are a good choice because the pump cylinder is in the water. With the cylinder in the water, the pump does not lose its prime and the pump leathers do not dry out. In shallow well pumps, the cylinder is in the pump body above ground.

A hand pump system consists of a hand pump stand, drop pipe, pump rod or sucker rod for deep wells, and a pump cylinder. For shallow wells, the cylinder is part of the hand pump stand. Some hand pump stands lift water to a spout or force it to a higher elevation or to a point located away from the well. Figure 1 shows both shallow well and deep well hand pumps. Hand pumps should be installed according to manufacturer's directions. This technical note only describes the basic steps in hand pump installation.



a. Shallow Well b. Deep Well

Figure 1. Hand Pump Systems

Useful Definitions

DEEP WELL PUMP - Any pump capable of pumping water from wells where the water level is more than 10m below the ground surface.

DROP PIPE - The pipe in the well connecting the water to the pump.

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

In all installations it is important that the water source not be contaminated. The top of the well should be fully enclosed with a well slab placed around the well. Only materials which are clean and made for use in potable water supplies should be used.

In preparing a materials list, careful measurements must be made to ensure sufficient material is available. Prior to cutting material for assembly, it is good practice to again make careful measurements. It is necessary to have the proper tools on site when installation begins. Table 1 lists the materials and tools needed for a typical hand pump installation.

As in all projects, careful preplanning will help assure that installation involves a minimum of wasted time. A sample work plan is shown in Table 2. This plan can be used to estimate the time needed to complete the job and to decide when materials and tools should be available. Figure 2 shows the installation of the drop pipe and cylinder using a tripod. Figure 3 shows the detail of installing a pump sleeve, and Figure 4 shows a finished dug well with a hand pump.

After the pump installation has been completed, but prior to bolting the pump stand to the mounting flange, the

Table 1. Sample Materials List for Hand Pump Installation

Item	Description	Quantity	Estimated Cost
Labor	Foreman	1	____
	Laborers	2	____
	(NOTE: Either the foreman or the laborers must have some experience in cutting and threading pipe)		
Supplies	32mm galvanized steel pipe with coupling	____m: enough to reach the desired depth in the well	____
	10mm galvanized steel pump rod	____m: enough to reach the desired depth in the well	____
	10mm pump rod couplings	____: one for each joint	____
	Well cylinder	____	____
	Hand pump stand with handle	____	____
	Pump mounting flange	____	____
	Packing material	____	____
	Small can of grease	____	____
	Cutting oil	____	____
	Chlorine solution	____	____
Tools	Portable pipe vise	____	____
	Large pipe wrenches	____	____
	Crescent wrenches (adjustable wrenches)	____	____
	Pliers	____	____
	Hacksaw with spare blades	____	____
	Metal file	____	____
	Pipe cutter	____	____
	Pipe threader, 10mm and 32mm	____	____
	Measuring tape, 3m and 12m	____	____
	Pipe holder	____	____
	Rope and pulley	____	____
	Tripod for lowering pipe	____	____
	Plumb bob and 50m of line	____	____
		Total Estimated Cost	____

well should be pumped until the water is clear and a strong chlorine solution should be used to disinfect the well. This is accomplished by raising the pump assembly from the flange and pouring the solution down the well. After 12-24 hours, the well can be pumped out and the water used.

Table 2. Sample Work Plan for Installing a Hand Pump

Time Estimate	Day	Task	Personnel	Tools/Materials
1 hour	1	Delivery materials to site and unload	Foreman and 2 laborers	Shown in Table 1
1 hour	1	Set up tripod	Foreman and 2 laborers	Tripod, wrenches
1 hour	1	Cut and thread pipe and pump rod as measured	Foreman and 2 laborers	Pipe vise, cutter threader, cutting oil
3 hours	1	Attach pump rod and cylinder and lower into well; add pipe and rod as required until desired depth is reached	Foreman and 2 laborers	Pipe, pump rod, pipe holder and pipe wrenches
1 hour	1	Attach pump mounting flange to well casing, screw pipe into bushing and bushing into base of pump stand	Foreman and 2 laborers	Pump mounting flange, pipe bushing, pump stand and wrenches
1 hour	1	Check pump packing and packing nut; lubricate pump bearing points; work pump until water is clear; add chlorine solution to well and let stand overnight	Foreman and 2 laborers	Packing material, grease, wrenches chlorine solution
2 hours	2	Pump well until no chlorine solution remains; attach stand to flange		

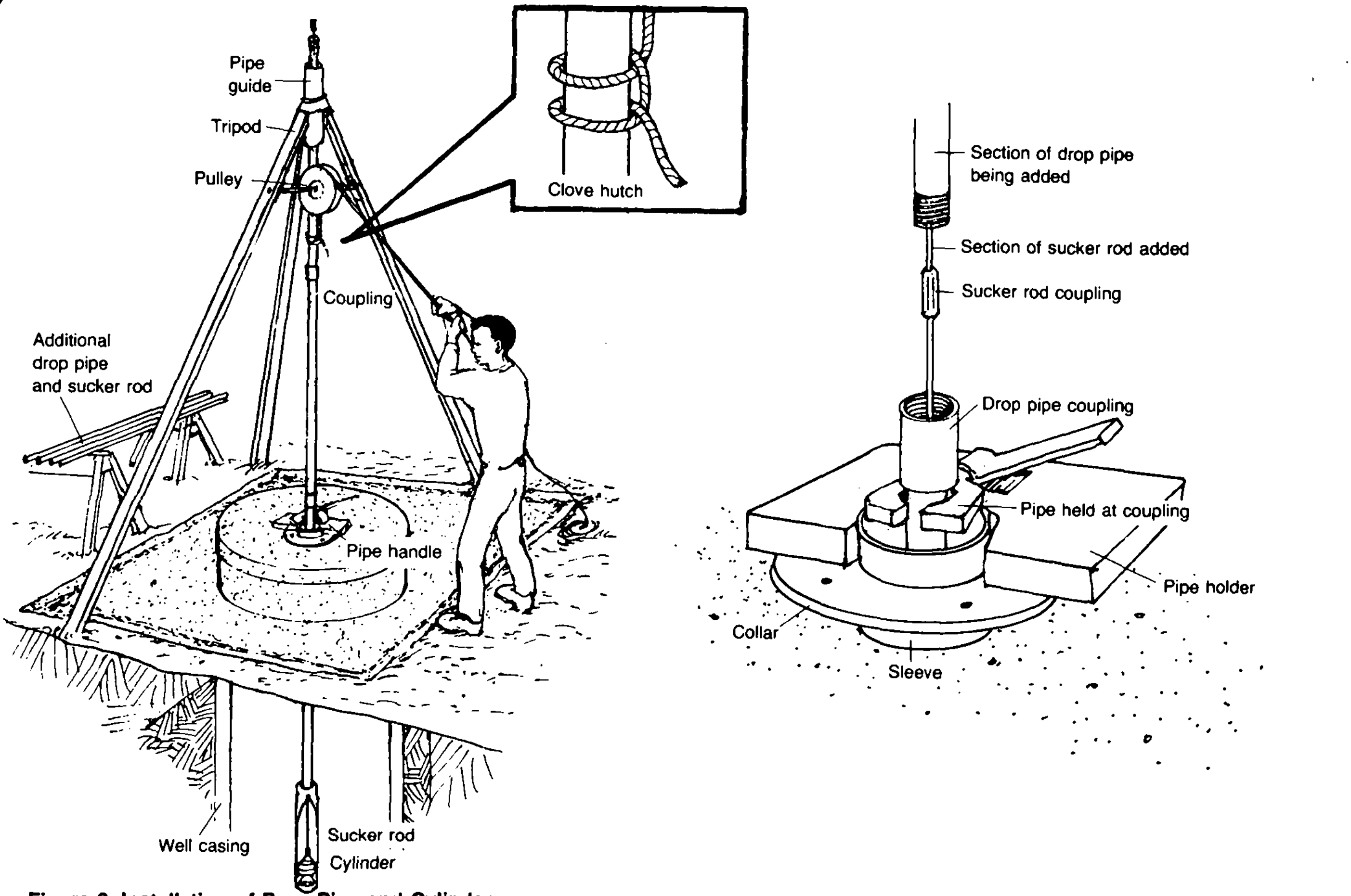


Figure 2. Installation of Drop Pipe and Cylinder

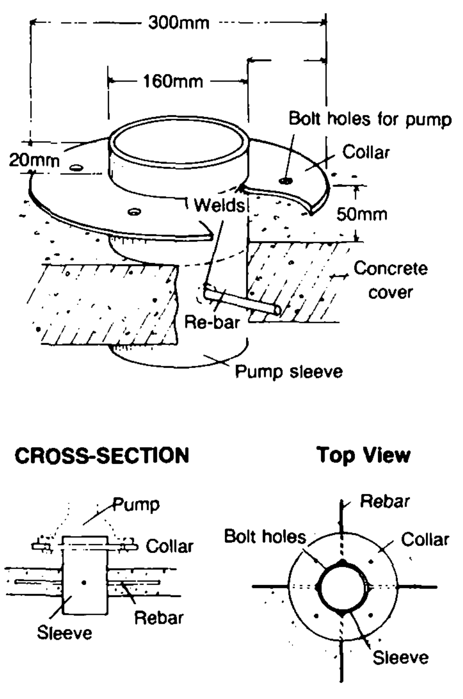


Figure 3. Installing Pump Sleeve

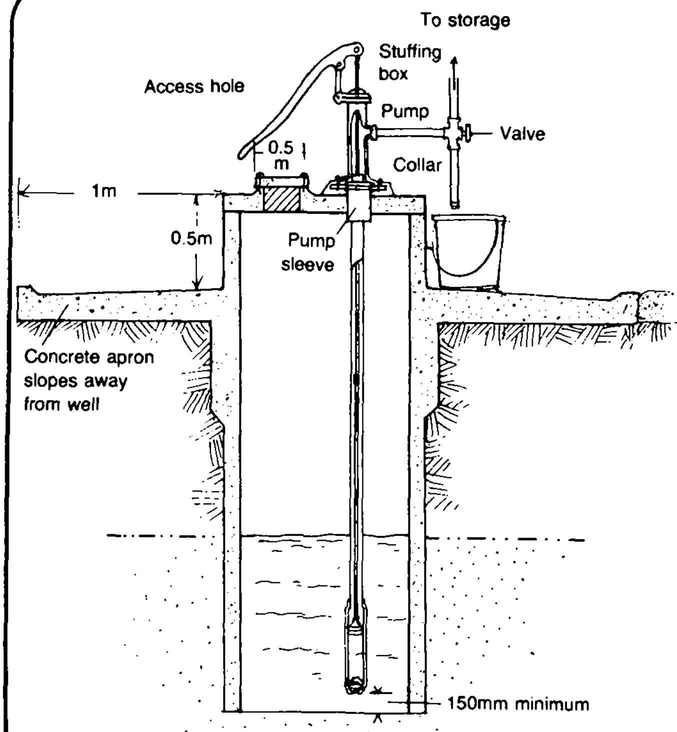


Figure 4. Finishing a Hand Dug Well

Notes

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1982

Water for the World

Constructing Community Distribution Systems

Technical Note No. RWS. 4.C.4

The successful construction of a community distribution system depends on careful planning and preparation, both before and during construction. Before beginning construction, see "Installing Pipes," RWS.4.C.1. Constructing a distribution system requires an experienced construction foreman and should involve an engineer to oversee the work. This technical note only describes the major steps in constructing a community distribution system.

Before construction begins, the following things must be done:

1. The construction drawings must be completed and available.

2. All appropriate clearances must be obtained.

3. Arrangements must be made for materials and labor.

4. Construction equipment must be identified.

5. Contracts, if used, must be signed.

6. Preliminary construction staking must be completed.

7. A construction schedule must be developed.

Construction drawings must be completed and available with sufficient copies for the foreman and the construction inspector if there is one. Drawings should include an overall plan view, profiles of individual lines, and details for constructing the standposts and other structures. Standard details should be included for installing valves and other fittings and equipment. Where appropriate, specifications should be included for the method of installation. Figure 1 shows a design map of a transmission main and distribution system and Figure 2 shows typical sections of a map that might be used for construction.

All appropriate clearances must be obtained. Clearances needed may include a water use permit, rights of way across public land, easements across private land, permits to cross other existing rights of way, including public roads, railways, and public utility lines. It is expensive to have to stop construction or remove pipe or fittings but this may happen if all clearances have not been obtained.

Materials, supplies and labor must be arranged for prior to construction. Make sure that the necessary materials and supplies have been purchased and are available at the construction site. Labor arrangements must be made and understood by the project manager and the community. When labor is to be supplied by the community as an in-kind contribution, keep in mind that the workers may have other jobs and will be available only for relatively short periods of time.

Construction equipment must be identified and arrangements must be made to have it on the site when needed. This equipment may include are compressors, trenching equipment, front-end loaders and dump trucks.

Contracts must be signed. If all or any part of a project is dependent on a contract, make sure it is ready when construction begins.

Preliminary construction staking must be completed. Construction stakes should be placed at all changes in direction, valve locations and public standposts. These stakes should indicate a number which corresponds to the same number on the plan.

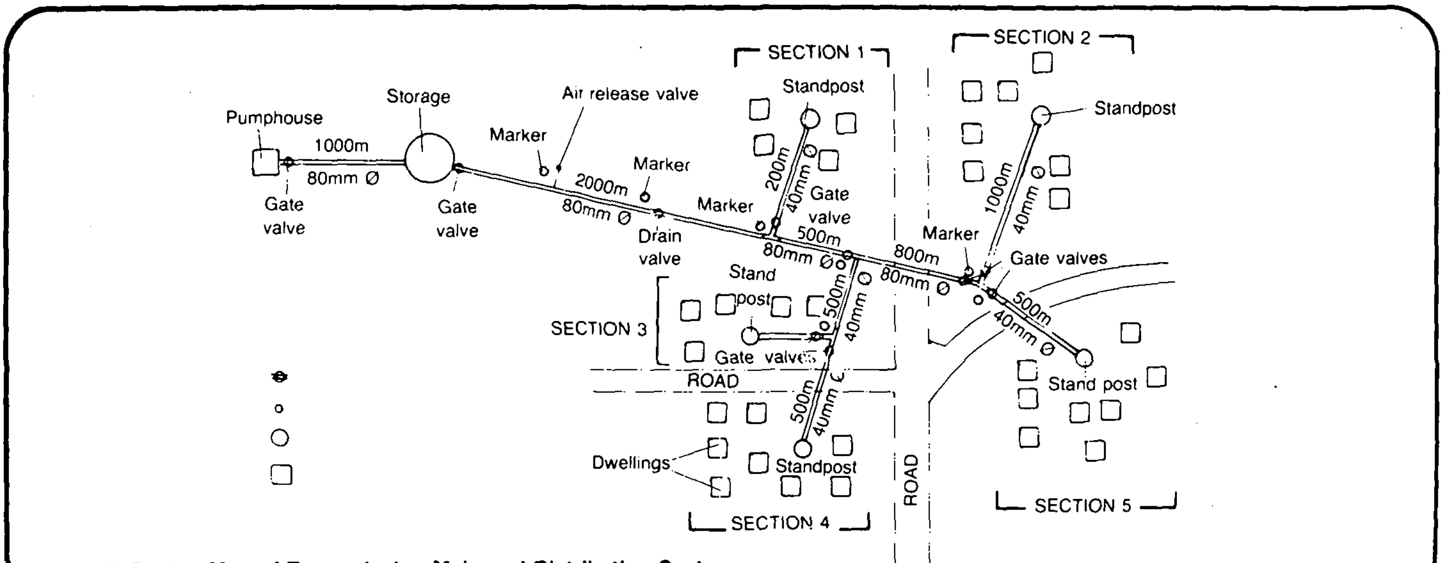

Figure 1. Design Map of Transmission Main and Distribution System

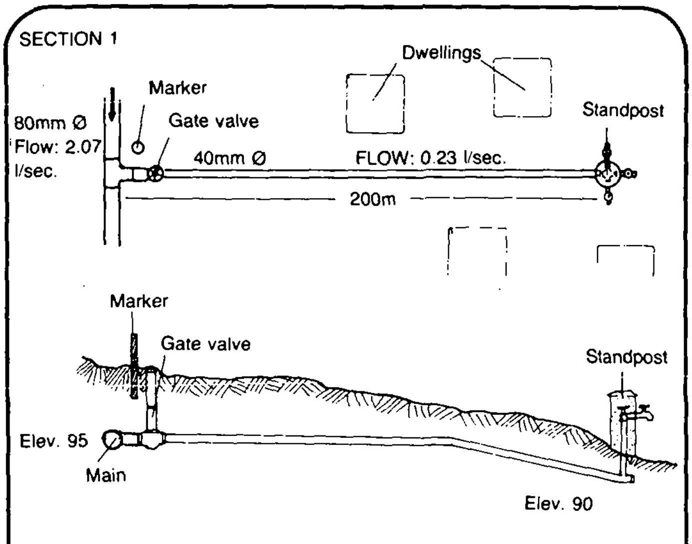

Figure 2. Plan and Profile of Typical Map Section

A construction schedule must be developed. Scheduling is important for several reasons. It provides a plan for when material is required on a job, gives laborers and contractors a goal to reach and helps to assure that construction is completed on time. In developing estimates of times needed for construction, there is usually a tendency to be overly optimistic about the time it takes to accomplish a job. For this reason, estimate the shortest time a job could be accomplished under ideal conditions and the longest time it would take if everything went wrong. The actual time required will usually fall between these. It is standard practice to average the two and use this for a construction schedule. Table 1 shows a typical format for project scheduling. This is filled out with the estimated times and dates for completing the project. These are changed to show the actual times and dates once construction is underway. Serious delays in meeting the project schedule can result from problems with labor availability and material delivery. Labor, particularly volunteer labor, may not be readily available because of illness, the need to work for food, the need to attend markets one or more times a week, and religious activities. Morale is a very important factor and usually remains high if the project stays on schedule. Material delivery can be a major problem. When material is not delivered on time, the morale of the laborers drops. It is important to keep material deliveries on schedule.

Construction Steps

If delivery of materials is reliable, work can start on schedule. If not, it is better to wait to begin construction until the material is on site. In either case, it is important that an area be designated to store project materials, tools and equipment. The storage site should be a secure shelter with a lock, at least for tools, and should be fenced to protect materials and equipment. Arrangements should be made to keep certain material, such as plastic and rubber rings, out of the sun. Accessibility should be good to allow for delivery and removal to the job site. Care should be taken not to locate materials where they might be contaminated by human or animal wastes.

Table 1. Construction Schedule

Project________________________________
Date prepared__________________________
Construction start_____________________
Construction finish____________________

Item	Week									
	1	2	3	4	5	6	7	8	9	10
Construction staking										
Material delivery										
Trenching										
Pipe laying										
_____m of _____mm										
_____m of _____mm										
_____m of _____mm										
Backfill										
Pressure test										
Storage tank start										
Storage tank complete										
Water source start										
Water source complete										
Equipment required*										
Chlorinate system										

*l-loader, d-dump truck, p-pickup, b-backhoe, t-trencher, o-other

It is common practice to deliver pipe directly along the route of the trench and unload it along the trench line. This is called stringing. This saves double handling of the pipe and is recommended.

Trench excavation can be done by hand labor or motorized equipment including backhoes and small and large trenching equipment. Hand labor can dig trench in meters per day per worker, backhoes in hundreds of meters per day, and trenching equipment in thousands of meters per day when trenching in easily moved soil. If rock is encountered, the backhoe is usually the fastest.

No matter how the trench is excavated, the bottom must be smooth and free of rocks and boulders. If they are encountered, the trench must be dug deeper than the finished grade will be. Then backfill the trench with material which is free of rocks to make a smooth bed. Figure 3 shows examples of good bedding backfill materials. Backfill usually should be 15cm deep and tamped to compact it. The installation of the pipe varies with the type of material and with the method of connection. This is covered in "Installing Pipes," RWS.4.C.1.

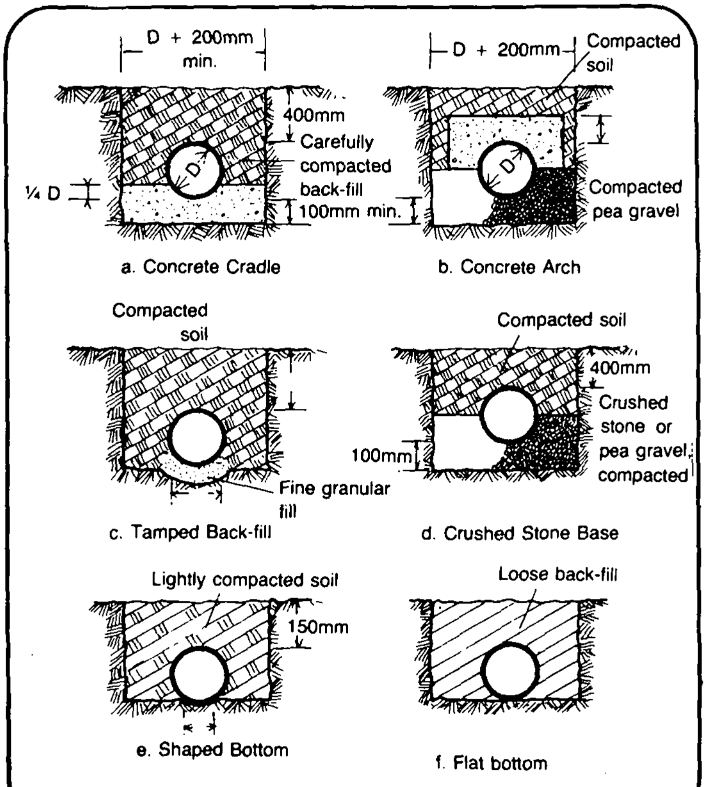

Figure 3. Examples of Bedding and Back-fill Materials

Once the pipe is installed, it should be partially covered with selected material to a depth of 30cm. The joints should be exposed. In small projects, the entire system would be installed this way and then pressure tested. Since the joints are exposed, any leakage can be quickly located. In large systems, it is good practice to pressure test the lines at the end of each day so that long lengths of trenches are not left open for long periods of time. This is accomplished by placing a valve at the end of the line and pumping water into the line under pressure. This way each day's work can be covered. Before pressure testing, be sure the pipe has earth over it and that thrust blocks are in place. Otherwise, the pipe will blow apart at the joints.

Whether the pipe is tested at the end of the day or of the job, it is essential that the pipe be capped each night and at all other times when installation is not underway. Otherwise, insects, rodents and snakes may crawl into the pipe or rain may deposit mud inside the pipe.

The depth of the trench will vary from place to place but normally will be from 45-75cm to protect it from the elements and from construction disturbances. Once the trench is dug, pipe is laid along one side and usually, except for polyethylene pipe, handed down by two men on top of the trench to two men in the trench who install the pipe. Most pipe used in a small system is light enough to be simply handed down to men in the trench. Small diameter cast iron pipe or larger diameters of asbestos cement must be lowered by ropes as shown in Figure 4. Large diameter cast iron or steel must be lowered by a boom. Usually several men will be backfilling behind the installation crew and several digging trench ahead of the crew and preparing the trench bed. Remember that select material must be used below and above the pipe.

In most instances, trenches for rural water systems are shallow. Occasionally, there is a need to dig deeper than 1-1.5m. This can be very hazardous for workmen in the trench and special care should be taken to prevent the trench from caving in either by

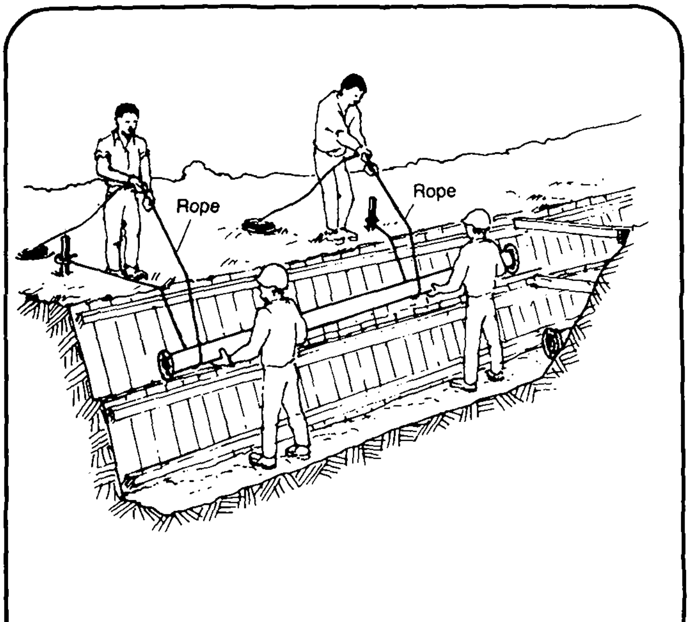

Figure 4. Lowering Heavy Pipe

sloping the banks or by shoring up the sides with support timbers or sheeting as shown in Figure 5. Care must be taken to keep rocks away from the edge of the trench.

Markers should be placed along the line at 1000m intervals and at all valves, changes in direction and laterals. These markers should be concrete or steel posts extending at least 60cm above the ground. These markers, as well as any changes in the construction system from the design system, should be clearly marked on a set of construction drawings as the changes occur. These are known as as-built plans and they are invaluable for the future operation and maintenance of the system.

The standposts should be constructed according to the plans. Figures 6 and 7 show typical standpost designs. Sand used for concrete or grouting must be clean and free of silt or organic material. Otherwise, premature failure of the concrete will occur. An important consideration is the drainage of wastewater and rainwater away from the standpost.

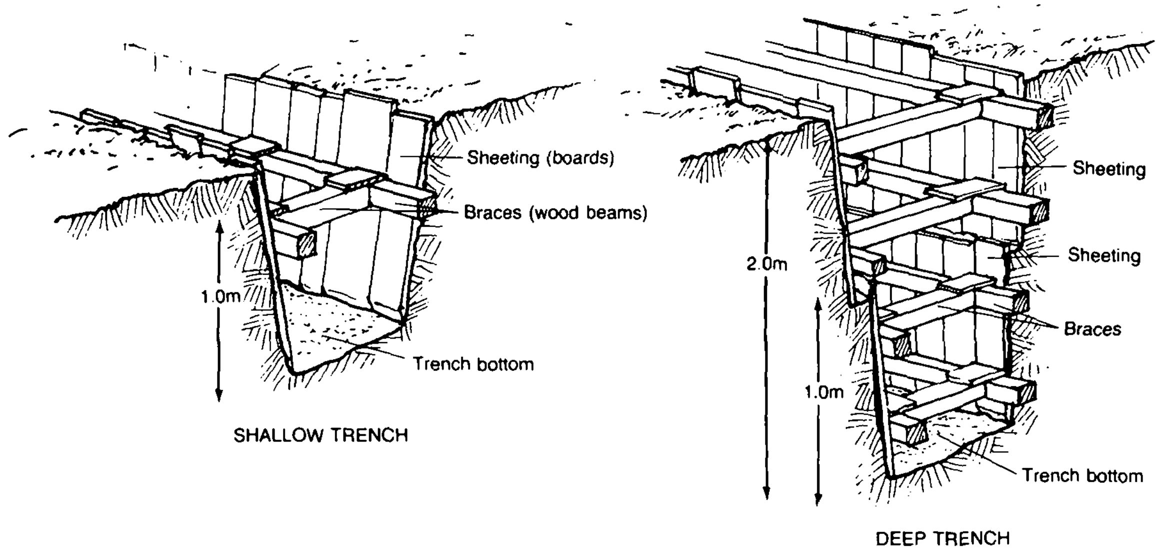

Figure 5. Sheeting and Braces

Once the pipe is installed, tested and covered to a depth of 15-30cm with rock free material, trench run material can be used to complete the backfilling. This can be done by hand or machine and, in either case, earth should be mounded over the line to allow for future settling.

After completing construction, thoroughly flush the pipe, including all laterals, with clean water and chlorinate as described in "Installing Pipes," RWS.4.C.1.

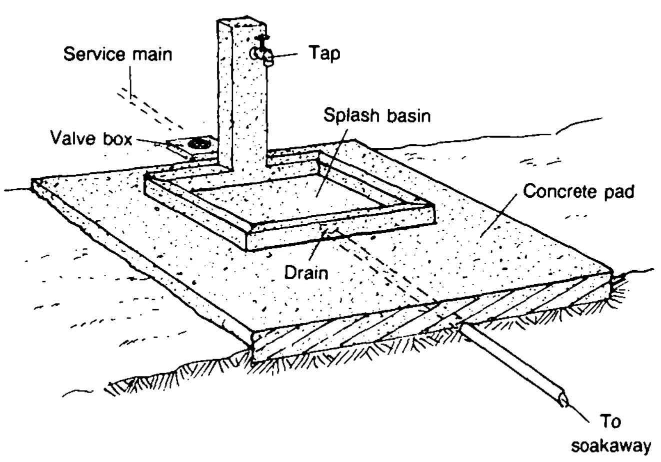

Figure 6. Standpost Design

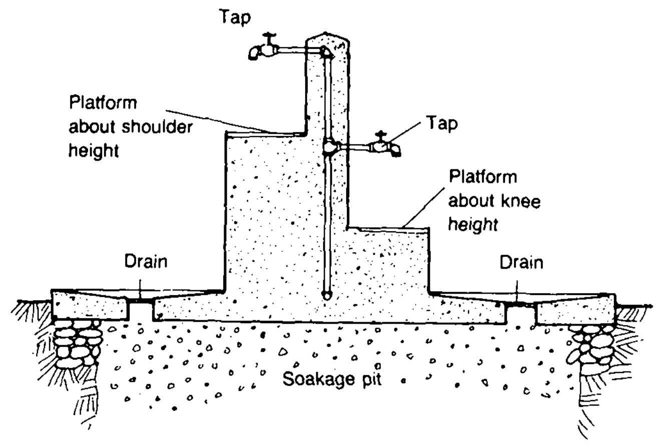

Figure 7. Standpost With Multiple Taps

Notes

Notes

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1982

Water for the World

Constructing a Distribution System with Household Connections

Technical Note No. RWS. 4.C.5

Constructing a distribution system with household connections consists of providing taps and extending service lines from the distribution system to each house. This is a continuation of the construction procedures described in "Installing Pipes," RWS.4.C.1, and "Installing Community Distribution Systems," RWS.4.C.4. Use all three technical notes together.

Useful Definitions

CURB STOP - A valve at the point of entry of a service line to a home or building used to shut-off flow to the point of use.

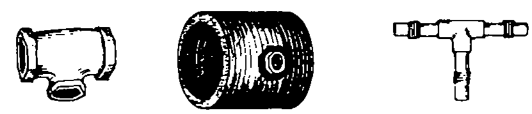
SERVICE LINE - A water line extending from a tap to the customer's property.

TAP - A point of connection to a water main for a service line.

Connections to the Distribution System

There are two ways of providing a household connection to the distribution system. One method is to install a service tap into the main line as it is being constructed. The other method is to install the main without service connections and then, before the line is backfilled, drill holes in the line opposite each home. Then either thread the hole or install a "saddle" over it.

With the first method, the outlet must be placed at the joints between pipe lengths. This requires a service tee which is expensive. The second method allows the outlet to be located anywhere on the line, but the tap must be made as a separate operation. Figure 1 shows several service tees that can be installed as the system is being constructed. For threaded steel pipe, a reducing "tee" is used. For



a. Galvanized Steel Reducing Tee

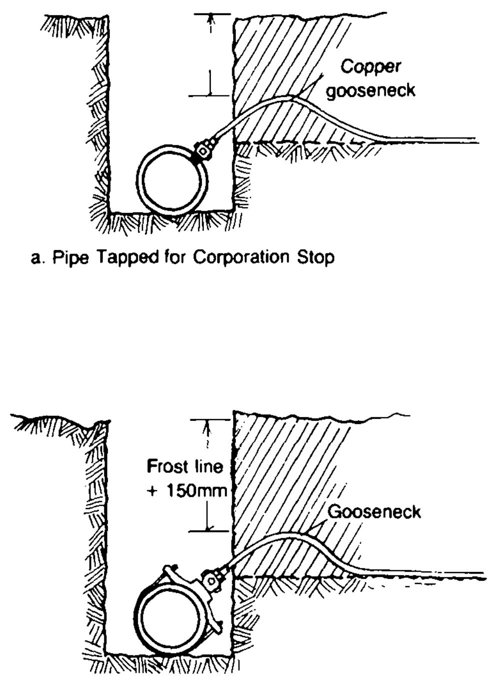
b. A/C Pipe Heavy-Wall Coupling with Threaded Bushing

c. Insert Tee for Polyethelene Pipe

Figure 1. Service Tees Installed During Construction

asbestos cement pipe, a heavy-wall coupling containing a threaded outlet is installed. For polyvinylchloride pipe with slip couplings, a tapped, plastic tee is used. Insert tees can be used with polyethylene pipe.

Figure 2 shows methods of tapping a main after it has been installed. A special drill can be used to drill a



a. Pipe Tapped for Corporation Stop

b. Service Clamp for Use with A/C Pipe

Figure 2. Tapping the Transmission Main After Construction

hole in the side of an asbestos cement pipe. The hole can then be threaded or a service clamp installed. Asbestos fibers should not be ingested, so after the pipe is drilled the line must be throughly flushed to remove cuttings before the system is put in service. Rigid plastic pipe can be drilled and a service clamp installed or a special threaded outlet may be solvent welded in place. Insert tees in polyethylene pipe can be either installed when the main is laid or cut in at a later time.

Regardless of the method used to provide an outlet for the service line, it is usually made at an angle that is 20-30° above the horizontal. This allows a bend to be placed in the service line so that pipe movement will not cause a break at the connection. The tap is not placed on top of the pipe because it may be broken off if the line is later uncovered. A corporation stop is then threaded into the outlet on the pipe. This special type of valve does not restrict the flow of water in the main line while installing the service lines. As each service line is installed, the corporation stop is opened. Figure 3 shows details of service connections.

