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ABSTRACT

This manual provides materials for a two-week inservice training program for Peace Corps volunteers on the planning, construction, and operation and maintenance of small-scale irrigation systems. The workshop is designed to be given by two experienced professionals: one with practical knowledge of irrigation system design, operation, and maintenance; the other with adult education experience. Part A is a brief outline of the objectives and methodology for each of the 33 subject-matter sessions. In each session, reference is made to the teaching unit that provides the basis of the content. Much of the material is very specific and lends itself to hands-on field experience. Part B of the manual contains the teaching units that serve as subject-matter content and organization. Components of each unit are general and behavioral objectives, a list of materials, and procedures. The 12 units are soil classification; irrigation safety and health practices; topographic surveying and land mapping; water source measurement and development; social factors that affect change and community cooperation; climate and its effect on water sources and seasonal water requirements of crops; resource identification; irrigation system planning and design; agronomic practices for irrigation; economic evaluation and feasibility; irrigation laws and regulations; and identifying and correcting drainage problems. (YLB)

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Peace Corps

SMALL SCALE IRRIGATION SYSTEMS: A TRAINING MANUAL

PLANNING - CONSTRUCTION - OPERATION AND MAINTENANCE
OF SMALL SCALE IRRIGATION SYSTEMS

A TWO-WEEK IN-SERVICE TRAINING PROGRAM FOR
PEACE CORPS VOLUNTEERS

Prepared for the Peace Corps

by

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June, 1983

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INTRODUCTION

Peace Corps volunteers are daily confronted with unknowns, situations for which their prior experience and training may not have prepared them. In an effort to remove, at least partially, one of the potential unknowns in their new world, this training program has been developed.

Given a basic understanding of irrigation principles and the requisite skills involved, the PCV will be able to help a farm family or a rural community evaluate the potential for and, if appropriate, develop a simple irrigation system or more effectively utilize an already existing system.

The authors realize fully the limitations of a two week training program in a subject as technically complex as irrigation. At the same time, they offer this with confidence, feeling that they will have provided the volunteer with the concepts and technical skills needed to operate intelligently in this complex area. Equally important, the volunteer will also know his or her limitations.

GENERAL PROGRAM OBJECTIVES

Given that the Peace Corps Volunteer is not an irrigation engineer and further that a two-week training program will not make the PCV an irrigation engineer. The following general objectives are identified:

At the completion of the training program, the PCV will:

- be able to identify the principle components of a simple irrigation system
- have the basic skills necessary to establish a simple irrigation system
- be able to consult with a farm family and help them evaluate the potential for an economically viable irrigation system given the particular constraints of their situation
- be able to find the necessary information relating to the legal constraints on irrigation in the local community
- be able to identify and locate the resources needed to support an irrigation program
- understand the health and safety factors involved in developing an irrigation system
- have developed additional skills and confidence to work with a farm family or rural community to help them identify their needs, establish priorities and, if appropriate, help them to construct, operate and maintain a simple irrigation system.

TRAINING GUIDES

Training Guide Number	
1.	Irrigation Principles and Practices, Peace Corps, Program and Training Journal Report Series Number 5, dated January 1969.
2.	Small Scale Irrigation, Peter H. Stern, Intermediate Technology Publication Ltd./International Irrigation Information Center, dated 1979.
3.	Soil-Water Plant Relationships, KSU/CES Publication Number MF 466, dated September 1978.
4.	Using a Level, KSU/CES Publication Number AF-19, dated June 1979.
5.	Terrace System Options, KSU/CES Publication Number AF-74, dated March 1981.
6.	Farm Pond Maintenance, KSU/CES Publication Number AF-3, dated November 1978.
7.	Contour Farming Pays, KSU/CES Publication Number R-14, dated January 1974.
8.	Useful Irrigation Data, KSU/CES Publication Number I-7, dated February 1976.
9.	Grain Sorghum Irrigation, KSU/CES Publication Number I-6, dated March 1975.
10.	Irrigation Soybeans, KSU/CES Publication No. I-5, dated October 1975.
11.	Irrigating Corn, KSU/CES Publication Number I-1, revised February 1977.
12.	Pipelines for Irrigation, KSU/CES Publication Number I-2, dated September 1967.
13.	A Concept of Needs, reprint, J. Paul Leagans, The Journal of Cooperative Extension, Vol. 2, No. 2, Summer 1964.

MATERIALS NEEDED FOR WORKSHOP PROJECT

1. Overhead projector
2. Slide projector (35mm)
3. Climate information for local area
4. Soil survey maps, if available
5. Meter stick or measuring tape (metric & English units)
6. Graph paper, 10 x 10 (metric or English)
7. Plastic 3/8" or 1/2" hose 30-meter lengths (3 minimum)
8. Marking pens - felt tip or crayons
9. Watch with second hand
10. Shovel
11. Training Guides Numbers 1 thru 19 (20 copies each)
12. Blackboard and Chalk
13. Glass jars, 1 liter or 1 qt. (4 minimum)
14. Cans, 2 liter or larger, w/end cut out (6 minimum)
15. Lumber as needed for construction of leveling instruments, stadia rods, stakes, etc.
16. One-foot rulers (metric and English units)
17. Soil auger
18. Newsprint
19. Hatchets (or local equivalent)
20. Hammers, nails, paint
21. Abney level and bubble levels, if possible
22. Carpenter level

USING THE MANUAL

The schedule for this two-week training workshop is divided into subject matter sessions within one-half day periods. Part A of the manual is a brief outline of the objectives and methodology for each of the sessions and Part B of the manual contains the teaching units which serve as subject matter content and organization. In each session, reference will be made to the teaching unit that provide the basis of the content for that session. While suggestions are made on teaching methodology, it is recognized that the local situation and preference of the teachers will dictate variations in the methodology used.

The time indicated for a particular session should be considered as a guide only. The actual time needed will depend on the specific teaching situation such as ability level of the participants, ratio of PCV's to HCN's, need for and skill level of translator, location of field work area in relation to classroom, etc. Not shown in the schedule are evening sessions or a Saturday session. Evening sessions may be scheduled to meet special needs. A Saturday morning field trip to observe an established irrigation system or any other appropriate field trip is a possibility.

In teaching each of the sessions, it is suggested that stress be placed on the lesson objectives. The material will be more meaningful if the learner understands the context in which the discrete items of information will fit. The materials needed for each session have been identified and where appropriate specific procedures and instructor notes have been included. It will help the progress of the learning experience if the learners will read the reference material prior to the instruction. Much of the material presented is very specific and lends itself to hands-on field experience.

Local and site-specific conditions will influence many of the specific examples, problems and field exercises. For example, climatic data for the locality will make the exercise of calculating water requirements for a particular crop more meaningful. Some field exercises, e.g. water flow measurement, cannot be done if water is not available.

This workshop has been designed to be given by two experienced professionals: one with a practical knowledge of irrigation system design, operation and maintenance, the other with adult education experience. Both professionals should have developing country experience.

It is recommended that one member of the team go into the country at least one week before the workshop to make a site visit and obtain local data and materials which will be required.

PART A

WORKSHOP SESSIONS, OBJECTIVES AND METHODOLOGY

DAY 1 - A.M.

SESSION I--Opening Statements and Introduction 30 Minutes

Training program coordinator may wish to introduce program, identify objectives, introduce participants, set procedural format, answer questions, etc. Introduction of workshop instructors should conclude this portion.

SESSION II--Climate Setting 3 Hours

a. Objectives

The participants will become acquainted with each other, form into permanent work groups and identify individual and workgroup expectations for the Workshop.

The basic workshop philosophy of a relaxed and open atmosphere will be established. The participants will feel that they are expected to participate and share their experiences and problems with the total group.

b. Methodology

There are many accepted techniques to accomplish the above. The following is suggested:

1. Participants are asked to pair off with another whom they do not know. (If the participants are both PCV's and HCN's, it is suggested that the initial pairings be crosscultural).

2. Each pair is asked to take 10 to 15 minutes getting acquainted.

3. Reform into groups of 3 pairs. (These will be the permanent work groups for the workshop. The remainder of the get acquainted exercise will take place within these work groups.)

4. Each participant introduces his/her partner to the rest of the group.

5. Write following items on chalk board:
   - My favorite color - Why?
   - The best thing that has happened to me this past year.

6. Each group selects one of the above categories and each participant shares his/her feelings on this topic with the rest of the group.

7. Break of 20-30 minutes.

8. Each group is to select a name for their group. With newsprint and marking pens provided, they are to design a group logo. In turn each group posts their logo on wall and explain its significance to the total class.

9. Each participant is asked to write down two or three things he/she specifically hopes to learn from the workshop (an individual exercise).

10. From these individual objectives, the group then develops a list of four or five objectives for the workshop and writes them on newsprint. Each group then in turn posts this list next to their logo and explains to the total class.

INSTRUCTOR NOTES:
The above or similar group building procedure is important for the future success of the workshop. Timing is important in this exercise as enough time needs to be allowed for ideas and discussion to generate without too much dead time. The instructor plays a very low key role in this process yet must keep the process moving.

The instructors should explain the format to be followed during the workshop and a tentative agenda should be developed and presented to the participants. Emphasis needs to be stressed on the expectation that the participants will learn by doing and are encouraged to ask questions and offer to share with the class any skills or abilities they have to contribute.

DAY 1 - P.M.

SESSION III--Soil Classification 4 Hours

a. Objectives

The participants will understand the relationship between soil class and irrigation practices and problems.

b. Methodology

Unit #1 in Part B of the Manual together with the training guides referred to in the unit form the basis for this session. The following is a suggested class procedure.

1. Class session of approximately one hour to explain the relationship between soil particle size and other soil characteristics such as water holding capacity, infiltration rate, percolation rates, soil texture, wilting point, etc. The use of the soil classification triangle needs to be explained.

2. The procedure to be followed during the field trip should be carefully explained.

3. Field trip to study infiltration, soil texture, percolation, soil profile, etc.

4. Classwork following the field trip should be used for graphing infiltration rates, illustrating soil profiles and their effect on percolation.

INSTRUCTOR NOTES:
The instructor will need to have previously identified the locations in the field where the various exercises can be carried out. The time involved in the field exercise will vary greatly depending on the situation. It may be necessary to only demonstrate the test for infiltration and leave the experiment to a future field trip when there is a full half day available in the field. The instructor may want to encourage attendance at an evening session to more thoroughly explain the above concepts. When participants first gather in the classroom the following day, it may be a good time to examine the jars of soil and note the soil classification.

DAY 2 - A.M.

SESSION IV--Irrigation Safety and Health Practices 1 Hour

a. Objectives

The participants should become aware of the health hazards peculiar to irrigation situations and be able to take appropriate precautions.

b. Methodology

Unit 2 in Part B of the Manual forms the basis for this session.

INSTRUCTOR NOTES:
The instructor needs to learn from local Peace Corps sources the health hazards that are peculiar to the specific situation.

SESSION V--Topographic Surveying and Land Mapping 3 Hours

a. Objectives

The participants will be able to construct and use simple surveying instruments and take accurate survey notes.

b. Methodology

Unit 3 in Part B of the Manual and its referenced training guides form the basis for this session. Suggested class procedure.

1. Explain the construction of simple level instruments, e.g., "A" frame, chorobates, carpenter level, plastic hose leveling, etc.

   INSTRUCTOR NOTES:
   Previous investigation by the instructor should uncover the locally accepted "leveling instrument." If none appears to exist, the chorobate as described in Unit 3 may be constructed. The important thing is that the participant understand the concept that a level line of sight must be able to be established by some means.

2. Work groups each construct their level instrument, stadia rod and marking stakes with material provided.

3. On chalk board work through the procedure for keeping level notes for line of sight instrument and plastic hose method.

DAY 2 - P.M.

SESSION VI--Topographic Surveying and Land Mapping 4 Hours

a. Objectives

Participants will be able to accurately run a differential topographical survey.

b. Methodology

1. Review keeping level notes and make field work assignments.

2. Trip to field where each group runs and stakes a differential survey on the assigned section of the project field site.

INSTRUCTOR NOTES:
Prior to the field trip, the instructors should have carefully selected and gotten permission to do field work on the site. Ideally, the site should be near a water source and be topographically complex enough to lend itself to a variety of solutions to an irrigation problem. Ideally, each group should have experience using at least two methods of making a differential survey.

DAY 3 - A.M.

SESSION VII--Making Topographic Map 4 Hours

a. Objective

Using the field notes obtained from the differential survey, the participants will be able to construct a topographic map of the field site.

b. Methodology

1. In a classroom session, each group will develop a rough contour map of the site using the field data collected during the field trip.

2. Have each group draw their map on the chalk board and explain to the group.

3. If time is available, return to the field site and have each group run contour lines in the field to check the accuracy of their rough topographic map.

DAY 3 - P.M.

SESSION VIII--Making a Topographic Map 1 Hour

a. Objective

Each work group will produce an accurate topographic map of the field site.

b. Methodology

Class work by groups under instructor supervision.

SESSION IX--Calculation of Irrigation Ditch Size 3 Hours

a. Objective

The participants will be able to calculate irrigation ditch size to carry a given quantity of water.

b. Methodology

Unit 3 in Part B of the manual and the referenced training guides form the basis for this session. Working as individuals within the group and with instructor assistance, each participant will have the opportunity to use Manning's formula to calculate ditch size for different quantities of water.

DAY 4 - A.M.

SESSION X--Designing an Irrigation Ditch 2 Hours

a. Objective

The participants will be able to design irrigation ditches appropriate for a variety of slopes, soil types and water quantities.

b. Methodology

1. Review Manning's formula.

2. Using graph paper each work group will design a ditch cross section for a given set of conditions.

SESSION XI--Water Source Measurement and Development 2 Hours

a. Objective

Participant will be able to measure water volume from different sources.

b. Methodology

Unit 4 in Part B of the manual and its referenced training guides form the basis for this session. For this first session on water source measurement, the concentration will be on the measurement of flowing water in streams, from pump discharge and in ditches using weirs.

INSTRUCTOR NOTE:
For later use, it is suggested that each work group calculate the size of and cut a V notch weir for a relatively small volume of water. These can then be used in Session XIV.

DAY 4 - P.M.

SESSION XII--Water Source Measurement 4 Hours

a. Objective

The participants will have the opportunity to measure water flow in a river and from a pump discharge.

b. Methodology

1. Review the procedure for measuring stream flow and make work assignments.

2. Trip to field work site.

3. Have the groups work in teams of 2 work groups and measure stream flow and pump discharge.

INSTRUCTOR NOTE:
Extreme care must be taken to determine that the stream selected for this exercise is safe to work in. While one group is measuring stream flow, another group can measure pump discharge. If both situations are not available at the same location, it will necessitate moving to the second location after the first source is measured. If the site for this field trip is the same as that chosen for the irrigation project, the time available may provide the opportunity to have a few participants conduct a more extensive infiltration test. (See Session III)

DAY 5 - A.M.

SESSION XIII--Social Factors Affecting Change & Community Action 3 Hrs

a. Objective

The participants will be able to identify community and social factors which influence individual and/or community adoption of new practices such as irrigation.

b. Methodology

Unit 5 in Part B of the manual and its referenced training guides form the basis for this session. The following sequence of topics is suggested:

1. Human response to change--why changes are accepted or resisted
2. Customs and culture
3. Social organization
4. The innovator or change agent
5. Needs
6. Planning for change
7. The Social Action Process.

INSTRUCTOR NOTE:
For this session to be a discussion session rather than a straight lecture, it is suggested that the participants read the referenced training guides prior to the session. Since there is considerable information, this assignment needs to be made two or three days in advance of this session.

SESSION XIV--Measuring Water Flow & Seepage Loss in an Irrigation Channel — 1 Hour

a. Objective

The participants will have experience calculating water flow in an irrigation channel and determining seepage loss.

b. Methodology

The following sequence of activities is suggested:

1. Adjacent to the classroom, dig a small ditch on a fairly steep (3% to 6%) slope.

2. Have each group install their V notch weirs (constructed during Session XI) in sequence down the ditch.

3. Run a known quantity of water into the ditch (measured from a hose or other steady source).

4. Each group to measure the water flow over their weir which will allow calculation of seepage loss.

INSTRUCTOR NOTE:
This exercise also very effectively demonstrates the principal of controlling water flow down a steep slope by using the small weirs as drop structures.

DAY 5 - P.M.

SESSION XV--Measuring Water Flow in an Irrigation Channel — 3 Hours

a. Objective

Participants will be able to construct a weir to measure water flow in an irrigation channel.

b. Methodology

1. Class session on constructing a weir.

2. Field trip to a preselected site to emplace the weir and measure irrigation water flow.

SESSION XVI--Review of the Week Activity 1 Hour

a. Objective

Participants will have the opportunity to clear up points of misunderstanding and, to a degree, integrate the disparate items of information.

b. Methodology

The instructors should briefly review the concepts covered during the week. This should be followed by a question and answer session.

DAY 6 - A.M.

SESSION XVII--Review & Preview 1 Hour

a. Objective

To review briefly the Lessons of the first week, answer questions, review group objectives and outline the plans for the 2nd week of the workshop.

b. Methodology

The instructors should involve the participants in a discussion of the first week's program. It is important to review the objectives as developed the first day of the workshop so the participants understand that their needs are being considered. This gives the instructors the opportunity to refocus their objectives or review past lessons as seems appropriate.

SESSION XVIII--Development of Water Sources for Irrigation Purposes 3 Hours

a. Objectives

Participants will be able to select and/or design appropriate equipment or structures to utilize the potential of available water sources.

b. Methodology

Unit 4 and its referenced Training Guides form the basis for this session. The local situation will dictate what can be done in the field, however, this session should leave the participants with an understanding of different methods to utilize water from a variety of sources.

INSTRUCTOR NOTE:
If there are any unique systems available nearby, a field trip would be appropriate. Since the participants will have come from a variety of localities, they should be able to contribute much from their past observations. These contributions should lead to the discussion and explanations of different systems.

DAY 6 - P.M.

SESSION XIX--Climatic Effect on Water Availability and Crop Use — 4 Hours

a. Objectives:

From climatological data available, the participants will be able to determine consumptive use of different crops grown in the locality. Using this data, the participants will then be able to determine irrigation water requirements for various crops.

b. Methodology:

Unit 6 of Part B of the manual and its referenced Training Guides form the basis for this session.

1. A review of soil class and its relation to water holding capacity (see Session III) may be appropriate at this time.

2. Working through problems in class the participants should learn to calculate consumptive water use of crops and irrigation water requirements.

INSTRUCTOR NOTE:
By prior arrangements, the instructor should be able to obtain from governmental sources climatological data appropriate for class use. If this is not available, the instructor will need to use the U.S. data provided in the Manual.

DAY 7 - A.M.

