

REVISED

DRAFT

MANUAL OF ON-FARM DEVELOPMENT WORKS



**GOVERNMENT OF MAHARASHTRA
IRRIGATION DEPARTMENT**

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**MUMBAI
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FOREWORD

• PREFACE •

1.0 The Manual of design for On-farm Development (O.F.D.) Works was published in 1982. In the past two decades, this Manual was used extensively by designers and field officers. The designers and the field officers have gained large base experience in respect of Micro Distribution Network and land forming as well. The Government has also issued various Circulars about planning and design of O.F.D. Works in last two decades to improvise and economize the implementation of O.F.D. Works. A long-term need was felt to revise the Manual of design for On-farm development works (1982) based on the large scale field experience and to incorporate Government's instructions contained in various Circulars and make the Manual more comprehensive to encompass various aspects of construction and quality control in addition to planning and design of O.F.D. Works. The Government in irrigation Department has, therefore, constituted a Committee of Members comprising of WALMI Faculty Members, Senior Officers and Engineers with field experience. The Committee is pleased to present this revised and comprehensive Manual. Since, this Manual covers overall activities pertaining to O.F.D. Works in addition to planning and design, the Manual is titled as "The Manual of O.F.D. Works".

2.0 In the context of improving Irrigation Water Management and to bridge the gap between created Irrigation Potential and its utilization, a well designed and carefully laid Micro Distribution Network plays an important role. Hence, a comprehensive strategy envisaging precision planning, accurate topographical and soil surveys and a high degree of accuracy in construction with appropriate quality control is very much required. The utility of O.F.D. Works would increase if farmers' participation is initiated since planning, designing and carried forward till construction and maintenance of O.F.D. Works. This Manual has set guidelines for technical and constructional aspects with active participation at appropriate stages.

3.0 In order to imbibe a ground touch of field experience regarding O.F.D. Works, the Committee organized a one-day "Experience sharing" workshop at WALMI. About 75 experienced field officers from Konkan, Marathwada, Vidarbha, West and North Maharashtra Region working in this area and Irrigation management attended this Workshop. The deliberations and suggestions received from the field engineers belonging to various regions have been given due consideration at appropriate places in this Manual. Guidance and discussions with Shri S.V. Sodal, Secretary (CAD) and Shri D.M. More, Chief Engineer (I) and Joint Secretary, Irrigation Department have helped in achieving right orientation in revising the manual. Manual could get the base of research and development through various research reports prepared by D.I.R.D., Pune and Diagnostic Analysis studies done on several projects by WALMI, Aurangabad.

4.0 The Manual of O.F.D. Works has eleven chapters. As compared to the O.F.D. Manual of 1982, the present one incorporates three additional chapters covering following topics.

- i) Key issues in planning, design, construction and maintenance
- ii) Flow measuring devices
- iii) Non-conventional methods of O.F.D. Works in hilly and high rainfall areas (like Konkan and Eastern part of Vidarbha region).

The Chapter-3 on “Key issues in planning, design, construction and maintenance of O.F.D. Works” is expected to create awareness regarding importance of O.F.D. Works and make the designer as well as field engineer conscious in different aspects of O.F.D. Works including the legal provisions.

The issue of flow measurement for volumetric supply of water to Water Users' Association has gained an important dimension in the Government policy to handover created irrigation potential to Water Users' Associations. Hence, a separate Chapter-6 on “Flow Measuring Devices” is added.

The Konkan and some part of Vidarbha region have typical topographical, climatic and soil conditions. The conventional O.F.D. Works with network of open channels do not fulfill the requirements of efficient irrigation water management. Hence, Chapter-10 on “Non-conventional Method of O.F.D. Works” is added to the Manual which is informative and deals about the non conventional O.F.D. Works like:

- a) Piped distribution system
- b) Taking water through R.C.C. half round pipes supported over concrete pedestals.
- c) Creating an interface between gravity irrigation network and pressurized irrigation system

- 4.1 The balance 8 chapters of the Manual describe the general approach to planning and cover detailed designs of O.F.D. Works. They have similar format as used in the Manual of design for On-farm development works (1982), but the details have been updated based on Government Circulars and reviewed at appropriate places to incorporate practical field experience.

The Chapter-1 describes the general approach to design and planning of O.F.D. Works with a emphasis on farmers' participation, organizational coordination, systems approach and levels of accuracies. Methods of Survey, Investigation and Mapping have been dealt in Chapter-2. The principles of chak layout and field channel alignment have been elaborated in Chapter-4. The Chapter-5 on chak water delivery system includes step-by-step procedure for finalizing the bed profile of field channels and ready reckoner for field channel design. This would help even a beginner to design the chak water delivery system. The details of structures in Black Cotton Soil have been specially incorporated. Exhaustive and elaborate information and guidelines on Lining covering selection, design, construction, quality control and economic aspects of F.C. lining is included in Chapter-7. This Manual covers design procedures for land forming / land shaping with standard norms of land slopes pertaining to the type of crops and method of irrigation duly illustrated with case studies in Chapter-8. Guidelines for Surface drains have been set out in Chapter-9. The Chapter-11 on “Record of O.F.D. Works” emphasizes on proper preparation maintenance and handing over of record of O.F.D. Works. This aspect has a special bearing in the changing scenario of irrigation management, with farmers' participation through formation of Water Users' Associations. The O.F.D. Manual of 1982 contained a chapter on Water distribution and application (Chapter-4). This has been deleted, as a part of it related to water application methods has been covered in the Chapter-8 of this Manual and the balance part which is related to capacity design of minor/distributory falls outside purview of this Manual.

5.0 Planning and design is a dynamic process. Evolutions in these aspects are necessary to cope up with the changing environment and advancing techniques. Day-by-day, water is becoming more and more precious. Hence, for efficient water management and O.F.D. Works, which form the prime components of distribution network, will have to be designed, planned and constructed with a new set up of mind to keep pace with the changing needs of the time. It may, therefore, be necessary to take up the work of further revision of this Manual in next few years.

6.0 The members of the Committee, Shri A.R. Kore, Shri R.B. Ghote, Shri D.G. Holsambre, Shri V.V. Patki, Shri A.B. Deshpande, Shri S.G. Lavekar and Shri C.B. Kulkarni have made significant contributions in preparing drafts of various chapters and participated in the discussions. The contribution of Shri V.V. Patki, Executive Engineer, Jayakwadi Land Drainage Division, Aurangabad in preparing drafts of three Chapters, modifying and editing other three Chapters, is commendable and praiseworthy. Thanks are due to WALMI, Aurangabad for intellectual support besides providing all the infrastructure facilities to the Committee in preparing this Manual. The Committee is thankful to the Government in Irrigation Department particularly Shri S.V. Sodal, Secretary (CAD) and Shri D.M. More, Chief Engineer (I) and Joint Secretary for continuous guidance and giving an opportunity to contribute, this way, in the development and management of irrigation potential of the State.

7.0 It is hoped that this Manual will be useful to the designer as well as to the field engineers to understand the basics of O.F.D. Works and will help them to implement actual design, and construction. The newly added chapters are expected to enhance the utility of this Manual. Any errors as well as any suggestions to improve any technical matter in the Manual are welcome, which may please be communicated to Government so that these can be incorporated in the next revision.

June 30, 2002

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TERMINOLOGY

1. Application Efficiency

The ratio of the quantity of water needed to maintain the soil moisture above a minimum level required for the crop to the quantity of water delivered at the farm gate.

2. Bentonite

Bentonite is a natural earth material in the form of hydrosilicates of aluminum with a high percentage of montmorillonite. It is characterized by high absorption of water and is expansive.

3. Chak

The command of the Govt. outlet, bounded by natural or artificial drainage, irrigation channels, roads etc.

4. Chak Water Delivery System

From the Govt. outlet downwards, the system comprises field channel, drop structures, measuring devices, division boxes, turnouts, crossings etc. for supplying the water down to the individual farms. This system has been called as chak water delivery system, and except for the watercourse, it is the property of the community of beneficiaries in the chak. It is to be maintained by the beneficiaries including watercourse.

5. CNS Layer

A layer with cohesive nonswelling soil. The material should be cohesive (unlike sandy material) and nonswelling (unlike black cotton soil). Some murums meet the requirements.

6. Community Items

Items of work below the Government outlet excluding the water course and the work of land shaping. These include the field channels, structures thereon, field drains and structures thereon and large bunds. They are also called Part I works.

7. Compartment

Compartment is part of holding, designed as a separate unit for on farm irrigation; it is either level or has a uniform grade in one direction, with or without some cross slope.

8. Construction Organization (CO)

The organization in charge of construction of the canal system namely the main canal, distributories and the minors including the Government outlets. Where the reference is to Executive Engineer of the Construction

Organization, it means the Executive Engineer in charge of design and construction of the distributories and minors.

9. Conveyance Efficiency of Field Channel

The ratio of water delivered at turnout to water delivered at irrigation outlet.

10. Con-Cure WB

It is water based curing compound. It forms a membrane, which acts as a barrier to loss of water.

11. Consumptive use or Evapotranspiration

During the growth of the crop in an irrigated farm, water is consumed in the form of transpiration from the plant, and evaporation from the plant as well as soil surface. This total consumption of water in any specified time is termed as evapotranspiration or consumptive use.

12. Delta

The quantity of water used or required to irrigate an area for the purpose of maturing its crop and expressed as mm. of water depth.

13. Depth of Irrigation

The volume of water supplied to a given area in one irrigation divided by the area. It is expressed in mm, at farm gate, at outlet or at the head of the minor.

14. Distributory

A channel with more than 0.7 cumecs discharge (700 litres per second) at its head taking its supply from a main canal or branch and feeding only minors and/or outlets.

15. Divisional Officer (DO)

Divisional Soil Conservation Officer or Executive Engineer in charge of land development division.

16. Evapotranspiration

See 'Consumptive Use, Serial No. 11 above.

17. Farm Gate or Turnout

The chak water delivery system is so designed that it can deliver water to each individual holding. The point at which the water can be supplied to each holding has been termed as farm gate. It does not necessarily mean that there is a gate structure. There will, however, be the turnout. It is considered as a legal intake point for taking water into the farm by a farmer.

18. Field Capacity

The amount of water held in the soil after the excess gravitational water has drained away. It is expressed as a percentage of the oven dry soil.

19. Field Channel

The water channel from the Government outlet upto the different individual farms is termed as a field channel. Legally the field channel excludes the length of the watercourse. In this manual however the words "Field Channel" are used to include both the water course and the field channel.

20. Fly ash

It is a by-product obtained from thermal power stations after burning of coal.

21. Individual items

Land forming work including the small bunds is done at the cost of and on behalf of the individual farmer. These items are therefore called as individual items. They are also called as Part II works.

22. Irrigated crop intensity

The percentage of the area irrigated during an irrigation season to the culturable command area.

23. Irrigation interval or rotation period

The elapsed time in days from the start of one irrigation to the start of the next irrigation.

24. Irrigation stream

Flow of water turned on to the farm to be irrigated.

25. LDPE

Low-density polyethylene is a polymer (synthetic organic material) and is tough and pliable over a wide temperature range.

26. Minor

A Government channel having a capacity at head of less than 0.7 cumecs (700 litres/second) and feeding sub-minors and/or outlets.

27. Modified Penman method

This is a method for estimating the evapotranspiration for reference crop and then using crop coefficients for different crops at different periods of growth for a given set of climatic conditions including temperature, humidity, hours of sunshine, wind etc. There is a computer programme available, from which

the reference crop evapotranspiration by Modified Penman method can be obtained. For this purpose FAO paper No. 24 is useful.

28. Outlet

This is the last irrigation structure of a canal system, owned and controlled by the Government for irrigating the areas in a chak.

29. Pressurized irrigation

Pressurized irrigation is on farm application of water under pressure, through a pipe system; it includes sprinkler irrigation in which water is applied as a spray and drip (or trickle) irrigation in which water is applied drop by drop near the root zone.

30. PVC

Polyvinylchloride is also a polymer. It is available in plastic sheets with various thickness.

31. Root Zone

The roots of a plant extend downwards in to the soil in search of moisture. The effective depth from which most of the moisture required is drawn up by the roots is termed as the root zone. This depth varies from crop to crop.

32. Runoff

A part of the rain falling on an area is lost by percolation, evaporation etc. The remaining part flows on the surface and is called runoff. It is expressed in mm on the area of drainage.

33. R.W.S. or Rigid Shejpali

Rotational Water Supply or Rigid Shejpali is a system of scheduling the supply of water, to irrigators in a command area, from tail to head, by pre-allocating the date and the hours of supply according to sanctioned areas and keeping the discharge of water flow in the chak constant.

34. Shahabad stone

It is naturally available construction material which is a flat slab of calcareous material.

35. Sprinkler irrigation

Method of irrigation in which water is sprinkled, under pressure, over the farm, through nozzle lines, perforated pipes or sprinklers.

36. Sub-divisional Officer (SDO)

The Sub-Divisional Soil Conservation Officer in charge of a land development sub-division and also the Deputy Engineer, the Sub-Divisional Engineer, the Sub-Divisional Officer or the Assistant Engineer in charge of a land development sub-division.

37. Surface irrigation

Method of irrigation in which water is applied to the field by gravity. (e.g. Border, Basin, Furrow, etc.).

38. Turnout

The chak water delivery system is so designed that it can deliver water to each individual holding. The point at which the water can be supplied to each holding has been termed as farm gate. It does not necessarily mean that there is a gate structure. There will, however, be the turnout. It is considered as a legal intake point for taking water into the farm by a farmer.

39. Warabandi

A system of scheduling of the water supply in the chak, for purposes of internal distribution of water among the co-sharers; the time schedule show: (i) order of turn, (ii) field number in units; (iii) name of co-sharer, (iv) area of the units; (v) length of turn in strict proportion of area; (vi) any additions or deductions; (vii) length of turn allotted. The period of rotation for Warabandi is usually a week.

40. Water course

A water course means the water channel from the Government outlet upto a point, from where the command of the outlet starts. As per Maharashtra irrigation Act of 1976 it is an idle length of channel between an outlet and a field channel.

41. Water front

The front of the advancing sheet of water let into a unit of farm, in surface irrigation.

42. Water logging

It is a state of agricultural land in which ground water level rises upto certain limit saturating the root-zone of the crop and affects the crop growth.

ABBREVIATIONS

B.C. Soils – Black Cotton Soils

CAD – Command Area Development

cm. – Centimetre

CO - Construction Organization

CCA – Culturable Command Area

Cumec – Cubicmetre per second

Cusec – Cubicfeet per second

DO – Divisional Officer

DIRD – Directorate of Irrigation Research and Development, Pune

FC – Field Channel

ha – hectare

hr – hour

IWM – Irrigation Water Management

ICA – Irrigable Command Area

I.S.S.S. – International Soil Science Society

Km – Kilometre

Lit – Litres

l.p.s. – litres per second (lit/sec)

LD – Land Development

m – metre

mm – milimetre

m³ - Cubicmetre

m³/s – cubicmetre per second

m/s – metre per second

Mha – Million hectare

Mm² - Million Square metre

NIR – Net Irrigation Requirement

OFD – On Farm Development

PCC – Plain Cement Concrete

RSR – Regional Schedule of Rates

RWS – Rotational Water Supply

SDO – Sub-Divisional Level Officer

SqM – Square metre (m²)

SR – Self Regulated

UCR – Uncourse Rubble

WALMI – Water And Land Management Institute, Aurangabad

WUA – Water Users' Association

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CONVERSION FACTORS

Metric Units to British Units			British Units to Metric Units		
Length					
1 mm	0.03937	inch	1 inch	25.40	mm
1 cm	0.3937	inch	1 inch	2.540	cm
1 cm	0.03281	foot	1 foot	30.48	cm
1 m	3.281	feet	1 foot	0.3048	m
1 km	0.6214	mile	1 mile	1.609	km
Area					
1 m ²	10.76	sq.feet	1 sq.foot	0.093	m ²
1 are	0.0247	acre	1 acre	40.47	are
1 ha	2.47	acre	1 acre	0.4047	ha
Volume					
1 m ³	35.31	cub feet	1 cub. foot	0.02832	m ³
1 litre	0.03531	cub foot	1 cub. foot	28.32	litre
1 Mm ³	35.31	mcft	1 mcft	0.02832	Mm ³
1 Tm ³	0.03531	mcft	1 mcft	28.32	Tm ³
1 Daylitre	0.03531	Daycusec	1 Daycusec	28.32	Daylitre
1 Ha mm	0.008107	Acrefeet	1 Acrefoot	123.4	Ha mm
1 Ha m	8.107	Acrefeet	1 Acrefoot	0.1234	Ha m
Velocity					
1 m/sec	3.281	ft/sec	1 foot/sec	0.3048	m/s
1 cm/sec	0.03281	ft/sec	1 foot/sec	30.48	cm/s
1 mm/day	0.03937	inches/day	1 inch/day	25.4	mm/day
Discharge					
1 cumec	35.31	cusecs	1 cusec	0.02832	cumec
1 l/s	0.03531	cusec	1 cusec	28.32	l/s
Miscellaneous					
1 cumec/Mm ²	3.281	cusecs/msft	1 cusec/msft	0.3048	cumecs/Mm ²
1 l/s/ha	0.0143	cusecs/acre	1 cusec/acre	70.88	l/s/ha
1 kg/cm ²	14.22	Pounds per	1 pound per	0.0703	kg/cm ²
sq.inch			sq.inch		

CHAPTER 1

APPROACH TO PLANNING, CONSTRUCTION AND MAINTENANCE OF ON FARM DEVELOPMENT WORKS

1.0 Introduction:

The purpose of irrigation is to enable the farmers to improve the agricultural production. The modern irrigation management aims at high efficiency of water conveyance and appropriate methods of water application, through participatory irrigation management at each stage of irrigation development. The Govt. of Maharashtra in Irrigation Department has taken appropriate decision to promote and implement the theme of participatory irrigation management in all the Irrigation projects through formation of Water Users' Associations (WUA). The approach to planning, design, construction and maintenance of OFD works needs to be, therefore, reoriented from this new angle.

1.1 On Farm Development Works:

The efficient management of irrigation water for maximizing productivity requires both, firstly the efficient on farm water management and secondly the optimization of the use of water and land, through appropriate methods of water application. The efficient on-farm water management is related to water delivery system and allied works in the command area of chak, which distributes the water to each farm. The items of works pertaining to on farm water management are termed as "On farm development works".

The on farm development works comprise of following,

- a) Field channels for conveyance of water
- b) Control structures
- c) Crossings
- d) Surface drainage system
- e) Farm roads
- f) Field channel protection works and
- g) Land forming (Smoothing / grading / levelling).

In Maharashtra, the OFD works are divided into two parts:

- | | |
|---------|---------------------|
| Part-I | (a) to (f) as above |
| Part-II | Land forming |

2.0 The General approach to design and execution of OFD works:

The general approach to design and execution of OFD works shall be in accordance with the Govt. technical circulars, the Govt. Resolution and other directives issued by the Govt. from time to time for this purpose. The participatory irrigation management and efficient water delivery system to provide timely as well as adequate water supply to each farm, shall be the main focus points in the design and implementation of OFD works.

The basic issues of general approach are,

- a) Systems approach
- b) Sequence of design and execution
- c) Functional utility
- d) Farmers' Participation
- e) Organizational coordination

2.1 Systems approach:

The conveyance system from the dam to the farm gate is one live system and it is necessary that the designs of the different components are matched properly. The water management proposed to be adopted on the canal system should always be kept in view as a reference frame. Presently, canals and branches are designed for a 14 day rotation (irrigation interval) including a 12 day running period and a 2 day closure (except in unusual peaks when there is a 14 days running period); minors and distributories are designed to complete the irrigation in half period. The chaks will be so laid out and designed that the entire irrigation thereon is completed in 6 days. The outlets are operated in sequence from tail to head of the minor. Outlets with a less than 6 day running period are alternated or rotated. Thus, basically a chak water delivery system will be designed to provide at the farm gates, (turnout or property head) within a 6 – day running period, water requirements of 14 days irrigation interval.

2.2 Sequence of design and execution:

- (a) The ideal sequence of finalization of design would be obviously from the tail to the head. First, according to the topography and soil conditions, the land forming of each farm would be decided, so as to ensure efficient irrigation. Next, the chak water delivery system and surface drains would be designed so as to ensure adequate water deliveries to the different farms and proper drainage. According to the number of outlets and period for which they would operate, the design capacity of the of minor is decided and in turn, that of the distributory and of the main canal.

Conditions do not always permit this ideal sequence of design and therefore the design may have to proceed from head to tail. Sometimes this may lead to designs with inadequate conveyance capacities in the distributories and minors. One should keep these limitations in mind.

- (b) The execution of OFD works shall be done only in places where canal water has actually reached. The OFD works get disturbed and deteriorated if these are not put to use immediately. As far as possible, the construction of OFD works may not be taken up till the formation of Water Users' Association.
- (c) After construction of OFD works, preparation of work-done drawings of OFD works (record drawings) form the basic record for planning irrigation management. Hence, these should be canvas mounted and hard bound. The completion report shall include design report and work done cost estimates. The design report should explain the chak

size, field channel alignments and gradients, network of surface drains and their design, details of OFD structures etc. The completion report shall explain for any deviations from the design and limitations, if any, arising out of these deviations for irrigation management.