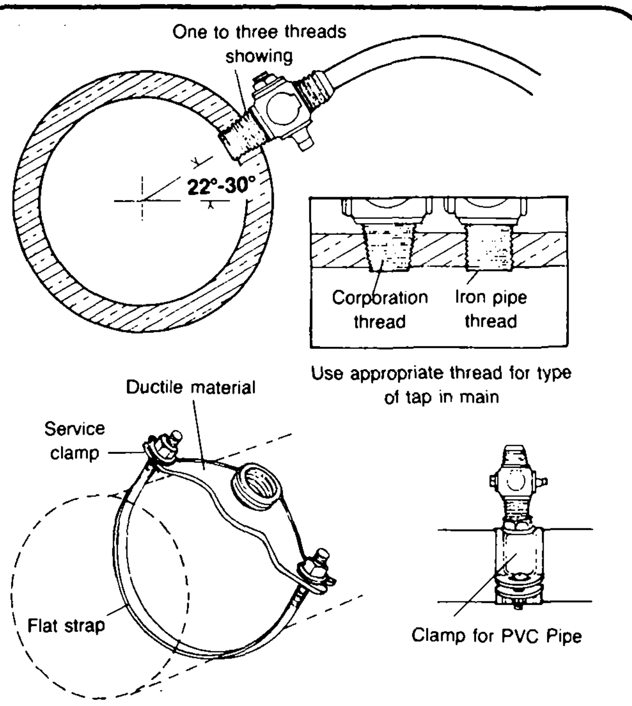


Figure 3. Detail of Service Connections

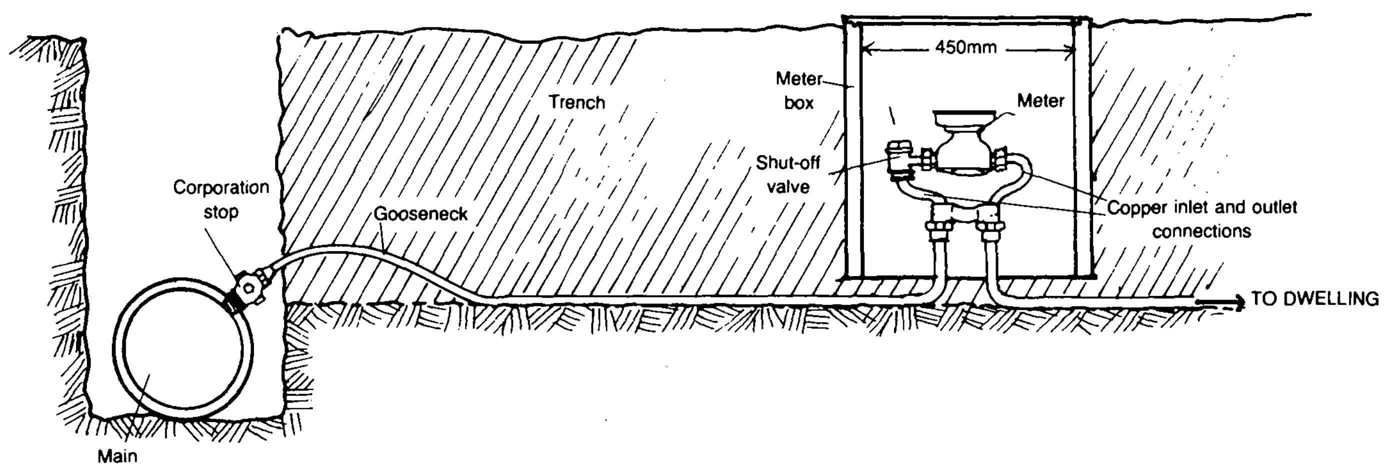


Figure 4. Meter Installation

Installing the Service Line

The service line extends from the corporation stop to the property of the homeowner. Always put a bend or "gooseneck" in the service line to provide flexibility in the event of a load due to settlement or to expansion or contraction of pipe. If a meter is installed, it is usually placed in a meter box near the edge of the property or within the home itself. A meter yolk is used to hold the meter and to provide a means to turn the water off should the meter need to be removed. See Figure 4. If a meter is not used, a shut-off valve should be installed in its place as shown in Figure 5.

Service lines are usually made of 20mm copper service pipe, type L or K, or polyethylene. It is essential that the corporation stop, the meter yolk, and/or the curb stop, are the proper type and size for the pipe used. Soldered joints should not be used on buried copper pipe because they will corrode and leak. Instead flair type joints should be used. The same precautions discussed in "Installing Pipes," RWS.4.C.1 and "Constructing Community Distribution Systems," RWS.4.C.4, concerning depth of bury, bedding, and backfilling should be observed when installing service lines.

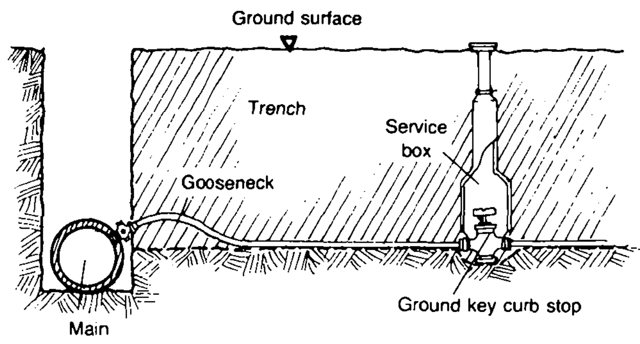


Figure 5. Curb Stop Installation

The construction of line from the meter or curb stop to the house is usually the responsibility of the homeowner but the line may be installed at the same time as the service line. In rural systems, 20mm polyethylene pipe is usually used. A shut-off valve should be provided outside the house so that the occupant can turn off the water to make repairs. The valve should have a "ground key" which requires a valve wrench to open or close.

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Water for the World

Detecting and Correcting Leaking Pipes
Technical Note No. RWS. 4.0.1

Leaks may occur without detection because they are often relatively small and do not create immediate problems such as washing out a road or draining a water tank. Small leaks can continue for years undetected. Even minor leaks, however, usually get worse, are costly and eventually can cause significant damage. Leaks are particularly expensive if the water has to be pumped or is scarce.

The benefits of a leak detection and repair program include:

1. Water saved. This is particularly important if water is scarce.

2. Money saved. Money is saved by reducing pumping costs and the need for system expansion.

3. Greater system reliability. Most leaks eventually get bigger causing system disruption or breakdown.

4. Improved customer satisfaction. This directly relates to items 1 through 3 above.

Detecting Leaks

A program to detect and correct leaking pipes should begin at the time the distribution system is designed and constructed. Leaks are less likely to occur if the proper pipe selection is made and the system is constructed in accordance with the manufacturer's recommendations and standards of good practice. Should leaks occur, they can be detected and located if the system is fully metered and accurate water production and use records are maintained. Leaks can be more easily repaired if accurate as-built drawings were done, if the system has an adequate number of properly located valves so the problem area can be isolated, and if a stock of spare pipe, fittings, and repair parts have been set aside.

The first step in detecting leaking pipes is to establish a routine leak detection program. This should consist of several elements. First, the pipeline should be walked or driven regularly. Visual observation should be made of signs of leaks such as a slump in the material over a trench, abundant vegetative growth or surface moisture. Any construction activities in the vicinity of the pipeline should be noted and investigated. Valve covers should be removed and the valve box visually inspected for moisture. Special attention should be paid to wash crossings and road crossings. Serious leaks will often occur in those locations.

Second, a water use analysis should be made. This is best accomplished by having a water meter at the source to measure total water production and water meters for each point of use. Water then can be checked by subtracting the amount used from that produced. Since many rural systems do not have flow recording capability, alternate methods must be found. One method of measuring water production is by checking the length of time the pumps run. An estimate can then be made of production if the pumping rate is known. If not, the pumping rate can be calculated by measuring the change in volume at the water storage tank over a set period of time. This should be done when there is no demand for water and the outlet valve can be closed. Once the amount of water produced is known, it can be compared to expected use. If the use is higher than estimated, leaking might be expected. Keep in mind that usage less than expected does not mean there are no leaks.

The following example illustrates water production and use estimation. A water utility wishes to estimate water production and compare this to expected usage. The system has a pump and a concrete water tank that has inside dimensions of 5m x 5m x 5m. There are 40 houses on the system, all with simple inside plumbing. The population served is 240 people.

At 1:00 a.m., the valve on the discharge side of the tank is turned off and the water level in the tank is accurately measured. The depth is 2m. The pump is started at exactly 1:30 a.m. At 2:30 a.m. the pump is shut off and the water level again measured. The water now is 2.42m deep. The level increased 0.42m in one hour.

Convert 0.42m to cubic meters to find the volume:

5m wide x 5m long x 0.42m high = 10.417m^3. Since there are 1000 liters in 1m^3, 10.417m^3 is 1000 x 10.417 or 10417 liters of water.

10417 divided by 60 minutes which is the pumping time = 173.5 liters per minute. The pumping rate is 173.5 l/min.

The expected water use might be 100-200 liters per day per person or 100 x 240 = 24000 l/day to 200 x 240 = 48000 l/day.

Since the pumping rate is 173.5 l/m, this demand should be met with a pumping time of $\frac{24000 \text{ l/d}}{173.5 \text{ l/m}}$ =

138 minutes to $\frac{48,000 \text{ l/d}}{173.5 \text{ l/m}}$ = 276 minutes.

If the pump operates longer than 138-276 minutes per day, leakage might be expected. Compare the actual pumping time per day with the expected time of 138-276 minutes per day.

Water production should be recorded routinely once the pumping rate is known. This is done by recording the amount of hours of pumping each day or week. Variances in pumping time should be analyzed taking into consideration the time of year, celebrations, religious ceremonies, or other unusual events. If there is no logical explanation for increased usage, then the line should be visually inspected and customers visited.

Even if individual water meters are not installed or are not read, the customers should be visited at least semi-annually to check for leakage on the property. A large amount of leakage occurs through faucets and flush valves, within individual homes. For this reason, it is important that the residents be aware of the need to keep leaks repaired.

Another likely place for leaks is a public standposts. Valve washers wear out, valves are damaged and occasionally left open. For these reasons, a daily inspection is best for public facilities.

If the above steps have been taken and undetected leaks are still suspected, there are three options available. The first is to uncover the pipeline in areas likely to leak or where leaks are suspected. The second is to obtain leak detection equipment or hire a company that performs this service. If the cost of producing water is high or the available quantity low, then this may be a good alternative. The third is to isolate parts of the system by closing valves and measuring the water lost from storage over a period of several hours. This should be done when water is not being used. A good time is 1:00 a.m. to 4:00 a.m. The exact method depends on the system and how it is valved. A more certain method of detecting flow is to install temporarily a small water meter at locations where the line branches as shown in Figure 1. The meter would be monitored between the hours of 1:00 and 4:00 a.m. as described above.

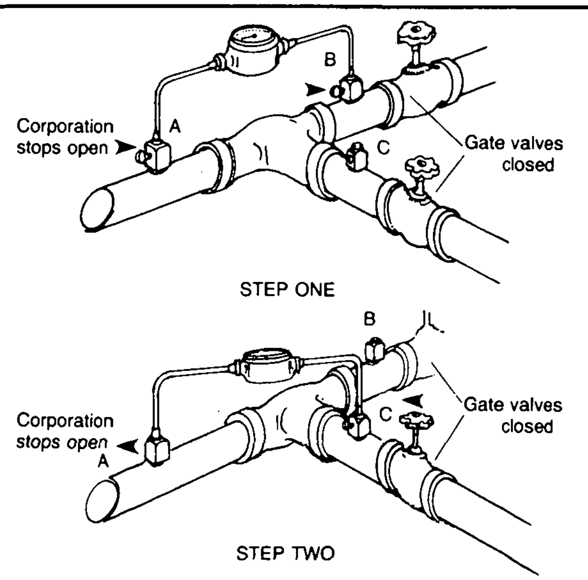

Figure 1. Metering for Leaks

With all valves closed, attach the temporary meter to line A to B and check for flow over an hour's time. Next, connect from A to C and check after another hour's time. Any flow registered on the meter indicates leakage in that line.

Repairs of Leaks

When a leak has been located, it will be necessary to first turn off the water to the section of line under repair. If valving is adequate, few people will be inconvenienced. In other cases, major portions of the system must be shut down. To minimize the time that service is interrupted while repairing a leak, be sure all necessary parts, tools and equipment are available before turning off the water. Whenever old pipes are disturbed, additional leaks may occur or the pipe may break, so be sure extra pipe and fittings are available. Residents should be notified that the water will not be available so they may store some water for essential use.

Leaks can be repaired in two basic ways. The first is to replace the defective pipe, coupling, or fitting. This is difficult, since normally pipelines are installed in sequence from one end to the other. In the case of a repair, however, there is no "free" end to work from so various repair devices and methods have been developed. For a hole or crack in a pipe, repair clamps are available that are wrapped around the pipe and secured with bolts. See Figure 2. If the break is too large to be covered by a repair clamp, a section of pipe must be removed. A new piece can then be installed using an original coupling and a special coupling or two special couplings or repair devices. See Figure 3.

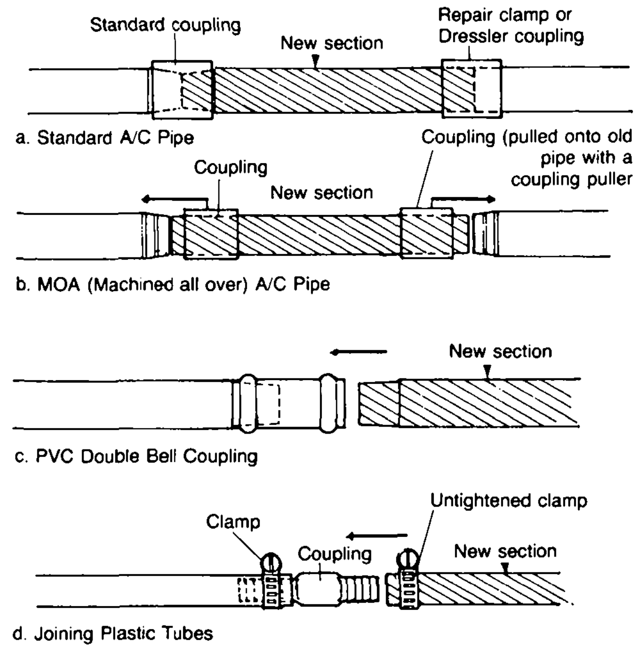

Figure 3. Replacing a Section of Pipe

Asbestos cement pipe is available in a diameter that allows the coupling to be slid back over its entire length. This is known as machined-all-over, MOA, pipe. A length of MOA pipe and two standard couplings can be used to make a repair. See Figure 3b.

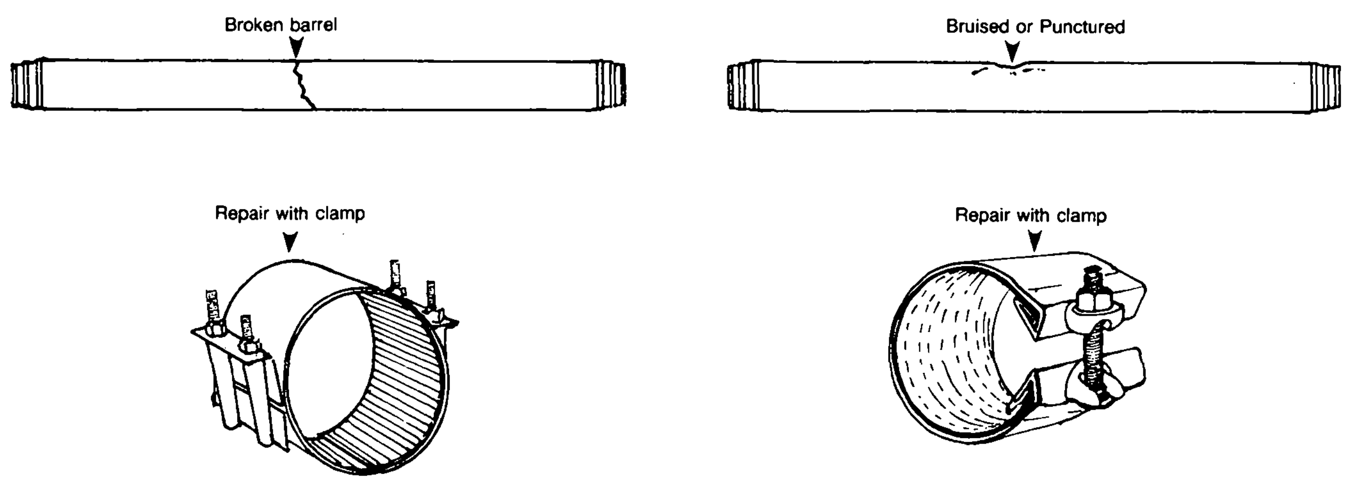

Figure 2. Methods of Repairing Defective Pipe

Polyvinylchloride, PVC, pipe can be repaired with a double bell coupling by the following method:

1. Push a double bell coupling onto the spigot end of a length of pipe as shown in Figure 3c.

2. Then push the spigot end of the next length of pipe into the coupling bell and adjust the positions of spigot ends and couplings so that the reference marks on each pipe are hidden under the coupling end.

In the same way, the double bell coupling may be used to put new pipe lengths into an existing line. After the replacement pipe has been cut to the proper length, mount a double bell coupling on each end. Push each coupling all the way onto the pipe end and position the new length in the line. Then slide each coupling into place, bridging the ends and aligning the coupling over the reference marks.

Because of its flexibility, polyethylene pipe can usually be repaired by simply cutting out the damaged section and installing a new piece with insert couplings and clamps. See Figure 3d.

Disinfecting the Line

After a repair is made, the line must be disinfected and flushed. One way to do this is to place some chlorine tablets in the line while it is open. When the repair is completed, enough water to just fill the line is let in. Do not allow enough water in to wash the chlorine away from the repaired section. After 30 minutes, the line can be flushed. An alternate method is to chlorinate the entire system, as is done when a new system is installed. See "Installing Pipes," RWS.4.C.1.

A sizable quantity of water can be wasted from leaks in household plumbing. This type of leakage will show up as water that is used, not wasted, when metered water production and usage are compared. It is difficult to detect by other means. A public information campaign and voluntary home leakage inspection are probably the most effective ways to reduce this type of leakage.

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Operating and Maintaining Mechanical Pumps

Technical Note No. RWS. 4.0.2

Proper operation and maintenance of mechanical pumping equipment is an essential part of managing a water system. Failure to provide timely maintenance, including making minor repairs before they become major, is a primary cause of system failure.

Operation and Maintenance Activities

Operation and maintenance normally includes the following activities for all types of pumping systems:

- Keep equipment and pump house clean and painted to prevent rust or weathering.

- Keep equipment lubricated.

- Record system pressure and water use as well as preventive maintenance and repairs.

- Recognize potential mechanical problems and make adjustments before failure occurs.

- Replace failing or failed parts of equipment.

- Keep buildings, including doors and windows, in good operating condition.

- Keep records, interpet information recorded and make recommendations to management.

- Load and store chemicals, take water samples and perform tests of the water if water treatment equipment is located in pump house.

When these duties are performed regularly and correctly, major breakdowns can be avoided. The result is an overall lower cost of providing water.

Maintenance Schedule

So that no maintenance task is overlooked, a schedule should be developed showing items which need to be attended to on a daily, weekly, monthly or other routine basis. A good place to start in identifying the routine maintenance required is by reviewing the manufacturers' equipment manuals which should have been supplied with each piece of equipment. These manuals, along with the as-built plans of the pumping system, should be stored in a safe place where they are readily accessible. If the manuals are not available, they should be ordered from the supplier or manufacturer. Tables 1 and 2 show a typical maintenance record and maintenance schedule.

Equipment

Many small systems will not have the resources to provide equipment for transportation and mechanical work and thus will have to rely on people. For larger systems where equipment can be provided, a backhoe, dump truck or heavy duty pick-up, an electric generator and an air compressor would be useful.

Supplies

Rural systems are often remote from sources of repair items. It is important that either a readily available supply source be identified or spare parts and supplies kept for those items most likely to be needed. This includes grease and oil, fuses, repair clamps and such items as magnetic breakers if they are difficult to obtain. Spare bearings, pumps and motors should be kept available if at all possible.

Table 1. Preventive Maintenance Schedule

Daily:	Turn pump on/off as required.
	Check pump for excess heat in motor or bearing.
	Check controls for proper operation.
	Check water level in well.
	Check piping for leaks.
	Check condensation in pump house.
	Check chemical levels.
	Check oil level, pressure and fuel level if internal combustion engine.
	Record water and electric motor readings.
	Record system pressure.
	Record chemical residuals.
	Record unusual observations.
	Record fuel used, hours run, for internal combustion engine.
	Correct problems identified.
	Order parts which have a long delivery time.
Monthly:	Lubricate pump.
	Check amperage on electric motor.
	Report on water use for month.
Semi-annually:	Lubricate pump house door hinges.
	Close and open gate valves in pump house.
	Test blow off is furnished.
Other:	Change oil, oil filters, fuel filters in accordance with manufacturers.
	-Each fall check backup heating system.
	-Do preventive maintenance as specified by manufacturer.

Table 2. Pump House Record Keeping

Date and Time	Pressure Reading	Water Meter Reading	Chlorine Residual	Fluoride Residual	Comments/Observations

Pump Operation

One of the most important considerations in operating a pumping plant is to keep it clean and orderly. Oil and grease should be removed, dirt swept up, and tools and parts stored in their proper places at all times. Touch up the paint to prevent rust when repairs are made and repaint on a regular basis. This not only helps to keep the plant clean but indicates a good, reliable operation.

As common a mistake as not providing sufficient oil or grease is to use too much. Do not over- oil and grease. Bearings run hotter if the grease is packed. Remove the lubricant every 6 to 12 months and replace it. Use the type of oil or grease recommended by the manufacturer.

If noise or vibration occurs, find the cause. Centrifugal pumps and motors are meant to run smoothly even at high speeds. Noise or vibration probably means there is a misalignment between the pump and motor. See Figure 1. If the situation is allowed to continue, wear and early failure will result.

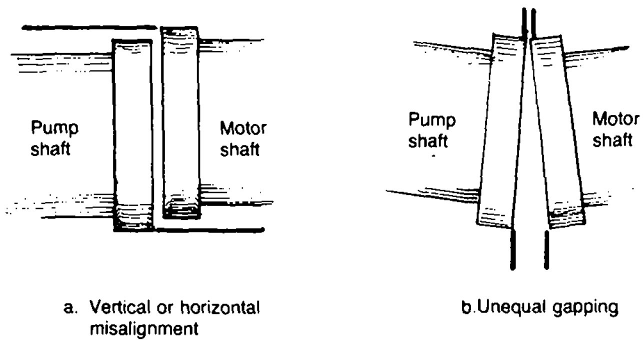

Figure 1. Causes of Noise or Vibration

Trouble Shooting

The system should be relatively trouble free if it is properly designed and installed and maintenance instructions from the manufacturer are followed.

Unfortunately, there are no perfect pumps or pump controls. Problems will be encountered from time to time. Table 3 provides a general check chart for common problems with centrifugal pumps. Tables 4 and 5 are typical of manufacturers' trouble shooting guides for jet and submersible pumps. Problems must be methodically checked for each possible cause of trouble and corrections made. Equipment failure may be caused by something quite different than expected. The underlying cause of the problem must be identified and corrected.

Table 3. Check Chart for Centrifugal Pump Troubles

Ten Symptoms	Possible Cause of Trouble (Each number is explained below)
Pump does not deliver water.	1-2-3-4-6-11-14-16-17-22-23
Insufficient capacity delivered.	2-3-4-5-6-7-8-9-10-11-14-17-20-22-23-29-30-31
Insufficient pressure developed.	5-14-16-17-20-22-29-30-31
Pump loses prime after starting.	2-3-5-6-7-8-11-12-13
Pump requires excessive power.	15-16-17-18-19-20-23-24-26-27-29-33-34-37
Stuffing box leaks excessively.	13-24-26-32-33-34-35-36-38-39-40
Packing has short life.	12-23-24-26-28-32-33-34-35-36-37-38-39-40
Pump vibrates or is noisy.	2-3-4-9-10-11-21-23-24-25-26-27-28-30-35-36-41-42-43-44-45-46-47
Bearings have short life.	24-26-27-28-35-36-41-42-43-44-45-46-47
Pump overheats and seizes up.	1-4-21-22-24-27-28-35-36-41

Explanation of Possible Causes of Trouble

Suction Troubles

1. Pump does not prime.
2. Pump or suction pipe not completely filled with liquid.
3. Suction lift too high.
4. Insufficient margin between suction pressure and vapor pressure.
5. Excessive amount of air or gas in liquid.
6. Air pocket in suction line.
7. Air leaks into suction line.
8. Air leaks into pump through stuffing boxes.
9. Foot valve too small.
10. Foot valve partially clogged.
11. Inlet of suction pipe insufficiently submerged.
12. Water-seal pipe plugged.
13. Seal cage improperly located in stuffing box preventing sealing fluid entering space to form the seal.

System Troubles

14. Speed too low.
15. Speed too high.
16. Wrong direction of rotation.
17. Total head of system higher than design head of pump.
18. Total head of system lower than pump design head.
19. Specific gravity of liquid different from design.
20. Viscosity of liquid differs from design.
21. Operation at very low capacity.
22. Parallel operation of pumps unsuitable for such operation.
23. Foreign matter in impeller.
24. Misalignment.
25. Foundations not rigid.
26. Shaft bent.
27. Rotating part rubbing on stationary part.
28. Bearings worn.
29. Wearing rings worn.
30. Impeller damaged.
31. Casing gasket defective permitting internal leakage.
32. Shaft or shaft sleeves worn or scored at the packing.
33. Packing improperly installed.
34. Incorrect type of packing for operating conditions.
35. Shaft running off center because of worn bearings or misalignment.
36. Rotor out of balance resulting in vibration.
37. Gland too tight resulting in no flow of liquid to lubricate packing.
38. Failure to provide cooling liquid to water-cooled stuffing boxes.
39. Excessive clearance at bottom of stuffing box between shaft and casing, causing packing to be forced into pump interior.
40. Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve.
41. Excessive thrust caused by a mechanical failure inside the pump or by the failure of the hydraulic balancing device, if any.
42. Excessive grease or oil in antifriction-bearing housing or lack of cooling, causing excessive bearing temperature.
43. Lack of lubrication.
44. Improper installation of antifriction bearings (damage during assembly, incorrect assembly or stacked bearings, or use of unmatched bearings as a pair).
45. Dirt getting into bearings.
46. Rusting of bearings due to water getting into housing.
47. Excessive cooling of water-cooled bearing resulting in condensation in the bearing housing of moisture from the atmosphere.

Table 4. Trouble Shooting Guide-Jet Pumps

Pump Will Not Start or Run

Cause of Trouble	How to Check	How to Correct
1. Blown fuse	Check to see if fuse is OK	If blown, replace with fuse of proper size
2. Low line voltage	Use voltmeter to check pressure switch or terminals nearest pump	If voltage under recommended minimum, check size of wiring from main switch on property; if OK, contact power company
3. Loose, broken, or incorrect wiring	Check wiring circuit against diagram; see that all connections are tight and that no short circuits exist because of worn insulation or crossed wire	Rewire any incorrect circuits; tighten connections, replace defective wires
4. Defective motor	Check to see that switch is closed	Repair or take to motor service station
5. Defective pressure switch	Check switch setting; excessive wear	Adjust switch settings; clean contacts with emory cloth if dirty
6. Tubing to pressure switch plugged	Remove tubing and blow through it	Clean or replace if plugged
7. Impeller or seal	Turn off power, then use screwdriver to try to turn impeller or motor	If impeller will not turn, remove housing and locate source of binding
8. Defective start capacitor	Use an ohmmeter to check resistance across capacitor; needle should jump when contact is made; no movement means an open capacitor; no resistance means capacitor is shorted	Replace capacitor or take motor to service station
9. Motor shorted out	If fuse blows when pump is started (and external wiring is OK) motor is shorted	Replace motor

Motor Overheats and Overload Trips Out

Cause of Trouble	How to Check	How to Correct
1. Incorrect line voltage	Use voltmeter to check at pressure switch or terminals nearest pump	If voltage under recommended minimum, check size of wiring from main switch on property; if OK, contact power company
2. Motor wired incorrectly	Check motor wiring diagram	Reconnect for proper voltage as per wiring diagram
3. Inadequate ventilation	Check air temperature where pump is located; if over 100°F., overload may be tripping on external heat	Provide adequate ventilation or move pump
4. Prolonged low pressure delivery	Continuous operation at very low pressure places heavy overload on pump; this can cause overload protection to trip	Install glove valve on discharge line and throttle to increase pressure

Table 4. Trouble Shooting Guide-Jet Pumps continued

Pump Starts and Stops Too Often		
Cause of Trouble	How to Check	How to Correct
1. Leak in pressure tank	Apply soapy water to entire surface above water line. If bubbles appear, air is leaking from tank	Repair leaks or replace tank
2. Defective air volume control	This will lead to a waterlogged tank; make sure control is operating properly; if not, remove and examine for plugging	Clean or replace defective control
3. Faulty pressure switch	Check switch setting; examine switch contacts for dirt or excessive wear	Adjust switch settings; clean contacts with emory cloth if dirty
4. Leak on discharge side of system	Make sure all fixtures in plumbing system are shut off; then check all units (especially ballcocks) for leaks; listen for noise of water running	Repair leaks as necessary
5. Leak on suction side of system	On shallow well units, install pressure gauge on suction side On deep well systems, attach a pressure gauge to the pump; close the discharge fine valve; then, using a bicycle pump or air compressor, apply about 30 psi pressure to the system; if the system will not hold this pressure when the compressor is shut off, there is a leak on the suction side	Make sure above ground connections are tight; then repeat test; if necessary, pull piping and repair leak
6. Leak in foot valve	Pull piping and examine foot valve	Repair or replace defective valve

Pump Will Not Shut Off		
Cause of Trouble	How to Check	How to Correct
1. Defective pressure switch	Arcing may have caused pressure switch points to "weld" in closed position; examine points and other parts of switch for defects	Clean points or replace switch
2. Water level in well too low	Well production may be too low for pump capacity; restrict flow of pump output, wait for well to recover, and start pump	If partial restriction corrects trouble, leave valve or cock at restricted setting; otherwise, lower pump in well if depth is sufficient; do not lower if sand clogging might occur
3. Leak in drop line	Raise pipe and examine for leaks	Replace damaged section of drop pipe
4. Pump parts worn	The presence of abrasives in the water may result in excessive wear on the impeller, casing, and other close-clearance parts; before pulling pump, reduce setting on pressure switch to see if pump shuts off. If it does, worn parts are probably at fault	Pull pump and replace worn components

Table 4. Trouble Shooting Guide-Jet Pumps continued

Pump Operates But Delivers Little or No Water

Cause of Trouble	How to Check	How to Correct
1. Low line voltage	Use voltmeter to check at pressure switch or terminals nearest pump	If voltage under recommended minimum, check size of wiring from main switch on property; if OK, contact power company
2. System incompletely primed	When no water is delivered, check prime of pump and well piping	Reprime if necessary
3. Air lock in suction line	Check horizontal piping between well and pump; if it does not pitch upward from well to pump, an air lock may form	Rearrange piping to eliminate air lock
4. Undersized piping	If system delivery is low, the discharge piping and/or plumbing lines may be undersized; refigure friction loss	Replace undersized piping or install pump with higher capacity
5. Leak in air volume control or tubing	Disconnect air volume control tubing at pump and plug hole; if capacity increases, a leak exists in the tubing of control	Tighten all fittings and replace control if necessary
6. Pressure regulating valve stuck or incorrectly set (deep well only)	Check valve setting; inspect valve for defects	Reset, clean, or replace valve as needed
7. Leak on suction side of system	On shallow well units, install pressure gauge on suction side; on deep well systems, attach a pressure gauge to the pump; close the discharge line valve; then, using a bicycle pump or air compressor, apply about 30 psi pressure to the system; if the system will not hold this pressure when the compressor is shut off, there is a leak on the suction side	Make sure above ground connections are tight; then repeat test; if necessary, pull piping and repair leak
8. Low well level	Check well depth against pump performance table to make sure pump and ejector are properly sized	If undersized, replace pump or ejector
9. Wrong pump-ejector combination	Check pump and ejector models against manufacturer's performance tables	Replace ejector if wrong model is being used
10. Low well capacity	Shut off pump and allow well to recover; restart pump and note whether delivery drops after continuous operation	If well is "weak," lower ejector (deep well pumps), use a tail pipe (deep well pumps), or switch from shallow well to deep well equipment
11. Plugged ejector	Remove ejector and inspect	Clean and reinstall if dirty
12. Defective or plugged foot valve and/or strainer	Pull foot valve and inspect; partial clogging will reduce delivery; complete clogging will result in no water flow; a defective foot valve may cause pump to lose prime, resulting in no delivery	Clean, repair, or replace as needed
13. Worn or defective pump parts or plugged impeller	Low delivery may result from wear or impeller or other pump parts; disassemble and inspect	Replace worn parts or entire pump; clean parts if required

Table 5. Trouble Shooting Guide-Submersible Pumps

Fuses Blow or Circuit Breaker Trips When Motor is Started

Cause of Trouble	How to Check	How to Correct
1. Incorrect line voltage	Check the line voltage terminals in the control box (or connection box in the case of the 2-wire models) with a voltmeter, make sure that the voltage is within the minimum-maximum range prescribed by the manufacturer	If the voltage is incorrect, contact the power company to have it corrected
2. Defective control box: a. Defective wiring	Check out all motor and power-line wiring in the control box, following the wiring diagram found inside the box; see that all connections are tight and that no short circuits exists because of worn insulation or crossed wires	Rewire any incorrect circuits; tighten loose connections; replace worn wires
b. Incorrect components	Check all control box components to see that they are the type and size specified for the pump in the manufacturers' literature; in previous service work, the wrong components may have been installed	Replace any incorrect component with the size and type recommended by the manufacturer
c. Defective starting capacitor (skip for 2-wire models)	Using an ohmmeter, determine the resistance across the starting capacitor; when contact is made, the ohmmeter needle should jump at once, then move up more slowly; no movement indicates an open capacitor (or defective relay points); no resistance means that the capacitor is shorted	Replace defective starting capacitor
d. Defective relay (skip for 2-wire models)	Using an ohmmeter, check the relay coil; its resistance should be as shown in the manufacturers' literature; recheck ohmmeter reading across starting capacitor with a good capacitor, no movement of the needle indicates defective relay points	If coil resistance is incorrect or points defective, replace relay
3. Defective pressure switch	Check the voltage across the pressure switch points; if less than the line voltage determined in "1" above, the switch points are causing low voltage by making imperfect contact	Clean points with a mild abrasive cloth or replace pressure switch
4. Pump in crooked well	If wedged into a crooked well, the motor and pump may become misaligned, resulting in a locked rotor	If the pump does not rotate freely, it must be pulled and the well straightened
5. Defective motor winding or cable: a. Shorted or open motor winding	Check the resistance of the motor winding by using an ohmmeter on the proper terminals in the control box (see manufacturers' wiring diagram); the resistance should match the ohms specified in the manufacturers' data sheet; if too low, the motor winding may be shorted; if the ohmmeter needle doesn't move, indicating high or infinite resistance, there is an open circuit in the motor winding	If the motor winding is defective--shorted or open--the pump must be pulled and the motor repaired
b. Grounded cable or wiring	Ground one lead of the ohmmeter onto the drop pipe or shell casing, then touch the other lead to each motor wire terminal; if the ohmmeter needle moves appreciably when this is done, there is a ground in either the cable or the motor winding	Pull the pump and inspect the cable for damage; replace damaged cable; if cable checks OK, the motor winding is grounded
6. Pump sand locked	Make pump run backwards by interchanging main and start winding (black and red) motor leads at control box	Pull pump, disassemble and clean; before replacing, make sure that sand had settled in well; if well is chronically sandy, a submersible should not be used

Table 5. Trouble Shooting Guide-Submersible Pumps continued

Pump Operates But Delivers Little or No Water

Cause of Trouble	How to Check	How to Correct
1. Pump may be air locked	Stop and start pump several times, waiting about one minute between cycles; if pump then resumes normal delivery, air lock was the trouble	If this test fails to correct the trouble, proceed as below
2. Water level in well too low	Well production may be too low for pump capacity; restrict flow of pump output, wait for well to recover, and start pump	If partial restriction corrects trouble, leave valve or cock at restricted setting; otherwise, lower pump in well if depth is sufficient; do not lower if sand clogging might occur
3. Discharge line check valve installed backward	Examine check valve on discharge line to make sure that arrow indicating direction of flow points in right direction	Reverse valve is necessary
4. Leak in drop pipe	Raise pipe and examine for leaks	Replace damaged section of drop pipe
5. Pump check valve jammed by drop pipe	When pump is pulled after completing "4" above, examine connection of drop pipe to pump outlet; if threaded section of drop pipe has been screwed in too far, it may be jamming the pump's check valve in the closed position	Unscrew drop pipe and cut off portion of threads
6. Pump intake screen blocked	The intake screen on the pump may be blocked by sand or mud; examine	Clean screen, and when reinstalling pump, make sure that it is located several feet above the well bottom-preferably 10 feet or more
7. Pump parts worn	The presence of abrasives in the water may result in excessive wear on the impeller, casing, and other close-clearance parts; before pulling pump, reduce setting on pressure switch to see if pump shuts off. If it does, worn parts are probably at fault.	Pull pump and replace worn components
8. Motor shaft loose	Coupling between motor and pump shaft may have worked loose; inspect for this after pulling pump and looking for worn components, as in "7" above	Tighten all connentions and setscrews

Pump Starts Too Frequently

Cause of Trouble	How to Check	How to Correct
1. Pressure switch defective or out of adjustment	Check setting on pressure switch and examine for defects	Reduce pressure setting or replace switch
2. Leak in pressure tank above water level	Apply soap solution to entire surface of tank and look for bubbles indicating air escaping	Repair or replace tank
3. Leak in plumbing system	Examine service line to house and distribution branches for leaks	Repair leaks
4. Discharge line check valve leaking	Remove and examine	Replace if defective
5. Air volume control plugged	Remove and inspect air volume control	Clean or replace
6. Snifter valve plugged	Remove and inspect snifter valve	Clean or replace

Table 5. Trouble Shooting Guide-Submersible Pumps continued

Motor Does Not Start, But Fuses Do Not Blow

Cause of Trouble	How to Check	How to Correct
1. Overload protection out	Check fuses or circuit breaker to see that they are operable	If fuses are blown, replace; if breaker is tripped, reset
2. No power	Check power supply to control box (or overload protection box) by placing a voltmeter across incoming power lines; voltage should approximate nominal line voltage	If no power is reaching box, contact power company for service
3. Defective control box	Examine wiring in control box to make sure all contacts are tight; with a voltmeter, check voltage at motor wire terminals; if no voltage is shown at terminals, wiring is defective in control box	Correct faulty wiring or tighten loose contacts
4. Defective pressure switch	With a voltmeter, check voltage across pressure switch while the switch is closed; if the voltage drip is equal to the line voltage, the switch is not making contact	Clean points or replace switch

Fuses Blow When Motor is Running

Cause of Trouble	How to Check	How to Correct
1. Incorrect voltage	Check line voltage terminals in the control box (or connection box in the case of 2-wire models) with a voltmeter; make sure that the voltage is within the minimum-maximum range prescribed by the manufacturer	If voltage is incorrect, contact power company for service
2. Overheated overload protection box	If sunlight or other source of heat has made box too hot, circuit breakers may trip or fuses blow; if box is hot to the touch, this may be the problem	Ventilate or shade box, or remove from source of heat
3. Defective control box components (skip this for 2-wire models)	Using an ohmmeter, determine the resistance across the running capacitor; when contact is made, the ohmmeter needle should jump at once, then move up more slowly; no movement indicates an open capacitor (or defective relay points); no resistance means that the capacitor is shorted Using an ohmmeter, check the relay coil; its resistance should be as shown in the manufacturer's literature. Recheck ohmmeter reading across running capacitor; with a good capacitor, no movement of the needle indicates relay points	Replace defective components
4. Defective motor winding or cable	Check the resistance of the motor winding by using an ohmmeter on the proper terminals in the control box (see manufacturer's wiring diagram); the resistance should match the ohms specified in the manufacturer's data sheet; if too low, the motor winding may be shorted; if the ohmmeter needle doesn't move, indicating high or infinite resistance, there is an open circuit in the motor winding Ground one lead if the ohmmeter onto the drop pipe or shell casing, then touch the other lead to each motor wire terminal; if the ohmmeter needle moves appreciably when this is done, there is a ground in either the cable or the motor winding	If neither cable or winding is defective-shorted, grounded, or open-pump must be pulled and serviced
5. Pump becomes sandlocked	If the fuses blow while the pump is operating, sand or grit may have become wedged in the impeller, causing the rotor to lock; to check this, pull the pump	Pull pump, disassemble, and clean; before replacing, make sure that sand has settled in well; if well is chronically sandy, a submersible should not be used

Table 5. Trouble Shooting Guide-Submersible Pumps continued

Pump Will Not Shut Off		
Cause of Trouble	How to Check	How to Correct
1. Wrong pressure switch setting or "drift"	Lower switch; if pump shuts off, this was the trouble	Adjust switch to proper setting
2. Defective pressure switch	Arcing may have caused switch contacts to "weld" together in closed position; examine points and other parts of switch for defects	Replace switch if defective
3. Tubing to pressure switch plugged	Remove tubing and blow through it	Clean or replace if plugged
4. Loss of prime	When no water is delivered, check prime of pump and well piping	Reprime if necessary
5. Low well level	Check well depth against pump performance table to make sure pump and ejector are properly sized	If undersized, replace pump or ejector
6. Plugged ejector	Remove ejector and inspect	Clean and reinstall if dirty

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

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Water for the World

Operating and Maintaining Hand Pumps
Technical Note No. RWS. 4.O.3

It is relatively easy to construct a water supply and to install the necessary pumping equipment to provide water to a village. A consideration too often overlooked is whether it will be operating one, two, five, or more years later. Too often, the system will become inoperative because of lack of knowledge of and attention to operation and maintenance.

