PLANNING FOR THE FUTURE
AGRICULTURE

ON FARM WATER MANAGEMENT FIELD MANUAL

Volume X

WATER HARVESTING
And
SPATE IRRIGATION

December 1996

Federal Water Management Cell
MINISTRY OF FOOD, AGRICULTURE & LIVESTOCK
Government of Pakistan
Islamabad

ON FARM WATER MANAGEMENT
FIELD MANUAL

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And
Spate Irrigation

Federal Water Management Cell
MINISTRY OF FOOD, AGRICULTURE & LIVESTOCK
GOVERNMENT OF PAKISTAN
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ON FARM WATER MANAGEMENT PROJECT
WATER HARVESTING AND SPATE IRRIGATION MANUAL

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PREFACE

The Federal Water Management Cell, Ministry for Food, Agriculture and Livestock, Islamabad, has developed various standards and specifications for On-Farm Management since 1980. These have contributed significantly to the overall success of the OFWM programme by providing field staff with appropriate technical know how.

Expansion of the OFWM programme into Barani areas has brought with it the challenge and need for different technologies than those applied in canal irrigated areas. Assistance is now also being provided to farmers under the OFWM Programme who do not have perennial irrigation supplies from either canals or tubewells. Where crops are rainfed, water harvesting programmes as described in this manual can provide significant benefits to farmers through field crop and forestry improvements and erosion protection works. Where farmers have spate or flood irrigation works (either Sailaba or Red Kohi) then chapter 12 of the manual explains simple on farm improvements to these.

I would like to thank Dr Shahid Ahmed and his colleagues at the Water Resources Research Institute at NARC for their assistance and advice in the preparation of this manual and in the development of the water harvesting programme of OFWM.

This is Volume X of the set of revised manuals which include:

Vol	I	Water User Associations
Vol	II	Topographic Surveying
Vol	III	Water Measurement
Vol	IV	Watercourse Design and Improvement
Vol	V	Land Development
Vol	VI	Irrigation Agronomy
Vol	VII	Irrigation Water Management
Vol	VIII	Water Storage Tanks
Vol	IX	Micro-Irrigation and Water Lifting Devices
Vol	X	Water Harvesting and Spate Irrigation
Vol	XI	On-Farm Drainage
Vol	XII	OFWM Training and OFWM Economics

These revised manuals now include new technical areas required to meet the growing needs and challenging demands of the On-Farm Water Management Programme. Materials in the manuals have been reorganised for better presentation and "Field Booklets" are being prepared on relevant areas of the manuals.

It is hoped that these Field Manuals will be useful not only to OFWM field staff but also to others involved in improvement of agriculture in Pakistan. Any suggestions to further improve this manual are welcome.

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1.0 INTRODUCTION

1.1 Introduction

Whilst much of Pakistan benefits from the Indus Irrigation System, a large proportion of the country falls outside the command area of the canal system served by the Indus and its tributaries. In these areas, known locally as barani or rainfed areas, farmers rely on direct rainfall, groundwater, occasional perennial and ephemeral streams and hill run off to irrigate their crops. The diversion of large spate flow rivers onto agricultural areas, called spate irrigation (and known locally as Rod Kohi irrigation in NWFP and the Punjab and Sailaba irrigation in Balochistan) is also practised in these areas.

Water harvesting is a term used to describe methods to enhance the quantity and reliability of rainfall water being delivered to the crop root zone. It may include field improvements to increase the infiltration and uniformity of infiltration of direct rainfall on fields to the root zone, the use of rainfall runoff water from adjacent micro catchments to supplement direct rainfall onto the fields, and the diversion of small streams (perennial or ephemeral) onto the fields. Water may be stored for use solely in the soil, or intermediate storage may be used in the form of ponds, check dams and reservoirs.

Water harvesting is synonymous with catchment management and soil conservation practices, since most water practices which harvest rainwater and cause it to infiltrate, rather than runoff, will also prevent soil erosion and can be integrated into a catchment management plan.

Chapters 2 to 11 of this manual set out a methodology for carrying out water harvesting programmes through the On Farm Water Management Project in Pakistan. Chapter 12 sets out some interventions which can be made to spate irrigation programes under the OFWM Programme. The manual is intended to provide a practical guide to field staff on these subjects.

1.2 Goals and Objectives for Water Harvesting

The goal of water harvesting projects is to:

> Manage water directly from rainfall for the production of field and tree crops and range grasses for livestock and human consumption in order to maximise farm income through improved sustainable productivity.

The objectives of the water harvesting projects are to:

- maximise infiltration and storage of water from rainfall in the soil to increase agricultural production;
- control run-off water from rainfall and store it for productive agricultural use;
- control soil erosion by integrating conservation practices into improved farming systems;
- minimize deficits in crop water demands and optimize water use efficiency;
- increase the productivity of farming systems including cropping sequences, forestry and livestock appropriate to specific socio-economic and cultural conditions;
- introduce appropriate farmer-tested technologies which can be readily adapted from a pilot area to larger area; and
- improve capabilities and practical skills of the field staff and the farmers.

The objectives of the spate irrigation programme described in Chapter 12 are to improve the efficiency with which water can be diverted from spate irrigation channels into fields and to improve the efficiency of irrigation application and crop production from spate floods.

1.3 Summary of Strategies

The following Chapters in this manual describe the application of a number of proposed strategies which can be used as part of an integrated catchment management plan in a typical sub catchment. A summary list of the strategies is given on Table 1.1 over, listed in terms of sub areas of the catchment for which each strategy might be considered.

Figure 1.1 shows a typical sub catchment which might be considered for a water harvesting project. Figure 1.2 shows the same sub catchment with potential water harvesting works superimposed on the typical sub catchment shown on Figure 1.1.

TABLE 1.1- SUMMARY OF ALTERNATE WATER HARVESTING DEVELOPMENT STRATEGIES

1. **Steeply Sloping Land**
   - 1.1 Erosion Protection
   - 1.2 Forestry Plantations on eye brow and reverse terraces
   - 1.3 Range Development

2. **Gently Sloping Land**
   - 2.1 Contour Terracing
   - 2.2 Grassed Waterways to control flow
   - 2.3 Pasture Development

3. **Terraced Land**
   - 3.1 Field Levelling (level or graded)
   - 3.2 Improvements to Field Bunds
   - 3.3 Field Spillways and Waterways
   - 3.4 Ridge and Furrow or Contour Furrows
   - 3.5 Improved Tillage Practices
   - 3.6 Development of Micro Catchments (where annual rainfall is less than 750 mm)
   - 3.7 Improved Farming Systems including development of rotations, improved varieties etc.

4. **Rainfall Regimes**

   Annual Rainfalls:

< 250 mm }	Develop Micro Catchments:
250-500 mm }	in Field- Field- Hill Runoff- Alternate
500-750 mm }	
> 750 mm	No additional catchment required.

5. **Eroded Land-Gullied**
   - 5.1 Check structures and other erosion protection structures

6. **Small Streams**
   - 6.1 Diversion Weirs and Channels
   - 6.2 Check Dams for Storage

7. **Depressions**
   - 7.1 Storage Ponds
   - 7.2 Reservoirs
   - 7.3 Check Dams

Figure 1.1 Typical Sub Catchment Suitable for A Water Harvesting Project

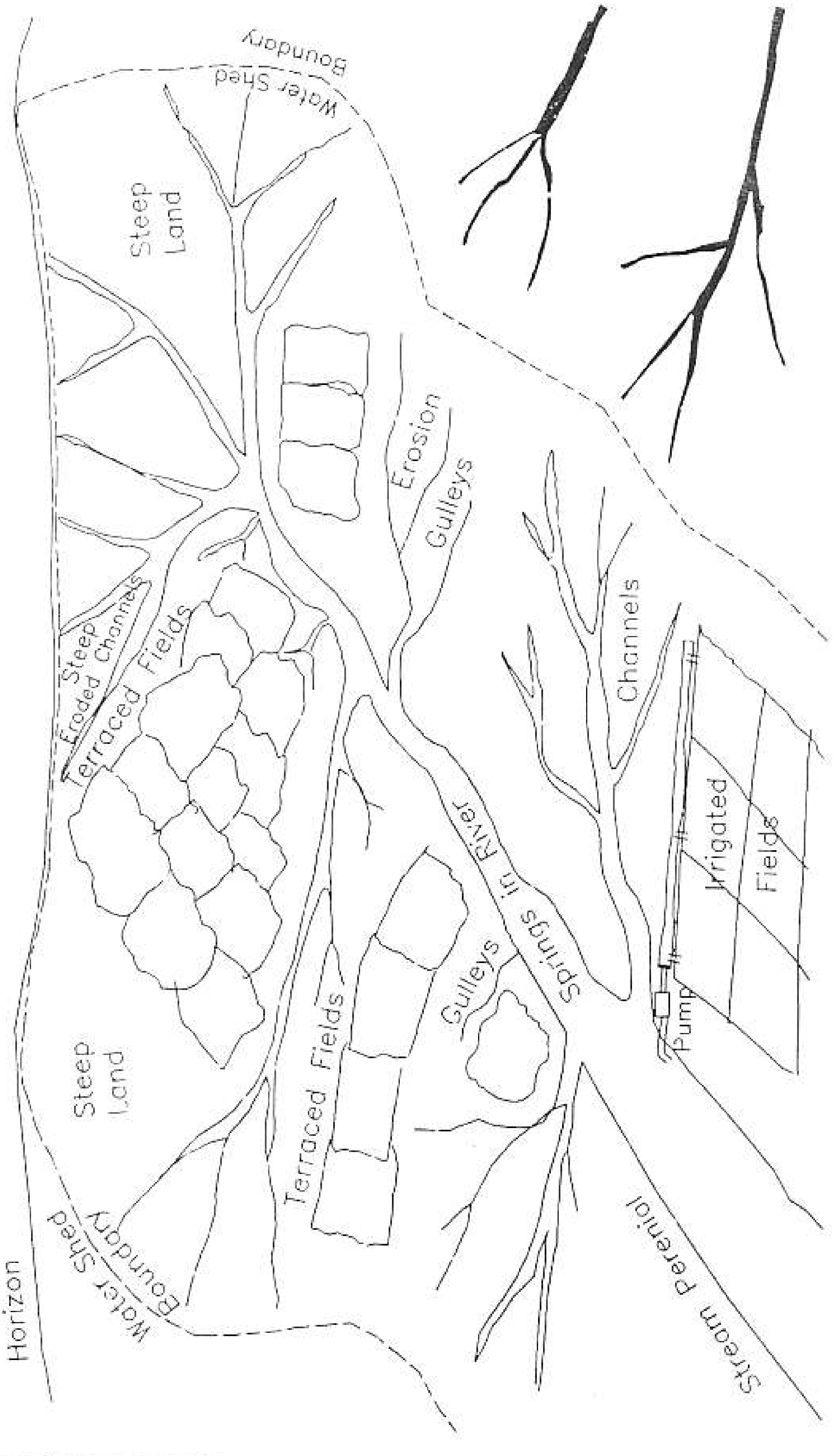
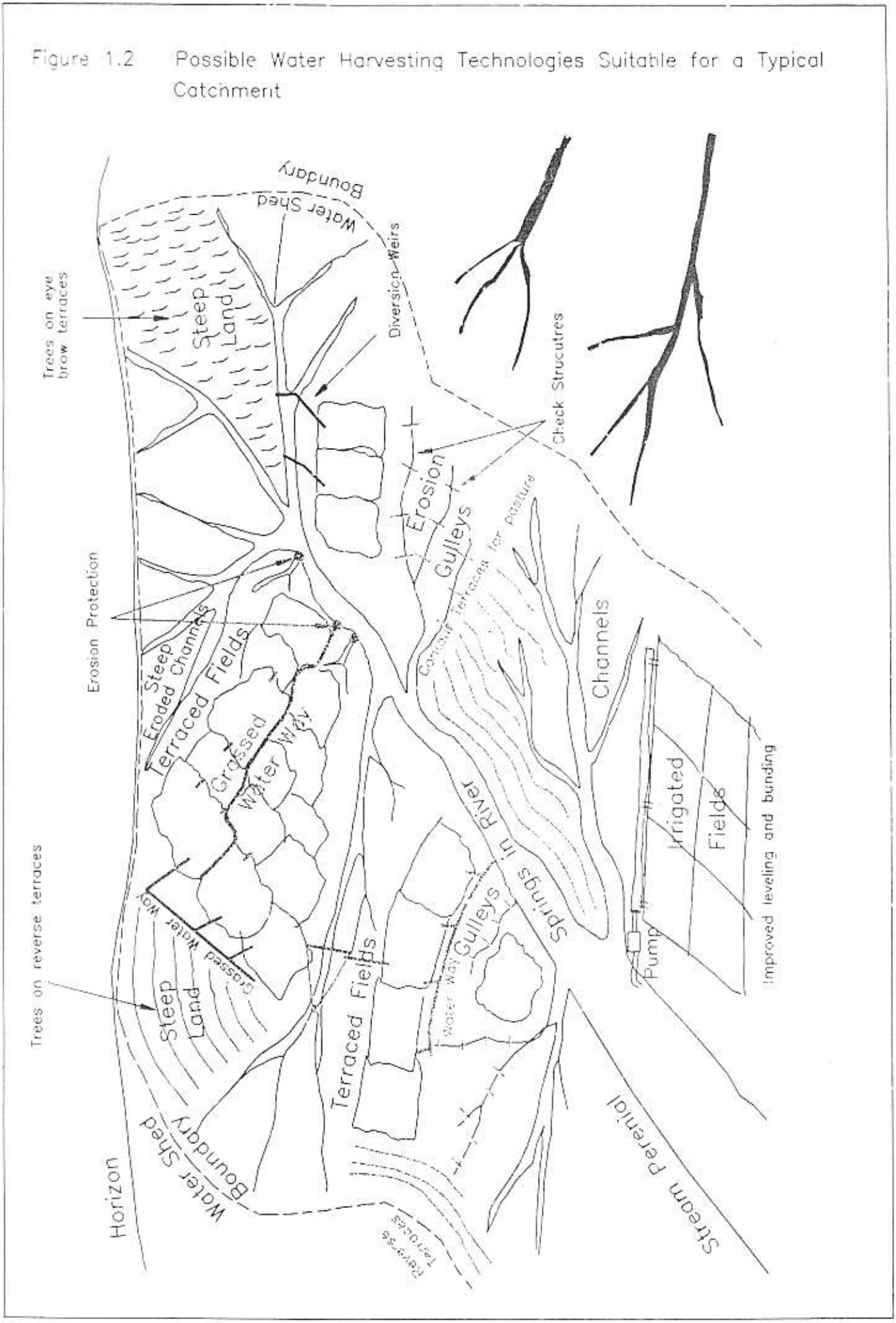


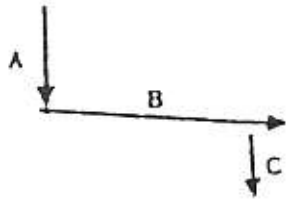
Figure 1.2 Possible Water Harvesting Technologies Suitable for a Typical Catchment



2. RAINFALL INFILTRATION VERSUS RUNOFF

When a drop of rainfall hits the ground, a physical impact occurs (see Figure 2.1). If the rain drop hits a bear earthen surface then a small explosion occurs as a result of the force of the inpact, loosening particles of soil and throwing the particles into the air. If the water is thereafter immediately absorbed by the soil, then no harm is done. However, if the water flows off the land, rather than being absorbed, then it will carry particles of the soil with it (Figure 2.2).

Fig 2.1
Raindrop Impact



A = rainfall
B = run-off
C = infiltration

Fig 2.2
Process of Erosion

An accumulation of such water and soil particles flowing down the slope will develop a strong scouring action which in turn loosens more soil particles, which causes erosion.

Where rainfall falls on a field and runs off rather than infiltrating, problems occur within the field and downstream:

- water which could have been used for the irrigation of crops in the field is lost to the field;
- soil is lost from the field causing both a loss of soil for future cultivation and erosion gullies in the field;
- erosion of downstream fields and waterways results;
- increased runoff causes increased flooding; and
- soil deposited in downstream rivers causes siltation and increased meandering problems and in downstream reservoirs causes loss of storage capacity.

The degree to which rainfall infiltrates in the soil where it lands, or runs off, depends on the following factors:

- the total volume and intensity of the rainfall. The more rain and the higher the intensity, the more will runoff;

- the soil type, infiltration into clayey soils is very low. Infiltration into silty soils is also low, also due to the low cohesive and shear strength of such soils they are very erosive and easily carried away by flowing water. Sandy soils have higher infiltration rates and also higher shear strengths and are more difficult to erode;

- the condition of the soil also affects both its ability to infiltrate moisture and erodibility. A compacted soil will have a low infiltration rate and due to its flat surface water will rapidly flow off it. A well cultivated soil will have a higher infiltration rate and will, due to the undulations on the surface, pond water for later infiltration;

- the degree of vegetation. Vegetation prevents runoff in two ways, firstly the vegetation takes the impact of the rainfall slowing its fall and allowing it to drop gently onto the soil with less erosive force. Vegetation also prevents runoff by ponding water up around its stalks and leaves on the ground (Figure 2.3);

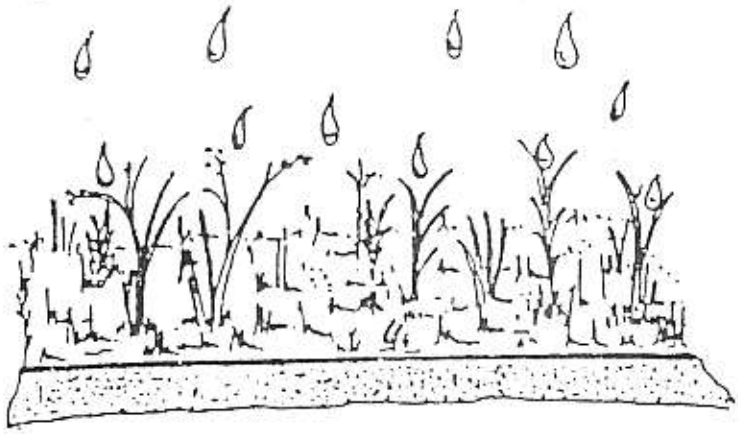


Fig 2.3
Vegetative Cover

- the slope of the land is most critical. level land allows the water to pond on the surface and infiltrate at a later time, following the rainfall. The steeper the land the more easily the water will runoff; and

- the way the land is cultivated and/or bunded and the size of each field are also important. A field which has been cultivated across the slope will pond water between the furrows, if cultivation has taken place down the slope then the furrows will form natural water channels down which the water and eroded soil particles will flow, causing increasing erosion as they flow. Similarly bunded terraces will pond water and prevent excess water from flowing off.

On large unlevel fields water will flow to low points causing erosion. On small fields this will probably be less and the water will infiltrate more evenly.

The interaction between the above factors and the degree of runoff and soil loss are shown on Table 2.1.

Table 2.1: Conditions for high and low runoff and erosion

CHARACTERISTIC	Low Runoff and Erosion	High Runoff and Erosion
Rainfall Intensity	Low	High
Soil	Coarse	Fine
Slope	Level/Shallow	Steep
Vegetation	Dense	None
Land Formation	Terraced or contour furrowed	Natural or down the slope cultivation
Tillage	Deep	Compact

Experiments on small (10 m^2) catchments near Fatejang in the Potwar region of the Punjab, by NARC, showed the following percentages of annual runoff for different surface conditions in the catchment. The relationship between the percentage of runoff and surface cover and slope is very clear.

Table 2.2: Average Annual Surface Runoff Data (1983-88) Collected at Fatehjang Sub-Watershed.

Surface Cover	Surface Gradient %	Annual Runoff %		
		Average	Min	Max
Fallow	1	47.4	17	78
	5	52.8	28	73
	10	56.4	33	70
Cropped	1	39.2	13	70
Wheat/Maize	5	46.2	22	69
	10	51.2	26	69

The objective of water harvesting is to reduce runoff and soil erosion and to increase the infiltration of water into the soil for the benefit of crop growth and for deep percolation to groundwater. Figure 2.4 shows the effect of different forms of

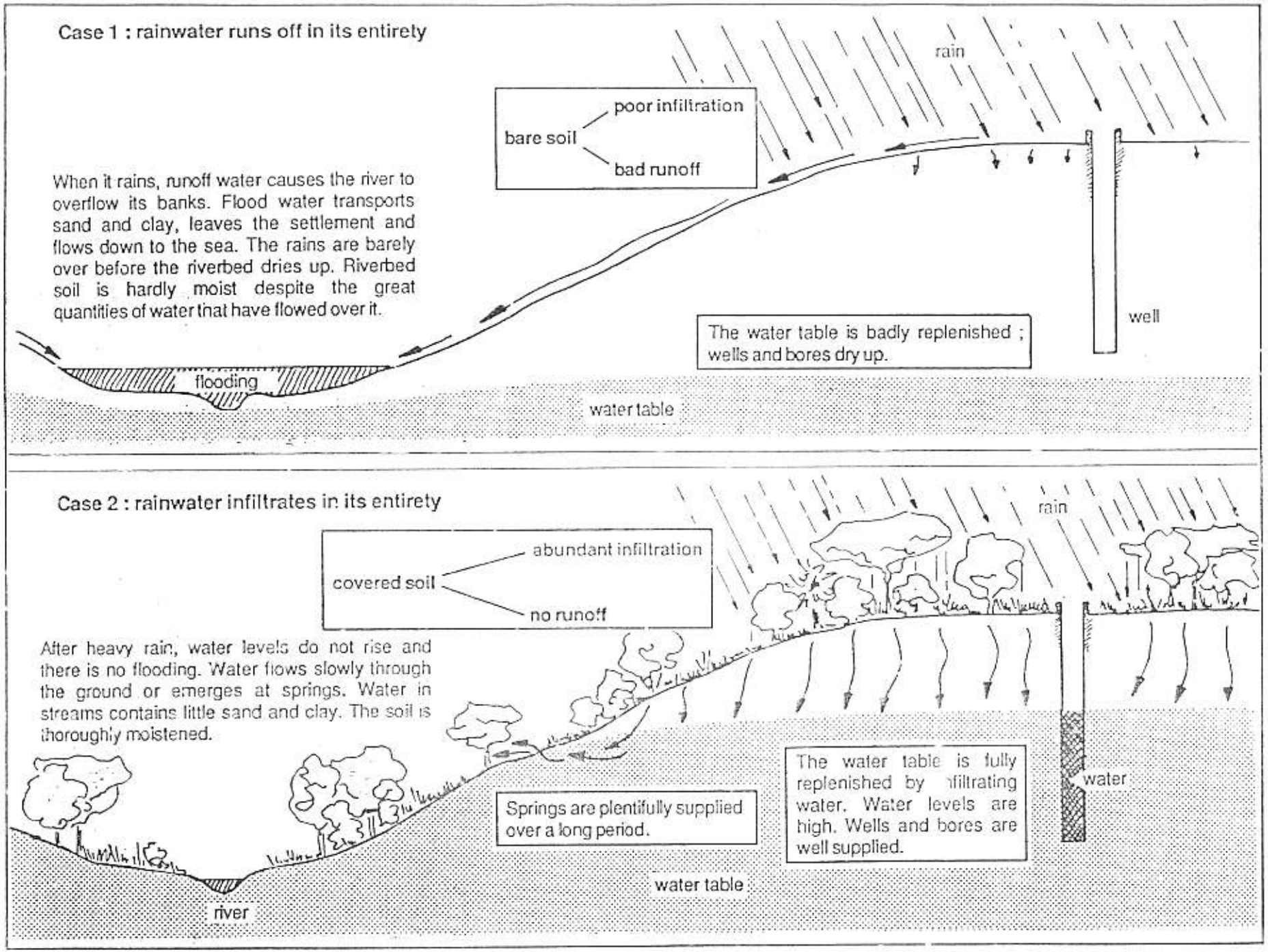


Figure 2.4 Alternative Runoff Conditions

catchment management of infiltration, runoff and erosion. The following chapters of this manual describe suitable strategies for achieving this in different climatic and land form conditions.

All the technologies proposed in the following chapters involve increasing the storage of water either in structures, on the field or in the soil profile of the field. Water harvesting schemes are designed to increase the water available to the crops during lower than average rainfall conditions. Danger occurs when very heavy rainfall events occur since the water harvesting scheme will tend to also try to store the water from such events and it is likely that the storage capacity of the field or pond will be inadequate for this and the system will overflow. Such events, unless the system is properly designed to accommodate them, can be highly damaging and cause extensive runoff and erosion since structures and bunds may rapidly overtop and erode causing all the ponded water to flow out in one go and hence causing massive erosion. Water harvesting schemes must therefore be designed to store water up to a certain design level, and also to pass flows above this in a managed non eroding manner through the system.

3. IMPLEMENTATION STRATEGIES

3.1 Introduction

The implementation process for developing a Water Harvesting project consists of the following four phases:

- **Selection Phase,** consisting of site selection.
- **Preparation Phase,** consisting of social preparation and organisation of the farming community, the topographical survey and a rapid rural survey.
- **Planning Phase,** consisting of developing a Land Use Plan, design of interventions which include civil works, agronomy, forestry and livestock, the budgets, cost sharing arrangements and the monitoring and evaluation of the project.
- **Implementation Phase,** consisting of executing the Land Use Plan developed during the preparation and planning phases. This involves makng an Action Plan, the management of its execution, linkages with other organisations and training of staff and farmers.

The actions in each of the four phases of the development of a Water Harvesting project are described below.

3.2 Site Selection

The Staff in each Field Team will select sites for the Water Harvesting project. The following selection criteria are recommended:

1. The project site should be an individual catchment unit of 200 to 300 ac.
2. The catchment unit should have a clearly defined crest at the head being the source of run-off and a stream at the tail receiving the surplus run-off. The catchment may be a sub-catchment of a larger catchment area.
3. There should be several types of land represented in the site, some steep slopes, some gentle slopes and some almost level land. There should be some fields with a good depth of soil with reasonable slopes that would immediately benefit from water harvesting techniques.
4. There should be social harmony, interest and willingness to cooperate presently existing among farm families at the site and this should also be evident in their recent past history.

5. Farmers should be dependent on their barani lands and interested in investing in them. There should be a low number of absentee landlords among the farmers, most of them operating their barani lands.

6. The farmers and their families who will benefit from the project should want to organise themselves into a WHA, agree to the terms and conditions to receive project assistance and actively participate in the development of the site.

7. There should be easy access to the site by staff and machinery for promotional and development activities.

3.3 Social Organisation

The aim of Social Organisation for a community interested in Water Harvesting is to take responsibility for their own development of Water Harvesting activities. This will need:

1. the community to understand the problems associated with water loss through uncontroiled run-off when it rains in their catchment area. They will need to also understand the possible ways of preventing run-off losses through water harvesting techniques;

2. the formation of a WHA with members who have a common interest in participating and taking responsibility for the planning and management of the water harvesting development in their catchment area;

3. the WHA to develop a plan for developing water harvesting with goals, tasks, an action plan and the delegated responsibilities; and

4. the links and coordination between the WHA and development agencies, such as the OFWM, the Department of Extension, Forestry Department, Livestock Department, the Department of Soil Conservation and the National Agricultural Research Centre (NARC).

Chapter 4 below gives more details on the development of Water Harvesting Associations (WHAs) for each Water Harvesting site.

3.4 Area Appraisals

The Area Appraisal (AA) is a survey of the entire Water Harvesting site and the farm families who use the land in the sub-catchment being developed. The AA consists of the following aspects:

- A description of the **Farming System** being practised.

- A description of the **Natural Resources** that are being used, including rainfall, soils, slopes and area.

- **Baseline Data** that describes the productivity of the Farming System before the Water Harvesting project starts.

The description of the Farming System reports how the farmers are farming in each season, the problems they are facing and some of the possible solutions that the Field Team could apply in the Water Harvesting project.

The description of the Natural Resources will include rainfall (historic data from nearest station showing probable rainfall, evapotranspiration and storm intensities), soils survey of each site showing depth, slope, texture and fertility (farmers' perception as well as lab tests).

The Baseline Data will be used to compare the productivity of the farming system before and after the various interventions of the Water Harvesting project are practised. This will help in the monitoring and evaluation aspects of the project.

Appendix C contains a sample survey form for the Area Appraisal.

3.5 Topographical Surveys

Each Field Team will conduct a topographical survey of its Water Harvesting project. The resulting map will show horizontal distances and elevations of the entire area of a Water Harvesting site, including cultivated, uncultivated steep land and streams. The team will use a scale of 1:1,000 for the map.

The Field Teams will survey barani terraces to show spot levels at the corners and the centre of each field. The teams will show the boundaries of each field using the centre-line of the bunds as the boundary. In those fields where the farmers wish to zero-level or do some minor levelling, the team will survey the field using a 10m grid. The team will survey steep land by showing contours at regular intervals. On steep land with more than 5% slope, the contour interval will be two metres and on moderate slopes (upto 5%), the interval will be ½ metre.

Field Teams will use the topographical sheets presently used for surveying watercourses and the M&E sites. Field Teams will put the same information on the maps as presently done for each watercourse; the name of the village, name of Field Team, name of Area Team and Province. The name of the surveyor, the signatures of the person who checks the survey and the Field Engineer. The team will use the same legend and symbols on the map as used for the watercourses.

Normally, the maps produced by Field Teams will be digitised on a computer so that areas and Land Use Plans can be superimposed onto the map. Field copies of the map will be easy to generate so that the Field Teams and the members of the WHAs will be able to work with maps of their area.

3.6 Land Use Plan

Land Use Plans are developed for each Water Harvesting scheme with the farmer members of the WHA. These are put onto topographical maps produced by surveys conducted by the Field Team. The Land Use Plan or Development Plan is put onto the maps as Land Types and their use. These Land Types are described below:

1. Barani Crops on existing terraces,

2. Land on gentle slopes (<15%) that could be converted into new terraces for barani crops or fruit trees,

3. Forest and Range land on steep slopes (>15%) for afforestation.

4. Irrigated land, either presently used or potentially could be used.

5. Wasteland with Rocky outcrops,

6. Wasteland with Wetlands, (swamps, marshes).

An example of a map of a typical Water Harvesting scheme is presented as Figure 3.3. This shows the land types and their potential use as a Land Use Plan or Development Plan on the map of the scheme.

The barani fields will be developed with improved agronomy practices for barani crops and associated civil works, including zero and graded levelling, spillways, waterways and strengthened bunds (see detailed list in Table 1.1).

The sloping land will be used for tree and range grasses using eyebrow terraces, reverse terraces and so on.

Irrigable soils which are deep and fertile will be used for irrigation of the farmers' choice of crops, such fruit, fodder and vegetable production, if water can feasibly be conveyed to these soils and applied to them.

The farm families in the project site will participate with the Field Teams in drawing up the Land Use Plan.

The Field Team will integrate all the possible uses of the land into one plan. Hence the project will help farmers improve their food crops, grazing, fodder crops, trees and range grasses for livestock and trees for fuel and commercial uses.

The Field Teams with help from the consultants will design the agronomic and engineering interventions specifically for each water harvesting site and for each land type in the site.

The Land Use Plan is then developed into an Action Plan, which will include estimates of costs, quantities and a timeframe with deadlines.

3.7 Action Plans

Action Plans (APs) are developed for each Water Harvesting scheme so that the work is given direction and focus. The APs are based on the Land Use Plans/Development Plans that are on the maps. The APs quantify the Land Use Plans as targets for each activity in terms of acres, numbers or metres. The APs give cost estimates and describe how the budget is to be used and the timeframe for reaching the targets. Often targets, estimates of costs and the timeframe need to be revised after a period of field experience. In this case, a Tentative Action Plan (TAP) is drawn up at first, which is revised into a Revised Action Plan (RAP) once the estimates of costs are more definite. Each province should appoint a "Rates Committee" responsible for determining cost estimates for the different activities in the Land Use Plans for Water Harvesting schemes.

A typical Action Plan is shown in Appendix D for the Kot Kohlian site, Rawalpindi. This based on the Development Plan shown on the map Figure 3.3.

Implementation of the Land Use Plan by the Field Teams will include earthworks (levelling, strengthening bunds, deep tillage, earthwork when needed in support of a hydraulic structure), planting barani crops, afforestation, planting range grasses and construction of civil works (spillways, waterways, structures to prevent erosion of gullies, check dams and so on).

Field Teams will arrange for the construction of the civil works designed according to the Land Use Plan. They will use the same procedures as for the watercourses in arranging contractors, applying for reimbursements and so on. The Field Engineers will verify the construction at each site. Those other activities for which there is a subsidy, such as afforestation, planting range grasses, deep tillage and earthworks will also require the verification by the Field Engineers.

3.8 Management of the Water Harvesting Site Development

The management of the site should be at two levels:

- **Coordination level** at the OFWM office. The Director in each province will coordinate the implementation of Water Harvesting sites together with his Water Management Coordinators or Deputy Directors in charge of Field Teams. There should be regular coordination meetings and monthly progress reports at Director level. Consultants and representatives of the other agencies involved with similar work should participate in this coordination and provide technical assistance. Consultants should arrange training of staff and members of the WHAs as required.

- **Field level** through the Area Team's office. Members of the WHA should be prominent in the management of the site at the field level together with staff members of the Field Teams. Participation of the WHA in the management and progress of the project will promote their feeling of ownership and will help sustain the development. Each Field Team will submit a monthly progress report to the Director's office.

A sample of a Progress Report used by the Field Teams is presented in Appendix E.

Management of each site should also promote the linkages with other agencies involved in the same type of work. These agencies include the Agency for Barani Areas Development (ABAD), the National Agricultural Research Centre's (NARC) Water Resource Research Institute (WRRI), the Department of Soil Conservation, Department of Forestry, Department of Extension and the Barani Agricultural Research Institute (BARI), National Rural Support Programme (NRSP), Balochistan Rural Support Programme and other agencies and projects involved such as the Social Forestry projects in NWFP and the FAO Catchment Development Project in Balochistan. The development of links with these other agencies and projects should be coordinated by the Director's office in each province together with help from consultants.

3.9 Work Plan

A Work Plan is to guide the Area Teams (ATs) and Field Teams (FTs) in the the implementation of their particular Water Harvesting scheme. The Action Plan guides the Field Team and the members of the WHA in implementing its Land Use Plan developed for each particular Water Harvesting scheme. The Work Plan should be developed by each Director in each Province to coordinate and give targets for all Field Teams under his control in the development of the Water Harvesting programme at Provincial level. Technical Assistance to help carry out the Work Plan should be provided by consultants and other agencies doing similar work. Each

aspect of the Implementation Process is included in the Work Plan. Dates are defined in the plan. In this way, progress can be measured against the plan for each site. Figure 3.1 presents a bar chart of a typical Work Plan for developing a Water Harvesting site.

The Implementation Process is also presented in the flow chart shown on Figure 3.2. This shows the flow of activities from site selection to the actual implementation of the Water Harvesting project. The whole work plan should largely be completed for all sites in time to harvest the first monsoon rains. Afforestation may spread over several seasons because of the need to restock after every six months or a year following mortality of the trees.

FIGURE 3.1 Work Plan for ATs and FTs for Developing Water Harvesting Projects

ACTION	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1. SITE SELECTION • Initial selection. • Farmers' meetings. • Site boundaries and list of farmers. • Submission to Director.												
2. SOCIAL ORGANISATION • Introductory meeting with farmers. • Identify leaders. • Meetings to clarify objectives, scope, subsidies, cost recovery. • Registration of WUA. • Formulation of bye-laws. • Agreement; WUA and OFWM. • Copies of agreement to Director.												
3. RAPID RURAL APPRAISAL • Situation analysis on proforma provided. • Base-line data on proforma provided. • Data on rainfall, evaporation and soils.												
4. TOPOGRAPHICAL SURVEY • Map of Water Harvesting site at 1:1,000. • Digitise map.												
5. LAND USE PLAN • Use map to make Land Use Plan, with participation of farmers. • Colour print Land Use Plan												
6. IMPLEMENTATION • Construction of pucca structures. • Earthworks, levelling, bunding, deep ploughing, to support structures. • Tree Planting • Verification of reimbursable costs												
7. MANAGEMENT • Coordination meetings at Director's office. • Progress report proforma for each site. • Field Meetings; ATs, WUA and Field Engineer to monitor and verify.												

Figure 3.2

IMPLEMENTATION PROCESS

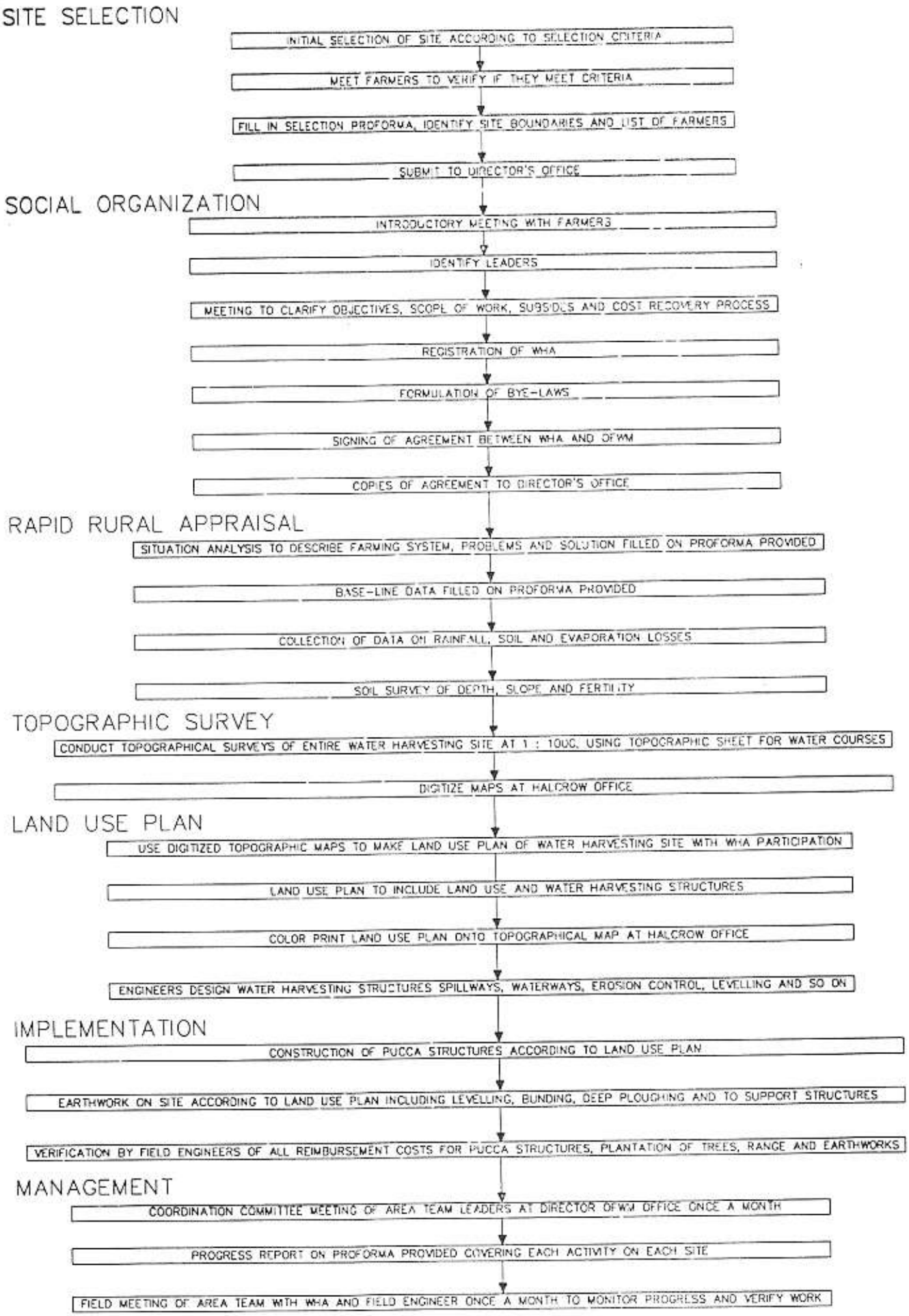
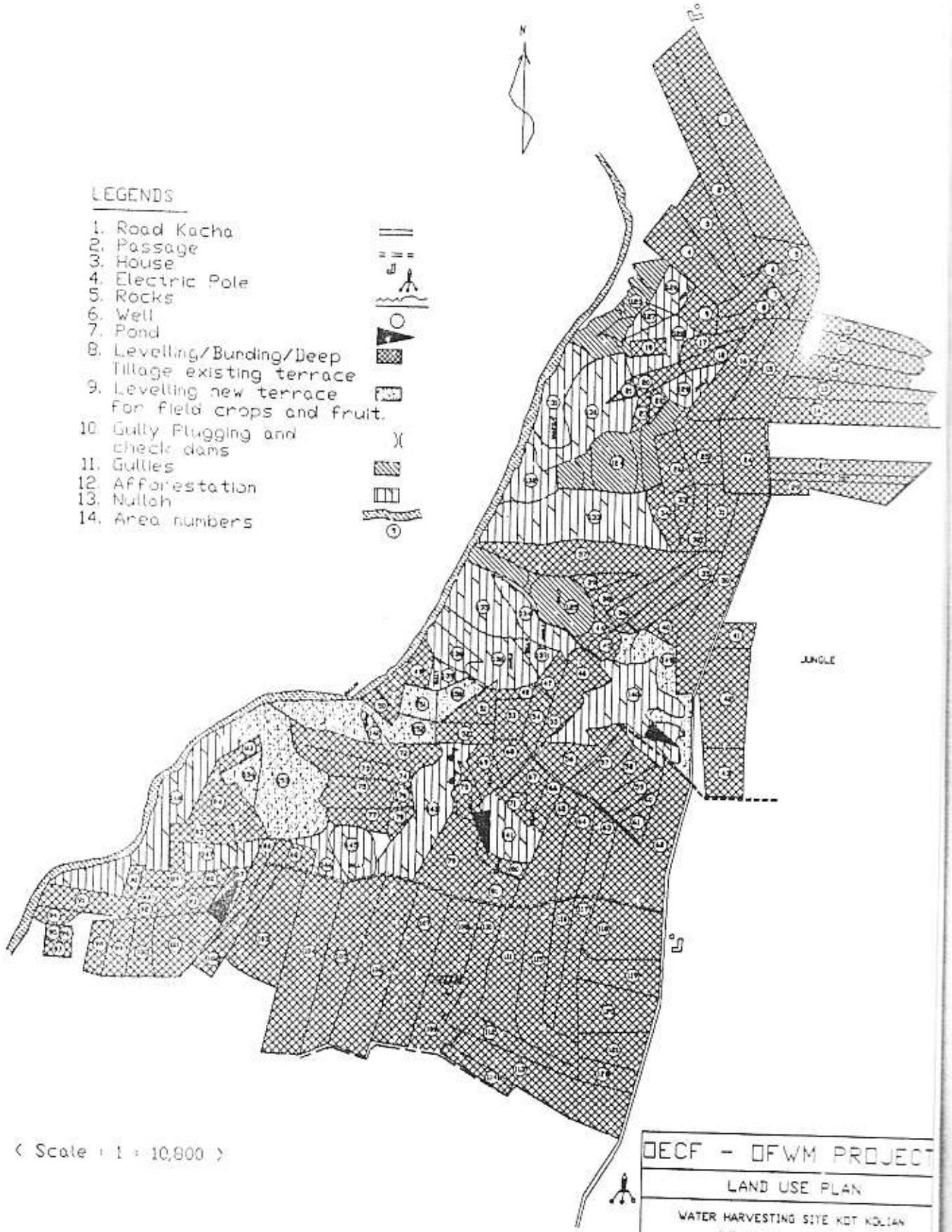


FIGURE 3.3 : EXAMPLE OF A TOPOGRAPHICAL MAP SHOWING LAND USE PLAN

TOPOGRAPHIC MAP OF WATER HARVESTING SITE KOT KOLIAN F-T RAWALPINDI



(Scale : 1 : 10,800)

DECF - DFWM PROJECT	
LAND USE PLAN	
WATER HARVESTING SITE KOT KOLIAN (Field Team Rawalpindi)	
Field Area numbers	DATE: Jun 1995

4. COMMUNITY DEVELOPMENT

1. Farmers need to understand:

   - The concept of water harvesting
   - How they have to participate
   - What it will cost to them
   - What benefits will accrue to them

   A new technology is adopted in reference to its relative advantage, its complexity of operation, its compatibility with values and observability of its results.

2. For imparting knowledge about a concept or a thing, the change agent must know how to communicate with his clients. For a successful communication it is imperative that the change agent providing information is:

   - knowledgeable
   - easily accessible
   - reliable
   - competent in the local language
   - empathic

3. For the purpose of organisation:

   - Contact everybody among the prospective beneficiaries.
   - Everybody must know what you are there for.
   - Identify factions if any. Approach each one at an equal level.
   - Unless the factional tendencies are too severe, the representative from each faction can be made to sit at one conference table. Let them decide how they would like to operate for a common and collective goal in reference to issues related with water harvesting activities.

4. Identify leaders through a Sociometric technique, i.e. by asking questions to randomly selected individuals "Whom would you go to for consultation or advice on farm or family matters". These individuals can then be ranked according to the number of choices they receive as consultants or advisors. The villages inhabited by small and medium size farmers, the leadership and power or influence is not concentrated into few hands. However, the following attributes of leadership still hold valid in most village situations:
   - Leadership roles are performed by dominant castes
   - Leadership flows from one situation to another
   - Informal leadership is a potent force

- Land ownership and good economic standing are important factors
- Among personal attributes, the common basis are free time, honesty, popularity, effective looks, ability to settle disputes, reputed family and contact with government officials.

5. Act as a catalyst for :

   - arranging farmers meetings
   - organisation of task committees
   - making farmers understand the rules of forming a water users association for water harvesting

   Refrain from influencing the decisions being taken by the farmers in anyway.

6. Rules for forming an association for water harvesting:

   Unlike the canal irrigated areas the barani area farmers are not bound by any restrictions like the fixed warabundi system. Also it is not mandatory for all in the given area to become members. Any common interest group can form an association. Nevertheless,

   - It remains a pre-requisite for starting any development activity
   - The WUA Ordinance of 1981 does not have provision to register an association for water harvesting. Rather, two agreements, one among the farmers themselves and one between the farmers and the OFWM Dept will be instrumental in mobilising farmers. (See Appendices A & B for Sample Agreements in English and Urdu).
   - Cost recovery is to be determined as per government or Project.
   - A management committee is to be elected through mutual consensus of the registered members or through a secret ballot
   - The development work done will be looked after by the association

7. Notwithstanding the legal provisions, there will be no blame on you, if you rely on the existing informal patterns of decision making prevailing in the community. Intervene as government official if it is unavoidable for you. But be recognised by all as just and fair. Traditions as against written rules may be more effective in some situations.

5. LAND DEVELOPMENT

5.1 Introduction

In Pakistan's barani area much of the land is already divided and cultivated as terraced fields. A number of improvements can be made to the layout, use and cultivation of such fields. In addition further land can be brought into production by the development of new terraces for the production of field crops, trees or pasture. Typical improvements which might be considered include:

- improved levelling (see section 5.2 below) in order to improve the uniformity of infiltration and crop production;
- the development of new terraces for field crop, tree and pasture production and for soil conservation (see Section 5.3 below);
- improved bunding in order to provide for a greater depth of flow that can be ponded and greater security (see section 5.5 below);
- development of spillways and waterways to convey excess flow safely away from the fields and through the system (see Chapter 7 below);
- improved tillage practices to improve infiltration, reduce bare soil evaporation and provide an improved environment for the crops (see section 5.6 below);
- development of micro catchments to deliver additional flow to the terraces, particularly where average annual rainfall is less than 1000 mm (see Chapter 6 below); and
- agronomic improvements, improved seed, inputs, rotations and farming systems (see Chapters 9, 10 and 11 below).

5.2 Levelling

Many existing barani terraces are not levelled, this results in water ponding and infiltrating at low points in the field during rainfall events, resulting in uneven crops due to uneven infiltration. Field levelling will improve uniformity of crop growth.

Disadvantages of levelling existing terraces are:

- it is expensive, since quite large volumes of earth have to be moved;
- where soil depth is limited, this is not an option. Auger holes should always be made to ensure that sufficient depth of soil (in excess of 1m) will still be available all over the field following levelling; and
- levelling ploughs the top soil into the profile, removing the natural fertility of the top soil from the crop. Fields can thus take about three years to recover from levelling operations, during which time lower yields can be expected.

As an alternative to land levelling, considerable improvement can be made by ensuring that the field is cultivated across the slope, thus ensuring that water is trapped in each furrow and cannot flow to the low points (See Section 5.6 below).

Where levelling is proposed to be undertaken, the maximum cut allowable should be 30cm. Fields should be levelled either with no slope or can be levelled with a small (up to 2%) slope either towards the field bund or away from it.

Calculation of the average field level and setting out for land levelling should be undertaken as described in Volume V "Land Development" of the OFWM Field Manuals.

Terrace levelling will normally be undertaken using a tractor towed scraper. Either a drag scraper or a laser controlled bottomless scraper would be suitable.

5.3 Terracing

This Section is largely taken from "Land Development Techniques For Soil and Water Conservation in Gullied Areas of the Potwar" by Mohammad Shafiq et al of NARC dated 1986 and "Soil and Water Conservation Training Modules" by MD Dawson and Shahid Ahmed for ABAD, 1994.

Since terracing requires an additional investment and also requires changes in farming systems it should therefore only be considered where other cropping or soil management techniques (singly or in combination) will not provide adequate control. The reasons for developing terraces for the proper conservation and utilization of water are:

- Increasing the time of water infiltration into soil profile and thereby allowing more runoff to be retained by the soil;
- Intercepting a long slope into several short ones so as to maintain less than critical velocity for runoff water; and
- providing protection against damage resulting from excessive runoff.