SESSION XX--Resources Necessary for Irrigation — 1 Hour

a. Objective

The participant will be able to identify those resources that must be available in a local community if irrigation is going to be a feasible alternative for producers.

b. Methodology

Unit 7 of Part B of the Manual forms the basis for this session. Problem solving by work groups should generate a number of ideas on this topic. Idea sharing by groups and general discussion should provide a good list of both "necessary" and "desirable" resources.

INSTRUCTOR NOTE:
If time is available and the situation appropriate, a field trip to a local community may be beneficial. The participants could, by work groups, go into the community and determine which of the resources identified were in fact available and at what price. If this is done, the time identified for this session would not be adequate.

SESSION XXI--Planning and Designing an Irrigation System 3 Hours

a. Objective

The participants will be able to plan appropriate irrigation systems for given conditions and crops and design the needed water control structures.

b. Methodology

Unit 8 in Part B of the Manual and its referenced Training Guides form the basis for this session.

1. Lecture and discussion can be used to help the participants learn the different kinds of irrigation systems appropriate for a variety of conditions and crops.

2. Design and construction of a variety of water control structures should be illustrated and discussed.

3. A field trip to observe furrow, border, drip, sprinkler, flood, etc. systems would be good if feasible.

INSTRUCTOR NOTE:
This session is a key one because in this the participants are starting to integrate the information from earlier sessions. The field trip suggested in Item 3 above should only be taken if there is more than one system nearby which can be observed. The field trip, if taken, will use more time than what has been suggested in the outline.

DAY 7 - P.M.

SESSION XXII--Planning and Designing the Class Irrigation Project 4 Hrs.

a. Objective

Each work group will design an appropriate irrigation system for the field project site.

b. Methodology

Given the information learned up to this time, each work group will design an irrigation system which they consider appropriate for the project field site.

1. Review briefly the information they have which they will need to consider, i.e.
   - Topography
   - Water source and volume
   - Soil class
   - Ditch size and construction
   - Crop consumptive use
   - Irrigation systems
   - Water control structures.

2. A review work session on using surveying equipment.

3. A field trip to the project work site for each group to review their information and gather any additional information they may need to design their irrigation system may be needed.

4. If time remains, participants can work on their project in the classroom.

DAY 8 -- A.M.

SESSION XXIII--Designing the Class Irrigation System 4 Hours

a. Objective

The class will develop the class irrigation system for the work site.

b. Methodology

1. Each work group will design an irrigation system for the work site which they feel appropriate.

2. Each work group will present their system to the class.

3. From all presentations, the class will select and develop more completely a "class solution."

INSTRUCTOR NOTE:
Allow the participants time to negotiate and come up with what they consider the best irrigation system for the project site. They should consider crops, soil class, water source and quantity and other relevant factors. At this time, however, cost factors should not be considered. It is important that all aspects of the system be designed such as ditch size for water volume needed, etc.

DAY 8 - P.M.

SESSION XXIV--Layout of the Class Irrigation System 4 Hours

a. Objective

The class will layout their irrigation system at the project site.

b. Methodology

1. Review the project.
2. Assign work groups to specific aspects of project.
3. Review any necessary skills.
4. Field trip to site.
5. System layout.

INSTRUCTOR NOTE:
Insofar as practical, as much of the system should be laid out including primary and secondary ditches, contours, etc. As the work is done, the participants will learn how accurately their topographic map was drawn. If the preliminary work was wrong, the participants may have to adjust their plan to meet actual conditions.

DAY 9 - A.M.

SESSION XXV--Review of Class Project 1 Hour

a. Objective

Clear up questions or problems arising out of field exercise.

b. Methodology

Class discussion on questions or observations raised by participants and/or instructor resulting from the previous day's session.

SESSION XXVI--Agronomic Practices under Irrigation Agriculture 3 Hours

a. Objective

Participants will be able to identify and describe those agronomic practices that are different with irrigation than with dry land farming.

b. Methodology

Unit 9 in Part B of the Manual and its referenced Training Guides serve as the basis for this session.

DAY 9 - P.M.

SESSION XXVII--The Economics of Irrigation 3 Hours

a. Objective

The participants will identify the factors that affect the economics of an irrigation system and be able to calculate the economic feasibility of a planned system.

b. Methodology

Unit 10 in Part B of the Manual will serve as the basis for this session.

1. Problems should be worked through on the board illustrating the concepts and methods.

2. Each work group should work through a class situation to determine the economic feasibility.

3. Each work group should determine the economic feasibility of the class irrigation project and defend their solution before the rest of the class.

INSTRUCTOR NOTE:
This session is critical for the participants so it is important to make the exercise as realistic as possible. The instructor should obtain local prices for the economic variables prior to the session in order that the exercise will be meaningful to the participants.

SESSION XXVIII--Review of Work Group Objectives 1 Hour

a. Objective

The participants and instructor will take this opportunity to review the objects which each work group established and answer specific questions in areas that have not been previously covered.

b. Methodology

Question and answer session.

INSTRUCTOR NOTE:
This provides the opportunity for each participant to find answers to specific questions on irrigation that may not have been included in the workshop material covered to this point.

DAY 10 - A.M.

SESSION XXIX--Irrigation Laws and Regulations 1 Hour

a. Objective

The participants will identify the laws and regulations--local, regional and national--which may affect any decisions on developing an irrigation system.

b. Methodology

Unit 11 in Part B of the Manual and its referenced Training Guide will serve as the basis for this session. The lecture-discussion format will probably be the most effective in this situation.

INSTRUCTOR NOTES:
The instructor will need to do the necessary background work for this session to discover the kinds of laws applicable and where they can be located. The crucial point is that the participants understand that there may be legal or social constraints on any decision to establish an irrigation system and that they have some idea where to get this information.

SESSION XXX--Surface and Subsurface Drainage 1 Hour

a. Objective

The participants will be able to identify surface or subsurface constraints on irrigation and to suggest remedies for the problem.

b. Methodology

Unit 12 of Part B of the Manual and its referenced Training Guides from the basis for this session.

1. Reference must be made to past sessions on soil class and topography.

2. By lecture and discussion, the participants will be helped to understand the various problems and related solutions to drainage problems with irrigation.

INSTRUCTOR NOTES:
This information is treated separately in this session in order to specifically identify it as a distinct subject for study. However, it could logically be included in other parts of the workshop. The field work in Session III should provide the opportunity to discuss percolation rates and subsurface drainage. Sessions VII and VIII will provide the opportunity to discuss surface drainage problems. This session will provide the opportunity to bring these concepts together.

SESSION XXXI--Workshop Review 2 Hours

a. Objective

The participants will have the opportunity to review any items that remain a major question.

b. Methodology

Question and answer session.

DAY 10 - P.M.

SESSION XXXII--Workshop Evaluation 1 Hour

a. Objective

Provide feedback to the instructors and PCV Program Coordinator on the workshop.

b. Methodology

A formal evaluation instrument will be prepared and administered.

SESSION XXXIII--Closing Ceremony 1 Hour

INSTRUCTOR NOTES:
A closing ceremony is at the discretion of the Peace Corps Program Coordinator. However, some type of a final session is suggested in order to obtain closure rather than just stopping after the last class or even after the evaluation session.

PART B

INSTRUCTIONAL UNITS

Unit #1

General Objective: Soil classification

Behavioral Objectives:

1. Classify soils by texture - percent of sand, silt and clay.

2. Estimate available soil moisture for plant use - per foot of soil for sand, silt and clay soils.

3. Determine infiltration rates for the three major soil types.

Materials:

1. Training Guides Number 1 and 3
2. Glass jars
3. Pocket measuring tape/yard stick
4. Cans with top and bottom removed
5. Watch with second hand
6. Shovel
7. Soil auger

Procedure:

Exercise 1-1

Complete Exercise 1. In addition, conduct "feel test" of material to correlate findings (refer Training Guide Number 1, page 27, Table 3).

Exercise 1-2

Complete Exercise 1-2 on a number of soil types and conditions on each soil sample type (sand, silt and clay). In addition, correlate results by comparing with Table 9, Page 36 of Training Guide Number 1.

Exercise 1-3

Dig a trench about 1 meter deep or use a soil auger if available. Take soil samples and classify the soil type as a function of depth.

Results:

1. What soil type(s) are present in this area?

2. Are there soil zones, vertically, which will affect water holding capacity and penetration?

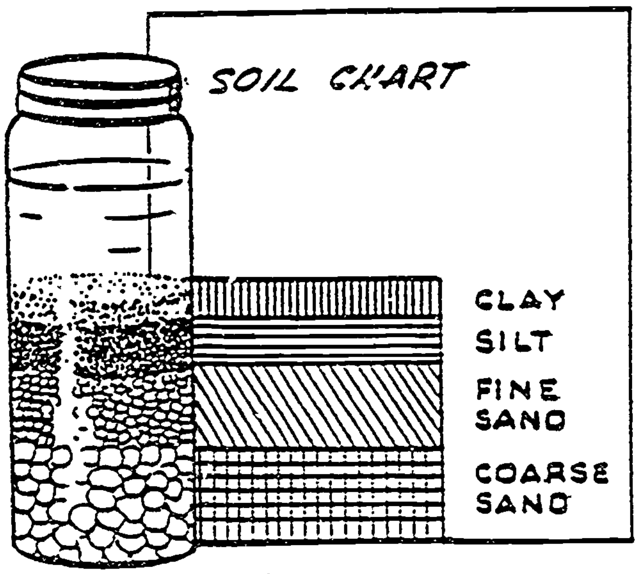
3. About how fast will the soils in this area take water?

4. If the soil(s) is filled to field capacity, about how much moisture will be available for crop growth?

Exercise 1-1. Soil Classification

Fill a fruit jar about two-thirds full of water. Pour in soil until the jar is almost full. Replace the cover or put one hand tightly over the top of the jar and shake it vigorously. Then put the jar on the table and let the soil settle. Allow plenty of time because the very small particles will be slow in settling.

Then hold a card or heavy piece of paper against the side of the jar and draw a diagram showing the different layers. Label each layer (clay, silt, sand).



Do this with several soils taken from different places and compare the diagrams or compare the jars directly.

Interpretation

Soil particles vary greatly in size. The largest particles settle to the bottom first. The fine particles settle slowly; some, in fact, are suspended indefinitely.

Soil scientists classify soil particles into sand, silt, and clay. Starting with the finest, clay particles are smaller than 0.002 millimeters in diameter. Some are so small that ordinary microscopes do not show them. Silt particles are from 0.002 to 0.05 millimeters in diameters. Sand ranges from 0.05 to 2.0 millimeters. Particles larger than 2.0 millimeters are called gravel or stones.

Most soils, as found in nature, contain a mixture of sand, silt, and clay in different proportions.

Size of soil particles is important. The amount of open space between the particles has a lot to do with how easily water moves through a soil and how much water it will hold.

Too much clay, in proportion to silt and sand, causes a soil to take in water very slowly. Such a soil also gives up its water to plants slowly. These soils are sticky when wet.

Loam and silt loam refer to soils that have a favorable proportion of sand, silt, and clay. A silt loam, for example, contains no more than 50 percent sand nor more than 27 percent clay. The rest, naturally, is silt.

Size of soil particles is important for other reasons, too. It affects the ease of working the soil, what crops can be grown, and the efficiency of certain fertilizers.

Sandy soils that have no fine clay or silt particles filling the pore space cannot hold as much moisture since there is less surface area for the water to cling to and the pores are so large that the weight of the water causes much of it to run down and out of the soil. For this reason, medium and coarse sandy soils low in clay, are known as drought soils--crops cannot live long in them without very frequent rains.

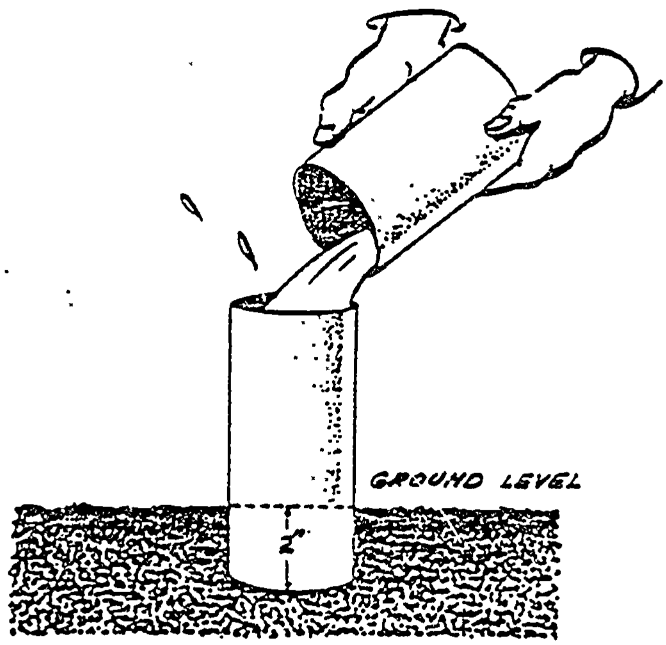
When fine soil particles fill the large pore spaces, the soil can hold more water for plants because there is more surface area for water to cling to. And since the size of the pores is reduced, the weight of the water is less and it doesn't run out of the soil so readily.

Exercise 1-2. Water intake into soil

You will need 6 large fruit or vegetable-juice tin cans; board 4 inches wide, 1 inch thick, and 12 inches long; hammer; 12-inch ruler; pocket watch with a second hand; pencils and paper; quart measure; and 2 gallons of water. It may take 2 to 3 hours to complete this activity.

Cut the bottom out of one end of the can just below the rim. This leaves a sharp edge that will drive into the ground easily. Cut out the other end, leaving the rim on for added strength.

Select soils of different types and different cover or compaction. Select 4 to 6 locations.



Mark the outside of each can 2 inches from the end without the rim. In each of the spots you have selected, set a can so that the end closest to the 2-inch mark, is on the ground. Place a board on each can and tap with the hammer until the 2-inch mark is level with the ground. Do not disturb the plant material or soil in the can. Avoid spots where sticks or stones make it hard to drive the can down. Add 1 quart of water, and then complete the following record for each locations:

1. Place. (Identify as ungrazed or unburned woodland, grazed woodland, fence row, heavily grazed pasture, eroded cultivated field.)
2. Condition of the soil.
3. Presence of leaves or sticks.
4. Time when quart of water was added.

5. Measure amount of water that has moved downward at the end of each minute for the first 10 minutes. thereafter, note the drop every 10 minutes or every hour, depending on the rate of water movement. (Measure from the top of the can to the water level.)

Compare the rates of water intake. Do the study all in 1 day so that, at the beginning of the activity, the soils will have, as nearly as possible, the same amount of moisture.

Unit #2

General Objective: Irrigation safety and health practices

Behavioral Objective:

1. Investigate and identify health hazards that might be exacerbated by an irrigation project.

2. Identify safety problems that might be incurred in developing an irrigation project.

Materials:

Procedure:

Exercise 2-1

Identify health hazards that might affect the project, e.g. filariasis, malaria, schistosomiasis, etc. Some problems such as schistosomiasis are not easily corrected and should be avoided.

Exercise 2-2

Identify safety hazards that might affect project e.g. construction accidents, dangers in clearing trees, etc.

SAFETY TIPS FOR SMALL IRRIGATION PROJECTS

Developing small-simple community irrigation projects in lesser developed countries is challenging and rewarding, however the small nature of the projects usually precludes elaborate safety measures. This does not mean that the technical advisors should not be prudent in observing safety measures that, for the most part, are good common sense.

Excavations

When digging village wells or embankment cuts, always "shore" up the walls with timber, especially in sandy soils. Never work on unshored cuts that are above chest height. A cubic meter of soil weights approximately one ton and has great crushing force.

Sanitation/Project Campsite Health

In many cases, small projects will be remote and time consuming to commute to, hence a small project campsite is usually established.

A few simple amenities and/or precautions should be used.

a. Never establish camp along a stream--locate in a well-drained bank above flood level.

b. Excavate a simple latrine 75 feet from quarters.

c. Provide for boiling drinking water.

d. Elevate sleeping quarters above ground to lessen snake hazard.

e. If possible obtain old oil drums to collect rainfall for bathing--thus avoiding use of streams and allowing for disinfecting of water.

f. Have a complete first aid kit available and a first aid manual.

g. Have a snake bit kit available and/or anti venom if supplies can be properly preserved and a knowledgeable person is available for its usage.

h. Store an emergency food supply such as Army or Forest Service rations.

i. Have mosquito nets.

Snake and Insect Protections

Most snakes, lizards, scorpions and other reptiles/insects with venomous bites or stings tend to avoid man, however, when caught unaware will attack. The following suggestions will be helpful in preventing snake bite or poisonous insect stings:

a. Wear boots and loose fitting clothes.

b. Avoid tall grass or dense brush.

c. Do not put hands under rocks or in holes without a careful check.

d. Some snakes, such as the bamboo viper, are colored to match the environment they live in. Know the reptiles/insects in your work area.

e. Use caution and some noise to make snakes aware of your presence and allow them time to move away.

f. When leaches attach to your skin, do not pull off. Use a lighted cigarette or match on their rear portion and they will drop off. If available, a bag of wet tobacco can be used to knock them off.

g. Use insect repellents if available.

Brush Clearing

a. Avoid personally using machetes for brush clearing. The local villagers are very skilled in using local tools and improper usage can be dangerous.

b. Be cautious if burning is used in brush clearing operations--stay upwind.

Miscellaneous Suggestions

a. Be careful when working in or around swift streams or streams with debris or tree snags.

b. Do not work in streams during flood season.

c. Avoid overexertion or excessive exposure to heat or sun.

d. Avoid walking around during the night and have good flashlights.

e. Avoid village work animals and dogs until they become familiar with your presence. Your scent is different from the local people and, for example, work carabao (water buffalo) are very docile with villagers, but resent strangers with a different scent.

f. Keep the local villagers informed of your activities--as you gain their confidence they can be helpful in providing useful suggestions. Take advice! Check security!

g. Do not enter isolated areas unless there are at least two companions with you.

h. Always have adequate fuel in a vehicle.

i. When traveling in a boat, wear a life jacket.

j. Observe land marks and/or mark trail to avoid getting lost in jungle or swamps.

k. Observe good housekeeping in camp. Garbage attracts rats, which in turn brings on snakes. Store tools, equipment and materials properly. Keep work areas clean and neat.

l. Keep the cooking area clean and sanitary and observe good food handling practices.

m. Store flammable materials away from open fires--provide for extinguishers if possible.

n. Wear gloves when using hand tools and hard hats around construction.

GENERAL HEALTH CONSIDERATIONS

Many health problems can arise as a result of contacts (including drinking) with water. These contacts are intensified when persons work with irrigation systems. The Peace Corps, the World Health Organization and other groups provide publications regarding the prevalence, symptoms and treatment of the most common diseases.