Hand pumps have been installed in many villages throughout the world and in a number of different situations. Unfortunately many of them have become inoperative. As a result, there has been considerable effort to develop a better hand pump. This has led to worthwhile and necessary improvements but there is not now, nor is there likely to be, a "perfect" pump that will continue working without proper operation and maintenance. See Figures 1 and 2. The easier it is to obtain water without a hand pump, the more likely it is that the pump will not be maintained and, once failure occurs, that the pump will not be repaired. For this reason it is essential that the village recognize the positive benefits of an improved water source. Only then will that village be motivated to see that the improvements are maintained or, as economics allow, increased.

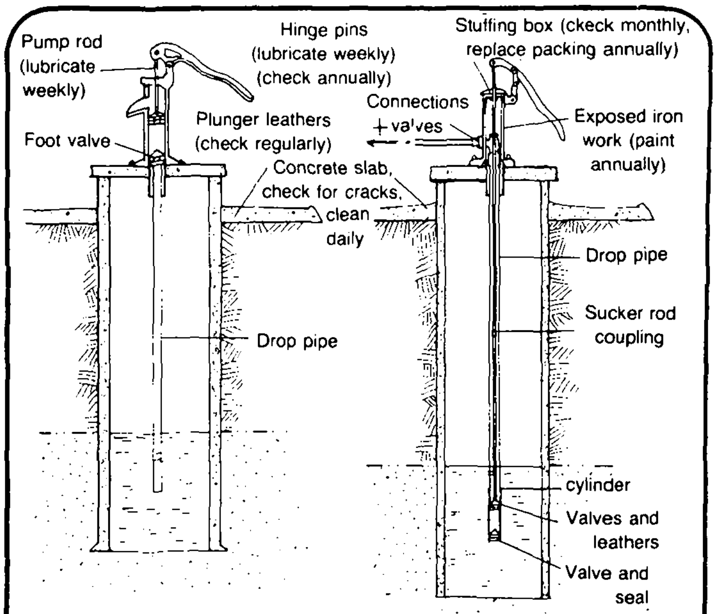

Figure 1. Maintenance Points on Hand Pumps

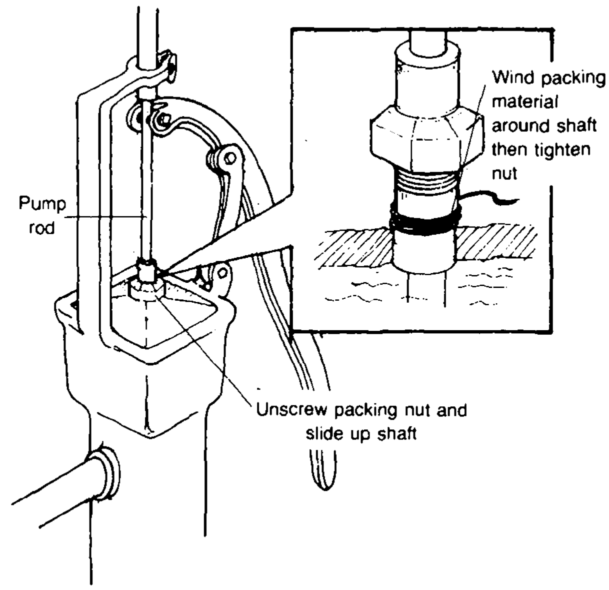

Figure 2. Repacking Stuffing Box

Useful Definition

SUCKER ROD - The rod which connects a windmill or hand pump to the pump cylinder in the well.

Operation and Maintenance Programs

Various programs have been proposed and implemented to assure proper operation and maintenance. When coupled with community involvement, all have a good chance of success. These programs range from the village being totally responsible for operation and maintenance of the system to a government unit taking full responsibility. An alternative is cooperation between the community and an agency of central government to provide needed operation and maintenance. The specific means adopted will vary from place to place, from country to country and, in some situations, from village to village. It is imperative that the community recognize the importance of operation and maintenance and support the improvement.

Whatever method is used to provide operation and maintenance, it is absolutely essential that the village play a role and that this role is understood and agreed to by the village. As discussed above, one method of providing for continued operation and maintenance is a cooperative agreement between a unit of government and the village. The following is an example covering preventive maintenance, major repairs and an educational program.

Example of Operational Procedures

Preventive Maintenance. Day-to-day maintenance of the hand pump is the responsibility of the village. In order to assure that this is accomplished, one of the villagers should be appointed the pump custodian. It is his or her responsibility to provide routine lubrication, keep the area around the pump clean and note wear for reporting to the field maintenance worker. Figures 1 and 2 identify key maintenance points.

A field maintenance worker should make routine inspections of all completed projects in the area. At the time of visits, he or she would determine what repairs could be made immediately. See Table 1 for examples of on-the-spot preventive maintenance repairs.

Table 1. Typical Preventive Maintenance Repairs by Field Maintenance Worker

1. Replace packing in hand pumps.
2. Replace worn bolts and cotter pins on pumps.
3. Replace worn or broken pump handles.
4. Replace washers in pump compression spouts.
5. Replace worn sucker rods.
6. Replace pump cylinders (worn leathers).
7. Replace defective valves at watering points.
8. Replace necessary fittings.
9. Replace manhole covers.

A member of the sanitation staff should accompany the field maintenance worker on the initial visit to each project to explain the project and make recommendations for a preventive maintenance schedule and procedure. The professional sanitation staff should assist the field maintenance worker in setting up routine inspection trips, advising on location and details of each project, and recommending methods of repair as shown in Figure 3. In addition, the professional sanitation staff should review inspection and repair reports so that they would be in a position to coordinate the field maintenance workers activities. The professional sanitation staff should notify the field maintenance worker upon the completion of a project and advise him or her of the details of all projects in the area. Table 2 is an example of an inspection report that can be used for the field work.

Major Repair of Breakdown. In case of major breakdown or failure of the project, the village leaders should notify the field maintenance worker who would then inspect the project and determine what is necessary for repairs. In the case of a major or unusual problem, the field maintenance worker should consult the professional sanitation staff and, if necessary, the professional sanitation staff should visit the project to make recommendations. If additional labor is necessary for repairs, the field maintenance worker will arrange hiring details with the village leaders. The necessary labor should be recruited from individuals who use the supply. The field maintenance worker would

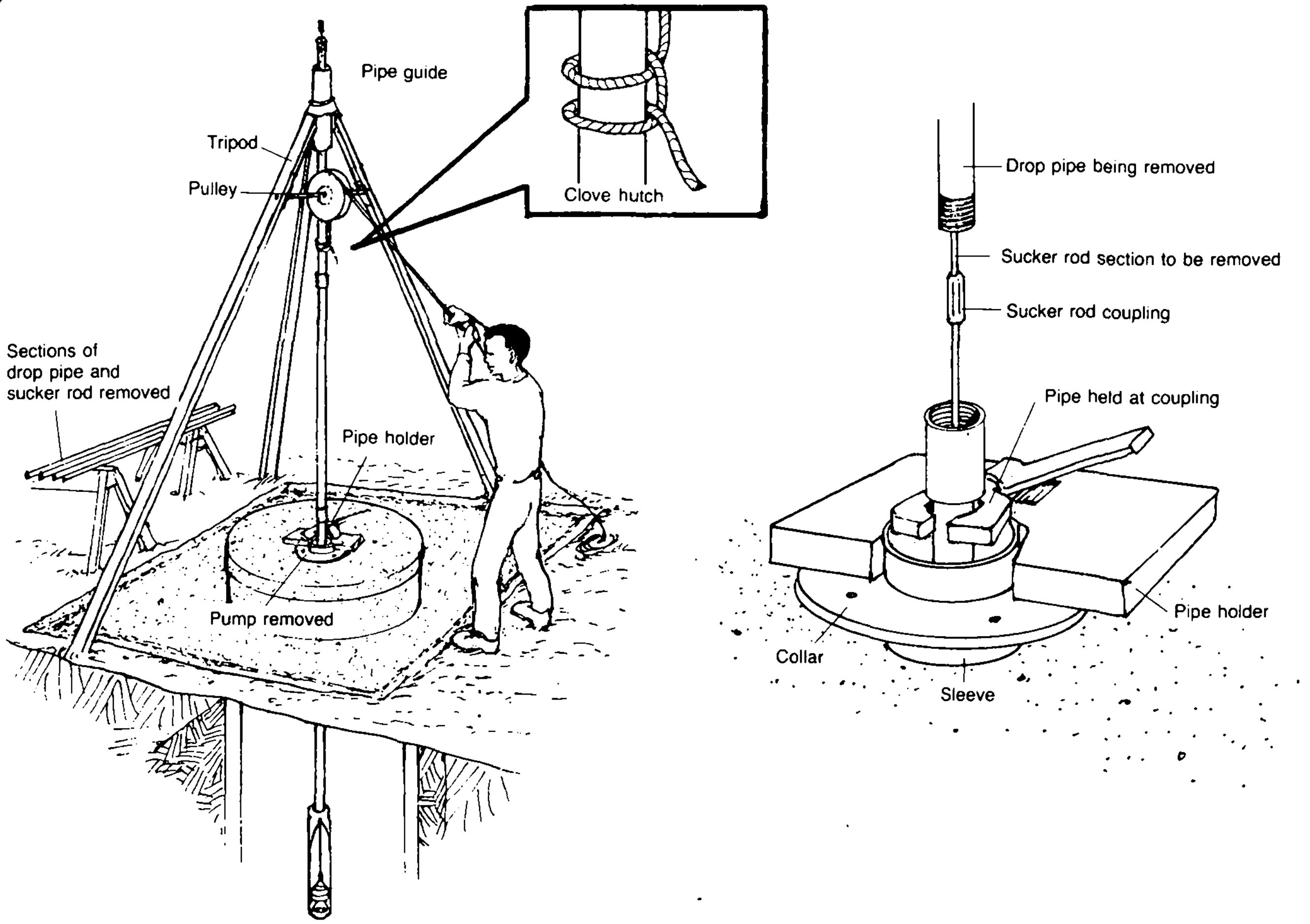

Figure 3. Raising Drop Pipe and Cylinder

estimate the labor and materials necessary for the repairs and submit this estimate to the professional sanitation staff for review and approval.

Educational Program. A cooperative effort between village community workers and the field maintenance worker should be undertaken to educate the village on preventive maintenance of the hand pump. They should inform the villagers of items to look for so that repairs can be made before they become too costly, and of the proper channels for requesting repairs, when necessary.

Table 2. Sample Inspection Report

Date________________

Region______________________ Village______________________
Location____
Type____
Description: (Check items which are a part of the system).

hand pump ( ); well slab ( ); watering point ( ); spring box ( );
storage tank ( ); pipe line ( ); manhole cover ( ); diversion wall ( );
windmill ( ); stock through ( ); other____________________

Hand Pump	Good Condition	Repair or Replace
packing	( )	( )
bolts	( )	( )
cotter pins	( )	( )
handle	( )	( )
shaft	( )	( )
compression spout	( )	( )
sucker rod	( )	( )
cylinder	( )	( )
mounting	( )	( )
Water Point		
valve	( )	( )
mill hose	( )	( )
fittings	( )	( )
stand	( )	( )
piping	( )	( )
vent	( )	( )
hose clamp	( )	( )
Storage Tank		
walls	( )	( )
cover	( )	( )
manhole cover	( )	( )
bottom	( )	( )
discharge	( )	( )
vent	( )	( )
valves	( )	( )
piping	( )	( )
fittings	( )	( )
Windmill		
packing	( )	( )
discharge	( )	( )
seal	( )	( )
Stock Through		
walls	( )	( )
piping	( )	( )
valve	( )	( )
apron	( )	( )

Well Slab	Repair or Replace
good condition	( )
cracked	( )
manhole cover in place	( )
manhole cover missing	( )
manhole cover replaced	( )
Spring Box	
good condition	( )
cracked	( )
manhole cover in place	( )
manhole cover missing	( )
manhole cover replaced	( )
overflow satisfactory	( )
overflow needs repair	( )
overflow repaired	( )
vent satisfactory	( )
vent needs repair	( )
vent repaired	( )
discharge satisfactory	( )
discharge unsatisfactory	( )
discharge repaired	( )
Pipeline	
good condition	( )
needs repair	( )
estimate made	( )
Diversion Wall	
condition good	( )
needs repair	( )
estimate made	( )
Other	
____________________	( )
____________________	( )
____________________	( )

____
Field Maintenance Worker

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

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Water for the World

Operating and Maintaining Household Water Connections

Technical Note No. RWS. 4.O.5

Operation and maintenance of a water system with household connections should be done on a routine, scheduled basis. This should be accomplished as a part of the operation and maintenance activities described in "Detecting and Correcting Leaking Pipes," RWS.4.0.1, "Operating and Maintaining Mechanical Pumps," RWS.4.0.2 and "Operating and Maintaining Hand Pumps," RWS.4.0.3.

An Operation and Maintenance Program

The first step in establishing a planned operation and maintenance schedule is to obtain an as-built plan of the system similar to Figure 1. If one does not exist, then a plan should be made. Valve locations in the main lines as well as for individual connections must be known. The location, type and size of pipe is important and necessary for emergency repairs or extensions. The plan may have to be approximate to start, but as valves are located and other information gathered, a good as-built can be developed.

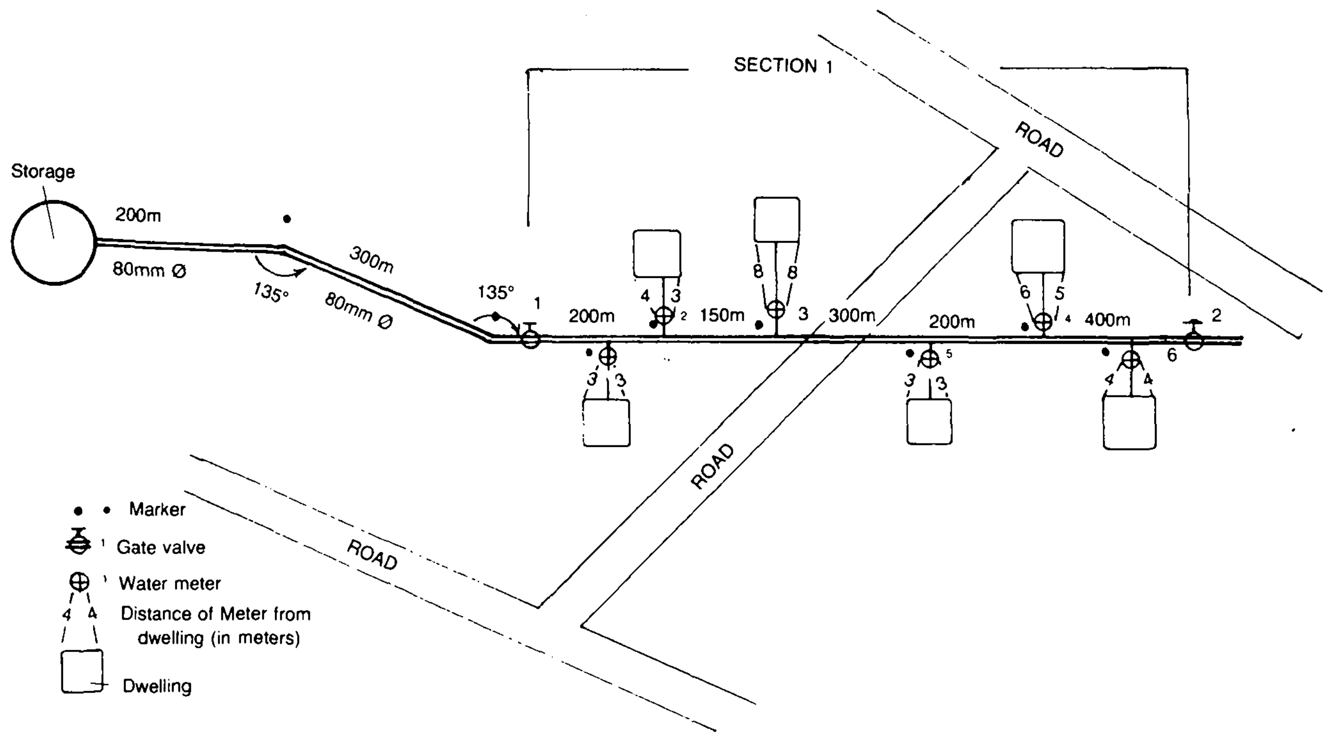

Figure 1. As-built Design Map of System (Section)

A good operation and maintenance program will include such activities as opening and closing all the gate valves in a system every six months and flushing fire or flush hydrants every six months. If valves fail to operate properly they should be replaced or repaired on a timely basis. The total system should be visually inspected by driving or walking it every week and by visiting each service regularly. Visiting each service can be done while water meters are being read if meters were installed. If not, the area should be visited regularly. For many rural systems, meters are read or the home visited on a 3-6 month basis. If water meters are installed, they should be removed and tested for accuracy every 3-5 years. Many operators routinely replace the parts subject to wear at that time.

The person responsible for operation and maintenance should record the results of inspections and activities for future reference. Table 1 is a list of activities that should be conducted on a scheduled basis.

Table 1. Operation and Maintenance Checklist for Community Water Systems

Daily	-Observe all public watering points morning and evening; make corrections as required -Record water level in storage tank -Make routine repairs -Provide service connections as required
Weekly	-Walk or drive water system; pay particular attention to wash stream and road crossings and to any construction activity near the water line
Monthly or Quarterly	-Read all water meters or visit service connection sites
Semi-annual	-Open and close all gate valves; record the number of turns both to open and to close -Look for signs of leakage in the gate valve boxes -Flush all hydrants until the water flows clear; note any odors
Annual	-Remove and test/repair one fifth of the water meters in the system; this will assure that all of the system meters are repaired or replaced every 5 years

Common Operation and Maintenance Problems

Although relatively few things go wrong with household water connections or service lines there are some common problems. One is covers left off of meter and valve boxes. Children often throw objects down valve boxes when they are open and this can cause a valve wrench to jam. Another common problem is damage from vehicles being driven over valve boxes. Corrosion of metal pipe is not unusual.

Occasionally, a service line crossing a street or road is crushed or develops leaks for other reasons. Repairing a leaking service line under a road can be a costly, time-consuming task. If the service line is copper, it can be replaced by coupling a new line to the existing line, tying the opposite end of the existing line to a backhoe bucket or other pulling device, and then pulling the old line out until the new line is positioned in place. As a safety precaution, keep personnel well out of the way, in case the line should break while pulling.

If the existing line is plastic tubing, it will probably break if pulled. In this case, a 16mm stainless steel aircraft cable is pushed through the existing line by hand. Tape the end of the cable with electrical tape to prevent snagging. Attach the new line to a tee. Loop the cable through the straight section of the tee. Clamp with a cable clamp and tape the loose end. Attach the opposite end of the cable to a backhoe or other pulling device and pull the cable until the new line is positioned under the street. See Figure 2.

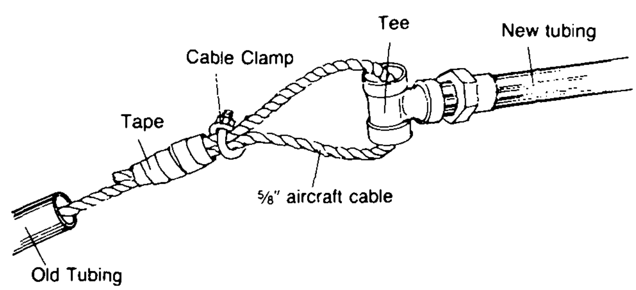

Figure 2. Replacing Plastic Pipe Under a Road

The primary problems with household water connections will be with leaking faucets and toilet bowls in the house. Since the water used is not metered in many rural systems, the customer does not pay for the wasted water and the leaks are allowed to continue or worsen. These systems usually have a shortage of water. When one or more people waste water, others have to do without or additional sources must be developed to serve them. This costs all the users money. It is important that the customers be motivated to repair all leaks. One method is to provide training and handouts telling how to repair the leaks.

Notes

Notes

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Water for the World

Methods of Storing Water
Technical Note No. RWS. 5.M

Water storage is often a necessary part of a rural water supply system. Storage ensures that a sufficient quantity of water without interruption is available to users. If no storage is used in piped distribution systems, the water source and the treatment and pumping systems must have sufficient capacity to meet the daily demand for water. Due to hourly changes in demand for water, it is economically and technically impossible for most systems to meet demand unless storage is provided. Not only is storage necessary for larger piped distribution systems, but it should be provided for individual families that capture rainfall for drinking water.

Three basic types of water storage reservoirs are available for use in rural areas. For individual supplies, household cisterns provide necessary storage. In large, piped distribution systems, either ground level or elevated storage reservoirs should be installed. This technical note describes each type of storage reservoir and explains under what conditions each should be used. Open reservoirs, such as those formed by dams, are not covered. Information about dams can be found in "Designing Small Dams," RWS.1.D.5.

Household Cisterns and Storage Facilities

Household storage jars and household cisterns can be used to collect rainwater. The choice depends on the following factors:

- the storage capacity needed,
- the availability of materials needed for construction,
- the economic resources available for each family, and
- the labor skills required.

Useful Definitions

EVAPORATION - Loss of surface water to the air as the surface water is heated by the sun and rises to the atmosphere as vapor.

FERROCEMENT - An economical and simple-to-use type of reinforced concrete made of wire mesh, sand, water and cement.

FRICTION - Resistance to flow caused by a moving object coming into contact with another substance; resistance to water flow caused by the water's contact with pipe.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

PEAK DEMAND - The greatest demand or need for water by the users; peak demands usually occur in the morning and late afternoon.

TOPOGRAPHY - The land surface features of a region including elevation, location of water bodies and other prominent features.

Cisterns and storage jars can be constructed for use above or below ground using many different types of materials. Concrete, ferrocement, reinforced concrete, corrugated iron, and wood are all suitable materials as long as appropriate measures are taken to make structures watertight.

Figure 1a shows a typical cistern used in collecting water from roofs. The rectangular tank is made of reinforced concrete and located as close to the house as possible. However, it should be at least 10-15m from a latrine or other sewage disposal system and on higher ground than these facilities. Construction materials may be costly because cement and reinforcing rod must be purchased. In some cases, costs can be lowered by using very hard bamboo for reinforcing if it is available. Rectangular tanks can be made of bricks and mortar. These materials may be more easily available and cheaper in rural areas.

Figure 1b shows a low-cost alternative cistern design. A circular, above ground cistern can be built from ferrocement using cement, sand, water and reinforcing wire mesh similar to chicken wire. In many rural areas, these materials are readily available which makes this type of reservoir attractive. Some skill is needed in using ferrocement.

A large capacity rectangular reinforced concrete or masonry tank can be constructed in the ground as shown in Figure 2. The design is similar to that shown in Figure 1a. Below ground storage offers several advantages:

- water is cool throughout the year,
- little or no loss of water through evaporation occurs,
- the ground offers good structural support for the reservoir walls, and
- space above ground is saved.

A major disadvantage of an underground storage is extraction of water. In above ground storage systems, simple tap arrangements can be used. When the reservoir is located below ground, a hand pump is needed to remove the water.

Jars can be used to store rainwater collected from roofs. Jars of various capacities made from clay or mortar without reinforcing make useful reservoirs. They are not expensive to make; they require basic skills that are known in most areas; and they use materials that are generally locally available.

Large storage jars as shown in Figure 3 can be made from reinforced mortar to capacities up to $4 m^3$ (4000 liters). The jars require no wire reinforcement. They are made with cement mortar and gunny cloth sewn together. Although the capacities of the jars are not great, several jars can be built and covered to store water during the dry season. Long term water storage is not only useful to meet water demand during the dry season but it also improves the quality of water that is stored for several weeks.

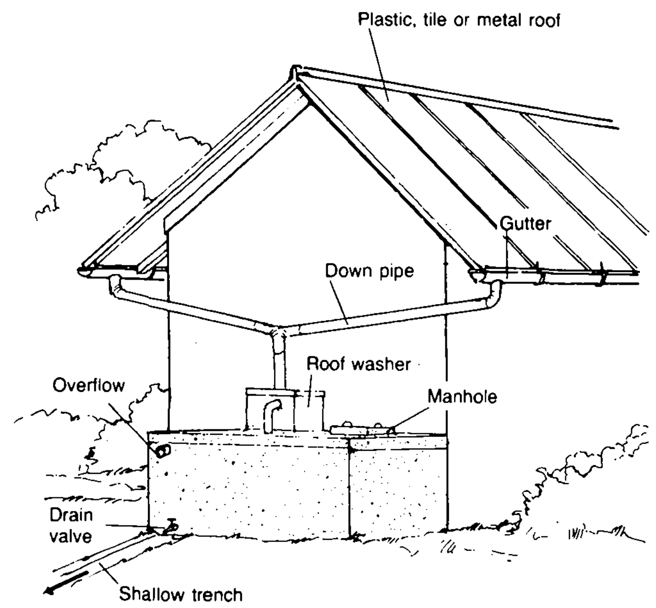

Figure 1a. Roof Catchment and Concrete Cistern

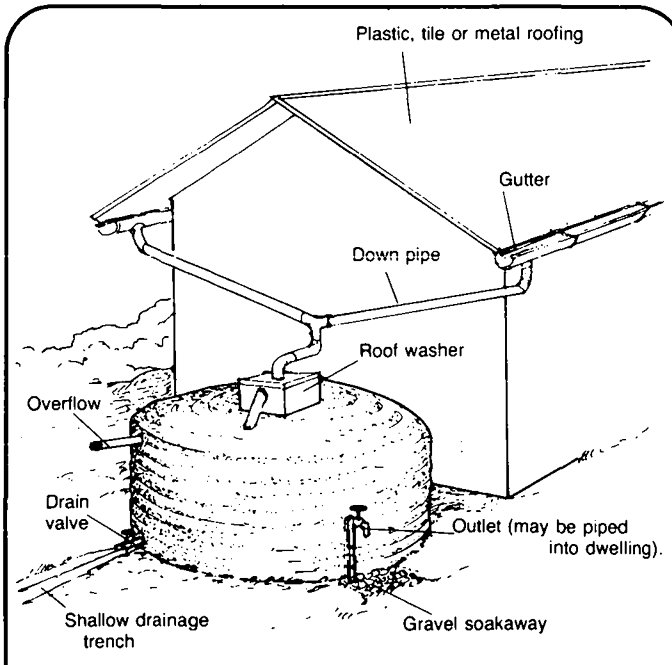

Figure 1b. Roof Catchment with Ferrocement Cistern

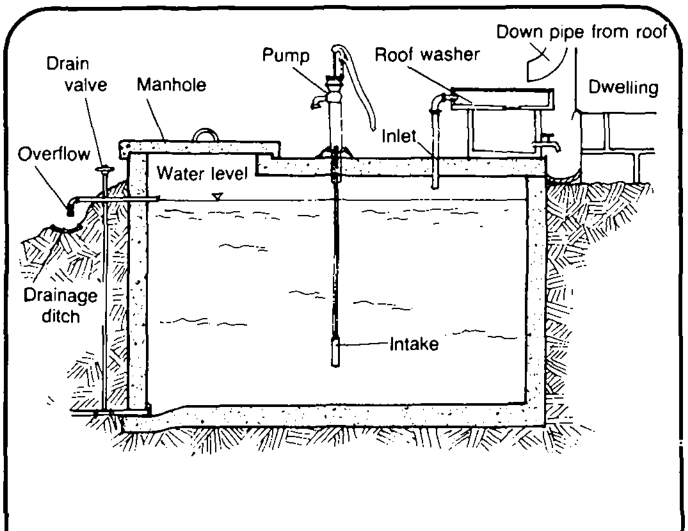

Figure 2. In Ground Storage for Roof Catchment

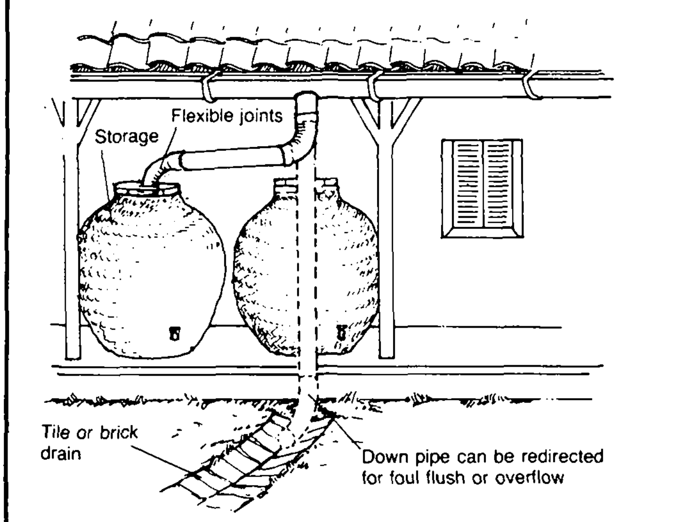

Figure 3. Flexible Down Pipe

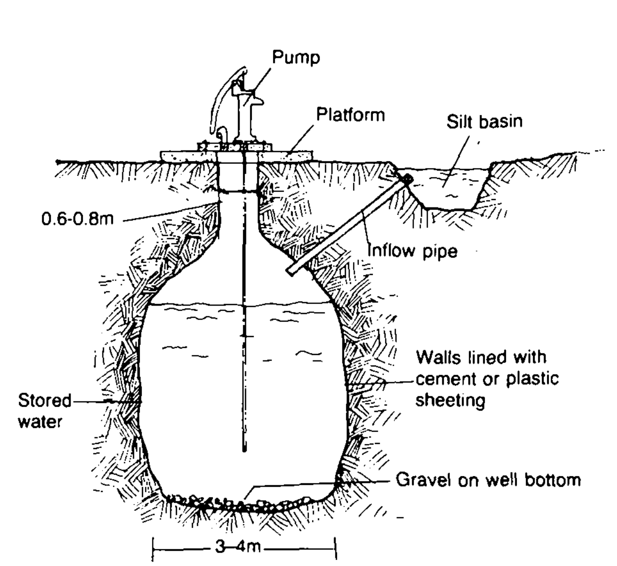

Figure 4. Underground Rainwater Storage Well

Underground storage wells like the one in Figure 4 are molded directly into the ground by compacting the earth. The walls are lined with a layer of concrete or mortar or with plastic sheeting. A special inlet should be installed to direct water to storage and a hand pump used to extract the water. This type of unit can be used where the water table is low and the ground is firm.

Any of these storage devices are suitable for household systems. Large cisterns are very costly and not practical unless several families use the same one. To ensure that adequate supplies of water are available during the entire year, cisterns should be well planned and designed. Information on designing cisterns is available in "Designing a Household Cistern," RWS.5.D.1.

Ground Level and Elevated Storage Facilities

When water is distributed to users through a piped distribution system, either by a pump or gravity flow, storage should be provided. A storage reservoir has the following advantages:

1. Allows the system to satisfy hourly variations and peak demand.

2. Provides for maintenance of adequate pressure throughout the distribution system.

3. Provides the means of repairing pipes or pumps between the supply source and storage without interruption of water service.

4. Where water is pumped to storage pumps can be run at a constant rate for a fixed period of time. Pumps that are smaller and cheaper than would be required if no storage were provided can be used, thereby reducing the cost of the distribution system.