2.3 Functional utility:

The purpose of the OFD works is to provide timely and adequate supplies of water to each holding and preserve environmental balance as well, by avoiding seepages, leakages and stagnations of water which trigger problems like water logging, causing adverse impact on environment. To achieve this functional utility, the planning and design of OFD works has to be hydraulically better and socially acceptable. The OFD works also need to be such that these are economical for the construction and maintenance. The functional utility of OFD works depends on levels of accuracies and quality of construction. In a water delivery system, accuracies are very important. Separate tolerances are, therefore, prescribed for different works of on-farm development. The quality of construction governs the cost of maintenance and overall life of OFD works.

Thus the functional utility of OFD works is governed by following aspects

- i) Hydraulic design
- ii) Economy for construction and maintenance
- iii) Social acceptance i.e. User friendliness to community of farmers who will be actually using OFD works and
- iv) Levels of accuracies and quality of construction.

These issues need to have a proper bearing in approach to design and execution of OFD works.

2.4 Farmers Participation:

Success of canal irrigation depends on the response of the farmer, both as an individual and as a member of the group benefited by the outlet. The irrigation facilities should be designed with a view to meet his requirements, particularly in respect of land forming. Active participation of the farmer at the stage of design should therefore be encouraged. This will also help in building up of an atmosphere of common purpose and thereby in the unification of the beneficiaries into a homogeneous group.

The Govt. of Maharashtra in Irrigation Dept. has taken a decision to promote and expedite the formation of WUA's, so that all the created potential under various projects is taken over by Water Users' Associations. The Govt. is also promulgating separate Act for farmers' management in Irrigation system. Hence, it would be necessary to revamp the approach, if necessary, in accordance with the provisions and procedures laid down by the Govt. from time to time

2.5 Organizational Coordination:

The works from the canal head down to the distributory and from the distributory head to the outlet are carried out by the Construction Organization (C.O.) of the Irrigation Department. The outlet of a capacity of about 30 liters/second, is the

last Government structure on the canal system. Below outlet, OFD works are the community works.

Presently the work below the outlet is entrusted to the Land Development Divisions (L.D Divisions). Design and construction proceed on the basis of the location of the outlet and its sill level. Experience has shown that when the work is done in isolation by construction Organization and Command Area Development wing, many a time errors creep in. The L.D. Divisions may not be aware of the problems faced on the design and construction of distributories/minors on the other hand the Construction Organization may not be aware of the problems that often come up, if the locations/elevations of outlets are not appropriate in relation to the chak topography. Providing irrigation facilities, is a joint effort by the Construction Organization and the L.D. Division. To ensure a coordinated effort, it is necessary at the stage of design, that the design of a minor is treated as an overlapping function. Thus the L.D. Division should not consider the design and layout of a minor as a work unrelated to the work below the outlet. Instead, at least conceptually, the process of design of the works below the outlet, should continue upto the head of the minor. For this purpose the Land Development Divisions should approach the Construction Organization for the details of the designs and layouts of the distributories/minors. There should be a continuous dialogue between the two wings on this aspect.

In near future, Water Users' Associations may take up the work of design and construction.

3.0 Procedure for taking up OFD works:

The OFD works are part of CAD works. The cost estimates for OFD works are generally formulated in two parts.

- a) Part I works.: Cost estimates for chak water delivery system, field channel protection works and surface drainage works in a chak.
- b) Part II: Cost estimate for land forming works for each holding.

3.1 The design and cost estimates for Part I works shall be done for “the chak system” i.e. a group of chaks under the command area of minor. This is essential because the design of a chak delivery system should not be done in isolation without consideration of the adjoining chaks. This helps to decide the efficient way of designing surface drains for the overall topography and so also the disposal of excess irrigation water. The overall average cost per ha for Part I works in “the chak system” may be compared with the prescribed cost norm.

3.2 The cost estimate for land forming works is prepared on individual holding basis after getting consent of concerned farmer and completing the financial formalities. The preparation of cost estimate for land forming is explained in chapter No. 8 on Land Forming for Irrigation.

3.3 The design and cost estimate for field channel protection works may be done for each chak separately.

3.4 The construction of OFD works may be taken up as per Govt.'s prevailing

circulars and instructions in accordance with various provisions in Govt. Resolutions and Acts in vogue. As far as possible the OFD works may not be taken up till the formation of WUA.

REFERENCES:

- Govt. of Maharashtra, Irrigation Dept. Resolution (Marathi) NO WUS/1001(442/2001)/IM(P) dt.23.7.2001
- Manual of design for On Farm Development works, Govt. of Maharashtra Irrigation Dept., Nov.1982.
- On Farm Development Works, Water And Land Management Institute (WALMI) Maharashtra Publication No 12 , Dec 1996.

CHAPTER - 2

SURVEY AND INVESTIGATIONS

1.0 General:

Before the design of the minor and the chaks can be taken up, it is necessary to carry out detailed surveys and investigations. The data so collected has to be analyzed so that the design is appropriate to the field situation.

2.0 Unit for Design:

- 2.1 The smallest unit for design will be a minor serving a group of outlets. This will ensure that the field conditions of the adjoining chaks (command of an outlet) are reflected in the design.
- 2.2 If the minor is too large, serving, say, more than 20 outlets, the design can be proposed in two or more parts so that only 10 to 12 outlets are considered at a time. However, to ensure that the adjoining topographical conditions are taken into consideration, in such cases, at least one outlet on each side of the minor should be included in each part of the design so that there is an overlapping area (The design of a chak should not be done in isolation, without consideration of the adjoining chaks). The term 'Chak System' will be used in this manual to indicate this primary unit of design.

3.0 Sill Levels:

- 3.1 After survey, design and construction of distributories and minors, tentative locations and sill levels of the outlets shall be fixed after joint inspection of Construction and CAD organizations. As far as possible outlets shall be located at the upstream of the drops. The sill levels of the outlet shall be taken at or near the bed of the distributory or minor. The locations and the sill levels of the outlets so fixed, will be supplied by the Construction wing to the Command Area Development Authority. The Construction Organization shall also fix stone indicating the sill levels and the locations of the outlets on site.
- 3.2 The survey and investigations for a chak system will be taken up after the sill levels of all the proposed outlets in the chak system are provided by the construction organization.

4.0 Farmers:

- 4.1 In canal irrigation, unlike in well irrigation, water that is supplied at the Government outlet is to be shared equitably by all the beneficiary farmers. This involves understanding and cooperation. Therefore, the number of beneficiaries has to be reasonably small. Generally, 10 to 15 beneficiaries can be organized for water sharing. If the number exceeds 20, it becomes practically un-manageable. Therefore, the

farmers organization at the outlet will have always to be at the focal point.

- 4.2 Suggestions from the farmers organization regarding alignment of F.C., tentative locations of turnouts, requirement and tentative location of graded bunds be sought. Details of the individual holding (pot hissa) in the chak system should be obtained so that the number of farmers under each outlet is known at the time of design. The boundaries of the individual holding should be marked on the village maps.

5.0 Soils:

- 5.1 The soil conditions in a chak affect the design of the water delivery system and land shaping in many ways.
 - (a) Channel Gradient: Fine Textured soils (Black Cotton Soils) and other clayey soils are easily erodible and hence the gradients of channels in such soils have to be relatively flat. In Coarse Textured (murumy) soils, steeper gradients can be allowed without affecting the stability of the channel bed and depth of water in the channel for diverting water in the field.
 - (b) Rate of flow: For efficient application of water on the farm the rate of flow has to be controlled according to the character of the soil. Generally in Fine Textured soil (Black Cotton Soils) the rate of flow has to be smaller than in Coarse Textured (murumy) soil.
 - (c) Land Forming: If the depth of soil is shallow, care has to be taken while designing the land forming work. Some soil cover is necessary even after land forming.
 - (d) Field Drains: Field drains have not only to carry excess water during irrigation but also to drain the excess run-off during the rainy season. In fine textured soils area, there is likely to be more runoff from rain than in medium and coarse textured soils area. Capacity of the drainage system will have to be varied to suit these variations.
 - (e) Structures: Design of structures in Fine textured (black cotton) soil is quite different from that in coarse (murumy) soils. The costs also vary accordingly.
- 5.2 The data about soil conditions should therefore be collected and the area in each chak roughly demarcated into different portions as coarse textured or fine textured soil etc. survey number wise, for designing of the water delivery system. The individual farm maps for land shaping should show whether the soils are shallow (less than 22.5 cm), medium (22.5 cm to 45 cm) or deep (45-90 cm) and very deep (more than 90 cm).
- 5.3 For land shaping, data regarding soils is necessary. For this purpose at least five trial pits should be taken, four at the four corners of the farm and one at the centre. The trial pits should have a depth of 1.0 m or should reach coarse-grained soil whichever is earlier. In case of difficulty in taking trial pits, 100 mm diameter auger holes can be taken. Soil samples should be

collected at every 0.15 m depth of soil from the top or part thereof and tested for texture.

Soil texture refers to the relative proportion of various groups of soils grains in a soil mass. These fractions are called “Soil separates” or “Soil fractions”. The International Soil Science Society (I.S.S.S.) System for soil separates may be adopted as given in Table 2.1 below:

Table – 2.1
Classification of soil separates, I.S.S.S. System

Sr. No.	Soil Separate	Diameter Range (mm)
1	Coarse sand	2.00 - 0.20
2	Fine sand	0.20 - 0.02
3	Silt	0.02 - 0.002
4	Clay	Below 0.002

The soil texture can be determined by simple field classification methods and the soils are classified in the following 5 broad groups:

For many purposes, the complete details of soil textural classes are arranged into groups as shown below:

General Soil Textural Group	Basic Soil Textural Classes
A) Coarse textured soils	Sandy, loamy sands
B) Moderately coarse textured soils	Sandy loam
C) Medium textured soils	Loam, silt loam, silt
D) Moderately fine textured soils	Clay loam, sandy clay loam, silty clay loam
E) Fine textured soils	Sandy clay, silty clay, clay

Field Method of determining soil texture:

Determination of soil texture in the field is made mainly by feeling the soil with fingers and noting the feel as grittiness, stickiness, slipperiness, plasticity, etc. This requires skill and experience. For high accuracy, the texture determined in field by surface feel should be checked against laboratory analysis. The basis of field determination of soil texture by surface feel is explained below:

- i) When felt between fingers, the sand particles in soil feel gritty or in case of very sandy samples, these can be seen by naked eye.
- ii) The feel of the silt is soft and floury when dry, and is slippery or soapy when moist; but does not stick to the fingers.
- iii) The clay when felt between thumb and fingers, is sticky if moist, plastic enough to form a flexible ribbon when pressed.

Thus by means of different feels among the sand, silt and clay, the soil textural class is estimated. However, errors are expected due to presence of organic matter gypsum, calcium carbonate, coarse fragments, soluble salts, etc. The individual textural class can be identified as described below.

Take a handful of soil free from coarse fragments and moist in condition. Rub the soil between thumb and fingers and ask yourself three questions, viz.

- a) Is the soil gritty?
- b) Is the soil silky, slippery and soapy?
- d) Is the soil sticky and plastic?

If the soils are equally gritty, silky and sticky, then the soils are 'loam' in texture. If in all the feelings, grittiness is more dominant, soils are 'sandy loam' in texture. If stickiness is much more dominant as compared to other two feelings, soils are 'silt loam' in texture. If stickiness is much more pronounced than grittiness and silkiness, soil is 'clay loam' in texture. If it is only silt, silky feeling is present and dominant, whereas other two feelings are almost absent. If the silkiness and stickiness are equally dominant and grittiness absent, then 'silty clay' is estimated. If grittiness and stickiness are equally and dominantly felt and slippery feeling absent, the texture is 'sandy clay'. If loam texture is felt, but sand and clay are felt equally high, it is 'sandy clay loam' texture. Similarly in loam texture if both clay and silt are felt dominant the texture is estimated as 'silty clay loam'. Thus, it is an approximate key to identify soil texture in the field, but should always be supported by laboratory analysis, skill and experience. For ready reference, steps to be followed in field classification are presented in Figure 2.1.

6.0 Other Facilities:

For the given chak system, data about the following should be collected and should form a part of the design report:

- (a) Roads
- (b) Distance to nearest market
- (c) Present area under well irrigation and number of wells
- (d) Present area under lift irrigation and bandhara irrigation.

7.0 Crops:

Data of the present crops grown in each chak should be presented in the design report. The data can be obtained from the village records.

8.0 Surveying and Mapping:

- 8.1 Accuracy required for the design of community items is different from that required for the individual items of land forming. Separate surveys are therefore carried out for the two works.
- 8.2 Survey for Community Items: For design of community items, maps are required in the scale of at least 1 : 1000 to 1 : 1250, with contours having an interval of 0.2 m to 0.3 m. Such contour maps can be produced either by Aerial Survey or Ground Survey.
 - (a) Aerial Survey: From rectified prints of aerial photographs, contour maps can be prepared by control survey on the ground. The survey of India provides the contour maps after aerial photography as well as ground control. Such maps are

generally adequately accurate. This however requires planning many years in advance.

The survey of India can also provide rectified prints from aerial photographs. With complimentary ground survey, accurate contour maps can be produced by the Land Development Divisions.

- (b) Ground Survey: The procedure followed presently is to have a grid survey with block levels on 15m X 15m grid. From these, contour maps with an interval of 0.2 m to 0.3 m can be prepared. The procedure is adequate for the design of community items.

The survey should however be carried out for the entire chak system. The closing of the benchmarks with reference to the outlet sill levels provided by the Construction Organization is most important. The design should not proceed unless this factor is satisfied. From this survey, contour maps with a contour interval of 0.2 m to 0.3 m should be prepared. However, taking into consideration the requirement of scale for the contour map of the chak and the contour map of the chak system, plotting for these two maps will be separately done as under:

For the map of the chak system the grid levels at 30 m. interval (omitting alternate levels) will be plotted on a scale of 1 : 2000 or 1 : 2500 and the contours drawn with 0.3 m interval. (If the command is big the map of chak system may be prepared to the scale of 1 : 4000 or 1 : 8000 and contours of 0.4 m or 0.6 m interval). For the contour map required for the individual chak, the entire grid levels will be considered (at 15 m interval) and contour map will be prepared with 0.2 m to 0.3 m contour interval to a scale of 1 : 1000 or 1 : 1250.

The above maps should be superimposed on village maps and following aspects be marked on it.

- 1) Alignment of Distributory / Minor / Subminor
- 2) Location of outlets with sill level and other structures on Distributory / Minor / Subminor
- 3) Un command portion
- 4) Gat number wise type of soil
- 5) Ridges, vallies, Nallas, depressions or ponds, hillocks, Goothan, hutments
- 6) Location of existing wells
- 7) Trees and permanent structures.

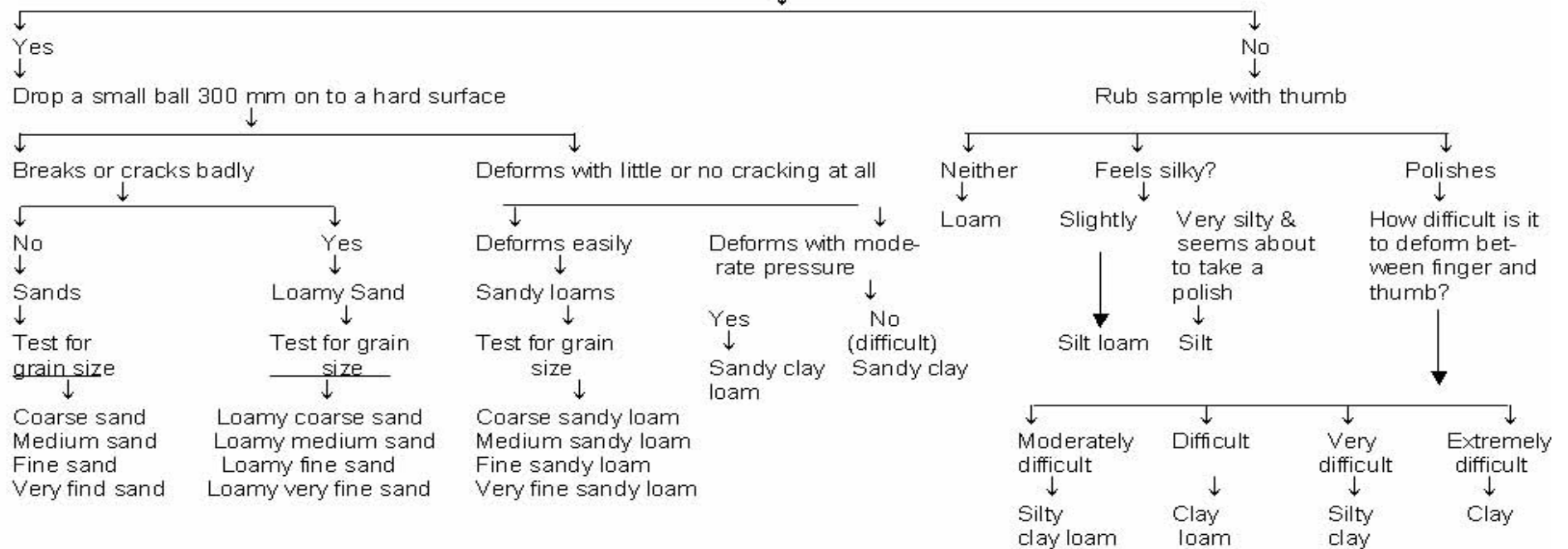
After the survey, a tracing of the contour map of the chak / chak system with the signatures of the surveyor and the plotter and the Agricultural Supervisor / Junior Engineer, thereon should be prepared.

8.3 Survey for Land Forming: The details for this are given in separate Chapter No. 8 on "Land Forming for Irrigation".

REFERENCES:

- Circulars issued on Technical Matters during 1958-63, Government of Maharashtra, I&P Department, 1967
- Manual of Design for On-Farm Development Works, Government of Maharashtra Irrigation Department, November 1982
- On-Farm Development Works including Micro Distribution Network and Land Shaping for Irrigation Water and Land Management Institute (WALMI), National Publication No. 12, December 1996.
- Soils of Maharashtra, Publication No. 54 of National Bureau of Soil Survey (NBSS)

Figure: 2.1 : Systematic procedure for determining the soil textural class of a moist mineral soil
Is it gritty?



CHAPTER - 3

KEY ISSUES IN IMPLEMENTATION OF THE ONFARM DEVELOPMENT WORKS

1.0 Introduction:

The OFD works have been taken up by the Irrigation Department in CAD as well as in selective non-CAD areas since 1980. The Maharashtra Water and Irrigation Commission has stated in its Report (June, 1999) that OFD works have been completed in 1.65 M ha area out of total created potential of 2.942 M ha by June 1995. It has been mentioned in this Report that land development works (Part I & Part II works) need to be expedited for efficient and complete utilization of created irrigation potential. It has been further stated in this Report that canal and distribution system shall be in good, working condition so as to utilize the created irrigation potential as per plan and program. The OFD works are last link in this distribution system. It is, therefore, necessary to address the key issues in planning, design, construction and maintenance of OFD works to overcome the shortfalls and difficulties experienced in irrigation management. The key issues to be attended to, in the approach, at each stage of planning, design, construction and maintenance are inter-related. These key issues based on the experience of various field officers and farmers are explained below,

- (a) To increase utility of OFD works
- (b) Difficulties experienced by the tail end farmers in the chak in getting benefits of OFD works and means to solve the difficulties.
- (c) Ways and means to reduce the cost of OFD works.
- (d) Legal aspects in construction and maintenance of OFD Works.
- (e) OFD works in hilly & high rainfall, command areas like Konkan and Eastern part of Vidarbha.

2.0 To increase utility of OFD works:

To increase the utility of OFD works, it is needless to emphasize that the end user i.e. the farmer should get a feel of usefulness of OFD works so that a confidence and sense of affinity is created in his mind about timely and adequate supplies of water to his farm. To attain this goal, following aspects shall be properly addressed,

- (a) Appropriate location of outlet :
 - i. The location of outlet shall be such that it avoids watercourse in deep cutting. A watercourse in deep cutting creates major problems of blockage of Field Channels due to collapse of side slopes.

- ii. The location of outlet near borrow pit be avoided so as to avoid FC crossing in the beginning because any fault or failure in this crossing hampers further supplies.

(b) Hydraulically efficient chak water delivery layout :

This aspect has been discussed in more details in chapter 5 of this manual.

(c) Level of accuracy in FC alignment and FC bed gradient shall be maintained during construction of OFD works (Field channel and structures thereon) and FC lining. The tolerances specified in this manual shall be adhered to achieve the required level of accuracy.

(d) Appropriate location and sill level of turnout :

Location and sill level of turn out is very important. Hence, it is emphasized that location of turnout shall invariably be decided after interaction with the respective farmer. The location of turnouts shall be decided based on the experience and convenience of concerned farmers to irrigate his fields in one or two seasons. As regards technical aspects of location and sill level of turnout, more details have been discussed in Chapter 5 of this manual.

(e) Timely maintenance and repairs of OFD works:

The responsibility of maintenance and repairs rests with the beneficiaries. The agreement with the Water Users' Associations should have adequate provisions for this aspect. Moreover, separate Act on farmers participation in IWM has also sufficient and adequate provisions in this respect. The irrigation managers shall study these provisions and be on alert to keep the OFD works in good condition by pursuing the respective WUA.

(f) Cost norms for OFD works:

The cost norms for OFD works have to be realistically based on optimum design requirements and latest RSR rates. The cost norms may have to be improved with changes and modifications in RSR each year. If this is not done, the design considerations get disturbed due to adhoc curtailment in OFD works and FC lining, to fit in the outdated cost norms. Secondly, the cost norms for OFD works should be region specific because of large variations in soil, strata and topography in various regions of Maharashtra.

