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WATER AND SANITATION FOR HEALTH PROJECT

WASH

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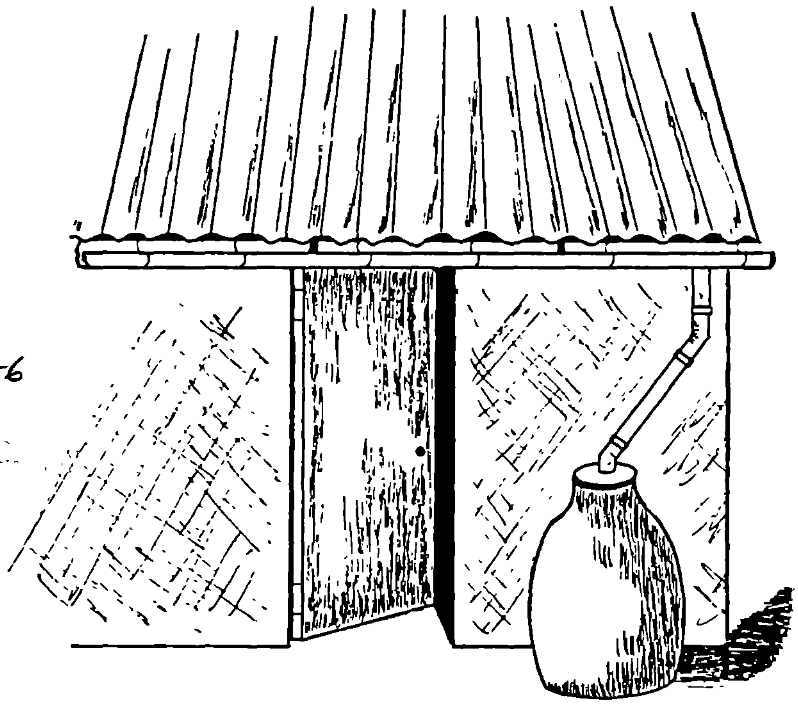
A WORKSHOP DESIGN FOR RAINWATER ROOF CATCHMENT SYSTEMS

A TRAINING GUIDE

WASH TECHNICAL REPORT NO. 27



Prepared for:

Office of Health
Bureau for Science and Technology
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A WORKSHOP DESIGN FOR RAINWATER ROOF CATCHMENT SYSTEMS

A TRAINING GUIDE

Prepared for the Office of Health, Bureau for Science and Technology
Agency for International Development
Under Order of Technical Direction No. 153

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INTRODUCTION

1. INTRODUCTION

1.1 Needs Addressed by the Training

The following training guide provides systematic skill development for training local project promoters in the steps and techniques necessary for a project in rainwater roof catchment systems.

It provides training in setting up systems intended for either dry or wet areas. The guide is a response to the need for water supply in developing countries where roof catchment for drinking and domestic use is feasible and often the only low-cost alternative.

The development of this manual is based upon extensive research in the full range of rainwater harvesting techniques which have been successfully used in all areas of the world.

1.2 Overall Workshop Goals for Participants

During the two-week workshop a balance is struck between the technical skills needed to select and construct a rainwater roof catchment and storage system and the community development skills needed to mobilize and involve village people in assuming responsibility for their rainwater harvesting project. In the workshop, participants will plan and implement a rainwater catchment project in a selected demonstration community. They will participate in all phases of the project. At the same time they will be learning effective methods of involving communities in decision-making related to project development.

At the end of this workshop, participants will be able to:

- Plan and develop a rainwater roof catchment project
- Determine the feasibility of a rooftop catchment program in light of local rainfall patterns
- Assess a community's willingness and ability to support a rooftop catchment system
- Conduct an inventory of local skills, materials, and techniques which can be used in rooftop catchment
- Choose the most appropriate technologies for tank and gutter construction
- Calculate an optimum size for a storage tank
- Mix and prepare cement and mortar
- Design and plan a rainwater catchment system using all of the steps and procedures necessary for detailing and ordering construction materials

- Design and construct a roof catchment and filtration system for thatch roofs
- Manage the ordering of material and labor necessary for constructing a rainwater roof catchment system
- Build a small household storage tank and a large cistern tank
- Develop strategies for involving communities in the construction of the system
- Develop a monitoring and maintenance plan for the system which the community can use and implement
- Construct, connect and hang gutters for the system
- Develop action plans for promoting rainwater roof catchment in their project areas

1.3 Approach of the Training Guide

This training guide uses a "project approach" to rainwater roof catchment. It is not primarily organized for either strictly technical training or community development training, but is a blend of the two. The sessions provide all of the basic steps necessary to develop and carry out a project, from the initial technical feasibility study through instructing the community in how to maintain a completed system. The guide does not present only one option for rainwater catchment, but introduces the participants to the best options for local conditions. As such, the training sessions follow a decision-making model with a variety of possible options for most of the steps in the project development process.

In order to aid this decision-making and support the variety of construction options, a Participant Reference Packet of all of the workshop handouts has been included as an appendix. This packet can later be used by workshop graduates as a reference in completing future projects. The packet contains all of the necessary reference materials needed to design and construct the system. These materials accompany the training sessions and are handed out as the workshop progresses.

In order to successfully use this training guide, the trainer will need to conduct some of the training in the field in a typical community. The sessions include actually constructing systems. A community which is ready and willing to participate must be selected ahead of time as a training site. It is possible to conduct the training in the absence of all of these ideal conditions but the training would become merely a theoretical exercise and would be much less useful. The assumption is that actual rather than simulated field conditions are necessary for learning how to develop and implement a project in rainwater roof catchment.

1.4 Intended Trainers and Participants: Minimum Skills

1.4.1 Trainers

The materials are designed to be used by a two trainer team: an individual skilled in community-level project promotion with background in training and an individual skilled in construction (such as a mason or engineer). In rare instances, one individual may possess both sets of skills and could conduct the training alone. Ideally, however, because someone has to supervise the construction while the training is going on, a minimum of two people is actually needed. The minimum combination of skills required by the trainers is as follows:

- Ability to follow written instructions and read diagrams and drawings
- Ability to use arithmetic
- Some background in the physical sciences (e.g., secondary school science classes)
- Willingness and ability to work with their hands in basic simple construction activities (i.e., mixing cement, making forms, plastering), and knowledge of how to organize and supervise hired construction workers or masons
- Ability to explain reasons for various construction activities and procedures
- Opportunity to take time away from routine obligations to conduct training
- Experience in project development/training
- Demonstrated ability to work with groups

This workshop could be delivered by one trainer if there were ten participants or fewer. The trainer, however, would need technical, training, and community development skills.

1.4.2 Participants

The participants in the training program are assumed to be village level workers or project promoters working for a health ministry or a community level project development organization. It is assumed that the promoter already knows how a community is organized and how to enter a community. Therefore, sessions in basic community dynamics (which may vary world-wide) are not included. Some of the training includes "new" skills, which are unique to the technical aspects of rainwater roof catchment projects, and some are "enhanced" skills, which build upon the assumption that the participants are already community workers. The training program can also be given for rural development project masons or construction foremen responsible for initiating village water supply projects. The minimum skills and conditions for the participants in this training are as follows:

- Ability to communicate with people and gain access to a community (knowledge of community entry skills)

- Willingness and the aptitude to learn enough about construction techniques to be able to supervise others in a proper sequence of construction steps

- Ability to include community people in project decisions

- Ability to use arithmetic

- Ability to follow written instructions

Since this course requires participants as trainees to become involved in and learn from actually working on a project with a good deal of access to the trainers throughout the course, the number of participants should be kept small. The optimum number of participants is 16 to 18. It would be possible to have 20 to 22 but with difficulty, and anything over 20 would seriously limit the workshop's effectiveness.

1.5 Session Organization and Methodology

1.5.1 Organization

The training is organized into a 12-day workshop with one day free half-way through the sessions (see the schedule). Each training session is organized according to a standardized format which provides the trainer with the information necessary to conduct training. Each session begins with a synopsis which indicates the steps, content, time, and materials. This is followed with a major goal, which is a general intention or outcome for the session. Following this a series of specific session objectives are stated which are measurable and indicate most of the session content. The session overview tells what the session is intended to accomplish within the perspective of the overall program and serves as a framework for the activities which follow. For the activities of a session the trainer is given specific instructions on what to do and say at each step in the session. Suggested times are provided for each activity. At the end of a session, trainer notes are provided when necessary and a list of materials needed for a given session is provided. In a few instances where a technique is particularly complex or requires material, trainer reference notes have been provided. When they occur, they follow the handouts.

If handouts are required for a session, they are at the end of the section. All of the handouts for all of the sessions (for purposes of duplication) are contained in the Participant Reference Packet, an appendix which is intended as a take-home packet for the trainees.

1.5.2 Methodology

The methods depend upon the active participation of the participants who are willing to try out activities, reflect upon and "process" those activities, and derive generalized learning which can be applied later in the work setting. The training activities are designed to be practical "hands-on" work. That is, an activity which is the same as or nearly the same as the actual work which will be done later on the job. The trainer acts as a guide or coach which allows the participant to try out the skill first and then learn from the experience. Theory is provided by using written handouts and an occasional "lecturette" by the trainer.

Since this workshop is designed on principles of adult learning and experiential methodologies, some of the common workshop activities are:

- Lecturettes/discussions (short trainer-led presentations and discussions)
- Demonstrations
- Large group discussions
- Small group work tasks
- Role plays
- Simulations
- Case studies
- Critical incidents (problems)
- Questionnaires
- Individual reading and reflecting

All methods are designed to put the learner in the active role--doing tasks, solving problems, working with others to plan activities, developing strategies, and trying things out, etc. Trainees work in this active role both as individuals and as members of a working group.

In a larger sense, the entire training program for which this material is designed is an extended case study. However, rather than provide a written case study which would be somewhat abstract, a real community is used as the training example. This allows the training program to take local conditions into account and provide a "tailored" approach to the many different conditions which may be encountered throughout the world where rainwater roof catchment may be used. However, this also creates special planning responsibilities for the trainer and the organization which sponsors and arranges for the training program (this is discussed in the next section).

1.6 Planning for the Training Program

There are a number of planning considerations for conducting this workshop. These are discussed in chronological order.

1.6.1 Selecting the Trainers

We have discussed the minimum skills necessary for using this training guide. The ideal training team would consist of an experienced trainer with a community promotion background and a construction foreman with experience in the construction technology to be used. While there is little "hard" engineering in this program, a knowledge of calculations and math and basic construction practice is essential to teach the technical parts of the program. An experienced mason who is literate could also work as the technical trainer.

WORKSHOP SCHEDULE

DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Session 1 Introduction to workshop Session 2 Developing a project	Session 4 Conducting a community social assessment		Session 7 Sizing the tank	Session 9 Designing the system	Session 11 Planning for construction Session 12 Mid-point evaluation	
LUNCH						
Session 3 Initial technical assessment Visit work site	Session 5 Conducting a community resource inventory Visit work site Observe laying foundation	Session 6 Choosing the appropriate storage and guttering technology Visit work site Observe laying footings	Session 8 Building small household cement tanks	Session 10 Thatch roof catchment	Session 13 Construction of the tank	

DAY 8	DAY 9	DAY 10	DAY 11	DAY 12
Session 14 Preparation for construction	Session 15 Developing a plan for maintenance	Session 16 Critique and refine design	Session 17 Making and connecting gutters	Session 18 Conclusion: applications of the workshop in home villages Session 19 Final Evaluation
LUNCH				
	Session 13 Construction of the tank (cont'd.) (masons)			

Both trainers need to be able to let the participants try out skills without wanting to do the work for them. The training designs are based upon a learning-by-doing approach with the trainers serving as facilitators. It may also be advantageous to the project sponsoring the workshop to assign an assistant trainer to work with the trainers to learn how to run the workshop in the future.

1.6.2 Selecting the Participants

The assumption of all of these training materials is that a community level promoter (such as a health extension worker) will be able to guide the development of rainwater roof catchment projects if he/she is provided assistance with the construction from local masons. We do not assume that a health promoter will be able to learn all of the skills necessary to become a mason, but he/she should understand all of the steps necessary to guide the process. Participants should be selected keeping this in mind. They should be involved in community promotion activities, be able to learn a certain amount of technical material, and be willing to work with their hands to demonstrate techniques and assist local masons.

1.6.3 Selecting a Training Site

There are a number of considerations for selecting the location for the training. The materials are designed to use an actual village as a training case study or laboratory. Therefore, it is important that the community's needs and point of view be taken into account before they are "invaded" by a group of participants to put up roof catchment devices and construct one or more tanks. The community should:

- Have the physical characteristics to make such systems technically feasible: i.e., have adequate rainfall and roofs that can be used to catch water. Along with zinc pan roofs, a thatch roof should be available for Session 10. At least one large roof such as a school or dispensary will be required. If a communal tank is to be demonstrated the site should be in an area which has enough rainfall so that such a project will work.

- Have demonstrated interest through prior investigation and promotion in a project: i.e., be willing to care for a system once installed, be willing to cooperate in community survey activities, construction, and project financing (if the project is not to be a demonstration "donation").

- Have the requisite local resources: construction materials, tools, aptitudes and labor. All construction technologies require local sand and water to be mixed with cement. Clean gravel will also be needed for some construction methods and steps. Bamboo, bush poles, wood boards, twine, wicker baskets, etc. are often needed. Local masons and iron workers, and masons, helpers and/or laborers are also needed.

- Have or be near a classroom facility, or a room large enough to handle the group, as well as suitable space for lodging and eating. The participants will be working in the community part of the time, and in a classroom setting part of the time. School dormitories are often the best alternative but are not always available. Lodging and food can become very important if they are inadequate. You need not have such facilities in the village, but the village should not be too far away from the classroom site and dormitories or unnecessary time will be spent traveling to and from the training room and the village. A good rule of thumb is to spend no more than 20 minutes travelling between sites (10 to 15 minutes is better).

- Possess a building with a large enough roof to fill a communal cistern: Many tanks and gutters may be added to meet the needs of a large village after the training demonstration. Or a small village may be selected which can be substantially helped with one large catchment system built with a school or a dispensary roof. This should be taken into account in the selection of a site. The training workshop is designed to demonstrate both individual family size tanks and a large tank and catchment system. It is important that the community be aware of what is going to take place in this regard.

Once a training site has been identified and chosen, a three-month process of site preparation can start. The amount of time needed to prepare a village site for this workshop will depend on the availability and proximity of construction materials, the amount of time available to the community to collect the materials, and the difficulty of securing rooms for lodging and a place for cooking and eating. The distance of the site from the project headquarters and the ease with which the workshop trainers and logistics coordinator can visit the site on a regular basis are also factors in how much lead time is required. Never underestimate the amount of time it may take to set up a village as a training site. An unprepared site or one with inadequate hastily prepared logistical support can ruin an otherwise well prepared workshop.

1.6.4 Preparation for Training Sessions

The trainers will need to carefully read through all of the training sessions well in advance of the workshop and double check all of the materials needed under local conditions. Written materials will need to be ordered or duplicated. The trainers will need to prepare their presentations and write instructions to the group and lecturette material outlines on newsprint. Each training session is designed as a guide to the trainer. He/she may need to adapt the session in some way to the learning needs of the participants, to available time and resources, or to his/her personal style.

<u>Preparation for Construction</u>

A considerable amount of preparation is required for the construction sessions of the training. The design of Session 13: Construction of the Tank is non-specific and must be completed for the specific construction technology selected. Construction guidelines with trainer suggestions for processing and generalizing questions for several common construction technologies are given in the trainer notes to help in finalizing the session design. This work will have to be undertaken by the lead trainer/training coordinator and the construction foreman in charge of supervising the construction of the demonstration systems and answering technical questions before the start of the training.

The construction sessions are designed to give the participants hands-on knowledge of the construction process which they will be called upon to supervise when implementing a rainwater roof catchment project. The goal of the practical sessions is to permit the participants to learn all the steps in the construction of a rainwater roof catchment system and to improve their skills in common construction techniques (mixing and pouring concrete, mixing and applying plaster, etc.). These learning needs must be balanced with the host community's needs for an alternative or supplemental potable water supply system.

In balancing these needs, the training staff must design a system that provides potable water using locally available resources. If the system is beyond the resources of the community it will not be replicable and its value as a model will be lost. The system should also approximate the kind of system most of the participants will have the resources to construct after the workshop. The choice of a construction technology (i.e., cement block or baked brick, poured concrete, ferrocement lined pit, etc.) therefore must balance the participants needs to practice a technology which they may use in their work with the technology most replicable for the community in which the training is taking place. This factor has to be considered in selecting the site.

The system must also be designed so that it can be finished by the participants with the help of local masons and workers by the end of the workshop. It is essential that the participants be able to complete an entire system and understand the entire process. The need to complete a large, community-size rainwater roof catchment system (with a tank of approximately 10 cubic meters supplied by a roof surface of from 40 to 80 square meters) during the course of the workshop in such a manner so that the participants can observe and participate in all the steps in the construction process takes careful planning and organization.

The task guide for the development of a rainwater roof catchment project (Handout 2-1) introduced in Session 2 and included in the Participant Reference Packet should be followed by the trainers in planning and designing the demonstration system two months before the start of the workshop to allow sufficient time to prepare the community and gather all the necessary construction materials. The actual construction of the system can take from two to four weeks depending upon its size, the technology used, and the number of participants and local masons and workers available. This means that some of the construction will have to be started before the participants have time to take part in the work. Wherever possible, the construction should be planned to permit key steps such as pouring the footings for the wall, to be observed by the participants during the first week of the workshop.

In general, plan the construction schedule by moving backwards from Day 10 when the tank should be completed to whenever it has to be started. In preparing the site for construction, remember that it should be a model of an efficient work site and must be able to accommodate up to 20 participants and five local workers.

In addition to preparing for the construction of the community system, the trainers will have to prepare materials and the community for the two practical sessions which occur during the first week of the workshop (building small household cement jars and a thatch roof catchment system). The bases for the household jars should be constructed five days prior to the practical sessions so they have adequate time to cure.

All times given for the practical construction sessions are approximate and will have to be adapted to local conditions and participant skills.

1.6.5 Ordering Materials

The following materials are needed for classroom training and construction demonstrations and must be ordered and ready ahead of time.

Classroom Supplies

- o Notebooks, graph paper, pen and pencils
- o A flipchart, or at least a blackboard
- o Tables and chairs
- o Magic markers or large writing pens, newsprint
- o Data on rainfall patterns in the area: month by month totals are most useful; yearly averages are least useful

Construction Materials

A variety of tools and materials will be needed to construct a large community roof catchment system, small family size tanks, and a thatch roof catchment system. The size of the tank and the method for its construction will depend upon the learning needs of the participants, water supply needs and preferences of the community, available local resources, the workshop time frame, and budget. The actual quality of construction materials and the number of tools will vary for each workshop and will have to be determined during the planning of the workshop. The following list should not be considered exhaustive but used only as a guide.

- Cement
- Clean gravel
- Clean coarse sand
- Water
- Reinforcing rod for reinforced concrete
- Wood boards for poured concrete molds, wood box filters, gutter braces
- Chicken wire for ferrocement construction
- Corrugated iron sheeting for gutters
- Bamboo, boards, PVC pipe for gutters
- Sacking materials (125 cm x 110 cm) for molds for Thailand jars
- Local wicker baskets (100-200 liter) for "ghala" basket jars
- Oil drum for filter
- Charcoal, rice husks, or coconut fibers for thatch filter
- Cement block molds for block construction
- Nails
- Wire or local tying material
- Bush poles
- Trowels (one per participant)
- Shovels
- Pickets
- Buckets

- Levels
- Tape measure and meter stick
- Woodworking tools (hammers, saws, drill)
- Iron working tools (shears, hacksaw, drill)
- Welding tools (blow torch and solder if available)
- Large needles and thread for sewing sacking materials
- Tar or local resin to seal gutters

1.6.6 Workshop Checklist and Timetable

The following table indicates the key steps and time frame for planning and implementing the Rainwater Roof Catchment Workshop:

Activity	Time to be Completed Before Workshop
Determine role, experience, and learning needs of participant group	4 months
Determine how workshop will fit in with on-going water supply and sanitation program, and how workshop activities (including training site demonstration) will be followed up	4 months
Develop preliminary budget	4 months
Identify/hire workshop coordinator/lead trainer	4 months
Identify potential villages and start site selection process	4 months
Get up-to-date information on local rainfall patterns, the existing water supply system, consumption patterns, etc., for prospective training sites	3 months
Select an appropriate village or community as a training site and start involving them in planning/preparation	3 months
Identify/hire rest of training staff (construction foreman, logistics coordinator, co-trainers)	2 months
Decide on number of participants; identify and recruit them	2 months
Locate and, if necessary, start preparing lodging, eating, and classroom facilities at site; identify all logistical needs and plan acquisition	2 months

Activity	Time to be Completed Before Workshop
Conduct a community resource inventory and community evaluation, and start motivating community to provide promised materials (sand, gravel, wood, etc.) and labor	2 months
Determine construction methodology to be used in the demonstration system, select site and design system, and start ordering materials and preparing construction plans	2 months
Finalize budget	2 months
Inform participants of workshop format and general goals, site, and travel arrangements, etc.	1 month
Work with the village or villages to prepare them for their involvement in the workshop; start gathering local materials and discuss work with local masons, ironworkers, etc.	1 month
Arrange all transportaton necessary for participants, materials, food purchase, etc.	1 month
Finalize all site logistics; hire cooks and develop menu and budget if needed; purchase site logistic materials; start preparing the site	1 month
Purchase all training and construction materials, tools, etc.	1 month
Design specifics of practical construction sessions based on choice of construction technology to be used at site	1 month
Prepare all handouts for participants	1 month
Identify and prepare storeroom and construction site for receiving materials	1 month
Entire staff arrives at training site and starts final workshop preparations, staff, training, and community mobilization	2 weeks
Construction foreman starts working with local skilled and unskilled labor to prepare construction site and work plan and starts some of the construction depending upon the technology	2 weeks

Activity	Time to be Completed Before Workshop
Lead and co-trainers hold final briefings for community to make sure they understand and are motiviated to fulfill their responsibilities	1 week
Trainers prepare all training materials, finalize design adaptations, and plan implementation of each session	1 week
Begin training	---

1.6.7 Preparing the Staff to Conduct the Training Program

In order for a training program of this complexity to be conducted effectively, with events running smoothly, the training staff must certainly work together as a team. A vital part of working together as a team is having time together before the workshop begins to plan and coordinate how the training activities will be delivered. These planning activities would include:

- A concerted effort to build the teamwork needed
- Arriving at a mutual understanding and clarity on how the training program will go
- Making decisions on which trainer will do what
- Preparation for conducting workshop sessions
- Advance preparation for trainee field work (at site and in the community)
- Planning how workshop time and site progress will be coordinated
- Getting training materials ready
- Personal preparation time to get ready to deliver a session
- Planning for brief, daily staff meetings throughout the course

1.7 Task Analysis

The following task analysis is a list of all the major tasks involved in developing a rainwater roof catchment project and system. The tasks are analyzed in three dimensions: difficulty, importance, and new or improved skills for the intended workshop participants. In this analysis the number one denotes the highest degree of importance or difficulty, the number three denotes the lowest. For example, a task which is rated one in importance, means that it is very important and a task which is rated three is not critical but important enough to be taught in the workshop. The task analysis is used as the basis of the workshop design. It is also used in slightly altered form in Session 2, Developing a Rainwater Roof Catchment Project, as a guide to project development.

Task Analysis

Determining Community Needs and Interest (initial)	Difficulty	Importance	New or Improved
1. Determine extent of community need	3	1	Imp
• find out how water is currently supplied	3	1	Imp
• find out role of women and children in carrying water and amount of time now spent on this activity	3	1	Imp
• does the need justify proceeding at this point?	2	1	Imp
2. Talk with community people and leaders to promote the idea of rainwater catchment; determine initial interest	3	1	Imp
• make individual house calls	3	1	Imp
• talk with community members in work settings	3	1	Imp
• begin promotion of ideas as a test of support	2	1	Imp
• discover potential supports	2	1	Imp
3. Decide if the community is interested enough to justify a promotional effort	1	1	Imp
• does leadership exist for community mobilization?	2	1	Imp

Initial Technical Assessment			
1. Identify best sources of information on local rainfall			
• find any weather statistics	3		New
• talk with local people (older people) about wet and dry periods	3	1	Imp

Initial Technical Assessment	Difficulty	Importance	New or Improved
• effectiveness of rainwater catchment systems in use	3	1	Imp
2. Identify acceptable roofs	3	1	Imp
• identify suitable surfaces			
• measure roofs			
3. Plot available rainfall data and rough calculation of yield from a local roof	1	1	New
4. Decide if there is enough rain and catchment area to proceed	3	1	New

Detailed Social and Community Assessment			
1. Collect opinions: would additional water increment from a rooftop catchment system be useful?	2	1	New
2. Explore commitment villagers would make:			
• sharing a roof and tank	2 or 1	1	Imp
• contributing labor and/or money toward construction			
3. Find out how many systems and people are concerned	3	1	Imp
4. Decide whether the community supports rooftop catchment enough to proceed	1	1	Imp

Inventory of Local Skills, Materials, and Experience			
1. Find out whether there are local masons who can build with cement or mortar/stone	3	1	Imp
2. Find out whether there are craftspeople who construct vessels using local fiber	3	1	Imp

	Difficulty	Importance	New or Improved
3. Determine availability and costs of tank construction materials	3	1	Imp
• cement, stone, sand, gravel, bricks	3	1	Imp
• reeds, bamboo, chicken wire, straight wire	3	1	Imp
• shovels, trowels, etc.	3	1	Imp
4. Determine local availability of guttering materials	2	1	New/Imp
• wood	2	1	
• PVC pipe	2	1	
• sheet metal	2	1	
5. Determine availability and cost of roofing materials	3	1	Imp
6. Determine how local people have collected and stored rainwater to date	2	1	Imp
• storage containers			
• water hauling vessels: buckets, tins, etc.			
• lined holes in ground			
7. Begin community promotion			
• will skilled people be willing to contribute time?	2	1	Imp

Choosing an Appropriate Combination of Technologies with the Community

1. Present the range of tank and guttering technologies	1	1	New
2. Decide on individual or community tank with community	1	1	New
3. Discuss maintenance activities and type of outlet for each type of tank	2	1	New

	Difficulty	Importance	New or Improved
4. List material requirements; estimate costs of different tank types	1	1	New
5. List levels of skills required to construct each type of tank	2	1	New/Imp
6. Evaluate amount of labor (e.g., person-days) required for construction of each tank type	2	1	New
7. Use these criteria to decide with community which option is best and mobilize community commitment for labor and cost contributions	1	1	New

<u>Designing the Rainwater Catchment System</u>

1. Using projected yield pattern from local roofs, figure optimum tank volume	1	1 or 2	New
2. Determine how big a tank available resources permit	2	1	New
3. Determine location(s) and type of outlet	2	1	New
4. Design gutters	1 or 2	1	New
and foul-flush routines or mechanism	1 or 2	1	New
5. Choose specifications: foundation, floor, walls, cover (use guidelines provided to determine materials and thickness)	1	1	New

<u>Ordering/Gathering Materials and Organizing to Construct</u>

1. Order materials: when will they arrive?	3	1	Imp
2. Devise sequence of steps and construction schedule with community participation	2	1	New

	Difficulty	Importance	New or Improved
3. Organize construction teams. Who will work? When will they work?	3	1	
4. Get materials to site at chosen time	3	1	Imp
5. Determine place to keep/store materials	3	1	Imp

Construction of System

	Difficulty	Importance	New or Improved
1. Prepare/excavate site	2/3	1	Imp
2. Prepare form work for floor	3	1	New
3. Place reinforcement (if necessary)	3	1	New
4. Mix/pour concrete floor	2	1	Imp
5. Prepare form work for walls	1-3	1	New
6. Place wall reinforcement (if necessary)	1-3	1	New
7. Mix mortar and construct wall	1	1	Imp
8. Mix and apply waterproofing plaster	1	1	Imp
9. Construct roof/cover and place	2	1	Imp
10. Cure-cement work	3	1	New
11. Provide for tank drainage	3	1	Imp
12. Prepare and attach gutters	2	1	New
13. Hook up down pipe/foul flush	2	1	New

Note: Nos. 5 and 6 vary depending on type of tank, e.g., above ground ferrocement tank is very difficult; ferrocement lined pit is easy.

Monitoring and Maintenance	Difficulty	Importance	New or Improved
1. Instruct users in			
• regular use of foul flush	3	1	New
• cleaning of catchment area/ gutter/screens/tank	3	1	Imp
• checking for cracks/leaks/overflow	3	1	Imp
• checking tank drainage	3	1	New
• checking water quality (taste/ color/odor)	3	1	Imp
2. Develop cleaning/inspection schedule	2	1	New
3. Organize community maintenance group	2	1	Imp

1.8 Pre-workshop Skill Assessment

The above task analysis also provides the basis for the pre-workshop skill assessment. The following skill assessment form should be filled out by the participants prior to the start of the workshop. It provides the trainer with an idea of the skill level and hence learning needs of the participants. If it can be completed a month before the start of the workshop it can be used in adapting the workshop design to the participants' learning needs; if not, it can be useful in determining how much stress to give to specific learning objectives in each session. It also provides trainers and participants with a basis on which to assess the participants' progress in improving or developing the skills needed to perform the tasks inherent in planning and implementing a roof catchment project.

[redacted]

PRE-WORKSHOP SKILL ASSESSMENT FORM

Please fill out the following form by checking in the appropriate column whether you feel that you have no experience, some skill, or adequate competency in the following skill areas:

Skill Area	No Experience	Some Skill	Adequate Competency
1. Identify the technical feasibility of a rainwater catchment project			
• identify best sources of information on local rainfall			
• identify suitable roof surfaces			
• calculate roof yield from above			
2. Social and community assessment			
• survey community needs			
• assess community interest			
• determine community preference for individual or group project			
• present information to a community			
3. Local resource inventory			
• identify available materials			
• identify available skills			
• determine resources needed for a roof catchment project			
• determine community's prior experience with such a project			
4. Choose an appropriate combination of technologies			
• familiar with alternative technologies used in constructing a water tank			

Skill Area	No Experience	Some Skill	Adequate Competency
• able to cost various technologies			
• identify various components of a catchment system and how to build them			
• identify maintenance characteristics of each component			
5. Designing a system			
• use projected yield data to determine optimum tank size			
• determine dimension, form, and placement of tank			
• determine gutters and foul-flush or filtering mechanisms			
• design construction specifications for foundations, walls, cover, etc.			
6. Ordering/gathering material and organizing the construction			
• determine materials needed for different construction technologies			
• order materials to be bought			
• organize community to provide local materials			
• plan construction steps and times			
• organize and supervise local masons and laborers			
• prepare a construction site			

Skill Area	No Experience	Some Skill	Adequate Competency
7. Construction skills			
• mix and apply mortar			
• mix and pour concrete			
• use reinforcing rod in reinforced concrete			
• use chicken wire in ferrocement			
• construct cement blocks			
• lay blocks or bricks			
• construct forms for pouring concrete walls, foundations, top slabs			
• waterproof a tank			
• construct and install gutters			
• construct and install down spout, foul flush and filters			
• disinfect the system			
• cure concrete and plaster			
8. Monitoring and maintenance			
• organize a community to maintain a roof catchment system			
• assess a community's skills and willingness to maintain such a system			
• teach community members to maintain the system			
• monitor water quality			

SESSION 1

SYNOPSIS

SESSION 1: Introduction to the Workshop in Rainwater Harvesting

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS*
1.	Session Introduction	Discuss	15	---	Session Goals
2.	Participant Expectations	Discuss	20	---	---
3.	Goals of Workshop	Discuss	15	Handout 1-1: Workshop Goals	Workshop Goals
4.	Workshop Schedule and Methodology	Discuss	10	Handout 1-2: Workshop Schedule	---
5.	Workshop Procedures and Norms	Discuss	15	---	Trainer Expectations
6.	Closure	Discuss	5	---	---
			TOTAL: 1 hour, 20 minutes		

* Flipcharts are to be available during all classroom sessions for recording responses.

GOALS

Total time: 1 hour & 20 min.

To familiarize participants with the overall workshop process and their expected participation in it.

OBJECTIVES*

By the end of the session, the participants will:

- Have discussed and clarified their expectations of the workshop
- Have received the workshop schedule
- Have discussed the workshop goals
- Be willing to commit themselves to workshop norms and procedures

OVERVIEW

This session introduces the participants to what they are going to do for the next several days and sets an overall atmosphere for learning and working together. The session should allow the participants to feel that they are partners in the learning process with the trainer(s). It should be made clear that the participants' ideas and contributions to the learning process are essential to the success of the workshop (just as the community's input is essential for a successful project).

ACTIVITIES

1. Session Introduction

Time: 15 minutes

First introduce yourself and the participants in the group if necessary. Then explain what this particular session will cover (refer to session goals and objectives) and that it will take an hour or so. (See Trainer Note 4 for additional suggested opening remarks.)

2. Participant Expectations

Time: 20 minutes

Ask the participants to take a few minutes to think about what they hope to learn in the workshop and make some notes to themselves about this. After about five minutes, ask them to turn to the person next to them and share their expectations for about five minutes. Then solicit expectations from the full group by taking one or two expectations from each pair and writing it on the flipchart (move this recording process along quickly by moving from group to group without discussing the responses). After it is clear that most

* See Trainer Note 3.

expectations have been recorded, discuss and clarify each expectation. In this discussion, clarify what will and will not be covered. This discussion will flow naturally into the workshop goals and schedule (Steps 3 and 4 below).

3. Goals of the Workshop — Time: 15 minutes

Distribute Handout 1-1: Workshop Goals for Participants* and have the goals written up on a chalkboard or flipchart. Go over the goals with the group and make sure they are clear and understood. If the group has comments on the goals or wishes clarification discuss the issues that are raised.

4. Workshop Schedule and Methodology — Time: 10 minutes

Distribute Handout 1-2: Workshop Schedule. Go over this and explain in general how the training activities are arranged to meet the goals. Explain the kinds of activities which will be taking place each day. Make sure it is clear that the participants are at a "workshop" and not a traditional course. They are going to learn principally by doing. The methodologies used will be case studies, field experiences, group and individual problem solving, discussions, role play, demonstration, and practice skill building.

5. Workshop Procedures and Norms — Time: 15 minutes

Since the group will be working together for two weeks, it is important to make clear and discuss how everyone will work together to avoid future misunderstanding. Have a list prepared of expectations that the trainer(s) has (have) of the group. List such things as starting and ending times, expectations for the use of time, and expectations of group participation and responsibilities. If you expect the participants to work with their hands sometimes, say so. Ask them if they have any particular expectations of the instructor or of each other. Add these to the list and discuss. By the end of this segment, all participants should be clear about how they will work together and what is expected of them.

6. Closure — Time: 5 minutes

Refer back to session goals. Ask if everyone is clear about what the workshop will cover and how it will be done. Link this session to the next session by saying, for example, "Now that we know what we are going to do, we will start with a review of everything one does in a rainwater roof catchment project."

* Handouts are located at the end of each session. They are also collected into a reference packet called the Participant Reference Packet which is an appendix to this training guide.

TRAINER NOTES

1. This session may seem very simple, and you may wonder why it is being done. It is important that the participants be treated as adults and know what they are getting into and why. If these matters are dealt with at the beginning, a lot of time and trouble is saved in the long run. It is also important that group members approach their work together with the trainer in the same way that a project is approached in the community. This session establishes this framework.

2. You will need to prepare the materials to hand out and/or have things written up on a flipchart or chalkboard. You will also need to think about the expectations you have for workshop norms ahead of time and have them listed on a flipchart.

3. A "get acquainted" exercise has not been included in the goals and the session design, except for a brief exchange in Step 1. It is suggested, if participants do not know each other, that this step be dealt with prior to this session (e.g. the night before). If this is not possible, then the time of this session should be expanded by about 30 minutes to do a short exercise. A useful exercise is to ask all participants to state who they are, what they do, where they come from and one thing they expect to learn in the workshop. The last point is recorded by the trainer and used to compare with the actual workshop goals in Step 2. Another exercise is to ask participants to interview each other in pairs and present the person interviewed to the group. This is a good ice-breaker and allows people to get to know each other.

4. In Step 1, the trainer may wish to briefly introduce the topic of rainwater roof catchment systems, explaining why one decides to use them as opposed to other water supply approaches.

5. If a formal "opening ceremony" is planned on the first day, it will be absolutely necessary to do this session the night before. Pilot testing of this workshop indicates that the first day of the workshop is very full. It is strongly suggested that participants arrive the day before the formal opening ceremony and settle in. Then this session can be conducted as an evening activity on the arrival day.

MATERIALS

- Flipchart for workshop goals
- Flipchart for workshop schedule
- Flipchart for workshop norms
- Handout 1-1: Workshop Goals for Participants
- Handout 1-2: Workshop Schedule

WORKSHOP GOALS FOR PARTICIPANT

At the end of this workshop, participants will be able to:

- Plan and develop a rainwater roof catchment project
- Determine the feasibility of a rooftop catchment program in light of local rainfall patterns
- Assess a community's willingness and ability to support a rooftop catchment system
- Conduct an inventory of local skills, materials, and techniques which can be used in rooftop catchment
- Choose the most appropriate technologies for tank and gutter construction
- Calculate an optimum size for a storage tank
- Mix and prepare cement and mortar
- Design and plan a rainwater catchment system using all of the steps and procedures necessary for detailing and ordering construction materials
- Design and construct a roof catchment and filtration system for thatch roofs
- Manage the ordering of material and labor necessary for constructing a rainwater roof catchment system
- Build a small household storage tank and a large cistern tank
- Develop strategies for involving communities in the construction of the system
- Develop a monitoring and maintenance plan for the system which the community can use and implement
- Construct, connect and hang gutters for the system
- Develop action plans for promoting rainwater roof catchment in their project areas

WORKSHOP SCHEDULE

DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Session 1 Introduction to workshop Session 2 Developing a project	Session 4 Conducting a community social assessment		Session 7 Sizing the tank	Session 9 Designing the system	Session 11 Planning for construction Session 12 Mid-point evaluation	
LUNCH						
Session 3 Initial technical assessment Visit work site	Session 5 Conducting a community resource inventory Visit work site Observe laying foundation	Session 6 Choosing the appropriate storage and guttering technology Visit work site Observe laying footings	Session 8 Building small household cement tanks	Session 10 Thatch roof catchment	Session 13 Construction of the tank	

DAY 8	DAY 9	DAY 10	DAY 11	DAY 12
Session 14 Preparation for construction	Session 15 Developing a plan for maintenance	Session 16 Critique and refine design	Session 17 Making and connecting gutters	Session 18 Conclusion applications of the workshop in home villages Session 19 Final Evaluation
LUNCH				
Session 13 Construction of the tank (cont'd.) (masons)				

SESSION 2

SYNOPSIS

SESSION 2: Developing a Rainwater Harvesting Project

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discussion	5	---	Goals of Session
2.	Project Steps	Question, Answer, Read	45	Handout 2-1: Task Guide	---
3.	Considering Local Options	Small Group Task	40	Handout 2-2: Decisions in the Process of Project Development	---
4.	Reports from Small Groups	Discussion	30	---	---
5.	Listing Project Prerequisites	Writing, Ask Examples	10	---	Instructions for Task
6.	Closure: Future Applications	Discussion	5	---	---

TOTAL: 2 hours, 15 minutes

GOALS

Total time: 2 hours & 15 min.

To learn the major steps and basic considerations in planning and developing a rainwater roof catchment project and how to adapt them to the unique conditions of the local setting.

OBJECTIVES

At the end of the session the participants will be able to:

- Analyze and review the task guide and decision diagram for rainwater roof catchment projects and describe what is involved in a project
- Consider how local conditions and needs produce variations in the project cycle
- List the basic prerequisites for undertaking a rainwater catchment project

OVERVIEW

This is a major orientation session which explains what is involved in the process of developing a rainwater catchment project. This session sets the stage for all of the learning activities which follow in the workshop. As such it is a key session. There are a lot of factors which must be taken into account to determine if a rainwater project makes sense. There are also a number of decisions which must be made along the way with local users. This session systematically takes the participants through the steps of project development and decision-making. The workshop sessions which follow also provide training in each of the steps.

ACTIVITIES

1. Introduction

Time: 5 minutes

Introduce the session by restating the content of the overview. Share the session goals and objectives (which should be written on a flipchart).

2. Project Steps

Time: 45 minutes

Distribute Handout 2-1: Task Guide and Handout 2-2: Decisions in the Process of Project Development. Ask the participants to briefly review these handouts. Go over each step in the task guide and explain it.

Refer to the necessary decisions along the way using the decision chart. Answer any questions that come up without going into all of the detail which will be covered in subsequent sessions. (See Trainer Note 2.)

3. Considering Local Options — Time: 40 minutes

Ask the participants to divide into small groups of four or five and go over the project steps, thinking about a particular community project and village they have worked in. Ask them to consider what might be feasible in that particular community situation and how its major steps or tasks may differ from those in the project guide. Ask them to note down the major points in their discussions so that they can explain them later to the rest of the group when they get back together. Write these tasks on a flipchart.

4. Reports from the Small Groups — Time: 30 minutes

Ask each group to report and ask for comments. Answer any questions and discuss all appropriate issues.

5. Listing Project Prerequisites — Time: 10 minutes

Say: "Now that you have had an opportunity to consider what it takes to do a project in general and in a community, take a few minutes to consider and list for yourself what conditions must be present in order to develop a rainwater roof catchment project." Ask for examples from people after they have completed this so that everyone has an idea of the thinking of the group.

6. Closure: Future Applications — Time: 5 minutes

Close the session by referring to the fact that the workshop will systematically provide training in each step in project development. Provide a linkage to the next session by leading into the fact that we are going to use the demonstration training community to learn how to conduct an initial technical assessment. Refer back to the session objectives to see if they have been reached.

TRAINER NOTES

1. At some point on Day 1 the first "Visit to the Work Site" should be scheduled. This 30 minute activity is described in Session 13, Visit #1.

2. The trainer should not hand out the entire Participant Reference Packet at this point because it may cause the participants to get involved with reading instead of listening. In this case, just hand out the two charts which are appropriate to the task (Handouts 2-1 and 2-2). Almost all of the Participant Reference Packet can be handed out in this manner (piece by piece) as the material is covered. At the end of the workshop the participants will have assembled their own Participant Reference Packet. For this reason the Participant Reference Packet has its own page numbering system for these handouts as they appear in the Appendix.

MATERIALS

- Flipchart for session goals and objectives
- Handout 2-1: Task Guide
- Handout 2-2: Decisions in the Process of Project Development

TASK [illegible]E: MAJOR STEPS IN PROJECT DEVELOPMENT OF RAINWATER HARVESTING

I. DETERMINING COMMUNITY NEEDS AND INTEREST: INITIAL PROMOTION

1. Determine extent of community need
   - find out how water is currently supplied
   - find out role of women and children in carrying water and amount of time now spent in this activity
   - does the need justify proceeding at this point?

2. Talk with community people and leaders to promote the idea of rainwater catchment; see if interest exists
   - individual house calls
   - talk with community members in work settings
   - begin promotion of idea as a test of support
   - discover potential supporters

3. Decide: Is this community interested?
   - enough to justify a promotional effort?
   - does leadership exist for community mobilization?

II. INITIAL TECHNICAL ASSESSMENT

1. Identify best sources of information on local rainfall
   - find any weather statistics
   - talk with local people (older people) about wet and dry periods
   - effectiveness of rainwater catchment systems in use

2. Identify acceptable roofs
   - identify suitable surfaces
   - measure roofs

3. Plot available rainfall data and rough calculation of yield from a local roof

4. Decide: Is there enough rain and catchment area to proceed?

III. SOCIAL AND COMMUNITY ASSESSMENT

1. Collect opinions: would additional water from a rooftop catchment system be useful

2. Explore commitment villagers would make
   - sharing a roof and tank
   - contributing labor and/or money toward construction

3. Find out. How many systems and people are involved?

4. Decide: Does the community support rooftop catchment enough to proceed?

IV. INVENTORY OF LOCAL SKILLS, MATERIALS AND EXPERIENCE

1. Find out: Are there local masons who can build with cement, mortar/stone?

2. Find out: Are there craftspeople who construct vessels using local fiber?

3. Determine availability and costs of tank construction materials:
   - cement, stone, sand, gravel, bricks
   - reeds, bamboo, wire, chickenwire
   - shovels, trowels, etc.

4. Determine availability of guttering materials:
   - local wood/grasses
   - PVC pipe
   - metal sheet

5. Determine availability and cost of roofing materials

6. Determine. How have local people caught and stored rainwater to date?
   - traditional water and food storing containers
   - water hauling vessels: buckets, tins, etc.
   - lined holes in ground

7. Begin community promotion:
   - will skilled people be willing to contribute time?

V. CHOOSING AN APPROPRIATE COMBINATION OF TECHNOLOGIES WITH THE COMMUNITY

1. Present the range of tank and guttering technologies
2. Decide with community: individual or community tank
3. Discuss maintenance activities and type of outlet for each type of tank
4. List material requirements; estimate costs of different types of tanks
5. List levels of skills required to construct each type of tank
6. Evaluate: amount of labor (e.g., person-days) required for construction of each type of tank
7. Use these criteria to decide with community which construction option is best and mobilize community commitment for labor and cost contributions

VI. DESIGNING THE RAINWATER HARVESTING SYSTEM

1. Using projected yield pattern from local roofs, figure optimum tank volume
2. Determine How big a tank do available resources permit?
3. Determine location(s) and type of outlet
4. Design gutters and foul flush routines or mechanism
5. Choose specifications: foundation, floor, walls, cover (use guidelines provided to determine materials and thickness)

VII. ORDERING/GATHERING MATERIALS AND ORGANIZING FOR CONSTRUCTION

1. Order materials: When will they arrive?
2. Devise sequence of steps and construction schedule with community participation
3. Organize construction teams: Who will work, and when will they work?
4. Get materials to site at chosen time
5. Determine place to keep/store materials

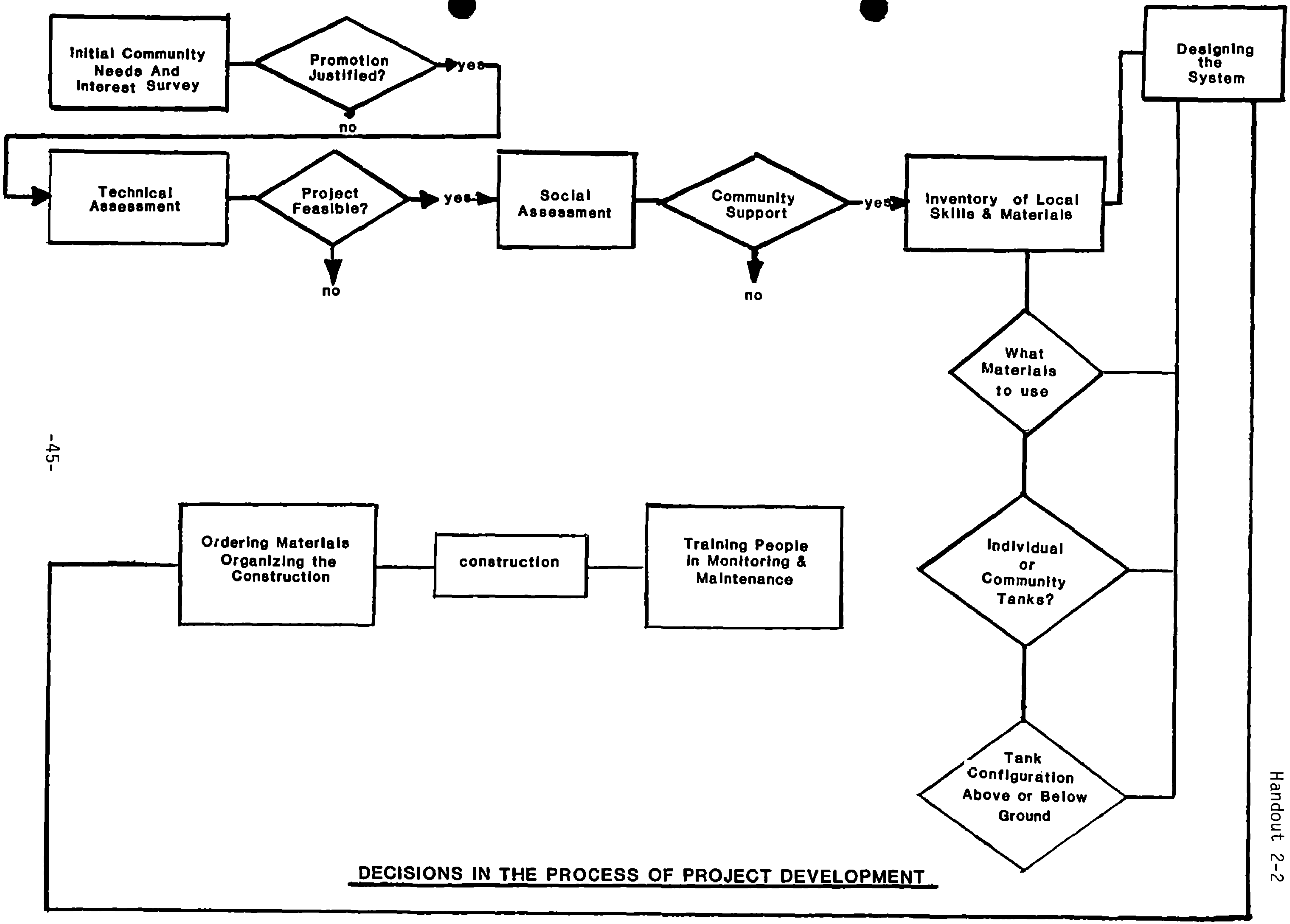
VIII. CONSTRUCTING THE CATCHMENT SYSTEM

1. Prepare/excavate site
2. Set-up forms, mixing boards, measuring containers
3. Mix cement/concrete
4. Prepare framework, if used
5. Build footing for cover
6. Trowel/apply mortar
7. Cure tank
8. Fabricate cover
9. Hook up gutter/foul flush

IX. MONITORING AND MAINTENANCE

1. Instruct users in:
   - watching for cracks/leaks
   - check water quality
     - a. visual checks
     - b. smell, taste, etc.

2. Develop cleaning/inspection schedule
3. Organize community maintenance group



DECISIONS IN THE PROCESS OF PROJECT DEVELOPMENT

Handout 2-2

SESSION 3

SYNOPSIS

SESSION 3: Initial Technical Assessment

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5	---	Goals of Session
2.	Lecturette on Rainfall Measurement	Lecturette	25	---	Talking Points of Lecturette
3.	Roof Yield Calculation	Group Activity	20	Monthly Rainfall Totals (obtained from local sources)	(Optional Recap of Handout on Rainfall) Bar Graphs
4.	Examine Calculations	Discussion	15	---	---
5.	Generalize	Discussion	10	---	---
6.	Application	Survey in Small Groups in Village	90		---
7.	Reports on Survey	Group Presentation	20	---	---
8.	Compare Information	Discussion	15	---	---

TOTAL: 3 hours, 20 minutes

GOAL

Total time: 3 hours & 20 min.

To learn how to examine the feasibility of a rooftop catchment program in light of local rainfall patterns.

OBJECTIVES

By the end of the session, the participants will be able to:

- Identify useful rainfall data
- Identify sources of rainfall data
- Gather information from local people on rainfall patterns
- Assess, identify, and measure suitable roofs for catchments
- Calculate and/or estimate the water yield from a local roof, using the above data

OVERVIEW

A rainwater roof catchment system will be effective only if enough water can be collected and stored. The yield or amount of water we can get from a rooftop catchment system depends on how much rain falls at different times during the year. It is possible to use information on how much rain has fallen in the past as a rough indicator of how much rain is likely to fall in the future. Then it is possible to calculate how much water could be collected from a particular roof in the community. These calculations are then checked by talking with local people, especially people who have tried rooftop catchment before.

There are two reasons why this information is important. First, the results will indicate whether there is enough rain collected on local roofs to make a rooftop catchment project worthwhile. Second, a decision about how big a tank is needed to store the water from the roof depends on how much time passes between periods of rain. For example, if an area has a long dry season, a water storage tank should be large so that people have water after the rains have stopped and until the next rains start. If, on the other hand, there is rain all year, water from the roof will refill a tank more frequently and the tank does not need to be as large.

This session raises these issues and gives the participants practice in assessing factors which will influence the decision to carry out a rainwater harvesting project.

ACTIVITIES

1. Introduction Time: 5 minutes

Give the group the information in the overview, and state the goals and objectives. Answer any questions.

2. Lecturette: Rainfall Measurement Time: 25 minutes

Explain what rainfall measurements are and explain the importance of correctly interpreting rainfall statistics derived from measurements.

Make the following points:

- A rainfall measurement is the depth of water which would accumulate in a container with straight vertical sides (like a glass) of a known size over a period of time (see Trainer Note 3).

- The amount of rainwater a roof will yield is calculated by first finding out the surface area of a roof. Multiplying the length times the width of a horizontal area (length x width) gives that area. Rainfall measurement is then obtained for a given geographic area from rainfall statistics. This figure is multiplied by the roof area to obtain the volume of water for a given roof at a given time. This is summarized by the equation: rainfall measurement x roof length x roof width = volume of water for the measurement period.

- In order to get a practical concept of this idea, step outdoors:

  - Examine a roof
  - Pace off or measure its horizontal dimensions
  - Discuss its effectiveness as a catchment surface. How well will it shed rain?
  - Identify other aspects of the roof which would reduce the yield. Note that any roof and guttering system is not 100 percent efficient but can be assumed to be about 80 percent efficient. This is because a certain amount of water will splash off or blow off in a storm or may overflow gutters at certain times.

- Explain that weather reporting agencies record rainfall measurements and publish them in a variety of forms. One common form is the monthly total. These totals can be used to figure what the yield of a roof would be for each of a succession of months:

  length x width x rainfall June 81 x .80 = roof yield June 81
  length x width x rainfall July 81 x .80 = roof yield July 81
  length x width x rainfall Aug. 81 x .80 = roof yield Aug. 81

  The .80 multiplication factor is because of an assumed 80 percent efficiency.

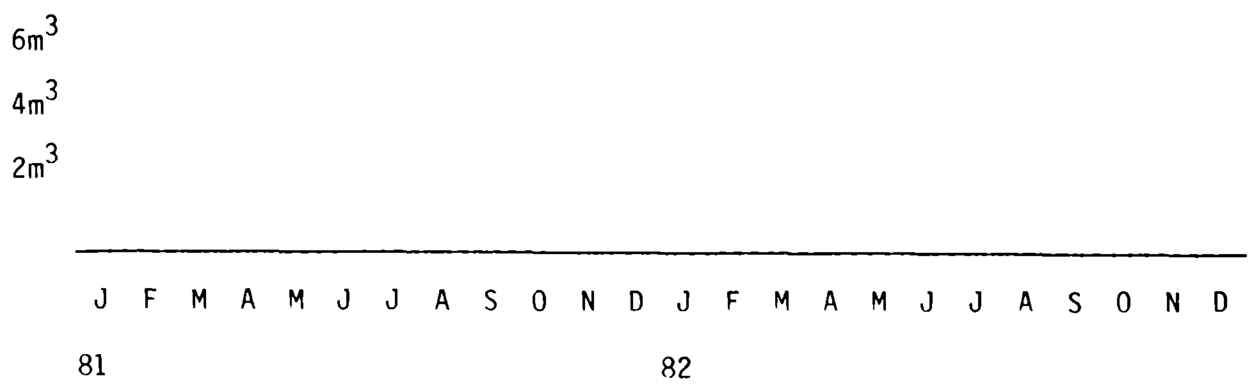
- A more common form of published rainfall data is the average monthly total. While average monthly totals take account of measurements recorded over several years, they conceal the variation in monthly totals from one year to the next. Thus they should only be considered a rough guide to the local rainfall pattern.

- It is preferable to calculate roof yields for a series of monthly totals over a period of several years. This gives an idea of how much the rainfall and the length of dry periods vary from year to year. But even if monthly totals are not available, roof yields calculated from average monthly totals can give some idea of the amount of rainfall and the length of dry periods.

3. Group Activity: Roof Yield Calculation — Time: 20 minutes

Roof yield calculation: exhibit or hand out a table of monthly rainfall totals, preferably for a nearby area. Calculate the roof yield for one month and start a bar graph on a chalkboard. Have participants calculate and enter subsequent monthly yields on the bar graph.

Monthly Total Roof Yield Bar Graph



Suggestions:

- Have each participant calculate and enter yields for one particular month for each year. This way each participant sees variations graphically from year to year.

- If time allows and if there is a hand calculator available, generate, from the monthly total bar graph, a bar graph showing monthly average over several years. Examine the difference between the two.

4. <u>Examine Calculations</u> Time: 15 minutes

Examine the roof yield data: add the heights of the bars, which are monthly volumes, for each wet season. Discuss the variability of this sum from year to year. Take the sum for one of the years and discuss how long that much water might last, depending on how many people use the water, how much they use, and what they use it for.

Suggestion: Introduce the idea of consumption as measured in liters/day/person; begin to explore what a reasonable local consumption figure might be. This should make participants more alert for clues regarding consumption during subsequent sessions in the village.

5. <u>Generalize/Discussion</u> Time: 10 minutes

Briefly review the use of rainfall data in figuring roof yields by going back over bar graphs, identifying wet and dry periods, noting variations from year to year, and emphasizing the caution needed with average totals. Review the assumption of 80 percent roof efficiency, emphasizing the fact that this and the unpredictable nature of rainfall mean that our results should not be taken as hard and fast, and trainees should refer to the experiences of local people.

6. <u>Application: Survey in Small Groups</u> Time: 90 minutes

Divide into groups of two or three. Each group should go to talk to villagers (individuals from three or four households). Ask each villager the following questions, which are written up on the flipchart (see Trainer Note 2):

- What are the periods of heavy rain, some rain, and no rain? How long are they?
- Could local roofs be used to catch useful quantities of rainwater? Why or why not?
- Do you know anyone who has done this? If so, how much water was collected, and how long did it last?
- What do local people think of drinking rainwater?
- What are the advantages and disadvantages of collecting rainwater?

7. <u>Group Presentation of Results of Survey</u> Time: 20 minutes

In class, informally tabulate answers to each of the above questions. Examine the tabulation for agreement or lack of agreement among respondents. (Note: This need not be a "report" from each group, just ask the question and get one response.) Then ask the group if others found out the same information and discuss.

8. Compare Information — Time: 15 minutes

Compare the information collected from villagers with the bar graphs showing the roof yield calculations done earlier, emphasizing points of consistency and inconsistency. Ask participants if they believe there is enough information to decide that a rooftop catchment project is feasible.

TRAINER NOTES

1. An alternative way to do this session is to conduct it at a rainwater measuring station if one exists nearby. Thus the assistance of the personnel at the station could be used in the session.

2. The community will need to be alerted in advance that participants will visit. If possible, individuals who will be home during the time scheduled for this session should be selected.

3. The trainer may need more time for Step 2, the lecturette, if the group is anxious about math. The lecturette may need to be slow paced. It is suggested that concepts be described first, and perhaps even visualized, before explaining mathematical material. For example, one way to visualize how much water a given roof will yield in one month is to assume that a roof is totally covered with tall drinking glasses which collect the rain. The monthly rain fall statistic which a weather station collects tells you how much rain would fall into only one of those glasses in a month. If you multiply the length times the width of a given roof times the rainfall statistic, you (in effect) can find out how much rain would fall into all of the glasses on a roof in a given month.

MATERIALS

- Flipchart for session goals and objectives
- Measuring tape, graph paper, ruler
- Handout to be prepared by trainer based on local rainfall data.

SESSION 4

SYNOPSIS

SESSION 4: Conducting a Community Social Assessment for a Rainwater Harvesting Project

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5	---	Session Goals
2.	Introduction to Group Task	Discuss	5	---	---
3.	Task Assignment	Group Activity	45	---	Team Tasks
4.	Communicating Group One's Strategy	Role Play	15	---	---
5.	Role Play Discussion	Discuss	20	---	---
6.	Generalize	---	5	---	(For recording answers)
7.	Communicating Group Two's Strategy	Role Play	20	---	---
8.	Meeting Simulation	Discuss	20	---	---
9.	Generalize	Discuss	15	---	(For recording answers)
10.	Application				
	- Option 1	Field Work	1-2 hrs.	---	(For recording answers)
	- Option 2	Paper and Pencil	10	---	---
11.	Closure	Discuss	5 (Option 1) 20 (Option 2)	Handout 2-2: Decisions in the Process of Project Development	---

TOTAL: 3 to 4 hours, 35 minutes (Option 1)
3 hours (Option 2)

Session 4: Conducting a Community Social Assessment for a Rainwater Roof Catchment Project

GOALS

Total time: 3-4 hours & 30 min. (Option #1)
2 hours & 45 min. (Option #2)

To improve the participants' skills in assessing a community's willingness and ability to support a rooftop catchment project.

OBJECTIVES

By the end of the session, the participants will have:

- Explored and developed strategies for collecting information on:
  - existing catchment technologies
  - opinions of local people on the usefulness of water supplied by a local roof
  - the community's desire for communal vs. individual catchment systems
  - the amount of time and money families would be willing to commit to the project
- Explored and developed strategies for communicating the following essential project information to the community:
  - the amount of money and labor required
  - the uses of the water

OVERVIEW

Once it has been established that it is technically feasible to do a rainwater roof catchment project, the next essential step is to find out if people are willing to participate in a project. The community will need to be included in the process. The project developer needs to find out what people have been doing in the past, how they see the collected rainwater being used, and what kind of system they envision. This information needs to be matched with technical feasibility. Ultimately, the community members will need to decide if they are willing to participate in the project and pay for it. Commitments need to be made to the process by the community. This session allows the participants to use their existing skills and knowledge of community work to develop strategies to gather and communicate this information to a potential project community. At the same time, participants will learn what should be communicated and investigated at this stage of project development.

ACTIVITIES

1. Introduction — Time: 5 minutes

Restate the content of the overview in your own words. State the goals and objectives of the session and see if there are any questions.

2. Introduction to Group Task — Time: 5 minutes

State the following to the group: "In order to find out if a community is able to undertake a rooftop catchment project, a certain amount of information must first be collected regarding the community's interest in such a project. For example, the project developer needs to know if the community is willing to cooperate in a communal or an individual catchment system. More information like this needs to be collected. Most of you have been involved in working with people in the community before, so this will not be totally new to you. You will need to develop a strategy to collect specific information and to communicate it to the village people so that they ultimately can decide if they are willing to make the commitments necessary to carry out a project. We would like to give you an opportunity to practice developing strategies to collect and communicate information. In order to do this, we want to divide the group into two teams. It will be one team's task to design a strategy to collect certain information, and the other team's task to design a strategy to communicate certain information and reach a decision with the community."

3. Task Assignment — Time: 45 minutes

Divide the participants into two teams. Assign the following tasks (written up on a chalkboard or flipchart):

Team One:

Design a strategy to collect the following information:

- Has the community collected rainwater before? If so, how?
- Do community members see how they might use a rooftop catchment system and what it might do for them?
- In what kind of a system might the community cooperate? An individual house system or a larger community system such as a school or health clinic rooftop system?
- How much time are people willing to put in to help in the project construction?
- How much money are they willing and able to pay for the system?
- What has been the community's history of project involvement?

Team Two:

Design a strategy to communicate the following information to community members and to reach a decision with them on whether they want to cooperate with the project:

- The project is going to cost approximately US $500 for each 100 inhabitants (this is an assumption for purposes of this exercise). Is the community willing to pay this much? How will they pay this? Assume that this is for a communal system on a school roof. (Note: If it is clear that this particular community does not want communal systems, then change to individual.)

- The community needs to understand that the water which comes from this system is limited and is only intended as a source of drinking water. It may not be used for bathing or washing clothes. How will this be made clear?

- Each family will need to commit six hours of labor (or supply a laborer) to help the masons with tank and gutter construction. How will you know if they are willing to do this?

Give the teams 30 minutes to develop a strategy. Tell them, they must not only develop a strategy but be prepared to try their strategy out on the other group in a role play (short dramatization) situation.

4. Communicating Group One's Strategy Using a Role Play — Time: 15 minutes

Ask the trainees in group one (developing information gathering strategies) to assume that they are going to use their process in a real community. Select some members of the other group to assume the role of the community members. If the strategy is an interviewing strategy, then role play the interview situation. If it is a meeting strategy, then role play a meeting. Select the members of both sides of the role play, and make sure they are prepared to play their roles. Let the role play proceed for five minutes or so until most of the strategy is revealed (don't let it drag on too long). Then discuss the role play.

5. Discussing the Role Play — Time: 20 minutes

Before starting the discussion, ask the trainees that were role playing how they felt about the role play. After any initial feelings are expressed, state that you will return to the role players shortly. Then, ask the trainees that were observing the role play the following questions (after each question, discuss the answers before moving on to the next question):

- What was the strategy used by the community workers? For example, how were questions asked? How did they get answers to their questions?

- Did the strategy work? Was it effective?

- What might you have done differently to gather the information if you had been in that situation?

Next, ask the person(s) who was (were) playing the roles:

- What, in fact, was the strategy you were using (or perceived you were using)?

- Do you think it was effective for you?

- What would you change next time?

Next, ask the persons who were playing the community people:

- How did it feel to be dealt with in the way you were in the role play?

- Was the community worker's strategy effective to you?

- How would you change it?

6. <u>Generalizing from the Role Play</u> Time: 5 minutes

State the following: "Now that we have discussed the different strategies for gathering the necessary information in a community social survey and have seen a role play, let us summarize what one should keep in mind when it is necessary to gather such information?" As the group responds, record the answers on a flipchart. "It is important to keep these things in mind, because later on in this session, you will get the opportunity to try them out in a real community."

7. <u>Communicating Group Two's Strategy Using a Community Meeting Situation</u> Time: 20 minutes

State the following: "Let us assume that the trainees in group number two have determined how they are going to let the community know about their information, and they have worked out a way to decide with the community if a rainwater catchment system is a good idea for them. We are going to have a community meeting to transmit this information. Some of you will need to assume the role of community members (from team number one). Some of you from team two will need to volunteer to be the community worker and use the strategy your group has designed. Be sure each person is clear about the role he/she will play." When they are prepared, then start the meeting and let it play out for up to 20 minutes.

8. <u>Discussing the Meeting Simulation</u> Time: 20 minutes

Before starting the discussion questions, ask the role players how they feel. Defuse any left over feelings. As in the previous role play, tell them you will return to them shortly. Then discuss the meeting by asking the following questions in the general order in which they appear. After each question, give the group time to answer and discuss it.

- What did you see happening in the simulation?
- What was the approach and strategy used by the community worker to communicate the project information to the community people?
- Did it appear to be an effective strategy?
- What would you do to improve it?

Then ask the community worker(s):

- What were you trying to do in the simulation to communicate to the community?
- Do you think it was effective?
- What would you change next time?

Then ask the person(s) who was (were) acting as community members:

- How did the community worker appear to you?
- Was he/she effective?
- Would you have preferred that the community worker do something differently?

9. <u>Generalizing from the Simulation</u> Time: 15 minutes

Discuss with the trainees the overall things they have learned from the simulation by asking the following:

- How does a community promoter get people involved and committed to a project such as this?
- How does a project developer make clear the community's responsibility in a project such as this?
- What are some of the things that are important to take into account when communicating this project information to communities in the future?
- What have you learned from this simulation?

Write the answers on a flipchart.

10. <u>Application from the Two Role Plays</u> Time: Option #1: 1-2 hours
Option #2: 10 minutes

State the following: "We have had an opportunity to consider the social information that must be both gathered and disseminated for a community rainwater roof catchment system. You have also considered strategies for how to do this and made some generalizations about this process. Now let us try to apply what you have learned."

Note to Trainer: At this point in the training design, there are two options: a field experience to apply the learning, or a paper and pencil exercise to reflect on future applications. You must judge whether the trainees have enough experience or know-how to do this work now or if they need some practice. Both options are presented. The field experience takes an additional hour or so and may even be completed during an evening in the community.

Option #1: State the following: "It is the group's task to go out into the community that we are using here for demonstration purposes and talk to the people and conduct a social assessment for the project now under consideration in this training program. After you collect the information, we will discuss it and consider what you have learned." (Note: the trainees should apply their strategy now in a reasonable time period, depending upon local conditions. They may need to talk with community people during an evening, or go out into the fields to talk with people, or find people where they are to conduct this social assessment.)