5. The pipe running from the supply source to storage can be smaller than if a direct line from the source to the village were installed. The use of a smaller pipe lowers cost.

Two basic methods of storing water for distribution systems are ground level and elevated storage tanks. The choice depends on the topography of the area where the system is installed. Elevation is the most important factor influencing the choice between a ground or elevated tank. The bottom water level of the storage facility should be high enough so that there is sufficient force to move the water to all users. In technical terms, after allowance for friction loss in the distribution system, a minimum residual head of ten meters should be available at delivery points.

Ground Level Tanks. If high ground is available, close to the community, a ground level tank can provide a gravity supply at adequate pressure. The arrangement would be similar to that shown in Figure 5 where water is pumped from the source to the reservoir. From the reservoir, it flows by gravity to the users. The cost of installing a ground level storage reservoir is much lower than an elevated tank.

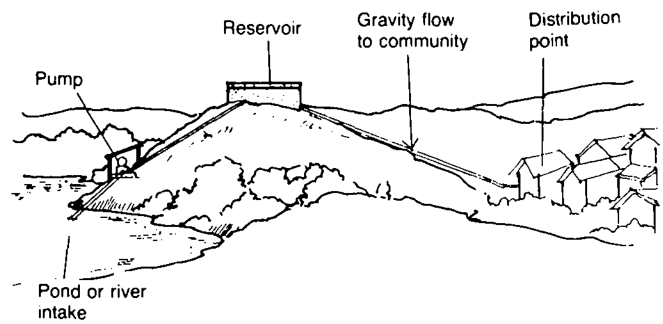

Figure 5. Locating Ground Level Storage Facility

Ground level storage tanks are generally made of masonry, concrete, reinforced concrete, steel sheeting or ferrocement. The choice of material depends on the capacity of the tank, the materials available, and the skills of available labor. Small capacity tanks of $5m^3$-$40m^2$ (5000-40000 liters) can be built from locally available materials such as brick and rock or from steel sheets. Small volume steel tanks can be purchased in some areas. Ferrocement tanks up to $40m^3$ in capacity can be economically installed in rural areas using local labor. Figure 6 shows an example of a circular ferrocement water tank and a rectangular masonry tank.

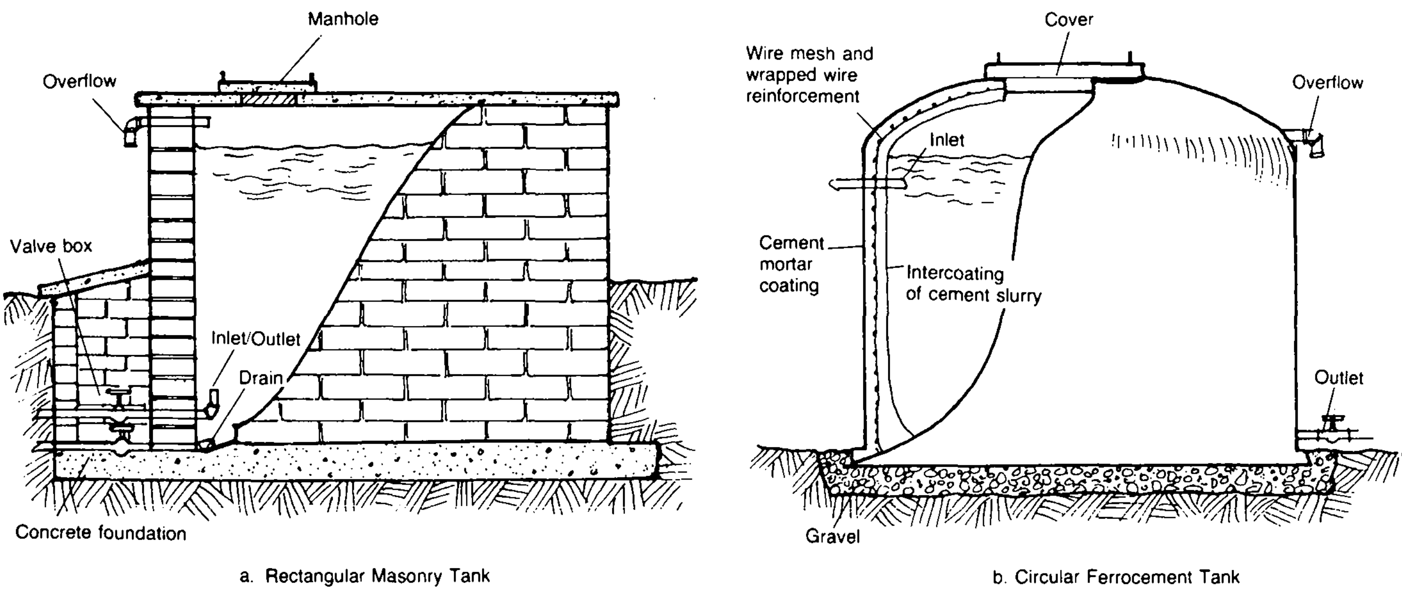

Figure 6. Small Water Reservoirs

Larger storage tanks of over $40m^3$ in capacity should be constructed of reinforced concrete to ensure their strength. Reinforced concrete reservoirs are normally rectangular in shape.

Ground level storage tanks can be buried partially or completely in the ground. The choice depends on the elevation of the water required. If the ground is not too hard, a typical construction method is to build the tank half below ground. The tank should be covered to protect the stored water from contamination and prevent the growth of algae, and it should have ventilation to allow air to escape from the reservoir when water enters.

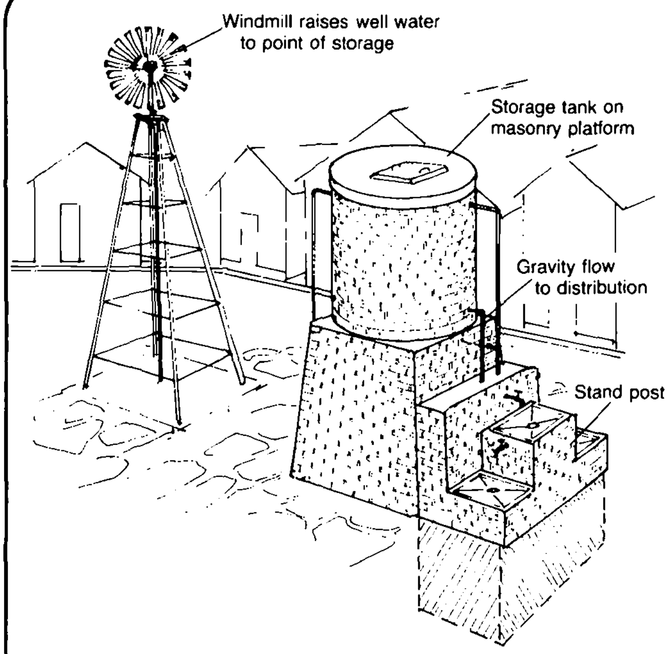

Figure 7. Storage and Distribution in Community

Elevated Tanks. In flat areas where no suitable hills or high points are available for ground level tanks, elevated tanks are necessary. Figures 7 and 8 show typical elevated tanks designs. Figure 7 shows a small elevated tank serving several standpipes. Figure 8 shows a steel or reinforced concrete structure serving a larger community through house connections. Figure 9 shows possible locations for the storage tank. In 9a the tank is located near the source, away from the area to be served. In 9b, the storage is directly in the center of the service area and water is pumped a quarter distance from the source.

Elevated storage tanks are normally constructed of either reinforced concrete, brick or steel, with steel usually in the form of pressed plates. The material used for the tower depends on the size of the tank and available materials. Smaller capacity steel and brick tanks can be elevated on small brick or wooden towers. For greater reliability, brick is recommended.

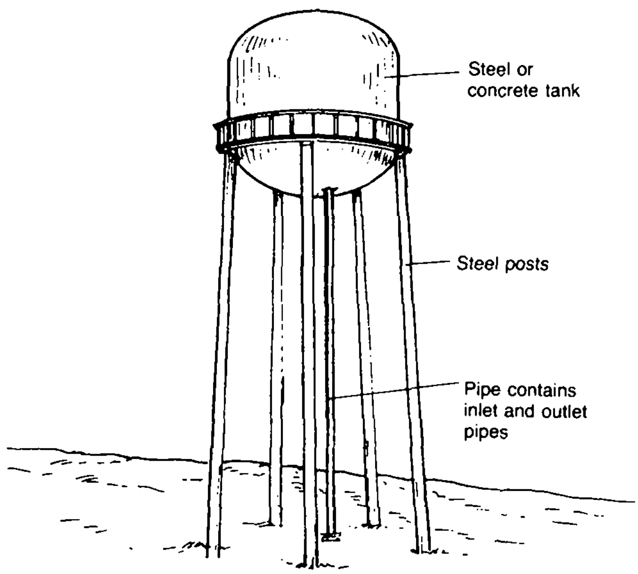

Figure 8. Typical Manufactured Elevated Storage Tank

Both large and small diameter steel tanks supported by steel towers are normally purchased from a manufacturer. In many areas, elevated storage tanks are made from reinforced concrete. The construction of reinforced concrete tanks is recommended for systems requiring a large storage capacity even through their construciton is expensive. Skilled labor is required,

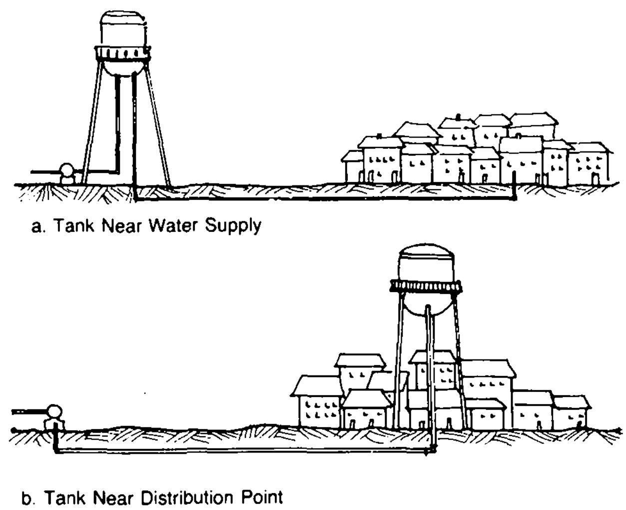

Figure 9. Locating Elevated Storage Tank

and supervision by an engineer is necessary. When a number of tanks are to be built in several villages in a region, forms and equipment can be reused and workers become skilled. Employment possibilities are created and money will probably be spent on nationally produced cement and other materials available locally. In many countries, steel tanks would have to be imported. Under these circumstances, the contruction of reinforced concrete tanks is more economical. The design of an elevated storage facility should be done by an engineer to ensure that strength of the structure.

Summary

Household cisterns and storage jars may be used by individual families to store water collected from roofs. Water stored in cisterns can be used as the principal source of water or as the secondary source if the primary one disappears during the dry season. The choice of household storage design depends on the needs of each individual family and on the materials, skills and economic resources available to each.

For community systems, large storage facilities are needed. The two principal types of storage tanks are ground level and elevated storage tanks. The choice between the two depends on local topographical conditions. Storage in ground level tanks should be the first choice if a site of sufficient elevation is available. For ground level reservoirs, the initial costs are lower, construction is less difficult and maintenance is easier. Where no suitable high land is available, elevated storage must be used. All water system normally need some type of storage capacity to ensure that there is always a sufficient quantity of water available to the users.

Notes

Notes

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Water for the World

Determining the Need for Water Storage

Technical Note No. RWS. 5.P.1

Many water systems require some form of storage. Storage is necessary (1) when rainwater is collected for drinking water, (2) for most distribution systems where the source's continuous supply is barely sufficient or is insufficient to meet the daily demand and (3) where a single well serves a community through a distribution system. Storage ensures that an adequate quantity of water is always available to users and that water quality is protected.

This technical note describes the procedure to follow in determining whether storage should be provided for a water system and establishes methods to determine the quantity of storage required.

Several factors should be considered in determining water storage needs: (1) the source of water, (2) the amount of water available for consumption (3) the demand for water and (4) the materials available and economic resources of the families in the community. From this information, the most appropriate form of water storage can be chosen.

Rainfall Storage in a Cistern

Rainwater needs to be collected and stored if people are to use it for drinking. In order to plan for adequate storage and design the most appropriate type of storage facility data on the following items should be collected:

- amount of monthly rainfall,
- potential rainfall supply available each month,
- the amount of water likely to be consumed by the family.

With this information, the size of the cistern can be estimated.

Data on average monthly rainfall can be acquired from a national weather agency, the military, or an airport. Data for a specific location may not be available, but regional data can be used for an estimate. Table 1 and Figure 1 show an example of distribution of rain by month for a location receiving an average annual rainfall of 1032.5mm.

The potential available water supply depends on the amount of rainfall and the catchment surface area. If a catchment area has a length of 8m and a width of 6m, the area of the catchment is 8m x 6m or $48m^2$. To determine the amount of available water, multiply the monthly rainfall figures by $48m^2$ and then by 0.8, a loss factor which takes into account water that does not make it to storage from the catchment area. For example, using January rainfall figures, the total amount of water available to the family is 8678 liters. This amount is arrived at using the following formula:

Volume of water = Catchment area x rainfall x 0.8

Table 1. Average Monthly Rainfall in Millimeters

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
Rainfall	226	188	173	46	2.5	0	0	5	5	41	130	216	1032.5

This data can be represented graphically as shown in Figure 1.

MONTH	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
RAINFALL (in mmm.)	226	188	173	46	2.5	0	0	5	5	41	130	210	1,032.5

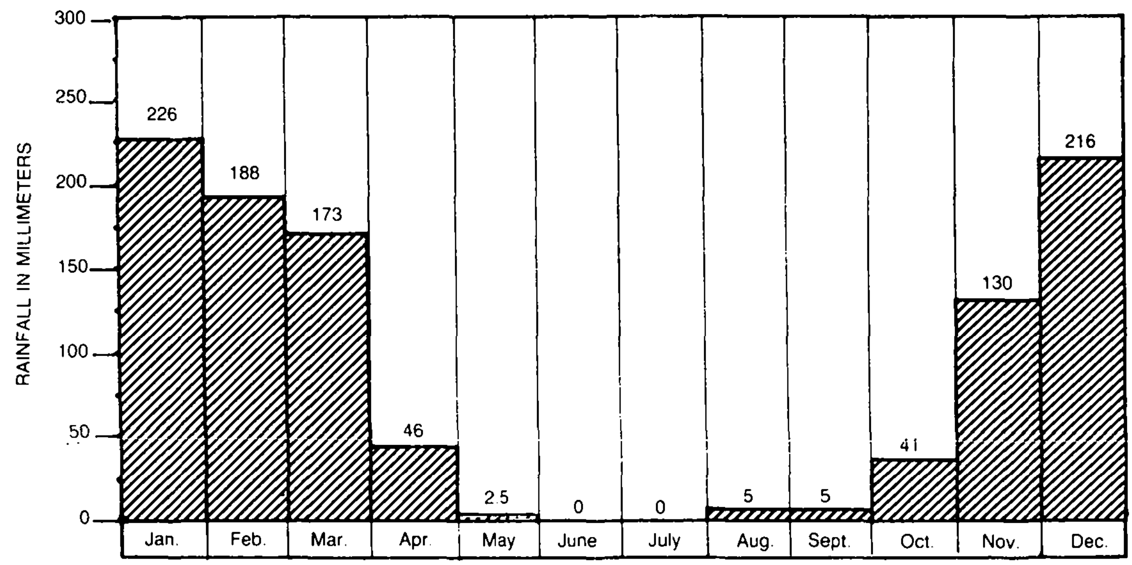

Figure 1. Average Monthly Rainfall in Millimeters

Volume = $48m^2$ x 226mm x 0.8

Volume = 8678 liters

Table 2 and Figure 2 give an example of the average amount of water available during each month of the year. Remember that these are average estimates that will differ with cyclical climatic changes. Each number is arrived at by taking the average monthly rainfall figure and using it in the above equation.

The next step in determining storage requirements is shown in Figure 3. First, a graph of the cumulative available rainfall is made. The graph represents the amount of rainfall run-off available from a catchment throughout the year. The heights of the bars are determined by adding a particular month's average rainfall to the sum of the rainfall for the previous months. For example, April shows a cumulative run-off of 24306 liters which is the sum of the run-off for January, February, March and April.

Secondly, a diagonal line representing yearly demand is drawn. The line assumes that people will use the same quantity of water each month, although generally greater quantities are used in the wet season and much less in the dry. The demand line should touch only one point on the run-off curve as shown. The desirable amount of storage is shown on the graph. It is the greatest distance between the demand line and the run-off curve. This amount of storage should be provided to ensure that water is available throughout the year at this level of consumption.

In this example, the yearly demand for water is 31000 liters, and average of approximately 2600 liters per month, or 87 liters per day per family. In order to supply a family with 87 liters per day throughout the entire year, a cistern or storage jar with a 16.5-$17m^3$ (16500 -17000 liters) capacity would be needed. Unless inexpensive ferrocement storage jars are constructed, the construction of a

Table 2. Potential Monthly Available Supply of Water

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (liters)	8678	7219	6643	1766	96	0	0	192	192	1574	4992	8294	39646

This data appears in graphical form in Figure 2.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL (year)
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

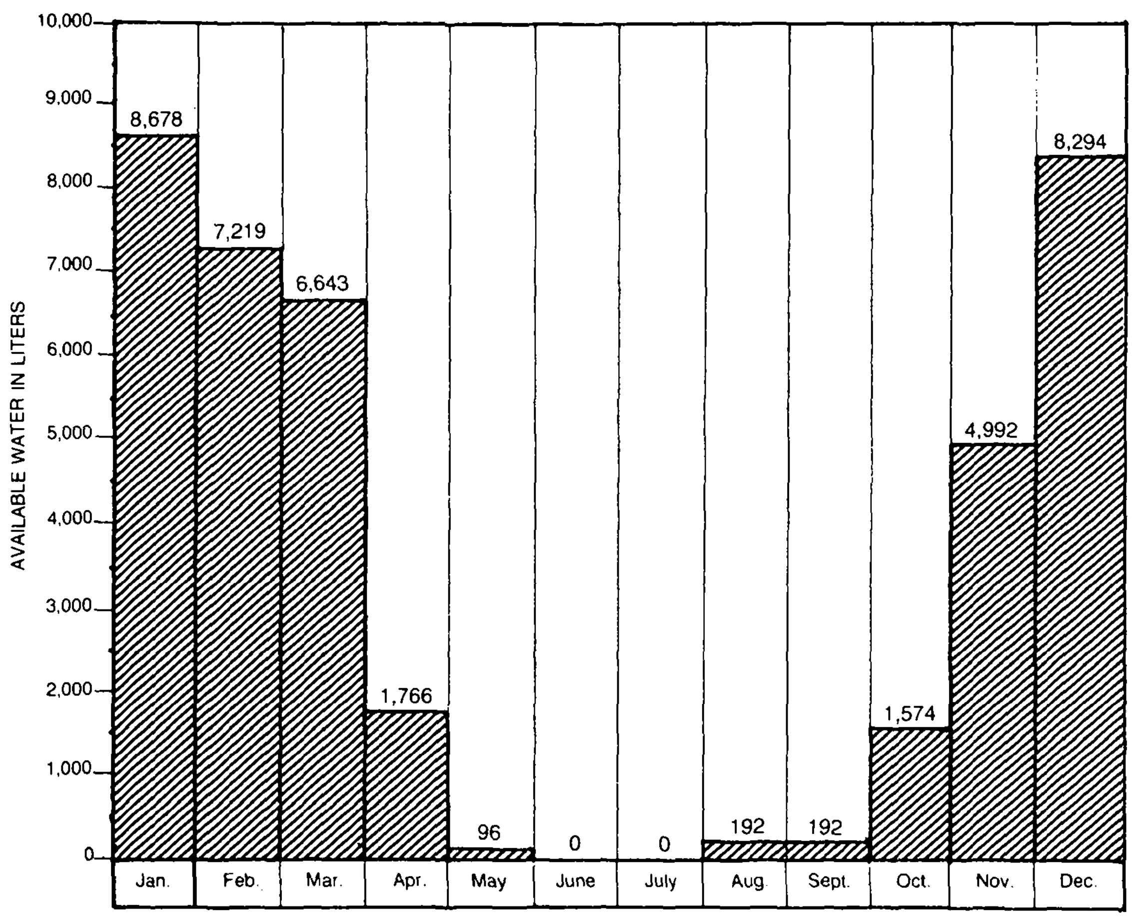

Figure 2. Available Monthly Water Supply in Liters

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall (millimeters)	226	188	173	46	2.5	0	0	5	5	41	130	216	1,032.5
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

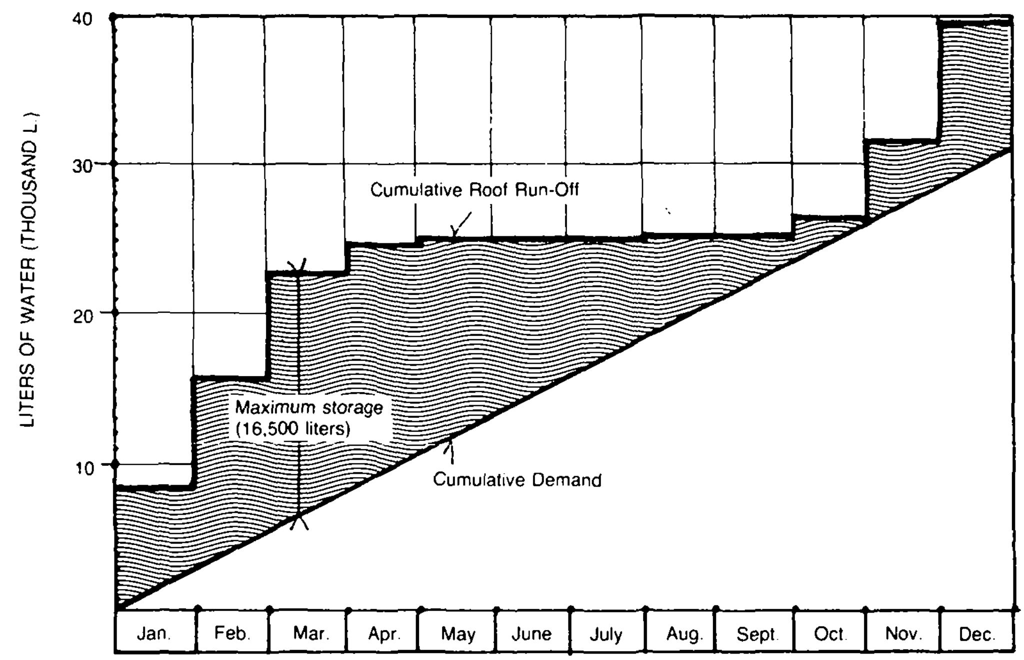

Figure 3. Determining Maximum Storage Capacity

cistern of such a large volume would be beyond the means of most families. A smaller structure would be designed instead. With a smaller cistern, water use during the dry season would have to be restricted to the essential minimum of drinking and some cooking.

Ideally, cisterns and storage jars should be large enough to store water for the entire year. Where economic conditions prevent this, special measures, like the use of storage jars, should be taken. Water should be collected during the rainy season and stored for use during the dry season. Special care should be taken to prevent water loss through evaporation. When planning a cistern or storage reservoir, attempt to build a cistern either of adequate volume or as close to the desired volume as economic resources permit. This is necessary when no other water source of suitable quantity, quality, accessibility or reliability is available.

Ground and Surface Water Storage for Distribution Systems

Storage of surface and ground water is necessary to provide sufficient quantities of water to the users. In some cases, a storage reservoir is not needed. When hand dug wells are installed in villages and water is extracted by buckets or hand pumps, no storage other than what the well holds is necessary. Where reservoirs are formed by dams, water sometimes can move from the reservoir to the users with no further storage. Usually, some sort of storage is required in systems where water is piped to the users.

To ensure that adequate storage capacity is provided, proper planning of the storage reservoir is necessary. The following factors should be considered in determining required storage capacity:

(1) Population served by the system taking into account population growth.

(2) Total daily demand for water in the community. This is found by multiplying the population to be served by the daily per capita consumption. Special consideration has to be shown for peak demand periods.

(3) Hourly demand and peak hour demand.

(4) The length of operation of the pump each day.

In planning for a water system and sufficient storage capacity for it, the number of people to be served should be determined. It is best to plan for a system that will operate effectively for 20 years. If a community has a present population of 1535 people who will be served by the system and the population growth is estimated at 2.5 percent per year, use Table 3 to determine the population in 20 years.

Table 3. Population Growth Factors

Design Period Years	Yearly Growth Rate (%) 1.5	2	2.5	3	3.5	4
7	1.1	1.15	1.19	1.23	1.27	1.32
10	1.16	1.22	1.28	1.34	1.41	1.48
15	1.25	1.35	1.45	1.56	1.68	1.80
20	1.35	1.49	1.64	1.81	1.99	2.19

Multiply the present population, 1535 in this example, by the population growth factor located in the row marked "20 years" under the column for a 2.5 percent yearly growth rate. This gives 1535 x 1.64 = 2520. The volume of the storage reservoir should be calculated assuming a population of 2520 people.

Next, the amount of water per day consumed by the population should be calculated. Assume that the average per capita daily consumption is 40 liters. Per capita water demand is:

Total consumption = Per capita consumption x population =
40 liters x 2520

Total consumption = 100800 liters per day.

To find hourly demand, use the following formula:

$$\text{Hourly demand} = \frac{100800 \text{ liters/day}}{24 \text{ hours}}$$

Hourly demand = 4200 liters per/hour.

The peak hourly demand generally occurs in the morning with a second smaller peak later in the afternoon. The peak demand ranges between four and five times the hourly demand.

The length that the pump is in operation should be determined. In some cases, the pump may work for a few hours in the morning and a few in the afternoon or it may be operated contLnously for eight to ten hours. Assuming 10 hours continuous pumping between 7:00am and 5:00pm, the pumping rate necessary would be 10080 liters/hour. From this information and the data on water demands as a percentage of the average hourly consumption rate, the required storage capacity can be determined. Table 4 shows a way to collect this information and determine the required storage. Figure 4 shows how this can be done graphically.

The storage capacity required is the sum of the excess supply of water after the pumping stops at 5:00pm, 32500 liters, and the maximum volume required during the morning. This volume is 13650 liters at 7:00am. The total storage required is 32550 + 13650 = 46200 liters or 46.2m^3. The same figure is arrived at graphically by looking at the distance between point A and point B on Figure 4.

In Figure 4, a diagonal line is drawn marking a continuous 24-hour pumping rate of 4200 liters per hour. Line PQ represents a pumping rate of 10800 liters per hour for ten hours. The curved line is the cumulative demand for water. To determine the storage capacity, draw a perpendicular line from the point at 7:00am (point Q) to the cumulative demand curve. From that point, draw a line parallel to PQ extending it to the vertical line at 17 hours, 5:00pm. Where this line ends is point A. Then draw a straight line

Table 4. Determining Storage Requirements

Daily Demand = 100800 liters

Average Hourly Demand = $\frac{100800 \text{ liter}}{24 \text{ hour}}$ = 4200 liters/hour

1 Time (hours)	2 Hourly Demand in Liters	3 Hourly Demand as % of Average Hour*	4 Cumulative Demand (liters)	5 Supply from Pump (liters/hour)	6 Supply Minus Draft Liters (5 - 2)	7 Storage Variation (liters) (6 + 7)
0-1	1050	25	1050	---	-1050	-1050
1-2	1050	25	2100	---	-1050	-2100
2-3	420	10	2520	---	-420	-2520
3-4	420	10	2940	---	-420	-2940
4-5	630	15	3570	---	-630	-3570
5-6	2520	60	6090	---	-2520	-6090
6-7	7560	180	13650	---	-7560	-13650
7-8	9660	230	23310	10080	420	-13230
8-9	4200	100	27510	10080	5880	-7350
9-10	4200	100	31710	10080	5880	-1470
10-11	5040	120	36750	10080	5040	+3570
11-12	6300	150	43050	10080	3780	+7350
12-13	6300	150	49350	10080	+3780	+11130
13-14	6300	150	55650	10080	+3780	+14910
14-15	5040	120	60690	10080	+5040	+19950
15-16	3780	90	64470	10080	+6300	+26250
16-17	3780	90	68250	10080	+6300	+32550
17-18	7770	185	76020	---	-7770	+24780
18-19	7140	170	83160	---	-7140	+17640
19-20	6300	150	89460	---	-6300	+11340
20-21	3780	90	93240	---	-3780	+7560
21-22	3150	75	96399	---	-3150	+4410
22-23	2310	55	98700	---	-2310	+2100
23-24	2100	50	100800	---	-2100	0

*Precentages are estimated averages.

**The storage capacity required is the sum the excess available at the end of the pumping period (32,550 liters) and the maximum volume during the morning hours (13,650 liters) or 32,550 + 13,650 = 46,200 liters.

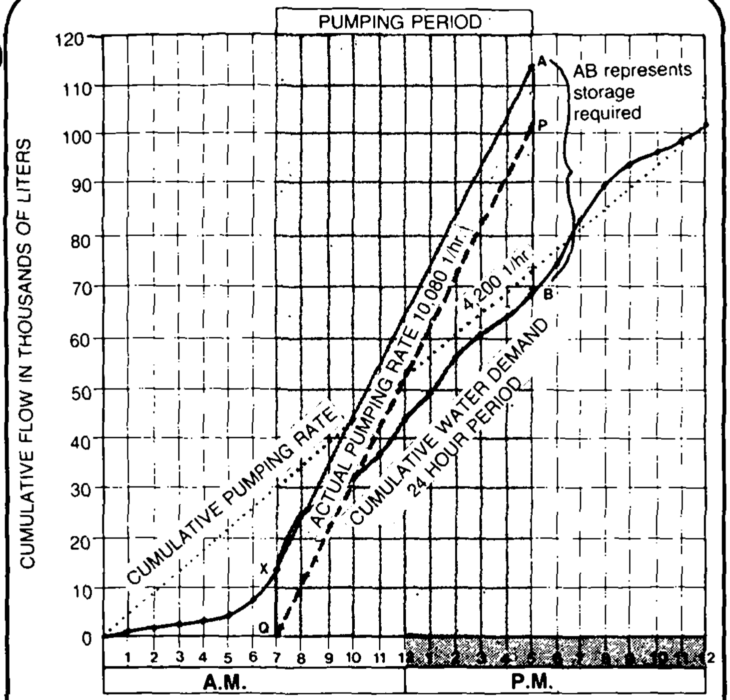

Figure 4. Determining Storage Requirements

from A through P to the cumulative demand curve, point B. The line AB represents the storage required, which is 46200 liters, or 46.2m^3. When designing the storage tank, some extra capacity can be included. In this case, a storage reservoir with a capacity of 50000 liters, 50m^3, would be appropriate.

Summary

Most water systems should have storage so that people can depend on a sufficient quantity, a certain quality and improved access and reliability. When rainwater roof run-off is used, storage is always necessary. For surface and ground water, either storage is provided for at the source or a storage reservoir must be constructed. Most water distribution systems rely on man-made storage reservoirs.

The most important factor in planning for the use of storage is determining the capacity of the reservoir. Capacity should be sufficient to adequately meet all water needs of the users throughout the year. The minimum goal should be to provide sufficient storage to at least meet basic drinking needs and minimal washing and cooking needs. Given scarce resources, these minimal needs may be all that can be met. When determining storage needs, follow the procedures outlined in Worksheet A.

It is desirable to project a storage capacity to meet needs caused by future population increases and water demand increases. In this example, 20 year future increase have been used. This requires a substantial commitment of money and materials. This may not be possible because funds are not available or the money may be needed for more immediate community needs. A careful review will help to make the best engineering and management decision. In any event, storage sites and facilities can be designed and built so that future expansion can be made readily and with least cost.

Worksheet A. Determining Water Storage Requirements

Identify water supply source ______________________________

1. If rainfall roof catchment, determine:

   a. area of catchment ______________________________

   b. number of people to be served ______________________________

   c. materials available for cistern or storage tank construction __________

   d. economic resources of family ______________________________

   e. capacity of storage reservoir from Figures 1, 2, 3 ____________________

2. If a ground water source:

   a. identify type of well--dug, bored, drilled ____________________

   b. determine best method of extraction--hand pump, windmill, fuel or electric pump ______________________________

   c. determine well yield and well storage capacity ____________________

   d. find out how many people use the source for water supply and whether storage is sufficient to meet demand ____________________

   e. if there is a community well with a pump serving people who must carry water, evaluate whether a distribution system or public stand posts would most benefit the community ______________________________

   f. evaluate whether the community has sufficient resources to install some sort of storage ______________________________

   g. determine storage capacity required using the methods described in this technical note and demonstrated in Table 4 or Figure 4 __________

   h. choose the appropriate storage method for the community given resources and available materials ______________________________

3. If a surface water source:

   a. identify the supply source ______________________________

   b. determine the number of uses and calculate demand for water using 40 liters per capita per day ______________________________

   c. determine whether sufficient storage is already provided; for example, a dam and reservoir may hold sufficient water to meet demand __________

   d. determine whether storage is necessary or how much storage is required, using Table 4 or Figure 4 ______________________________

   e. choose the most appropriate design given available materials and resources, needs and topographical features ____________________

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Designing a Household Cistern
Technical Note No. RWS. 5.D.1

Useful Definition

CATCHMENT - A surface from which rainfall run—off is collected; common catchments are roofs and especially prepared ground areas.

Household cisterns are an important means of storing rainwater for family use. In areas where rainwater is the primary source of drinking water, adequate storage is necessary to ensure that people have access to a sufficient quantity of good quality water year-round. One major problem is that rainfall often is not reliable throughout the year or from year to year. People cannot count on a certain supply. Therefore, cistern design is very important to provide water for times when rainfall is seasonably or abnormally scarce.

This technical note describes the design of several types of household cisterns and the conditions under which each should be used. Follow all design steps carefully. The design process should result in the following items which should be given to the person in charge of construction:

1. A list similar to Table 1 or 2 of all materials and tools needed to build the type of cistern or storage reservoir chosen.

2. A plan of the cistern similar to Figure 1 showing the dimensions and important design features.

The choice of the type of cistern to build depends on two very important factors:

1. The purpose of the cistern. Rainwater may be the only source of water. If so, a cistern must be designed to hold a sufficient volume of water to meet people's needs throughout the entire year. Cisterns may be used only during the dry season to replace a source that disappears during times of little or no rain. Such cisterns need only sufficient capacity to store water during the rainy season to be used during the dry season.

2. The materials available for construction, the skills of the people, and the amount each family is able to spend. Whenever possible, locally available materials should be used to keep costs low.

Table 1. Sample Materials List for a Reinforced Concrete Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers	____	____
Supplies	Portland cement	____	____
	Clean sand and gravel	____	____
	Clean water for mixing cement	____	____
	Reinforcing rods	____	____
	Screened mesh	____	____
	Boards and plywood for frames	____	____
	Nails	____	____
	Old motor oil or other oil for lubricating forms	____	____
	Galvanized pipe for overflow	____	____
	Tap for outlet	____	____
	Guttering	____	____
Tools	Shovels and picks	____	____
	Measuring tape	____	____
	Hammers	____	____
	Saws	____	____
	Carpenter's square	____	____
	Pliers	____	____
	Wire cutters	____	____
	Mixing bin (mortar box)	____	____
	Buckets	____	____
	Trowel	____	____
	Adjustable wrench	____	____
	Screw drivers	____	____
	Paint brush	____	____
	Level	____	____

Total Estimated Cost = ____

Table 2. Sample Materials List for a Ferrocement Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers	____	____
Supplies	Portland cement	____	____
	Plain wire, 2.5mm	____	____
	Chicken wire	____	____
	Water pipe	____	____
	Water tap	____	____
	Overflow pipe	____	____
	Galvanized iron sheet and angle iron	____	____
	Sand	____	____
	Gravel	____	____
	Bolts	____	____
	Water	____	____
Tools	Shovels and picks	____	____
	Wire cutters	____	____
	Wrenches (adjustable and open)	____	____
	Screw drivers	____	____
	Paint brushes	____	____
	Trowels	____	____
	Mixing bin (mortar box)	____	____
	Wheelbarrow	____	____
	Buckets	____	____
	Hacksaw and blades	____	____
	Hammers	____	____

Total Estimated Cost = ____

Storage Tank Capacity

The capacity of the cistern depends on the maximum amount of water that must be stored to meet individual family needs. To find the ideal capacity, determine:

- average annual and monthly quantities of rainfall;
- amount of water available from the catchment area;
- number of people who must use the water;
- average daily water use per family.