The PCV will have been provided with immunizations and medicines which are effective and farmers should be advised of health problems and precautionary measures. In training programs, attempt to solicit the assistance of physicians who are familiar with local problems.

One specific disease Schistosomiasis is a particular and severe hazard when working in irrigation water. Symptoms are discussed in the references; blindness frequently occurs after extensive exposure.

If possible, avoid irrigation projects in areas or watersheds where Schistosomiasis exists; however, in Egypt, the problem is endemic and cannot be avoided. Physical protection using boots is recommended. Heavy canvas "stockings" impregnated with oil may be effective if rubberized boots are unavailable.

For further details, refer to the current Peace Corps Health Manuals.

Unit #3

General Objective: Topographic surveying and land mapping

Behavioral Objectives:

1. Construct and use simple survey equipment
2. Survey proposed project area and draw a three-dimensional map or sketch.
3. Survey a diversion ditch from water source to area to be irrigated
4. Calculate erosive water flows in a conveyance ditch.
5. Calculate seepage loss of the proposed diversion ditch.

Materials:

1. Training Guides Number 1, 2 and 3
2. Carpenter tools: hammers, wood chisels, saws, screwdriver
3. Pocket measuring tape/meter stick - English or metric
4. Plastic tubing 5 or 6mm, 30m long
5. Two 1/2 inch screw eyes
6. Graph paper 10x10/inch
7. Lath/stakes, 1/3 to 1 meter lengths, modified grid will require approximately 20 stakes per hectare
8. Boards 1 cm x 5 cm x 2m
9. Boards 2.5 cm x 7.5 cm x 3m (3) (Paint lines at 2 cm intervals)
10. Marker pen or crayon
11. Materials for chorobates: 1 board 5 cm x 10 cm x 6.5m, 3 boards 5 cm x 10 cm x 3m, 1 board 2.5 cm x 10 cm x 3m, 6-penny nails or 5 to 6 cm long wood screws
12. Abney level
13. Bubble level
14. Carpenter level.

Procedures:

Exercise 3-1

Build a chorobate, See Figure 3-1.

Exercise 3-2

This exercise will consist of designing and staking out an irrigation channel to the proper grade and determining the amount of water which the channel will carry.

The calculations will follow the procedures shown in Chapter 14 of Reference 2 plus other materials included here.

Since the actual parameters will depend upon the site where this exercise is carried out, particularly in relation to slope and soil type, a sample problem is worked through here.

For the example problem, assume that the slope of the channel is 0.005 m/m (0.5 cm/m) and the soil type is a clay.

Table 27 shows that side slopes of 2:1 (2 horizontal to 1 vertical), or K=2, should be conservative. Assume a useful depth of 0.3m.

Then referring to Figure 34, we find that the useful area will be:

$$A = K D^2$$

$$= 2 \times .3^2 = 18m^2$$

The hydraulic radius is:

$$R = \frac{KD}{2\sqrt{1+K^2}}$$

$$= \frac{2 \times .3}{2\sqrt{1+2^2}} = \frac{.3}{\sqrt{5}} = \frac{.3}{2.2} = .14$$

(Table 3-1 shows some convenient values of $\sqrt{1+k^2}$). From Table 28 we might select a value of n = .02 for this type of channel.

Velocity is now calculated using Manning's formula from p. 107.

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

or for this example

$$V = \frac{1}{.02} (.14)^{2/3} (.005)^{1/2}$$

From Figure 3-1 (attached), we enter at a hydraulic radius of 0.14 and find $R^{2/3}$ = .26 and from Figure 3-2 (attached), we find for S = .005 that $0.005^{1/2}$ = .07. Hence:

$$V = \frac{1}{.02} \times .26 \times .07 = .9 \text{ M/S}$$

Checking maximum allowable velocities in Table 29, we find that a maximum velocity of 1.2 M/S is allowable on clay soils so our velocity is "safe."

We can calculate the quantity of flow from:

$$Q = AV$$

or

$$Q = .18 \times .9 = .16 \text{ M}^3/\text{S}$$

or in a 24-hour period, the total flow would be:

$$Q(\text{day}) = .16 \times 24 \text{ hrs} \times 3600 \text{ S/hr} = 13800\text{M}^3.$$

This amount may be more or less than is needed to irrigate the area. If it is too much, reduce the depth (or if it is too little, increase the depth) and recalculate the total flow.

Due to ground irregularities, it is almost impossible to expect to run a channel in a straight line between two points at a given slope and cross section. Three alternatives are possible. If the ground is very uneven, it is probably best to run the channel with the contour of the land and let it curve as required to maintain a constant cross section. An alternative is to run it straight, or straighter, and let the cross section vary. The third alternative is to let the cross section and slope vary along the course of the ditch.

The "best" final solution will be the one which requires the least excavation.

For this exercise, the group might divide into three or four subgroups and design alternative channels and calculate the total excavation required.

SURVEYING LEVELS

Chorobates

Most surveyors now use levels or transits which consist of a telescope with a cross hair to determine the elevation of the "target." Since these instruments are costly and rarely available in rural communities of developing countries other alternatives may be useful.

The Roman surveyors used a "chorobates" shown in Figure 3-1.

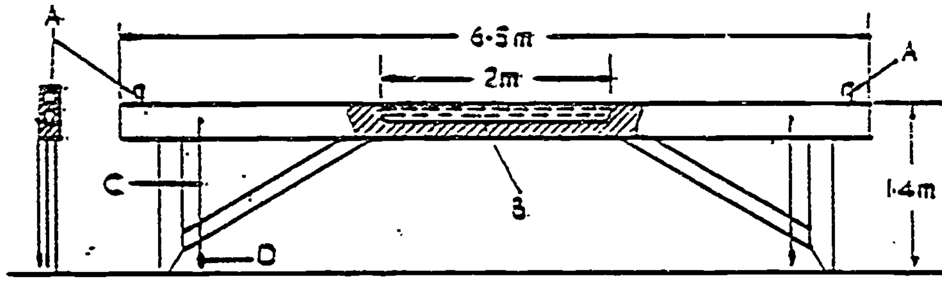


Figure 3-1. Reconstruction of chorobates, levelling instrument (note from Vitruvius' measurements). No examples have survived. A: sights; B: water channel; C: plumb line; D: plummet

This level-transit can be made using locally available materials, wood. It can be used as a line-of-sight instrument, similar to a surveyor's level, or as a level, similar to a carpenter's level.

The illustration should be largely self explanatory and sufficient to build the instrument. The "sights" might be small screw eyes or a piece of sheet metal with a hole bored through for sighting.

The water trough would be about 1½ to 2 cm deep and about the same width. It could be cut with a wood chisel. To avoid water soaking into the wood and causing it to warp the trough should be "waterproofed" with varnish, shellac, oil, wax, pitch on some other suitable material. Also, do not leave water in the trough when the instrument is not in use.

To check to see that the instrument is working properly and built right, drive two stakes into the ground until the chorobates indicate they are "level." Then turn the chorobates end-for-end and the water should still be level. If not, look for warpage, unequal leg length or other factors which might be causing the difficulty.

To use the chorobates as a line-of-sight instrument, drive two stakes into the ground until the instrument is level then sight ahead to the target on the leveling rod. The difference in elevation between the two points will

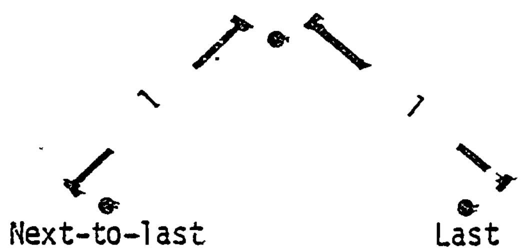
*Copied from The Roman Land Surveyors, O. A. W. Dilke, Barnes & Noble, Inc., New York, 1971.

be the difference in height above the ground of the sights on the chorobates and the target on the rod. Note that it is always more convenient to survey downhill than uphill.

To use the chorobates as a level, raise the leg on the downhill side until the body of the chorobates is level and then measure the distance from the raised leg to the ground. A wedge under the raised leg may make leveling convenient.

If a long course is being run, it is probably best to drive stakes in the ground for each leg to rest on if the chorobates is being used as a level.

At the end of the course, there will normally be a distance between the next-to-last and last stake which will be shorter than the distance between the legs. Set an intermediate stake to the side which is equidistant from the next-to-last and last stake as shown



where "l" is the distance between the legs of the chorobates.

LEVELING RODS

A leveling rod is used to measure the vertical distance from the surface of the ground to the line of sight of a surveying level. It can be constructed about the same as a land measuring rod but the "0" m must be the end of the rod. The overall length could be about 3 m and the rod could be marked in meters, decimeters and centimeters.

Attach a moveable target to the rod. This might be a small board held against the rod with something such as a short piece of rubber (from an old inner tube) to hold it in place after the height is adjusted.

When the surveying instrument is sighted on the rod, the target is moved up or down until it is centered on the line-of-sight. The vertical distance is then read.

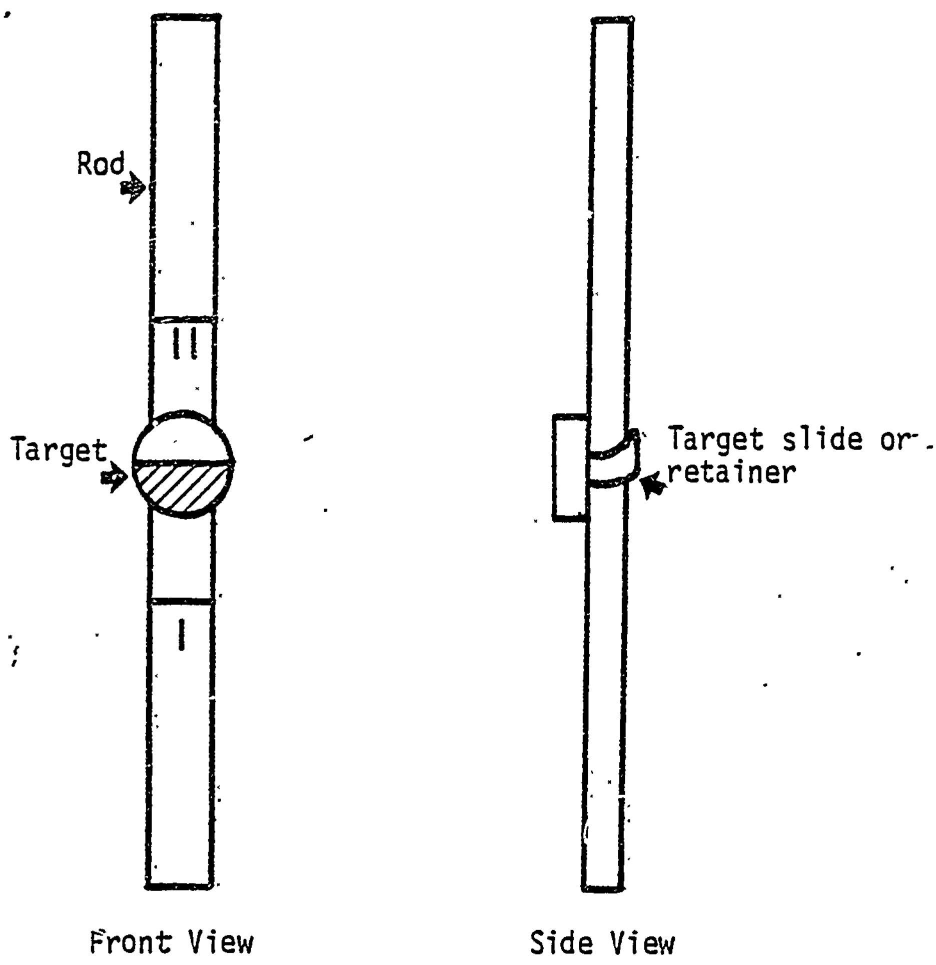
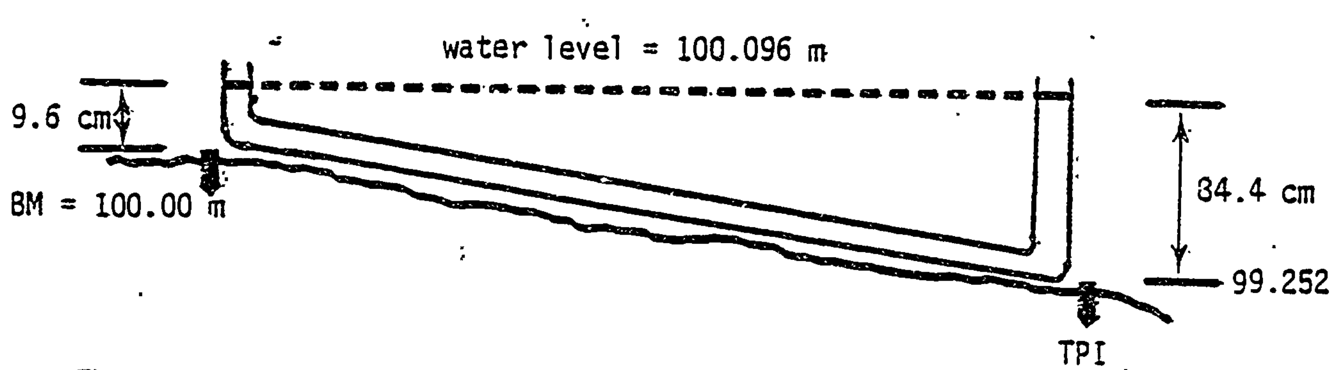


Figure 3-2. A leveling rod with marks at one meter intervals. Distances of less than one meter are measured with a meter stick.

PLASTIC TUBE LEVELING

If plastic tube is available, it will be faster than a chorobates. Tubing of about 6 mm diameter is probably best and it normally is available, in the U.S., in 100 ft. lengths (30.48m). Hence, the difference in elevation between two points about 25 to 30m apart can be measured. If longer courses are to be measured then successive elevations will be determined.

To establish the elevation of one point with respect to another, the tube use and calculations will be as follows when referring to the attached figure. For convenience, two stakes are shown and the actual ground level will be slightly lower.



The level of the top of the upper stake is assumed to be at 100.00m, a benchmark elevation.

The distance from the water level is 9.6 cm or .096m. Hence the elevation of the water level is 100.096 (in actual practice, it is usually unnecessary to measure elevations so accurately and the 9.6 cm would probably be read as 10 cm).

The top of the lower stake is 84.4 cm (.844m) below the water level hence the elevation is 100.096 - .844 = 99.252.

If surveying notes similar to the ones shown in Reference 9 were being made, the notes would be as follows.

STA	BS(t)	HT	FS(-)	Elev.
BM	.096			100.000
INST.		100.096		
TPI			.844	99.252

In standard surveying notes HT (height of instrument) corresponds to the term "water level."

LAND MEASURING RODS

The measurement "rod," is still sometimes used in the measurement of land. One rod is equal to 16½ ft. in the English system.

The land measuring rod (spelled "rood" in German) was brought to England from Germany centuries ago. In Germany, it was 16 (German) feet long but since the German "foot" was slightly longer than the English "foot" it became 16½ (English) feet long.

When measuring a longer distance on land it is inconvenient to use a short measuring tool such as a meter stick or yardstick. Therefore, a longer measuring tool such as a rod or a surveyor's "chain" (4 rods) are more convenient. Most modern surveys are made using surveyor's metallic tapes of at least 100 ft. lengths. However, the rod is simple to construct and use.

The metric equivalent of a rod would be about 5 meters long. To construct a rod, take a board about 2 to 4 cm square and perhaps 5 m 20 cm long. The extra length is provided so meter marks do not have to be made at the end of the rod. If boards of this size are not commonly available, then a good straight bamboo pole might be a good substitute in some countries.

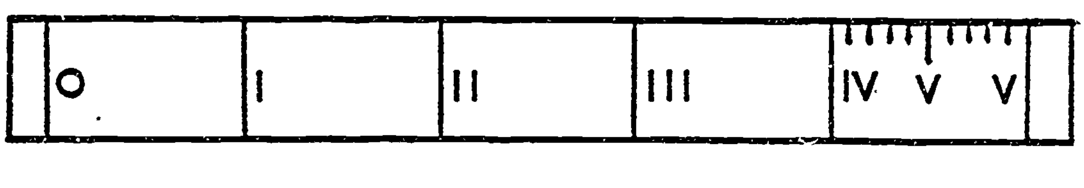
Make marks (cut in with a knife) at one meter intervals along the rod beginning about 10 cm from one end. If you want to label the marks to avoid counting from one end, then Roman numerals I, II, III, IV, V, etc. are easier to carve than Arabic numerals.

To give a finer measurement at the end of the course, the last meter, between IV and V, might be divided into decimeters (10 cm).

It would be customary to make the fifth decimeter mark a little longer than the others but shorter than the meter marks. Again, the decimeters could be counted or labeled. Centimeters could be estimated fairly accurately between the decimeter marks.

To measure a distance, place the rod on the ground successively making marks in the earth at 5 meter intervals or place markers such as a short piece of wire or nail to mark the end of the rod. Two rods could also be used successively.