Option #2: Ask the trainees to take out a pencil and paper, and to reflect on and answer the following questions:

- The next time I work on a rainwater harvesting project in a community, what should I plan to do when conducting a social assessment?

- What is the most important thing I must keep in mind while doing a social assessment?

Ask the group for any comments on the questions.

11. Closure

Time: Option #1: 5 minutes
Option #2: 20 minutes

Option #1: State the following: "Now that you have had a chance to conduct a real social assessment in a community, what have you learned that you did not know before about how to conduct one?" (Discuss) "In what ways did the real experience differ from the role play in terms of strategy?" (Discuss)

Refer back to the goals and objectives of the session and go over them. Ask the group if they have been accomplished. Tell the group what the next session is and how it relates to this step in the project development process. Refer to the project development steps in the flow-chart in Handout 2-2: Decisions in the Process of Project Development.

Option #2: Refer back to the goals and objectives of the session. Ask the group if they have been accomplished. Tell the group what the next session is and how it relates to this step in the project development process. Refer to the project development steps in the flow chart in Handout 2-2: Decisions in the Process of Project Development.

TRAINER NOTE

During the field testing of the training session, the role plays developed a great deal of rich and lively discussion material. Much of this material is valuable in later sessions which involve organizing community participation in construction and maintenance. The processing discussions of these role plays (in particular the role play in Step 7) may tend to move quickly to generalizations (which should follow the processing discussion). To avoid this, the trainer will need to keep the discussion focused on what actually took place in the role play.

MATERIALS

- Flipchart for session goals
- Flipchart for team tasks
- Handout 2-2: Decisions in the Process of Project Development (from Session 2)

SESSION 5

SYNOPSIS

SESSION 5: Conducting a Community Resource Inventory

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5	---	Session Goals
2.	Catchment System Components	Lecturette	10	Handout 5-1: Ferrocement Tank Installation in Java	---
3.	Group Brainstorming Checklist and Preparation for Inventory	Group Activity	5	---	---
4.	Formulation of Checklist and Preparation for Inventory	Discuss	5	Handout 5-2: Community Resource Inventory Checklist	---
5.	Planning the Inventory	Group Activity	15	---	---
6.	Making the Inventory	Groups in Village	1-2 hrs.	---	---
7.	Discussing the Inventory	Discuss	60	---	---
8.	Generalizations and Conclusions	Discuss	20		

TOTAL: 3 to 4 hours

Session 5: Conducting a Community Resource Inventory

GOALS

Total ti

To learn how to conduct an inventory of local skills, materia niques which can be used in rooftop catchment.

OBJECTIVES

By the end of this session, the participants will be able to:

- List the types of materials and the crafts/skills involved in building rooftop catchment systems

- Use checklists to survey a community for availability of materials and skills

OVERVIEW

A rooftop catchment system which is built with materials which are easy to obtain by local people who know how to work with the materials will be cheap and easier to build and repair. This is why it is important to determine availability and prices of the materials which can be used in construction as well as the availability and level of construction skills. This session is aimed at collecting this information through a village survey. An example of an inventory checklist is included as Handout 5-2: Community Resource Inventory Checklist.

ACTIVITIES

Time: 5 minutes

1. Introduction

State the goals and objectives of the session and introduce the session linking it to the prior session. Restate the material in the overview.

2. Lecturette: Catchment System Components

Time: 10 minutes

Outline the functions of each of the components of a rooftop catchment system, giving an example of the material best suited to each of the functions. Refer to the system diagram, Handout 5-1: Ferrocement Tank Installation in Java (or have a scale model of a system on display) and make the following points:

o Roof surfaces should be smooth and impermeable (should shed water). Recall there is an "efficiency" factor (80 percent) used to calculate roof yields. Roofing material should also be light in weight. This reduces the cost of transportation and reduces the materials needed to support it. An example of a suitable roofing material is corrugated aluminium sheet.

- If the area has only thatch roofing, it is still quite possible to use rainwater from thatching. However, it will need to be filtered using a simple charcoal filter (refer to Session 10: Thatch Roof Catchment) and the yield will be slightly less.

- Gutters catch water flowing or dripping off the lower edges of the roof and carry the water to the tank. While they do not need to shed water as well as the roof surface, they should not leak. The trough of the gutter must be wide enough to catch both water gushing off the roof edge during a heavy rain and water which drips straight down off the roof edge during lighter rains. However, the material used to make the trough must be light enough that the gutter can be hung from the roof or the roof supports. An example of a suitable material for gutters is metal sheet from food, oil, or water tins or a "V" trough made from wood. The gutters must also be hung with a slight slope in the direction you want the water to move.

- A tank functions as a reservoir, providing water during periods of no rain. It also protects the water from contamination. Thus the walls and floor of a tank must be very strong to withstand the pressure from a large volume of water without cracking or breaking and to support a cover. Tanks must be sealed or impermeable so stored water does not leak out and contaminated water does not get in. An example of suitable material for tank construction is mortared brick (for walls and floor) coated with a surface of cement.

3. Full Group Brainstorming Task — Time: 5 minutes

Ask the group for a list of locally available materials of all kinds which might be suitable for construction of roofs, gutters, and tanks. Make a master list by writing down local materials available for each component on a board or flipchart.

4. Formulation of a Checklist and Preparation for Inventory — Time: 5 minutes

From the master lists of materials, draw up a checklist (see below). Ask the trainees to look at the example in Handout 5-2 and add materials which they have overlooked (such as baskets for tank wall structure or local rope fiber for hanging gutters). Go over the checklist noting materials which require a craft or skill and add the crafts/skills to the checklist as follows:

Material	Available?	Price	Skill	Available?	Rate
Cement	x	$7.00/bag	Mason	x	$4.00/day

A list of materials which might appear on the checklist follows:

Roofs: corrugated metal sheet, fired local tile, fiber-reinforced cement sheet, slate, shingles made from local wood or fiber or thatch.

Gutters: metal sheet of almost any kind, cut and bent to shape; planks (nailed edge-to-edge in a "V"); wood pieces hollowed out; split bamboo or the like; PVC pipe cut in half lengthwise; wire and local fiber for hanging gutter sections; pitch, tar, or the like for sealing joints.

Tanks: cement, stones, sand, gravel, fired brick, concrete block, bamboo (for bamboo cement walls), wire netting (chicken wire), straight wire, steel reinforcing rod, baskets, large clay jars, steel drums.

Skills: masonry, carpentry, basketry, pottery, brazing, or soldering (tinsmith), welding, plumbing, and unskilled labor for excavation and construction.

5. Planning the Inventory — Time: 15 minutes

Divide the participants into four groups, one group for each of the above categories. Direct the groups to devise a strategy for filling out their portion of the checklist (where to go, whom to seek out, etc.) Emphasize the importance of getting good information on material prices.

6. Making the Inventory — Time: 1-2 hours

After agreeing on a time to reconvene, the groups go to the village. (Perhaps the trainees could have lunch in village.)

7. Receiving and Discussing the Inventory — Time: 60 minutes

On reconvening, direct each group to write its portion of the checklist on the blackboard or flipchart sheets. This should be done so that everyone can see all the information, including the material prices. Direct someone in each group to briefly summarize the information and identify the materials which are lowest in cost and those which might be most useful for a local project. Ask the groups to report:

- The strategy used to get the information
- Problems encountered and solutions found
- Results

8. Generalizations and Conclusions — Time: 20 minutes

Seek ideas from the trainees as to what type of tank might be most appropriate for the local situation, given the information on materials and skills just collected and analyzed. Ask them what they have learned about how to conduct a community resource inventory. Ask how long one would need to do it as a project developer. Ask how one might involve the community in this process. After the discussion, conclude the session by reviewing the session objectives.

TRAINER NOTES

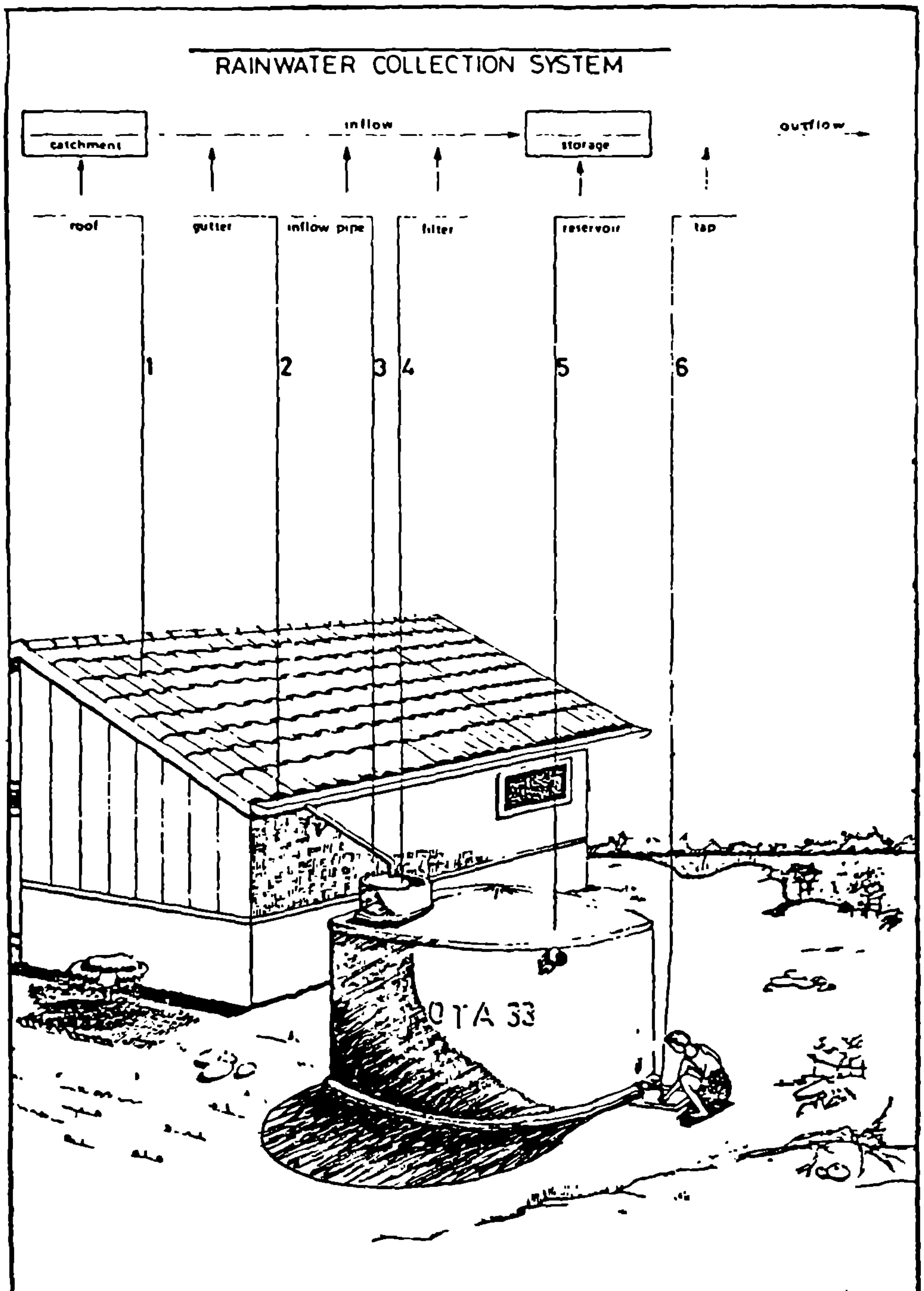
1. If you chose the shorter option in the prior session, it may be possible to start this session on the same day as Session 4. In this case time would be saved and the trainer could cover Steps 1 to 5 in this session in the morning and Steps 6 to 8 in the afternoon.

2. Advance planning for interviewing families will need to be made. It may be a good idea to survey a village different from the one at the project site to determine if different materials might be used in different villages.

MATERIALS

- Flipchart for session goals
- Handout 5-1: Ferrocement Tank Installation in Java
- Handout 5-2: Community Resource Inventory Checklist
- Paper pads, pencils

FERROCEMENT TANK INSTALLATION IN JAVA.



Pompe et al, 1982 , by permission

From Keller, Kent, Rainwater Harvesting for Domestic Water Supplies in Developing Countries, WASH Working Paper No. 20, Water and Sanitation for Health Project, Arlington, VA 1982.

COMMUNITY RESOURCE INVENTORY CHECKLIST

Here is one way to organize a checklist for finding out availabilities and costs of local materials and skills. The checklist below is an example; in any particular area, other materials and skills would be included.

Category	Material	Available	Price
Roofs	Corrugated metal sheet Fired local tile Fiber-reinforced cement sheet Shingles/local wood or fiber Slate		
Gutters	Metal sheet, any kind Wood planks or boards Wood pieces (hollowed) Bamboo PVC pipe Wire (hanging) Fiber (hanging) Pitch (sealing) Tar (sealing)		
Tanks	Cement Stones Sand Gravel Fired brick Concrete block Bamboo Local baskets Chicken wire Straight wire Steel reinforcing rod		
Skills	Masonry Carpentry Basketry Pottery Tinsmith Welding		Rate

SESSION 6

SYNOPSIS

SESSION 6: Choosing the Appropriate Storage and Guttering Technology

ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1. Introduction	Discuss	10	---	Session Goals
2. Lecturette on Storage Tanks and Materials	Lecturette	40	---	Outline of Lecturette
3.a. Deciding Tank Location and Configuration	Group One to Village		Handout 6-1: Decision Matrix for Tank Type	Task Outline
b. Guttering Considerations	Group Two in Classroom	2 hrs.	Handout 6-2: Guttering Systems	---
Listing Materials	Discuss		Handout 5-2: Community Resource Inventory Checklist	---
Preliminary Recommendations	Discuss		---	---
4. Reports from Two Sub-groups	Presentation	30	---	---
5. Foul Flush Discussion	Discuss	30	Handout 6-3: Diverting "Foul Flush"	---

(cont'd)

SYNOPSIS

SESSION #6 (cont'd)

ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
6. Making a Decision on Tank Type				Task Outline
Option 1	Presentation	60	---	---
Option 2	Small Group Activity and Presentation and Critique	2 1/2 hrs.		
7. Conclusion	Discuss	15	---	---

TOTAL: 5 hours, 5 minutes (Option 1)
6 hours, 35 minutes (Option 2)

GOAL

Total time: 5 hours & 35 min. (Option #1)
6 hours & 35 min. (Option #2)

To learn how to use a series of criteria to decide on which storage and guttering technology to design and use.

OBJECTIVES

By the end of this session, the participants will be able to:

- Describe and review all project steps covered to date
- Determine or estimate the materials, material costs, skills and labor requirements of a variety of tank and gutter combinations
- Take into account the following local factors which influence choice of technology:
  - soil type and water table
  - water carrying practices
  - possible tank locations
- Review/restate a decision between household vs. community systems
- Apply all the above information to choice of tank and guttering technology

OVERVIEW

This session is the point at which all the information collected and skills gained in the previous sessions are brought together and an important conclusion is reached. The importance of the task and the difficulty of presenting and considering all factors at the same time, mean that the training group must be prepared to digest a great deal of information fairly quickly. A decision matrix is used to organize and streamline the process. This session should take most of a training day. Breaks are indicated as a guideline, but use your own best judgement. You will need to explain to participants that the trainers have chosen a particular storage and guttering technology for purposes of training demonstration. These choices may or may not be the correct ones for this village or setting. The group will need to make its own choices and be able to justify them putting the trainers' choices to one side. The objective of the training session is to learn how to make these choices.

ACTIVITIES

1. Introduction Time: 10 minutes

Give the participants the information in the overview. Go over the goal and the objectives.

Stress the following point: "Choosing a locally appropriate technology depends on thoughtful consideration of many interrelated features in a local situation. Decisions made in this session will refer to a particular community. In fact, we will learn how to make those decisions by actually doing it in this community."

(Note: Prepare for the following lecturette by reading Trainer Reference Notes: Storage Technologies or "Tanks", which follow the handouts for this session, and Handout 6-2: Guttering Systems and Handout 6-3: Diverting the "Foul Flush".

2. Lecturette on Storage Tanks and Materials Time: 40 minutes

Begin by emphasizing that there are many ways in which people around the world have collected and stored rainwater. Mention examples like:

- Food storage pots for tanks (e.g., China, Thailand)
- Petrol drums for tanks (e.g., Kenya and the Pacific Islands)
- Barrels and buckets
- Stone cisterns (e.g., throughout North America and Europe)
- Clay pots (e.g., Thailand, India, Nepal, Sri Lanka)

Mention any other examples that come to mind and probe for additional examples from the participants. Propose a categorization of rooftop catchment systems according to the kind of tanks used in the system by listing the following categories on a flipchart. (Note: Leave enough space after each category to be able to write in examples.)

- Existing containers
- Masonry containers made of bricks, blocks, or stones
- Lined or sealed holes in the ground
- Containers made by applying cement mortar to a framework which provides strength
- Containers made by pouring concrete into a form or mold

Include each example given earlier under the appropriate category, again probing for additional examples or ideas from the group, and list them under the category. Nudge the process along by giving a description of a type of tank and asking the group to assign it to the proper category. Additional types of tanks include:

o Ghala baskets: baskets woven from sticks and reeds are fabricated with no bottom. The walls of the circular basket are pressed into the wet surface of a concrete foundation. The inside surface of the wall is plastered with cement mortar

- Concrete rings, strengthened with strips of bamboo cast into them

- Tanks made by applying cement mortar to a mesh of wire netting wrapped around a sheet metal form

- Grain storage pits up to 3 meters deep, lined with a layer of cement mortar, a layer of wire netting, and another layer of cement mortar

- Traditional adobe granaries built into homes in Mali, lined with steel netting and cement mortar

When sufficient examples are given to open up ideas for the group, ask the group to consider which materials are used most frequently in this country and list them. Note that some materials are used in almost every type of container (e.g., cement, sand-cement mortar, or cement and sand). Then discuss the advantages and disadvantages of each type of container (cost, water temperature, cleaning). Conclude the discussion by asking the group what tank configuration is most common (square, cylindrical, or rectangular). Distribute Handout 6-1: Decision Matrix for Tank Type at this point and tell participants that they will be using it in the following task.

3. Group Task: Considerations for Tank Location and Guttering Time: 2 hours

Divide the group in half and assign the following tasks:

A. Group One: Collect the following information in the community which relates to tank configuration and location(s). (Note: Write the task on flipchart.)

- Vessels used by villagers to carry water

- Villagers' ideas on how they would get water out of a tank

- Villagers' suggestions on good places to locate a tank, including ideas on whether and where tanks could be excavated into the soil

- Approximate total roof area which would fill a tank at each location

- Which proposed locations would drain well

Ask this group to assign these questions among its members and decide where each will go in the village. Tell them that during their survey they should be thinking about recommendations they will be asked to make to the whole group on:

- Tank configuration: above or below ground, type of outlet

- Tank location(s) (Note: It might be good to caution the group against a tank location which would present the possibility of contamination such a heavily travelled area, a very low area, etc.)

Send this group out to do its task. Then turn to group two.

B. Group Two: Explain to the members of this group that their task is to combine information collected in the community resource inventory (Session 5) with ideas from published accounts of guttering from other parts of the world summarized in Handout 6-2: Guttering Systems. Distribute this handout to each of the participants for them to read. When they are finished, have them add additional kinds of guttering to the list. Direct a "brainstorm" of ways to gutter roofs, writing each idea on a flipchart/blackboard.

Listing Materials

When the members of group two can think of no more ways to gutter roofs, ask them to list the materials required for each guttering method and refer back to the guttering section of the community resource inventory to check its availability. (Note: make sure the group does not forget material for attaching gutters.)

Preliminary Recommendation for Guttering

Ask the group to come to a consensus and make a preliminary recommendation on how to gutter local roofs.

4. Reports from the Two Subgroups Time: 30 minutes

Ask group one to report its findings. Its presentation should include a rough map of the locale on a flipchart/blackboard to illustrate the various possible locations, especially if community tanks are being considered. When the information on water handling and locations has been presented, make a list of the sites (possibly by number, referring to numbered locations on a rough map). Then, list the requirements and characteristics of each of these sites in simple tabular form, as below:

	Above or Below Ground	Approximate Area Available	Roof Catchment Area	Type of Outlet
Site 1				
Site 2				

With the above table before the trainees, ask them to comment on the locations.

Then ask group two to present its findings on guttering. The trainees in this group will need to get an idea of vertical and horizontal distances from roofs to tank inlets (from the other subgroup) in order to recommend guttering strategies for each of the sites in the table. Add additional columns for "guttering" and "cover" to the table and ask group two to put in its recommendations.

5. Foul Flush Discussion — Time: 30 minutes

Distribute Handout 6-3: Diverting the "Foul Flush". Give the trainees 10 minutes to read it. Then begin to discuss ideas for foul flush systems and how to connect them to the gutters and a tank. Throughout the discussion, the following points should be kept in mind:

- The best foul flush system is simple and easy to take care of
- If a system requires attention before and/or after each rain, thought should be given to who will be given the task and how the task could be built into a person's daily routine.

(Note: If time allows the participants should go out and experiment with the foul flush ideas after this session).

6. Making a Decision on Tank Type — Time: Option #1: 60 minutes; Option #2: 2 1/2 hours

Now that the group has made some preliminary decisions on the best location(s) and whether the storage should be placed above or below ground, it needs to consider what type of storage tank should be constructed. There are many factors which could be considered in this process, but the key factors are:

- How much water is needed for drinking, cooking, and washing?
- How much can be collected and stored?
- How big a storage tank would be needed?
- What technology is known locally and can be feasibly used or taught (bricks, blocks, ferrocement, reinforced concrete, plastered containers, etc.)
- What materials are available or obtainable locally?
- What is the least cost option the project can afford and construct?

A project developer may, in fact, have little or no choice about the type of tank to construct (beyond size and shape), because available technologies and materials may be the determining factors. Therefore, it may not be necessary to conduct an exercise on how to make this decision.

If so, Option #1 (below) should be used. If there is a great variety of different local conditions, materials, technologies and possible choices, then Option #2 (below) should be followed.

Option #1: Justifying the Option Taken

Conduct a presentation, question-answer discussion which completely explains and justifies why the option under consideration was chosen and recommends this option as the most practical choice for future project development. Go over each of the six choice factors listed above. As each point is explained to the full group, ask the group what other alternatives could have been chosen and why. Entertain questions at each step. Consider such factors as cost, time required, the type of cover, how to get the water out of the tank, how to clean the tank and maintain it, and foul flush.

Option #2: Choosing the Best Alternative

Small Group Activity

Divide the participants into small groups of five or six members each. Give them the following task (written on a flipchart):

First take about 20 minutes to discuss and answer the following questions:

- How much water do you need (refer to previous calculations in Session 3, ? people x ? liters per day x ? days per year when water is not available)?

- How much water will the roof chosen produce (refer to calculation made previously in this session).

- How big a storage container would hold this amount of water (cubic meters of water stored is equal to cubic meter of space in tank)? (Note: This is a rough calculation at this point. Session 8 goes into tank size in detail.)

- What technologies are known or easy to teach to local masons and project workers?

- What materials are available locally?

After discussion of the above questions, take about 30 to 40 minutes to make a list of at least two types of tanks the group considers to be locally feasible. For each tank, list and discuss all of the advantages and disadvantages on a flipchart and be prepared to present these to the larger group. Consider such factors as cost, time required, the type of cover for the tank, how to get the water out of the tank, how to clean the tank, maintenance, tank life, and foul flush. Be prepared to decide which type of tank you would recommend.

Small Group Presentation and Critique

Ask each group to present its selected choice and justify its choice factors, advantages, and disadvantages. Give each group 15 minutes. Afterwards entertain questions from the full group and discuss (10 minutes). This should require no more than one hour and a half.

9. Conclusion Time: 15 minutes

State the following: "In this session we have discussed the major types of rainwater storage facilities for projects of this nature. In the following sessions, we will test our selections against the realities of tank size and, later, system design. When you work with the community in your future projects, you will need to take all of the factors we have discussed into account." Ask if there are any remaining questions. Refer back to the objectives of the session to see if they have been achieved.

TRAINER NOTES

Following Session 6 on Day 3, the third visit to the work site should be scheduled. This one hour activity is described in Session 13.

MATERIALS

- Flipcharts for session goal and objectives
- Flipcharts with lecturette material outlined for Step 2
- Flipcharts with group tasks for Steps 3 and 9
- Handout 6-1: Decision Matrix for Tank Type
- Handout 6-2: Guttering Systems
- Handout 6-3: Diverting the "Foul Flush"

Decision Matrix for Tank Type

Tank Types	LABOR & SKILLS					SITE & TYPE					OUTLET, COVER				MATERIALS												
	≤ 2 days for construction	≥ 5 days for construction	simple masonry	bricklaying or stonework	digging crew	stable, excavatable soils	low water table	above ground	above or below ground	below ground	pump or bucket	bucket or tap	tap	reinforced cover	0-5 bags cement	5-20 bags cement	20 bags cement	sand	gravel	wire netting	wire	steel rod	metal sheet:forms	stones	brick, concrete block	sacking	baskets
cement mortar jar, $< 1m^3$																											
plastered basket, $3m^3$																											
cast concrete ring tank, $7m^3$																											
ferrocement tank $10m^3$																											
small stone tank $10m^3$																											
small brick or concrete block tank $10m^3$																											
bamboo-cement tank $5m^3$																											
reinforced concrete tank, $12m^3$																											
ferrocement lined pit, $25m^3$																											
large stone tank $25\text{-}50m^3$																											
large brick tank $25\text{-}50m^3$																											
large concrete block tank $20\text{-}70m^3$																											

Handout 6-1

Chapter 4

GUTTERING SYSTEMS*

Clearly, effective guttering is a key to rooftop catchment systems; water can be neither stored nor consumed if it is not channelled efficiently from the capture area to the tank. Yet the materials and techniques for construction of effective gutters is a topic that is omitted from almost all accounts. Technically, guttering is far less challenging than construction of cost-effective water storage, and its cost is usually a relatively small part of total costs. Possibly guttering has been largely ignored in published accounts for these reasons.

4.1 General Considerations

How big do gutters need to be? Size needs will obviously vary with the intensity of local storms and the ground area covered by the roof. Ree (1976), investigating runoff yields from sloping metal roofs, used sheet metal gutters 20 cm wide by 10 cm deep, each with a downpipe 15 cm in diameter. Each of these gutters had a capacity of twice the greatest runoff rate recorded from half a 12 x 18 m area of roof over a period of one year in Oklahoma. Thus, gutters half as wide or half as deep would have handled the year's heaviest rain from the roof. In general, gutters and downpipes with a cross-sectional area (width x depth) of 100 cm^2 will probably be big enough to handle all but the most torrential rains from most roofs.

A greater problem than gutter size is probably hanging gutters securely so that they do not sag or fall during heavy rainfall, and keeping them positioned so that they catch both gushing flow and dripping flow from the edges of the roof. Ensuring adequate slope for the entire system, so that water does not stand and damage gutters or attract mosquitoes, is equally important.

4.2 Manufactured Metal Gutters

Aluminum or galvanized sheet metal guttering is the technology of choice in most areas in developed countries. The gutter sections are joined with special brackets and hung with metal straps or long spikes with sleeves which are driven through the upper part of the gutter's width and into wood backing. As of this writing, in the U.S. aluminum guttering and downpipe sections cost about $US1.85/m (galvanized sheet is slightly less expensive but tends to corrode more quickly unless coated with high-quality rust-resistant paint). Hardware for joining and hanging the system costs another $0.60 per meter. This would make the materials costs of guttering and downpipe for a building 6 m long approximately $30.00. Higher cost or unavailability are likely to eliminate manufactured metal gutters as possibilities in most rural areas of developing countries.

4.3 Alternatives Using Local Materials

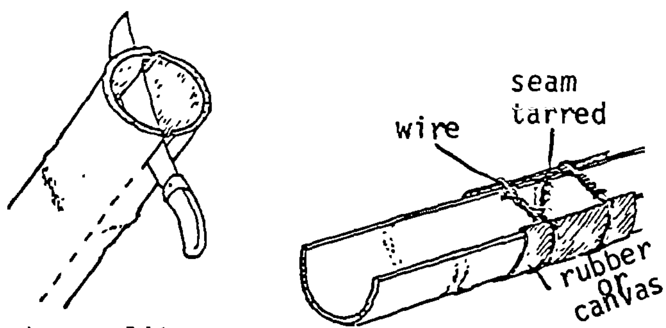
McDowell (1976, page 33)** observes:

"It is noticed that, in many areas, houses will have a short length of roughly fashioned guttering fixed under the eaves just above the door, and that water

From Keller, Kent, Rainwater Harvesting for DOMESTIC Water Supplies in Developing Countries, WASH Working Paper No. 20, Water and Sanitation for Health Project, Arlington, VA 1982.

from this will be collected in an old oil drum or other container. It seems that this type of device is used more for the purpose of preventing water from running in through the doorway of the hut than as a serious approach to water collection. However, the existence of this "technology" could provide the link point for development of simple but effective roof catchment systems."

McDowell also reports on the use of split bamboo culms with joints removed, and "V"-shaped gutters made by nailing two boards together at right angles edge-to-edge. This construction seems likely to leak but the "V" might be sealed with tar, pitch, or some local gum. The Institute for Rural Water (1982; see section

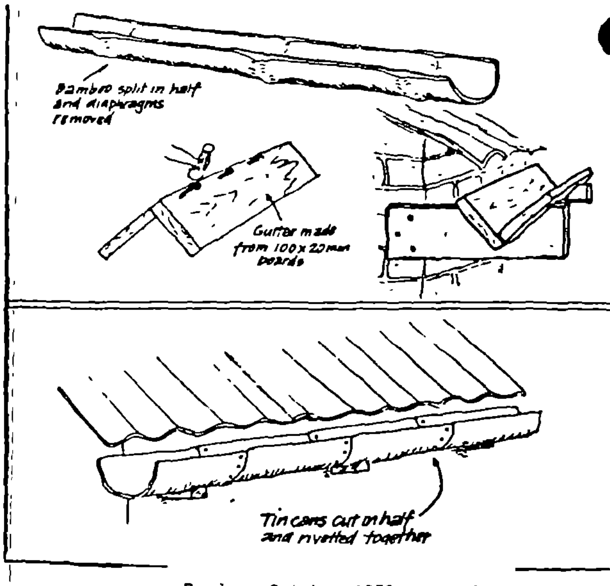


a. Bamboo split lengthwise

b. joining 2 pieces of bamboo

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

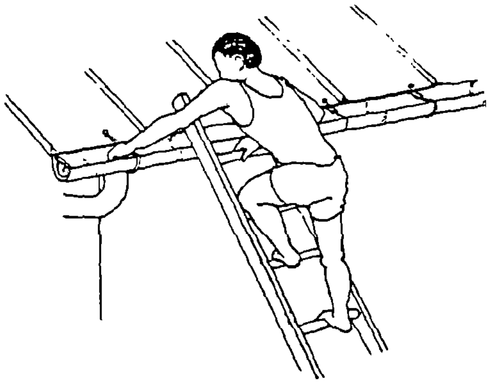
Figure 2, Bamboo Guttering Joining Sections.



Basics, October 1978, page 4

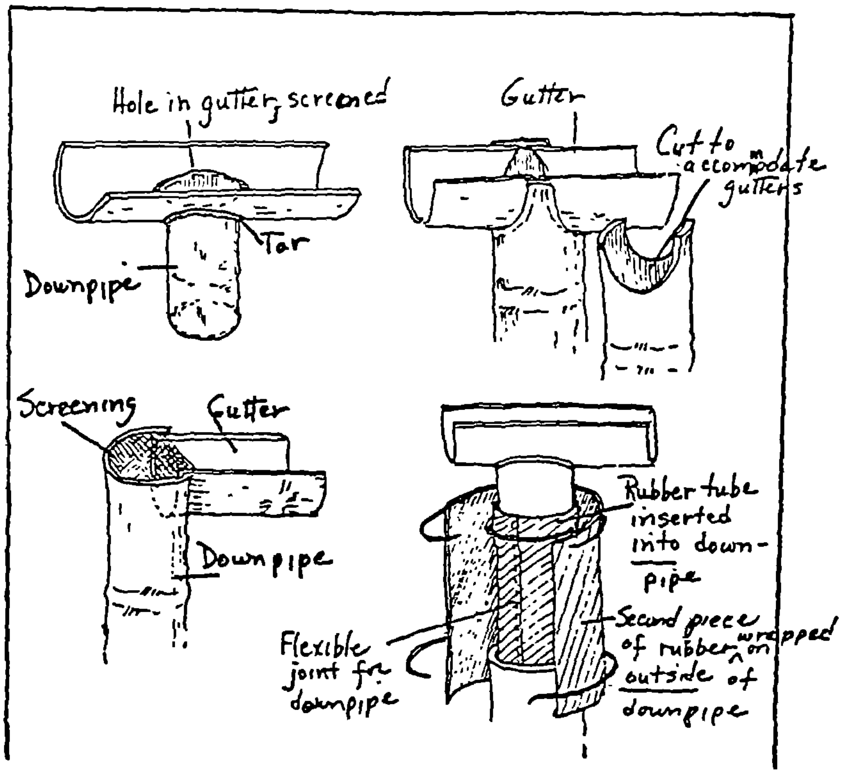
Figure 3, Alternative Forms of Guttering.

8.1) provides good ideas for joining sections of bamboo guttering with wire and some flexible sheet materials such as rubber or canvas, and joining gutters and downpipes with similar materials (see figures 2 and 3 above). The Institute for Rural Water also suggests hanging gutters with twisted wire or local fiber, wrapped around the gutter and tied to holes in roof sheeting or to the ends of roof supports (see figures 4 and 5).



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

Figure 4. Hanging Guttering



Institute for Rural Water, 1982, by permission

Figure 5. Joining Gutters and Downpipes

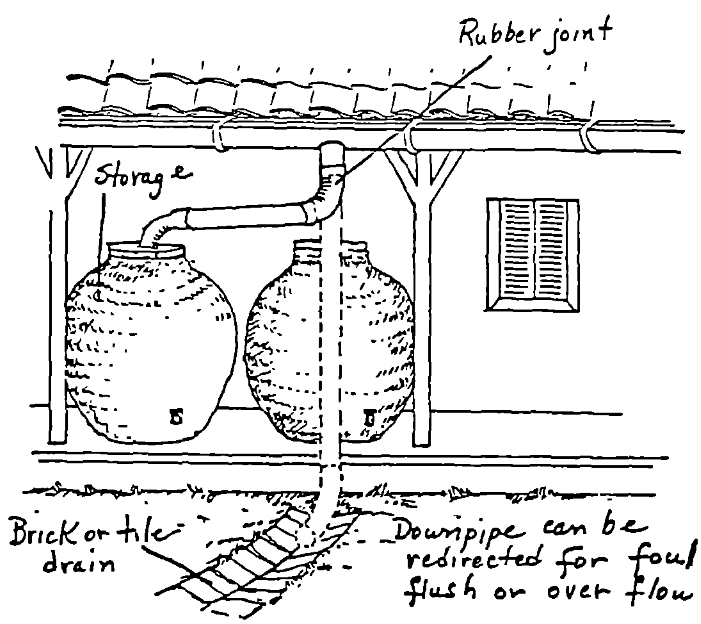
Chapter 5

DIVERTING THE "FOUL FLUSH"*

The crucial importance of some routine or technique for keeping dirty water flowing off a roof at the beginning of a storm out of the storage tank is discussed below in section 7.4. In general, there is more to be gained by devising an effective "foul flush" method than by investing in filters, which clog and become contaminated quickly (e.g. Midwest Plan Service, 1979). There are two kinds of foul-flush devices, those which require the flow of water to be switched manually from waste to the tank after the appropriate interval and those which are "automatic".

5.1 Manual Systems

Usually lower in cost and easier to devise, these will be the obvious choice in most poor areas. An attractive and simple approach is to attach the downpipe so that it can be propped in the "waste" position, then propped in the tank inlet after the roof is clean. Open trough downpipes like split bamboo can be suspended beneath the outflow of the gutter with wire or local fiber; closed downpipes with a flexible joint can be moved in the same manner (see figure 6 below).



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

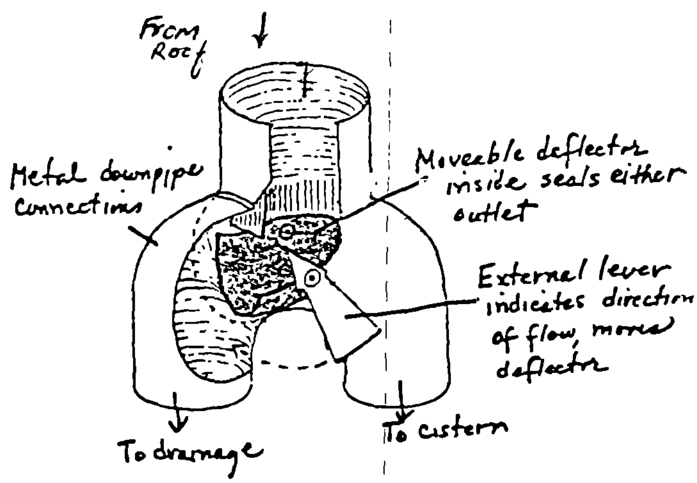
Figure 6, Manual System for Diverting Foul Flush.

*From Keller, Kent, Rainwater Harvesting for Domestic Water Supplies in Developing Countries, WASH Working Paper No. 20, Water and Sanitation for Health Project, Arlington, VA 1982.

The task of moving the downpipe can be performed consistently by anyone including children. People in developing countries tend to be conscious of the precise moment it begins to rain because drying laundry must be brought in.

Another simple technique for tanks with small covers is to leave the cover on, blocking the flow of water into the tank, until the roof is clean. A similar approach (for very small containers like jars) is to move the container into position under the downpipe only after an appropriate interval. Both these routines may be objectionable from a public health point of view: they cause mud and pools of standing water at the tank. Nevertheless, they may be the method of choice where a more complex downpipe and foul flush arrangement is impracticable.

By-pass valves built into metal downpipes may be an option in some areas. Often referred to as "butterfly" valves, they are made of sheet metal and thus would be expensive or impossible to fabricate in many situations. It might be possible to devise a similar valve for downpipe arrangements made of other materials, but a movable downpipe will probably be the cheaper, more functional alternative (see figure 7 below).

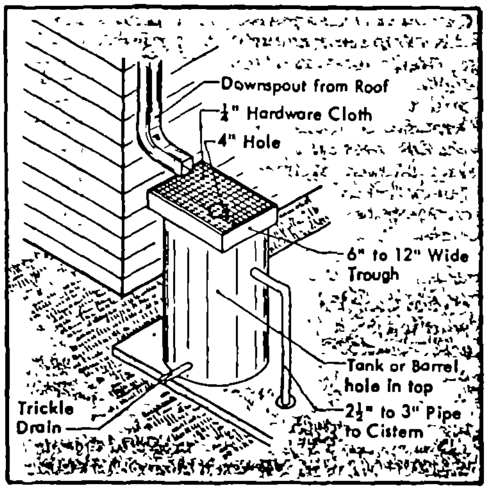


Institute for Rural Water, 1982b (draft), by permisssion

Figure 7, By-pass Valve.

5.2 Automatic Systems

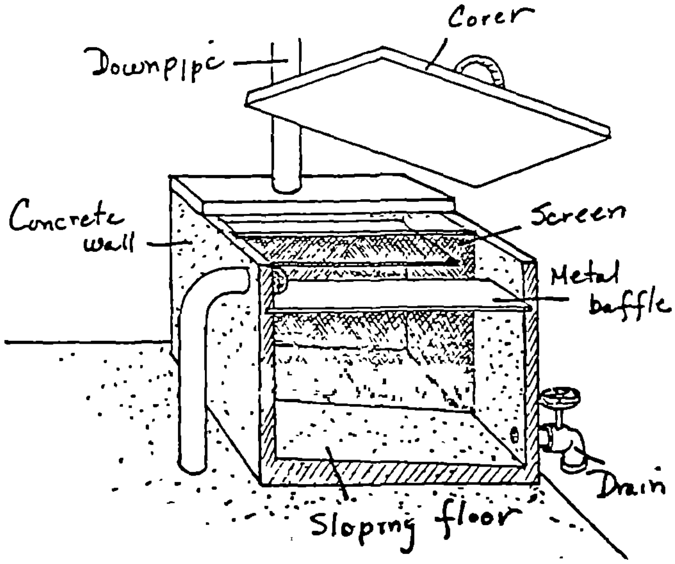
Automatic roof cleaning devices are available commercially only in a few areas, but they may be fabricated from local materials in some situations. One simple automatic device is a container or receptacle for dirty water called a "roofwasher" (Midwest Plan Service, 1979; see figure 8 below). After the roofwasher receptacle fills up with the foul flush, water begins to overflow into the storage tank. A screen is usually attached between the downpipe and the foul flush container as shown in the figure to keep out leaves and other large pieces of debris that would float on the water in the receptacle and clog the overflow pipe to the tank. Oil or fuel tins, used for hauling water in many areas, might be converted to roofwashers. Midwest Plan Service (1979) recommends about 10 liters of roofwasher receptacle capacity for every 30 m^2 of roof area. Other sources (e.g. Dooley, 1978) say a roofwasher should be big enough to hold the first 20 minutes of runoff.



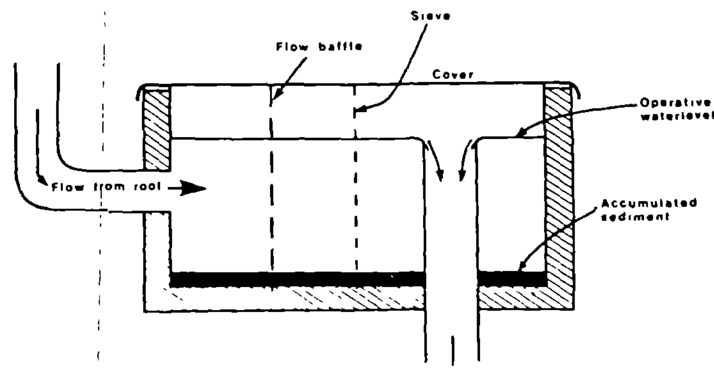
Midwest Plan Service (1979) by permission

Figure 8, Homemade Roof Washer.

A problem with such a simple device is that when the beginning of a rainstorm is torrential, water will pour vigorously into the roofwasher from the downpipe, stirring dirt and bird droppings so that they are carried through the overflow pipe into the tank instead of settling at the bottom of the receptacle. To inhibit this stirring action a baffle can be mounted crossways, inside the roofwasher and/or a vertical screen can be installed dividing the downpipe side from the tank inlet side (see figures 9 and 10). Roofwashers must have a drain and removable cover so that they can be cleaned after each rain.



Institute for Rural Water, 1982
(draft) by permission



UNEP (1979)
by permission

Figure 9, Roof Washers.

More complicated "automatic" foul flush devices tend to require more attention and stronger structures with more hardware for mounting in the downpipe. Reported in use in Australia are, "swing funnels" made of sheet metal, with a large inflow side divided into two compartments, and hinged on a horizontal pin (see figure 10 below). At the start of a storm, water pours from the gutter into the first compartment. As the weight of the assembly increases, the funnel swings so that water pours from the gutter into the second compartment which leads through the downpipe into the tank. Such a funnel would have to be quite large to hold the recommended volume of foul flush. Mounting and hinge-pins would also have to be quite strong. This particular device is unlikely to be the most attractive of foul flush options in most places, but it is an interesting idea.

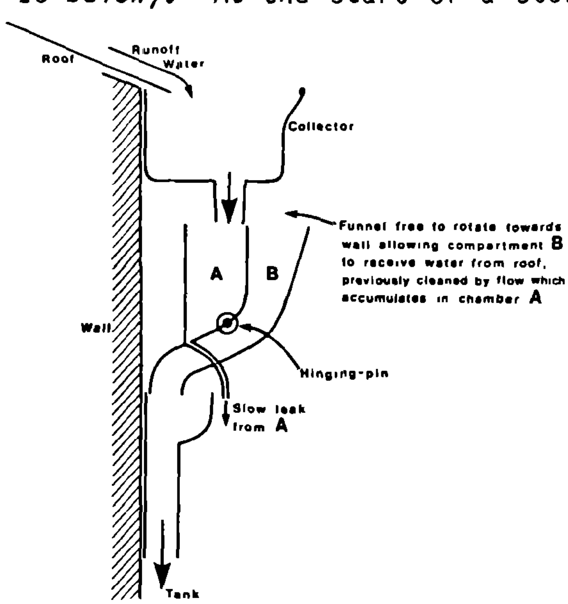


Figure 10, Swing Funnel.

Chapter 6

STORAGE TECHNOLOGIES OR "TANKS"*

6.1 General Considerations

A satisfactory storage tank is the key element in a rooftop catchment system. As has been noted in other sections, the water storage facility or "tank" is usually the most expensive part of simple RWH systems and at the same time the most difficult to construct so that it will perform satisfactorily over a long period. An adequate tank must not leak. It must be structurally strong enough to support the great load of the water it will hold and it must be covered to keep out sunshine, dirt, insects, and (if the tank is buried) dirty surface and ground water.

As far as users are concerned, the tank is also the focus of the system. It is usually both the storage and distribution point, requiring cleaning and maintenance to ensure both these functions.

Tanks can be categorized into three groups:

1. those used with individual household rooftops (mostly above ground).
2. those used with larger rooftops or several rooftops (above, partially buried, and below ground).
3. those used with surface catchments.

Within each of these three groups there are many different kinds of tanks, each with its own construction methods, materials costs, and labor requirements. Each of these factors, along with the required capacity of the tank (see technical note on using rainfall data to design a RWH system, Appendix A), enters into decisions about what kind of tank to build.

The tank's function--as an individual household source or source for a group of families--is probably the single most important determinant of tank size and design. This choice can be made only in close consultation with the people who will build and use the tank. Without their participation and genuine support a tank-building effort has little prospect of success. In their comments on the slow progress of open tank construction for irrigating school gardens in Botswana, Farrar and Pacey (1974) note:

"In any community where a tank programme is contemplated, it would seem important to inquire into the 'felt needs' of the people. To which category of water use do they give highest priority?

"a) drinking water: for home or school use?
"b) washing water
"c) water for gardens: again, at home or at school?

"In most parts of southern Africa, water for school gardens would be given the lowest priority."

*From Keller, Kent, Rainwater Harvesting for Domestic Water Supplies in Developing Countries, WASH Working Paper No. 20, Water and Sanitation for Health Project, Arlington, VA 1982.

**For References in text see annotated bibliography which follows the Session Guides in this Training Guide.

Whether to build an above-ground tank or an excavated (underground) tank deserves considerable thought. Watt (1978) notes:

"Storing water in tanks built on the surface has many advantages when compared with storage tanks excavated into the ground. Besides avoiding the need for laborious excavation which is almost impossible in some hard dry soils, the tanks can be observed for leaks and easily repaired by trowelling a layer of mortar onto the inside of the empty tank. In addition, although the stored water is likely to become hotter in the sun, the risks of polluted material falling into the tanks are reduced. Water stored above ground can flow out under its own weight whereas it has to be pumped out of a ground tank."

The main advantage of underground tanks, on the other hand, is that the earth supports the tank lining and contents, making it possible to build deeper tanks with thinner walls. This means that building materials can be conserved and used to make leakproof wall surfaces instead of structural wall reinforcement.

Underground tanks do not always require a pump. Figures in section 6.3 (below) show how a concrete block tank supported with earth embankments can be fitted with a tap.

Larger tanks require fewer materials per unit of water storage capacity than smaller tanks, which tend to give them a cost advantage. Constructing smaller tanks, though, tends to require less expertise and preparation, fewer tools, and less cash "up-front". Large tanks may bring with them structural problems. For example, large areas of flat plastered wall are more vulnerable to cracking than smaller walls (e.g. Maikano and Nyberg, 1980). Thus, in many cases, smaller tanks or groups of smaller tanks will be chosen in preference to a single larger one.

Different kinds of tanks demand different standards of workmanship in construction. Ferrocement and other tanks made with mortar plaster will crack and leak if mortar is not made with clean components in proper proportions, and applied properly to the reinforcing framework. A prototype made by people who have never made one before may not perform satisfactorily. A failure should be planned on or experience sought.

The walls of underground tanks must be built carefully, especially if they are of brick or masonry. Cairncross and Feachem (1978) say these tanks should only be built by an experienced builder (and indeed, local masons should always be involved). Individual Water Supply Systems (Office of Water Programs/EPA, 1974) emphasizes the importance of high-quality workmanship and recommends against "unskilled labor".

6.2 Household Tanks

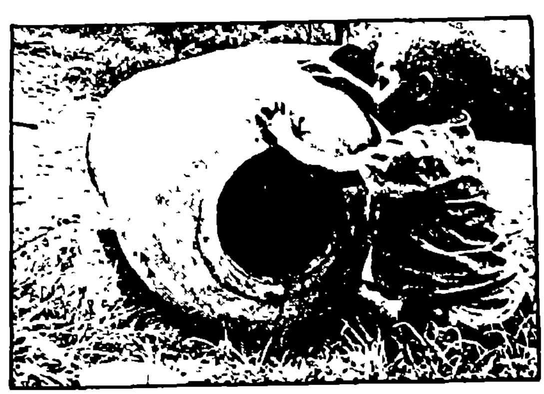
6.2.1 Recycled Used Containers

A wide variety of locally-available containers can be used to catch water flowing from guttering or simply dripping off the edge of roofing. White et al (1973) describe the use in West Africa of steel petrol drums with one end cut out (see picture at the front of this report). These drums hold about 0.17 m^3 and cost about US $2.50 (1969); they can be covered with a board and a rock. Watt (1975) notes that Thais collect rainwater from roofs in large pottery jars. He reports a price of about US $5.00 (1975) for a 0.3 m^3 jar.

6.2.2 Cement Mortar Jars

Apparently first devised in Thailand (Watt, 1975), these jars have been enthusiastically built in other parts of southeast Asia and Africa (McDowell, 1976). Cloth sacking filled with rice hulls or some vegetable waste is used as a jar-shaped mold, onto which cement mortar is plastered. McDowell (1976) says that jars can be constructed with capacities up to 3 m^3 using this method. Prototypes of even larger models, made of soil-cement, have been made in Java. A great attraction of this method of storing rainwater is its low cost. Watt (1975) reports materials costs of US $0.50 per 0.25 m^3 jar. That entire sum was for cement (see figure 11 below).

Most jars of this type are apparently made in the size range of 0.15-0.5 m^3, as larger jars, lacking reinforcement, tend to crack where the wall meets the base. See Chapter 8 for Watt's instructions for making a 0.25 m3 jar.



McDowell (1976)
both by permission

Figure 11, Homemade Cement Jar

James Bell*(personal communication) reported on a variation of this method widely practiced in Liberia for making water jars of about the same size. A hole the shape of the jar is excavated in the soil. Wire netting ("chickenwire") is pegged to the wall of the hole, which is then plastered with cement mortar. After the jar has cured, it is dug out of its earthen "mold".

6.2.3 Traditional Baskets Plastered With Cement Mortar

Originating in Thailand, this technique has been used to build hundreds of tanks in Kenya, Burundi, Rwanda, Swaziland, Tanzania, Lesotho, and Zambia. The usual technique is to plaster a granary basket which is set into a cement or concrete foundation.

"In Kenya, the basket frame is made from sticks cut from woody shrub which grows throughout the country. In Rwanda and Burundi, the frame is made from bamboo. Presumably provided that the material is strong, the basket could be made from any number of shrubs or sticks which can be woven into basket form. The basket is constructed on the ground by weaving the sticks into round shapes. The actual shape does not seem very important, but it is recommended that the bottom be omitted so that the sides can bond with the base" (UNICEF, Eastern Africa Regional Office, 1982) (figure 12 below).

Apparently tanks up to 7.5 m^3 in capacity have been constructed by reinforcing the basket frame with bands of straight wire or wire mesh. The more common size, requiring no metal reinforcement, is about 1.5 m high and has a capacity of about 2.3 m^3. Assuming a cement price of $7.14 per 50-kg bag (rural Zaire, 1981) and allowing about 20 percent of total materials costs for sand, gravel and outlet pipe, a 2.3 m^3 tank of this type could be built for about US $42.00 (1981). See Chapter 8 for detailed notes on tank construction using a "Ghala" basket in Kenya (UNICEF East Africa Regional Office, 1982).

Figure 12, Plastered Basket

* Peace Corps Water and Sanitation Specialist

picture at the front of this report). These drums hold about 0.17 m^3 and cost about US $2.50 (1969); they can be covered with a board and a rock. Watt (1975) notes that Thais collect rainwater from roofs in large pottery jars. He reports a price of about US $5.00 (1975) for a 0.3 m^3 jar.

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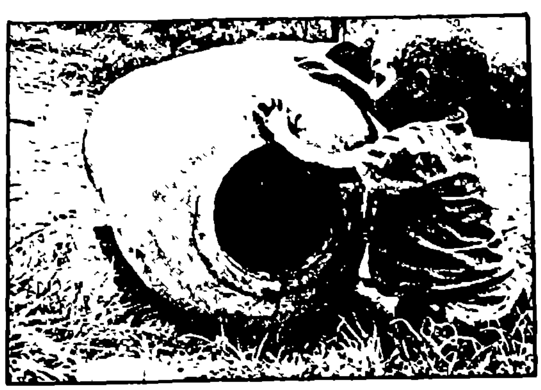

McDowell (1976)
both by permission

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Figure 12, Plastered Basket

* Peace Corps Water and Sanitation Specialist

6.2.4 Cast Concrete Ring Tank

Relying on thin unreinforced concrete rings, poured between concentric steel forms, these tanks have been promoted by the Thai Ministry of Health for use at schools in a country where many buildings in rural areas have galvanized sheet metal or tile roofs (Watt, 1978 b). The rings, which are about 1.5 m in diameter and 0.6 m high, can be stacked to give tank capacities of up to 7 m^3. Watt estimates materials costs of US $40.00 (1977) for a tank of this size, not including the cost of the forms. Watt points out that forms could be used again and again in a tank construction project and suggests central production of the rings under skilled supervision. The cured, high-quality rings could then be transported by truck to the tank location for placement on their concrete foundations.

Brian Grover (personal communication) reports that the Thai Ministry of Health and the Population Development Association of Thailand, in collaboration with the U.S. Peace Corps, are building similar tanks with bamboo staves cast into the rings for reinforcement.

6.2.5 Ferrocement Tanks

These tanks are built using a technique in which cement mortar paste is applied by hand to a reinforcing wire mesh. "True" ferrocement has much more steel reinforcement than called for in the tanks described here. Still the principle is the same: metal reinforcing strands distribute loads evenly through the cement mortar, preventing the cracking that would occur in unreinforced materials of similar thickness (NAS, 1973). Tank walls 4 cm thick are strong enough to hold 2 m depths of water above ground. Thus reinforced cement walls require much less total material than conventional concrete walls. (Briscoe, 1981, notes that ferrocement tank walls do not necessarily require less cement than concrete walls.)

In his handbook for field workers (Watt, 1978, Ferrocement Water Tanks and Their Construction, see section 8.2 below), Watt notes:

"The main advantages...of this material over other tank construction materials, such as galvanized corrugated iron, are its cheapness and easy working using the minimum of expensive materials, equipment and skills. It is, in addition, very durable. Some of the tanks described in the manual have been in constant use for over 25 years with only a few instances of failure--due in the main to poor workmanship in construction."

Watt goes on to say that ferrocement techniques are particularly suited for low-income rural areas because 1) they use commonly available materials (cement, sand, water, and wire); 2) only simple skills are needed: "...untrained people can make satisfactory tanks after only a few days supervision..."; 3) users of the tanks can help in construction; and 4) only simple hand tools are required.

Clearly an important advantage of ferrocement tank construction is that it can be taught and learned readily. Early development of these techniques was done at the Friends Rural Training Center, Hlekweni, near Bulawayo, Zimbabwe. Roy Henson of the Center reports training of a half-dozen craftsmen and construction of 210 9 m^3 tanks in Matabeleland in 1971-72 (Farrar and Pacey, 1974). At the Asian Institute of Technology (AIT) in Bangkok, training is provided for field workers from developing nations who, in turn, train local craftsmen in the techniques. AIT-trained field workers in Central Java make modified ferro-cement tanks and have begun using woven bamboo staves to reinforce smaller tanks. They and their trainees have reportedly built 1,400 tanks up to 10 m^3 in capacity (Winarto, 1981) (figure 13). And in West Java, two separate programs are planned to construct a total of 650 tanks using the Central Java techniques (Pompe et al, 1982).

Ferrocement tanks are typically built by one of two methods. In the first, layers of wire netting ("chickenwire") are attached to a grid framework of 6 mm (or larger) steel rod (see figure 14). Mortar is trowelled directly onto this framework from the outside (Sharma and Gopalaratnam, 1980) or against a sheet of woven bamboo mat tied temporarily against the inside of the framework wall to act as a "form" (Winarto, 1981; Pompe et al, 1982). When the reinforcing vertical rods are continuous from the floor through the wall and into the cover, cured tanks can be moved on makeshift rollers. The materials costs for a 1.2 m^3 tank of this type with integral floor and cover were estimated at US $33.00 (Thailand; Sharma and Gopalaratnam, 1980).

In the second construction method, no reinforcing framework of steel rods is used. Wire netting and plain straight wire are wrapped around a sturdy inner cylindrical form and plastered with thin coats of cement mortar (Watt, 1978; Watt, 1977; Farrar and Pacey, 1974; see Ferrocement Water Tanks and Their Construction, and "Catchment Tanks in Southern Africa: A Review", section 8.2). Like tanks with steel rod reinforcement, these tanks are installed on a concrete foundation; but unlike them, they must be built in place. Materials costs are usually substantially less than for tanks of the first type because a single layer of wire netting and plain wire cost less than the steel rod framework. Assuming a cement price of US $7.14 per 50-kg bag and a wire netting price of $1.00 per m^2, the 10 m^3 tank described by Watt (his construction steps are presented in Appendix B) could be built for about $150.00. Similar tanks of 9 m^3 capacity built at the Friends Rural Training Center, Hlekweni, cost $62.50 including gutters (1973, Zimbabwe; Farrar and Pacey, 1974).

These costs do not include money spent on materials for the cylindrical inner forms around which the wire and netting are wound. Calvert and Binning (1977) report using mats woven from wood and bamboo, pitpit, or wildcane for forms in the New Hebrides. However, the forms recommended by Roy Henson and Watt, made of sections of corrugated iron roof sheet bolted together, make it much easier to plaster to a uniform wall thickness and build consistently good tanks. If corrugated iron sheeting costs US $2.20 per m^2, this kind of form for a 10 m^3 tank would cost $50.00 plus costs of angle iron, hardware, and fabrication. The form will, in some areas, cost as much as the materials for one tank. However, the form is portable and can be used to build many tanks. Where a large number of tanks are to be built in one area, this technique should be considered.

In New Zealand, ferrocement water tanks are manufactured by a number of firms using methods similar to those described by Watt. With a welded grid of 10 mm rod in the floor, tanks with capacities of 0.7 m^3 to 18 m^3 are portable (hauled from factory to farms in trucks) and often guaranteed for 25 years (Office of the Foreign Secretary/NAS, 1973).

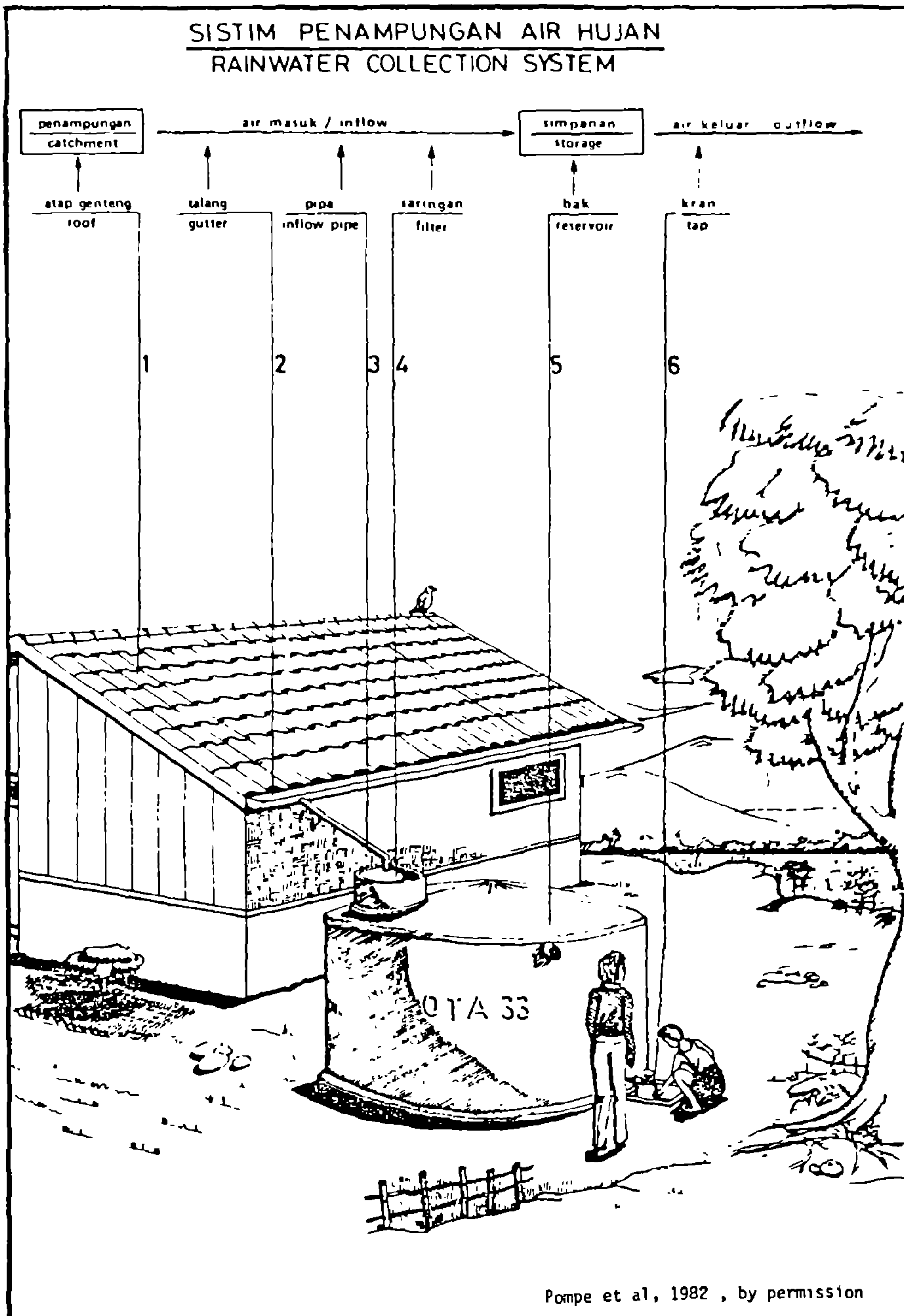

Figure 13, Ferrocement Tank Installation in Java.

A paste of mortar is forced into the layers of mesh by hand . (Smith Kampempool, Applied Scientific Research Corporation of Thailand)

. or trowel. The mortar is dry enough to remain in place when applied; a formwork is not needed. (Noel D. Vietmeyer, National Academy of Sciences)

Office of the Foreign Secretary/NAS, 1973
by permission

Figure 14, Building Ferrocement Tank.

6.2.6 Manufactured "Tin" or Corrugated Sheet Metal Tanks

These tanks have been used for many years in many areas. Farrar and Pacey (1974) report that in parts of southern Africa, most foreigners have "tin" tanks alongside their homes. The costs of these tanks are high and extremely variable, depending on distance from point of manufacture. Farrar and Pacey give the cost of a 9 m^3 version as US $112.00 in 1973 Zimbabwe; White et al (1973) say that "tin" tanks of 1.4 m^3 capacity cost $39.00 to $84.00 in East Africa (1972). The corrugated metal from which these tanks are fabricated may not last longer than 5 years in a damp climate, even then galvanized. Calvert and Binning (1977) report that in the salt-laden atmosphere of New Hebrides, 16 gage tanks fail after 3 or 4 years.

6.3 Tanks For Use With Larger Rooftops or Several Rooftops*

6.3.1 Underground Ferrocement Tanks

Most tanks of this type are basically an earthen pit lined with wire-reinforced mortar. As with other underground tank designs, structural strength is provided by the confining earth walls, meaning that the ferrocement lining can be made only a centimeter thick. A further advantage of these tanks is that their construction requires neither the steel rod framework nor forms needed to build aboveground ferrocement tanks.

Calvert and Binning (1977; see "Low Cost Water Tanks in the Pacific Islands" in section 8.2 below) describe an innovative design complete with reinforced cover, 3.5 m in diameter and 2 m deep, volume 15-20 m^3. First a circular concrete ring or "footing" is poured; soil from the footing trench is used to make a gently sloping earthen dome in the center of the circle. A 5 cm layer of cement plaster reinforced with wire netting and steel rod is laid over the dome, and two 0.6 m holes are left near opposite edges. After this ferrocement dome cures digging begins through the holes, and the tank is excavated beneath. Two layers of wire netting are used to strengthen the plaster applied to the earth walls.

The authors believed that these tanks should not cost more than about US $250 in 1976 in New Hebrides. They suggest that the design is suitable for "collecting a village's water supply drained from the roof of a large public building." While fabrication of a cover which will not crack may require some experimentation, the approach seems promising. Maikano and Nyberg (1980) report trials of similar covers for underground tanks in Botswana.

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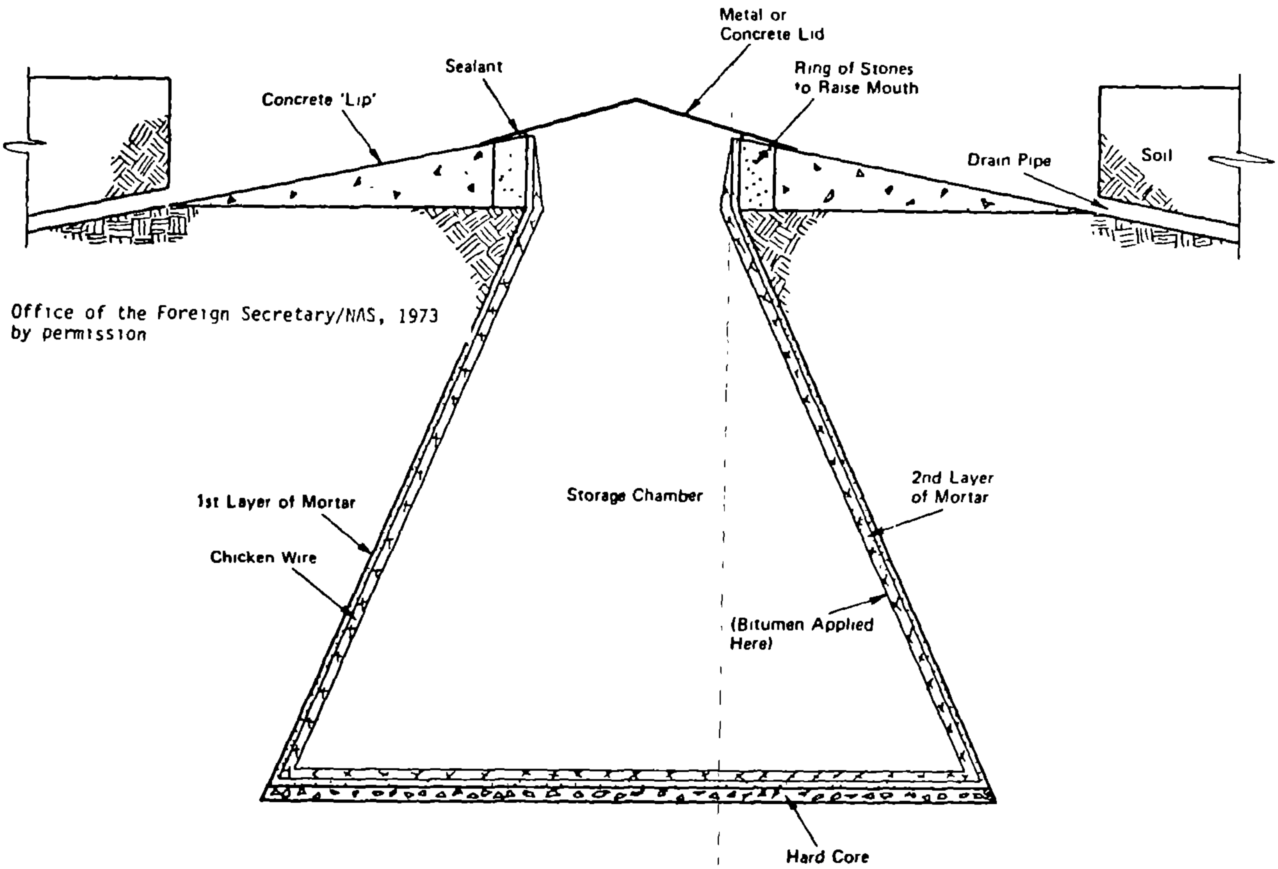
*This report does not deal with tanks used with surface catchments (see section 3.1.2). There are, however, at least 3 types of tanks used with surface catchments which should be briefly mentioned here because they might also be used with larger rooftops or several rooftops. Maikano and Nyberg (1980) describe 10-25 m^3 ferrocement-lined pits collecting water from grain threshing floors in Botswana; Farrar and Pacey (1974) describe the "Water Harvester" (three linked brick cisterns) with 9 m^3 capacity in Zimbabwe; and Ionides et al (1969) describe a project in Botswana to promote "beehive" tanks, built of polythene "sand sausages", with capacities in the 50 m^3 range. Cost information for these tanks is included in section 7.4.