3.0 Difficulties experienced by tail end farmers in the chak in getting benefits of OFD works and means to solve the difficulties:

The tail-end farmers generally do not receive water in appropriate quantity for designated period. This is because of following difficulties,

- (a) The irrigation operation schedule within the chak is not followed scrupulously. The farmers in the upper reach grab major share of the flow-time and water. Hence, the tail end farmers are deprived off their water rights. Sometimes due to unreliable supply of water, farmers take water out of turn due to fear of non-receipt of water.
- (b) Some of the farmers in the upper/middle reach of FC are not able to draw water in sufficient quantity because of faulty location or sill of their turnout. These farmers, therefore, block the FC to raise the water level in order to draw more water in their fields. This illegal practice hampers the supply of irrigation waters to the tail-end farmers and creates nuisance in the chak delivery system.
- (c) The F.C. lengths in the upper reaches are not maintained by respective farmers. Hence, the bed gradient and cross section of F.C. get disturbed. Hence, tail-end farmers do not get water. The tail-end farmers cannot afford to maintain all the F.C. length. They are, therefore, dependent on the wish and will of farmers in the upper reach in the chak delivery system.
- (d) If there are crossings on upstream side of F.C. and if the head-loss due to crossings is not considered in the design of F.C., the water depth immediately d/s of crossing is not sufficient to make a flow through turnouts.

Sometimes, the pipes in the crossings are faultily placed with a reverse bed gradient; hence, the flow on downstream of crossing is not sufficient to supply the appropriate quantity of water in designated time.

- (e) Leakages through F.C. in the upstream reaches also create difficulties for tail-end farmers. Firstly, they do not receive the appropriate quantity of water. Secondly, the leakages through F.C. create a heavy muddled path on farm roads, which makes them difficult to access their farms with farm equipments and cattle.
- (f) In the chak delivery layout, the tail of F.C. is required to be connected to nearby link drain or main drain, so that the excess water through F.C., when the farmers in the upper reaches do not take water, is safely let out. But this facility is generally not provided in the chak delivery system. Hence, the farms at tail-end, at times get flooded, crops are damaged and upper cover of soil is disturbed.
- (g) At some locations at tail-end of the Distributory, the command area is near to a river or major nalla, and the farmers have been irrigating their fields through individual lift-pumps or some other lift irrigation schemes. Such farmers are generally not interested in getting water from irrigation channel because of its uncertainty and other shortfalls. Hence, O.F.D. works in such farms, where lift irrigation is in vogue, become redundant and are not maintained by the tail-end farmers. Such O.F.D. works unattended for a longer time become defunct and when the tail-end farmers feel the need of water through irrigation channel due to shortage of water flow in

river/nalla, such defunct O.F.D. works create difficulties for tail-end farmers.

3.1 Means and Measures to solve the difficulties:

- (a) To overcome the difficulties arising out of shortfalls in the chak delivery system, it is essential that the guidelines elaborated in the Chapter 5 of this manual shall be followed religiously by all concerned responsible for design and construction of O.F.D. works and farmer's participation be enhanced in these activities.
- (b) As regards blocking the field channel and reluctance towards maintenance of FC by farmers in the upper reach of FC, it is necessary to implement positive action as per section 31, 32, 33 of Maharashtra Irrigation Act – 1976, by competent Canal Officer.
- (c) If it is observed that the farmers don't get water because of frequent difficulties in maintaining the watercourse, (i.e. initial length from the outlet to the first turnout) it is necessary that canal officer may take action as per Rules and orders.
- (d) The dispute solving mechanism is also available in Maharashtra Irrigation Act – 1976. The canal officers may make use of suitable provisions to solve the difficulties.

4.0 Ways and means to reduce the cost of O.F.D. Works :

The O.F.D. works consists of two types of works, viz.

- (a) Part – I works : These works include the chak water delivery system, surface drains and field channel protection works.
- (b) Part – II works : These works include the land forming works.

4.1 Steps to reduce the cost of Part – I works :

The major share of cost of construction of Part-I works is the cost of control structures, crossings on water delivery system and the surface drains. These structures are as follows:

- i. Drop or falls.
- ii. Division Boxes
- iii. Road crossings and Nalla crossings
- iv. Turnouts
- v. Flow measuring device

The larger the number of above structures, the higher the cost of Part-I works. These structures are linked to the chak layout and alignment of the field channel and field drains. Hence, if the chak layout and the field channel alignment are thoughtfully designed and laid out, the cost of Part-I works can be reduced considerably. At some locations, even the location of outlets on Distributory / Canal, influences the cost of Part-I works.

Some of important aspects to be considered are listed below :

(A) 'Zero Drop' F.C. gradient:

The F.C. bed is designed in such a way that the bed gradient of field channel follows the natural ground slope, to avoid drop structures and at the same time it is observed that it avoids to generate velocities higher than the permissible velocities in respective soil strata. Drops will be proposed only at appropriate locations, of suitable depth, where velocities are higher than permissible velocities. This has been prescribed in the Chapter 5 of this manual.

(B) 'Zero Division box' F.C. alignment:

The F.C. alignment has to be more or less straight and on the ridge with farmlands on either side of the F.C. to avoid provision and construction of division box. It is true that such situations are very few. But unless this aspect is kept in mind while finalizing chak layout, the number of division boxes cannot be restricted to minimum, because this aspect mostly depends on the chak layout and on the location of outlet in turn.

(C) 'Zero crossing' F.C. alignment :

This is basically dependent on the chak boundaries, the chak layout and the location of the outlet.

(a) A road crossing can be avoided by following means :

- 1) By shifting the location of outlet on d/s of road, if most of the area to be irrigated is on the d/s of road. The marginal area on u/s of the road can be amalgamated in some chak on u/s of the road.
- 2) By limiting the boundaries of the chak to road and amalgamating the area on d/s of road in some chak on d/s of road.

(b) A Nalla crossing can be avoided, if the layout of chak is done after demarcating the natural drainage lines on contour plan

(c) If the outlet on a Distributory or minor is located on a partial cutting-partial banking section, the watercourse for such chaks, starts with a crossing to tide over borrow pit. This type of crossing not only increases the cost of O.F.D. Part-I work, but also becomes a vulnerable point in chak delivery system. Hence, such location of outlet may be avoided as far as possible from the point of view of economy and from the point of view of better utilization of O.F.D. works as well.

(D) Reduce number of turnout structures:

The number of turnout structures also depends on the size of holding. If the size of the single property holding is more than 1 to 1.5 Ha, two or more turnouts are required to be provided for better supply and distribution of water through appropriate equalizers.

Hence, a chak layout with proper combination of size of single property holding in a chak and the number of farmers, the number of turnout structures can be optimized to minimize the cost of Part-I works.

For providing turnout, low cost construction materials, structures and procedures may be adopted.

(E) Eliminate measuring device:

The measuring device is generally treated as an obstruction to flow by farmers. The Parshal flume or cut throat flumes are not socially acceptable because of the constricted flow through narrow throat width and a hump. Secondly, the construction of measuring device is a skilful job. The measuring device functions well only if the dimensions & settings are provided as per design. Due to small size and being at remote place, this is generally not achieved. The functionality of measuring device is, therefore, is doubtful. Hence, it is better to eliminate the measuring device and provide a self-regulated outlet instead of a conventional pipe outlet whenever possible. Baffle distributor (Self Regulated outlet) with standard discharge of 30 lit / sec. have been used in pilot project of dynamic regulation at Majalgaon Project. These are tested by MERI, Nashik and manufactured by mechanical wing of Irrigation Department. These are functioning well. Hence, cost of measuring device may be dispensed with by providing a S.R. outlet.

4.2 Steps to reduce the cost of Part-II works :

The cost of Part-II works i.e. land forming mainly depends on the volume of earth to be moved, which in turn depends on :

- a. The natural farm slopes to be rectified and maximum permissible slope.
- b. The size of compartment.
- c. The crops to be grown, and
- d. The method of irrigation

Considering all these aspects specifications of land forming for reducing cost are incorporated in this manual in Chapter 8 On Land Forming for Irrigation.

To further reduce the burden on farmer, it is suggested that only land smoothening be done initially. The land grading may be achieved in 2 to 3 phases over a period of 5 to 6 years by using local equipments like bullock driven buck-scrapers. If the farmers are educated to adopt contour farming, land grading may be avoided at some locations.

Since the irrigation management is to be handed over to Water User's Associations, the land smoothening, land grading and land leveling may be got done through them at their cost under technical guidance from technical staff of Irrigation Department. The members of Water User's Associations may be educated about contour farming.

The cost of land forming can be eliminated by encouraging the farmers to adopt pressurized irrigation systems like drip and sprinkler. For this, an interface will have to be provided between gravity flow and pressurized irrigation systems.

4.3 To reduce cost of field channel protection works :

These works include field channel lining works. The field channel lining is mainly done to reduce seepage losses and for protection at vulnerable locations on FC alignment like FC length on curves, FC length near drop structures and for portion of FC in banking section.

To economize on cost of these works, the lining may be done on selective lengths of FC. Thus, if the FC alignment is laid out in such a way as to avoid curves, and sections in banking and also minimize drop structures, diversion boxes, the cost of these works can be reduced considerably.

5.0 Legal aspects in construction and maintenance of OFD works:

If the legal aspects about construction and maintenance of OFD works are not known to field officers working in Land Development divisions or working in irrigation management divisions, difficulties are likely to crop up during construction and irrigation management in the chak. Such difficulties may sometimes affect the timely and adequate supplies of water to needy farmers. Hence, the field irrigation engineers should get acquainted with the legal aspects about construction and maintenance of OFD works.

The O.F.D. works are considered to be community items under Land Development Works. The OFD works in irrigation projects are, therefore, implemented under the provisions of "The Bombay Land Improvement Act-1942" (BLIS – 1942). The draft scheme of O.F.D. works prepared under section 4 is published under section 5 (1) of this Act in official Gazette. Under section 5 (2) of this Act, objections, and suggestions in writing are called for, to be submitted to enquiry officer within 21 days from the date of publication of Gazette. The draft scheme is finalized under section 9(1) with due modifications, if the suggestions are received from farmers of the respective area in more than 33% area under consideration. The competent authority then sanctions the scheme and the same is published in the Gazette under section 9(2) of the Act. The section of the BLIS Act 1942 states that such scheme becomes judicially obligatory and any person infringing or opposing

the scheme for implementation is liable for a penalty of Rs. 50/- or one months imprisonment under section 12(A) of this Act. Thus, a legal apparatus is available for implementation of O.F.D. works in BLIS (1942) Act. For the construction, maintenance and repairs of OFD works, there are provisions in the Maharashtra Irrigation Act 1976.

The irrigation officers and the field irrigation engineers should study the above provisions by reading the above-mentioned BLIS Act-1942 and Maharashtra Irrigation Act 1976 in original. The provisions in the separate Act on farmers participation in IWM shall also be studied to revamp the approach in planning, design, construction and maintenance of OFD works, if necessary.

6.0 OFD works in hilly and high rainfall command area

Conventional chak delivery system and allied works with open field channels can not cater the requirements in hilly and high rainfall command areas like Konkan and eastern part of Vidharbha region. The chak delivery system and allied works in such areas may be provided with following alternatives.

- (a) Piped distribution system
- (b) Half round R.C.C. pipes on pedestals.
- (c) Developing an interface in gravity irrigation network to adopt pressurized irrigation (Sprinkler, rain-gun, drips etc.) methods.

An introductory information is included in this manual on above alternatives in chapter 10 on “Non Conventional OFD works “.

REFERENCES:

- Bombay Land Improvement Act – 1942
- Bombay Canal Rules of 1934
- Maharashtra Irrigation Act of 1976
- Manual of design for OFD works, Govt. of Maharashtra, Irrigation Department, Nov. 1982.
- Maharashtra Water and Irrigation Commissions report, June 1999.
- Pipe Distribution system for Irrigation, Report of Indian National Committee on Irrigation and Drainage. (INCID)
- Self Regulated outlets for field channels, MERI Nashik, Technical Report No. HD-I/432,1988.

CHAPTER 4

CHAK LAYOUT AND ALIGNMENT OF FIELD CHANNELS

1.0 Preliminary:

The chak or outlet command is a basic unit for irrigation management in the command of Minor, distributary or any other parent channel. Therefore, establishing layouts of the chaks in the command of a given channel is the first step of the planning process. For this purpose, the contour map of the command of minor or distributary to the scale of 1 : 2000 (1:4000 if command is very big) with contour interval of 0.2 or 0.3 m should be available.

2.0 Layout of Chaks:

Following factors are considered for finalizing chak boundaries and total layout of chaks.

- i) Topography (Ridges, vallies, local depressions, high patches, etc.)
- ii) Maximum permissible area which can be irrigated in peak rotation by a prescribed discharge in a given flow period
- iii) Maximum length of field channel
- iv) The number of farmers to be served
- v) Other factors like village boundary, road/railway lines, etc.

2.1 Topography:

Mark vallies, local depressions, gullies, natural drains, high patches, ponds, gaothans, roads, railway lines, village boundaries etc. in different colours on the contour plan so as to limit the boundary of the Chak to natural drain / village boundary / road / railway lines.

2.2 Maximum Permissible Chak Size:

The chak size plays an important role in the efficient scheduling of irrigation. It is the area served by an outlet. It depends mainly on discharge of the outlet, flow period, crop pattern and peak irrigation water requirements.

The Government of Maharashtra has standardized the capacity of the field channels at 30 litres/sec. Previously, the flow period in most of the projects used to be 12 days in a rotation period of 14 days. Now the flow period of 6 days in a rotation period of 14 days is adopted for chak design.

With the discharge of 30 litres/sec and the flow period of 6 days in a rotation, the only variable factor in determining the chak size is the peak net irrigation requirement.

Net irrigation requirement (NIR) based on modified Penman Method is worked out for crops as per the approved project-cropping pattern. This is generally the NIR at root zone (expressed in mm) considering effective rainfall and the special needs of different crops. Since the water is released at outlet head, the net irrigation requirement at outlet head has to be determined. This can be computed by applying efficiency factors, from field to turnout and from turnout to outlet. The field application efficiency (root zone to the turnout) depends on preparation of land, irrigation methods and the flow rate. It normally varies from 70% to 80%. With the developed lands and good irrigation method, 75% application efficiency can be achieved and may be adopted. The conveyance losses in field channel depend on length of field channel, soil strata, channel condition, type of lining, distribution of fields along the length of the channel which determine running time of each unit lengths of field channel, etc. However, average conveyance efficiency of field channel from the turnout to the out let may be taken as 85%. The efficiency from root zone to outlet is therefore $75\% \times 85\% = 63.75\%$. The efficiency figures can be modified if specific data is available.

The net irrigation requirement for every fortnight of year is calculated for the project crop pattern. Based on this, the master statement of crop water requirement is prepared. The maximum value of the irrigation water requirement is then adopted for the determination of chak size. One such sample calculation is presented in Table 4.1.

As per Table 4.1, Fortnightly Peak Net Irrigation Requirement for the given crop pattern is in the 26th fortnight (17/12 to 31/12) and is = 46610 m³ per 100 ha of I.C.A.

NIR = 46610 m³ for 100 ha of ICA
i.e. 466.10 m³/ha of ICA

Assuming field application efficiency of 75% and average conveyance efficiency of field channel as 85%, the overall efficiency between outlet and root zone works out as $75\% \times 85\% = 63.75\%$ i.e. 0.6375.

$$\therefore \text{NIR at outlet head} = \frac{466.10}{0.6375} = 731 \text{ m}^3$$

Water delivered at outlet
At the rate of 30 lps (108 m³/hr) = 108 m³ x 6 days (flow period) x 24 hrs
= 15552 m³

$$\therefore \text{Chak Size (ha of I.C.A.)} = \frac{15552}{731} = 21.27 \text{ ha}$$

If intensity of irrigation (ICA/CCA) for project under consideration is Say 80% then

$$\text{Chak Size (ha of C.C.A.)} = \frac{21.27}{0.8} = 26.58 \text{ ha.}$$

Maximum chak size for the project is say 25 ha.

2.3 **Length of Field Channel:**

Excessive length of field channel results into more conveyance losses and complaints from tail Enders about non-receipt of desired discharge. Therefore, the maximum length of field channel in one stretch from outlet generally should not be more than 1000 m (1 Km).

2.4 **Number of Farmers:**

In canal irrigation, the water that is supplied at the Government outlet is to be shared equitably by all the beneficiary farmers. This involves understanding and cooperation and therefore the number of beneficiaries has to be reasonably small. Generally 10 to 15 beneficiaries can be organized properly for water sharing. The number of beneficiaries in a chak will depend upon the sizes of the holdings. Where the average size of holding is smaller, the chak size may be adjusted such that the maximum number of beneficiaries should not exceed 30.

2.5 **Other Considerations:**

As far as possible the chak should lie in one village only. Similarly roads, railway lines should be considered while fixing chak boundaries. As far as possible chak boundaries may be restricted upto road/railway line in order to avoid crossings.

Considering above-mentioned factors the boundaries of the chaks be fixed and layout of chaks in the whole command of a given canal be finalized. The cost economics of OFD works should also have bearing while finalizing the chak area and layout.

3.0 **Alignment of Water Courses and Field Channels:**

3.1 After the layout of the chaks is prepared, the locations of the outlets, jointly decided by the concerned Organizations are marked on the contour plan. Following aspects may be considered while finalizing the location of the outlet.

- i) The outlet to be located upstream of drop/fall on parent channel
- ii) The FC should command the area within short distance (Say within 15 m)
- iii) As far as possible it should not cross borrow pit
- iv) To avoid the road crossing on F.C., if possible, the location of the outlet should be taken d/s of the road.

If these locations are not suitable for the layout obtained earlier, changes are made by relocating the outlets and increasing the number where necessary.

3.2 The sill level (of the outlet) should be taken at or near the bed of the minor or distributory, so that the outlet can draw its full discharge of 30 litres/sec. even when the minor is flowing half full. From the sill level, the bed level of the field channel near the outlet is obtained.

3.3 The alignment of the field channel is then marked along high ground so that it can command maximum area. As far as possible, it should be taken along the boundary of a holding so that the field is not artificially divided by the channel. The field channels will be aligned either along the ridge so that irrigation can be done on both sides or along the contour with irrigation only on one side, depending upon topography. The field channel should be marked down to each individual holding. It should be ensured that the turnout can be placed in the holding it serves and near the boundary.

While marking the alignment of the field channel, it should be seen that the channel can command the fields included in the design. For this purpose preferably the water level in the field channel be kept as 15 cm higher than the ground, it is designed to serve.

3.4 A field channel must necessarily tail into a drain (natural or otherwise). In any case F.C. should not be used as a tail of minor or distributory.

3.5 In case, the field channel is being aligned on a sloping ground leaving some area above the field channel as uncommanded, then it is obligatory to provide a catch water drain along-side the field channel on the upstream side. It should terminate in a natural gully.

3.6 The marking of the alignment should be done by the SDO. The locations of the outlets and the alignments of the field channels should then be marked on site and verified by the Agricultural Supervisor/Junior Engineer and also by the SDO (and so certified) before the plans are submitted by SDO to DO for approval. The beneficiaries should also be consulted and their suggestions, if found suitable, may be incorporated. After these are approved, the location of the outlets can be finally informed to the Construction Organization so that the construction can proceed. If required, a joint inspection should be carried out by Executive Engineer of Construction Organization and the Divisional Officer of a Land Development Division. The approval of the Divisional Officer will be accorded on the plan (tracing on cloth/paper), on which locations of outlets and the alignments of field channels are shown, in ink.

REFERENCES:

- Circulars issued on Technical Matters during 1958-63, I&P Department, Government of Maharashtra, 1987
- Manual of design for On-Farm Development Works (First Edition), Irrigation Department, Government of Maharashtra, November 1982.
- On-Farm Development Works including Micro-Distribution Network and Land Shaping for Irrigation, (5th Edition), Water and Land Management Institute (WALMI), Maharashtra, Publication No.12, December 1996.