In order to determine the most suitable development form and utilisation of a particular piece of land, detailed contoured topographic surveys and land use plans must first be developed as detailed in Chapter 3 of this manual. Following this the most appropriate form of development from amongst the following techniques may be considered for development of the land

5.3.1 Land Development for Field Crops

Field crops are usually cultivated on Contour Bench Terraces. Large areas with regular gentle slopes can be developed as wide contour bench terraces for crop production.

Figure 5.1 shows 4 different types of bench terraces:

Level Bench Terraces are the most common type found, particularly in the higher rainfall barani areas, where no run on or run off is required. In the highest rainfall areas, spillways are required between the terraces as discussed in Chapter 7.

Outward Sloping Terraces are not recommended since severe erosion can take place down the face of the terrace.

Conservation Bench Terraces are most suitable for low rainfall areas, where a part of the land is used as a catchment area and part of the land is used for production. The ratios of catchment to productive area suitable for different zones are discussed in Chapter 6 below.

Reverse Sloping Terraces are suitable for intermediate rainfall areas. They are very stable because the water is ponded on the cut side of the terrace. They are not suitable where runoff is proposed from a supplemental catchment or in conjunction with spillways in high rainfall areas, unless spillways are developed from the side of the terrace.

When designing bench terraces, the following should be considered:

- In order for the terrace to be constructed from a balance of cut and fill (i.e. no soil is required to be imported or exported), the line of the original ground will intersect the middle of the terrace. Soil will then need to be moved from above this line to below the line.

- Cuts should be kept to a minimum, both to reduce the cost and to reduce the amount of sub soil which is exposed. Terraces should normally be designed with a maximum cut of 0.3m, although higher cuts will be required through small areas of high land and may have to be taken in order to get a wide enough terrace in steep areas.

- The vertical interval between terraces (VI) is dependent on the slope of the land and local factors. The VI suitable for an individual location should be calculated using the following equation:

$$VI = 0.3 * (XS + Y)$$

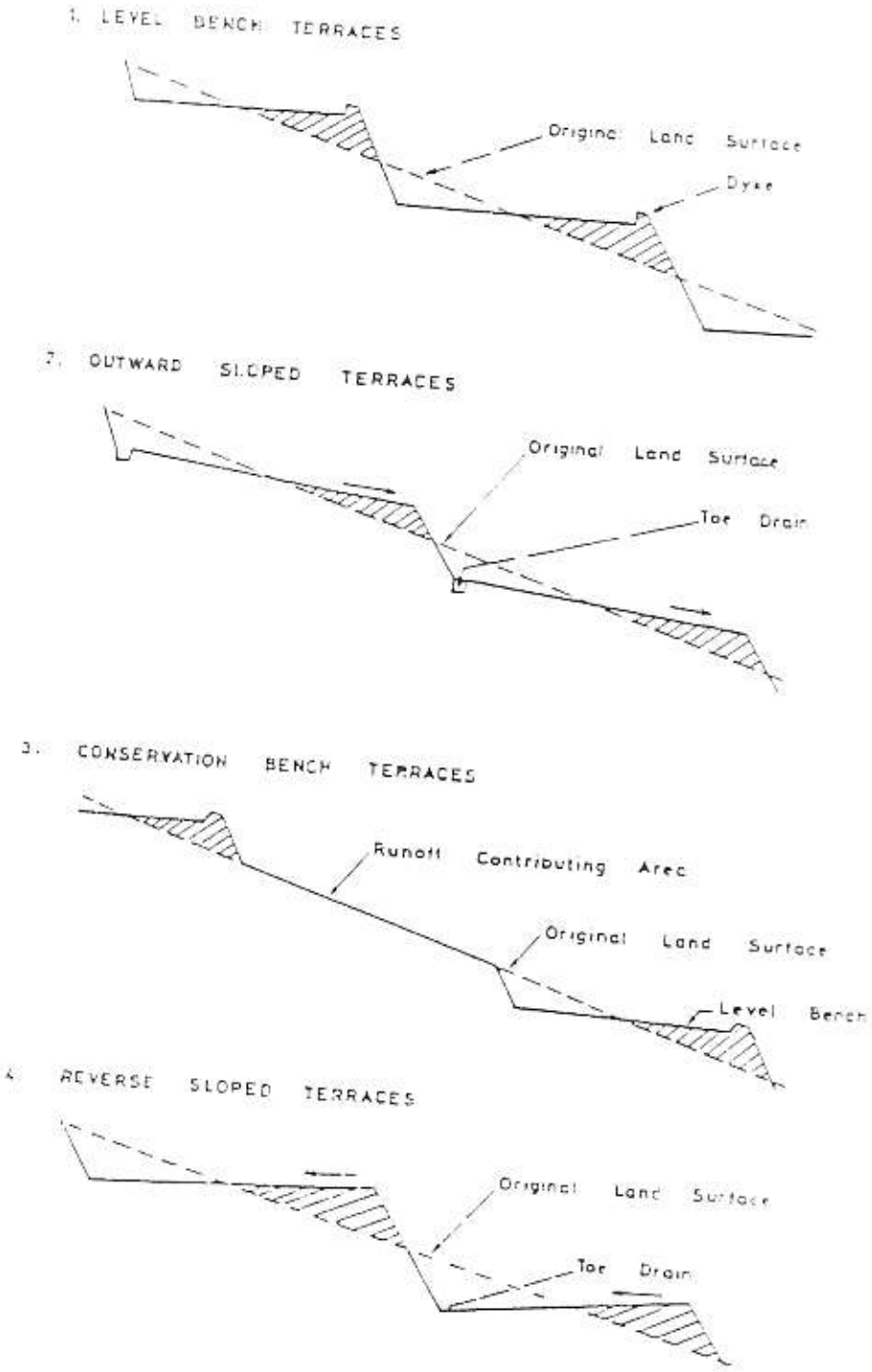


FIGURE 5.1 Types of Bench Terrace

Where: S is the slope of the land expressed as a percentage.
X is a rainfall factor, as follows:
Scanty rainfall less than 640 mm/year, X = 0.8
Moderate rainfall between 640 and 900 mm/year, X = 0.6
Heavy rainfall over 900 mm/year, X = 0.4
Y is the infiltration and crop cover factor determined from the following:

Intake rate	Crop cover during Erosive rainfalls	Y
Below average	Low coverage	1.0
Average or above	Good Coverage	2.0
One of the above favourable and the other unfavourable		1.5

- The width of a terrace (W) will be the vertical interval (VI) divided by the slope of the land (S) expressed as a decimal. Hence for terraces with a vertical interval of 0.6m:

Slope = 2% (0.02) terrace width (W) = 30m
Slope = 5% (0.05) terrace width (W) = 12m
Slope = 10% (0.10) terrace width (W) = 6 m

As can be seen on the steeper land the width of the terrace is becoming too small and for slopes of above 7% a 1 m vertical interval will be required for which:

Slope = 7% (0.07) terrace width (W) = 14m
Slope = 10% (0.1) terrace width (W) = 10m
Slope = 12% (0.12) terrace width (W) = 8.3m

- The height of the bund should be the equal to the depth of water proposed to be stored in the bund, plus a generous freeboard. The depth of water should normally be 0.2 to 0.3m. A freeboard of 0.3 to 0.4m is proposed, giving a total bund height of 0.6m on the upstream side and (for a VI of 0.6m) a height of 1.2m on the downstream side. In order to give a safe seepage gradient through the bund, a cross section as shown on Figure 5.2 should be adopted.

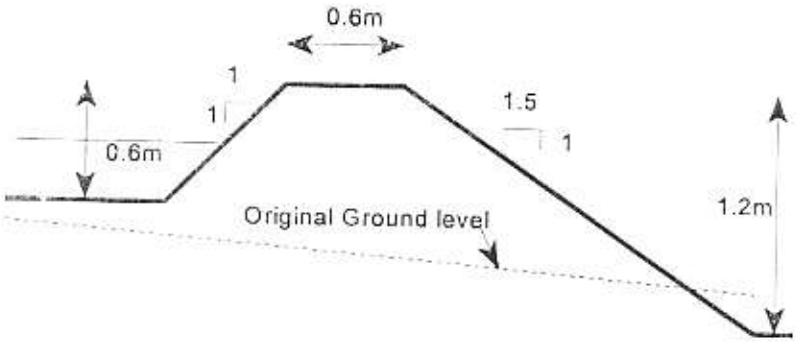


FIGURE 5.2 Cross Section Through a Terrace Bund .

- During construction the bund should be well compacted by keeping the soil moist and rolling it in layers as the bund height is increased.

- Micro catchments to supplement the flow to terraces should be designed as per Chapter 6, whilst spillways between terraces and to waterways should be designed as per Chapter 7.

5.3.2 Land Development for Bushes, Trees and Soil Conservation

The side slopes of gullies are usually too steep and are not suitable for utilisation under crops or Pasture. Moreover, such areas can not be economically developed for crops. Steep landscapes should be terraced for bushes, trees and in order to conserve soils using the following techniques:

a. Eye brow terraces
b. Microcatchments
c. Contour trenches
d. Reverse slope terraces
e. Orchard terraces.

(a) Eye Brow Terraces (Fig. 5.3)

The eye brow terrace is a small terrace usually on a steep slope, designed to support an individual tree or bush. Terraces are placed along the contours with their convex shaped ridges constructed on the down-hill side. The distance between terraces should be just less than the width of a terrace. Alternate lines of terraces should be constructed out of phase from one another so that each terrace catches the water flowing from the area between each terrace in the line above. Eye brow terraces should have a reverse slope towards the hill side.

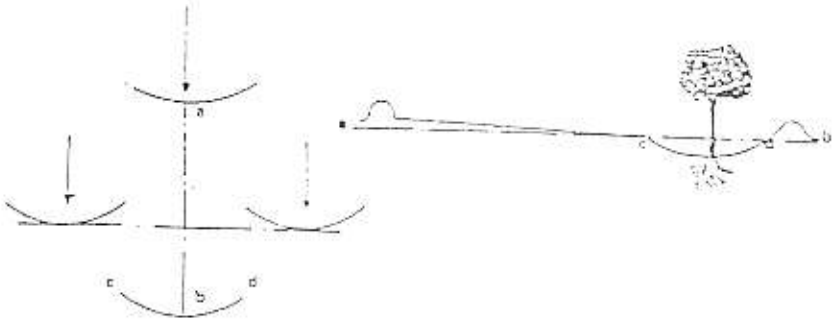


FIGURE 5.3 Plan and Cross Section of an Eye Brow Terrace for Trees/Orchards. Arrows Indicate the Direction of Runoff Flow.

(b) Microcatchments (Fig 5.4)

While eye brow terraces are particularly suitable for growing individual trees on steep slopes, individual micro catchments are suitable for growing individual trees on shallower slopes.

Diamond shaped micro catchments are bunded up across the area, with the diagonal of the catchment pointing down the slope. The arrows on figure 5.4 show the direction of flow. In high rainfall areas squares of 4 by 4 m may be used rising to squares of 30 by 30 m in areas of very low rainfall. The cultivated plot C-D is placed at the lowest point of the natural terrain within the micro catchment. The bunds should be at least 0.2 m high. The cultivated area should be dug out about 0.4 m below the surrounding catchment. Whilst the micro catchment should be smooth and well compacted, the productive area should be rough and well cultivated to promote infiltration.

Micro catchments can be cheap to develop given the right terrain and are most suitable for fruit trees.

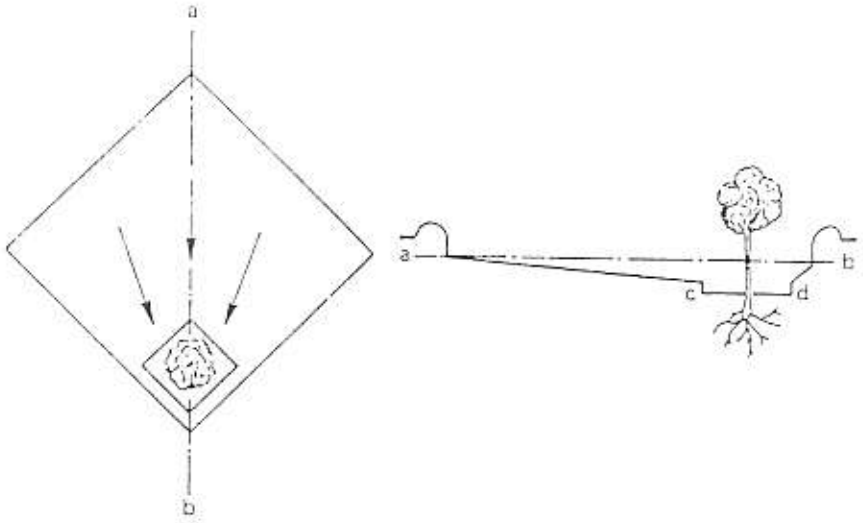


FIGURE 5.4 Plan and Cross Section of a Micro Catchment.

(c) Contour Trenches (Fig 5.5)

These are trenches placed along the contours with their excavated earth on the down-hill side and separated from each other by the trenches placed on the consecutive contour lines. The distance between two trench lines should be determined on the basis of the size of the trees/bushes to be grown in the trenches. Two plants are planted in each trench at the corners. Contour trenches are suitable for small undulating areas having irregular slopes.

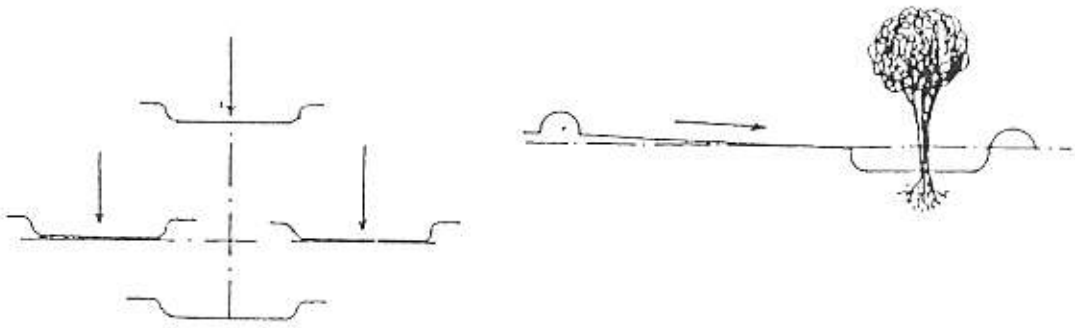


FIGURE 5.5 Plan and Cross Section Through Contour Trenches. Arrows Indicate the Direction of Surface Flow.

(d) Reverse Slope Terraces (Fig 5.6)

This system of terracing consists of a watershed comprising the steep slope of the hill side and a reverse slope to the outer part of the terrace with a flat productive area/channel at the inside of the terrace. This method of

conservation can be adopted for high value plants/orchards. Where waterways are available through the area, properly developed diversion structures could be developed to control the flow to and from the waterways and the terrace channels to provide optimum irrigation and drainage.

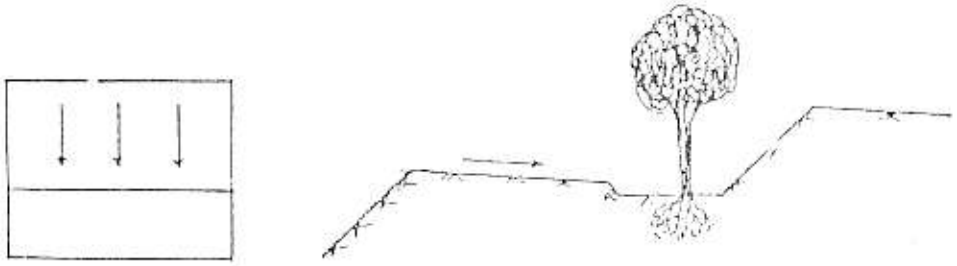


FIGURE 5.6 Plan and Cross Section of Reverse Slope Terraces. Arrows Indicate the Direction of Flow.

(e) Orchard Terraces (Fig 5.7)

Theoretically, orchard terraces are narrow bench terraces built on very steep slopes and their spaces are determined by the planting distances of the orchard trees. Each terrace is served by a catchment comprising sloping land on each side as shown on Figure 5.7.

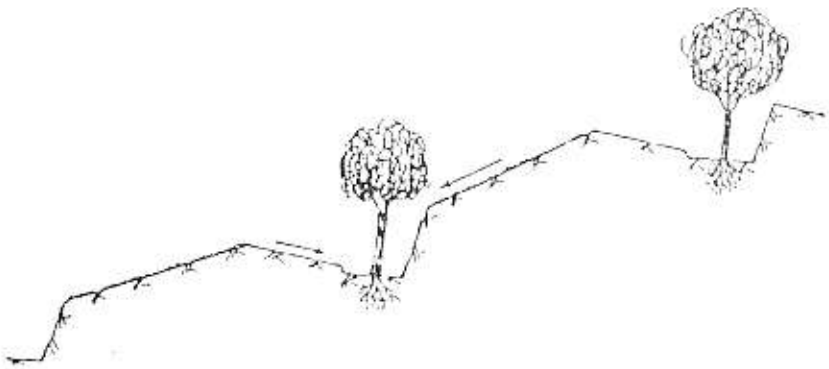


FIGURE 5.7 Design of Orchard Terraces. Arrows indicate the direction of Surface Flow.

5.3.3 Land Development for Pasture.

The areas which cannot be developed economically for crop production, particularly areas of shallow soils, can be used for the production of perennial pasture provided the topography and slope of the land are suitable. The development of contoured

bunds used to retain water and the plantation of perennial pastures, strictly along contours, will help to conserve moisture and reduce soil loss.

In areas of low rainfall strip cropping may be suitable, particularly on slopes of less than 6%. As shown on Figure 5.8, grass strips are planted across the contours, with bare areas, acting as runoff catchments in between. Contour bunds are constructed at the down stream side of each grass strip. Waterways need to be provided at low points at regular intervals to cater for surplus flow.

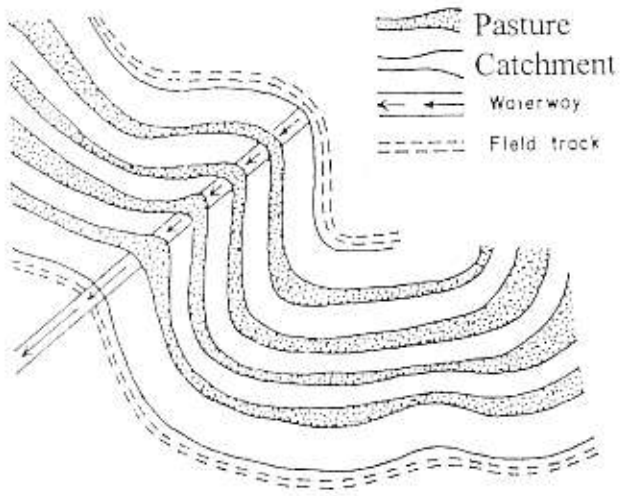


FIGURE 5.8 Layout of Strip Cropping System for Pasture Development.

5.4 Setting Out Contour Terraces

Water Harvesting, Sailaba and Rod Kohi Schemes often require contour furrows or contour terraces to be set out. The procedures for this are given below.

In designing terraces, natural features should be used, where possible, in siting waterways, paths, etc.

A base line at right angles to the contours (directly up and down the slope) should be established near their centre, and on a line of approximately average slope of the area to be terraced. Using a level, pegs should be placed at one metre vertical intervals or such other interval as may be determined, on the base line. The level will have to be set up several times if the land is steep (see Figure 5.9).

These pegs form the base from which the "contour lines" are pegged out on the ground. Once again using the level, pegs are placed at the same elevation, about 20 m apart (or closer if the terrain is irregular) and then joined with a rope. After setting out, the pegs are realigned, to smooth out the contour lines for easier construction and subsequent cultivation between them.

During setting-out the position of the waterways should be determined. Where possible these should be sited in small natural depressions if they occur, but on no account should they be more than 100 m apart. The minimum width for a waterway is 50 cm at the bottom but may be as wide as 4 m for large catchment areas and steep slopes. The bed of the waterway has to be level, thus spreading the water, and well sodded or seeded with grass, in order to reduce water velocity. Also it is necessary to construct drop structures to reduce velocity. These should be constructed of stone, but as an alternative, well sodded drops may be used, see Chapter 7 for details.

If the area to be terraced does not extend to the top of the watershed, the runoff from above must be diverted into waterways passing through or around, the terraced area. Therefore, it is necessary to construct diversion ditches. The maximum length of the ditches should be half the distance between the waterways, and their grade should be between 0.5 and 1.0 percent. For further details see Chapter 7, Section 7.3.

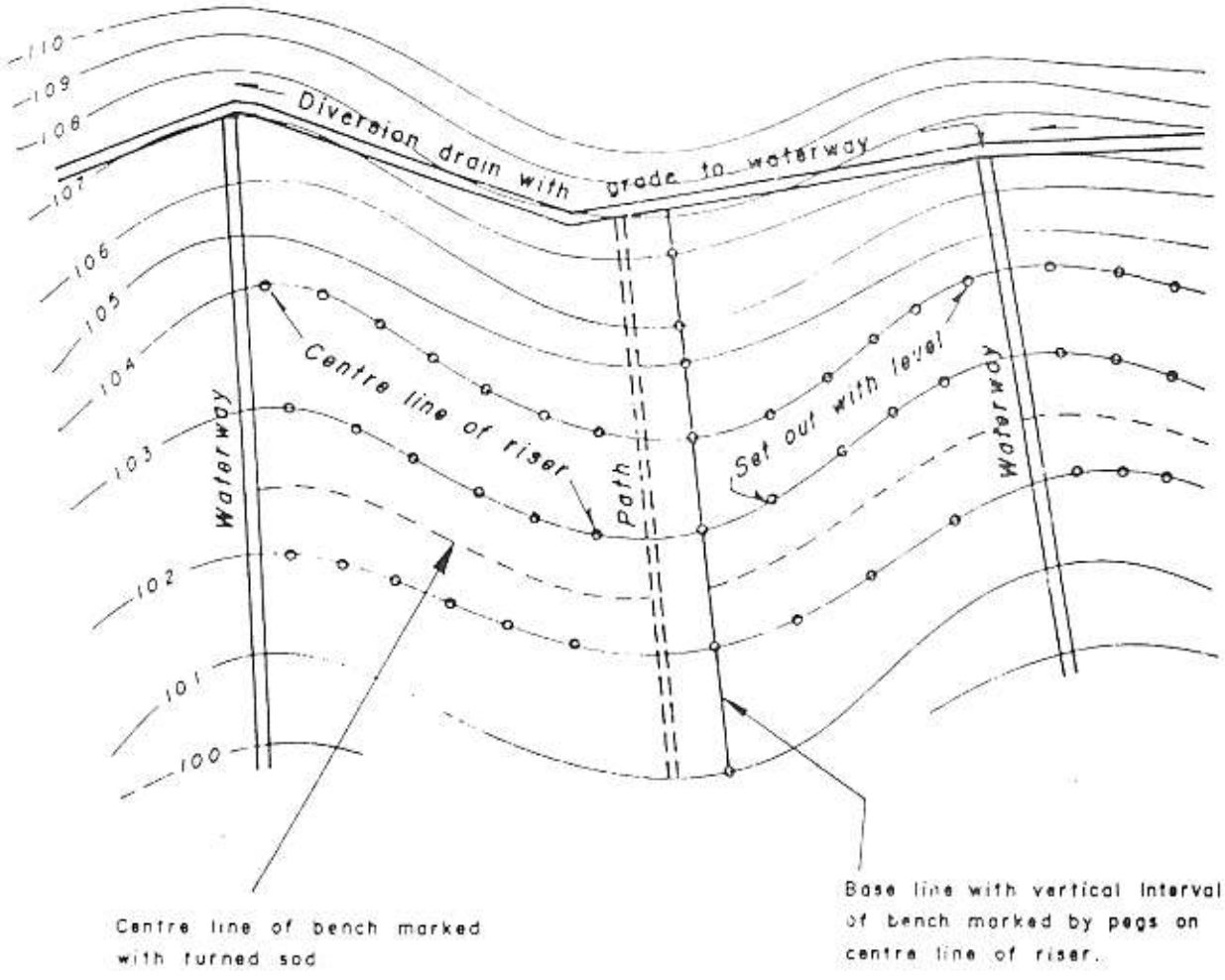


FIGURE 5.9 Layout of Contour Furrows and Terraces

A simple way of marking out contours is shown on Figure 5.10. One person (A) has a level, the other (B) has a staff, some means of marking (stakes or powdered chalk or limestone), and a hammer. The first line is marked at the upper end of the field, starting at the field boundary, a track or a gully. B marks the first point of the line with a stake (B1), while A sets up the level about 50m along the contour but offset from the contour (A1). B stands the staff on the ground at B1 and A reads the staff using the level. B then walks approximately along the contour for about 20m and stands the staff on the ground (B2). A directs B up and down until the staff reading is the same as it was at the first point and the point is then marked.

B then walks forward another 20m and the procedure is repeated for as many readings as can easily be taken from one level position (up to B4). A then carries the level forward and sets it up again at another convenient point (A2). A takes a back site on the last point set out by B (B4) and this then becomes the new reading which he uses to set B out for further points.

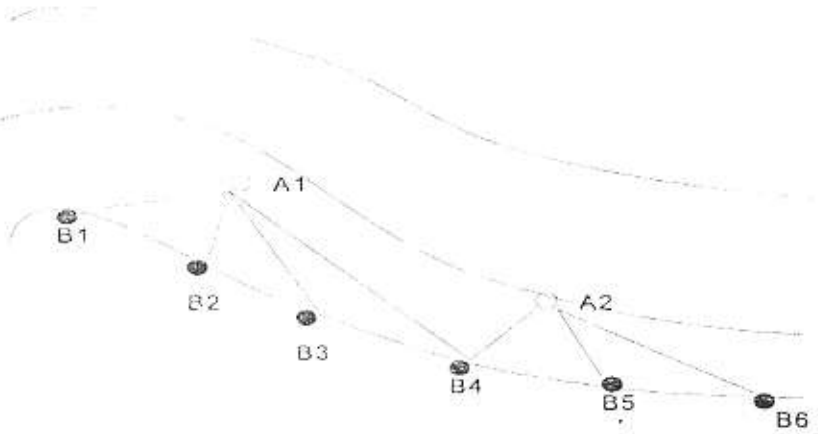


FIGURE 5.10 Method Of Establishing a Contour Line.

5.5 Improved Bunds

Improvements to a terrace will normally include improvements to the bund to ensure that it is of sufficient height all around to prevent overtopping and of sufficient thickness to prevent water seeping through it. Bunds should be at least 60 cm high and have a top width of at least 60 cm. The bund cross section should be sufficient to give a seepage gradient through it of at least 3:1 (as shown on Figure 5.2) to ensure that water does not seep through the bund and cause a piping failure (where flow passing through the bund carries away soil particles causing the bund to fail).

Improved bunds should always incorporate a spillway structure, as described in Section 7.1.

5.6 Improved Tillage

Improved tillage practices include methods to increase infiltration and deep percolation of harvested water into the soil profile and methods to prevent its subsequent evaporation from the soil surface before it can be used by the crop. In field cultivation to hold water at different elevations may also be included.

Prior to the onset of rains, particularly the monsoon rains it is highly beneficial if the soil can be cultivated as deeply as possible, either using a deep tined ripper or plough or a deep mould board plough. The general idea is to promote seepage paths deep into the soil so that the water can penetrate rather than runoff.

The field should be levelled after deep mould board ploughing. It is not necessary to deep plough the field every year, once in two years is sufficient. Deep ploughing should be done before the monsoon season in May and June. The plough should penetrate at least 25cm (10 inches).

Following the monsoon rains there is often a period of several months before the wheat or other crop is planted. If the field is left uncultivated then much soil moisture will evaporate from the bare soil surface (and considerable weed growth may occur causing further loss of water). The bare surface evaporation and weed growth can be much reduced by providing a shallow cultivation using a conventional cultivator or "swaga". This creates a dust mulch which breaks the flow path from the sub surface soil to the surface and causes weeds which have started to geminate to be disturbed.

When cultivating the soil it is very important that the soil is always cultivated across the slope so that rainwater is trapped between the ridges of the cultivation and infiltrates into the soil. Where cultivation is done down the slope, water will run down the gullies created between the ridges, causing soil erosion, ponding of water in the lower parts of the field and a deficit at the upper end, with a resultant highly variable crop. In the undulating fields that generally exist before the improvements described above, this is perhaps the cheapest and most effective technology that can be promoted as water harvesting.

6. HYDROLOGY AND CROP WATER REQUIREMENTS

6.1 Climate

Pakistan's barani zones may be sub divided into 6 climatic zones as described below:

Extreme North of the Punjab (Figure 6.1), including Rawalpindi, Islamabad, Murree, Kahuta, Gujrat and Sialkot. This is a high rainfall zone with average annual rainfall between 750 and 1,000 mm, which provides in most years adequate rainfall to cultivate crops of good yield without irrigation during both the kharif and rabi seasons.

Southern Potwar in the Punjab (Figure 6.1), including Attock and Chakwal districts. Semi arid climate with average annual rainfalls between 400 and 600 mm. Crop yields are limited by moisture shortage at the wheat planting time and during the initial growth period. Micro catchments providing higher applications of monsoonal rainfall onto productive areas could benefit rabi crop production.

Northern NWFP (Figure 6.2), including most districts north of Kohat. This area comprises the sub humid and humid tropical highland, with elevations between 1,000 and 5,000 m and average annual rainfalls between 500 and 1,500 mm. Snowfall is common in winter on higher ground.

Southern NWFP (Figure 6.2), including Kohat and all Districts South, and North and South Wasiristan. Arid zone with average annual rainfall between 250 and 350 mm.

Upland Balochistan (Figure 6.3), Comprising land above 1,500m in the north of the Province. Semi arid mountain areas with average annual rainfall between 150 and 400 mm. Cold in winter with precipitation falling as snow at higher elevations. Warm summers.

Lowland Balochistan (Figure 6.3), Comprising land between sea level and 1,500 m. Climate is sub tropical continental to coastal in the south with average annual rainfall between 50 mm (in the west) and 250 mm (in the east). Winters are pleasant with extremely hot dry summers.

Average monthly rainfall for representative Districts are given on Table 6.1.

6.2 Crop Water Requirements

For Average Monthly Evapotranspirations of some Districts see Table 6.2.

For graphical representation of evapotranspiration against rainfall in four

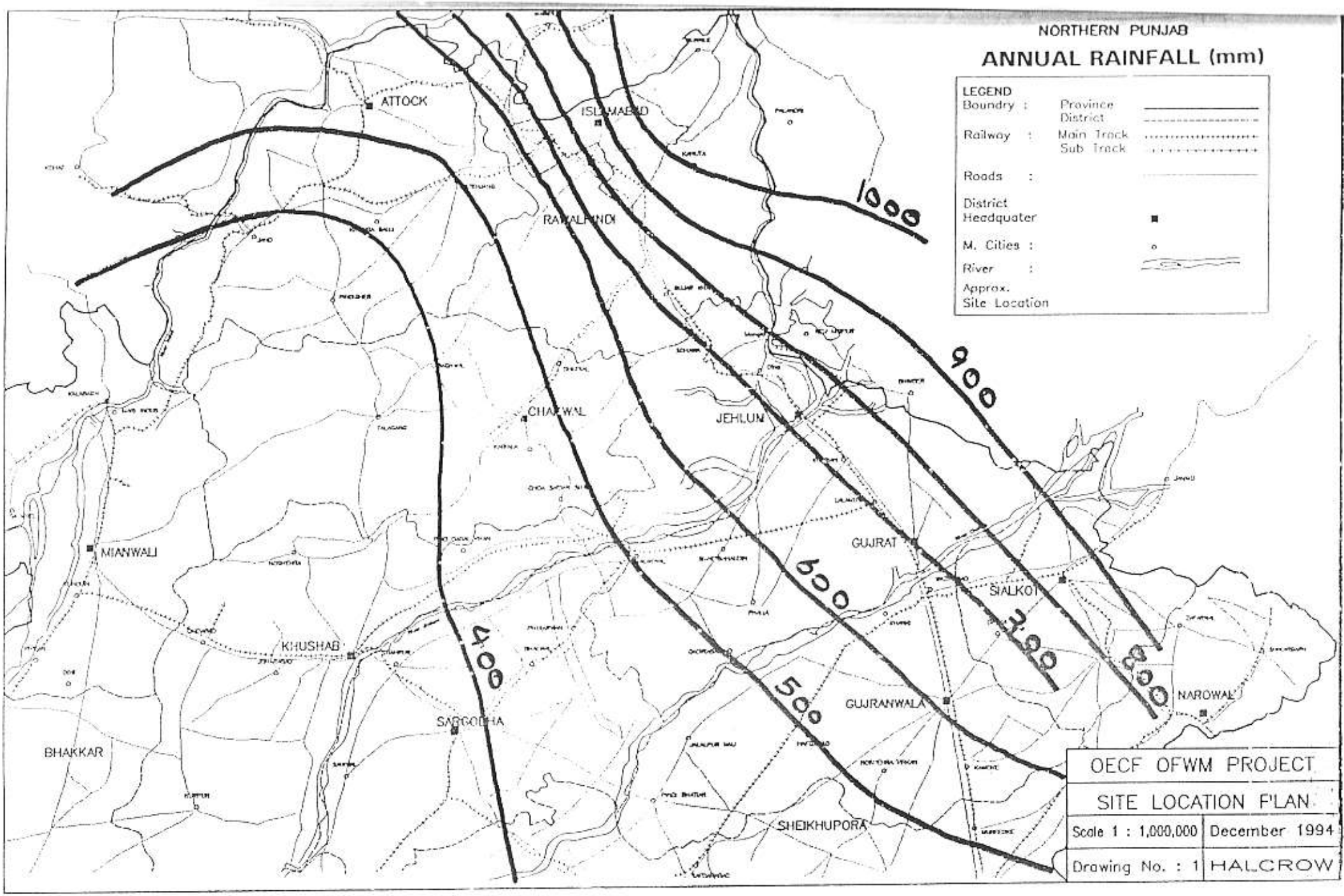
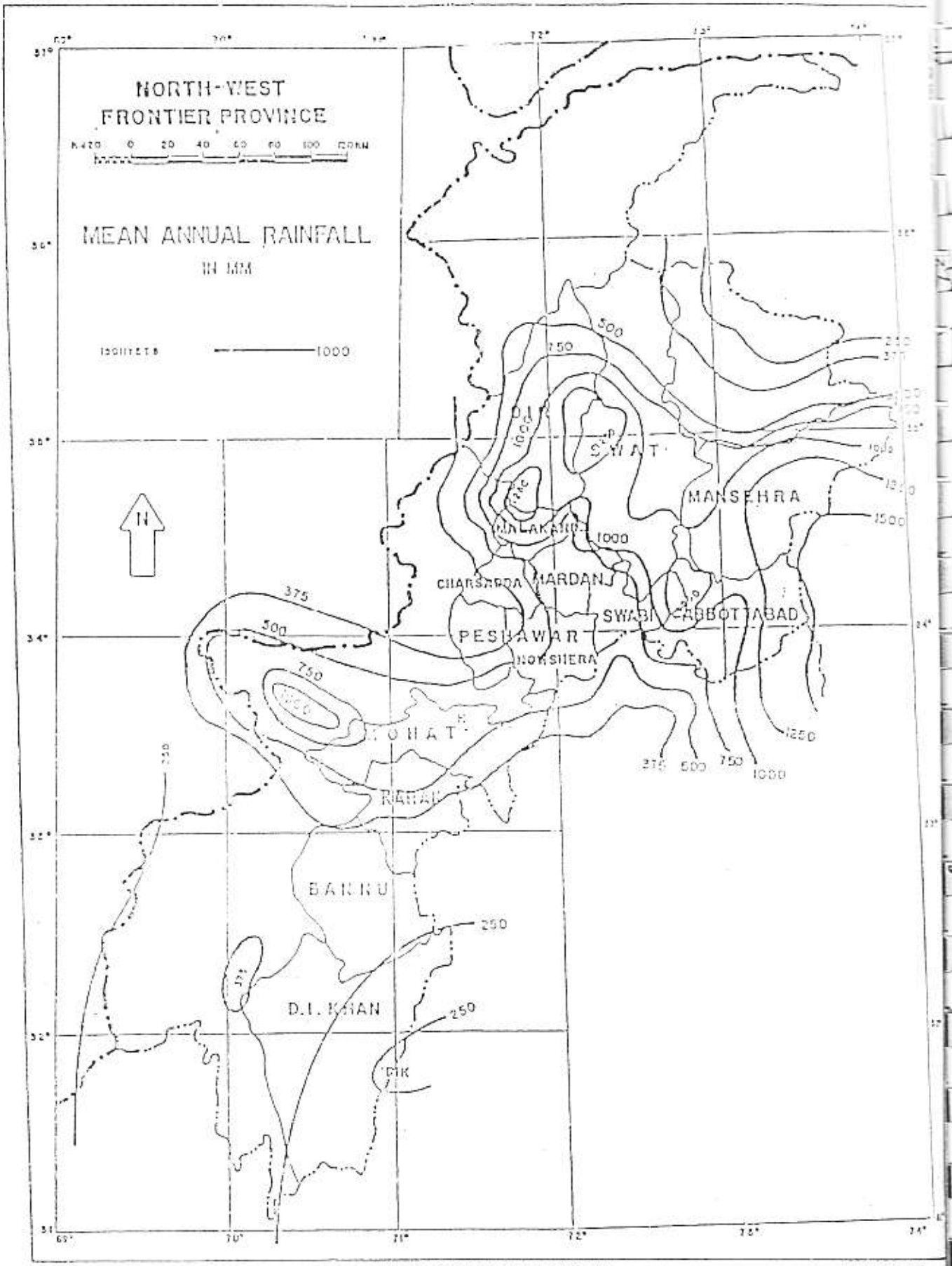

NORTHERN PUNJAB
ANNUAL RAINFALL (mm)
LEGEND
Boundry : Province
District
Railway : Main Track
Sub Track
Roads :
District Headquater
M. Cities :
River :
Approx. Site Location
1000
900
800
700
600
500
400
ATTOCK
ISLAMABAD
RAWALPINDI
CHAKWAL
JEHLUM
GUJRAT
SIALKOT
NAROWAL
GUJRANWALA
MIANWALI
KHUSHAB
SARGODHA
BHAKKAR
SHEIKHUPORA
OECF OFWM PROJECT
SITE LOCATION PLAN
Scale 1 : 1,000,000
December 1994
Drawing No. : 1
HALCROW

FIGURE 6.1

FIGURE 6.2



SOURCE: SURVEY OF PAKISTAN, ATLAS OF PAKISTAN, FIRST EDITION, 1:2,000,000 MAP OF PAKISTAN.

DATE: DEC 1990

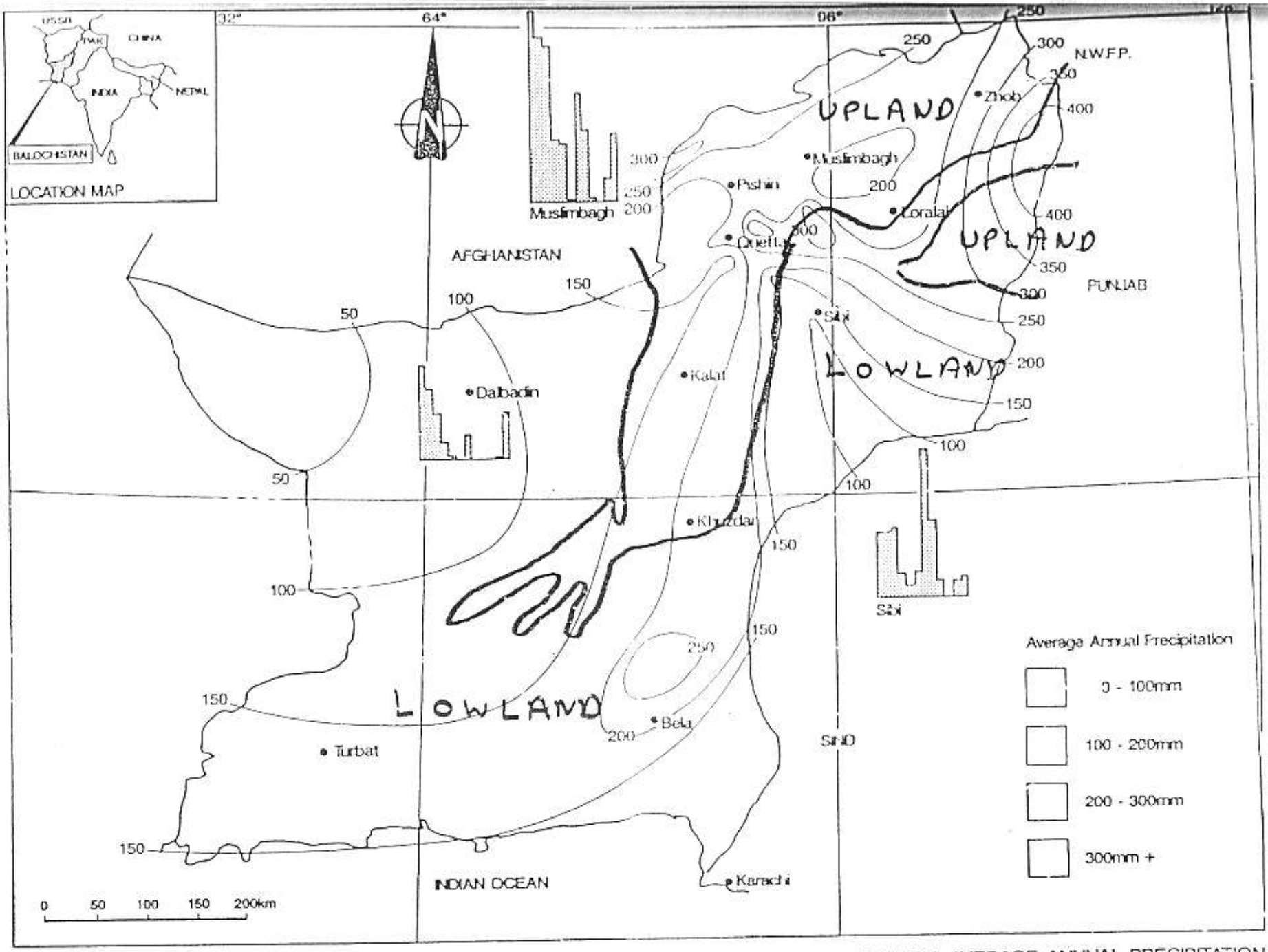


FIGURE 6.3

BALOCHISTAN PROVINCE: AVERAGE ANNUAL PRECIPITATION

AVERAGE MONTHLY RAINFALL (mm) IN OECF OFWM PROJECT AREA DISTRICTS

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Kharif May to Sep	Total Rabi Oct to Apr	Annual Total
PUNJAB															
Rawalpindi	63.5	63.5	81.3	42.4	23.4	54.6	232.1	258.1	85.1	21.1	11.9	22.6	653.2	306.3	959.5
Jhellum	40.0	40.0	60.0	37.3	20.0	45.0	200.0	230.0	70.0	16.5	10.0	20.0	565.0	223.8	788.8
Attock	45.0	50.0	60.0	37.5	25.0	25.0	100.0	125.0	40.0	15.0	10.0	20.0	315.0	237.5	552.5
Chakwal	30.0	33.0	35.0	28.0	24.0	34.0	101.0	130.0	57.0	8.0	6.0	14.0	346.0	154.0	500.0
Lahore	25.0	20.0	25.0	12.0	10.0	37.5	130.0	125.0	70.0	17.0	10.0	10.0	372.5	119.0	491.5
Shikarpura	22.0	21.0	22.0	10.0	10.0	37.5	120.0	125.0	55.0	10.0	10.0	10.0	347.5	105.0	452.5
Gujrat	30.0	37.5	45.0	21.0	10.0	40.0	200.0	200.0	78.0	12.0	10.0	20.0	528.0	175.5	703.5
Sialkot	45.0	40.0	45.0	30.0	10.0	50.0	250.0	280.0	110.0	17.5	10.0	20.0	700.0	297.5	997.5
Gujranwalla	25.0	25.0	37.5	15.0	10.0	50.0	190.0	160.0	75.0	10.0	10.0	17.5	505.0	140.0	645.0
ICTA															
Islamabad	50.0	50.0	85.0	48.0	22.5	45.0	250.0	270.0	100.0	25.0	17.5	35.0	687.5	320.5	1,008.0
SINDH															
Thatta	10.0	10.0	10.0	10.0	10.0	25.0	85.0	50.0	12.0	10.0	10.0	10.0	182.0	70.0	252.0
Larkana	10.0	12.0	10.0	10.0	10.0	10.0	27.0	25.0	10.0	10.0	10.0	10.0	82.0	72.0	154.0
Shikarpur	10.0	10.0	10.0	10.0	10.0	10.0	25.0	20.0	10.0	10.0	10.0	10.0	75.0	70.0	145.0
BALOCHISTAN															
Musa Khel	14.0	17.0	31.0	27.0	19.0	26.0	98.0	74.0	14.0	0.0	0.0	5.0	231.0	94.0	325.0
Quilla Saifullah													0.0	0.0	0.0
Kalat	28.0	26.0	21.0	8.0	2.0	0.0	6.0	0.0	0.0	0.0	0.0	13.0	8.0	96.0	104.0
Jafferabad	10.0	10.0	10.0	10.0	10.0	10.0	25.0	20.0	10.0	10.0	10.0	10.0	75.0	70.0	145.0
Las Bela	7.0	5.0	4.0	4.0	9.0	1.0	42.0	10.0	0.0	0.0	0.0	0.0	62.0	20.0	82.0
NWFP															
DI Khan	7.2	20.3	25.9	22.5	16.8	18.4	52.9	55.2	14.3	3.1	9.5	9.1	157.6	97.6	255.2
Tank	9.0	22.0	28.0	25.0	24.0	14.0	59.0	50.0	11.0	1.0	4.0	14.0	158.0	103.0	261.0
Bannu	20.0	30.0	43.0	40.0	18.0	10.0	70.0	52.0	20.0	9.0	6.0	13.0	170.0	161.0	331.0
Laki Marwat													0.0	0.0	0.0
Kohat	48.0	75.0	90.0	48.0	37.5	25.0	100.0	100.0	25.0	10.0	10.0	25.0	287.5	306.0	593.5
Karak													0.0	0.0	0.0
Swat	82.5	90.0	100.0	80.0	50.0	35.0	125.0	100.0	60.0	25.0	17.5	60.0	370.0	455.0	825.0
FATA															
Kurram Agency													0.0	0.0	0.0
N Waziristan													0.0	0.0	0.0
S Waziristan	50.0	48.0	50.0	40.0	21.0	15.0	50.0	35.0	10.0	10.0	10.0	18.0	131.0	226.0	357.0

NOTES: Source: NARC except Kidd et al, Climate of Balochistan for Balochistan data and Preparation report for Barani Area Development Project for NWFP Data

TABLE 6.1

AVERAGE MONTHLY EVAPOTRANSPIRATION (mm) IN OECF OFWM PROJECT AREA DISTRICTS

S Wasiristan	50.0	48.0	50.0	40.0	21.0	15.0	50.0	35.0	10.0	10.0	10.0	18.0	131.0	226.0	357.0	

NOTES Source: NARC except Kidd et al, Climate of Balochistan for Balochistan data and Preparation report for Barani Area Development Project for NWFP Data