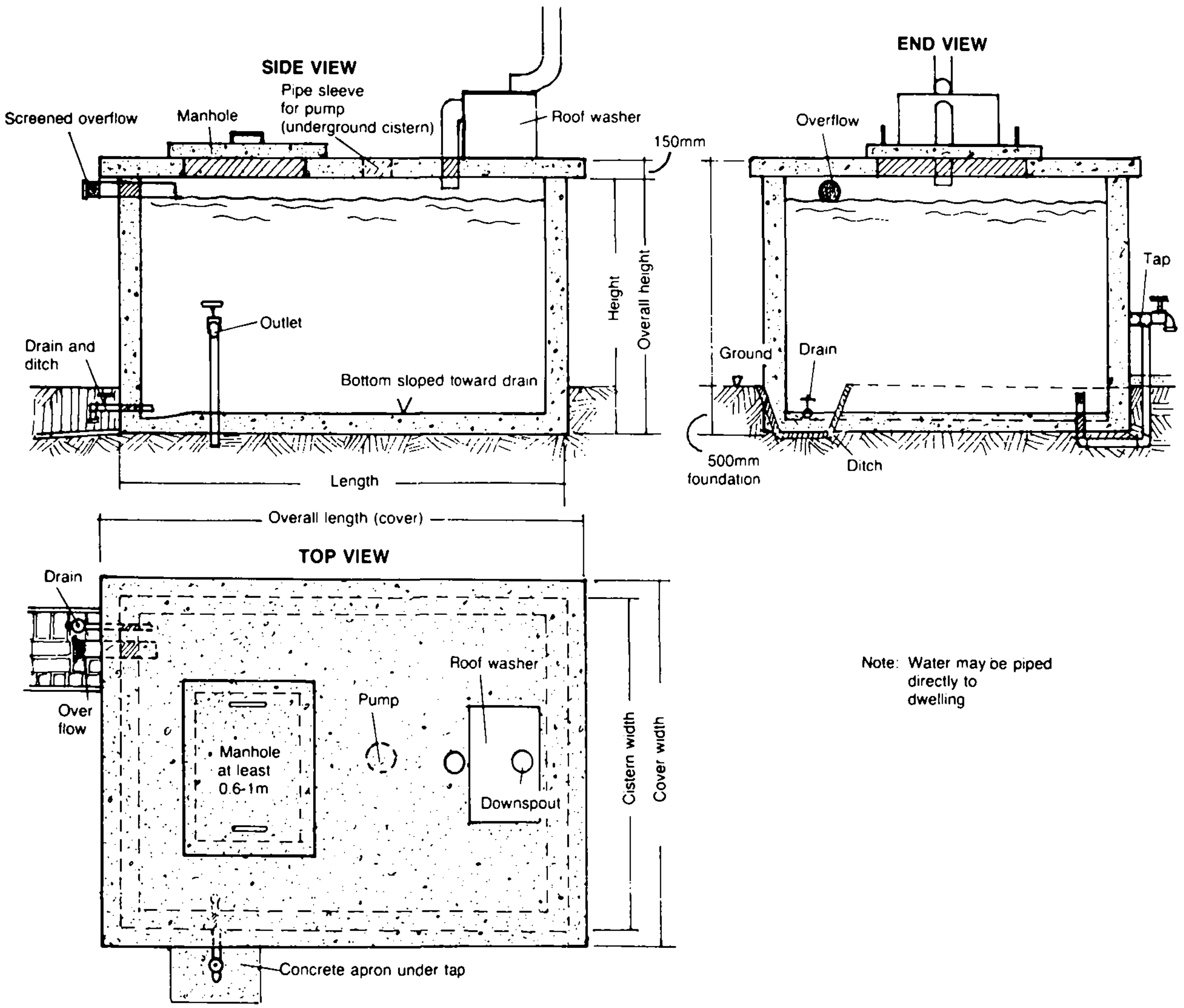

Figure 1. Plan for Household Cistern

Regional data on average monthly rainfall may be available from a government agency, airport or weather station. Try to obtain at least estimates of monthly rainfall rates.

The catchment area is the complete surface area of the roof: the length of the roof times the width of the roof base. Figure 2 shows the dimensions of a catchment area $48m^2$. The amount of water in millimeters each month from a catchment area is found by multiplying the average monthly rainfall by the catchment area and then by 0.8 to take into account losses: catchment area x rainfall x 0.8 = available monthly rainfall. A complete discussion of the technique used to determine the volume of available rainfall may be found in "Determining the Need for Water Storage," RWS.5.P.1.

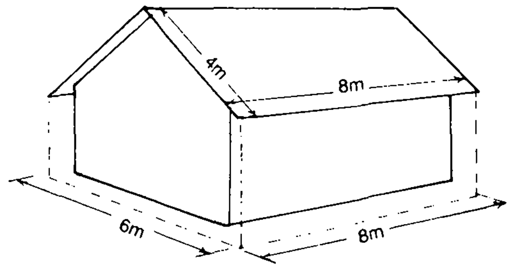

Figure 2. Roof Catchment Area

Determine the maximum storage capacity using Figure 3. The average monthly rainfall figures are in the table at the top of the page. These rainfall figures are only an example. The rainfall is great during several months but in June and July no rain falls at all. Design of storage jars and cisterns should take these variations into account.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall (millimeters)	226	188	173	46	2.5	0	0	5	5	41	130	216	1,032.5
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

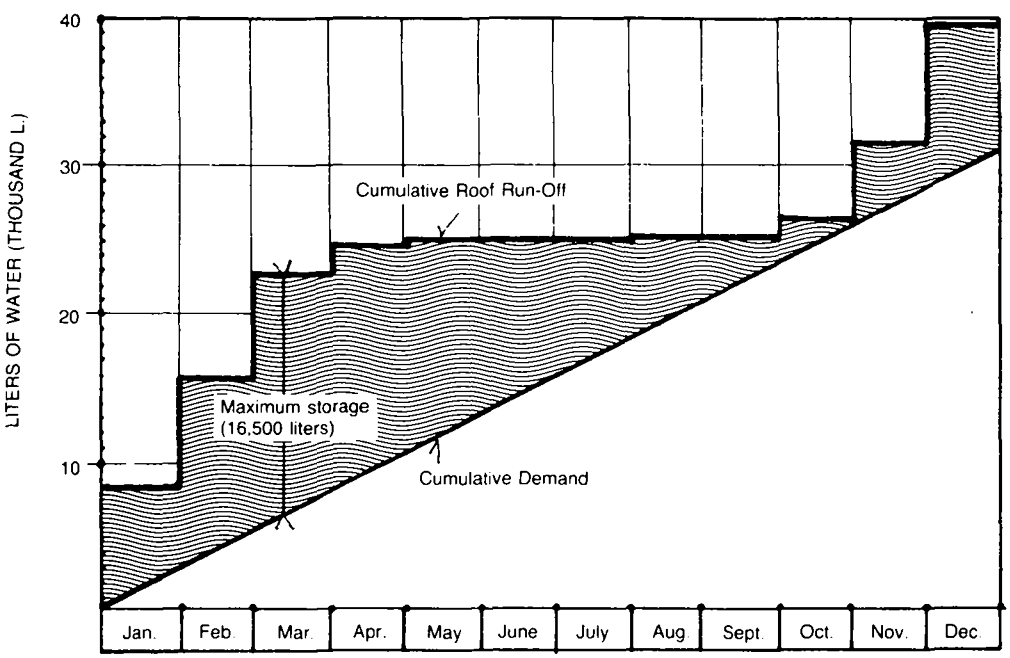

Figure 3. Determining Maximum Storage Capacity

The second set of figures on Figure 3 shows the potential monthly available supply of water. These figures are obtained by multiplying the average rainfall by the catchment area x 0.8. For example, in March rainfall is 173mm. Therefore, the amount of water potentially available is:

$$173\text{mm} \times 48\text{m}^2 \times 0.8 = 6643 \text{ liters.}$$

The graph in Figure 3 has two curves. The top curve is called the cumulative run-off and is the sum of each month's potential supply. The diagonal line represents the cumulative demand. The demand is assumed to be constant and the line should touch the supply curve at only one point as shown. In this example, demand is approximately 2580 liters/month or 86 liters/day.

Maximum storage capacity needed is determined by finding the greatest distance between the two curves. In the example, the greatest distance represents 16500 liters or a storage capacity of 16.5m^3.

Remember that this is only a rough estimate to use in planning and design. During the rainy season when water is plentiful, people will use greater quantities of water. During the dry season, people tend to conserve water, using their best sources only for drinking and some cooking. It is unlikely that a tank of this volume would be constructed by an individual household. In most cases, the cost would be too great. Instead, smaller volume tanks would be used. Rather than 86 liters per family per day, consumption might fall to 50 or even 40 liters per day. This would lower the storage volume needed to 4000-5000 liters. A tank just under 10m^3 would then be practical. A general rule to follow is that if cisterns are to be used for supplementary water supply, a minimum storage of 500 liters should be provided. Where such water is the principal supply, a much greater capacity is needed. Whenever resources permit, install the largest possible cistern to meet estimated needs. Design of a cistern with maximum capacity may be impossible but an attempt should be made to come as close as possible. Users should be educated in wise water use practices so that they can count on a year-long supply.

Cistern Design

Concrete, ferrocement, mortar or clay storage jars or underground cisterns are all useful and practical for storing rainwater. Reinforced concrete cisterns are usually rectangular in shape and are located adjacent to the house. They can either be built at ground level as shown in Figure 4 or underground as in Figure 5. Reinforced concrete is preferred because it is watertight.

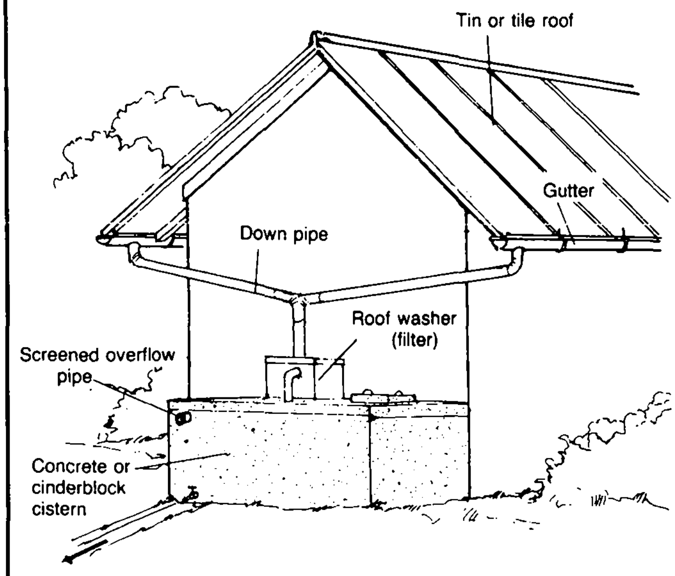

Figure 4. Rainfall Catchment with Cistern

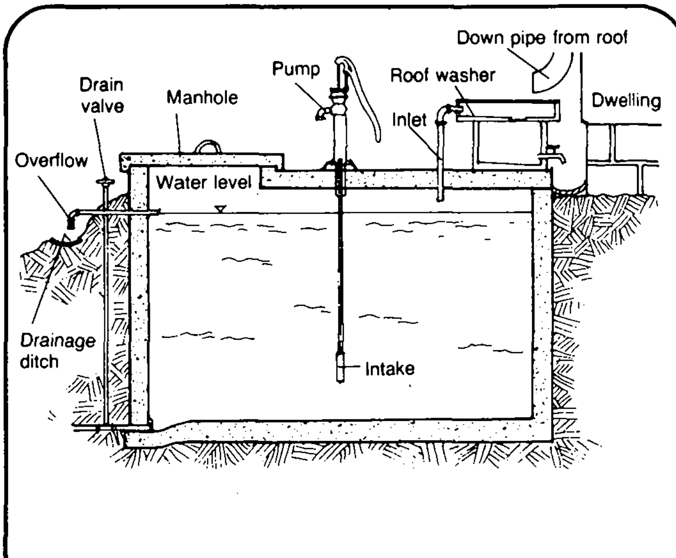

Figure 5. Underground Storage for Roof Catchment

In designing a cistern, follow these steps:

1. Choose the best site for the cistern and determine whether to build it underground. Underground cisterns offer the advantages of improved structural strength in construction and cooler water temperatures. The major disadvantages is that water must be taken from the cistern with a pump. Always make sure that the cistern is on higher ground than excreta disposal systems and is separated from them by at least 15m.

2. Determine the capacity of the tank needed. For example, if 10000 liters should be stored, design an above ground tank 2.8m x 2.3m x 1.6m or an underground tank narrower but taller; perhaps 2m x 2m x 2.5m. All walls should be reinforced and have a minimum thickness of 200mm.

3. Design above ground cisterns so that there is at least a small foundation in the ground. Make this foundation at least 300mm deep. Underground tanks should extend about 200-300mm above the ground's surface to provide for the installation of an overflow and to prevent any difficulties in maintenance.

4. Use a thick concrete mix to ensure that the walls are watertight. Use a mixture of one part cement to two parts sand and three parts gravel (1:2:3). To make the correct paste, use 23 liters of water for each bag of cement. Worksheet A shows how to determine the correct quantity of materials needed.

5. Each cistern should have an impermeable, reinforced concrete cover with a manhole that allows access for maintenance. Manhole openings should be covered tightly to prevent entrance of light, dust or other substances that could contaminate the water.

6. Install a screened overflow pipe at the top of the cistern as shown in Figure 4. Slightly above the bottom of the tank, place an outlet pipe or tap. The tap should be high enough so that a container used for collecting the water can be placed underneath it. For an underground tank, the outlet will probably be a hand pump installed on the top cover. The pump's intake pipe should extend to near the bottom of the cistern.

7. On top of the cistern, install a device for diverting the run-off from the roof. The first run-off is likely to be contaminated. Several designs of run-off diversion devices are shown in "Designing Roof Catchments," RWS.1.D.4.

8. Pile dirt around the base of above ground cisterns to provide support for the walls and drainage away from the tank. Adequate drainage should be provided at the overflow pipe so that standing water does not accumulate at the cistern. Standing water is a breeding place for mosquitoes.

9. Brick and masonry cisterns can be constructed and are recommended when the materials are available locally at low prices. Brick or stone cisterns are built in the same way as reinforced concrete tanks but special care should be taken to ensure their strength and impermeability. Masonry walls should be at least 300mm thick and should be lined on the inside with two 130mm coats of mortar in a mixture of 1:3 (one part cement to three parts sand).

10. All walls should be very carefully built with strong cement mortar joints. A general rule to follow is that brick or masonry tanks should only be made by an experienced builder since construction must be especially good to make them watertight. Tanks more than 2m across should be circular rather than rectangular.

Ferrocement Tanks and Storage Jars

Cylindrical ferrocement water tanks are built by hand. Cement mortar (one part cement to three parts sand) is trowelled onto a mesh of wire reinforcement. A 10cm^3 capacity ferrocement tank similar to the one shown in Figure 6 can be made by one experienced builder and several unskilled laborers.

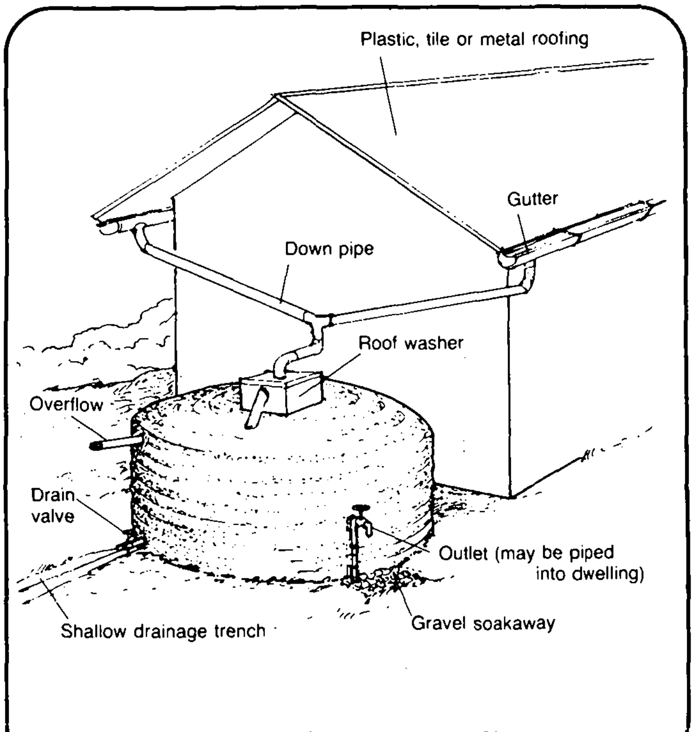

Figure 6. Roof Catchment with Ferrocement Cistern

The cistern shown in Figure 7 has a diameter of 2.8m and a height of 1.6m for a total capacity of $10m^3$:

Volume = $.785 \times d^2 \times h$

Volume = $.785 \times 2.8m^2 \times 1.6m$

Volume = $.785 \times 7.84m^2 \times 1.6m$

Volume = $10m^3$

The walls should be 40mm thick to support the weight of the water. For best results in building the ferro-cement cistern, use sheets of standard galvanized roofing iron approximately 0.6m thick with 75mm corrugations. The forms are put together as shown in Figure 7. The tank sits on a foundation slab made of concrete.

The cistern needs a roof to protect the water from contamination and evaporation. Two basic roof designs are available. A curved roof, 30-50mm thick, made of ferrocement can be constructed. The roof is cast in the same method as the walls and actually is no more than a continuation of the walls. The roof should be either thickened or painted white to protect it from heat.

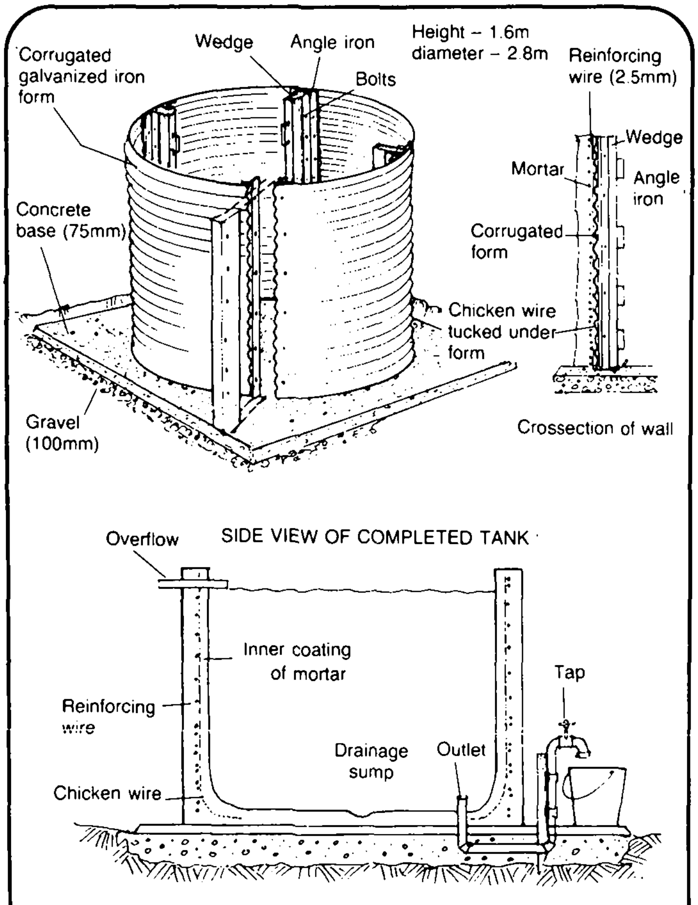

Figure 7. Ferrocement Cistern Construction

The roof can also be built from light weight sheet metal attached to a typical roof structure. This method is less practical than the curved roof design and it is best used only when the diameter of the tank is greater than 5m.

Figure 7 shows the installation of the outlet and tap system and the overflow. A drainage sump is included to capture sediment that settles out from the stored water.

Storage Jars

Rainwater can be stored in jars. Typical pottery jars can be used to collect small volumes of water. Larger volumes can be collected using jars made with wire mesh reinforcing and mortar. Jars with a capacity of $4m^3$ can be made in several days using simply mortar, mesh and gunny cloth as shown in Figure 8. Because of the curved design, stress is not a big factor and reinforcing is not necessary.

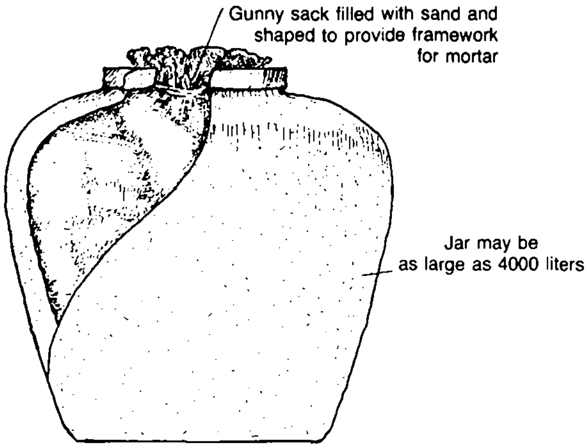

Figure 8. Storage Jar of Unreinforced Concrete

Sew together pieces of gunny cloth to the design desired and fill the cloth with sand or sawdust. The mortar is simply troweled onto the sack. Several $4m^3$ capacity jars can be built to provide large storage. For example, three of the jars will provide a 12000 liter capacity. A typical jar may have a bottom diameter of approximately 1m and a height of between 1.3-1.7m. Special care must be taken to form the gunny cloth to the correct shape and volume. As with other cisterns, install a cover to prevent contamination and a tap for easy access to the stored water.

Summary

This technical note describes several practical and efficient methods for storing water and rainwater for domestic use. Choice of the most appropriate design is very important when deciding to install a system. When choosing a design:

- identify which materials are most readily available and whether sufficient funds are available to buy them,

- choose a design that can be constructed with available technical skill,

- identify demand needs and the storage capacity which will meet them; design to meet these needs or for the largest affordable capacity.

Well-designed and constructed cisterns and storage jars will provide water for many years and should be considered where other suitable sources of water are not available. Information on construction of storage reservoirs discussed in this paper is in "Constructing a Household Cistern," RWS.5.C.1.

Worksheet A. Calculating Quantities Needed for Concrete (Calculations for a cistern 2.8m × 2.3m × 1.6m)

Total volume of cistern = length (l) x width (w) x height (h). Thickness of walls = 200mm.

1. Volume of cover = 3.0 m x 2.5 m x .2 m = 1.5 m^3
2. Volume of bottom = 2.8 x 2.3 x .2 m = 1.29 m^3
3. Volume of two sides = 2.8 m x 1.6 m x .2 m x 2 = 1.79 m^3
4. Volume of two ends = 2.3 m x 1.6 m x .2 m x 2 = 1.47 m^3
5. Total volume = Sum of steps 1, 2, 3, 4 = 6.05 m^3
6. Unmixed volume of materials = Total volume x 1.5 = 6.05 m^3 x 1.5 = 9.1 m^3
7. Volume of each material (cement, sand, gravel 1:2:3)

   Cement: 0.167 x volume from line 6 9.1 m^3 = 1.52 m^3

   Sand: 0.33 x volume from line 6 9.1 m^3 = 3.0 m^3

   Gravel: 0.5 x volume from line 6 9.1 m^3 = 4.55 m^3
8. Number of 50kg of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$

   Volume of cement = 1.52 m^3 ÷ .033 m^3/bag = 46 bags
9. Volume of water = 23 liters/bag x 46 bags = 1058 liters
10. Number of reinforcing bars = $\frac{\text{length}}{.15} + \frac{\text{width}}{.15}$

    Number of rods in cover = $\frac{3.0}{.15} + \frac{2.5}{.15}$ = 20 + 17 = 37

    Number of rods in two ends x 2 = $\frac{2.3}{.15} + \frac{1.6}{.15}$ x 15 + 11 x 2 = 26 x 2 = 52

    Number of rods in two sides = $\frac{2.8}{.15} + \frac{1.6}{.15}$ x 2 = 19 + 11 x 2 = 30 x 2 = 60

Note: To determine the length of each bar, subtract 0.05 from the total length (0.025m from each side). For example, the bars in the cover should be 2.8m - 0.5 = 2.25m and 2.3m - 0.5m = 2.25m.

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Designing a Ground Level Storage Tank
Technical Note No. RWS. 5.D.2

Under suitable circumstances, ground level storage tanks may be used to deliver water to users by gravity flow. Storage tanks are a very important part of a water system because they ensure that adequate quantities of water are available to meet demand. Storage tanks also help in preserving water quality.

This technical note discusses the design of ground level storage tanks and offers suggestions for locating a suitable site, determining adequate capacity and selecting appropriate construction materials. Read the technical note carefully and attempt to adapt the suggestions to the local environment to ensure successful design of, the storage tank.

The design process should result in the following three items which should be given to the construction supervisor.

1. A map of the area showing the location of the storage tank in relation to the water source and the community. Include important landmarks, elevations, if known, and distances on the map. Figure 1 gives an example of the type of map which should be provided.

2. A list of all labor, materials and tools needed similar to Table 1. The list will help make sure that adequate quantities of materials are available to prevent construction delays.

3. A plan of the storage tank with dimensions shown as in Figure 2. The plan shows a side, top and end view.

Useful Definitions

ALGAE - Tiny green plants usually found floating in surface water; may form part of pond scum.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

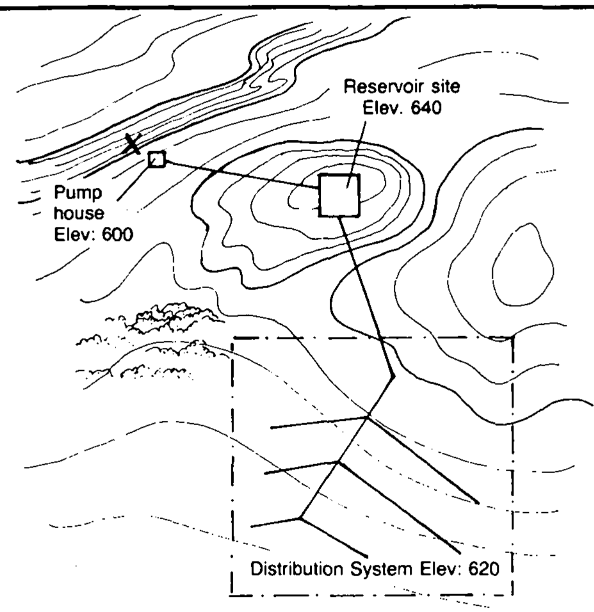

Figure 1. Location Map

Site Selection and Tank Location

The most important consideration in the choice of a site for a storage tank is the elevation. The height of water stored, measured from the bottom of the tank, must produce sufficient head or pressure to enable water to flow through a pipeline to the users. The height needed is determined by the height of the taps in the system and the amount of pressure desired for the distribution system.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	____	____
	Laborers	____	____
Supplies	Portland cement	____	____
	Clean sand and gravel	____	____
	Clean water	____	____
	Reinforcing rod	____	____
	Pipe for inlets, overflow and drain (PVC or steel)	____	____
	Screening and wire mesh for pipes	____	____
	Boards and lumber for forms	____	____
	Lubricating oil	____	____
	Rocks, if masonry tank	____	____
	Float valve (if needed)	____	____
	Cut-off valves	____	____
	Lock for manhole cover	____	____
	Iron for steps in tank	____	____
	Lumber and rafters, if wooden tank	____	____
	Cover structure	____	____
	Shingles	____	____
	Plywood	____	____
	Rope or string	____	____
	Nails, tie wire	____	____
Tools	Shovels, picks and other digging tools	____	____
	Measuring tape	____	____
	Plumb line	____	____
	Hammer	____	____
	Saw	____	____
	Buckets	____	____
	Carpenters square	____	____
	Level	____	____
	Mixing bin or machine	____	____
	Pipe wrench	____	____
	Adjustable wrench	____	____
	Trowel	____	____
	Hoe	____	____
	Wheelbarrow	____	____
	Sieve	____	____

Total Estimated Cost = ____

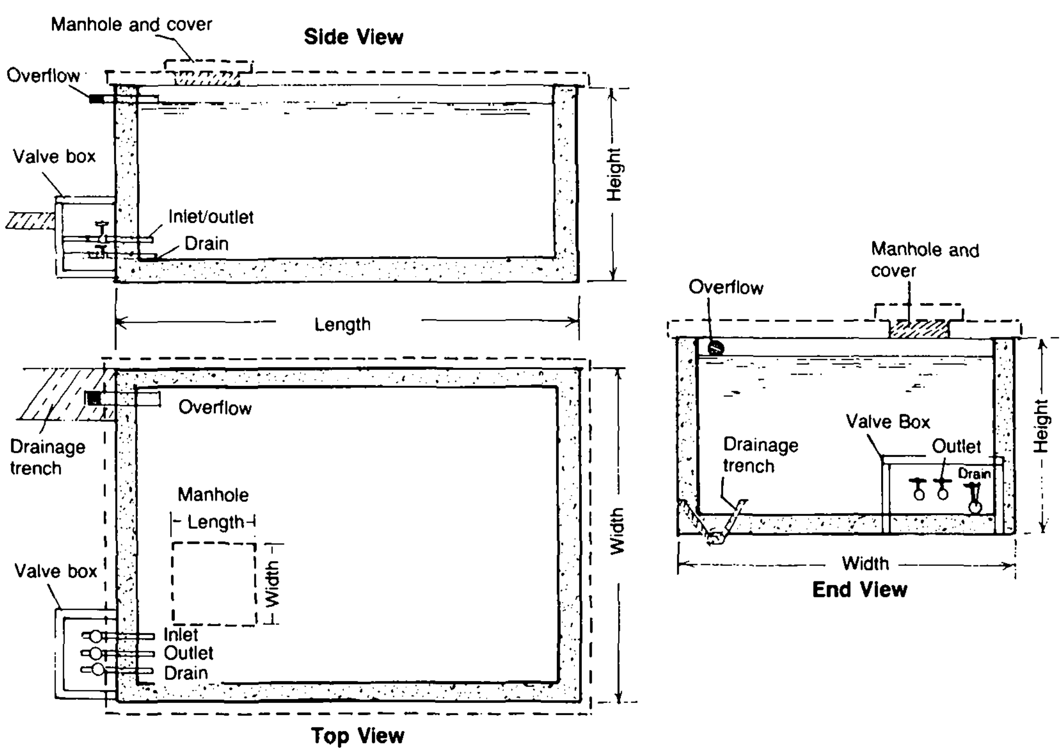

Figure 2. Storage Tank Design

A general rule to follow is that small water systems should have at least 14m of pressure. This means that the bottom of the storage tank must be at least 14m higher than the highest tap. A general rule is that the minimum water level in the storage tank should be 20-40m above the area served. Figure 3 shows a profile of a system. Note that the elevation of the highest tap is 210m and that the system is built for a minimum of 14m pressure. The ground storage is on a hill at an elevation of 230m which provides sufficient pressure to reach the highest tap in the community. If no location of suitable height is available, an elevated storage tank may be needed. For information of the design of elevated storage tanks see "Designing an Elevated Storage Tank," RWS.5.D.3.

In order to save money, try to locate the storage tank as close as possible to the water source and the population being served. If possible, put it between the source and the population to limit the need for long lines of pipe. The location of storage shown in Figure 3 is distant from the pump. This has the advantage of drawing water from the pump and tank drum peak demand periods. For complete information about the design of water transmission lines, the choice of pipe, and head losses due to friction, see "Designing a Transmission Main, RWS.4.D.3 and "Designing Community Distribution Systems," RWS.4.D.4.

Tank Capacity

The capacity of the storage tank is important for the efficient operation of a water supply system. The tank should be large enough to store sufficient water to meet both average and peak daily demands. When designing a storage tank keep in mind that demand for water varies during the year. In the hotter months, people use more water than in cooler months and on certain religious or cultural occasions water use may increase.

The first step in determining storage capacity is calculating the demand for water in the community. Follow the steps below in estimating demand.

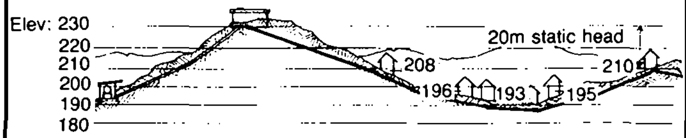

Figure 3. Distribution System with Ground Storage

Table 2. Population Growth Factors

Design Period Years	Yearly Growth Rate (%)					
7	1.5	2	2.5	3	3.5	4
10	1.1	1.15	1.19	1.23	1.27	1.32
15	1.16	1.22	1.28	1.34	1.41	1.48
20	1.25	1.35	1.45	1.56	1.68	1.80
25	1.35	1.49	.64	1.81	1.99	2.19

1. Determine the population of the community. Use census data or initiate a survey to obtain population figures. Check past records to determine the rate of population growth over the years. If funds permit, the storage tank should be designed to last for twenty-five years. Therefore, use the estimated population for 25 years in the future to determine demand for water. Use the growth factors in Table 2 when estimating future population. If money is short, the storage tank can be sized to serve only the current population and the size increased later on, if necessary.

For example, the present population of a community is approximately 1300 and it has been growing at a rate of 3 percent per year. To determine the population in 25 years multiply 1300 by the population growth factor 1.81 found in the row marked 20 and the 3 percent column in Table 2.

Population = 1300 x 1.81

Population = 2350 or approximately 2400.

The reservoir should be designed for a population of 2400 people.

2. Once the population is known, the demand for water can be calculated. Demand can be estimated by considering the type of distribution system used. Table 3 shows estimated water consumption rates for different types of distribution arrangements. Another important factor affecting demand is the use of water for purposes other than household drinking and cleaning. If the community has hotels and restaurants or if animals will be watered from the public system consumption figures would reflect these uses. Table 4 shows estimated water use for various institutions and for animals. Use these figures when designing the capacity of the reservoir.

The total daily demand for water can be calculated using Worksheet A. The calculations are done for a population of 2400 people in a town that has a small hospital with twenty beds, one hotel for 75 people and two schools. A large chicken farm with 5000 chickens also uses water from the public system. It is estimated that 40 percent of the population will be served by multiple taps, 35 percent by single taps in the yard and 20 percent by standpipe. Five percent will have no service.

3. Once the total daily demand is determined, peak demand should be considered. Peak demand is the highest rate of demand during the day. Usually peak demand occurs during the morning when people get up to begin the day and in the early evening after work is completed. Peak demand is estimated by adding 20-40 percent to average daily demand. Multiply the average daily demand by 1.2 or 1.4. For example,

Average day = 120000 liters/day

Peak day = 1.2 x 120000 = 144000 liters/day

A general rule to follow is that the capacity of the storage tank should be 20-40 percent of the peak day water demand. With a peak daily demand of 144000 liters, the capacity of the tank should be at least $30m^3$: 144000 liters x .2 = 30000 liters. At the 40 percent value, the tank would be $58m^3$: 144000 liters x .4 = 58000 liters. In this case, a reservoir of between 40-50m3 would be needed to meet peak demand. A possible design size would be 5.5m x 4m x 2.3m. For this capacity tank, the water height in the tank should be at least 2m and some space should be available between the high water level and top of the tank.