TABLE 4.1
FORTNIGHTLY (14 days)
NET IRRIGATION REQUIREMENT BY MODIFIED PENMAN METHOD
(for 100 ha. of I.C.A.) of Kukadi Irrigation Project

Sr. No.	Net Irrigation Requirement in mm/m ³ (Kharif Season : 2.7 to 21-10)																(Rabi Season 22-10 to 11-3)									
	% Area in ha		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	1	2	3	4	5				
	4/6	18/6-17/6	27-1/7	16/7	30/7	13/8	27/8-9/9	23/9	24/9-7/10	8/10-21/10	22/10-4/11	5/11-18/11	19/11-2/12	3/12-16/12	17/12-31/12	1/1-14/1	15/2-28/1	29/1-11/2	12/2-25/2	26/2-11/3						
1.	Hy. Jawar (K) (1 July - 5 Oct.)	20	20	--	24	46	69	69	59	58	41	--	--	--	--	--	--	--	--	--	--	--				
2.	Hy. Bajra (1 July - 3 Oct.)	10	10	--	2	12	25	50	66	54	34	29	--	--	--	--	--	--	--	--	--	--				
3.	Rice (Drilled) (16 June - 23 Oct.)	2	2	*13	57	43	51	57	70	61	64	48	67	*10	--	--	--	--	--	--	--	--				
4.	Ground Nut (16 June - 13 Oct.)	15	15	600	1050	3000	6300	8400	9150	9000	7650	7800	6750	--	--	--	--	--	--	--	--	--				
5.	Chillias (16 June - 12 Dec.)	2	2	1560	160	40	320	580	1040	1180	1380	1640	1500	1200	1060	740	60	53	37	740	--	--				
6.	Tomato (16 June - 13 Oct.)	3	3	2340	210	60	540	1200	2160	2340	1980	810	--	--	--	--	--	--	--	--	--	--				
7.	Wheat (1 Nov. - 28 Feb.)	16	16	--	--	--	--	--	--	--	--	*80	19	34	59	74	68	75	12000	10880	11100	1120				
8.	Local Jawar (R) (1 Oct. - 28 Jan.)	15	15	--	--	--	--	--	7	20	48	67	10050	9450	9900	9300	7200	3600	--	--	--	--				
9.	Hy. Jawar (R) (1 Oct. - 28 Jan.)	12	12	--	--	--	--	--	--	9	28	50	61	7320	7560	7920	8280	7800	5400	45	45	--				
10.	Jawar (Ratoon) (16 Oct. - 23 Jan.)	2	2	--	--	--	--	--	--	--	--	12	33	54	66	70	52	27	27	27	27	--				
11.	Peas/Gram (16 Oct. - 23 Jan.)	5	5	--	--	--	--	--	--	--	--	9	22	33	54	68	76	65	44	--	--	--				
12.	Onion (16 Oct. - 12 Feb.)	2	2	--	--	--	--	--	--	--	83	21	560	880	1200	1380	1220	1300	65	69	5	--				
13.	Potato (16 Oct. - 27 Jan.)	3	3	--	--	--	--	--	--	--	82	19	24	40	60	75	65	70	4	4	120	--				
Total (m ³)		4769	2760	5160	15480	25520	34150	32940	28280	30700	33870	34440	29490	36390	44300	46610	40100	30650	13340	8260	1120					

- Figures in the numeration indicate Qty. in m³ Peak Demand is in the 26th Fortnight (17-12 to 31-12) i.e. (46610 m³ / 100 ha. of I.C.A.)

The crop pattern of this project does not contain any crops growing in Hot Weather season.

viz. 1 - 3 to 30 - 6.

CHAPTER – 5

CHAK WATER DELIVERY SYSTEM

1.0 General:

Assured and timely irrigation water supply to each farm is the basic need for maximizing the agricultural production per unit area of irrigated land in command area. Properly designed and constructed water delivery system only can function efficiently and help to achieve above target. The system should be such that it will supply adequate water efficiently even at peak demand period upto farthest and highest location of each individual farm in command area under the outlet. The system should also be economical.

2.0 Elements of chak water delivery system:

Chak is the area under outlet. Following are the elements of the delivery system.

- 1) Channel for conveyance of water.
- 2) Control structures.
- 3) Crossings.

Channels convey water from outlet to farm head. Control structures control water distribution and velocities. Crossings are for transportation facilities.

3.0 Channels for conveyance include watercourse and field channel upto farm gate. Equalizer is channel within the farm for internal distribution by the farmer. Field channels convey water from outlet to each farm gate. Watercourse is initial part of field channel near outlet which is dead channel not serving command area. The chak water delivery system (excluding the watercourse and equalizers) is executed accordance with the provisions of the Bombay Land Improvement Scheme Act – 1942.

4.0 Planning & Design of Field Channel:

Field channels form the tertiary distribution network in the canal system. These are the last link in the water delivery system of an irrigation network. The planning and design of field channels are, therefore, key issues, which determine the success of an irrigation project. Since the reliability of water supply and credibility of irrigation engineers is dependent on these issue, it is necessary to attend to planning and design of field channels, carefully and judiciously.

4.1 Data and maps for planning:

This aspect has been covered in general in chapter-2, “Survey and Investigations” of this manual.

For planning of field channels in particular, following data and maps are necessary:

- a) Contour maps of chak to the scale of at least 1:1000 to 1:1250 with contours having an interval of 0.2m to 0.3m. This map shall also

show gut numbers and the field boundaries of gut numbers. The natural drains and Govt. nallas occurring within the chak shall also be marked on this map.

- b) Statement showing names of beneficiaries and their gut numbers with respective ownership area.
- c) Type of soil in chak command, as assessed in soil survey maps prepared by D.I.R.D., Pune. If these maps are not available type of soil shall be decided by taking trial pits.

4.1.1 Field verification of field channel alignment:

Layout and alignment of the field channel network within the chak is obtained as already described in Chapter-4, "Chak layout and alignment of field channels." This layout and alignment of the field channels shall be verified on the field, before detailed survey and actual design of field channels is taken up in hand. This is necessary to accommodate the changes in ownership or division of ownership etc. The field verification of field channel layout helps to modify the alignment to avoid fruit bearing and any other trees or newly dug wells etc. on the F. C. alignment. Secondly, F. C. alignment may also be discussed with beneficiaries / members and office bearers of Water Users' Association related to the chak. This will be in line with participatory irrigation management and minimize the divergent views taken by beneficiaries during actual construction / taking over the area for management by the W.U.A.

4.1.2 Detailed survey along the alignment of F.C.:

Before the actual design of field channels is taken up in hand, the longitudinal section is run along the alignment recording spot levels at 30m interval. Cross section across the alignment may be taken at 60m interval and at the location of turnouts. The cross section may extend adequately on either side to judge the sill levels of turnouts, with respect to area it has to serve. The L section for each segment of field channel is surveyed separately, with appropriate survey equipments.

Trial pits, if necessary be taken along the alignment of F.C. to access the soil variation and depth of black cotton soils.

4.2 Design of field channels:

The design of field channels envisages design of following three aspects,

- a) Discharge
- b) Cross section
- c) Bed gradient

4.2.1 Design discharge of field channel:

The design prescriptions for the discharge of field channel varies from State to State. The planning commission has prescribed a range of 30 to 70 lit/sec depending upon the type of soil and crops to be served. The Govt. of Maharashtra in Irrigation Department has prescribed design discharge for field channel to be 30 lit/sec vide Govt. circular CDA-1087/1553/209/87-CAD (LD&Engg) dt. 12th January 1988.

4.2.2 Cross section of field channel:

A trapezoidal cross section of field channel is most suitable for unlined field channels. The design parameters to design a trapezoidal cross section for unlined field channel are as follows:

- a) Bed width (B),
- b) Side Slope (Z:1, Horizontal : Vertical)
- c) Rugosity coefficient (N)
- d) Free board (FB)
- e) Top width in banking (T)

Typical cross section of unlined field channel is shown in fig. 5.1.

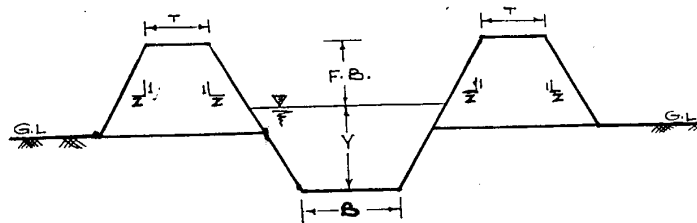


Fig. 5.1

Typical trapezoidal cross section of unlined field channel.

a) Bed width (B):

The bed width of field channel governs the total cross sectional area of field channel to be constructed i.e. it governs the earthwork quantities. It also governs the depth of water flow in the field channel i.e. it governs the driving head at turnout and also the velocity of flow in the field channel. Thus, this is an important dimension from economic as well as hydraulic design point of view. Minimum bed width of 30cms shall be provided in unlined field channel, which caters above requirements. But in very flat topography, this can be increased.

b) Side slope (Z:1, Horizontal : Vertical)

The side slopes for the unlined field channel cross section are designed according to structural stability of soils through which field channel passes. The recommended side slopes in accordance with type of soil are given in Table 5.1.

Table 5.1
Side slopes recommended for unlined field channels in different soils.

Sr. No.	Type of soil	Side slope (Horizontal : Vertical)
1.	Fine Texture Soil (Black cotton soil)	2½ : 1
2.	Medium Texture Soil (Clay loam)	1½ : 1
3.	Coarse Texture soil and soft murum	1½ : 1
4.	Hard Murum	1 : 1

c) Rugosity coefficient (N):

Rugosity coefficient (N) is characteristic of the condition and type of contact surface. For unlined field channels, recommended values of rugosity coefficient (N) are given in Table 5.2.

Table 5.2
Recommended values of N for field channels

Sr. No.	Type of surface	Recommended values of rugosity coefficient (N)
1	Earthen channel	0.04
2	Earthen channel with grass soddling	0.04
3	Rock cuts, Hard murum	0.04
4	UCR masonry lining OR Brick masonry lining	0.03
5	RCC half round pipe lining	0.022

d) Free board (FB):

Free board is a vertical distance between full supply depth (Y) and the top of retaining banks for field channel. This is necessary for preventing overtopping of banks under unprecedented conditions.

For field channel in banking, the minimum free board of 30cms should be kept. For field channels in cutting, the minimum free board shall be about 15 cms to 20 cms, lesser free board may be adopted for field channels in cutting in murum. In case of field channels with R.C.C. half round pipe lining / UCR masonry lining minimum free board shall be 10 cms to 15cms.

e) Top width of section in banking (T):

The field channel cross section may be in full banking or in partial banking – partial cutting. The top width of banking section in such cases may be minimum 0.3cms and may increase upto 0.45cms in accordance with height of banking. Since, the seepage losses through banking are more, the height of banking may not be more than 1.0m in any case.

4.2.3 Hydraulic design of field channels:

The field channels are designed as unlined, open channels to have a uniform flow. The hydraulic design of field channel is an iterative process to arrive at design discharge with an appropriate bed gradient which generates permissible, non erodible velocity and results in minimum requirement of drop/falls structures. To determine the bed gradient to suit these requirements, is the key issue in the hydraulic design of field channel.

The bed gradient (S) of field channel is the ratio of its vertical drop (H) for a length (L) of channel.

$$S = \frac{H}{L}$$

The gradient for each segment of field channel is designed separately. The gradient of field channel should give non-errodible velocity and adequate depth of water to provide sufficient driving head at each turnout to serve maximum area of every farm in the command with minimum land shaping.

The Govt. of Maharashtra in Irrigation Department has prescribed vide even no. circular dt. 12th January 1988, that maximum permissible gradient consistent with the maximum permissible velocities, shall be adopted wherever required so that the number of drop structures is minimized. To minimize the number of drop structures or falls, ground slope be adopted in the first trial as bed gradient. To obtain the best fit bed gradient for the given segment of field channel, following points are adhered to,

- (i) Non-errodiable velocity:
The velocity in the unlined field channel has to be non-errodiable. Hence, the permissible velocities have been recommended in the Table 5.3 for design purposes.

Table 5.3
Permissible velocities in unlined channels in different soils

Sr. No.	Type of Soil	Permissible velocity (M/sec.)
1.	Silt	0.45
2.	Black cotton soil (Fine texture soils)	0.5
3.	Clay loam	0.65
4.	Soft murum	0.8
5.	Grass sodded section	0.9
6.	Hard murum	1.0

- (ii) Depth of water flow:

The gradient governs the depth of water-flow in the field channel and the depth of water-flow in the field channel near turnout with reference to highest ground level in the farm governs the driving head for efficient water distribution through turnout. Hence, the field channel bed gradient should be such that it would evolve a elevation of field channel elevation near turnout to get a minimum driving head of 15cms.

4.2.3.1 The design process:

The commonly accepted formula for the hydraulic design of an open channel is Manning's formula as given below:

$$V = \frac{R^{\frac{2}{3}} S^{\frac{1}{2}}}{N} \text{ M/sec.}$$

Where,

V = Velocity of flow (M/sec.)

R = hydraulic mean depth = $\frac{A}{P}$ m.

A = Cross sectional area of water flow (m²).

P = Wetted perimeter (m)

S = Bed Gradient

N = Rugosity of coefficient

The typical trapezoidal cross section of unlined field channel is shown in fig. 5.1 The dimensions are decided in accordance with the discussions in 4.2.2.

For the first trial,

1. Assume the natural ground slope along the F C alignment, to be the bed gradient (S) of field channel in that segment, and

2. Assume full supply depth of flow = Y meters.

The cross sectional parameters in the Manning's formula are as below:

B = Bed width of field channel.

Y = Full supply depth

Z = Side slope of trapezoidal cross section of field channel.

A = Wetted cross section area = $(B + Z * Y) * Y$

P = Wetted perimeter = $B + 2 * Y * \sqrt{1 + Z^2}$

R = hydraulic mean depth = $\frac{A}{P}$ m.

N = Rugosity of coefficient

S = Bed gradient of field channel

= the natural ground slope in that segment (In the first instance of trial)

Then, using Manning's formula,

$$V = \text{velocity of flow} = \frac{1}{N} R^{\frac{2}{3}} S^{\frac{1}{2}} \text{ m/sec.}$$

Find out Q = A × V cumecs.

This trial would be successful & finally accepted for design if,

- a. Q is nearly equal to 0.03 cumecs.
- b. V is within permissible, non-erodible range of velocity for soil type specified in Table 5.3
- c. Y, the full supply depth of flow near turnout is at-least 15cms higher than the ground level in the command of respective turnout. If there is no turnout to be served in the field channel segment, this criteria may be relaxed.

If any of these requirements is not fulfilled, next trial with appropriate depth of flow and bed gradient is conducted as above till the hydraulic and structural requirements of field channel design are satisfied.

The tables for design of field channel section for different values of rugosity coefficient, side slopes and bed slopes are

given in Table 1 to 3 in Annexure 5.1. These tables may be used as guidelines to design the field channel to suit the actual field conditions.

4.2.4 Longitudinal section of field channel:

The longitudinal section of field channel is finalized as given below. This will facilitate minimum drops/fall or zero drops which will reduce the cost of structure.

1. Plot the ground profile of field channel (main or branch) on L-Section sheet.
2. Mark turnout positions on the L-Section.
3. Divide the whole length of field channel into different reaches/segments having more or less uniform ground slope and workout respective ground slopes.
4. Mark outlet sill level of outlet at the start of FC / WC.
5. Decide bed gradient to be provided to FC / WC. As far as possible natural ground slope be adopted as bed gradient to minimize number of drops / falls. However, care should be taken that bed gradient should neither result in the velocity more than the permissible, nor it should result into full supply depth less than 15cm if turnout is to be served at that chainage. If there is no turnout in a particular reach and strata is hard, bed gradient as steeper as possible (limiting it to natural ground slope) may be adopted even if the full supply depth in F.C. is less than 15cm provided the velocity is within permissible limits.
6. Too many changes in slopes are avoided to ease of construction and better hydraulic conditions.
7. Start marking F.C. bed profile considering designed bed gradient. If the bed gradient is flatter than the ground slope fall / drops will have to be proposed. The location of fall and its depth (bed fall) may be decided considering following guidelines:
 - a. Fall / drop should not be located U/s of turnouts.
 - b. The bed level U/s of fall / drop should at least be 10cm in cutting.
 - c. The depth of drop i.e. bed fall will be governed by the requirement of downstream turnout. Therefore considering downstream turnout, mark the bed profile from downstream turnout going upstream. If necessary more than one fall will have to be provided to avoid excessive height of drop. (i.e. 1 m).
 - d. Standardized fall / drop designs are available. Where actual bed fall required is different than standard design, the fall as per actual requirement be provided, however the design of next higher fall be adopted (e.g. if fall of 0.4m is necessary, provide 0.4m drop, but the design of 0.45m drop be adopted)
 - e. Try to provide a sloping bed drop (rapid) wherever F.C. is passing through hard strata like hard murum or soft rock etc. and no turnout is to be served.

4.2.5 Construction of Field Channels:

The construction of field channel envisages following aspects:

- a) Period of construction
- b) Mark-out for construction
- c) Quality of construction.

a) Period of Construction:-

- i) The construction of field channels gain utility when these are constructed just ahead of first arrival of canal water. If there is a wide gap of time between construction of field channels and their actual use, the field channels and structures thereon get deteriorated due to non-use. Hence it is important to commence the construction of field channels where /there is immediate need. According to Govt. Circular (Marathi) No. CDA 1002/(91/2000) CAD(Works) dated 23rd April 2002, the work of Field Channel should be carried out only after the completion of irrigation network upstream of outlet and water is made available for irrigation.
- ii) The construction of field channels are required to be taken-up in hand when the farms are fallow. This facilitates the easy approach to site and transportation of construction materials and equipments without damaging the crops. The interference by construction labour in the crops is also avoided. Due to less farming activities, construction labour is locally available at optimum rates. The most favourable period of construction is generally from 15th February to 15th June.

b) Mark-out for construction:

- (i) To give mark-out for construction is to translate the design onto ground. Hence, this needs to be done with accuracy and judgment. Field channel alignment should not be given without using appropriate surveying equipments. Eyesight judgments lead to serious mistakes, and may result in reverse slope to field channels, which ultimately disturbs of functioning of F.C. Field Channel alignment and field channel bed elevations should necessarily be recorded in the field book and these should form the basic measurements for earthwork calculations.
- (ii) The actual sill level of outlet is cross checked with the outlet sill level adopted for design of watercourse and further field

channel lengths, before further bed elevations of field channel are given. Reconciliation of these levels should be done before giving mark-out for field channel. The outlet sill level starting point for giving mark-out for watercourse, field channels and structures on field channels.

- (iii) F.C. section and bed gradient is designed for straight F.C. alignment. Hence, right angle turn to F.C. may be avoided. Proper curvature be given at such locations.
- (iv) In case of field channels running parallel to main canal where natural ground slope is very flat, giving markout with level for field channel bed elevation as per designed gradient is very important. If this is not done, F.C. with constant depth of execution in such reaches gives nearly zero slope which causes overtopping due to inadequate capacity.
- (v) In case of control structures like division boxes and falls, sill levels of these structures be given with appropriate leveling instrument so that full capacity discharge is not obstructed or reduced, any where in the chak delivery system.

c) Quality of Construction:

To maintain the quality of field channel construction irrigation engineer has two aims to be achieved for field channels.:

- (a) Better hydraulic functioning of field channel.
- (b) Structural safety for field channel.

(a) Better hydraulic functioning for field channel.

To attend better hydraulic functioning of field channels, it is necessary to give the accurate markout as per design and follow the same during construction with proper vigilance.

The following tolerances may be accepted in case of construction of field channel:

Departure from designed alignment:

20 mm on straight section

50 mm on tangents

100 mm on curves

- * Departure from designed gradient: 20mm
- * In case of drops, division boxes, turnouts, crossings, the tolerance can be ± 20 mm in elevation.
- * In case of measuring devices, the tolerance can be ± 5 mm in elevation and ± 5 mm in dimension.

b) Structural safety of Field Channel:

To attain structural safety, some of the important measures are as given below:

- * The earthwork of field channel should be well compacted. Shrinkage allowance of about 25% in Black cotton soils and 15% in other soils be given for bank work. This means that section in banking should be constructed with extra dimensions in specified percentage as above measurements be recorded as per design and amount of earthwork in banking shall be deducted in payment in above specified percentages, which shall be released after passing of one rainy season or six months (5 to 6 irrigation rotations) in use for irrigation.
- * For high banks, fill and cut method may be adopted if suitable compacting equipment is available and approach to site for this equipment is available.
- * In case of contour alignment and in side long ground, drainage arrangement for rain water in the form of catch water drain or pipe crossing be provided.
- * Murum casing should be provided for field channel in black cotton soils, wherever possible.
- * All masonry junctions should be adequately covered by proper earthwork and stone pitching.
- * Proper fluming and widening of field channels at entry and exit of water at each structure with stone pitching needs to be done. Profile walls at the end of such pitching is necessary.
- * For performance testing of Part-I OFD Works, 10% of payment at each bill shall be kept in deposit, which shall be released after satisfactory test performance.

5 Structures on Field Channel:

The structures on field channel include measuring device, drop/falls, Diversion Boxes, Turnouts, Road crossing, etc.

The design, construction and other aspects of these structures except flow measuring devices are discussed below. The details of flow measuring devices are given in separate Chapter No.6 titled as "Flow Measuring Devices".

5.1 Outlet:

Although outlet provided at the head of WC/FC does not form a part of OFD Works, however in order to get reliable supply of water to chak system, constant discharge outlet called Self Regulated Outlet (SR outlet) developed by MERI, Nashik is proposed to be used at new locations instead of presently used pipe outlet. However the existing conventional pipe outlets need not be replaced immediately. The design and construction details of this type of outlet is included here for the benefit of construction as well as Command Area Development organization.

Self-Regulated (SR) Outlet:

The presently used pipe outlet is of non-modular type, the discharge through which varies to great extent with the small variation in the driving head. This problem was referred to MERI, Nashik by field officers for developing suitable outlet which will pass almost constant discharge under fluctuating water level within a

certain range (i.e. modular range). MERI, Nashik after studying and conducting model studies recommended to use "double baffle self regulated outlet" (based on Neyrtec module, France). The details of this study are available in MERI's Technical Report No. HD-1/432. The working details of double baffle self-regulated outlet (with U/s baffle modified and crest of weir 7.5 cm above CBL) are given in Figure No.5.2 and 5.3. Some salient features of this type of outlet are as given below.