6.1

AVERAGE MONTHLY EVAPOTRANSPIRATION (mm) IN OECF OFWM PROJECT AREA DISTRICTS

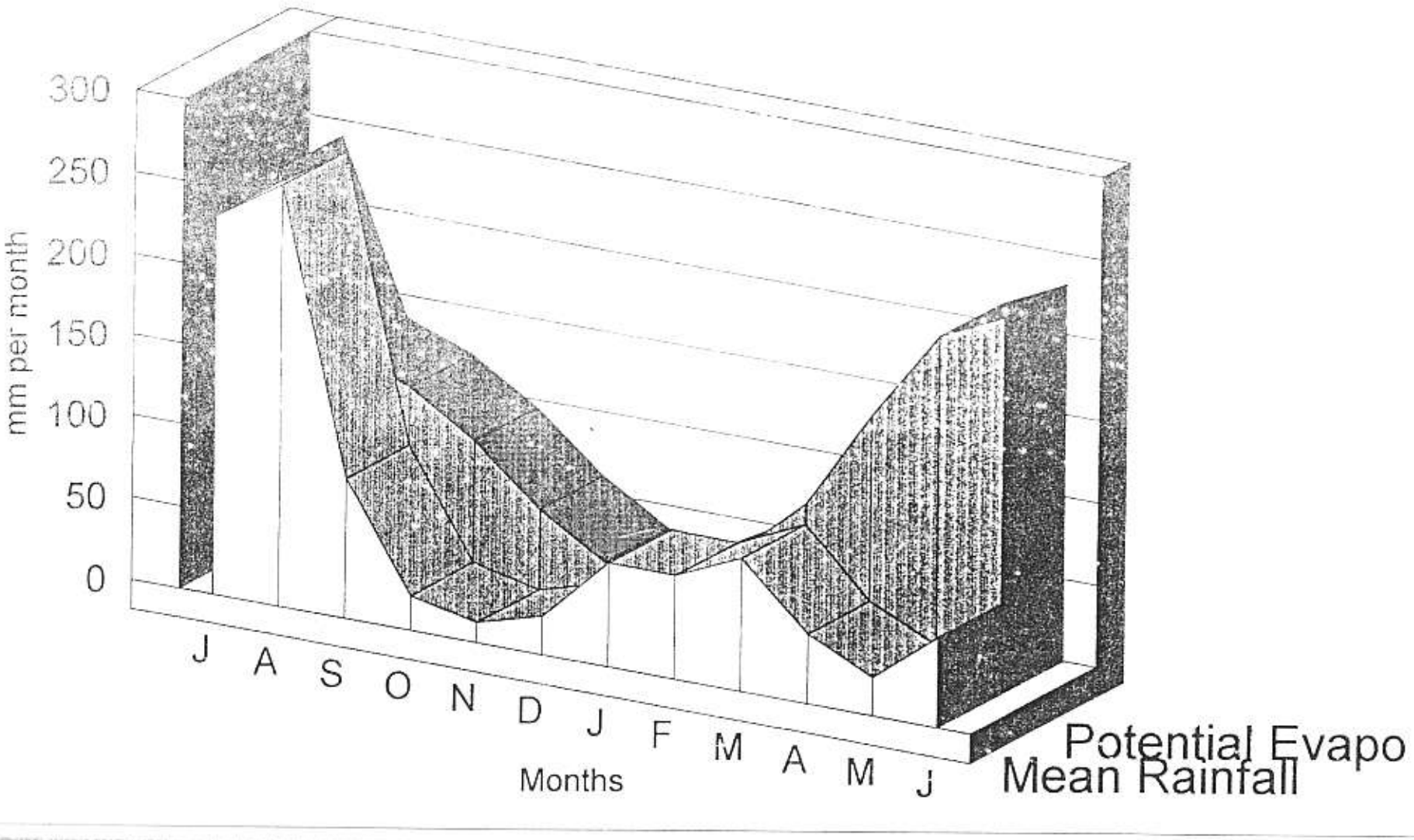
District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Kharif May to Sep	Total Rabi Oct to Apr	Annual Total
PUNJAB															
Rawalpindi***	35.0	58.0	94.0	155.0	212.0	231.0	240.0	136.0	121.0	95.0	61.0	36.0	940.0	534.0	1,474.0
Jhellum	46.5	66.0	99.0	144.0	192.0	210.0	168.0	147.0	132.0	108.0	69.0	48.0	849.0	580.5	1,429.5
Attock													0.0	0.0	0.0
Chakwal													0.0	0.0	0.0
Lahore	52.7	72.8	120.0	177.0	213.0	222.0	180.0	162.0	150.0	114.0	75.0	52.7	927.0	664.2	1,591.2
Shikarpura													0.0	0.0	0.0
Gujrat													0.0	0.0	0.0
Sialkot													0.0	0.0	0.0
Gujranwalla													0.0	0.0	0.0
ICTA															
Islamabad	42.0	56.0	90.0	132.0	180.0	204.0	171.0	144.0	129.0	99.0	63.0	42.0	828.0	524.0	1,352.0
SINDH															
Thatta													0.0	0.0	0.0
Larkana													0.0	0.0	0.0
Shikarpur													0.0	0.0	0.0
BALOCHISTAN															
Musa Khel													0.0	0.0	0.0
Quilla Saifullah													0.0	0.0	0.0
Kalat*	64.0	85.0	138.0	187.0	238.0	252.0	234.0	216.0	188.0	147.0	98.0	59.0	1,128.0	788.0	1,916.0
Jafferabad*	100.0	128.0	207.0	279.0	341.0	354.0	304.0	268.0	233.0	192.0	128.0	93.0	1,500.0	1,127.0	2,627.0
Las Bela*	96.0	117.0	177.0	223.0	271.0	274.0	242.0	226.0	210.0	178.0	125.0	95.0	1,223.0	1,011.0	2,234.0
NWFP															
DI Khan**	9.0	18.0	78.0	143.0	198.0	214.0	213.0	198.0	168.0	121.0	41.0	13.0	991.0	423.0	1,414.0
Tank**	8.0	13.0	57.0	159.0	205.0	220.0	220.0	206.0	176.0	134.0	43.0	14.0	1,027.0	428.0	1,455.0
Bannu**	50.0	60.0	102.0	139.0	200.0	223.0	200.0	186.0	160.0	123.0	84.0	50.0	969.0	618.0	1,587.0
Laki Marwat													0.0	0.0	0.0
Kohat**	11.0	19.0	48.0	110.0	199.0	217.0	221.0	205.0	168.0	115.0	40.0	21.0	1,010.0	364.0	1,374.0
Karak													0.0	0.0	0.0
Swat													0.0	0.0	0.0
FATA															
Kurram Agency													0.0	0.0	0.0
N Waziristan													0.0	0.0	0.0
S Wasiristan													0.0	0.0	0.0

Source
** Preparation Report for the NWFP Barani Project
* Estimation of Evaporation in Balochistan (Halcrow-BMIADP)
Rest FAO Cropwat Program using CLIMWAT Data and Penman Monteith equation.
*** Soil and Water Conservation Training Modules, ABAD

TABLE 6.2

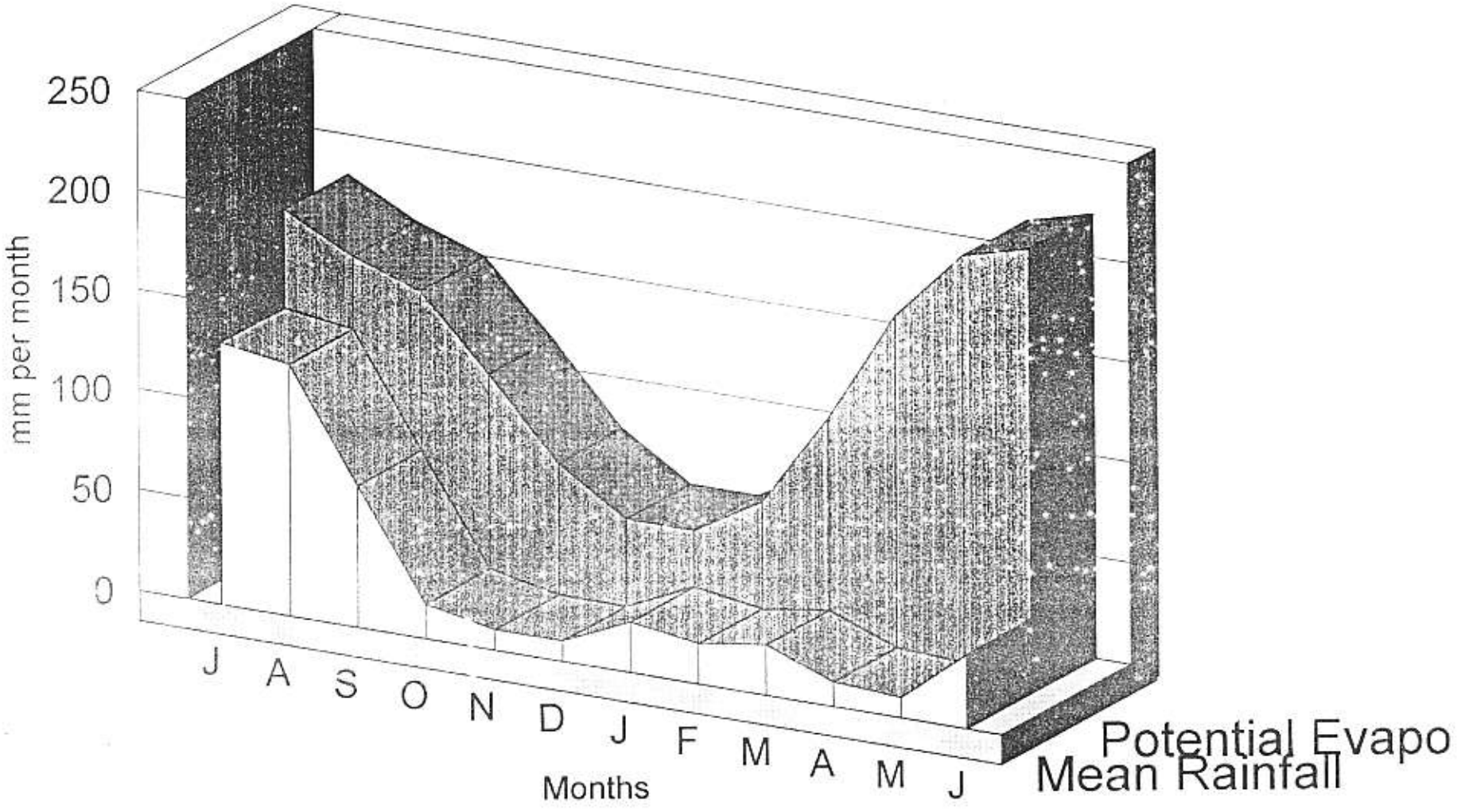
CLIMATE AT RAWALPINDI

Figure 6.4



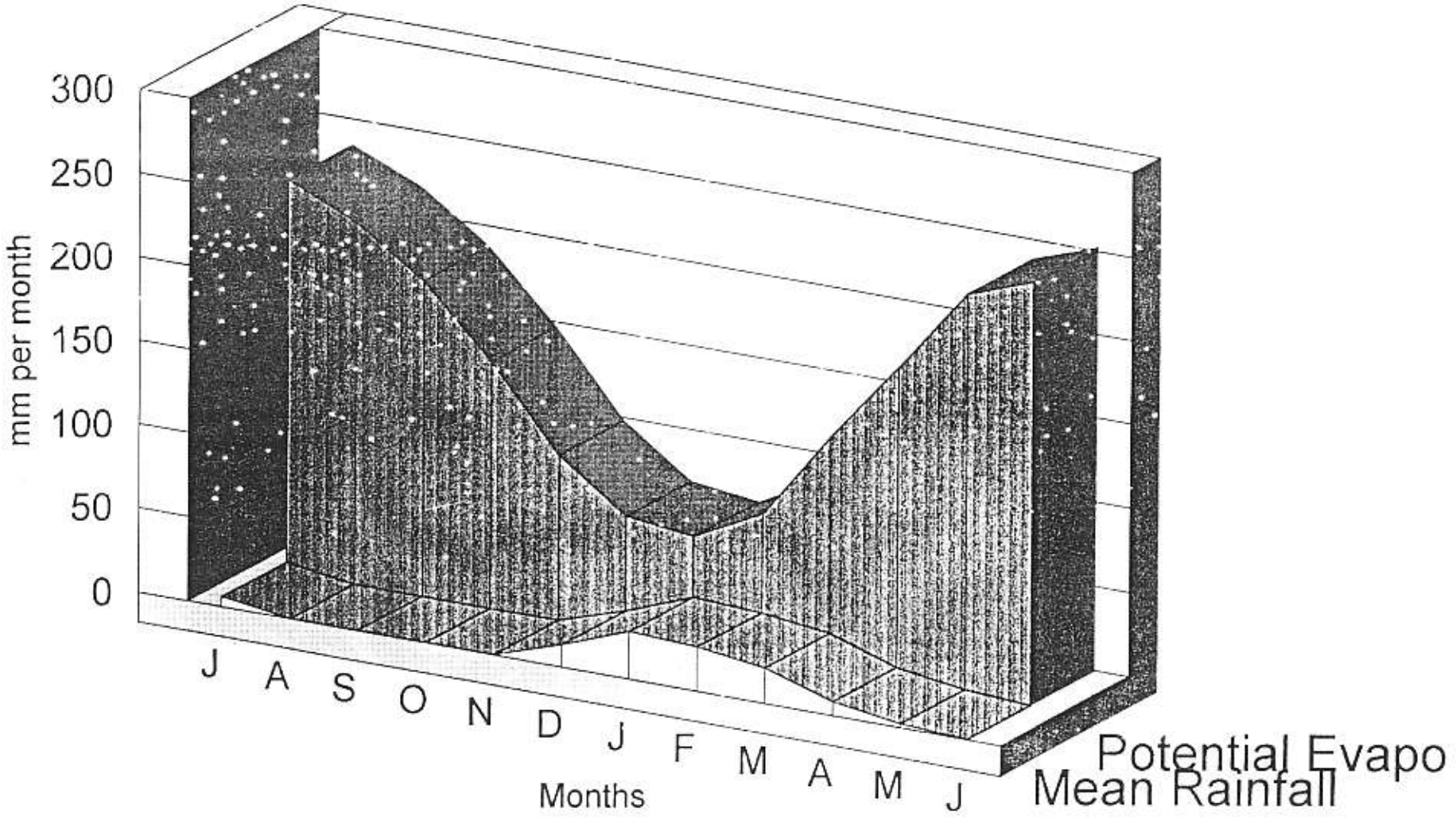
CLIMATE AT LAHORE

Figure 6.5



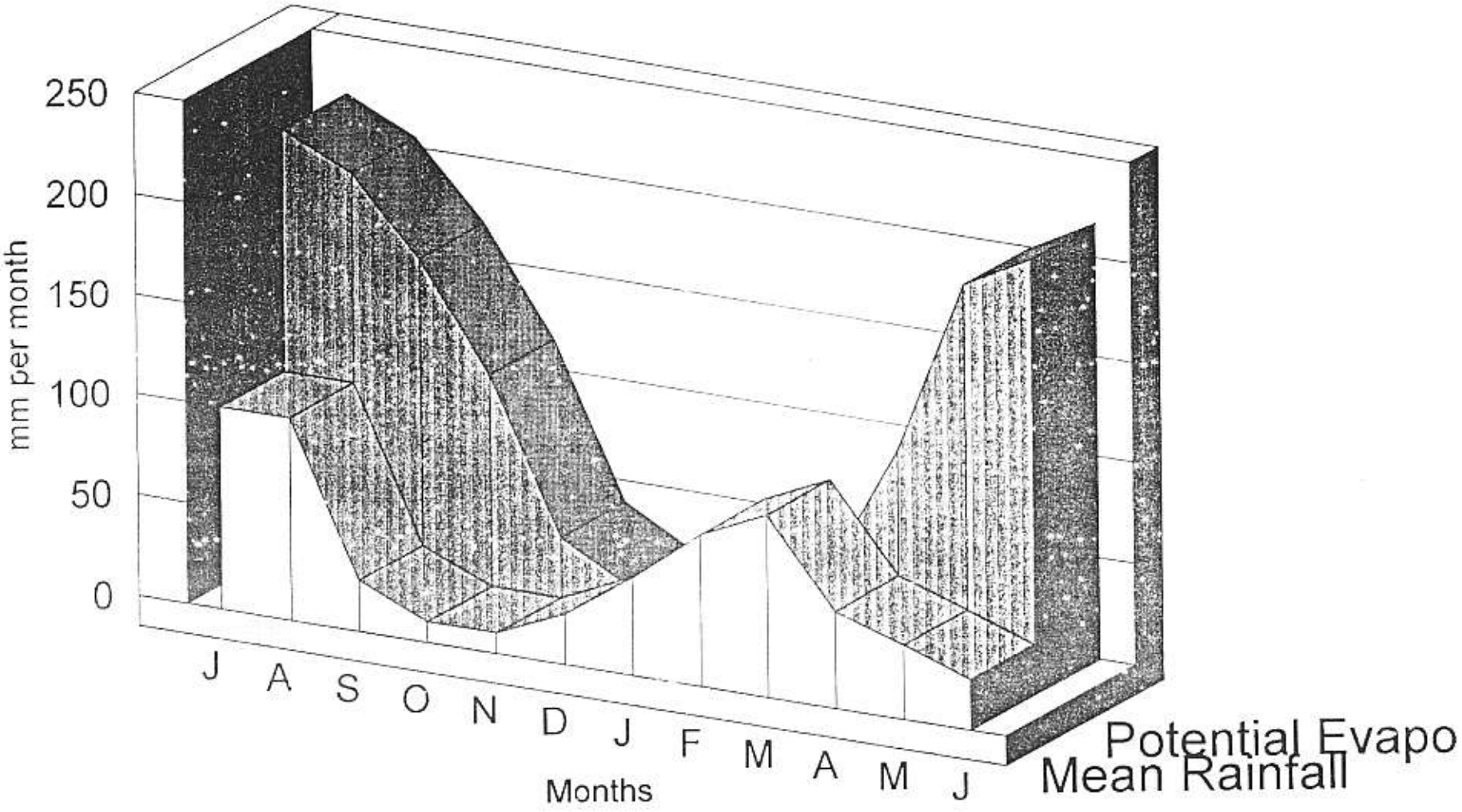
CLIMATE AT KALAT

Figure 6.6



CLIMATE AT KOHAT

Figure 6.7



representative districts see Figures 6.4 to 6.7. These graphs show that for most of the year, with the exception of the monsoon period around Rawalpindi, evaporation considerably exceeds rainfall.

In order to estimate the amount of supplemental irrigation required for a crop, the crop water Requirement (ETc) for the crop is required to be known. The two most commonly cultivated crops under water harvesting are wheat and tree crops (including forest trees and sub tropical fruit crops). Rough crop water requirements for each of these have been estimated as follows:

- For wheat, the kharif rains will irrigate the crop from planting in October/November through to the commencement of the winter rains. For this period the estimated crop water requirement is 120mm. The winter rains (plus carry over from the summer) are then required to irrigate the crop through to maturity for which an additional 350 mm of water is required.

- For tree crops (with bare soil cover) the crop water requirement has been estimated at 0.7 times the actual evapotranspiration. From the beginning of the monsoon rains through to the end of November, the period for which the crops must be irrigated from the monsoon rains, about 450mm of irrigation is required. For the rest of the year, which must be irrigated by the winter rains, plus carry over from the monsoon, the crop water requirement is about 550mm.

6.3 Rainfall-Runoff

The estimation of the amount of run off which can be expected from a given catchment in order to provide additional water to a field or fields is very difficult to predict, although is a crucial problem in assessing the size of a catchment in relation to a proposed productive area. The variables concerned include the precipitation, soil quality, steepness and micro topography of the catchment and the condition of the catchment:

- The precipitation will be extremely variable for any given location. Designs have to not only to accommodate the average conditions but also drought periods and periods of very high rainfall when flow must be disposed of;

- Soil type will have a significant effect on the rate of infiltration of rainfall, both on the catchment and productive areas, as will any cultivation the soil may receive;

- As can be seen from Table 2.2, the steepness and surface cover of a catchment has an effect. The figures given in this table are for very small smooth catchments. For large catchments, hollows provide areas of storage which will

reduce the percentage runoff.

The ratio of catchment to cultivated area may be calculated from the following equation:

$$Ratio = \frac{Catchment\ Area}{Cultivated\ Area} = \frac{ETc - ERainfall}{ERainfall \cdot ROC}$$

Where:

ETc	=	Seasons Crop Evapotranspiration (mm)
Rainfall	=	Average Seasonal Rainfall (mm)
ERainfall	=	Effective Seasonal Rainfall, estimated to be 75% of the Average Seasonal Rainfall
ROC	=	Run off Coefficient (fraction).

Based on the above equation a simple spreadsheet model has been developed which estimates the catchment to productive area ratio for a winter wheat crop and tree crop for different areas of the country. The outputs from the two models are shown on Tables 6.3 and 6.4 respectively.

The rainfall data for each season is taken from Table 6.1. It is assumed that the monsoon rainfall supports the crop, from planting in the case of wheat or from the beginning of July in the case of tree crops, to end November and the winter rainfall supports the crop from December through to harvest in the case of wheat or the end of June in the case of tree crops. It is assumed that there is no residual soil moisture at the end of June, but that residual soil moisture is carried over from the autumn season to the spring season.

Runoff coefficients (ROC) have been estimated using the data given in Table 2.2 from data at the NARC Fatehjang site for a bare soil catchment with a slope of less than 5% and an even topography. Using the range of results from the Fatehjang site, the data has been correlated to seasonal rainfalls, as follows:

Seasonal Rainfall (mm)	Assumed Runoff Coefficient
0 - 99	0.2
100 - 199	0.3
200 - 299	0.4
300 - 399	0.5
400 - 499	0.6
500 - 599	0.7
600 - 700	0.75

TABLE 6.5

RECOMMEMDED RATIOS OF CATCHMENT TO PRODUTIVE AREAS

(A) FOR WHEAT

Average Annual Rainfall (mm)	Catchment to Productive Area Ratio
600 +	0
500-600	0.5
400 - 500	1.0
300 - 400	2 to 3
200 - 300	5 to 8
100 - 200	15 to 40
50 - 100	30 +

(A) FOR TREE CROPS

Average Annual Rainfall (mm)	Catchment to Productive Area Ratio
800 - 1000	0.5 to 1.0
700 - 800	1.0 to 1.5
600 - 700	1.5 to 2.0
500-600	2 to 4
400 - 500	4 to 5
300 - 400	10 to 12
200 - 300	14 to 16
100 - 200	40 to 50
50 - 100	90 +

DETERMINATION OF CATCHMENT TO PRODUCTIVE AREA RATIO FOR TREE CROPS

TABLE 6.4

District	TOTAL RAINFALL Total Kharif May to Sep	Total Rabi Oct to Apr	Annual Total	EFFECTIVE RAINFALL Kharif May to Sep	Rabi Oct to Apr	Total	ETc July to End Nov	Dec. to End June	ROC Kharif	Rabi	RATIO	SOIL MOISTURE BALANCE Autumn	Spring
PUNJAB													
Rawalpindi	653.2	306.3	959.5	489.9	229.7	719.6	450	550	0.75	0.5	0.6	260.3	9.0
Jhellum	565.0	223.8	788.8	423.8	167.8	591.6	450	550	0.7	0.4	1.2	329.7	28.1
Attock	315.0	237.5	552.5	236.3	178.1	414.4	450	550	0.5	0.4	3.0	140.6	(17.5)
Chakwal	346.0	154.0	500.0	259.5	115.5	375.0	450	550	0.5	0.3	4.0	328.5	32.6
Lahore	372.5	119.0	491.5	279.4	89.3	368.6	450	550	0.5	0.3	4.0	388.1	34.5
Shikarpura	347.5	105.0	452.5	260.6	78.8	339.4	450	550	0.5	0.3	4.5	397.0	32.1
Gujrat	528.0	175.5	703.5	396.0	131.6	527.6	450	550	0.7	0.3	1.5	361.8	2.7
Sialkot	700.0	207.5	907.5	525.0	155.6	680.6	450	550	0.75	0.4	0.7	350.6	(0.2)
Gujranwalla	505.0	140.0	645.0	378.8	105.0	483.8	450	550	0.7	0.3	1.8	406.0	17.7
ICTA													
Islamabad	687.5	320.5	1,008.0	515.6	240.4	756.0	450	550	0.75	0.5	0.5	259.0	9.5
SINDH													
Thatta	182.0	70.0	252.0	136.5	52.5	189.0	450	550	0.3	0.2	16.0	341.7	12.2
Larkana	82.0	72.0	154.0	61.5	54.0	115.5	450	550	0.2	0.2	40.0	103.5	39.5
Shikarpur	75.0	70.0	145.0	56.3	52.5	108.8	450	550	0.2	0.2	40.0	56.3	(21.2)
BALOCHISTAN													
Musa Khel	231.0	94.0	325.0	173.3	70.5	243.8	450	550	0.4	0.2	9.0	347.0	(5.6)
Quilla Saifullah	100.0	100.0	200.0	75.0	75.0	150.0	400	400	0.3	0.3	15.0	12.5	25.0
Kalat	8.0	96.0	104.0	6.0	72.0	78.0	600	600	0.2	0.2	200.0	(354.0)	1,998.0
Jafferabad	75.0	70.0	145.0	56.3	52.5	108.8	600	600	0.2	0.2	50.0	18.8	(3.7)
Las Bela	62.0	20.0	82.0	46.5	15.0	61.5	600	600	0.2	0.2	95.0	330.0	30.0
NWFP													
DI Khan	157.6	97.6	255.2	118.2	73.2	191.4	450	550	0.3	0.2	17.0	271.0	43.1
Tank	158.0	103.0	261.0	116.5	77.3	195.8	450	550	0.3	0.3	14.0	166.2	17.9
Bannu	170.0	161.0	331.0	127.5	120.8	248.3	450	550	0.3	0.3	10.0	60.0	(7.0)
Laki Marwat	0.0	0.0	0.0	0.0	0.0	0.0	450	550	0	0	0.0	0.0	0.0
Kohat	287.5	306.0	593.5	215.6	229.5	445.1	450	550	0.4	0.5	2.7	(0.0)	(8.7)
Karak	0.0	0.0	0.0	0.0	0.0	0.0	450	550	0	0	0.0	0.0	0.0
Swat	370.0	455.0	825.0	277.5	341.3	618.8	450	550	0.5	0.6	1.2	(6.0)	30.9
FATA													
Kurram Agency	0.0	0.0	0.0	0.0	0.0	0.0	450	550	0	0	0.0	0.0	0.0
N Waziristan	0.0	0.0	0.0	0.0	0.0	0.0	450	550	0	0	0.0	0.0	0.0
S Wasiristan	131.0	226.0	357.0	98.3	169.5	267.8	450	550	0.3	0.4	12.0	1.9	435.1

- **Average annual rainfall between 400 and 600 mm.** Catchment areas of 2 to 5 times the productive area required. Trees should be planted on a 7 by 7 m to 9 by 9 m grid.

- **Average annual rainfall between 200 and 400 mm.** Catchment areas of 10 to 16 times the productive area required. Trees should be planted on a 13 by 13 m to 16 by 16 m grid.

- **Average annual rainfall between 50 and 200 mm.** Catchment areas of 40 to 90 times the productive area required. Trees should be planted on a 25 by 25 m to 36 by 36 m grid.

Where the areas between the tree crops are likely to be cropped or not be kept clear of weeds then the above ratios need to be increased by at least 20%.

6.4 Flood Estimation

As well as calculating the amount of run off that can be expected from seasonal rainfall, the run off from storm rainfall is also required to be calculated in order that spillways and waterways from fields, catchments, reservoirs and ponds may designed.

Structures need to be designed to carry the peak runoff which will result from a storm that is statistically likely to occur in the catchment within a defined period, termed the return period. The design return period for a structure depends on its importance and the consequences of failure of the structure. For the type of small structures to be used in water harvesting, the following design return periods are recommended:

o Field spillways	5 years
o Waterways	10 years
o Small ponds	25 years
o Small reservoirs	100 years

There are three main methods currently used in predicting peak runoff rates; a) the Rational Method, b) Cook's Method and c) the Hydrologic Soil-Cover Complex Method. The assumptions upon which the three methods are based are similar. Traditionally for small works the Rational Method has been used in Pakistan. The Rational method is the simplest to use and for very small catchments, will give results of sufficient accuracy for our purposes. The Rational Method is based on the following equation:

$$Q = 0.003 * CIA$$

Where:

Q = Peak runoff rate in m^3/sec.
C = Runoff Coefficient representing the ratio of rainfall to runoff
I = Design rainfall intensity in mm/hour
A = Catchment area in hectares

The value of "C" is dependent on the intensity and amount of rainfall, the surface cover and gradient and the antecedent soil moisture content. Values of "C" appropriate to Pakistan conditions have been estimated by Dr S Ahmed and are given in ABAD's Soil and Water Conservation Training Modules. These are reproduced here as Table 6.6.

The design rainfall intensity will vary from area to area and will increase as the return period increases. Values for selected stations in Pakistan are given in Table 6.7.

Example: calculate the design capacity for a field spillway in Chakwal for a level 5 ha field, with a light soil, half of which is cultivated and half of which is pasture.

From Table 6.6, average Run off Coefficient = 0.2

Design return period = 5 years

From Table 6.7 design rainfall for 25 year return period = 100 mm/hour.
Estimate 5 year return period rainfall = 60 mm.

$Q = 0.003 * CIA$
$Q = 0.003 * 0.2 * 60 * 5$
$Q = 0.18$ m^3/sec = 180 litres/second

TABLE 6.6

VALUES OF RUNOFF COEFFICIENT "C" FOR USE IN THE RATIONAL METHOD

Vegetative Cover and Slope	Soil Classes		
	Light	Medium	Fine
1. Cultivated Land			
0 to 5%	0.3	0.4	0.5
5 to 10%	0.4	0.5	0.6
10 to 30%	0.5	0.6	0.7
2. Pasture Land			
0 to 5%	0.1	0.2	0.3
5 to 10%	0.15	0.3	0.4
10 to 30%	0.2	0.4	0.5
3. Forest Land			
0 to 5%	0.1	0.2	0.3
5 to 10%	0.25	0.3	0.4
10 to 30%	0.3	0.4	0.5

Table 6.7

DESIGN RAINFALL INTENSITIES FOR SELECTED AREAS

Location / Return Period (years)	5	10	25	100
	Design Rainfall Intensity (mm/hour)			
Pallandri - AJK	100	125	150	190
Haripur - NWFP	95	115	140	180
Chakwal - Punjab	65	80	100	130
Jhelum - Punjab	50	60	75	95
Barkhan - Balochistan	30	45	50	65
Zhob - Balochistan	30	35	45	55
Loralai - Balochistan	30	35	40	50
Bostan - Balochistan	25	30	35	45
Quetta - Balochistan	25	25	30	40
Khuzdar - Balochistan	25	30	35	42
Las Bela - Balochistan	35	45	55	75
Saruna - Balochistan	40	50	65	85

Source:

Punjab 1 in 25 Year Data ADAB Training Modules - NARC

Other return period Punjab data estimated from 1 in 25 year Punjab data using same ratios as Balochistan data

Balochistan, Halcrow Flood Estimation Manual for BMIADP

7. CONSERVATION STRUCTURES

7.1 Field Spillways

Spillways are required between fields in order to that excess rianfall and run on to the fields can be safetly drained, either to a water way or on to a lower field. This is particularly important in the higher rainfall areas of the country. Field spillways must be flexible, since on a fallow field or prior to planting the farmer will want to pond as much water in his field as possible. However, while the crop is in the field, crop damage will occur if the water is allowed to pond in the field for any length of time.

A design for a spillway is given on Figure 7.1. The spillway is essentially a short length of double brick lined channel with a concrete base. No gate has been provided, since gates tend to get lost and damaged very easily. In order to pond water in the upper field the farmer has to construct a small dam in the entrance of the spillway. This has the advantage that the farmer can select the height of the dam and in a large storm, the dam will be washed away, preventing the main field bund from being damaged. A small nib is constructed across part of the channel in the entrance, this will assist the farmer in constructing his dam. The nib is only constructed part way across the spillway channel in order that the field can drain down to soil level.

In order that the spillway structure does not settle and crack and that erosion does not take place at its outlet two things are critical:

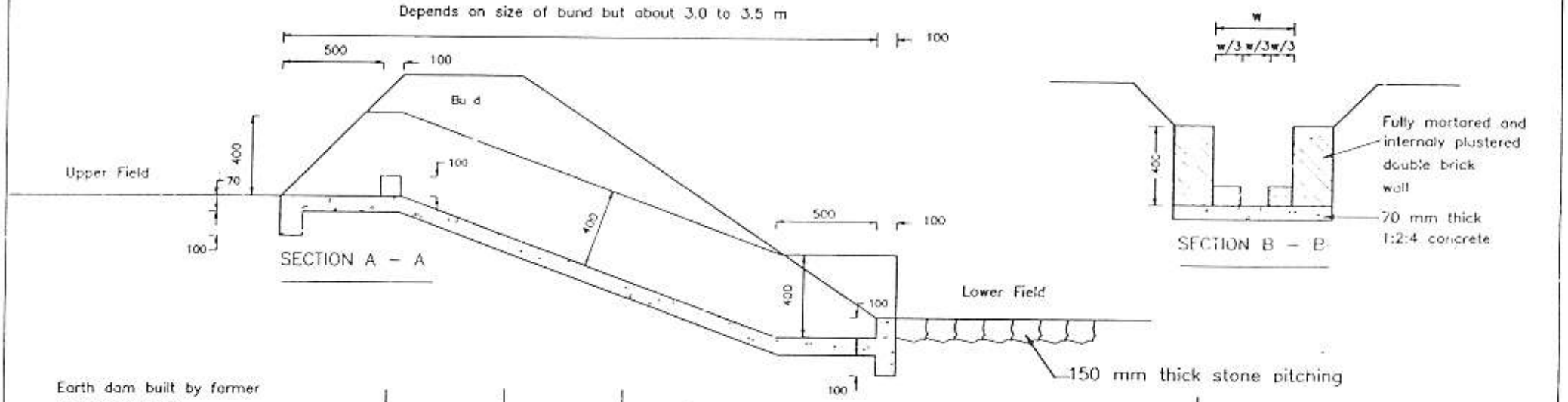
- The spillway must be constructed on a well compacted base and the backfill to the sides of the structure must also be well compacted; and
- downstream of the structure a layer of 150 mm thick dry stone or brick pitching needs to be laid, 500 mm long, for erosion protection.

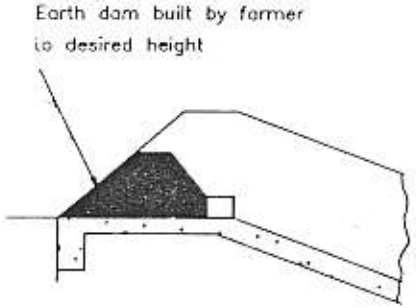
The design capacity required for each field spillway should be calculated according to the method given in Section 6.4.

The width of the spillway should be varied according to the capacity required. The following Table 7.1 gives spillway capacities for various widths.

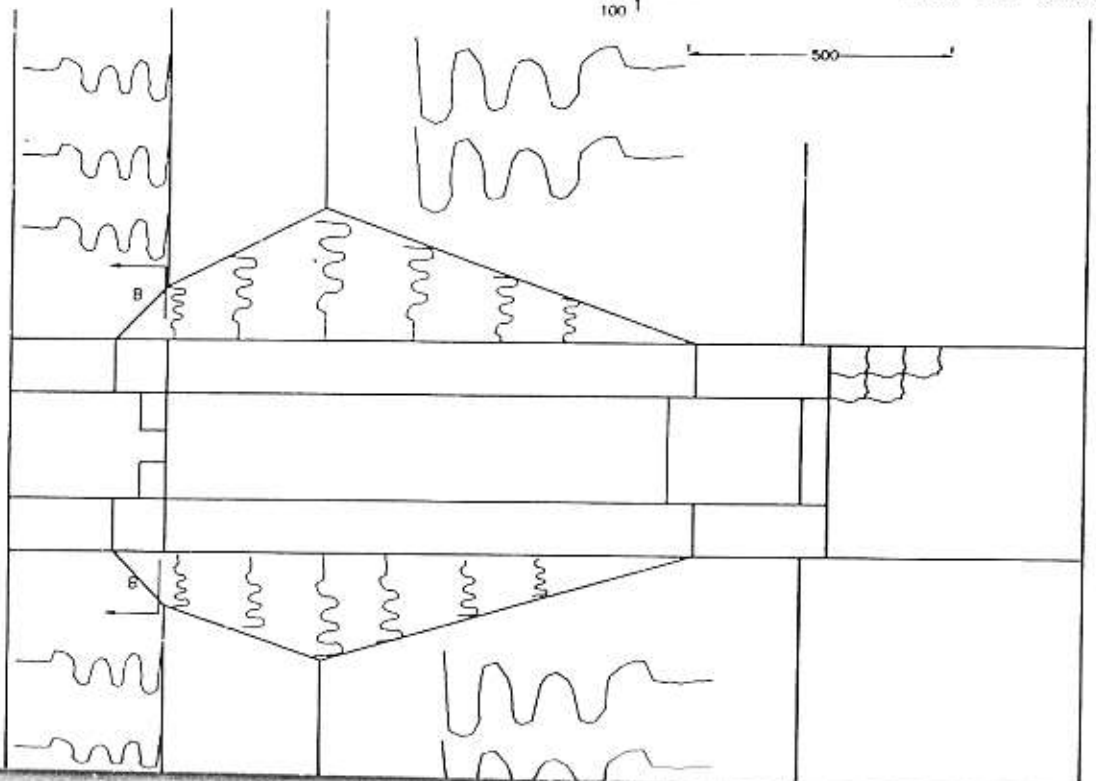
TABLE 7.1 Capacity of Spillways

Width W (mm)	Capacity (Litres/Sec)	Width W (mm)	Capacity (Litres/Sec)
300	90	700	200
400	100	800	250
500	140	900	300
600	170	1000	375





DETAIL SHOWING FARMER CONSTRUCTED DAM IN MOUTH OF SPILLWAY.



NOTES

1. All dimensions in mm
2. Bund to be well compacted beneath and arround structure
3. Width W depends on copacity required see manual for dimensions
4. Earth dam built by farmer to 200 to 300 mm high will overtop and wash away if water level becomes to great.

OFWM PROJECT

FIELD SPILLWAY

7.2 Waterways

Waterways are an integral part of terracing in higher rainfall areas. In most cases, a natural depression without shaping and protection is not safe to accommodate extra runoff concentrated by terracing. On average, a hectare needs 100 m of waterway. For larger blocks of land, the same waterway could serve up to two hectares.

The site and kind of waterway for a field depends on the slope, velocity and amount of runoff and the tools to be used for cultivation. It is always desirable to find a gentle depression area for the site of a waterway and to shape and revegetate this. When the velocity of runoff exceeds 1.5 m per second, engineering structures are usually needed for additional protection. A grassed waterway alone is seldom safe to be applied on steep slopes, i.e. more than 20% slope. In steep hilly regions, waterway structures cannot be avoided.

The waterway is usually situated at one end of the field. Sometimes, however, two waterways instead of one are needed, one at each end of the terraces to handle large quantities of runoff and when the terraces are longer than 100 m.

The size of a waterway is determined by the peak runoff of the area, which should be calculated in accordance with the method given in Section 6.4. The waterway should be sized, using Mannings equation in order to have sufficient capacity to pass the design flow, but the slope should be shallow enough that the velocity is low enough to prevent channel scour or erosion. Typical values of Manning N and maximum allowable velocities are given in the following Table.

TABLE 7.2 Mannings N And Max Allowable Velocities For Waterways

Waterway Type		Mannings N	Max Allowable Velocity m/sec
Grassed	-No vegetation	0.025	0 3
	-short grass	0.030	1.0
	-Long grass	0.035	1.5
Stone		0.030	2.0
Concrete		0.015	1.8

There are many types of waterways depending on material available, shape of the channel, purposes and structure needs. A waterway can also have many different sections according to the protection needs. The following are brief descriptions of some major types of waterway. Their uses and approximate limits are shown in Table 7.3 and Figure 7.3.

(1) Grassed Waterway: A parabolic shaped channel planted with low and rhizome type grass. The channel should be shaped as a uniform cross section with a consistent gradient as possible. It is the most inexpensive type of waterway on gentle slopes and its maintenance is easy.

waterway on gentle slopes and its maintenance is easy.

(2) Grassed Waterway with Drop Structures: On moderately steep slopes or in a discontinuous type of channel, small drop structures can be used in conjunction with grass channels to take care of the steep sections. Structures taller than 0.6 m should be avoided except on very steep land and the gradient between the apron of the upper structure and the weir of the structure immediately below should not be over 3% to ensure stability.

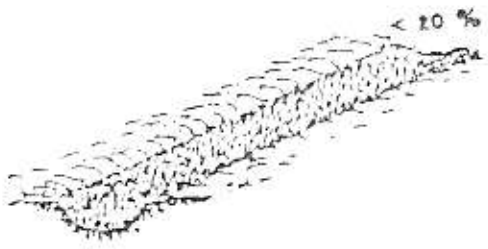
(3) Stone Waterway: Also on moderately steep slopes where large quantities of head-size stones are available, lining the parabolic channel with stones keyed in the ground can provide good protection. On steeper slopes or a for large runoff volumes, wire mesh crated stones should be used.

(4) Stepped Waterway: A series of drop structures with basins are used to protect the steep risers of the terraces whereas on flat benches, parabolic grassed waterways of 3% slope are employed to connect the drop structures. The grassed portion on benches can be easily crossed by a tractor and the structures on steep risers can be used for collecting the silt and as pathways. These are usually built in the middle of terraced fields.

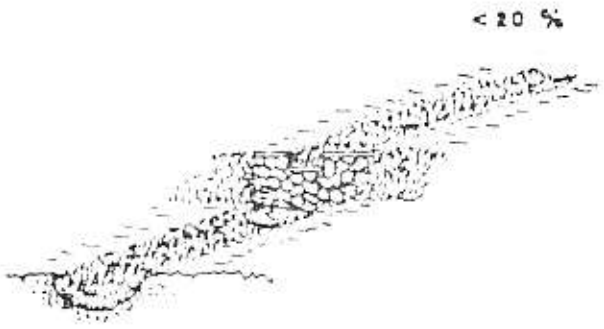
TABLE 7.3 Major types of waterways: their uses and limits(1)

Type	Shape	Channel Protection	Velocity Limit (m/sec)	Slope Limit	Uses
1. Grassed Waterway	Parabolic	By Grass	short 1.0m/sec long 1.5 m/sec	20%	For new waterway or uniform sloped depression
2. Grassed Waterway with Drop Structure	Parabolic	By Grass with Concrete and Masonry Structures	As above	3% between structures, 20% overall	For discontinuous types of channel
3. Stone Waterway	Parabolic	By Stones or by wire mesh crated stones	2m/sec	26%	Where stones are available
4. Stepped Waterway	Parabolic and Rectangular	By Grass with Concrete or Masonry Drops	On Grass part 1.8 m/sec	Overall slope 36%	For 4 wheel mechanisation and in the middle of bench terraces

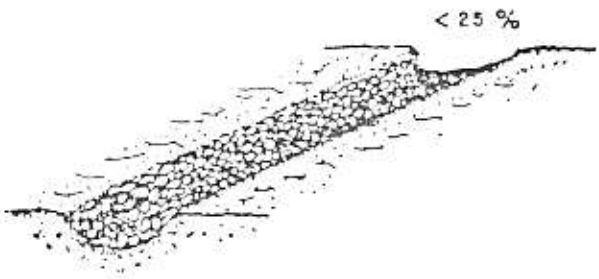
1. These limits are approximate for general reference. In practice, the volume and velocity of runoff and site conditions should all be taken into account for determining the type of waterway required. Most of the types described above handle only a few hectares of runoff.



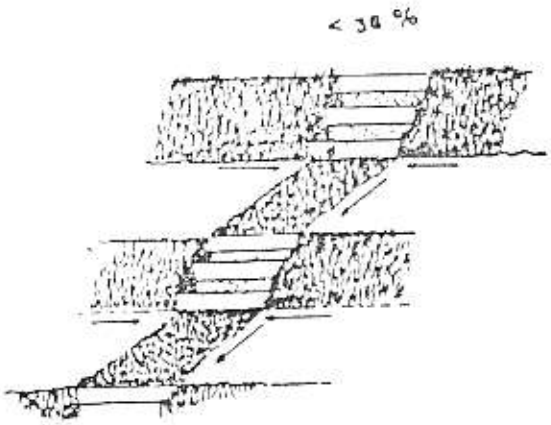
1. Grassed Waterway



2. Grassed Waterway with Drop Structures



3. Stone Waterway



4. Stepped Waterway

FIGURE 7.3 MAJOR TYPES OF WATERWAYS

Waterway Installation

(1) Shaping: All types of waterways should be shaped as uniformly as possible in cross-section and gradient. Sharp turns and sudden falls should be avoided unless at locations where a water collecting basin is planned or drop structure is to be built. Structures should be installed on solid cut soils or solid rock wherever possible. Stakes, strings or bamboo arches to mark the shaping area and depths are in many cases needed. It is also important to shape the waterway lower than the terrace outlets to ensure water flowing in.

(2) Grass Planting: An ideal grass for lining the waterway is one that is available locally and is the rhizome type or sod-forming type. Seeding is cheaper than sodding but it should be done with shallow ditching and mulching at the beginning of the rainy season. Strip-sodding can provide quick protection. Sometimes pegs are used to stabilize the sods.

(3) Construction of Drop Structures. A design for a typical drop structure on a waterway is shown as Figure 7.4. The dimensions for a particular drop structure should be determined as follows:

- first determine the design flow for the drop structure according to the method given in Section 6.4;

- then determine the breadth "B" of the structure required for the above flow, from the following table:

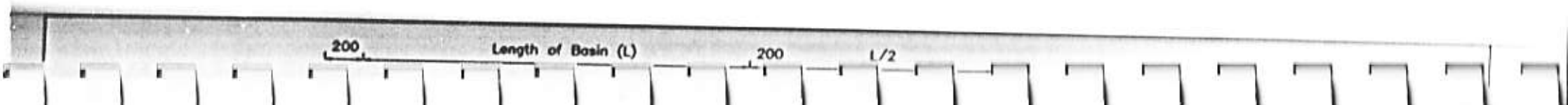
TABLE 7.5 Flow to breadth ratios for drop structures

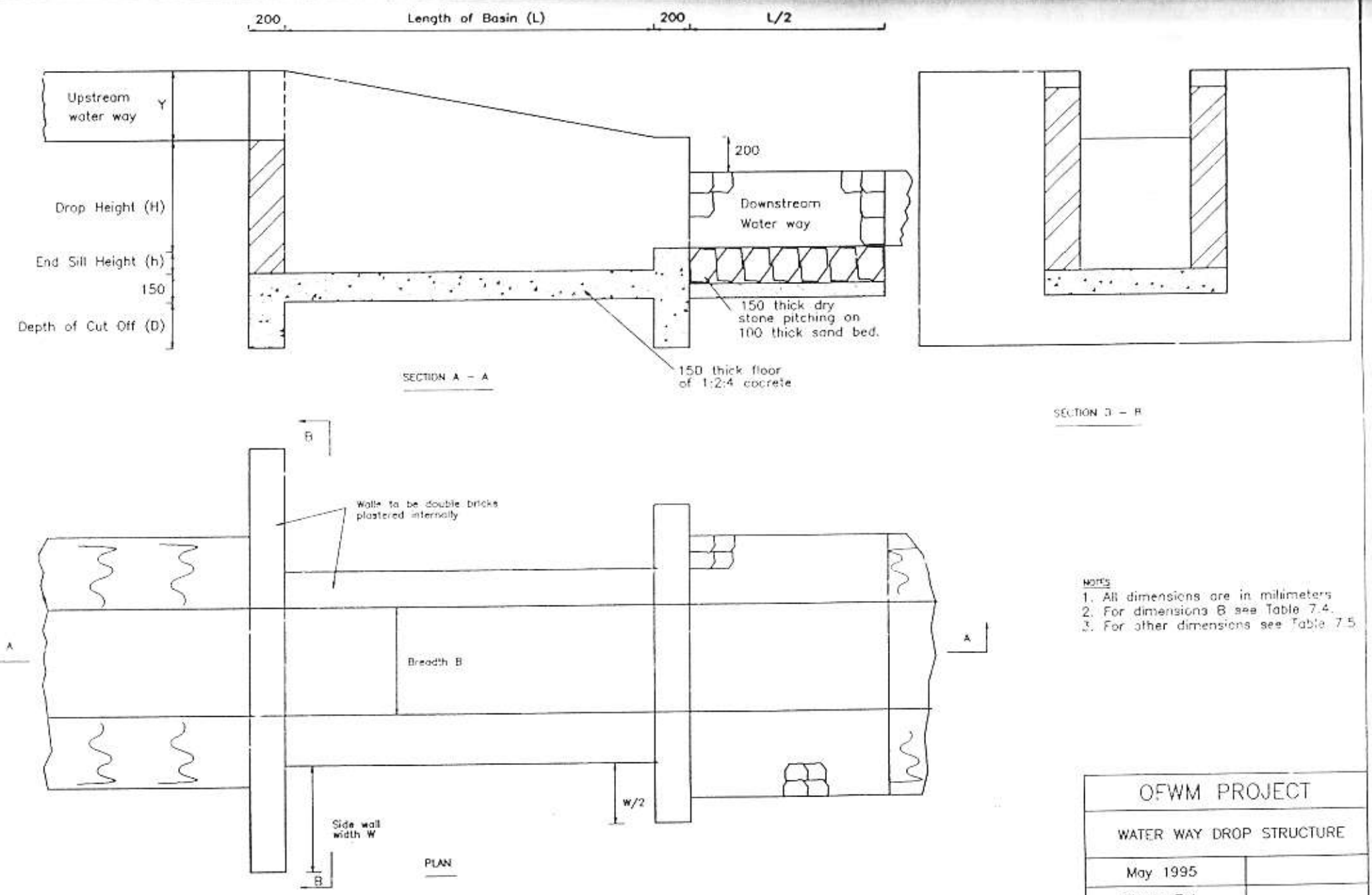
Flow Q (m3/sec)	Depth of Flow (mm)		
	200	300	400
	Breadth of Structure "B" (mm)		
0.05	300	150	
0.10	600	300	200
0.15	900	500	300
0.20	1100	600	400
0.30		800	500
0.35		1000	600
0.40			700
0.50			800
0.60			900
0.70			1000

- Determine the other dimensions of the drop structure from Table 7.5 from the drop height, the depth of flow in the upstream channel and the velocity of flow in the upstream channel.

TABLE 7.5 Dimensions of drop structures

DROP HEIGHT (H) (metres)	DESIGN DEPTH OF FLOW IN UPSTREAM CHANNEL (Y) (mm)	VELOCITY IN UPSTREAM CHANNEL (M/SEC)			HEIGHT OF END SILL (h) (mm)	DEPTH OF CUT OFF (D) (m)	SIDE WALL WIDTH (W) (m)
		0 - 1	1 - 1.5	1.5 - 2.5			
		LENGTH OF BASIN (L) (M)					
0.2-0.3	150	0.9	1.5	1.8	100	0.2	0.5
	300	1.5	1.8	2.4	150		
	600	1.8	2.4	3.3	250		
0.3-0.6	150	1.5	1.8	2.1	100	0.3	0.9
	300	1.8	2.1	2.7	150		
	600	2.4	2.7	3.6	250		
0.6-0.9	150	1.8	2.1	2.4	100	0.5	1.4
	300	2.1	2.4	3.0	150		
	600	2.4	3.0	4.0	250		
0.9-1.3	150	2.1	2.4	2.7	100	0.6	2.0
	300	2.4	2.7	3.3	150		
	600	3.0	3.3	4.3	250		
1.3-1.5	150	2.4	2.7	3.0	100	0.7	2.2
	300	2.7	3.0	3.6	150		
	600	3.3	3.6	4.6	250		
1.5-1.8	150	2.7	3.0	3.3	100	0.8	2.5
	300	3.0	3.3	4.0	150		
	600	3.6	4.0	4.9	250		





NOTES
1. All dimensions are in milimeters
2. For dimensions B see Table 7.4.
3. For other dimensions see Table 7.5

OFWM PROJECT	
WATER WAY DROP STRUCTURE	
May 1995	
Figure 7.4	

7.3 Diversion Ditches

A diversion ditch is a channel that is generally built across the slope to divert surface flow from its natural course to another outlet and serve the following purposes.