A ferrocement-lined underground grain storage bin suitable for storing water has been documented in the Harar Province of Ethiopia (NAS, 1973; Sharma et al 1979; see Ferrocement: Applications in Developing Countries and "State-of-the-art Review on Ferrocement Grain Storage Bins", section 8.2 below). Traditional grain pits, conical in shape with sides sloping inward to a narrow mouth at the surface, are lined with plaster reinforced with wire netting and given a concrete floor. A small cover is needed, and provision made so that surface water will run away from the mouth of the pit. Ferrocement linings have been installed in pits of this type with depths of up to 3 m and floor diameters of 4 m (see figure 15).



Office of the Foreign Secretary/NAS, 1973 by permission

Figure 15, Cross-section of Ferrocement-lined Underground Storage Pit.

Soil type will affect smoothness of earthen walls and the ease with which plaster can be applied to the sides of an excavation. Calvert and Binning (1977) say that their tanks should be dug out in "soft" soil. Sharma et al (1979) say that traditional grain pits have been lined successfully in all the major soil types of the Harar province of Ethiopia.

The lining of traditional Dogon granaries with ferrocement pioneered by Hans Guggenheim and described by Watt (1978), represents an interesting above-ground version of the Ethiopian scheme. Existing adobe-brick granaries, about 2.4 m high and 2.6 m in diameter, are lined with plaster reinforced with wire netting and covered in the traditional manner with timber-reinforced adobe. The flat roofs of the adjacent houses are already equipped with water spouts to drain the torrential (if infrequent) rains. The system seems to be an extremely inexpensive and elegant way to provide a rooftop catchment system with storage capacity of about 13 m^3. Clearly only very sturdy adobe walls would be suitable, Watt noted that trouble can begin when adobe walling begins to erode in the rain.

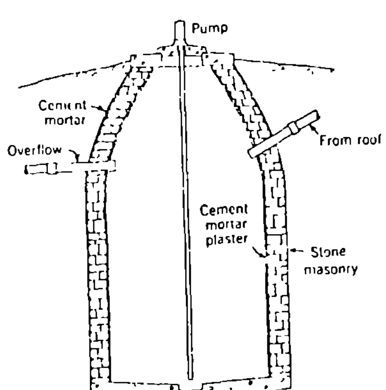
6.3.2 Buried and Partially Buried Brick and Masonry Tanks

Stones and bricks have been used all over the world to build structures to hold water. Stones or bricks laid with mortar have great strength under compressive loads, but lack strength to resist loads from the side. This means that the lower parts of walls in deep tanks, where the water pressure is greatest, tend to buckle outward if they are not built strongly enough. This fact, in turn, is the principal motivation for burying (or partially burying) this type of tank: the deeper parts of the walls are supported by earth. Brick and masonry tanks when covered properly also tend to keep water cooler than above-ground tanks, and can be built into a basement or share a foundation wall.

Buried brick and masonry tanks have their disadvantages, however. Cracks and leaks, which allow stored water to escape and contaminated ground and surface water to enter, are difficult to detect and in many cases difficult to repair. If a pump is used to raise water, the tank must be fitted with a strong (and expensive) cover that will bear human traffic safely. A pump, in itself, may bring with it serious maintenance problems.

A wide variety of shapes and sizes is possible. Rectangular tanks are easy to design and can be readily incorporated into a building. Circular and elliptical tanks require less wall surface (and hence less material) per unit volume of storage capacity. The walls of circular and elliptical tanks are also stronger, and there is a shorter zone of weakness where mortar cracks are most likely to develop along the line where the wall meets the floor (Maikano and Nyberg, 1980; Cairncross and Feachem, 1978; see Small Water Supplies, section 8.2). Cairncross and Feachem say, in fact, that stone and masonry tanks more than 2 m across should be circular.

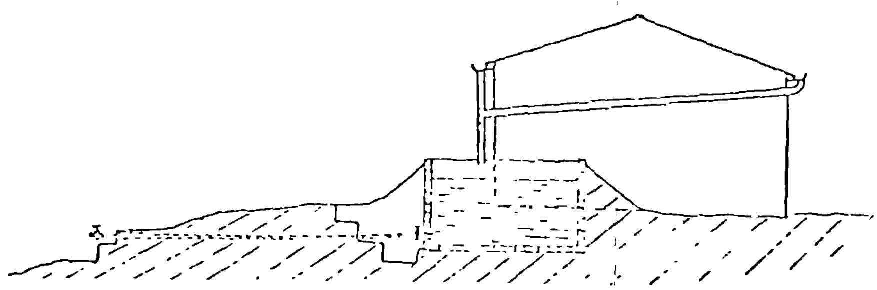
There are few accounts of brick and masonry tanks in use, probably because their construction is nothing new or noteworthy. Wright (1956) shows a drawing of an underground tank "...walled up with stone or bricks and mortar and plastered with cement mortar" (see figure 16 below).



Wright (1956)
by permission

Figure 16, Cross-section of Underground Masonry Storage Tank.

In Southern Africa, "...the occasional large buildings in rural areas--schools, churches, halls, etc.--can provide a water supply to the community on about the same scale as that from 'beehive' tanks (45-90 m^3). Four or five 9,000 liter tanks would be needed for many school buildings, though a more usual method of providing this capacity is to build a single large tank of concrete blocks. The difficulty is that tank walls built in this way are ill-suited to resist the sideways pressure of the water, so concrete block tanks are usually built in shallow excavations with piled earth used to buttress the sides. (Figure 17 below) illustrates a tank of this kind, showing how the tap may be placed so that water can be drawn off by gravity flow" (Farrar and Pacey, 1974; see "Catchment Tanks in Southern Africa: A Review", section 8.2). In this same



Farrar and Pacey, 1974 by permission

Figure 17, Concrete Block Tank.

paper, a 71 m^3 tank of this type built in Ghana (Parker, 1973) is said to have cost US $260.00 (1973). At $3.63/$m^3$ (1973) of storage capacity, this would be one of the cheaper tanks (in cost/m^3 of storage) we have seen documented.

Many of the cisterns built into the basements of residences in Bermuda, where provision for rooftop catchment and storage is required by building codes, are made of concrete block plastered with cement mortar. Volume of these cisterns varies with the size of the dwelling, but most fall within the range of 50 m^3 to 90 m^3 (John Sands, Solar Engineering Technology, personal communication).

One of the strongest arguments for considering tanks of this type is that they can readily be designed and built into or alongside new public buildings for a relatively small increment in procurement and labor costs. See the discussion of construction details of stone and masonry tanks in Appendix B.

6.3.3 Underground Concrete Tanks

These tanks have been widely used for rainwater storage in the developed countries. In the United States they are usually referred to as "cisterns" and are frequently built into or alongside basements with capacities ranging from 10 m^3 to 50 m^3. Properly reinforced with steel rod, concrete is probably the strongest material for walls for water storage. It is resistant to cracking and leaking, and its cover can be cast with an inspection hole so as to effectively seal out contaminants from the surface. The great disadvantage of underground concrete tanks is their expense: they require large quantities of cement, gravel, sand, and steel; and materials for forms, and expertise in the methods, are often also expensive and scarce in rural areas of developing countries.

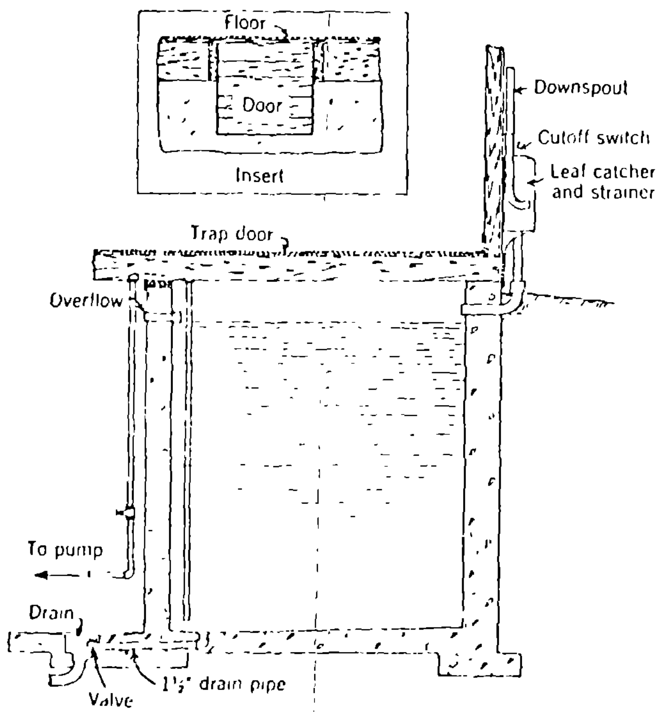
This type of tank or "cistern" is widely documented in U.S. textbooks on rural water supply and sanitation. Salvato (1958) and Wright (1959) describe a cistern with simple sand filters, overlapping manhole covers and hand pumps, and "butterfly" valves in the downpipe for diverting dirty water from the roof at the beginning of a rain. Both sources give simple guidelines for matching cistern size to roof area in light of the water needs of farming households in the U.S. Wagner and Lanoix (1959) give simple sizing guidelines and discuss location: tanks should be higher than and at least 3 m from any sewage disposal installation. They also emphasize the need to keep gutters clean and sloping evenly toward the downpipe to prevent setting water. VITA's Using Water Resources (see section 8.2) gives tools and materials lists, and quantitities, proportions, and procedures for constructing a cistern and sand-gravel filter. The Village Technology Handbook (VITA, 1973; see section 8.2) gives detailed information on building with concrete. The sizing guidelines given for matching cistern volume to roof area assume that the cistern should hold a full year's water supply for the family using it. (See the note in Appendix A on using rainfall data to plan a rooftop catchment system.)

The Manual of Individual Water Systems (Office of Water Programs/EPA, 1974), originally published by the U.S. Public Health Service in 1950, presents the text and cross-section drawings of a cistern which are referred to and appear in Salvato (1959), Wagner and Lanoix (1959), and VITA (1973). Henderson and Smith (1973; see Planning for an Individual Water System, section 8.2) and Midwest Plan Service (1979) are two more recent books published by government extension programs in the U.S. for use in rural areas. They give similar information on cisterns, with useful color sketches and cross-sections. Midwest Plan Service recommends against use of filters for the water from the downpipe, noting that they can quickly become contaminated. They suggest, instead, an adequate "roofwasher".

Heaven's Water: in Rural Places, Cisterns Gather the Rain (1980) is a useful presentation of the pros and cons of cistern systems written for a popular audience. The users emphasize the importance of some kind of a "roofwasher" system, discussing several alternatives. This article also relates some of the potential problems with rooftop catchment systems in industrialized countries: "Rainfall itself carries dust and even chemicals. Near highways, there is probably a significant lead content in the air. Downwind from industrial plants, there will be a problem with pollution. You need to be site-specific with cisterns." Also mentioned are cleaning solutions for yearly scrubbing of the insides of cistern walls: 3 parts vinegar to one part water; 1 kg baking soda dissolved in 8 liters of water. This was the only source which recommended against the addition of chlorine to water being stored in a tank, saying that it can interact with impurities to form chloroform. A chlorinator which treats the water as it is pumped to the house, or iodine solution or pasteurization, is recommended instead. Other sources recommend periodic chlorination of the water in the tank.

Dooley (1978) discusses cisterns for the rural U.S. in another popular journal. She uses chlorine bleach to disinfect cistern water and describes a chlorine level test using hydrochloric acid. Dooley also recommends scrubbing the inside of the cistern with bleach to disinfect it every two or three years. Even in the U.S., where the materials are readily available, concrete cisterns are expensive. Dooley (1978) estimates materials costs of a 36 m^3 underground reinforced tank at about US $1,000 in the U.S. in 1977. Such a tank would be impossible to build in most situations in rural areas of developing countries. The discussion of underground reinforced concrete tanks is included here because elements of their design may be useful when large rectangular tanks are built into public buildings. Wright (1956) shows a design in which one wall of a cistern is the wall of a building foundation or basement (figure 18).

Wright (1956)
by permission



The foundation wall serves as one or more sides of the cistern, the other walls being constructed of concrete. Note that the cistern is entirely enclosed to keep out dust and rodents and that a leaf catcher and strainer is provided on the down spout. Entrance to the cistern for cleaning and repairs may be through a trap door, as shown, or through a special door in the side between two floor sills as shown in the insert.

Figure 18, Cistern Suitable for Basement.

6.4 Other Tanks

This section describes tanks which have been used with ground surface catchments but which could also be adapted and used with rooftop systems.*

One particularly interesting kind of tank is used with traditional threshing floors in Botswana (Maikano and Nyberg, 1980; see Rural Water Supply in Developing Countries, section 3.3.6). The tanks are about 2 m deep, 2.5 to 4 m in diameter, and hold 10-25 m^3 of water. The first of these tanks were rectangular, but circular ones have been recommended to the pilot project because their wall area is

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*A widely-known ground surface catchment tank, known as the "sand-sausage" or "beehive" tank, grew out of a pilot project for providing water to irrigate school gardens in Bostwana (Ionides et al, 1969). These tanks--now apparently abandoned--have no immediate applications in rooftop systems, but they represent an innovative approach to effective use of local resources.

less for an equal storage capacity, and the finished walls should be less likely to crack. Water is channeled into the tanks through a short length of PVC pipe from a shallow settling basin in one corner of floor, where some sedimentation occurs. A brick curb is built around the perimeter of the tank to keep out surface water and provide a foundation for the cover, made of lengths of tree trunk or precast concrete slabs reinforced with barbed wire. Domed cement covers, plastered over wire mesh on an earthen mold, are also being tried. These covers are allowed to cure and then lifted into place on the curb. The construction of the cover seems to be much like the method of Calvert and Binning (1977). Inside the excavation a "thin layer" of cement mortar plaster is applied on wire netting pegged to the sides. Again the approach seems to be much like that of Calvert and Binning (1977), who splashed a liquid cement mixture on the soil walls and plastered cement mortar onto the surface. The materials costs of the tanks appear to be fairly low: for a 25 m^3 tank, the authors estimate about US$135.00 for cement, chicken wire, and PVC pipe (Botswana, 1980). It is not clear if this amount includes the cover.

The tanks are intended to provide water for people and cattle. Maikano and Nyberg (1980) note that "The cistern will require cleaning before the beginning of the next rains. Plastering of the tank and cover may have to be done as cracks are noticed." Farrar and Pacey (1974) give a brief description of the "Water Harvester", built by the Christian CARE Organization in Zimbabwe: "The cylindrical holes are dug to about 2 meters depth, lined with brick or stone, then plastered with cement to make them water proof. Concrete lids are made to keep the water clean." The system shown uses three tanks linked underground with pipe, so that only one pump is needed. The rough estimate of the cost of these linked cylinder tanks is US$75.00 for 9 m^3 of storage (1973, Zimbabwe).

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SESSION 7

SYNOPSIS

SESSION 7: Sizing the Tank

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5	---	Session Goals
2.	Review, Calculate and Graph Roof Yields	Discuss, Calculate, Making Graphs	40	---	Monthly Total Roof Yield Bar Graph Roof Yield Tables
3.	Determine Cumulative Yield	Computation	15	---	Same Tables as Above
4.	Location Consumption Rate	Small Group Discussing, Calculating	15	---	Consumption Equation
5.	Comparing Roof Yield to Consumption Estimates	Discussion	20	---	Above Tables
6.	Computing Cumulative Consumption and Comparing to Cumulative Yield	Calculating	15	---	Cumulative Consumption and Yield Table
7.	Determining Optimal Tank Size	Discuss, Calculating	20-35	(Materials for Optional Demonstration)	Same Table as Above
8.	Practice Applications and Review Concept	Calculating, Discuss	30		Same Table as Above
9.	Closure	Discuss	5	---	---

TOTAL: 2 hours, 45 minutes to 3 hours

GOAL

Total time: 2 hours & 45 min. to 3 hours

To learn how to calculate an optimum tank size and evaluate the result.

OBJECTIVES

By the end of this session, the participants will be able to:

- Calculate the water yield from the roof(s) which will supply the tank
- Make and use a table showing cumulative yield from the roof(s)
- Discuss how consumption of water from the tank is limited by yield from the roof during rainy and dry periods
- Determine an optimum tank size from the roof-yield table
- Consider alternatives for increasing the supply of rainwater

OVERVIEW

This session follows the choice of appropriate guttering and tank types. Before the group can determine specifications and costs of materials, it must decide how large the tank should be (how much water the tank should be able to hold). This session takes the group through exercises to a decision on how large the tank should be based on the rainfall data (discussed in Session 3: Initial Technical Assessment). If the rainfall totals calculated are not representative of local rainfall patterns or are of doubtful use, the trainer may choose to go through all the steps in this session as an example for future use and estimate the data.

The activities in this session require arithmetic and working with graphs and tables. Because in any group some are more adept at handling numbers than others, the trainer should organize small groups so that each has some of the more capable members. It is important that participants understand that the reservoir must be large enough to hold a surplus of water during the rainy season, that is, more water coming in than being taken out to get the users through the dry season when the reservoir is not being refilled by rainfall. Once they understand the concept they can move to learning how to compute the net cumulative surplus (the difference between the cumulative roof yield and the estimated cumulative consumption) reached at the end of the rainy season. Enough time has been allotted for Steps 5 to 8 to allow the participants to work together using different roof yield and consumption figures to do several computations.

ACTIVITIES

1. Introduction Time: 5 minutes

Give the information in the overview explaining the basic principle behind determining the tank size (see Trainer Note 1), and explain what the session objectives are.

2. Review, Calculate, and Put Roof Yields on a Graph Time: 40 minutes

Review the decision made in the previous session approving the site and type of tank under construction, and ask participants how they think the size of the tank was determined. Ask what factors have to be considered in determining the size of the tank. Explain that this session will show how to compute optimum size by comparing roof yields to estimated consumption patterns.

Review Step 3 of Session 3: Initial Technical Assessment by looking at the Monthly Total Roof-Yield Bar Graph done at that time and recalling how it was generated. (The height of the bar for each month, in cubic meters of water, was calculated by multiplying roof area x rainfall x 0.80.)

If rainfall totals used in Step 3 (mentioned above) are thought to be representative of local rainfall patterns, the group can use them to fill out a new monthly total graph using the actual roof area for the system selected in Session 6. Before the group calculates these monthly roof-yields, review the assumption of roof-yield efficiency (80 percent) in light of the chosen roof and guttering system. Use a lower figure if appropriate.

Divide the group into pairs and trios and using the actual roof area for the proposed system, fill in a blank Monthly Total Roof Yield Bar Graph for two years already prepared on a flipchart (see example below). Have each group fill in two or three months on the graph. Explain that the graph is only a visual means of showing roof yield. Point out rainfall patterns at the start and end of the rainy and dry seasons. Put the same figures in the Roof Yield Table (below) at the same time as they are being put onto the bar graph. Cover up the column for cumulative yields until the next step.

Monthly Total Roof Yield Bar Graph

Roof
Yield
In
M^3

J F M A M J J A S O N D J F M A M J J A S O N D

1982 1983

Roof Yield Table
(in M^3/Month)

Month	Monthly Roof Yield	Cumulative Roof Yield
Jan.		
Feb.		
Mar.		
April		
May		
June		
July		
Aug.		
Sept.		
Oct.		
Nov.		
Dec.		

3. Determine Cumulative Yield Time: 15 minutes

Explain that the determination of tank size is based on cumulative yields (i.e., the accumulated yield over any period--in this case months of the year or the rainy season). The cumulative yield is determined by adding each month to the total of the previous months. The total is always greater than or, in the case of a month with no rainfall, the same as the previous months. Point out that the last figure is the total for the year.

Using the same small groups, have participants compute cumulative yield using figures in the Roof Yield Table above and also in a Roof Yield Table which starts with the first month of the heavy rainy season (see Trainer Note 3). Finish both tables and ask if there are any questions. Point out that the cumulative yield at the end of the rainy season in the second table gives the total amount of rainfall during that rainy season. Point out other similarities and differences in the two tables.

4. Local Consumption Rates Time: 15 minutes

Write the following equation on the blackboard or flipchart:

__?__ people x __?__ liters/person/day x 30 month/days = __?__ liters/month

Explain that the point of this activity is to choose values for the question marks in the left of the equation, so that a value for the right of the equation can be calculated. With the group, establish the number of people who will be using water regularly from the tank. Then divide the group in two and direct each small group to independently come up with a liters-per-person-per-day figure. Remind the small groups to assume that the tank cannot provide water for all needs and that it is better to have a small amount of water for high priority uses (like drinking) than to use up all the stored water in a short time. Point out that it will be interesting to compare the two figures from the two groups and that these figures will be added to the Cumulative Consumption and Yield Table to compare monthly and cumulative consumption with monthly and cumulative roof yields. Give the groups 10 minutes (see Trainer Note 2).

Take a short break at this point.

5. Comparing Roof Yield to Consumption Estimates Time: 20 minutes

Reconvene and ask the groups to briefly present their consumption figures and outline the assumptions they made to reach them. Briefly discuss the figures and assumptions and agree upon a liters-per-person-per-day consumption figure. Return to the above equation (_____people x _____liters/person/day x 30 days = _____liters/month) and compute the number of liters per month. Turn the liters per month into cubic meters per month (1,000 liters = 1 cubic meter).

Compare the monthly consumption estimate (in cubic meters) to the monthly roof yield figures in the Roof Yield Table for the rainy season.. See if there is a sufficient monthly roof yield during the rainy season months to meet the estimated consumption. Point out that "water into" the tank (roof yield) must be greater than the "water out" of the tank (consumption) for the system to work. If consumption is greater than the roof yield, discuss ways to increase the roof yield or decrease consumption and rework the figures.

If monthly roof yields are greater than monthly consumption during the rainy season, compute the annual consumption (i.e., multiply monthly consumption by 12) and compare to the annual roof yield (the last cumulative yield figure). Point out that if the annual net (the difference between yield and consumption) is positive, i.e., a surplus, there is enough water to get through the entire year. If the annual net is negative, i.e., a deficit, there is not enough water to get through the year. Discuss both options in light of the purpose of the system. For example, if the system is a supplement to another source of potable water it can run out at the end of the dry season, but if it is the only source of water this cannot be allowed to happen and roof yield must be increased or consumption decreased. For the purposes of the following exercise, determine a consumption figure that results in a small annual surplus.

6. <u>Computing Cumulative Consumption and Comparing to Cumulative Yield</u> Time: 15 minutes

Using the following table, compute the cumulative consumption based on the monthly consumption decided upon in Step 5. During the break between Steps 4 and 5, fill in the monthly and cumulative roof yield figures from the Roof Yield Table for the rainy season. To compute cumulative consumption, first fill in the monthly consumption figures, and then, adding each month to the preceding months, fill out the cumulative comparison column. Ask participants to do the computations and fill in the table.

Cumulative Consumption and Yield Table

Month from start of rains*	Monthly Roof Yield (water in) in M3	Monthly Consumption (water out) in M3	Monthly Net +/- (remains in tank)	Cumulative Roof Yield (water in) in M3	Cumulative Consumption (water out) in M3	Cumulative Net +/- (remains in tank)
Mar.						
Apr.						
May						
June						
July						
Aug.						
Sept.						
Oct.						
Nov.						
Dec.						
Jan.						
Feb.						

* See Trainer Note 3 for the importance of starting the table with the start of the rainy season or whenever there is a monthly surplus.

Quickly subtract monthly consumption from monthly roof yield and point out surplus and deficits for each month. Explain that the optimum size of the tank can be determined by adding the total monthly surpluses during the rainy season (total water in) and comparing them with the total monthly deficits during the dry season (total water out), but that it is easier to do it by looking at the difference in the cumulative yield and consumption. Ask the group to subtract the cumulative consumption from the cumulative yield for each month on the Cumulative Consumption and Yield Table, and fill in that column on the table.

7. Determining Optimal Tank Size Time: 20 minutes (with option 35 minutes)

With the entire Cumulative Consumption and Yield Table filled out, ask the participants to tell you how large the tank has to be. If no one volunteers the figure which is the largest surplus between cumulative consumption and cumulative yield, or if that person cannot explain why that should be, ask the group to remember the theory behind determining tank size discussed at the start of this session. Review, if necessary, the fact that the tank has to be large enough to hold all of the surplus water that can be generated during the rainy season needed to last through the dry season.

Point out that the largest cumulative surplus (i.e., the greatest difference between cumulative yield and cumulative consumption) represents the largest quantity of water remaining in a tank large enough to hold it after months of more water going in (yield) than being taken out (consumption). This will always occur near the end of the rainy season if the consumption figures remain the same because the accumulated roof yield is highest in relation to the cumulative consumption at that point. The tank has to be big enough to hold that much water. If the annual yield is the same or greater than the annual consumption, that figure will be enough to get through the dry season when water is being drawn out of the tank. Ask participants if they understand the concept and how to use these figures to determine optimal tank size. If they understand both the concept and the computations they can go on to the next step and use different yield and consumption figures to determine the size of another tank. If they are still having trouble visualizing the concept, before going on with the next step, use the following optional demonstration using cups of water and a bucket while filling out a blank table with the figures given in the example in Trainer Note 3.

Optional Demonstration

Take a full bucket of water and two empty buckets of water and a large tin cup, and a blank Cumulative Consumption and Yield Table. Use the figures in the Trainer Note 3 example. Each time you fill in a monthly yield column, pour that many cups into the "tank" bucket, and each time you fill in a monthly consumption column, take that many cups out and pour into the other bucket. Go one month at a time starting with the start of the rainy season. After August (month of highest cumulative surplus, 13 cubic meters) ask everyone how many cups of water are in the tank bucket. If someone doesn't believe that there are in fact 13 cups in the tank or isn't sure, measure all the water out to show him or her, pour the 13 cups back in and continue with the rest of the year. Point out throughout the demonstration where you are in terms of the rainy and dry seasons. At the end of the demonstration ask the participants if the bucket (the tank) was big enough for the difference between the cumulative yield and cumulative consumption. Ask if the bucket would be big enough if there was twice as much roof yield and twice as much consumption. (Answer: the tank will have to be twice as large, i.e., it must be able to hold 26 cubic meters unless the pattern of consumption changes. See Trainer Note 4.) They can double the monthly yield and consumption figures and compute that tank size in the practice in the next activity. Ask if the concept is now clear and answer any questions.

8. Practice Application and Review Concept — Time: 30 minutes

Before practicing the concept in small groups with different data, explain that while it is easier to determine tank size with a table which starts with the first monthly net surplus (i.e., at the start of the heavy rains), it can be done at any point during the year. When computing tank size from a table that contains cumulative net deficits (i.e., ones starting during the dry season) it is necessary to add the largest deficit as if it were a positive number to the largest surplus to get the total figure for the optimal size of the tank. (See Trainer Note 3 for an example.) Use a blank Cumulative Consumption and Yield Table to redo the figures from Step 7 starting with January if it falls within the dry season or any other month which has a net deficit. In closing, point out that it is much easier to start with surplus months and have all the months positive than to start with deficit months, especially if there are two rainy and dry seasons or rainy seasons with small dry seasons in the middle of them.

Split the group into pairs and trios and give people the roof-yield and consumption figures from the example in Trainer Note 3 or ask them to use the rainfall figures for their own areas given out in Session 3 (if done) or other figures, and compute an optimal tank size based on different roof-yield and consumption figures. Walk around and help groups that need assistance. For those who understand the concept and computations give them examples with problem situations such as split rainy seasons, fluctuating consumption rates, etc.

After everyone has had a chance to practice the computations and has demonstrated an understanding of how to do them, discuss the following concepts with the participants:

- The relationship of roof size (hence roof yield) to tank size: a higher roof yield means tanks can refill quicker even with higher rainy season consumption and can be smaller. See the example in Trainer Note 4.

- The consumption patterns and the use of rainwater for limited needs

- The rainfall patterns and whether the system can be an alternative to other potable water sources or just a rainy season supplement

- The need to consider factors other than mathematical computations to take into account potential fluctuations in normal rainfall patterns, people's tendencies to use more water when they have it, the system's potential for leaks or waste, etc. See Trainer Note 5.

9. Closure — Time: 5 minutes

Refer back to the session goals and objectives to make sure the trainees feel they have been met and they will be able to calculate the tank size in a future project on their own. If not, set up ways for individuals to get help from each other practicing computations until they feel confident. Refer to the comment made in Trainer Note 5.

TRAINER NOTES

1. It is necessary for the participants to understand the basic concept for determining tank size before learning how to do the actual mathematical computations. The computations can become confusing if the concept is not already there. If the concept is understood, the computations become easier to understand because they can be related to the concept. They start making sense, instead of just being numbers.

   Basically the tank has to be big enough to hold enough water to last through the dry season. For this water to exist in the tank there must be more water coming in (roof yield) than being taken out (consumption). This can be measured by looking at the difference between the monthly roof yield and the monthly consumption. This is called the monthly net. Rather than adding up all the monthly net surpluses and monthly net deficits to determine how much water remains after the rainy season and how much is needed during the dry season, a running total of cumulative nets can be computed by subtracting the cumulative consumption (the total water taken out over the course of several months) from the cumulative roof yield (the total of water going in over the course of several months). The highest cumulative net will occur near the end of the rainy season and will represent the total of the monthly surpluses. The tank has to be big enough to hold that amount. If a table listing these figures is started in the dry season or at any point when there is a deficit (i.e., more water going out than in) these figures become distorted by the deficit and the deficit has be added to the highest surplus as if it were a positive number (see Trainer Note 3).

2. In Step 4 the minimum liters per person per day for drinking, washing hands, and cooking is about 15 liters/day. This figure may be greater than a roof catchment system can provide to a large community from just one roof, so a lower figure may have to be used when doing Step 5.

3. It is important to introduce the computations for determining tank size with a table which starts with the first month of the rainy season or the start of the heavy rains during the rainy season. The following table* illustrates this point.

Cumulative Consumption and Yield Table

Month	Monthly Yield (water in)	Monthly Consumption (water out)	Monthly Net (remains in tank)	Cumulative Yield (water in)	Cumulative Consumption (water out)	Cumulative Net (remains in tank)
March	2	2	0	2	2	0
April	4	2	+2	6	4	+ 2
May	5	2	+3	11	6	+ 5
June	6	2	+4	17	8	+ 9
July	3	2	+1	20	10	+10
Aug.	3	2	+1	23	12	+11
Sept.	1	2	-1	24	14	+10
Oct.	0	2	-2	24	16	+ 8
Nov.	0	2	-2	24	18	+ 6
Dec.	0	2	-2	24	20	+ 4
Jan.	0	2	-2	24	22	+ 2
Feb.	0	2	-2	24	24	+ 0

* All figures are in cubic meters

In the table, the figures start with March, the first month in which there is rain. Since the yield and consumption are the same, there is no net surplus or deficit. Throughout the next five months of the rainy season the monthly yield is greater than the monthly consumption and the monthly net (the water remaining in the tank or added to or subtracted from that amount each month) is positive, i.e., a surplus. The cumulative net shows the total of those monthly surpluses and represents the actual water in the tank after any given month. For example there could be 11 cubic meters of water in the tank at end of August, if the tank is big enough to contain that amount. From September through February less water goes into the tank than is taken out and the monthly nets are all negative and the cumulative net decreases proportionately.

4. In Step 8, the point is made that increasing the roof yield can, in some cases, reduce the size of the tank because the tank can be refilled quicker. This is true if there is more water remaining in the tank after the rainy season than is needed for dry season consumption. The tank must hold enough water to provide the minimal needs for the dry season, but construction costs may not allow for the construction of a tank to meet all needs. In the optional demonstration in Step 7 participants are asked if the tank (the bucket) would be big enough if both the roof yield and consumption were doubled. If the consumption for each month is doubled, then the tank has to be twice as large because the community needs twice as much water during that period of time.

   But if the yield were doubled to a total yield of 52 cubic meters instead of 26 cubic meters (using the example below) and the consumption remained at 2 cubic meters during the five month dry season, a smaller tank could be built to hold only enough water needed to get through the dry season. In the following example the roof yield is doubled during each of the months it rains and consumption is increased accordingly. The following figures tell us that we need a tank with a minimal capacity of only 10 cubic meters even though we have doubled the roof yield.

Cumulative Consumption and Yield Table

Month	Monthly Yield (water in)	Monthly Consumption (water out)	Monthly Net (remaining)	Cumulative Yield (water in)	Cumulative Consumption (water out)	Cumulative Net (remaining)
Mar.	4	4	0	4	4	0
Apr.	8	6	+2	12	10	+ 2
May	10	7	+3	22	17	+ 5
June	12	8	+4	34	25	+ 9
July	10	9	+1	44	34	+10
Aug.	6	6	0	50	40	+10
Sept.	2	2	0	52	42	+10
Oct.	0	2	-2	52	44	+ 8
Nov.	0	2	-2	52	46	+ 6
Dec.	0	2	-2	52	48	+ 4
Jan.	0	2	-2	52	50	+ 2
Feb.	0	2	-2	52	52	0

This is the smallest tank which can provide 2 cubic meters of water to everyone during the dry season. Slight changes in consumption will alter the size of the tank. If you reduce August's consumption by 2 cubic meters and increase September's by the same amount (i.e., 4 cubic meters for both months) the tank size will have to be increased to 12 cubic meters from 10 cubic meters to hold the 2 cubic meters extra that will accumulate by the end of August in order to have 10 cubic meters in the tank by the end of September. Try the new monthly consumption figures and see how the cumulative net column will give you a different result for the size of the tank.

5. Finally, it should be pointed out to the group that designing the size and configuration of the tank is not based only on mathematical considerations of how much water is needed to get through the dry season and how much surplus can be generated during the rainy season. The cost of tank construction and the time required to build a large tank have to be taken into consideration as do the desires of a community to use more water when it is available. The mathematical computations are only one set of factors which have to be considered.

MATERIALS

- Flipchart for session goals and objectives
- Flipchart for Monthly Total Roof Yield Bar Graph from Session 3
- Flipchart for blank Monthly Total Roof Yield Bar Graph
- Flipcharts with Roof Yield Tables (one for a calendar year, one starting with the first month of the heavy rainy season)
- Flipchart with the equation for calculation consumption in liters per month
- Flipcharts with three or four blank Cumulative Consumption and Yield Tables for Steps 6, 7, and 8
- Three buckets and a cup for the optional demonstration in Step 7

This is the smallest tank which can provide 2 cubic meters of water to everyone during the dry season. Slight changes in consumption will alter the size of the tank. If you reduce August's consumption by 2 cubic meters and increase September's by the same amount (i.e., 4 cubic meters for both months) the tank size will have to be increased to 12 cubic meters from 10 cubic meters to hold the 2 cubic meters extra that will accumulate by the end of August in order to have 10 cubic meters in the tank by the end of September. Try the new monthly consumption figures and see how the cumulative net column will give you a different result for the size of the tank.

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SESSION 8

SYNOPSIS

SESSION 8: Building Small Cement Household Storage Tanks

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5		Session Goals
2.	Work Orientation	Discuss	30	Handout 8-1: Building Water Tanks	---
3.	Construction Activity	Field Work	2 1/2 hrs.	See Materials List	---
4.	Discussion	Discuss	60		Discussion Questions
5.	Closure	Discuss	5		

Total: 4 hours, 10 minutes

GOAL

Total time: 4 hours & 10 min.

To learn the basics of cement mixing and use of mortar using small household storage tanks as examples.

OBJECTIVES

By the end of this session, the participants will be able to:

- Demonstrate all the basic steps in small cement mortar tank construction
- State proper ratios of cement, sand, and water for mixing mortar
- Describe proper procedure for cleaning sand and mixing mortar
- Tell how to cure cement mortar
- Consider local options for household storage containers

OVERVIEW

This is the first practical construction session in which the participants have the chance to do most of the work themselves. They will have an opportunity to work with cement mortar and concrete and develop or improve their skills in this basic construction technique so that they will be better prepared to supervise local masons and villagers doing this kind of work. In addition, they will be introduced to three ways of making low cost small household storage tanks (approximately one meter in height by 60 cm in diameter) which can hold from 200 to 300 liters of water. Most of these tanks can be built with from 25 to 40 kg of cement depending on the construction method and size. The three tanks are:

- Thailand Jar: a jar formed by filling a burlap sack with sand, shaping it into a jar and plastering it with two coats of mortar
- Ghala Basket: a woven basket which is plastered with cement mortar inside and out
- Ferrocement Tank: a tank made of chicken-wire mesh supported by reinforcing rod and wire which is plastered inside and out

This session is designed to provide relatively easy-to-build examples of small household storage tanks as another option for rainwater harvesting. It also provides some practical experience with cement mortar and concrete. The session procedures are listed for all three tanks consecutively. As the participants will be divided into six or nine teams of two or three each, depending upon their number and the availability of materials, the session is structured to stop at specific points so that teams working on one method can see what the other teams are doing. See Trainer Notes for further information.

ACTIVITIES

1. Introduction Time: 5 minutes

Open the session by explaining the material in the overview given above and stating the goals and objectives of the session.

2. Work Orientation Time: 30 minutes

Distribute Handout 8-1: Building Water Tanks and ask everyone to read it. Then go over all of the steps for the three methods and explain what will be done that day. See if there are any questions at each step. Depending on the number of participants and availability of construction materials, divide the group into six or nine work teams of two or three people each. Assign two or three teams to each of the three technologies to be demonstrated and go out to the work site.

3. Construction Activity Time: 2 hours & 30 minutes

The following construction activity is presented in three columns--one for each type of tank. There are periodic breaks in the work sequence so that all participants can observe the work being done on each tank. Fuller technical information is provided in the Trainer Notes.

THAILAND JAR	GHALA BASKET TANK	FERROCEMENT TANK
Pre-session preparation: • construct concrete bases (see Trainer Notes, 1 & 2) • cut open burlap bags • have all materials ready	Pre-session preparation: • mix concrete for base (see Trainer Notes 1 & 3) • have base mold and foundation ready • have all materials ready	Pre-session preparation: • mix concrete for base (see Trainer Notes 1 & 4) • have base mold ready • have all materials ready

(Have all participants look at the finished concrete bases for the jar and the concrete mixed for the other tanks. Have all participants look at the various materials and answer any questions about them.)

THAILAND JAR	GHALA BASKET TANK	FERROCEMENT TANK
Make jar mold: • draw jar pattern on burlap • sew the two burlap sacks together leaving top and bottom open; turn inside out • place sack on base and fill with sand	Make base and place basket: • pour concrete into mold on foundation, compact and level • place pipe in base if desired • place basket into base securely	Make 70 cm wide base and place re-rod and wire mesh into base: • pour concrete into form, compact and level • place reinforcing rod in base • wrap chicken wire around re-rod frame and tie securely

(Have all participants review the work done by the other teams starting with the teams doing the same technique and then as a group go around to the other methods and have the teams explain what they are doing and answer any questions. Trainer can ask questions and provide responses as well.)

THAILAND JAR	GHALA BASKET TANK	FERROCEMENT TANK
Measure and mix mortar: • use 1:2 mixture of cement to sand • keep mortar dry--just wet enough to work (see Trainer Note 2) • starting at bottom apply two coats of mortar thickness of 0.5 cm for each coast to mold that has been lightly dampened • put extra mortar at bottom of mold, fixing it to base	Measure and mix mortar: • use a 1:3 mixture for 1st coat and 1:2 for 2nd coat both applied to inside • add water, keep mortar dry (see Trainer Note 3) • apply two coats of mortar to basket from inside starting on bottom following instructions to a thickness of 1 cm for each coat • put remaining mortar on outside of basket to cover fibers	Measure and mix mortar: • use a 1:3 mixture for 1st coat and 1:2 for 2nd coat • add water, keep mortar dry (see Trainer Note 4) • apply first mortar coat outside of mesh and push through and smooth on both sides to thickness of 1 cm • apply second mortar coat to inside of tank to cover same thickness

(Have all the participants look at the work of the other teams. Discuss wetness of mortar, ease of application and specifics of working on burlap mold and basket and chicken wire frames.)

Top hole construction: • make round frame and plaster against it (see Trainer Note 2)	Top hole construction: • if basket has circular top, plaster right up to it or leave wide mouthed (see Trainer Notes 2 & 3)	Top hole construction • bend wire mesh into a smaller circular mesh or or leave wide mouthed (see Trainer Notes 2 & 4)
Let dry and cure for 2 days; pour out sand and apply cement slurry and cure for 2 weeks	Apply inside coat of cement-water slurry Let dry and cure for 2 weeks	Apply coat of cement-water slurry to interior Let dry and cure for 2 weeks

4. Discussion — Time: 60 minutes

After finishing the construction and wrapping the tanks to allow them to cure, bring the trainees back together and discuss the afternoon's work.

- Ask the trainees for the advantages and disadvantages of each kind of small household tank. List them and discuss how they would improve on what they did.

- Ask the trainees to identify the problems they encountered in constructing the tanks. List and discuss how they would improve on what they did.

- Discuss local options for small household tanks and the difficulty and estimated cost of each (for a discussion of costs and their calculation see Trainer Reference Notes which follow the handout).

- Ask the trainees to discuss the applications of what they learned today for their work.

5. Closure Time: 5 minutes

Refer to the session objectives, summarize the major points of the discussion and refer to the following day's practical session on thatch roof systems and bamboo gutters.

TRAINER NOTES

1. Before the start of the workshop, carefully read Handout 8-1: Building Water Tanks for the three construction methods. Discuss the construction methods and session's learning objectives with the construction foreman. Have the foreman brief the masons on their responsibilities in preparing for the session and helping the participants make the tanks. It is very important to make sure that the masons understand that they are not to do the work for the participants or take over for them when they make a mistake but merely to suggest to them how they can do the work better or easier. Local masons must be supervised to avoid having them take over from the participants during practical sessions.

2. Thailand Jars

   Make the bases for the jars out of concrete (1:2:4--cement:sand:gravel) to a thickness of 3 cm if they do not need to be moved to the construction site or 5 cm if they do need to be moved. Bases being moved should be made before the start of the workshop so they have a full week to cure; those not being moved can be made five days before this activity.

   The sacking material can be burlap bags used for transporting rice or other foods, and should be at least 125 cm x 110 cm when opened. They can be filled with rice husks, sawdust, or small pebbles if sand is not available.

   Be very careful when the participants are dampening the mold before applying the mortar (a dry mold will absorb the moisture in the mortar) to make sure that they do not pour water over the mold or splash on too much. Any excess water will be absorbed into the sand and will then filter slowly down to the base of the mold and leak out, breaking the mortar at the base.

The rich 1:2 mixture of cement to clean, coarse sand should be mixed with only a little water and applied as dry as possible. This makes the application more difficult but results in a stronger jar. Most local masons are used to using mortar as plaster on walls and work with a very wet mortar which is easier to apply. In all tank construction methods, the foreman will have to explain the reasons for the drier mixture and closely supervise the work of the local masons and help in this area.

The mold for the top of a jar can be made out of wood or sand held in place with a narrow band of thin corrugated iron sheet formed into a circle. The plaster is applied against the circular mold to produce an attractive circular top to the jar.

The jars need to be cured for two weeks before moving and using. The mold can be poured out and the sack removed after 48 hours. Finish the inside with a cement slurry and cure out of direct sunlight and keep wet with the empty burlap bag.

• Ghala Basket

A woven basket common to the area can be used as an inexpensive basis for making a strong tank. The term "ghala basket" comes from the large grain storage baskets woven in East Africa. Any sturdy woven basket will do. For the purposes of the demonstration it should be big enough to hold 100 to 300 liters of water when finished. If no such baskets are made in your country do not do this demonstration and just demonstrate the other two methods.

The bases for these tanks must be made during the demonstration. Some time can be saved by having the concrete dry mixed and ready for the water to be added before the demonstration. The form for the foundation and base, if it is to have one, can also be prepared ahead of time. Use a mix of 1:2:4 cement-sand-gravel for the concrete. Do not add too much water as the concrete should be fairly dry. Drier concrete and mortar makes a stronger final product. The base should be about 5 cm thick for a small basket unless a pipe is used to get the water out in which case it can be little thicker. The base of the basket should be placed firmly into the concrete base. The bottom of the basket can be cut off as the concrete does not need the additional structure.

In choosing or ordering a basket for this demonstration consider size, shape, and the access into the inside, as it has to be plastered from the inside. Also try to find a weave that is open enough for the mortar to go through the holes--a very tightly woven basket is not suitable. Elaborate weaving designs and dyed materials are also not necessary. Apply two coats of mortar to a thickness of 1 cm each. The first coat (1:3 cement to sand) is applied to the inside and left to dry for a few minutes. The second coat (1:2 cement to sand) is then applied. The remaining mortar (first and second coats) should be applied to the outside of the basket to cover and seal it when done. For other general instructions see Trainer Note 2 (Thailand Jar).

4. Ferrocement Tank

The tank resembles an oil drum when finished but is a little larger and much heavier. The concrete base should be 70 cm in diameter and 5 cm thick and should be made with a 1:2:4 mixture of cement, sand, and gravel. The concrete should not be too wet. The one meter wide chicken wire mesh (1" [2.54 cm] mesh in 20 gauge wire is preferable to 2" [5 cm] mesh) should be wrapped around the reinforcing rod frame tightly and anchored into the wet concrete base. Use six one meter lengths of 8 mm or 10 mm reinforcing rod spaced 30 cm apart in a circle 5 cm inside the outer rim of the base. Tie the mesh in place with 20 gauge wire. If only 2" chicken wire is available, wrap it around twice to reduce the size of the holes. If no chicken wire or other suitable metal wire material is available a mesh can be made by weaving thinly cut bamboo strips together. Thicker bamboo slats can also replace the reinforcing rod.

Apply the first coat of mortar (made with a 1:3 ratio of cement to sand) to the outside of the mesh and push through and smooth on both sides to a thickness of 1 cm. When dry, mix the second coat of mortar (made with a richer 1:2 ratio of cement to sand) and apply to the inside of the tank to a thickness of 1 cm. Start both coats from the bottom and add a little extra where the sides join the concrete base. Make sure all of the reinforcing wire is well covered and sealed. See Trainer Notes 1 and 2 on wetness of mortar and working with local masons, curing mortar, etc.

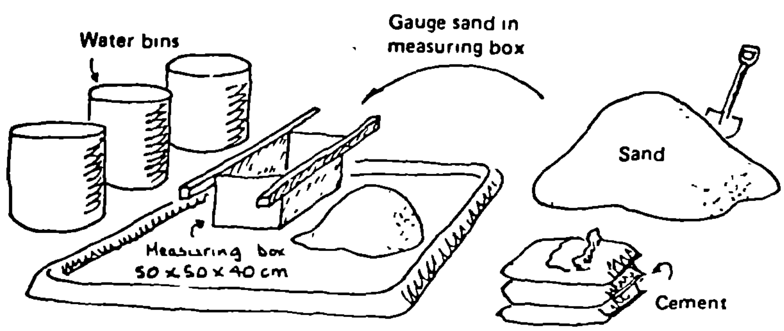
MATERIALS

- Flipchart for session goals, objective and questions (Step 4)
- Handout 8-1: Building Water Tanks
- Materials from lists in Handout 8-1

BUILDING WATER TANKS*

The construction information in this section is for three of the most widely documented of the tanks. Here is detailed information on the materials, tools, and skills involved in their construction; some readers with confidence in their manual skills would be able to attempt construction from the information given. These are not necessarily the three "best" tank designs for household rooftop catchment; in fact, each of these three tanks requires a relatively great amount of cement per cubic meter of storage (see below). They are, however, three of the most "teachable" of the designs documented.

Each of the tanks described in this section is made with cement mortar, which is a mixture of sand and cement and water. It is always important to make mortar with the cleanest available materials, and to keep soil and other contaminants out of the mortar mixture. Watt (1978) suggests using a mixing board or making a small concrete pad on a layer of gravel. The board is probably a better choice where the tanks or jars will be built far from each other (see figure below).



Watt (1978) by permission

Equipment and Material for Mixing Cement Mortar.

* From WASH Working Paper No. 20, "Rainwater Harvesting for Domestic Water Supplies in Developing Countries" by Kent Keller, as adapted for this session by David Yohalem, 1984.

The mortar mixtures used for the following tanks and jars contain proportions of cement:sand ranging from 1:2 to 1:3 (measured by volume). Mixtures with more cement are easier to plaster with and may be stronger and more waterproof for the surfaces of smaller jars with little reinforcement. For larger containers, a 1:3 cement:sand mixture is strong enough and less likely to crack when curing.

Sand for mortar should be clean. A range of sand grain sizes is permissible but sand with lots of find silt should be avoided because it causes flaking of dry mortar. Sand and any other materials to be used in construction should be gathered before any work starts. Study the list of materials for each of the tanks, and read through the instructions carefully before beginning.

Clean water should be added to the cement and sand after they have been thoroughly mixed together with a trowel or shovel. Make a hole in the pile of cement/sand mix and pour the water in, a little at a time. While a mix that is too "dry" will be difficult to apply, a "wet" mix will not be as strong when cured. Use as little water as possible to obtain a workable mixture. Start with an amount of water that is half the volume of the cement, and add water sparingly.

Do not mix more mortar than can be applied to the tank or jar in about one half hour! After about this amount of time, mortar begins to set and cannot be applied properly (Watt, 1978).*

Concrete is used instead or mortar for the foundations of most tanks and jars because it contains gravel or small stones and is less likely to break or weaken under the load of a heavy tank and its contents. The gravel used in concrete ideally contains a range of sizes, and the stones should not be flat. Like sand, gravel must be clean, or the concrete will be weak.

Concrete used for foundations can be mixed in proportions of cement:sand: gravel ranging from 1:2:3 to 1:3:6. Regardless of the proportions, concrete should be made with as little water as possible and mixed in a clean place. Containers like those shown in the figure above can be used to measure the proportions of materials in mortar and concrete mixes. Resist the temptation to estimate proportions or use the blade of a trowel to measure with; this will result in a weaker mix.

The <u>Village Technology Handbook</u> (VITA, 1978) includes an excellent section on selecting mixes, preparing, and building with concrete.

* See Annotated Bibliography at the end of the Session Guides.

1. Quarter Cubic Meter Cement Plaster Jar ("Thailand Jar")

Unlike the other water containers in this section, this jar is built entirely of mortar. It contains no strengthening fibers nor wires. The mortar is applied to a "mold" which is usually made of sacking material (like burlap) filled with something heavy enough to plaster against.

Because these jars have no reinforcing material, they are made with a mortar mix which is "rich" in cement. The proportions of materials recommended in the following instructions (copied by permission from Watt, 1978 are 1:2, cement: sand (measured by volume). Watt does not mention the proportion of watar to be used. He says instead that the mortar should be mixed as "dry" as possible, for maximum strength. Refer back to the discussion of making mortar above.

The following instructions are for construction of a small jar which holds approximately a quarter of a cubic meter of water (figure 2). Watt says that people with no experience have been taught to make the jars in less than two days. Much larger jars which have screens, lids, and taps have been constructed using this method. Substituting soil and lime for some of the cement and sand in the mortar has also been tried.

MATERIALS: 1/2 bag of cement (less than this should be required) per jar
clean sand
clean water
burlap, "gunny cloth", or other strong sacking material
sand, grain husks, or sawdust to fill the sacking
prepared concrete bases

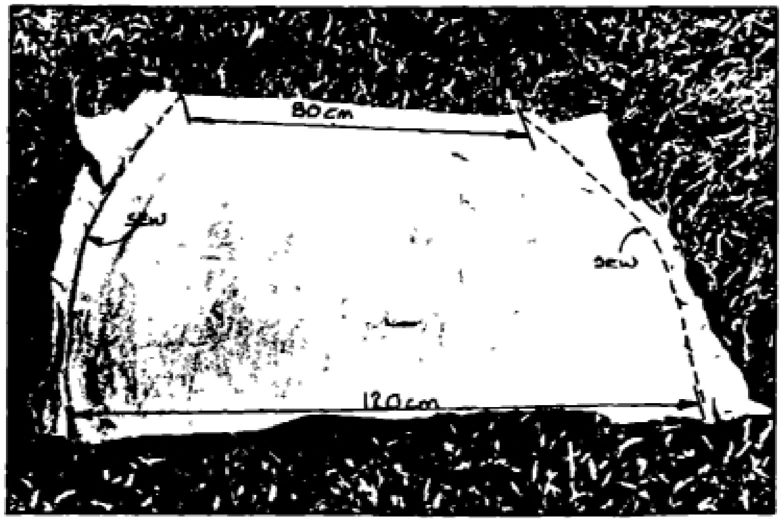
TOOLS: needle and thread, or other tool for sewing the sacking
mixing board or pad and containers for measuring and mixing mortar
shovel for mixing mortar
trowel and wooden stick
bucket for carry mortar

STEPS IN CONSTRUCTION REQUIRING SPECIAL CARE:

Making sure that the material used to fill the sacking (Step 2.4 in figure 2) is heavy enough to keep its shape during plastering. It is a good idea to try filling the sack on the ground before beginning construction.

Making the mortar. Do not make the mortar for applying to the mold until you are actually ready to begin (Step 2.8 in figure 3). This should allow you to work with a "dry" mortar mixture for maximum strength. Mixing the cement and sand well, before adding the water, is especially important.

Curing the new jar (Step 2.10 in figure 3), also requires particular attention.



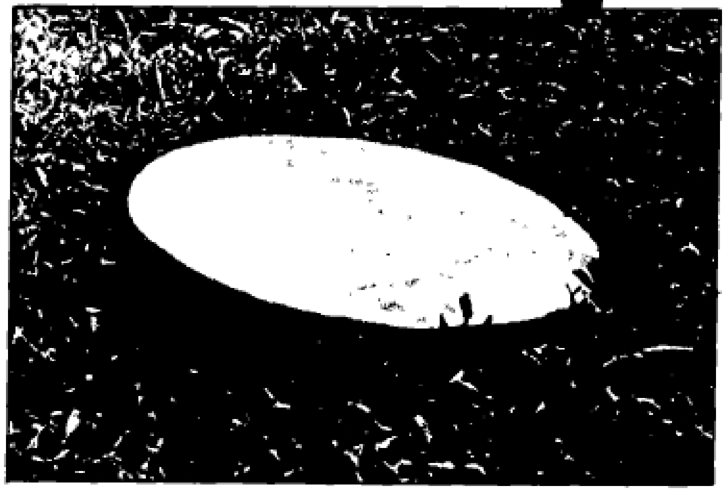
2.1 *Place two pieces of gunny cloth (hessian sacking) 125cm by 110cm together and mark out. Sew the two pieces together along the curved lines leaving the top and bottom open.*

2.2 *After sewing, turn the sack inside out.*

FIGURE 1

Making Small Water Jar, Thailand

(From Watt, 1978, by permission, ITDG)



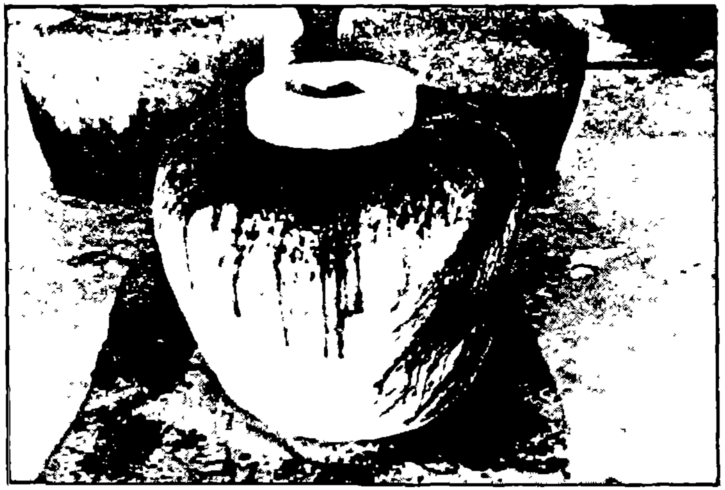
2.3 *Make a precast mortar bottom plate, 60cm in diameter and 1.5cm thick. Make the mortar from a mix of 1:2 cement:sand by volume as dry as possible consistent with easy trowelling.*

2.4 *Place the sack on the bottom plate with the smaller opening downwards and fill the space inside with paddy husk, sawdust or sand. The weight of the fill will hold the lower edge of the sack firmly on the bottom plate. Make sure that the mortar bottom plate sticks out from under the sacking.*

2.5 *When the sack is filled up, fold the top and tie it into the shape of a traditional water jar. Use a piece of wood to tap on the mould to make it round and fair.*

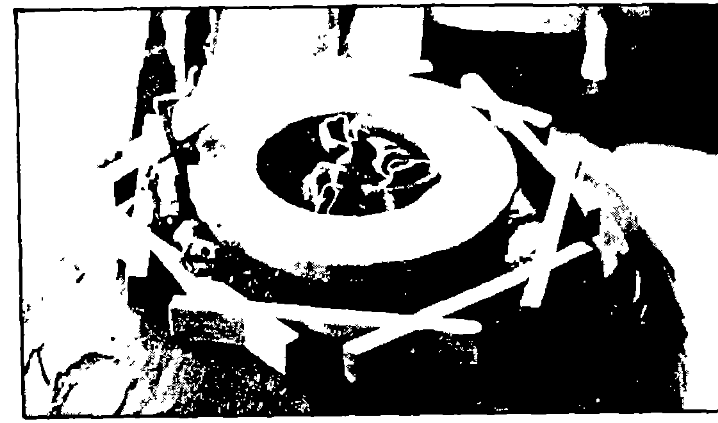
2.6 *Spray some water on the mould before plastering to make it damp.*

FIGURE 2
Constructing a Cement Plaster Jar

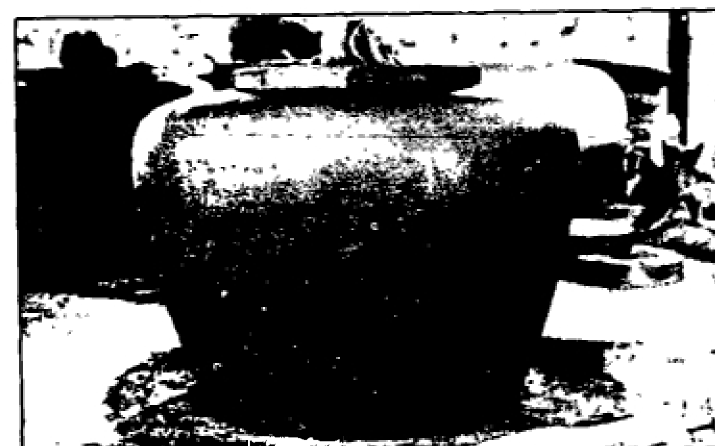


2.7 *Place a circular ring on the top of the sack to make a mould for the opening of the jar. This can be made of wood or precast mortar.*

2.8 *Trowel a first layer of mortar onto the mould to a thickness of about 0.5cm.*



2.9 *Plaster the second layer of 0.5cm in the same manner as the first layer. Check the mortar layer for thickness by pushing in a nail: any weak or thin spots should be built up with an extra layer of mortar. Build up the opening.*



2.10 *Remove the contents of the gunny bag and the bag 24 hours after the jar has been made. Check the jar for any defects and correct these with mortar; the inside of the jar should also be painted with a cement slurry. Cure the jar out of sunlight and drying winds, preferably under damp sacking or plastic sheet for at least 2 weeks.*

This technique has been used with great success in Thailand and pots of up to 4000 litres (approx 1000 galls.) capacity have been made in this way.

FIGURE 3

Constructing a Cement Plaster Jar (continued)

2. Woven "Ghala" Basket Reinforced Tank

The following guidelines are adapted from Keller's instructions for a larger 2.3 m^3 tank made out of ghala basket. These guidelines are for similar size tank as above and can be made out of any appropriate basket with about one half a sack of cement.

Choosing an Appropriate Woven Basket

The basket should be made out of a thick sturdy weaving material so that the basket will stand on its own and not bend while being plastered. The weave should be open enough to enable the mortar to go through the weave. Intricate weaving designs and different colored fibers are not necessary and only increase the cost of the basket. The top of the basket should be large enough to allow an adult to reach in to plaster the basket from the inside. The base of the basket should not be too small relative to the widest diameter or it will be unstable.

Base

Follow the same instructions for a ferrocement tank base to make a base a little bigger than the basket. Place the basket into the base while it is still wet. If the bottom weave of the basket is very tight and the concrete cannot go through it, cut the bottom of the basket off and push the lower sides of the basket into the concrete so it is firmly in place. Allow the base to dry enough so that the basket doesn't move when being plastered.

Mortar and Plastering

Apply a first coat of mortar made with a ratio of 1:3 cement to sand to the inside of the basket starting at the bottom and working up to a thickness of 1 cm. As with the above tanks, keep the mortar as dry as possible. Place extra mortar on the bottom where the basket joins the base. Push the mortar through the weave of the basket and smooth on the outside as well as inside. Let the mortar basket dry while mixing the second coat of mortar with a richer mixture of 1:2 cement to sand. Apply the second coat to the inside of the basket including the base of a thickness of 1 cm. Use any leftover mortar to cover the outside of the basket so that the woven basket frame is entirely covered with plaster. This will protect the frame from insects, moisture, etc. and make the tank last longer. When the second coat is dry enough apply a cement slurry to seal the inside.

Curing

Cure and cover as in above instructions.

MATERIALS

1/2 sack of cement per tank
clean sand gravel and water
woven basket

3. Ferrocement Tank for Small Household Use

The following construction guidelines are adapted from Keller's instructions for the construction of a larger 10 m^3 ferrocement tank. The tank to be built with these guidelines is approximately 1 m tall and 60 cm in diameter and will hold about 280 liters (0.28 m^3) of water. If made with walls 2 cm thick of mortar mixed to a ratio of 1:3 cement to sand it will use a half a sack of cement, 6 meters of #8 reinforcing rod and 2-4 meters of 1 m wide chicken wire depending on the size of the wire mesh.

Base

A concrete base 70 cm in diameter by 5 cm thick is poured with a mixture of 1:2:4 cement:sand:gravel in a 5 cm deep x 70 cm wide circular form excavated in clay soil. Make sure the sand and gravel are clean and free of any organic matter. Mix in only enough water to make the concrete workable. The drier the concrete the better. Let dry a little as you prepare the other materials.

Wire Mesh and Supports

Cut a 6 meter length of #8 reinforcing rod into six one meter lengths (#6 or 10 re-rod can be used but the #6 is a little weak for this purpose and the #10 is stronger than needed and more costly). Place the rods about 30 cm apart in a circle 5 cm inside the outer rim of the still wet base. This will produce a new circle with a diameter of 60 cm. Take the wire mesh and wrap it around the reinforcing rod and push the bottom into the concrete base. If you are using chicken wire with a one inch (2.54 cm) mesh you only have to wrap it around once. If you have to use 2 inch (5 cm) mesh chicken wire, wrap it around twice and make sure that the second layer overlaps the first in such a way as to cut the size of the holes in half. Tie the chicken wire itself and secure to the reinforcing rod.

Mortar and Plastering

Mix mortar with a 1:3 ratio of cement to sand and as little water as needed to make it workable. The drier the mortar, the stronger the tank will be when it dries. Apply a coat of mortar plaster 12 cm thick to the outside of the chicken wire mesh, starting at the base and working up. Put a little extra mortar onto the bottom of the mesh where it joins the base. Push the mortar through the wire mesh so it completely covers the inside of the reinforcing rod and wire mesh. Smooth the plaster on both sides and let dry a little. When the mortar is dry enough to be worked (about 20 minutes) put on a second coat of mortar made with a richer mixture (1:2 cement to sand) to the same thickness to the inside of the tank. Plaster the concrete base and use more plaster as above where the wall and base meet.

Start from the bottom and work up to the top. Make sure that all the mortar walls are to a uniform thickness and fill in any thin spots. When completed, the walls should be 2 cm thick and no reinforcing rod or chicken wire should be visible. Finish the top of the wall to make a smooth lip for the barrel. Apply a cement slurry to the inside to smooth and seal the interior.

Curing

Dry in the direct sunlight, and keep damp for two weeks before moving. A wet burlap sack can be placed over the tank to keep it wet during this time. After a day, put 20 cm of water in the tank to keep the inside moist. A wooden top can be made to sit over this tank as a cover.

MATERIALS

1/2 sack of cement per tank
clean sand, gravel and water
6 m of #8 reinforcing rod per tank
2-4 m of 1 m wide chicken wire or similar wire mesh per tank
wire

TOOLS

shovels and buckets for mixing and carrying mortar and concrete
tools for cutting re-rod and wire mesh
trowels, floats, etc.

COSTS OF CONSTRUCTION

B.1 Materials Quantities For Four Tanks

Below (figure 25) are some comparisons of the materials inputs for construction of tanks discussed in Chapter 6 and listed in the table in that chapter. Using this kind of information, local prices can be applied to roughly determine costs and make cost-based judgements about the relative attractiveness of different designs.

"Trade-offs" are evident: for example, the cement mortar plastered basket (UNICEF, 1982) requires more cement per m^3 of storage than any of the other three, but needs no metal reinforcing material and little gravel.

The subsequent section B.2 gives guidelines and examples for roughly calculating amounts of cement needed to build a variety of tanks.

B.2 Calculating Costs of Materials

The following discussion on figuring costs shows how to obtain rough amounts for some of the main materials needed for construction of roof catchment systems. The procedures are simple, Computations like them can be used to get an idea of whether materials for a proposed catchment are affordable, and to compare the costs against the costs of alternatives. They do not take many important questions into account: they ignore the time required for delivery, and any costs of labor, for example.

Here is a summary of the computations on materials costs:

$$\text{cost of cement (for concrete)} = \text{volume of concrete} \times \frac{\text{7 bags cement*}}{m^3 \text{ concrete}} \times \frac{\text{price}}{\text{bag}}$$

$$\text{cost of cement (for mortar)} = \text{volume of mortar} \times \frac{\text{10 bags cement}}{m^3 \text{ mortar}} \times \frac{\text{price}}{\text{bag}}$$

$$\text{cost of roofing material (sheet)} = \text{area of roof} \times \frac{\text{price}}{m^2}$$

The first two examples are worked out for materials that would be needed for construction of the 10 m^2 ferrocement tank described in section C.2 (figure 26) (see also table in Chapter 6 above, no. 10, and section B.1). Other materials, in addition to the ones mentioned here, would be needed--sheet metal for forms, for example. The final example concerns costs of sheet metal for roofing. See Appendix A for how to calculate how much rainwater a given roof can collect.

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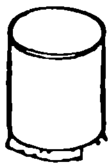
*From Keller, op. cit.
**Each bag weighs 50 kg.