Table 3. Estimated Water Consumption

Type of Water Supply	Average Water Consumption (Liters/Capita/Day)	Range (Liters/Capita/Day)
Community water point (i.e., well, spring, public standpipe)		
At distance 1000m	7	5-10
At distance 500-1000m	10	8-12
Village well (250m)	12	10-15
Standpipe (250m)	15	10-20
Yard connection or single tap	40	20-60
House connection (multiple taps)	70	50-120 (or more)

Table 4. Water Use Requirements

Category	Typical Water Use (Liters/Day)
Schools	15-30 per pupil
Hospital	
(with laundry)	200-300 per bed
(without laundry)	120-220 per bed
Clinics	15-30 per patient
Hotels	80-120 per guest
Restaurants	60-90 per seat
Office	25-40 per person
Bus Station	15-20 per user
Livestock*	
Cattle	25-35 per head
Horses and Mules	20-25 per head
Sheep	15-25 per head
Pigs	10-15 per head
Poultry*	
Chickens	0.15-0.25 per head

*If at all possible, use of water from a public supply for livestock and poultry should be avoided.

Tank Design

Ground level storage tanks are generally made from reinforced concrete, masonry or brick depending on the materials available in the area and the skills of the local people. Steel tanks may be purchased.

Reinforced concrete is used in many areas. Its advantages are that it provides a very sturdy watertight structure that will last many years, and it uses less concrete than mass concrete structures which reduces construction costs. A disadvantage of using a reinforced structure is that steel, lumber for forms and skilled labor and supervision are needed to build the tank. Neither the materials nor the expertise may be affordable or available; if not, an alternative structure design should be chosen.

If large building stone is available, the tank can be built of masonry. When building with masonry, no forms are necessary and construction is generally easier. Masonry tanks are not watertight, however. For best results, make thin masonry walls and fill in between them with concrete as shown in Figure 4.

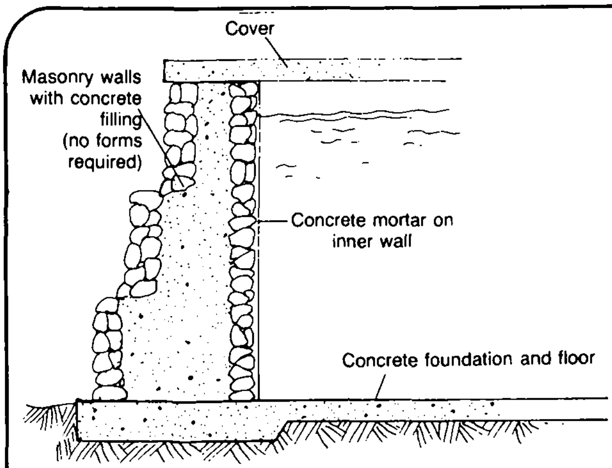

Figure 4. Example of Mass Concrete Wall Construction

The storage tanks can be built either above or partially or completely below ground. Underground structures provide added support for the walls. If soil conditions permit and elevation is sufficient, a storage tank partially or totally underground is recommended. Where such a tank cannot be installed, at least build the form work in the ground for support. If a steel tank is purchased, the tank will be placed directly on a concrete slab on the surface of the ground. Steel tanks provide good storage but may not be feasible in many places due to their cost.

All tanks must have covers. In some cases, reinforced concrete is used but forms are expensive and construction difficult. Cast-in-place roofing may not be possible. A concrete cover can be built by casting several sections and fitting them together on the top of the tank. See Figure 5. The advantage of casting in sections is that the smaller sections can be cast at ground level and lifted into place.

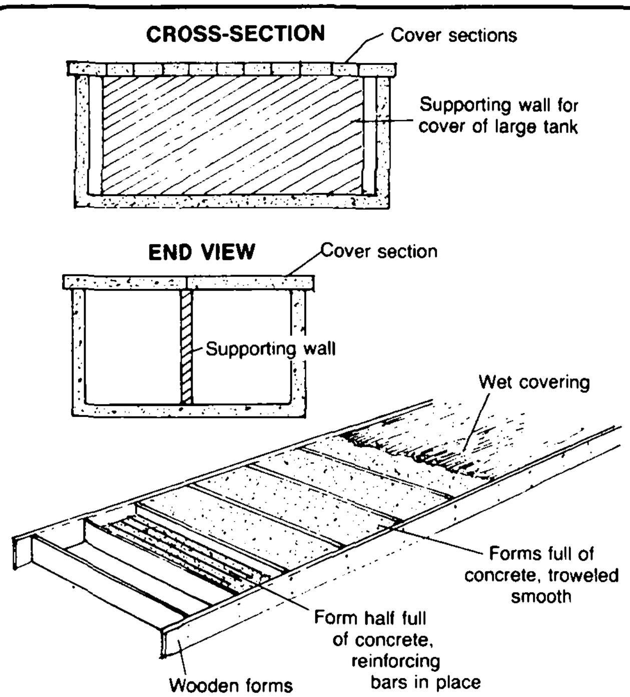

Figure 5. Casting Cover Sections

A wooden roof structure can be made with shingles, slate, or roofing tar placed on it to make it watertight. Roofing structures follow the general design pattern for house roofs and should extend well beyond the ends of the tank so that rain runs away from the structure.

All ground level storage tanks should be designed with the following features. See Figure 6.

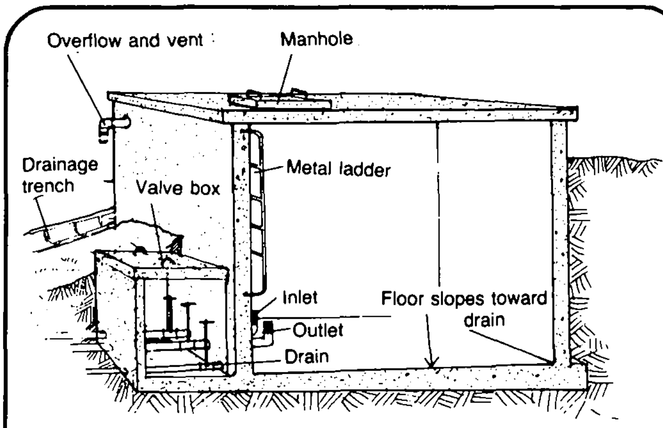

Figure 6. Ground Level Storage Tank

Manholes and Tightly Fitting Manhole Covers. Manholes with raised covers should be installed in each tank. They prevent the entrance of dust, debris and sunlight which is a major factor in the growth of algae. The manholes should have a diameter of 0.8-1m, sufficient to allow a person access to the tank for cleaning.

Ventilation. A screened ventilation pipe should be installed to allow air to escape from the tank when water enters. The pipe should be screened so that no insects, bats or debris can enter the storage tank.

Inlet, Outlet, Overflow and Drain. The inlet pipe should be located near the bottom of the tank. In many cases, the same pipe acts as both intake and outlet. The end of the pipe should be screened and should be at least 150mm above the floor of the tank. Below the intake-outlet pipe, water is not able to leave the reservoir. Instead, this area acts as a settling zone for particles. Plastic, PVC, or steel pipe can be used for the outlet. The choice depends on availability and cost.

The overflow pipe should be located above the expected high water level in the tank. The overflow pipe should be screened. Water that overflows from the tank should be moved away from it to prevent contamination and the accumulation of standing water in which mosquitoes can breed. Lay rock around the tank or line a small diversion ditch to move all water away from the area. The overflow pipe can also serve as an air vent.

A drain pipe should be installed at the bottom of the tank. To ensure adequate drainage, slope the floor toward the drain. Install a drain pipe with a diameter large enough, perhaps 200mm, so that sediment can be flushed without clogging the pipe.

Other Design Features. To control the level of water in the tank, the installation of a float valve is recommended. If a float valve is not used, the operator must be well trained to ensure that water is pumped to storage when needed and not wasted through the overflow.

Small tanks can either be built as a single unit as shown in Figure 6 or divided into two sections as shown in Figure 7. A wall divides the two storage compartments and pipes and valves are arranged so that each can be used separately. This arrangement allows for continuous service when one side is being cleaned. One alternative is to build a single storage tank as in Figure 6 and make a wall strong enough to act as a partition if expansion is desired in the future. Another compartment can be added when and if it is needed, and the cost can be postponed to a later date.

Where suitable conditions exist, ground level storage tanks are a good choice. They require a great deal of material for construction. Worksheet B shows the general calculations for a one compartment storage tank made of reinforced concrete. Using these calculations, determine the specific amounts needed and cost of all materials.

The concrete mixture should be 1 part cement to 2 parts sand to 3 parts gravel (1:2:3) and 10mm reinforcing bars laid in a grid pattern should be used for the walls and cover. All bars should be separated by 150mm.

For all storage facilities, experienced builders are needed to do the work properly whether masonry tanks or reinforced tanks are built, construction expertise is essential. Never attempt construction without the expert advice of an engineer or builder.

Worksheet A. Calculating Water Demand

Population 2400	
1. Multiple taps in homes of 40% of population 40% x 2400 x 70 lpcd	67200
2. Single tap in yards of 35% of population 35% x 2400 x 40 lpcd	33600
3. Standpipe for 20% of population 20% x 2400 x 15 lpcd	7200
4. Two schools with 500 students 1000 x 20 lpcd	2000
5. Chickens (5000) 5000 x 0.2 lpcd	1000
6. Hospital with 20 beds without laundry 20 x 160 lpcd	3200
7. Hotel 75 guests 75 x 75 lpcd	5625
Total	119825

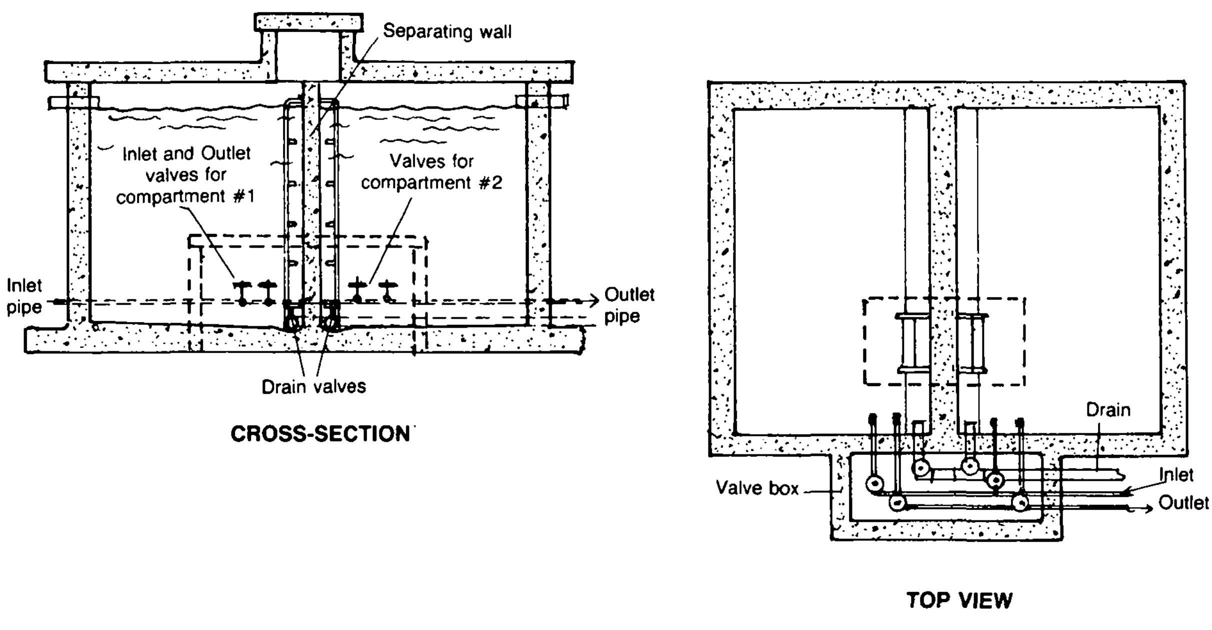

Figure 7. Storage Tank with Two Compartments

Worksheet B. Calculation of Quantity of Materials Needed for a Reinforced Concrete Reservoir (5.5m × 4m × 2.3 with Cover of Concrete Sections)

Total Volume of Reservoir = length x width x height

Thickness of walls = 0.2m

1. Volume of top cover[1] = 5.7 x 4.2 x 0.2 m = 4.8 m^3
2. Volume of two front walls = 5.5 x 2.3 x 0.2 x 2 = 5.0 m^3
3. Volume of two side walls = 4.0 x 2.3 x 0.2 x 2 = 3.7 m^3
4. Volume of bottom including foundation = 5.7 x 4.2 x 0.2 = 4.8 m^3
5. Total volume = sum of 1, 2, 3, 4, = 18.3 m^3
6. Unmixed volume of materials = total volume x 1.5 = 18.3 m^3 x 1.5 = 27.5 m^3
7. Volume of each material (cement, sand, gravel 1:2:3 or 1/6, 1/3, 1/2)[2]

   Cement: .167 x total volume 27.5 m^3 = 4.6 m^3 cement

   Sand: .33 x total volume 27.5 m^3 = 27.5 m^3 = 9 m^3 sand

   Gravel: .5 x total volume 27.5 m^3 = 13.75 m^3 gravel

8. Number of 50k bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag } (.033 m^3/\text{bag})}$
9. Volume of cement = 4.6 m^3 ÷ 0.033 m^3 = 140 bags
10. Volume of water = 28 liters/bag x 140 bags = 3920 liters
11. Number of reinforcing bars placed at 150mm apart

    Length ÷ 150mm + height ÷ 150mm = number of bars needed[3]

    Sides = 5.5 ÷ .15 + 2.3 ÷ .15 x 2 = 36.67 + 15.33 x 2 = 52 x 2 = 104

    2 ends = 4 ÷ .15 + 2.3 ÷ .15 x 2 = 26.67 + 15.33 x 2 = 42 x 2 = 84

    Top and Bottom 5.7 ÷ .15 + 4.2 ÷ .15 x 2 = 38 + 28 x 2 = 66 x 2 = 132

Total = 320 bars

Notes: [1]Cover overhangs 0.1m on each side
[2]To save cement, use a mixture of 1:2:4
[3]Rods are placed so that last rod parrallel to the edge is .75mm from the edge; tips of rods are 25mm from the end of walls; place reinforcing rods in forms so that they are one-third the distance from the outside edge

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1982

Water for the World

Designing an Elevated Storage Tank
Technical Note No. RWS. 5.D.3

Elevated storage tanks are used to deliver water either through large distribution systems or through standpipes located at or near the source or at other communal watering points. Elevated storage tanks are used where ground storage tanks cannot be built due to lack of sufficient natural elevation and where standpipes are served from a well with a windmill or other powered pumps. Elevated tanks can serve either a large community or a small group of families. Elevated tanks do not have as large a capacity as ground storage due to the need for a tower structure to support the tank.

This technical note discusses the design of elevated storage tanks and offers suggestions for choosing the appropriate tank design and construction materials. Read the technical note carefully and adapt the suggestions to local conditions to ensure that the storage meets users' needs.

The design process should result in the following three items which should be given to the construction supervisor.

1. A map of the area showing the location of the storage tank in relation to the water source and the community. Include important landmarks, elevations, if known, and distances on the map. Figure 1 gives an example of the type of map which should be provided.

2. A list of all labor, materials and tools needed. The list will help make sure that adequate quantities of materials are available to prevent construction delays. See Table 1 for a sample materials list for an elevated ferrocement storage tank.

Useful Definition

HEAD - Difference in water level between the inflow and outflow ends of a water system.

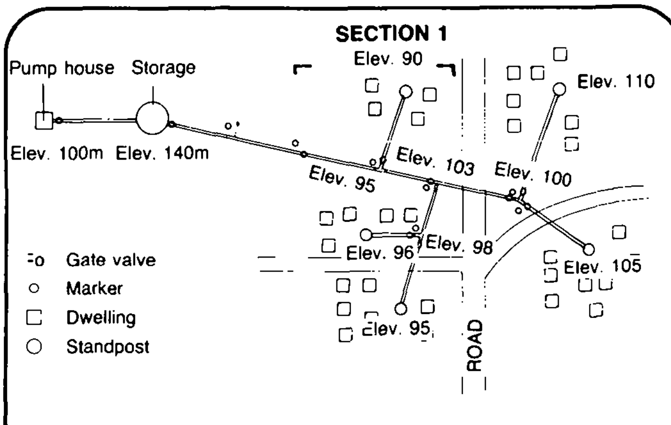

Figure 1. Design Map of Storage and Distribution System

Table 1. Sample Materials List for Elevated Ferrocement Storage Tanks

Item	Description	Quantity	Estimated Cost
Labor	1 Foreman 6-10 Workers		
Supplies	Cement Weld mesh 0.15m, 5mm diameter, 4m x 2m sheets Woven mesh 0.2m openings, 30m long, 1m high Sand Gravel Timber and plywood for roof Bricks Lime Pipe, PVC or steel for inlet and outlet Wire screening Valves Nails Pipe glue		
Tools	Shovels Pliers Wire cutters Wrenches, adjustable and open Mortar box Hoes Hack saw Hammer Screwdriver Measuring tape Plumb bob		

Total Estimated Cost = ____

3. A plan of the storage reservoir with dimensions shown as in Figure 2. The plan shows a side, front and top view.

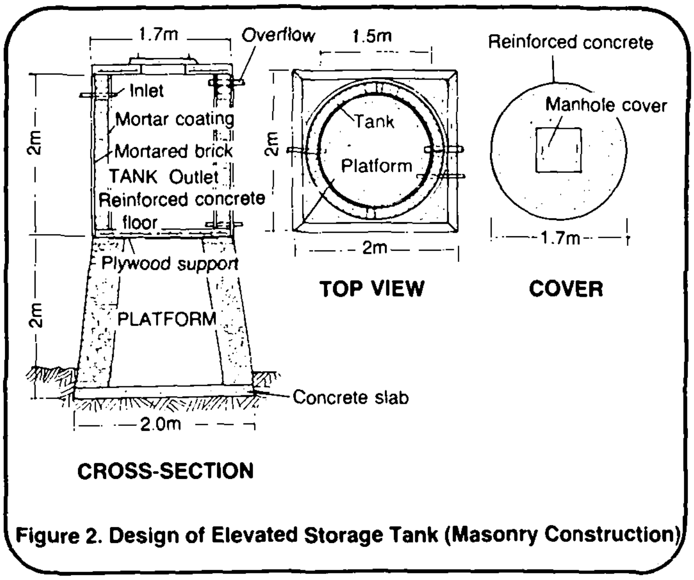

Figure 2. Design of Elevated Storage Tank (Masonry Construction)

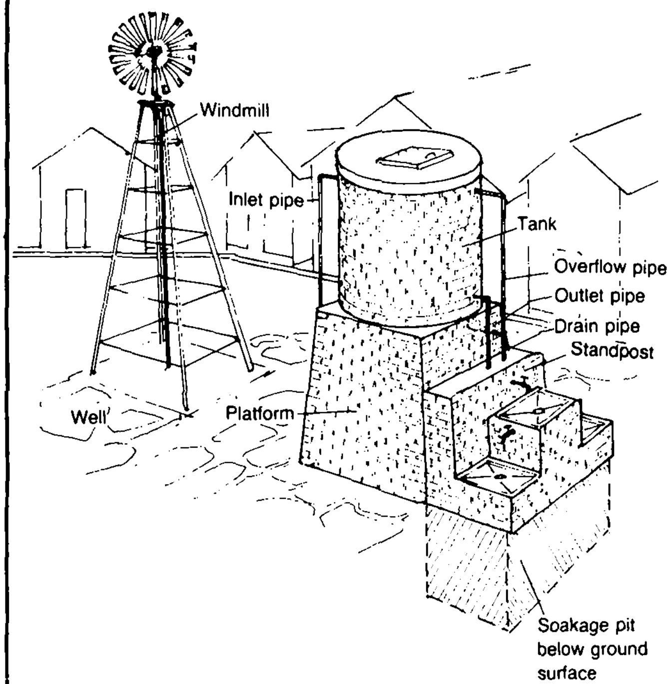

Figure 3. Example of Elevated Storage Fed by Windmill

Choice of Storage Tank

The choice of the best type of elevated tank to use depends on the type of system being installed, the materials available for construction and the availability of skilled labor. Elevated storage tanks are useful for providing water to standpipes as shown in Figure 3 and to large distribution systems are shown in Figure 4.

Elevated tanks which serve standpipes generally have small capacities and are supported by small towers. The towers are usually made from brick or masonry and have a height of 1-3m. Steel and wood can be used although steel is expensive and wood is less durable than other materials. The base of the tower should be at least 1.2 times wider than the top. Since not much head is needed to serve standpipes, the height of the tower does not have to be great. Shorter towers require less material which reduces cost. Determine the size of the tower desired and the design which uses the fewest bricks. Figure 5 shows one design. Approximately 50 bricks are needed for each m^2 of construction. If possible, use wide bricks to form a wall 100-150mm thick. A design using four walls that come together at a

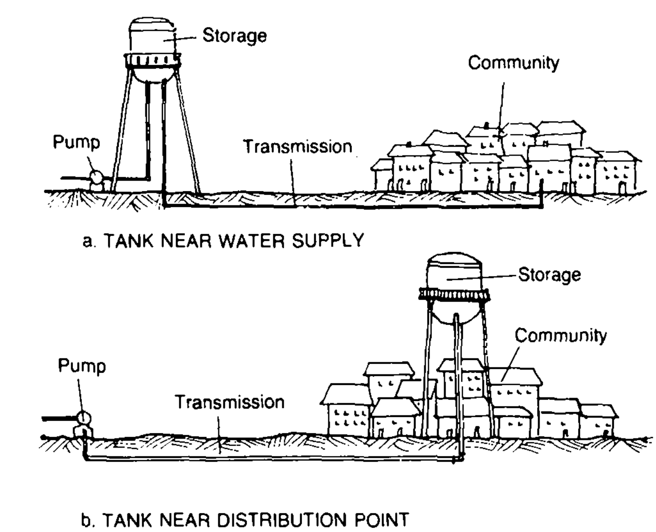

Figure 4. Constructing Storage for Large Population

center point is useful and effective. The base should be well designed and constructed to ensure adequate strength to support the water tank. Before designing an elevated tank, consult an engineer or someone with experience in designing water tank bases.

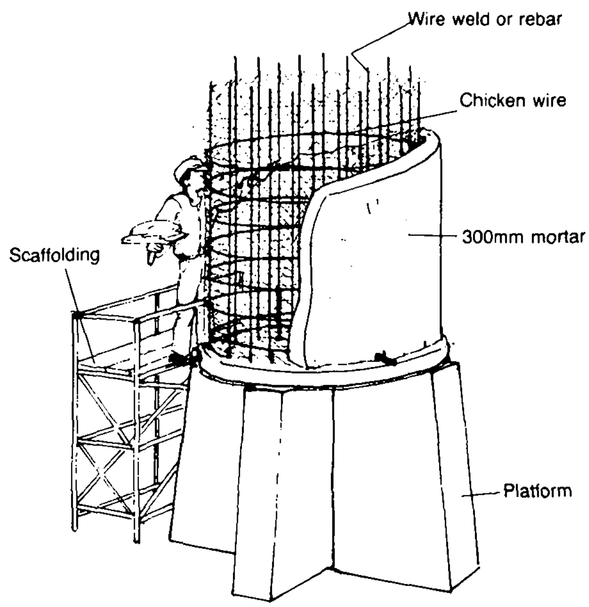

Figure 5. Ferrocement Tank

To choose the type of tank, first determine the capacity needed. The capacity can be found by multiplying the number of users by the per capita consumption per day. When water is distributed from a standpipe, an average estimate of water use is 15 liters per capita per day, lpcd, as shown in Table 2. If animals will be watered from the public supply, their rate of consumption should be included as shown in Table 3.

Table 2. Estimated Water Consumption

Type of Water Supply	Average Water Consumption (Liters/Capita/Day)	Range (Liters/Capita/Day)
Community water point (i.e., well, spring, public standpipe)		
At distance 1000m	7	5-10
At distance 500-1000m	10	8-12
Village well (250m)	12	10-15
Standpipe (250m)	15	10-20
Yard connection or single tap	40	20-60
House connection (multiple taps)	70	50-120 (or more)

Table 3. Population Growth Factors

Design Period Years	Yearly Growth Rate (%)					
7	1.5	2	2.5	3	3.5	4
10	1.1	1.15	1.19	1.23	1.27	1.32
15	1.16	1.22	1.28	1.34	1.41	1.48
20	1.25	1.35	1.45	1.56	1.68	1.80
25	1.35	1.49	.64	1.81	1.99	2.19

For example, if several standpipes with one reservoir serve a small community of 200 people and no animals and water consumption is 15 lpcd, the total daily consumption is 3000 liters. Assume a peak demand of 20 percent of total daily demand for storage purposes and design the storage tank for 3000 liters + 20 percent x 3000 liters or 3000 liters + 1.2 x 3000 liters = 3600 liters. The tank should have a minimum capacity of 3600 liters. Assuming some growth in population and an increase in demand, the total capacity should be at least 4000 and possibly even 5000 liters. Table 3 provides population growth factors for different design periods.

Where the population is spread out, more than one elevated tank with standpipes in several locations can be constructed. The capacities of these tanks can be smaller. This type of elevated tank can receive water from a well via a windmill, a simple gravity flow system if the terrain permits, or a hydraulic ram. If pumps powered by electricity or petrol are used, larger storage tanks are recommended.

One of the cheapest and easiest materials to use for a small capacity tank is steel. Pressed steel plates can be bolted together on top of a tower with little or no skilled labor. Tank size will be influence by the amount of water that needs to be stored and the size of pressed steel sheets available. A tank using pressed sheets 1.6m x 1.6m x 1.6m will provide a storage capacity of just over 4000 liters.

If steel tanks are impossible to obtain or are very costly, a storage tank can be constructed using brick masonry or ferrocement. Elevated ferrocement tanks are best when they are small diameter circular tanks with relatively small capacities. A circular ferrocement tank similar to the cistern described in "Designing a Household Cistern," RWS.5.D.1, can be constructed on a raised tower. A small, 4-6m^3, capacity ferrocement tank can be built on the tank tower without using formwork. An initial circle of bricks forming the outside diameter of the tank should be placed so that the floor diameter is 1.5-2m. A weld and chicken wire mesh cylinder 3m high should be assembled as shown in Figure 5. The tank itself should be only 2m high; the extra wire mesh is used for roofing. Table 1 is a sample list of materials for this kind of tank.

Once the mesh is assemble, mortar mixed in a proportion of 1 part cement to 3 parts sand is applied in a coat 300mm thick. Inlet, outlet and overflow pipes should be installed. The inlet should enter the top of the tank while the screened outlet should be at the bottom.

Brick masonry tanks can be constructed upon the tower itself. Special care should be taken to ensure that the tank is water-tight by coating the inside with a layer of mortar. Construction follows the basic steps for masonry tanks. For small water storage tanks, a circular tank design as shown in Figure 5 is recommended. The mortar between the bricks or rocks should be mixed in the ratio of 1 part cement to 4 parts sand. If sand is not of good quality, then a ratio of 1:3 may be used. To strengthen the mix, lime can be added to the cement in a proportion of 1 part lime to 5 parts cement. Lime is especially useful when mortar is being mixed for brick-laying. The mortar used to line the inside walls of the tank does not require lime. Two coats of mortar each 150mm thick should be applied to the inside of the tank. To give the tank and tower a good finish a 200mm layer of mortar should be applied to the outside of the tank and tower if resources permit.

An inlet pipe should be attached to the tank so that it enters near the top. See Figure 2. A screened outlet leads from the bottom of the tank to the standpipe connections. The screen strains out sediment that collect on the tank bottom. An overflow should be installed near the very top of the tank.

Large Capacity Tanks

Large capacity elevated tanks for more populated communities are generally made of steel or reinforced concrete. Figure 4 shows a typical reinforced tank while Figure 6 is a steel tank. Steel tanks raised on steel platforms are generally paid for by national water authorities or governments. They are very expensive and generally must be imported. The choice to use this type of tank depends on whether they are manufactured in the country or can be acquired at an appropriate price.

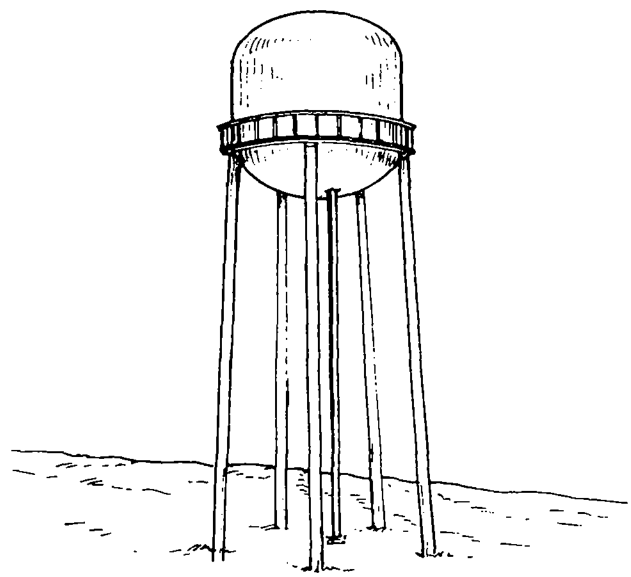

Figure 6. Large Capacity Steel Tank

Reinforced concrete tanks are more commonly used than steel tanks. Their construction requires cement and other materials which may be available nationally or else must be imported. If a tank of standard design is manufactured, the forms used in building the first tank can be reused in constructing later tanks and will result in lower construction costs. Furthermore, local employment opportunities will be created and the local economy will be helped by increased incomes. An elevated reinforced concrete tank should not be constructed without an engineer. Tanks must be well designed to work efficiently and a great deal of expertise is needed in construction. An engineer should be at the construction site to supervise all construction and no work should be done without expert advice.

The decision to use an elevated tank is a result of the need to provide sufficient head in the system. The water level in the tank must be higher than the highest tap in the system so that tap has enough discharge pressure. To provide 14m of pressure in the system, the water in storage should be more than 14m above the height of the highest tap. Consult an engineer when determining minimum and maximum heights for the storage reservoir.

Capacity. The capacity of the storage tank is important to the efficient operation of a water supply system. It should be large enough to store sufficient water to meet both average and peak daily demands. When designing a storage tank, keep in mind that demand for water varies during the year. In the hotter months, people use more water than in cooler months and on certain religious or cultural occasions water use may increase.

The first step in determining storage capacity is calculating the demand for water in the community. Follow the steps below in estimating demand.

1. Determine the population of the community. Use census data or initiate a survey to obtain population figures. Check past records to determine the rate of population growth over the years. If funds permit, the storage tank should be designed to last for twenty years. Therefore, use the estimated population for twenty years in the future to determine demand for water. Use the growth factors in Table 3 when estimating future population.

For example, the present population of a community is approximately 1300 and it has been growing at a rate of 3 percent per year. To determine the population in twenty years, multiply 1300 by the population growth factor 1.81 found in the row marked 20 and the 3 percent column in Table 3.

Population = 1300 x 1.81

Population = 2350 or approximately 2400.

The reservoir should be designed for a population of 2400 people.

2. Once the population is known, the demand for water can be calculated. Demand can be estimated by considering the type of distribution system used. Table 2 shows estimated water consumption rates for different types of distribution arrangements. Another important factor affecting demand is the use of water for purposes other than household drinking and cleaning. If the community has hotels and restaurants or if animals will be watered from the public system, consumption figures would reflect these uses. Table 4 shows estimated water use for various institutions and for animals. Use these figures when designing the capacity of the reservoir.

The total daily demand for water can be calculated using Worksheet A. The calculations are done for a population of 2400 people in a town that has a small hospital with twenty beds, one hotel for 75 people and two schools. A large chicken farm with 5000 chickens also uses water from the public system. It is estimated that 40 percent of the population will be served by multiple taps, 35 percent by single taps in the yard and 20 percent by standpipe. Five percent will have no service.

Table 4. Water Use Requirements

Category	Typical Water Use (Liters/Day)
Schools	15-30 per pupil
Hospital	
(with laundry)	200-300 per bed
(without laundry)	120-220 per bed
Clinics	15-30 per patient
Hotels	80-120 per guest
Restaurants	60-90 per seat
Office	25-40 per person
Bus Station	15-20 per user
Livestock*	
Cattle	25-35 per head
Horses and Mules	20-25 per head
Sheep	15-25 per head
Pigs	10-15 per head
Poultry*	
Chickens	0.15-0.25 per head

*If at all possible, use of water from a public supply for livestock and poultry should be avoided.

3. Once the total daily demand is determined, peak demand should be considered. Peak demand is the highest rate of demand during the day. Usually peak demand occurs during the morning when people get up to begin the day and in the early evening after work is completed. Peak demand is estimated by adding 20-40 percent to average daily demand. Multiply average daily demand by 1.2 or 1.4. For example,

Average day = 120000 liters/day

Peak day = 1.2 x 120000 = 144000 liters/day.

A general rule to follow is that the capacity of the storage tank should be 20-40 percent of the peak day water demand. With a peak daily demand of 144000 liters, the capacity of the tank should be at least $30m^3$; 144000 liters x .2 = 30000 liters. At the 40 percent value, the tank would be $58m^3$; 144000 liters x .4 = 58000 liters. In this case, a reservoir of between $40\text{-}50m^3$ would be needed to meet peak demand.

Structure Design. Large capacity reinforced concrete tanks should be designed by engineers to ensure that the structure is sound. A typical tank is elevated on a tower made of reinforced concrete with a tank built as a continuation of the supporting structure. Large quantities of material are

Worksheet A. Calculating Water Demand

Population 2400	
1. Multiple taps in homes of 40% of population 40% x 2400 x 70 lpcd	67200
2. Single tap in yards of 35% of population 35% x 2400 x 40 lpcd	33600
3. Standpipe for 20% of population 20% x 2400 x 15 lpcd	7200
4. Two schools with 500 students 1000 x 20 lpcd	2000
5. Chickens (5000) 5000 x 0.2 lpcd	1000
6. Hospital with 20 beds without laundry 20 x 160 lpcd	3200
7. Hotel 75 guests 75 x 75 lpcd	5625
Total	119825

required for building the tank. The community should be sure that all materials can be obtained before deciding to contruct such a tank.

The below ground base, the legs of the tower and cross pieces should all be reinforced using at least 8mm diameter reinforcing rods. A larger diameter rod may be preferable if it is available at a cost that is not too high.

The inlet and outlet pipes should be connected as described for smaller tanks. The outlet pipe should be screened to prevent sediment from entering the distribution system. A tight-fitting cover should be placed at the top of the tank so the tank can be entered for cleaning. A ladder on the outside of the tank gives access to the manhole. A small ladder or rings should be placed on the inside of the tank so people can enter safely.

Summary

There is little chance that a community can build a large capacity elevated storage tank without outside technical and financial assistance. Such tanks are recommended for use only when these resources are easily available to the community. Smaller elevated tanks, as described in the earlier section of this paper, can be built with local supplies and labor with minimal outside assistance. The choice of storage tank design should be made only after careful consideration of the needs of the community and the resources available.

Notes

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

1982

Water for the World

Constructing a Household Cistern

Technical Note No. RWS. 5.C.1

Well constructed cisterns play an important role in providing families with an accessible supply of potable water. Cisterns and storage jars constructed of locally available materials offer improved access to water supply in many areas where good supplies are limited. They also provide a means of controlling the water quality.

This technical note describes construction steps for building reinforced concrete cisterns, ferrocement tanks, and medium and large reinforced mortar storage jars. The steps discussed are offered as guidelines and can be changed to fit local needs and situations. Before attempting the construction of any cistern, seek advice and assistance from people experienced in working in concrete and ferrocement construction.