- Where a cultivated field of moderate slope lies at the foot of a steeper slope or hill which is not cultivated, the first conservation measure is to isolate the field to be treated from the larger watershed lying above it. This can be done by building a diversion ditch along the upper border of the field. The water thus diverted should be discharged into some protected waterway or other safe outlet. The measures subsequently applied to the field, such as terracing, will have to handle only the water from the incident rainfall. This is the principal reason for constructing a diversion ditch.

- In the case of a deep gully which is being eroded by an overfall at its upper end, a diversion ditch may be built around the eroding gully head before other control measures are attempted.

- If a spring or other form of groundwater breaks out at the surface of a sloping field, it may be captured and led off to a prepared outlet by means of a diversion ditch. Such a drain may act as an intercepter of groundwater seepage close to the surface, along its entire length.

- The diversion ditch may be used to safely carry away a discharge of water from some source point, such as flow from the roofs and paved lots of a built-up area that discharges on to an agricultural field, or the spillway discharge from a small reservoir.

The general cross section of a diversion ditch will be as for a waterway except that the side of the ditch adjacent to the upper catchment should be designed to allow water to flow into it from the higher land.

7.4 Gully Erosion Control

7.4.1 Introduction

The mechanics of gully erosion can be reduced to two main processes: down cutting and head cutting. Down cutting of the gully bottom leads to gully deepening and widening. Head cutting extends the channel into ungullied headwater areas, and increases the stream net and its density by developing tributaries. Thus, effective gully control must stabilize both the channel gradient and channel headcuts.

The types of gully control which are discussed below are:

- Watershed restoration
- Concrete or masonry check structures
- Rock fill check dams
- Gabion check dams
- Staking and wattling
- Vetiver (khus khus) grass

7.4.2 Watershed Restoration

Gulleys generally occur where rainfall has been allowed to runoff and then run down steep soil slopes accumulating in larger quantities the further down the catchment one travels.

The first method of gully control, which must always be used in conjunction with the other methods described below, is to promote infiltration, prevent runoff and control runoff above the gully. Other sections of this manual describe terracing, afforestation, pasture development, and the construction of waterways and diversion ditches, all of which should be used to conserve the rainfall and control runoff such that it does not form new gullys or flow to existing gullys.

7.4.3 Concrete or Masonry Check Structures

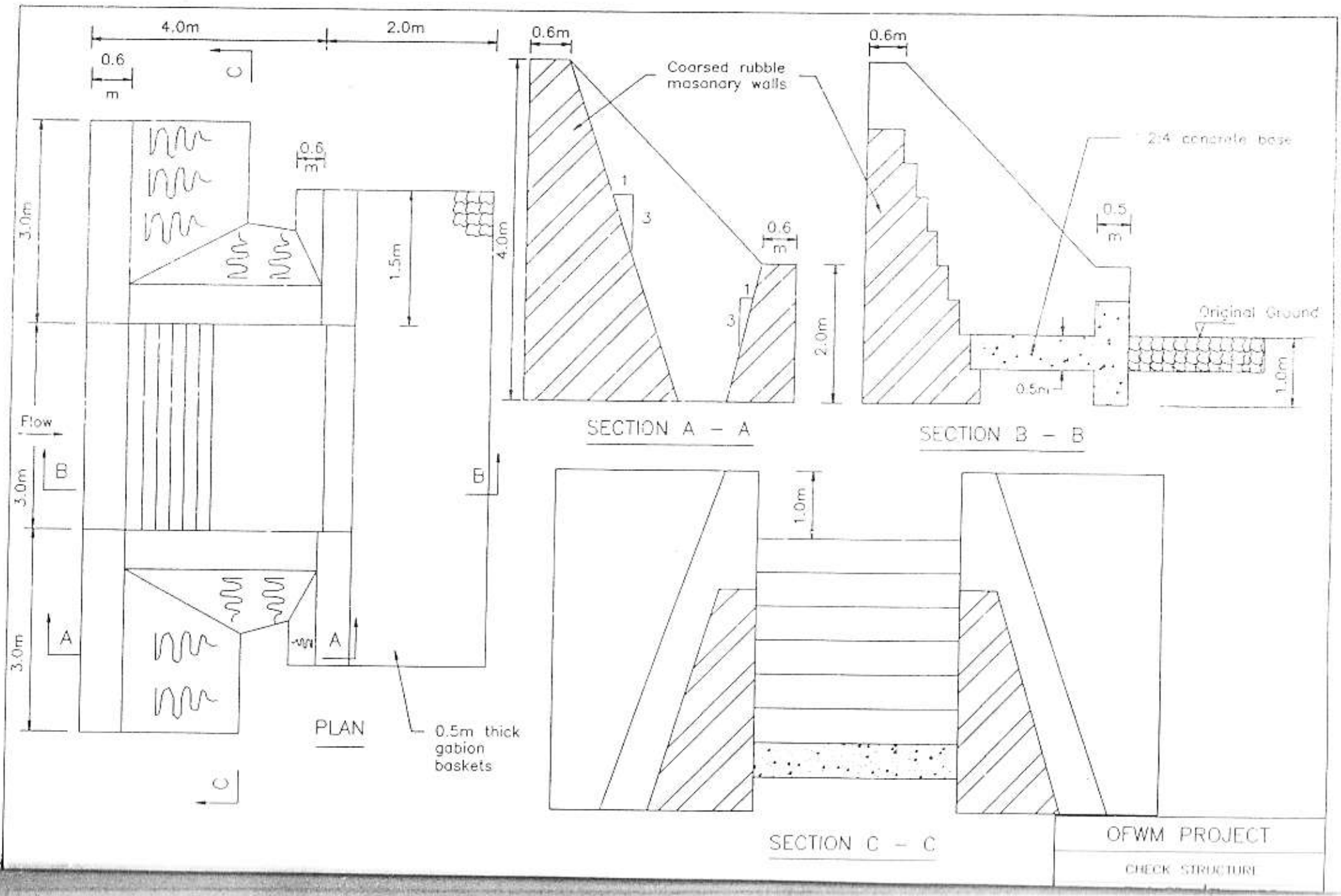
These are the traditional tool of the soil conservation service as a means of plugging deeply eroded gullies. A typical structure is shown on Figure 7.5.

A masonry wall is constructed across the gully, with a weir section in the centre, the crest of the weir being several metres above the bottom of the gully. The base of the wall is about 1m below the gully bottom level to prevent the structure sliding and the wall is supported by side and wing walls to prevent overturning. The side walls must be embedded at least 1m into the side of the gully to prevent the gully going around the structure. The dimensions of the structure shown on Figure 7.5 would need to be amended to meet the above criteria to suit the dimensions of individual gullys.

The capacity of the spillway weir should be determined to take a 1 in 50 year flood, calculated according to the rational method given in Section 6 of this Manual. The breadth of the weir should then be calculated from the following weir equation:

$$b = Q / (C_d * h^{1.5})$$

Where: b = the breadth of the spillway, in m
Q = the design flow in m^3/sec


4.0m
2.0m
0.6
m
C
0.6m
Coarsed rubble masonary walls
0.6m
2:4 concrete base
0.6
m
3.0m
1.5m
4.0m
1
3
0.6
m
1
3
0.5
m
Original Ground
2.0m
0.5m
1.0m
Flow
B
3.0m
B
A
3.0m
A
C
PLAN
0.5m thick gabion baskets
SECTION A – A
SECTION B – B
1.0m
SECTION C – C
OFWM PROJECT
CHECK STRUCTURE

C_d = coefficient of discharge, to be taken as 1.7
h = head over weir in m.. Allowing 0.25 m freeboard, h should be taken as 0.75 and hence $h^{1.5} = 0.65$

Hence the above equation can be reduced to $b = 0.9 * Q$

When a flood flow passes down the gully, the water ponds up behind the structure until it can overflow the weir. In doing so it deposits silt upstream of the structure, which within a season or two infills the gully back up the weir level, allowing the land behind the weir to be brought back into production.

These structures are expensive and should only be used where other more cost effective means cannot be used. Check structures should also only be used in conjunction with other techniques including watershed restoration, in an integrated gully erosion control programme.

7.4.4 Rock Fill Check Structures

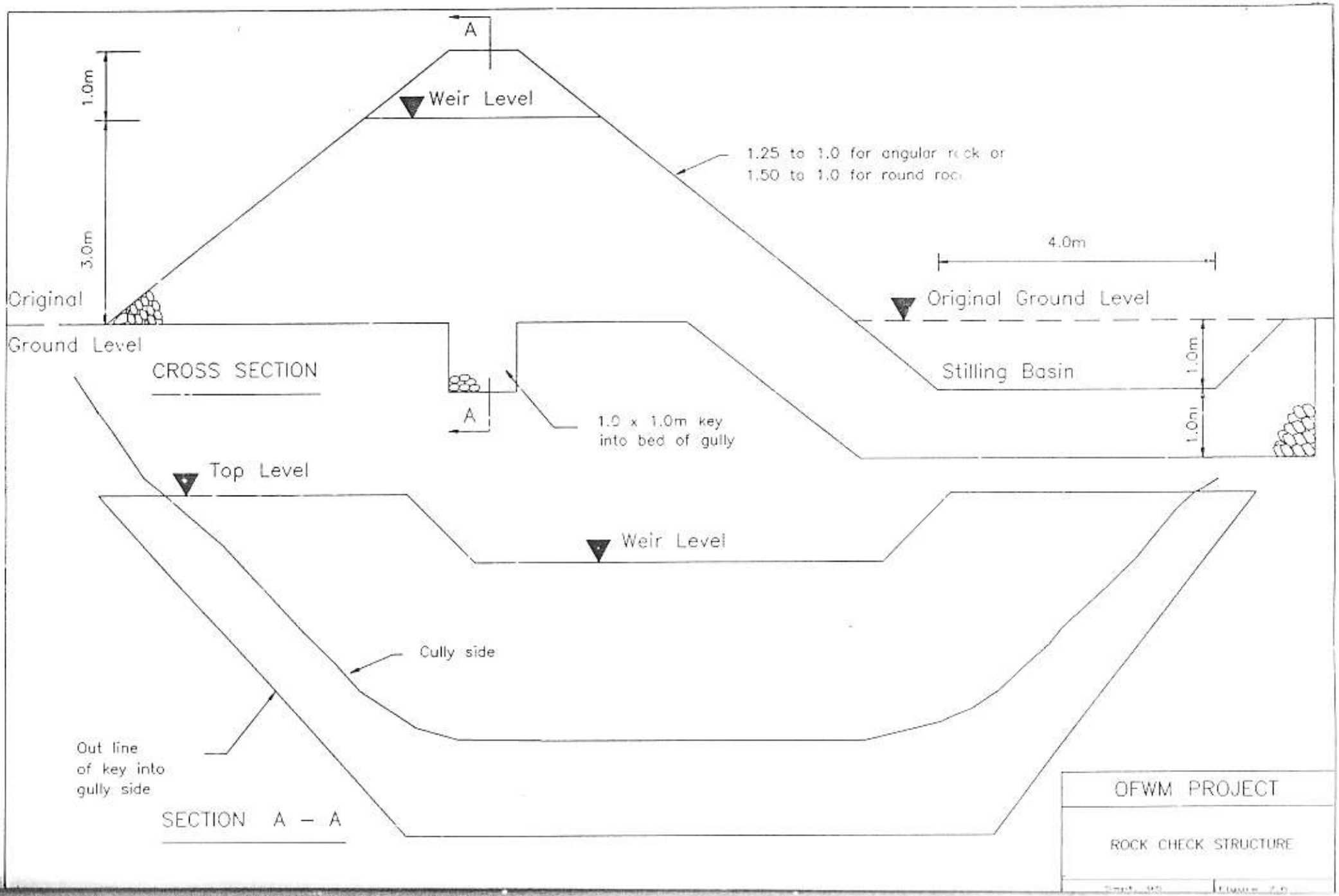
The basic design for a rock check structure is shown on Figure 7.6. The function of the structure is the same as that described for the masonry structure above. Rock fill check structures are most suitable where well graded rocks of an average size of at least that of a head, are easily found within the vicinity of the gully. The rocks should be carefully placed in such a way that the rocks are well packed and the size of the voids are minimised by infilling between the rocks with smaller stones.

As for the masonry check structure above, a weir section is formed in the middle of the gully in order that the water passing over the structure does not scour the sides of the gully. The rock structure is also embedded in the sides of the gully to stop the flow cutting around the structure. A stilling basin is provided to prevent the structure from being undermined downstream. The dimensions of this structure will have to amended to suit actual site conditions.

7.4.5 Gabion Check Structures

Gabion check structures are essentially the same as rock check structures except that they are more suitable where only smaller rocks are available and hence the rocks are required to be packed into galvanised steel wire baskets in order to ensure that the rocks do not wash away.

The shape of a gabion check structure would be essentially the same as that shown on Figure 7.6 for the rock check structure.


A
1.0m
Weir Level
1.25 to 1.0 for angular rock or
1.50 to 1.0 for round rock
4.0m
3.0m
Original
Ground Level
Original Ground Level
CROSS SECTION
Stilling Basin
1.0m
1.0m
A
1.0 x 1.0m key
into bed of gully
Top Level
Weir Level
Cully side
Out line
of key into
gully side
SECTION A – A
OFWM PROJECT
ROCK CHECK STRUCTURE

7.4.6 Staking and Wattling

This is a technique suitable for smaller gullies than the above techniques.

As shown on Figure 7.7, wooden stakes are driven into the bed of the river at about 150mm intervals across the line of the flow. The stakes can either be dead wood, or better still can be live stakes of a fast growing tree which will root from a stake. Where the stake is live this technique is best undertaken at the beginning of the summer or winter rainy seasons in order to have the best chance of the stake rooting.

Once the stakes have been driven into the river bed, thinner branches are woven between the stakes to provide a woven porous mat across the line of the flow, up to about 30 cm high.

When the gully flows, trash will tend to get caught in the structure and if a series of such structures have been constructed at about 20m intervals down the gully (or closer on steep gullies), the bed of the gully will silt up behind each structure. If the procedure is repeated regularly as the level of the gully is raised, then the gully can quite quickly (in a matter of a few season) be first stabilised and then filled in.

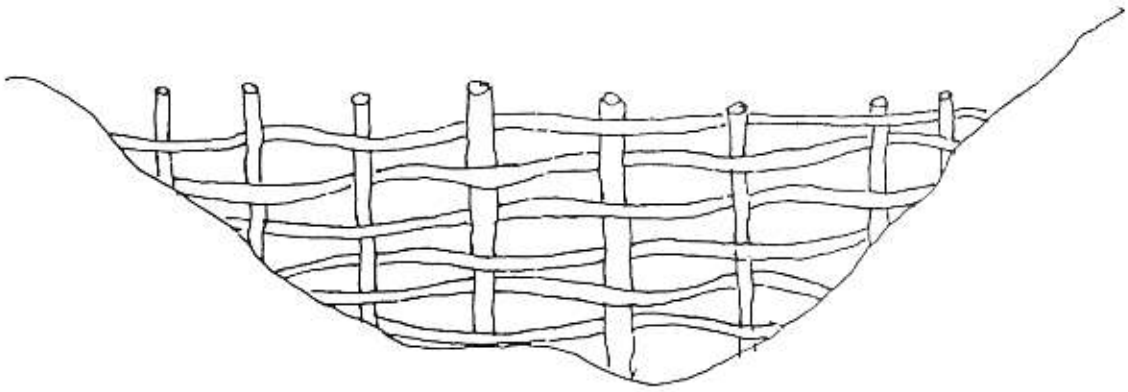


FIGURE 7.6. Wattling and Staking.

7.4.7 Vetiver (Khus Khus) Grass

Planting the bottom and sides of the gully with grass and other ground covering shrubs and plants is a very effective means of erosion control. Vetiver grass which is described in detail in the Chapter on Livestock and Pasture Management of this manual, is particularly effective for this purpose and is much used in India for erosion control.

8. STORAGE STRUCTURES

8.1 Introduction

Much rainwater which has runoff into small water ways and streams in a catchment could be saved and used within the catchment if it could be stored in ponds and reservoirs created by dams. The water so saved may be used for supplemental irrigation during dry seasons of the year and can be used for stock watering and domestic use. The ponds and reservoirs may also be used for fish culture.

Dams are constructed across streams or rivers and result in lakes or reservoirs forming upstream of the dam in the old bed of the river or stream. Dams can be constructed of earth, concrete, masonry or rock or a combination of all these. Because dams are constructed across rivers or streams they must incorporate spillways to take the flood flows in the river, without damaging the dam.

This manual deals only with relatively small dams, up to about 5m high. Sites for large dams require special investigations which can take years to undertake before sufficient data is obtained to design the dam. Furthermore the design of large dams is a very specialised undertaking which requires the services of very experienced engineers and hydrologists. The technical aspects of this are outside the scope of this manual.

Ponds usually have less storage than reservoirs created by dams and are not constructed across a stream or river and hence do not require such a large spillway.

The design of both dams and ponds are discussed below, but first the amount of water entering a storage structure must be calculated and the use to which it can be put defined.

8.2 Water Balance

In order to determine the most appropriate size for a dam, reservoir or pond, and to determine whether the construction of such a structure is likely to be worthwhile, a water balance must be undertaken which balances the water estimated to run off into the pond or reservoir against that which will be lost by evaporation and seepage and that which can be used and hence the area which could irrigated from the reservoir or pond.

Table 8.1 gives an example of a typical water balance. The method of calculation for each step is given on the Table. A blank of the form may be found in Appendix F.

TABLE 8.1 Typical Water Balance for a Small Dam.

STEP NO	FACTOR	CALCULATION	UNIT	MONSOON SEASON	WINTER SEASON
1	Rainfall Station	CHAKWAL			
2	Average Rainfall	From Table 6.1	mm	346	154
3	Runoff Coefficient	From Section 6.3		0.5	0.3
4	Catchment Area	Measured from map	ha	10	10
5	**Runoff Volume**	2 * 3 * 4 * 10	m3	17,300	**4,620**
6	Pond/Reservoir Area	From Survey Plan	m2	6,000	6,000
7	Evaporation Rate	From Table 6.2 (monthly figures/30)	mm/day	10	5
8	Seepage Rate	Estimated or measured using an infiltrometer	mm/day	20	10
9	Length of Crop Season		Days	90	90
10	**Water Loss**	6 * 9 * (7 + 8) / 1000	m3	10,800	**8,100**
11	**Useable Water**	5 - 10	m3	6,500	**0**
12	Seasonal Crop Water Requirements	From Volume 5 of these Manuals	mm	400	400
13	Supplemental Irrigation Required	12 - 2	mm	54	246
14	Irrigation Efficiency	Estimated	%	50%	50%
15	**Area Irrigable**	(11 * 14) / (13 * 10000)	ha	6	**0**

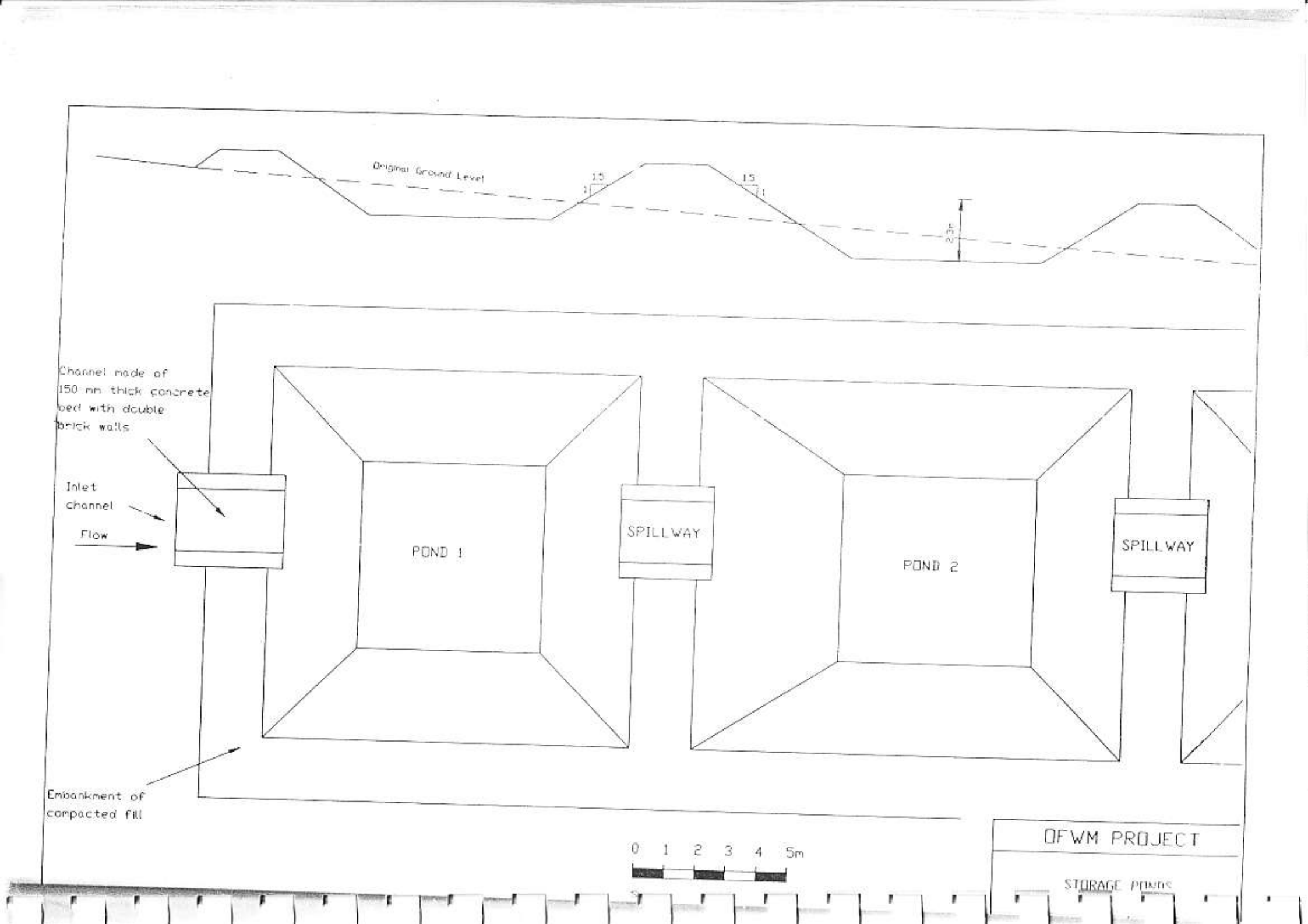
The above analysis does not take into account loss of reservoir volume due to siltation. It is critical that if reservoirs and ponds are to last more then a few years then they must be sited in catchments which are not highly erosive and which do not produce vast quantities of silt. Afforestation, terracing and other catchment control measures described elsewhere in this manual can go a long way to ensuring the long life of a storage pond or reservoir.

8.3 Ponds

Ponds need to be sited where they will receive runoff from surrounding areas to fill them, where they can serve by gravity (or by pumping) the surrounding area and should be on clay or silt soils in order that infiltration losses are not excessive.

An outline design is shown on Figure 8.1.

Design considerations for ponds are essentially the same as for dams described below.


Original Ground Level
1:5
1:5
2.5m
Channel made of 150 mm thick concrete bed with double brick walls
Inlet channel
Flow
POND 1
SPILLWAY
POND 2
SPILLWAY
Embankment of compacted fill
0 1 2 3 4 5m
OFWM PROJECT
STORAGE PONDS

8.4 Dams

The selection of a dam site is critical to its technical and economic viability. Dam sites need to be narrow, have a good foundation and a large area upstream for storage of the water. The following characterise a good dam site:

- Generally narrow points in the valley of the stream or river are the best since they will result in a short dam;
- The valley above the dam site should be as wide as possible with a gentle bed slope in order to maximise the reservoir volume in relation to the size of the dam. Hence a wide valley immediately above a narrow gorge is ideal;
- The bottom of the dam should be above the area to be irrigated in order to avoid pumping and there should be a clear route for a channel to carry the water from the dam to the fields;
- The dam site should have a good sound foundation, preferably of rock; and
- The reservoir should preferably be deep rather than shallow in order that evaporation and seepage losses are minimised.

Two types of dams are proposed, earth dams and masonry (or concrete) dams, these have very different cross sections to each other as shown on Figures 8.2 and 8.4.

All dams require a spillway, and these can be the most expensive part of a dam, particularly an earth dam. As shown on Figure 8.2, an earth dam can either have a spillway constructed across the top of it, or if the site allows, the adjacent rock can be excavated to form the spillway, this often being the safest and most economical way of forming the spillway to an earth dam. For masonry dams it is usually easiest to form the central part of the dam into the spillway, and provide protection downstream to ensure that the toe of the dam is not scoured away (see Figure 8.4).

8.5 Site Investigations

Adequate site investigations are an absolute requirement for a dam, what ever its size. Site investigations fall into three categories, topographical, hydrological and geotechnical.

Topographical Surveys. Three levels of topographical survey are required:

- a detailed survey of the dam site itself;
- a semi detailed survey of the reservoir site in sufficient detail to assess the

volume of water to be contained behind the dam; and

- a reconnaissance level survey of the catchment area in order to assess its area, slope and the nature of the catchment in order to estimate the volume of runoff. If the catchment area can be clearly shown on existing Survey of Pakistan or other topographic maps then no further surveying may be required. If not then a survey showing the boundary of the catchment with levels all around the catchment boundary will be required.

Hydrological Investigations. Are required in order to assess the mean annual flow from the catchment for the water balance given in Table 8.1 and in order to assess the one in one hundred year flood flow in the catchment, in accordance with the methodology given in Section 6.4, in order to design the spillway.

Geotechnical Investigations. It is critical that the dam is:

- founded on a firm foundation that will not settle unduly with the weight of the dam, this is particularly critical for masonry or concrete dams; and
- that the foundation will not be permeable and hence allow the ponded water to flow out of the reservoir under or to the sides of the dam. Fractured rock which would allow the flow to disappear through cracks or sandy or other permeable soils are therefore to be avoided.

Pits should be dug both across the floor of the valley where the dam is proposed to be built and up the sides of the valley at this point. It is recommended that pits between 2 and 3m deep are dug and that the pits should be examined and logged by a soil scientist or engineer. Samples should be taken from representative horizons in each pit and sent to a laboratory for examination of:

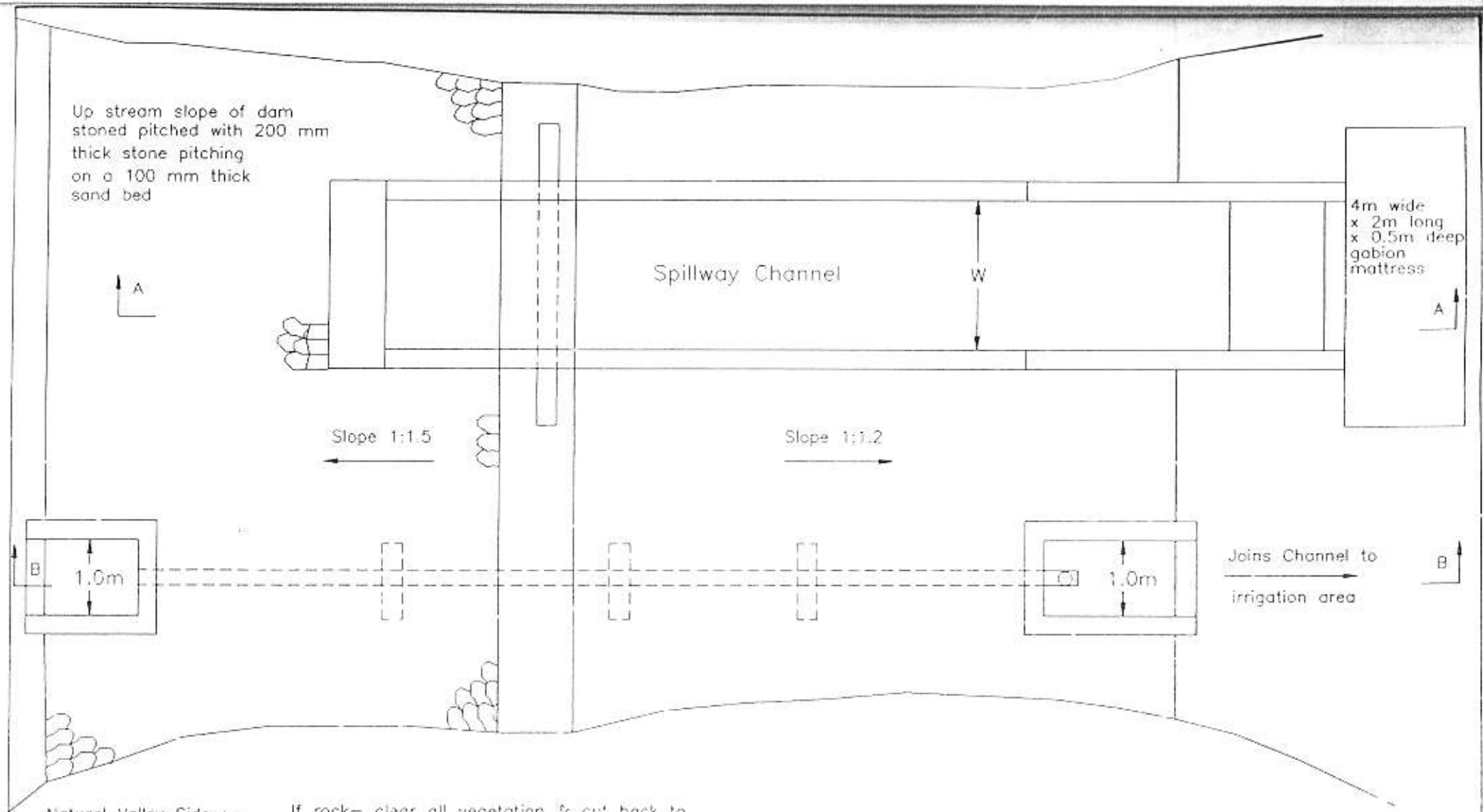
- Texture;
- Atterberg (liquid and plastic) limits; and
- Shear strength and cohesion.

Where an earth dam is going to be constructed, pits should also be dug in the borrow area from where the earth is to be taken and the pits logged and samples taken and tested as described above.

8.6 Earth Dams

Designs for a typical earth dam are shown on Figure 8.2. The design is discussed below.

Prior to constructing and earth (or any other) dam, the foundation material must be made suitable for the dam. First all organic matter including decaying vegetation should be stripped from the site of the dam (across the valley sides as well as the



Natural Valley Side :- If rock- clear all vegetation & cut back to sound unfractured rock- fill all cracks and joints with sand cement mortrar (1:4)

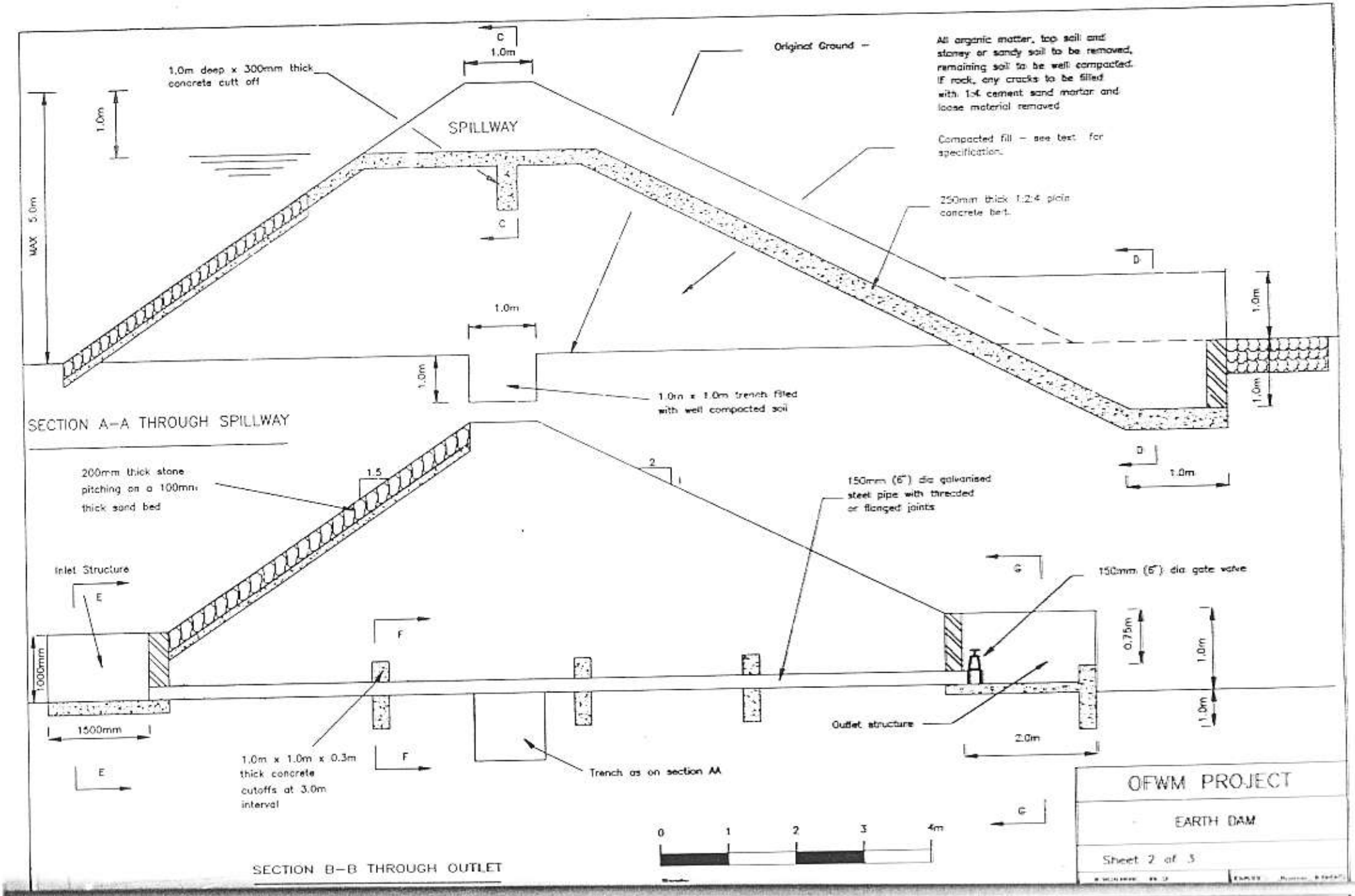
:- If earth - clear all vegetation, roots and other organic matter as well as soft spots, ensure sides are well compacted

PLAN

0 1 2 3 4m

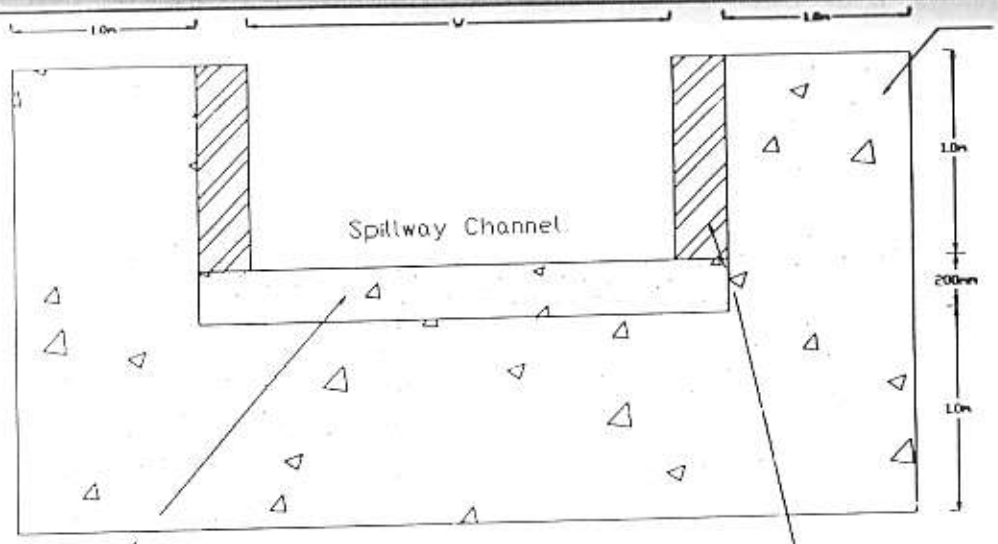
Scale

OFWM PROJECT	
EARTH DAM	
Sheet 1 of 3	
FIGURE 8.2	DATE: Jun,1995


1.0m deep x 300mm thick concrete cutt off
SPILLWAY
Originct Ground
All organic matter, top soil and stoney or sandy soil to be removed, remaining soil to be well compacted. IF rock, any cracks to be filled with 1:4 cement sand mortar and loose material removed
Compacted fill - see text for specification
250mm thick 1:2:4 plain concrete bed
MAX 5.0m
1.0m
1.0m x 1.0m trench filled with well compacted soil
SECTION A-A THROUGH SPILLWAY
200mm thick stone pitching on a 100mm thick sand bed
150mm (6") dia galvanised steel pipe with threaded or flanged joints
150mm (6") dia gate valve
Inlet Structure
1000mm
1500mm
0.75m
2.0m
Outlet structure
1.0m x 1.0m x 0.3m thick concrete cutoffs at 3.0m interval
Trench as on section AA
0 1 2 3 4m
SECTION B-B THROUGH OUTLET
OFWM PROJECT
EARTH DAM
Sheet 2 of 3

SECTION B-B THROUGH OUTLET

Sheet 2 of 3

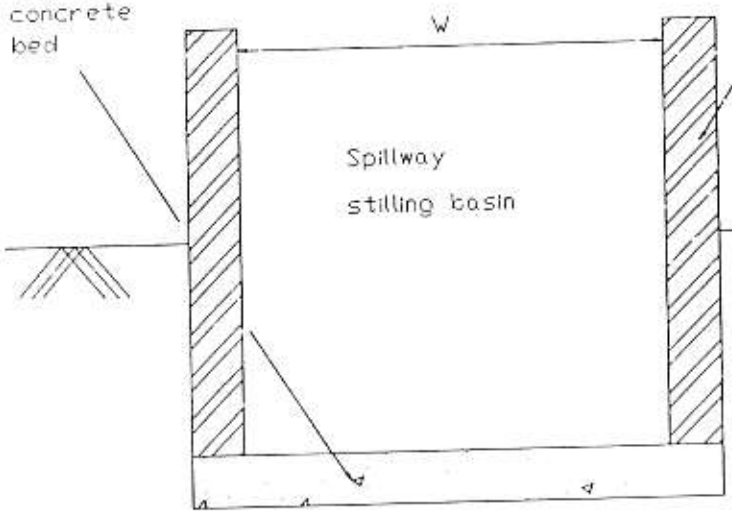


300mm thick 1:2:4 plain concrete cut off wall around spillway channel

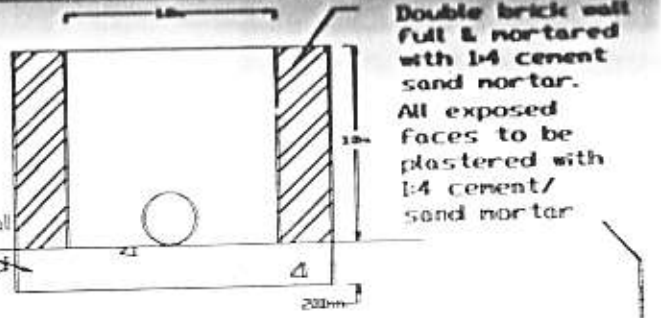
SECTION C-C

250mm thick 1:2:4 plain concrete bed

Double brick thick wall fully mortared with 1:4 cement-sand mortar All exposed wall surfaces plastered with 10mm thick 1:4 cement sand mortar



SECTION D-D

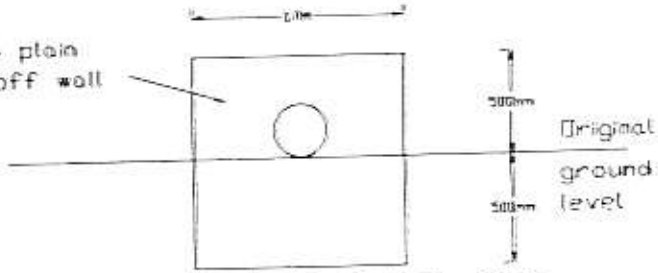


Double brick wall full & mortared with 1:4 cement sand mortar. All exposed faces to be plastered with 1:4 cement/ sand mortar

1:2:4 plain concrete base

Original ground level

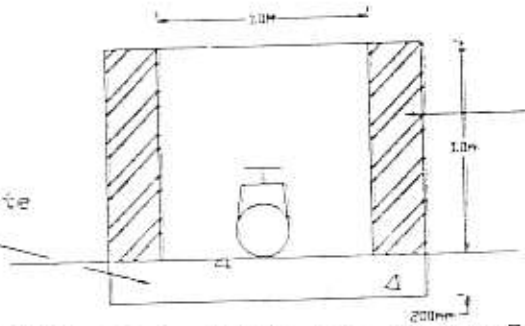
SECTION E-E INLET STRUCTURE



300 thick 1:2:4 plain concrete cutoff wall

Original ground level

SECTION F-F CUTT OFF



1:2:4 plain concrete base

SECTION G-G OUTLET STRUCTURE

0 1 2 3 m

Scale

OFWM PROJECT
EARTH DAM
Sheet 3 of 3
FIGURE 8.2 — DATE: June.1995

floor) as should any top soil or pockets of unsuitable soil such as permeable sands. The foundations should then be watered to bring the moisture content of the soil to close to optimum for compaction and the foundations rolled to provide a compact foundation.

Where the dam is to be constructed on a rock foundation, any overburden should first be removed and then all loose and unsound rock also removed to provide a sound rock foundation. Any cracks in the rock should be filled with a 1:4 cement sand mortar.

Whether the dam is to be founded on soil or rock, a trench should be constructed beneath the dam to cut the flow path along the interface between the dam and the foundations as shown on Sheet 1 of Figure 8.2. The trench should be filled with the same material to be used in the dam (see below), the material should be well compacted into the trench by hand ramming or using a vibrating plate compactor. The trench should run across the bottom of the valley floor and up the sides of the valley to the top of the dam.

The type of soil to be used in the construction of the dam is critical as is its compaction. Suitable soil comprises a stone and organic matter free well graded soil such a clay loam, loam or silty clay loam. The texture analysis proposed in the previous Section should be used to determine the soil classification by plotting the percentages of clay, silt and sand on the soil classification triangle given on Figure 8.3, in order to determine whether the soil falls into one of the above classifications.

The dam must be constructed of well compacted soil. In order to achieve this the soil must be laid in layers of 150 to 200 mm thick, watered to bring it to optimum moisture content and then rolled to compact each layer before laying the next layer. This is a skilled job and advice should be sought from an experienced engineer. In order to compact the sides of the dam, the dam must be constructed beyond its finished profile, compacted and then excavated back to the design side slopes, this is because it is impossible to compact the edges of an embankment.

The spillway must be designed to handle the flow calculated from the hydrological investigations described in Section 8.6. The width of the spillway required to carry the one in one hundred year return period flood flow may be determined from the equation given in Section 7.4.3. The spillway may be located on the dam, as shown on Figure 8.2 or, if a suitable rock outcrop exists beside the dam, may be constructed by excavating a suitable flow path into the rock. This latter solution is usually both the safest and may be the cheapest where suitable conditions exist. Where the spillway is to be constructed on the dam body, a channel section with a small stilling basin at the toe is proposed as shown on Figure 8.2. A cut off trench is proposed beneath and around the spillway to ensure that flow does not creep along the outside of the spillway.

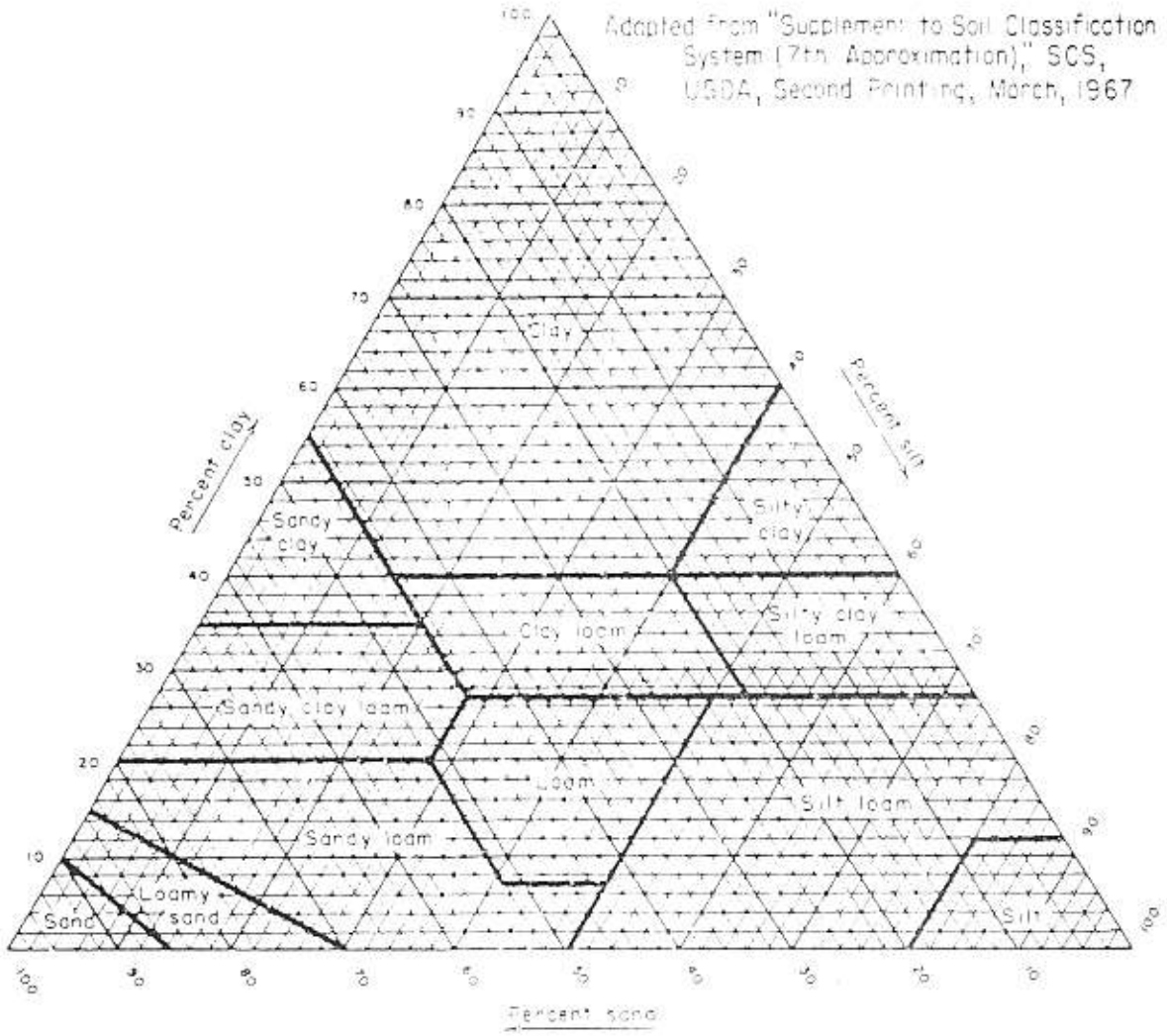


FIGURE 8.3 Soil Triangle of the Basic Soil Textural Classes

Both the spillway and the cutoff trench should be constructed by excavating into the dam body once it has been brought up to its overall height, this is to ensure that the material around the structure is properly compacted. The trench should then be excavated and filled with 1:2:4 plain concrete with the concrete being placed into the trench without shuttering, in order that the concrete makes good contact with the soil and no voids remain between the concrete and the foundations.

An outlet is required to abstract flow from the bottom of the reservoir for irrigation and other use. It is proposed that a 150 mm (6 inch) galvanised steel pipe be used for the outlet at the bottom of the dam as shown on Figure 8.2. Small inlet and outlet boxes are provided up and downstream, with a gate valve being provided on the downstream end of the pipe in order to control the flow. Concrete cut off trenches, constructed as described for the spillway, should be constructed at 3 m intervals along the pipe in order to ensure that flow does not creep along the outside of the pipeline. Special care should also be made to ensure that the soil around the pipeline is well compacted and that the pipeline is not damaged by heavy compaction equipment passing immediately above it before sufficient cover has been established.

8.7 Design of Masonry Dams

The design of a typical concrete or masonry dam is shown on Figure 8.4 and is described below.