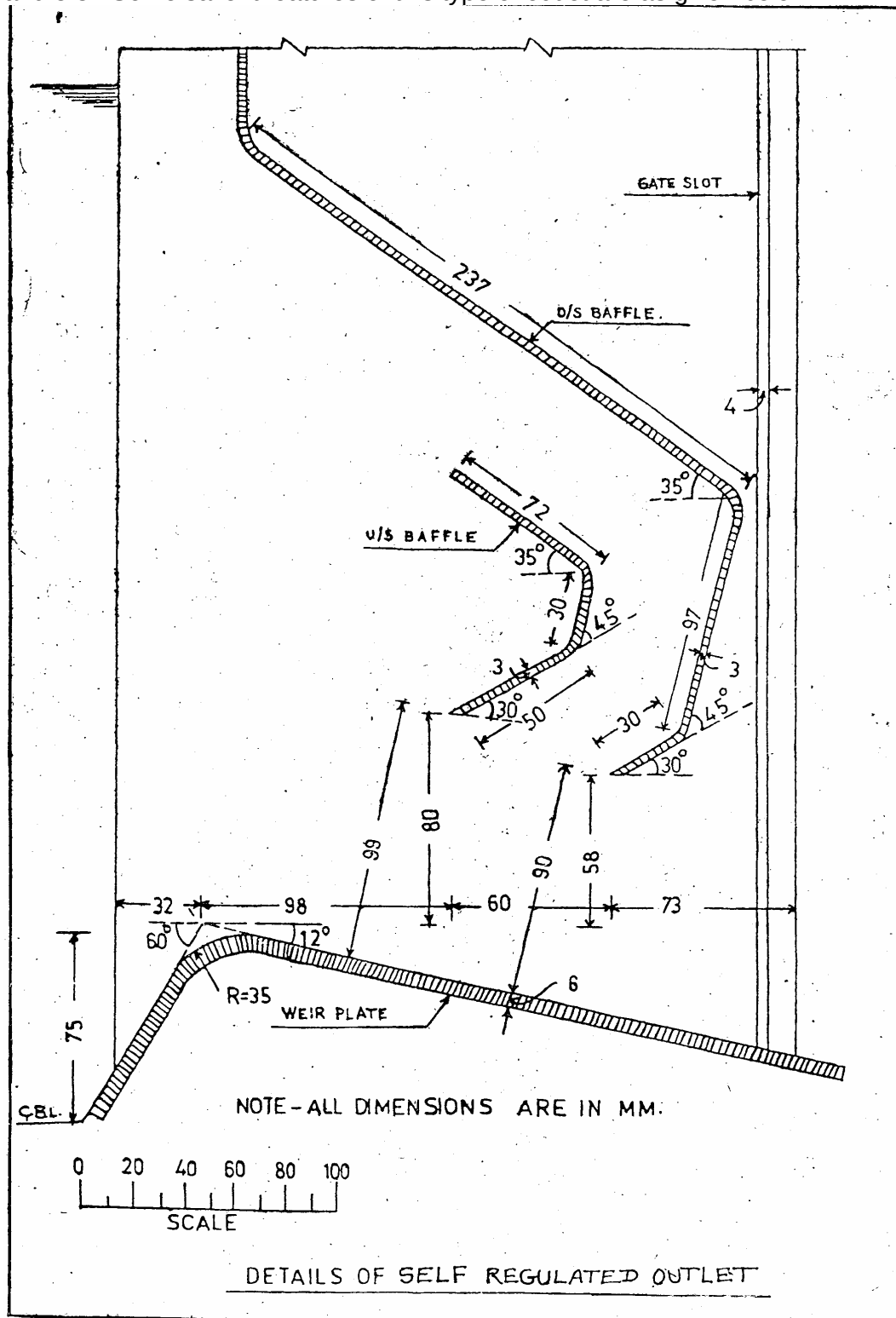
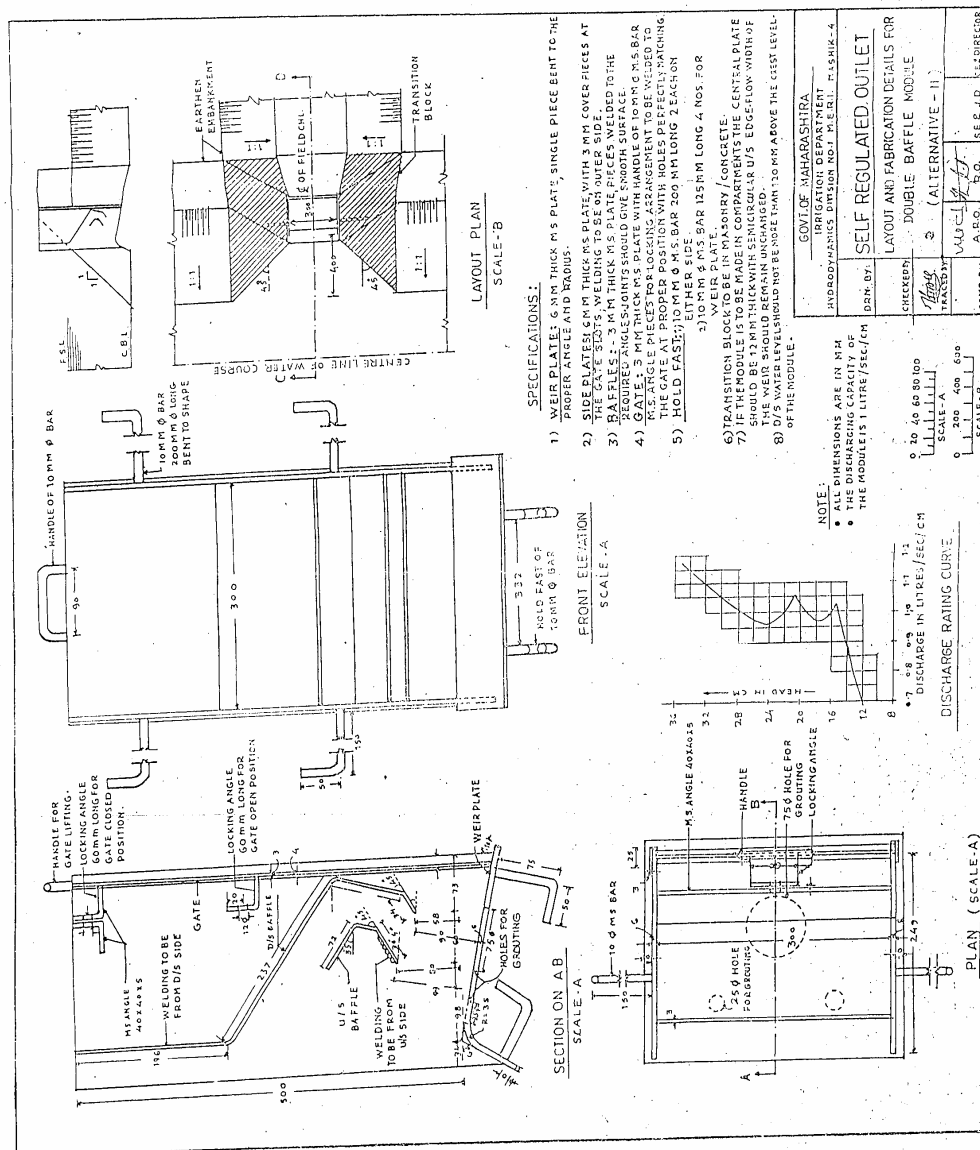


FIGURE No. 5.2



- Discharge capacity 1 lit/sec per cm width of outlet
- Minimum height of weir crest above CBL i.e. sill height is 7.5 cm.
- Minimum head over the crest to pass 30 lit/sec. discharge is 13.9 cm.
- Maximum head over the crest for 10% variation in the discharge is 32 cm.
- Allowable fluctuation in water level is 18.1 cm (modular range for 10% variation in discharge) i.e. total depth in parent channel varying from 21.4 cm to 39.5 cm.

- vi) 30 cm width of outlet giving 30-lit/sec discharge can be divided into suitable compartments by a separating pier. This will permit flexibility in letting out discharge into the field channel as per seasonal requirements.
- vii) The study of effect of down stream submergence due to higher water levels in the offtaking channel shows that upto drowning head (submergence) of 8 cm (i.e. downstream water level is 8 cm above the crest of the outlet), discharge capacity of the outlet remains unaffected. For 10 cm drowning head the discharge reduction is about 5%. However, it is better to ensure free flow condition on the downstream side of the outlet in order to ensure correct discharge.
- viii) The outlet has a sliding gate, which opens the outlet fully or closes completely. Condition of partial opening of gate does not exist.
- ix) It may not be necessary to install flow measuring device in the field channel downstream of this type of outlet as discharging capacity of the same is almost constant. It will save the cost of measuring device.

The detailed field installation instructions are given in MERI's report. It is recommended that henceforth for the new as well as channels under construction having full supply depth upto 40 cm, this type of self regulated outlet be used. Of course, it can also be used in the channels having full supply depth more than 40 cm provided crest level of the outlet shall be so adjusted that the head over the outlet weir crest does not go beyond 32 cm and water level fluctuations are within the modular range. For existing channels, if it is necessary to replace the existing outlets, they should be replaced by this type of self-regulated outlet. Before installing outlets to the canals deeper than 40 cms supply depth, it is necessary to confirm that the water level fluctuations fall within the modular limits. This aspect needs to be examined especially for the lean rotations or during concluding phase of rotation, when canal tends to carry low discharges resulting into low water levels.

5.2 Drop or Falls:

The important structure on the field channel is a drop, or a fall. As has been explained earlier, the field channel gradient should follow the natural slope of the land, to have minimum number of drop structures. However, many a times the natural slope of the lands is steeper than the allowable steepest gradients in field channels. In such cases, the gradients have to be flattened by providing small vertical drops on channels.

In the vertical drop, water falls through a certain height and potential energy is converted into kinetic energy, thus resulting in a high velocity downstream. This high velocity is likely to cause erosion and damage to the channel downstream. It is therefore necessary to dissipate the extra energy and ensure that the velocity at the end of structure is reduced to non-erodible velocity. Various types of fall structures, developed mostly on model studies, are available. Since these structures are usually small structures but large in numbers, individual design is not practically feasible. The type designs are, therefore, used.

The drops in the field channels are basically similar to those on the distributory or main canal and their functioning is the same. The only difference is

that these structures are small in size but large in numbers and hence their construction has to be simpler. The drop basically consists of three components:

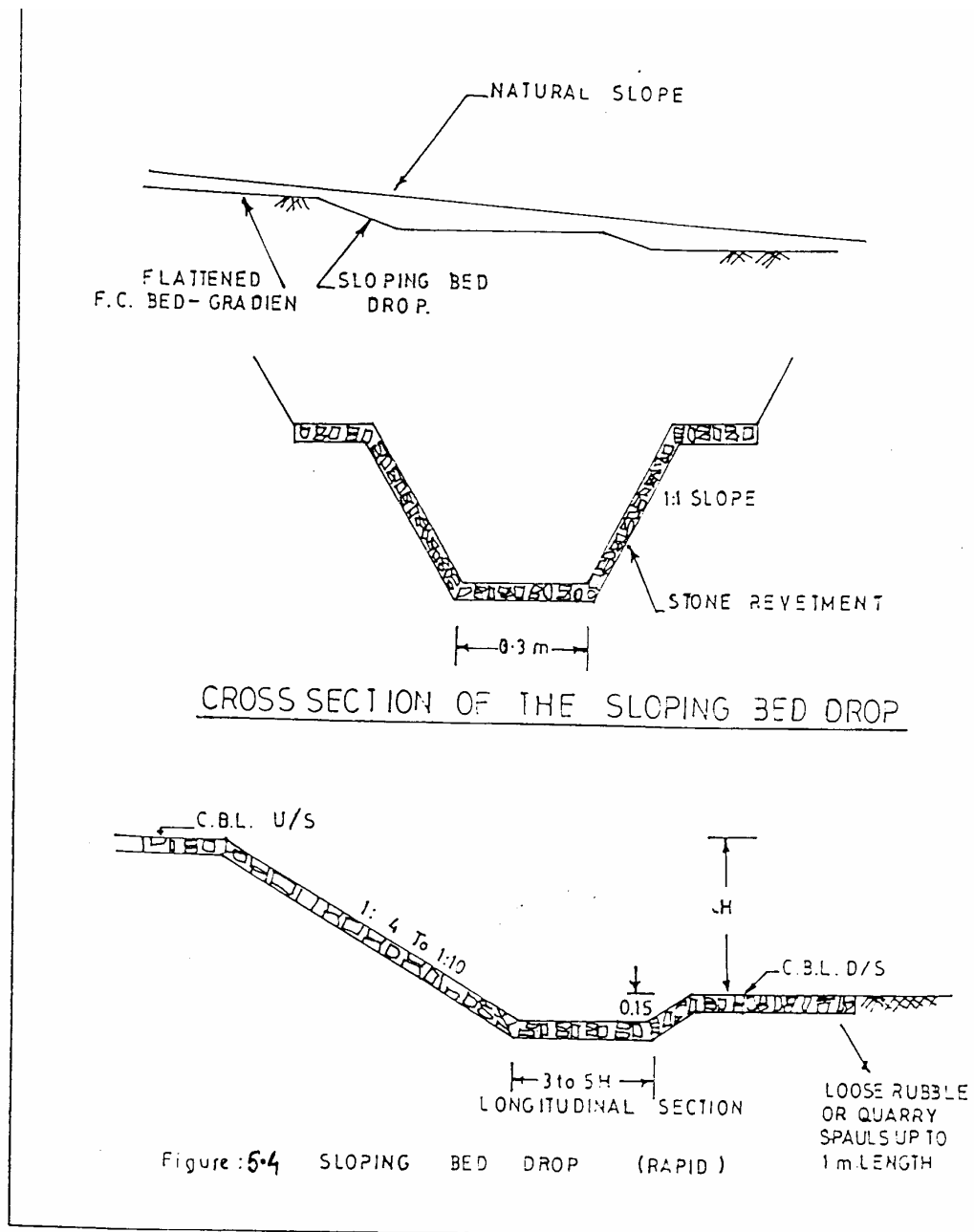
- Cut-off walls, long and deep enough to prevent leakage and outflanking of channel flow
- an opening in the channel, and
- a stilling basin with some sort of end sill.

All the type designs in use are basically combinations of these three, with variations in dimensions of each component.

The conventional type designs are described below:

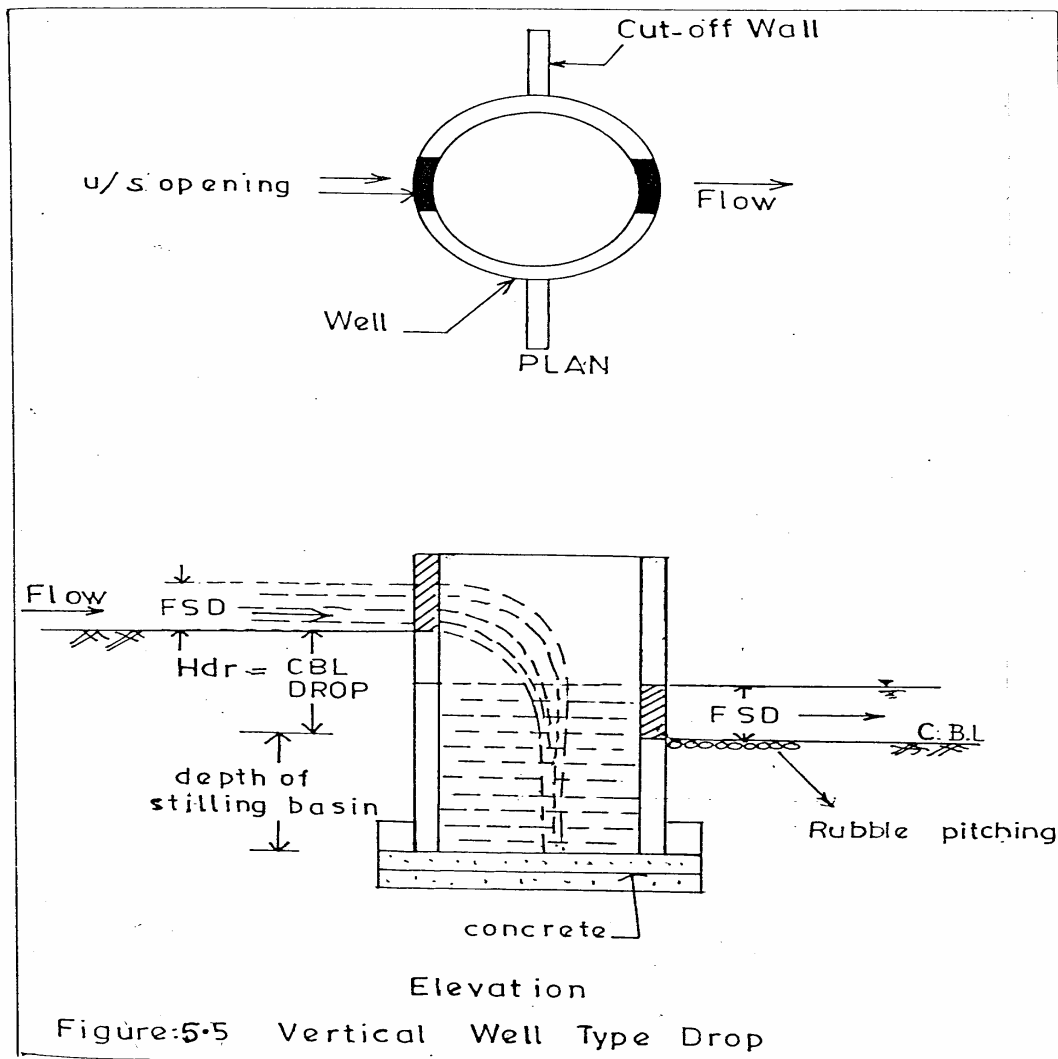
(a) Sloping Bed Drop (rapid):

The sloping bed drop is one of the low cost designs. It can be used only where good hard strata is available, it can be used upto 1 m drop height. Moreover, the channel has to be in cutting. The sketch in Figure-5.4 explains the details. This structure can be constructed with RCC half round 450 mm diameter pipes laid on sloping ground with energy dissipation arrangement at the end.



(b) Vertical Well Type Drop:

Another low cost structure is the vertical well type drop. It consists of a vertical well with a concrete bottom and two openings. One opening in the well at a higher level is on the upstream side and allows the water in the channel into the well. The second opening is at the downstream and allows water into the downstream channel from the well. The bottom of the two openings are at the bed levels of the upstream channel and the downstream channel respectively. The bed level of the well is at a lower level than the downstream opening. The portion of the well between the sill level of the downstream opening and the bed level of the well acts as a stilling basin for dissipation of the energy. A cut-off wall is also provided to arrest the leakage or bypassing (out-flanking) of the water. A schematic arrangement is shown in Figure-5.5. The length of cut-off wall should be adequate to eliminate out flanking.



Wells have been tried with steel barrels, R.C.C. spun pipes and masonry, it is experienced that the R.C.C. spun pipes serve well. They can be procured very early in bulk quantity and erected on site. They are cheaper than masonry and equally sturdy. However, if the selected diameter of the well is different from standard pipe dimensions, masonry well can be used. RCC hume pipe of 600 mm to 800 mm diameter of required depth attached with horizontal RCC hume pipe of 300 mm diameter at U/s and D/s end embedded in UCR masonry head wall can be used as a fall. This type of pipe fall can be used as field road crossing also.

The opening should be equal to the width of the channel. The height of the opening should be about 1.5 times the depth of water in the channel. The diameter of the well has to be carefully selected, so that energy dissipation is satisfactory. The diameter can be selected from,

$$V = \frac{\text{Hdr} \times Q}{150}$$

where V = the volume of the stilling basin in m³

Hdr = Height of drop in m.

(i.e. the difference between the sill level of upstream and downstream)

Q = discharge of the channel in litres per second.

Once the volume of the stilling basin is determined, the height of the stilling basin and the diameter of the well can be computed by selecting one parameter and calculating the other. The height of the stilling basin should not be less than half the height of the drop. The above formula gives the minimum value of the volume but a slightly greater volume is always welcome.

(c) Vertical Rectangular Drop:

A commonly used type of drop is the vertical rectangular drop. At the inlet there is a vertical wall over which water falls from a higher level to a lower level in a vertical rectangular well.

At the downstream, the wall of the well is dwarf. The water forms a pool in the stilling basin of the well and flows over the dwarf wall in the downstream channel. The bed level of downstream channel coincides with the top of the dwarf wall. The general arrangement is illustrated in Figure-5.6 to 5.8.

TYPE DESIGN OF B.B. MASONRY DROP 0.30 M. FOR F.S.D. 0.20 M.

5/1

SCALE 1=20 cm.