The finished rod will appear as shown:



(Not to scale)

Table 3-1. Table giving $\sqrt{1+K^2}$ values

K	$\sqrt{1+K^2}$
1/4	1.03
1/2	1.12
1	1.41
1 1/2	1.80
2	2.23
2 1/2	2.69
3	3.16

Figure 3-1. Chart to determine power of hydraulic radius for Manning's Formula

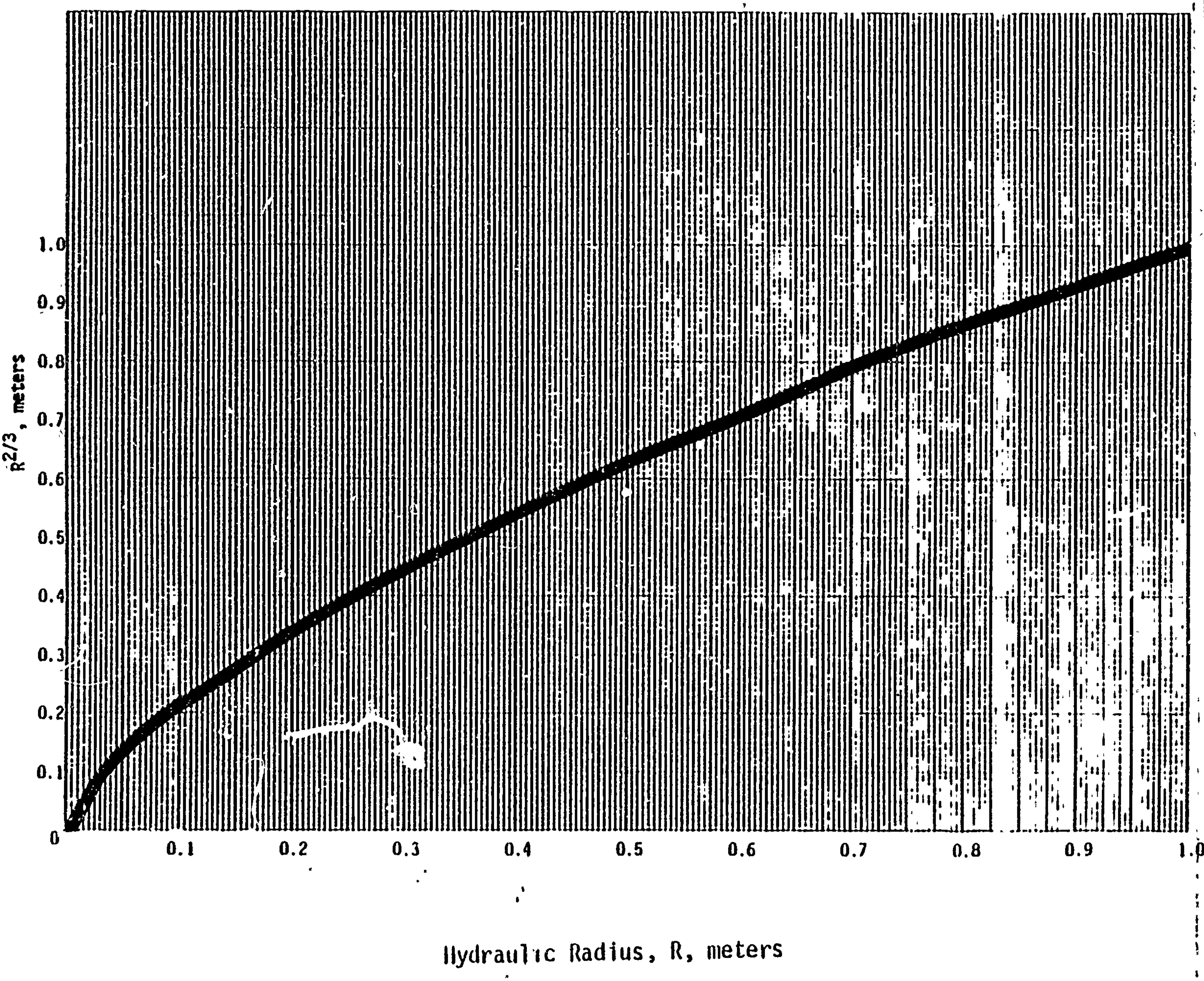
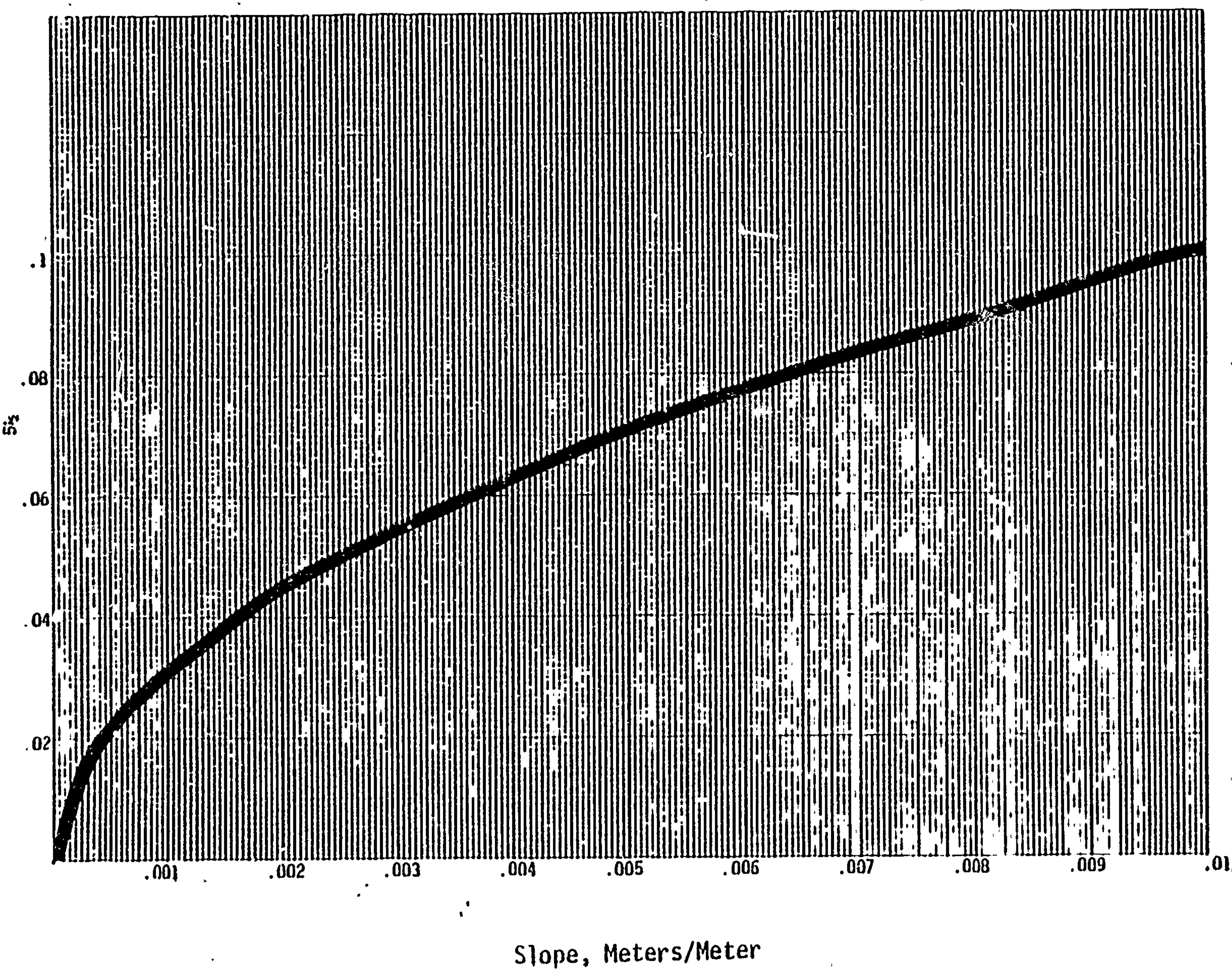


Figure 3-2. Chart to determine square root of slope for Manning's Formula



IMPORTANT NOTE

There are some serious errors in Figure 34 of Reference 2. These should be corrected immediately:

At the end of Column 2, the formula should be:

$$R = \frac{KD}{2\sqrt{1+K^2}}$$

In Column 3, the area should be:

$$A = \frac{\pi D^2}{8}$$

$$= \frac{3.142\ D^2}{8}$$

In Column 3, the wetted perimeter should be:

$$P = \frac{\pi D}{2}$$

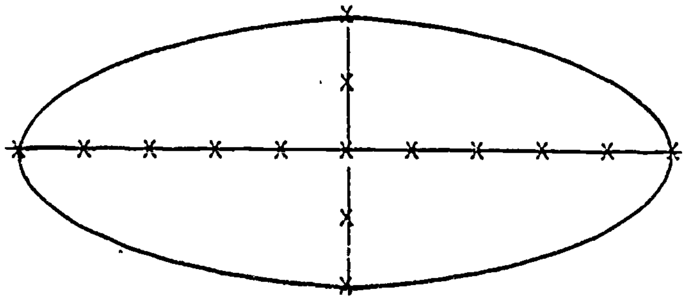
$$= \frac{3.142\ D}{2}$$

and in Column 3, the hydraulic radius should be:

$$R = \frac{D}{4}$$

Exercise 3-3

a. Stake project area using a modified grid system - every 15m. The hand made level instrument does not have any amplification lenses, hence has accuracy for only approximately 50 feet. Given, that most small areas to be irrigated are elongated--we use a grid system. Layout a straight line of stakes every 15m down the longest longitudinal axis of the area to be irrigated and a line of stakes across the center at right angles. Use the center of the cross as a bench mark. Determine the elevation at all other points, then complete the grid if necessary.



b. A topographic map is constructed by determining the elevations at the separate points on the grid. Contour lines at appropriate intervals are then plotted by first interpolating between grid points and then connecting the points of equal elevation with smoothed curved lines.

Figure 3-3 shows a topographic map of an area with the contours drawn in. The elevation of the intersection of the two main coordinates is assumed to be 100m and contours are shown at 1m intervals difference in elevations.

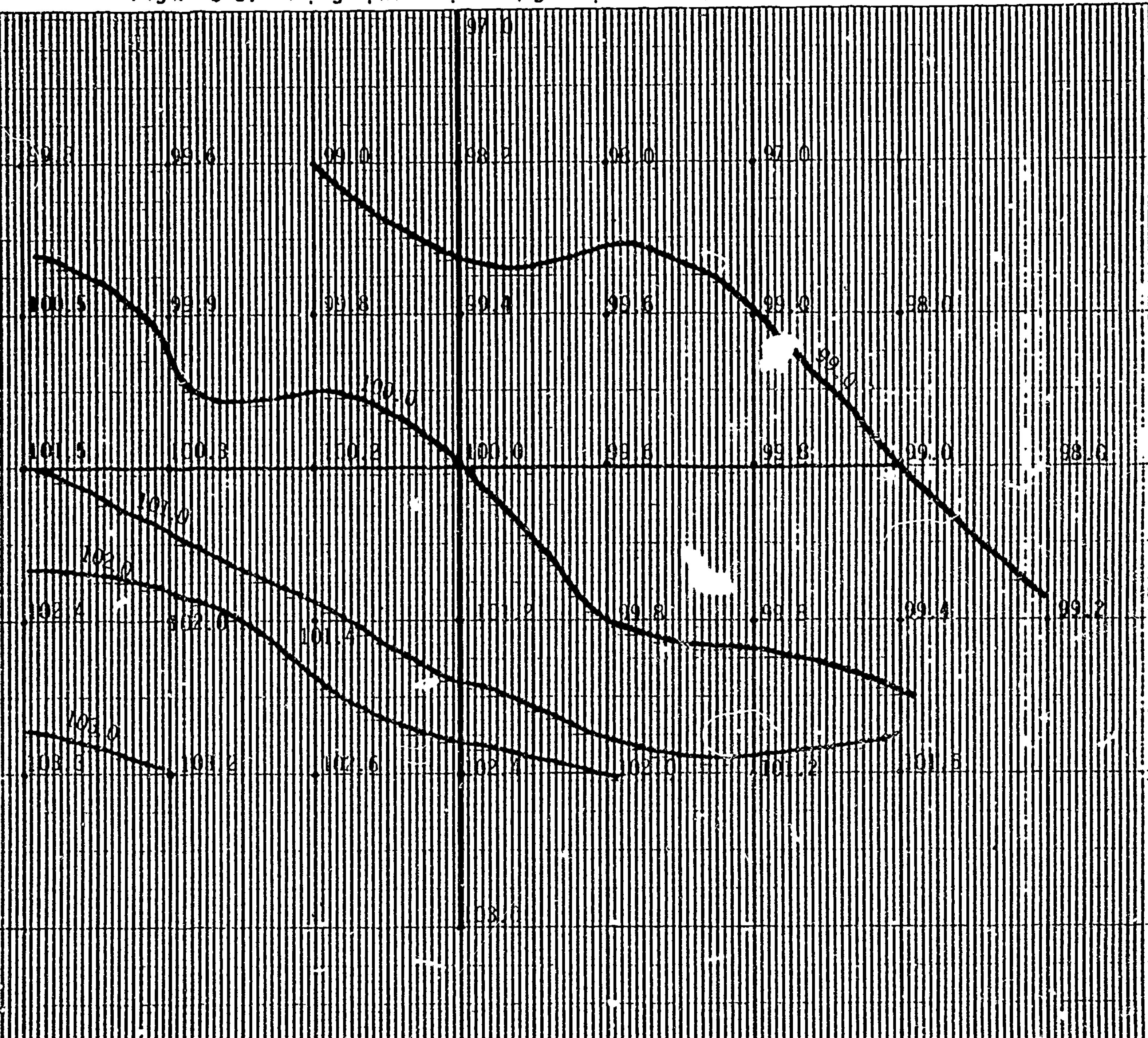
Exercise 3-4

Using the topographic map construct/dig small ditches at various slopes (grades) to observe erosive water flows. (This can only be done if water is available.)

Exercise 3-5

Using soils information on proposed project--calculate seepage loss of a diversion ditch (see Training Guide Number 2). Table 24 page 87 depicts soil infiltration rates, with further discussion on page 111. A more accurate method of establishing seepage losses is measuring water flows at two points with measuring structures and calculating the loss between and correlating with soil type. Session Number 3 will provide training in water measurements.

Figure 3-3. Topographic map with grid point elevations



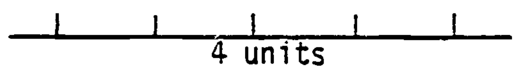
SOME ELEMENTS OF GEOMETRY

Forming Right Angles

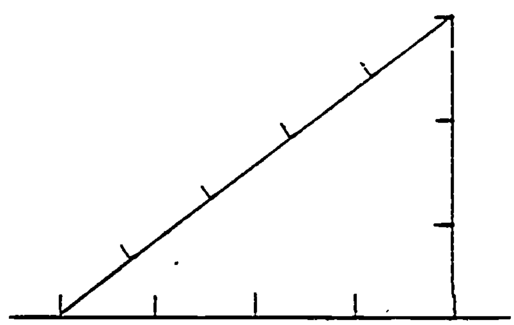
It is frequently necessary to form accurate right angles when surveying land or making instruments. Two practical methods for field use are:

a. The 3-4-5 triangle

A right triangle is formed when the dimensions of the three sides of a triangle are in the ratio of 3:4:5 (ratios of 6:8:10, etc. are also useful). To form the right triangle, form a base of say 4 units of length (Step 1). Then find the intersection of the other two sides, one of three units (at a 90° angle) and one of five units (Step 2).



Step 1



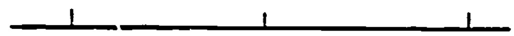
Step 2

The resulting triangle will contain the desired right angle.

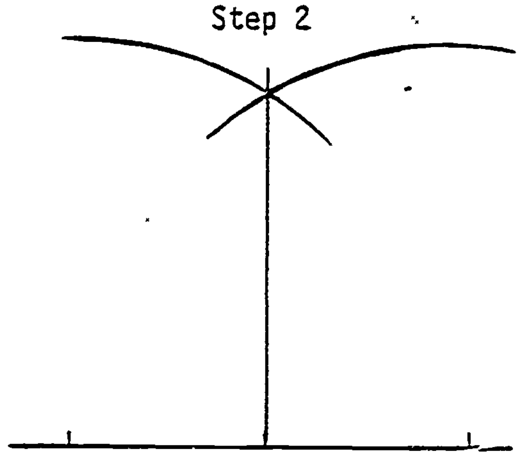
b. Perpendicular to a straight line

Mark off a straight line and locate a point from which a perpendicular will be marked off (Step 1). Mark off equal distances from the selected point (Step 2). For Step 3, draw an arc from each of the two points marked in Step 2, which is a greater distance than one unit of the baseline. In this example, twice the distance of one unit of the baseline is used.

Step 1



Step 2



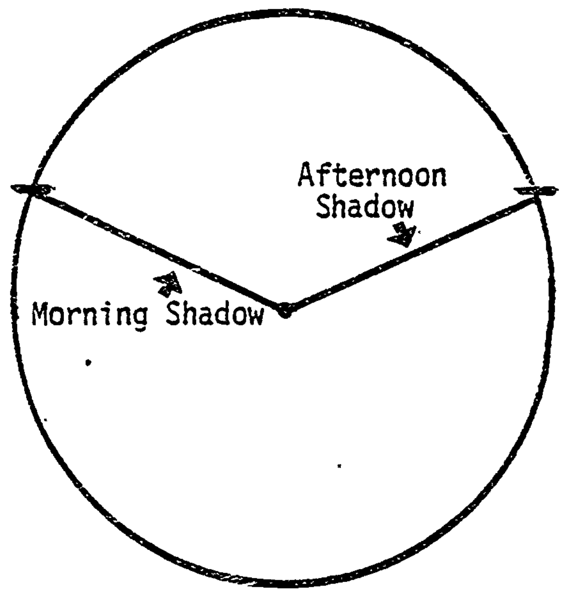
Step 3

The perpendicular drawn through the original center point and the intersection of the two arcs will be perpendicular to the first line.

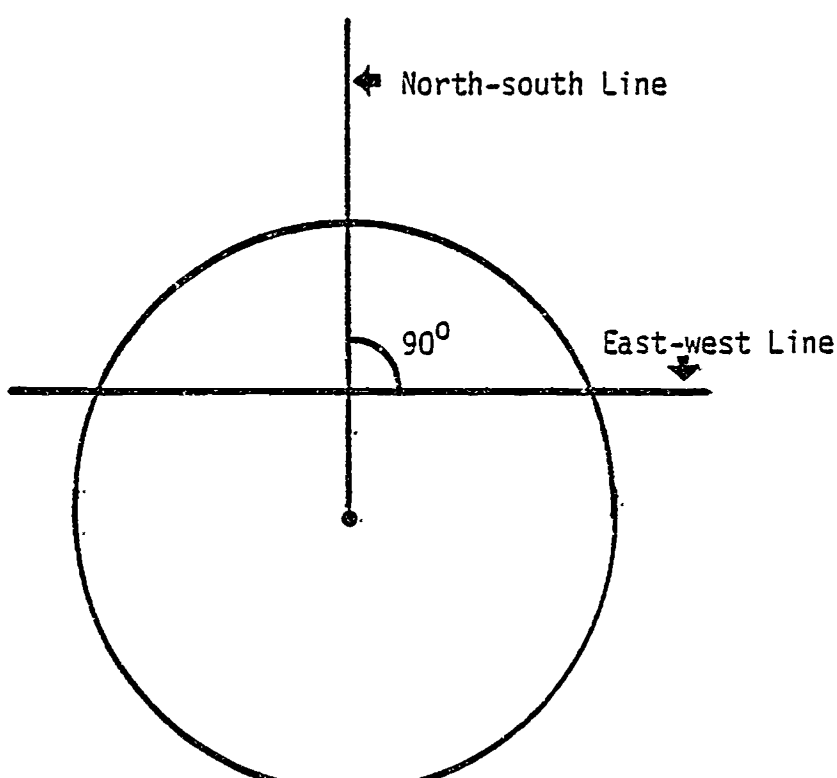
Locating a North-South Line

Draw a circle on a level surface and mark the center accurately. Erect a pole at the center with the top of the pole exactly above the center of the circle. This can easily be done with a plummet. Guy the pole with three guys to hold it accurately in position.

At some time during the morning, the shadow of the top of the pole will just touch the circle, mark this point. At some time in the afternoon, the shadow of the top of the pole will again just touch the circle, mark this point. Now connect the two points to give a line which will be east and west. Draw a perpendicular to the east-west line to obtain a north-south line.