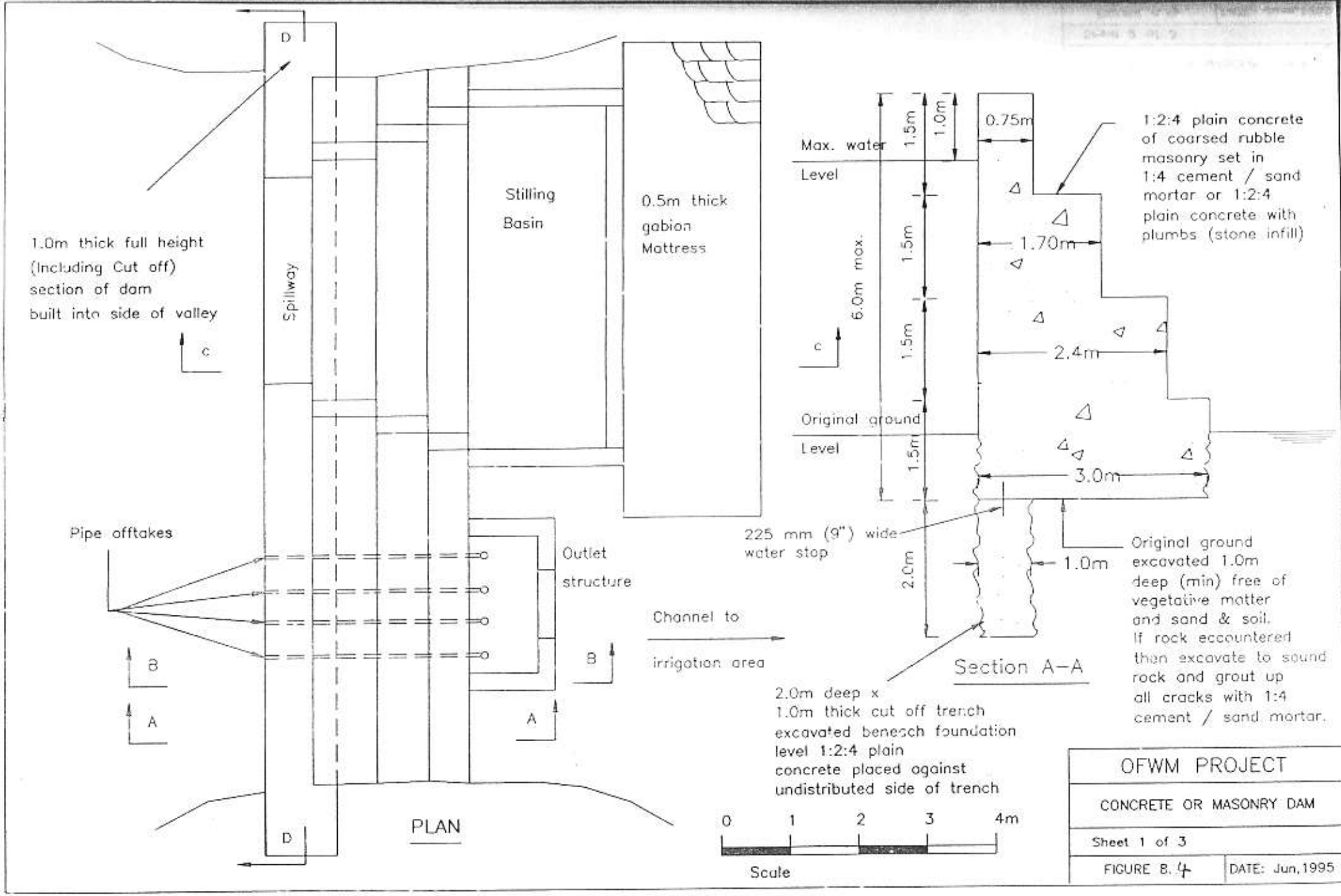
Site investigations and foundation treatment for the concrete or masonry dam will be as described for the earth dam above.

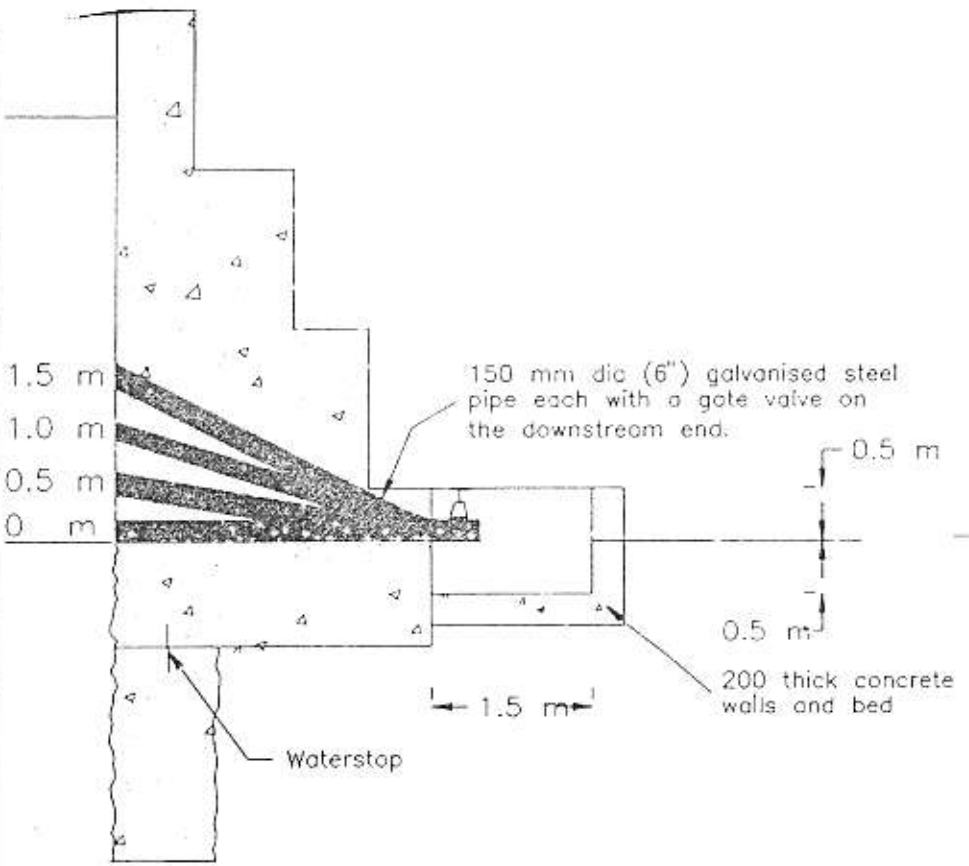
The design for the concrete or masonry dam shown on Figure 8.3 is typical only. The following safety checks on the design of each dam should be undertaken by an experienced Engineer:

- Overturning (see sample calculations on Table 8.2);
- Sliding;
- Ground pressure;
- Creep around the structure; and
- Uplift.

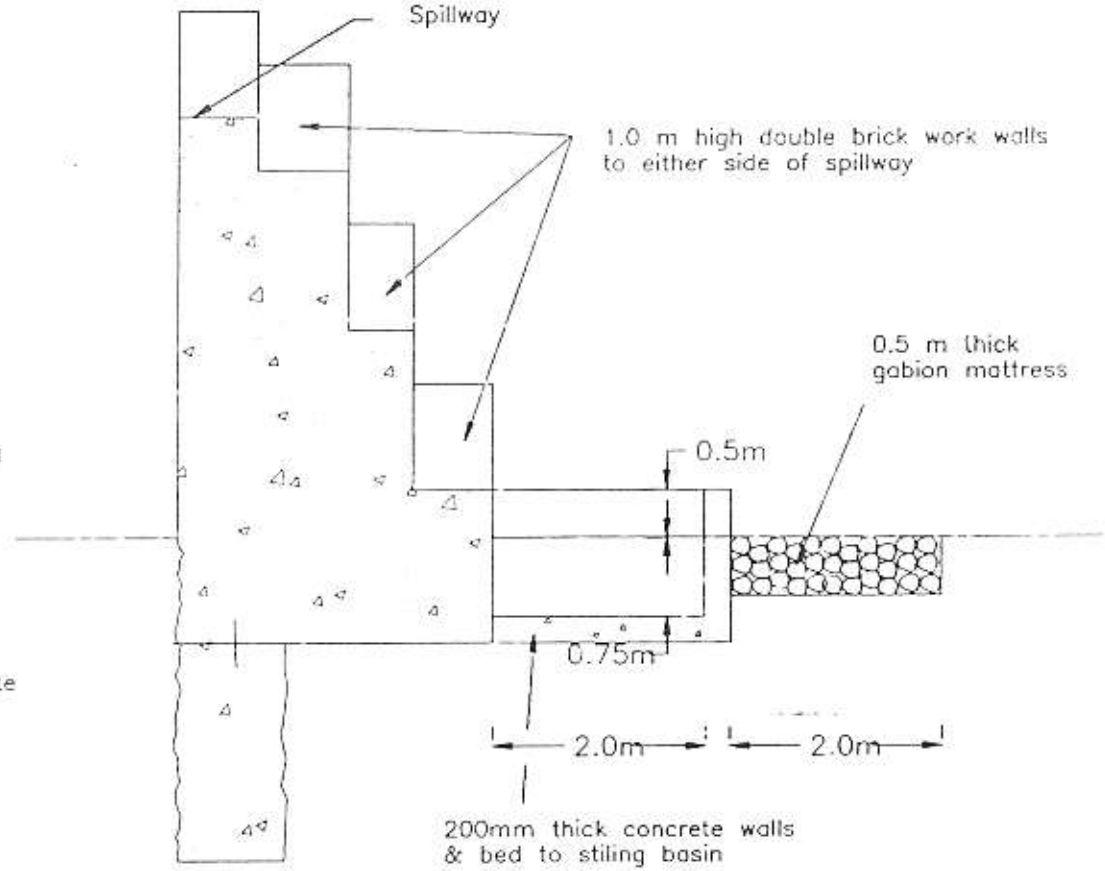
The spillway will normally be located on the dam body for a concrete or masonry dam as shown on Figure 8.4. The width of the spillway should be adjusted to suit the 1 in one hundred flood flow calculated as described in the preceding section for the earth dam.

Four outlet pipes have being provided in the design for the concrete/masonry dam shown attached, with their inlets at different levels, this allows for the lower pipes to be gradually blocked by siltation of the reservoir. The higher pipes slope down

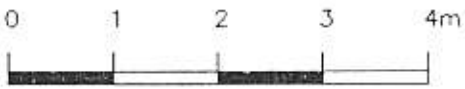

1.0m thick full height
(Including Cut off)
section of dam
built into side of valley
C
D
Spillway
Stilling
Basin
0.5m thick
gabion
Mattress
Pipe offtakes
Outlet
structure
B
A
Channel to
irrigation area
PLAN
Max. water
Level
1.5m
1.0m
0.75m
1:2:4 plain concrete
of coarsed rubble
masonry set in
1:4 cement / sand
mortar or 1:2:4
plain concrete with
plumbs (stone infill)
1.70m
6.0m max.
2.4m
Original ground
Level
3.0m
225 mm (9") wide
water stop
2.0m
1.0m
Original ground
excavated 1.0m
deep (min) free of
vegetative matter
and sand & soil.
If rock eccountered
then excavate to sound
rock and grout up
all cracks with 1:4
cement / sand mortar.
Section A–A
2.0m deep x
1.0m thick cut off trench
excavated benesch foundation
level 1:2:4 plain
concrete placed against
undistributed side of trench
0 1 2 3 4m
Scale
OFWM PROJECT
CONCRETE OR MASONRY DAM
Sheet 1 of 3
FIGURE 8.4
DATE: Jun, 1995



SECTION B–B



SECTION C–C

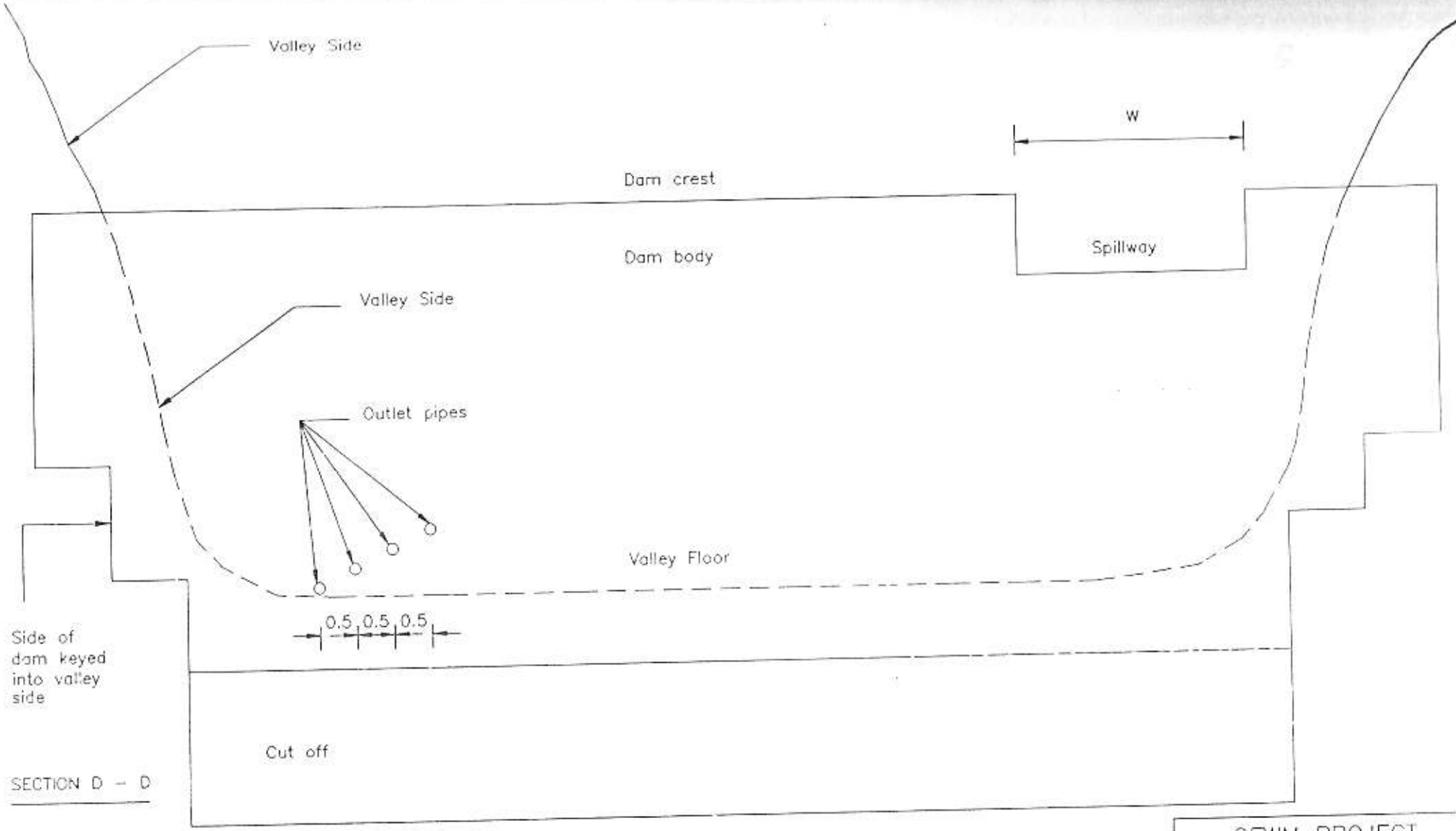


Scale

OFWM PROJECT

CONCRETE OR MASONRY DAM

Sheet 2 of 3



SECTION D – D

OFWM PROJECT
CONCRETE OR MASONARY DAM
SHEET 3 OF 3
FIGURE 8.4 | DATE: Sept.1995

DESIGN OF CONCRETE DAM AGAINST OVERTURNING

TABLE 8.2

(A) DESIGN PARAMETERS

Density of wall material (D) =	20	KN/m3
Desnsity of Backfill (d) =	13	KN/m3
Backfill angle of interal friction	20	degrees
Backfill passive earth coefficien	2.04	

P = Overturning Force
W = weight of section of wall
R = Restoring Force
Note: moments taken around outer toe of wall

(B) CHECK OVERTURNING WITH NO BACKFILL TO DAM

Step	height	thickness	Earth level	P	Overturn moment	W	Restore Moment	F of S
	m	m	m	KN	KNm	KN	KNm	
Top	1.50	0.75	0.00	11.25	5.63	22.50	8.44	1.50
2	1.50	1.70	0.00	45.00	45.00	73.50	73.16	1.63
3	1.50	2.40	0.00	101.25	151.88	145.50	230.14	1.52
bottom	1.50	3.00	0.00	180.00	360.00	235.50	540.64	1.50
TOTAL	6.00		0.00					

(C) CHECK FOR OVERTURNING WITH BACKFILL TO GROUND LEVEL

Step	height	thickness	Earth level	P	Overturn moment	W	Restore Moment	P Earth = R	Restore M Earth		F of S
	m	m	m	KN	KNm	KN	KNm	KN	KNm		
Top	1.50	0.75	0.00	11.25	5.63	22.50	8.44	0.00	0.00		1.50
2	1.50	1.70	0.00	45.00	45.00	73.50	73.16	0.00	0.00		1.63
3	1.50	2.40	0.00	101.25	151.88	145.50	230.14	0.00	0.00		1.52
bottom	1.50	3.00	1.00	180.00	360.00	235.50	540.64	13.26	4.42		1.51
TOTAL	6.00		1.00								

through the dam body so that the outlet of each is at the same level in a small outlet box. Each pipe has a gate valve on its downstream end to control the flow.

8.8 Fish Culture in Ponds and Reservoirs

Many ponds and reservoirs will be constructed for dual irrigation and fish culture usage. Where this is the case then a minimum of 1m of water must remain in the pond/reservoir at the end of the season for the fish and this must be taken into account in the water balance.

9 AGRONOMY FOR BARANI AREAS

9.1 Field Crops

The paragraphs below describe the technology of barani field crops. The first eight sections describe the general principles and the last section summarises the present recommendations for particular crops in each climatic zones described in chapter 6.1 of this manual.

9.1.1 Multiple End Use of Most Barani Crops

Food security and the maintenance of livestock are the main aims of farmers of the barani areas. Food is still the main objective of barani crop culture in Pakistan. Pakistan's barani agriculture is still a cereal based system with wheat being the dominant cereal, the others being maize, sorghum and millet. The main field crops grown are wheat, gram, pulses, groundnuts, maize, sorghum, millets and rape and mustard. The production patterns of these crops are determined by the rainfall and the consumption habits of the rural people. These field crops have a wide range of uses for people as well as livestock. End uses of some of the important crops are given below:

S.No	Crop	Primary Product	By-Product
1	Wheat	Grain (staple food)	Straw (Bhoosa)
2	Gram	Grains (used as pulse)	Straw (Bhoosa)
3	Maize	Grain	Green fodder, dry fodder for food, animal feed, starch, oil or fresh cobs for bosting
4	Sorghum	Grain	Green fodder, dry fodder, feed for animals and poultry
5	Millet	Grain	Green fodder, dry fodder, feed for animals and poultry
6	Groundnut	Dry nuts	Dry fodder, edible oil, cake meal
7	Rape & Mustard	Grains for oil	Grain fodder, leaves for eating, cake meal.
8	Sunflower	Grains for oil	Cake meal, stems for fuel
9	Cotton	Fibre	Oil, cotton seed cake, cotton seed meal, sticks for fuel.

Agronomists who are responsible for developing barani field crops must understand what the end-uses, the farmers require from their crops. This will affect crop management, such as plant density, thinning, weeding and fertilizing and the varieties grown. For example, sorghum grown primarily for fodder will be a tall leafy variety planted with high density and high N fertilizer, while sorghum for grain will be shorter and more widely spaced.

9.1.2 Primary Tillage

Of paramount importance is that all tillage and planting should be done across the slope. In this way, rain water will be hindered from concentrating and running down off the slope and off the field.

The fundamental purposes of tillage are:

(i) to improve the physical conditions of the soils.
(ii) to remove weeds that compete with the crop,
(iii) to prepare a suitable seed bed. This may involve destruction of wild vegetation, weeds or the stubble of other crops.
(iv) to bury manure and crop residues in the soil.

Primary tillage includes all four of these purposes. This can be achieved through deep ploughing with a mould board or disc plough to a depth of 30 cm (1 ft). This will bury green or dried plant material, minimize competition with weeds, break the ploughpan, loosen the soil for more vigorous root growth and for other implements to operate more easily. This will also roughen the soil surface to check runoff and increase infiltration of rainwater. Other purposes of deep tillage are to control insects and diseases, and promote the process of decomposition of organic matter and nitrification of minerals in the soil. Deep ploughing also recycles to the surface materials that have leached down the soil profile out of reach of most of the crops' root zone.

Deep ploughing is usually done before a period of expected rainfall. In the Potwar area, this would be in May/June or Dec/Jan.

9.1.3 Secondary Tillage

Secondary tillage is applied for the preparation of a good seed bed so that the soil particles are in close contact with the seed. This is important for good emergence of seed. Secondary tillage also levels the soil surface for uniform, adequate absorption of water from rainfall to varying depths for germination of the seed and subsequent growth. Another purpose of secondary tillage is to make a "dust mulch". The top 2 in (5 cm) of soil are pulverised and dry out. This layer of dry soil prevents the soil moisture in the seed zone and deeper in the soil profile from drying out.

These purposes can be achieved with use of a field cultivator disc, harrow or rotovator. A leveller should be used for proper levelling of the seedbed. On fairly level fields, this is normally done with a heavy planer (*Sohaga*) following the cultivator. The sohaga also helps seal the soil with a dust mulch. Secondary tillage is normally done just before planting is expected to be done.

9.1.4 Planting Techniques

These techniques include the timing of planting, the quantity and quality of seed to provide adequate plant population for better yield, the method and depth of planting and proper spacing and seed rate.

In general the season of planting should be selected to coincide with the beginning of a rainy season. Prompt planting at the start of a rainy season is important to obtain high yields to take the advantage of soil fertility and early growth to avoid or resist insect attacks. Optimum planting dates for important barani crops are listed below:

Optimum Planting Dates of Important Barani Crops

Crop	Optimum Planting Dates
Wheat	In NWFP, Balochistan and Punjab, end October to mid November.
	Sindh, 7 November to 15 December.
Maize	Kharif season, NWFP and Punjab (>750 mm rainfall) at the onset of monsoon in early July.
	Spring season, NWFP and Punjab, mid February.
	Winter season in Sindh, mid October to end November.
Groundnuts	Punjab and NWFP, mid March to mid April.
Gram and Rape/Mustard	Punjab and NWFP, end September to end October.
Cotton	Punjab and Sindh in April and May.

There are two planting seasons in the country i.e. rabi which is from Sept to April and kharif from April to Sept. In the rabi season there is normally a shortage of soil moisture at the planting season in September/October. Any delay in planting will result in poor crop establishment since seed beds tend to be dry at this time. Rains in Sept/Oct are beneficial for the sowing of rabi crops like wheat, barley, gram and other pulses. However, if there is no rain, then the seed has to be placed in moist soil with a rabi drill or with a traditional "pora" planter. Most of the annual rain is received during the kharif season in July and August. Prompt sowing of kharif crops like maize, sorghum, millets and pulses at the onset of the monsoon is highly desirable.

The quantity of seed planted should be such as to produce an optimum plant population sufficient to fully utilize soil fertility and moisture but not so dense that soil moisture and fertility are exhausted before maturity. Recommended plant populations and seed rate for some barani crops are listed below:

Crop	Seed Rate (kg/ac)	Plant Population per acre
Wheat	40-60	250,000
Maize	10-15	30,000
Sorghum	4-5	250,000
Groundnuts	60	88,000
Gram	20-24	88,000

The depth of the seed should be adjusted to the depth of moisture in the seed bed at the time of planting. Seed requires moist soil for its germination and so must be placed at 1 to 2 cm below the surface where it gets enough moisture and is well protected from drying out and birds. Heavy texture soils that tend to crust as a result of rains pose a serious problem. Crusts are formed when rain pulverises the soil surface. This is more likely in the monsoon season. Seed must be placed shallow enough to break through crusts that may develop but deep enough to remain moist for germination.

Larger seeds tolerate deeper planting and have greater germination power to force the seedling shoots through the hard crusts. To combat crusts, seed can be planted at high seed rates which can be thinned out later to the desired stand after full emergence. The seed can be planted using a drill in rows and placed deep in to a proper moisture zone. The rows should run across slopes along the contour to reduce soil erosion and runoff losses.

Before planting, the quality of seed should be checked. Farmers will often recognise a good quality seed, however, the most certain way of ensuring the seed is good is to test its viability. A simple test is given in the Irrigation Agronomy Manual, Volume VI of this series.

9.1.5 Fertilizer Management

Fertilizers are applied to the soil to promote better plant growth and crop yields through the addition of the extra plant nutrients.

Fertilizers supply major plant nutrients. These are nitrogen (N) phosphorous (P_2O_5) and potassium (K_2O) and are written as NPK. These major nutrients are essential for plant growth and development. Nitrogen encourages vegetative growth and phosphorous is essential for early fruiting and maturity and potassium ensures efficiency in photosynthesis. There are about 13 other minor and trace elements such as calcium, magnesium, iron, zinc, copper, molybdenum, sodium, and so on. These are essential for plant growth but are normally sufficient in the soils and need not be added.

The usual commercial fertilizers used in barani areas are listed below. Their nutrient content is given. Normally farmers and extension agents give their recommendations

for particularly crops in bags per acre of each kind of commercial fertilizer. Research stations give their recommendations in kg of nutrients per ac., the table below helps to convert these.

To Calculate Nutrients Supplied with 1 Bag of Fertilizer Per Acre (50 Kg/Acre)

Commercial Fertilizer	Percent Nutrient	Nutrient supply (Kg/ac) in 1 bag/ac of Fertilizer
Urea	46% N	23 kg N
Calcium ammonium Nitrate	26% N	13 kg N
Diammonium phosphate (DAP)	18% N	9 kg N
Ammonium Phosphate	21% N	10.5 kg N
Nitrophos	23% N 23% P_2O_5	11.5 kg N 11.5 kg P_2O_5
Single Superphosphate (SSP)	16% P_2O_5	8 kg P_2O_5
Triple Super Phosphate (TSP)	46% P_2O_5	23 kg P_2O_5
Potassium Chloride (Muriate of Potash)	60% K_2O	30 kg K_2O
Sulphate of Potash	50% K_2O	25 kg K_2O

By using combinations of these kinds of fertilizer, one can supply the recommended rates (see Table 8.1 for fertilizer recommendations for different barani crops).

Recommended fertilizers are usually applied at or immediately before planting as a basal dose. A portion is applied later about 30 days after planting as a top dressing.

Fertilizers are usually broadcast as a basal dose into the soil before planting or as a top dress after planting. However, a more efficient use of fertilizer is achieved by placing it beside the seed. This is only possible with precision placement of seed and fertilizer with a mechanical drill.

Various principles have to be followed for efficient use of fertilizers.

1. Recommendations from the Department of Extension should be followed.

2. All crops require a balance of the major nutrients and occasionally a minor element.

3. Allowance should be made for a residual fertilizer left from the previous crop for example if P_2O_5 was applied to wheat in the rabi season, then this fertilizer can be reduced for maize immediately following the wheat in the kharif season.

4. Fertilizer is only effective where there is adequate soil moisture.

5. Seed and fertilizer cannot be mixed.

6. Fertilizer will give maximum benefit where the following recommended practices are followed with the same crop:

- o Deep ploughing
- o An improved variety
- o A full plant stand
- o Optimum planting date
- o Weed control

Green manures are used primarily to increase the yield of a subsequent crop as well as to improve the fertility status of the soil. Green manures add humus to improve the texture of the soil and counter balance the losses of fertility which occur through cultivation. A green manure is grown to be turned under for soil improvement while in a succulent condition preferably before the flowering stage. This may require about 40 days of growth of the green manure crop before ploughing it in and preparing to plant the following crop.

Leguminous crops like berseem, alfalfa, clover, dhancha (Sesbania) are used for green manure purposes.

9.1.6 Affect of Cropping System

The proceeding crop has an important influence on crop yields. The amount of nitrogen left in the soil by a crop may influence the yield of the crop that follows. The yield of wheat may be higher when planted after groundnut or soyabean crops than after another cereal crop. Corn that follows deep rooted legumes such berseem or sweet clover may yield more as a result of better root penetration. Legumes in the rotation greatly improve soil fertility and yields of crops because of their capacity to fix atmospheric nitrogen and place it in the root zone of the soil.

9.1.7 Weed Control

Weeds constitute a major threat to high crop yields. Fields that are continuously cropped to annual crops, usually experience a rapid increase of weeds from crop to crop. Weed competition then becomes a serious threat. It is essential that seed used for planting should be weed free but this is generally ignored. As a result, the fields in barani areas are full of weeds particularly the Kharif crops.

Weeds are best controlled when they are young as they are more easily controlled at this stage. The crucial weeding period is in the first 2-3 weeks of the crop growth. The labour is less but the returns to the labour are more than with a delayed weeding. Late control of weeds does not help in improving crop yield. It is essential to

eradicate the weeds before they reach the flowering stage.

There are three broad approaches to weed control, cultural, mechanical and chemical. The **cultural weed control** includes the practice of good agronomy which favours crop growth over weed growth and over the years, the weed population will decrease. Delayed sowing of wheat to allow weeds to germinate before cultivating them is another example of cultural weed control. Deep ploughing to bury weed seeds before seed bed preparation is a further example of cultural weed control. **Mechanical weed control** is the hand hoeing or inter row weeding of crops with a cultivator.

Chemical weed control is the application of herbicides such as 2-4-D, Buctril M or Tribunal to control weeds without harming the crops. These herbicides should be selected to eradicate specific weeds and must be used precisely following the instructions of the experts or the manufacturer. Chemical weed control requires the use of a sprayer which needs calibration in order to apply the correct amount to a given area. Mixing of herbicides with water before applying also requires strict following of manufacturers' instructions. Before the application of a herbicide, the farmer has to judge whether it will be economical to use it. This depends on how many weeds there are in the crop and how good the crop is. Only use a herbicide if the extra benefit from it will give a good extra profit.

An obvious advantage of an appropriate herbicide is that rapid treatment of extensive areas is possible, whereas weeding by hand with a hoe takes longer and allows weeds to grow and reduce crop yield.

9.1.8 Pest Control

It is estimated that most farmers have crop losses of upto 30% due to pests. If the pest reaches epidemic levels, there may be a complete failure of a crop, as with gram when blight attacks or with wheat affected by rusts.

While pests vary widely with the type of crop and the climatic zone there are certain principles or control measures that are applicable to successfully prevent them:

1. Resistant varieties/Strains: Some varieties have been specifically bred for pest or disease resistance. They should be used when available.

2. Use disease free seed. For example, use certified potato seed that has been inspected when it was harvested in the field and is certified by seed experts that it was disease free.

3. Cultural Methods: The rapid multiplication of insect pest and diseases can be controlled through cultural methods. Deep ploughing and turning over of the soil will expose the underground insects to birds and hot sun. An example is the rice stem borer in the stubble of rice fields. Hoeing and weeding will also help in controlling the harmful pests and diseases as the alternative hosts for certain pests are effectively removed which are sources of infection. Crop rotations are also very effective in controlling serious insects and diseases such as stem borer, white fly, aphids and diseases like blight and wilt.

4. Chemical methods: The use of appropriate insecticides and fungicides to combat insect pests and diseases has been most highly developed for food and cash crops such as sugarcane, cotton and oilseed crops. The first requirement in this regards is to accurately identify the pest, study its life history and the way it attacks the crop. The recommended pesticides should be used at the appropriate time and stage in the life of the pest. Pesticides should also be used only when the farmer judges that his extra return from using them will more than cover his costs.

5. Integrated Pest Management (IPM): Indiscriminate and continuing use of insecticides may be more harmful than beneficial. There may be harmful residual effects or the pest may develop resistance against a particular pesticide, so it is advisable to adopt other methods, where possible for combating serious pests and diseases. It is best for the farmers to use cultural methods to control pests before resorting to chemicals. A major disadvantage of chemical pest control is that it controls both beneficial organisms such as spiders, frogs and birds as well as harmful pests. IPM uses all the known cultural techniques in an integrated way.

6. Biological control: Recently some biological methods for controlling of pests have been developed which are based on the principle of "set a thief to catch thief". Natural predators are used which attack harmful pests. Hormones are also used to trap and kill the male population of an insect so that the pest no longer breeds or multiplies. With the use of pheromones, fruitfly can be effectively controlled in guava and melons.

9.1.9 Harvest and Post Harvest Storage

Crop should be harvested as soon as the grain is mature and it is dry enough to be stored. The preferred moisture content of grain in the field should be less than 15-20%. An appropriate moisture level of grain for safe storage is less than 11%. Sun drying may be necessary to dry to this moisture level. When seed is dry enough that it cracks when bitten between the teeth, the moisture level is probably at the right level for storage.

In order to reduce post harvest losses, crops should be harvested without delay with manual labour or using mechanical reapers and threshers. These should be extensively used especially for harvesting wheat and rice crops because the standing crops are subjected to serious losses due to winds, hailstorms and unseasonal rains.

TABLE 9.1: CROP PRODUCTION TECHNOLOGY FOR CROPS IN BARANI TRACTS

S. No.	Crop	Soil & Climate	Recommended Varieties	Candidate Varieties	Sowing Time	Spacings (cm)	Seed Rate (kg/ha)	Fertilizer KPK (kg/ha)	Insect pests	Diseases
RABI										
1.	Wheat	Can be grown in a variety of soils, except in highly water-logged and saline soil. Minimum rainfall required is 300mm.	Chakwal-56, Rawal-87, Rohtas, Kohsar-92	90013	15 Oct to 13 Nov	30 x 7-10	100	90-60-0	-	Rust, Smut
2	Brassica	As above.	RI-18, Wester, Sherali, Peela Raya	CL-2	-"-	45 x 20	5	75-50-0	Aphids	Phylloidy
3	Chickpea	Sandy loam soil. Minimum rainfall of 50mm.	C-44, CN-72, Ph-91, Noor-91, Paidar-91	8900003, 8900004, 9100079	Oct	30x10-15	50 to 60	30-90-0	Cut worm, Termites, Pod borer	Gram blight, Stem rot/roht rot, Entrytus, stunt virus, Iron deficiency
4	Lentil	As above.	Kasoor -35, Nansahra-59	98503	Mid Oct - early Nov	25-30 x 5-7	20	30-65-0	Cut worm, Termites, lentil pod borer, gram pod borer	Rust, blight, Stem, rot, root rot.
KHARIF										
5	Groundnut	Sandy or sandy loam. Rainfall 250-400mm.	No. 334, Banki, Chakori, BARI-89, BARD-699, BARD-479	-	20 May-15 Apr	45 x15/20	100	20 80-20	Hairy Caterpillar, Termites, rats Wild bore	Leaf spot, collar rot
6	Mungbean	As above.	NM-13, NM-19-19,NM-20-21, NM-51, NM-54, NM-121-51	890Kg005, 890Kg005	July	30 x10	20-25	25-60-0	White fly, hairy caterpillar, Aphids	Yellow mosaic, Cerco Spora leaf spot bacterial blight. Leaf crinkle virus
7	Mash	Sand, loam soil. Rainfall 300mm.	Mash-48, Mash-80 (hairy), Mash-88 (hairy)	900N077, 900N057	July	30 x10	20-25	25-60-0	-"-	-"-
8	Sorgum	As above.	J-263, J-100, J-1, DG. Pearl, Pak.S.S.	JS 12, JS-23	July	30-45	50 fodder 10-15	57-57-0	Borer	Red rot
9	Bajra	As above.	BY-18, Y-84	BS-208, Bs-41	July	30-45	10-12	57-57-0	-	-
10	Maize	As above	Sultan, Sonehri, Sadaf, Neelam, Agati-72	-	July	75-25	20-25	75-50-0	Borer	-
11	Seseame (Till)	Sandy loam soil. Rainfall 300-400mm	P.T-90, T-5	-	July	45x10-15	5	60-60-0	White fly, Aphid, Hairy caterpillar, Cut worm	-
12	Rice	Loamy rice clay soil. Rainfall 750-1000mm	Basmati 385, J.P-5, IRRi 6 SWAT-1	-	June-July	30-40	8-10kg	100-50-50	Stone borer, Leaf Curlers	-f

9.2 Fruit Crops

9.2.1 Species Adaptability

Pakistan lies between the Tropic of Cancer and 38°N, with very high mountains to the North and West. There is great diversity in the climatic conditions ranging from humid tropics on the southern coasts, arid desert bordering the central plains, dry tropics in central regions and sub-tropics in the mountainous foothills and temperate to cold regions at altitude in the North. Thus there is a wide range of agro-climatic conditions allowing the cultivation of a wide range of tropical, sub-tropical and temperate fruits. The Indus River with its main tributaries form the rich fertile plain with abundant water for irrigation.

Soils tend to be light, alluvial soils, the lower reaches of the Indus being slightly barren. There is very little gradient in the Indus plains i.e. 1 per mile. Rising water tables are leading to serious waterlogging and salinity problems. This problem is increasing in severity due to the intensive crop production system and lack of drainage.

The Barani areas of Pakistan cut across different ecological zones. These areas have been classified on the basis of rainfall patterns, temperature regimes and varying elevations into six distinct climatic zones. A wide range of plant species ranging from papaya and cheku in coastal areas to apples and cherries at higher altitudes in NWFP and Balochistan can be commercially grown. The suitability of these zone for different fruit trees is indicated as under:

ZONE	AREA	FRUIT TREES GROWN
Zone 1	Extreme North of Punjab including Rawalpindi, Islamabad, Murree, Kahuta, Gujrat and Sialkot. This is a high rainfall zone ranging 750-1000mm	Apple, Pear, Peaches, Plum, Walnut, Citrus, Mango.
Zone 2	Southern Potohar in Punjab including Attock, Chakwal districts Semi arid, rainfall 400-600mm.	Citrus, Loquate, Guava, Mango, Apricots, Ber, Plums and Pears
Zone 3	Northern NWFP including districts North of Kohat. Sub-humid, humid tropical highland with elevation 1000-5000 m. Rainfall 500-1500mm	Apples, Pears, Peaches, Plums, Apricot, Grapes and Citrus.
Zone 4	Southern NWFP including Kohat, all districts and Agencies. Arid zone. Rainfall 250-350mm	Pear, Plum, Peaches, Apricot, Citrus, Guava, Loquot.
Zone 5	Upland Balochistan comprising uplands above 1500m in the North. Semi arid mountain. Rainfall 150-400mm.	Apple, Apricot, Peaches, Cherries, Almond, Plums and Walnut
Zone 6	Low land Balochistan comprising land between sea level and 1500m. Climate sub-tropical. Rainfall 50-250mm	Papaya, Chicku, Apples, Almond, Pomegranates, Pistachios.

The evergreen fruit trees such as Citrus, Mangoes and Papaya require frost free climate i.e. mild winters, long humid summers. Whereas the deciduous fruits like apples, peaches, plums, apricots and so on, grow well in areas having cold winter below 0°C and comparatively mild summers i.e. 40-42°C.

9.2.2 Market Situations Affecting Choice of Fruits

Fruit and vegetable production has a wide base in Pakistan because of great diversity in soil-climatic conditions. All types of temperate and tropical fruits can be grown and marketed in the internal and external markets. The total area of fruit trees reported is 463,000 hectares and production as 4,000,000 tonnes. Citrus, Mango, Guava and Apples occupy above 70% of the total area. Punjab followed by Sindh are the major producers of fruit.

The Pakistan home market is based upon a consumer taste, colour and flavour. There is little or no concept of appearance, condition and uniformity so essential for establishing a sound export trade. Furthermore, the shelf life, ability of the fruit to withstand the shocks of handling, transportation and storage are the essential aspects which are not fully understood by the persons engaged in the production and marketing of farm produce. Poor root stocks, lack of quality control in the nurseries, poor orchard management practices, no regard to consumer preferences and price competitiveness are some of the serious constraints in improving the marketability of fruits in Pakistan. It is evident that great improvement is required in the production base through well planned research and development endeavours as well as sound government policies with respect to quality control and marketing practices for domestic and external trade of fruits. Price is the only index or incentive for the farmers. At present growers only get a very small share, upto 30%, in the market price of their produce. A reasonable margin of profit should be ensured to the growers through sound price policies and by establishing standard markets in the country.

9.2.3 Planting Techniques

Fruit growing is a most profitable enterprise. Careful planning and a good deal of attention while planting the orchard assures maximum success. A mistake committed in the beginning if allowed to go un-identified and is not rectified at the proper time may be the major cause of failure. Great care should be exercised in the selection of varieties. Only the recommended varieties should be planted according to the suitability of the area and demand in the markets.

Site Preparation. Growers should select such sites where the fruit plantations have been successfully established because there are obvious advantages of learning from the experience and techniques of others. The site should be accessible and near the road.

The soil selected for fruit trees should be well drained, rich, fertile and deep as these are long duration crops. The land should be cleared of grasses, weeds, stones and stubble, deeply ploughed and well levelled for better irrigation and intercropping system.

Timing. There are two planting systems in Pakistan. The deciduous plants such as apple, apricot, plum, peaches, almond which shed their leaves in winter and go into dormancy should be planted in January-February. The evergreen plants like Citrus and Mango should be planted with earth ball during spring in February-March and in Monsoon season i.e. July-September.

Planting Techniques. Fruit trees are planted into pits dug out well in time. The size of pits should the same size as the roots and top of the nursery plant. The average size is 600 by 450 mm (2'x1.5'). The guiding principle is that the plant should be as deep in the pits as it was in the nursery. If the soil is rich, fertile, there may be no need of adding farm yard manure. However, in light soils, for achieving better results the pits may be filled with 50% well rotten Farm Yard Manure and 50% silt. The plant should be immediately watered after planting and later on when the soil settles down the pit should be filled up with soil upto the original level. There are different planting systems. In plains and well-levelled land the trees can be planted in the shape of regular orchards on Square system or Rectangular system according to the convenience of the farmers. Planting distance should be kept according to the growing habit of the tree, fertility status of the soil and root stock used for variety. Recommended distances for some major fruits are given below:

S. No.	Fruit	Distance	No. of Tree/acre
1	Apple	7 x 7 m (24' x 24')	76
2	Apricot	7 x 7 m (24' x 24')	76
3	Citrus	6.5 x 6.5 m (22' x 22')	90
4	Mango	10 x 10 m (35' x 35')	36
5	Dates	5 x 5 m (18' x 18')	134
6	Guava	6 x 6 (20' x 20')	109

On slopes or terraces the trees may be planted on the contour or the boundaries of the fields. Linear plantations on terrace systems can be adopted for efficient use of rainwater.

For close plantation and in areas of water scarcity plant varieties budded on dwarf root stocks are preferred.

9.2.4 Fruit Tree Management

Fruit trees require intensive care from the very start i.e. just after transplanting the young saplings in the field and also during their whole economic bearing age. After setting them into pits watering is immediately required for compacting of soil and maintaining moisture level.

Heading Back. The young deciduous plants are headed back or cut back at a height of 450 to 500 mm (18-20") leaving at least 2-3 branches around the stem. This is done to maintain a balance between the top and roots and to obtain strong scaffolds to train the tree into the desired shape. Evergreen plants are not severely cut back instead diseased or dried branches and some leaves are removed to maintain a balance between the roots and top and to minimize transportation losses.

Intercropping. Enough space is available in between tree lines which can be profitably used for crop production, until the trees become full grown or until their canopy occupies the whole land. In Punjab fodder crops like maize, sorghum and berseem and vegetables like peas, onion and chillies can be intercropped depending upon the availability of water. Field crops, such as wheat, barley, rape and mustard, can also be grown without causing set back to young plants.

In NWFP intercropping with berseem, soya beans, vegetables and tobacco is a common practice. There is great scarcity of water in Balochistan. The tendency is to get maximum return from the limited water resources by growing high value crops. The young plants have in the early years comparatively less water requirements. After meeting their requirements, the water is used for growing potato, onion, tomato or tobacco in the land in between the tree lines. However, when trees the become large enough berseem or other fodder crops are raised. The guiding principle should be that only those crops should be selected for intercropping which are compatible with the fruit trees in terms of their water and food requirements and which do not spread pests and diseases.

Fertilizing. Fruit trees are deep rooted and remain in the field for a long period. They take considerable nutrients from the soil and are very exhaustive. In order to replace soil nutrients and to obtain good growth and yield from the trees, applications of fertilizers in judicious amounts is very essential.

Manure. The young plants during the winter season should be given Farm Yard Manure at the rate of 2-5 kg per tree. This should be spread away from the main stem under the crown in the root zone. The full grown trees should receive 20-40 kg of well rotten farm yard manure during December-January each year. The full amount of phosphorus and potassium (1 to 1.5 kg per tree) should also be well mixed in the soil for better results.

Nitrogen Fertilizers. Young trees will require about 1/4-1/2 kg of nitrogen which may be applied in 2-3 doses during the vital growth period. Full grown trees will require 1-2 kg of nitrogen per tree which should be applied in 2-3 doses through the season. The first dose should be given before flowering, the second dose after fruit setting and the third one when the fruit has reached Walnut/Almond size. The application of water is essential after each dose of fertilizer.

In case there is any deficiency of minor or trace elements, the recommended compounds should be applied through spraying as foliar application or as recommended by the experts.

Tillage. Fruit trees require a good soil environment for the development of roots and intake of essential nutrients. Growing crops in between the lines at one depth makes the soil compact and hard for roots. So it is essential to break this hard pan though deep ploughing with a mould board plough or with chisel plough. The soil should then be pulverized with a disc plough or cultivator to increase its water absorbing capacity and to provide for proper aeration. Deep tillage is also essential to control weeds and other wild growth in the orchards.

Tillage is also required for proper levelling of the land and making basins and water channels for proper application of irrigation water.

Pruning. Pruning is an important orchard management practice. In early years the pruning is done for training the young plants into vigorous and productive trees. The deciduous trees may be trained on open centre system or modified open centre system or on a central leader system. Peach, plum and apricot trees are trained in a modified open system, whereas apple and pears are on the central leader system. However, in Balochistan very little training of trees is done as the growers are interested in early bearing rather than in a long bearing age and vigour of the tree.

The full grown trees are pruned for obtaining fruit bearing branches because in the case of peach, plum, apricot and grapes fruit is borne on the last years growth. Apple and pears bear fruit on their spurs which have a life span of 5-7 years. Pruning in such trees is limited to maintaining the spurs and obtaining new spurs for future economical yields. Pruning is also done for removal of congestion, provision of air and light for better coloration and thinning of fruit for better size and grade.

In case of citrus and mango very little pruning is applied for training purposes. In full grown trees pruning is confined to the removal of diseased branches, undesirable growth and controlling the height of the trees.

Pruning is an highly specialized job and only skilled and experienced people who understand the art and science of pruning should be employed for pruning.

Pest Control. Fruit trees are high value crops. Pests and diseases cause great damage to fruit trees and reduce their yields and quality of their produce. To maintain health and vigour of the trees and improve yield and quality it is necessary to effectively combat serious pests and diseases. At present insecticides and fungicides are being indiscriminately used for controlling pest and diseases. These chemicals are not only very expensive but also create serious hazards of human health, environmental pollution and destruction of natural enemies of pests thus disturbing the natural

biological balance and causing new pest problems. To overcome all these hazards and problems Integrated Pest Management (IPM) system should be adopted. This approach includes all the methods of mechanical cultural, biological and chemical control according to the crop pest situation and resources of the growers. In this management technique chemical control is the last resort adopted on the basis of the economic threshold of the pest. Much dependence is on other methods which create less environmental problems and biological imbalances. Some of the major pests and diseases of important fruit trees and their recommended control measures are given in the table below. For further details the Bulletin titled "Integrated Pest, Diseases Control of Fruit Crops in Pakistan", published by the Pak/Swiss Fruit and Vegetable Development Project is referred. Local Agricultural Extension Agents or experts from Research Stations should also be contacted for proper guidance and assistance.

Fruit	Pest/Disease	Control Measures
Apple	Ceddling Moth	1. Traps baited with pheromone or predator can be used. 2. Lorsban, Metasytox, Malathion may be used as recommended by experts.
	Mites	Use Gusathion, Lorsban, Malathion as per recommendations of experts
	Scab	1. Hygienic measures such as pruning and burying the infected fruits. 2. Use Benlate or Dithane M-45 as per recommendations.
Peach	Flat Headed Peach Borer	1. Infected branches should be remove 2. Use Folidal-M, Lorsban and Gusathion as recommended by experts.
	Fruit Fly	1. Collect and bury the fallen fruits. 2. Use Dipterex or any other insecticide recommended by experts.
	Leaf Curl	1. Remove diseased and dead shoots. 2. Spray Cabox, Antracol or Captan as recommended by experts
Citrus	Rod Scale	Use Folidol-M, Malathion as per recommendation
	Lemon Butterfly	Losban or Gusathion may be use
	Citrus Leaf Minor	as above
	Citrus Canker	Use resistant root stock and spray with Cobex

Harvesting & Marketing. Harvesting of fruits is also a highly specialized job and demands great skill and experience. Harvesting fruit at the right stage of maturity for different purposes improves yield, quality and returns from fruit farming. There is a tendency among the contractors who purchase orchards and fruit trees from the farmers to pick earlier immature fruits and sell it in the market for an early income. Some time this fruit is artificially coloured through chemicals (Carbide/Ethane) so as to give it a uniform yellow colour stopping complete maturity. This use of chemicals does not help in maturity rather it imparts a bad taste to the fruit. Morally and legally it is not a good practice. In most of the countries this malpractice is a recognizable offence and the person is liable for prosecution in a court of law.

Picking of fruit at precisely the right stage is very important. The under ripe fruit will shrink badly and will not develop any taste or flavour. Thus it will fetch a very low and unattractive price in the local as well as in the foreign markets. Many fruits such as mango and apple set fruits over a prolonged period, ripening at different intervals. Thus they demand harvesting selectivity over a period. Some 8 to10 pickings from the tree are required. In fact there are two types of fruits. Climacteric fruits which are reduced into sugars during maturity of which apple, pear, mango and banana are the examples. All these fruits continue the ripening process after harvest. The second category is of non climacteric fruits which contain no starch and the sugar is actually transported during the maturation period. Typical example of such fruits are grapes, pear, apricot etc and in these the sugar level does not change after harvest.

The following methods may be used to determine the correct time of maturity:

- Refratrometers which measure sugar content of individual fruits.
- Penetrometer which measures the level of softness
- Colour charts for measuring colour changes.
- Starch Iodine test which measures starch percentage.
- Seed colour is an indicator as in apples.
- Ease of separation from the tree.
- Aroma.

Frost, winds, hailstorms and temperature have major effects on the quality of the fruits causing deformity, skin burn and blemishes and poor development of colour and aroma. Climatic factors are beyond the control of growers but good site selection, wind breaks, and other standard orchard management practices can reduce their losses to some extent.

Marketing is the weakest link in fruit production. The major share of profit goes to the middlemen and not the growers. Growers hardly get 20-30 percent of the market price. No standard packing and grading practices are followed. The fruit is purchased/auctioned in heaps or in bags or in non standard crates/boxes. Most of the cold storages are owned by big contractors and not by farmers or their associations. The fruit processing industry is not properly developed to absorb the surpluses of fruit during gluts. The availability of quality fruits and returns to farmer could be considerably improved with the adoption of following measures:

- Use of plant varieties ripening at different intervals to extend availability period and avoid gluts in the market.