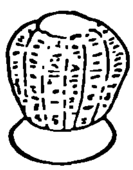


Ferrocement Tank with foundation (no cover) (after Watt, 1978)
10 m3

materials per m3 storage:
1.2 bags cement
0.1 m3 sand
.05 m3 gravel
16 m2 chickenwire

cement	:12 bags (50 kg. each)
sand	: 1 m3
gravel	: 0.5 m3
chickenwire	: 16 m2

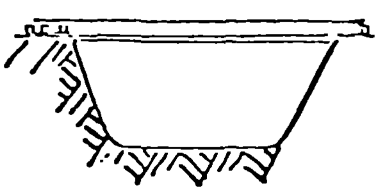
plus: straight wire, use of forms



Cement mortar plastered basket with foundation (no cover) (after UNICEF, 1982)
2.3 m3

materials per m3 storage:
2.2 bags cement
.06 m3 sand
.02 m3 gravel

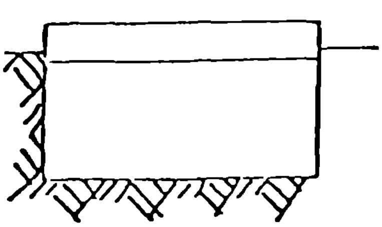
cement	: 5 bags
sand	: .13 m3
gravel	: .04 m3



Reinforced cement mortar plastered underground tank (after Maikano and Nyberg, 1980)
20 m3

materials per m3 storage:
0.6 bag cement
.05 m3 sand
1.6 m2 chickenwire

cement	: 12 bags
sand	: 1 m3
chickenwire	: 32 m2



Underground concrete tank with cover
12 m3

materials per m3 storage:
1.1 bag cement
.0 8 m3 sand
.12 m3 gravel

cement	: 13 bags
sand	: 1 m3
gravel	: 1.4 m3

plus: reinforcing rod, material for forms

FIGURE 25
Materials Quantities for Four Tanks

<u>Cement in concrete floors, footings, and foundations of tanks</u>

1. Figure the volume of concrete needed. For a 2.9 m diameter floor which will be 7.5 cm thick,

$$\text{area} = \pi r^2 = 6.2\ m^2$$

$$\text{volume} = \text{area} \times \text{thickness} = 6.2\ m^2 \times 0.075\ m = 0.47\ m^3.$$

2. Figure the amount of cement needed to make the concrete. Concrete mixed in the proportions 1:2:3, cement:sand:gravel, is plenty strong for self-help floors, footings, and walls when made with clean materials and cured properly.* Concrete mixed 1:2:3 contains about 7 bags (@ 50 kg per bag) per m^3. Using this information, we can figure the number of bags needed:

$$\text{bags of cement} = \text{volume of concrete} \times \frac{7\ \text{bags}}{m^3\ \text{concrete}}$$

$$= 0.47\ m^3 \times \frac{7\ \text{bags}}{m^3\ \text{concrete}}$$

$$= 3.3\ \text{bags}$$

3. Figure the cost, using the price of a bag of cement in your area. For example,

cost = # of bags x price per bag

= 3.3 bags x $7.14 (US$, Zaire, 1981)

= $23.49

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* Determined using the "concrete calculator", VITA (1973). You may decide to use a lower proportion of cement. The "concrete calculator" shows how to adjust the volumes of the other materials.

Mortar for plastering floors, walls, and roofs of tanks

1. Figure the volume of mortar needed. For a floor plastered with 5 cm. of mortar, 2.5 m in diameter,

$$\text{area} = \pi r^2 = 4.9\ m^2$$

$$\text{volume} = \text{area} \times \text{thickness} = 4.9\ m^2 \times 0.05\ m = 0.25\ m^3$$

For a cylindrical tank with walls 2 m high, plastered with a total of 4 cm of mortar,

$$\text{area} = 2\pi r \times \text{height} = 15.7\ m^2$$

$$\text{volume} = \text{area} \times \text{thickness} = 15.7\ m^2 \times 0.04\ m = 0.63\ m^3$$

So the total volume needed, for walls and floor, is $0.25\ m^3 + 0.63\ m^3 = 0.88\ m^3$.

2. Figure the amount of cement needed to make this volume of mortar. Mortar mixed 1:3, cement:sand, is recommended for waterproof walls. This mix contains about 10 bags (@ 50 kg) per m^3 always check with local masons and collect opinions on mixes, if you are inexperienced). So:

$$\text{bags of cement} = \text{volume of mortar} \times \frac{10\ \text{bags}}{m^3\ \text{mortar}} = 0.88\ m^3 \times \frac{10\ \text{bags}}{m^3\ \text{mortar}} = 8.8\ \text{bags}$$

3. Figure the cost of the cement, using the price of a bag of cement in your area. For example, in Zaire,

$$\text{cost} = \#\ \text{of bags} \times \text{cost per bag} = 8.8\ \text{bags} \times \frac{\$7.14}{\text{bag}} = \$62.83$$

k ing materıal (corrugated metal sheet)

1. Figure the area of roof to be covered with the metal sheet. Allow for overhang, and consider where gutters will be hung, when making measurements. A building 8 m long with a pitched roof might have 2 roof surfaces of equal area:

total area = 2 (length x width)
= 2 (8 m x 3 m)
= 48 m^2

2. Using this area, figure the cost, using the local price of metal sheet. For example,

cost ea x price per m^2
- m^2 x $2.20 / m^2 (Monrovia 1981, US$)
= $105.60

This is only a rough figure, because it ignores the size of the individual sheets and how much they must be cut to fit the roof surface. Also, the sheets must overlap a little to shed water properly. This means that the actual area of sheet needed, and the cost, may be 15-20 percent more.

If gutters are to be made with the sheet material, this may increase the cost again. Sometimes sections of gutter and hanging straps can be made with pieces cut when the sheets are fit to the roof.

SESSION 9

SYNOPSIS

SESSION 9: Designing the System

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	10	Handout 9-1: Tank Design Guide Handout 9-2: Calculation Sheets	Session Goals Objectives
2.	Guided Discussion on Rainwater Harvesting Systems	Guided Discussion	20	---	---
3.	Determining Tank Dimensions	Lecturette, Discussion, Writing	60	---	Computation Examples
4.	Calculating Quantities of Materials	Lecturette and Small Group Calculations	40	---	---
5.	Calculating Materials for the Tank Under Consideration	Small Group Calculations	15	---	---
6.	Examining Results	Discuss	30	---	---
7.	Conclusion	Discuss	5	---	---
			Total: 3 hours		

GOAL

Total time: 3 hours

To describe all the components of the system to be built in enough detail to plan construction.

OBJECTIVES

By the end of this session, the participants will be able to:

- Use Handout 9-1: Tank Design Guide and tank size as calculated in Session 7 to determine tank dimensions
- Use Handout 9-2: Calculation Sheets to determine the quantities of materials needed for construction of the tank
- Calculate quantities of materials needed for gutters and downpipe/foul flush

OVERVIEW

The aim of this session is to use the selected tank size to determine the tank's dimensions and materials required. Once this is done construction can be planned (Session 11). The activities involve the use of tables and some arithmetic, so those with numerical ability should be dispersed in the group to work with the others.

Ability to work with Handout 9-1: Tank Design Guide and Handout 9-2: Calculation Sheets, which go with it, is important. Participants can use the guide to help make design decisions in the different areas where they work. However, the design guide and calculations cannot provide all the information needed. Some of the tanks require materials (such as wire and steel bar) which are not mentioned in the guide, and the calculations for cement quantities do not describe how to determine amounts of sand and gravel needed in mortar and concrete. While cement is usually the most costly material in a rooftop catchment system, clean sand and gravel may be hard to get locally. Because of this, it is particularly important to stress Steps 5 and 6.

Before the session, the trainer should review the Trainers Notes for the calculation sheets.

ACTIVITIES

1. Introduction

Time: 10 minutes

Go over the goal and objectives, give out Handout 9-1: Tank Design Guide and Handout 9-2: Calculation Sheets and explain how they will be used during the session. Answer any questions.

2. Guided Discussion on Rainwater Roof Catchment Systems — Time: 20 minutes

The aim of this activity is to review the different components of a rainwater roof catchment system and to explain the function and composition of each component. Solicit from the group the information that a rainwater roof catchment sytem has four components: a water collecton surface (a roof or any other suitable surface), a water transmission line (the gutters), a water treatment device (the foul flush, screen, and/or filter), and a water storage and distribution device (the cistern).

The following design characteristics should be elicited if possible from the group and discussed for each component. Provide whatever information is not brought up.

- The collection surface: type of suitable material, slope, efficiency of surface, etc.
- The transmission line: type of material, minimum cross section area, minimum slope, connection devices, etc.
- The water treatment device: foul flushes, screen, and filters.
- The water storage tank: type of tanks (above ground, underground, partially underground), configuration of tanks (circular, square, rectangular), tank appurtenances (in-flow pipe, overflow pipe, manhole, withdrawal device, sediment handling device), type of material for tank construction (concrete blocks, reinforced concrete, rocks, bricks, ferrocement, etc.)

3. Determining Tank Dimension — Time: 60 minutes

The purpose of this activity is to demonstrate and provide practice in how to determine the dimension of the tank from a given volume (found in Session 7: Sizing the Tank). The trainer will introduce the concept, present an example and then allow the participants to practice the calculations for each of the three possible tank forms: rectangular, square, and cylindrical.

State that the dimensions of a tank can be determined given the volume in two ways:

1. The designer can reverse the mathematical equation for determining volume to find the dimensions of the length, width, or height; or

2. The designer can try different sizes for the sides and height until the result is close to the desired volume.

For example, the size of a rectangular tank with a volume of 10 m^3 can be computed as follows:

1. Take the formula for determining the volume of a rectangular tank: length x width x height = volume, and reverse it to find the length and width: length x width = volume ÷ height.

2. Choose a height for the tank that makes sense given the height of the gutters, construction method, etc. For the purposes of this example use 2 meters. Point out that you are basically dividing the volume of the tank (10 cubic meters) by a desired height (2 meters) to determine the area of the tank surface (i.e., 5 cubic meters): that is, $\frac{10}{2} = 5$.

3. The length and width of the tank with an area of 5 square meters can be computed the same way. If length x width = area, the length can be found by dividing the area by the width (length = area ÷ width). For an area of 5 square meters a width of 2 meters will produce a length of 2.5 meters: that is, $\frac{5}{2} = 2.5$.

4. Reversing the whole process to verify the calculation gives the computation: 2.5 meters (length) x 2 meters (width) = 5 square meters (area); 5 square meters (area) x 2 meters (height) = 10 cubic meters (volume).

5. Guessing sizes would have produced a similar result:

2 x 2 = 4 x 2 = 8	too small
2 x 3 = 6 x 2 = 12	too large
2 x 2.5 = 5 x 2 = 10	just right

Give the participants 10 minutes to compute rectangular tank dimensions from dimensions from different volumes. Break them into pairs, give them the task and walk around the room checking on their work. When everyone understands the principle and has had success doing several calculations move on to squares.

A square tank has two equal sides, so it is best to start with the sides first and then compute the height by dividing the volume by the area (height = volume ÷ area). As it is difficult to compute square roots without a calculator it does not pay to try to compute the dimension of the sides from the area.

For example, to determine the dimensions of a square tank needed to hold 10 cubic meters of water, try tanks with 2 and 3 meter sides:

2 x 2 = 4; 10 ÷ 4 = 2.5 (height of the tank)
3 x 3 = 9; 10 ÷ 9 = 1.11 (height of the tank)

As 2.5 meters in height may be too tall and 1.11 meters too short, you could then try 2.5 meters for each side as follows:

2.5 x 2.5 = 6.25; 10 ÷ 6.25 = 1.6

A square tank with sides 2.5 meters and a height 1.6 meters will hold 10 cubic meters of water.

Point out that these dimensions are the interior dimensions of the tank, and that additional centimeters would have to be added for the width of the tank walls. Ask the participants to spend a few minutes computing the dimensions of square tanks in pairs using different volumes and verify their results before continuing.

Next, introduce the equation for determining the volume of a cylindrical tank:*

Volume = pi r^2 x h or pi $\frac{D^2}{4}$ x h (either are the same).

Remind people that pi = 3.14 and the radius is half the diameter. As a square root is required to compute the diameter from the area of the circle it is easiest to guess at the size of a diameter and try it with a given height. For example, to determine the dimensions of a cylinder with a volume of one cubic meter and a height of 1 meter try the equation with a diameter of 1 meter:

$$\text{pi} \times \frac{D^2}{4} \times h = V \quad \text{or} \quad 3.14 \times \frac{1^2}{4} \times 1 = 0.79\ m^3$$

Since that is too small, try it again with a diameter of 1.25 m:

$$3.14 \times \frac{1.25^2}{4} \times 1 = 1.23 \text{ (too large)}$$

Trying again with a diameter of 1.1 m: $3.14 \times \frac{1.1^2}{4} \times 1 = .95$

This is close enough. The actual diameter is 1.129, so 1.1 is close enough.

Do another example with a volume of 9 cubic meters and an arbitrary height of 1.5 meters to determine area:

$9\ m^3 \div 1.5\ m = 6\ m^2$. What is the diameter of a circle with an area of $6\ m^2$?

-Try a diameter of 2 m. $\frac{2^2}{4}$ x pi = 3.14 (too small)

-Try a diameter of 3 m. $\frac{3^2}{4}$ x pi = 7 (too large)

-Try a diameter of 2.75 $\frac{2.75^2}{4}$ x pi = 5.94 (close enough)

* pi = 3.14

Ask the participants if they understand how to determine the diameter of a cylindrical tank and are ready to try a few examples in pairs. If they are, let them try some themselves, if not give a third example and go through the math slowly. Give the pairs 15 minutes to practice the determination of the diameter.

Note: For participants who are adept at using calculators with square root computations on them you can introduce them to the following equation for determining exact diameter from a given area of a circle.

$$D = 2 \times \sqrt{\frac{\text{Area}}{3.14}}$$

(The diameter is equal to two times the square root of the area divided by pi. First, divide the area by 3.14; take the square root of that number and multiply it by two. Give them a chance to practice the formula.)

Finally, after the group has had a chance to practice all three computations and you have answered any of their question about how to do these computations, ask the pairs to compute the dimensions of various kinds of tanks using the tank volume arrived at in Session 7. Draw plans of these various tanks on a flipchart and discuss the advantages and disadvantages of the various sizes and configurations for the selected site and system. During the discussion make the following points:

- Walls of an above-ground tank cannot be higher than the level of the gutters.
- It is very important that the walls of a buried or partially buried tank come up above ground surface to keep dirty water from flowing in.
- Rock in the soil may limit the depth of the hole for an underground tank.
- Underground tanks require pumps or buckets to lift water out.
- Not all the water in a tank can be used: buckets cannot lift out the last several centimeters, and a tap must be located several centimeters above the floor so it will not clog.
- Local conditions must be taken into consideration.

Decide on the tank dimensions. Write them on a sketch on the blackboard.

Take a break at this point.

4. <u>Calculating Quantities of Materials</u> Time: 40 minutes

Ask the participants to turn to <u>Handout 9-1: Tank Design Guide</u> and <u>Handout 9-2: Calculation Sheets</u> (there are eight of them) and look at the first two sheets. Point out that the formula used for the volume of a cylinder in this guide is $\frac{D^2}{4}$ which is the same as $\left(\frac{D}{2}\right)^2$. The computation can be done either way.

Explain that the numbers in the last column of Handout 9-1 refer to the number of the calculation sheet used to determine the quantity of the materials needed to construct such a tank. Tell the trainees that the next 45 minutes of the session will be devoted to using these sheets to determine quantities of materials.

Go over Calculation Sheet #1 with everyone. Point out first that the sheet is used to determine the amount of cement that will be needed in a variety of cylindrical tanks made out of mortar. In order to do this one must first determine the thickness of the wall and multiply it by the total area of the wall (i.e., the circumference x the height). Once the amount of mortar in the wall is determined, one can compute the amount of cement needed to make that much mortar with the formula given in the sheet, i.e., bags of cement needed = mortar needed x $\frac{\text{10 bags cement.}}{\text{m3 of mortar}}$

(Note: This formula is based on a 50 kg. sack of cement and mortar made with a 1:3 mixture of cement to sand.)

Go through each step of the calculation sheet ("a" to "e") with the trainees and make sure that they understand the reason for each step and how to do the calculation. Give a simple example such as a cement mortar jar with a height of 1 meter and a diameter of 60 cm and do the computation. Do another example with the group. Then ask the group to return to their pairs and do a couple of examples on their own for five minutes. When they are done ask for some of the examples and answer any questions.

Go on to the next calculation sheet and repeat the same process, explaining the subject of the calculation and the individual steps and giving one or two examples from the Trainer Refernce Notes which follow Handout 9-2. Explain that the thickness of plaster will depend on the job being done and that some common applications are given in the construction procedures in Session 13. Ask if the trainees understand the sheet and give them five minutes to practice computations in pairs.

Then briefly introduce the next three calculation sheets (2 through 5) as above, ask if there are any questions, and give the participants 10 minutes to do a few examples. See Trainer Reference Notes for the information you will need to have available for doing calculation sheets 4 and 5. This includes brick or block size and the number per square meter of wall, and mortar needed to lay 100 bricks. After they have finished ask if there are any questions. Then introduce the last three sheets and tell participants that they should use them to practice some examples after the session and that there will be time to discuss problems if they have any with their calculations.

5. <u>Calculating Materials for the Tank Under Construction</u> Time: 15 minutes

Divide the group into the number of calculations relevant to the type of tank under construction or the one agreed upon for the purposes of the design exercise, and have each group calculate the materials needed for the tank (i.e., cement for plastering, cement for laying brick, concrete for foundation, number of bricks, etc.). Have each group complete the calculations in 10 minutes and write the material quantity up on the blackboard or flipchart. Ask the groups what other materials they will need for each task (i.e., sand and water for mortar; sand, gravel and water for concrete; reinforcing rod for foundation, pipes for above-ground walls, etc.) and write these on the blackboard or flipchart as well. With the group try to estimate or calculate the quantities of these materials as well.

6. Examine Results and Discuss Materials Needed — Time: 30 minutes

Go over the list of materials developed in Step #5. Return to the list of rainwater catchment system components developed in Step 2 and solicit all other materials needed for each component of the system. Each of the following should be covered in this exercise:

- Foundation of tank
- Walls and floor of tank
- Waterproofing finish for floors and walls of tank (usually cement mortar)
- Tap or bucket hole (hardware for tap or reinforcement for rim of hole)
- Inlet hole and screen
- Tank cover
- Overflow hole and screen
- Rock or gravel for drainage in overflow and outlet areas, if needed
- Foul flush mechanism or filter
- Downpipe
- Gutters (including materials for hanging them)

The resulting list of materials will be a shopping list including items ranging from rock and gravel to coarse metal screen. For each of the materials on the list, write a quantity and a source and an estimate of cost.

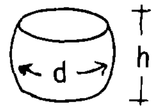
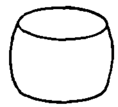
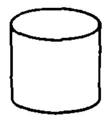
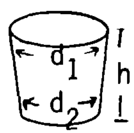
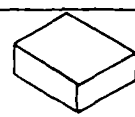
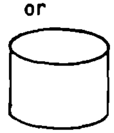
7. Conclusion — Time: 5 minutes

At the end of the above activity there will be some question marks: unsolved quantities, sources, and costs. Have the group assign one or more of its participants the task of finding the information needed in consultation with the trainer. Review the session objectives and goals. Link to the afternoon practical session on inexpensive guttering technologies and Sesson 11 on the next day.

MATERIALS

- Handout 9-1: Tank Design Guide
- Handout 9-2: Calculation Sheets
- Flipchart for session goals and objectives
- Flipcharts with examples of computations for Step 3

TANK DESIGN GUIDE

Tank Group	Shape	Formula	Example	Materials	Calculation #
Cement a. mortar jar		$\frac{d^2}{4} \pi h$	if V=0.5m^3 d=0.8m h=0.8m	Cement mortar (walls) Concrete (foundation)	1 3
b. plastered baskets or bamboo-cement tanks		$\frac{d^2}{4} \pi h$	If V=2.7m^3 d=1.5m h=1.5m	Cement mortar (walls) Concrete (foundation)	1 3
c. ferrocement tank		h slightly less than d $\frac{d^2}{4} \pi h$	If V=10m^3 d=2.5m h=2.0m	Cement mortar (walls & floor) Metal sheet (cover) Wire netting (walls, floor, cover) Concrete (foundation)	1 No calculation 7 3
d. ferrocement lined		$\frac{d_1 + d_2}{8}^{2} \pi h$	If V=20m^3 d=3.5m h=2.0m	Cement mortar (walls & floor) Cement mortar (cover) Wire netting (walls, floor, cover)	6 8 7
e. poured (or cast) concrete		h usually less than l and w	If V=20m^3 h= 2m l=3.2m w=3.2m	Concrete (walls, floor) Reinforced concrete (cover)	3 No calculation
f. brick, stone, or concrete block tank	 or 	V = l x w x h, w usually less than 2m $\frac{d^2}{4} \pi h$ d may be more than 2 m, h usually less than d	If V=20m^3 w=1.5m l=5m If V=20m^3 d=3m h=2.8m	Brick, stone, or block (walls, floor) Cement mortar (laying walls, floor) Cement mortar (surfacing) walls, floor)	4 5 2
g.	area of circle area of circular wall (cylinder) area of rectangle	$\pi \frac{d^2}{4}$ πdh = l x w x h			

CALCULATION SHEETS

1. Calculation #1: Cement in mortar walls for above ground cylindrical containers

Height		Wall Thickness	Typical Container Type
1.0 m	=	1.0 cm	Cement Mortar Jar
1.5 m	=	2.5 cm	Plastered Basket
1.75 m	=	3.0 cm	Ferrocement Tank (1.75 m^3 volume)
2.0 m	=	4.0 cm	Ferrocement Tank (10 m^3 volume)

[Note: Walls in these kinds of tanks are rarely more than 2 m high]

Steps:

a. Using wall height (h), determine wall thickness from above chart.

b. Calculate the area of the wall:

> Area = pi x diameter x height

c. Multiply the wall area by the wall thickness to determine the amount of mortar needed:

> Mortar needed = area x thickness

d. Multiply the amount of mortar needed by 10 bags cement/m^3 mortar, to determine the amount of cement needed.

> Bags of cement needed = mortar needed x $\frac{\text{10 bags cement*}}{m^3 \text{ mortar}}$

e. Cost = bags of cement needed x price/bag

* 50 kg bags of cement. Based on a cement to sand ratio 1:3. This is a recommended figure for watertight mortar. Local masons may use less cement (more sand), and the formula would have to be adjusted accordingly. Mortars with 1:2 cement:sand use 13 bags of cement per m^3 of mortar.

2. Calculation #2: Cement mortar for plastering over walls and floors made of other materials

Steps:

a. Calculate area to be plastered:

Area = See Handout 9-1: Tank Design Guide, item "f".

b. Multiply the area by the thickness of mortar to be applied to determine the amount of mortar needed:

Mortar needed = area x thickness

c. Multiply the amount of mortar needed by 10 bags cement*/m^3 mortar, to determine the amount of cement needed:

$$\text{Bags of cement needed} = \text{mortar needed} \times \frac{\text{10 bags cement*}}{m^3 \text{ mortar}}$$

d. Cost = bags of cement needed x price/bag

---

* 50 kg bags. Based on a cement to sand ratio of 1:3. This is a recommended figure for watertight mortar. Local masons may use less cement (more sand), and the formula would have to be adjusted accordingly. Mortars with 1:2 cement:sand mixtures for final waterproofing coats use 13 bags cement per m^3 of mortar.

3. Calculation #3: Cement in concrete walls, foundations and floors

Steps:

a. Choose a thickness, checking with local people who work with building materials.

Some suggested thicknesses for tanks:

Foundations (tanks up to 2 m high or deep): 7.5 cm
Walls and floors: 10-20 cm, depending on reinforcement.

b. Calculate the area of the wall, foundation, or floor:

Area = See Handout 9-1: Tank Design guide, item "f".

c. Multiply the area by the thickness to determine the amount of concrete needed:

Concrete needed = area x thickness

d. Multiply the amount of concrete needed by 7 bags cement*/m^3 concrete, to determine the amount of cement needed.

$$\text{Bags of cement needed} = \text{concrete needed} \times \frac{\text{7 bags cement*}}{m^3 \text{ concrete}}$$

e. Cost = bags of cement needed x price/bag

---

* 50 kg bags. This is a recommended amount of cement for strong all-purpose concrete using a mixture of 1:2:3 cement to sand to gravel. Local practices may vary. Mixtures with more gravel and therefore less cement use a lower cement per m^3 concrete formula.

4. Calculation #4: Amounts of brick, stone, or block in tank walls and floors

Steps:

a. Consult masons (who have built walls to hold water) to choose wall thickness.

Suggestions:

Walls (supported by earth): 15-20 cm
Walls (more than 1 m height unsupported by earth: 30 cm
Floors: Same as walls

b. Determine the number of bricks (stones or blocks) needed to build 1 m x 1 m of wall or floor: $\frac{\text{bricks}}{m^2}$

c. Calculate the area of wall or floor to be laid:

Area = See Handout 9-1: Tank Design Guide, item "f".

d. Calculate the number of bricks (stones or blocks) required:

Number of bricks = area x $\frac{\text{bricks}}{m^2}$

e.

Cost = number of bricks x price/brick

5. Calculation #5: Cement in mortar for laying walls and floors of brick (stones or block)

Steps:

a. Consult masons to find out how much mortar (in m^3) they need to lay 100 (or any number of) bricks:

$$\frac{\text{mortar } (m^3)}{100 \text{ bricks}}$$

b. Multiply by the number of bricks (calculated in calculation 4d) to determine the amount of mortar required:

$$\text{Mortar needed} = \text{number of bricks} \times \frac{\text{mortar } (m^3)}{100 \text{ bricks}}$$

c. Multiply the mortar needed by 10 bags cement*/m^3 mortar, to determine the amount of cement needed:

$$\text{Bags of cement needed} = \text{mortar needed} \times \frac{10 \text{ bags cement*}}{m^3 \text{ mortar}}$$

d. $$\text{Cost} = \text{bags of cement needed} \times \text{price/bag}$$

---

* 50 kg bags. Note same as for calculation #2

6. Calculation #6: Cement in mortar walls and floor of circular ferrocement-lined pit

Steps:

a. Calculate the area of the pit to be lined:

Area of walls = pi x diameter x height
Area of floor = pi x $(1/2 \text{ diameter})^2$
} Total area

b. Multiply the area by the thickness of plaster to be applied. To be safe, assume a thickness of 4 cm (less may actually be needed):

Mortar needed = area x thickness

c. To find the amount of cement needed, multiply the amount of mortar by 10 bags cement*/m^3 mortar:

Bags of cement = mortar needed x 10 bags cement*/m^3 mortar

d. Cost = bags of cement x price/bag

* 50 kg bags. Same note as for calculation #2

7. <u>Calculation #7</u>: Wire netting in circular ferrocement tank (above ground) and ferrocement pit (below ground) floors, walls, and covers

Steps:

a. Decide on the number of layers of wire netting to be used. Recommendations:

Ferrocement tank walls (with wire reinforcement)	:	1 layer
Ferrocement pit walls and floors	:	2 or 3 layers
Ferrocement cover	:	3 layers

b. Calculate the area of wall, floor, and/or cover:

Area of wall	=	pi x diameter x height
Area of floor	=	pi x $(1/2 \text{ diameter})^2$
Area of cover*	=	pi x $(1/2 \text{ diameter})^2$

c. Multiply the areas by the number of layers to get the area of netting needed:

Netting needed = area x number of layers

d. Cost = netting needed x price/m^2

Note: wire netting is sold in widths which may need to be trimmed to correct size during construction. Thus, one must buy more than will actually be used.

---

* Ferrocement covers are higher in the middle (domed) to support their weight. The area of the dome is slightly greater than the circle it covers.

8. <u>Calculation #8</u>: Cement mortar for covers of ferrocement lined pits

Steps

a. Calculate the area of the cover. The diameter must be slightly larger than the diameter of the top of the pit.

$$\text{Area} = \text{pi}\ (1/2d)^2 *$$

b. Determine the thickness of the cover. This is about 5 cm for a cover 3-4m in diameter which is reinforced with steel netting and steel bar.

c. Go to step b in calculation #2 and finish the calculation.

---

* Note: the cover is domed, so its area is slightly greater than the circle it covers. Allow an extra bag of cement for this increase in area. A simpler formula is pi $\frac{(d)^2}{4}$ this calculates to .77 x d^2.

TANK DESIGN AND CALCULATIONS

1. Calculation Sheet #1: Cement in mortar walls for above ground cylindrical containers

	Height		Wall Thickness	Typical Container Type
(1)	1.0 m	=	1.0 cm	Cement Mortar Jar
(2)	1.5 m	=	2.5 cm	Plastered Basket
(3)	1.75 m	=	3.0 cm	Ferrocement Tank (1.75 m^3 volume)
(4)	2.0 m	=	4.0 cm	Ferrocement Tank (10 m^3 in volume)

[Note: Walls in these kinds of tanks are rarely more than 2 m high].

The table shows how wall thickness is related to height for four particular containers described in published accounts. For example, (1) represents a cement mortar jar with height just under 1 m. The thickness of its walls was about 1.0 cm. The second item (2) represents a Kenyan plastered basket, which was taller (1.5 m) and had thicker walls (2.5 cm) than the jar. The third (3) is for a small ferrocement tank, and the fourth (4) the ferrocement tank with volume of 10 m^3.

Wall area = pi dh
= pi (2.5 m) x (2 m)
= pi 15.7 m^2

Mortar needed for wall = area x thickness
= 15.7 m^2 x 0.04 m*
= 0.63 m^2

* Walls 2.0 m in height have to be 4 cm or 0.04 m in thickness according to the above table.

2. Calculation Sheet #2

The same procedure can be used to calculate the amount of mortar needed to plaster over a wall made of another material such as stone, brick, or concrete. For example, to plaster the floor of the same tank used in the previous example (i.e., with a diameter of 2.5 m) to a thickness of 5 cm (.05 m),

Floor area = pi $(1/2d)^2$
= pi $(1.25\text{ m})^2$
= pi 4.9 m^2

Mortar needed for floor = area x thickness

$= 4.9\ m^2 \times 0.05\ m$

$= 0.25\ m^3$

To plaster the inside walls of the brick tank with interior dimensions of 2 m x 3 m x 1.5 m to a thickness of 3 cm, the calculation would be:

Total Wall Area = $2 \times (l \times h) + 2 \times (w \times h)$*

$= 2 \times (3\ m \times 1.5\ m) + 2\ (2\ m \times 1.5\ m)$

$= 2\ (4.5\ m^2) + 2\ (3\ m^2)$

$= 15\ m^2$

Mortar needed for wall plaster = area x thickness

$= 15\ m^2 \times 0.03\ m$

$= .45\ m^3$

* The interior wall area of a tank requires adding all four surfaces (length x height) + (length x height) + (width x height) + (width x height) or 2 (l x h) + 2 (w x h).

3. <u>Calculation Sheet #3</u>

The prescribed thickness of concrete to be used in a watertight wall varies a great deal. In rich countries, the reinforced concrete walls of cisterns are often 25 cm thick. In Thailand unreinforced (or bamboo-reinforced) concrete rings, only 5 cm thick, hold the same depth of water. Methods of mixing, pouring, reinforcing, and curing all greatly affect the ability of concrete to withstand loads without cracking.

Below is an example of how to calculate the cement needed for a concrete floor.

- Figure the volume of concrete needed for a 2.8 diameter floor which will be 7.5 cm thick:

  Area = pi x r^2

  3.14×1.4^2 = pi x r^2 = Area

  $3.14 \times (1.4)^2 = 6.2\ m^2$

Volume = area x thickness
= $6.2\ m^2 \times 0.075\ m$
= $0.47\ m^3$

- Figure the amount of cement needed to make the concrete. Concrete mixed in the proportions 1:2:3, for cement:sand:gravel is strong enough for self-help floors, footings, and walls when made with clean materials and cured properly.* Concrete mixed 1:2:3 contains about 7 bags of cement (@ 50 kg per bag) per cubic meter. Using this information, we can figure the number of bags needed.

Bags of cement = volume of concrete x $\frac{7\ \text{bags}}{m^3\ \text{concrete}}$

= $0.47\ m^3 \times \frac{7\ \text{bags}}{m^3\ \text{concrete}}$

= 3.3 bags

- Figure the cost, using the price of a bag of cement in your area. For example:

Cost = # of bags x price per bag
= 3.3 bags x $20.00 (for example)
= $66.00

---

* Determined by using the "concrete calculator," Village Technology Handbook, VITA (1973). You may decide to use a lower proportion of cement. The "concrete calculator" shows how to adjust the volumes of the other materials.

4. Calculation Sheets #4 & 5

Water-holding walls of brick, stone, or block are built to a wide variety of specifications. Quality of materials, whether or not walls are supported by earth, and construction technique all determine how thick a wall must be. People who have lined wells with masonry have done much the same thing as building tank walls. Learn from their experience. Ask the construction foreman or local mason to give you the size of locally available bricks or blocks. Compute the number needed for one square meter of wall or foundation at the desired thickness (for sheet #4) and the amount of mortar (in m^3) they need to lay 100 bricks (or any specific number of bricks or blocks)(for sheet #5). Have these figures available when introducing these sheets.

5. Preparing the Hole for the Tank

Dig down to firm soil or rock, in most cases at least 50 cm. As you plan the depth of the hole, remember that the wall of the tank should rise at least 30 cm above ground level (to keep out surface water and dirt); however, the wall should not rise more than 100 cm above ground level unless it is thickened, or an earth bank is later built against it.

Deepen the hole slightly where the "sump" will be located. The "sump" is a depression built into the floor for scooping out mud and debris each time the tank is emptied. If the tank is much longer than it is wide, the sump can be a shallow trough along the length of the tank floor.

If the materials are available, the floor should be made of concrete laid on top of 10 cm of sand and gravel. A floor thickness of 15 cm is probably sufficient for a tank 3 m deep; some sources recommend 20 cm. If wire mesh of any kind is available, it should be laid on the gravel foundation. If the floor of the tank is to be made of the same material as the walls, it should be at least as thick as the walls (explained below). Reinforcing mesh can be placed between brick or stone layers.

If the walls of the tank are to be more than two meters high, they should be built on a supporting pad or "footing" which can be made of concrete or masonry at the same time as the floor. Extend any mesh or reinforcing material from the floor into the footing.

If concrete is used for the floor, make the depression or trough for the sump before the concrete stiffens. Figure 1 is a drawing showing the details of the floor.

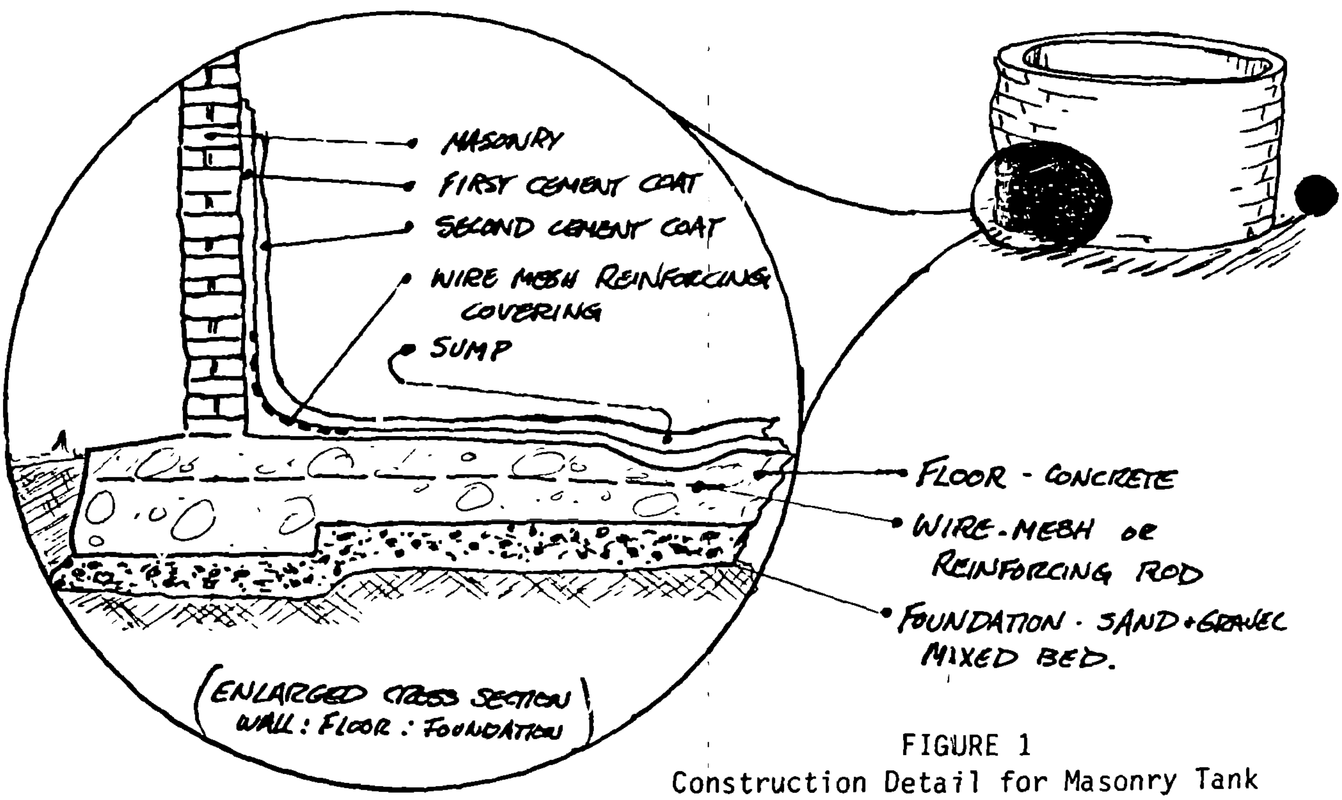


FIGURE 1
Construction Detail for Masonry Tank

6. <u>The Walls of the Tank</u>

The walls are built up from the floor or from the footing. Cairncross and Feachem (Small Water Supplies) recommend that brick or masonry walls be at least 30 cm thick. In fact, masonry walls to retain water are often built somewhat thinner than this, even when they are not supported by earth. The thickness chosen will depend upon local experience, and this choice should be made in consultation with local brick-layers or masons.

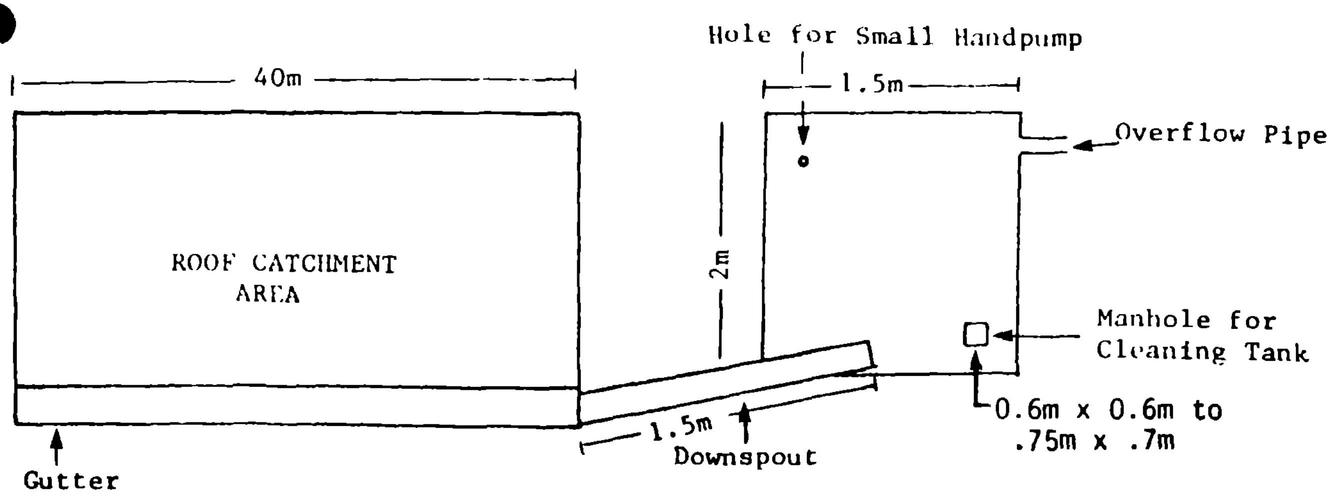
The mortar used should be mixed carefully in the proportions 1:4 cement:sand (measured by volume). If the walls are built of brick, wet the bricks before laying them. This will help the mortar to cure more completely.

If water is to be drawn out of the tank by a tap, an outlet pipe for the tap should be built into the wall about 10 cm above the floor level so that it will not be clogged with mud or debris. Every tank must have some kind of outlet for overflow which does not allow the water level to rise all the way to the roof; usually this overflow outlet is a piece of pipe built into the upper part of the wall. This pipe should have a diameter at least as large as the diameter of the pipe or gutter bringing water into the tank, and it must be screened to prevent insects or small animals from getting in.

7. <u>Using a Diagram</u>

- The trainer may wish to add to the training in Step 6 to give the group more experience in working with the design and communicating the design to construction masons. To do this, the following is suggested:

- The trainer explains that in order to look at the design in more detail, we need to consider each part of the tank and system and be able to communicate it to the construction masons who will build the system. Using the system which is now under construction, the trainer sketches a top view diagram with appropriate dimensions. For example:



Then the trainer asks for a volunteer to draw a side view of the demonstration tank that will show all of the elements of the construction. The trainer monitors and guides this activity to ensure that nothing is forgotten (foundation, walls, top slab, slope of the foundation floor or sump for cleaning, wire mesh to cover overflow pipe, size of pipe, etc.).

The trainer should then add in the other parts of the system and include the costs and materials needed: gutter and downspouts. (If time is short, this may be given as an assignment to be done before the next session.)

SYNOPSIS

SESSION 10: Thatch Roof Catchment with Bamboo Gutters and Charcoal Filter

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discussion	5	Handout 10-1: Design Drawings for a Simple RWC System for a Thatched Roof	Goals and Objectives
2.	Constructing the Guttering System	Lecturette/ Discussion	20		Major Talking Points from Design Sketches
3.	Choosing a Suitable Thatch Roof	Observation/ Discussion	15	Handout 10-2: Typical Materials Estimates	
4.	Constructing the Guttering System	Practical Work	1 hr. 15 min.	Construction Materials	
5.	Constructing the Filtration System	Lecturette/ Discussion	15	Handout 10-3: Filtering System (Handout 10-4: Using Coconut Fiber Filters)	Major Talking Points Regarding Filtering Systems
6.	Constructing the Filtration System	Demonstration/ Practical Session	30-60	Construction Materials	
7.	Reviewing Maintenance	Discussion	5	Handout 10-4: Using Coconut Fiber Filters	
8.	Reviewing the Learning	Discussion	15		
9.	Closure	Summary	5		
			TOTAL: 3 hours, 5 to 35 minutes		

Session 10: Thatch Roof Catchment with Bamboo Gutters and Charcoal Filter*

GOAL

Total time: 3 hours & 5 to 35 min.

To learn how to design and construct a roof catchment and filtration system for thatch roofs.

OBJECTIVES

At the end of this session participants will be able to:

- Select an appropriate thatch roof for collecting rainwater
- Construct and attach or place bamboo gutters appropriately using a bush pole support structure
- Build one of two alternative charcoal filtering systems using burnt rice husk or crushed charcoal as the filtering medium**
- Understand the maintenance requirements of the filtration device

OVERVIEW

In many parts of the world it is not always possible to use zinc or other hard surface roofs for rainwater catchment. Many villages will have roofs which are constructed with thatching using locally available materials such as palm leaf, woven grass, or other thatching. These materials are quite inexpensive (usually free) and very durable over many years. The first major objection to using a thatch roof to collect run-off is that the water appears dirty (often yellowish) and has the smell of decomposed leaves. However, with a simple filtration device made of crushed charcoal or burnt rice husk, the water will become clear. Foul flush procedures are followed as in the other systems. The second major objection to thatch is the relative difficulty of guttering. This obstacle is overcome in this session with the use of a free-standing tripod or bush-pole supported gutter which can be removed easily and stored during the dry season to prevent cracking if split bamboo is used. The major advantage to using this system is its simplicity and low cost.

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* If thatch roofing is not used in the workshop location and bamboo is either unavailable or inappropriate for guttering, this session may not be necessary. In that case, move Session 13 up to Day 5 and keep Saturday afternoon free.

** For an alternative filtering medium using coconut fiber instead of gravel and charcoal, see Handout 10-4.

ACTIVITIES

1. Introduction Time: 5 minutes

Introduce the session by presenting the material in the overview (above) in your own words. It is important to point out the normal reservations people have about using thatch roof catchment and to counter these reservations which are overcome with proper filtration and guttering. The advantages of low cost, simple materials should be pointed out. Relate this to the previous day's practical session on building small storage tanks. After discussing this, state the goals and objectives of the session. Tell the participants what they can expect to do in the session (construct a guttering system and make a filter) and inform them of the time available.

2. Lecturette/Discussion: Constructing the Guttering System Time: 20 minutes

Display a sketch of the Figure on page 1 of Handout 10-1: Design Drawings for a Simple RWC System for a Thatched Roof on the flipchart. Point out each part of the system (using split bamboo, split palm, wood or other material for gutters, supports, ties) on the drawing and explain how it is constructed. Explain the need for building the flow path of the water by sloping the gutters gradually.

Referring to the sketch of the guttering system, make the following key points:

- The gutters can be made of split bamboo, split palm or wood boards. Bamboo, if available, is the best choice.
- Bamboo should be thick (15-20 cm) and strong. It can be simply split lengthwise with a machete and the diaphrams removed with a machete or knife. Bamboo can be cut in the lengths needed or overlapped at supports and tied firmly.
- The gutters can be supported by simple poles with a V notch at the top, or by simple tripods which are tied together at the top and buried about 30 cm in the ground at the bottom to make them stable.
- The gutters are tied on the tripods using wire or a locally available heavy string.
- Each pole or set of three poles (making up a tripod) in a row is cut shorter than the last in order to ensure a slope into the filter and storage vessel (this is demonstrated in the practical session).

Before leaving the classroom for the construction site ask the group to describe the characteristics of a thatch roof which would be suitable for a rainwater catchment system. Discuss size and height of the roof, quality of the thatch, strength of the rafters, etc. After this discussion, ask if there are any final questions before starting work.

3. Choosing a Suitable Thatch Roof for a Rainwater Catchment System — Time: 15 minutes

On the way to the construction site, walk through the village and point out thatch roofs and discuss their suitability for catching water. Discuss the materials used for the thatch, how well it sheds water, how often it has to be replaced, the height of the roof line, condition of the rafters and how gutters could be attached or whether they have to be free-standing. When arriving at the house selected for the demonstration, point out why it was chosen and discuss.

4. Constructing Bamboo Gutters and Supporting Them with Poles — Time: 1 hour 15 minutes

Have all materials ready at the site (see Handout 10-2: Typical Materials Estimate). Break the group into three or four teams based on the number of participants and the design of the guttering system to be constructed. Distribute Handouts 10-1: Design Drawings for a Simple RWC System for a Thatched Roof.

Give the teams the following instructions:

A. Split bamboo lengthwise with a machete and heavy stick for pounding the machete blade. Cut out diaphrams when split.

B. Design supports for the bamboo gutters so they will be held securely in position to catch water running off the roof, and slope at 1 percent down toward the downspout.

C. Cut the V-notch poles or tripod poles and place them in the ground for the 1 percent slope. Verify the slope with string. Fix the poles securely with stones and dirt and lash gutters into place with wire or local rope. Attach to downspout or position above platform for filter depending on design.

(Note: The easiest guttering system to demonstrate is a single, straight line of bamboo gutters supported by V poles pouring freely into a filter. There are advantages for demonstrating how to attach gutters at right angles and to downspouts and for collecting water from both sides of the roof, but the decision whether or not to demonstrate these fine points should be based on the number and skills of the participants. See Handout 6-2 from Session 6 for information on guttering systems).

When the gutters are connected, test them with water and discuss what the participants have learned about constructing and installing bamboo gutters. Remaining at the site, go on to the next step.

5. <u>Lecturette/Discussion: Constructing the Filtration System</u> Time: 15 minutes

Distribute a copy of Handout 10-3: Filtering Systems to each participant and explain the major component of the filter (depending upon local conditions, you will have selected either a 200 liter metal drum or wooden box for demonstration purposes) by pointing out each element as follows:

- The pea gravel in the bottom keeps the rice nusk charcoal or the crushed wood charcoal from clogging the perforated holes in the bottom of the filter. The wood charcoal must be crushed to the size of rice husks to work properly.

- The charcoal does the job of filtration. It will remove the odor and the yellowish color of the rainwater. (The use of sand is optional; it will help remove insects and any dirt. A 30 cm layer of sand over the gravel will suffice).

- The large gravel on top keeps the rice husk or crushed charcoal from blowing out and compacts it with its weight so that the filter is tight and stable.

- The box or barrel has holes perforated in the bottom (either with a hammer and spike or drill). Place holes only in the center of the tank in case the jar has a narrower mouth than the oil drum. Punch holes from inside out to make the filter easier to clean inside.

- The filter is placed directly over the cistern or set on a platform over a large clay jar (from which the water is dipped into other containers).

- A filter such as this will produce clear water for several weeks. If it gets clogged, or the water starts getting yellow, then it is time to change the charcoal (usually once or twice a rainy season, depending upon rainfall).

- The dimensions of the filter and the depth of the charcoal and gravels, have proven to be effective in tests in Southeast Asia. This filter will handle the run-off for a 40 square meter roof (an average sized rural family dwelling). If you have a larger area, we suggest you construct two filters and divide the run-off with a supplementary downspout (a Y shaped connector should work).

After making the above points, answer any questions. Then prepare to move the trainees to a hands-on experience in the next step where they put a filter together and mount it on top of the storage facility.

6. <u>Constructing the Filtration System, Demonstration</u> Time: 30 to 60 minutes

In this demonstration, the group will learn how to burn rice husk into a charcoal-like medium (if this is the chosen option) and put together the filter. We assume that the process of loading the material into the container is very straightforward. Therefore, let volunteers from the group put the materials into the container referring to the materials list in Handout 10-2: Typical Materials Estimate and the diagram in Handout 10-3: Filtering Systems.

We suggest that the trainer have all of the materials prepared in advance and ready to go. If a metal drum is used (the easiest option), the process of perforating holes in the bottom can be done by the group using a hammer and a large spike or a hand drill (if readily available in the local environment). The construction steps for building the wooden box filter are included in the trainer notes. For the rice husk demonstration, the trainer will need to have a "before and after" exhibit set up (i.e., some unburned raw rice husk and some already prepared and burned rice husk). If wood charcoal is to be used have it crushed to the size of rice husks before the start of the demonstration. Conduct the demonstration as follows:

A. Rice Husk Charcoal Making:

1. Pile 100 litres of raw rice husk in a place out of the wind.

2. Set it on fire and let it burn slowly, occasionally mixing the pile with a shovel until the rice husk is charred and uniformly "toasted" but not burned to ash (i.e., what you are looking for is a fiberous, darkly roasted husk, not an ash).

3. When the husk is charred sufficiently, douse it with water and let it cool.

4. After it is cool, it is ready for use.

B. Loading the Filter:

Load the filter following the diagram in Handout 10-3. Putting in the pea gravel, the charcoal, and the large gravel in that order, measuring the depth after each step.

(Note: It will be easier if the oil drum is on top of the cistern platform before the filtering materials are put in. In order for the participants to remember the depth measurements of the three materials (5 cm pea gravel, 45 cm husk or crushed charcoal, 15 cm large gravel), have them mark the three measurements on their arms or legs so they will have a future reference point on their own bodies.)

After the group has put together the filter, test it with water off the roof and see if there are any questions about the procedure.

7. Reviewing the Maintenance Requirements — Time: 5 minutes

In the previous talk about the filter, you have mentioned when to change the filter (when the filtered water turns color or once or twice a season). At this point the trainer should reiterate these points and hold a brief discussion with the group about what problems might arise in maintenance and some ways the group might anticipate maintenance needs or ways to make it easier to provide maintenance such as preparing enough charcoal for the season in advance and having it stored. (Note: the gravel need not be replaced, it can be saved and used again; it may need to be washed a bit before it is put back into the filter.)

8. Reviewing the Session — Time: 15 minutes

After the field work, return to the classroom or meet in any convenient location and ask the group to review what they have learned. Close the session by asking the group to meet in sub-groups of three persons and to review each of the steps in putting together both gutters and filters. Ask them to record questions they still have; and potential problems they feel they will have in doing this again in the village setting.

After about five minutes, ask each group to report on its discussions and hold a full group question, answer, and discussion session on any issues that have come up.

9. Closure — Time: 5 minutes

Close the session by reviewing the original goals and objectives. Ask the group if they have been met. If there are some areas of doubt left, clear them up at this point. Link this to the next sessions (11 and 13) on planning for the construction of a large rooftop catchment system and starting the work on the tank.

TRAINER NOTES

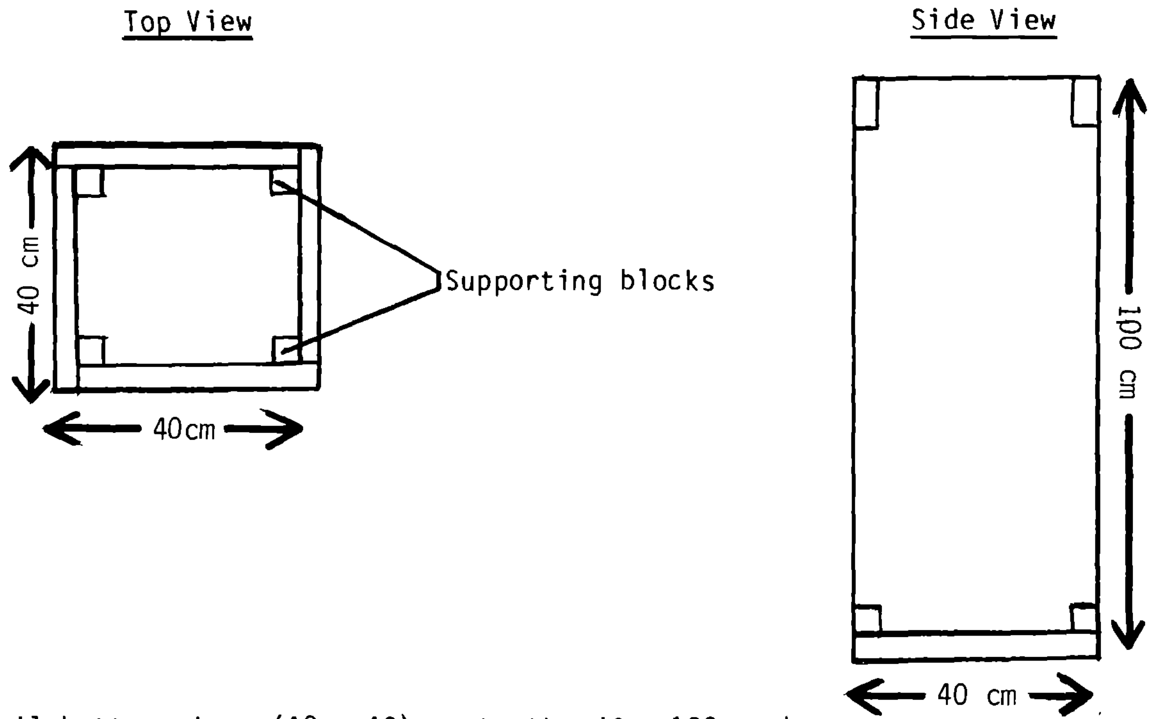
Construction Steps for Wooden Box Filter

1. Cut 4 pieces of 2 cm thick lumber 98 x 38 cm--sides
   1 piece of 2 cm thick lumber 40 x 40 cm--bottom
   8 pieces of 4 cm thick lumber 8 x 10 cm--supporting blocks

2. Drill or punch 10-15 holes .05 mm in diameter in the 40 x 40 cm bottom piece.

3. Nail together the 4 sides piece (98 x 38 cm) at right angles.

4. Nail the 8 supporting blocks in the 4 corners at the top and bottom of the box (see diagram below)



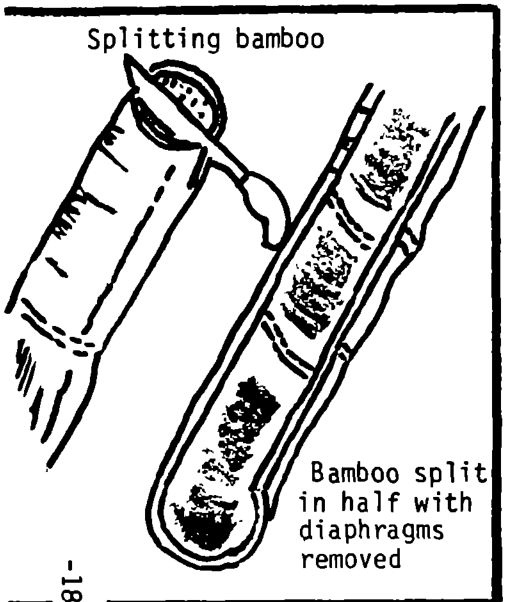
5. Nail bottom piece (40 x 40) on to the 40 x 100 cm box.

6. See box filter illustration in Handout 10-3 for comparison.

MATERIALS

- Flipchart diagrams prepared from Handout 10-1
- Flipcharts prepared of the goals and objectives
- Flipcharts prepared for the major talking points in the lecturettes
- Handout 10-1: Design Drawings for a Simple RWC System for a Thatched Roof
- Handout 10-2: Typical Materials Estimate
- Handout-10-3: Filtering Systems
- Construction tools and materials (see Handout 10-2)

DESIGN DRAWING FOR A SIMPLE RAINWATER CATCHMENT SYSTEM
FOR A THATCHED ROOF



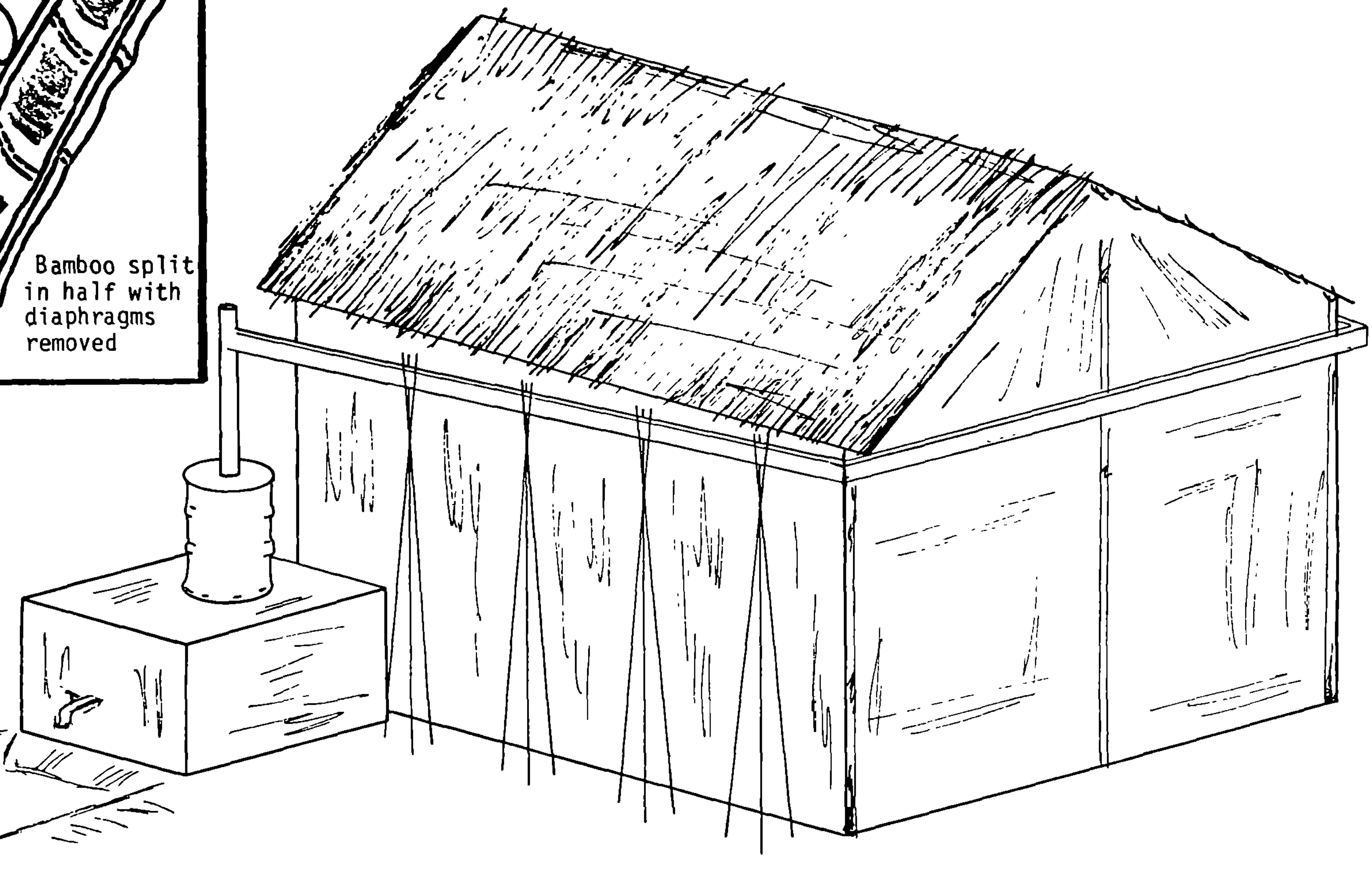


FIGURE 1

HOW TO DETERMINE THE SLOPE OF GUTTER

Assume a slope of 3% - In 10m of gutters, the first tripod is 30cm higher than the last one. Put the tripods (3 poles each) in their place. The slope is determined by placing a string between tripod A and Tripod B. Mark the intermediate tripods accordingly and cut.

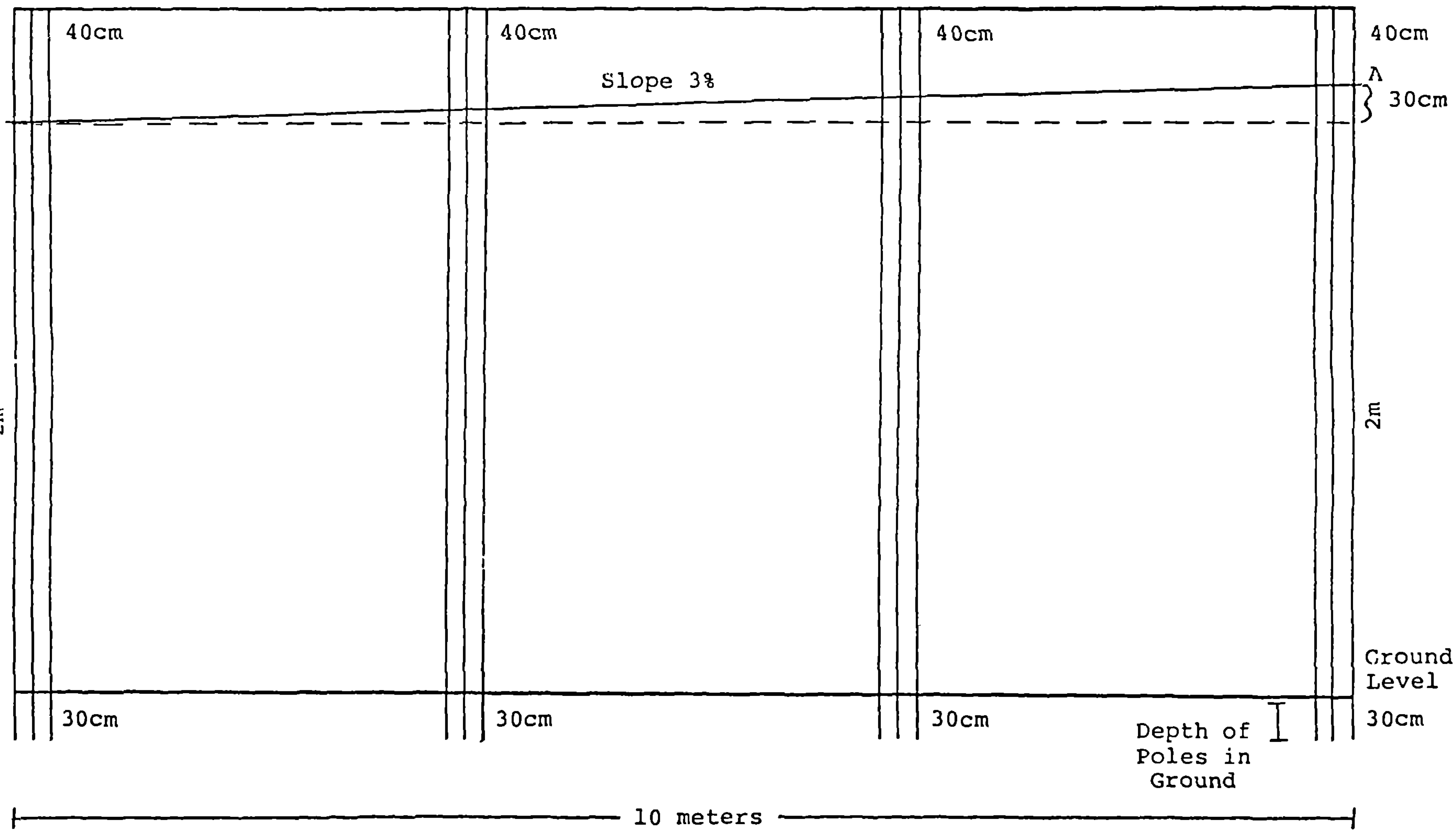
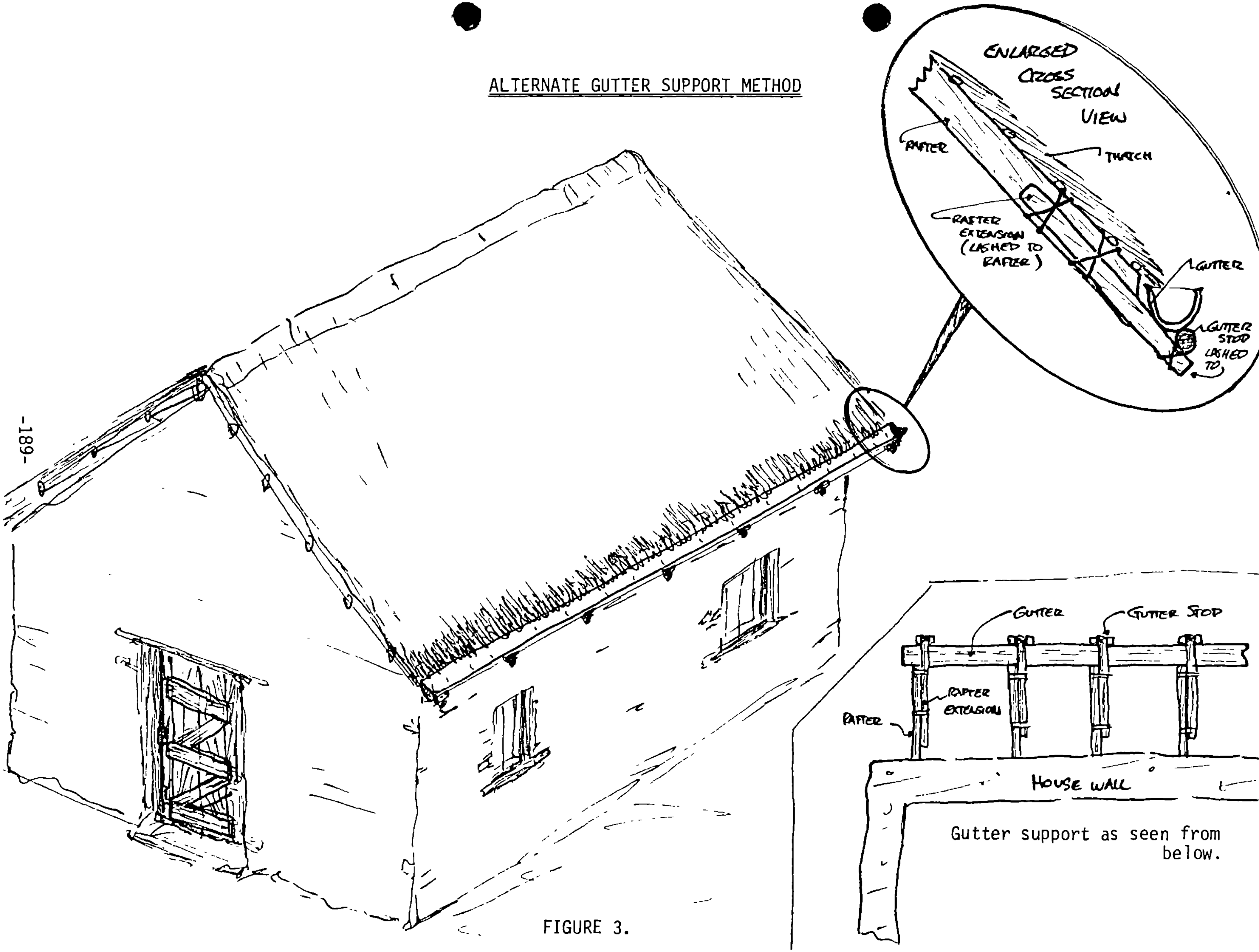


FIGURE 2

ALTERNATE GUTTER SUPPORT METHOD



Gutter support as seen from below.