Useful Definitions

FERROCEMENT - An economical and simple-to-use type of reinforced concrete made of wire mesh, sand, water and cement.

VOIDS - Empty spaces; open areas between particles or substances.

Materials Needed

Before beginning the construction process, be sure to have the following items:

1. A plan of the cistern showing the design and dimensions as shown in Figure 1.

2. A list of materials, tools and other supplies needed to complete the job. Similar to the list in Table 1 or 2. All materials should be available before construction begins in order to avoid delays.

Table 1. Sample Materials List for a Reinforced Concrete Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers		
Supplies	Portland cement		
	Clean sand and gravel		
	Clean water for mixing cement		
	Reinforcing rods		
	Screened mesh		
	Boards and plywood for forms		
	Nails		
	Old motor oil or lubricant for forms		
	Galvanized pipe for overflow		
	Tap for outlet		
	Guttering		
Tools	Shovels and picks		
	Measuring tape		
	Hammers		
	Saws		
	Carpenter's square		
	Pliers		
	Wire cutters		
	Mixing bin, mortar box		
	Buckets		
	Trowel		
	Adjustable wrench		
	Screw drivers		
	Paint brush		
	Level		

Total Estimated Costs = ____

Table 2. Sample Materials List for a Ferrocement Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers		
Supplies	Portland cement		
	Plain wire, 2.5mm		
	Chicken mesh, 1m wide		
	Water pipe		
	Water tap		
	Overflow pipe		
	Galvanized iron sheet and angle iron		
	Sand		
	Gravel		
	Bolts		
	Water		
Tools	Shovels and picks		
	Wire cutters		
	Wrenches, adjustable and open		
	Screw drivers		
	Paint brushes		
	Trowels		
	Mixing bin, mortar box		
	Wheelbarrow		
	Buckets		
	Hacksaw and blades		
	Hammers		

Total Estimated Cost = ____

Construction Steps for a Reinforced Concrete Cistern

Follow the construction steps below. Refer to the appropriate diagrams during the construction process.

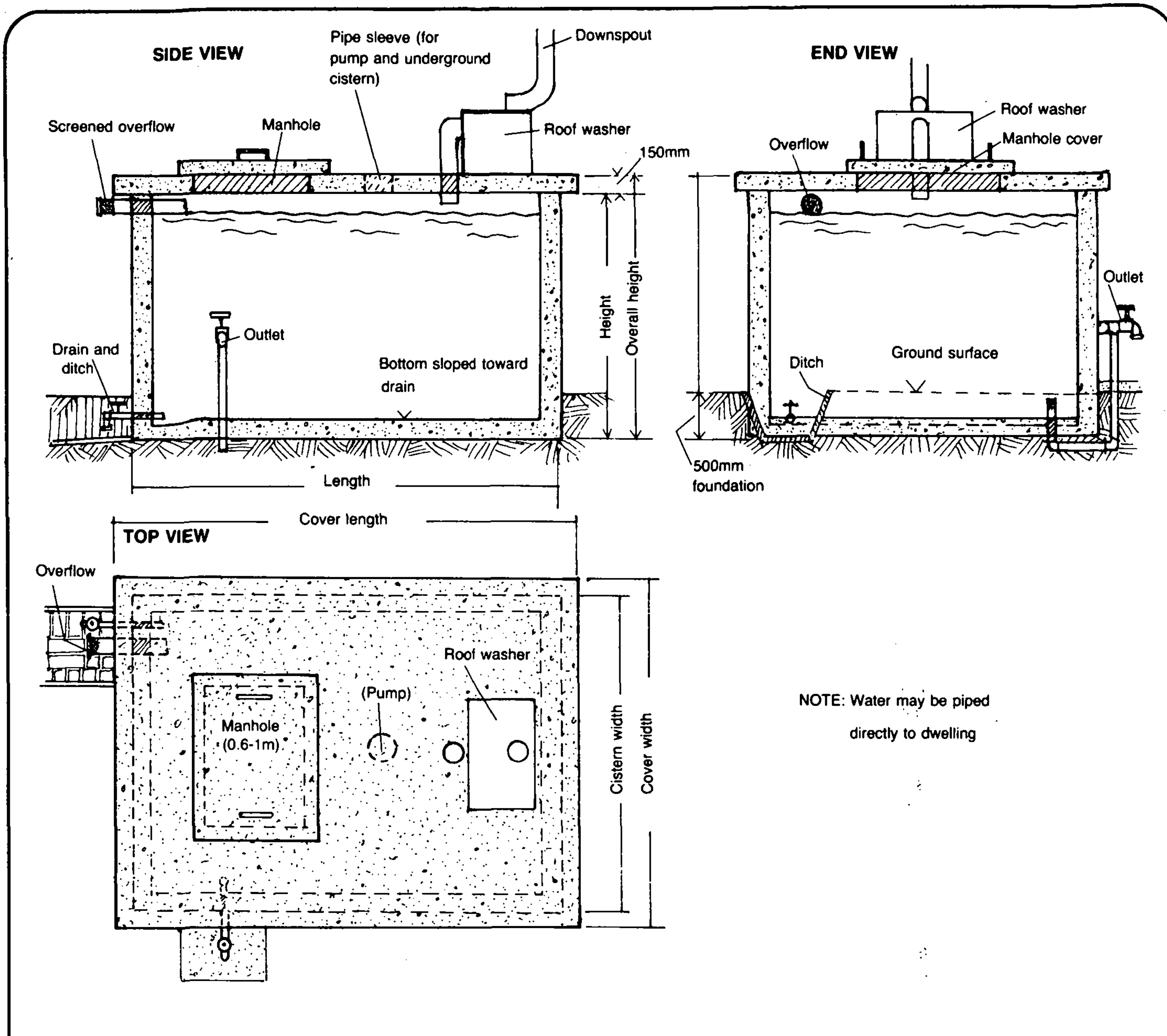

Figure 1. Plan for Household Cistern

1. Find the best location near the house to build the cistern. It should be located on high ground for good drainage and should not be located closer than 15m to the nearest waste disposal site. Once the site is located, mark it out using a measuring tape, wooden stakes and cord, as shown in Figure 2.

2. Dig out a base in the ground to fit the dimensions of the cistern. The hole should be only 50-100mm deep. This will allow installation of an outlet near the bottom of the cistern to take advantage of the entire volume of the cistern. Level the excavated area using flat-nosed shovels and scrapers made from wood.

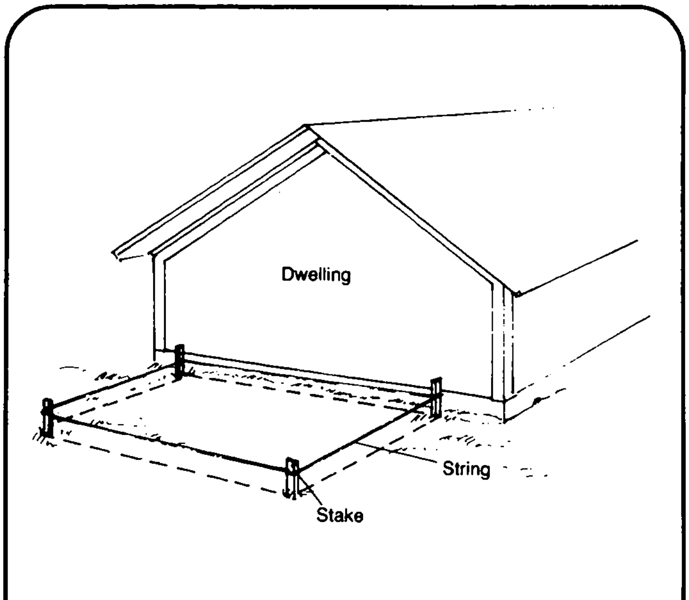

Figure 2. Marking Cistern Site

3. Prepare the forms for the structure. Use plywood sheets, if available, for the faces and small pieces of wood for bracing. All formwork for the cistern should be completed before any concrete is poured.

• Nail all forms together to the design size of the cistern. Walls should be 200mm thick.

• Brace the forms well. Place small holes in the forms and slide wire through them. At the end of each piece of wire, attach a stick to hold the wire in place. Then tighten the wire to create enough pressure to withstand the force of the poured concrete. See Figure 3. Dirt should also be piled up against the outside of the walls to give them support against the weight of the concrete.

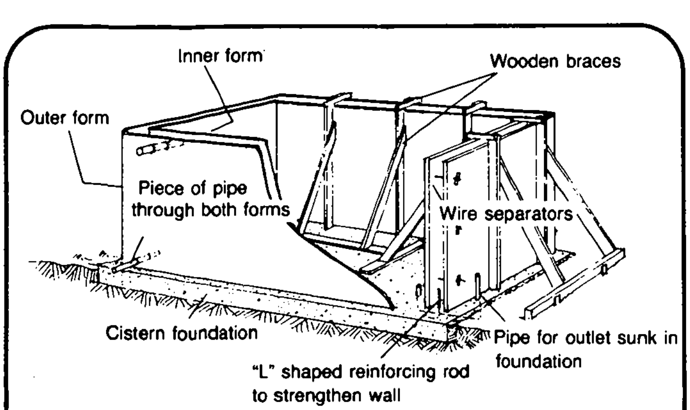

Figure 3. Forms for Cistern Walls

• Place reinforcing rods in the forms. For best results, lay the rod for the floor in a grid pattern as shown in Figure 4. The cross bars should be long enough to cross the entire length of width of the floor and extend at least 300mm into the wall. The reinforcing rods should be bent to fit into the wall forms to a height of 300mm. Other lengths of rod are then tied with these lengths to complete the installation of the reinforcing rod.

This technique is recommended to provide a solid connection between the wall and the floor. Figure 4 demonstrates the placement of reinforcing bars in concrete. The steel bars should be separated 150mm with the first cross bar laid 75mm from the edge of the pour. The bars should be placed one third of the distance from the outside or, as in the example given, about 70mm in from the outside edge.

4. Make holes in the form for placement of the overflow and outlet pipes. The pipes should be placed directly in the forms when pouring the concrete to ensure a good pipe installation.

5. Oil all forms before pouring concrete. Use old motor oil or other available lubricant to prevent the concrete from sticking to the forms.

6. Formwork and steel bar placement for the cover follow the same procedures as outlined above. After forms are complete, mix the cement, sand and gravel in a 1:2:3 ratio adding 23 liters of water for each bag of cement. These proportions will ensure a thick paste.

Pour the floor and about 200mm up the side of the wall in the first pour. Tamp down the cement with steel rods and shovels to make sure that all voids are filled. Once all reinforcing rods are attached, finish the pour, tamp the mixture well and smooth all surfaces.

Cover the concrete with canvas, burlap, empty cement bags, plastic or other protective material to prevent loss of moisture. Keep the covering wet so the concrete does not become dry and crack. When pouring the cover, be sure to leave an opening for access to the cistern. The opening should be fitted with a cover which either can be locked or is difficult to remove.

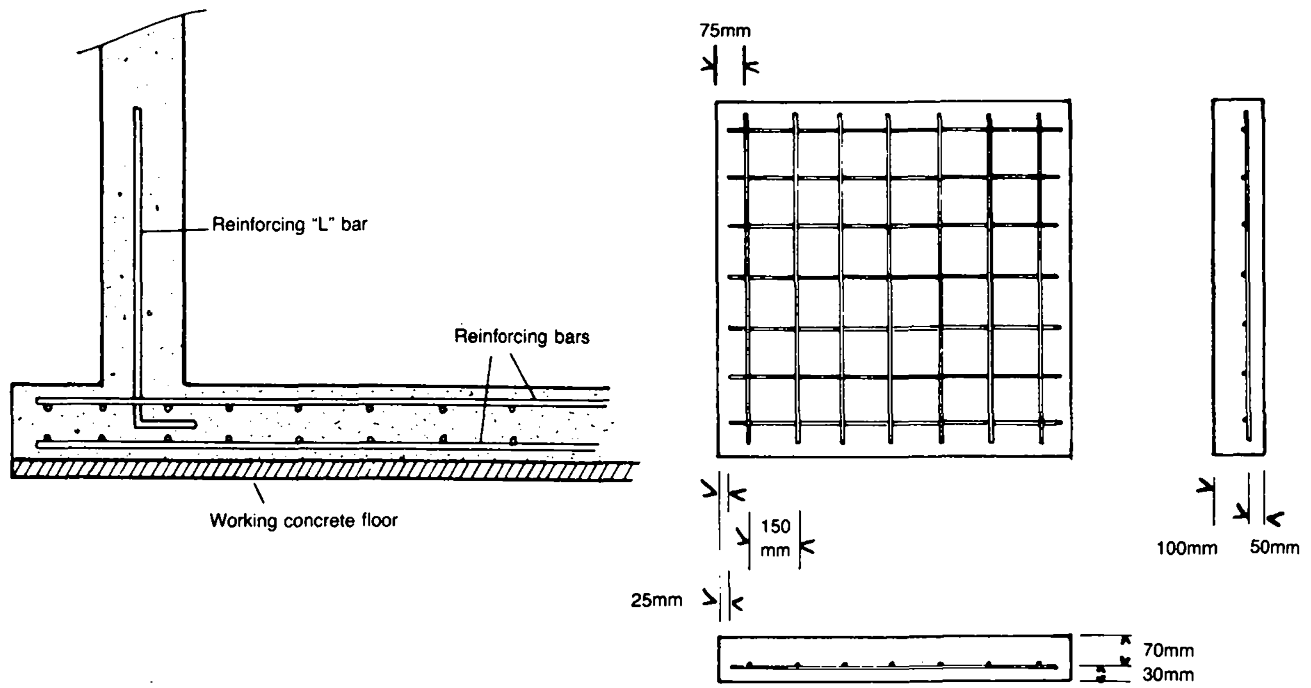

Figure 4. Placement of Rebar in Foundation and Walls

Reinforced concrete cisterns can be built underground. They are usually equipped with hand pumps for extraction of the stored water. To build an underground cistern, follow the same basic construction steps for above-ground cisterns. Make sure that the walls extend at least 300mm above the ground surface. A tight fitting cover with an access opening and a small base for a hand pump should be cast.

Other Types of Cisterns

Brick and masonry tanks can be used for rainwater storage. Skilled workers should construct them. Keep the following points in mind when constructing a masonry or brick tank:

- Make all walls at least 300mm thick.

- For shallow tanks, the walls can be built on the floor. For deep tanks, over 1.5m, a concrete footing or foundation built below the base should be constructed.

- Line the inside of the cistern with two layers of mortar each 10mm thick to prevent leaks. The mortar, and all mortar used in the construction process, should contain cement and sand in the proportion 1:3.

Ferrocement cisterns are generally circular in shape and made with locally available materials. Some experience and skill are needed. The construction steps described below are for relatively large capacity cisterns, about 10m^3. Both smaller and larger cisterns can be constructed following the general construction guidelines.

1. Measure and stake out a circular area 2.8m in diameter. A easy way is to drive a stake into the ground at the center and attach to it a length of rope 1.4m, the radius. Tie a stick or pointed object to the other end and trace the circle on the ground. Dig out a base 300mm in the ground.

2. Place a 100mm layer of sand and gravel over the excavated area, and then a 75mm layer of concrete on top of this. Use a concrete mix of 1:2:4, cement: sand: gravel.

3. Before the concrete sets, cast a 1m length of 20mm steel pipe into the foundation, as shown in Figure 5. This will be the outlet. The pipe should extend 80-100mm above the tank floor, high enough above the ground on the outside of the tank to allow a bucket or ceramic container to sit underneath. A tap will be placed on the pipe when construction is completed.

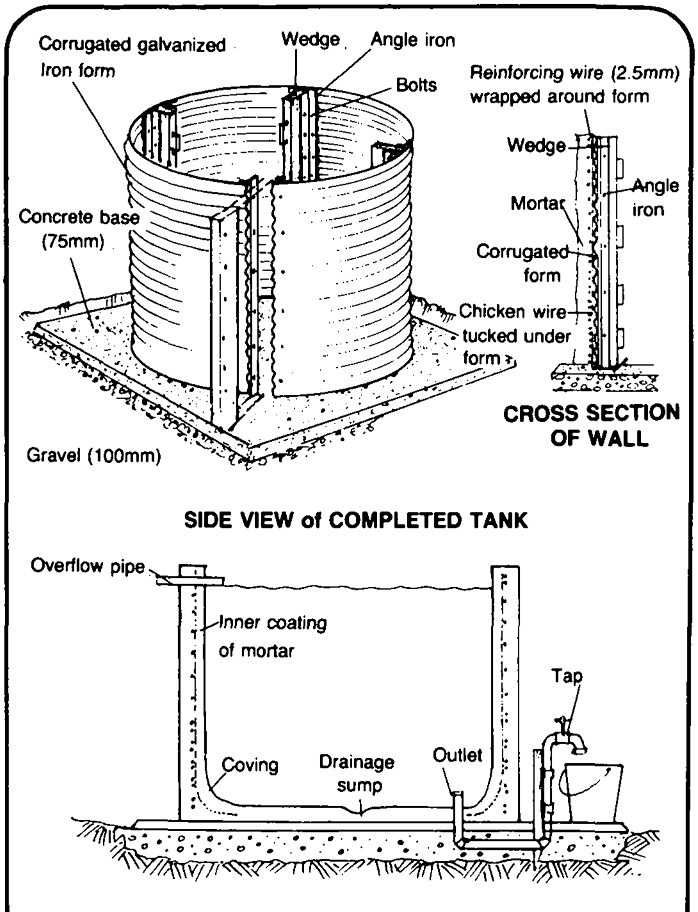

Figure 5. Ferrocement Cistern Construction

4. When the floor hardens, build the formwork for the tank. See Figure 5 for details on formwork preparation. Use 16 sheets of galvanized roofing iron 0.6mm thick. Place four sheets together to form four sections. Bolt the sections to angle iron verticals to form a circle. The steel angle iron, 40mm x 40mm x 5m, is bolted vertically on the inside face at the ends of each set of sheets. Place a wedge between the ends of each section. The wedge can be pulled out to dismantle the forms. Wood can be used for forms. A design similar to that shown in Figure 6 is useful in many areas. This design is especially good where materials such as roofing metal is not available.

5. Clean the forms, removing any dirt, and oil them. Then wrap 50mm wire mesh, chicken wire, around the forms. The netting should be wound around to a single thickness and tucked underneath the forms to hold it in place. The mesh provides vertical reinforcement and keeps the straight wire out of the corrugation.

6. Wrap 2.5mm straight galvanized iron wire tightly around the formwork starting at the base. Use the following spacings:

- two wires in each of the first eight corrugations from the bottom,

- one wire in each remaining corrugation except for the top one,

- two wires in the top currugation.

7. Plaster the outside of the forms with a layer of mortar that covers the wire. The mortar mix should be 1:3, cement:sand. When this layer begins to harden, trowel on mortar to cover the wire with a layer 15mm thick. Give the mortar a smooth finish.

8. Take apart the forms after the mortar has set for two or three days. Remove the holding bolts and wedges so that the forms are easily removed.

9. Place an overflow pipe 200mm long and about 80mm in diameter at the top of the tank. Then to finish the cistern, plaster the inside to fill in the corrugations. When this mortar dries, trowel on a final coat.

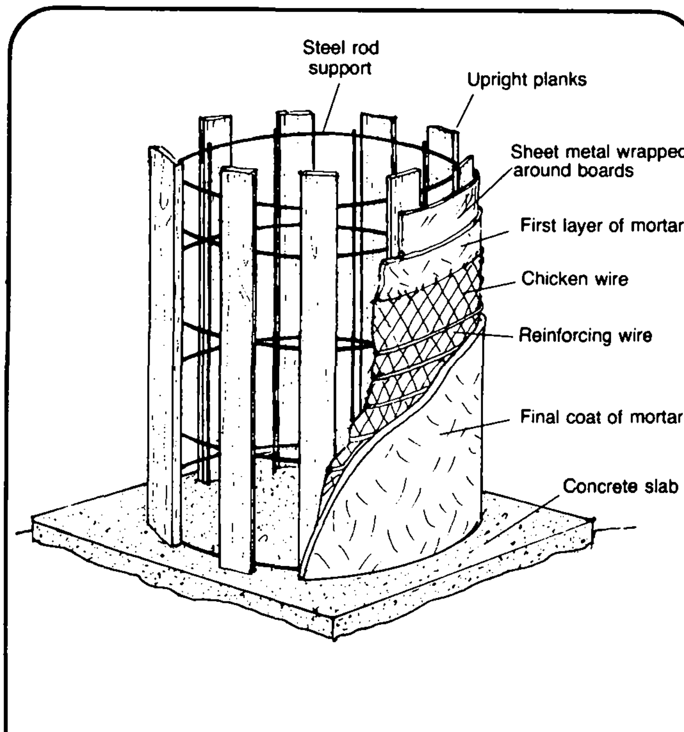

Figure 6. Ferrocement Tank Using Wooden Forms

10. Finally, place a 50mm thick layer of mortar on the floor of the tank. Before the mortar stiffens, make a shallow depression in the middle of the floor to act as a sediment trap for tank cleaning. Sediment can be swept into the sump and removed with a cup.

Roof Structures

Install a roof on the cistern to prevent the evaporation of water, the growth of algae and contamination by rubbbish, insects or rodents. A choice of two roof structures is possible as shown in Figure 7. Figure 7a shows a shell roof built of wire-reinforced mortar between 3-5mm thick. The structure is cast continiously with the walls. After the tank has dried for two days, lay mortar onto shaped form-work made with two layers of wire mesh supported from below by boards. Tie the wire mesh onto the mesh extending from the walls. Install an iron frame to form an access opening in the roof. Remove the frame after construction is completed. Trowel in a layer of mortar and allow three days for curing. After three days, or when the roof is strong enough, take off the formwork and trowel a layer of mortar onto the underside of the tank. Figure 7b shows a completed roof of this type. Let the roof cure for at least seven days. Keep the surfaces moist during the curing process.

Figure 7c shows a more traditional roof structure made from wood. Attach lightweight roofing such as a sheet aluminum or galvanized iron with wire. Screen any open areas between the tank and the roof to prevent the entrance of insects and debris.

Unreinforced Mortar Storage Jars

Unreinforced mortar storage jars can be constructed by people with little or no previous experience. The jars are an inexpensive and relatively easy way to store rainfall for drinking water. Small, 25m^3 capacity, as well as larger 4m^3 jars can be built following the basic construction steps given below. This example is for a 4m^3, 4000-liter, storage jar like the one shown in Figure 8.

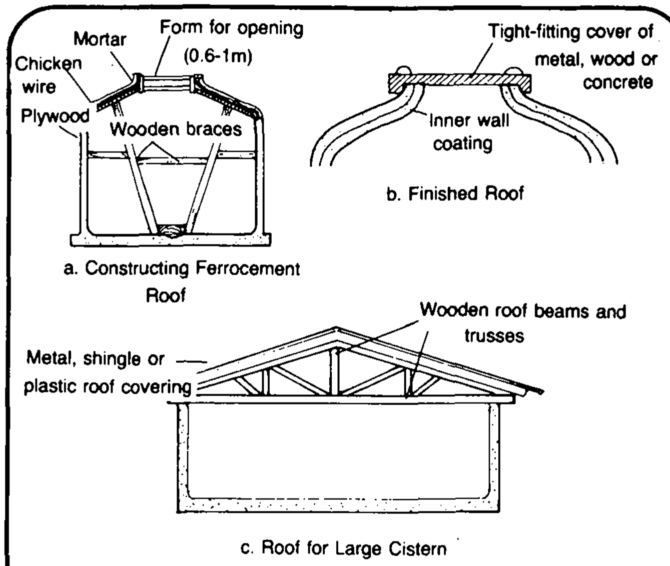

Figure 7. Cistern Roofs

1. The first step in the construction process involves preparation of the mold. Place two pieces of gunny cloth together and mark them out as shown in Figure 8. The bottom width should be marked at 1.2m and the top width at 2.0m. Draw a curved line along the sides connecting the top and the bottom and sew the sack together with heavy tread or twine. The sack height should be 1.7m.

2. Make a precast mortar bottom plate 1m in diameter and 15mm thick. To make forms for the plate, mark out a circle on the ground using a nail as a midpoint and a piece of twine 0.5m long. Trace the circle and lay half bricks or other suitable material around the outside of the circle to act as a form. Place paper, an empty cement bag or other material on the ground within the circle so the mortar does not stick to the ground. Make a mortar mixture of 1:2, cement:sand.

3. Once the bottom plate dries, place the sack narrow end down on the plate and begin filling it with sand, sawdust or rice husks. The weight of the filling material will hold the sack on the plate. Make sure the mortar base sticks out from under the sack, as shown in Figure 8.

4. Completely fill the sack, then fold the top and tie it into the desired shape. With a piece of wood, smooth and round out the jar. When the jar is in the final form spray it with water to completely dampen it.

5. Place a circular ring on the top of the sack to make an opening for the jar. The ring can be made from wood, precast mortar or other suitable material.

6. Begin placing a layer of mortar on the jar. The mortar should be about 5mm thick. Apply another 5mm layer of mortar, checking the thickness by pushing a sharp object like a nail into the side. Be sure to build up any thin spots and add mortar to weak places. Finally, build up the jar thickness and shape as shown in Figure 8. Place a small tap near the bottom of the jar.

7. Twenty-four hours after the jar is constructed, remove the contents of the sack. This operation is easier for small jars. When the jar is empty, check for defects and make any necessary repairs. Paint the inside with a wet mortar mix and then cure the jar outside for two weeks. For best results, cover the jar with damp sacks or plastic sheeting during the curing process.

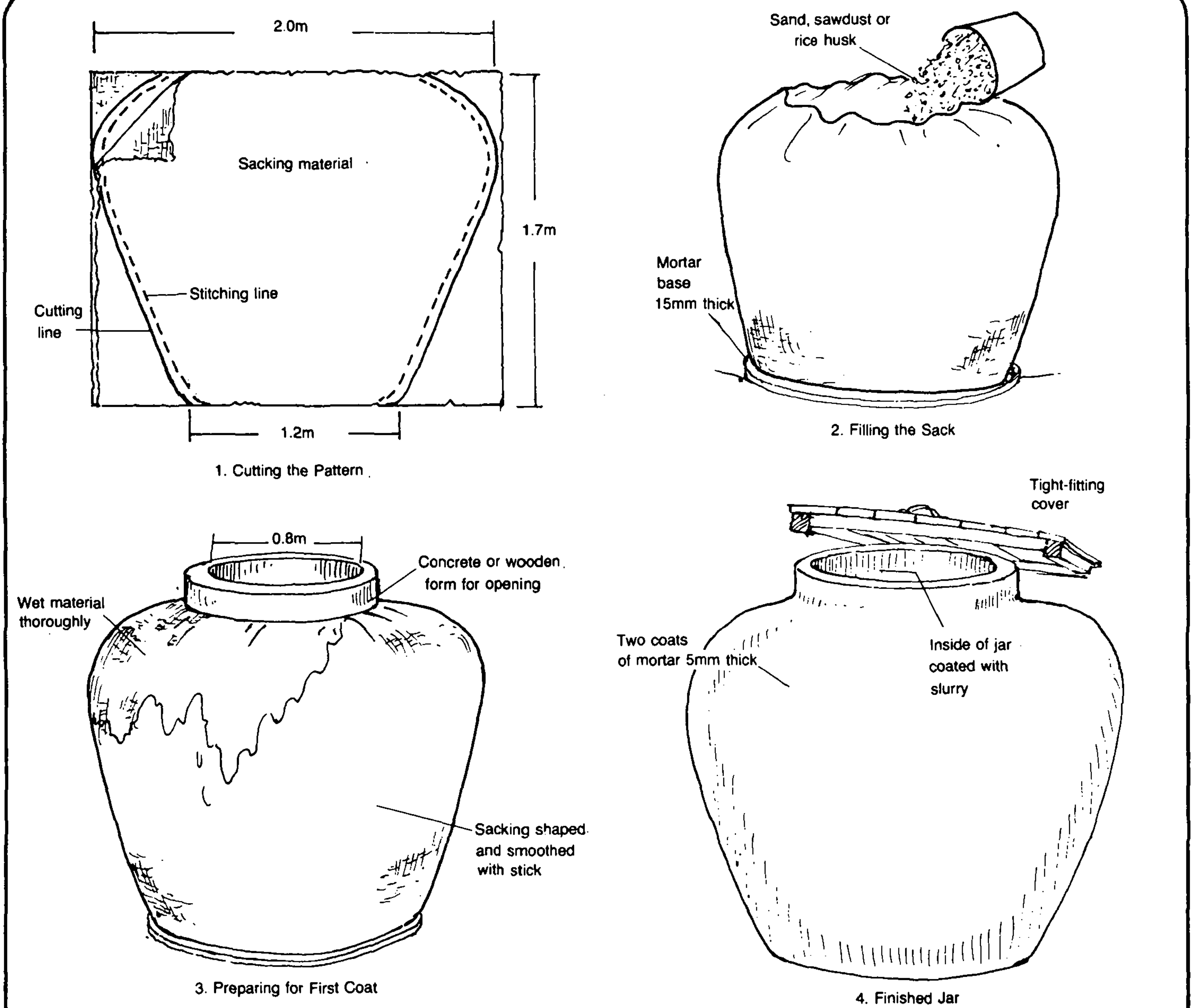

Figure 8. Constructing Mortar Storage Jars

Notes

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1982

Water for the World

Constructing a Ground Level Storage Tank
Technical Note No. RWS. 5.C.2

For effective water storage and water system operation, ground level storage tanks should be built for sufficient, and even excess, capacity and must be watertight to prevent leakage.

This technical note discusses the basic steps to follow in constructing a ground level storage tank. The actual construction process and materials used will differ with each situation or area. The construction of all storage tanks should be supervised by experienced builders or masons and, whenever possible, engineering assistance should be sought.

Useful Definition

ALGAE - Tiny green plants usually found floating in surface water.

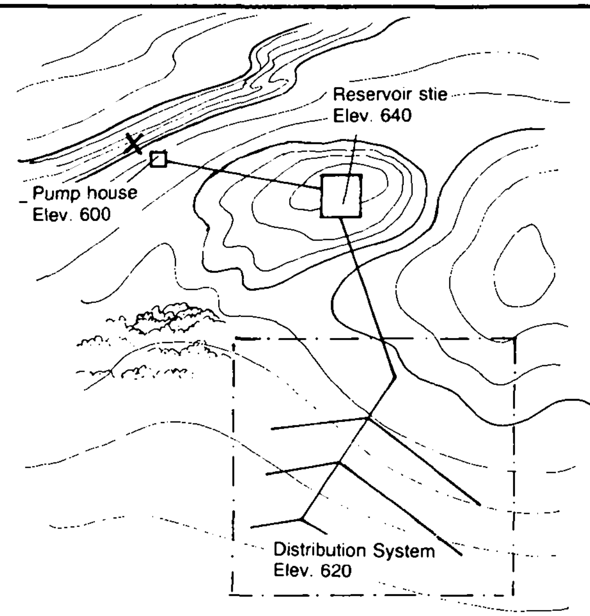

Figure 1. Location Map

Materials Needed

Before construction begins, the project designer should give you the following items:

1. A map of the area including the location of the reservoir, the distribution system, location of users, houses and elevations. Figure 1 is an example of a map showing these reference points.

2. A list of all labor materials and tools needed similar to that shown in Table 1. Ensure that all needed materials are available and at the work site before work begins to prevent construction delays.

3. A plan of the reservoir with all dimensions as shown in Figure 2. This plan shows a top, side and end view.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman	___	___
	Laborers	___	___
Supplies	Portland cement	___	___
	Clean sand and gravel	___	___
	Clean water	___	___
	Reinforcing rod	___	___
	Pipe for inlets, overflow and drain (PVC or steel)	___	___
	Screening and wire mesh for pipes	___	___
	Boards and lumber for forms	___	___
	Lubricating oil	___	___
	Rocks, if masonry tank	___	___
	Float valve (if needed)	___	___
	Cut-off valves	___	___
	Lock for manhole cover	___	___
	Iron for steps in tank	___	___
	Lumber and rafters, if wooden tank	___	___
	Cover structure	___	___
	Shingles	___	___
	Plywood	___	___
	Rope or string	___	___
	Nails, tie wire	___	___
Tools	Shovels, picks and other digging tools	___	___
	Measuring tape	___	___
	Plumb tool	___	___
	Hammer	___	___
	Saw	___	___
	Buckets	___	___
	Carpenters square	___	___
	Level	___	___
	Mixing bin or machine	___	___
	Pipe wrench	___	___
	Adjustable wrench	___	___
	Trowel	___	___
	Hoe	___	___
	Wheelbarrow	___	___
	Sieve	___	___

Total Estimated Cost =

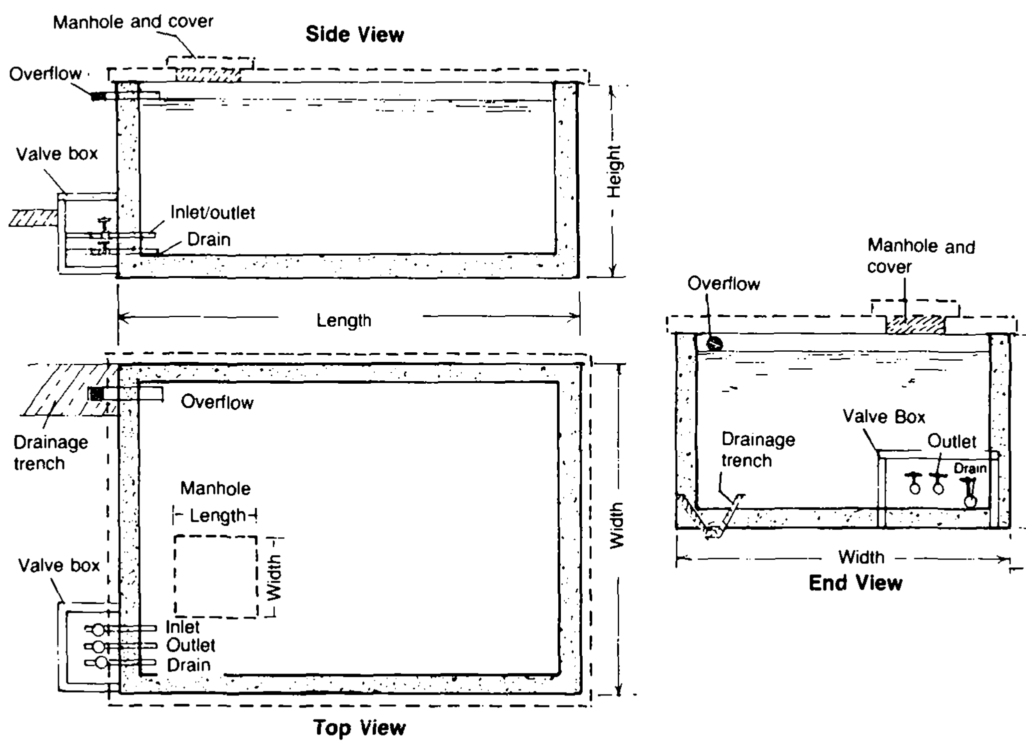

Figure 2. Storage Tank Design

General Construction Steps

Decide on the construction method to use. The reservoir can be completely built into the ground, partially in the ground, or completely above ground. Choice of the construction method will depend heavily on soil conditions and the desired height of the tank. If soil can easily be excavated, it may be best to at least partially bury the tank in order to provide support for the walls. A buried tank is effective as long as the height of the water does not fall below the minimum required to provide adequate pressure in the water system.

Follow the construction steps below. Refer to diagrams as indicated. Remember that the diagrams and construction steps are suggestions that should be adapted to local conditions.