- Follow recommended orchard management practices for increased yield. The quality is actually produced in the field, it is cashed through marketing and enjoyed on the table.

- Adopt standard picking, grading and storage practices to extend the shelf life and to serve different markets (local/abroad).

- Refrigerated vans and storage should be provided.

- Packing and grading laws should be enforced and standard markets should be established to provide all modern facilities for dealers, growers and the consumers.

- Farmers should organise and form their own associations for marketing and processing of fruits and eliminate the middlemen where possible.

- Production should be planned and regulated according to consumers demand and preference and export potential to avoid gluts and losses to the growers.

TABLE 9.2. MAJOR FRUIT CROPS IN BARANI AREAS OF PUNJAB

S.N.	NAME OF THE FRUIT TREES	SOIL & CLIMATE REQ	PLANTING TIME	PLANTING DISTANCE	METHOD OF PLANTING	WATER REQUIREMENTS	PRUNING OF THE TREES	MANURE/ FERTILIZER	RECOMM VARIETIES	INSECT/ DISEASES
	TROPICAL FRUITS									
1	Ber (Zizyphus)	All types of soils but recommended for dry and salt affected land. Can be grown in all types of climates but extremely humid and hot climate not good	Spring Feb to Mar Summer July to Sept	40 x 40'	Through budding and also by seed irrigation	May be grown under low rainfall conditions fruit ripening is good for fruit development	No pruning is required except removal of diseased and crowded branches	2-3 kg well rotten FYM at the time of planting	L-6, L-11, L-13, Cantonment and Lalwali Harvested in March & April	Fruitfly can be controlled with Diptrax
2	Citrus Fruits	Loamy soil rich in organic matter are good. Citrus plants are damaged by winter frosts to varying degree. Lime, Lemon and grape fruits are comparatively more susceptible to frosts	Spring Feb to Mar, Summer Aug to Sept depending on rains	20 x 20'	Through budding	Has tolerance for water stress condition. If least 6-7 irrigation or 20" rainfall is required for obtaining economic yield.	Removals of diseased and crowded branches is essential	10-12 cart load of FYM For young trees apply 0.25 to 1.5 kg of Ammonium sulphate and to full grown trees 2 kgg A/s and 2 kg single super phosphate and 1 kg potassium	Malta Moussami, Red Blood, Pine apple Grapes Marsh seedless, Foster, Red Blush, Flamber Sweet Palestine Lemon Kaghzi Chinese Eureka Harvested throughout the year	Citrus Psylla, Leaf Miner and Scales are the main pests Contact Agri Dept for proper control
3	Guava	Sandy and loamy sandy loam soil are comparatively good. highly susceptible to low temperature	Feb to Mar and Apr to Sept	20 x 20'	Through seeds Layering and side grafting	As above	FYM 10-12 c/t A sulphate 2-3 kg per tree	Allahabad Kohati Karella Type Safaida Chilodzi	Fruitfly is the major pests Control with Diptex use Phenomon traps	
4	Loquate	Well drained sandy loam soil are good. Extremes of water or summer are not good. hot winds not good for flower and fruit development	Feb to Mar and Aug to Sept	20 x 20 ' but lower planting can be done	By seed Budding side grafting	Regular watering is required Rainfall 300-600 mm) and irrigation on weekly basis in winter season	Very little pruning is done Removal of diseased branches is required	FYM 10-15 c/t and A sulphate 1 to 1.5 kg per tree	1 yellow 2 Thomson pride 2 sufaids and 4 Marymoth	Stem borer is the main pest Dimecron at the rate of 2 ml per tree is effective.
5	Mango	Well drained loamy sand highly Susceptible to frost and hot winds	Feb to Mar and Aug to Sep	35 x 35 Lower plantation is also done	By seed and Anarching Budding also done	Rainfall 500-700cm Irrigation on weekly basis in summer	As above	FYM 10-15 c/t, A Sulphate and super phosphate 3-4 kg per tree	Maldah, Langra, Dashri, Sameras, Baheshti and seedled varieties are harvested during Jan/Feb	Mango hoppers, Mealybugs and Fruitfly are main pests

DECIDUOUS FRUITS

S.N.	NAME OF THE FRUIT TREES	SOIL & CLIMATE	PLANTING TIME	PLANTING DISTANCE	METHOD OF PLANTING	WATER REQUIREMENTS	PRUNING OF TREES	MANURE/ FERTILIZER	RECOMM. VARIETIES	INSECT/DISEASE
1	Almond	Well drained sandy loam of loamy sandy soil. Avoid salt affected and wet soils. Requires mild winter as compared to peach and apricot	Jan to Feb	20x20'	By budding	Rainfall 200-500 mm, irrigation fortnightly intervals	Pruning is essential for the removal of diseased and barren branches for good development	FYM 10-15 C/t, A/sulphate 3-4 kg, SSP 1 kg and Zinc sulphate 50-100 gm per tree	Non parrel, Jordonola, Mission, Neples Ultra, Quetta Selection	Aphids and stem borer are the main pests can be controlled with Dimecron and Gusathion
2	Apple	Well drained loamy sandy soils. Long cold winter are good. Spring frost or hailstorms are harmful for flowering	Jan to Feb	20x20'	budding and grafting	Rainfall 900-800 mm, Irrigation weekly in summer fortnightly in winter	Pruning is required for training and obtaining spurs for regular bearing	FYM 10-15 C/t, A sulphate 4-5 kg, SSP 2-3 kg and Potassium Sulphate 0.5 to 1 kg per tree	Anna variety with very low chilling requirement is recommended for plains. At higher elevation golden, Red delicious, Amen and Kashmiri are the main varieties	Aphids, codling moth and fruitfly are the main pests
3	Apricot	Require heavy [illegible] soils and severe [illegible] than peaches, plums	As above	24x24	As above	As above	As above	FYM 10-15 C/t, A sulphate 4 kg per tree, SSP 2 kg and Potassium 5 kg per tree	Trevett and Red French	Aphids, stem borer and fruit flies are the main pests
4	Grape	Requires deep loam, [illegible]	as above	10x10'	Cuttings/budding	Rainfall 300-400 mm and irrigation fortnightly basis	Pruning is required in early years for training. Pruning is done every year for obtaining good fruit bearing branches	FYM 6-8 C/t, A Sulphate 2-3 kg, SSP 2 kg and Potassium 3 kg	Sahibi, Kishmishi, Black Muscat Thompson seedless	powdery mildew, is a serious disease and use Dithane M-45 in its control
5	Pear	Like deep fertile [illegible] winter as compared apricot	[illegible]	20x20'	By budding on [illegible] stock	Rainfall 100-500 mm and irrigation weekly in winter and fortnightly in summer season	Pruning is required for removal of diseased branches	FYM 10-15 C/t, A Sulphate 3-4 kg, SSP 1 kg and potassium 3 kg per tree	1. Leconte 2. Kieffer 3. Hardy	
6	Plum	Jan to Feb	[illegible]	By budding	Rainfall 500 mm, irrigation on weekly basis in winter and fortnightly in summer	Require pruning every year for fruits bearing shoots and removal of diseased branches	FYM 10-12 C/t, A sulpoate 4 kg, SSP 4 kg, P Sulphate 1 kg	Marhlo, Formosa, Fazli Mamra, Santa Rosa, Fazal-e Manan	Stem borer, Gummosis and fruit fly are major diseases of this tree	

10 SOCIAL FORESTRY AND PLANTATIONS

10.1 Role of Forest Trees

Forest trees have the following beneficial impacts on water harvesting and soil conservation:

- Forest trees intercept heavy rainfall and snow and reduce the direct impact on the soil.
- Forest trees enhance the water absorbing capacity of the soil and improve moisture availability through increasing the infiltration of water.
- Forest trees control soil erosion and check formation of deep gullies. They can be used to line waterways.
- Forest trees improve the texture and fertility status of the soil by adding organic matter and increasing the activity of insects, worms and other micro-organisms.
- Trees act as a vertical drainage and pump out surplus water from water logged soils.
- Trees protect the land from damage by wind.
- Trees act as a filter to prevent silting of ponds and reservoirs.

In addition to the role of trees in general conservation, there are many useful income generating products. These products usually include fuel wood, timber for construction and furniture making, fodder for animals, charcoal making, wood for paper, matches and crates for transporting fruit and vegetables. Table 10.1 gives a list of some of the end-uses of the common trees suitable for different zones.

10.2 Choice of Trees

The choice of trees will depend on the climate (rainfall and temperature) as well as the soils. Table 10.2 shows the most common trees that can be grown in barani areas.

10.3 Agro-Forestry

Agro-forestry is the term used when trees are grown with crops. In the Barani conditions which prevail in most water harvesting schemes, trees are commonly grown on the bunds or scattered in the fields.

Table 10.1

END USES OF SOME COMMON TREES

1.	Kiker (Acacia nilotica)	i)	Wood for timber, furniture and fuel.
		ii)	Pollen grain for honey bees.
		iii)	Pods have medicinal value.
		iv)	Branches used for making tooth brushes.
2.	Ber (Zizyphus)	i)	Wood is used for timber/furniture.
		ii)	Leaves for fodder.
		iii)	Pollens for honey bee.
3.	Bakain (Malia azaderach)	i)	Wood is used for timber/furniture.
		ii)	Leaves for fodder.
		iii)	Pollens for honey bee.
4.	Shisham (Dalbergia sissoo)	i)	Best wood for furniture and timber.
		ii)	Good for making charcoal.
5.	Eucalyptus (Eucalyptus Sp)	i)	For making chipboards.
		ii)	For paper industry
		iii)	For fuel purposes.
6.	Mulberry	i)	Wood for implements.
		ii)	Wood for fuel.
		iii)	Branches for baskets.
		v)	Leaves for sericulture.
7.	Ipil Ipil (Lucaena lucocephela)	i)	Good fodder for animals.
		ii)	Provide fire wood.
		iii)	Improve soil fertility and its water absorbing capacity.
8.	Pines (Pinus Sp)	i)	Wood for timber.
		ii)	Wood for furniture
		iii)	Resin.
9.	Poplar (Populus Sp)	i)	Wood for timber.
		ii)	Wood for match factories.
		iii)	Wood for crates, boxes for fruits and vegetable packing and transportation.
10.	Simbol	i)	Wood for match box industries.
		ii)	Seed fibre for pillows.

MOST COMMON FOREST TREE SPECIES FOR BARANI AREAS

S. No.	NAME OF TREE	CLIMATE	PLANTING SEASON	PROPAGATION	PLANTING METHODS	AFTER CARE	USES	HARVEST
1	Bakain (Dhrake) (Melia azedarach) Persian lilac	Can be grown up to an elevation of 700 m. It is grown for shade beauty	Feb to March (Spring)	By seed By cuttings	May be planted on the border of the bunds roadside or on block at a distance of 10'x 10'	In early days should be watered at week intervals. Later on at 10-15 days intervals Protect from wild animals	Wood is used for timber and fuel wood and leaves as fodder	After 5-10, 15 years
2	Neem (Azadirachta indica)	Can be grown in dry area but susceptible to frosts but can tolerate higher temperatures up to 50°C. Rainfall between 350-700 mm. Can be grown in rocky, salt affected and waterlogged areas	Feb-March (Spring) July-August (Monsoon)	By seed and by root cuttings never shoot cuttings	It is planted with earth ball. Distance 20' x 20' to 30'x30'	In case the rainfall is very low, it is watered on weekly basis in early days	Its leaves, fruit bark, wood has great medicinal value. It is also used for timber, firewood purposes. It is a very good shady tree, seed contain oil upto 40% which is used as lubricant and making soap and medicines	After 5-20 years
3	Shisham (Dalbergia sissoo)	Well drained deep soils free from salts are good. Can tolerate low and high temperature	January-February (Spring)	By seed and Root cuttings. Through plants only in Spring season	Planted in guts on the borders or in blocks. Distance 10 x 10' or 10x15'	Apply water after every 3-4 days after planting then at 8-10 days intervals Protect trees from wild animals and goats	Its wood is considered the best for furniture, broiler, Sumbel firewood for making agri. tools and decoration pieces	After 25 years
4	Poplar (Populus sp)	Well drained fertile soil free from salts are good.	January-February (Spring)	By cuttings, plants	Planted in trenches/pits distance 18 x18' for farm forestry and in block forest keeping a distance of 6' x 10' or 12' x 12'	Ensure good water supply during growth period (Feb-Aug). At least on weekly intervals. Pruning for removal of branches from lower stems be done. Protect from roaming animals	Its wood being light for match factory and chin industry. Also extensively used in package industry and house building material	After 7-8 years
5	Sufaida (Eucalyptus Sp)	Can be grown throughout the province except at higher elevation. Also good for saline, water logged area. Do well in a wide range of soil	Feb to march (spring) July to August (Monsoon)	By seed	Planted in pits or in blocks keeping a distance of 6' x 10' or 10 x 10'	Ensure water supply during early days Remove weeds and grasses from pits	It is quick growing tree. Good for paper industry and crop board and plywood. Good quality charcoal, medicines, perfumes are produced. Used as windbreaks	After 5-15 years
6	Babul/Kikar (Acacia Sp.)	It can be grown under extreme dry condition and can tolerate temperature above 50°C. Rainfall may vary from 250-1000 mm. It has good tolerance for salt	Febeuary to March (Spring) July to August (Monsoon)	By seed	Planted in rows along the road or for fence purposes	it requires water in early stage	Its wood is used for furniture, fire wood and for making charcoal. Also provide fodder. Improve soil fertility	After 5-20 years
7	Ber (Zizyphus mauritiana)	Can tolerate a wide range of temperature from 0-55oC. Can be grown in rainfall areas ranging 12-230 mm. It can also be grown in saline or less fertile soils	February to March (Spring) July to August (Monsoon)	By seed	Planted in rows along the road or for fence purposes	Can survive with irrigation but water in early will accelerate growth	Wood is used for timbers for making handles of tools and implements and for fire wood. It is also a good fodder tree. Honey produced with flowers is considered best in quality	After 20 years

1 Trees from which a second cutting can be taken include Shisham, Eucalyptus (Sufaida) and Ipil Ipil. With these trees, the main stem is cut at 2 m above ground level and 2-3 side shoots allowed to grow for a second harvest. Other trees should be uprooted when harvested

trees from which a second cutting can be taken include Shisham, Eucalyptus (Sufaida) and Ipil Ipil. With these trees, the main stem is cut at 6 in above ground level and 2-3 side shoots allowed to grow for a second harvest. Other trees should be uprooted when harvested and a new tree seedling planted in their place.

8	Frash Tamarix (Tamarix aphylla)	Can tolerate temperatures from -8 to 55oC. Can be grown under rainfall conditions ranging from 150-200 mm	Feb to March (Spring) August to Sept (Monsoon)	By seed and by cuttings	Plants 2 m rows along the road or for fence purposes	Can survive with irrigation. But water in early days will accelerate growth	A good tree for checking soil erosion. Wood is used for making fire wood. A good shady tree. Also used for making decorative pieces	After 15 years
9	White Siris (Albizzia procera)	Tolerant to salt and moisture stresses. Can not tolerate low temperature. Require high rainfall	Feb to March (Spring) August to Sept (Monsoon)	By seed	Planted on roadsides	Require water on weekly basis in early stage. Also requires removal of grasses and weeds	Wood is used for fire wood, fuel and leaves are used as fodder for animals	After 15-20 years
10	Simal (Salmalia malabarica)	Can be grown in all parts of the province except dry areas. Grows well at temperature 10-40oC and rainfall between 400-450 mm susceptible to low temperatures	Feb to March (Spring) August to Sept (Monsoon)	By seed and by cuttings	Planted in pits and distance should be 10 x 15'	Keep the soil moist. Do not allow water standing Do not allow grasses and weeds to grow around the tree	Can be harvested in 10 years. Wood is used in match factory. Seed fibre are used in pillow. Trees are planted for decorative purposes	After 10-15 years
11	Pines/Kail or Chir (Pinus sp)	It is grown on higher elevation from 1300-4000 m. Grows well on fertile soil under higher rainfall (1000-1200 mm) areas	March to April (Spring)	By seed (Mostly natural)	Planted in pits (6 x 10' & (10' x 10')	Do not allow the pits to dry. Protect the young trees from snow, fire and goats. Pruning should be done regularly for proper development of stem girth (10 years intervals)	Wood is used for house building and making furniture mostly house panelling. Resin and turpentine oil are produced. Planted for decorative purposes also to check erosion on slopes	After 100-120 years
12	Mulberry (Morus alba)	Grows well in loamy soil. Waterlogged and soil affected soils are not good. Can tolerate temperatures ranging from 0oC to 48oC. Good growth from sea levels to higher elevations	July-Sept (Monsoon)	By seed and root cuttings	Planted in pits and distance should be 10 x 10 or 15 x 10'	Apply water every week in early days. When establish water may be applied after 10-15 days intervals. Protect the trees from wild animals and goats	It is used as timber and also as fodder tree for firewood, making baskets, sports goods. Very successfully for sericulture	After 15 years
13	Ipil Ipil (Leucaena leucocephala)	It can be grown in strong soil and under low rainfall conditions from (250 mm). It is a deep rooted tree. Adds nitrogen to soil and checks erosion	July to September (Monsoon)	By seed and cuttings. Transplanting full plants	Planted in rows and in blocks also	Protect from over grazing	It is a good fodder tree. Also provides firewood and adds fertility to soil	After 10 years

TABLE 10.3

RECOMMENDED SPACING FOR IMPORTANT BARANI TREE SPECIES

S. No	Tree Species	Area of Plantation	Recommended Spacing for Block Plantation	No. of Plants per Acre	Recommended Spacing for Avenue Plantation	No. of Plants Per Mile
1	Eucalyptus *(Eucalyptus Sp.)*	Irrigated	10'x10' (pure plantations)	435	5'	1056
			12'x12' (Agroforestry plantation)	300	-	-
		Barani	5'x5'	1742	5'	1056
2	Shisham *(Dalbergia sissoo)*	Irrigated	10'x6'	726	10'	528
		Barani	10'x10'	435	10'	528
3	Phulai (Acacia modesta)	Irrigated	-	-	3'-5' (fencing)	1056
		Barani	5'-5'	1742	5'-10'	1056-528
4	Farash (Tamarix Sp.)	Irrigated	10'x6'	726	10'	528
		Barani	10'x10'	435	5'-10' (Shelterbelts)	1056-528
5	Kikar (Acacia nilotica)	Irrigated	10'x6'	726	(Apart) 10'	528
		Barani	Broadcasting or 5'x5'	1742	10'	528
6	Bakain (Melia azaderach)	Irrigated	-	-	5' (Along watercourses)	1056
		Barani	-	-	10' (Also watercourses bunds)	528
7	Siris (Albizzia Sp)	Irrigated	-	-	Solitary trees for shade/homestead	-
		Barani	-	-		-
8	Ipil Ipil (Leucaena leucocephala)	Irrigated	3'x3'-5'x5'	1742	-	-
		Barani	3'x3' 5'x5'	1742	-	-
9	Jand *(Prospos Fineraria)*	Barani	10'x10'	435	10'	528
10	Ber *(Ziziphus Sp)*	Barani	-	-	15'-30' (for grafted 10'-15' (along bunds)	
11	Simal (Silmalia malabrica)	Barani (high rainfall)	-	-	10' (along watercourses or roadsides)	
12	Poplar (Populus sp) (Intercropping with agriculture crops is recommended)	Irrigated	18'x18'-20'x20'	137-111	5'-10'	1056-528
		Barani (high rainfall)	18'x18'-20'x'20'	137-111		1056-528
13	Robinia (Pseudacacia)	Barani (high rainfall and low temp.)	10'x10'	435	5'	1056
14	Ailanthus	Barani	10'x10'	435	5'	1056

In rainfall conditions below 300 mm per year, trees will compete with field crops for moisture and will reduce yields. Block planting of trees would therefore be recommended in regions with annual rainfall less than 500 mm rather than planting them in association with crops.

The choice of tree species to be grown with field crops is crucial in Barani conditions. Farmers often know from experience which tree species grow well with field crops and they should be consulted in the choice of species. Eucalyptus (Safaida) has a reputation for drying the environment and should not be planted near field crops in Barani conditions.

10.4 Performance of Trees in Rainwater Conservation and Income Generation

The preformation of trees is measured in terms of conservation as well as in production of fuel wood, and fodder. At the Water Harvesting Site of NARC at Fatehjang about 30 to 60% of the rainfall received during monsoon season went to waste as surface runoff. The loss of incident rainfall as runoff was reduced through appropriate land forming into eyebrow terraces and planting techniques. After 7 years of plantation, the runoff was 64% and 95% less under catchments planted respectively with *Eucalyptus camaldulensis* (Sufaida) and *Leucaena leucocephala* (Ipil Ipil) than that of the area without trees.

At Fatehjang, several kinds of forest trees were planted in gullied areas. The performance of *Eucalyptus camaldulensis* (Sufaida) and *Leucaena leucocephala* (Ipil Ipil) was excellent when planted in eye brow terraces.

The performance of *Leucaena leucocephala* (Ipil Ipil) with respect to reducing run-off was superior to *Eucalyptus camaldulensis* (Sufaida). The reason for this is probably that there was good under-storey growth of tree seedlings and other plants such as grasses under the Ipil Ipil. The under storey area under Saifeda was not as good. In the choice of trees for conservation purposes, it is important that there be good under-storey growth of plants in association with the mature trees to more efficiently reduce run-off.

Costs and returns of Eucalyptus trees at Fatehjang are given below:

COST OF TERRACES & PLANTING (Rs/Ac)	NET INCOME PER ACRE AFTER 7 YEARS (Rs/ac)
1600 - 2400	1800 - 2200

SOURCE: *Soil and Water Conservation for Barani Lands and Watersheds: An Overview. Shafiq M. Shahid A. WRRI, NARC, Islamabad 1995*

Different species will mature in different span of time. The *Eucalyptus camaldulensis* (Sufaida) will be exploitable in 5-6 years, poplar 6-7 years, shesham 30-50 years and pines in 7-10 years. It is essential to measure the wood available from a mature tree in order to assess the income. For this purpose the diameter of the tree or its girth is measured at a height of 1.5 m (4.5 ft) preferably at 3 places. While assessing the total volume, the use of wood and the market is kept in view. It will be better to consult the local forest experts for appropriate advice and assessment of tree yield and when to market. The Forest Department carried out an exercise to estimate the yields of the *Eucalyptus camaldulensis* (Sufaida) plantations established using different planting distances. The results are tabulated below:

***Eucalyptus camaldulensis* (Sufaida)**

Spacing (Ft)	Age (Years)	Height (Ft)	Diameter (Inches)	Wood (Cu ft)	Gross Income (note 1) (Rs/ac)	Equivalent (note 2) Annual Income (Rs/ac)
5x5	5	51	15.3	2278	32462	6492
10x6	5	48	15.2	1856	26448	5290
10x10	5	51	15.9	1340	19095	3819

SOURCE: *"Eucalyptus"* Publicity Section, Department of Forestry, Punjab.

1. Paper factory offered Rs 30 per maund (40 kg) 1 cu ft weighs 19 kg.

2. Gross income divided by 5.

10.5 Forest Tree Nurseries

Projects should encourage members of Water Harvesting Associations to raise their own tree seedlings for their own catchments as well as for neighbouring catchments. The Project may supply trees to WHAs free of cost. In keeping with this, the project may buy trees from private nurseries including those produced by the WHA members themselves.

Proper planning is essential for establishing a Forest Nursery on scientific lines. The WHA should contact the local staff from the Forest Department for technical guidance.

Type of Nurseries

There are three types of nurseries.

1. Bed nurseries: Seed is planted on flat or raised beds for obtaining flat plants.
2. Seed is sown in the base of furrows.

3. Seed/planting material is sown in polythene bags and earthen pots of different sizes.

10.5.1 Site Selection

The site of the nursery should be accessible and preferably be located near the road. Soil should be well drained deep and fertile free from salts and waterlogging. Availability of water should also be ensured for timely watering of seed beds and the nursery plants. The essential tools and implements such as spades, shovels, sprinklers, khurpa pointed iron rods (.5 meter), measuring tapes, ropes, troileys, trays, earthen pots should be available for carrying out different operations at the nursery. Experienced and skilled manpower is also an essential prerequisite for propagation of the forest trees. The local Forest Department could train WHA members.

The following are the essential steps/operations involved in nursery raising.

10.5.2 Land Preparation

Deep tillage should be done to prepare the land. It should be cleared from weeds wild grasses, stones and from other undesirable material. Well rotten farm yard manure and silt should be mixed in the field and it should be properly levelled for efficient use of water. The nursery may be square shaped or rectangular. It should be divided into plots of convenient sizes for sowing of seeds and raising nursery plants. The irrigation channels/turns should be laid out in a manner that the water is used conveniently and efficiently especially during the critical periods.

10.5.3 Planting Material (Seedlings - Cuttings)

- **Seedlings.** Most of the forest trees are multiplied by seed. The seed selected for propagation should be healthy, viable, pure and free from the undesirable seed or material. If hard it may be scarified by soaking in water for 24-48 hours. Seed can be broadcasted in a well prepared seed bed or planted in the furrow in lines. Some seed which are very minute and need great care are planted in big earthen pots and then transplanted to plastic bags or small gamlas (sand made pots) plastic bags are cheaper and easier to transplant than earthen pots.

  After six months or one year, when the roots are well developed and there are 2 to 3 branches with healthy leaves, the seedlings are ready for transplanting in the field. The plastic bags should be cut and removed very carefully before transplanting the seedlings. Similarly the plants should be taken out from the pots very carefully without damaging the roots. Plants with earth balls should be transplanted without breaking the earth boll.

- **Cuttings.** A large number of forest trees which have difficulty in seed germination or it is desired to maintain their genetic purity are easily propagated through stem cuttings, root cuttings or budding/grafting on the compatible root sticks. Ipil Ipil, Willow, Poplar, Mulberry and Tamarix are the trees which can be successfully propagated by stem cuttings.The following are the main points which should be kept in view, while propagating trees through cuttings:

  - Prepare the land well. Remove all type of weeds , stones and stubbles.
  - Add farm yard manure and silt in the soil according to its fertility status.
  - Divide the field into plots of convenient sizes.
  - Ensure timely irrigation.
  - Obtain cuttings from healthy trees when they are in dormancy. The cuttings should be taken from 6 month or one year old wood. Soft wood will not be successful. The size of the cutting may be 9" x 1/4" or of pencil or thumb thickness with 2 to 3 buds at least.
  - Plant the cuttings into the well prepared deep and soft seed beds in lines at a distance of 6" x 12" as the space permits. Plant the cuttings with 3/4 of the length in the ground and at least 2 buds above the ground.
  - Water the field immediately after planting and do not allow the bed to dry.
  - Protect the sprouted cuttings from hot winds and low temperatures.

The following are few examples of appropriate propagation methods:

SN	Method	Trees
1.	By seed	Acacia, Ipil Ipil, Bekain, Eucalyptus, Pines, Tamarix, Jaman etc.
2.	By stem cutting	Poplar, willow, mulberry, tamarix, ipil ipil.
3.	Sucker	Datepalm, oilpalm, bamboo and grasses.

10.5.4 Seasons for Planting Seed

Preparation of seed beds for seed sowing should start from December and January. Actual sowing is usually done in Feb and March. Sowing of seed of some species

such as Jaman, Mango, Guava, Bakain, Shesham etc. is also done during August and September. Seed can be sown in the raised bed or on the side of furrows or in flat bed or earthen pots. In case of earthen pots, the young seedlings when they attain 2-3 leaves are transplanted in plastic bags and placed in deep beds for watering and other operations. Eucalyptus and Ipil Ipil plants are generally raised through these techniques. Their seed can be sown from February to September. Seed beds, furrows and pots should not be allowed to dry. This requires a reliable source of water.

10.6 Planting and After-Care

The choice of species and recommended cultural techniques are summarized in Tables 10.2 and 10.3 and further described below.

10.6.1 Transplanting of Young Trees

For most forest trees transplanting of seedlings is best done in the spring (February and March) or in the summer after the 1st or 2nd monsoon rain, usually in July.

Young plants are transplanted into pits dug out according to the space required for different species. The guiding principles are that the size of the pits should be according to the size of the roots. It should be as deep as it was in the nursery. For plastic bags, the size is generally kept as 10" x 4-5" for earth boll or potted plants the average size is 2' x 2'.

In rainfed areas where there is scarcity of water, forest trees should be planted in trenches to store more water for the young plants. On slopes, the eye brow terrace system should be adopted for moisture preservation and utilisation.

While planting a tree, it should be held in the centre of the pit and then gradually filled with good soil or with well rotten farm yard manure and silt and pressed with the handle of the spade and feet and watered immediately. After watering, the soil in the pits will settle down, such pits should be immediately refilled up to the original level.

10.6.2 Spacing Under Different Conditions and Transplanting of Young Trees

There is a tendency among the farmers to plant many trees in a small area to have maximum production. This is not right and advisable, plants are living organisms, they also need proper food, water and space for their growth and survival. If there are too many plants in one plot there will be great competition for food and other inputs among these plants. Naturally their growth will be less and some of them may be weak and may not survive. For proper health, vigour and obtaining good yield of quality wood, it is essential to plant the trees at proper distance according

to their growing habit, the fertility status of the soil and the actual situation at the water harvesting site.

If the trees are to be planted in the farm yard for shade purposes such as Shesham, Bakain and Siris, they may be spaced at a distance of 20 to 30'. If the trees are to be planted at the boundaries of farms/fields, the planting distance may be kept as 10'. If it is desired to establish block plantations of trees like Ipil Ipil, Eucalyptus, Poplar or Shesham, the appropriate spacing may be as 6x6'. After 2 to 3 years if there is congestion, some plants may be then thinned out by selecting the weaker trees and cutting them. Trees in crop fields should be planted at a distance of 12'. For fruit trees, use the planting distance as recommended by the experts. Also refer to Table 10.3 for spacings.

10.6.3 Cultural Techniques

Young plants will not grow by themselves. Young trees require food and water and protection against grazing animals, bad weather and fire.

Watering. If there are enough timely rains and there is harvesting of water onto the trees, there may be no need for watering. However, it is recommended that the WHA has a water bowser or some other arrangement for watering the trees while their root systems are establishing. If the trees are planted so that they can establish themselves at a time when rains are expected, the rate of success will be higher. The young plants should be watered once a week in summer and after 10 to 15 days in winter. A plant would require one gallon of water for one irrigation. Once the root systems are established deep into the soil and water from rainfall is being harvested around the trees in terraces, these irrigation requirements will not be so necessary. The condition of the trees will show whether irrigation will be required.

Pruning. Pruning of young plants is essential for the removal of diseased trees. Pruning also gives the trees a proper shape. After planting them in the field, pruning should be limited to the removal of side-shoots and extra branches coming out from the main stem. This will help in producing quality wood without many knots and will bring good returns to the growers.

Interculture. In the early years, enough space is available in between the tree lines or on the sloping terraces to intercrop with a second crop. Some compatible crops like wheat, soybeans, fodder grasses (Dhaman grass) can be planted in the vacant land to enhance farm income. However, it should not be at the expense of the actual tree crops and the farmers will need to judge when competition is too high between the intercrop and the trees.

Weeding. It is necessary to remove weeds and wild grasses which are competing with the trees. In the presence of these weeds, the tree growth will be very slow. At least 3 hoeings will be required to the plantation to keep it clean from obnoxious weeds and grasses. Once the trees are bigger and provide shade that reduces weed growth, the number of weedings can be reduced.

Grazing. In early years farm cattle should not to be allowed to enter into plantation blocks for grazing purposes, otherwise the young plants will be severely damaged which may result in absolute failure. Chowkidars must be employed to protect and look after the trees from grazing animals. A fence made from the branches of acacia or ber can be provided to check animal entry. The cooperation and participation of the entire community is very essential in controlling grazing in forest plantations. Absolute grazing protection is critical for the first two or three years until the trees are mature and can withstand a certain amount of grazing.

To make fences, trees and plants like Acacia, Opuntia, Agave and Sisal can be planted along the perimeter of tree blocks. These plants should be planted in two or three lines along the fence boundary in order to make a thicker barrier. Barbed wire fencing is normally too expensive for WHAs.

Fire Protection. Prevention is better than fighting a fire. There is every chance that the forest plantation may catch fire causing great damage to the trees and losses to the farmers. It is essential to protect the trees from fire, especially during the hot summer season in the months of May and June. Measures to prevent fires are:

- If a water tank is available, keep it full of water in the hot season.
- Teach everybody in the community the danger of fires to forests.
- Do not allow anybody in the community to cook or burn fires in or near the forest area.
- Train everybody in the community not to throw burning cigarette butts or coals from the Hukka in or near the plantation.
- Train the people in the community to fight a fire by using beaters made of wet sacks. They should not use the beaters against the direction wind but with the wind.
- Contact the Forest Department for help and guidance.
- A fire-break can be made to surround the forest. This consists of a strip of land about 5 m (15') width in which no trees or grasses are allowed to grow. In this way, if a fire starts, it will not be able to cross the fire break and the trees will

be protected.

Harvesting. Different species become exploitable at different times. Eucalyptus will be ready for harvesting after 5-6 years, Poplar after 7 years, Simal 10 years, Shisham after 30 years and Pines after 10 years.

When forests of eucalyptus and ipil ipil are harvested, the main stem should be cut and 2-3 sides shoots should be allowed to grow. This process is called "coppicing". In this way, a forest will produce wood each year. Where trees do not coppice, there should be replanting of fresh seedlings to immediately replace the harvested trees. Harvesting and planting is best done in blocks.

10.6.4 Tips for Successful Tree Planting

The following tips are a summary of the cultural techniques required for trees.

1. Select trees according to the suitability of the areas and the end uses of trees.
2. Procure healthy, well balanced saplings from a reliable source.
3. Make pits according to the size and spread of roots. Average size is 2'x1.5' but may be adjusted according to size of the plant. Add well rotten farm yard manure and silt in 50:50 for better results, particularly in light soils.
4. Store saplings in a shady place and do not allow them to dry.
5. Place the sapling as deep in the pits as it was in the pots, plastic bags or in the nursery. Remove dry and diseased leaves if any and cut the plastic and place the tree very carefully in the pit. Water it immediately after planting.
6. Plant trees when it is cloudy. Plant the trees in the correct season
7. Replace the dried trees immediately.
8. In the early years water the trees twice in a week depending on the climate and rainfall. After this, water as required. The WHA should procure a water bowser in order to take water to the trees.
9. Protect trees from wild or domestic animals, grazing, cutting and fire.
10. Remove grasses and weeds from young plants to avoid competition for food.
11. Ensure that contour trenches, micro-catchments and eyebrow terraces are well maintained so that water is harvested where the tree is growing.

11 LIVESTOCK AND PASTURE MANAGEMENT

11.1 Animal Health Through Links With Veterinary Department

The OFWM Programme should assist members of the WHAs to have healthy livestock by linking them with the veterinary and animal husbandry departments. Animal health will improve through the development of water harvesting projects by:

- Establishment of pasture and range grasses in the unculturable areas of the catchment (Banjar land type). This will improve the level of nutrition of livestock and as a result, the production of animal products.
- Harvesting and storing water in ponds in order to water livestock.
- Trees will provide shade for livestock especially during the hot season.
- Animal medicines and other services will be provided by the veterinary department. The project should facilitate the linkages.

11.2 Establishment of Fodder Trees and Range Grasses

Fodder trees, range shrubs and grasses are best planted in either spring (Feb and March), when temperatures are low and there may be some rain or at the onset of the monsoon season in July.

There should be a period of complete protection; no cutting or grazing in the area where range and fodder plants are being established. Two years will be required for the establishment of mature plants that could then be safely grazed without being destroyed.

Overgrazing is the arch enemy of all range and fodder plants.

11.3 Fodder and Grazing Management

There are three principles to be followed in the management of fodder and grazing in a water harvesting site:

1. As much of the uncultivated land type (Banjar) as possible should be planted to trees, shrubs and grasses that provide fodder for animals. There will be two benefits. The water will be harvested through reducing runoff and fodder will be produced to increase animal production.

2. Trees and shrubs will provide browse and grasses will provide grazing. In order to exploit this fodder supply fully the animals in the catchment should be a mix

of browsers (goats) and grazers (cattle, buffalo and sheep).

3. The intensity of browsing and grazing must be controlled so that fodder plants are not destroyed in the long term, through too many animals grazing and browsing.

There are three systems of grazing; continuous, rotational and zerograzing. There are also combinations of these:

1. **Continuous Grazing:** The animals are free to graze and browse in the range area continuously.

Advantages	Disadvantages
Less labour to herd animals	Selective grazing by animals which can destroy more palatable plants, unless grazing pressure is low.
	It is not possible to establish new range trees, shrubs and grasses.

2. **Rotational Grazing:** The range area is divided into units and only one unit is grazed at time. After a period of time, the first unit is rested and the animals graze another unit. In this way a grazing cycle is completed over a season or several seasons through rotating animals between units. The period of rotation may vary from several weeks to two or more years.

Advantages	Disadvantages
Fodder plants can be rested to recover from grazing and set seed	More labour is required to keep animals off rested units.
There is high grazing pressure and more uniform grazing as a result.	Management is difficult.
A unit can be planted and allowed to establish before it is grazed.	

3. **Zero Grazing:** All fodder is cut and carried from the range area to the animals.

Advantages	Disadvantages
Less energy is used by animals and their housing conditions are good giving high productivity.	High labour requirements
	Low growing grasses in less accessible places, are not harvested.

Complete protection of range area is possible to help in establishment	No organic manner from animal waste is added to the range plants.

The optimum grazing arrangement is probably one which has herds grazing and some cut-and-carry of fodder for storage and during periods of establishing trees and other new range plants.

For better pasture range one should always keep the following points in view:

- While animals are owned by individuals, range and grazing plants are often owned and used by a community
- Rights of local people should not be violated
- Keep in view the agreed boundaries of the range area
- Involve local community with the management of rangelands and the deciding the grazing systems to be followed.
- Regeneration of vegetation should be allowed.

11.4 Important Sources of Fodder

Animals take fodder in different forms. Some of the major forms are as under:

- Grasses, fodder crops
- Leaves of bushes and fodder trees
- Pruning from the evergreen trees.
- Mixed fodder, it is a balanced food and is good for animals.

The following are the important grasses bushes and forest trees found in the rainfed areas.

Important Grasses

1. Chloris gayana - Rhodes grass
2. Cenchrus ciliaris - Dhaaman
3. Elionurus hirsutus - Kaira
4. Cymbopogan jawaracusa - Khari
5. Desmostachya hipinnata - Dab
6. Cynodon dactylon - Khabal
7. Sorghum halepense - Bru

Important Grazing Bushes

1 Calligonum polygonoides- Phog
2 Salsola foetida - Lani
3 Zizyphuys nuraularia - Ber
4 Capparis aphylla - Kareer
5 Vetiver - Khus khus

Important Fodder Trees

1 Acacia - Kiker
2 Albizia lebbek - Siris
3 Bhauhinia - Kachnar
4 Codia dichotoma - Lasura
5 Leucaena leucocephala - Ipil Ipil
6 Morus Alba - Tut (Mulberry)
7 Olea ferruginea - Kahu
8 Prospis cineraria - Jand
9 Rubinia psuedoacacia - Ainal Asl
10 Tamarix - Farash
11 Zizyphus - Ber

Important Cultivated Fodder

1 Atriplex - Salt Bush
2 Avena sativa - Oats
3. Millet- Bajra
4 Cyamopsis - guara
5 Medicago sativa - Leucern
6 Melilotus parviflora - Sweet clover
7 Pennisetum purpureum - Napier fodder
8 Sesbania - Dhaincha
9 Sorghum vulgare - Jowar

11.5 Use of Vetiver Zizanioides (Khus Khus) in Pasture Management and Water Harvesting

Farmers in India have been using Vetiver grass (Khus Khus) very successfully over many years to reduce run-off, conserve soil and provide fodder.

Vetiver grass (Khus Khus) has been used for water harvesting to reduce run-off and soil erosion in various ways.

- It is planted in lines on the contour across the slope;
- It is planted on field bunds to strengthen them;
- It is planted under trees to provide more ground cover and better erosion control;

- It is planted across gullies to help plug and reclaim them;
- It is planted in waterways to prevent scouring during floods;
- It is grown in the catchment areas above dams and reservoirs to catch the silt and filter the water.

Vetiver grass is suited to most climatic zones found in Pakistan.

Vetiver is planted through cuttings. This is best done in February-March or in July and August.

The following benefits have been ascribed to Vetiver grass by farmers from the Gundalpet Taluka near Mysore in India (Proceedings, Seminar on Dryland Agriculture in Pakistan, Lahore, PFC, Nov 1988).

Direct Farm Benefits

- fodder cut every two weeks throughout the year; equivalent production of 14 tons per ha(140maunds/ac);
- soil moisture improvements as evidenced by more even crop growth and good yields in dry years particularly;
- less risky farming - higher use of fertilisers compared to non practioners';
- retention of fertiliser in farmers' fields;
- complete barrier against creeping weed grasses such a Cynodon dactylis;
- terrace protection against rats and snakes.

Erosion Control

- soil erosion control - terraces up to 1 meter high on slopes of about 3% have developed over time;
- micro catchments have fully stabilised, with virtually no evidence of erosion;
- stream bed/bank erosion has been minimized.

Soil Moisture Improvement

- ground water tables appear higher in protected areas as measured by well water levels;
- soil moisture improvement particularly when associated with contour cultivation - significant yield improvements recognised by farmers.

System Cost to Farmer

- maintenance cost is virtually zero;
- establishment cost per ha when using hired labour; digging of planting material Rps 80; planting slips Rps 40. Total cost Rps 120.

Other Characteristics Confirmed at Gundalpet

- Vetiver grass is resistant to ail pests and diseases (farmer observation during living memory);
- crops grow close to Vetiver with no yield loss;
- hedges are easily maintained to 50cm width by close ploughing - thus minimum land loss to cultivation (compared to 5 to 6 meters for contour bunds)
- fire resistant;
- seeds do not germinate and therefore Vetiver does not become a weed;
- it makes excellent mulch, thatch and brooms.

12. FLOOD IRRIGATION

12.1 Introduction

Traditional flood or spate irrigation schemes have been constructed and operated in Pakistan by farming communities for hundreds of years. In Balochistan, NWFP and Western Punjab such schemes account for significant proportions of the irrigated land. In Balochistan, flood irrigation is known as sailaba irrigation whilst in DG Khan in the Punjab and DI Khan in NWFP, where very large floods emanate for the eastern side of the Sulliman range, such irrigation is known as Rod Kohi irrigation. A map of the Rod Kohi system in DI Khan is shown over as Figure 12.1.

More recently both the irrigation and water management departments have begun improving flood irrigation schemes. The irrigation departments have concentrated on the construction of major diversion structures on large nullahs, whilst the water management directorates have under the OECF OFWM programme, begun to develop programmes to assist the farmers in improving the lower levels of the system and diversion structures for small schemes.

Flood irrigation is a risky business for the farmers concerned. The systems are dependent on timely rainfall and runoff from the rainfall. The size and severity of floods varies enormously, large floods are difficult for farmers to control and often result in damage to structures and erosion and flooding of land. Sediment carried with the floods causes choking of channels, and accretion (gradual rise) in the levels of land and channels, which in turn causes land to move out of command and channels to tend to change their course. In designing any flood irrigation scheme it is important to understand the magnitude and nature of the above risks and to design to mitigate them as far as possible. It is also important to understand that the farmers practices will have developed to minimize their risks, rather than to maximize returns in the good years only. In this way famine is prevented in bad years and the best overall performance is obtained from the system.

The benefits of flood irrigation include of course the production of agricultural crops in dry land areas, however benefits also include the reduction in the severity of floods and hence damage to infrastructure downstream, and groundwater recharge. In many areas the beneficiaries of flood irrigation schemes are some of the poorest farmers in Pakistan (although this is by no means always so) and hence the improvement of their schemes is contributing to poverty alleviation.

When designing a flood irrigation scheme the costs, benefits and risks must all be weighed up. Large scale concrete diversion structures are unlikely to be found to be economic, the increase in production from largely subsistence crops does not warrant the cost of such structures. Appropriate schemes using low cost structures (including gabions), and programmes which concentrate as much on improved

Gomal Side : 8657.056 Km^2

River Side : 2833.268 Km^2

LEGENDS

Roads

Nullas

Sl. No.	PROJECT	CCA IN ACRES	COST IN BILLION	SHOWN IN THUS
1	C.R.B.C GRAVITY	350000	17.16	
2	FIRST LIFT	285700	17.17	
3	GOMAL ZAM	163100	9.49	
4	TANK ZAM (C.C.A 132000 AC)	45000		
	TOTAL WITH OVERLAP	843800	46.12	
	TOTAL WITHOUT OVERLAP	796700		

1	OVERLAP BETWEEN GOMAL & TANK ZAM	27000 ACRES
2	OVERLAP BETWEEN FIRST LIFT & GOMAL	20070 ACRES
3	ROT KOHI AREA UNDER (1) C.R.B.C GRAVITY = 53500 ACRES (2) FIRST LIFT = 67000 ACRES	

	NAME OF ZAMS / NULLAHS	AREA WITH FLOOD WATER RIGHTS CULTIVA-ED (ACRES)	MAX. FLOOD DISCH. (CUSECS)	PEREN-NIAL DISCH (CUSECS)	AREA UNDER PEREN-NIAL RIGHTS (ACRES)	LENGTH OF NET WORK WATER (MILES)	NO. OF SADS / GUND-IES	TOTAL WATER RIGHTS (ACRES)	CATCH-MENT SQ. MILES	RUN OFF (M.A.F) ON 25 YEARS R.P.
1	2	3	4	5	6	7	8	9	10	11
1	GOMAL	250044	160000	100	21384	165	128	281428	13908	0.360
2	TANK	101304	120000	40	28750	191	-61-	130054	910	0.152
3	DARABAN	30950	70000	35	2489	28	INCLUDED IN CHUDWAN	33449	423	0.032
4	CHOUDWAN	39637	55000	20	4230	143	90	43867	351	0.055
5	CHEKH HAIDER	53355	40000	10	1100	83	18	54455	175	0.020
	SUBTOTAL OF ZAMS	485320	445000	205	57933	610	297	543253	15759	0.631
6	OTHER NULLAHS	51840	6637	-	-	132.4	60	51840	98.2	0.030
	TOTAL	537160	451637	205	57933	742.4	357	595093	15857.2	0.661
7	PANYALA CIRCLE	98600	-	-	-	141	-	98600	-	-
	TOTAL WITH PANYALA	635760	451637	205	57933	883.4	357	693693	15857.2	0.661

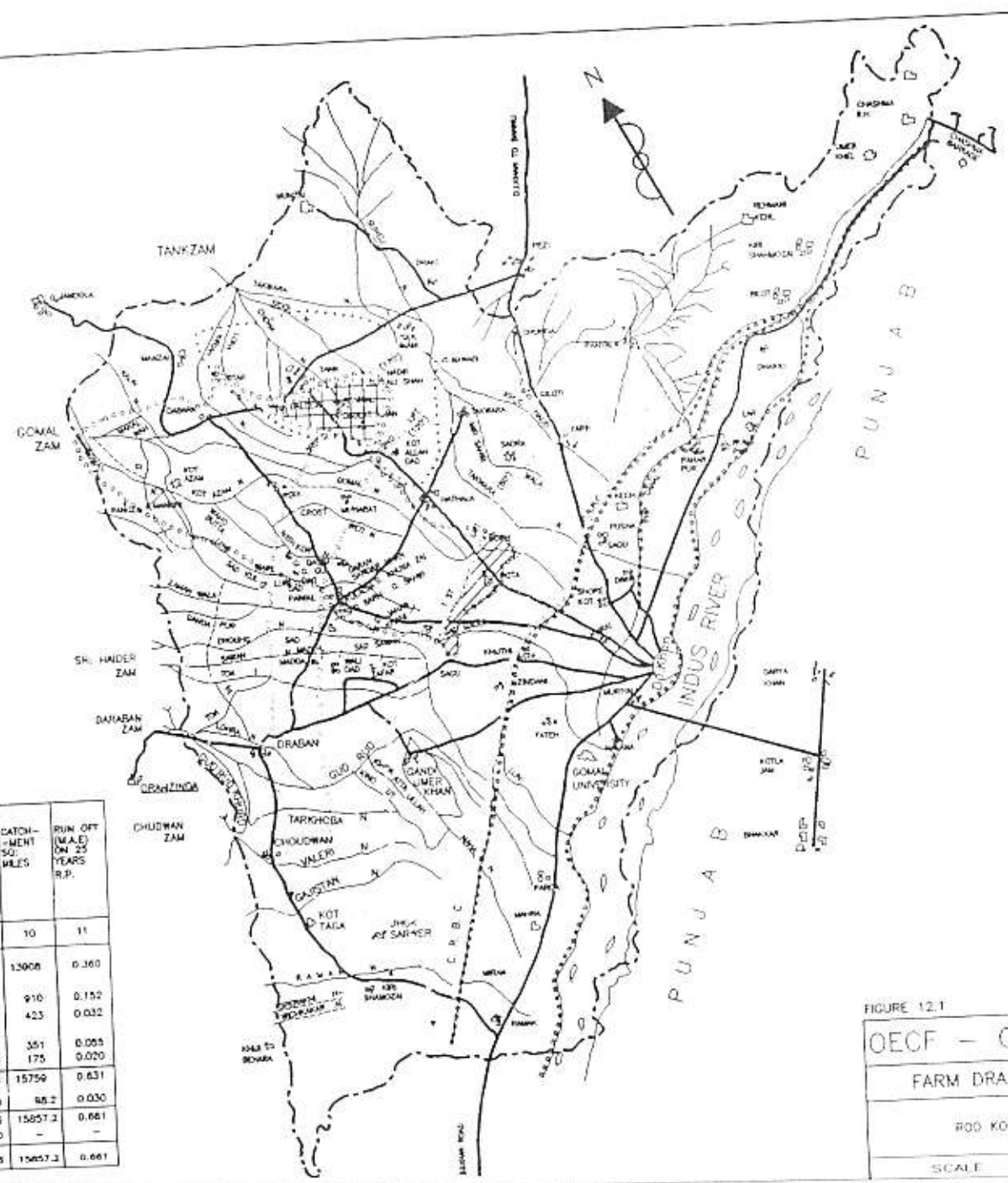


FIGURE 12.1

OECF – OFWM PROJECT

FARM DRAINAGE COMPONENT

ROD KOHI, D.I. KHAN DISTT.