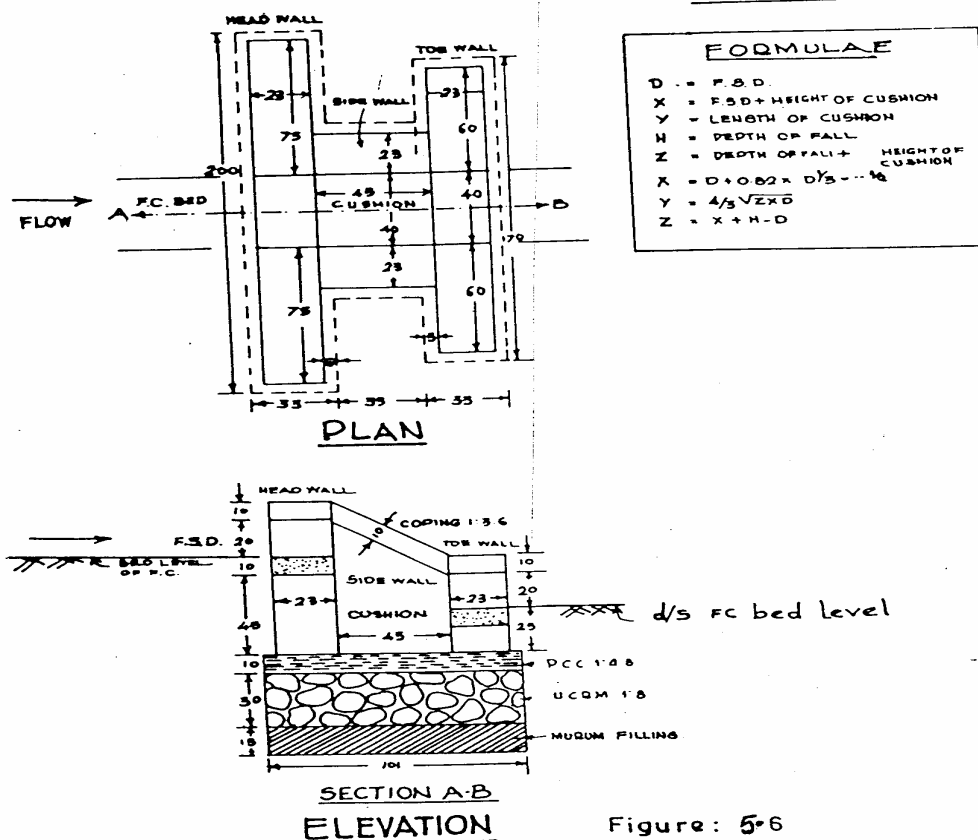
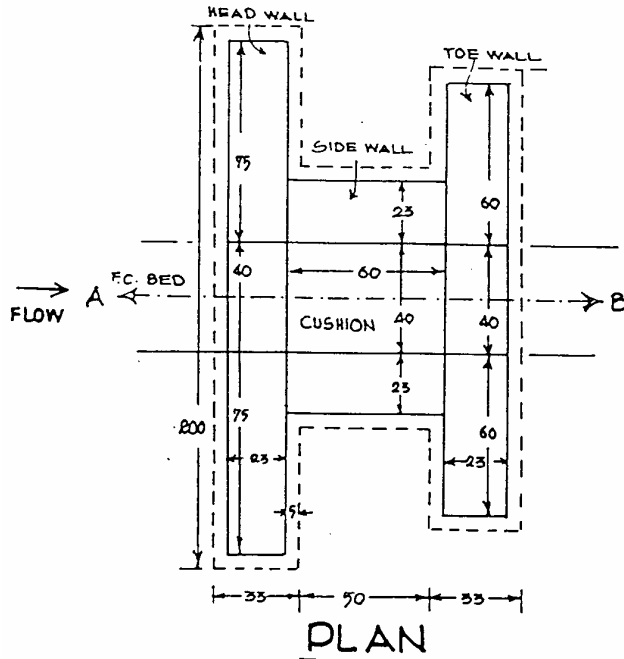


Figure: 5.6

TYPE DESIGN OF B.B. MASONRY DROP 0.60 M.
FOR F.S.D. 0.20 M.
5/2

SCALE 1 = 20 cm.



FORMULAE

- D = F.S.D.
 X = F.S.D. + HEIGHT OF CUSHION
 Y = LENGTH OF CUSHION
 H = DEPTH OF FALL
 Z = DEPTH OF FALL + HEIGHT OF CUSHION
 $X = D + 0.82 \times D^{1/2} \times H^{1/2}$
 $Y = \frac{4}{3} \sqrt{Z \times D}$
 $Z = X + H - D$

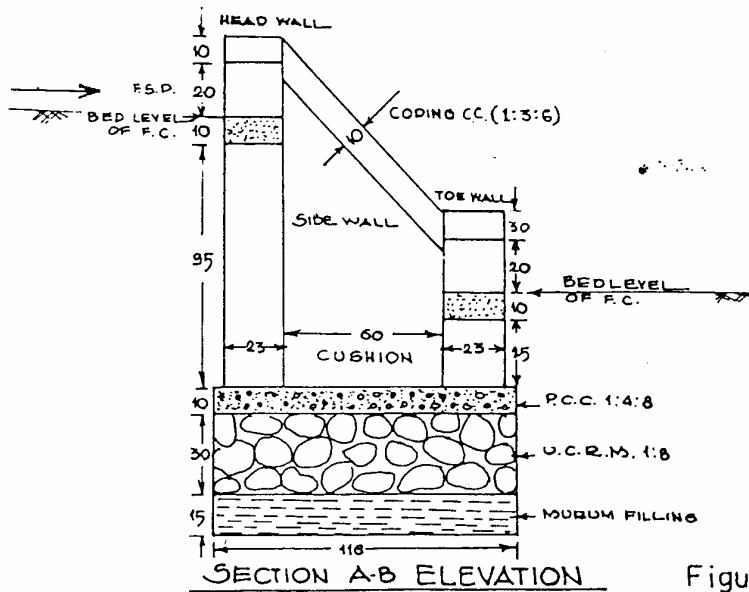
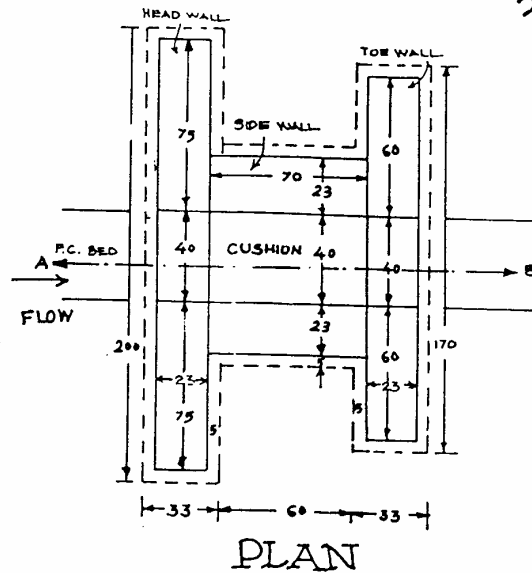


Figure: 5.7

**TYPE DESIGN OF B.B MASONRY DROP 0.90 M.
FOR F.S.D. 0.20 M.**

5/3

SCALE 1 = 20 CM.



FORMULAE	
D	= F.S.D.
X	= F.S.D. HEIGHT OF CUSHION
Y	= LENGTH OF CUSHION
Z	= DEPTH OF FALL + HEIGHT OF CUSHION
H	= DEPTH OF FALL
X	= $D + 0.82 \times D^{1/3} \times H^{1/2}$
Y	= $\frac{4}{3} \sqrt{Z \times D}$
Z	= $X + H - D$

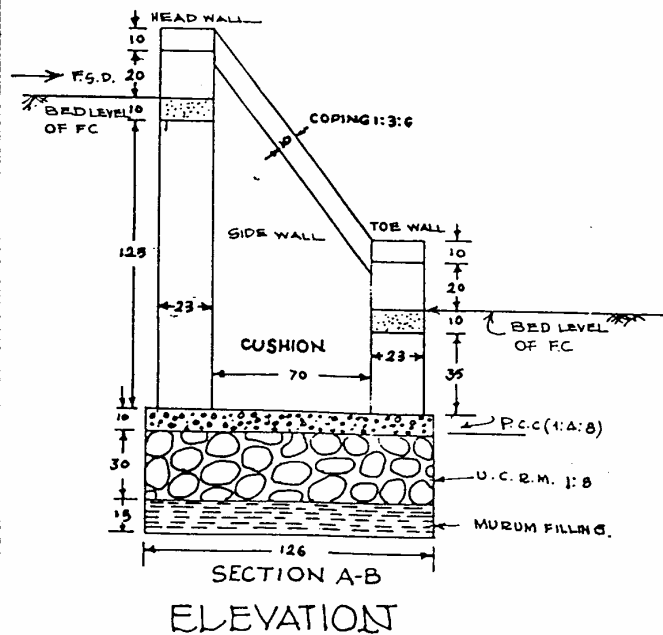


Figure 5.8

The walls are about 0.23 m thick in B.B. masonry and 0.4 m. thick in U.C.R. masonry with 0.10 m concrete coping. The length, breadth and depth of the rectangular basin is to be designed. The commonly used formulae as per F.A.O. Paper No. 26/2 are:

$$\text{Volume of basin, } V = \frac{Q \times H_{dr}}{150} \text{ m}^3 \quad \dots\dots\dots (1)$$

Where Q = Discharge in lps
 H_{dr} = Height of drop in meters
 Length of basin, $L_{bs} = 1.5 H_{dr}$ meters

$$\text{Width of basin} = \frac{V}{L_{bs} \times (Y_2 + d_{bs})} \text{ meters}$$

The depth of the basin, d_{bs} , is from - 0.1 to 0.3 m and other dimensions are worked out by trial and error.

Presently, in Maharashtra State, the width of the basin is kept the same as the bed width of the upstream channel for ease of construction and design. As per norms, the basin depth and length are worked out by,

$$d_{bs} = 0.82 \times Y_2^{1/3} \times H_{dr}^{1/2}$$

$$L_{bs} = 1.33 \times Y_2^{1/2} (H_{dr} + d_{bs})^{1/2}$$

Where Y_2 = upstream F.S.D.

Three type designs, for drops of 0.3 m, 0.6 m, 0.9 m, B.B. masonry are given in Figure 5.6, 5.7 and 5.8 respectively. These illustrate only the general arrangements. The dimensions have to be modified to suit the specific conditions.

The Manual of Minor Irrigation Works of Government of Maharashtra gives the following formulae for the water cushion in the vertical drop. The bed width of the cushion is the same as the bed width of the upstream channel.

(Referring to Figure 5.9)

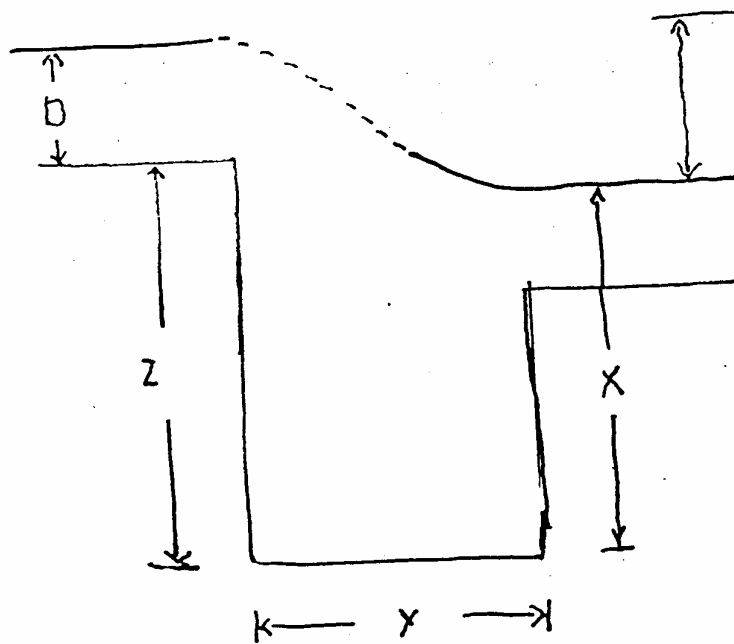


Figure: 59 RECTANGULAR VERTICAL DROPS ON M. I. WORKS IN MAHARASHTRA

- D = F.S.D. in U/s channel
 H = Height i.e. difference in u/s and d/s water surface levels
 Z = The difference between the crest of weir and the bottom of the cushion
 Y = Length of cushion chamber
 X = Depth of cushion chamber, below d/s FSD Level
 then

$$X = D + 0.82 D^{1/3} \times H^{1/2} \quad \dots\dots\dots (1)$$

$$Z = X + H - D$$

$$Y = \frac{4}{3} \sqrt{Z \times D} \quad \dots\dots\dots (2)$$

Where all dimensions are in ft.

Such falls have been constructed and are working very well for considerable period.

Physical Norms for providing Drops:

In order to keep overall expenditure of OFD works within reasonable limits (or cost norms laid down by Government) the number of drops on Field Channel should be minimum. However, following physical norms are enumerated as guidelines and these indicate ceiling limits, as laid down in Government (Irrigation Department) Circular No. CDA 1087/1553/209/87-CAD(LD & Eng), dated 12/1/1988.

Sr. No.	Ground slope	No. of drops per ha of chak
1.	Less than 1%	NIL
2.	1% - 2%	½
3.	2% - 3%	1
4.	Above 3%	1½

5.3 Diversion Box (DB):

The diversion or division box is provided in the field channel where it branches off in two or three directions. The purpose of the box is to divert the flow into any one branch. The structure consists of a rectangular box with openings in the vertical sidewalls, and wing walls extending in the directions of the field channel and branches.

If the field channel branches into two directions, a two way divisions box is provided while if it branches into 3, three - way division boxes are provided. These are constructed in situ, in brick or in stone masonry, depending upon the availability of the material locally. Precast concrete division boxes are also readily available. They can be transported in places to the site and assembled there. A sketch of precast two-way D.B. and rubble masonry three-way division boxes are given in Figure-5.10 to 5.11. The height of D.B. be restricted upto top of F.C. bank to reduce the cost.

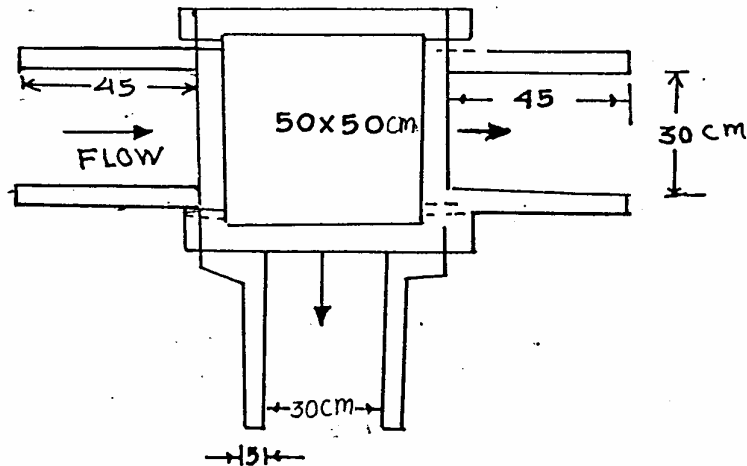


Figure: 5.10 Precast Division Box (Two-Way)

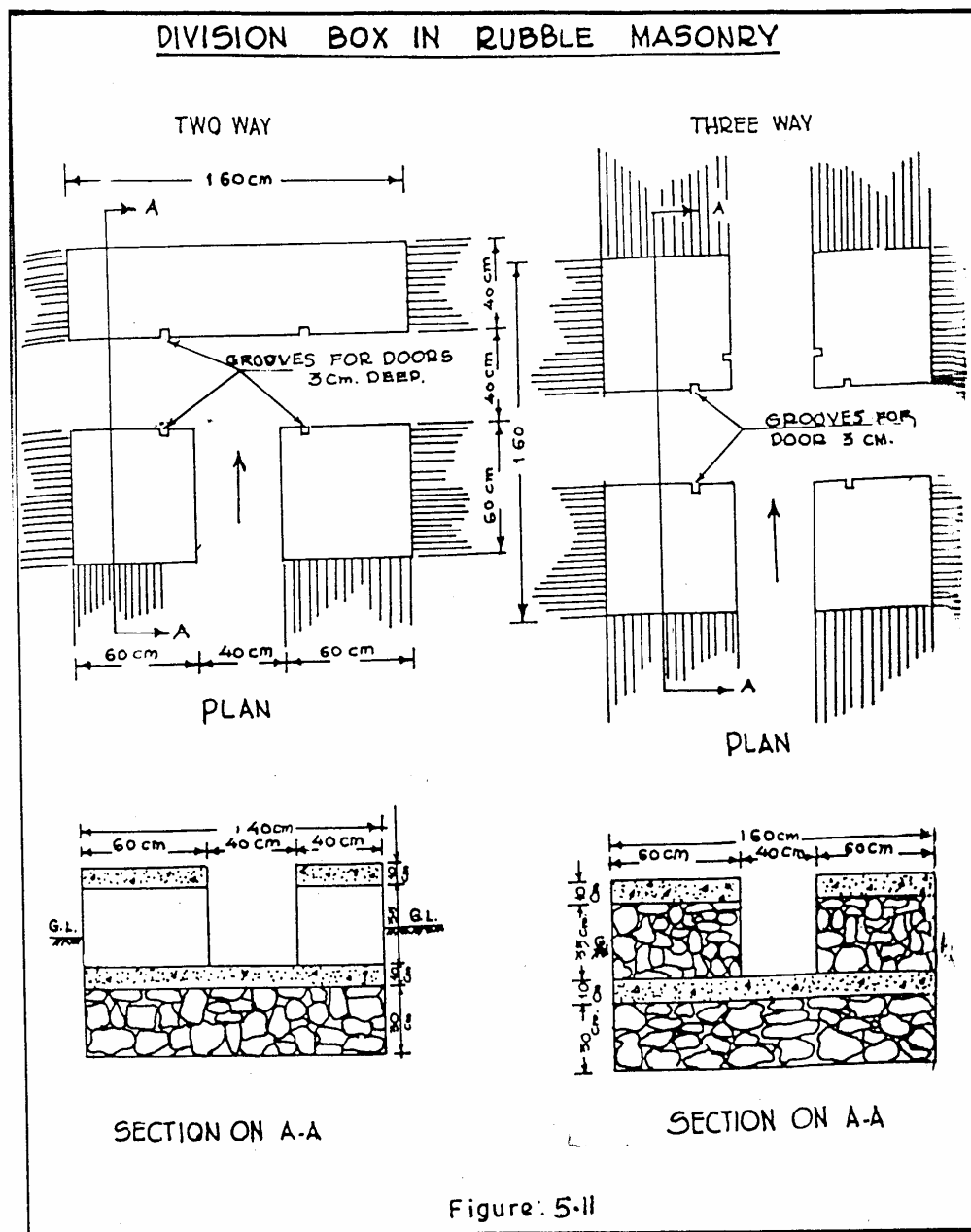


Figure: 5.11

5.4 Turnout:

Turnout is a structure on field channel from where water is diverted from field channel to the field. It is either a clay or cement spun pipe embedded in masonry. The location of the turnout should be such that it should be able to cater to the maximum area in the individual holding. The location should invariably be fixed in consultation with the farmer, so that he will not be tempted to open the field channel at some other location to get water. If two turnouts are located at one point, normally a diversion box is cheaper and serves the purpose equally well. A type drawing of the turnout is presented in Figure-5.12 & 5.13. In order to have smooth entry of water into turnout, it may be laid at 45° if possible (Figure 5.13). If the turnouts are more in number, dry rubble turnouts may be used to reduce the cost. Pipe turnout can also be used.