FIGURE 3.

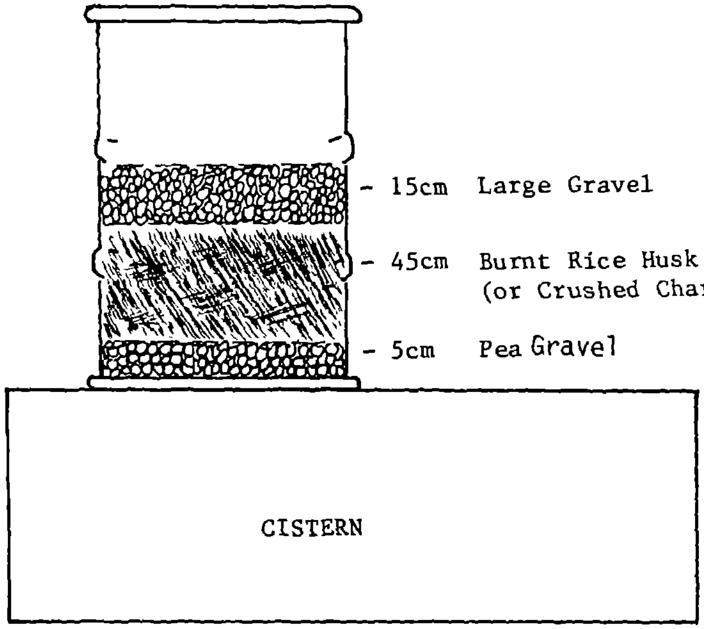
TYPICAL MATERIALS ESTIMATE*

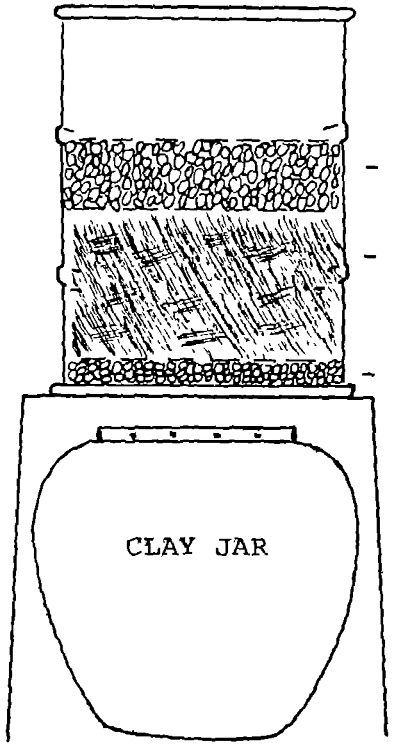
Materials	Quantity	Cost
A. Guttering materials using bamboo, bush pole supports for a roof 10 M long x 4 M wide, collection on both sides of the roof.		
1. Bamboo 15-20 cm in diameter	15 M	
2. 9 V notch poles 5-10 cm in diameter, or 9 sets of poles for tripods (27 poles), 5 cm in diameter and 4 meters long	36-110 M of pole	
3. Twisted wire, or locally available twine	20 M	
Tools: machetes, mallets, knives, digging tools, bucket for water		
B. Filtration System Using a Barrel		
1. Barrel, 200 Liter	1	
2. Gravel (large)	35 Liters	
3. Pea gravel	12 Liters	
4. Raw rice husk	100 Liters	
5. Or charcoal	50 Liters	
Tools: drill or hammer and nail or spike; hammer or mallet for crushing charcoal, tools and materials for making stand for filter		
C. Filtration System Using a Box		
1. Lumber: 40 cm x 2 cm	5 M	
2. Nails	1 Kg	
3. Gravel, rice husk (same as B)		
Tools: Hammer, saw, drill; tools and materials for making stand		

*Note: Since costs vary widely, the cost column is left open for the trainers to fill in depending on the local prices.

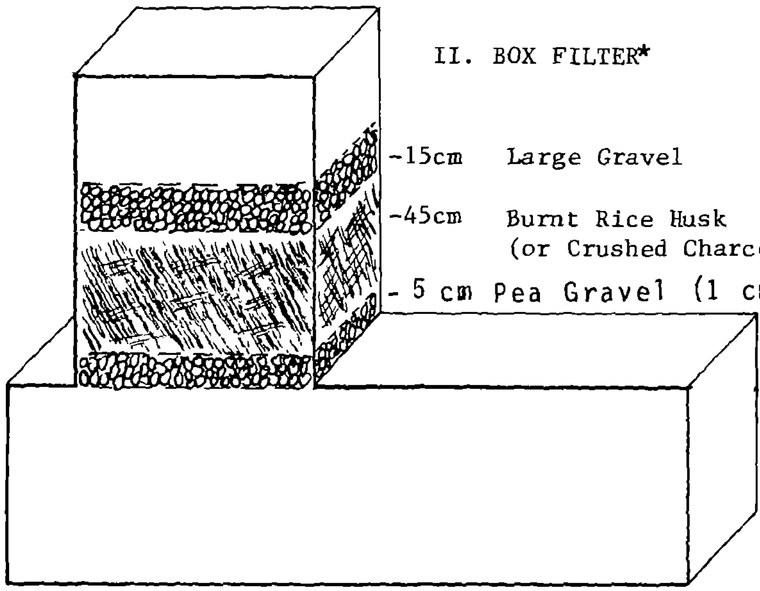
FILTERING SYSTEMS

I. BARREL FILTER





II. BOX FILTER*



*See Trainer Notes

USING COCONUT FIBER FILTERS

Filters using shredded coconut fibers for the filter medium have been said to be successful in Thailand (Frankel, 1974) and have been installed in over 100 rural villages in Southest Asia (Frankel, 1981). The raw coconut husks are found throughout Southeast Asia and have little market value, hence they provide a low-cost filter medium for treatment plants in that part of the world.

Shredded coconut fiber may be prepared manually by soaking the husk for 2 to 3 days in water and then shredding the husk by pulling off the individual fibers and removing the solid particles which bind the fibers. Shredded coconut fibers may also be purchased directly from upholstery stores or coir (coconut fiber) factories. The shredded fiber should be immersed in water for about three days, until the fiber does not impart any more color to the water (Frankel, 1977). The depth of the coconut fiber in the filter box is usually 60-80 cm. There are no backwashing arrangements for cleaning the coconut fibers as the fibers do not readily relinquish entrapped particles because of their fibrous nature. Instead, water is drained from the filter box and the dirty fibers are removed and discarded. Coconut fiber stock, which has been properly cleaned, is then packed into the filter. The filter medium generally must be replaced every three or four months. The availability of the raw coconut husks at low cost, as well as the elimination of backwash pumps and ancillary equipment, combine to make this manual filter bed regeneration process economical in areas where coconut trees are common. The use of such indigenous materials for filter media is also a practical alternative to conventional filter design.

Several small water filter plants ranging in capacity from 24 to 360 m^3/day were constructed from 1972 to 1976 in the Lower Mekong River Basin countries (Thailand, Viet Nam, Cambodia) and in the Philippines (Frankel, 1981). Two-stage filtration, using shredded coconut fibers and burnt rice husks for the roughing and polishing filters, respectively, was typical for all filter plants. The filtration systems generally produced a clear effluent (less than 5 NTU) when treating raw water with a turbidity less than 150 NTU. The units were designed at a filtration rate of 1.25-1.5 m/hr., which is about 10 times higher than that used for conventional slow sand filters. Bacterial removals averaged 60 to 90 percent without the use of any disinfectant. The media generally required changing once very 3-5 months depending on the level of turbidity in the raw water.

SESSION 11

SYNOPSIS

SESSION 11: Planning and Management of the Construction Operations

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5	---	Session Goals
2.	Lecturette/Guided Discussion	Compile Lists	60	---	
3.	Application	Discuss	45	Handout 11-1: Blank Calendar Handout 11-2: Filled Out Calendar	Blank Calendar of Construction Events
4.	Generalization	Discuss	30		
5.	Summary/Closure	Discuss	10	---	

TOTAL: 2 hours, 30 minutes

GOAL — Total time: 2 hours & 30 min.

To learn all of the steps and procedures necessary for detailing, ordering, and managing the materials and labor necessary for constructing a rainwater roof catchment system.

OBJECTIVES

By the end of the session, the participants will be able to:

- Develop a list of all the construction steps needed to complete the system
- Develop a list of key considerations in each construction step necessary to assure completion of the system
- Propose a complete plan for the proper management of materials and resources needed for the construction

OVERVIEW

This session provides training in systematically thinking through all of the little details necessary to conduct a construction project for a rainwater roof catchment system. It uses the experience of the training group to develop check lists and a construction events calendar which will be added to and completed in subsequent sessions.

ACTIVITIES

1. Introduction — Time: 5 Minutes

Present the content of the overview and the goal and objectives for the session. Stress the importance of this session by pointing out that this will be the first review of all activities needed to achieve a complete roof catchment system. A basic planning tool, the construction events calendar (Handout 11-1) for the demonstration site, will be developed and completed by participants during future sessions. This calendar will be added to the project guide for the participants' future reference.

2. Lecturette/Guided Discussion: Compiling Lists — Time: 60 minutes

Present the idea that construction "operations" involve three major aspects: human resources, materials, and financing. To make the most efficient use of these often scarce resources, it is necessary to plan the construction operations well. Ask the participants what the advantages of good planning are. Write their responses on a flipchart. The following points should be made:

- To save time
- To reduce loss
- To avoid improvisation and potential mistakes
- To reduce cost
- To foresee and thus avoid potential problems
- To make the most of the community's participation
- To avoid mixing up other parts of the total work schedule

Discuss these points and solicit examples of problems that the trainers have had in their work because of inadequate planning. Close by pointing out to the trainees that this session is designed to improve their ability to plan and monitor the construction of the large rainwater catchment demonstration system already under construction.

Briefly review with the group the type of tank being built for the demonstration. Ask the participants to describe the major design features and construction materials and technologies being used in the tank construction and to enumerate the steps they think need to be gone through in doing the actual construction project. Write down on a flipchart the steps they mention. Each system design and choice of construction technology will produce a different list. The following example is for a tank made with cement blocks and covered with a concrete slab. Similar steps should be listed for the actual construction which is in process. Point out that these are construction steps and not planning or management steps, which will be considered later:

- Clearing and lay out
- Excavation
- Putting in bed of gravel
- Building the foundation form
- Preparing the reinforced iron grill for the foundation
- Pouring the foundation (including curing)
- Making the cement blocks (or assembling stone for mortared stone wall)
- Constructing the walls and placing the pipes
- Building the forms for the top slab
- Preparing the iron grill for the top slab
- Pouring, curing, and placing the top slab
- Plastering
- Constructing and placing the gutters, downspout, foul flush or filter
- Disinfection of the system
- Putting the system into operation

After all the steps have been listed, review them and place in chronological order along with an estimate of the time it will take to complete each step.

Now lead the group to consider the factors that are needed to assure that the construction can go forward. Give them five minutes to make individual lists of these factors and then list on a flipchart the factors mentioned by them. Make sure that the following are brought out:

- Financing (sources, timing, and management)

- Estimate of all needed materials

- Identification of resources and places for obtaining the materials most inexpensively when needed

- Time needed to acquire materials (include a realistic estimate of potential logistic and transporation problems)

- Storage/security plan for the materials

- Involvement of community in identification and organization of the labor force needed

- Detailed daily construction work plan

- Clear management plan that spells out the responsibilities of each person. Point out that this management plan must be very clear regarding three key items:

  - division of responsibilities
  - training responsibilties (i.e., project masons training village masons)
  - supervision responsibilities

As a wrap-up to this guided discussion, ask what additional step needs to be considered to assure that all the above goes as planned. This should bring out the need to have a continuous evaluation aspect throughtout the entire process.

3. Application Time: 45 minutes

Review the major goals of good planning identified in the previous activity. Explain that the major planning tool to be used throughout the rest of the training will be a calendar of construction events for the demonstration system. Present the blank calendar on a series of flipcharts that will remain posted until the end of the workshop. Have the participants review the list of construction activities they developed in the previous activity and fill in the 15 major activities on the blank calendar and the relevant labor, material, and tool categories. After clarifying any questions about the calendar, assign one or two participants the responsibility of getting the information necessary to complete the line for each of the construction activities. Then distribute Handout 11-1: Blank Calendar and Handout 11-2: Filled Out Calendar.

4. Generalizing Discussion Time: 30 minutes

Divide the group into three or four smaller groups depending on the number of participants. Give them the following task:

- Identify the activities of the involved community in the planning, organization, and construction of a rainwater catchment system.

- Discuss how you would plan their involvement in these activities.

- List the most important factors in guaranteeing the community's involvement on a sheet of newsprint.

Give the groups 15 minutes to complete this task.

Post the four sheets of newsprint. Ask the groups to clarify any unclear points. Discuss the major points starting with those that were common. The discussion should touch on the following points:

- Communities are more involved in project implementation if they have a role in the planning of the project.

- Communities develop "ownership" of a water supply system if they contribute money to the purchase of the materials as well as providing free labor.

- Construction projects can be a chance for villagers to learn or improve their construction skills if the construction work is organized so that they can learn.

- Adequate preparation and village "animation" is needed to keep people informed and involved.

Close the discussion by emphasizing that in village water supply projects what the people learn in doing the project can be as important as the water supplied if it encourages them to undertake other projects.

5. <u>Summary/Closure</u> Time: 10 minutes

Review the objectives of the session and clarify any remaining questions. Make sure that the assignment regarding completion of the calendar is clear and state that the trainees should complete their line as soon as they can get the information from the construction foreman or masons.

<u>TRAINER NOTE</u>

The construction foreman and masons should be shown the completed calendar of events after this session, so that they will be prepared to provide answers to questions posed by the participants filling out the calendar. The participants can gather this information before or after the work session scheduled for the afternoon of the sixth day.

<u>MATERIALS</u>

- Flipchart with session goals and objectives
- Flipcharts for listing points the participants generate during the guided discussions
- Flipcharts with the blank calendar of construction events for the demonstration system
- Handout 11-1: Blank Calendar
- Handout 11-2: Filled Out Calendar

CALEN

Handout 11 - 2

Construction Activities	Date Begun	Date Ended	Number Days	Number Hours	Number Masons	Number Iron-workers	General Observations or Remarks
1 Clearing/Lay out							
2 Excavation							
3 Placing bed of gravel							
4 Building foundation form							
5. Preparing iron grill for foundation							
6. Pouring the foundation (including curing)							
7. Making cement blocks							
8. Constructing the walls							
9. Building forms for top slab							
10. Preparing iron grill for top slab							
11. Pouring, curing, placing top slab							
12 Plastering							
13. Constructing and placing gutters							
14. Disinfecting the system							
15. Putting system into function							

SESSION 12

SYNOPSIS

SESSION 12: Mid-Point Evaluation/Feedback

ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
Open Discussion	Presentation/ Question & Answer	30-90	---	Summary of Objectives of All Sessions to Date

GOAL

Total time: 30-90 minutes

To review the work done during the first week and identify those areas where additional work or explanation are necessary.

OBJECTIVES

This session enables the trainers to better understand the positive and negative factors which have affected the workshop as a whole during the first week and to be able to respond in an appropriate manner to the needs of the participants.

The trainers are to make a resume or synthesis of the strengths and problems noted by the participants and to suggest possible solutions. This feedback and review session should be scheduled for one to three hours the day after the planning session (Session 10 or Monday morning if the session is held on Saturday of the first week). The amount of time necessary for the review session will obviously depend on the number of questions that need to be clarified.

ACTIVITIES

Time: 30 minutes

Review the objectives for Sessions 1 through 11 that have been covered, write them on a flipchart, and have these posted around the room. Ask the following questions:

1. Do you feel capable of accomplishing all the objectives of the sessions? If not, which ones pose difficulties for you? Please note the number of the session and the specific objective. Also state what it is that gives you difficulty with the objective.

2. What things have you learned during this first week that you did not know before? Among these, which ones seem the most useful for your work?

3. In general, what problem have you encountered during the first week? What do you think could be done to alleviate or solve these problems? (Note: Clarify that this is the place for them to mention problems related to room, board, transport, per diem, etc.)

TRAINER NOTE

These questions can be answered anonymously on a piece of paper and handed in or orally and recorded on a flipchart and discussed.

MATERIALS

- Flipcharts with Sessions 1-11 goals and objectives.
- Flipcharts with evaluation questions.

SESSION 13

SYNOPSIS

SESSION 13: Construction of the Tank

ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
Visits				
#1 Day 1	Observe	30	Handout 13-1: Construction Guidelines Handout 13-2: Construction Procedures	
#2 Day 2	Observe	30		
#3 Day 3	Observe	60		
#4 Day 6	Field Work	3 hrs.		
#5 Day 8	" "	3 hrs.		
#6 Day 9	" "	3 hrs.		
#7 Day 10	" "	3 hrs.		
#8 Day 11	" "	3 hrs.		

TOTAL TIME:

5 afternoons of field work (3 hours each); and

3 short observational visits (30-60 minutes each)

Session 13: Construction of the Tank

GOAL

Total time: 3-1/2 days

To learn the basic steps and processes in larger (community) storage tank construction.

OBJECTIVES

Note: The following objectives are generic to most tank construction methods. They will have to be made specific to the actual construction technology and tank design decided upon.

At the end of the session the trainees will be able to:

- Demonstrate all the basic steps for construction of the tank type selected
- Describe how to organize a construction site
- Describe how to lay out and dig the hole for in-ground tanks or to prepare for above-ground tank foundations and/or footings
- Demonstrate how to prepare and use all materials and processes for the construction of the tank foundation and/or footings
- Demonstrate how to prepare and use all materials and processes for the construction of the tank walls and cover
- Demonstrate knowledge of proper cement/sand/gravel ratios and mortar and concrete mixing techniques for the various construction processes using these materials
- Apply skills in mortar and concrete placing, tamping, leveling, plastering, surfacing, and curing
- Demonstrate how to connect a finished tank to the other components of the system and make the entire system operational

OVERVIEW

(Note: Before continuing, read Preparation for Construction under Section 1.6.4 in the introduction to this guide and the introduction to the Trainer Reference Notes which follow the handouts for this session.)

This session is designed to expose the participants to all the steps in the construction of a large storage tank for a community rainwater roof catchment system. In addition, it will give them practical, hands-on experience in the basic procedures required for tank construction. On the first three visits, which occur on the first three days of the workshop, the participants observe the preparatory work being done by local masons and laborers. On the other five visits (Days 6-11) the participants work on various stages of the tank's construction and the completion of the system. The work schedule should be structured to permit the participants to pour the concrete foundation, construct and waterproof the walls, and finish the tank and system during the five afternoon practical sessions. See the Trainer Reference Notes for how to organize the work schedule for different construction technologies so that the system can be completed by the end of the workshop and the participants have the opportunity to work on the major construction tasks.

The following plan for this session is organized around the eight visits to the construction site and the basic steps in tank construction which occur at those times. While the specific activities will depend on the choice of technology, materials, and tank design, it is recommended that the work schedule be coordinated with these general tasks according to the following schedule wherever possible.

Visit 1 (Day 1):	Observe site preparation and excavation
Visit 2 (Day 2):	Observe foundation/footing preparation
Visit 3 (Day 3):	Observe cover construction; laying footings
Visit 4 (Day 6):	Pour foundation
Visit 5 (Day 8):*	Wall construction
Visit 6 (Day 9):	Wall construction/plastering
Visit 7 (Day 10):	Waterproofing
Visit 8 (Day 11):	Complete system

The same general procedures are followed for each visit: the trainer introduces the objectives and tasks for the visit, organizes the group into work teams wherever necessary, points out the key things learned during and/or after the work as suitable, and leads a final discussion at the end of the visit. The following session plan is organized by visits and includes introductory comments, key things to be learned, and suggested questions for the final discussion for each visit. Specific examples are drawn from two commonly used construction methods and tank designs: an in-ground ferrocement lined pit and an above-ground brick masonry tank. They are used as examples to help the trainer understand the kinds of generic learning which should be emphasized. The specific introductory comments, learning objectives, and final discussion questions will have to be developed by the trainer and construction foreman based on the construction technology, materials, tank design and work schedule chosen. The following procedures should be used as a guide to that task.

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* If the workshop begins on a Monday, Day 8 will also fall on a Monday and Day 7 will be a day off on which the foundation can dry and start curing, permitting people to work on the wall on Day 7. Adapt for schedules with other days off.

ACTIVITIES

Visit One (Day 1) Time: 30-60 minutes

1. Introduction

The initial visit to the construction site should be structured to introduce the group to the site and the construction workers, show them the site preparation, excavation, etc. already done, and discuss how the site and work is organized. Tell the group to spend 10 minutes observing:

- How the work site is organized
- Placement of tank in relation to catchment surface
- Method of excavation

2. Key Things Learned

The key things learned for this visit are:

Construction Site Organization

- Placement of materials in relation to tank site and method
- Site and method for cleaning sand and gravel
- Site for mixing mortar and concrete
- Storage, transport, and control of tools and materials
- Amount of open space needed for work force
- Protection of excavation

Location of future tank

- Relative to catchment surface
- Relative to lay of land
- Relative to water supply use
- Relative to rest of the construction site

How is/was the excavation laid out

- Pegs and string for straight lines
- 3, 4, 5 triangle, or other appropriate methods for getting right angles or
- Method for tracing circle for cylindrical tank
- Plumb bobs or levels for vertical surfaces

How is/was the excavation dug

- Soil conditions, lay of land
- Number of workers and time; labor costs
- Tools and digging techniques

3. Final Discussion

Pose questions to elicit the key things learned; volunteer information where necessary; discuss key points. If time permits ask a generalizing question about the organization of the work site such as, "What kinds of problems can be avoided by organizing a construction site like this?" and discuss. Conclude with mention of the purpose of the next visit.

Visit Two (Day 2) Time: 30-60 minutes

1. Introduction

The goal of the second visit is to allow the participants to observe how the masons are preparing the base for the foundation or footings and making the reinforcing rod frame for the foundation or floor. Ask the trainees to look at the stone or broken brick base first and ask questions of the mason for five minutes. Then discuss key things learned (below) with them for five minutes before repeating the same procedure with the re-rod grill. Total time for both observations and discussions is 20 minutes.

2. Key Things Learned

The key things learned for this visit are:

Floor, foundation and footing bases

- Why put down a base first?
- Why use the materials chosen; what other materials could be used?
- What is the relationship of soil type to base?
- What thickness should the base be? Why?
- How is the base attached to the foundation, floor, or footing?

Reinforcing rod grill for foundation

- Why does concrete have to be reinforced?
- What size reinforcing rod is best?
- What other materials can be used to reinforce concrete?
- What is the proper spacing of re-rod in a grill? Why?
- How much time and material is required? How much does it cost?

3. Final Discussion

If all the key learning objectives were brought out during the previous discussions, use this time to generalize about the materials, skills and labor used in tank construction and relate to the day's sessions on community evaluation and local resource inventories. For example:

- What do you think it took to get all these materials here on time? (Bring out community involvement and participation, as well as planning, budgeting, transport, etc.)

- How are skilled and manual laborers provided for a community rainwater catchment project? Should the community pay these laborers?

- How are the laborers organized at the work site? Who is in charge? What responsibility should the community have for their supervision?

Visit Three (Day 3) Time: 30-60 minutes

1. <u>Introduction</u>

The goals of this visit will vary with the construction technology and work schedule. For example, for a masonry tank the footings for the walls have to be laid or poured at this time. For some other tanks the foundations have to be laid more than two days before constructing the walls. The tank's roof can be constructed at this time as well. As in the two previous brief visits to the construction site, the participants should observe the work then in progress and already completed during the morning and discuss what was learned about the specific construction activities. The discussions can occur during the observations and/or at the end of the visit.

2. <u>Key Things Learned</u>

The key things learned about above-ground masonry and ferrocement pit tanks could be:

For masonry wall footings for the above-ground part of a ferrocement pit tank

- How large do the footings have to be for a specific wall?
- How are they constructed (materials, construction method)?
- How are they levelled?
- How are the footings joined to the wall and tank floor?

For poured concrete foundations and floors

- Proper concrete mixture, materials, moisture?
- Pouring, compacting and levelling concrete. How much concrete?
- How is the re-rod grill (or other reinforcing structure) placed?
- How is the floor tied into the wall, footings, etc.?
- How is the concrete cured?
- (See key things learned for Visit #4 for more detail)

For wood and corrugated iron roofs

- How is the wood frame shaped and constructed?
- What size corrugated iron sheet is used and how is it fixed to the frame?
- Special design features (access for person to clean tank; connection of downpipe, filter or foul flush; keeping dirty water and insects out, venting tanks).

3. Final Discussion

Review what was learned on this and the previous two visits. If time permits, dicuss the use of available materials and chosen construction technologies in terms of the choices made during Session 6. Compare actual construction to the alternative technologies considered that morning. For example, why build a corrugated iron sheet and wood frame roof rather than a concrete slab?

Visit Four (Day 6) Time: 3 hours

1. Introduction

The participants start working on the tank themselves on the fourth visit to the construction site which occurs on the sixth day of the workshop. On the previous two afternoons, they have made small household cement tanks and a guttering and filtering system for a thatch roof. This practical session follows on the concrete work in Session 8 and builds upon it. If the work schedule permits, this session can be devoted to pouring the concrete foundation for a ferrocement pit or the floor for an above ground masonry tank.

Before starting, review the work that has been accomplished during the first three days of the workshop and any work that has been done over the previous two days such as completing the tank roof or continuing the masonry wall. After reviewing the work done up to this point, break the group into work teams of from two to four participants each and explain their tasks. Give clear instructions concerning concrete mixture, wetness of the concrete and how to pour, compact, and level it. Keep people informed of the time and bring them together at appropriate times to bring out what they are learning. For example, if two groups are about to pour concrete of different consistencies ask them which is preferable and why, and discuss briefly before having them continue.

2. Key Things Learned

The learning objectives regarding reinforced concrete in tank foundations and floors are:

Quality of Materials

- Age, dryness, and condition of cement
- Cleanliness, coarseness, and composition of sand
- Cleanliness, composition, and size of gravel

Ratio of Ingredients

- Difference among 1:1-1/2:3, 1:2:3, and 1:2:4 mixtures of cement to sand to gravel and when to use which mixture
- Amount of water in concrete for different tasks
- "Feel" of concrete when ready to pour

How to pour, compact, level, and cure concrete

- How much to pour at one time
- Time in which concrete starts to set
- Tools and techniques for compacting and levelling concrete
- Time and method of curing concrete

Special tank design features

- Slope of tank floor
- Sump, drainage and cleaning

Reinforcing materials

- Size and spacing of reinforcing rod in re-rod grill
- Depth of grill in concrete
- Attaching reinforcing rod to walls, footing, etc.
- Other reinforcing materials

Using forms other than clay soil excavations

- Materials for forms
- Form construction
- Laying floor inside walls on footings

3. Final Discussion

Review what was learned and discussed during the practical. Bring out through further discussion and question and answer any of the key session points not already discussed. Leave sufficient time for several general and practical questions about working with concrete such as:

- What is the most important thing to remember when working with concrete?

- What would you do differently the next time you use concrete?

If time permits, lead a discussion about the organization of their labor and what they learned from it about supervising a large group of community laborers. Mention the next practical session and Session 14 in closing.

Visit Five (Day 8) Time: 3 hours

1. Introduction

If the workshop begins on a Monday, Day 6 falls on a Saturday and Day 8 on a Monday, giving the foundation or floor 48 hours to set and start curing before the participants work on the wall of the tank during Visit #5*. The work on the tank should be scheduled so that the participants have an opportunity to

* Adapt for cultures which use Friday or Saturday as a traditional day of rest.

lay enough bricks, blocks, or stones in a masonry tank wall and apply enough of the second coat of mortar in a ferrocement tank to learn the basic procedures of wall construction for their selected tank technology. For example, in a brick masonry tank, the participants should have several courses of brick to lay for two hours to gain experience in preparing mortar and in the techniques and problems of bricklaying. In a ferrocement pit tank, the participants should be involved in working on the reinforcing mesh and mortar mixing and application. As in other practical sessions, explain the purpose of the afternoon's work, give the trainees specific technical instructions, organize them into work teams and get them working. Stop the work at appropriate times to point out and discuss what was learned during the session.

2. Key Things Learned

The key things learned during this session for masonry tanks are:

Masonry design

- Thickness of masonry walls
- Placement of bricks, blocks, or stones
- Bonding bricks or bondstones
- Thickness of mortar

Materials

- Size, choice, condition of baked clay bricks, cement or cindaram bricks, stone
- Reason for soaking bricks and blocks
- Cleanliness of materials
- Comparative costs of masonry materials
- Cement, sand, and mortar

Masonry construction mortar

- Cement to sand ratio for mortar
- Wetness of mortar
- Thickness of mortar
- Applying mortar evenly and keeping bricks level

Laying bricks, blocks, or stones

- Keeping course level
- Choosing stones while laying wall
- Spacing of bricks and blocks in mortar

Placing water pipes in a masonry wall

- Connection of wall to footings, foundaton and tank floor
- Setting and curing mortar

The key learning objectives of this session for ferrocement pit wall construction are:

Preparing the pit wall

- Finishing excavation and the need for a clean wall
- Use of reinforcing rod to hold chicken wire mesh or other internal structure

Applying mortar

- Why use mortar with a cement to sand ratio of 1:3?
- How much water should be mixed into the mortar? Why?
- How much mortar is applied in each coat?
- How long does it need to dry between coats?
- How long does it need to cure?

Reinforcing mesh

- What materials can be used in the mesh? Which is best?
- When and how is it put into the mortar?
- How is it attached to the reinforcing rod in the foundation?

3. Final Discussion

After the work is completed for the afternoon, bring the trainees together and ask them what the most significant things they learned that afternoon were. Review what was discussed during the work activity and bring up other things not already mentioned. Discuss. Ask the participants what problems they think might arise supervising village artisans and laborers responsible for doing this work and what other problems might arise in using this tank construction technology in a village. In closing, mention the next afternoon's session.

Visit Six (Day 9) Time: 3 hours

1. Introduction

During the sixth field visit the participants continue working on the walls of the tank. For a ferrocement lined pit, this means adding the second two coats of plaster. For a masonry tank, the walls should be laid at this point so that work can start on plastering them. As usual, break the group into work teams, give them their instructions, and get them started.

2. Key Things Learned

The key things learned with regard to a ferrocement lined pit are the same as the previous day.

For plastering a masonry tank they are:

Preparing the masonry wall for plaster and mortar combinations and plastering

- Why a 1:3 cement to sand mixture for first coat?
- How dry should the plaster be?
- How thick does the plaster need to be?
- Specific technical facts about plastering.

3. Final Discussion

Review the day's work and what was learned, concentrating on working with mortar. Ask general question linked to the morning's session on maintenance and community responsibility such as, "How can the community be better prepared to maintain the system while they are involved in building the tank?"

Visit Seven (Day 10) Time: 3 hours

1. Introduction

This visit is very similar to the previous day's work. A second coat of plaster is put on the masonry tank and the ferrocement pit is plastered with a waterproofing coat. By the end of this visit, both tanks should be almost finished. Have the groups work as they did the previous day.

2. Key Things Learned

Most of the learning objectives are the same as those of the previous visit. The following should be stressed:

- Why the waterproofing coat is done with a 1:2 mixture of cement to sand.

- How wet the plaster should be. What it feels like when ready.

- How many materials are used to plaster a tank. How long it takes. The costs.

3. Final Discussion

The final discussion after this visit should review the tank construction in light of the conclusions of Session 16: Critiquing and Refining the Design. Ask the participants to list the advantages and disadvantages of the construction method used to build the tank. Discuss the availability and cost of materials, the tools and skills needed to do the job, and the time and cost of labor. Also ask if this method could be easily taught to village masons and workers and if they feel competent to supervise the construction of such a tank. Close with mention of the practical sessions scheduled for the next day on guttering and connecting the tank to the gutters.

Visit Eight (Day 11) Time: 3 hours

1. Introduction

The last visit is designed to complete the rainwater roof catchment system: finish the tank, finish attaching gutters, put tank roof in place and connect downpipe and foul flush or filter to the gutters and tank, and see that all the systems work. The actual work will depend on how much was accomplished during the morning (Session 17), and what has been previously done to complete the other components of the system. Plan the work tasks accordingly and split the group up into work teams, give them their tasks and start work. If several different work teams are doing different tasks, stop the work as in Session 8 and let people show each other what they are doing and discuss what they have learned at that time.

2. Learning Objectives

The specific learning objectives for this visit will depend upon the tasks requiring attention. They will probably include:

Waterproofing the Tank

- What is the function of the final cement slurry?
- How moist should the slurry be?
- How much should be applied?
- How much can be mixed at any one time?

Finishing the tank top to receive the roof

- How is the top of the tank finished to hold the roof?
- How is the reinforcing rod connected to the wall? To the roof?

Placing the roof

- What has to be considered in putting a roof on a tank?
- If a concrete slab roof was made prior to the workshop (it requires two weeks to cure), how can it be placed on a tank in the easiest and safest fashion?

Connecting gutters (see Session 17)

Connecting downpipe and foul flush or filter to gutters and tank

- How is foul flush water evacuated?
- How is the filter or foul flush system supported by the tank or roof?
- What are the regular operations and maintenance requirements of these systems?

Finishing around the tank

- How will the area around the tank be kept clean and dry?
- How will dirty water or excess water be evacuated?

- How will dirty water, insects, etc., be kept out of the tank (especially a pit tank)?

Putting the system into operation

- How much time does the tank have to cure before it can hold water?
- How will the system be cleaned and disinfected before being put in use?
- Who is responsible for maintenance and monitoring of the system?

3. Final Discussion

(Note: If the processing and final discussions for Session 17 were not held that morning they should be combined with the following final discussion.)

This discussion should concentrate on reviewing briefly the key things learned which were brought out during the periodic breaks in the construction work. This should lead to generalizing from the practical construction sessions about what trainees have learned which will improve their abilities to plan and supervise the constructon of a large (community) roof catchment system. Sample questions to generate such a discussion could be:

- What is the most important thing you have learned from working on the construction of this system? Why?

- What have you learned from working on the construction of this system which will be most helpful to you in planning and organizing a village construction project in the future?

- What have you learned about working with village masons and organizing a large work force that will be most helpful the next time you are in charge of a village construction project?

TRAINER NOTES

1. The construction materials and tools will vary depending on the construction technology, the design of the system, and the number and skills of the participants. See Section 1.6.5 of the Introduction to this guide for a suggested list.

2. Pedagogic tools should be kept simple so they can be easily used at the work site. Participants can be given small pocket notebooks and pencils so they can jot down technical notes to themselves while working. The trainer may want to have a flipchart and newsprint available for emphasizing the key points during the final discussions.

MATERIALS

- Construction materials
- Handout 13-1: Construction Guidelines
- Handout 13-2: Construction Procedures

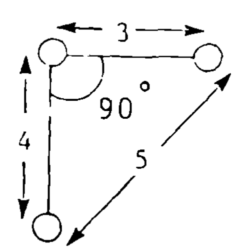
CONSTRUCTION GUIDELINES

CLEARING AND EXCAVATION

Initially, the tank site must be cleared of debris and vegetation. All tanks require some excavation. Even if the tank is to be above ground it is necessary to excavate and level the ground for the foundation. The foundation typically extends 15-30 cm beyond the outside of the tank wall. This must be taken into consideration when determining the area to be excavated. After the correct depth has been excavated, the ground should be leveled using a carpenter's level and board.

SETTING OUT

The outer wall of the tank or edge of the floor slab should be outlined using wooden stakes and string. For square or rectangular tanks, the corners are squared using the 3-4-5 triangle method. Length of 3 and 4 feet, meters, or any unit are staked out at approximately right angles. If the corner is square, the diagonal between the two end stakes should be 5 (same units as before). If not, the stakes are adjusted accordingly.



3-4-5 Triangle Method

A circular tank wall or floor can be outlined by tying a string of the correct radius (r) to a stake placed at the center of the proposed site and rotated around. Several stakes or markers can be placed around the outline at intervals of approximately 1 meter.

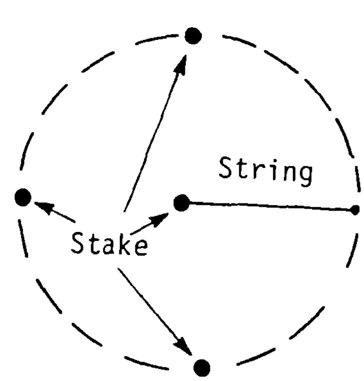


Fig. 1. Setting out a Circular Tank

FOUNDATION/FOOTING

Before the floor slab can be laid, a foundation of gravel or crushed stone is necessary. The thickness should be approximately 10 cm. The gravel bed should be tamped and leveled before proceeding with the floor construction. If the tank is to have a sump, then a depression should be made in the foundation for this. For masonry walls it is common practice to construct a footing of masonry or concrete. The footing should be approximately 20 cm thick and extend 10 cm beyond the base of the tank wall on both sides. This also requires a 10 cm thick foundation of either gravel or lean concrete (1 part cement, 3 parts sand, 6 parts gravel).

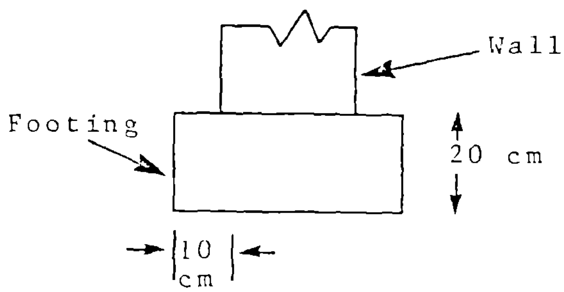


Fig. 2 Masonry Footing

PLACING FORMS

All concrete work requires a form into which the concrete is poured. Forms are usually made from boards or planks, although other materials are also used. Wooden forms are nailed together according to the proper measurements. To ensure that the concrete does not stick to the forms it is advisable to coat them with oil first. It is very important that the forms be supported on the outside. Otherwise, when the concrete is being compacted the forms can bulge or burst apart.

MIXING CONCRETE

Proper mixing of concrete is essential if it is to meet its requirements of strength and durability. The first step is to prepare a mixing pad or platform. For this, boards, metal sheets, or a hardened concrete slab is suitable. The aggregate and cement are then measured and piled into a heap. This then should be turned over using shovels or trowels until the mixture is uniform. The mix is then heaped and a depression is made in the center of the pile. Water is slowly poured into the depression and worked into the dry mix. It is important not to add too much water. Otherwise the concrete will not reach its full strength. A rule of thumb is to add approximately 3/4 parts of water for each part of dry cement. The concrete should be mixed in volumes no larger than that which can be poured within 30 minutes. At this point the concrete begins to set.

PLACING CONCRETE

After mixing, the concrete should be placed into the forms immediately. Floor slabs are poured beginning with one side or corner and working towards the opposite one. The concrete should be placed in adjacent piles, compacted, and leveled. The simplest way this can be done is to assign teams to carry out each of these 3 tasks. The first team transports and places the concrete. The second team follows by compacting, and the third team levels the slab.

Compacting is usually done by means of a tamping foot. The concrete should be compacted until the top surface is fairly smooth with none of the coarse aggregate jutting out.

Leveling is carried out using a trowel or screed (short, smooth piece of wood) and a carpenter's level. The floor should slope towards the sump or drain.

Walls should be poured in a similar manner with the exception that the compacting or rodding should be carried out in 30-40 cm layers. Iron rods are best for doing this.

REINFORCED CONCRETE

The tensile strength of concrete can be greatly increased with the use of reinforcing bar or mesh. Reinforcing bar (rebar) is tied with wire into a mesh and placed in the form. It should be covered by a minimum of 3 cm of concrete. The spacing and size of the rebar should be determined by the design engineer.

ROOF/WALL ANCHORS

In any tank the walls, floor, and roof should be anchored into one another. This is usually done by embedding rebar into both the floor and wall, or the wall and roof at the joint as shown in Figure 3.

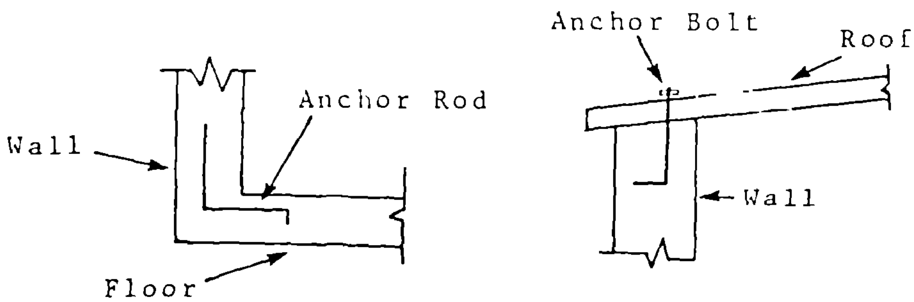


Fig. 3 Roof and Wall Anchors

MASONRY

Tanks are often constructed of brick or stone masonry. Regardless of the building material used (i.e., brick, stone, concrete block) it must be cleaned of all dirt and organic material first. Bricks and cement blocks should first be soaked in water. Otherwise they may absorb too much of the water in the mortar. The walls should be built so that no two joints form a continuous line across the thckness of the wall or up and down the side of the wall. At intervals of approximately 60 cm, bondstones or bonding bricks should be laid across the thickness of the wall. This helps to hold the wall together. This is illustrated in Figure 4 below.

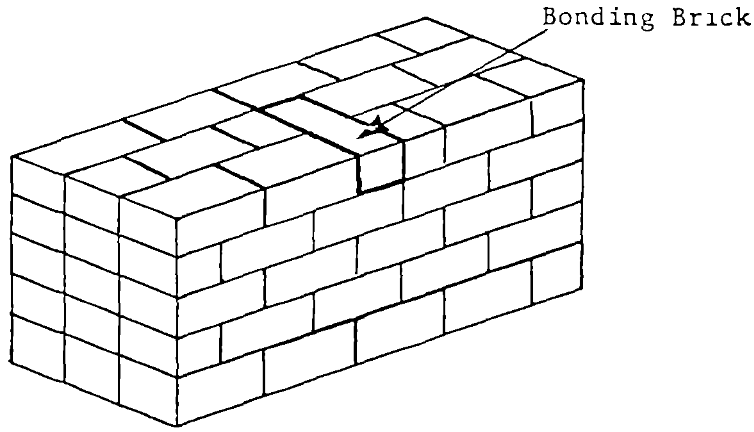


Fig. 4 Brick Masonry

To ensure the strength of the wall it is very important that no two adjacent stones or bricks touch. The recommended thickness of all mortar joints is 1.0 cm. In masonry tanks, it is more common to construct the walls first beginning with the corners and then pour the floor slab. In this case, the wall is not anchored into the floor as for other types of tanks. This is shown in Figure 5.

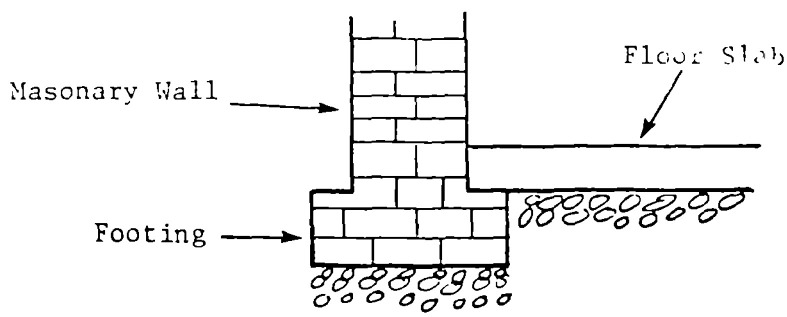


Fig. 5 Masonry Tank Wall

The roof of a masonry tank is usually attached to an anchor bolt embedded 10-15 cm into the top of the masonry wall.

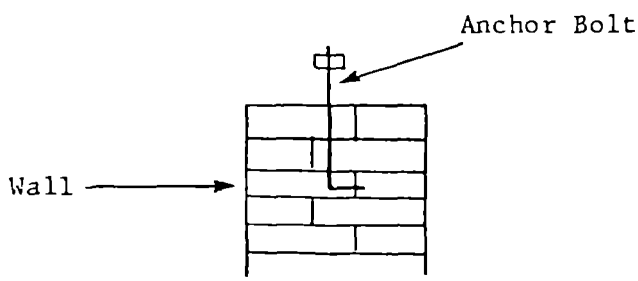


Fig. 6 Anchor Bolt

The minimum thickness of a masonry wall is 30 cm. The actual dimensions should be determined by the design engineer.

PLACING OF PIPES

The tank may have several pipes depending upon the type of tank. A typical above ground tank should have an overflow, drain, and outlet pipe. Below ground tanks do not have a drain or outlet pipe but must have an overflow. When mounting any type of pipe in concrete or masonry it is important that the pipe be firmly cemented in all the way around, with either mortar or concrete. Once a pipe has been placed it should not be touched until the wall has hardened. Otherwise the tank may leak around the pipe. It is also important that the pipe is clear of dirt and oil before it is placed. Recommended locations of pipes are as follows:

DRAIN PIPE	-	on the floor of the tank
OUTLET PIPE	-	10-15cm above the floor of the tank
OVERFLOW PIPE	-	15 cm below the top of the tank wall

Because of the thin wall of ferrocement tanks it is better that the drain and outlet pipes be located in the floor of the tank rather than the wall as shown in Figure 7.

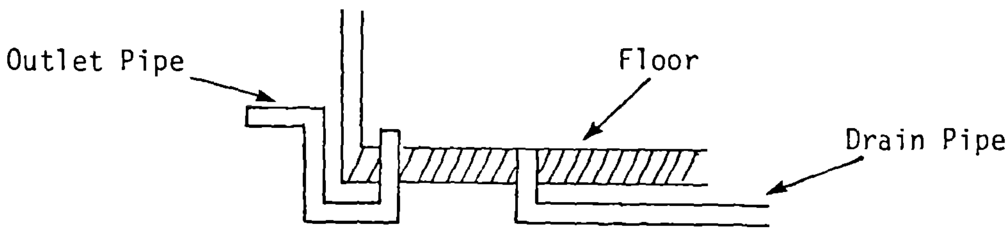


Fig. 7 Pipe Placement for Ferrocement Tank

FERROCEMENT

Ferrocement is cement mortar reinforced with mesh, wire and sometimes reinforcing bar. A ferrocement tank is constructed in the following manner. A cylindrical form is made around which wire mesh is wrapped. Unlike forms used for reinforced concrete, ferrocement forms should not be oiled. One layer is usually sufficient. Around this 2-3 mm wire is wrapped for additional reinforcement. This is then plastered on the outside with 1:3 cement mortar. A second coat of plater is then applied after the initial coat has begun to stiffen. Each coat should be approximately 1.0-1.5 cm thick. The mortar is allowed to harden for two days. At this time the forms can be removed and the inside of the tank is then plastered in two more coats. The total thickness of the wall should be 4-5 cm. It is very important that the tank be kept covered and moist, particularly during the first few days. Otherwise the mortar will crack and the tank may leak.

After approximately one week a roof can be built on the tank. A ferrocement roof can be constructed using two layers of mesh instead of the single layer as for the walls. Again it is important to anchor the roof to the walls using rebar.

PLASTERING

To ensure that the tank is waterproof it should be internally plastered. Recommended plastering procedures vary from two to four coats. Regardless of the number of coats, only one coat should be applied each day.

The following plastering method is recommended here:

> Initially a 1:3 cement mortar coat is applied to a thickness of 1.0-1.2 cm. This coat is applied roughly and is not smoothed out. Next a coat of 1:2 mortar is applied to a thickness of 0.8-1.0 cm, and smoothed. finally, a thin 0.2-0.4 cm coat of cement paste (cement & water only) is applied.

CURING

All cement work must be cured for a minimum of one week and preferably two. The structure must be kept moist and protected from direct sunlight. Other wise the cement will dry out too rapidly, crack and will not reach its full strength. Curing should begin immediately after the cement has finished setting, usually 2-4 hours after it has been placed. This can be best done by wetting the structure and then covering it with damp burlap, paper leaves or other suitable material. Concrete slabs can be cured by building up a rim of soil around the edge of the slab and flooding it with a few centimeters of water.

DRAINAGE

The area surrounding the tank should be graded so that rain and overflow water drains away from the tank. This is especially important for below ground tanks where surface runoff can enter the tank and contaminate the water.

MANHOLE AND AIR VENTS

In addition to the structural features mentioned above, the tank should be provided with a manhole or access door, since it will be necessary to enter the tank for cleaning and maintenance. The door should be locked at other times to prevent unauthorized persons from entering. Also, the tank should be well ventilated. In most cases, this will occur naturally but for certain types of tanks such as reinforced concrete or ferrocement tanks with tight-fitting covers it may be necessary to provide an air vent.

CONSTRUCTION PROCEDURES
BRICK MASONRY TANK
(Square, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. SITE PREPARATION				
1. Clear Site	Digging, Clearing Tools		1-4 Hrs.	Clear all vegetation, boulders, etc.
2. Set out tank floors/ walls	Measuring tape, string, hammer, stakes		1 Hr.	3-4-5 triangle method.
3. Excavate	Digging, tools, tape		2-8 Hrs.	Include trench for footing, hole for sump (depth depends on design decisions previously made)
4. Level	Digging tools, carpenter's level, board		1 Hr	
5. Place foundation	Level, shovels, compacting tools	Gravel, stone	1-2 Hrs	10 cm gravel or stone layer, compact with hammer, tamping foot or other tool.
6. Outline wall footing	Measuring tape, string hammer, stakes		1 Hr	Outline with string tied to corner stakes.
B. FOOTING & WALL CONSTRUCTION				
1. Clean & soak bricks	Water container, wire brush	Bricks, water	1-2 Hrs	
2. Measure quantities for mix	Measuring container	Sand, cement	1/2 Hr.	1:4 Cement/sand ratio.
3. Dry mix mortar	Mixing pad, trowels, shovels.	Sand, cement	1/4 Hr.	Mix to uniform color & consistency.
4. Wet mix mortar	Mixing pad, trowels, shovels. Measuring container.	Water, mortar mix.	1/4 hr.	Add water gradually until mortar is workable; mix only volume which can be used in 1/2 hour or less.

<u>CONSTRUCTION PROCEDURES</u>
<u>BRICK MASONRY TANK</u>
<u>(Square, Above Ground)</u>

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
5. Lay footing	Tape, trowels, hammers & other masonry tools.	Mortar, bricks [Alternative: concrete mixed 1:3:6]	1-4 Hrs.	Begin with corners & work towards center of wall; cover & wet at end of day.
6. Place drain pipe	Level, masonry tools	GI pipe, mortar	5 Min.	Place pipe level or sloping slightly downward from tank.
7. Lay tank wall - first courses	Masonry tools, plumbob	Mortar, bricks	1 to several days	Same as B.5 above.
8. Place outlet pipe				Same as B.6 above, 10 cm above floor.
9. Lay tank wall to overflow pipe.				Same as B.5 above.
10. Place overflow pipe and roof anchor bolts.		Galvanized Iron pipe, roof anchor bolts		Same as B.6 above - 15 cm from top of tank wall.
11. Complete tank wall				Same as B.5 above.
12. Allow to harden/cure	Water container	Water, burlap, paper or other such material	2-4 days	Wet several times each day keep covered.
C. FLOOR				
1. Measure quantities for concrete	Measuring containers	Cement, sand, gravel	1/2 Hr.	1:1 1/2:3 cement/sand/gravel ratio.
2. Dry mix concrete	Mixing pad, trowels, shovels	Cement, sand,	1/2-1Hr	Mix to uniform color and consistency overturning several times.

CONSTRUCTION PROCEDURES
BRICK MASONRY TANK
(Square, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
3. Wet mix concrete	Mixing pad, trowels, shovels	Dry mix, water	1/4 Hr	Gradually add water to approximately 3/4 parts water to 1 part cement. Mix thoroughly in volumes which can be poured in 1/2 hour or less.
4. Pour concrete	Transport containers, compacting tools, trowels screed, level	Concrete	1-3 hrs	Place in adjacent piles, compact and level; slope towards drain
5. Allow to harden/cure	Water container	Water, burlap, paper or other	2-3 days	2-3 hours after concrete has been poured flood with 2-5 cm of water.
D. PLASTERING (WATERPROOFING)			3 days	See guidelines for plastering method for masonry tanks.
E. ROOF	Hammer, nails, wrenches, etc. Require for specific type of roof.	Depends on type of roof	1-4 days	Include locking access door.
F. FINAL GRADING/FINISHING	Digging tools		1-2 days	Slope ground away from tank allow for overflow drainage.

CONSTRUCTION PROCEDURES
PLASTERING OF MASONRY TANKS

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. FIRST COAT				
1. Clean wall	Wire brush, trowels		1-2 Hrs	Scrape off loose mortar, dirt, etc.
2. Measure quantities for mortar mix (first coat.	Measuring container	Sand, cement	1/2 Hr	1:3 cement/sand ratio.
3. Dry mix mortar	Mixing pad, trovels, shovels	Sand, cement	1/4 Hr	Mix to uniform color & consistency.
4. Wet mix mortar	Mixing pad, trowels, shovels, measuring container	Water, mortar	1/4 Hr	Add water gradually until mortar is workable; mix only volume which can be used in 1/2 hour or less.
5. Apply mortar	Trowels	Mortar	1-2 Hrs	Apply in rough coat of approximately 1.0-1.2 cm thickness; do not smooth.
6. Allow to set		Water, burlap, paper, etc.	1 day	Cover sprinkle with water occasionally.
B. SECOND COAT				
1. Dampen wall		Water	1/2 Hr	Sprinkle with water.
2. Measure quantities	Measuring container	Sand, cement		1:2 cement/sand ratio
3. Mix mortar				As in steps A.3 - A.4 above.
4. Apply mortar	Trowels	Mortar	1-2 Hrs	Apply coat of approximately 0.8-1.0 cm thickness and smooth.
5. Allow to set				Same as step A.6 above.

CONSTRUCTION PROCEDURES
PLASTERING OF MASONRY TANKS

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
C. FINAL COAT				
1. Dampen wall		Water	1/2 Hr	Sprinkle with water.
2. Mix mortar	Mixing pad, trowels	Sand, Cement	5 min	Cement & water only mixed to a thick paste; mix only small amounts.
3. Apply mortar	Trowels			Apply 0.2-0.4 cm coat and smooth.
4. Allow to harden/cure		Water, burlap, paper, etc.	2-4 days	Wet several times per day and cover.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. SITE PREPARATION				
1. Clear site	Digging, clearing tools		1-4 Hrs	Clear all vegetation, boulders, etc.
2. Set out tank floor	Measuring tape, string, hammer, stakes		1 hr	Rotate string around center stake at proper radius.
3. Excavate	Digging tools, tape		2-8 Hrs	Include depression for sump, drain and outlet pipes.
4. Level	Digging tools, level, board.		1 Hr	
5. Place outlet/drain pipes	Level	GI pipes	15 min	Place level
6. Place foundation	Level, shovels, compacting tools.	Gravel, stone	1-2 Hrs	10 cm gravel or stone layer, compact with tamping foot, hammer or other tools.
B. FLOOR				
1. Construct floor slab form	Level, hammer, nails, etc, according to type of form.	Form work	1-2 Hrs	
2. Place reinforcement (if required)	Pliers, wire cutters, tape.	Wire, rebar or mesh.	1-2 Hrs	Space reinforcement according to design; include wall anchors.
3. Measure quantities for mix	Measuring containers	Sand, cement, gravel	1/2 Hr	1:1 1/2:3 cement/sand/gravel ratio.
4. Dry mix concrete	Mixing pad, trowels, shovels.	Cement, sand, gravel	1/2-1Hr	Mix to uniform color and consistency overturning several times.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
5. Wet mix concrete	Mixing pad, trowels, shovels, measuring container	Dry mix, water	1/4 Hr	Gradually add water to approximately 3/4 parts water to 1 part cement; mix thoroughly in volumes which can be poured in 1/2 hour or less.
6. Pour concrete	Transport containers, compacting tools, trowels, level, screed	Concrete		Place in adjacent piles, compact and level; slope towards drain.
7. Allow to harden/cure	Water container	Water, burlap, paper or other	2 Days	2-3 hours after pouring concrete flood with 2-5 cm water.
C. WALLS				
1. Remove floor slab form	Depends on type of form		1/2-1Hr	
2. Place wall form work	Depends on type of form		1-2 Days	Check that form walls are vertical and stable.
3. Place wire mesh	Pliers, wire cutters	Wire mesh, binding wire	1/2 Hr	One layer of mesh around form wall with 20-30 cm overlap; tie in place.
4. Lace wire reinforcement up and down mesh	Pliers, wire cutters, measuring tape.	2.0-3.0 mm wire	1/2-1 Hr	Wrap wire around form every 2-3 cm for first 60 cm, then every 6-8 cm to top of wall; double layer at top; tie into wall anchor bolts at base.
5. Place roof anchor bolts and overflow pipe.	Pliers, wire cutters	Binding wire, rebar, pipe	1/2 Hr	Tie into wall reinforcement.
6. Measure quantities for mortar	Measuring container	Sand, cement	1/2 Hr	1:3 cement/sand ratio.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
7. Dry mix mortar.	Mixing pad, trowels, shovels	Sand, cement	1/4 Hr	Mix to uniform color and consistency.
8. Wet mix mortar	Mixing pad, trowels, shovels, measuring container	Water, mortar mix	1/4 Hr	Add water gradually until mortar is workable; mix only volume which can be used in 1/2 hour or less.
9. Apply first coat (outside)	Masonry tools	Mortar	1-2 Hrs	Apply 1.0-1.5 cm thick rough coat without smoothing.
10. Allow to set			2 Hours	
11. Apply second coat (outside)	Trowels	Mortar	1-2 hrs	Same as C.6-C.9 above; smooth finish
12. Allow to harden/cure	Water container	Water, burlap, paper or other material	2 Days	Wet several times per day and cover.
13. Remove wall forms	Depends on type of form		1-3 Hrs	Carefully remove without disturbing wall.
14. Apply 2 inside coats of plaster			1-1 1/2 Days	Same as C.6-C.11 above.
15. Allow to harden/cure		Water, burlap, paper, etc.	2 Days	Wet several times per day and cover.
D. PLASTERING (WATERPROOFING)				
1. Apply first coat	Mixing containers, pad trowels, measuring containers, etc.	Cement, sand, water	1-2 hrs	Apply 1:2 cement/sand mortar 1.0 cm thick and smooth according to steps C.6-C.9 above.
2. Allow to set			1 Day	Protect from direct sunlight.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
3. Apply second coat	Trowels, mixing pad	Cement, sand, water	2-3 hrs	Apply cement paste and smooth to 0.2-0.4 cm thickness.
4. Allow to harden/cure		Water, burlap, etc.	4-5 Days	Wet several times per day and cover.
E. ROOF	Depending upon type of roof		1-4 Days	If ferrocement roof is constructed use 2 layers of wire mesh and proceed as for the walls.
F. FINAL GRADING/FINISHING	Digging tools		1-2 Days	Slope ground away from tank allow for drainage.

CONSTRUCTION PROCEDURES
FERROCEMENT LINED PIT

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. SITE PREPARATION				
1. Clear site	Digging, clearing tools		1-4 Hrs	Clear all vegetation, boulders, etc.
2. Set out tank floor	Measuring tape, string hammer, stakes		1 Hr	Rotate string around center stake at proper radius.
3. Excavate	Digging tools, tape		4-8 hrs	Pit walls should be smooth.
4. Level	Digging tools, level, board		1 Hr	
5. Place foundation	Level, shovels, compacting tools	Gravel stone	1-2 hrs	10 cm stone or gravel layer compacted.
B. FLOOR				
1. Place reinforcement (if required)	Pliers, wire cutters, tape	Wire, rebar or mesh	1-2 Hrs	Include wall anchors
2. Measure quantities for concrete mix	Measuring container	Sand, cement, gravel	1/2 Hr	1:1-1/2:3 cement/sand/gravel ratio.
3. Dry mix concrete	Mixing pad, trowels, shovels	Cement, sand, gravel	1/2-1 Hr	Mix to uniform color and consistency overturning several times.
4. Wet mix concrete	Mixing pad, trowels, shovels, measuring container	Water, concrete dry mix	1/4 Hr	Gradually add water to approximately 3/4 parts water to 1 part cement; mix thoroughly in volumes which can be poured in 1/2 hour or less.
5. Pour concrete	Transport containers, compacting tools, level, screed, trowels.	Concrete	1-3 Hrs	Place in adjacent piles, compact, and level.

CONSTRUCTION PROCEDURES
FERROCEMENT LINED PIT

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
6. Allow to harden/cure	Water container	Water, burlap, paper or other	1 Day	2-3 hours after pouring concrete, dampen and cover.
C. WALLS				
1. Measure quantities for mortar mix.	Measuring container	Sand, cement	1/2 Hr	1:1 cement/sand ratio.
2. Dry mix mortar	Mixing pad, trowels, shovels	Sand, cement	1/4 Hr	Mix to uniform color and consistency.
3. Wet mix mortar	Mixing pad, trowels, shovels, measuring container	Water, mortar mix	1/4 Hr	Add water gradually until mortar is workable; mix in volumes which can be used in 1/2 hour or less.
4. Apply first coat	Trowels	Mortar	1-2 Hrs	Apply 1.0 cm thick rough coat to walls without smoothing.
5. Allow to set			2 Hrs	Keep protected from sunlight.
6. Apply second coat	Trowels	Mortar	1-2 hrs	Same as C.1-C.4 Above.
7. Place reinforcement	Wire cutters, pliers	Wire mesh, binding wire	1/2-1 Hr	Place 1 layer immediately after applying 2nd coat; tie into floor reinforcement.
8. Allow to harden/cure	Water container	Water, burlap, paper or other	1 Day	Wet several times per day and cover.
9. Apply inside plaster in 2 coats.			4-8 Hrs.	Same as steps C.1-C.6 above.
10. Allow to harden/cure	Water container	Water, burlap, etc.	1 Day	Wet several times per day and cover.

<u>CONSTRUCTION PROCEDURES</u>.
<u>FERROCEMENT LINED PIT</u>

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
D. WATERPROOFING				
1. Apply first coat	Shovels, trowels, measuring container, mixing pad	Cement, sand water	1-2 Hrs	1:2 cement/sand ratio applied as in steps C.1-C.4 above and smoothed.
2. Apply second coat	Shovels, trowels, measuring container, mixing pad	Cement, water	1-3 hrs	Apply cement paste 0.2-0.4 cm thick and smooth on day following application of first coat.
3. Allow to harden/cure		Water, burlap, etc.	2-4 Days	Wet several times per day and cover.
E. ROOF	Depending on type of roof		2-4 Hrs	Place roof on pit.
F. FINAL GRADING/FINISHING	Digging tools		1-2 Days	Slope ground away from tank and allow for drainage.

CONSTRUCTION OF THE TANK

Introduction

The following trainer notes should be read in conjunction with Preparations for Construction in the Introduction to this training guide under Section 1.6.4, and the two handouts for Session 13 should be given to the participants. General comments on preparing for the workshop and choosing the construction technology and system design for the demonstration system are discussed in the former, and specific construction instructions for masonry tanks and ferrocement pits and tanks are given in the latter. Analagous descriptions of construction guidelines and procedures will have to be written and distributed to the participants if other technologies are used.

These Trainer Reference Notes cover: (1) planning the practical session; (2) organizing and supervising the work of village artisans and laborers; (3) maximizing the practical session as an experiential learning session; and (4) several specific construction recommendations.

1. Planning the Practical Session

The demonstration system of practical construction work is the major activity of this workshop. For it to be successful, it must be well planned, organized and conducted. As mentioned in the introduction to this guide, this planning must start several months before the start of the workshop. Once a certain construction technology has been selected and materials needed to build it have been determined, the materials, workers and tools have to be assembled and prepared. If local communities are to be involved in gathering locally available materials such as sand, gravel, water, boards, etc., they must be informed and involved well enough in advance so that all these materials are at the work site before the start of the work. Adequate time is also needed for ordering and purchasing cement, reinforcing materials, corrugated iron sheeting, and tools--especially if these materials are being procured in rural areas rather than a capital city. A workshop which has been planned for four months cannot be delayed a week because the cement hasn't arrived on time.

The large roof catchment system constructed during the workshop must be planned so that it will be completed by the end of the workshop. The construction schedule should be designed accordingly. Wherever possible, the major construction procedures such as laying the concrete foundation, building the walls, waterproofing the tank, and connecting the various components should be scheduled to occur on Days 6-11 when the afternoons are set aside for the practical sessions. Specific practical construction technologies and system designs should be chosen which permit such a construction schedule if at all possible. Local village artisans and laborers should be hired to do as much work as necessary to keep the construction on schedule. They will have to start work before Day 6 and in some cases will have to start some work before the arrival of the participants. In planning the schedule, remember that some of the artisans or laborers may need to be involved in the other two construction sessions which occur on Days 4 and 5 (Session 8 and 10).

2. Organizing and Supervising Village Artisans and Laborers

The following local artisans may be needed to work on the system's construction:

- Masons for all mortar and concrete construction
- Carpenters for forms, roof frames, and gutter supports
- Metal workers for reinforcing rods, mesh, and gutter construction (if using corrugated iron sheet for gutters and downpipes)
- Plumbers for connecting pipes, faucets, pumps, etc.

In addition to these local artisans, day laborers with relevant construction experience will also be needed to help the artisans complete their work in the required time and to do such tasks as gathering materials, preparing the work site, cleaning sand and gravel, excavating the tank site, etc.

These artisans and laborers should be drawn from the local community so that the construction techniques demonstrated are shared with the community. Depending on the community's interest and involvement, they can be donated and supported by the community or paid on a daily wage basis by the project sponsoring the workshop. If workers are provided by the community and not paid by the project, the training staff must be very sure that they understand their responsibilties and are available for all the work required of them. The workshop construction foreman must thoroughly brief and supervise these artisans. They must understand that they have dual responsibilities which may at times seem to conflict. Along with having to take primary responsibility for completing all the work, they also have to provide technical assistance to the workshop participants during the practicals when they have an opportunity to do some of the work. Local artisans are not experienced trainers, and they have to be thoroughly briefed beforehand and adequately supervised to assure that they help the participants learn by doing rather than taking over from them.

In developing the construction schedule, the lead trainer and foreman must work closely together to plan what specific tasks will be done by the local construction workers and what tasks by the participants. The workers will be doing most of the work, but the key tasks mentioned above should be done by the participants. The workers can complete the work started by the participants or start it so the participants can complete it, whichever makes more sense given the construction schedule, procedure, and participants' learning needs. For example, the workers might start the wall of a masonry tank and bring it up 60-80 cm before Visit #5 when the participants spend 2-1/2 hours working on the wall. The participants might do another 40-60 cm at that visit and the remaining wall could be completed by the masons after the participants leave so that the wall is ready for plastering the next day.

3. Maximizing the Learning Experience

The trainer must keep in mind that the construction of the tank is primarily a learning event and not a constructon project. At times, the pressure to complete the tank by the end of the workshop makes it seem more like the latter than the former. All efforts should be made to complete the demonstration system because the participants need to learn all the construction procedures and see what a finished system looks like and how it operates. It is also important for their feelings of self-confidence to have been able to complete an entire system. But the completion of the system should not be accomplished at the price of the participants' learning.