SCALE

DATE: Dec 1995

agronomic practices and improved organisations for O&M etc are the most likely to meet the needs of the farmers and to be at least marginally economic.

A flood irrigation programme should therefore include each of the following components which are discussed in turn in the following Sections:

- river diversion structures
- conveyance channels and channel diversion structures
- field development
- agronomic improvements
- beneficiary organisation and participation

12.2 Diversion Structures

Flood irrigation diversion weirs can provide many benefits to farming communities on traditional flood irrigation schemes:

- They can stabilize the diversion point and introduce a degree of control of the division of flow down the river and into the intake channel:

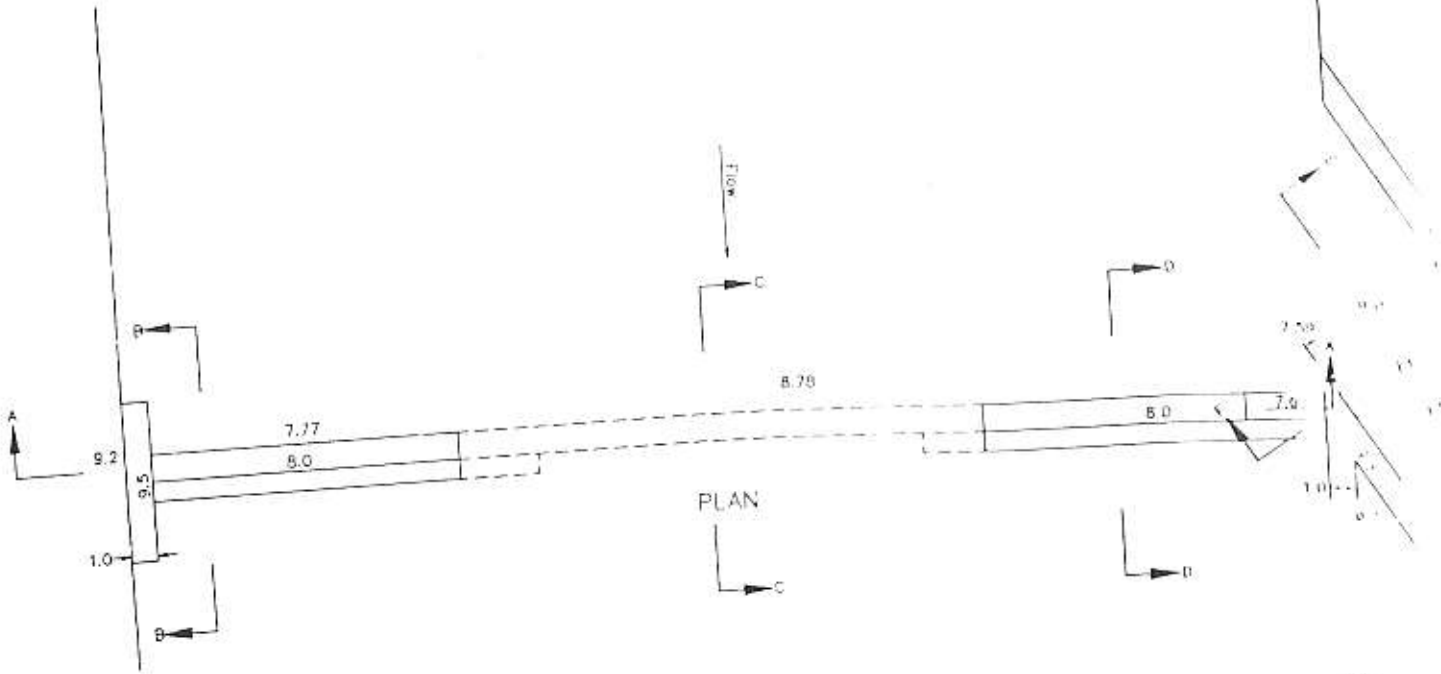
- On most traditional schemes diversion is by means of an earth bank built up in the river bed. This washes away in the first major flood. A diversion weir saves the farmers in reconstructing such bunds and is available to divert subsequent floods onto the command area, whilst the traditional bund might not be reconstructed in time to do so:

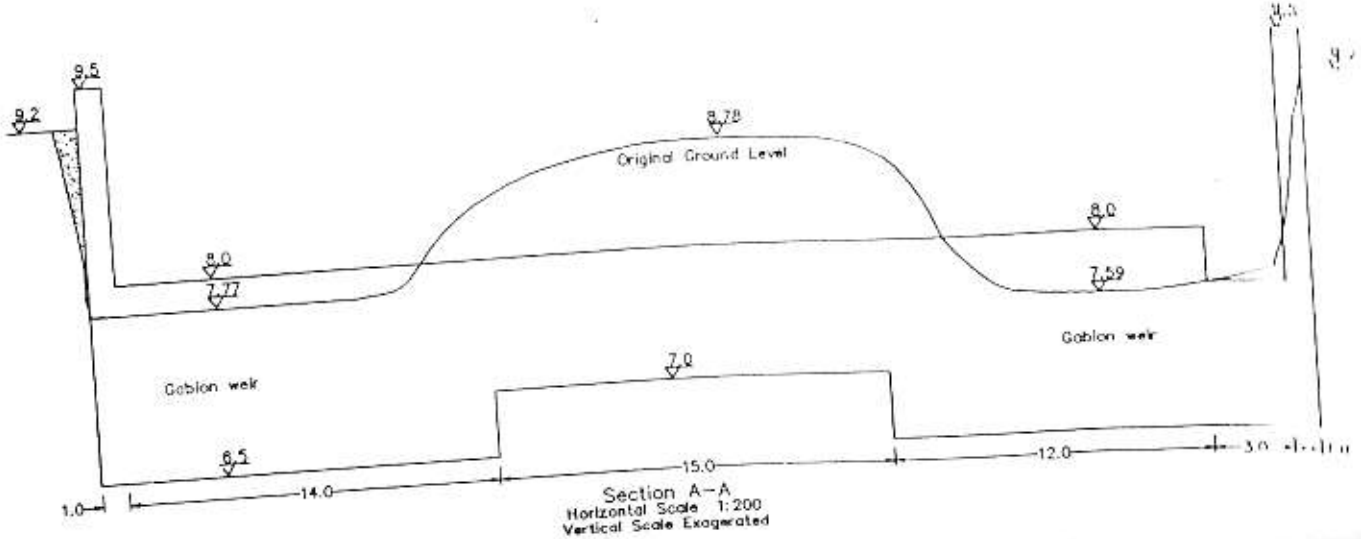
- Well designed offtakes can limit the flow into the offtake channel at high floods, thus preventing flooding and damage to the command area; and

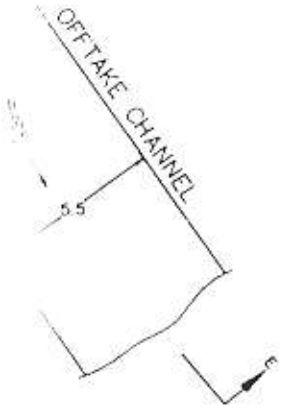
- Well designed offtakes can limit the diversion of bed load sediment into the offtake channels which often choke such channels, at the same time fine material can pass through the system to the land where it provides significant benefits.

Many flood weirs have been designed in the same way as one would design a perennial irrigation weir, with little consideration for the differences in scheme concept between flood and perennial schemes. Flood irrigation weirs have to be cheaper than perennial weirs, do not have to be impermeable and the geometry of the weir and offtake are more critical as far as silt exclusion are concerned.

One way in which the cost of the weir body can be reduced considerably is the avoidance of concrete and masonry, which can be replaced by gabions or rock weirs. Figures 12.2 and 12.3 show details of two small and simple gabion diversion weirs designed under the OECF OFWM Project. The design differs to meet the





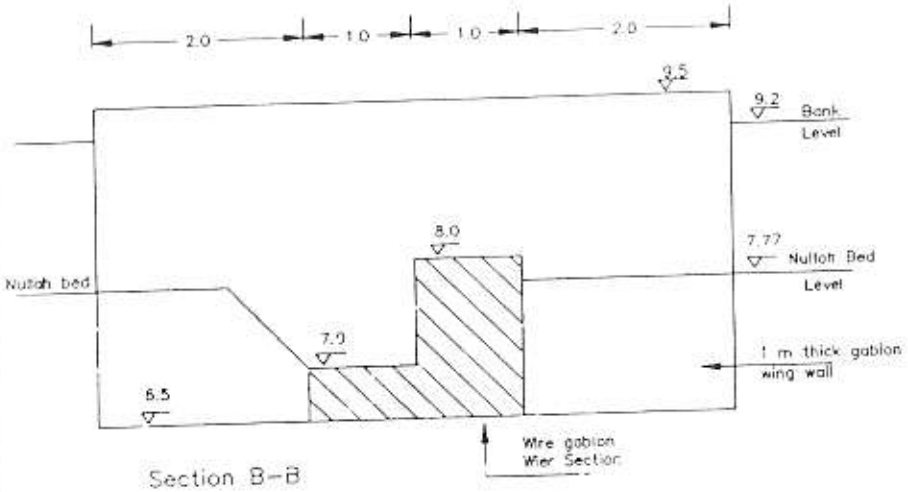


12.2

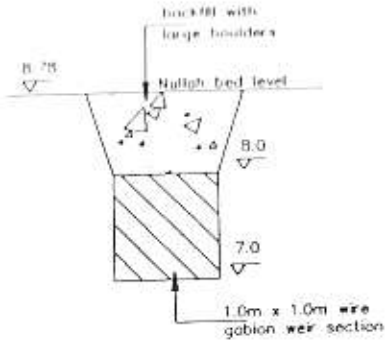
DECF ASSISTED OFWM PROJECT

IBSHOBI FLOOD IRRIGATION WEIR

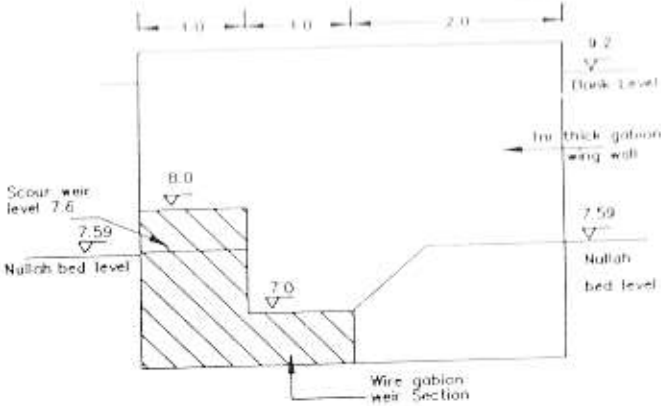
Scale 1: 200 | Sheet 1 of 2



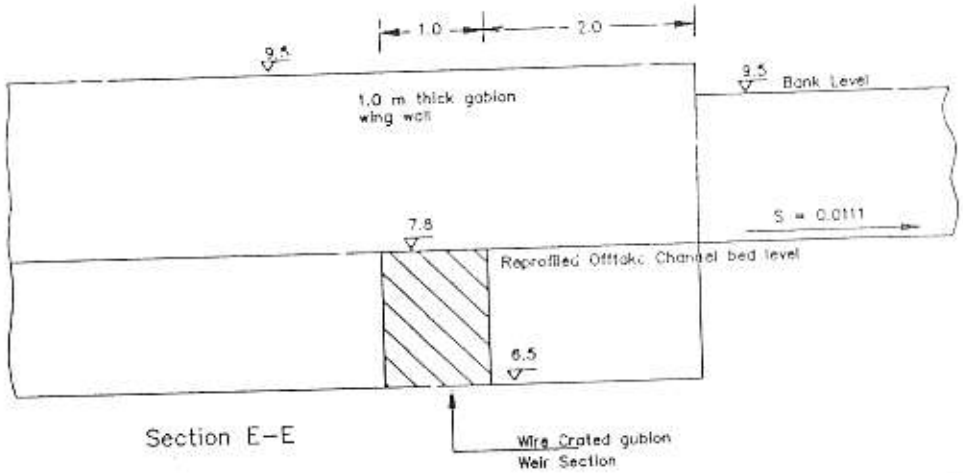
Section B-B



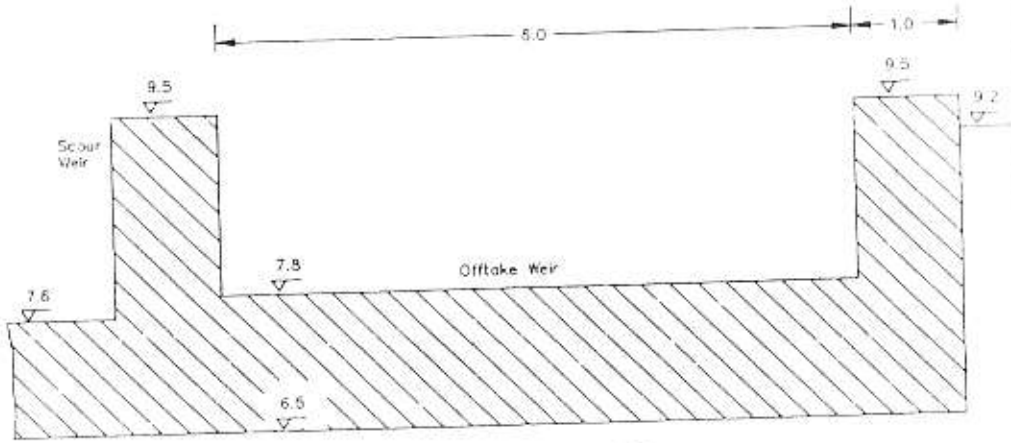
Section C-C



Section D-D



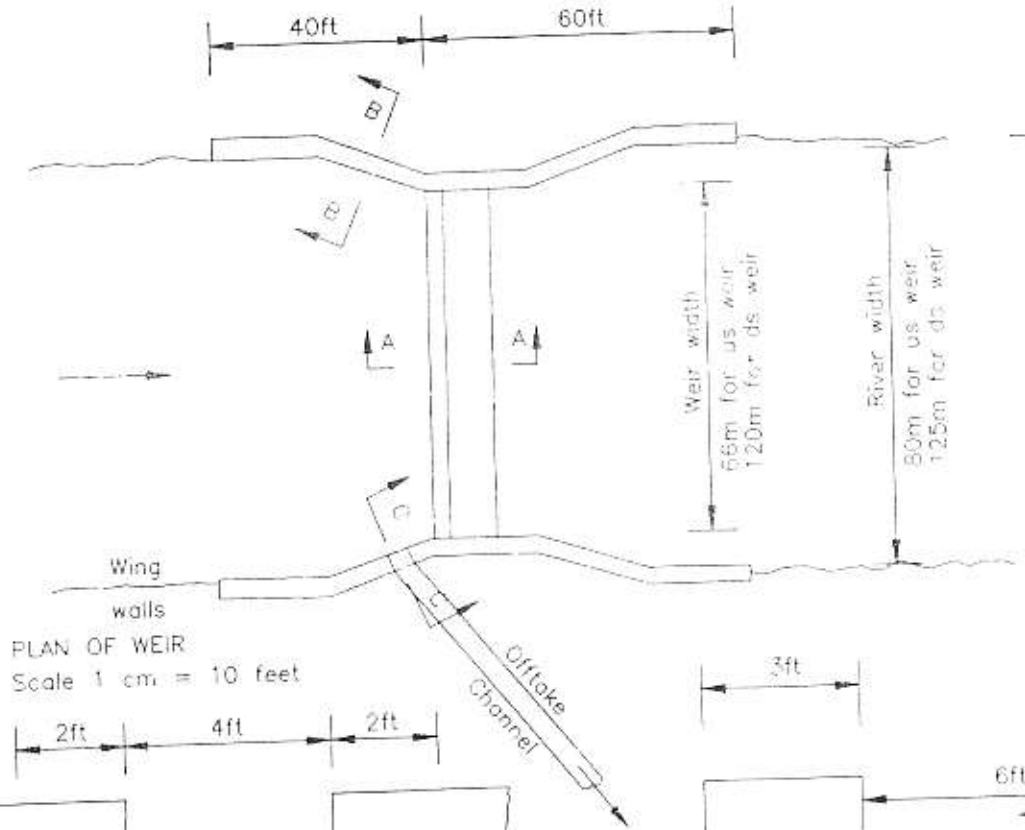
Section E-E



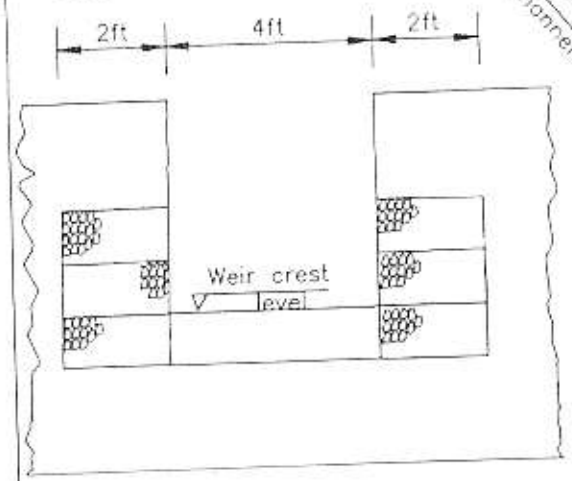
Section F-F

FIGURE 12.2

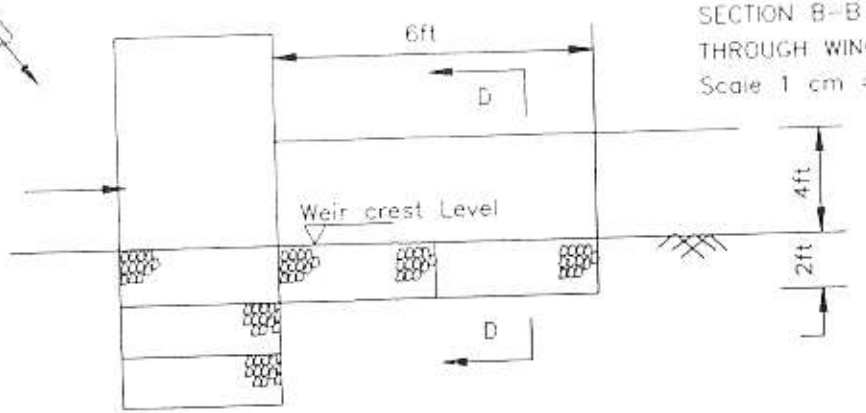
OECF ASSISTED OFWM PROJECT	
KHOSHOBI FLOOD IRRIGATION WEIR	
Scale	Sheet 2 of 2
HALCROW RURAL MANAGEMENT	AUGUST 1994



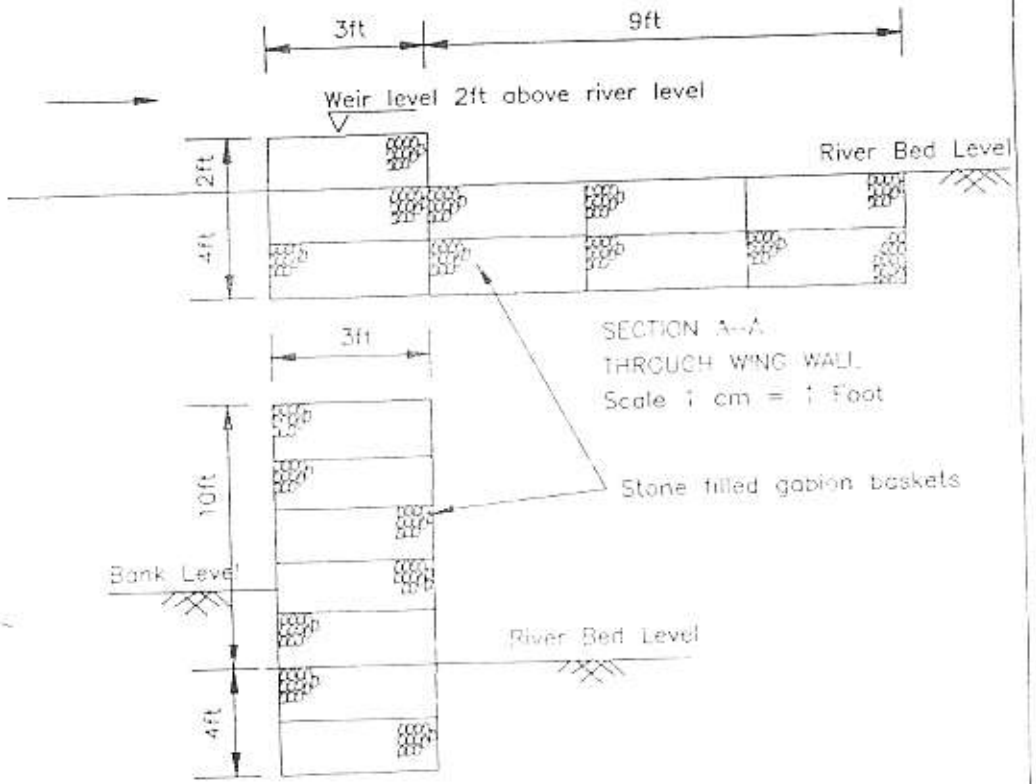
PLAN OF WEIR
Scale 1 cm = 10 feet



SECTION D–D
THROUGH OFFTAKE CHANNEL
Scale 1 cm = 1 Foot



SECTION C–C
THROUGH OFFTAKE CHANNEL
Scale 1 cm = 1 Foot



SECTION A–A
THROUGH WING WALL
Scale 1 cm = 1 Foot

SECTION B–B
THROUGH WING WALL
Scale 1 cm = 1 Foot

FIGURE 12.3

OECF – OFWM PROJECT	
KHARLACHI SAILABA WEIR	
HALCROW	
DAVID R. BIRCH	DATE: Jan.1997

geometry, layout and flow distribution requirements of each of the two sites, but several points are consistent and important:

- The weir goes across the channel to stabilise the bed;
- The stilling basin downstream of the weir is designed to withstand scour of the river bed;
- Wing walls are provided at either end of the weir to prevent the river cutting round and bypassing the weir. The wing walls are high enough not to be overtopped in an extreme event and deep enough to not be undermined by scour;
- The configuration of the offtake channel is designed to divert the optimum percentage of the flow from the main channel, the relative width of the diversion channel and the relative levels of the main weir and diversion channel weir are important in this respect and require considerable care in design;
- On the weir shown on Figure 12.2, a notch is cut in the main weir adjacent to the diversion weir, this notch is intended to channel the flow carrying the heaver bed load sediment past the diversion weir and hence reducing the amount of very coarse material entering the diversion channel (a more sophisticated version of this is discussed below and shown on Figure 12.4);

The details of the design calculations for these weirs is considered beyond the scope of this manual, however, the design process must include:

- Detailed discussions with the beneficiary groups as to what they want a weir to do and what problems they anticipate that it may be able to overcome (see also Section 12.6 below);
- Topographic surveys of the weir site, and the nullah upstream and downstream of the weir site, as well as the route of the offtake channel and the command area;
- Obtaining a good map of the catchment area and an understanding of the geomorphological characteristics of the catchment area;
- Obtaining climatic data for the area including return periods for different rainfall events;
- An estimation of flood events of different return periods based on the catchment area and catchment geomorphology and the rainfall regime in the area;
- Selection of the design return period flood;
- Selection of the weir and offtake geometry based on the optimum amount of water to be diverted at different flood conditions and sediment exclusion requirements;
- Design of the weir and stilling basin to resist scour, sliding and overturning; and

- Design of the wing wall geometry to prevent the structure being by passed and for the walls not to be overtopped by the design flood or to be undermined by erosion.

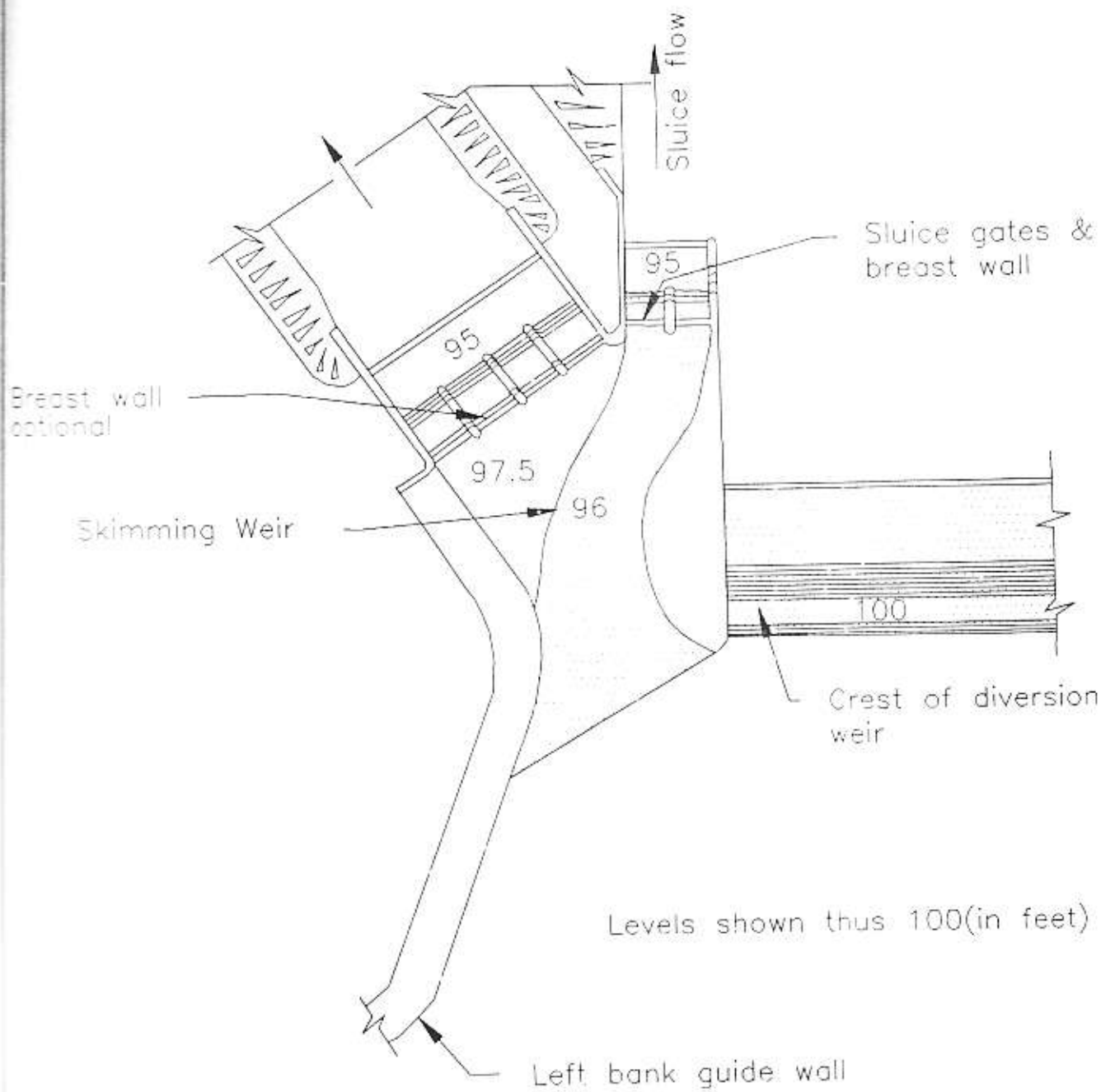
In traditional flood irrigation systems, the sediment deposited in the fields eventually raises their average level sufficiently to limit command. Under the traditional system the diversion bund can usually then simply be repositioned a bit further upstream to recover the lost head. Sediment also tends to collect and choke the intakes of diversion weirs and to be deposited in the distribution channels, requiring costly desilting operations to be undertaken on an annual basis. One way to reduce siltation problems is by the construction of desilting devices at the headworks. Such solutions are often however expensive, requiring considerable amounts of complex construction work.

One relatively simple desilting device, developed by Halcrow and used by both Halcrow and Nespak in Pakistan, is shown on Figure 12.4. In this device the weir is provided with a curved sluice channel, the sluice channel incorporates a skimming weir which feeds the offtake channel. The sluice channel is curved with the offtake channel on the outside of the bend in the sluice. The bed load sediment tends to move to the lower layers of flow and to the inside of the bend, thus reducing the bed load in the vicinity of the skimming weir. The smooth geometry of the sluice channel means that the bottom layers pass through the sluice channel whilst the upper layers of flow, containing only the finer silts, are skimmed off into the offtake channel. These finer silts are beneficial to the flood irrigated agriculture as a natural source of fertilizer. Model tests have shown that it is possible to remove up to 75% of the sediment entering the excluder, however, 33% of the offtake flow is required for sluicing.

One factor in the high cost of weirs is the very large floods for which they have to be designed for. To some extent this can be avoided by the use of fusible plugs. These are analogous to fuses in an electrical system; a small part of the system which is designed to fail under excessive load conditions, and can be subsequently easily replaced. In the case of a weir, the fuse can be a section of the side bund, which is designed to wash away in floods of 5 to 10 year return periods, as shown on Figure 12.5, and which is then easily replaced following the flood event. Such fusible plugs must however be designed to prevent progressive failure to the rest of the structure, particularly by scour of adjacent sections of wall.

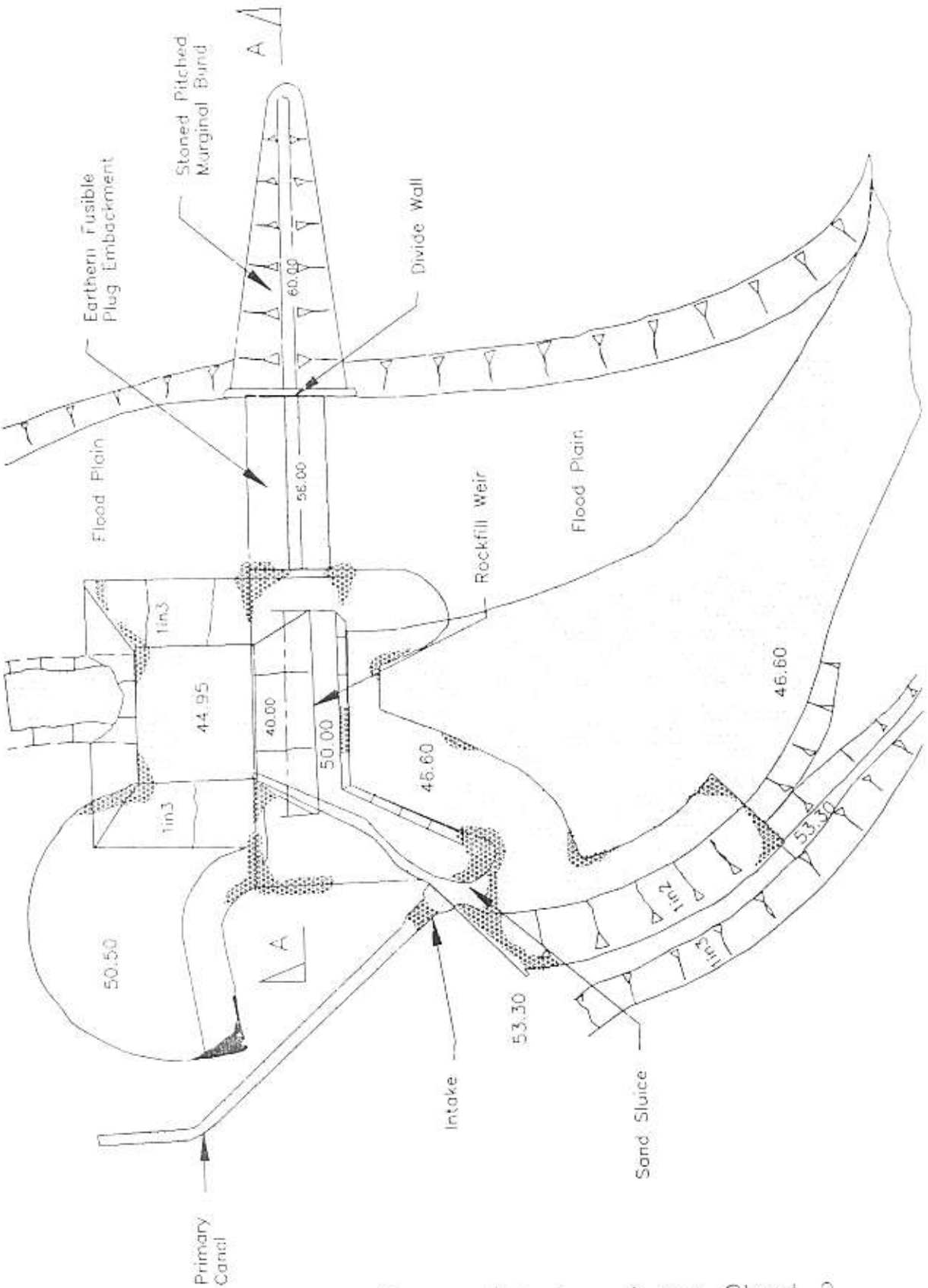
Another way of dealing with the problems of large floods is though the construction of groynes. In parts of Balochistan the traditional earthen diversion bund structure is replaced by a groyne angled upstream, which protrudes only a fraction of the width of the river. The groyne is sufficient to divert a manageable proportion of the flow into the offtake channel. Pucca versions of these groynes could be constructed as alternatives to full width weirs. The groynes could also include fusible plugs to

Figure 12.4



RECOMMENDED LAYOUT OF A FLOOD WEIR, SLUICE AND OFFTAKE CHANNEL FOR COARSE SEDIMENT EXCLUSION

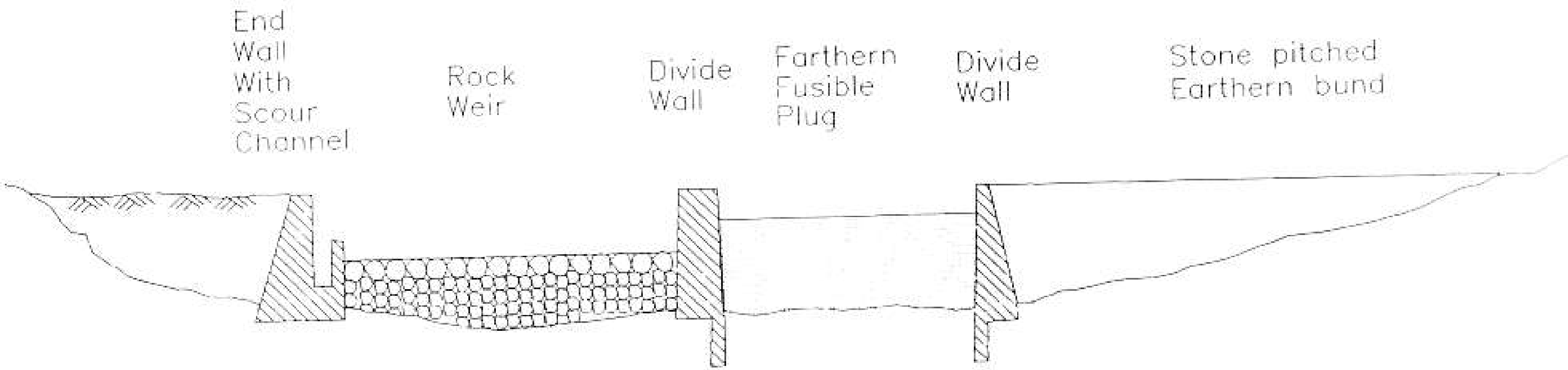
Figure 12.5
Sheet 1



For section A – A see Sheet 2

TYPICAL DIVERSION WEIR WITH A FUSIBLE PLUG

SECTION THROUGH WEIR SHOWN ON SECTION SHEET 1



SECTION A – A

Figure 12.5
Sheet 2

prevent excessive flow entering the distribution system.

12.3 Conveyance Channels

Virtually all systems exploiting flash flood and hill torrent water for irrigation operate on a first come first served basis, so that farmers at the head of the system receive the first irrigation and those at the tail may only receive water in exceptional years.

One of the main problems in designing the feeder and distribution channels is the constraints imposed upon the system by the farmers. The location of the diversion structure is normally dictated by physical features and sociological considerations such as the limit of land owned by the beneficiaries. The farmers often want the command area to commence as high as possible in order that landowners at the head of the system, often the most influential ones, will benefit. The design engineer is then left with the difficulty of achieving sufficient fall on the channels such that they do not choke with sediment.

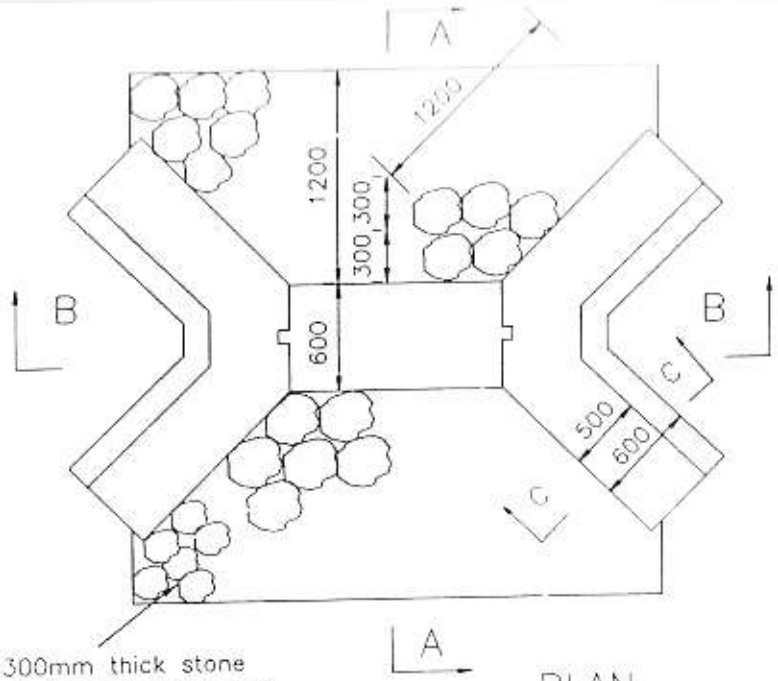
The levels of the channels and the weir in relation to the fields must be such as to allow silting up of the fields without relocation of the headworks.

Whilst the above criteria are difficult to achieve, design engineers cannot overlook these problems and must ensure that the location of the main components of the system will allow sufficient fall on the channels for the system not to fail or become and unacceptable maintenance burden on the farmers, which would also result in failure.

Control of the flow in the distribution channels is also often a problem for farmers, as is the control of flow from one field to another. The farmers usually construct earth bunds across the distribution channels and then breach these one by one down the system as each field is filled to capacity. Such earth bunds can be replaced by pucca check structures and field inlets. Sample designs for such structures as used on the OECF OFWM Project in Balochistan are shown on Figures 12.6 and 12.7. These structures stabilise the channel and the offtake and are provided with wooden boards which act as shutters to enable the main channel or the offtake to be closed off.

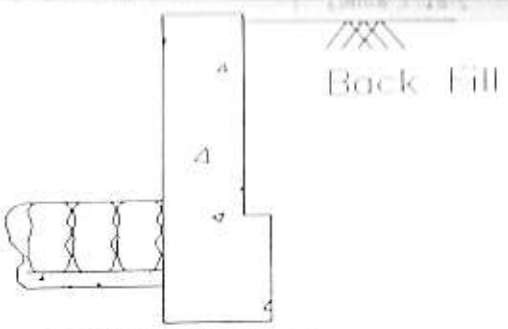
12.4 Field Development

The efficiency of application of flood water to the fields can be improved through improved layout of the fields, land levelling and improvements to the field bunds.



PLAN

300mm thick stone pitching on 100 thick sand bed

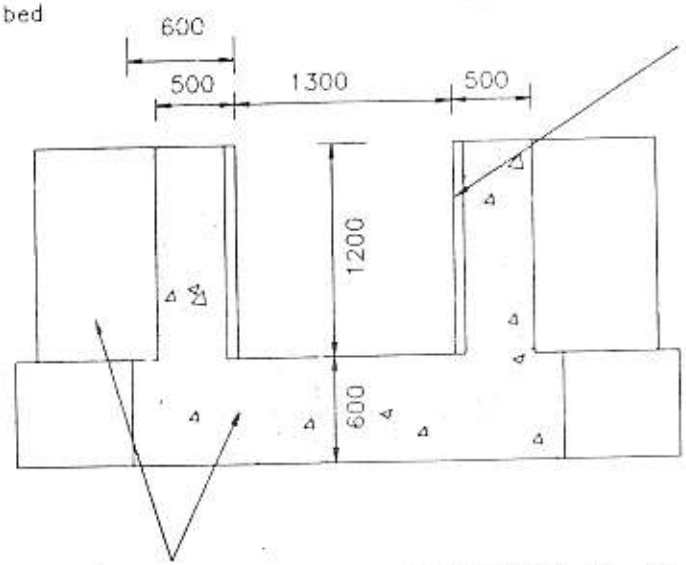


SECTION C–C

NOTES

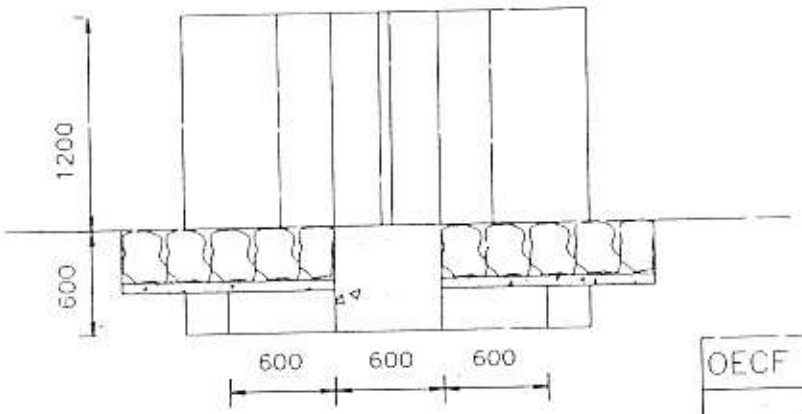
1. All dimensions are in milimeters
2. No wooden boards are required since check structure boards will also be used for the offtake

Grooves made from 100mm wide x 75 deep steel channel section



1:2:4 concrete or coarsed rubble masonry

SECTION B–B

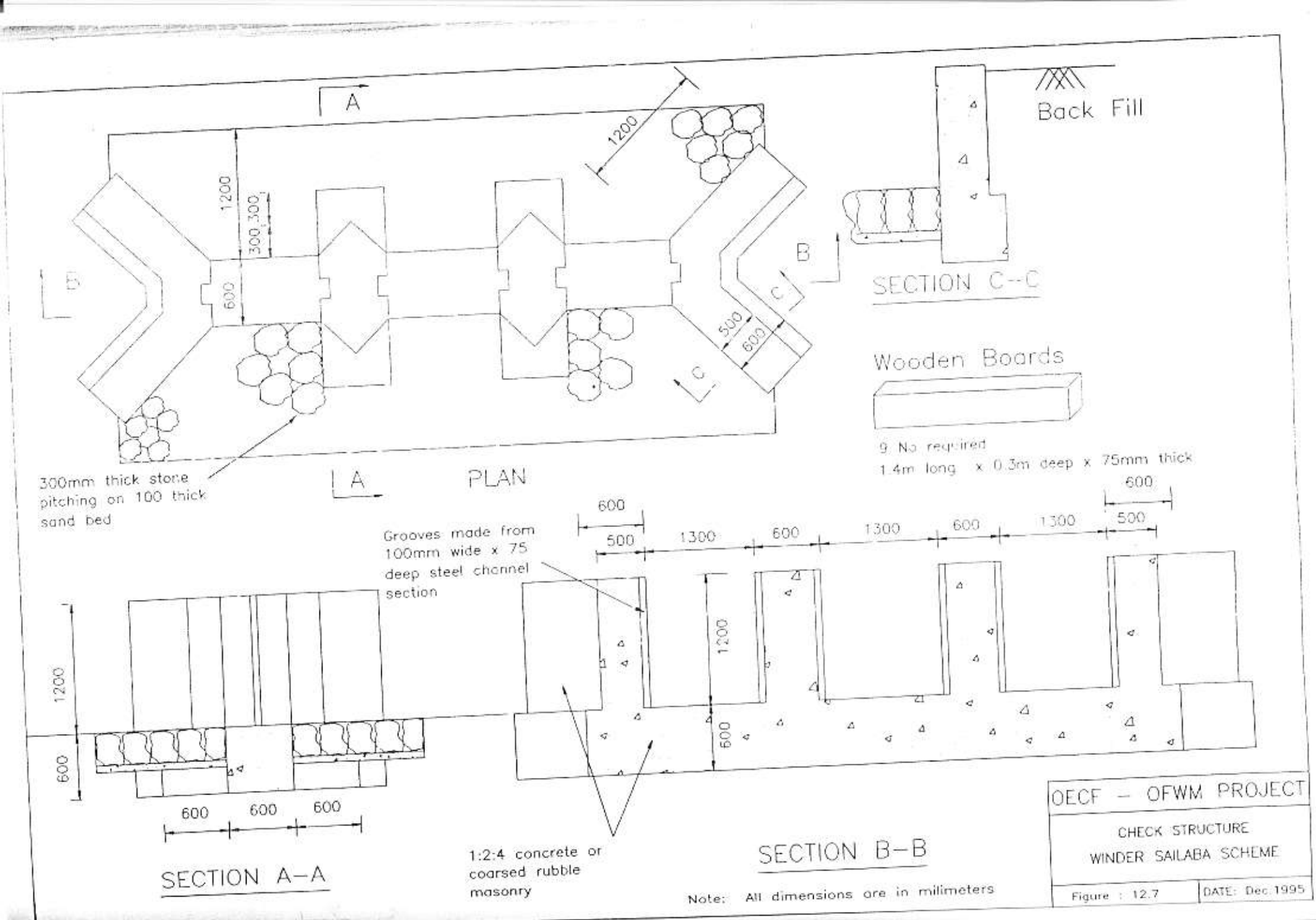


SECTION A–A

OECF – OFWM PROJECT

OFFTAKE STRUCTURE
WINDER SAILABA SCHEME

Figure : 12.6 | DATE: Dec.1995


A
1200
1200
300
300
600
B
C
C
500
600
Back Fill
SECTION C--C
Wooden Boards
9 No required
1.4m long x 0.3m deep x 75mm thick
300mm thick stone pitching on 100 thick sand bed
A
PLAN
600
500
1300
600
1300
600
1300
600
500
Grooves made from 100mm wide x 75 deep steel channel section
1200
600
1200
600
600
600
600
1:2:4 concrete or coarsed rubble masonry
SECTION A–A
SECTION B–B
Note: All dimensions are in milimeters
OECF – OFWM PROJECT
CHECK STRUCTURE
WINDER SAILABA SCHEME
Figure : 12.7
DATE: Dec.1995

Filed layouts may be improved to ensure that water can easily be managed and fields are levelled without excessive cut and fill. In designing appropriate field layouts, attention should be given as to ensuring that the flow can be efficiently managed, that water will pond to the correct depth, often about 0.5 m for sailaba irrigation and will then spill to the next field or the flow can be diverted down the distribution channel.

Fields should be levelled. Precision land levelling is not required for sailaba schemes, but fields should be levelled such that the difference in level across a field is less than 10 cm, if a reasonable distribution is to be obtained.

All bunds should be at least 1 m high and with a 0.5 m top width. Where bunds are designed to spill from one field to the next, then stone pitched spillways with stone masonry wing walls would be appropriate.

12.5 Agronomic Aspects

Flood irrigation development projects need to concentrate as much on the improvement of the crop production as they do on other aspects of the project. When advising farmers on improved agronomy it is important to tailor the advise to reduce the farmers risk as much as it is to improve crop production only when optimal conditions are available. In Balochistan farmers indicate that they believe that they get two good years, four medium years and four bad years in a run of ten years. Drought resistant crops, which ensure that some harvest is obtained during the poor and bad years is as, if not more, important as obtaining high yields in the good years.

Irrigation agronomy advise to the farmers of sailaba schemes should include:

- appropriate drought resistant crops for rabi and kharif seasons, well adapted to the climatic and rainfall patterns of the area;
- appropriate cultivation practices and planting and harvesting times for the above;
- appropriate fertilizer applications again taking into account the need to reduce risk;
- appropriate tillage practices including the benefits of deep ploughing to assist infiltration, moisture control and root growth and the benefits of mulching following rainfall to reduce bare soil evaporation; and
- adaptive research may be required in many areas on the above. Demonstration centres showing the improvements which can be obtained though packages of

APPENDIX A

SAMPLE APPLICATION

APPENDIX - A
SAMPLE APPLICATION
FOR ASSISTANCE TO DEVELOP A CATCHMENT AREA

We, the farmers of the catchment area of _____ acres, belonging to village _____ have agreed o form a Water Harvesting Association (WHA). We request for technical and financial assistance (available under the rules) to develop our catchment area for which we are ready to sign an agreement with the On-Farm Water Management Project of the Department of Agriculture of the province. The particulars of the association are given below. A sketch map of the catchment area is also attached herewith.

1. Name of the Association WHA, Village _____
2. Official Address _____
3. Total number of shareholders in the catchment area _____
4. Number of members of WHA _____
5. List of all the shareholders

S.No	Name	Father's Name	Caste	Landholding in the Catchment Area
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				

14				
15				
16				
17				
18				
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21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

6. Amount of funds Held by the Association _____

7. Names of the Management Committee:

1 Chairman . . . . . .
2 Vice Chairman . . . . . .
3 Secretary . . . . . .
4 Treasurer . . . . . .
5 Member . . . . . .
6 Member . . . . . .
7 Member . . . . . .