Afternoon Shadow
Morning Shadow

Step 1


North-south Line
90°
East-west Line

Step 2

Unit #4

General Objectives: Water source measurement and development

Behavioral Objectives:

1. Identify possible water sources for irrigation such as streams, wells, springs, catchment ponds, irrigation canals, etc.

2. Measure water flows by appropriate methods such as floats, weirs, barrel method, pipe discharge, etc.

3. Establish appropriate type of structures required to develop irrigation potential of a water source.

Materials:

1. Training Guides Number 1 and 2
2. Watch with second hand
3. Small wood block (3-10 units)
4. Pocket measuring tape or meter stick
5. Carpenter tools as for Unit 3
6. Boards of about 2 cm x 30 cm and sufficient length to build appropriate weirs
7. Assorted diameters of plastic pipe (if locally available)

Procedures:

Exercise 4-1

Most readily accessible sources of irrigation water have been established and/or developed by the government or local communal/village groups, however in many cases, the individual farmer has not been able to utilize the project water for irrigation. Training Guide Number 2, Chapter 13, page 98 identifies various methods of developing water sources.

Identify the source of water that might be developed at a minimal expense. Many pumping projects usually require expensive fuel and equipment, whereas gravity water systems can utilize local materials and labor intensive costs to divert water to the project area. Chapter 15 of Reference 2 shows many types of pumping devices which can be built from local materials and which use human or animal power.

Exercise 4-2

Measure the flow of water for the proposed project by the most appropriate methods. Training Guide Number 2, Appendix D, page 140 and Training Guide Number 1, Unit 13, page 41 describes the various methods for measuring streams, canals, springs and wells.

a. Measure a stream by the float method
b. Measure using a simple rectangular V-notch weir
c. Measure pipe discharge

Exercise 4-3

Identify appropriate types of small structures required for developing a water source--given understanding that the government has authority and capability to develop major sources. Small, simple projects usually are less than six (6) foot high (diversions), with usual provisions for flood flows.

a. Design a simple gabion structure for diverting water into a canal--take into account foundation, cut-off walls, mass support, spillway, energy dissipation, etc.

b. Design a simple outlet structure to diversion ditch that has a water control system (gate, check boards, etc.)

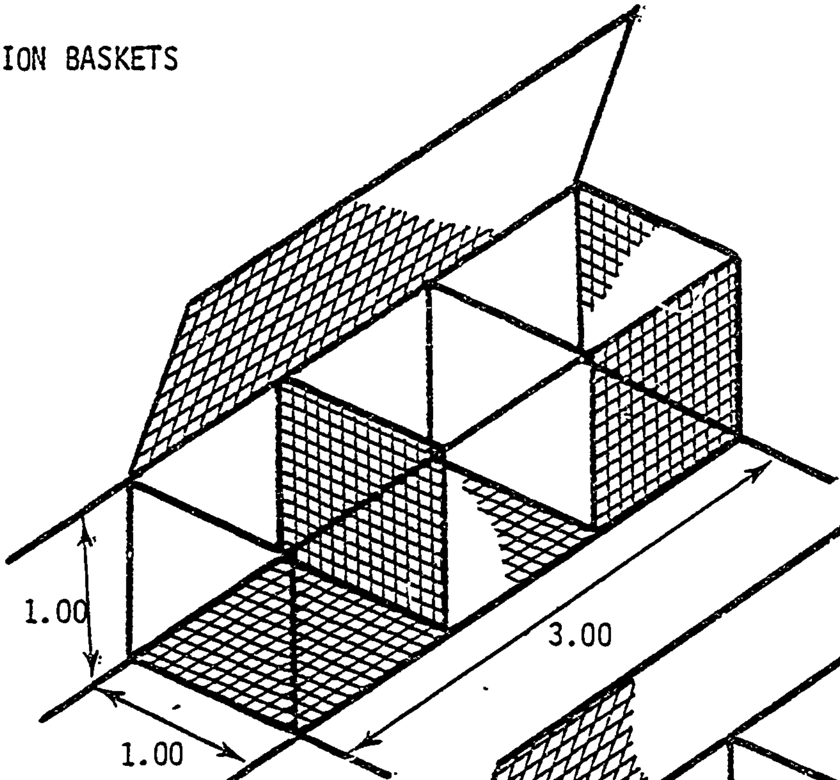
c. Design the diversion ditch from water source to irrigable land. Use Training Guide Number 2, Chapter 12 and 14, Training Guide Number 1, page 54-57 and Training Guide Number 3, pages 36 and 37 (Table 5).

d. Design a simple drop structure.

Exercise 4-4

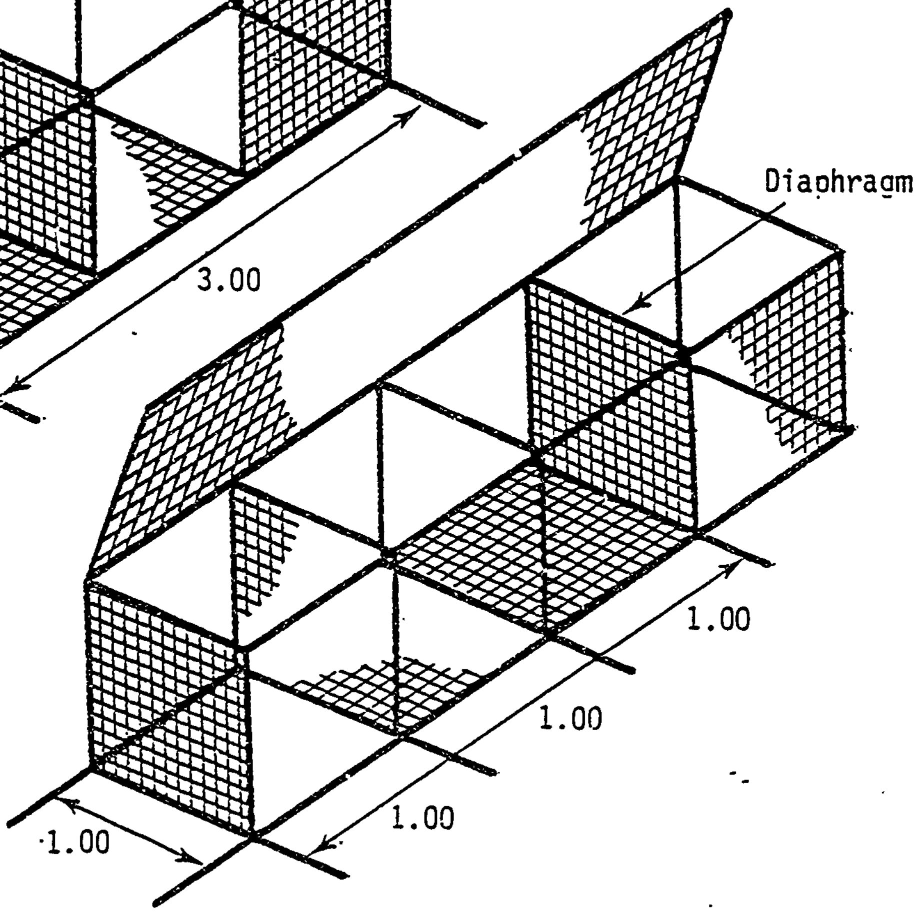
Measure seepage loss in a ditch between two points by use of suitable devices such as weirs.

GABION BASKETS

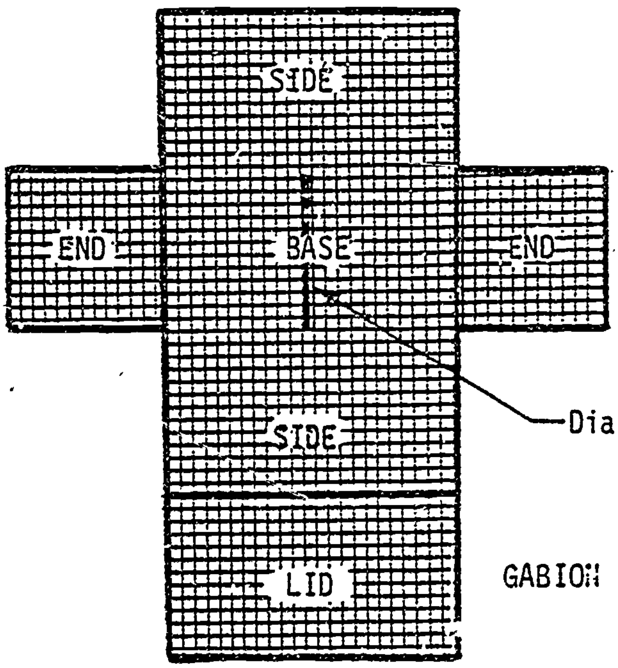


Size of Basket

Length - 2.00M, 3.00M, 9.00M
Width - 1.00M
Depth - .30M, .50M, 1.00M
Diaphragms - Spaced 1.00M



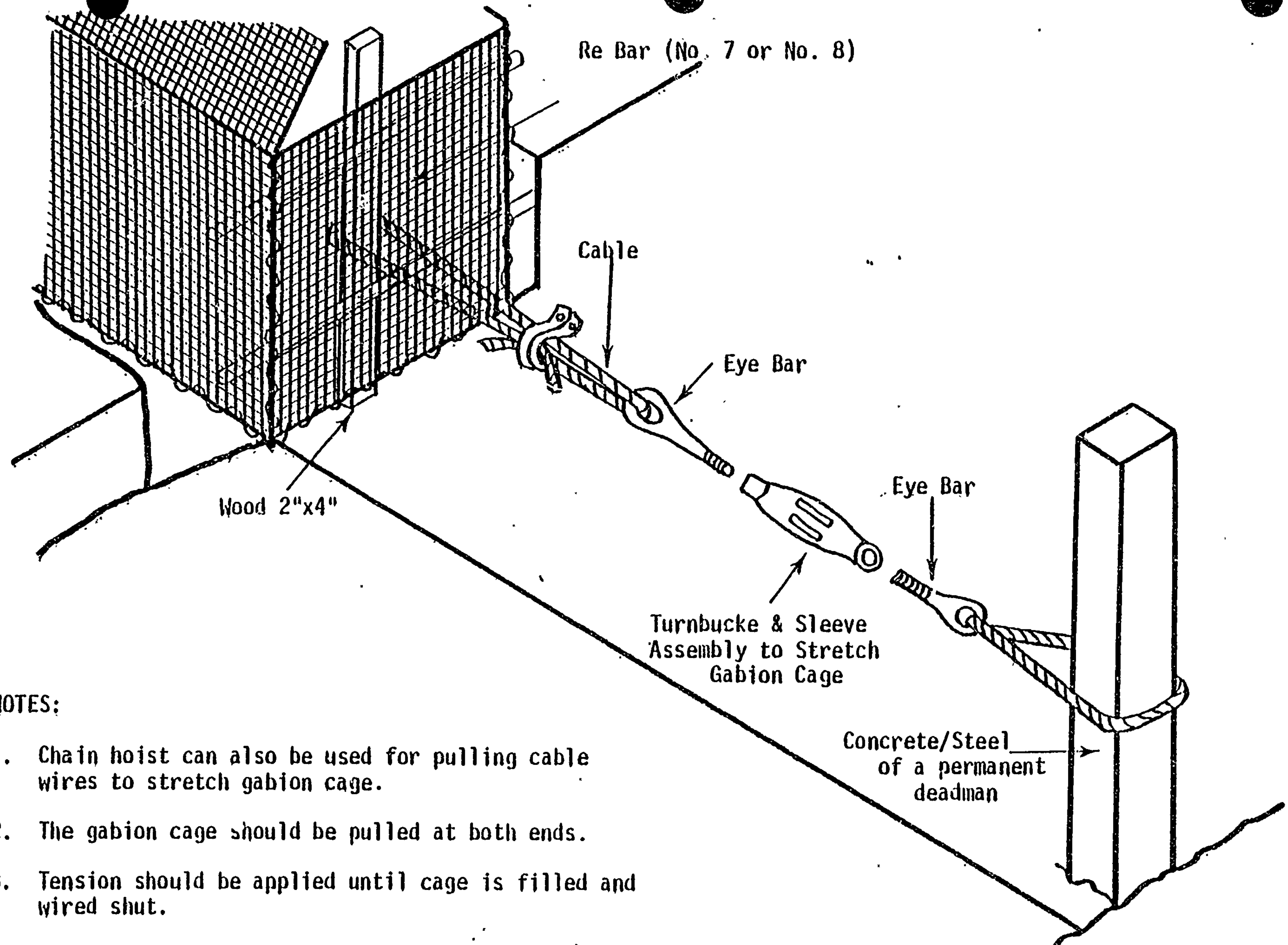
TYPICAL GABION BASKET



U.S. Standard Cage No. 11 to No. 8
Wire Mesh Opening of 2½" x 3¼" or 2" x 2 3/4"

Zinc Coated or Galvanized

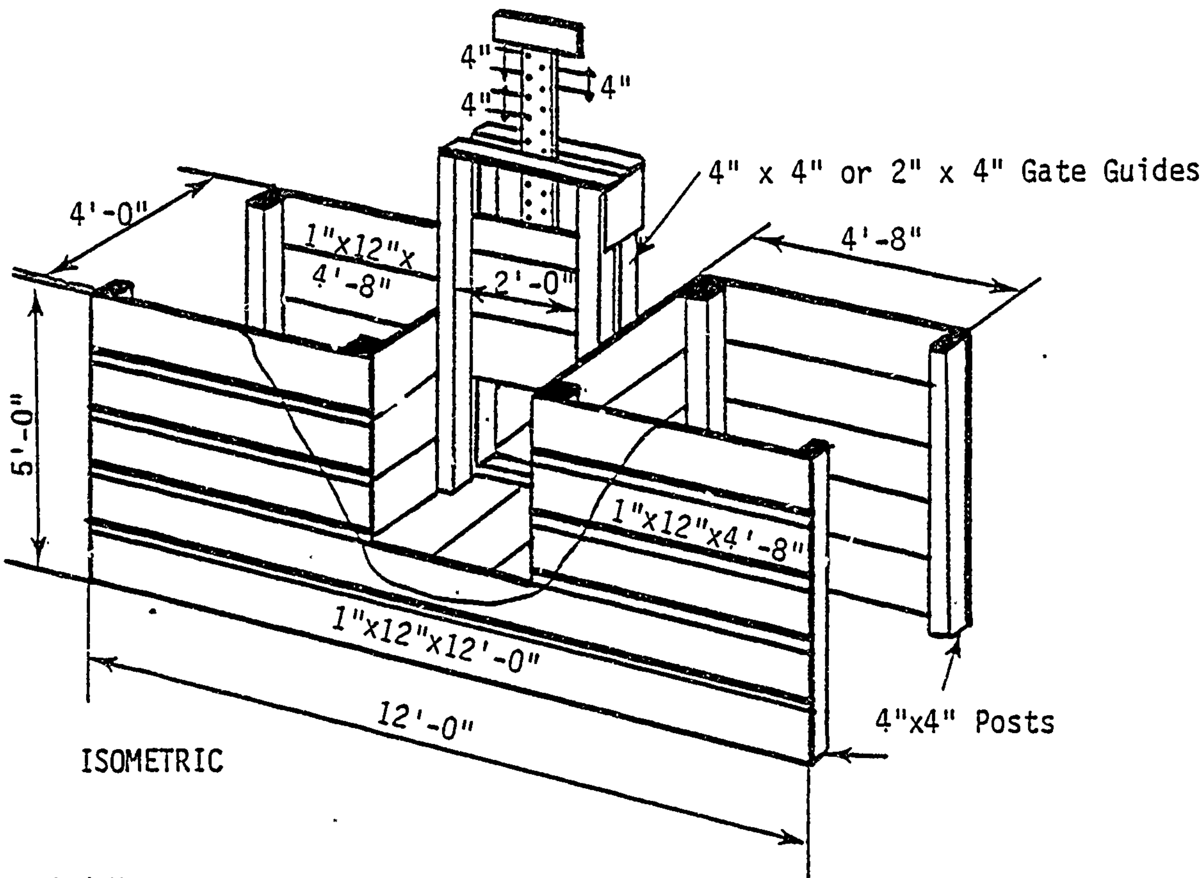
GABION SHAPE WHEN FLAT



NOTES:

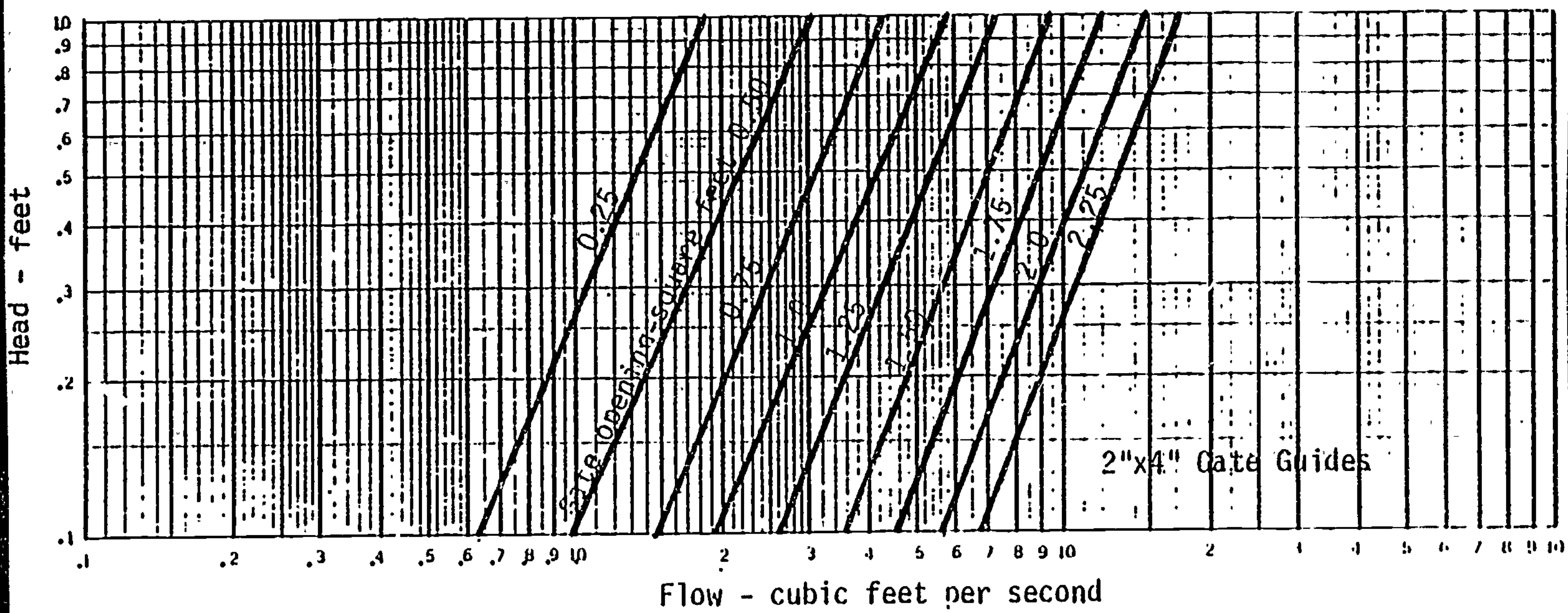
1. Chain hoist can also be used for pulling cable wires to stretch gabion cage.
2. The gabion cage should be pulled at both ends.
3. Tension should be applied until cage is filled and wired shut.
4. Stretching may not be necessary in smaller gabion units.