As with all activities in this workshop, the practical, "hands-on" learning objectives of this session can only be met by following all the steps in the experiential learning cycle. The participants will have ample opportunity during the practical sessions to become familiar with constructing a roof catchment system. The trainer must intervene in the practical work to help the participants "process" what they have learned, and to make sense out of what they are doing by reflecting upon their activity and pulling out the most important things learned. The participants must also be brought together after the work to discuss what they did and what they learned and to generalize from the experience and relate it to the rest of what they know. Finally, they are given several opportunities to apply what they have learned during one afternoon on other afternoons. The design of this session which stresses introductory instructions, key learning objectives, and topics and sample questions for final discussions should maximize the learning in this session. Given the fact that there are many construction technologies and system designs to choose from, it is the responsibility of the workshop trainers to adapt this design to the specific construction methods chosen, to develop lists of key things learned, and to develop processing and generalizing questions based on them.

4. Construction Recommendations

The following recommendations regarding construction are specific to the two examples used throughout this design.

<u>Masonry Tank Construction</u> (See <u>Handout 13-2: Construction Procedures</u>)

Materials

- Baked brick and stones should be of good quality and clean.
- Cement blocks should be well made and given adequate time to cure before using in wall construction.

- All cement mortar and concrete materials (sand, gravel, and water) should be well cleaned and free of organic matter.
- Corrugated iron sheet for roofs has to be thicker and stronger than sheeting for gutters.

Site Preparation

- The site should be well organized to accommodate up to 25 people working on the tank at any one time and also to serve as a model for how to organize a construction site. Emphasize placement and storage of materials, the area needed for mixing mortar and concrete, adequate space, and flow of workers.
- See Handout 13-1: Construction Guidelines for preparing and laying wall and floor footings.
- Set construction schedule for these tasks so that as much work as possible is being done while the participants are visiting the site.

Wall Construction

- Follow Handout 13-1: Construction Guidelines and Handout 13-2: Construction Procedures
- 1:4 cement:sand ratio is recommended for laying bricks, etc., rather than a less rich mixture (1:5 or 1:6) because of the need for the tank to hold water and be leakproof.
- A finished masonry wall only needs one day to cure before starting plastering. It should have several days of curing before placing a heavy cover on it.

Floor Construction

- Follow guidelines and procedures handouts.
- 1:1-1/2:3 cement-sand-gravel is recommended because it is richer than 1:2:3 or 1:2:4 and floor has to hold water.
- Reinforcing rod grill for the floor should be made with 6 mm or 8 mm re-rod tied by wire into a grill with spacing of from 10 to 20 cm apart. It should be tied into re-bar (8 or 10 mm) embedded vertically in the inside lip of the wall footing, or coming out horizontally from under the first course of bricks.

Roof

- It is recommended to make the roof out of corrugated iron sheet and a sturdy wood board frame rather than trying to lay reinforced concrete slabs and place them on the tank as a cover. The former is less expensive and easier to construct in a village. It should be bolted to the top of the wall securely so that it cannot be lifted off the tank. The manhole cover should be made with a lock. The roof should slop so that water from the system or rainfall will flow off the roof. Reinforced concrete slabs are not suitable for the demonstration tank because of their cost, weight, the time needed for curing (2 weeks), and the technical sophistication of building slabs which can span two meters.

Ferrocement Lined Pit (See Handout 13-2: Construction Procedures)

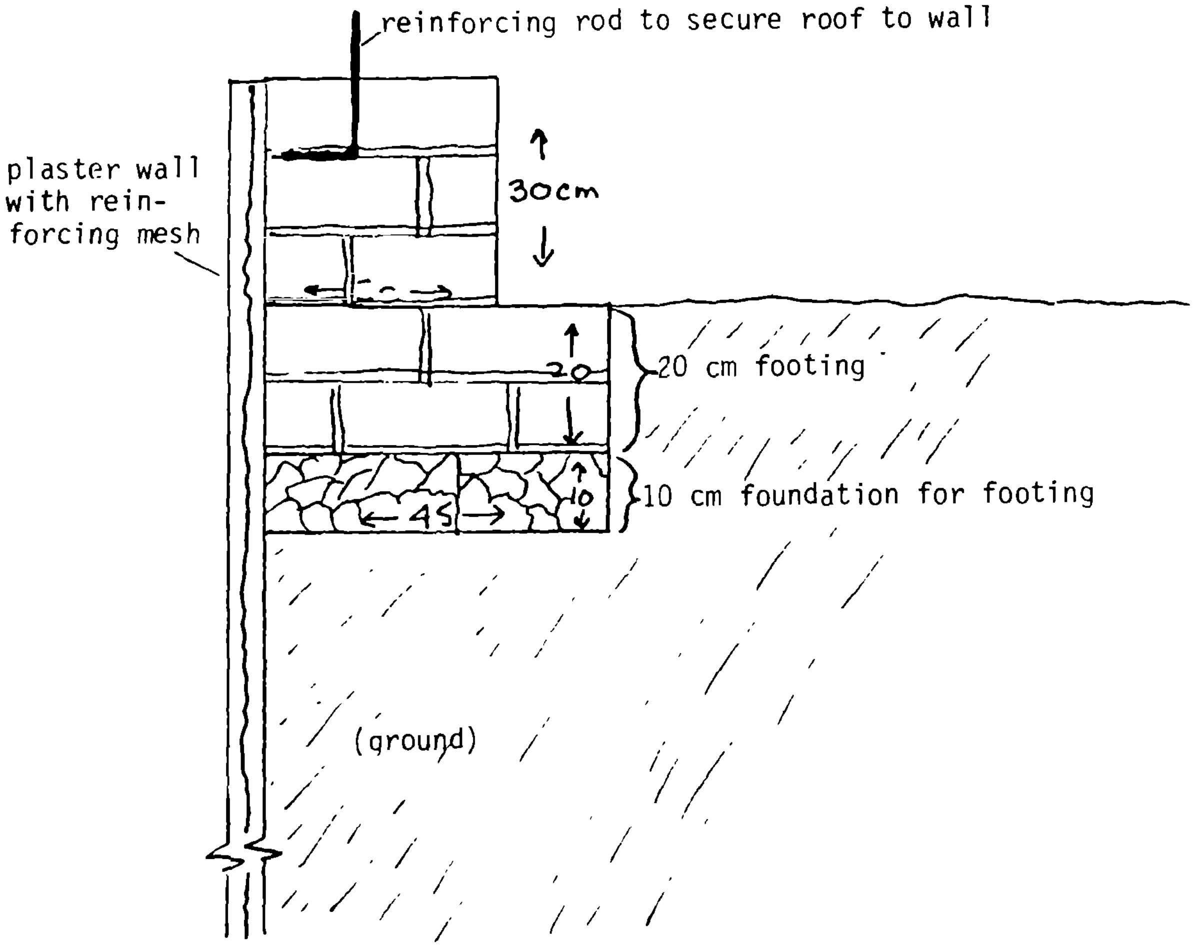
Design Issues

- The pit can be built to hold large quantities of water but should not be made much bigger than 10 m^3 for the purposes of the demonstration so it can be completed in the time allotted for construction during the workshop. It can be made in any form (rectangular, square, or cyclindrical). It should have an above-ground portion coming up 30 cm so that water does not run into the pit and people do not walk on the cover. The pit should not be deeper than one and a half meters and the total height of the tank should be under two meters so that it is easy for the participants to work in it. The means of drawing or pumping water out of the tank will have to be decided before the roof is constructed.

Preparation

- Prepare the site as in the above notes for a masonry tank.

- Construct the above-ground wall out of masonry using the notes, guidelines, and procedures for that method. Excavate the pit in line with the inside wall and footings of the masonry wall, and build the ferrocement wall against the masonry wall as well as the surface of the pit. See illustration below.



Floor

- Follow instructions in guidelines and procedures handouts, and the above trainer notes for masonry tank floors.

Walls

- As with all mortar construction, use as dry a mixture of mortar as workable. Surpervise local masons carefully as they prefer working with a very wet mortar which is not suitable for this type of construction.

- Reinforcement for the wall should be 1" (2.54 cm) mesh chicken wire. The thinner the wire and smaller the holes in the mesh, the better it is for reinforcing.

Roof

- The roof should be strong enough to support the weight of an adult, and should be designed to be visible and obvious.

- The roof should be made to support a pump or other mechanism for lifting water. If a door is built into the roof it should be watertight when closed.

- See above notes on roofs for masonry tanks.

SYNOPSIS

SESSION 14: Preparation for Construction: Community Participation

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction/Linkage	Discuss	5	---	Session Goals
2.	Small Group Task	Read and Discuss Case Study	30-45	Handout 14-1: Case Study	---
3.	Group Presentation of Case	Discuss	30	---	---
4.	Role Play	Actors/Observers	20	---	---
5.	Role Play Discussion	Discuss	30	---	---
6.	Generalizing	Guided Discussion	20	---	---
7.	Application & Closure	Discuss	10	---	---

TOTAL: 2 hours, 25 to 40 minutes

Session 14: Preparation for Construction: Community Participation

GOAL — Total time: 2 hours & 25-40 min.

To consider the process of organizing the community for the project.

OBJECTIVES

At the end of this session the trainees will be able to:

- Develop strategies for involving the community in organizing the tank construction
- List some of the problems which can occur when insufficient community participation has taken place
- State the linkage between community social assessment and community project involvement

OVERVIEW

In the session on conducting a community social assessment, the trainees considered the minimum social criteria necessary for developing a rainwater roof catchment project, but minimal consideration was given to the process of how to actually work with the community in doing it. This session takes the project development process a step further and considers some of the elements necessary for actual community participation at the point just prior to construction. The session uses a case study which poses certain problems which can occur when proper community participation has not been planned.

ACTIVITIES

1. Introduction/Linkage — Time: 5 minutes

Refer back to Session 4 on community social assessment and explain the linkage to this session (explained above in the overview). Explain the goals of the session. Lead into the next step which uses a case study, by telling the trainees that the exercise will consider the factors necessary for engaging the community members in organizing to carry out the construction work and committing themselves to the next step in the project.

2. Read and Discuss Case Study — Time: 30-45 minutes

Distribute Handout 14-1: Case Study. Divide the group into two smaller groups and ask them to read the case study individually and then discuss the tasks at the end of the case study and prepare their answers for the full group discussion.

3. Group Presentation of Case Time: 30 minutes

Discuss the first two questions in the case study, reserving the community meeting strategy for the next step, which is a role play. Each group should be given the opportunity to discuss its points.

(Note: One of the things which may need to be asked is the question of the role of women in the project organization and the relationship of the two women on the project committee to the men who could provide the construction. The group should consider some of the possible solutions to the problem within the appropriate cultural context.)

4. Role Play (Optional, See Trainer Notes) Time: 20 minutes

Ask one of the two groups to select one or two of their members to play the role of the community health worker. Give this person time to review the strategy which his/her group prepared and be ready to interact with a community health committee in a role play. While this role player is preparing, ask the other group members to think about how they will act as the community health committee. The people who are not role playing can be observers. Ask them to get together and decide what some of the things are that they will observe (for example, community reactions, approach of the worker to the committee, non-verbal communication, etc.).

When everyone is well prepared, conduct a short role play. Ten minutes or less should be enough time.

5. Role Play Discussion (Optional, See Trainer Note) Time: 30 minutes

Process the role play by "debriefing" first the role players, then the observers. A suggested list of questions follows:

Role Players:

- Community Group: What reactions do you have about the way the health worker worked with you? What worked well? Was the strategy successful? What might have been more effective?
- Community Worker: What was the strategy you had planned to use? Do you feel it worked? What might you do differently next time?
- Observers: From your point of view, what did you see happening in the role play? What worked well? What would you do to make the strategy work better? Note: if someone has a good suggestion, ask this person to try out this improved strategy by doing another role play. Then discuss this role play following the same format of questions above. This is suggested if time permits.

6. Generalizing from the Session Time: 20 minutes

Draw out what the group has learned from both the discussion of the case study and the role play by asking the following questions:

- What are the best strategies for involving the community in organizing to work on tank construction; what are the essential steps and minimum criteria? (List on a flipchart.)

- What are the major problems which may occur when the community is not properly involved?

- How can one assess if a community will cooperate in a project during the initial social assessment and avoid cooperation problems at a later stage, such as the construction phase?

- What other things can we learn from this session?

7. Application and Closure Time: 10 minutes

Ask the trainees to note in their project guides what they have learned from this session that they want to make sure they do not forget when they develop their own projects in the future. Ask for one or two examples from the group. Refer back to the session objectives and check to see if they have been achieved. Close the session.

TRAINER NOTES

1. If this group is very experienced at community promotion, the role play may not be necessary. It is designed to enhance or build skills for working with community people. If the role play and the role play discussion (Steps 4 and 5) are eliminated, an additional 50 minutes is gained. Some of this time may be used to deepen the discussion and broaden the generalization of the case study.

MATERIALS

- Flipchart with goals and objectives of the session
- Handout 14-1: Case Study

CASE STUDY

Project History

Dry Spot is a community which the community health worker selected some months ago to work in to develop a rainwater roof catchment project. The initial technical assessment indicated that indeed it was feasible to develop a rainwater collection and storage project. Rainfall data was sufficient for a ten cubic meter communal tank to be constructed using an existing school roof for catchment. The community was currently carrying water long distances for family drinking purposes. This work was done by women and children. The stream where the water was collected was contaminated and sometimes was completely dry during the dry season.

During the project social assessment phase, the community worker had worked through a local health committee which had been previously formed to assist a small community clinic, sponsored by the Ministry of Health. The committee had been very enthusiastic. They agreed to build a communal tank because everybody would have an equal interest in the benefits of the project. They had also heard that in the past some other villages had problems with individual family tanks because the wealthier families would build their own storage systems and make money by selling water to people. Those who seemed most committed to the project were the two women on the health committee. The committee had agreed to collect a small amount from each family monthly until the necessary community quota had been raised to match the amount that the Ministry of Health would provide for the project. Dry Spot has 500 inhabitants. The community lives by working in subsistence agriculture and by selling charcoal and goat cheese.

Current Situation

There is only one month left to construct the tank in order to use it during the upcoming rainy season. The Ministry of Health has ordered all of the necessary materials upon the recommendation of the community health worker. This was done without informing the committee, because the worker did not want the community to know that it was going to receive the materials until they had collected their share of the quota. The supervisor of the health worker has informed him/her that if the community does not provide its share of the quota, the materials will be given to another community which has collected money on its own and asked for assistance in another project.

The community worker has also found out that the health committee has not yet been able to provide a list of the men who will be available to work on the project, even though the community resource inventory conducted earlier indicated that there were at least two men who were somewhat experienced in construction and had worked with cement before. It seems that most of the men in the village want to collect and sell as much charcoal as possible before the rains come. If the project is to proceed, the community worker must provide to his/her supervisor both the community quota, and a statement by the health committee of which people will work on tne estimated ten days of project construction. This must be done within one week.

Task in Small Groups

1. List the possible mistakes the project developer has made.

2. Analyze the above case study. Discuss and decide what you would do.

3. Prepare a strategy for a meeting with the health committee which will address the problems of collecting the quota and organizing the community workers.

SYNOPSIS

SESSION 15: Developing a Plan for Rainwater Roof Catchment System Monitoring and Maintenance

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	10	---	Session Goals
2.	Monitoring/Maintenance	Discuss/Brainstorm	30	---	Maintenance Checklist
3.	Lecturette on Disinfection	Lecturette	30	Chlorine Test Kit, Bucket and Rope, Bleach and Chlorine, Measuring Cup, Meter Stick	
4.	Small Group Work	Three Groups	45	---	---
5.	Small Group Strategies	Presentation/ Discussion	30	Handout 15-1: Maintenance Checklist	---
6.	Presentations to Village Groups	In Village	45	---	---
7.	Generalizing and Applying	Discuss	30	---	---
8.	Closure	Discuss	5	---	---

TOTAL: 3 hours, 45 minutes

Session 15: Developing a Plan for Rainwater Roof Catchment System Monitoring and Maintenance

GOAL   Total time: 3 hours & 45 min.

To learn how to develop and communicate a monitoring and maintenance plan for the rainwater roof catchment system which the community will be able to use.

OBJECTIVES

At the end of the session, the trainees will be able to:

- Describe the importance of monitoring and maintenance activities to the life and use of the rainwater catchment system
- Describe the basics of system monitoring and maintenance
- Develop a strategy to communicate basic procedures relating to water transportation and sanitary water extraction to community members
- Develop a strategy to communicate system monitoring and maintenance procedures to community members.

OVERVIEW

The results of this session are critical to the long-range success of the rainwater roof catchment project. There are many such systems in the world that have been abandoned because they were not maintained (and not properly designed in the first place). This session is designed to cover some basic information and allow local project developers to adapt their knowledge to local conditions and develop strategies which have a good chance of success.

This session should take place with the community workers during construction.

ACTIVITIES

1. Introduction   Time: 10 minutes

Present the overview in your own words and explain the goal and objectives of the session.

2. Discussion/Brainstorming   Time: 30 minutes

Open the discussion by asking the participants whether they think monitoring and maintenance are necessary for a rainwater catchment system. Lead them to a consideration of the activities necessary for inspecting all aspects of the system by dealing in turn with each of the major parts of the system as follows:

1) Roof: leaks, debris, etc.
2) Gutters: leaks, debris, bird nests, incline, etc.
3) Down Spout: leaks, debris, foul flush system, etc.
4) Tank: cracks, sediment, quality of water, screen for overflow pipe, sanitary conditions, etc.

Write on a flipchart the points they mention as being necessary for the inspection of each part of the system, adding any that may be missed (see Trainer Note 1). When all pertinent points have been listed, ask the trainees when the critical inspection times are. This should bring out the end of the rainy season, the end of the dry season, and after any major storms.

Explain that after a lecturette on disinfection procedures they will work in small groups to develop presentations for appropriate village groups regarding monitoring, disinfecting and maintenance of the system.

3. Lecturette on Disinfection — Time: 30 minutes

First define disinfection as the reduction of pathogenic germs in an area and then list the most common types of disinfectants: chlorine, iodine, permanganate of soda, $CaCI_2O_2$ calcium hypochlorite. Explain that chlorine is the most common disinfectant used for water and that the most available and least costly form of chlorine is bleach used for laundry (sodium hypochlorite).

Describe the qualities and effects of chlorine as a disinfectant. Explain the oxidation effect chlorine has on organic matter and how its effect diminishes as the temperature of the water rises. Also explain that the effect of chlorine is related to the time it has to work, i.e. disinfection is proportional to the concentration of the disinfectant and the time of contact ($D \propto C \times T$).

(Optional)*

> The normal dosage recommended is 1 mg chlorine for each liter of water. An instrument called a chlorine test kit is used to measure the residual chlorine left after the oxidation or disinfection process.
>
> To disinfect a tank or well, put the chlorine in a bucket and pour it into the water in the tank or well. Let it work for fifteen minutes and then measure the residual chlorine with a chlorine test kit.
>
> Give practical experience at calculating the amount of chlorine needed to disinfect the demonstration tank and a pre-selected village well.

4. Small Group Work — Time: 45 minutes

Divide the group into two sub-groups and assign them the following tasks:

Group 1: Prepare a 30 minute presentation for members of the Village Health Committee on monitoring and maintenance aspects/responsibilities for the roof catchment system.

* If chlorine test kits are available.

Group 2: Prepare a 30 minute presentation for the users of the demonstration system on how to extract, transport, and store the water in a sanitary manner.

Explain that they have 40 minutes to develop their strategy for the presentations. This will be followed by a brief explanation and discussion of their strategy before the whole group.

5. Presentation/Discussion of Small Group Strategies — Time: 30 minutes

A reporter from each group presents how they plan to communicate this information to the community (five minutes). Then the trainer leads a five minute discussion on what was good about it and on suggestions to improve the strategy. Stress that this is definitely the time to offer constructive suggestions and not to criticize.

6. Presentations to Village Groups — Time: 45 minutes

The two groups from step 4 make their presentations in the village. Make sure that adequate arrangements have been made for meeting places for each group and that the respective audiences have been notified and have agreed to attend.

7. Generalizing and Applying — Time: 30 minutes

After the groups have had the opportunity to try out their strategies in the demonstration community, bring them back together for a half hour and draw out what they have learned from this experience. Suggested questions are:

- Did your strategies work?
- How did the community receive your efforts?
- What did you learn from this exercise?
- What will you do differently next time you do this?

8. Closure — Time: 5 minutes

Refer back to the objectives of the session to check goal attainment.

TRAINER NOTES

1. In Step 2, add these points to the discussion if they do not arise:

   a. The roof, gutters and cistern should be periodically inspected to identify problems (cavings, cracks, and leaks; potential environmental problems such as ground shifts or slides; or behavioral problems such as children playing in or on the system).

   b. Gutters should be replaced when worn out or waterproofed when needed or realigned when the slope is altered.

c. Debris should be swept off roof and gutters when needed.

d. The cistern water should be inspected for taste and odor.

e. The cistern should be cleaned periodically (at the beginning of the rainy season or at the end of the dry season).

f. The environment should be monitored for health hazards such as standing water or animal contamination.

2. If time permits, the trainer may wish to demonstrate how to disinfect the tank on the last day of the workshop as a follow-up practical exercise to this session. This will only be possible if the tank is completed and operational. If not, the trainer could use a nearby well if one were available. For this reason materials for disinfecting and testing are included in the materials list.

3. In Step 6 the group will be making presentations to community groups at the work site. This will require advance planning on the part of the trainers. It is suggested that those people who will be taking care of the tank (such as a village health committee) and those who will be handling the water (such as school children or others) be prepared to receive these two presentations.

4. Handout 15-1: Maintenance Checklist is included as a reminder for promoters to use after the workshop. It is suggested that this be referred to during Step 8 (closure). Each participant may wish to modify this checklist for his/her own use.

MATERIALS

- Flipchart with session goal and objectives
- Flipchart for Step 2
- Flipchart for Step 3
- Chlorine test kit (optional)
- Bucket and rope
- Bleach/chlorine
- Measuring cup
- Meter stick
- Handout 15-1: Maintenance Checklist

MAINTENANCE CHECKLIST

FREQUENCY	ACTIVITY	WHO IS RESPONSIBLE
A. At the beginning of each rain	1. Engage foul flush mechanism	
B. At the end of each dry period	1. Clear debris from catchment area 2. Check gutter supports and repair	
C. At the end of each dry period and weekly during rainy periods	1. Clean gutters of debris 2. Check and clean screen at downpipe 3. Check gutters for leaks and repair accordingly 4. Check gutters for overflowing and adjust position or slope accordingly 5. Check drainage around tank	
D. Monthly throughout the year	1. Check tank cover and ventilation 2. Check tank for leakage	
E. Weekly throughout the year	1. Check water quality in tank and clean out if necessary	
F. Annually	1. Clean out and disinfect tank	

SESSION 16

SYNOPSIS

SESSION 16: Critiquing and Refining the System Design

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	10	Handout 13-1: Construction Guidelines	Session Goals
2.	Design Review	Small Group	90	Handout 13-2: Construction Procedures (from Session 13)	
3.	Presentation to Group	Take Notes -- Discuss at End	30-45	---	---
4.	Group Discussion	Discuss -- Write (Project Handouts)	60	---	---
5.	Closure	Discuss	10	---	---

TOTAL: 3 hours, 20 to 35 minutes

Session 16: Critiquing and Refining the System Design

GOAL

Total time: 3 hours & 20-35 min.

To critically examine the tank design under construction and refine it for future use.

OBJECTIVES

At the end of this session the trainees will be able to:

- Compare the design of the tank with the actual tank under construction and propose possible improvements in the design of future tanks
- Compare the plan they made for the construction of the tank with the actual construction process and suggest possible improvements in the planning of future tanks

OVERVIEW

Now that the tank is well underway, it may be possible to make minor adjustments in the design (such as foul flush, water intake, outlet) and critically examine the design of the tank for improvements the next time a tank is constructed in the area.

It will also be possible for the trainees to look at the plan and discuss what assumptions were made which did not turn out to be realistic and suggest ways to avoid similar problems in the future construction of the tank.

This session is designed to take the training group through this process so they may make changes and incorporate them in their project handouts.

ACTIVITIES

1. Introduction

   Review the goals and purposes of the session. Time: 10 minutes

2. Small Group Task: Design Review Time: 1 hour 30 min

Ask the trainees to form into groups of three or four including one mason and two or three promoters and complete the following tasks (write tasks on flip-chart):

- Review all of the steps in the construction and estimated times.
- Review Handout 13-1: Construction Guidelines and Handout 13-2: Construction Procedures.
- Organize and write an inspection checklist which consists of all of the construction features the teams of two want to review in a tank inspection

- Visit the tank and critically review each design feature, considering what modifications should be made the next time a tank is constructed.

- Organize a presentation for the rest of the group on what changes they would make and be prepared to present their recommendations in a 5 to 10 minute time period.

3. Presentations to Group Time: 30-45 minutes

Ask each group to present its recommendations on design modifications and construction changes to the full group. The presentations will be easier to manage if every one gets to present his/her recommendations before they are discussed by the group. The group can take notes, holding comments until the next step.

4. Group Discussion Time: 1 hour

Conduct a group discussion based upon the recommendations presented previously. Try to arrive at a consensus on design and construction modifications, recording the agreed upon modifications. At the end, give the group time to record these changes in their handouts.

5. Closure: Generalizations and Applications Time: 10 minutes

Ask the trainees to review all they have done in this session. Ask if they could have forseen any of these changes when they first started. Ask what factors will need to be considered as contingencies the next time they construct a tank on their own.

TRAINER NOTE

In the introduction some explanation may be necessary to explain that this session is not intended to be a review of how to design the system (an earlier session); rather it is intended as a way to learn from mistakes so that they will not be repeated when the participant works alone on a project after the workshop.

MATERIALS

- Handouts 13-1 and 13-2 from Session 13

SESSION

SYNOPSIS

SESSION 17: Making and Connecting the Gutters

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introducton	Discuss	5	---	Session Goals
2.	Design of Gutters	Discuss	25	Handout 17-1: Construction Guidelines for Gutters Handout 17-2: Procedures for Construction and Placement of Gutters	---
3.	Visit to Work Site	Field Work	3 hrs.	See Above	---
4.	Follow-up Discussion	Discuss - Write (Project Handout Changes)	20	---	---
5.	Summary	Discuss	10	---	---

TOTAL: 4 hours

Session 17: Making and Connecting the Gutters

GOAL

Total time: 4 hours

To learn the basic steps and procedures in constructing and connecting gutters.

OBJECTIVES

At the end of the session, the trainees will be able to:

- Make simple gutters, using the materials used in the construction of the gutters of the demonstration tank
- Install gutters on roofs similar to the one used in the demonstration project
- Discuss how to avoid some of the problems which may occur during the installation of gutters

OVERVIEW

In this session the trainees will review the design of the gutters in the previous session and their selection of materials and procedures for installing the gutters. They will also have practical experience with the construction and installation of such gutters. During the practical work the trainer should point out what problems to avoid and what may happen if the gutters are improperly made or installed.

ACTIVITIES

1. Introduction — Time: 5 minutes

Give the group the information in the overview and state the goals and objectives. Answer any questions.

2. Design of Gutters — Time: 25 minutes

Review the design of the gutters which was developed in the earlier sessions. Discuss the rationale for the choice of materials and review the plans that were made for gutter construction and placement. Emphasize the plans for building the gutter supports, attaching the gutters to the roof so that they catch all the runoff, and making sure they have an adequate slope to carry the water to the tank fast enough so they do not overflow or leak.

3. <u>Visit to the Work Site</u> Time: 3 hours

Read the Trainer Reference Notes which follow the handouts for this session first and plan the construction activity accordingly. Divide the group into work teams. Explain the work to be accomplished in the next three hours. Give the specific teams their tasks and say how much time they will have before trading tasks with another team (if there are several different tasks to be accomplished and not enough tools or space for each team to do all the tasks), and get them started.

If it has been decided to spend most of the time on gutter installation rather than construction, show the participants the completed gutters and demonstrate how they were constructed based upon the design decided upon in Sessions 6 and 16. Answer any questions about the construction procedures. Review the main points made in Step 2 on installing the gutters and then get the group working on that task.

Bring up the following key learning objectives at appropriate times during the work. See Trainer Refernece Notes and handouts for details.

- Dimensions and form of the gutters
- Costs of alternative guttering technologies (from Session 6)
- Any special problems in gutter construction (check with foreman)
- How to securely attach gutters to roof
- How to line up slope of gutters using measuring tape or ruler and string
- Placement of gutter in relation to roof to catch heavy and light rains
- Connection of gutter to downspout or foul flush mechansim
- Connecting lengths of gutter to minimize leaking. Are resin sealants or tar locally available?
- What tools and skills are needed to accomplish the task?
- How much time does the task take?

When the work is completed, reconvene the group at the work site or return to the classroom for the next step i.e., the follow-up discussion.

4. <u>Follow-Up Discussion</u> Time: 20 minutes

Discuss the experience the trainees have had and answer any questions they may have had. Review the changes in the design (if any) which had to be made and how these could have been avoided by better planning. The three basic questions for processing are: What did you learn? What would you change next time? And what have you learned which you could apply to the rest of your work?

5. Summary   Time: 10 minutes

Summarize the two discussions. Review key things learned. Mention the afternoon practical session on completing the system.

MATERIALS

- Flipchart with goals and objectives.
- Handout 17-1: Construction Guidelines for Gutters
- Handout 17-2: Procedures for Construction and Placement of Gutters
- Construction materials (based on chosen technology and materials)
  Note: You may choose to have gutters, downspout, etc. built before the session and ready for installation. See Trainer Reference Notes.
- Construction and installation tools and equipment depending on technology and design

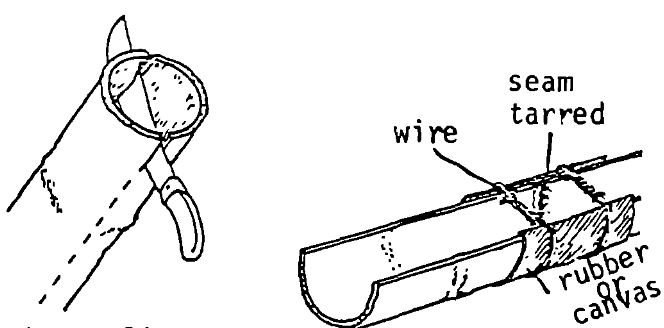
CONSTRUCTION GUIDELINES FOR GUTTERS*

Materials

The gutter material selected should be light in weight, water resistant, and easily joined. To reduce the number of joints and thus the likelihood of leakages, a material which is available in long straight sections is preferred. Some examples of materials commonly used for gutters are split bamboo, wood, and metal sheeting.

Size and Shape

The gutter must be large enough to channel water from heavy rains without overflowing. The shape is also very important. If the gutter is too shallow it may overflow. If it is too narrow the water from the roof may shoot over the gutter and be lost. For most roof catchments a gutter with a cross-sectional area of 70-80 cm^2 is sufficient for the range of slopes recommended here. The minimum recommended width for square and semi-circular gutters is 8 cm. For a triangular shaped gutter the width should be at least 10 cm. The minimum recommended depth is 7.0 cm for any gutter.

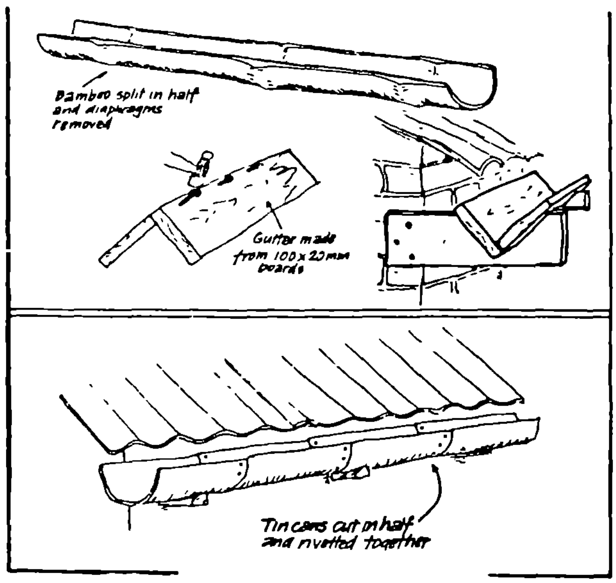


a. Bamboo split lengthwise

b. joining 2 pieces of bamboo

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

Figure 2, Bamboo Guttering Joining Sections.



Basics, October 1978, page 4

Figure 3, Alternative Forms of Guttering.

* From Keller, op.cit.

Slope

The gutter should be placed at a uniform slope to prevent water from pooling and overflowing the gutter. For most roof catchments the slope should be in the range of 0.8 cm/meter to 1.0 cm/meter.

Location

The gutter must collect all of the water running off the roof during light and heavy rainstorms. To achieve this the gutter should be located so that the roof overhangs the gutter by 1 or 2 cm, and the gutter extends beyond the edge of the roof by at least 7 cm.

Supports

The gutter must be well supported. The number of supports depends upon the type of guttering material but it is recommended that most gutters be supported at least every 50-60 cm. The simplest means of support is by tying wire around the gutter and fastening it to the roof. The gutter can also be nailed to the roof or be provided with wooden supports underneath.

Joints

All joints should be leak proof. Joints can be sealed using tar, pitch or a similar material. Strips of plastic can also be laid in the gutter to prevent leakage. The joining material should be one which does not contaminate the water.

Procedures for Construction and Placement of Gutters

ACTIVITY	MATERIALS AND TOOLS	COMMENTS
1. Make gutter	Hammer, nails, wire, etc, depending on type of material, measuring tape or ruler	70-80 cm^2 minimum cross sectional area 8 cm minimum width 7 cm minimum depth
2. Join sections & seal	Hammer, nails, wire, etc. and sealing material	All joints should be made leakproof.
3. Attach to roof	Wire, nails, etc.	Should be supported at intervals of 50-60 cm.
4. Check position	Measuring tape or ruler	Roof should overhang by at least 1-2 cm. Gutter should extend at least 7 cm beyond edge of roof.
5. Adjust slope	Level	Recommended range of slope: 0.8 cm/meter - 1.0 cm/meter.
6. Attach downpipe and foul flush	Wire, nails, sealing material, etc., and screen	All joints should be leakproof; screen should be placed at mouth of downpipe.
7. Attach to tank	Downspout pipe	7 cm diameter

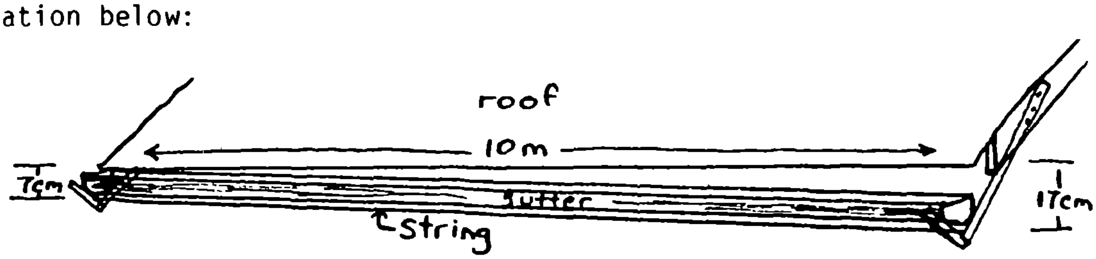
CONSTRUCTING AND PLACING THE GUTTERS

Constructing and placing the gutters, like building the tank, is probably not a task which can be completed by the participants by themselves in the time alloted for the practical demonstration. The practical session is designed to let them have hands-on experience with the construction and placement procedures so they understand them well enough to supervise the village artisans responsible for the actual construction. They should have an opportunity to learn how to do these tasks, but time may not permit them to complete all the work themselves. The specific work assigned to the participants during the three hours at the work site will depend on their learning needs, the guttering technology, and the size of the roof surface to be guttered.

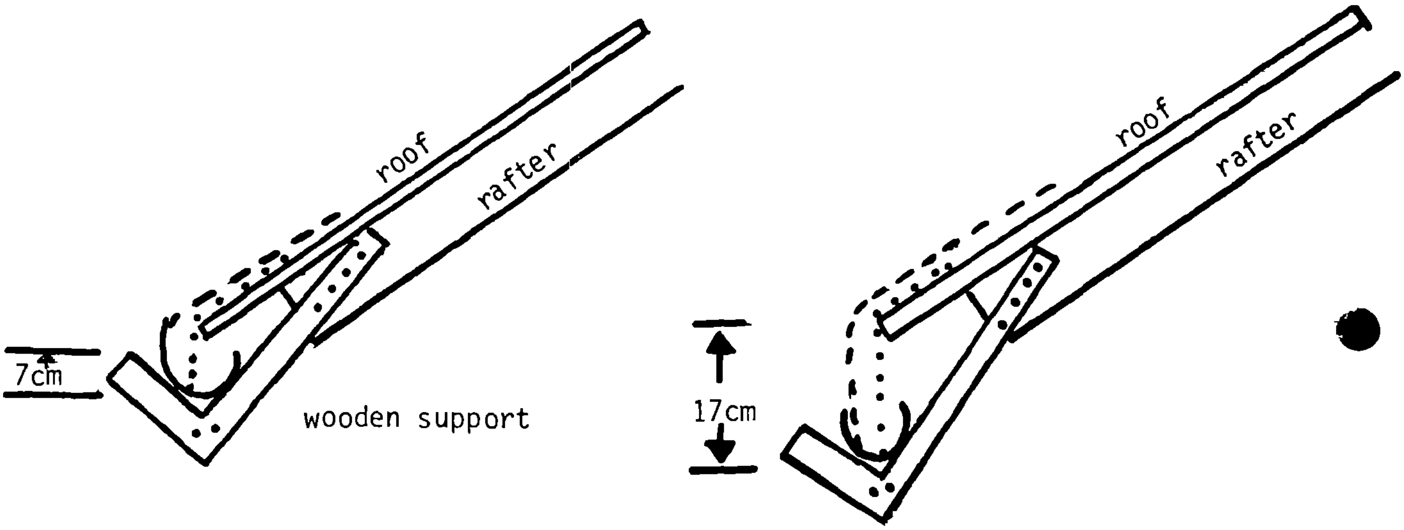
For example, if a large roof is being guttered on both sides, the participants might do one side and the workers the other. If a simple but time-consuming technology is being used to make more than 10 meters of gutters, it is recommended that the gutters be made prior to this session and be ready to be installed. One of the workers can briefly demonstrate how the gutters were made (such as flattening a small piece of corrugated iron sheeting, cutting it in half lengthwise, bending it into a semi-circular gutter and tying it in that shape with wire). Answer any questions. This will permit the participants to concentrate on the more difficult task of installing the gutters.

To whatever extent possible, in installing the gutters, the participants should learn by doing. This does not include making time-consuming mistakes, but should include solving the major installation problems such as how to set the 0.8 to 1.0 percent slope, how far away from the roof the gutter has to be to catch a heavy rain, and how to attach the gutters securely to the roof. The trainer and construction foreman should answer their questions, but they should be allowed to make most of the decisions and try them out.

One way of lining up the gutters to follow the chosen slope is with a string. The longer the run of gutters and the less friction in the material (corrugated iron sheet compared to wooden boards) the less the slope has to be. Choose a slope from 0.8 to 1.0 cm per meter and measure the total length of the gutters. A gutter 15 meters long will have to be 12 to 15 cm lower at the end by the tank depending on the chosen slope. Fasten a piece of gutter in place at the far end of the roof away from the tank (the start of the gutter) and measure the distance from the bottom of the gutter or a fixed point on the gutter support to the edge of the roof. Then add the number of centimeters, determined by the total length of the gutter, to that figure and fix the support or gutter to the roof at the end of the gutter. Run a string from one point to the other and line up the gutters or supports with the string. See illustration below:



You may want to point out that as the gutter drops farther below the roof line (over 10 meters, the gutter will be 10 cm lower at the end near the tank than at the start of the gutter. Since the gutter itself has to start off at least 7 cm from the roof it will be 17 cm below the roof after 10 meters) and has to be farther away from the roof to catch the water flowing off the roof. See the drawings below:



.......light rain, drips off edge of roof

— — — — — —heavy rains, runs past edge of roof

If the participants cannot finish the work they are doing in the three hours scheduled for this activity in the morning, Steps 4 and 5 can be put off and completed in the afternoon by adding 30 minutes to the construction time. If necessary some of the task can be completed in the afternoon session (Visit #8 of Session 13). It is important that the participants have the opportunity to install completely one run of guttering to see how the entire procedure is done.

Finally, if there are too many participants for all of them to be working at the same time making and installing gutters, some of them can be occupied in preparing for some of the tasks to be done in the afternoon such as making the downpipe, foul flush or filter, completing the roof so it is ready to be placed on the tank, etc.

SESSION 18

SYNOPSIS

SESSION 18: Planning Applications of the Workshop in "Home" Villages

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5	---	Session Goals
2.	Unresolved Questions	Review; Discuss List	10	Trainees should have individual workshop notes at hand	---
3.	Changes in the Project Process	Brainstorm	45	---	---
4.	Future Project Promotion	Respond; Record; Discuss; Write	60	---	---
5.	Institutional Support Needs	---	30	---	---
6.	Closure	Discuss	5	---	---

TOTAL: 2 hours, 35 minutes

Session 18: Planning Applications of the Workshop in "Home" Villages

GOAL — Total time: 2 hours & 35 min.

To plan applications of the workshop to the work setting.

OBJECTIVES

- To specify the changes that local promoters would make in the project development and construction process on the basis of the workshop experience
- To state and clarify unresolved questions that have surfaced on the basis of the workshop experience
- To consider what important factors should be considered in future project promotion
- To develop an action plan for promotion of rainwater catchment in the project area of responsibility

OVERVIEW

This session is designed as a workshop wrap-up. It should allow the participants to critically review the work they have done to date, answer any lingering questions, and look to the future of rainwater catchment in their work areas.

ACTIVITIES

1. Introduction — Time: 5 minutes

Introduce the goals and objectives of the session. Briefly review the content in the overview and add any appropriate comments.

2. Unresolved Questions — Time: 10 minutes

Ask all participants to think through all of the things they have done during the workshop. Have them look through their notes and their Project Development Guide (handouts packet) as well. As they do this they should write down all of the questions that still remain about the project process and the technical process. After this is done, explain that each individual will need to take responsibility to get the required information from colleagues or instructors after the session. At this point major points of curiosity should have been answered.

3. Brainstorm: Changes in the Project Process — Time: 45 minutes

Write down the following question: What changes would you make in either the project steps we have gone through or the technical information and skills that you have used in this workshop? Ask the group to consider these questions for a minute and then elicit a series of responses by listing everything that is said. At this point do not comment or discuss the responses, just list them on the flipchart or blackboard.

Once this has been done, go back through the responses and ask the group to consider the merits of each response, holding a group discussion. In the process, clarify the viability of the changes that are suggested.

4. Future Project Promotion — Time: 60 minutes

The following is a beginning project planning exercise. Give the following instructions to the group: "Now that we have a very good idea of how to develop projects in rainwater roof catchment, let's look a bit to the future. What essential criteria is important to consider in the selection of a village for a project?" Elicit responses and record. Then discuss (10 minutes).

Planning Task: Instruct the participants: "Individually, write down all of the villages in your project area which you feel meet the criteria we have just discussed. Then begin to plan the steps in your work plan for the next month that you will take to start project promotion, include the following: people to contact, technical feasibility studies, schedule, resources needed to do promotion, and strategies to get people interested in projects. After you have completed a work plan for one month, discuss this with one other person in the group to add ideas and try out your thinking.

Bring the participants back together and ask them to share a sample of their project planning so that others may get ideas.

5. Institutional Support Needs — Time: 30 minutes

Explain to the participants that now that they have a beginning plan of action for getting started, they will need to consider what kind of institutional support they are going to need. In order to do this, we have one last group task.

Divide the group into four sub-groups and give them the following task:

Discuss the needs you will have for institutional support from the official agencies for which you work or which are funding your work to enable you to obtain the goals you have just set for yourselves in your action plan. Be prepared to share your conclusions with other groups (15 minutes).

Bring the full group back together and ask each of the sub-groups to share their conclusions with each other. Record and discuss the major points (15 minutes).

6. Closure Time: 5 minutes

Review the goals of the session. See if any questions have been left unanswered. Close the session in the locally appropriate manner with appreciation for the group's participation in the workshop.

TRAINER NOTE

In step 5 some important institutional supports might include but not be limited to the following:

- Funding for expendable materials
- Tools
- Transport of supplies to sites
- Expert technical assistance for system design, problem-solving, etc.
- Follow-up training and continuing skill development

MATERIALS

- Flipchart

SYNOPSIS

SESSION 19: Workshop Evaluation

	ACTIVITY	PROCEDURE	TIME (In minutes unless otherwise indicated)	HANDOUTS/MATERIALS	FLIPCHARTS
1.	Introduction	Discuss	5	---	---
2.	Written Evaluation	Write	30	Handout 19-1: Evaluation Form	---
3.	Oral Feedback	Discuss	20-30	---	---
4.	Closure	Discuss	10	---	---

TOTAL: 1 hour, 5 to 15 minutes

SESSION 19

GOALS

Total time: 1 hour & 5-15 min.

To conduct an evaluation of the workshop.

OBJECTIVES

- To fill out the workshop evaluation questionnaire
- To provide oral feedback to the trainers on the workshop

OVERVIEW

It is assumed that the trainers will be able to evaluate the workshop in a variety of ways, formally and informally. Each session contains objectives which are generally verifiable by observation: skills can be either demonstrated or not. It is also assumed that the recipients of this training are well motivated adults who will seek help if they don't understand something. The ultimate evaluation measure, however, will be demonstrated long after the workshop when the participant develops his/her own rainwater roof catchment project. If the training has been successful, the participant will be able to use the handouts introduced in the workshop (see Participant Reference Packet) to promote a project which is technically and socially sound.

This evaluation session provides one additional source of data. It is based upon the participants' feelings and observations about the workshop. The information gained from this session can be used both to improve the training design and to help the trainer do a better job next time in conducting this workshop. This session uses two tools, a written opinionnaire and an informal oral feedback session. The written portion should be given to provide a record for the trainer. It is intended to be done anonymously to ensure more open feedback. The oral portion is designed to gather information about the workshop which will help explain and interpret the written data and provide opportunity for give and take between the trainers and the participants.

PROCEDURES

1. Introduction

Time: 5 minutes

Introduce the evaluation session by explaining that the evaluation is important to the trainers as a way of learning how the training has been received and for future learning purposes. Describe the two parts of the evaluation (written and oral) and the time constraints.

2. Written Evaluation

Time: 30 minutes

Hand out the written evaluation form (attached) and answer any questions about the instructions on the form. Then give the group time to fill it out.

3. Oral Feedback — Time: 20-30 minutes

Write on the flipchart a two column divided space as follows:

Workshop Strengths	Constructive Suggestions for Improvement

Ask the group to volunteer comments on both sides of the question. Record the comments as they are given. At each comment, it is good to verify the comment with others in the group to see if the comment is shared by others or is only one person's opinion. It is particularly important that the trainer not act defensively and spend a lot of time explaining weaknesses. This will only serve to discourage constructive feedback.

4. Closure — Time: 10 minutes

When the participants have discussed their feedback sufficiently, close the session by acknowledging all of the good ideas and feedback.

MATERIALS

- Flipchart prepared for feedback
- Handout 19-1: Evaluation Form

EVALUATION FORM

(Please do not sign your name)

A. Goal Attainment: Please circle the appropriate number to indicate the degree to which the workshop goals have been achieved.

Session #1: To familiarize the participants with the overall workshop process and the expectations of their participation.

1	2	3	4	5
Low				High

Session #2: To impart knowledge of the major steps and basic considerations in planning and developing a rainwater harvesting project. To adapt these factors to the unique conditions of the local setting.

1	2	3	4	5
Low				High

Session #3: To examine the feasibility of a rooftop catchment program in light of local rainfall patterns.

1	2	3	4	5
Low				High

Session #4: To enable the participants to learn how to assess whether a community is willing and able to support a rooftop catchment project.

1	2	3	4	5
Low				High

Session #5: To enable the participants to learn how to conduct an inventory of local skills, materials, and techniques which can be used in rooftop catchment.

1	2	3	4	5
Low				High

Session #6: To introduce and practice using a series of criteria to reach an informed consensus on which storage and guttering technology to design and construct.

1	2	3	4	5
Low				High

Session #7: To teach participants how to calculate an "optimum" tank size and evaluate the result.

1 Low	2	3	4	5 High

Session #8: To teach the basics of mixing cement and plastering and how to build cement plaster jars for individual rain catchment storage.

1 Low	2	3	4	5 High

Session #9: To describe, in enough detail to plan construction, all the components (parts) of the system to be built.

1 Low	2	3	4	5 High

Session #10: To learn how to design and construct a roof catchment and filtration system for thatch roofs.

1 Low	2	3	4	5 High

Session #11: To teach all of the steps and procedures necessary for detailing and ordering the materials for construction.

1 Low	2	3	4	5 High

Session #13: To learn the basic steps and processes in larger (community) storage tank construction.

1 Low	2	3	4	5 High

Session #14: To consider the process of organizing the community into construction working groups and develop a plan to do so.

1 Low	2	3	4	5 High

Session #15: To learn how to develop and communicate a maintenance plan which the community will be able to use and follow.

1 Low	2	3	4	5 High

Session #16: To critically examine the tank design under construction and refine it for future use.

1	2	3	4	5
Low				High

Session #17: To learn how to construct and connect gutters.

1	2	3	4	5
Low				High

Session #18: To plan applications of the workshop to the work setting.

1	2	3	4	5
Low				High

B. <u>Workshop Feedback and Learning</u>: Please answer the following questions as fully as possible so that the trainers can learn how effective the workshop methodology was.

1. What have been the most positive things about this workshop? Comments:

2. What have been the most negative things about this workshop? Comments:

3. What one thing stands out as important to you in this workshop? Comments:

4. What things have you learned that you did not know before? Comments:

C. <u>Workshop Organization and Training</u>

1. What comments do you have about the way the workshop was planned and organized?

2. What can be done in the future to improve a workshop like this?

3. What specific steps in developing a rainwater harvesting system do you feel you will need to learn more about in order to successfully promote and develop a project in the future?

4. What comments do you have about the trainers?

8.1 Catchment Technologies

Frasier, G.W., ed., 1974, Proceedings of Water Harvesting Symposium, Phoenix, Arizona, March 26-28, 1974, Agricultural Research Service/USDA report no. ARS-W-22, 323 pages, currently out of print. Request information from the editor, Southwest Rangeland Watershed Research Center, 442 East 7th Street, Tucson, Arizona 85705, USA.

A wide-ranging compilation of 40 papers and reports on rainwater harvesting. Much of the material is quite technical and most of it concerns development of systems for agriculture. It is, however, a fine overview of the spectrum of developments in ground surface catchment. Of particular interest: "Engineering aspects of water harvesting research at the University of Arizona" (Cluff, 1974, pages 27-39) and "Storage systems for harvested water" (Dedrick, 1974, pages 175-191).

Hall, N., 1981, "Has Thatch a Future?", Appropriate Technology, London, Vol. 8, no. 3, December 1981, pages 7-9, £ 1.50 for the issue with Air Speeded Post from Intermediate Technology Publications, Ltd., 9 King Street, London WC2E 8HN, United Kingdom.

"Thatch is currently out of favour almost everywhere. It is being replaced by modern sheet materials or expensively manufactured tiles. However, as the essential ingredients of modern building become more and more costly with the rising price of raw materials and the fuel required to process them, it is undoubtedly worth re-appraising traditional materials." The author, who is studying thatch and has found little information available on the topic, presents a concise summary of thatch grass types and methods of thatching roofs, highlighting Balinese "prefabricated" techniques. There is no mention of guttering thatch roofs for rainwater catchment. The author's address: Open University, Walton Hall, Milton Keynes, Bucks, United Kingdom.

Institute for Rural Water, 1982, "Constructing, Operating, and Maintaining Roof Catchments", Water for the World technical note no. RWS.1.C.4, USAID, request from the Development Information Center, Agency for International Development, Washington, D.C., 20523, USA.

A good overview of simple rooftop catchment systems, discussing roofing and gutter installation, foul flush disposal, and maintenance. About four pages of text, the remainder figures, several of which are reproduced above with permission. (Request "Evaluating Rainfall Catchments," RWS.1.P.5, "Designing Roof Catchments," RWS.1.D.4, "Designing a Household Cistern," RWS.5.D.1, and "Constructing a Household Cistern," RWS.5.C.1, from the same source.)

*From Keller, Kent, Rainwater Harvesting for Domestic Water Supplies in Developing Countries, WASH Working Paper No. 20, Water and Sanitation for Health Project, Arlington, Va. 1982.

I.T. Building Materials Workshop, "Production and Installation of Corrugated Roof Sheet made from Fibre Reinforced Cement: Basic Operating Manual from Honduras and Guatemala", 19 pages, request from I.T. Building Materials Workshop, Corngreaves Trading Estate, Overend Road, Larley, West Midlands, B64 7DD, United Kingdom.

Describes, in good detail and with excellent line drawings, the tools, sheetmaking table and molds, and techniques for FRC sheets outlined in Parry (1981, below). "This manual describes the basic production and application techniques for the roofing products. Modifications have been incorporated to suit local circumstances in Honduras and Guatemala. The document is intended as a manual for assisting groups who already have I.T. equipment to make corrugated roof sheets and ridge tiles, and have received firsthand training from an experienced operator". (See also figure 19).

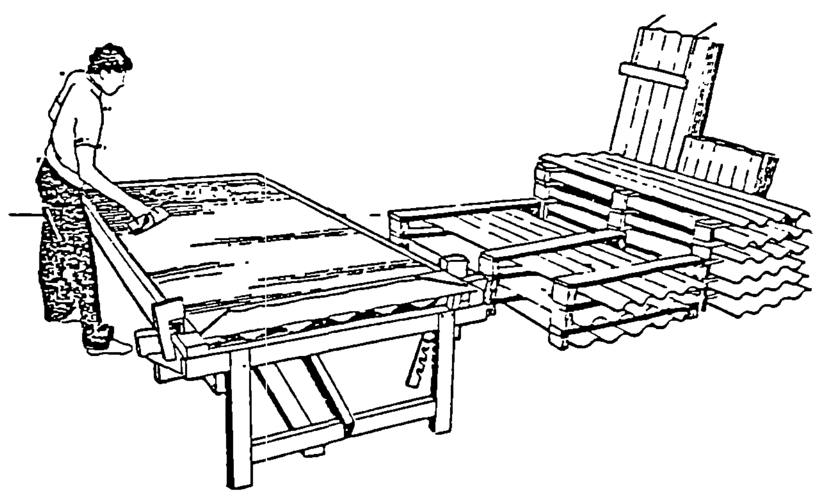


Figure 19, Ideal Deployment of Sheetmaking and Curing Equipment.

NAS, 1974, Roofing in Developing Countries: Research for New Technologies, book, 57 pages. Give name of group or institutional affiliation when requesting a free copy from BOSTID (JH215), Office of the Foreign Secretary, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C., 20418, USA.

A useful overview of the range of possible low-cost roofing materials relying on local materials and/or new techniques. Includes appendices on low-cost roofing research in India.

Parry, J.P.M., 1981, "Development and Testing of Roof Cladding Materials Made from Fibre Reinforced Cement", Appropriate Technology, London, Volume 8, no.2, September 1981, pages 20-23, £ 1.50 for the issue and Air Speeded Post from Intermediate Technology Publications Ltd., 9 King Street, London WC2E 8HN, United Kingdom.

A summary of the I.T. Building Materials Workshop findings on fibre-reinforced cement sheeting for use in the manufacture of roofing components, "The final outcome of the development work was a complete low-cost roofing system involving a new corrugated cladding panel which has the coverage of a one metre sheet but which is fitted like an extremely large but lightweight tile." Manufacturing processes for implementation on a small scale in developing countries (see I.T.

Building Materials Workshop, this section) are outlined. The author believes that FRC sheets were being made at the combined rate of about 2,000 a month by several production teams in at least seven countries in April 1981. Cost and roof structure requirements comparisons are made with conventional materials; cost advantages hinge on the lifetime of the new sheets: "only time will tell the eventual lifespan of the FRC products, but the development has now reached the point where it can be considered as a viable alternative to conventional materials and one which is especially appropriate because of its facility to be produced labour-intensively, on a small scale, in virtually any urban or rural situation."

8.2 Storage Technologies

Cairncross, S., and Feachem, R., 1978, Small Water Supplies, book, 78 pages, £1.50 from the Ross Institute, London School of Hygiene and Tropical Medicine, Keppel Street (Gower Street), London WCIE 7HT, United Kingdom.

This book is a compact presentation of basic information on building small-scale water supply systems. Discussions include sources of water, water treatment, water lifting, and storage and distribution. Contains a two-page section on building water tanks of bricks and masonry. No diagrams, but text gives guidelines for wall, footing, and floor thicknesses; plastering and waterproofing; cleaning and maintenance; inlets, outlets, overflows, screening, and covers; and drainage. In some cases the construction specifications given provide for more strength, and use more materials, than necessary.

Calvert, R.C., and Binning, R.J., 1977, "Low Cost Water Tanks in the Pacific Islands", article, 3 pages, in Appropriate Technology magazine, Vol 4, no. 3, November 1977, £0.75 for the issue including Air Speeded Post, from Intermediate Technology Publications, Ltd., 9th King Street, London WC2E 8HN, United Kingdom.

Describes fabrication of ferrocement cover on an earthen dome, excavation of tank from beneath the cover, and plastering of ferrocement lining for 15-20 m^3 tanks built in "soft" soil in the New Hebrides. The authors believe the tanks can be built for under US $250.00. They also describe a method for building above-ground ferrocement tanks using locally available wood and reed materials for forms.

Farrar, D.M., and Pacey, A.J., 1974, "Catchment Tanks in Southern Africa: A Review", Africa Fieldwork and Field Technology Report no. 6, 13 pages, request from Paul Sherlock, OXFAM, 274 Banbury Road, Oxford OX2 7DZ United Kingdom.

An excellent critical description and evalution of open and "beehive" "sand-sausage" ground surface catchment tanks, ferrocement roof catchment tanks, and combinations of these designs in Swaziland, Botswana, and Zimbabwe. The authors give the most complete construction cost information we have seen, and also discuss manual labor requirements as a barrier to completion of some of the technically sound "sand-sausage" tank projects. Step-by-step instructions for making a 7.5 m^3 version of the ferrocement tanks built by the hundreds around the Friends Rural Center, Bulawayo. Anyone considering a rooftop catchment system or project in Africa should read this report.

Henderson, G.E., Jones, E.E., and Smith, G.W., 1973, Planning for an Individual Water System, book, 156 pages, $5.00 from American Association for Vocational Instructional Materials, Engineering Center, Athens, Georgia, 30602, USA.

A well-written book on conventional water installations for rural and farming families in the U.S. Includes good color drawings of cisterns, roofwashers, and a filter. Better pictures, but less construction detail, than in Using Water Resources (below).

Maikano, G.J., and Nyberg, L., 1980, "Rainwater Catchment in Botswana", paper, 5 pages, in the book Rural Water Supply in Developing Countries: Proceedings of a Workshop on Training held in Zomba, Malawi, 5-12 August 1980. Ask for a free copy of the book from International Development Research Center, Box 8500, Ottawa, Canada K1G 3H9.

An account of a pilot program for popularizing underground ferrocement tanks to store water caught on traditional grain threshing floors. Scant rainwater harvested using these systems is for families and cattle early in the growing season, and should allow seasonally migrating farmers to move to their land and begin plowing 17 days earlier than otherwise. Not many construction details are given, but domed ferrocement covers and poured concrete covers reinforced with barbed wire are mentioned. Maintenance of the tank and catchment floor are emphasized. "Today, the pilot project has about 10 underground tanks built and more are under construction. In all it is hoped to have 80 completed by the end of 1980".

National Academy of Sciences, 1973, Ferrocement: Applications in Developing Countries, book, 91 pages, mention your institutional affiliation or name of your group when requesting a free copy from: Board on Science and Technology for International Development (BOSTID)(JH215), Office of the Foreign Secretary, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418, USA.

A basic book on the range of ferrocement techniques and potential applications, widely referred to throughout the literature on the topic. Chapters cover ferrocement for boatbuilding, food storage facilities, food-processing equipment, low-cost roofing, and the basics of construction of shells and walls. Appendices include diagrams of construction steps, and cost breakdowns for food-storage silos in Thailand and Ethiopia which can be used for storing water. (These silos are also described in the article by Sharma, et al, below).

Pompe, C., van Kerkvoorden, R., and Siswoyo, H., 1982, "Ferrocement Applications in the West Java Rural Water Supply Project", article, pages 51-61 in Journal of Ferrocement, Vol. 12, no. 1, January 1982. Ask for a reprint or xeroxed copy at $.20 per page plus $2.00 per request. from International Ferrocement Information Center, Asian Institute of Technology, P. O. Box 2754, Thailand.

An overview of the project which plans to construct hundreds of 5 m^3 and 10^3 ferrocement tanks, as well as a reservoir and community water supply system built largely of ferrocement. Presents a chart comparing costs of various rainwater storage tanks in Java, including gutters and labor costs of Rp 1000 (US$1.60) per man-day. Also includes good drawings showing construction details of the 10 m^3 tank and 2.5 m^3 bamboo-cement tank.

Sharma, P.C., Pama, R.P., Valls, J., and Gopalaratnam, V.S., 1979, "State-of-the-art Review on Ferrocement Grain Storage Bins", article, pages 135-150 in Journal of Ferrocement, Vol 9, no. 3, July 1979. Reprint or xerox copy at $0.20 per page plus $2.00 from International Ferrocement Information Center, Asian Institute of Technology, P. O. Box 2754, Bangkok, Thailand.

Describes construction techniques and costs for four ferrocement grain storage structures "...developed in different parts of the world that have been extensively field tested satisfactorily." An above-ground conical bin which has been called the "Thailo", holding 4 tons of grain or 9.5 m^3 of water, and an underground pit silo lined with reinforced plaster are two models which have been used to store water. The cost of a 9.5 m^3 underground plastered pit built in India is given as US$62.00.

UNICEF East Africa Regional office, 1982, "From Kenya--How to Make Plastered basket tanks for storing water", article (pages 7-8) in Appropriate Technology magazine, Vol 8, no. 4, March 1982, £ 1.50 from Intermediate Technology Publications, 9 King Street, London WC2E 8HN, United Kingdom. Also available from UNICEF, East African Regional Office, P. O. Box 44145, Nairobi, Kenya.

Describes activities and gives background of the Karen Appropriate Technology Unit outside Nairobi. Cement mortar jars (like those described by Watt, 1975, below) and a PVC bag suspended in a thatch-covered bamboo-lined pit are two tank designs tried at the center. Also mentions other ideas in passing: "It is noticed that, in many areas, houses will have a short length of roughly fashioned guttering fixed under the eaves just above the door, and that water from this will be collected in an old oil drum or container...(this) could provide the link point for development to simple but effective roof catchment systems." And, "Collection of water from grass roofs, even on circular huts, is possible by using a polythene film guttering or by simple guttering made from split bamboo or from two planks joined to give a "V" section." Many other ideas for food production/storage/preparation, and effective institutional involvement in village technology activities.

VITA, 1977, Using Water Resources, book, 143 pages, $5.95 from Volunteers in Technical Assistance, 1815 North Lynn Street, Suite 200, Arlington, VA 22209 USA.

This is a reprint of a part of VITA's Village Technology Handbook, available for $10.00 (387 pages) from the same address. The Handbook includes excellent sections on concrete and bamboo construction as well as health and sanitation, agriculture, and food processing and preservation. Using Water Resources contains a good 6page piece on planning and building a conventional US-type concrete cistern with a capacity of 10 m^3 or more, including drawings of a filter and a "roofwasher". The book as a whole is good basic reading for anyone considering construction of a small water supply.

Watt, S.B., 1978, Ferrocement Water Tanks and Their Construction, book, 118 pages, £ 2.95 from Intermediate Technology Publications, Ltd., 9 King Street, London WC2E 8HN, United Kingdom.

For those considering a rooftop catchment system, this book may be the singl most useful publication listed here. Gives straightforward guidelines for design, descriptions of materials and tools required, and a detailed, step-by-step summary of methods for building the ferrocement tanks (using metal forms) which have been "used successfully for over 25 years in different parts of the world" (see technical note in Appendix C). Also describes construction of several variations on the basic method, including small jars of unreinforced mortar (see technical note -- Appendix C), 1-25 m^3 manufactured tanks in New Zealand, a 6 m^3 tank built without formwork in the U.K., 10 m^3 ferrocement-lined traditional adobe grain storage bins in Mali, a 40 m^3 roofed tank built with makeshift formwork in Zimbabwe, and a 150 m^3 open tank built with makeshift formwork in Arizona, USA. Lists amounts of materials required for each design, and gives a brief discussion of using rainfall data to plan a rooftop catchment system (see technical notes in Appendices A and B below).

Watt, S.B., 1978, "Rainwater Storage Tank in Thailand", article (pages 16-17) in Appropriate Technology magazine, Vol 5, no. 2, August 1978, £ 0.75 for the issue including Air Speeded Post, from Intermediate Technology Publications, Ltd., King Street, London, WC2E 8HN, United Kingdom.

Describes construction of tanks made out of stacked ureinforced concrete rings, cast in 1.5 m. diameter cylindrical steel forms. The 60-cm-high rings can be stacked up to four high and have low materials costs (US $40.00 for a 7 m^3 tank) but the inner and outer steel forms would be expensive. Watt suggests that high-quality rings could be cast centrally under supervision and trucked to location for assembly.

Winarto, 1981, "Rainwater Collection Tanks Constructed on Self-Help Basis", article (pages 247-253) in Journal of Ferrocement, Vol 11, no. 3, July 1981. Ask for a reprint or xeroxed copy at $.20 per page plus $2.00 per request from International Ferrocement Information Center, Asian Institute of Technology, P. O. Box 2754, Bangkok, Thailand.

An account of the adaptation of standard ferrocement tank methods to the materials available in rural Java. Detailed verbal instructions for building a steel rod reinforced 9 m^3 tank with integral floor and cover. Bamboo mats are used as plastering forms. Some pictures; construction could be attempted with basic knowledge of the techniques in Ferrocement Water Tanks and Their Construction (Watt, 1978). Also describes construction of smaller tanks built with bamboo (instead of steel rod) reinforcement cages. The steel rod and bamboo cage designs presented here have been adopted by the West Java Rural Water Supply Project (Pompe et al, above).

8.3 General*

Commission on International Relations/NAS, 1974, More Water for Arid Lands: Promising Technologies and Research Opportunities, book, 154 pages, mention name of your group or institutional affiliation when requesting a free copy from BOSTID (JH215), Office of the Foreign Secretary, National Academy of Sciences, 2101 Avenue, Washington, D.C. 20418, USA.

Still useful after eight years in print, this overview is divided into two halves, "water supply" and "water conservation". Topics include runoff agriculture, reuse of water, reducing evaporation from water and soil surfaces, trickle irrigation, selecting water-efficient crops. The chapter on rainwater harvesting discusses techniques and research in Australia, Zimbabwe, and the western United States as well as the ancient gravel mounds and strips used to harvest rainwater from hillsides in the Negev 4,000 years ago. Includes good photographs of the "sand-sausage" tanks described in Ionides et al (1969) and Farrar and Pacey (1974).

Frasier, G.W., and Myers, L.E., in preparation, a handbook on rainwater harvesting with parts devoted to domestic water supply. Will be published as a USDA handbook, available from the Superintendent of Documents, Washington, D.C., in 1983. For further information contact Dr. Frasier (see section 8.1 above).

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*The Intermediate Technology Development Group (ITDG), is preparing "a practical manual describing rainwater harvesting techniques as an option for water supply." This book will probably not be available until late 1983, but the consistent quality of ITDG publications leads us to believe that it will be well-researched and useful to a broad range of workers. "The emphasis will be on low-cost systems for small communities and the scope will cover the provision of water for domestic and agricultural purposes. The manual is intended for use by project holders and field workers and consequently is planned to include, wherever possible, practical information derived from experience in the field. In order to achieve this objective ITDG is anxious to make contact with field personnel who would be willing to "A handbook/source document on technology of small community water supply systems." This useful overview contains a 12-page section which is probably the best short published summary for rainwater as a source of domestic water supply that we have share something of their experiences---successes and failures." (personal communication, Adrian Cullis, ITDG.) Write to Mr. Cullis at: Applied Research Section, Shinfield Road, Reading, Berkshire RG2 9BE, United Kingdom.