Signature of
Chairman
WHA

Signature of
Secretary
WHA

Attach copy of the holdings of all the shareholders duly verified by the Revenue Patwari.

ضمیمہ "الف"

درخواست برائے

اصلاح کیچمنٹ ایریا ☆

ہم زمینداران کیچمنٹ ایریا ایکڑ کے مالک ہیں اور موضع کے رہائشی ہیں
انجمن برائے تحفظ آب بنانے پر رضامند ہیں ہم مروجہ قوانین کے تحت اپنے مذکورہ رقبہ کی اصلاح کے لئے فنی اور مالی امداد کی درخواست کرتے ہیں اور اس مقصد کے لئے محکمہ اصلاح آبپاشی کے ساتھ قانونی معاہدہ کرنے کو تیار ہیں ہماری انجمن کے کوائف درج ذیل ہیں مذکورہ کیچمنٹ ایریا کا ایک خاکہ بھی درخواست ہذا کے ساتھ منسلک ہے

۱۔ نام انجمن برائے تحفظ آب

۲۔ پتہ: موضع ڈاک خانہ تحصیل ضلع

۳۔ تعداد حصہ داران انجمن برائے تحفظ آب

۴۔ تعداد ممبران انجمن برائے تحفظ آب

۵۔ تمام حصہ داران کی فہرست

نمبر شمار	نام	ولدیت	کیچمنٹ ایریا میں ملکیتی رقبہ
۱			
۲			
۳			
۴			
۵			
۶			
۷			

☆ کیچمنٹ ایریا وہ رقبہ ہے جہاں سے بارش کے پانی کے بہاؤ کی رفتار کو کم کر کے زمین میں اس کے جذب ہونے کی صلاحیت کو بڑھانا مقصود ہو

نمبر شمار	نام	ولدیت	کچہمنٹ ایریا میں مکینی رقبہ
۸			
۹			
۱۰			
۱۱			
۱۲			
۱۳			
۱۴			
۱۵			
۱۶			
۱۷			
۱۸			
۱۹			
۲۰			
۲۱			
۲۲			
۲۳			
۲۴			
۲۵			
۲۶			
۲۷			
۲۸			
۲۹			
۳۰			

۶۔ انجمن کے اپنے فنڈ کی مالیت

۷۔ انتظامیہ کمیٹی کے ارکان کے نام بمع ولدیت

۱۔ صدر

۲۔ نائب صدر

۳۔ سیکریٹری

۴۔ خزانچی

۵۔ ممبر

۶۔ ممبر

۷۔ ممبر

دستخط صدر انجمن برائے تحفظ آب

پتہ _____

دستخط سیکٹریری انجمن برائے تحفظ آب

پتہ _____

نوٹ:۔ تمام حصہ داران کی زمین کے فرد منسلک ہیں

APPENDIX B

SAMPLE AGREEMENT

APPENDIX - B
SAMPLE AGREEMENT

(Between Water Harvesting Association and the On-Farm Water Management Project, Dept of Agriculture of the Province)

THIS agreement has taken place today, the _____ of ____ 199 ____ between shareholders of catchment area of ____ acres of _____ Tehsil/Taluka _____ District _____, through its WHA, who will be the first party, and the Department of Agriculture, of the province through the Area Coordinator or Deputy Director _____ of the On-Farm Water Management Project who will be the second party to this agreement.

WHEREAS the landowners of the above named village want to get their catchment area developed through the Coordinator or Deputy Director and the Coordinator or Deputy Director has agreed to undertake this assignment, it is agreed upon between both parties that:

1. The Coordinator or the Deputy Director will prepare the design for the proposed catchment area and its related construction and installations. He will prepare an estimate of the work to be done and the rental cost of implements to be used. He will provide to the shareholders free of charge such technical advice as necessary for development of the catchment area.

2. Masons and labourers where needed will be arranged and paid by the shareholders of the catchment area as per rules for other OFWM civil works in each province.

3. Where the cost of material for a particular pucca structure exceeds Rs 20,000 recovery from the shareholders of the catchment area will be made as per rules for other civil works undertaken under the OFWM programmes.

4. Cost sharing on the use of tractors and implements for mechanised earth moving operations.

    - The Coordinator or the Deputy Director will estimate the number of tractor hours required for land forming, including levelling, bunding and earthwork for reservoirs and associated with other civil works. The beneficiaries will pay in advance at a subsidised rate of Rs 20/hour of tractor running where project tractros are made available.

- The WHA will be responsible to collect the above said money for tractor work from its members and deposit it with the Coordinator or the Deputy Director of an area team.

- Where project tractors are not available and/or where project tractors are insufficient and/or where front blade tractors are required for the designed amount of work then private tractors would be hired and would be paid at the market rates. In this case farmers would pay 20% of the rate and the project 80%.

5. Agricultural inputs, operations, plantation and forestry:

   - All kinds of normal inputs for crop production like seeds, fertilizers, pesticides etc. will be at the farmers costs.

   - Use of tractors and other agricultural machinery for field cultivation and planting will be at farmers cost.

   - Planting Material for Tree Plantations and Range Grassland would be at the Project cost, whereas the farmers would be responsible for the planting, constructing terraces, watering and care of trees. Trees would include fruit and forest trees. Funds would also be available to distribute to farmers seed of improved varieties of crops.

6. Training Centre Cum Store, comprising a temporary shed of 13 by 5 m with a small verandah and a rain gauge will be provided by the project as a training centre and store. The beneficiaries would provide the land for the training centre at a suitable spot in the overall demonstration area. The training centre would be used by the Project for the duration of the Project and will be property of the OFWM Project at the end of the Project. The WHA will provide a Chowkidar to look after the Training Centre and the store.

7. The Management Committee of WHA will work closely with the staff of the OFWM Project. The WHA will be responsible to:

   - Arrange labour as and when needed and get people to work.

   - Resolve disputes among members arising out of any activity associated with the development of the catchment area.

   - Prescribe the share of work and payments to be made by the shareholders according to the area owned by each.

   - Get the work done under the technical supervision of the OFWM staff and according to the prescribed standard.

- Look after the material provided for the civil work and keep record of its receipt and disposal.

- Keep record of the plants and grasses received and distributed among the members.

8. The Coordinator or the Deputy Director or his staff will not be responsible for any damage done to crops, implements or any property during the course of development of the catchment area. Nor will he be obliged to pay for the loss or injury caused to anyone in this regard.

9. If a dispute or difference of opinion cannot be effectively resolved by the members of the WHA by themselves, the decision of the coordinator or the Deputy Director will be binding on them.

10. The shareholders will be responsible to maintain the pucca structures installed for an effective water harvesting and for the reasonable growth of the plants and the grasses planted for the development of the catchment area.

11. Names of the shareholders with their signatures:

S.No	Name	Father's Name	Signature
1			
2			
3			
4			
5			
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7			
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30

Signature of
the Chairman
WHA _____

Signature of
the Coordinator/The Deputy Director
Area Team _____

Stamp _____

ضمیمہ "ب"

نمونہ اقرار نامہ

(مابین انجمن برائے تحفظ آب اور منصوبہ اصلاح آبپاشی صوبائی محکمہ زراعت)

یہ اقرار نامہ آج مورخہ ماہ ۱۹ حصہ داران کیچمنٹ ایریا ایکڑ موضع تحصیل ضلع نے بوساطت انجمن برائے تحفظ آب محکمہ زراعت کے زیر انتظام منصوبہ اصلاح آبپاشی کے کوارڈینیٹر یا ڈپٹی ڈائریکٹر ایریا ٹیم سے کیا ہے انجمن تحفظ آب پارٹی اول اور منصوبہ اصلاح آبپاشی پارٹی دوئم کہلائیں گی

کیچمنٹ مذکورہ کے زمیندار ان چاہتے ہیں کہ کوارڈینیٹر یا ڈپٹی ڈائریکٹر منصوبہ اصلاح آبپاشی اُن کے رقبہ کی اصلاح کے لئے ضروری اقدام کریں اور انہوں نے اس کام کے لیے رضامندی ظاہر کی ہے لہذا دونوں پارٹیوں کے درمیان یہ طے پایا ہے کہ

۱۔ کوارڈینیٹر یا ڈپٹی ڈائریکٹر منصوبہ اصلاح آبپاشی مجوزہ کیچمنٹ ایریا اور اس سے متعلقہ تعمیرات اور تنصیبات کا ڈیزائن تیار کرے گا تعمیراتی کام اور زرعی آلات جو اس کام کے لئے استعمال ہوں گے ان کے اخراجات کا تخمینہ لگائے گا وہ حصہ داران کو ایسی تکنیکی معاونت مہیا کرے گا جو اس کیچمنٹ ایریا کی اصلاح کے لئے درکار ہوگی

۲۔ جہاں ضرورت ہوگی حصہ داران کیچمنٹ ایریا صوبائی منصوبہ آبپاشی کے قوانین کے تحت مزدور یا مستری کا انتظام کریں گے اور انہیں معاوضہ دیں گے

۳۔ جہاں کہیں کسی پکی تعمیر کے لئے میٹریل کی لاگت کا تخمینہ ۲۰۰۰۰ روپے سے زائد ہوگا کیچمنٹ ایریا کے حصہ داران سے معاوضہ اُسی تناسب سے لیا جائے گا جو دوسری آبپاشی کی سکیموں کے لئے کئے جانے والے سول ورکس کے لئے پہلے سے مقرر ہے

مشینی طریقے سے مٹی ہٹانے کے لیے ٹریکٹر اور اس سے متعلقہ آلات کے استعمال پر رعایت:

اصلاح اراضی کے لئے

ٹریکٹر کتنے گھنٹے کام کرے گا اس کا اندازہ کوارڈینیٹر یا ڈپٹی ڈائریکٹر کرے گا اس میں زمین کی ہمواری، بند باندھنا اور پانی کے سٹوریج کے لئے اور دوسرے سول ورکس کے لئے مٹی کو ہٹانے کا کام شامل ہوگا ٹریکٹر چلنے کا خرچ زمینداروں سے صرف ۲۰ روپے گھنٹہ کے حساب سے لیا جائے گا یہ رقم ان سے پیشگی وصول کی جائے گی یہ اُس صورت میں کہ ٹریکٹر پراجیکٹ مہیا کرے ممبران سے مذکورہ رقم اکٹھا کرنا انجمن برائے تحفظ آب کی ذمہ داری ہوگی اور یہ رقم کوارڈینیٹر یا ڈپٹی ڈائریکٹر کی ہدایت کے مطابق سرکاری خزانے میں جمع کرائی جائے گی

جہاں سرکاری ٹریکٹر مہیا نہیں کئے جائیں گے یا جہاں وہ کام کے لئے ناکافی ہوں گے یا جہاں فرنٹ بلیڈ ٹریکٹر کی ضرورت ہوگی وہاں پرائیوٹ ٹریکٹر کرایہ پر حاصل کئے جائیں گے اس صورت میں کیچمنٹ ایریا کے حصہ داران مذکورہ شرح کا ۲۰ فیصد اور پراجیکٹ ۸۰ فیصد ادا کرے گا

زرعی لوازمات، معمولات اور شجرکاری

زرعی لوازمات مثلاً بیج، کھاد، کیڑے مار ادویات کا تمام خرچ زمینداروں کا اپنا ہوگا

کھیتوں میں معمول کی کاشت اور فصل لگانے کے لئے ٹریکٹر اور اس کے متعلقہ آلات کے استعمال کے تمام اخراجات زمینداروں کے اپنے ہوں گے ۳ میٹر لمبا اور ۵ میٹر چوڑا عارضی نوعیت کا ایک شیڈ پراجیکٹ تعمیر کرے گا اس کے لئے مناسب جگہ پر زمین انجمن کی طرف سے مہیا کی جائے گی اس شیڈ کے ساتھ ایک چھوٹا برآمدہ اور ایک بارش پیما ہوگا یہ شیڈ

تربیتی مرکز اور سٹور کمانے گا پراجیکٹ کی مدت ختم ہونے پر یہ تربیتی مرکز منصوبہ اصلاح آبپاشی کی ملکیت ہوگا منصوبہ کے دوران اس تربیتی مرکز کی حفاظت کے لئے زمیندار ایک چوکیدار مہیا کریں گے جس کا خرچ ان کے ذمہ ہوگا

انجمن برائے تحفظ آب کی انتظامی کمیٹی منصوبہ اصلاح آبپاشی کے عملہ کے ساتھ مل کر کام کرے گی

درخت اور گھاس پراجیکٹ کی طرف سے مہیا کی جائیں گے اور وہی ان کی قیمت ادا کرے گا تاہم زمیندار ایا پودوں کو لگانے انہیں پانی دینے اور ان کی دیکھ بھال کے ذمہ دار ہوں گے درختوں میں پھلدار اور جنگلاتی دونوں قسم کے سے شامل ہوں گے کچھ رقم فصلوں کی نئی اقسام کے بیج مہیا کرنے کے لئے بھی مخصوص ہوگی

انجمن کی ذمہ داریاں اس طرح ہوں گی

۱۔ ضرورت پڑنے پر راج اور مزدوروں کا انتظام کرنا اور ان سے کام لینا

۲۔ حصہ داران کے لئے کام کی تقسیم اور رقوم کی ادائیگی کا تعین کرنا رقوم کی ادائیگی کا انحصار انفرادی ملکیت اراضی پر ہوگا

۳۔ اس بات کو یقینی بنانا کہ منصوبہ اصلاح آبپاشی عملہ کی فنی استعداد سے بھرپور فائدہ اٹھایا جائے اور تمام کام متعین کردہ معیار کے مطابق سرانجام پائے

۴۔ پودوں اور گھاس کی وصولی اور ممبران میں ان کی تقسیم کا ریکارڈ رکھنا

۵۔ کیچمنٹ ایریا کی اصلاح کے دوران فصلات، آلات یا کسی قسم کی جائیداد کو نقصان پہنچنے کی ذمہ داری کوارڈینٹر یا ڈپٹی ڈائریکٹر یا اس کے عملہ پر نہیں ڈالی جائے گی نہ ہی وہ کسی شخص کے زخمی ہونے یا اس کے مال نقصان کا معاوضہ دینے کا پابند ہوگا

۶۔ اگر انجمن کے ممبران کسی تنازعہ کا تصفیہ موثر طور پر نہ کرپائیں تو اس ضمن میں کوارڈینٹر یا ڈپٹی ڈائریکٹر کا فیصلہ حتمی ہوگا اور اس کی پابندی ممبران پر لازم ہوگی

۸۔ حصہ داران اس بات کے ذمہ دار ہوں گے کہ وہ کیچمنٹ ایریا کی اصلاح کے لئے کئے جانے والے تعمیراتی کام کی حفاظت کرتے رہیں گے اور اس ضمن میں لگائی جانے والی گھاس اور پودوں کی نشوونما کی طرف مناسب توجہ دیتے رہیں گے

۹۔ تعمیراتی کام کے لئے موصول ہونے والے میٹریل کی حفاظت کرنا اور اس کے استعمال کا مکمل ریکارڈ رکھنا

۱۰۔ تمام حصہ داران کے نام ولدیت اور دستخط یا نشان انگوٹھا

نمبر شمار	نام	ولدیت	دستخط یا نشان انگوٹھا
۱			
۲			
۳			
۴			
۵			
۶			

نمبر شمار	نام	ولدیت	دستخط یا نشان انگوٹھا
۷			
۸			
۹			
۱۰			
۱۱			
۱۲			
۱۳			
۱۴			
۱۵			
۱۶			
۱۷			
۱۸			
۱۹			
۲۰			
۲۱			
۲۲			
۲۳			
۲۴			

نمبر شمار	نام	ولدیت	دستخط یا نشان انگوٹھا
۲۵			
۲۶			
۲۷			
۲۸			
۲۹			
۳۰			

دستخط

کوارڈینٹر یا ڈپٹی ڈائریکٹر

ایریا ٹیم _____

مہر

دستخط صدر

انجمن برائے تحفظ آب

پتہ _____

APPENDIX C

SAMPLE SURVEY FORMS FOR AN AREA APPRAISAL

AREA APPRAISAL OF WATER HARVESTING SITE

1. SOCIO-ECONOMIC AND INFRASTRUCTURE

Field Team [1] _____ Village Name [2] _____ Total Area (ac) [3] ___ No of Households [4] ___

% Dependent on Agriculture [5] _____ No of Households by Size of Holding [6] < 5 ac _____

5 - 12 ac _____

12 - 25 ac _____

> 25 ac _____

Machinery [7] _____ Water Supply [8] _____ Organisations presently in the catchment _____

Problems of the Socio-Economy or Infrastructure in the catchment in order of PRIORITY:

1. Farmers' View [10] :

2. Field Team's View [11] :

---

1 The name of the Field Team responsible for the Water Harvesting site.

2 Name of the main village in the catchment.

3 Total Area of the Catchment in acres

4 The number of households living and using the land inside the catchment.

5 % of the households who live inside the catchment boundaries who are dependent on agriculture for their livelihood.

6 Write down the number of households in each category of land holdings inside the catchment.

7 Machinery owned individually or by a group in the boundaries of the catchment. Tractor: TR, Pump: PU, Truck: TK, Other: specify.

8 Communally or individually supply within the boundaries of the catchment, Spring: SP, Open Well: OW, Tubewell: TW, Dam/Pond: DP, Stream/River: ST, Lake: LA

9 Cooperative: CO, Association: AS, Other: O

10 List in order of priority the problems from the farmers' point of view concerning the socio-economy and infrastructure of the catchment.

11 List in order of priority the problems from the Field Team's point of view concerning the socio-economy and infrastructure of the catchment.

2. PRESENT CROP PRODUCTION IN CATCHMENT SITE

2.1 Barani Crop (Lapara); BC(L) [12] Area (ac).....

MAJOR CROPPING PATTERNS [13] :

Pattern 1 Crop Names Crop 1 _____ Crop 2 _____
Area % [14] ___ Planting Dates Crop 1 _____ Crop 2 _____
Harvest Dates Crop 1 _____ Crop 2 _____

Pattern 2 Crop Names Crop 3 _____ Crop 4 _____
Area % ___ Planting Dates Crop 3 _____ Crop 4 _____
Harvest Dates Crop 3 _____ Crop 4 _____

Pattern 3 Crop Names Crop 5 _____ Crop 6 _____
Area % ___ Planting Dates Crop 5 _____ Crop 6 _____
Harvest Dates Crop 5 _____ Crop 6 _____

Pattern 4 Crop Names Crop 7 _____ Crop 8 _____
Area % ___ Planting Dates Crop 7 _____ Crop 8 _____
Harvest Dates Crop 7 _____ Crop 8 _____

TOTAL CROP VALUE PRODUCED ON LAPARA LAND IN THE CATCHMENT SITE:

Crop	AREA (ac)	YIELD (mds/ac)	TOTAL PRODUCTION (mds, kg)	FIELD PRICE (Rs/md, Rs/kg)	TOTAL VALUE (Rs)
CROP 1 _____ [15] MAIN PRODUCT					
BY-PRODUCT					
CROP 2_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 3_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 4_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 5_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 6_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 7_____ MAIN PRODUCT					
BY-PRODUCT					

---

12 Lapara landtype is the land around the village which receives Farm Yard Manure and is the most fertile. Barani crop production on Lepara is on the Mapping Unit "existing terraces which are around the village houses".

13 A cropping pattern describes the crops that are grown in sequence on a field during the year. For example, Wheat (crop 1) followed by Maize (crop 2) will be written as Crop 1 Wheat - Crop 2 Maize. A fallow is also a crop. Wheat (crop 1) followed by a fallow (crop 2) is written as Crop 1 Wheat - Crop 2 Fallow. There may be three or four patterns grown by farmers in a mapping unit, such as Wheat - Fallow, Wheat - Fallow, Sarson - Maize Peas - Maize, and so on.

14 Area % is the proportion of the total area of this mapping unit, Barani Crop production on Lapara land, BC(L) which is used for the particular crop pattern.

15 Main product of a crop is the most important product and the by-product is the product of secondary [illegible] For example, in wheat, the main product is grain and the by-product is bhussa.

CROP	AREA (ac)	YIELD (mds/ac)	TOTAL PRODUCTION (mds. kg)	FIELD PRICE (Rs/md. Rs/kg)	TOTAL VALUE (Rs)
CROP 8_____ MAIN PRODUCT					
BY-PRODUCT					
TOTAL VALUE (Rs)					

Soils of Lapara lands: Slope % [16] _____ Depth [17] _____
Texture [18] _____

Problems of the Barani crop production on Lapara land in the catchment in order of PRIORITY:

1. Farmers' View [19] :

2. Field Team's View [20] :

---

16 Slope % is the average slope of land in this mapping unit 1-2% 1-2 2-5%: 2-5, >5%: >5

17 Depth is the depth of soil in the mapping unit S (0- m) S. Medi (30-100c M. Deep

18 S. S, Sandy Loam: SL, Loam: L, Cla- L CL Clay: C.

List in order of priority the problems from the farmers' point of view con barani crop production on Lapara land in the catchment.

List in order of priority the prob from the Field Te s point of view concerning the barani crop production on Lapara land in the catchment.

2.2 Barani Crop (Mehra); BC(M) [21] Area (ac).....

MAJOR CROPPING PATTERNS [22] :

Pattern 1 Area % [23] ___
Crop Names — Crop 1 _____ Crop 2 _____
Planting Dates — Crop 1 _____ Crop 2 _____
Harvest Dates — Crop 1 _____ Crop 2 _____

Pattern 2 Area % ___
Crop Names — Crop 3 _____ Crop 4 _____
Planting Dates — Crop 3 _____ Crop 4 _____
Harvest Dates — Crop 3 _____ Crop 4 _____

Pattern 3 Area % ___
Crop Names — Crop 5 _____ Crop 6 _____
Planting Dates — Crop 5 _____ Crop 6 _____
Harvest Dates — Crop 5 _____ Crop 6 _____

Pattern 4 Area % ___
Crop Names — Crop 7 _____ Crop 8 _____
Planting Dates — Crop 7 _____ Crop 8 _____
Harvest Dates — Crop 7 _____ Crop 8 _____

TOTAL CROP VALUE PRODUCED ON MEHRA LAND IN THE CATCHMENT SITE:

CROP	AREA (ac)	YIELD (mds/ac)	TOTAL PRODUCTION (mds, kg)	FIELD PRICE (Rs/md, Rs/kg)	TOTAL VALUE (Rs)
CROP 1 _____ [24] MAIN PRODUCT					
BY-PRODUCT					
CROP 2_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 3_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 4_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 5_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 6_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 7_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 8_____ MAIN PRODUCT					

21 Mehra is the landtype away from the houses in the village which does not receive any Farm Yard Manure. This landtype is therefore, less fertile than the Lapara landtype, which generally receives Farm Yard Manure. Barani crop production on Mehra is on Mapping Unit "existing terraces with Mehra land types".

22 A cropping pattern describes the crops that are grown in sequence on a field during the year. For example, Wheat (crop 1) followed by Maize (crop 2) will be written as Crop 1 Wheat - Crop 2 Maize. A fallow is also a crop. Wheat (crop 1) followed by a fallow (crop 2) is written as Crop 1 Wheat - Crop 2 Fallow. There may be three or four patterns grown by farmers in a mapping unit, such as Wheat - Maize, Wheat - Fallow, Sarson - Maize, Peas - Maize, and so on.

23 Area % is the proportion of the total area of this mapping unit, Barani Crop production on Mehra land, BC(M) which is used for the particular crop pattern.

24 Main product of a crop is the most important product and the by-product is the product of secondary importance. For example, wheat, the main product is grain and the by-product is bhussa.

CROP	AREA (ac)	YIELD (mds/ac)	TOTAL PRODUCTION (mds, kg)	FIELD PRICE (Rs/md, Rs/kg)	TOTAL VALUE (Rs)
BY-PRODUCT					
TOTAL VALUE (Rs)					

Soils of Mehra lands: Slope % [25] _____ Depth [26] _____
Texture [27] _____

Problems of the Barani crop production on Mehra land in the catchment in order of PRIORITY:

1. Farmers' View [28] :

2. Field Team's View [29] :

---

25 Slope % is the average slope of land in this mapping unit 1-2%: 1-2, 2-5%: 2-5, >5%: >5

26 Depth is the depth of soil in this mapping unit: Shallow (0-30cm): S, Medium (30-100cm): M, Deep (> 100 cm): D.

27 Sand: S, Sandy-Loam: SL, Loam: L, Clay-Loam: CL, Clay: C.

28 List in order of priority the problems from the farmers' point of view concerning the barani crop production on Mehra land in the catchment.

29 List in order of priority the problems from the Field Team's point of view concerning the barani crop production on Mehra land in the catchment.

2.3 Irrigation Land; IL [30] Area (ac)_____

MAJOR CROPPING PATTERNS [31] :

Pattern 1 Crop Names Crop 1 _____ Crop 2 _____
Area % [32] ___ Planting Dates Crop 1 _____ Crop 2 _____
Harvest Dates Crop 1 _____ Crop 2 _____

Pattern 2 Crop Names Crop 3 _____ Crop 4 _____
Area % ___ Planting Dates Crop 3 _____ Crop 4 _____
Harvest Dates Crop 3 _____ Crop 4 _____

Pattern 3 Crop Names Crop 5 _____ Crop 6 _____
Area % ___ Planting Dates Crop 5 _____ Crop 6 _____
Harvest Dates Crop 5 _____ Crop 6 _____

Pattern 4 Crop Names Crop 7 _____ Crop 8 _____
Area % ___ Planting Dates Crop 7 _____ Crop 8 _____
Harvest Dates Crop 7 _____ Crop 8 _____

TOTAL CROP VALUE PRODUCED ON IRRIGATED LAND IN THE CATCHMENT SITE:

CROP	AREA (ac)	YIELD (mds/ac)	TOTAL PRODUCTION (mds, kg)	FIELD PRICE (Rs/md, Rs/kg)	TOTAL VALUE (Rs)
CROP 1 _____ MAIN PRODUCT [33]					
BY-PRODUCT					
CROP 2_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 3_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 4_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 5_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 6_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 7_____ MAIN PRODUCT					
BY-PRODUCT					
CROP 8_____ MAIN PRODUCT					
BY-PRODUCT					
TOTAL VALUE (Rs)					

---

30 Crop production on Irrigated Land is on Mapping Unit IL

31 A cropping pattern describes the crops that are grown in sequence on a field during the year. For example, Wheat (crop 1) followed by Maize (crop 2) will be written as Crop 1 Wheat - Crop 2 Maize. A fallow is also a crop. Wheat (crop 1) followed by a fallow (crop 2) is written as Crop 1 Wheat - Crop 2 Fallow. There may be three or four patterns grown by farmers in a mapping unit, such as Wheat - Maize, Wheat - Fallow, Sarson - Maize, Peas - Maize, and so on.

32 Area % is the proportion of the total area of this mapping unit, Irrigated Crop production on Irrigated Land (IL) which is used for the particular crop pattern.

33 Main product of a crop is the most important product and the by-product is the product of secondary importance. For example, when the main product is grain and the by-product is bhussa.

Soils of Irrigated lands: Slope % [34] _____ Depth [35] _____
Texture [36] _____

Problems of the Crop production on Irrigated land in the catchment in order of PRIORITY:

1. Farmers' View [37] :

2. Field Team's View [38] :

---

34 Slope % is the average slope of land in this mapping unit 1-2%: 1-2, 2-5%: 2-5, >5%: >5

35 Depth is the depth of soil in this mapping unit Shallow (0-30cm): S, Medium (30-100cm): M, Deep (> 100 cm): D.

36 Sand: S, Sandy-Loam: SL, Loam: L, Clay-Loam: CL, Clay: C.

37 List in order of priority the problems from the farmers' point of view concerning the irrigated crop production on Irrigated land in the catchment.

38 List in order of priority the problems from the Field Team's point of view concerning the irrigated crop production on Irrigated land in the catchment.

3. PRESENT FOREST AND RANGE AREA (BANJAR) IN CATCHMENT SITE.

3.1 Forest, Range and Livestock Production in Banjar Area.

Area (ac) [39] _____ Total number of Livestock in the Catchment site;

Sheep _____ Goats _____ Cattle _____ Buffaloes _____ Others _____

Production of Trees and Bushes and Pasture and Grasses in the Catchment.

	CONDITION [40]	PRODUCTION [41]	FIELD PRICE [42]	VALUE [43]
TREES AND BUSHES				
PASTURE AND RANGE				

Present Composition of Trees, Bushes, Pastures and Range in the Catchment [44]:

TREES & BUSHES	LOCAL NAMES	LOCATION	USES	OWNERSHIP
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10				

PASTURE & RANGE	LOCAL NAMES	LOCATION	USES	OWNERSHIP
1.				
2.				
3.				
4.				
5.				
6.				

---

39 The total area in acres in the catchment site of the Forest and Range grown in the Banjar Area.

40 Condition of the trees and bushes or the pasture and range is judged by the proportion of the ground of most of the catchment that is covered: Dense (>50% of ground covered): D, Moderate (20-50% of ground covered): M, Poor (< 20% of the ground covered): P

41 Total Production of fuelwood, timber and fodder (maunds) from trees and bushes or pasture and range in the entire catchment area.

42 The price (Rs per maund) of fuelwood from trees and bushes or fodder from range and grasses.

43 Total value (Rs) for fuelwood from trees and bushes or fodder from range and grasses harvested from the entire catchment area.

44 The composition of the trees, bushes, pasture and range in the catchment is given by local names; their location, in barani fields (F), around houses (H), in woodlots (W), in orchards (O), Wetlands (W); their end uses, Fuel (F), Poles (P), Shade (S), Fruit (Ft), Fodder (Fd), Other (O); Ownership, Communal (C), Individual (I).

Present Practices [45] : _____

Problems facing: 1. **Tree, bushes, pasture or range production in the catchment in order of priority are:**

2. **Livestock Production in order of priority are:**

Farmers' Views:

Field Team's Views [46] :

45 Present practices include Fencing (Fc), Grazing control (Gr), Fire control (Fr), Replanting (Rp), Other (O).

46 The field team's views will be supported by the technical advice of the local Forestry Officer and Extension agent. These people should be asked to assist the Field Teams in making this baseline report of the trees and range in the catchment.

3. PRESENT FOREST AND RANGE AREA (BANJAR) IN CATCHMENT SITE.

3.1 Forest, Range and Livestock Production in Banjar Area.

Area (ac) [39] _____ Total number of Livestock in the Catchment site:

Sheep _____ Goats _____ Cattle _____ Buffaloes _____ Others _____

Production of Trees and Bushes and Pasture and Grasses in the Catchment.

	CONDITION [40]	PRODUCTION [41]	FIELD PRICE [42]	VALUE [43]
TREES AND BUSHES				
PASTURE AND RANGE				

Present Composition of Trees, Bushes, Pastures and Range in the Catchment [44]:

TREES & BUSHES	LOCAL NAMES	LOCATION	USES	OWNERSHIP
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10				

PASTURE & RANGE	LOCAL NAMES	LOCATION	USES	OWNERSHIP
1.				
2.				
3.				
4.				
5.				
6.				

---

39 The total area in acres in the catchment site of the Forest and Range grown in the Banjar Area.

40 Condition of the trees and bushes or the pasture and range is judged by the proportion of the ground of most of the catchment that is covered: Dense (>50% of ground covered): D, Moderate (20-50% of ground covered): M, Poor (< 20% of the ground covered): P

41 Total Production of fuelwood, timber and fodder (maunds) from trees and bushes or pasture and range in the entire catchment area.

42 The price (Rs per maund) of fuelwood from trees and bushes or fodder from range and grasses.

43 Total value (Rs) for fuelwood from trees and bushes or fodder from range and grasses harvested from the entire catchment area.

44 The composition of the trees, bushes, pasture and range in the catchment is given by local names; their location, in barani fields (F), around houses (H), in woodlots (W), in orchards (O), Wetlands (W); their end uses, Fuel (F), Poles (P), Shade (S), Fruit (Ft), Fodder (Fd), Other (O); Ownership, Communal (C), Individual (I).

7.				
8.				
9.				
10.				

Present Practices [45] : _____

Problems facing: 1. **Tree, bushes, pasture or range production in the catchment in order of priority are:**

2. **Livestock Production in order of priority are:**

Farmers' Views:

Field Team's Views [46] :

---

45 Present practices include Fencing (Fc), Grazing control (Gr), Fire control (Fr), Replanting (Rp), Other (O).

46 The field team's views will be supported by the technical advice of the local Forestry Officer and Extension agent. These people should be asked to assist the Field Teams in making this baseline report of the trees and range in the catchment.

4. WASTELANDS, ROCK OUTCROPS (WR) AND WETLANDS (WW) [47] :

Area (ac) of WR _____ Area (ac) of WW _____

Present Uses of WR [48] _____ Present Uses of WW _____

Production of Wastelands, Rock Outcrops and Wetlands in the Catchment.

	CONDITION [49]	PRODUCTION [50]	FIELD PRICE [51]	VALUE [52]
WASTELANDS, ROCK OUTCROPS (WR)				
WASTELANDS, WETLANDS (WW)				

Problems facing the use of the Wastelands (WR) and (WW) in the catchment in order of priority are:

Farmers' Views:

Field Team's Views [53] :

---

47 Wastelands include uncultivated lands due to rock outcrops as well as wetlands, such as marshes and swamps.

48 Present uses of WR and WW include Fuel (Fl), Fodder (Fd), Grazing (Gr) and Other uses (O).

49 Condition refers to the plant cover. Dense cover (> 50% groundcover): D, Moderate cover (20-50% groundcover): M, Poor cover (< 20% groundcover): P.

50 Total Production of fuelwood, timber and fodder (maunds) from wastelands in the entire catchment area.

51 The price (Rs per maund) of fuelwood, timber and fodder from wastelands in the catchment area.

52 Total value (Rs) for fuelwood, timber and fodder from wastelands harvested in the catchment area.

53 The field team's views should be supported by the technical advice of the local Forestry and Livestock Officers and Extension agent. These people should be asked to assist the Field Teams in making this [illegible] report of the wastelands in the catchment.

5. SUMMARY OF THE PROBLEMS AND POSSIBLE SOLUTIONS FOR THE CATCHMENT IN ORDER OF PRIORITY [54].

PRIORITIES	FARMERS' VIEWS	FIELD TEAM'S VIEWS
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

54 The views of the farmers and the Field Team for each of the sections reported above should be summarised in this section. This will form the basis of the Land Use Plan for the catchment.

APPENDIX D

TYPICAL ACTION PLAN

4. FARMERS' COSTS	Rs
Land Forming	
Farmers' share of tractor hours	
Levelling existing terraces 80 ac @ 10hrs/ac @ Rs20/hr	16,000
New Terraces @ 40ac @ 30 hrs/ac @ Rs20/hr	24,000
Deep Ploughing 50ac @ 3hrs/ac @ Rs20/hr	3,000
Waterways 4km @ 20hrs/km @ Rs20/hr	1,600
Planting Trees	
Labour to prepare planting basins for 7,000 fruit trees @ 1hr/tree @ Rs10/hr	70,000
Labour to complete eye-brow terraces for 50,000 forest trees @ 1hr/5 trees @ Rs10/hr	100,000
Labour to plant fruit trees @ 10 trees/hr @ Rs10/hr	7,000
Labour to plant forest trees @ 50 trees/hr @ Rs10/hr	10,000
Civil Works	
Labour associated with 44 spillways/drop structures @ 20 days/spillway/drop structure @ Rs100/manday	88,000
Shed	
Construction of the shed @ 30 mandays of labour @ Rs100/manday	3,000
Crop Inputs	
42ac of barani crops @ Rs3,000/ac	126,000
GRAND TOTAL	**448,600**

5. TIMEFRAME [1]

ACTIVITY	DEAD-LINES FOR 1995						
	15 MAY	30 MAY	15 JUNE	30 JUNE	20 JULY	30 SEP	30 DEC
PONDS (7 DAYS POND)	1	1	1	1	0	1	0
LEVELLING EXISTING TERRACES (1.25 days/ac)	5ac	5ac	1ac	1ac	0ac	25ac	20ac
NEW TERRACES @ 3days/ac	0ac	0ac	2ac	2ac	0ac	10ac	17ac
WATERWAYS (m)	200	200	200	200	200	1000	1000
DEEP PLOUGHING (3ac/day)	0ac	3ac	3ac	3ac	0ac	0ac	40ac
FRUIT TREES (NO OF PLANTING SITES PREPARED ON TERRACES) [2]	0	300	300	300	0	1000	1000
PLANTING FRUIT TREES	0	0	0	0	900	1000	1000
FOREST TREES (PREPARE EYE-BROW TERRACES)	0	4000	4000	4000	0	10000	10000
FOREST TREES (PLANTING)	0	0	0	0	12000	10000	10000
SPILLWAYS & DROP STRUCTURES	10	10	10	10	0	0	0
GULLY PLUGGING STRUCTURES	2	2	0	0	0	0	0
SHED						1	
NO OF AVAILABLE WORK DAYS	15	15	15	15	20	72	92
TOTAL TRACTOR DAYS REQUIRED	14	15	15	15	1	71	92
TOTAL MANDAYS REQUIRED	240	378	338	338	41	443	413

---

1 The Action Plan assumes that one tractor would work in the site. Output will double or treble if two or three additional private tractor are employed at the site. The Action Plan assumes that few people would be available to work until 15 May because of the wheat harvest and Eid festival. However, a tractor would be available to work on these days.

2 Tropical fruit such as citrus and lychees can be planted during the monsoon. Deciduous fruit trees such as apple, peaches and apricots, should be planted after December and do not therefore appear in this timeframe.

APPENDIX E

SAMPLE PROGRESS REPORT

FIELD TEAM'S PROGRESS REPORT OF WATER HARVESTING DEMONSTRATION AND TRAINING CENTRES, OECF OFWM.

Field Team .....
Name of Water Harvesting Site .....
Total Area (ac) .....
Staff Presently Working at the site (Supervisor, AO, Field Assistant, Rodman). .....
.....
Water Harvesting Association: Number of Members .....
Name of Chairman .....
Agreement Signed (Yes or No) .....
Topographical Survey and Map Completed (Yes or No) .....
Area Appraisal Completed (Yes or No) .....

WORK COMPLETED TO DATE: DAY..... MONTH..... YEAR.....

	WORK ACTIVITY		WORK COMPLETED			
			TOTAL TARGET	PREVIOUS ACHIEVEMENT	CURRENT ACHIEVEMENT	TOTAL PROGRESS
1	Existing Terraces:	Watbandi (ac)				
		Rough Levelling (ac)				
		PLL (ac)				
2	New Terraces: [1]	Watbandi (ac)				
		Rough Levelling (ac)				
		PLL (ac)				
3	Orchard Terraces:	Levelling and Bunding (ac)				
4	Contour Bunds/ Cross Ditches (m)					
5	Deep Ploughing (ac)					
6	Structures Designed:	Ponds (number)				
		Spillways/Drop structures/Gully Plugging [2] (no)				
7	Structures Completed:	Ponds (number)				
		Spillways/Drop structures/Gully Plugging [3] (no)				
8	Water Ways contructed (m)					
9	Earthwork Done :	Total Volume (m^3)				
		Private tractors (hours)				
		Government tractor (hours)				
		Bulldozer (hours)				
10	Crop Production:	Kharif crops (ac)				
		Rabi crops (ac)				
		Irrigated crops (ac)				
		Crop improvements introduced [4] (specify)				
11	Eye Brow Terraces completed (number)					
12	Forest Trees planted (number)					
13	Fruit Trees planted (number)					
14	Private nursery developed at the Water Harvesting site (number)					
15	Area planted to range grasses for protection against erosion (ac)					
16	Other Activities such as supplementary irrigation from pond					
17	Reimbursements:	Amount Actually reimbursed (Rs)				
		Amount of Reimbursements applied for (Rs)				

1 New Terraces for field crops

2 Gully Plugging may include both pucca and vegetative structures across gullies to reclaim them

3 Gully plugging may include both pucca and vegetative structures across gullies to reclaim them

4 Crop improvements introduced may include new varieties, new planting or weed control techniques and so on.

APPENDIX F

FORM FOR WATER BALANCE CALCULATIONS

Water Balance for a Small Dam.

Dam Name Location

STEP NO	FACTOR	CALCULATION	UNIT	MONSOON SEASON	WINTER SEASON
1	Rainfall Station				
2	Average Rainfall	From Table 6.1	mm		
3	Runoff Coefficient	From Section 6.3			
4	Catchment Area	Measured from map	ha		
5	**Runoff Volume**	*2 * 3 * 4 * 10*	m3		
6	Pond/Reservoir Area	From Survey Plan	m2		
7	Evaporation Rate	From Table 6.2 (monthly figures/30)	mm/day		
8	Seepage Rate	Estimated or measured using an infiltrometer	mm/day		
9	Length of Crop Season		Days		
10	**Water Loss**	*6 * 9 * (7 + 8) /* 1000	m3		
11	**Useable Water**	*5 - 10*	m3		
12	Seasonal Crop Water Requirements	From Volume 5 of these Manuals	mm		
13	Supplemental Irrigation Required	*12 - 2*	mm		
14	Irrigation Efficiency	Estimated	%		
15	**Area Irrigable**	*(11 * 14) / (13 ** 1000)	ha		

APPENDIX G

ILLUSTRATED TECHNIQUES FOR FOREST TREE DEVELOPMENT IN WATER HARVESTING SITES

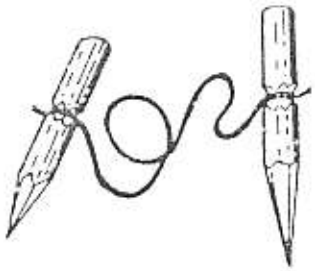
APPENDIX G

Illustrated Techniques for Forest Trees Development in Water Harvesting Sites

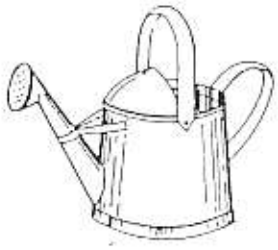
1. Tools and Implements Used in Forest Nursery
2. Care in Handling Nursery Plants
3. Different Planting Materials for Trees
4. Planting A Forest Tree
5. Training of Poplar Trees.

Tools and Implements used in Forest Nursery

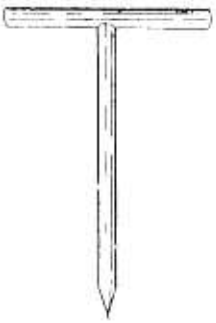
Pegs & Rope



Sprinkler



Planting Rod

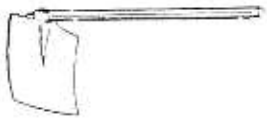


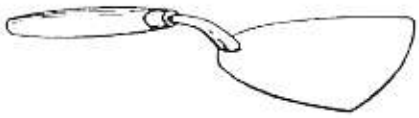
Hand Trolly

Knife

Gaiti (Pick Axe)

Phawara (Hand Hoe)

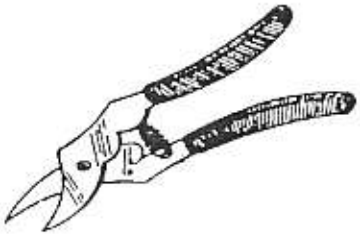




Shavel (Khurpa)

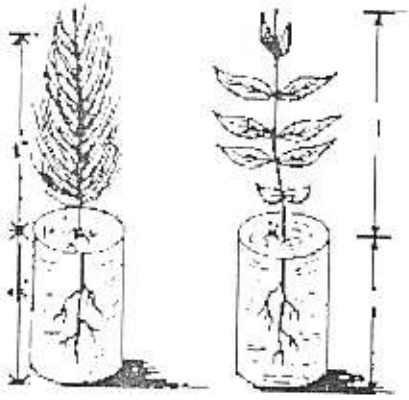
Belcha (spade)

Scissor



CARE IN HANDLING NURSERY PLANTS

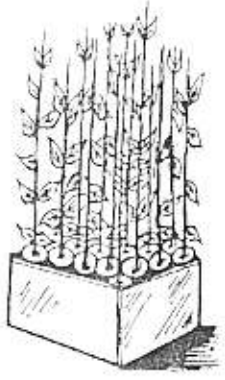
Select healthy plants having top two times more than roots



Water the plant before transportation

Lift the plant by holding the plastic bag

Place the nursery plants straight in the box for long destinations

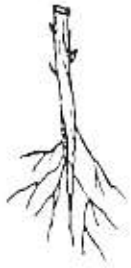


Different Planting Materials For Trees

Seed

Stem Cutting

Root Cutting



A plant with root ball

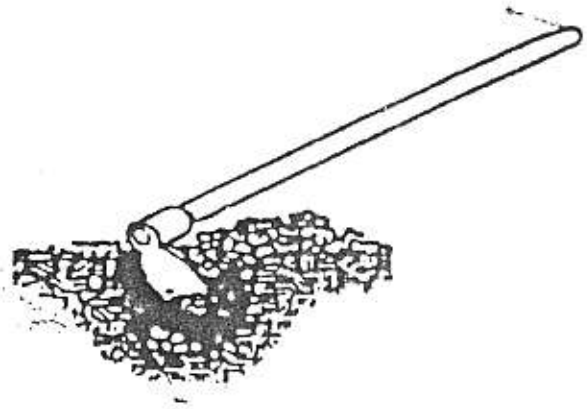
Deciduous Plant without roots

Plant grown in earthen pots

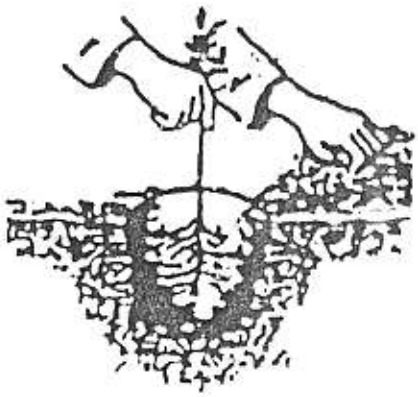
Plant grown in plastic bag

Planting a forest tree

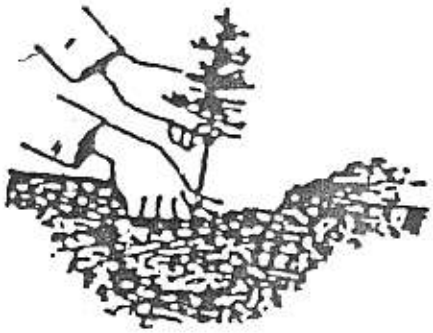
Make a pit of (2 x 1.5') size



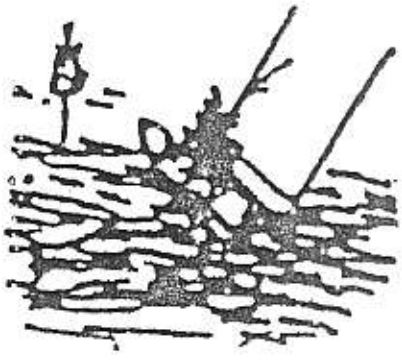
Keep the plant in the centre and transplant at the same level the plant had in the nursery



Press the soil in the pit

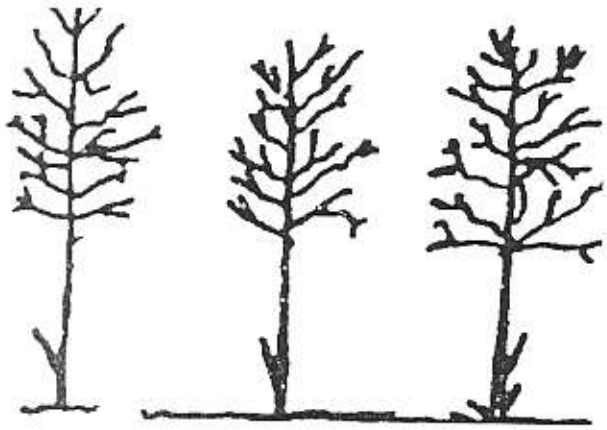


Press the soil with the heel of the foot

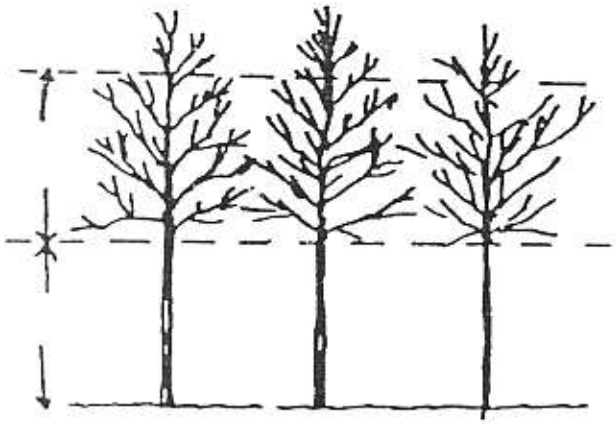


Training of poplar trees

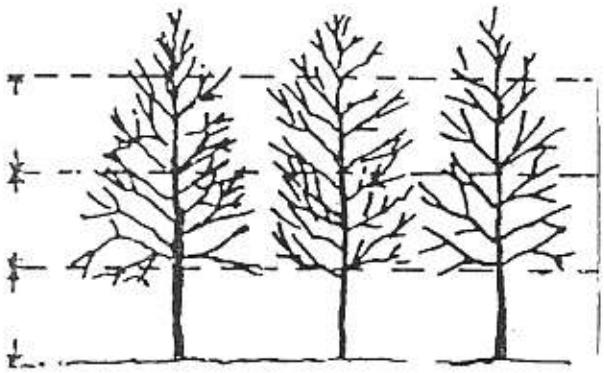
First stage after transplanting (age 1 year)



Second stage 1/3 branches removed (age 2 year)



Third stage half of the branches removed (age 5 year)



Fourth stage 2/3 branches removed (age 8-10 years)