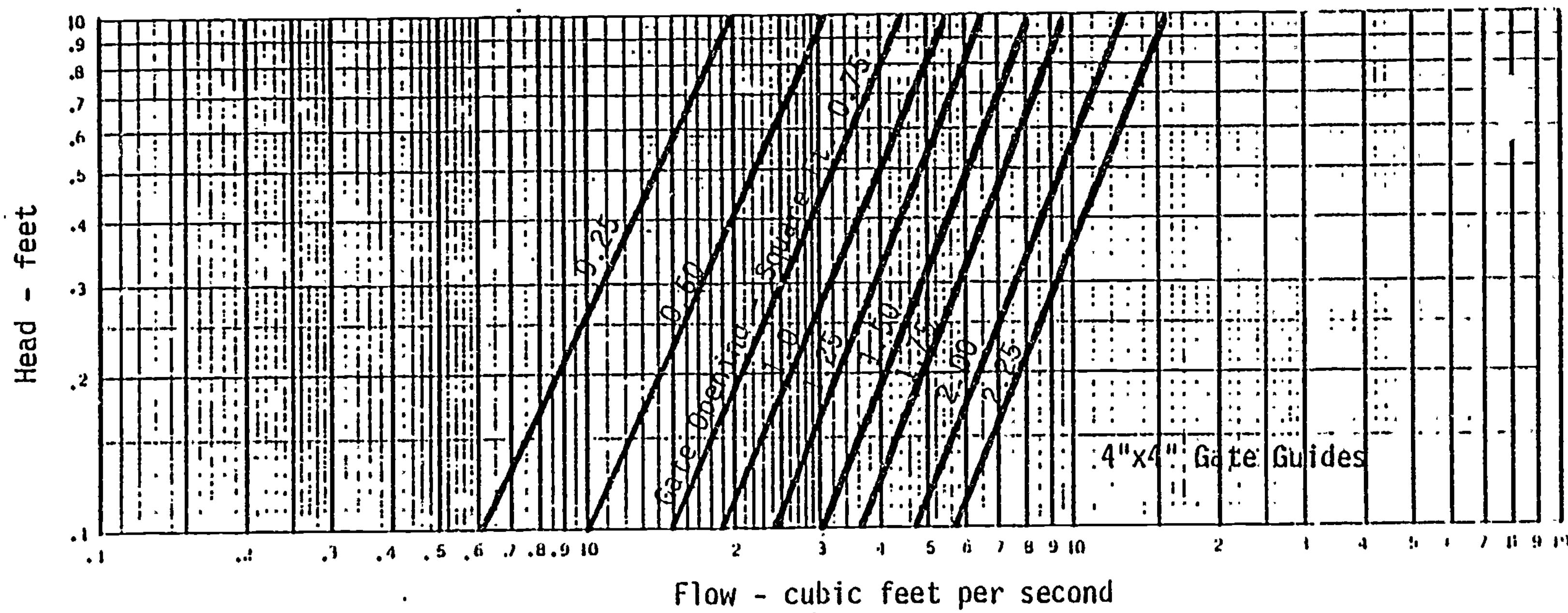
Drawing showing typical method of applying tension to a gabion basket before filling with rocks



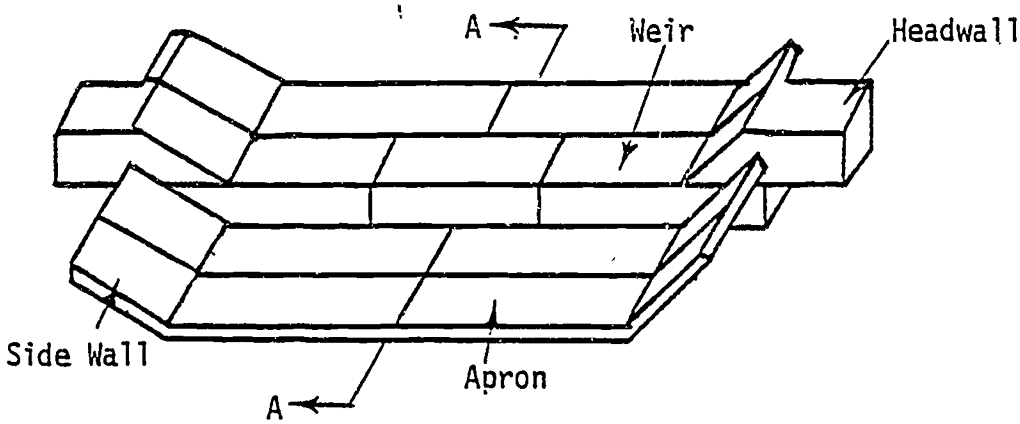
Recommended Use:
As a temporary headgate on new lands or for approximate measurements to divide water between two or more fields on farm.

Accuracy may be only within 10% of true flow.

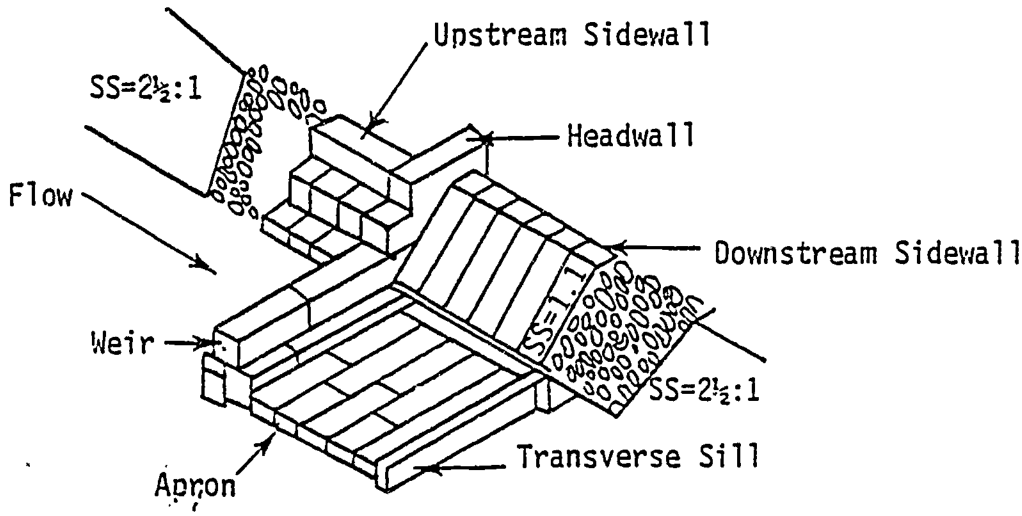

Head - feet
Flow - cubic feet per second
Gate Opening-Square Feet
0.18
0.25
0.50
0.75
1.0
1.25
1.50
1.75
2.0
2.25
2"x4" Gate Guides


Head - feet
Flow - cubic feet per second
4"x4" Gate Guides
0.25
0.50
0.75
2.00

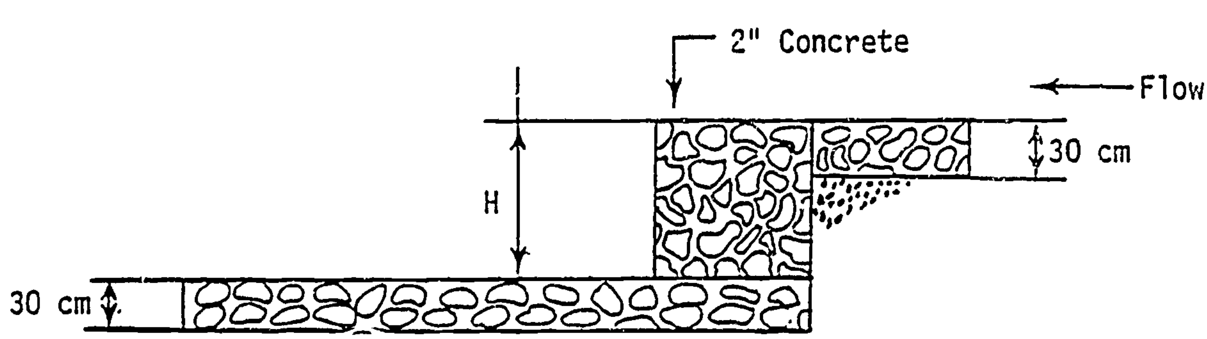
COMPONENT PARTS OF A GABION DAM



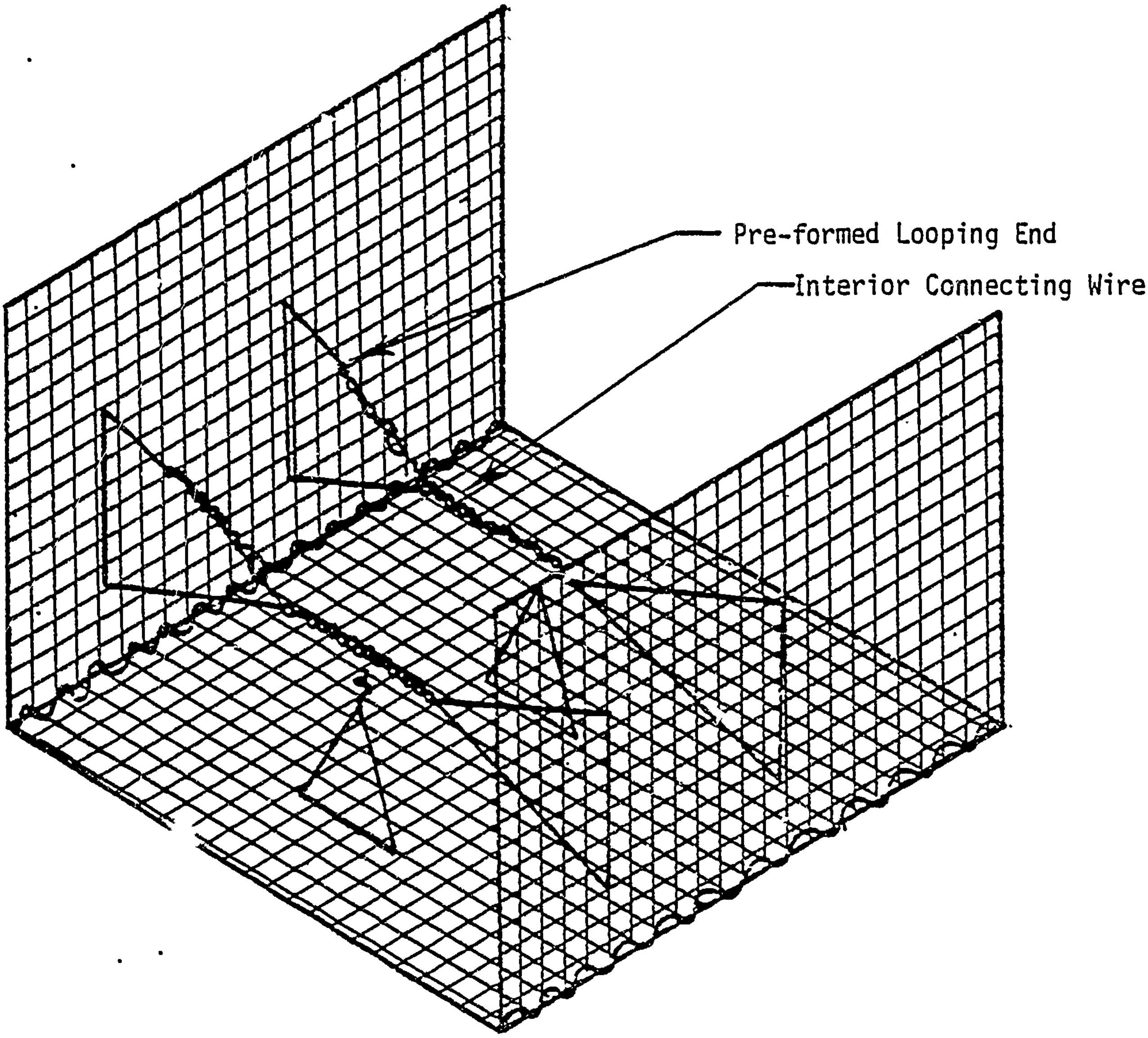
ISOMETRIC VIEW OF A GABION WEIR FOR USE IN EASILY ERODIBLE STREAMBED MATERIAL



HALF ISOMETRIC VIEW OF A GABION STRUCTURE



SECTION A-A



Partial view of Gabion Basket showing interior connecting wires. Each face shall be tied internally as shown. If there is a diaphragm the tie points should be between diaphragms.

Continuous spiral wire for hinge connection and for inter-tying individual Gabion Baskets.

Pre-formed looping end to lengthen interior connecting wire.

Unit #5

General Objectives: Social factors that affect change and community cooperation

Behavioral and Procedural Objectives:

1. Identifying individual and community needs.

2. Identifying formal and informal community leadership.

3. Understanding the community decision making process.

4. Identifying existing community organizations and their leadership.

5. Understanding the community land tenure systems and marketing structure.

6. Understanding prior community cooperative ventures.

7. Identifying organizations or systems in the community that function based on cooperative efforts.

8. Identifying community and family labor patterns.

9. Understanding sex differences in labor, management and decision making within the family system.

Materials

1. Training Guides 13 thru 18.

Procedure

The training guides must be read by the students prior to the teaching session.

The instructor will need to identify the various objectives and through group discussion and questioning techniques help the students to discover the implications of these various elements for individual and community change.

Teaching Notes

It must be emphasized that there is no substitute for time spent with the people of a community if the PCV is to gain an understanding of how the community operates. The information in the various training guides do not present a specific way to approach community action and change. Rather it will give the students some tools for looking at the community.

It is important that the students develop an understanding of the community's cultural and social systems and how these will influence the approach or even feasibility of a community irrigation project. The complexity of initiating, designing, completing and maintaining an irrigation system for a single farm should not be underestimated. So much more complex is a community irrigation project that it should be initiated only after very careful study, community involvement and community support.

This lesson is designed to do no more than acquaint the student with some of the questions that must be asked and some of the community elements that must be considered in such a community development project.

Unit #6

General Objectives: Climate and its effect on stream flow and other water sources and seasonal water requirements of crops.

Behavioral Objectives:

1. Determine seasonal water flows by climatology data and/or stream flow records/measurements or local village estimates.

2. Calculate irrigation requirements of area's primary crop using rainfall records and the crop's water requirement to establish the amount of land that can be irrigated with available water.

Materials:

1. Training Guides Number 1, 2, 3, 9, 10 and 11
2. Available climatic data
3. Villager information on climate

Procedures:

Exercise 6-1

a. Using climate/village data--estimate approximate seasonal yield from water source (wet and dry seasons). When dealing with stream flows and inadequate runoff data--ask villagers to locate high and low water flows on permanent objects such as trees or rocks, then measure cross sections and using formula Q = AV described in Training Guide Number 2, page 106 plus Table 28 and 29 and Figure 35, estimate runoff potential.

b. Estimate runoff from the project watershed by use of formula Q = CiA described in Training Guide Number 2, pages 43 and 94 and in Training Guide Number 1, page 69. This exercise is valuable in double checking on stream flow data and will in a subsequent Unit assist in designing a drainage system.

Exercise 6-2

a. Using local weather data calculate (find) the "20% dry" rainfall for the area being considered.

b. Make a table similar to Table 15, Reference 2 and enter the values of "20% dry" rainfall by months, column Rd.

c. Using some reference, such as: Table 10, Reference 1 or References 14, 15, 16, prepare a column showing the estimated ETcr (Evapotranspiration for the crop being considered) by month.

d. Subtract ETcr from Rd; if the result is negative then the crop requirements are not met by normal rainfall and the difference is the amount of irrigation water which must be provided. (This neglects subsoil moisture which may be available).

e. Compare the peak season crop requirements with water source and availability and calculate the area which can be irrigated with the supply available.

f. As an example Table 6-1 shows precipitation data for Goodland, Kansas for 30 years (1951 through 1980). An examination of this data for the month of January shows the six (20%) dryest years to be 1953, 1957, 1961, 1964, 1968 and 1970 with 0.13 in. recorded in January 1957; the value 0.13 is entered in the bottom row. Each other month is examined in a similar fashion to complete the bottom row of the table.

g. Now a table similar to Table 15 of Reference 2 is started as shown in Table 6-2. Rd is entered from Table 6-1. The average moisture use per day at various periods during the growing season is taken from Reference 14. (Note that Reference 14 shows a maximum crop water requirement of about 0.25 in./day while Table 10 of Reference 1 shows a maximum requirement of 0.20.)

h. From the last column "In" it is evident that in the "dryest" years 7.35 in. (18.7cm) would need to be applied in August and a total of about 20 inches would be needed throughout the season to achieve optimum crop growth.