Hofkes, E.H., ed., 1981, Small Community Water Supplies, Technical Paper no. 18, IRC/WHO, book 413 pages, free for groups in developing countries, from IRC, P.O. Box 5500, 2280 HM RIJSWIJK, The Netherlands.

"A handbook/source document on technology of small community water supply systems." This useful overview contains a 12-page section which is probably the best short published summary on rainwater as a source of domestic water supply that we have seen. Includes good drawings of an underground rainwater storage well (as used in China) and a Venetian cistern. Bibliography of 12 items. IRC says that the editor is currently working on a "design manual for RWH systems".

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PARTICIPANT
REFERENCE PACKET

PARTICIPANT REFERENCE PACKET

PRE-WORKSHOP SKILL ASSESSMENT FORM

Please fill out the following form by checking in the appropriate column whether you feel that you have no experience, some skill, or adequate competency in the following skill areas:

Skill Area	No Experience	Some Skill	Adequate Competency
1. Identify the technical feasibility of a rainwater catchment project			
• identify best sources of information on local rainfall			
• identify suitable roof surfaces			
• calculate roof yield from above			
2. Social and community assessment			
• survey community needs			
• assess community interest			
• determine community preference for individual or group project			
• present information to a community			
3. Local resource inventory			
• identify available materials			
• identify available skills			
• determine resources needed for a roof catchment project			
• determine community's prior experience with such a project			
4. Choose an appropriate combination of technologies			
• familiar with alternative technologies used in constructing a water tank			

Skill Area	No Experience	Some Skill	Adequate Competency
• able to cost various technologies			
• identify various components of a catchment system and how to build them			
• identify maintenance characteristics of each component			
5. Designing a system			
• use projected yield data to determine optimum tank size			
• determine dimension, form, and placement of tank			
• determine gutters and foul-flush or filtering mechanisms			
• design construction specifications for foundations, walls, cover, etc.			
6. Ordering/gathering material and organizing the construction			
• determine materials needed for different construction technologies			
• order materials to be bought			
• organize community to provide local materials			
• plan construction steps and times			
• organize and supervise local masons and laborers			
• prepare a construction site			

Skill Area	No Experience	Some Skill	Adequate Competency
7. Construction skills			
• mix and apply mortar			
• mix and pour concrete			
• use reinforcing rod in reinforced concrete			
• use chicken wire in ferrocement			
• construct cement blocks			
• lay blocks or bricks			
• construct forms for pouring concrete walls, foundations, top slabs			
• waterproof a tank			
• construct and install gutters			
• construct and install down spout, foul flush and filters			
• disinfect the system			
• cure concrete and plaster			
8. Monitoring and maintenance			
• organize a community to maintain a roof catchment system			
• assess a community's skills and willingness to maintain such a system			
• teach community members to maintain the system			
• monitor water quality			

WORKSHOP GOALS FOR PARTICIPANT

At the end of this workshop, participants will be able to:

- Plan and develop a rainwater roof catchment project
- Determine the feasibility of a rooftop catchment program in light of local rainfall patterns
- Assess a community's willingness and ability to support a rooftop catchment system
- Conduct an inventory of local skills, materials, and techniques which can be used in rooftop catchment
- Choose the most appropriate technologies for tank and gutter construction
- Calculate an optimum size for a storage tank
- Mix and prepare cement and mortar
- Design and plan a rainwater catchment system using all of the steps and procedures necessary for detailing and ordering construction materials
- Design and construct a roof catchment and filtration system for thatch roofs
- Manage the ordering of material and labor necessary for constructing a rainwater roof catchment system
- Build a small household storage tank and a large cistern tank
- Develop strategies for involving communities in the construction of the system
- Develop a monitoring and maintenance plan for the system which the community can use and implement
- Construct, connect and hang gutters for the system
- Develop action plans for promoting rainwater roof catchment in their project areas

WORKSHOP SCHEDULE

DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Session 1 Introduction to workshop Session 2 Developing a project	Session 4 Conducting a community social assessment		Session 7 Sizing the tank	Session 9 Designing the system	Session 11 Planning for construction Session 12 Mid-point evaluation	
LUNCH						
Session 3 Initial technical assessment Visit work site	Session 5 Conducting a community resource inventory Visit work site Observe laying foundation	Session 6 Choosing the appropriate storage and guttering technology Visit work site Observe laying footings	Session 8 Building small household cement tanks	Session 10 Thatch roof catchment	Session 13 Construction of the tank	

DAY 8	DAY 9	DAY 10	DAY 11	DAY 12
Session 14 Preparation for construction	Session 15 Developing a plan for maintenance	Session 16 Critique and refine design	Session 17 Making and connecting gutters	Session 18 Conclusion: applications of the workshop in home villages Session 19 Final Evaluation
LUNCH				
Session 13 Construction of the tank (cont'd.) (masons)				

TASK G[illegible]: MAJOR STEPS IN PROJECT DEVELOPMENT OF RAINWATER HARVESTING

I. DETERMINING COMMUNITY NEEDS AND INTEREST: INITIAL PROMOTION

1. Determine extent of community need
   - find out how water is currently supplied
   - find out role of women and children in carrying water and amount of time now spent in this activity
   - does the need justify proceeding at this point?

2. Talk with community people and leaders to promote the idea of rainwater catchment; see if interest exists
   - individual house calls
   - talk with community members in work settings
   - begin promotion of idea as a test of support
   - discover potential supporters

3. Decide: Is this community interested?
   - enough to justify a promotional effort?
   - does leadership exist for community mobilization?

II. INITIAL TECHNICAL ASSESSMENT

1. Identify best sources of information on local rainfall
   - find any weather statistics
   - talk with local people (older people) about wet and dry periods
   - effectiveness of rainwater catchment systems in use

2. Identify acceptable roofs
   - identify suitable surfaces
   - measure roofs

3. Plot available rainfall data and rough calculation of yield from a local roof

4. Decide: Is there enough rain and catchment area to proceed?

III. SOCIAL AND COMMUNITY ASSESSMENT

1. Collect opinions: would additional water from a rooftop catchment system be useful

2. Explore commitment villagers would make:
   - sharing a roof and tank
   - contributing labor and/or money toward construction

3. Find out: How many systems and people are involved?

4. Decide: Does the community support rooftop catchment enough to proceed?

IV. INVENTORY OF LOCAL SKILLS, MATERIALS AND EXPERIENCE

1. Find out: Are there local masons who can build with cement, mortar/stone?

2. Find out: Are there craftspeople who construct vessels using local fiber?

3. Determine availability and costs of tank construction materials:
   - cement, stone, sand, gravel, bricks
   - reeds, bamboo, wire, chickenwire
   - shovels, trowels, etc.

4. Determine availability of guttering materials:
   - local wood/grasses
   - PVC pipe
   - metal sheet

5. Determine availability and cost of roofing materials

6. Determine: How have local people caught and stored rainwater to date?
   - traditional water and food storing containers
   - water hauling vessels: buckets, tins, etc.
   - lined holes in ground

7. Begin community promotion:
   - will skilled people be willing to contribute time?

V. CHOOSING AN APPROPRIATE COMBINATION OF TECHNOLOGIES WITH THE COMMUNITY

1. Present the range of tank and guttering technologies
2. Decide with community, individual or community tank
3. Discuss maintenance activities and type of outlet for each type of tank
4. List material requirements; estimate costs of different types of tanks
5. List levels of skills required to construct each type of tank
6. Evaluate: amount of labor (e.g., person-days) required for construction of each type of tank
7. Use these criteria to decide with community which construction option is best and mobilize community commitment for labor and cost contributions

VI. DESIGNING THE RAINWATER HARVESTING SYSTEM

1. Using projected yield pattern from local roofs, figure optimum tank volume
2. Determine: How big a tank do available resources permit?
3. Determine location(s) and type of outlet
4. Design gutters and foul flush routines or mechanism
5. Choose specifications: foundation, floor, walls, cover (use guidelines provided to determine materials and thickness)

VII. ORDERING/GATHERING MATERIALS AND ORGANIZING FOR CONSTRUCTION

1. Order materials: When will they arrive?
2. Devise sequence of steps and construction schedule with community participation
3. Organize construction teams: Who will work, and when will they work?
4. Get materials to site at chosen time
5. Determine place to keep/store materials

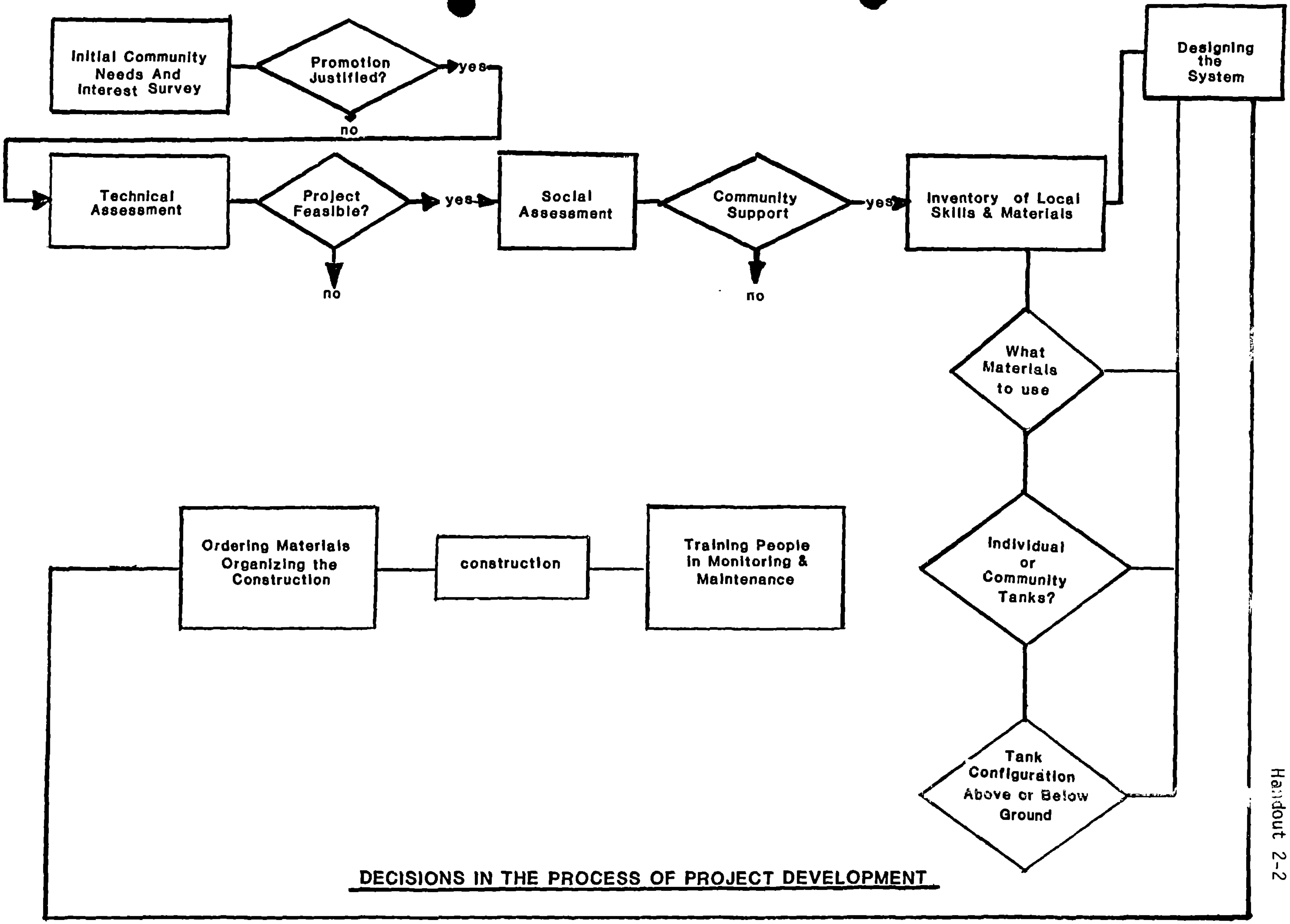
VIII. CONSTRUCTING THE CATCHMENT SYSTEM

1. Prepare/excavate site
2. Set-up: forms, mixing boards, measuring containers
3. Mix cement/concrete
4. Prepare framework, if used
5. Build footing for cover
6. Trowel/apply mortar
7. Cure tank
8. Fabricate cover
9. Hook up gutter/foul flush

IX. MONITORING AND MAINTENANCE

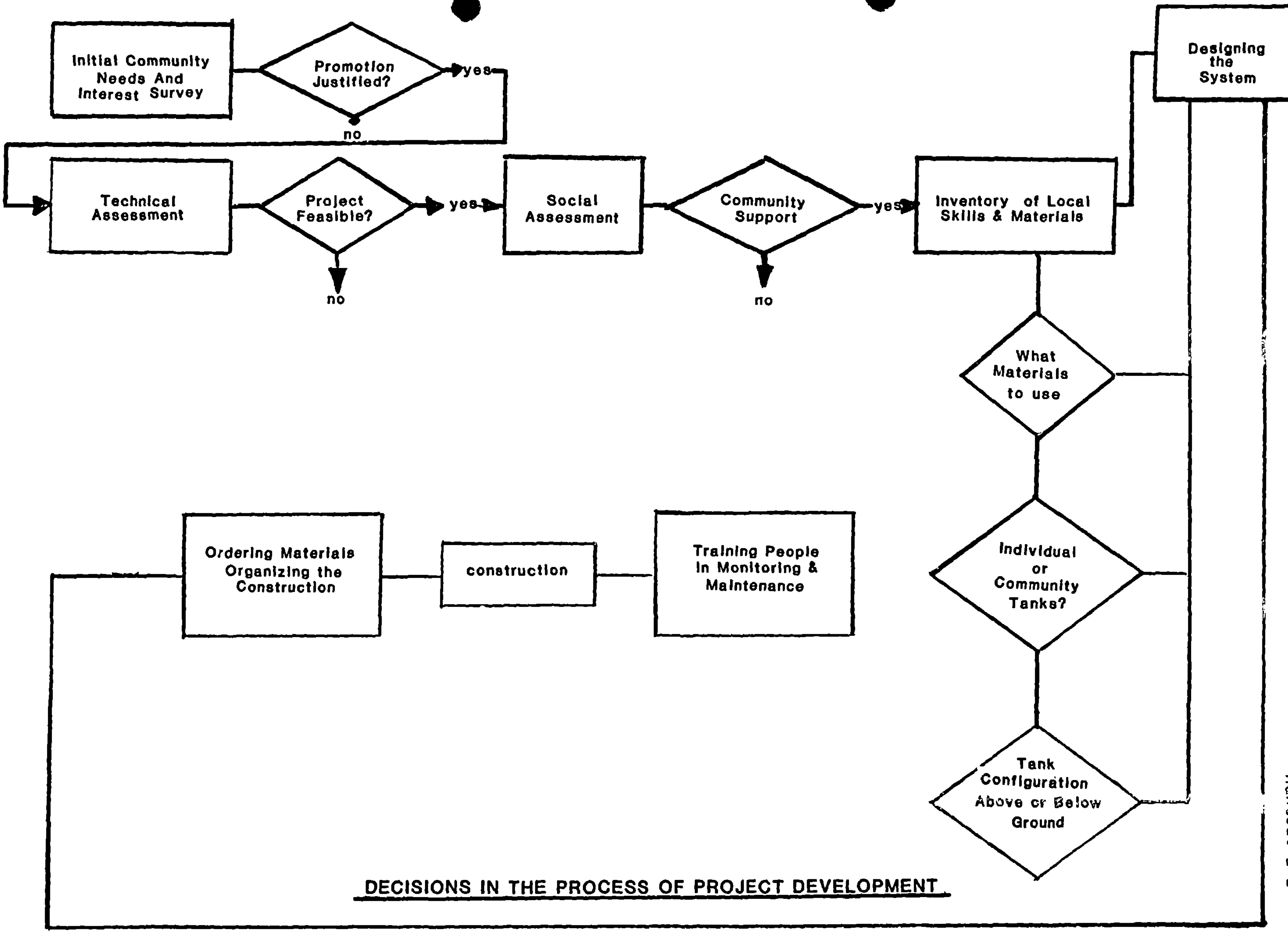
1. Instruct users in:
   - watching for cracks/leaks
   - check water quality
     a. visual checks
     b. smell, taste, etc.

2. Develop cleaning/inspection schedule
3. Organize community maintenance group



DECISIONS IN THE PROCESS OF PROJECT DEVELOPMENT

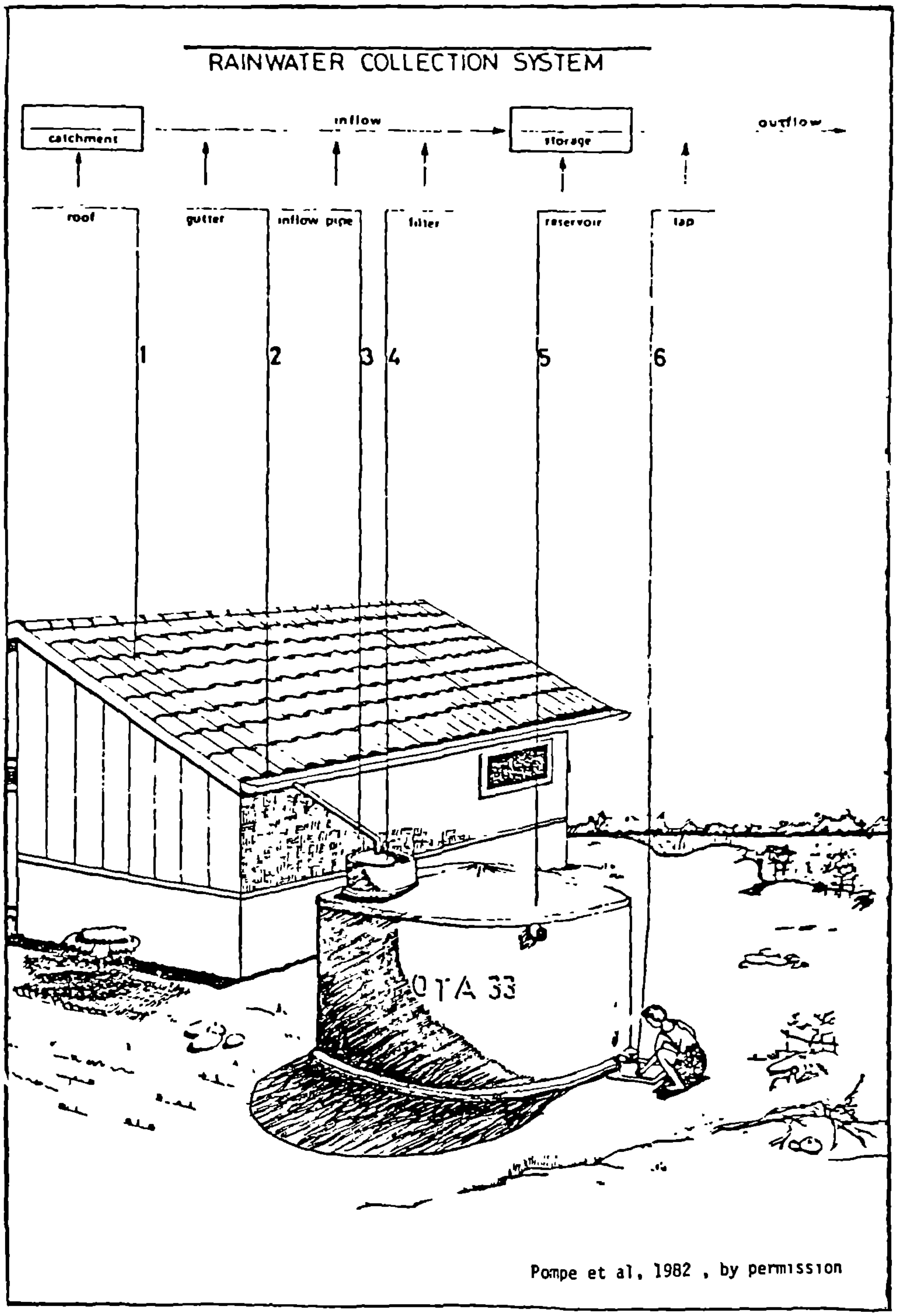
Handout 2-2



DECISIONS IN THE PROCESS OF PROJECT DEVELOPMENT

Handout 2-2

FERROCEMENT TANK INSTALLATION IN JAVA.



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COMMUNITY RESOURCE INVENTORY CHECKLIST

Here is one way to organize a checklist for finding out availabilities and costs of local materials and skills. The checklist below is an example; in any particular area, other materials and skills would be included.

Category	Material	Available	Price
Roofs	Corrugated metal sheet Fired local tile Fiber-reinforced cement sheet Shingles/local wood or fiber Slate		
Gutters	Metal sheet, any kind Wood planks or boards Wood pieces (hollowed) Bamboo PVC pipe Wire (hanging) Fiber (hanging) Pitch (sealing) Tar (sealing)		
Tanks	Cement Stones Sand Gravel Fired brick Concrete block Bamboo Local baskets Chicken wire Straight wire Steel reinforcing rod		
Skills	Masonry Carpentry Basketry Pottery Tinsmith Welding		Rate

Decision Matrix for Tank Type

Tank Types	LABOR & SKILLS					SITE & TYPE					OUTLET, COVER				MATERIALS												
	< 2 days for construction	> 5 days for construction	simple masonry	bricklaying or stonework	digging crew	stable, excavatable soils	low water table	above ground	above or below ground	below ground	pump or bucket	bucket or tap	tap	reinforced cover	0-5 bags cement	5-20 bags cement	20 bags cement	sand	gravel	wire netting	wire	steel rod	metal sheet forms	stones	brick, concrete block	sacking	baskets
cement mortar jar, $< 1m^3$																											
plastered basket, $3m^3$																											
cast concrete ring tank, $7m^3$																											
ferrocement tank $10m^3$																											
small stone tank $10m^3$																											
small brick or concrete block tank $10m^3$																											
bamboo-cement tank $5m^3$																											
reinforced concrete tank, $12m^3$																											
ferrocement lined pit, $25m^3$																											
large stone tank $25\text{-}50m^3$																											
large brick tank $25\text{-}50m^3$																											
large concrete block tank $20\text{-}70m^3$																											

Handout 6-1

Chapter 4

GUTTERING SYSTEMS*

Clearly, effective guttering is a key to rooftop catchment systems; water can be neither stored nor consumed if it is not channelled efficiently from the capture area to the tank. Yet the materials and techniques for construction of effective gutters is a topic that is omitted from almost all accounts. Technically, guttering is far less challenging than construction of cost-effective water storage, and its cost is usually a relatively small part of total costs. Possibly guttering has been largely ignored in published accounts for these reasons.

4.1 General Considerations

How big do gutters need to be? Size needs will obviously vary with the intensity of local storms and the ground area covered by the roof. Ree (1976), investigating runoff yields from sloping metal roofs, used sheet metal gutters 20 cm wide by 10 cm deep, each with a downpipe 15 cm in diameter. Each of these gutters had a capacity of twice the greatest runoff rate recorded from half a 12 x 18 m area of roof over a period of one year in Oklahoma. Thus, gutters half as wide or half as deep would have handled the year's heaviest rain from the roof. In general, gutters and downpipes with a cross-sectional area (width x depth) of 100 cm^2 will probably be big enough to handle all but the most torrential rains from most roofs.

A greater problem than gutter size is probably hanging gutters securely so that they do not sag or fall during heavy rainfall, and keeping them positioned so that they catch both gushing flow and dripping flow from the edges of the roof. Ensuring adequate slope for the entire system, so that water does not stand and damage gutters or attract mosquitoes, is equally important.

4.2 Manufactured Metal Gutters

Aluminum or galvanized sheet metal guttering is the technology of choice in most areas in developed countries. The gutter sections are joined with special brackets and hung with metal straps or long spikes with sleeves which are driven through the upper part of the gutter's width and into wood backing. As of this writing, in the U.S. aluminum guttering and downpipe sections cost about $US1.85/m (galvanized sheet is slightly less expensive but tends to corrode more quickly unless coated with high-quality rust-resistant paint). Hardware for joining and hanging the system costs another $0.60 per meter. This would make the materials costs of guttering and downpipe for a building 6 m long approximately $30.00. Higher cost or unavailability are likely to eliminate manufactured metal gutters as possibilities in most rural areas of developing countries.

4.3 Alternatives Using Local Materials

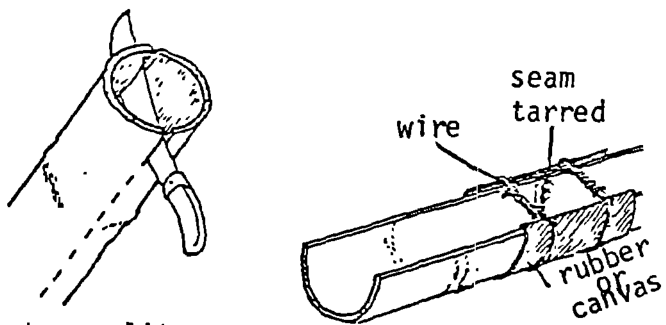
McDowell (1976, page 33)** observes:

"It is noticed that, in many areas, houses will have a short length of roughly fashioned guttering fixed under the eaves just above the door, and that water

From Keller, Kent, Rainwater Harvesting for DOMESTIC Water Supplies in Developing Countries, WASH Working Paper No. 20, Water and Sanitation for Health Project, Arlington, VA 1982.

from this will be collected in an old oil drum or other container. It seems that this type of device is used more for the purpose of preventing water from running in through the doorway of the hut than as a serious approach to water collection. However, the existence of this "technology" could provide the link point for development of simple but effective roof catchment systems."

McDowell also reports on the use of split bamboo culms with joints removed, and "V"-shaped gutters made by nailing two boards together at right angles edge-to-edge. This construction seems likely to leak but the "V" might be sealed with tar, pitch, or some local gum. The Institute for Rural Water (1982; see section

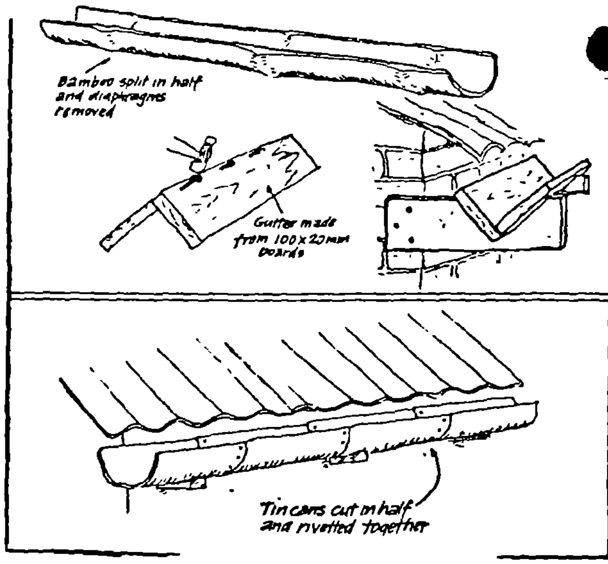


a. Bamboo split lengthwise

b. joining 2 pieces of bamboo

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

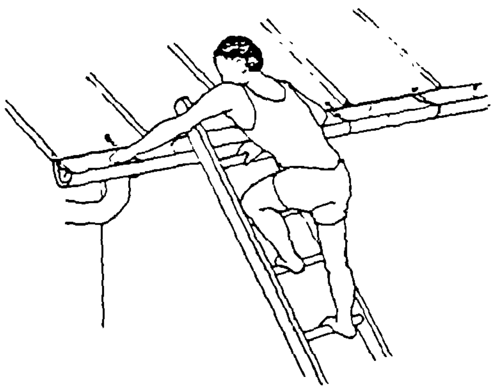
Figure 2, Bamboo Guttering Joining Sections.



Basics, October 1978, page 4

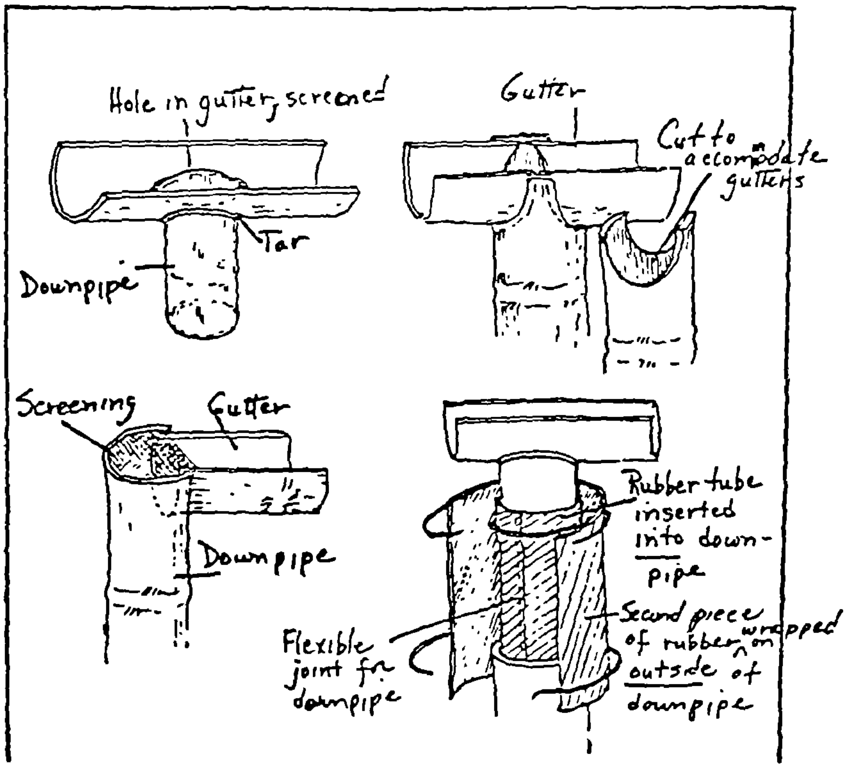
Figure 3, Alternative Forms of Guttering.

8.1) provides good ideas for joining sections of bamboo guttering with wire and some flexible sheet materials such as rubber or canvas, and joining gutters and downpipes with similar materials (see figures 2 and 3 above). The Institute for Rural Water also suggests hanging gutters with twisted wire or local fiber, wrapped around the gutter and tied to holes in roof sheeting or to the ends of roof supports (see figures 4 and 5).



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

Figure 4. Hanging Guttering



Institute for Rural Water, 1982, by permission

Figure 5. Joining Gutters and Downpipes

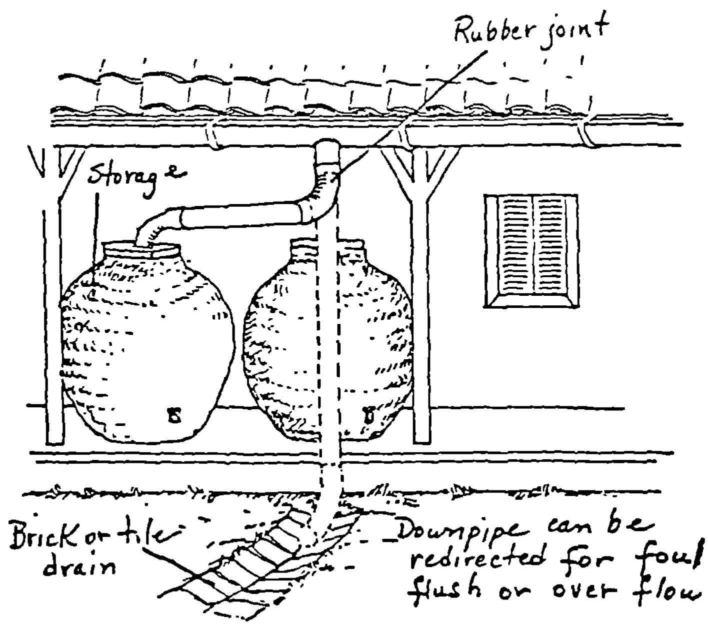
Chapter 5

DIVERTING THE "FOUL FLUSH"*

The crucial importance of some routine or technique for keeping dirty water flowing off a roof at the beginning of a storm out of the storage tank is discussed below in section 7.4. In general, there is more to be gained by devising an effective "foul flush" method than by investing in filters, which clog and become contaminated quickly (e.g. Midwest Plan Service, 1979). There are two kinds of foul-flush devices, those which require the flow of water to be switched manually from waste to the tank after the appropriate interval and those which are "automatic".

5.1 Manual Systems

Usually lower in cost and easier to devise, these will be the obvious choice in most poor areas. An attractive and simple approach is to attach the downpipe so that it can be propped in the "waste" position, then propped in the tank inlet after the roof is clean. Open trough downpipes like split bamboo can be suspended beneath the outflow of the gutter with wire or local fiber; closed downpipes with a flexible joint can be moved in the same manner (see figure 6 below).



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

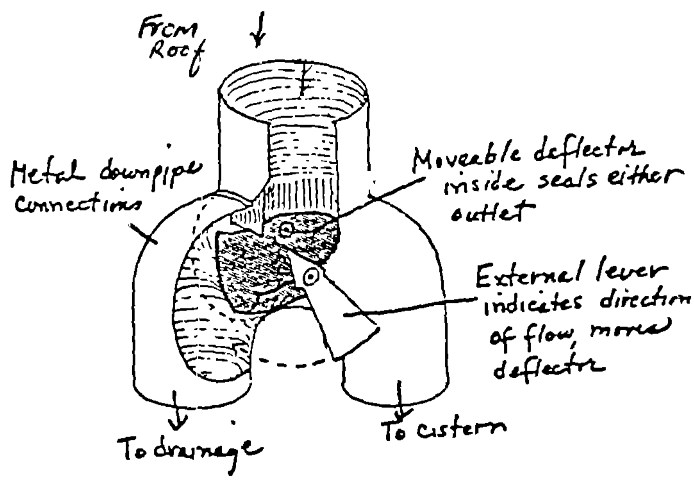
Figure 6, Manual System for Diverting Foul Flush.

*From Keller, Kent, Rainwater Harvesting for Domestic Water Supplies in Developing Countries, WASH Working Paper No. 20, Water and Sanitation for Health Project, Arlington, VA 1982.

The task of moving the downpipe can be performed consistently by anyone including children. People in developing countries tend to be conscious of the precise moment it begins to rain because drying laundry must be brought in.

Another simple technique for tanks with small covers is to leave the cover on, blocking the flow of water into the tank, until the roof is clean. A similar approach (for very small containers like jars) is to move the container into position under the downpipe only after an appropriate interval. Both these routines may be objectionable from a public health point of view: they cause mud and pools of standing water at the tank. Nevertheless, they may be the method of choice where a more complex downpipe and foul flush arrangement is impracticable.

By-pass valves built into metal downpipes may be an option in some areas. Often referred to as "butterfly" valves, they are made of sheet metal and thus would be expensive or impossible to fabricate in many situations. It might be possible to devise a similar valve for downpipe arrangements made of other materials, but a movable downpipe will probably be the cheaper, more functional alternative (see figure 7 below).

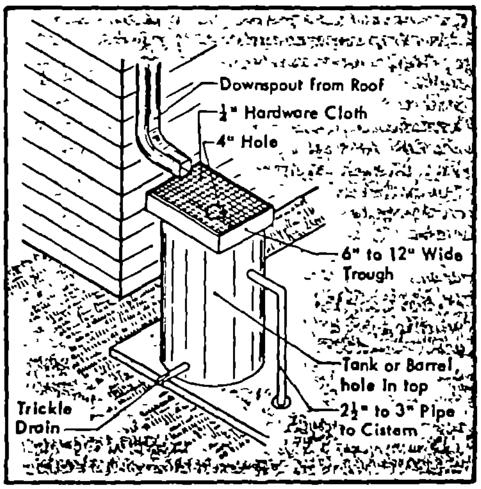


Institute for Rural Water, 1982b (draft), by permisssion

Figure 7, By-pass Valve.

5.2 Automatic Systems

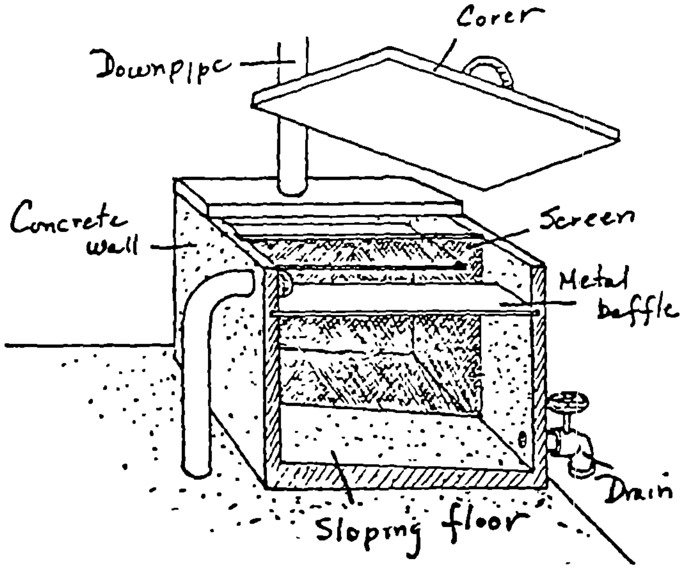
Automatic roof cleaning devices are available commercially only in a few areas, but they may be fabricated from local materials in some situations. One simple automatic device is a container or receptacle for dirty water called a "roofwasher" (Midwest Plan Service, 1979; see figure 8 below). After the roofwasher receptacle fills up with the foul flush, water begins to overflow into the storage tank. A screen is usually attached between the downpipe and the foul flush container as shown in the figure to keep out leaves and other large pieces of debris that would float on the water in the receptacle and clog the overflow pipe to the tank. Oil or fuel tins, used for hauling water in many areas, might be converted to roofwashers. Midwest Plan Service (1979) recommends about 10 liters of roofwasher receptacle capacity for every 30 m^2 of roof area. Other sources (e.g. Dooley, 1978) say a roofwasher should be big enough to hold the first 20 minutes of runoff.



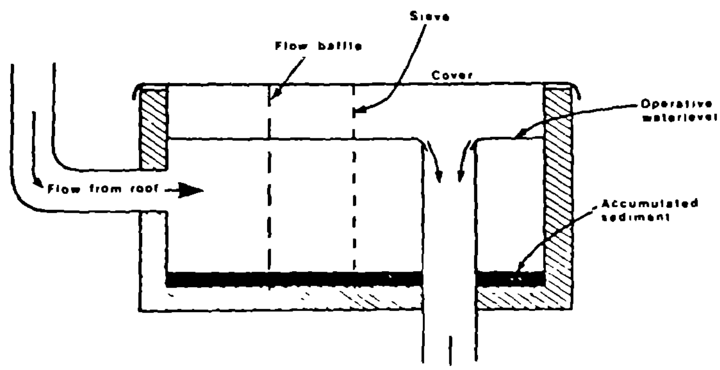
Midwest Plan Service (1979) by permission

Figure 8, Homemade Roof Washer.

A problem with such a simple device is that when the beginning of a rainstorm is torrential, water will pour vigorously into the roofwasher from the downpipe, stirring dirt and bird droppings so that they are carried through the overflow pipe into the tank instead of settling at the bottom of the receptacle. To inhibit this stirring action a baffle can be mounted crossways, inside the roofwasher and/or a vertical screen can be installed dividing the downpipe side from the tank inlet side (see figures 9 and 10). Roofwashers must have a drain and removable cover so that they can be cleaned after each rain.



Institute for Rural Water, 1982 (draft) by permission



UNEP (1979) by permission

Figure 9, Roof Washers

More complicated "automatic" foul flush devices tend to require more attention and stronger structures with more hardware for mounting in the downpipe. Reported in use in Australia are, "swing funnels" made of sheet metal, with a large inflow side divided into two compartments, and hinged on a horizontal pin (see figure 10 below). At the start of a storm, water pours from the gutter into the first compartment. As the weight of the assembly increases, the funnel swings so that water pours from the gutter into the second compartment which leads through the downpipe into the tank. Such a funnel would have to be quite large to hold the recommended volume of foul flush. Mounting and hinge-pins would also have to be quite strong. This particular device is unlikely to be the most attractive of foul flush options in most places, but it is an interesting idea.

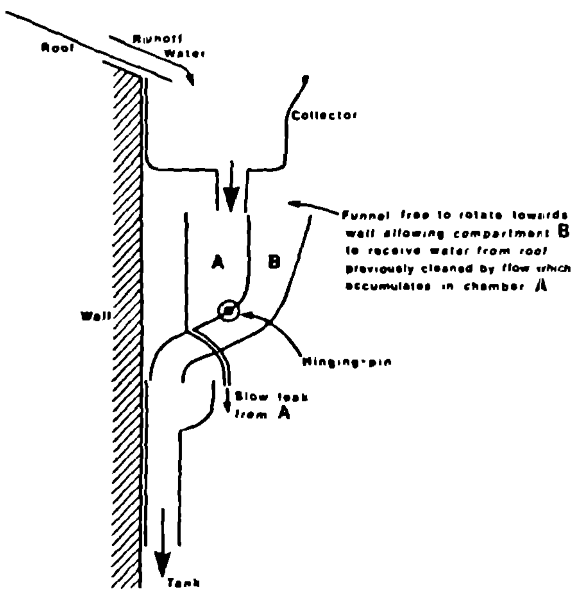
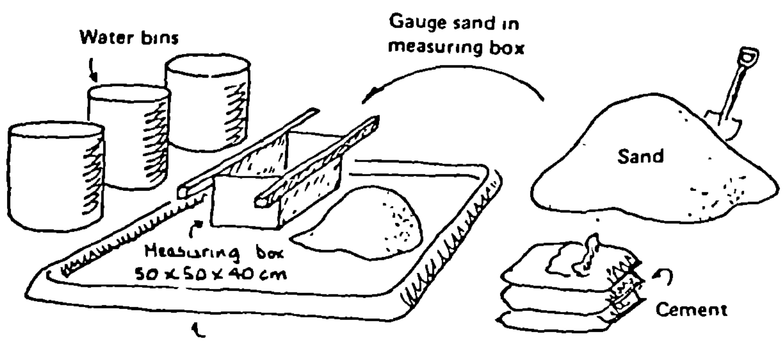


Figure 10, Swing Funnel

BUILDING WATER TANKS*

The construction information in this section is for three of the most widely documented of the tanks. Here is detailed information on the materials, tools, and skills involved in their construction; some readers with confidence in their manual skills would be able to attempt construction from the information given. These are not necessarily the three "best" tank designs for household rooftop catchment; in fact, each of these three tanks requires a relatively great amount of cement per cubic meter of storage (see below). They are, however, three of the most "teachable" of the designs documented.

Each of the tanks described in this section is made with cement mortar, which is a mixture of sand and cement and water. It is always important to make mortar with the cleanest available materials, and to keep soil and other contaminants out of the mortar mixture. Watt (1978) suggests using a mixing board or making a small concrete pad on a layer of gravel. The board is probably a better choice where the tanks or jars will be built far from each other (see figure below).



Equipment and Material for Mixing Cement Mortar

* From WASH Working Paper No. 20, "Rainwater Harvesting for Domestic Water Supplies in Developing Countries" by Kent Keller, as adapted for this session by David Yohalem, 1984.

The mortar mixtures used for the following tanks and jars contain proportions of cement:sand ranging from 1:2 to 1:3 (measured by volume). Mixtures with more cement are easier to plaster with and may be stronger and more waterproof for the surfaces of smaller jars with little reinforcement. For larger containers, a 1:3 cement:sand mixture is strong enough and less likely to crack when curing.

Sand for mortar should be clean. A range of sand grain sizes is permissible but sand with lots of find silt should be avoided because it causes flaking of dry mortar. Sand and any other materials to be used in construction should be gathered before any work starts. Study the list of materials for each of the tanks, and read through the instructions carefully before beginning.

Clean water should be added to the cement and sand after they have been thoroughly mixed together with a trowel or shovel. Make a hole in the pile of cement/sand mix and pour the water in, a little at a time. While a mix that is too "dry" will be difficult to apply, a "wet" mix will not be as strong when cured. Use as little water as possible to obtain a workable mixture. Start with an amount of water that is half the volume of the cement, and add water sparingly.

Do not mix more mortar than can be applied to the tank or jar in about one half hour! After about this amount of time, mortar begins to set and cannot be applied properly (Watt, 1978).*

Concrete is used instead or mortar for the foundations of most tanks and jars because it contains gravel or small stones and is less likely to break or weaken under the load of a heavy tank and its contents. The gravel used in concrete ideally contains a range of sizes, and the stones should not be flat. Like sand, gravel must be clean, or the concrete will be weak.

Concrete used for foundations can be mixed in proportions of cement:sand: gravel ranging from 1:2:3 to 1:3:6. Regardless of the proportions, concrete should be made with as little water as possible and mixed in a clean place. Containers like those shown in the figure above can be used to measure the proportions of materials in mortar and concrete mixes. Resist the temptation to estimate proportions or use the blade of a trowel to measure with; this will result in a weaker mix.

The <u>Village Technology Handbook</u> (VITA, 1978) includes an excellent section on selecting mixes, preparing, and building with concrete.

* See Annotated Bibliography at the end of the Session Guides.

1. <u>Quarter Cubic Meter Cement Plaster Jar</u> ("Thailand Jar")

Unlike the other water containers in this section, this jar is built entirely of mortar. It contains no strengthening fibers nor wires. The mortar is applied to a "mold" which is usually made of sacking material (like burlap) filled with something heavy enough to plaster against.

Because these jars have no reinforcing material, they are made with a mortar mix which is "rich" in cement. The proportions of materials recommended in the following instructions (copied by permission from Watt, 1978 are 1:2, cement: sand (measured by volume). Watt does not mention the proportion of watar to be used. He says instead that the mortar should be mixed as "dry" as possible, for maximum strength. Refer back to the discussion of making mortar above.

The following instructions are for construction of a small jar which holds approximately a quarter of a cubic meter of water (figure 2). Watt says that people with no experience have been taught to make the jars in less than two days. Much larger jars which have screens, lids, and taps have been constructed using this method. Substituting soil and lime for some of the cement and sand in the mortar has also been tried.

MATERIALS: 1/2 bag of cement (less than this should be required) per jar
clean sand
clean water
burlap, "gunny cloth", or other strong sacking material
sand, grain husks, or sawdust to fill the sacking
prepared concrete bases

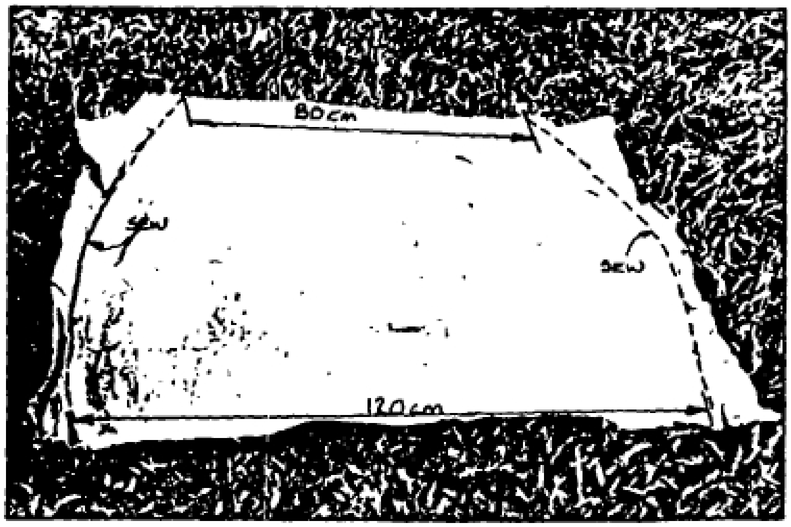
TOOLS: needle and thread, or other tool for sewing the sacking
mixing board or pad and containers for measuring and mixing mortar
shovel for mixing mortar
trowel and wooden stick
bucket for carry mortar

STEPS IN CONSTRUCTION REQUIRING SPECIAL CARE:

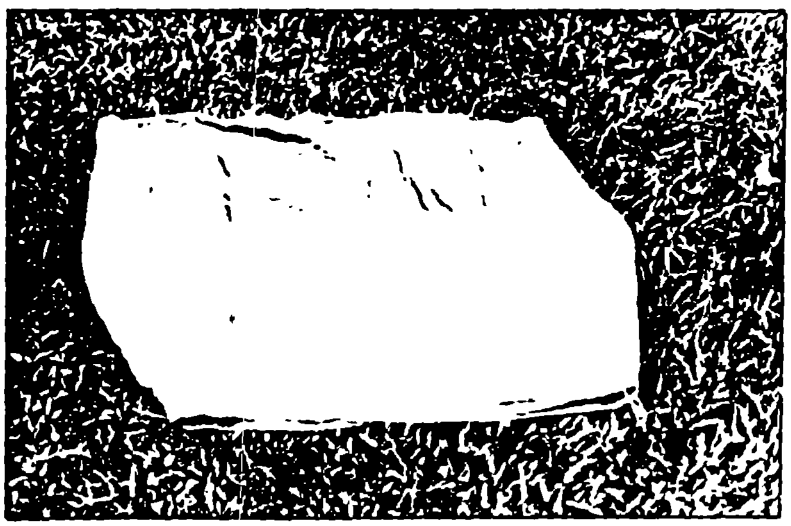
Making sure that the material used to fill the sacking (Step 2.4 in figure 2) is heavy enough to keep its shape during plastering. It is a good idea to try filling the sack on the ground before beginning construction.

Making the mortar. Do not make the mortar for applying to the mold until you are actually ready to begin (Step 2.8 in figure 3). This should allow you to work with a "dry" mortar mixture for maximum strength. Mixing the cement and sand well, before adding the water, is especially important.

Curing the new jar (Step 2.10 in figure 3), also requires particular attention.



2.1 *Place two pieces of gunny cloth (hessian sacking) 125cm by 110cm together and mark out. Sew the two pieces together along the curved lines leaving the top and bottom open.*

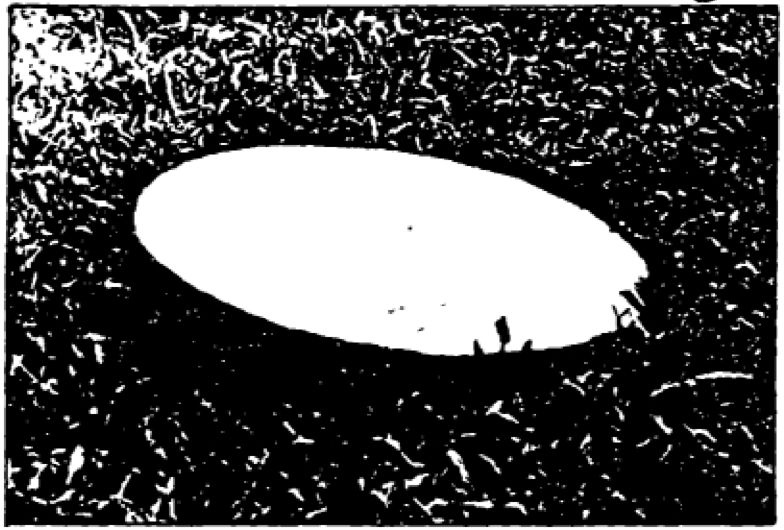


2.2 *After sewing, turn the sack inside out*

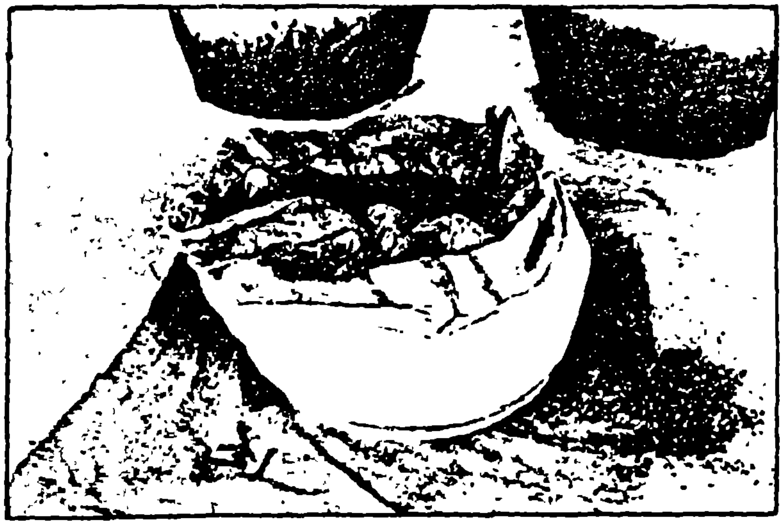
FIGURE 1

Making Small Water Jar, Thailand

(From Watt, 1978, by permission, ITDG)



2.3 *Make a precast mortar bottom plate, 60cm in diameter and 1.5cm thick. Make the mortar from a mix of 1:2 cement:sand by volume as dry as possible consistent with easy trowelling.*

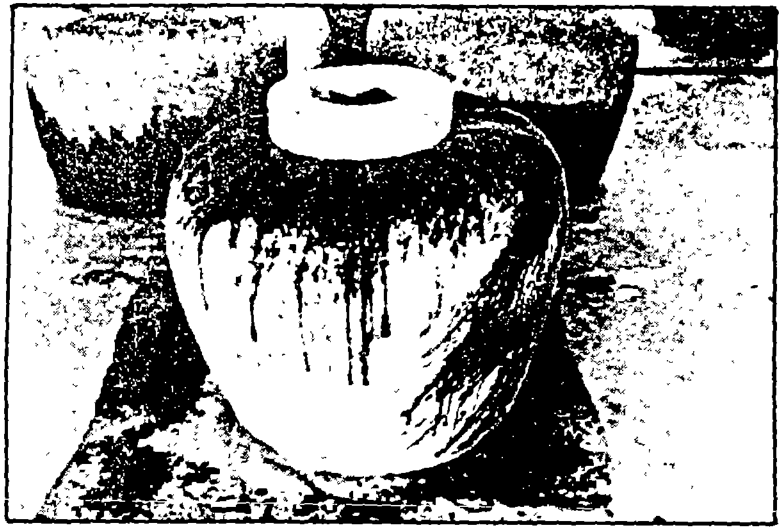


2.4 *Place the sack on the bottom plate with the smaller opening downwards and fill the space inside with paddy husk, sawdust or sand. The weight of the fill will hold the lower edge of the sack firmly on the bottom plate. Make sure that the mortar bottom plate sticks out from under the sacking.*

2.5 *When the sack is filled up, fold the top and tie it into the shape of a traditional water jar. Use a piece of wood to tap on the mould to make it round and fair.*

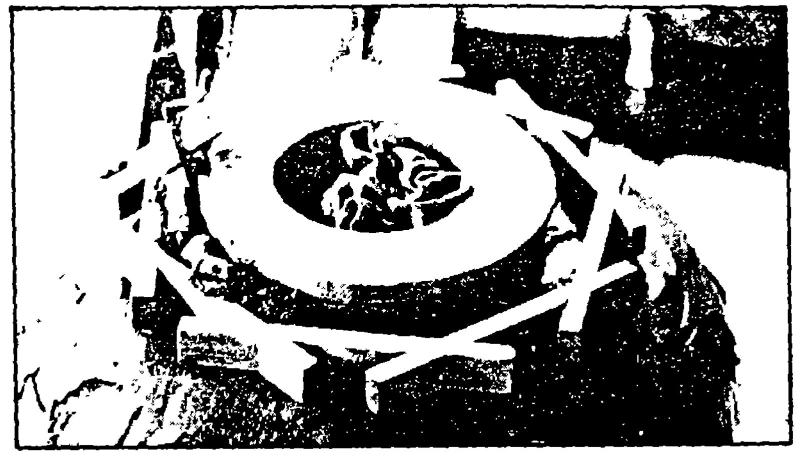
2.6 *Spray some water on the mould before plastering to make it damp.*

FIGURE 2
Constructing a Cement Plaster Jar

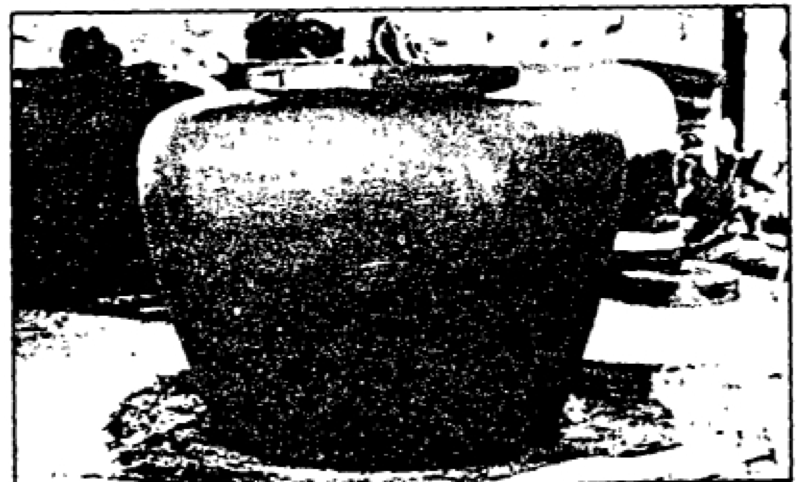


2.7 *Place a circular ring on the top of the sack to make a mould for the opening of the jar. This can be made of wood or precast mortar.*

2.8 *Trowel a first layer of mortar onto the mould to a thickness of about 0.5cm.*



2.9 *Plaster the second layer of 0.5cm in the same manner as the first layer. Check the mortar layer for thickness by pushing in a nail: any weak or thin spots should be built up with an extra layer of mortar. Build up the opening.*



2.10 *Remove the contents of the gunny bag and the bag 24 hours after the jar has been made. Check the jar for any defects and correct these with mortar; the inside of the jar should also be painted with a cement slurry. Cure the jar out of sunlight and drying winds, preferably under damp sacking or plastic sheet for at least 2 weeks.*

This technique has been used with great success in Thailand and pots of up to 4000 litres (approx 1000 galls.) capacity have been made in this way.

FIGURE 3

Constructing a Cement Plaster Jar (continued)

2. Woven "Ghala" Basket Reinforced Tank

The following guidelines are adapted from Keller's instructions for a larger 2.3 m^3 tank made out of ghala basket. These guidelines are for similar size tank as above and can be made out of any appropriate basket with about one half a sack of cement.

Choosing an Appropriate Woven Basket

The basket should be made out of a thick sturdy weaving material so that the basket will stand on its own and not bend while being plastered. The weave should be open enough to enable the mortar to go through the weave. Intricate weaving designs and different colored fibers are not necessary and only increase the cost of the basket. The top of the basket should be large enough to allow an adult to reach in to plaster the basket from the inside. The base of the basket should not be too small relative to the widest diameter or it will be unstable.

Base

Follow the same instructions for a ferrocement tank base to make a base a little bigger than the basket. Place the basket into the base while it is still wet. If the bottom weave of the basket is very tight and the concrete cannot go through it, cut the bottom of the basket off and push the lower sides of the basket into the concrete so it is firmly in place. Allow the base to dry enough so that the basket doesn't move when being plastered.

Mortar and Plastering

Apply a first coat of mortar made with a ratio of 1:3 cement to sand to the inside of the basket starting at the bottom and working up to a thickness of 1 cm. As with the above tanks, keep the mortar as dry as possible. Place extra mortar on the bottom where the basket joins the base. Push the mortar through the weave of the basket and smooth on the outside as well as inside. Let the mortar basket dry while mixing the second coat of mortar with a richer mixture of 1:2 cement to sand. Apply the second coat to the inside of the basket including the base of a thickness of 1 cm. Use any leftover mortar to cover the outside of the basket so that the woven basket frame is entirely covered with plaster. This will protect the frame from insects, moisture, etc. and make the tank last longer. When the second coat is dry enough apply a cement slurry to seal the inside.

Curing

Cure and cover as in above instructions.

MATERIALS

1/2 sack of cement per tank
clean sand gravel and water
woven basket

3. Ferrocement Tank for Small Household Use

The following construction guidelines are adapted from Keller's instructions for the construction of a larger 10 m^3 ferrocement tank. The tank to be built with these guidelines is approximately 1 m tall and 60 cm in diameter and will hold about 280 liters (0.28 m^3) of water. If made with walls 2 cm thick of mortar mixed to a ratio of 1:3 cement to sand it will use a half a sack of cement, 6 meters of #8 reinforcing rod and 2-4 meters of 1 m wide chicken wire depending on the size of the wire mesh.

Base

A concrete base 70 cm in diameter by 5 cm thick is poured with a mixture of 1:2:4 cement:sand:gravel in a 5 cm deep x 70 cm wide circular form excavated in clay soil. Make sure the sand and gravel are clean and free of any organic matter. Mix in only enough water to make the concrete workable. The drier the concrete the better. Let dry a little as you prepare the other materials.

Wire Mesh and Supports

Cut a 6 meter length of #8 reinforcing rod into six one meter lengths (#6 or 10 re-rod can be used but the #6 is a little weak for this purpose and the #10 is stronger than needed and more costly). Place the rods about 30 cm apart in a circle 5 cm inside the outer rim of the still wet base. This will produce a new circle with a diameter of 60 cm. Take the wire mesh and wrap it around the reinforcing rod and push the bottom into the concrete base. If you are using chicken wire with a one inch (2.54 cm) mesh you only have to wrap it around once. If you have to use 2 inch (5 cm) mesh chicken wire, wrap it around twice and make sure that the second layer overlaps the first in such a way as to cut the size of the holes in half. Tie the chicken wire itself and secure to the reinforcing rod.

Mortar and Plastering

Mix mortar with a 1:3 ratio of cement to sand and as little water as needed to make it workable. The drier the mortar, the stronger the tank will be when it dries. Apply a coat of mortar plaster 12 cm thick to the outside of the chicken wire mesh, starting at the base and working up. Put a little extra mortar onto the bottom of the mesh where it joins the base. Push the mortar through the wire mesh so it completely covers the inside of the reinforcing rod and wire mesh. Smooth the plaster on both sides and let dry a little. When the mortar is dry enough to be worked (about 20 minutes) put on a second coat of mortar made with a richer mixture (1:2 cement to sand) to the same thickness to the inside of the tank. Plaster the concrete base and use more plaster as above where the wall and base meet.

Start from the bottom and work up to the top. Make sure that all the mortar walls are to a uniform thickness and fill in any thin spots. When completed, the walls should be 2 cm thick and no reinforcing rod or chicken wire should be visible. Finish the top of the wall to make a smooth lip for the barrel. Apply a cement slurry to the inside to smooth and seal the interior.

Curing

Dry in the direct sunlight, and keep damp for two weeks before moving. A wet burlap sack can be placed over the tank to keep it wet during this time. After a day, put 20 cm of water in the tank to keep the inside moist. A wooden top can be made to sit over this tank as a cover.

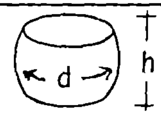
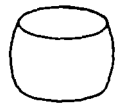
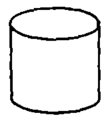
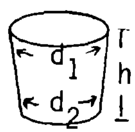
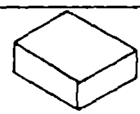
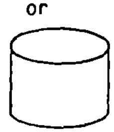
MATERIALS

1/2 sack of cement per tank
clean sand, gravel and water
6 m of #8 reinforcing rod per tank
[illegible]-4 m of 1 m wide chicken wire or similar wire mesh per tank
wire

TOOLS

shovels and buckets for mixing and carrying mortar and concrete
tools for cutting re-rod and wire mesh
trowels, floats, etc.

TANK DESIGN GUIDE

Tank Group	Shape	Formula	Example	Materials	Calculation #
Cement a. mortar jar		$\frac{d^2}{4} \pi h$	if $V=0.5m^3$ d=0.8m h=0.8m	Cement mortar (walls) Concrete (foundation)	1 3
b. plastered baskets or bamboo-cement tanks		$\frac{d^2}{4} \pi h$	If $V=2.7m^3$ d=1.5m h=1.5m	Cement mortar (walls) Concrete (foundation)	1 3
c. ferrocement tank		h slightly less than d $\frac{d^2}{4} \pi h$	If $V=10m^3$ d=2.5m h=2.0m	Cement mortar (walls & floor) Metal sheet (cover) Wire netting (walls, floor, cover) Concrete (foundation)	1 No calculation 7 3
d. ferrocement lined		$\frac{d_1 + d_2}{8}^{2} \pi h$	If $V=20m^3$ d=3.5m h=2.0m	Cement mortar (walls & floor) Cement mortar (cover) Wire netting (walls, floor, cover)	6 8 7
e. poured (or cast) concrete		h usually less than l and w	If $V=20m^3$ h= 2m l=3.2m w=3.2m	Concrete (walls, floor) Reinforced concrete (cover)	3 No calculation
f. brick, stone, or concrete block tank	 or 	V = l x w x h, w usually less than 2m $\frac{d^2}{4} \pi h$ d may be more than 2 m, h usually less than d	If $V=20m^3$ w=1.5m l=5m If $V=20m^3$ d=3m h=2.8m	Brick, stone, or block (walls, floor) Cement mortar (laying walls, floor) Cement mortar (surfacing) walls, floor)	4 5 2
g.	area of circle area of circular wall (cylinder) area of rectangle	$\pi \frac{d^2}{4}$ πdh = l x w x h			

CALCULATION SHEETS

1. Calculation #1: Cement in mortar walls for above ground cylindrical containers

Height		Wall Thickness	Typical Container Type
1.0 m	=	1.0 cm	Cement Mortar Jar
1.5 m	=	2.5 cm	Plastered Basket
1.75 m	=	3.0 cm	Ferrocement Tank (1.75 m^3 volume)
2.0 m	=	4.0 cm	Ferrocement Tank (10 m^3 volume)

[Note: Walls in these kinds of tanks are rarely more than 2 m high]

Steps:

a. Using wall height (h), determine wall thickness from above chart.

b. Calculate the area of the wall:

> Area = pi x diameter x height

c. Multiply the wall area by the wall thickness to determine the amount of mortar needed:

> Mortar needed = area x thickness

d. Multiply the amount of mortar needed by 10 bags cement/m^3 mortar, to determine the amount of cement needed.

> Bags of cement needed = mortar needed x $\frac{\text{10 bags cement*}}{m^3 \text{ mortar}}$

e. Cost = bags of cement needed x price/bag

* 50 kg bags of cement. Based on a cement to sand ratio 1:3. This is a recommended figure for watertight mortar. Local masons may use less cement (more sand), and the formula would have to be adjusted accordingly. Mortars with 1:2 cement:sand use 13 bags of cement per m^3 of mortar.

2. Calculation #2: Cement mortar for plastering over walls and floors made of other materials

Steps:

a. Calculate area to be plastered:

Area = See Handout 9-1: Tank Design Guide, item "f".

b. Multiply the area by the thickness of mortar to be applied to determine the amount of mortar needed:

Mortar needed = area x thickness

c. Multiply the amount of mortar needed by 10 bags cement*/m^3 mortar, to determine the amount of cement needed:

Bags of cement needed = mortar needed x $\frac{\text{10 bags cement*}}{m^3 \text{ mortar}}$

d. Cost = bags of cement needed x price/bag

* 50 kg bags. Based on a cement to sand ratio of 1:3. This is a recommended figure for watertight mortar. Local masons may use less cement (more sand), and the formula would have to be adjusted accordingly. Mortars with 1:2 cement:sand mixtures for final waterproofing coats use 13 bags cement per m^3 of mortar.

CALCULATION SHEETS

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Steps:

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b. Calculate the area of the wall:

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Mortar needed = area x thickness

c. Multiply the amount of mortar needed by 10 bags cement*/m^3 mortar, to determine the amount of cement needed:

$$\text{Bags of cement needed} = \text{mortar needed} \times \frac{\text{10 bags cement*}}{m^3 \text{ mortar}}$$

d. Cost = bags of cement needed x price/bag

---

* 50 kg bags. Based on a cement to sand ratio of 1:3. This is a recommended figure for watertight mortar. Local masons may use less cement (more sand), and the formula would have to be adjusted accordingly. Mortars with 1:2 cement:sand mixtures for final waterproofing coats use 13 bags cement per m^3 of mortar.

3. Calculation #3: Cement in concrete walls, foundations and floors

Steps:

a. Choose a thickness, checking with local people who work with building materials.