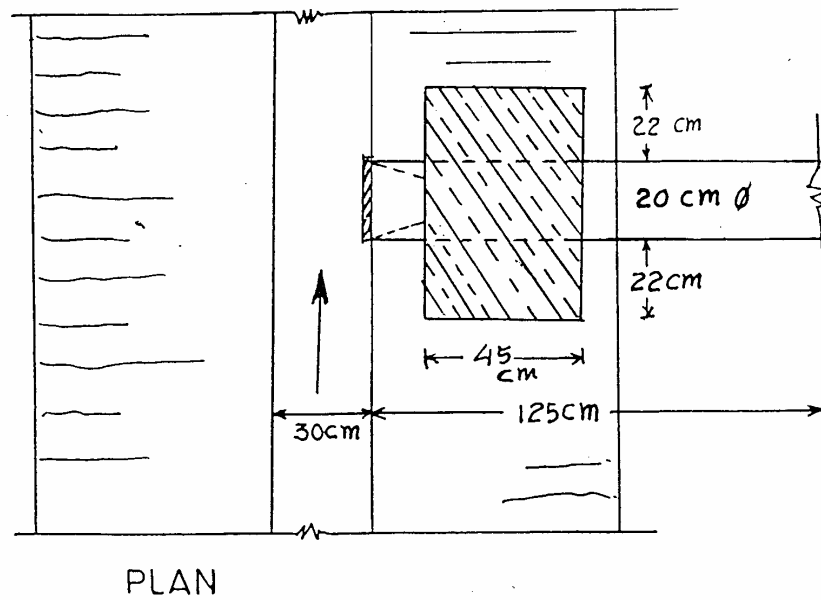
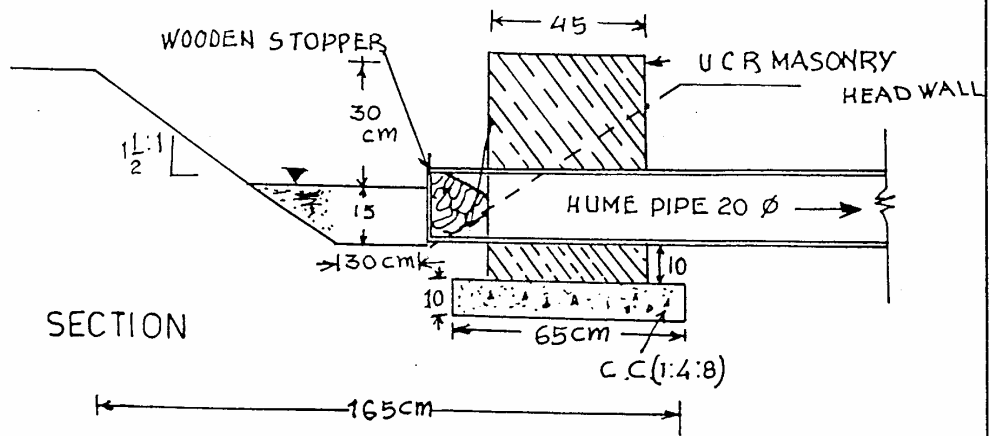
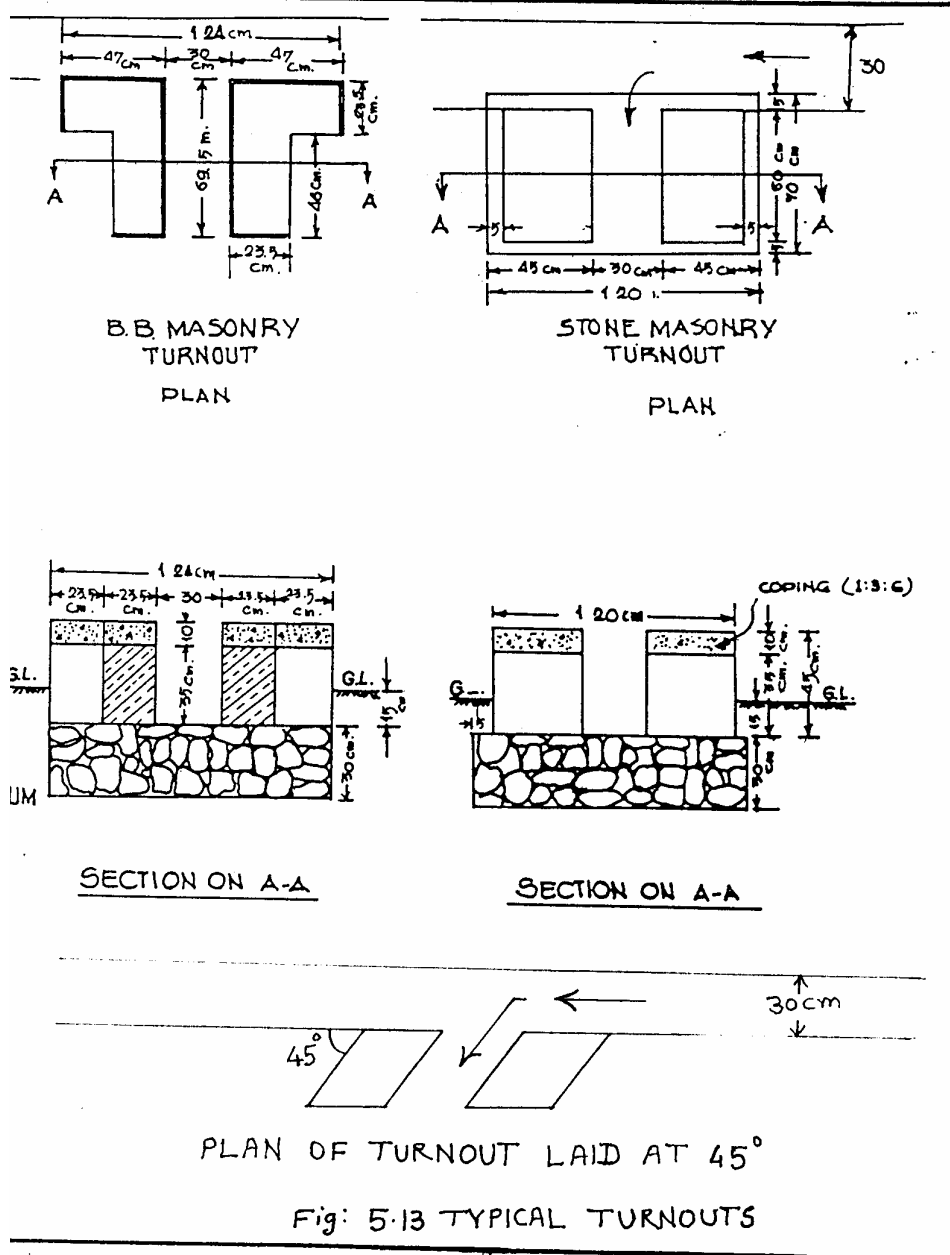


Figure: 542 Pipe Turn Out



5.5 Crossings:

The channel normally runs on a local ridge or the field boundaries. A case of field channel, crossing the natural drain, is therefore, almost an exception. The field channel has, however, to cross the cart tracks in the field. In this case, the bed gradient and the alignment of the field channel need not be changed. A simple arrangement is to provide a spun pipe of 300-mm dia (NP-3) as waterway to the field channel, fixed in two masonry headwalls. The width of the crossing i.e. the distance between the head walls depends on the width of the road. The foundation of the head walls should rest on hard strata like hard murum, or else the foundation treatment for soft soils may be given. A minimum cover of 30 to 45 cm of hard murum over the Hume pipe is necessary. Earth filling should be provided in the space surrounding the Hume pipe and between the head walls. A sketch of the

arrangement is given in Figure-5.14. If there is a scope for sufficient cushioning, pipes of diameter more than 300 mm may be used.

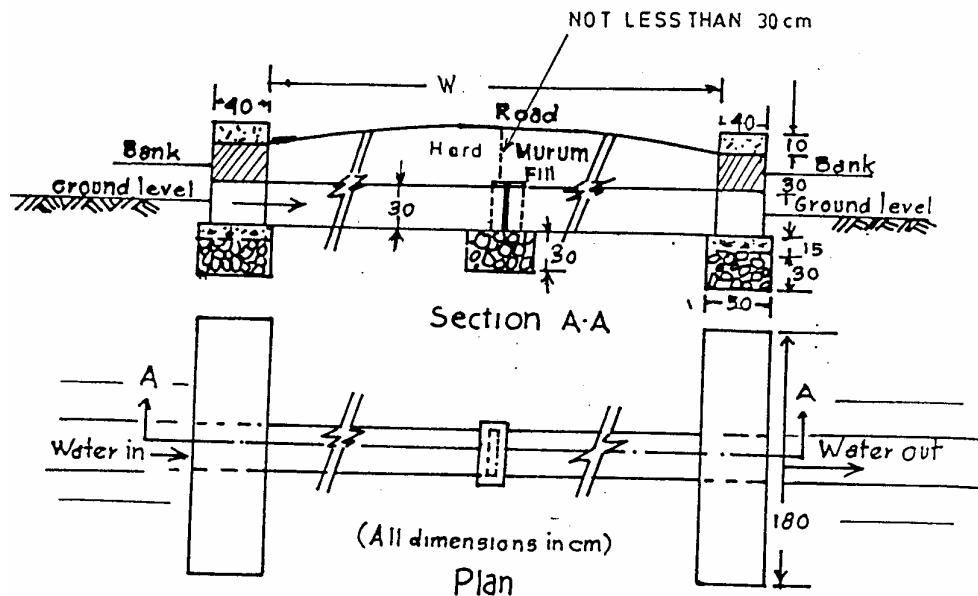


Figure 5.14 FIELD CHANNEL CROSSING

5.6 Farm Roads:

One of the difficulties faced by the cultivators is to take their produce out of the chak and to carry the inputs to the fields. The old cart track-cum-natural drains are not useful to them when irrigation starts. As yet, except in few states where consolidation of land holdings is practiced, no farm roads are constructed or planned. The necessity of farm roads, is however, now realized and a day is not far off when farm roads will be a part of the O.F.D. Works. In a well-laid out system every farm should have an approach to the link road, leading further to the villages or markets. Therefore, it would be advisable, during the design of O.F.D. Works, to at least plan the farm roads and decide the crossings, so that the planning is comprehensive.

The construction of farm roads may be taken up afterwards when circumstances permit. As a rough estimate, the length of the farm roads per ha is 30 m and the number of crossing per ha. is 0.4.

6.0 Structures in Black Cotton Soils:

The structures on the micro-distribution system are very small hydraulic structures and since the cost of each structure involved is comparatively low, not much attention is paid to the design of the foundation. It is often argued that the load of the structures is so small that the foundation presents no problem. But the failure cases show that the structures fail mainly because of developments of crack in structures, which can be attributed to volume changes in the foundations. Thus, the failure is not because of the load involved., but because of the alternate expansion and contraction in the foundations in expansive clayey soils. it is therefore

recommended that whenever the soils met with are expansive clays, special treatment for foundation should be given.

The evaluation study of O.F.D. structures in B.C. Soil carried out by D.I.R.D., Pune (March 1988) recommends as follows:

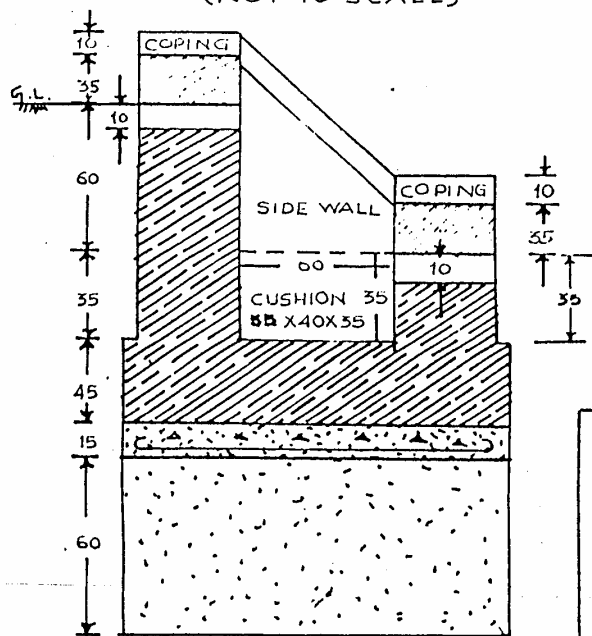
- (i) Depth of foundation should necessarily be below the cracking depth i.e. 1 to 1.2 m where actual observed data is not available.
- (ii) The foundation should be first filled with well compacted murum for the depth of about 60 cm.
- (iii) Over this, concrete with nominal reinforcement of 15 cm depth be placed.
- (iv) Above this, will be provided U.C.R. masonry.
- (v) The extra cost of the structure with such foundation treatment will be though substantial but with added advantage.
- (vi) Structures in B.C. soil should be of local material for facilitating easy repairs.
- (vii) Quality of construction plays important role in making them durable. Hence rigid quality control is necessary.
- (viii) Non-conventional structures like pre-cast structures are liable for tampering and are difficult to maintain. Moreover they are costly. Though, they facilitate quick construction, their life is short. Their use, therefore, should be kept to the minimum as far as possible.
- (ix) Vertical Hume pipe drops with horizontal pipe, facilitates Field Channel Crossings. These can be tried. Such drops would also be much cheaper and easy for construction.

The details of typical structures in B.C. Soil are shown in Figure-5.15 to 5.18.

The diagram is a plan view of a deep beam-cum-slab (D.B.C.S.) structure. It features a central rectangular region labeled "CUSHION 55 X 20". The overall dimensions and internal details are as follows:

- Overall Dimensions:** The total width is 127.5 and the total depth is 295.
- Internal Dimensions:**
 - The central cushion has a width of 55 and a depth of 20.
 - The top and bottom sections have a height of 127.5.
 - The left and right side sections have a width of 40.
 - The central horizontal section has a width of 55.
 - The bottom section has a width of 35.
- Reinforcement Details:**
 - Top reinforcement is indicated by a line with a hook and a dimension of 40.
 - Bottom reinforcement is indicated by a line with a hook and a dimension of 35.
 - Vertical reinforcement is indicated by a line with a hook and a dimension of 40.
 - Horizontal reinforcement is indicated by a line with a hook and a dimension of 40.
- Labels:** The top edge is labeled "HEAD WALL", the bottom edge is labeled "TOE WALL", and the central region is labeled "CUSHION 55 X 20". The overall dimensions are labeled "127.5" and "295".

(NOT TO SCALE)



SECTION A A
(NOT TO SCALE)

NOTES:-

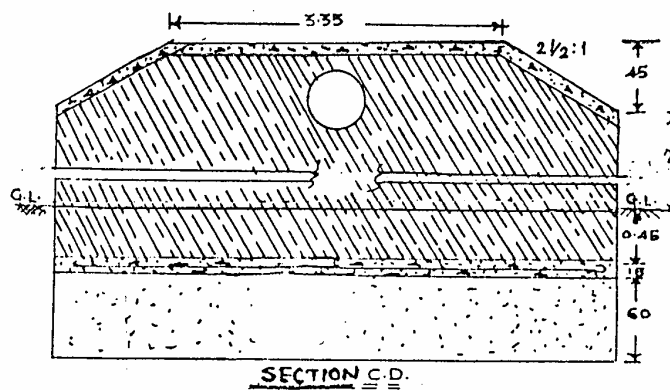
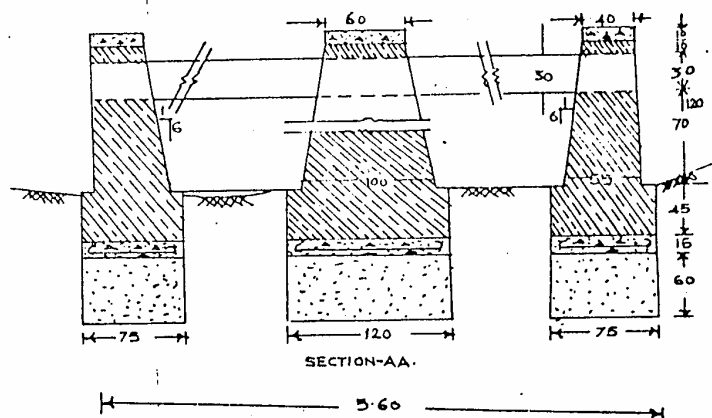
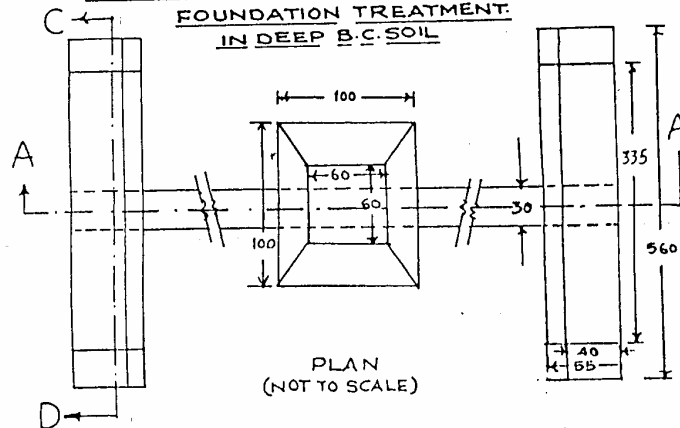
ALL DIMENSIONS
ARE IN C.M.

LEGEND

- 1 U.C.R.MASONRY.
IN C.M.1:5
- 2 C.C.1:3:6 WITH NOMINAL
REINFORCEMENT 12 MM
Ø MAIN 6MM.Ø DIST
- 3 MURUM FILLING
- 4 C.C. COPING 1:4:8

Fig: 5.15

**CROSSING FOR F.C. (IN U.C.R. MASONRY) ON NALA WITH
FOUNDATION TREATMENT
IN DEEP B.C. SOIL**



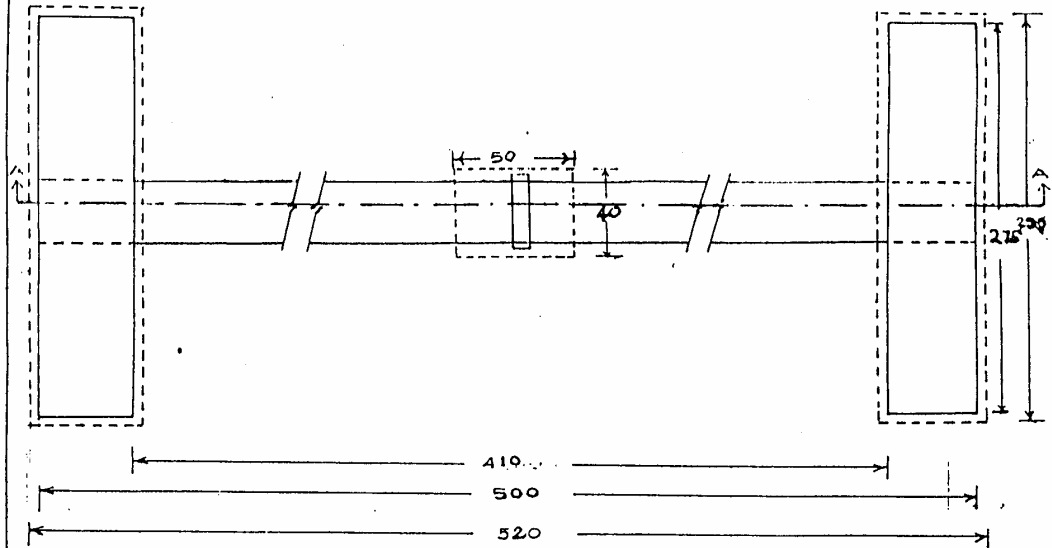
NOTE:-

- 1) WATER WAY TO BE TAKEN AS PER SITE CONDITIONS
- 2) ALL DIMENSIONS ARE IN C.M.

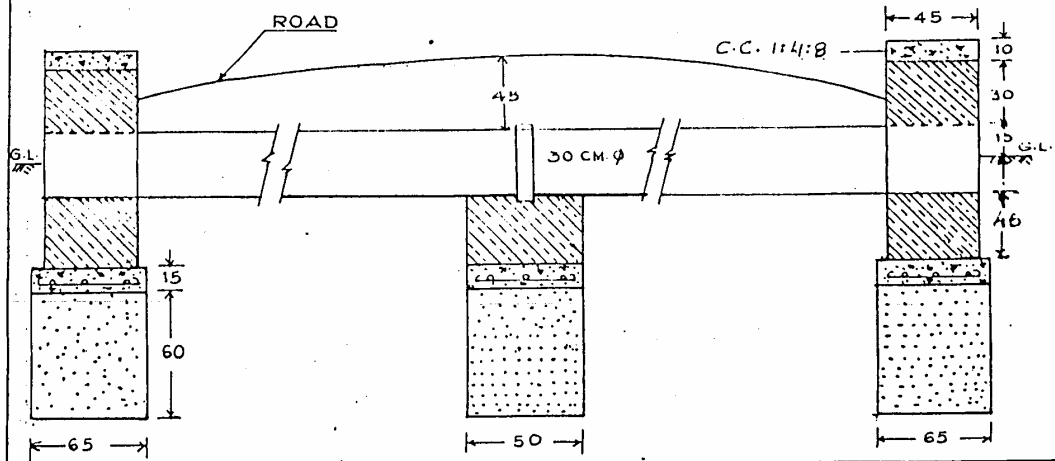
LEGEND	
1 U.C.R. MASONRY INC. M. 1:5	
2 C.C. 1:5 WITH NOMINAL REINFORCEMENT 12MM MAIN 6MM @ 150	
3 MURUM FILLING	
4 C.C. COPING	

Fig: 5-16

ROAD CROSSING ON F.C. WITH
FOUNDATION TREATMENT
[IN DEEP B.C. SOIL]



PLAN
(NOT TO SCALE)



SECTION-AA
(NOT TO SCALE)

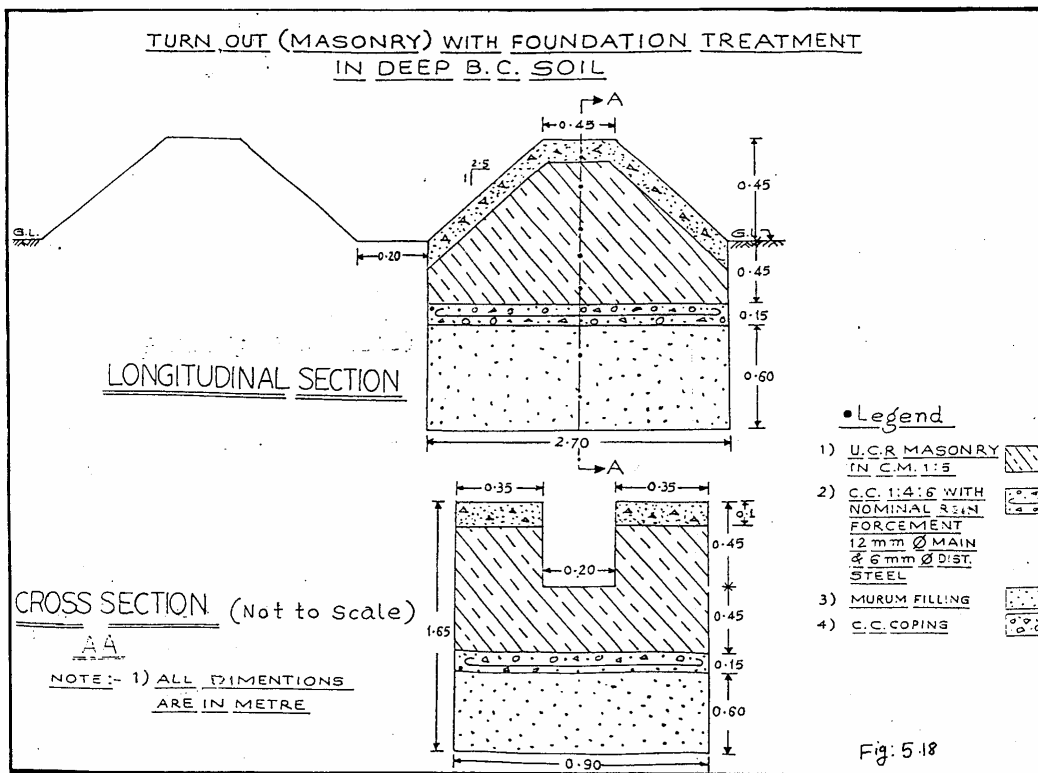
• NOTES :-

1. ALL DIMENSIONS
ARE IN C.M.

• LEGEND

1. U.C.R. MASONRY
IN C.M. 1:5 
2. C.C. 1:3:6 WITH NOMINAL
REINFORCEMENT 12 mm Ø
MAIN 6 mm Ø DIST. 
3. MURUM FILLING 
4. C.C. COPING 1:4:8 

Fig: 5.17



7.0 Non-Conventional Structures:

The cost of precast structures presently being used with modifications is 3 to 3½ times more than conventional structures. They are very costly and cannot fit into the prescribed cost norms. Hence their use is prohibitive. Moreover, on tampering, they cannot be easily replaced.