Table 6-1. Precipiation in Goodland, Kansas

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1951	0.28	0.08	0.18	1.60	2.45	7.14	4.58	1.81	1.46	0.58	0.61	0.18	20.95
1952	0.17	0.18	0.99	1.98	2.56	0.67	2.48	2.25	0.31	0.05	0.38	0.36	12.38
1953	0.04	0.58	1.20	1.83	2.39	1.82	1.41	4.48	0.03	0.30	2.07	1.22	17.37
1954	0.20	0.03	1.28	0.06	2.53	1.78	1.00	1.77	0.79	1.39	0.06	0.23	11.12
1955	0.82	0.99	0.35	1.01	1.22	2.59	1.03	0.54	1.69	0.10	0.09	0.38	10.81
1956	0.68	0.43	0.49	0.67	0.98	0.59	1.93	1.35	0.05	0.56	1.29	0.17	9.19
1957	0.13	0.26	2.21	2.15	6.00	2.99	1.69	1.81	0.31	0.83	0.26	0.05	18.69
1958	0.45	0.77	1.49	1.73	1.91	1.64	3.62	2.01	1.39	0.32	0.41	0.25	15.99
1959	0.62	0.12	0.97	0.62	1.36	1.14	2.54	2.45	2.97	1.83	T	0.44	15.06
1960	1.23	1.60	0.51	0.83	1.72	2.78	1.21	0.29	0.65	2.05	0.27	0.78	13.92
1961	0.01	0.19	1.01	1.26	3.69	2.88	3.91	2.33	1.64	0.36	1.10	0.36	18.74
1962	0.34	0.17	0.82	0.33	4.25	7.64	2.29	1.46	0.79	0.67	0.45	0.32	19.53
1963	0.52	0.09	2.00	T	1.72	1.36	3.22	1.76	4.84	0.03	0.29	0.41	16.24
1964	T	0.75	0.56	1.36	2.68	1.50	1.97	0.13	1.56	0.02	0.26	0.02	10.81
1965	0.30	0.51	0.48	0.10	3.43	3.46	1.72	2.94	4.31	3.06	0.01	0.55	20.87
1966	0.50	0.23	0.52	0.50	0.55	2.12	2.26	2.15	1.00	1.23	0.04	0.24	11.40
1967	0.16	0.02	0.46	0.74	2.66	3.23	1.20	1.76	4.13	0.52	0.41	0.43	15.72
1968	0.06	0.12	0.20	0.46	1.89	3.48	2.85	2.09	0.46	0.44	0.34	1.31	13.70
1969	0.11	0.41	0.97	1.86	3.83	2.22	2.46	1.78	0.36	4.10	0.31	0.26	18.67
1970	0.03	T	0.91	1.21	2.27	1.68	1.92	2.37	1.11	1.10	0.57	0.03	13.20
1971	0.53	1.36	0.57	1.93	4.24	2.35	1.62	0.65	1.38	1.32	1.31	0.21	17.47
1972	0.32	0.06	0.15	0.60	6.04	4.76	2.64	2.46	0.73	0.82	1.56	0.94	21.08
1973	0.73	0.02	2.90	1.90	2.96	2.03	1.82	1.16	5.39	0.47	0.66	0.90	20.94
1974	0.17	0.42	0.99	1.52	1.10	3.95	1.15	1.63	0.02	0.96	0.86	0.77	13.14
1975	0.20	0.14	0.64	1.03	4.75	5.25	2.43	0.37	0.19	0.02	1.92	0.06	17.00
1976	0.48	0.21	0.31	0.87	1.17	0.10	2.61	0.60	2.03	0.43	0.40	0.01	9.22
1977	0.38	0.05	1.79	1.94	6.11	1.30	1.28	5.45	1.02	0.15	0.45	0.14	20.06
1978	0.38	0.85	0.29	1.33	3.82	2.25	1.71	1.85	0.12	1.29	0.68	0.43	15.00
1979	0.88	0.08	3.11	1.09	4.48	5.08	4.53	3.17	0.21	2.00	0.78	1.15	26.56
1980	0.61	0.49	2.75	2.67	2.80	1.92	7.25	3.38	2.24	0.19	0.12	T	24.42
20% dryest yr.	0.13	0.06	0.35	0.46	1.36	1.36	1.28	0.65	0.31	0.15	0.26	0.06	

Table 6-2. Example of irrigation water requirements for sorghum at Goodland, Kansas. (Only the crop growth months, June through October, are considered)

Month	Rd, in 1/	ETcr 2/	In
June	1.36	2	.64
July	1.28	5	3.72
August	0.65	8	7.35
September	0.31	6	5.96
October	0.15	3	2.85
Total	3.75	24	20.52

1/ Taken from Table 6-1.

2/ Taken from Reference 9, daily requirements in inches/day is multiplied by days in month.

RICE CULTURE AND IRRIGATION REQUIREMENTS

Rice is the principle grain crop for most Asian countries, where it constitutes the major dietary food component. In addition, rice is a commonly used grain in many African, Middle East and South American countries. Rice culture, with the exception of non-irrigated hill land rice, requires special soil, water and agronomic practices that differ from practices used on most other crops. Numerous variables in varieties of rice, such as plant growth, grain production and tolerance to sodic-saline soils, plus variations in soil texture and structure further complicate rice culture. However, by relying heavily on averages, common practices and normal situations, the following practices generally typifies rice culture.

Land Preparation

Proper irrigation of rice depends on how well the depth of water can be controlled, and upon how uniformly the irrigation water can be applied. A recommended practice is to use contour border levees on six (6) centimeters (cm) of elevational spacing. This interval allows a minimum water depth of 10 cm and a maximum depth of 15 cm. Water depths of less than 10 cm are ineffective in controlling grasses, a depth over 15 cm is injurious to rice. Level and smooth the seed bed. Water leveling can move large amounts of soil, provides a smooth bed and allows for water depth measurements of the field.

The levees should have a top width of approximately 30 cm and a height of 30 cm and be well compacted to prevent breaking and seepage. Wooden gates should be constructed to control depth of water, remove stress on levees and provide field drainage.

Plow the field 15 cm deep and harrow to control weeds prior to pre-irrigation. Continual use of a uniform plowing depth on rice land builds up a "plow sole" or compacted layer. For most crops, this layer is not desirable, however in rice culture, it tends to seal the soil and reduce excessive water percolation (water losses) and provide some support for equipment/animals even under flooded conditions.

Pre-Irrigation-Puddling-Planting

Pre-irrigate the fields and puddle the soil with plows and harrows. Rice is planted as seedlings, usually by hand, in most Asian countries; it can be broadcast or seeded with a grain drill. The soil moisture of the seed bed can be anywhere from saturated to 3 cm of water depth.

Irrigation

Start applying water three days after planting--taking care to not submerge the seedlings. If seeds are broadcast or drilled, wait till emergence of seedlings and irrigate after seedlings are 10 to 15 cm high. Increase depth of water as seedlings grow until water is 10 cm+ and for early maturing varieties, submerge continuously at this depth up to full grain development. Drain field two weeks prior to harvest.

Some rice varieties (low land and late maturing) require drainage to the saturated soil state at the end of the first 30 days or 60 days, respectively, and then re-submergeness until maturity.

Water Requirements

It is difficult to provide definitive figures for the total water requirements of a rice crop from seed bed to harvest, because the amount is determined by many factors such as different soil types, growing periods, rice varieties, methods of irrigation, climate and irrigation efficiency. Rice usually requires 800 mm to 1,200 mm of water with extremes between 520 mm and 2,550 mm during the growing season. Daily crop water requirements are usually between 6 to 10 mm, however excessive percolation losses in sandy soils can double water consumption and also increase fertilizer requirements. Sandy soils are not normally recommended for rice culture. The table below shows typical consumption for various soil types when growing rice and includes transpiration and infiltration.

Soils	Daily Consumption (mm)
Sand	26.9
Sandy Loam	22.5
Loam	17.3
Clay Loam	14.7
Clay	13.0

In addition, the irrigation demand increase with production (high yielding varieties require more water). Quick growing varieties (100 days) require less water per crop than slow growing traditional varieties that require up to six months for a complete cultural cycle.

It may be safe to conclude that a total of about 1,300 mm of water will be required for the complete growth cycle of rice--40 mm for seedling nursery, 260 mm for land preparation and 1,000 mm for irrigation on a clay loam soil, with a moderate climate.

Unit #7

General Objective: Resource identification

Behavioral and Procedural Objectives:

1. Identification of the infrastructure, commodities and services that are essential to a successful irrigation program.

Materials:

1. None.

Procedure:

The instructor will lead a group discussion drawing from the students their ideas of the kinds of commodities and services that need to be available in a community before an irrigation system can be successful.

The students will then take a field trip into the community to discover which of the items identified are available in the community.

Teaching Notes:

The instructor may want to initiate the discussion by asking the students to identify the kinds of commodities and services that will be needed if there is an irrigation system in the community causing a move from a subsistence to a market economy.

Following is a partial list of services or commodities that could be considered.

- dependable credit source
- ag extension service
- fertilizer - improved seed varieties
- pesticides
- equipment and farm supplies
- equipment repair facilities
- market roads
- fuel supply
- crop storage and/or processing
- market news service
- weather data
- labor pool
- schools or adult literacy program
- transportation

Some of these items will be more crucial than others and the students will want to evaluate them in order to help decide which are the critical ones that need to be available before initiating a community irrigation scheme.

Unit #8

General Objective: Irrigation system planning and design

Behavioral Objective:

1. Determine the type of irrigation field practices needed.

2. Using topographic data of project and water source information--design the field irrigation ditch system, providing slopes, sizing and measurements (length of ditches).

3. Identify land preparation measures required for project.

Materials:

1. Training Guides Number 1, 2, 5, 7 and 12
2. Soils information from Unit 1
3. Topography map from Unit 3
4. Crop water requirements from Unit 6
5. Graph paper

Procedures:

Exercise 8-1

From previous units, the principal crop has been established plus seasonal water usage and availability, soils data, and topography of area to be irrigated. Using Training Guide Number 2, Chapter 5;

a. Identify the type of irrigation system needed e.g. basin, furrow, border, etc.

b. Determine the type and locate the necessary structures e.g. drops, weirs and farm turnouts, etc.

Exercise 8-2

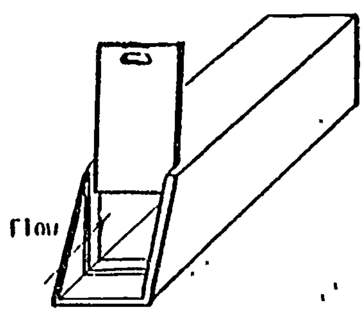
Plan and design a field irrigation system--providing slopes, sizing of structures and measurements (lengths).

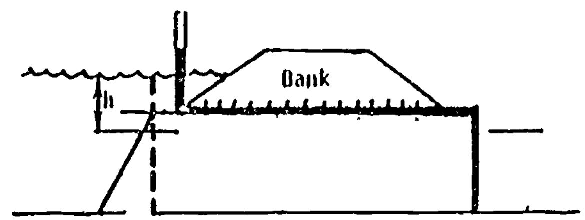
Exercise 8-3

Identify irrigation land preparation practices/measures required by project e.g. tree removal, land clearing, terraces, etc. and through local contacts establish time and expense required.

Figure 8-1. Flow through rectangular submerged orifices

Head (h) centimeters	Cross sectional area of orifice (square centimeter)					
	232 (15x15)	464 (15x30)	696 (30x23)	928 (30x30)	1392 (60x23)	1856 (30x60)
	(l/sec)					
3	11,0	21.9	32.8	44.2	65.7	87.5
6	15.5	30.9	46.4	62.0	92.8	124.0
9	19.0	37.9	56.9	75.8	113.8	151.7
12	22.0	43.9	65,7	87.5	131.3	175.2
15	24.5	49.0	72.3	97.9	146.9	195.8
18	26.8	53.8	80.4	107.3	160.7	214.5
21	28.9	58.0	86,9	115.8	173.8	231.5
24	30.9	62.0	92.8	124.0	185.7	247.6

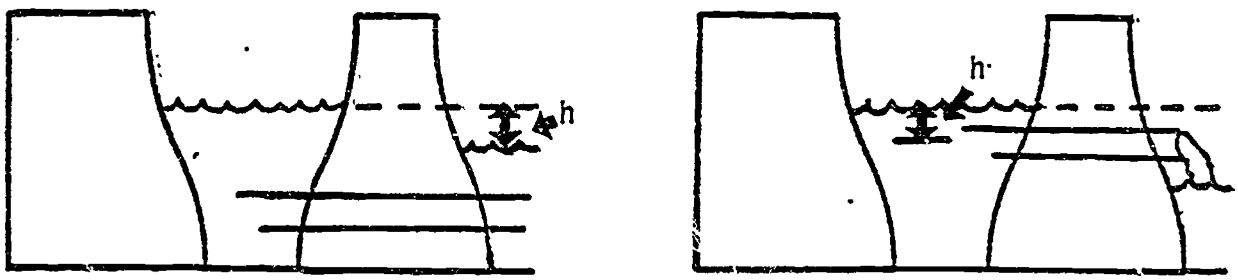




CAPACITIES OF SHORT TURN-OUT PIPES

Frequently to supply water to furrows or border strips, it will be desirable to use short lengths of pipe through a channel berm. These pipes may be of clay, plastic, metal or wood. (Even bamboo might be appropriate in many countries.)

The critical dimension is the effective head (depth) "h" of water as shown in the two illustrations



(Note: Bevel inlet end of pipe as shown to help prevent vortex formation which reduces flow.)

Table 8-2 shows capacities of short pipes used for farm turn-outs.

Table 8-1. Capacities of short pipes in liters/sec 1/

h, cm	Pipe diameter, cm 2.5	5.0	7.5	10	15	20	25
2	.2	--	--	--	--	--	--
5	.3	1.1	2.5	4.5	--	--	--
10	.4	1.6	3.6	6.4	14.3	25.4	--
15	.5	1.9	4.4	7.8	17.5	31.1	48.65
20	.6	2.2	5.1	9.0	20.2	36.0	56.2
30	.7	2.7	6.2	11.5	13.6	44.0	68.8
40	.8	3.2	7.1	12.7	28.6	50.8	79.4
50	.9	3.5	8.0	14.2	32.0	56.8	88.8
75	1.1	4.3	8.5	17.4	39.2	69.6	108.8
100	1.3	5.0	11.3	20.1	45.2	80.4	125.6

1/ Calculated using $n = 3\frac{V^2}{2g}$.

SELECTION OF FARM TURN-OUTS

Example A:

Select a farm turn-out to apply 5 cm of water in one hour to a one hectare ($10{,}000 m^2$) field. The volume of water required in one hour is:

$$\frac{5 \text{ cm}}{100 \text{ cm/m}} \times 10{,}000 m^2 = 500 \ m^3/hr$$

$$\frac{500 \ m^3/hr}{3600 \text{ sec/hr}} = .14 \ m^3/sec$$

$$.14 \ m^3/sec \times 1000 \ l/m^3 = 140 \ l/sec$$

Referring to Table 8-1, we find that a rectangular orifice turn-out with an orifice area of 60 x 23 cm and a head of 15 cm could be used. Referring to Table 8-2, a 25 cm pipe with a head of slightly over 100 cm would also be adequate.

Example B:

Assume a furrow irrigation system on a silt loan soil with an application of 200 mm. Assume furrows 1m apart and 100m long. Select a suitable turn-out pipe. Referring to Table 6 of Reference 2, we find a suggested inflow rate of 0.3-0.5 l/sec/100m.

Referring to Table 8-2, we find that a pipe of 2.5 cm diameter with a head of 1C cm would provide the flow required.

Table 8-2. Water flow conversion table

GPM*	l/sec	ha cm/hr or ac in/hr	GPM	l/sec	ha cm/hr or ac in/hr
100	6.3		900	56.8	2.00
112	7.1	.25	950	60.0	
158	10.0		1000	63.1	
200	12.6		1012	64.0	2.25
225	14.2	.50	1100	69.5	
300	18.9		1110	70.0	
317	20.0		1125	71.0	2.50
335	21.2	.75	1200	75.7	
400	25.2		1237	78.0	2.75
450	28.4	1.0	1268	80.0	
475	30.0		1300	82.0	
500	31.6		1350	85.3	3.00
562	35.4	1.25	1400	88.3	
600	37.8		1426	90.0	
634	40.0		1462	92.4	3.25
675	42.6	1.50	1500	94.7	
700	44.2		1575	99.4	3.50
787	49.6	1.75	1585	100.0	
793	50.0		1600	101.0	
800	50.5				

* U.S. Gallons per minute

DESIGN OF CHANNELS

Principles of flow in channels and furrows have been discussed. Water distribution system design does not necessarily consist of finding the one best solution but of considering the cost and feasibility of a few logical solutions.

Whenever land slopes are relatively moderate, channels may be designed to run essentially on the contour with just enough fall to carry the quantity required without causing erosion of the channel.

If slopes are too great then lined channels or stepped channels may be required. Lined channels may be too expensive to consider if cost of concrete or other masonry materials is high. Stepped channels may be more satisfactory and may make use of local rock with minimum amount of cement required. Figures 8-2, 8-3 and 8-4 show how stepped channels might be designed for use in sand, loam and clay soils taking into consideration the maximum velocities for each soil type.

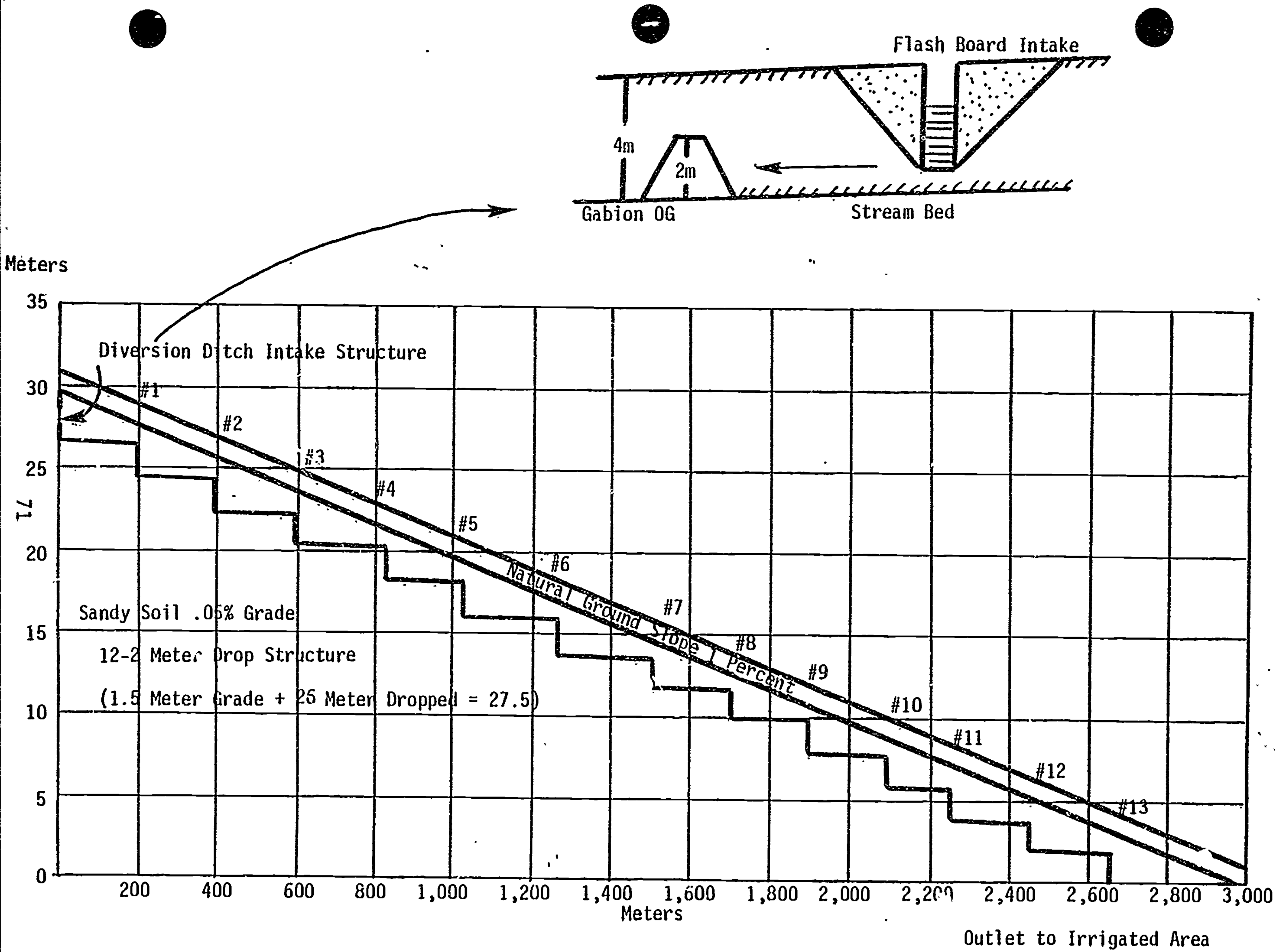

Flash Board Intake
4m
2m
Gabion OG
Stream Bed
Meters
35
30
25
20
15
10
5
0
Diversion Ditch Intake Structure
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
#13
Natural Ground Slope 1 Percent
Sandy Soil .05% Grade
12-2 Meter Drop Structure
(1.5 Meter Grade + 26 Meter Dropped = 27.5)
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
2,800
3,000
Meters
Outlet to Irrigated Area

Figure 8-2.