Some suggested thicknesses for tanks:

Foundations (tanks up to 2 m high or deep): 7.5 cm
Walls and floors: 10-20 cm, depending on reinforcement.

b. Calculate the area of the wall, foundation, or floor:

Area = See Handout 9-1: Tank Design guide, item "f".

c. Multiply the area by the thickness to determine the amount of concrete needed:

Concrete needed = area x thickness

d. Multiply the amount of concrete needed by 7 bags cement*/m^3 concrete, to determine the amount of cement needed.

$$\text{Bags of cement needed} = \text{concrete needed} \times \frac{\text{7 bags cement*}}{m^3 \text{ concrete}}$$

e. Cost = bags of cement needed x price/bag

---

* 50 kg bags. This is a recommended amount of cement for strong all-purpose concrete using a mixture of 1:2:3 cement to sand to gravel. Local practices may vary. Mixtures with more gravel and therefore less cement use a lower cement per m^3 concrete formula.

4. <u>Calculation #4</u>: Amounts of brick, stone, or block in tank walls and floors

Steps:

a. Consult masons (who have built walls to hold water) to choose wall thickness.

Suggestions:

Walls (supported by earth): 15-20 cm
Walls (more than 1 m height unsupported by earth: 30 cm
Floors: Same as walls

b. Determine the number of bricks (stones or blocks) needed to build 1 m x 1 m of wall or floor: $\frac{\text{bricks}}{m^2}$

c. Calculate the area of wall or floor to be laid:

Area = See Handout 9-1: Tank Design Guide, item "f".

d. Calculate the number of bricks (stones or blocks) required:

$$\text{Number of bricks} = \text{area} \times \frac{\text{bricks}}{m^2}$$

e. Cost = number of bricks x price/brick

5. Calculation #5: Cement in mortar for laying walls and floors of brick (stones or block)

Steps:

a. Consult masons to find out how much mortar (in m^3) they need to lay 100 (or any number of) bricks:

$$\frac{\text{mortar } (m^3)}{\text{100 bricks}}$$

b. Multiply by the number of bricks (calculated in calculation 4d) to determine the amount of mortar required:

$$\text{Mortar needed} = \text{number of bricks} \times \frac{\text{mortar } (m^3)}{\text{100 bricks}}$$

c. Multiply the mortar needed by 10 bags cement*/m^3 mortar, to determine the amount of cement needed:

$$\text{Bags of cement needed} = \text{mortar needed} \times \frac{\text{10 bags cement*}}{m^3 \text{ mortar}}$$

d. $$\text{Cost} = \text{bags of cement needed} \times \text{price/bag}$$

---

* 50 kg bags. Note same as for calculation #2

6. <u>Calculation #6</u>: Cement in mortar walls and floor of circular ferrocement-lined pit

Steps:

a. Calculate the area of the pit to be lined:

Area of walls = pi x diameter x height
Area of floor = pi x (1/2 diameter)^2
} Total area

b. Multiply the area by the thickness of plaster to be applied. To be safe, assume a thickness of 4 cm (less may actually be needed):

Mortar needed = area x thickness

c. To find the amount of cement needed, multiply the amount of mortar by 10 bags cement*/m^3 mortar:

Bags of cement = mortar needed x 10 bags cement*/m^3 mortar

d. Cost = bags of cement x price/bag

---

* 50 kg bags. Same note as for calculation #2

7. <u>Calculation #7</u>: Wire netting in circular ferrocement tank (above ground) and ferrocement pit (below ground) floors, walls, and covers

Steps:

a. Decide on the number of layers of wire netting to be used. Recommendations:

Ferrocement tank walls (with wire reinforcement)	:	1 layer
Ferrocement pit walls and floors	:	2 or 3 layers
Ferrocement cover	:	3 layers

b. Calculate the area of wall, floor, and/or cover:

Area of wall = pi x diameter x height

Area of floor = pi x $(1/2 \text{ diameter})^2$

Area of cover* = pi x $(1/2 \text{ diameter})^2$

c. Multiply the areas by the number of layers to get the area of netting needed:

Netting needed = area x number of layers

d. Cost = netting needed x price/m^2

Note: wire netting is sold in widths which may need to be trimmed to correct size during construction. Thus, one must buy more than will actually be used.

---

* Ferrocement covers are higher in the middle (domed) to support their weight. The area of the dome is slightly greater than the circle it covers.

8. Calculation #8: Cement mortar for covers of ferrocement lined pits

Steps

a. Calculate the area of the cover. The diameter must be slightly larger than the diameter of the top of the pit.

$$\text{Area} = \text{pi} \ (1/2d)^2 *$$

b. Determine the thickness of the cover. This is about 5 cm for a cover 3-4m in diameter which is reinforced with steel netting and steel bar.

c. Go to step b in calculation #2 and finish the calculation.

---

* Note: the cover is domed, so its area is slightly greater than the circle it covers. Allow an extra bag of cement for this increase in area. A simpler formula is pi $\frac{(d)^2}{4}$ this calculates to .77 x d^2.

DESIGN DRAWING FOR A SIMPLE RAINWATER CATCHMENT SYSTEM FOR A THATCHED ROOF

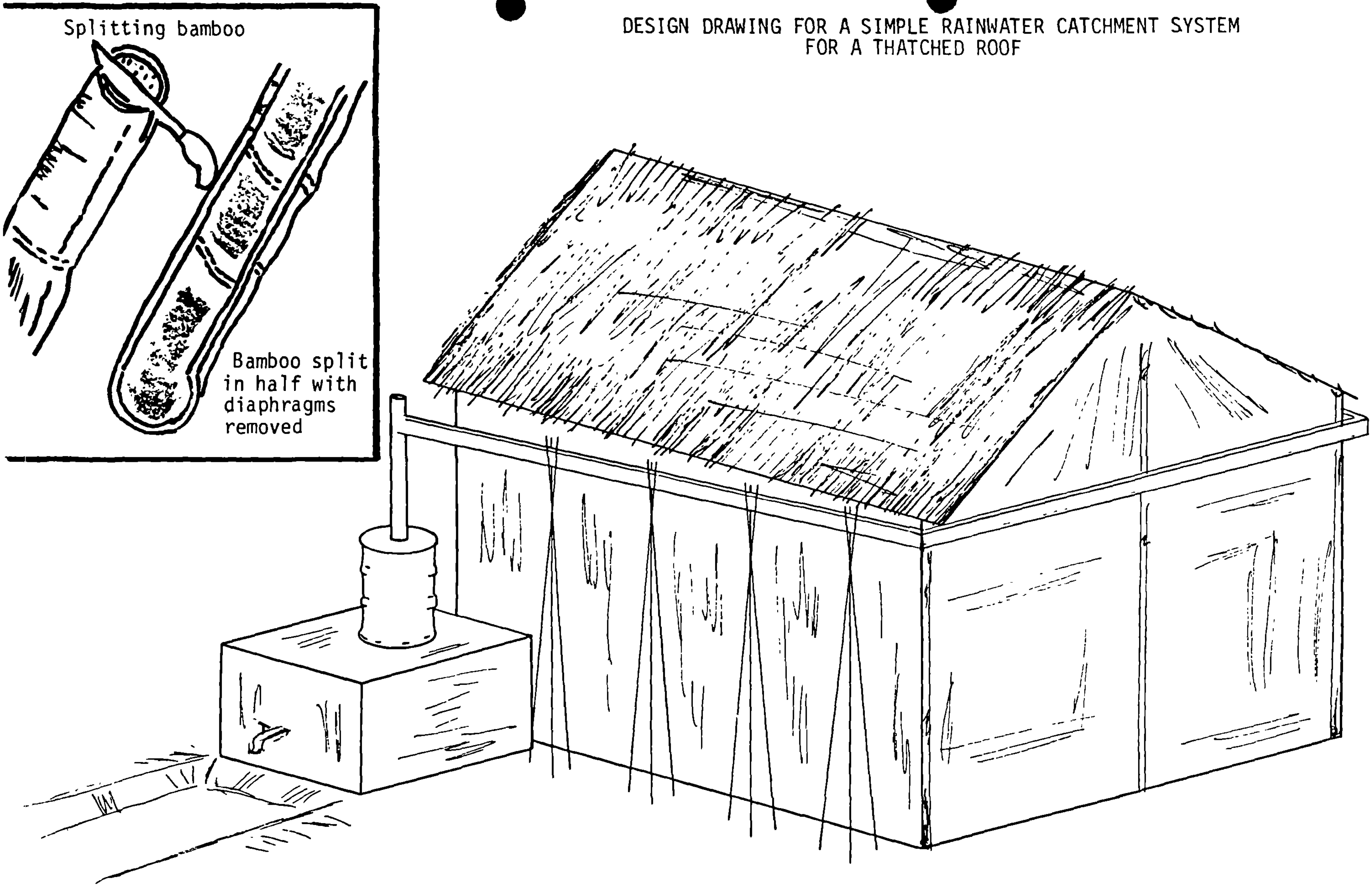


FIGURE 1

Assume a slope of 3% - In 10m of gutters, the first tripod is 30cm higher than the last one. Put the tripods (3 poles each) in their place. The slope is determined by placing a string between tripod A and Tripod B. Mark the intermediate tripods accordingly and cut.

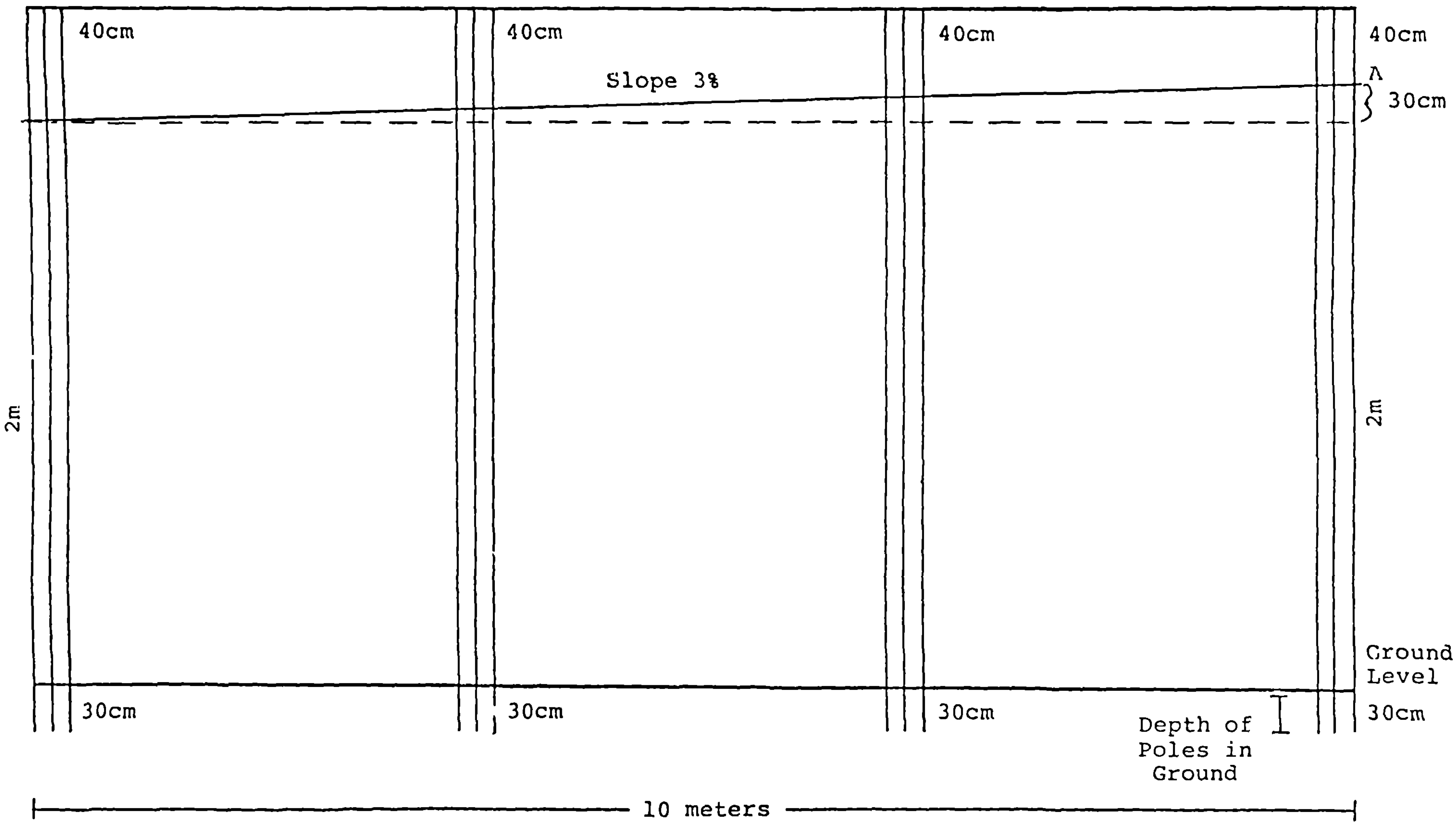
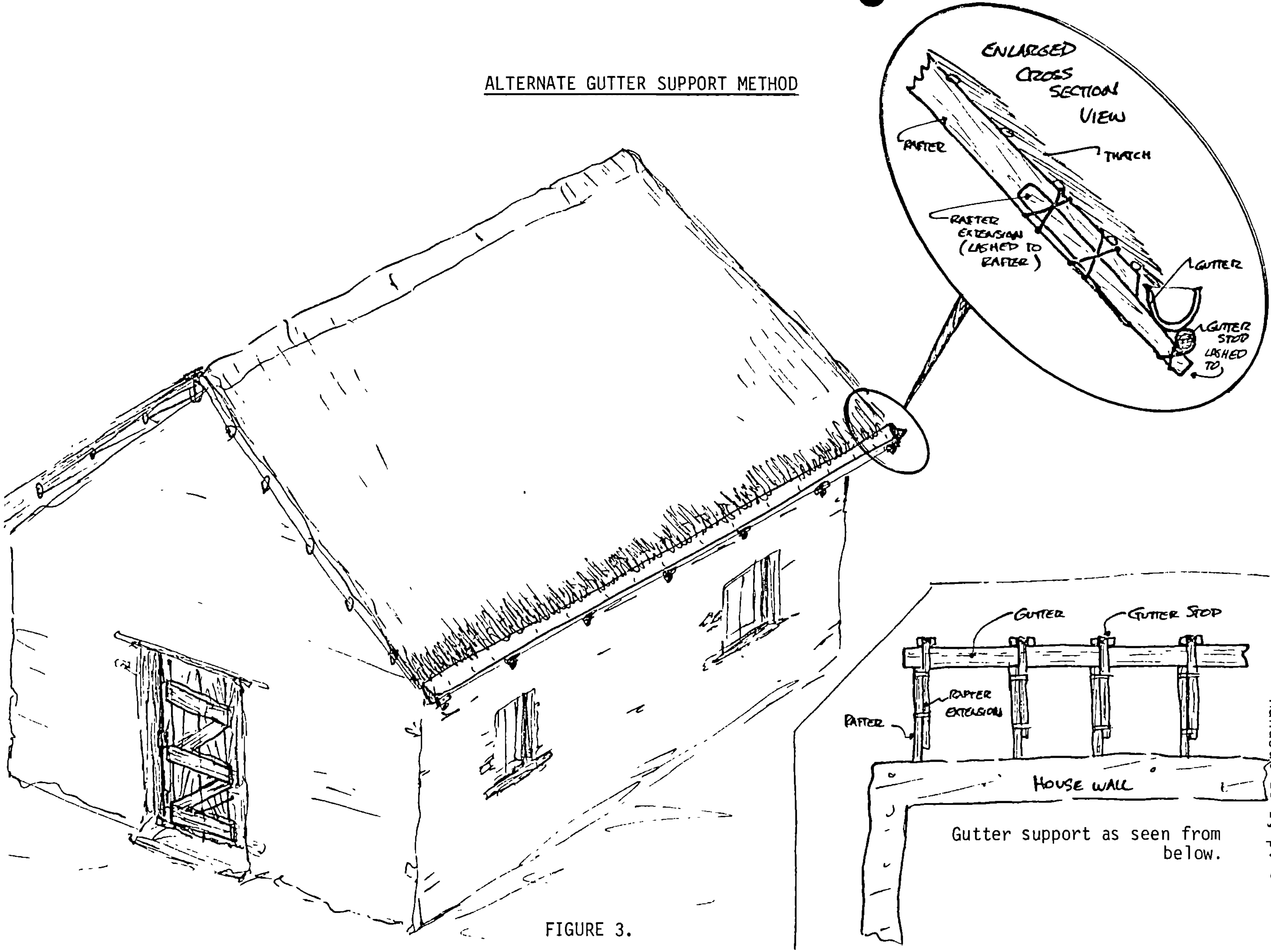


FIGURE 2

ALTERNATE GUTTER SUPPORT METHOD



Gutter support as seen from below.

FIGURE 3.

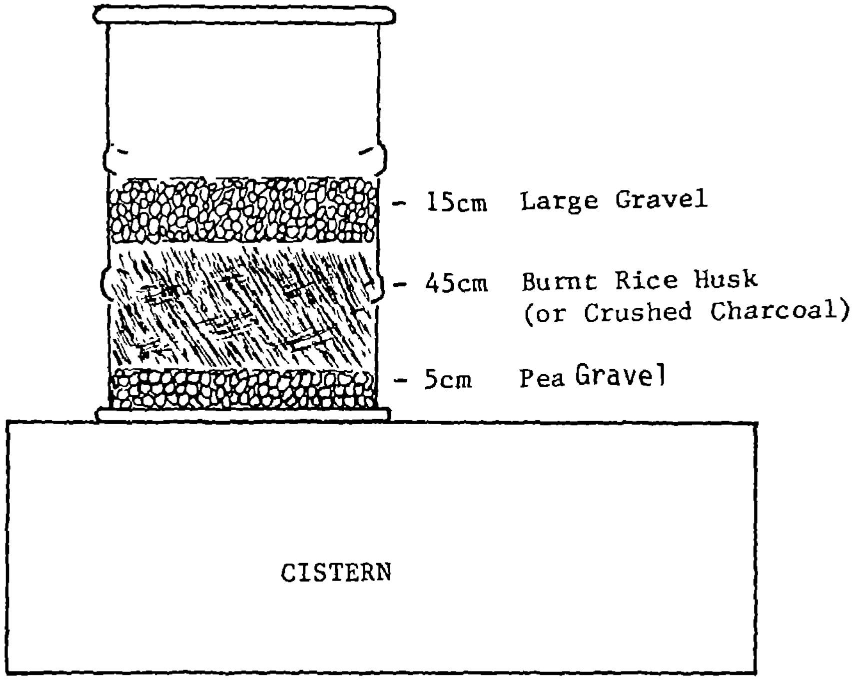
TYPICAL MATERIALS ESTIMATE*

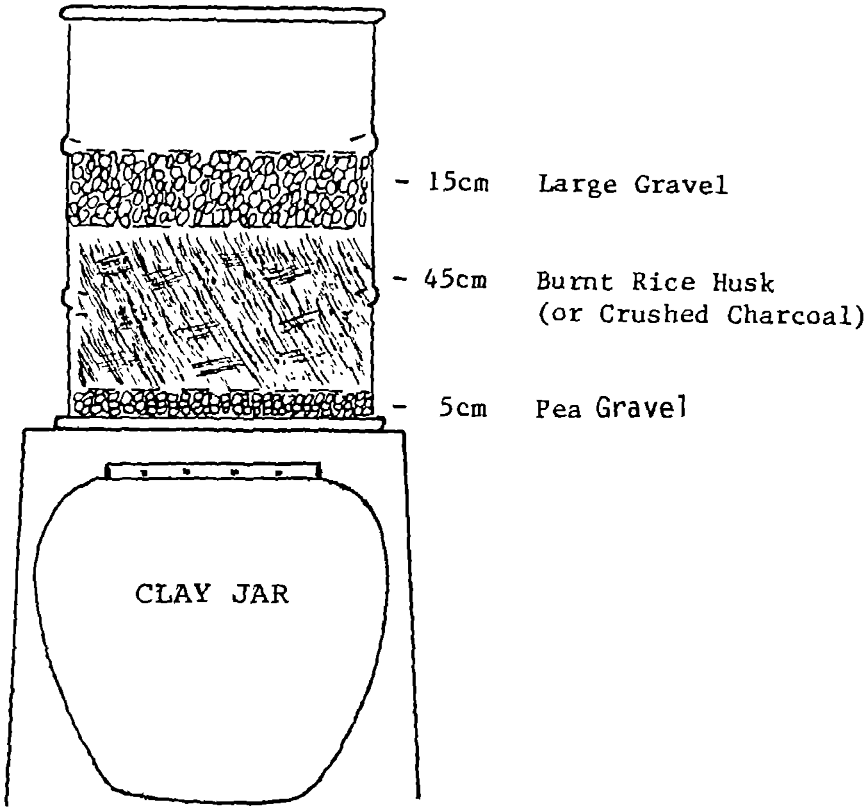
Materials	Quantity	Cost
A. Guttering materials using bamboo, bush pole supports for a roof 10 M long x 4 M wide, collection on both sides of the roof.		
1. Bamboo 15-20 cm in diameter	15 M	
2. 9 V notch poles 5-10 cm in diameter, or 9 sets of poles for tripods (27 poles), 5 cm in diameter and 4 meters long	36-110 M of pole	
3. Twisted wire, or locally available twine	20 M	
Tools: machetes, mallets, knives, digging tools, bucket for water		
B. Filtration System Using a Barrel		
1. Barrel, 200 Liter	1	
2. Gravel (large)	35 Liters	
3. Pea gravel	12 Liters	
4. Raw rice husk	100 Liters	
5. Or charcoal	50 Liters	
Tools: drill or hammer and nail or spike; hammer or mallet for crushing charcoal, tools and materials for making stand for filter		
C. Filtration System Using a Box		
1. Lumber: 40 cm x 2 cm	5 M	
2. Nails	1 Kg	
3. Gravel, rice husk (same as B)		
Tools: Hammer, saw, drill; tools and materials for making stand		

*Note: Since costs vary widely, the cost column is left open for the trainers to fill in depending on the local prices.

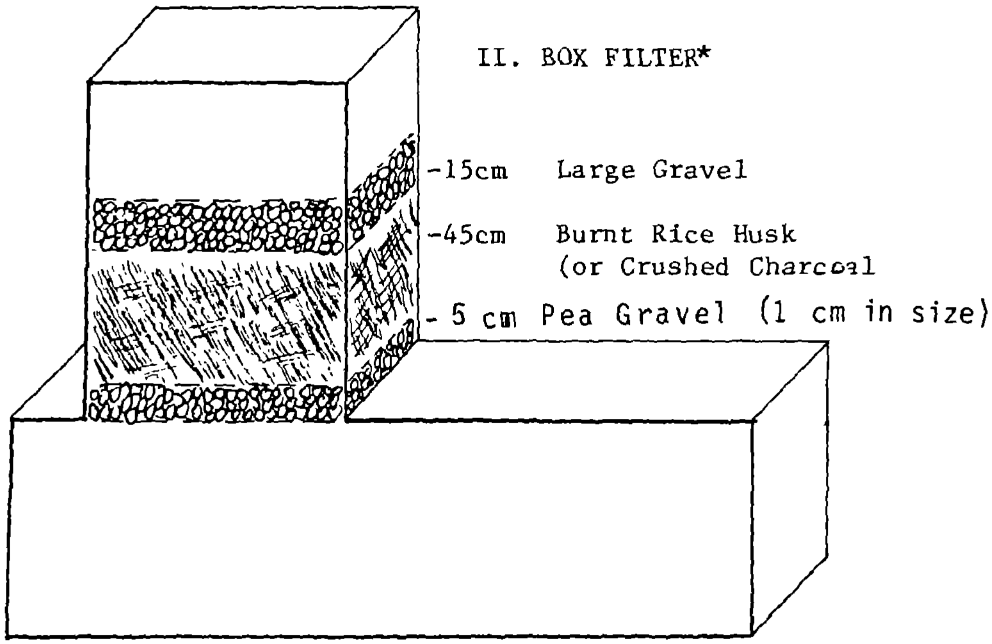
FILTERING SYSTEMS

I. BARREL FILTER





II. BOX FILTER*



*See Trainer Notes

USING COCONUT FIBER FILTERS

Filters using shredded coconut fibers for the filter medium have been said to be successful in Thailand (Frankel, 1974) and have been installed in over 100 rural villages in Southest Asia (Frankel, 1981). The raw coconut husks are found throughout Southeast Asia and have little market value, hence they provide a low-cost filter medium for treatment plants in that part of the world.

Shredded coconut fiber may be prepared manually by soaking the husk for 2 to 3 days in water and then shredding the husk by pulling off the individual fibers and removing the solid particles which bind the fibers. Shredded coconut fibers may also be purchased directly from upholstery stores or coir (coconut fiber) factories. The shredded fiber should be immersed in water for about three days, until the fiber does not impart any more color to the water (Frankel, 1977). The depth of the coconut fiber in the filter box is usually 60-80 cm. There are no backwashing arrangements for cleaning the coconut fibers as the fibers do not readily relinquish entrapped particles because of their fibrous nature. Instead, water is drained from the filter box and the dirty fibers are removed and discarded. Coconut fiber stock, which has been properly cleaned, is then packed into the filter. The filter medium generally must be replaced every three or four months. The availability of the raw coconut husks at low cost, as well as the elimination of backwash pumps and ancillary equipment, combine to make this manual filter bed regeneration process economical in areas where coconut trees are common. The use of such indigenous materials for filter media is also a practical alternative to conventional filter design.

Several small water filter plants ranging in capacity from 24 to 360 m^3/day were constructed from 1972 to 1976 in the Lower Mekong River Basin countries (Thailand, Viet Nam, Cambodia) and in the Philippines (Frankel, 1981). Two-stage filtration, using shredded coconut fibers and burnt rice husks for the roughing and polishing filters, respectively, was typical for all filter plants. The filtration systems generally produced a clear effluent (less than 5 NTU) when treating raw water with a turbidity less than 150 NTU. The units were designed at a filtration rate of 1.25-1.5 m/hr., which is about 10 times higher than that used for conventional slow sand filters. Bacterial removals averaged 60 to 90 percent without the use of any disinfectant. The media generally required changing once very 3-5 months depending on the level of turbidity in the raw water.

CALI

Handout 11 - 2

Construction Activities	Date Begun	Date Ended	Number Days	Number Hours	Number Masons	Number Iron-workers	General Observations or Remarks
1. Clearing/Lay out							
2. Excavation							
3. Placing bed of gravel							
4 Building foundation form							
5. Preparing iron grill for foundation							
6. Pouring the foundation (including curing)							
7. Making cement blocks							
8. Constructing the walls							
9. Building forms for top slab							
10. Preparing iron grill for top slab							
11 Pouring, curing, placing top slab							
12 Plastering							
13. Constructing and placing gutters							
14. Disinfecting the system							
15. Putting system into function							

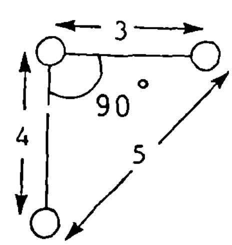
CONSTRUCTION GUIDELINES

CLEARING AND EXCAVATION

Initially, the tank site must be cleared of debris and vegetation. All tanks require some excavation. Even if the tank is to be above ground it is necessary to excavate and level the ground for the foundation. The foundation typically extends 15-30 cm beyond the outside of the tank wall. This must be taken into consideration when determining the area to be excavated. After the correct depth has been excavated, the ground should be leveled using a carpenter's level and board.

SETTING OUT

The outer wall of the tank or edge of the floor slab should be outlined using wooden stakes and string. For square or rectangular tanks, the corners are squared using the 3-4-5 triangle method. Length of 3 and 4 feet, meters, or any unit are staked out at approximately right angles. If the corner is square, the diagonal between the two end stakes should be 5 (same units as before). If not, the stakes are adjusted accordingly.



3-4-5 Triangle Method

A circular tank wall or floor can be outlined by tying a string of the correct radius (r) to a stake placed at the center of the proposed site and rotated around. Several stakes or markers can be placed around the outline at intervals of approximately 1 meter.

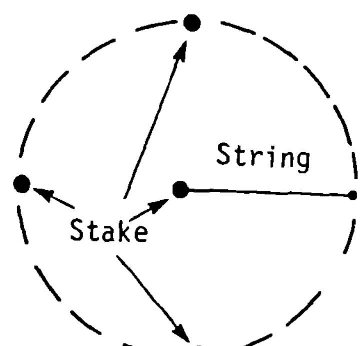


Fig. 1. Setting out a Circular Tank

FOUNDATION/FOOTING

Before the floor slab can be laid, a foundation of gravel or crushed stone is necessary. The thickness should be approximately 10 cm. The gravel bed should be tamped and leveled before proceeding with the floor construction. If the tank is to have a sump, then a depression should be made in the foundation for this. For masonry walls it is common practice to construct a footing of masonry or concrete. The footing should be approximately 20 cm thick and extend 10 cm beyond the base of the tank wall on both sides. This also requires a 10 cm thick foundation of either gravel or lean concrete (1 part cement, 3 parts sand, 6 parts gravel).

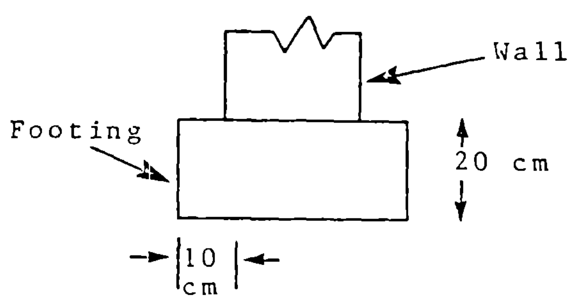


Fig. 2 Masonry Footing

PLACING FORMS

All concrete work requires a form into which the concrete is poured. Forms are usually made from boards or planks, although other materials are also used. Wooden forms are nailed together according to the proper measurements. To ensure that the concrete does not stick to the forms it is advisable to coat them with oil first. It is very important that the forms be supported on the outside. Otherwise, when the concrete is being compacted the forms can bulge or burst apart.

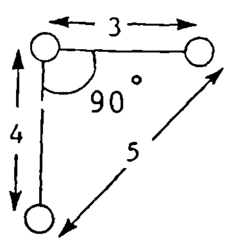
CONSTRUCTION GUIDELINES

CLEARING AND EXCAVATION

Initially, the tank site must be cleared of debris and vegetation. All tanks require some excavation. Even if the tank is to be above ground it is necessary to excavate and level the ground for the foundation. The foundation typically extends 15-30 cm beyond the outside of the tank wall. This must be taken into consideration when determining the area to be excavated. After the correct depth has been excavated, the ground should be leveled using a carpenter's level and board.

SETTING OUT

The outer wall of the tank or edge of the floor slab should be outlined using wooden stakes and string. For square or rectangular tanks, the corners are squared using the 3-4-5 triangle method. Length of 3 and 4 feet, meters, or any unit are staked out at approximately right angles. If the corner is square, the diagonal between the two end stakes should be 5 (same units as before). If not, the stakes are adjusted accordingly.



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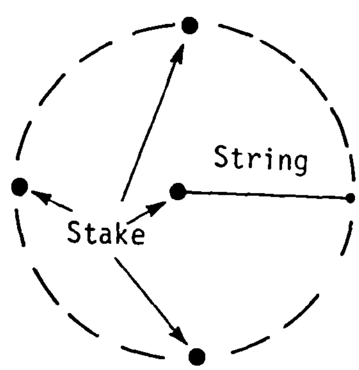


Fig. 1. Setting out a Circular Tank

FOUNDATION/FOOTING

Before the floor slab can be laid, a foundation of gravel or crushed stone is necessary. The thickness should be approximately 10 cm. The gravel bed should be tamped and leveled before proceeding with the floor construction. If the tank is to have a sump, then a depression should be made in the foundation for this. For masonry walls it is common practice to construct a footing of masonry or concrete. The footing should be approximately 20 cm thick and extend 10 cm beyond the base of the tank wall on both sides. This also requires a 10 cm thick foundation of either gravel or lean concrete (1 part cement, 3 parts sand, 6 parts gravel).

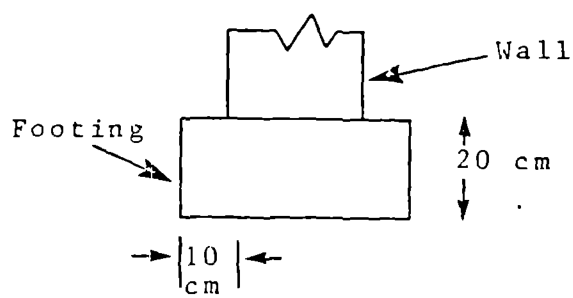


Fig. 2 Masonry Footing

PLACING FORMS

All concrete work requires a form into which the concrete is poured. Forms are usually made from boards or planks, although other materials are also used. Wooden forms are nailed together according to the proper measurements. To ensure that the concrete does not stick to the forms it is advisable to coat them with oil first. It is very important that the forms be supported on the outside. Otherwise, when the concrete is being compacted the forms can bulge or burst apart.

MIXING CONCRETE

Proper mixing of concrete is essential if it is to meet its requirements of strength and durability. The first step is to prepare a mixing pad or platform. For this, boards, metal sheets, or a hardened concrete slab is suitable. The aggregate and cement are then measured and piled into a heap. This then should be turned over using shovels or trowels until the mixture is uniform. The mix is then heaped and a depression is made in the center of the pile. Water is slowly poured into the depression and worked into the dry mix. It is important not to add too much water. Otherwise the concrete will not reach its full strength. A rule of thumb is to add approximately 3/4 parts of water for each part of dry cement. The concrete should be mixed in volumes no larger than that which can be poured within 30 minutes. At this point the concrete begins to set.

PLACING CONCRETE

After mixing, the concrete should be placed into the forms immediately. Floor slabs are poured beginning with one side or corner and working towards the opposite one. The concrete should be placed in adjacent piles, compacted, and leveled. The simplest way this can be done is to assign teams to carry out each of these 3 tasks. The first team transports and places the concrete. The second team follows by compacting, and the third team levels the slab.

Compacting is usually done by means of a tamping foot. The concrete should be compacted until the top surface is fairly smooth with none of the coarse aggregate jutting out.

Leveling is carried out using a trowel or screed (short, smooth piece of wood) and a carpenter's level. The floor should slope towards the sump or drain.

Walls should be poured in a similar manner with the exception that the compacting or rodding should be carried out in 30-40 cm layers. Iron rods are best for doing this.

REINFORCED CONCRETE

The tensile strength of concrete can be greatly increased with the use of reinforcing bar or mesh. Reinforcing bar (rebar) is tied with wire into a mesh and placed in the form. It should be covered by a minimum of 3 cm of concrete. The spacing and size of the rebar should be determined by the design engineer.

ROOF/WALL ANCHORS

In any tank the walls, floor, and roof should be anchored into one another. This is usually done by embedding rebar into both the floor and wall, or the wall and roof at the joint as shown in Figure 3.

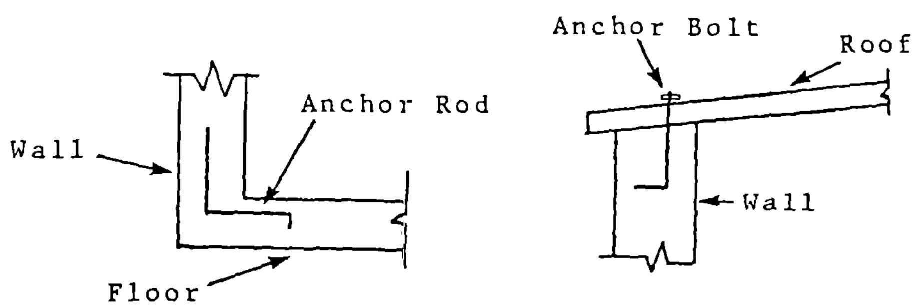


Fig. 3 Roof and Wall Anchors

MASONRY

Tanks are often constructed of brick or stone masonry. Regardless of the building material used (i.e., brick, stone, concrete block) it must be cleaned of all dirt and organic material first. Bricks and cement blocks should first be soaked in water. Otherwise they may absorb too much of the water in the mortar. The walls should be built so that no two joints form a continuous line across the thckness of the wall or up and down the side of the wall. At intervals of approximately 60 cm, bondstones or bonding bricks should be laid across the thickness of the wall. This helps to hold the wall together. This is illustrated in Figure 4 below.

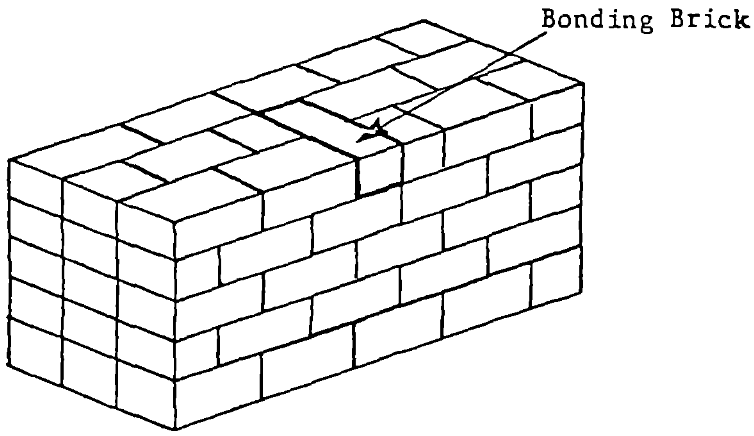


Fig. 4 Brick Masonry

To ensure the strength of the wall it is very important that no two adjacent stones or bricks touch. The recommended thickness of all mortar joints is 1.0 cm. In masonry tanks, it is more common to construct the walls first beginning with the corners and then pour the floor slab. In this case, the wall is not anchored into the floor as for other types of tanks. This is shown in Figure 5.

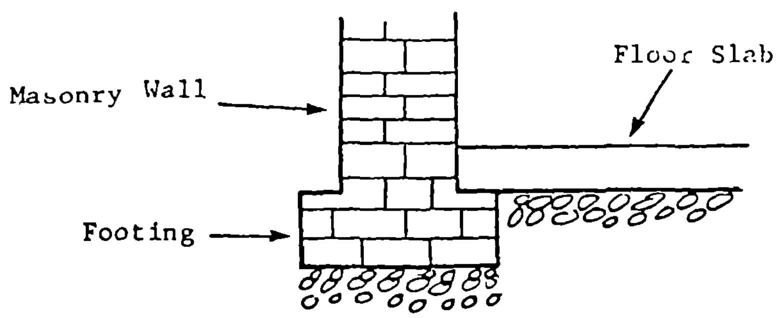


Fig. 5 Masonry Tank Wall

The roof of a masonry tank is usually attached to an anchor bolt embedded 10-15 cm into the top of the masonry wall.

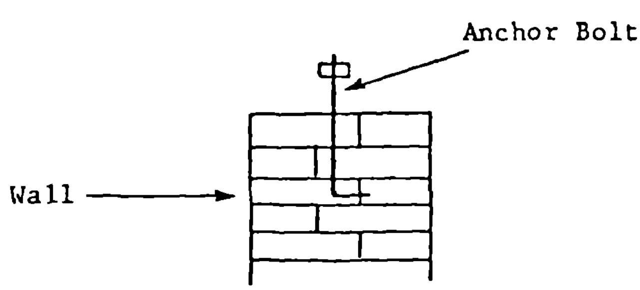


Fig. 6 Anchor Bolt

The minimum thickness of a masonry wall is 30 cm. The actual dimensions should be determined by the design engineer.

PLACING OF PIPES

The tank may have several pipes depending upon the type of tank. A typical above ground tank should have an overflow, drain, and outlet pipe. Below ground tanks do not have a drain or outlet pipe but must have an overflow. When mounting any type of pipe in concrete or masonry it is important that the pipe be firmly cemented in all the way around, with either mortar or concrete. Once a pipe has been placed it should not be touched until the wall has hardened. Otherwise the tank may leak around the pipe. It is also important that the pipe is clear of dirt and oil before it is placed. Recommended locations of pipes are as follows:

DRAIN PIPE	-	on the floor of the tank
OUTLET PIPE	-	10-15cm above the floor of the tank
OVERFLOW PIPE	-	15 cm below the top of the tank wall

Because of the thin wall of ferrocement tanks it is better that the drain and outlet pipes be located in the floor of the tank rather than the wall as shown in Figure 7.

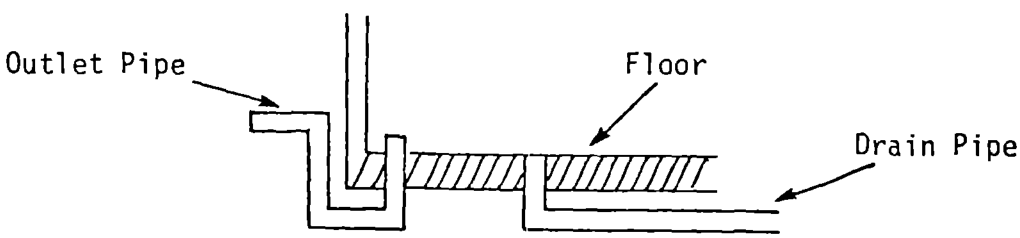


Fig. 7 Pipe Placement for Ferrocement Tank

FERROCEMENT

Ferrocement is cement mortar reinforced with mesh, wire and sometimes reinforcing bar. A ferrocement tank is constructed in the following manner. A cylindrical form is made around which wire mesh is wrapped. Unlike forms used for reinforced concrete, ferrocement forms should not be oiled. One layer is usually sufficient. Around this 2-3 mm wire is wrapped for additional reinforcement. This is then plastered on the outside with 1:3 cement mortar. A second coat of plater is then applied after the initial coat has begun to stiffen. Each coat should be approximately 1.0-1.5 cm thick. The mortar is allowed to harden for two days. At this time the forms can be removed and the inside of the tank is then plastered in two more coats. The total thickness of the wall should be 4-5 cm. It is very important that the tank be kept covered and moist, particularly during the first few days. Otherwise the mortar will crack and the tank may leak.

After approximately one week a roof can be built on the tank. A ferrocement roof can be constructed using two layers of mesh instead of the single layer as for the walls. Again it is important to anchor the roof to the walls using rebar.

PLASTERING

To ensure that the tank is waterproof it should be internally plastered. Recommended plastering procedures vary from two to four coats. Regardless of the number of coats, only one coat should be applied each day.

The following plastering method is recommended here:

> Initially a 1:3 cement mortar coat is applied to a thickness of 1.0-1.2 cm. This coat is applied roughly and is not smoothed out. Next a coat of 1:2 mortar is applied to a thickness of 0.8-1.0 cm, and smoothed. finally, a thin 0.2-0.4 cm coat of cement paste (cement & water only) is applied.

CURING

All cement work must be cured for a minimum of one week and preferably two. The structure must be kept moist and protected from direct sunlight. Other wise the cement will dry out too rapidly, crack and will not reach its full strength. Curing should begin immediately after the cement has finished setting, usually 2-4 hours after it has been placed. This can be best done by wetting the structure and then covering it with damp burlap, paper leaves or other suitable material. Concrete slabs can be cured by building up a rim of soil around the edge of the slab and flooding it with a few centimeters of water.

DRAINAGE

The area surrounding the tank should be graded so that rain and overflow water drains away from the tank. This is especially important for below ground tanks where surface runoff can enter the tank and contaminate the water.

MANHOLE AND AIR VENTS

In addition to the structural features mentioned above, the tank should be provided with a manhole or access door, since it will be necessary to enter the tank for cleaning and maintenance. The door should be locked at other times to prevent unauthorized persons from entering. Also, the tank should be well ventilated. In most cases, this will occur naturally but for certain types of tanks such as reinforced concrete or ferrocement tanks with tight-fitting covers it may be necessary to provide an air vent.

CONSTRUCTION PROCEDURES
BRICK MASONRY TANK
(Square, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. SITE PREPARATION				
1. Clear Site	Digging, Clearing Tools		1-4 Hrs.	Clear all vegetation, boulders, etc.
2. Set out tank floors/ walls	Measuring tape, string, hammer, stakes		1 Hr.	3-4-5 triangle method.
3. Excavate	Digging, tools, tape		2-8 Hrs.	Include trench for footing, hole for sump (depth depends on design decisions previously made)
4. Level	Digging tools, carpenter's level, board		1 Hr	
5. Place foundation	Level, shovels, compacting tools	Gravel, stone	1-2 Hrs	10 cm gravel or stone layer, compact with hammer, tamping foot or other tool.
6. Outline wall footing	Measuring tape, string hammer, stakes		1 Hr	Outline with string tied to corner stakes.
B. FOOTING & WALL CONSTRUCTION				
1. Clean & soak bricks	Water container, wire brush	Bricks, water	1-2 Hrs	
2. Measure quantities for mix	Measuring container	Sand, cement	1/2 Hr.	1:4 Cement/sand ratio.
3. Dry mix mortar	Mixing pad, trowels, shovels.	Sand, cement	1/4 Hr.	Mix to uniform color & consistency.
4. Wet mix mortar	Mixing pad, trowels, shovels. Measuring container.	Water, mortar mix.	1/4 hr.	Add water gradually until mortar is workable; mix only volume which can be used in 1/2 hour or less.

CONSTRUCTION PROCEDURES
BRICK MASONRY TANK
(Square, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
5. Lay footing	Tape, trowels, hammers & other masonry tools.	Mortar, bricks [Alternative: concrete mixed 1:3:6]	1-4 Hrs.	Begin with corners & work towards center of wall; cover & wet at end of day.
6. Place drain pipe	Level, masonry tools	GI pipe, mortar	5 Min.	Place pipe level or sloping slightly downward from tank.
7. Lay tank wall - first courses	Masonry tools, plumbob	Mortar, bricks	1 to several days	Same as B.5 above.
8. Place outlet pipe				Same as B.6 above, 10 cm above floor.
9. Lay tank wall to overflow pipe.				Same as B.5 above.
10. Place overflow pipe and roof anchor bolts.		Galvanized Iron pipe, roof anchor bolts		Same as B.6 above - 15 cm from top of tank wall.
11. Complete tank wall				Same as B.5 above.
12. Allow to harden/cure	Water container	Water, burlap, paper or other such material	2-4 days	Wet several times each day keep covered.
C. FLOOR				
1. Measure quantities for concrete	Measuring containers	Cement, sand, gravel	1/2 Hr.	1:1 1/2:3 cement/sand/gravel ratio.
2. Dry mix concrete	Mixing pad, trowels, shovels	Cement, sand,	1/2-1Hr	Mix to uniform color and consistency overturning several times.

CONSTRUCTION PROCEDURES
BRICK MASONRY TANK
(Square, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
3. Wet mix concrete	Mixing pad, trowels, shovels	Dry mix, water	1/4 Hr	Gradually add water to approximately 3/4 parts water to 1 part cement. Mix thoroughly in volumes which can be poured in 1/2 hour or less.
4. Pour concrete	Transport containers, compacting tools, trowels screed, level	Concrete	1-3 hrs	Place in adjacent piles, compact and level; slope towards drain
5. Allow to harden/cure	Water container	Water, burlap, paper or other	2-3 days	2-3 hours after concrete has been poured flood with 2-5 cm of water.
D. PLASTERING (WATERPROOFING)			3 days	See guidelines for plastering method for masonry tanks.
E. ROOF	Hammer, nails, wrenches, etc. Require for specific type of roof.	Depends on type of roof	1-4 days	Include locking access door.
F. FINAL GRADING/FINISHING	Digging tools		1-2 days	Slope ground away from tank allow for overflow drainage.

CONSTRUCTION PROCEDURES
PLASTERING OF MASONRY TANKS

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. FIRST COAT				
1. Clean wall	Wire brush, trowels		1-2 Hrs	Scrape off loose mortar, dirt, etc.
2. Measure quantities for mortar mix (first coat.	Measuring container	Sand, cement	1/2 Hr	1:3 cement/sand ratio.
3. Dry mix mortar	Mixing pad, trovels, shovels	Sand, cement	1/4 Hr	Mix to uniform color & consistency.
4. Wet mix mortar	Mixing pad, trowels, shovels, measuring container	Water, mortar	1/4 Hr	Add water gradually until mortar is workable; mix only volume which can be used in 1/2 hour or less.
5. Apply mortar	Trowels	Mortar	1-2 Hrs	Apply in rough coat of approximately 1.0-1.2 cm thickness; do not smooth.
6. Allow to set		Water, burlap, paper, etc.	1 day	Cover sprinkle with water occasionally.
B. SECOND COAT				
1. Dampen wall		Water	1/2 Hr	Sprinkle with water.
2. Measure quantities	Measuring container	Sand, cement		1:2 cement/sand ratio
3. Mix mortar				As in steps A.3 - A.4 above.
4. Apply mortar	Trowels	Mortar	1-2 Hrs	Apply coat of approximately 0.8-1.0 cm thickness and smooth.
5. Allow to set				Same as step A.6 above.

CONSTRUCTION PROCEDURES
PLASTERING OF MASONRY TANKS

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
C. FINAL COAT				
1. Dampen wall		Water	1/2 Hr	Sprinkle with water.
2. Mix mortar	Mixing pad, trowels	Sand, Cement	5 min	Cement & water only mixed to a thick paste; mix only small amounts.
3. Apply mortar	Trowels			Apply 0.2-0.4 cm coat and smooth.
4. Allow to harden/cure		Water, burlap, paper, etc.	2-4 days	Wet several times per day and cover.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. SITE PREPARATION				
1. Clear site	Digging, clearing tools		1-4 Hrs	Clear all vegetation, boulders, etc.
2. Set out tank floor	Measuring tape, string, hammer, stakes		1 hr	Rotate string around center stake at proper radius.
3. Excavate	Digging tools, tape		2-8 Hrs	Include depression for sump, drain and outlet pipes.
4. Level	Digging tools, level, board.		1 Hr	
5. Place outlet/drain pipes	Level	GI pipes	15 min	Place level
6. Place foundation	Level, shovels, compacting tools.	Gravel, stone	1-2 Hrs	10 cm gravel or stone layer, compact with tamping foot, hammer or other tools.
B. FLOOR				
1. Construct floor slab form	Level, hammer, nails, etc, according to type of form.	Form work	1-2 Hrs	
2. Place reinforcement (if required)	Pliers, wire cutters, tape.	Wire, rebar or mesh.	1-2 Hrs	Space reinforcement according to design; include wall anchors.
3. Measure quantities for mix	Measuring containers	Sand, cement, gravel	1/2 Hr	1:1 1/2:3 cement/sand/gravel ratio.
4. Dry mix concrete	Mixing pad, trowels, shovels.	Cement, sand, gravel	1/2-1Hr	Mix to uniform color and consistency overturning several times.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
5. Wet mix concrete	Mixing pad, trowels, shovels, measuring container	Dry mix, water	1/4 Hr	Gradually add water to approximately 3/4 parts water to 1 part cement; mix thoroughly in volumes which can be poured in 1/2 hour or less.
6. Pour concrete	Transport containers, compacting tools, trowels, level, screed	Concrete		Place in adjacent piles, compact and level; slope towards drain.
7. Allow to harden/cure	Water container	Water, burlap, paper or other	2 Days	2-3 hours after pouring concrete flood with 2-5 cm water.
C. WALLS				
1. Remove floor slab form	Depends on type of form		1/2-1Hr	
2. Place wall form work	Depends on type of form		1-2 Days	Check that form walls are vertical and stable.
3. Place wire mesh	Pliers, wire cutters	Wire mesh, binding wire	1/2 Hr	One layer of mesh around form wall with 20-30 cm overlap; tie in place.
4. Lace wire reinforcement up and down mesh	Pliers, wire cutters, measuring tape.	2.0-3.0 mm wire	1/2-1 Hr	Wrap wire around form every 2-3 cm for first 60 cm, then every 6-8 cm to top of wall; double layer at top; tie into wall anchor bolts at base.
5. Place roof anchor bolts and overflow pipe.	Pliers, wire cutters	Binding wire, rebar, pipe	1/2 Hr	Tie into wall reinforcement.
6. Measure quantities for mortar	Measuring container	Sand, cement	1/2 Hr	1:3 cement/sand ratio.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
7. Dry mix mortar.	Mixing pad, trowels, shovels	Sand, cement	1/4 Hr	Mix to uniform color and consistency.
8. Wet mix mortar	Mixing pad, trowels, shovels, measuring container	Water, mortar mix	1/4 Hr	Add water gradually until mortar is workable; mix only volume which can be used in 1/2 hour or less.
9. Apply first coat (outside)	Masonry tools	Mortar	1-2 Hrs	Apply 1.0-1.5 cm thick rough coat without smoothing.
10. Allow to set			2 Hours	
11. Apply second coat (outside)	Trowels	Mortar	1-2 hrs	Same as C.6-C.9 above; smooth finish
12. Allow to harden/cure	Water container	Water, burlap, paper or other material	2 Days	Wet several times per day and cover.
13. Remove wall forms	Depends on type of form		1-3 Hrs	Carefully remove without disturbing wall.
14. Apply 2 inside coats of plaster			1-1 1/2 Days	Same as C.6-C.11 above.
15. Allow to harden/cure		Water, burlap, paper, etc.	2 Days	Wet several times per day and cover.
D. PLASTERING (WATERPROOFING)				
1. Apply first coat	Mixing containers, pad trowels, measuring containers, etc.	Cement, sand, water	1-2 hrs	Apply 1:2 cement/sand mortar 1.0 cm thick and smooth according to steps C.6-C.9 above.
2. Allow to set			1 Day	Protect from direct sunlight.

CONSTRUCTION PROCEDURES
FERROCEMENT TANK
(Cylindrical, Above Ground)

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
3. Apply second coat	Trowels, mixing pad	Cement, sand, water	2-3 hrs	Apply cement paste and smooth to 0.2-0.4 cm thickness.
4. Allow to harden/cure		Water, burlap, etc.	4-5 Days	Wet several times per day and cover.
E. ROOF	Depending upon type of roof		1-4 Days	If ferrocement roof is constructed use 2 layers of wire mesh and proceed as for the walls.
F. FINAL GRADING/FINISHING	Digging tools		1-2 Days	Slope ground away from tank allow for drainage.

CONSTRUCTION PROCEDURES
FERROCEMENT LINED PIT

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
A. SITE PREPARATION				
1. Clear site	Digging, clearing tools		1-4 Hrs	Clear all vegetation, boulders, etc.
2. Set out tank floor	Measuring tape, string hammer, stakes		1 Hr	Rotate string around center stake at proper radius.
3. Excavate	Digging tools, tape		4-8 hrs	Pit walls should be smooth.
4. Level	Digging tools, level, board		1 Hr	
5. Place foundation	Level, shovels, compacting tools	Gravel stone	1-2 hrs	10 cm stone or gravel layer compacted.
B. FLOOR				
1. Place reinforcement (if required)	Pliers, wire cutters, tape	Wire, rebar or mesh	1-2 Hrs	Include wall anchors
2. Measure quantities for concrete mix	Measuring container	Sand, cement, gravel	1/2 Hr	1:1-1/2:3 cement/sand/gravel ratio.
3. Dry mix concrete	Mixing pad, trowels, shovels	Cement, sand, gravel	1/2-1 Hr	Mix to uniform color and consistency overturning several times.
4. Wet mix concrete	Mixing pad, trowels, shovels, measuring container	Water, concrete dry mix	1/4 Hr	Gradually add water to approximately 3/4 parts water to 1 part cement; mix thoroughly in volumes which can be poured in 1/2 hour or less.
5. Pour concrete	Transport containers, compacting tools, level, screed, trowels.	Concrete	1-3 Hrs	Place in adjacent piles, compact, and level.

CONSTRUCTION PROCEDURES
FERROCEMENT LINED PIT

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
6. Allow to harden/cure	Water container	Water, burlap, paper or other	1 Day	2-3 hours after pouring concrete, dampen and cover.
C. WALLS				
1. Measure quantities for mortar mix.	Measuring container	Sand, cement	1/2 Hr	1:1 cement/sand ratio.
2. Dry mix mortar	Mixing pad, trowels, shovels	Sand, cement	1/4 Hr	Mix to uniform color and consistency.
3. Wet mix mortar	Mixing pad, trowels, shovels, measuring container	Water, mortar mix	1/4 Hr	Add water gradually until mortar is workable; mix in volumes which can be used in 1/2 hour or less.
4. Apply first coat	Trowels	Mortar	1-2 Hrs	Apply 1.0 cm thick rough coat to walls without smoothing.
5. Allow to set			2 Hrs	Keep protected from sunlight.
6. Apply second coat	Trowels	Mortar	1-2 hrs	Same as C.1-C.4 Above.
7. Place reinforcement	Wire cutters, pliers	Wire mesh, binding wire	1/2-1 Hr	Place 1 layer immediately after applying 2nd coat; tie into floor reinforcement.
8. Allow to harden/cure	Water container	Water, burlap, paper or other	1 Day	Wet several times per day and cover.
9. Apply inside plaster in 2 coats.			4-8 Hrs.	Same as steps C.1-C.6 above.
10. Allow to harden/cure	Water container	Water, burlap, etc.	1 Day	Wet several times per day and cover.

CONSTRUCTION PROCEDURES
FERROCEMENT LINED PIT

ACTIVITY	TOOLS	MATERIALS	TIME	TECHNIQUE
D. WATERPROOFING				
1. Apply first coat	Shovels, trowels, measuring container, mixing pad	Cement, sand water	1-2 Hrs	1:2 cement/sand ratio applied as in steps C.1-C.4 above and smoothed.
2. Apply second coat	Shovels, trowels, measuring container, mixing pad	Cement, water	1-3 hrs	Apply cement paste 0.2-0.4 cm thick and smooth on day following application of first coat.
3. Allow to harden/cure		Water, burlap, etc.	2-4 Days	Wet several times per day and cover.
E. ROOF	Depending on type of roof		2-4 Hrs	Place roof on pit.
F. FINAL GRADING/FINISHING	Digging tools		1-2 Days	Slope ground away from tank and allow for drainage.

CASE STUDY

Project History

Dry Spot is a community which the community health worker selected some months ago to work in to develop a rainwater roof catchment project. The initial technical assessment indicated that indeed it was feasible to develop a rainwater collection and storage project. Rainfall data was sufficient for a ten cubic meter communal tank to be constructed using an existing school roof for catchment. The community was currently carrying water long distances for family drinking purposes. This work was done by women and children. The stream where the water was collected was contaminated and sometimes was completely dry during the dry season.

During the project social assessment phase, the community worker had worked through a local health committee which had been previously formed to assist a small community clinic, sponsored by the Ministry of Health. The committee had been very enthusiastic. They agreed to build a communal tank because everybody would have an equal interest in the benefits of the project. They had also heard that in the past some other villages had problems with individual family tanks because the wealthier families would build their own storage systems and make money by selling water to people. Those who seemed most committed to the project were the two women on the health committee. The committee had agreed to collect a small amount from each family monthly until the necessary community quota had been raised to match the amount that the Ministry of Health would provide for the project. Dry Spot has 500 inhabitants. The community lives by working in subsistence agriculture and by selling charcoal and goat cheese.

Current Situation

There is only one month left to construct the tank in order to use it during the upcoming rainy season. The Ministry of Health has ordered all of the necessary materials upon the recommendation of the community health worker. This was done without informing the committee, because the worker did not want the community to know that it was going to receive the materials until they had collected their share of the quota. The supervisor of the health worker has informed him/her that if the community does not provide its share of the quota, the materials will be given to another community which has collected money on its own and asked for assistance in another project.

The community worker has also found out that the health committee has not yet been able to provide a list of the men who will be available to work on the project, even though the community resource inventory conducted earlier indicated that there were at least two men who were somewhat experienced in construction and had worked with cement before. It seems that most of the men in the village want to collect and sell as much charcoal as possible before the rains come. If the project is to proceed, the community worker must provide to his/her supervisor both the community quota, and a statement by the health committee of which people will work on the estimated ten days of project construction. This must be done within one week.

Task in Small Groups

1. List the possible mistakes the project developer has made.

2. Analyze the above case study. Discuss and decide what you would do.

3. Prepare a strategy for a meeting with the health committee which will address the problems of collecting the quota and organizing the community workers.

MAINTENANCE CHECKLIST

FREQUENCY	ACTIVITY	WHO IS RESPONSIBLE
A. At the beginning of each rain	1. Engage foul flush mechanism	
B. At the end of each dry period	1. Clear debris from catchment area 2. Check gutter supports and repair	
C. At the end of each dry period and weekly during rainy periods	1. Clean gutters of debris 2. Check and clean screen at downpipe 3. Check gutters for leaks and repair accordingly 4. Check gutters for overflowing and adjust position or slope accordingly 5. Check drainage around tank	
D. Monthly throughout the year	1. Check tank cover and ventilation 2. Check tank for leakage	
E. Weekly throughout the year	1. Check water quality in tank and clean out if necessary	
F. Annually	1. Clean out and disinfect tank	

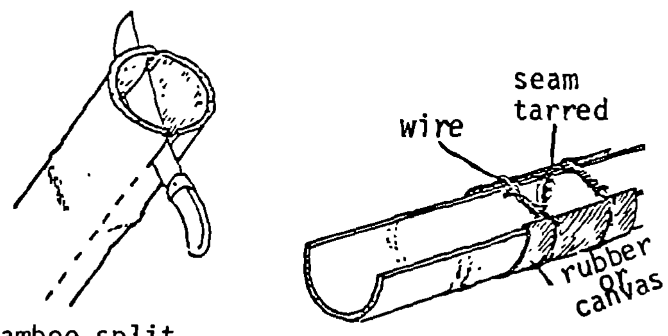
CONSTRUCTION GUIDELINES FOR GUTTERS*

Materials

The gutter material selected should be light in weight, water resistant, and easily joined. To reduce the number of joints and thus the likelihood of leakages, a material which is available in long straight sections is preferred. Some examples of materials commonly used for gutters are split bamboo, wood, and metal sheeting.

Size and Shape

The gutter must be large enough to channel water from heavy rains without overflowing. The shape is also very important. If the gutter is too shallow it may overflow. If it is too narrow the water from the roof may shoot over the gutter and be lost. For most roof catchments a gutter with a cross-sectional area of 70-80 cm^2 is sufficient for the range of slopes recommended here. The minimum recommended width for square and semi-circular gutters is 8 cm. For a triangular shaped gutter the width should be at least 10 cm. The minimum recommended depth is 7.0 cm for any gutter.



a. Bamboo split lengthwise

b. joining 2 pieces of bamboo

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

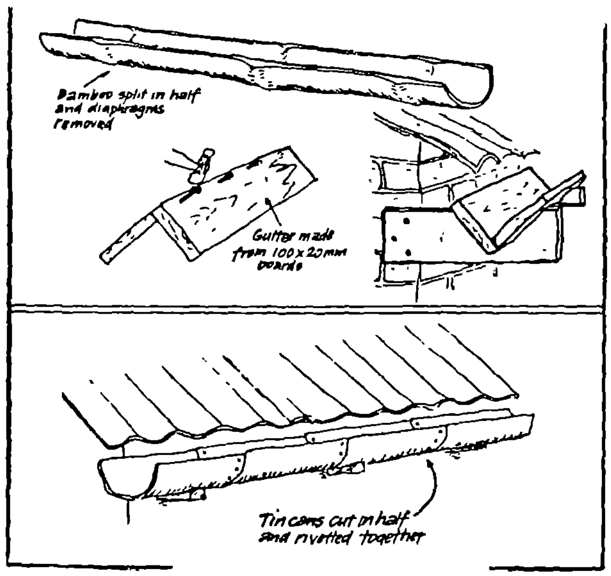


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Figure 2, Bamboo Guttering Joining Sections.

Figure 3, Alternative Forms of Guttering.

* From Keller, op.cit.

Slope

The gutter should be placed at a uniform slope to prevent water from pooling and overflowing the gutter. For most roof catchments the slope should be in the range of 0.8 cm/meter to 1.0 cm/meter.

Location

The gutter must collect all of the water running off the roof during light and heavy rainstorms. To achieve this the gutter should be located so that the roof overhangs the gutter by 1 or 2 cm, and the gutter extends beyond the edge of the roof by at least 7 cm.

Supports

The gutter must be well supported. The number of supports depends upon the type of guttering material but it is recommended that most gutters be supported at least every 50-60 cm. The simplest means of support is by tying wire around the gutter and fastening it to the roof. The gutter can also be nailed to the roof or be provided with wooden supports underneath.

Joints

All joints should be leak proof. Joints can be sealed using tar, pitch or a similar material. Strips of plastic can also be laid in the gutter to prevent leakage. The joining material should be one which does not contaminate the water.

Procedures for Construction and Placement of Gutters

ACTIVITY	MATERIALS AND TOOLS	COMMENTS
1. Make gutter	Hammer, nails, wire, etc, depending on type of material, measuring tape or ruler	70-80 cm^2 minimum cross sectional area 8 cm minimum width 7 cm minimum depth
2. Join sections & seal	Hammer, nails, wire, etc. and sealing material	All joints should be made leakproof.
3. Attach to roof	Wire, nails, etc.	Should be supported at intervals of 50-60 cm.
4. Check position	Measuring tape or ruler	Roof should overhang by at least 1-2 cm. Gutter should extend at least 7 cm beyond edge of roof.
5. Adjust slope	Level	Recommended range of slope: 0.8 cm/meter - 1.0 cm/meter.
6. Attach downpipe and foul flush	Wire, nails, sealing material, etc., and screen	All joints should be leakproof; screen should be placed at mouth of downpipe.
7. Attach to tank	Downspout pipe	7 cm diameter

EVALUATION FORM

(Please do not sign your name)

A. Goal Attainment: Please circle the appropriate number to indicate the degree to which the workshop goals have been achieved.

Session #1: To familiarize the participants with the overall workshop process and the expectations of their participation.

1	2	3	4	5
Low				High

Session #2: To impart knowledge of the major steps and basic considerations in planning and developing a rainwater harvesting project. To adapt these factors to the unique conditions of the local setting.

1	2	3	4	5
Low				High

Session #3: To examine the feasibility of a rooftop catchment program in light of local rainfall patterns.

1	2	3	4	5
Low				High

Session #4: To enable the participants to learn how to assess whether a community is willing and able to support a rooftop catchment project.

1	2	3	4	5
Low				High

Session #5: To enable the participants to learn how to conduct an inventory of local skills, materials, and techniques which can be used in rooftop catchment.

1	2	3	4	5
Low				High

Session #6: To introduce and practice using a series of criteria to reach an informed consensus on which storage and guttering technology to design and construct.

1	2	3	4	5
Low				High

Session #7: To teach participants how to calculate an "optimum" tank size and evaluate the result.

1 Low	2	3	4	5 High

Session #8: To teach the basics of mixing cement and plastering and how to build cement plaster jars for individual rain catchment storage.

1 Low	2	3	4	5 High

Session #9: To describe, in enough detail to plan construction, all the components (parts) of the system to be built.

1 Low	2	3	4	5 High

Session #10: To learn how to design and construct a roof catchment and filtration system for thatch roofs.

1 Low	2	3	4	5 High

Session #11: To teach all of the steps and procedures necessary for detailing and ordering the materials for construction.

1 Low	2	3	4	5 High

Session #13: To learn the basic steps and processes in larger (community) storage tank construction.

1 Low	2	3	4	5 High

Session #14: To consider the process of organizing the community into construction working groups and develop a plan to do so.

1 Low	2	3	4	5 High

Session #15: To learn how to develop and communicate a maintenance plan which the community will be able to use and follow.

1 Low	2	3	4	5 High

Session #16: To critically examine the tank design under construction and refine it for future use.

1 Low	2	3	4	5 High

Session #17: To learn how to construct and connect gutters.

1 Low	2	3	4	5 High

Session #18: To plan applications of the workshop to the work setting.

1 Low	2	3	4	5 High

B. Workshop Feedback and Learning: Please answer the following questions as fully as possible so that the trainers can learn how effective the workshop methodology was.

1. What have been the most positive things about this workshop? Comments:

2. What have been the most negative things about this workshop? Comments:

3. What one thing stands out as important to you in this workshop? Comments:

4. What things have you learned that you did not know before? Comments:

C. Workshop Organization and Training

1. What comments do you have about the way the workshop was planned and organized?

2. What can be done in the future to improve a workshop like this?

3. What specific steps in developing a rainwater harvesting system do you feel you will need to learn more about in order to successfully promote and develop a project in the future?

4. What comments do you have about the trainers?