1. Using measuring tape, cord and wooden stakes, mark out the construction site as shown in Figure 3.

2. Clean the area and begin excavation down to the level desired for the tank. If the tank is to be built above ground, or a steel tank is used, then a

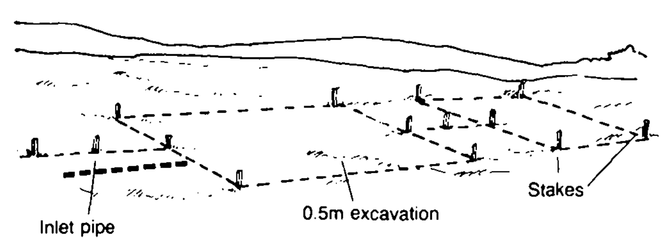

Figure 3. Stakes Marking Site of Storage Tank

shallow excavation which serves as foundation should be sufficient. For deeper excavations, walls can be excavated to slope or be built in a step form as shown in Figure 4. This type of design should be used when combined concrete and masonry are used as construction materials.

Once the level for the bottom of the tank is reached, dig out the area for the foundation. For both concrete and masonry tanks, a concrete foundation and floor is recommended. Make sure the excavation is level around the entire foundation and that plans are made to slope the floor three percent.

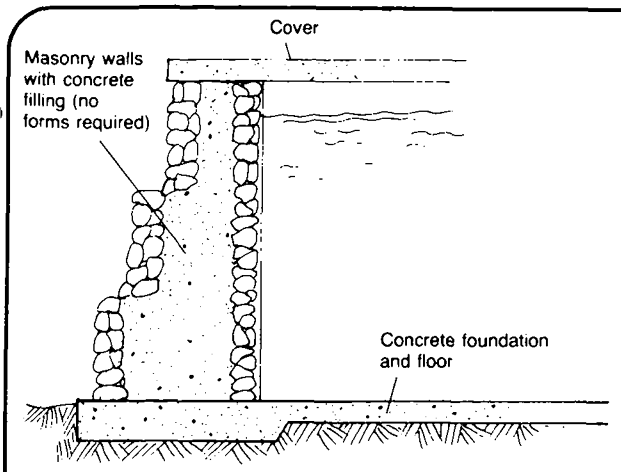

Figure 4. Example of Mass Concrete Wall Construction

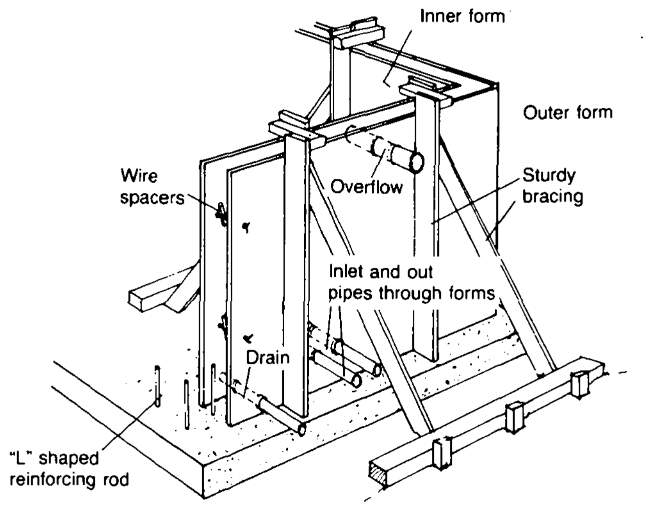

Figure 5. Detail of Forms for Walls Construction

Tank Construction

1. Once the foundation area has been dug out, begin preparing the formwork. Be sure to nail together the forms and secure them well at both top and bottom. It is especially important to brace the inside form, as the outside section will already be braced against the ground. The concrete will push out from the wall toward the inside and adequate pressure against this movement should be applied. See Figure 5.

2. Set up the reinforcing rod as shown in Figure 6. A raft foundation should be used for the structure. Install the rod so that a short length extends into the wall section. This is done by bending the rod at the base where the wall meets the floor. Before pouring the concrete:

- Make sure that all rods are tied together with wire at points of intersection;

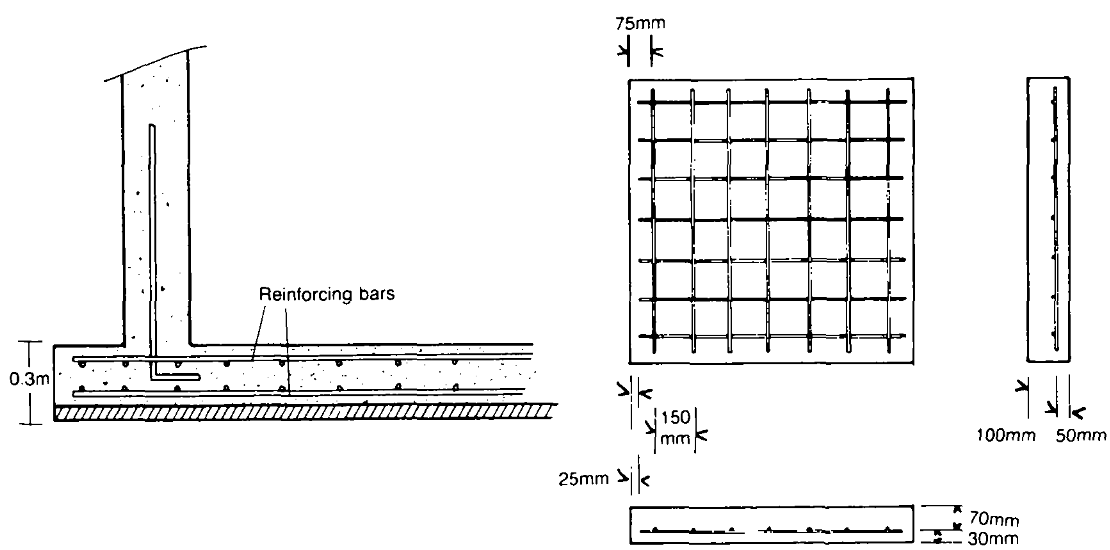

Figure 6. Placement of Rebar in Foundation and Walls

- Place small pebbles or stones under the reinforcing rod grid so that it does not rest on the ground;

- Oil the forms with a lubricant such as old motor oil;

- Cut holes and place pieces of pipe through the forms so that the intake and drain pipe can be installed.

3. Mix the cement in the proportion of one part cement, two parts sand and three or four parts gravel. Pour the entire foundation in a day so that the pour is smooth and drying is even. Smooth the top layer of cement to form the floor. At this time, build up the floor so there is a three percent slope. Hollow out a small channel for the drain pipe. The pipe should range in diameter between 40-70mm.

If structure is reinforced concrete, finish building the forms to the desired height. Remember all forms should be sturdily braced to withstand the force of the concrete. Wire placed in the forms and tightened helps in bracing. Wood braces and cross-pieces should be attached to the forms to provide adequate support. Lubricate all forms before pouring the concrete. Make a hole in the forms for a pipe ranging in size from 40-70mm in diameter. The larger the flow, the larger the pipe diameter should be. The holes in the forms should be located 150mm above the floor. Place the pipe directly into the forms before pouring. Follow the same technique for an overflow pipe. See Figure 5.

When stone masonry is used as construction material, no forms are required but skilled builders are needed. Adequate care should be taken to ensure that walls are straight (plumb) and are at least 300mm thick. A useful technique is to build the outside walls and fill the center of the wall with concrete. When building this type of structure use a step formation.

For both reinforced concrete and masonry-concrete tanks prepare a 1:2:3 or 1:2:4 concrete mixture and pour it evenly around the structure. If possible, use a portable cement mixer which will make the work move much more quickly than if the cement is mixed by hand.

Try to avoid making joints in the concrete. Leakages often occur in joints where a new layer of cement has been poured on a previous day's cement. When pouring from one day is over, leave the edge rough. The next day, clean the surface and paint over it with water and cement to form a good bond.

Once the concrete is poured, 10-14 days are needed for curing. During this time, the cement should be kept moist. A daily wetting of the structure is recommended. If cement dries too quickly, it may crack and leakage will be likely. Forms can be removed after the third or fourth day of curing. To ensure watertightness, the walls of the structure should be roughened with a trowel or a wire brush and painted with a mixture of mortar (one part cement to four parts sand).

Roof Structure

All reservoirs should be covered to prevent the entrance of contaminants, growth of algae and possible accidents. Covers can be made from reinforced concrete or lumber and shingles.

Covers cast in place are both expensive and difficult to construct. Very sophisticated formwork is needed for construction. A better method of construction using concrete is to cast sections as shown in Figure 7. Make several sections and place handles in the top so that they can be lifted into place. Construction of the slabs requires reinforcing rod and a 1:2:3 mixture of cement.

An access hole should be left in one of the covers and a lip built up to allow a cover to be secured to it. Possibly half a hole can be cut from two slabs. Once the slabs are in place, seal the joints between them with mortar to make them watertight.

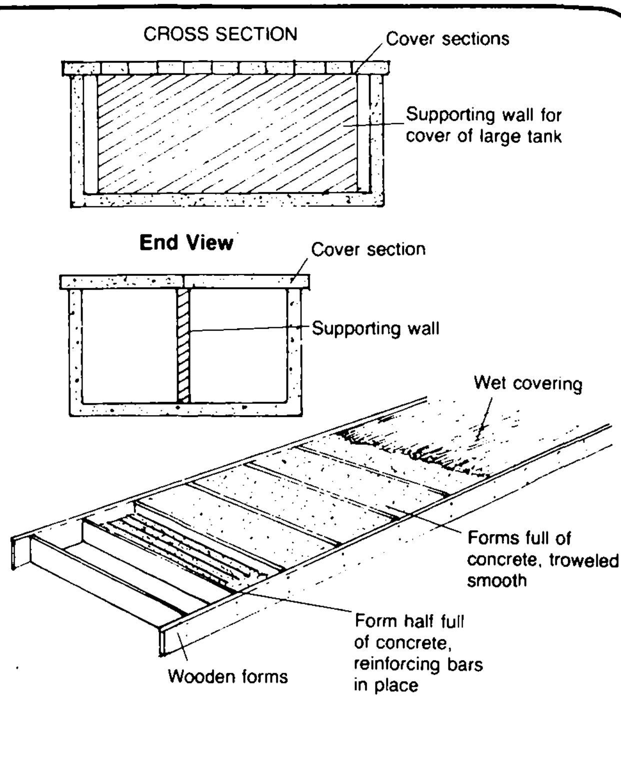

Figure 7. Casting Cover Sections

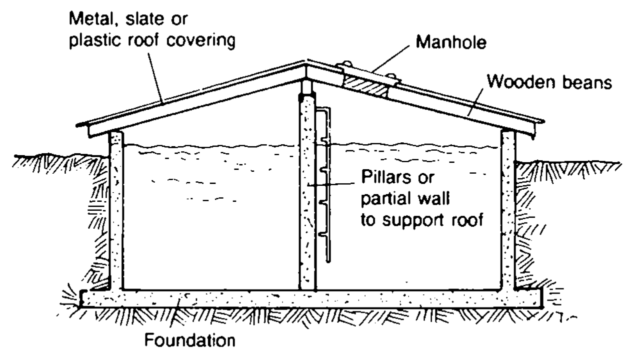

Figure 8. Cover for Large Storage Tank

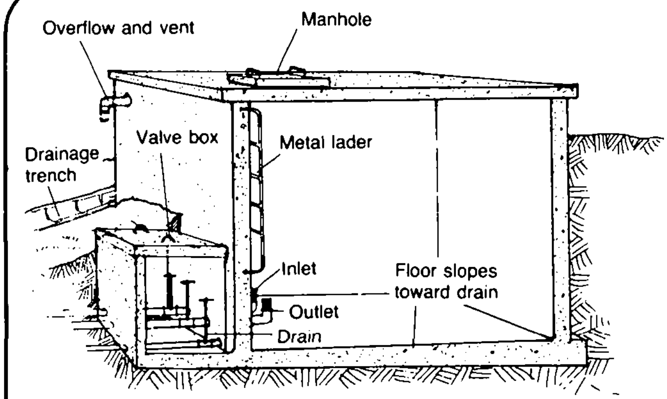

Figure 9. Ground Level Storage Tank

Another alternative is to build a roof structure as shown in Figure 8. The construction should be done by someone experienced in putting roofs on houses. The slope of the roof need not be as great as for a house but should be steep enough to allow water to run off it easily. The most important consideration is that the roof be watertight. Do not cover the roof with thatch or tile which are likely to leak. Use aluminum sheeting or slate or tar shingles for best results. Build up to the earth around the tank so that rainwater drains away from the storage area.

Valve Box

A small box to protect the valves that control inflow and outflow should be constructed at the side of the reservoir. The box can be made from stone masonry, reinforced concrete or wood. The box should have a cover and should be buried. The cover should both protect the valves and provide easy access to cut-off valves installed on the inlet and drain pipes. See Figure 9.

The valve box should be approximately 350-500mm high and can vary in length and width between 750-1500mm. Small globe and gate valves should be installed. The small box should not be difficult to construct. Construction steps can be similar to those followed for the large tank. Make sure that all valve covers are tight so that no water is wasted through leakage.

Notes

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1982

Water for the World

Constructing an Elevated Storage Tank
Technical Note No. RWS. 5.C.3

Elevated storage tanks provide storage capacity for community water systems where water is distributed to the users through hand pumps or distribution pipes. A storage tank provides both needed storage capacity and sufficient head to deliver water to all parts of the distribution system.

This technical note discusses various construction procedures that can be followed for constructing elevated storage tanks of different capacities. Construction of most tanks requires a certain amount of expertise and should be overseen by an engineer or someone with a great deal of construction experience.

Useful Definitions

HEAD - Difference in water level between the inflow and outflow ends of a water system.

SLURRY - A watery mixture of cement used on the outside of tanks as a finish.

Materials Needed

Before construction begins, the project designer should provide the following items:

1. A map of the area including the location of the storage facilities and the distribution system. The map should include all water points and distribution lines. All elevations should be marked. Figure 1 is a sample location map.

2. A list of all labor, materials and tools needed similar to the sample shown in Table 1. Ensure that all needed materials are available and can be at the work site before work begins. Make sure that adequate quantities of materials are available to prevent construction delays.

3. A plan of the storage tank showing all dimensions. Figure 2 shows an example of a small capacity elevated storage tank with standpipes distribution.

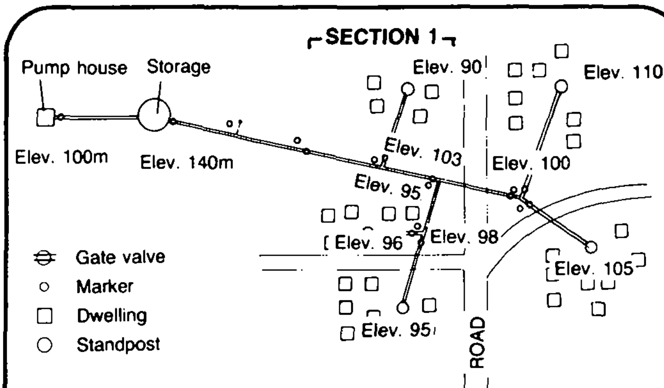

Figure 1. Design Map of Storage and Distribution System

Table 1. Sample Materials List for Elevated Ferrocement Storage Tanks

Item	Description	Quantity	Estimated Cost
Labor	1 Foreman 6-10 Workers		
Supplies	Cement Weld mesh 0.15m, 5mm diameter, 4m x 2m sheets Woven mesh 0.2m openings, 30m long, 1m high Sand Gravel Timber and plywood for roof Bricks Lime Pipe, PVC or steel for inlet and outlet Wire screening Valves Nails Pipe glue		
Tools	Shovels Pliers Wire cutters Wrenches, adjustable and open Mortar box Hoes Hack saw Hammer Screwdriver Measuring tape Plumb bob		

Total Estimated Cost =

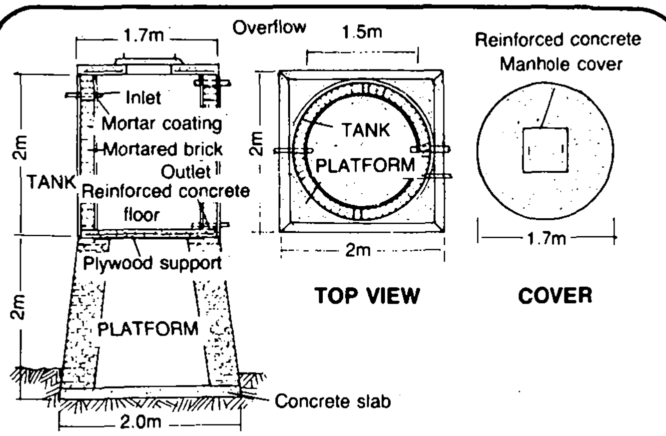

Figure 2. Design of Elevated Storage Tank (Masonry Construction)

Platform Construction

In very small communities, a single elevated storage tank may be sufficient, whereas in more heavily populated areas or those with widely dispersed populations, several tanks may be needed. Alternate tank locations are shown in Figure 3.

There are several types of tanks and support structures. If steel tanks and platforms are used, assembly of the structure is all that is necessary. Instruction for assembly should be provided by the manufacturer.

Supporting platforms can be made from wood, brick, reinforced concrete, or masonry. All platforms must be well constructed to withstand the weight of the tank when full of water. The following section discusses the construction of a brick platform built to support a circular masonry tank of 1.5m diameter.

1. First dig out an area in the ground the diameter of the base. Dig down approximately 0.2-0.4m. Lay a base of concrete and bricks.

2. Begin building up the walls. If wide bricks are available, the walls can be built to a one brick thickness, otherwise a two brick thickness is recommended.

3. Mix concrete in a 1:3 proportion; that is, one part cement by volume to one part sand. Begin laying the brick by usual methods of brick work. Make sure each row is plumb and level. Vertical joints should not line up from one course to that above.

4. Build the platform to the desired height. Scaffolding of some type will be needed to reach the upper platform and to build the tank at the top. Scaffolding can be made of wood or other available materials.

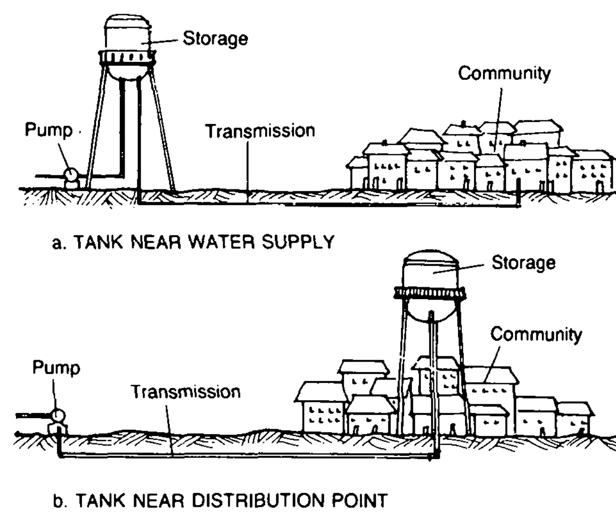

Figure 3. Elevated Storage for Large Populations

Small Tank Construction

A brick masonry tank is constructed as a continuation of the platform. Lay the bricks in a circular pattern. Place both mortar and some small gravel in the spaces between the cracks to ensure a good bond. Lay the bricks in the tank until a height of approximately 2m is reached.

1. Leave an opening in the bricks for an intake pipe and outflow pipe near the uppermost part of the tank. The outlet pipe is placed at the base of the tank as shown. It should be screened so that sediment is filtered out. Make sure to seal around the pipe with a thick mortar paste.

2. Prepare a cover for the tank. A reinforced cover should be made using scrap wire, cement and sand. Mark out a circle on the ground which represents the size of the cover and place bricks around the outside as shown in Figure 4. Place bricks or wood in a square pattern near the middle to construct an access hole for tank maintenance. Lay down paper or plastic on the ground to prevent the cement from sticking. Pour in the 1:3 mixture to cover the bottom, placing scrap strips of wire in the mold as shown. Finally finish the cover by pouring in the concrete. Let it cure for 10 days. Sprinkle water on the cover during the curing process to prevent the formation of cracks, and to allow the cover to gain strength.

3. When construction of the tank is complete, prepare a mixture of mortar. Mortar should be used to line both the inside and outside of the water tank to make it watertight. The layer of mortar should be about 150mm thick to prevent leaking.

4. When the tank is finished, the pipes should be connected to the water source. In some cases, the inlet will be connected to the gravity-fed pipeline from a spring or other source. In other cases, the connection will be to a pump installed in a community well. Figure 5 shows a completed system with a windmill pump and brick masonry storage tank. Several standpipes can be serviced from a single storage tank if there is sufficient capacity.

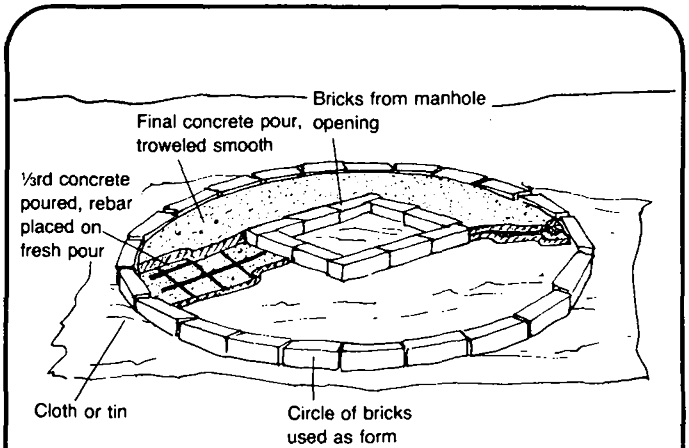

Figure 4. Constructing Tank Cover

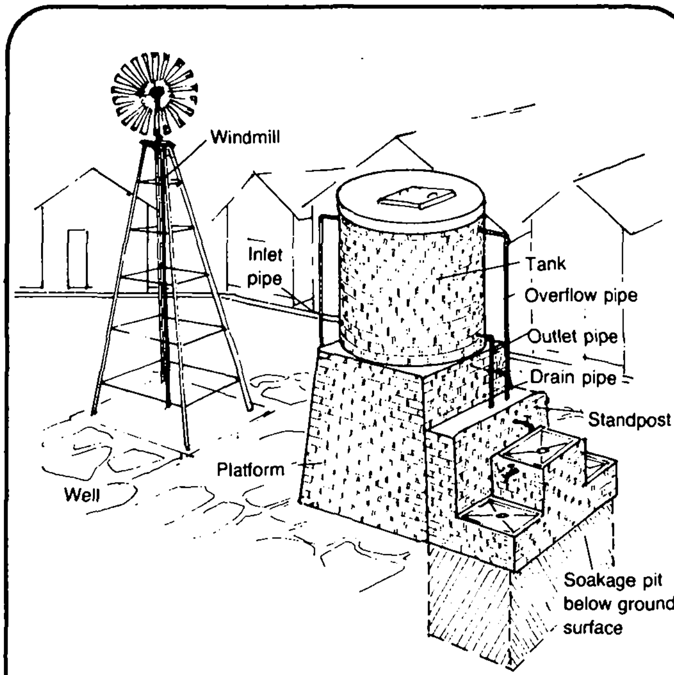

Figure 5. Example of Elevated Storage Fed by Windmill

Storage tanks can be made of rock masonry or ferrocement. Ferrocement requires the use of bricks and wire mesh reinforcement. A weld mesh frame and chicken wire to form and support the walls are used.

1. Build the ferrocement tank by building up from the platform with bricks and wire as shown in Figure 6. Add the weld mesh for walls and add the chicken wire to it. Chicken wire should be placed both inside and outside of the wire mesh. Be sure to leave places for the appropriate piping before applying the mortar.

2. Mix cement in a 1:3 mixture. Apply the prepared mortar to the walls being sure to line both the inside and the outside of the frame.

3. Build up a roof structure of weld mesh and chicken wire. Pieces of plywood shuttering should be propped up from the bottom to support the roof structure. The mortar can then be applied to the roof structure to complete the construction of the tank.

After the tank dries, apply a coat of cement slurry, 1 part cement to 2 parts sand. This mixture is applied to the tank to finish the construction. The slurry ensures that the tank is watertight.

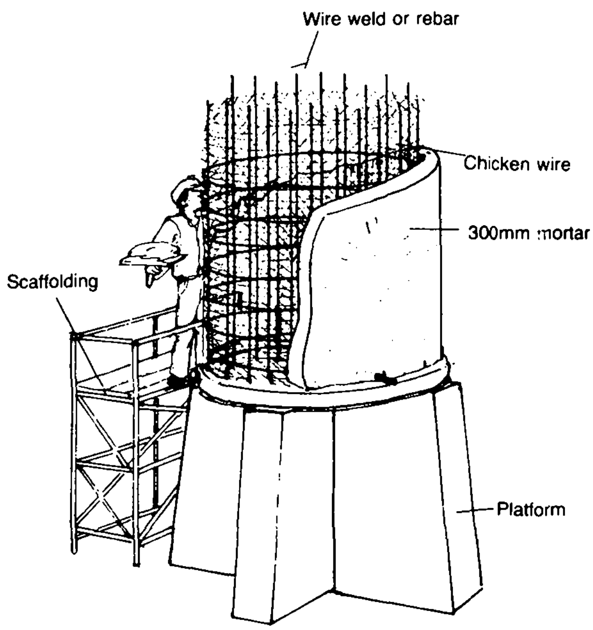

Figure 6. Ferrocement Tank

Large Tank Construction

Large capacity storage tanks, over $5m^3$ in capacity, may be required in towns with fairly large concentrated populations. The construction of large elevated tanks is very expensive because of the large quantities of materials needed for construction. Large elevated tanks are very complicated to build, requiring engineering expertise. An example of a 200000 liter tank with a tower made from reinforced concrete is shown in Figure 7. Under no circumstances should construction of large capacity elevated storage tanks be undertaken without both technical advice from a competent engineer and engineering supervision throughout the entire construction process. Poor design and construction procedures could result in a waste of money and serious damage due to tank collapse or failure.

If a large capacity elevated tank is needed, use "Designing an Elevated Storage Tank," RWS.5.D.3, to determine the amount of storage capacity needed. Discuss plans with the local water development agency or sanitation service. Seek expert advice. Then, obtain cost estimates for the project and determine its feasibility.

In many cases the best choice may be to purchase prefabricated steel tanks and towers. These have the advantage of easy installation and no construction delays. Unfortunately, they are expensive and may not be available in some countries. Many countries prefer to use reinforced tanks in order to save money or to reduce imports. Construction of reinforced concrete tanks requires large quantities of sand, cement, gravel and reinforcing bar, which may be scarce or very expensive.

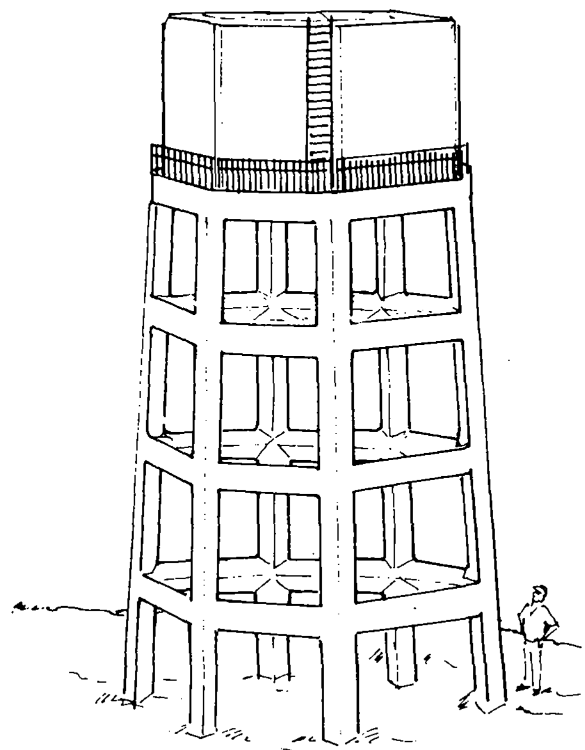
Figure 7. Large Capacity Concrete Storage Tank

Where water tank construction is part of a national plan, costs will generally be lower. Forms can be re-used and construction expertise is gained and passed on. Construction costs are lowered and construction delay reduced.

Summary

Elevated storage tanks are important both for providing storage and for creating sufficient water pressure. Small elevated storage tanks are good for water from gravity flow systems where springs are sources or where water is pumped from community wells by windmills or small power pumps. The advantage of these tanks are that they can be constructed using local workers. Many communities can afford such tanks for their water supply.

Large elevated storage tanks are much more complicated in design and costly to build than small ones. Their construction by local people is not recommended unless expert advice is available. Their cost is high and they are only economical when there are many users. The better alternative may be to purchase and install a prefabricated steel tank.

Notes

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1982

Water for the World

Maintaining Water Storage Tanks
Technical Note No. RWS. 5.O.1

The maintenance of water storage tanks is necessary to ensure the quality of the water stored. Maintenance of tanks basically involves two important procedures: prevention of contamination, and cleaning the tank periodically to ensure that water is fresh. This technical note describes the maintenance of cisterns, ground level storage tanks, and elevated tanks.

By following preventive procedures and by making necessary repairs as soon as possible, good quality water can be assured.

Useful Definition

ALGAE - Tiny green plants usually found floating in surface water.

General Maintenance

Water quality in storage tanks should be preserved. All storage tanks should be checked monthly to ensure that all necessary maintenance is done when needed. Never delay in attending to any problems that arise.

When looking at the tank, make sure to check the following:

• Covers. Make sure the cover fits tightly over the cistern. There should be no space for dust or leaves to enter the cistern or storage tank. The cover should fit tightly enough to prevent the entry of light. Light stimulates the growth of algae in the tank.

• Potential Sources of Contamination. Check the area around the cistern or storage tank to make sure that no contaminants have been introduced to the area. No waste disposal or garbage disposal site should be near the cistern or storage tank, especially when they are located below ground. Under no circumstances should any disposal sites or animal pens be placed on ground above the cistern. Contaminants can flow downhill and destroy the quality of water. A ditch should be dug near the cistern to direct surface water away from the cistern or storage area. Keep animals out of the drainage area.

• Screens. Check screens covering pipe ends to make sure they are in good repair. Broken screens on outlet and overflow pipes are easy entry points for mosquitoes and small animals. All damaged screens should be replaced.

• Pipes. Check all pipe connections to ensure that there are no leaks in the system. When leaks occur, pipes should be tightened or repaired. Check all valves for proper functioning.

• Structure. Repair any damage that may occur to the cistern or storage tank. Add concrete to repair any chips, broken edges or cracks.

Cleaning the Tank

No matter how much prevention is practiced, a storage tank requires disinfecting and cleaning. Where a cistern which collects rainwater from a roof is the only water source, there may be some difficulty in emptying the tank to clean it. The difficulty is especially great because the supply of water depends on rainfall. The use of a pot chlorinator can solve the problem of the quality of water in the cistern. If a special filter or a foul flush runoff device is installed and a chlorinator is used, the quality of water in the tnak will be satisfactory. For information on the use of pot chlorinators see "Designing Basic Household Water Treatment Systems," RWS.3.D.1.

Ground level and elevated storage tanks are much less difficult to empty and clean. Because the source is the constant flow of a spring, well or surface source, the tank can be emptied, cleaned and refilled again. Users should be notified of any decision to close off the flow of water. The cleaning process should not take more than half a day. The tank should be cleaned between peak demand periods. To clean and disinfect the tank do the following:

- Drain all water out of the storage tank. Usually, this is easily accomplished by letting the supply in the tank fall over time and draining the last bit.

- After the tank is drained, sweep and scrub it until all dirt and loose material are removed.

Then choose the most appropriate method for disinfecting the tank.

- Fill the tank to overflowing with clean water and add enough chlorine to make a 50mg/l solution. Add the chlorine to the tank as it is filling to get sufficient mixing. After the tank is filled, allow it to stand for at least six hours and preferably more. After sufficient time has passed, drain the tank and allow it to refill for regular use.

- A second and faster method can be used when little time is available. Directly apply a very strong, 200mg/l, chlorine solution to the inner surfaces of the tank. For best results, brush the walls with the solution and allow the chlorine to stay on the walls for at least 30 minutes before the tank is refilled.

- Another method can be used but it does not disinfect the upper walls of the tank. Feed water with a chlorine solution of 50mg/l into the tank at a

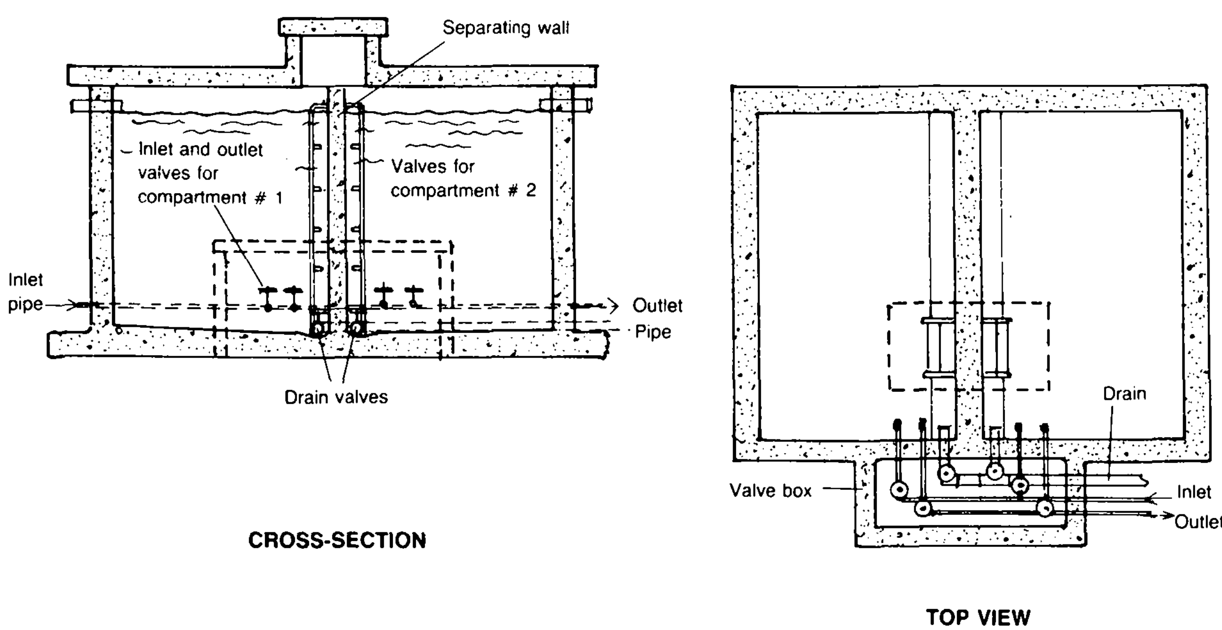

Figure 1. Storage Tank with Two Compartments

volume that makes the chlorine concentration only 2mg/1 when the tank is full. Keep the chlorinated water in the tank for 24 hours before new water is added. With this method, there is no need to drain the tank.

To avoid some of the problems involved with the cleaning of tanks, a tank with two compartments as shown in Figure 1 can be used. One compartment can be shut down for cleaning while the other is used. There is no problem of an interruption of the water supply. Both small and large storage tanks can use this technique.

Whenever a system must be temporarily closed down for cleaning, the users should be forewarned. This allows storage of extra water and should lead each person to use less water during the time where the supply is cut down. Cleaning should be necessary only two or three times annually.

Summary

The maintenance of storage tanks, involves two processes: The care of the different parts of the tank and the area around it to prevent the introduction of contamination, and cleaning and disinfecting the tank to ensure the water quality. Proper planning is needed so that a maintenance program is established. Periodic checks of the tanks should be programmed and a schedule for tank cleaning should be established to ensure that maintenance is not neglected.

Notes

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