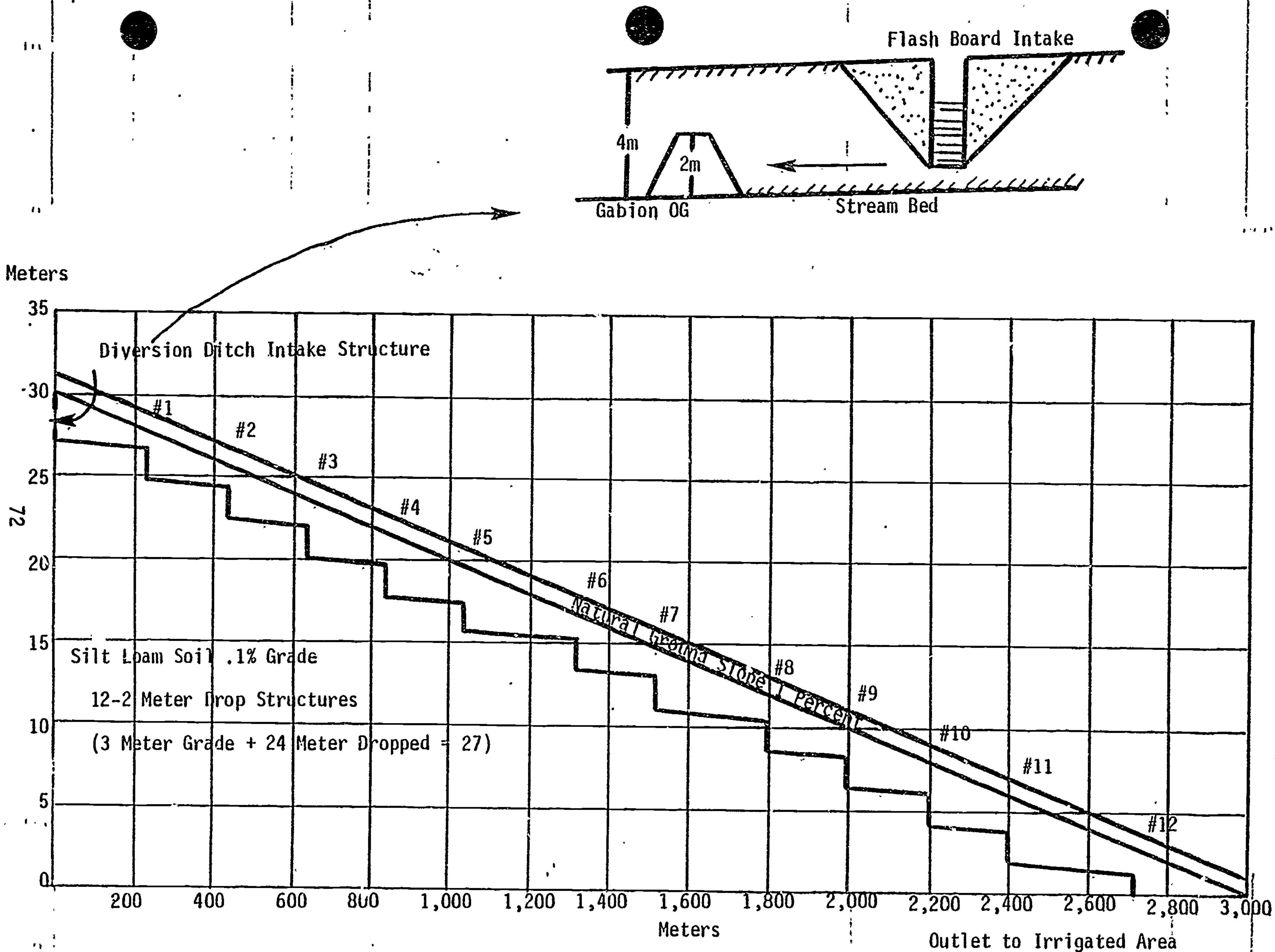

Flash Board Intake
4m
2m
Gabion OG
Stream Bed
Meters
35
30
25
20
15
10
5
0
Diversion Ditch Intake Structure
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
Natural Ground Slope 1 Percent
Silt Loam Soil .1% Grade
12-2 Meter Drop Structures
(3 Meter Grade + 24 Meter Dropped = 27)
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
2,800
3,000
Meters
Outlet to Irrigated Area

Figure 8-3.

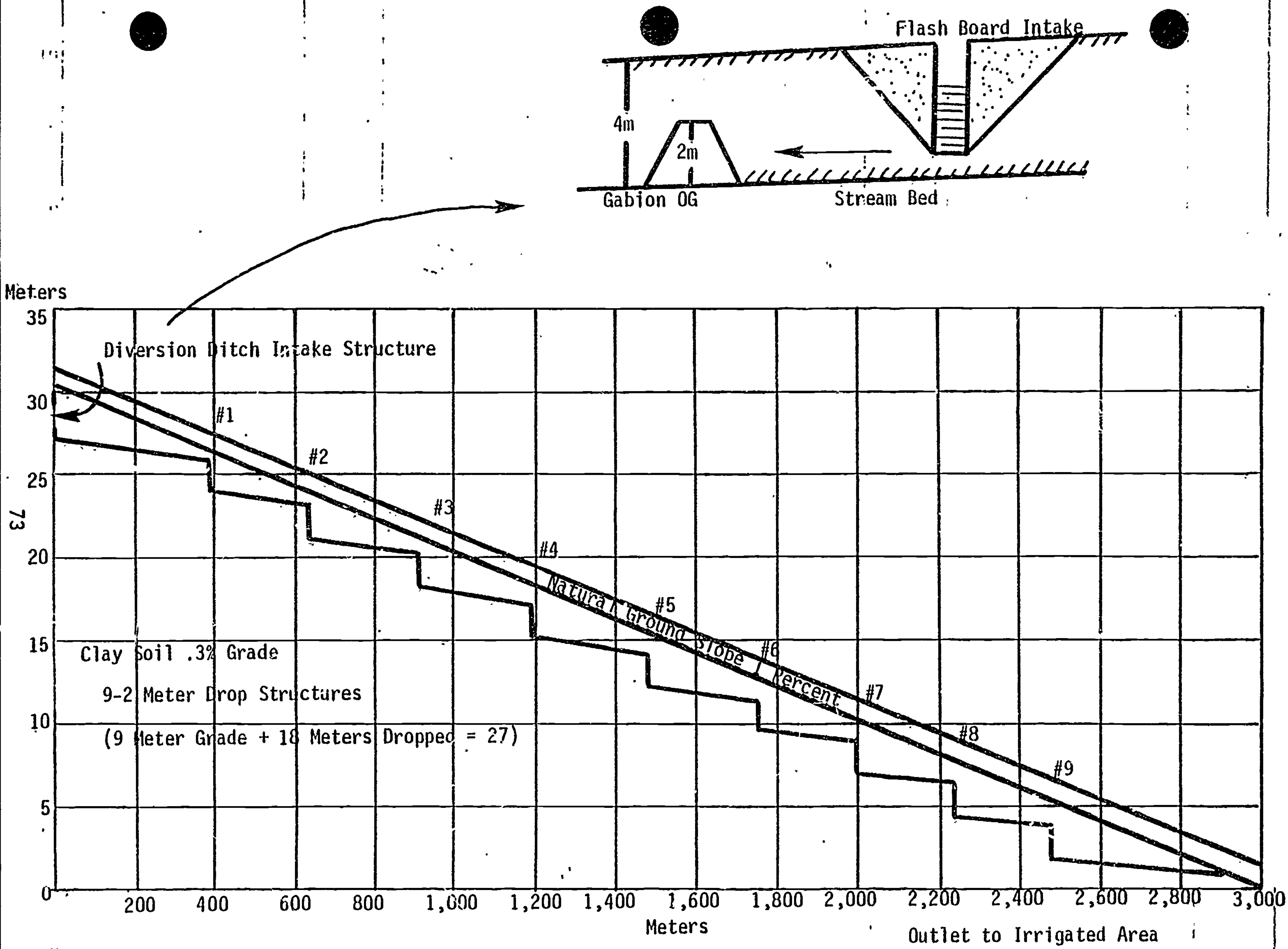

Flash Board Intake
4m
2m
Gabion OG
Stream Bed
Meters
35
30
25
20
15
10
5
0
Diversion Ditch Intake Structure
#1
#2
#3
#4
#5
#6
#7
#8
#9
Natural Ground Slope
Percent
Clay Soil .3% Grade
9-2 Meter Drop Structures
(9 Meter Grade + 18 Meters Dropped = 27)
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
2,800
3,000
Meters
Outlet to Irrigated Area

Figure 8-4.

Unit #9

General Objectives: Agronomic practices for irrigation

Behavioral Objectives:

1. Using previously identified crop, water, soil and irrigation practices calculate irrigation applications and water diversion structural requirements.

2. Identify land/crop preparation practices required for irrigation--as compared to dry land practices previously performed.

3. Identify fertilization requirements and availability.

4. Identify weed control practices.

Materials:

Training Guides Number 1, 2, 3, 9, 10 and 11

Procedures:

Exercise 9-1

Calculate intervals between irrigation and amount of water to apply per irrigation (reference - Chapters 5 and 11 of Guide No. 2)

Exercise 9-2

Training Guide Number 2, Chapter 10 briefly and simply brings to your attention the need to protect soil fertility. The "payback" for fertilization with irrigation is greater than when moisture is a limiting factor. Table 9-1 shows the soil nutrients removed by some common crops.

Table 9-1. Soil nutrients extracted by staple crops. The data are expressed as kilograms nutrient extracted per ton of dry matter harvested

Crop	Nitrogen	Phosphorus	Potassium
Maize (grain plus cob)	21	5	6
Rice (grain plus hulls)	13	3	4
Potatoes (tubers)	10	2	22

Local recommendations regarding fertilizer requirements should be available from local agricultural extension agents.

To achieve near optimum yields with irrigation, the seeding rate, plant population, will have to be increased.

Weed control will be very important--weeds also respond to good soil moisture conditions and will rob the crop of water and nutrients.

Since irrigation may be used to hasten germination of seed, the crop may be started earlier so that the time of maximum water requirements may come at a better time, e.g. during a short rainy season.

General Objective: Economic Evaluation and Feasibility

Behavorial and Procedural Objectives: To learn to identify the benefits and costs of installing and using an irrigation system. Installing an irrigation system and using it properly and economically usually involves cash costs and probably will involve noncash costs such as unpaid labor. Benefits may include additional cash income from the sale of crops but may include additional food produced for home consumption or greater freedom from dangers of hunger if a severe drought occurs. Several studies have shown that in developing countries farmers are reluctant to spend cash for production inputs if they cannot expect to get the cash investment back in one year, or crop season. For example, farmers are more likely to adopt the use of fertilizer or improved seed where the extra production will pay for the cash outlay in one crop than they are for a machine which would not pay for itself within one year.

Noncash costs, such as labor used to dig an irrigation ditch during a surplus labor season, may have a different value in the farmer's mind than cash outlays.

Benefits:

If an irrigation project can be shown to have a definite and positive effect on crop production and the additional production can be easily sold at a predictable price, the benefit will be fairly easy to evaluate. For example, assume a farmer has produced one ton of maize on a one hectare field and it is just enough to feed the family and that with irrigation, the use of fertilizer, improved seed and a thicker plant population will increase production to two tons. This then clearly indicates a benefit of the value of one ton of corn.

Noncash benefits might include such benefits as reducing the risk of a crop failure if a drought occurs or being able to grow some more desirable food, such as vegetables or melons, than grain.

When evaluating the benefits of increased production of crops such as grain, do not overlook the increased production of forage which may be a valuable by-product. In some cases, irrigation might provide the opportunity to produce two or even three crops per year rather than one.

Try to avoid using anything but benefits which can be expressed quantitatively in money.

Costs:

Cash costs would include:

- Cost of buying pumps, pipe and other materials to develop and operate the system,
- Costs of fuel, or electricity, to operate a pump,
- Costs of fertilizer and/or seed to take advantage of the extra water available to produce a crop,
- Costs of hiring labor and/or equipment to construct and/or maintain the irrigation system.

Noncash costs include:

- Farm (or community) labor required to construct the system and maintain it,
- Locally available materials which require only the labor for collecting and assembling,
- Additional labor required to plant, cultivate and harvest the crop under irrigated conditions.

Agronomic and crop costs and benefits should be made with the assistance of a local agronomist who is familiar with the additional inputs (e.g., fertilizer) and outputs (yield) associated with irrigated crop production.

Analysis:

If all costs and benefits can be assumed to be an annual cost then the ratio

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{\text{Benefit (1)} + \text{Benefit (2)} + \ldots}{\text{Cost (1)} + \text{Cost (2)} + \ldots}$$

If the benefit/cost ratio is less than one the project is not economically justified.

If some items, particularly for equipment costs, have a useful life of more than one year, then they may be reduced when making the analysis. For example, if a pump has an expected life of five years and costs $200 then only one fourth of the cost might be included in the above operation. However, as noted earlier most subsistence farmers prefer to get all cash back in one year.

Example:

Assume that a farmer can dam a small stream and obtain water for one hectare of maize. Further assume there will be a yield increase from 1 T/ha to 4 T/ha, if 100 Kg of urea fertilizer (cost $50) and 10Kg (Cost $20) more hybrid seed is used. Assume a price for maize of $150/T.

Constructing the dam and irrigation ditch will require 200 hours of labor at a time of a labor surplus, between crops when the farm family has little other productive work. Construction materials are locally collected rocks for the dam. Slightly more labor will be required to weed and harvest the crop - an estimated 40 hours total.

Neglecting labor the benefit/cost ratio becomes:

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{\$150/T \times 3T}{\$50 + \$20} = \frac{450}{70} = 6+$$

The first year net cash profit is:

$$(150 \times 3) - (50 + 20) = \$380$$

The farmer will have to decide if he and the family are willing to invest their 240 hours.

Unit #11

General Objective: Irrigation laws and regulations

Behavioral Objectives: Identify existing laws and/or regulations that have an effect on the proposed project

Materials: Training Guide Number 2, Chapter 3

Procedures:

Exercise 11-1

Training Guide Number 2, page 29, briefly identifies laws and regulations that not only aid and assist, but might preclude its development. In addition, read Appendix E for social mores that might affect the project.

Identify laws and regulations that might affect project. These may usually be obtained from the Ministry of Agriculture or Ministry of Land Development.

Unit #12

General Objectives: Identifying and correcting drainage problems

Behavioral Objectives:

1. Survey project soils for drainage problems that might affect irrigation.

2. Design and layout a simple surface drain system for project area--including a disposal system/area.

Materials:

1. Training Guides Number 1 and 2
2. Shovel and/or soil auger
3. Graph paper

Procedures:

Lesson Number One (1)

Using Training Guide Number 1, Unit D as a guide, dig a hole to five feet or if available use road cuts, channel banks, etc. to plot soil profiles for drainage impediments in subsoil that could or has created a subsurface drainage problem. Plot profiles and record locations on the project map.

Lesson Number Two (2)

Using the topographic map and runoff estimates from Unit 6, Lesson 1, design and layout a simple surface drain system for the project--including provisions for disposal e.g. stream channel, ponding area, etc.

SALINE SODIC SOILS

Soil normally contains soluble salts which are a necessary requirement to provide the nutrient elements essential for plant growth. The amount of salt in a soil is dependent on various factors such as the soils parent material, soil texture and structure, climate, soil drainage and the chemical and physical characters of the various salts.

An excess of soluble salts can damage plants. Soils with an excess amount of exchangeable sodium salt are called sodic soils. Sodic soils are more difficult to reclaim or cultivate due to chemical affect sodium has on the soil structure provided that the soil is properly drained.

In humid regions, the amount of rain tends to leach the salts from the soil so that the soil rarely accumulates salt to a dangerous level. Rainfall in arid regions is rarely adequate to leach the salt from soil and a combination of inadequate drainage and irrigation water with high salt content tends to cause a buildup in the soil's salt content.

Some crops are extremely sensitive to soil salts and others are more tolerant. Table 18 on page 76 of Training Guide Number 2 lists some major crops by their tolerance to salts. In addition, plants are usually more sensitive to salt during early growth stages. By providing adequate irrigation and drainage procedures and using appropriate planting practices and choosing salt tolerant crops--salinity problems can be minimized. Soil management practices such as soil leaching and use of soil amendments for sodic soils might be necessary in severe situations, however, this requires soil tests and an available source of inexpensive soil amendments such as gypsum.

Salt accumulates on the top of a furrow, hence to assure a good seed bed and stand, plant the seeds on the lower side of a furrow seedbed. In addition, irrigate more often to leach the salts and provide adequate water. Saline sodic soil does not have the same level of soil moisture as non-saline sodic soils.

A sodic soil is highly dispersed (no structure) and when wet, tends to be very sticky. If plowed too dry, large hard clods results and if plowed too wet the soil is gummy and does not have structure.

Most fruits and nuts are extremely sensitive to saline/sodic soils and are not recommended. With the exception of wheat, barley, cotton, tomatoes and beets, most crop growth are stunted by saline sodic soils, with resultant lowering of yields. Another indicator of saline sodic soils is plant response and appearance. Plants growing on sodic soils have leaf burn (yellowing) progressively inward from the tip or edges. In extreme cases, the leaves dry up and fall off.

Professional assistance is usually required when severe saline sodic conditions are encountered. If the condition is prevalent in an area, extreme caution is required not to intensify the condition with improper irrigation or poor soil management practices.

GPO 906-074

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