Fiberglass structures are 1.5 to 2 times costlier than the conventional structures. But these are lightweight, and liable for tampering. This material lacks bondage with Field Channel material and is difficult to be fixed with the foundation, making it prone for undercaving. Considering the long life of the system, such structures are not recommended.

8.0 Tips for ensuring Quality in Construction of Structures:

- (a) The concrete or mortar shall not be prepared by mixing on natural ground, due to which the quality gets deteriorated by mixing earth and other deleterious materials in concrete or mortar. Galvanized iron sheet 1.5 m x 1.5 m shall be used as platform for mixing. The iron sheet may be provided with wired handle so that it can be dragged easily from one spot to other.
- (b) For the good quality and strength, curing of concrete and mortar shall not be ignored. If sufficient water for curing is not available, it can be achieved by apply curing compounds.
- (c) Earth back filling behind the structures should be done properly and compacted well.

- (d) To achieve the level of accuracies in construction of field channel and structures, the sequence of construction shall be as follows.
- i) Excavate field channel as per given alignment, bed gradient and cross section.
 - ii) Construct Division boxes with design sill levels and check that these match with bed gradients as at that location.
 - iii) Construct falls and crossings with required level of accuracy.

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- Small Hydraulic Structures, Irrigation and Drainage Paper No. 26/1 and 26/2 of FAO, 1975.

Annexure 5.1

Table No.1

Design of Field Channel for 30 lps discharge and bedwidth of 30 cm

a) n = 0.22

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(mts)	(Mts)	1 in	1 in		(sqm)	m		m/sec	cum/sec
0.3	0.094	1.5	100	0.022	0.041454	0.638922	0.064881	0.733264	0.030397
0.3	0.113	1.5	200	0.022	0.053054	0.707427	0.074995	0.571096	0.030299
0.3	0.126	1.5	300	0.022	0.061614	0.754299	0.081684	0.493641	0.030415
0.3	0.135	1.5	400	0.022	0.067838	0.786749	0.086225	0.443215	0.030067
0.3	0.143	1.5	500	0.022	0.073574	0.815594	0.090209	0.408547	0.030058
0.3	0.15	1.5	600	0.022	0.07875	0.840833	0.093657	0.382401	0.030114
0.3	0.156	1.5	700	0.022	0.083304	0.862466	0.096588	0.361387	0.030105
0.3	0.162	1.5	800	0.022	0.087966	0.884099	0.099498	0.344805	0.030331
0.3	0.166	1.5	900	0.022	0.091134	0.898522	0.101427	0.329275	0.030008
0.3	0.171	1.5	1000	0.022	0.095162	0.916549	0.103826	0.317288	0.030194

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(mts)	(Mts)	1 in	1 in		(sqm)	m		m/sec	cum/sec
0.3	0.09	2	100	0.022	0.0432	0.702492	0.061495	0.707514	0.030565
0.3	0.107	2	200	0.022	0.054998	0.778519	0.070644	0.548779	0.030182
0.3	0.119	2	300	0.022	0.064022	0.832184	0.076932	0.474299	0.030366
0.3	0.128	2	400	0.022	0.071168	0.872433	0.081574	0.427123	0.030397
0.3	0.135	2	500	0.022	0.07695	0.903738	0.085146	0.393109	0.03025
0.3	0.141	2	600	0.022	0.082062	0.930571	0.088185	0.367349	0.030145
0.3	0.147	2	700	0.022	0.087318	0.957404	0.091203	0.34782	0.030371
0.3	0.151	2	800	0.022	0.090902	0.975293	0.093205	0.330102	0.030007
0.3	0.156	2	900	0.022	0.095472	0.997653	0.095697	0.316748	0.030241
0.3	0.16	2	1000	0.022	0.0992	1.015542	0.097682	0.304637	0.03022

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(mts)	(Mts)	1 in	1 in		(sqm)	m		m/sec	cum/sec
0.3	0.086	2.5	100	0.022	0.04429	0.763124	0.058038	0.680726	0.030149
0.3	0.103	2.5	200	0.022	0.057423	0.854672	0.067187	0.530713	0.030475
0.3	0.1132	2.5	300	0.022	0.065996	0.909601	0.072554	0.456121	0.030102
0.3	0.1215	2.5	400	0.022	0.073356	0.954298	0.076869	0.410528	0.030115
0.3	0.129	2.5	500	0.022	0.080303	0.994686	0.080731	0.379394	0.030466
0.3	0.134	2.5	600	0.022	0.08509	1.021612	0.08329	0.35362	0.03009
0.3	0.139	2.5	700	0.022	0.090003	1.048538	0.085836	0.334031	0.030064
0.3	0.144	2.5	800	0.022	0.09504	1.075464	0.088371	0.318582	0.030278
0.3	0.148	2.5	900	0.022	0.09916	1.097004	0.090392	0.304925	0.030236
0.3	0.152	2.5	1000	0.022	0.10336	1.118545	0.092406	0.293561	0.030342

Annexure 5.1

Table No.2

Design of Field Channel for 30 lps discharge and bedwidth of 30 cm

b) n = 0.03

bed width	normal depth	side slope	bed gradien	n	Area	P	R	V	Q
(mts)`	(Mts)	1 in	1 in		(sqm)	m		m/sec	cum/sec
0.3	0.1103	1.5	100	0.03	0.051339	0.697692	0.073584	0.584823	0.030024
0.3	0.1324	1.5	200	0.03	0.066015	0.777375	0.08492	0.455002	0.030037
0.3	0.147	1.5	300	0.03	0.076514	0.830016	0.092183	0.392411	0.030025
0.3	0.1583	1.5	400	0.03	0.085078	0.870759	0.097706	0.353286	0.030057
0.3	0.1675	1.5	500	0.03	0.092334	0.90393	0.102148	0.325499	0.030055
0.3	0.1753	1.5	600	0.03	0.098685	0.932053	0.105879	0.304335	0.030033
0.3	0.1823	1.5	700	0.03	0.10454	0.957292	0.109204	0.28763	0.030069
0.3	0.1885	1.5	800	0.03	0.109848	0.979646	0.112131	0.273842	0.030081
0.3	0.194	1.5	900	0.03	0.114654	0.999477	0.114714	0.262133	0.030055
0.3	0.199	1.5	1000	0.03	0.119102	1.017505	0.117053	0.252051	0.03002

bed width	normal depth	side slope	bed gradien	n	Area	P	R	V	Q
(mts)`	(Mts)	1 in	1 in		(sqm)	m		m/sec	cum/sec
0.3	0.1047	2	100	0.03	0.053334	0.768233	0.069425	0.562559	0.030004
0.3	0.1249	2	200	0.03	0.06867	0.85857	0.079982	0.437179	0.030021
0.3	0.1383	2	300	0.03	0.079744	0.918496	0.08682	0.377031	0.030066
0.3	0.1484	2	400	0.03	0.088565	0.963665	0.091904	0.339152	0.030037
0.3	0.1568	2	500	0.03	0.096212	1.001231	0.096094	0.312502	0.030067
0.3	0.1638	2	600	0.03	0.102801	1.032536	0.099562	0.292099	0.030028
0.3	0.17	2	700	0.03	0.1088	1.060263	0.102616	0.275937	0.030022
0.3	0.1756	2	800	0.03	0.114351	1.085307	0.105363	0.262703	0.03004
0.3	0.1806	2	900	0.03	0.119413	1.107668	0.107806	0.251495	0.030032
0.3	0.1852	2	1000	0.03	0.124158	1.12824	0.110046	0.241885	0.030032

bed width	normal depth	side slope	bed gradien	n	Area	P	R	V	Q
(mts)`	(Mts)	1 in	1 in		(sqm)	m		m/sec	cum/sec
0.3	0.1004	2.5	100	0.03	0.05532	0.840671	0.065805	0.542822	0.030029
0.3	0.1192	2.5	200	0.03	0.071282	0.941912	0.075678	0.421342	0.030034
0.3	0.1316	2.5	300	0.03	0.082776	1.008688	0.082063	0.363125	0.030058
0.3	0.141	2.5	400	0.03	0.092003	1.059308	0.086851	0.326598	0.030048
0.3	0.1486	2.5	500	0.03	0.099785	1.100235	0.090694	0.300676	0.030003
0.3	0.1552	2.5	600	0.03	0.106778	1.135778	0.094013	0.281137	0.030019
0.3	0.161	2.5	700	0.03	0.113103	1.167012	0.096916	0.265617	0.030042
0.3	0.1662	2.5	800	0.03	0.118916	1.195014	0.09951	0.252878	0.030071
0.3	0.1708	2.5	900	0.03	0.124172	1.219786	0.101798	0.242058	0.030057
0.3	0.1749	2.5	1000	0.03	0.128945	1.241865	0.103832	0.232686	0.030004

Annexure 5.1

Table No.3

Design of Field Channel for 30 lps discharge and bedwidth of 30 cm

c) n = 0.04

bed width (mts)	normal depth (Mts)	side slope 1 in	bed gradient 1 in	n	Area (sqm)	P m	R	V m/sec	Q cum/sec
0.3	0.1285	1.5	100	0.04	0.063318	0.763313	0.082952	0.475114	0.030083
0.3	0.1535	1.5	200	0.04	0.081393	0.853452	0.09537	0.368716	0.030011
0.3	0.1702	1.5	300	0.04	0.094512	0.913665	0.103443	0.317822	0.030038
0.3	0.1829	1.5	400	0.04	0.105049	0.959455	0.109488	0.285869	0.03003
0.3	0.1934	1.5	500	0.04	0.114125	0.997314	0.114433	0.263335	0.030053
0.3	0.2022	1.5	600	0.04	0.121987	1.029042	0.118544	0.246118	0.030023
0.3	0.21	1.5	700	0.04	0.12915	1.057166	0.122166	0.232481	0.030025
0.3	0.217	1.5	800	0.04	0.135734	1.082405	0.1254	0.221289	0.030036
0.3	0.2232	1.5	900	0.04	0.141687	1.104759	0.128252	0.211786	0.030007
0.3	0.229	1.5	1000	0.04	0.147362	1.125671	0.13091	0.203686	0.030015

bed width (mts)	normal depth (Mts)	side slope 1 in	bed gradient 1 in	n	Area (sqm)	P m	R	V m/sec	Q cum/sec
0.3	0.1213	2	100	0.04	0.065817	0.84247	0.078124	0.456487	0.030045
0.3	0.1441	2	200	0.04	0.08476	0.944435	0.089746	0.354069	0.030011
0.3	0.1593	2	300	0.04	0.098543	1.012411	0.097335	0.305179	0.030073
0.3	0.1706	2	400	0.04	0.109389	1.062946	0.102911	0.274297	0.030005
0.3	0.1801	2	500	0.04	0.118902	1.105432	0.107562	0.25268	0.030044
0.3	0.1881	2	600	0.04	0.127193	1.141209	0.111455	0.2362	0.030043
0.3	0.195	2	700	0.04	0.13455	1.172067	0.114797	0.223031	0.030009
0.3	0.2015	2	800	0.04	0.141655	1.201135	0.117934	0.212411	0.030089
0.3	0.207	2	900	0.04	0.147798	1.225732	0.120579	0.203249	0.03004
0.3	0.2121	2	1000	0.04	0.153603	1.24854	0.123026	0.195419	0.030017

bed width (mts)	normal depth (Mts)	side slope 1 in	bed gradient 1 in	n	Area (sqm)	P m	R	V m/sec	Q cum/sec
0.3	0.1158	2.5	100	0.04	0.068264	0.923602	0.073911	0.439914	0.03003
0.3	0.137	2.5	200	0.04	0.088023	1.037768	0.084819	0.340981	0.030014
0.3	0.151	2.5	300	0.04	0.102303	1.11316	0.091903	0.293711	0.030047
0.3	0.1615	2.5	400	0.04	0.113656	1.169704	0.097166	0.263987	0.030004
0.3	0.171	2.5	500	0.04	0.124403	1.220863	0.101897	0.243724	0.03032
0.3	0.1776	2.5	600	0.04	0.132134	1.256405	0.105169	0.227228	0.030025
0.3	0.184	2.5	700	0.04	0.13984	1.29087	0.10833	0.21457	0.030005
0.3	0.19	2.5	800	0.04	0.14725	1.323181	0.111285	0.204347	0.03009
0.3	0.195	2.5	900	0.04	0.153563	1.350107	0.113741	0.195486	0.030019
0.3	0.2	2.5	1000	0.04	0.16	1.377033	0.116192	0.18811	0.030098

CHAPTER – 6

FLOW MEASURING DEVICES

1.0 Introduction:

In any irrigation systems, there should be a commitment to deliver a specific amount of water in a specific time to the irrigators. This means flow volume is assured. Not only the management staff should be able to measure the stream flow rate, but also the irrigator should be able to verify that the promised stream flow (30 l.p.s. in Maharashtra) is being delivered to him. This facility can create a confidence in the minds of farmer towards the system.

Reasonable accurate water measurement is also necessary to ensure proper delivery schedules, to determine the amount of water delivered and to estimate or detect the conveyance losses. It also helps in field trials and evaluation of actual irrigation efficiencies, etc.

A measuring device is, therefore, fixed in the initial reach of the field channel system of every chak. The device should be located on a straight reach. (Generally 10 times the average width). If a drop is available in this portion, it can be combined with the measuring device.

If Self-Regulated (SR) outlet is used to deliver the water, separate measuring devices may not be necessary as this outlet delivers almost constant discharge (upto 10% variation) under given modular range.

A good measuring device indicates the discharge with preferably single guage reading and it should be reasonably accurate within the given range of discharge. The device should not be unduly sensitive to changes in the type of flow and levels of upstream and downstream, particularly the approach velocity in the upstream and some silting or erosion on the downstream.

For small discharges the above conditions are satisfied by the following measuring devices:

- a) V-notch
- b) Cut-throat flume
- c) Replogle flume.

If drop/fall is available, V-Notch is suitable device. If not, Replogle Flume may be selected, as it is easy to construct, low in cost. The Cutthroat flume if available in pre-fabricated form can also be used provided setting is properly worked out and executed.

2.0 V-Notch:

Generally 90° V-notch is quite often used to measure small discharge (say upto 30 to 40 l.p.s.) in field channels where falls are available. The downstream water level must be at least 15 cm below the vertex or crest of the notch. This implies an available drop of about 45 to 50 cm. Advantages of V-notch are its low cost and ease in construction. Figure-6.1 shows the fixing of 90° V-notch in field channel.

Discharge Formula:

The Kindsvater-Shen formula for thin plate V-notch is:

$$Q = C_e \times \frac{8}{15} \tan \frac{\alpha}{2} \sqrt{2g} h_e^{5/2}$$

Here α is the angle of notch. For a 90° notch the formula becomes,

$$Q = C_e \times \frac{8}{15} \sqrt{2g} h_e^{5/2}$$

In which

Q = discharge in cumec

C_e = Co-efficient of discharge, and

h_e = effective head = $h + kh$ (M)

(For a 90° notch, $kh = 0.85$ mm, or 0.085 cm)

$g = 9.81 \text{ m/sec}^2$

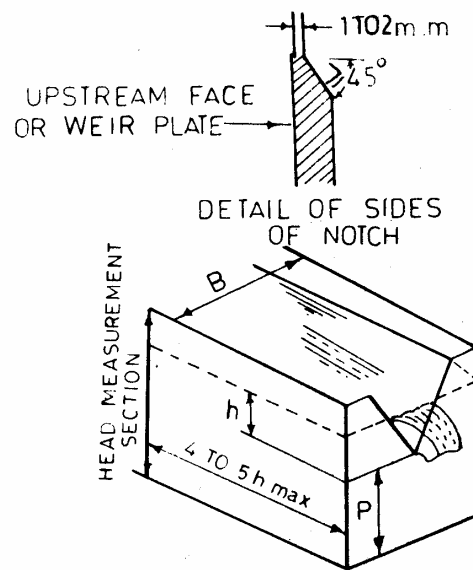


Figure-6.1 Sharp Crested 90° V-Notch

For a 90° notch, the co-efficient of discharge C_e is a function of two variations

$$\frac{h}{p} \quad \text{and} \quad \frac{P}{B}$$

In which,

P = height of the vertex of the notch above the channel bed

B = Width of the approach channel

h = head above the vertex of the notch measured at a distance 4 to 5 times h max u/s of the notch

For a 90° V-notch, the value of co-efficient of discharge C_e varies from 0.58 to 0.61 with following limitations.

- a) h/p should be limited from 0.2 to 2.
- b) p/B should be limited from 0.1 to 1
- c) h should not be less than 6 cm
- d) p should be nearly 10 cm
- e) The nappe should be fully ventilated.

In general, the approach channel should be smooth, straight and rectangular for a reach not less than 20 times $h_{\max}$, when $B/h_{\max}$ is less than 3 and/or $h_{\max}/p$ is greater than 1 (which is generally the condition).

Table-6.1 gives the discharge for head h varying from 6 cm to 38 cm for a 90° V-notch taking Co-efficient of discharge C_e equal to nearly 0.68 (for greater accuracy, refer IS-9101 – 1979. “Liquid Flow Measurement in Open Channels using Thin Plate Weirs” and establish the exact value of C_e for the given condition of the setting).

Precaution must be taken to see that the weir plate is truly vertical after installation and at equal distance from channel sides. The plate should be firmly embedded either in concrete or masonry. The edges of the notch should be rounded smoothly so that small eddies are not formed near the weir. The sharp-edge is chamfered on down-stream side.

TABLE – 6.1
Discharge Table for Sharp - Crested 90° V notch

Head H (cm)	Discharge (lps)	Head h (cm)	Discharge (lps)	Head h (cm)	Discharge (lps)
6.0	1.3	20.0	24.7	34.0	93.2
6.5	1.5	20.5	26.3	34.5	96.6
7.0	1.8	21.0	27.9	35.0	100.2
7.5	2.2	21.5	29.6	35.5	103.8
8.0	2.6	22.0	31.4	36.0	107.5
8.5	3.0	22.5	33.2	36.5	111.3
9.0	3.4	23.0	35.0	37.0	115.2
9.5	3.9	23.5	37.0	37.5	119.1
10.0	4.4	24.0	39.0	38.0	123.1
10.5	5.0	24.5	41.0		
11.0	5.6	25.0	43.2		
11.5	6.2	25.5	45.4		
12.0	6.9	26.0	47.6		
12.5	7.7	26.5	49.9		
13.0	8.5	27.0	52.3		
13.5	9.3	27.5	54.8		
14.0	10.2	28.0	57.3		
14.5	11.1	28.5	59.9		
15.0	12.1	29.0	62.6		
15.5	13.1	29.5	65.3		
16.0	14.2	30.0	68.1		
16.5	15.3	30.5	71.0		
17.0	16.5	31.0	74.0		
17.5	17.7	31.5	77.0		
18.0	19.0	32.0	80.1		
18.5	20.3	32.5	83.2		
19.0	21.7	33.0	86.5		
19.5	23.2	33.5	90.0		

3.0 Cut-Throat Flume:

Cut-throat flume have been developed to over come the difficulties experienced in construction of the Parshall flumes. The shape of Parshall flume especially its bottom, presents some problems of construction in the interior places, where good workmanship is not available. In Cut-throat flume, there are only two sections, a converging inlet section and a diverging outlet section. The floor of the flume is horizontal. Since the flume has no longitudinal throat portion, it is named “Cut-throat Flume”. Advantages of the Cut-throat flume over Parshall flume are:

- Ease of construction

- Angles of convergence and divergence remain the same for all size
- The rating of intermediate sizes can be developed from the available rating equations.
- It gives nearly as accurate measurements as Parshall flume in free flow condition for smaller throat widths (5% errors).

The diagrammatic sketch of the Cut-throat flume is shown in Figure-6.2. L is the total length of the flume. W is the throat width, L_1 and L_2 are the length of converging and diverging sections and L_a and L_b are the upstream and downstream gauge locations. Cut-throat flume is recognized by its throat width W and length L . In field channels 10x90 cm. And 20x90 cm, flumes can be used which can measure a discharge upto 54 lps and 115 lps respectively under free flow condition. In Table–6.2 various dimensions for 10x90 cm and 20x90 cm cut-throat flumes are given. However, in order to minimize the problem of head loss and afflux it is advisable to use 20x90 cm flume. The total height of the flume from bottom may be restricted to 35 cm for economy and necessary.

Table – 6.2
Dimensions for 10x90 cm & 20x90 cm Cut-Throat Flumes

Throat Width W (cm)	L (cm)	L_1 (cm)	L_2 (cm)	L_a (cm)	L_b (cm)	B (cm)
10	90	30	60	20	50	30
20	90	30	60	20	50	40

For both 10x90 cm and 20x90 cm Cut-throat flume, free flow limit (h_b/h_a) is 65.3%, it is observed that cut-throat flumes are not suitable for measurements of discharges under submerged flow conditions i.e. for h_b/h_a more than 65%. However, in order to compute discharges under submerged flow condition, a submerged flow equation is proposed in literature. It still needs full rectification.

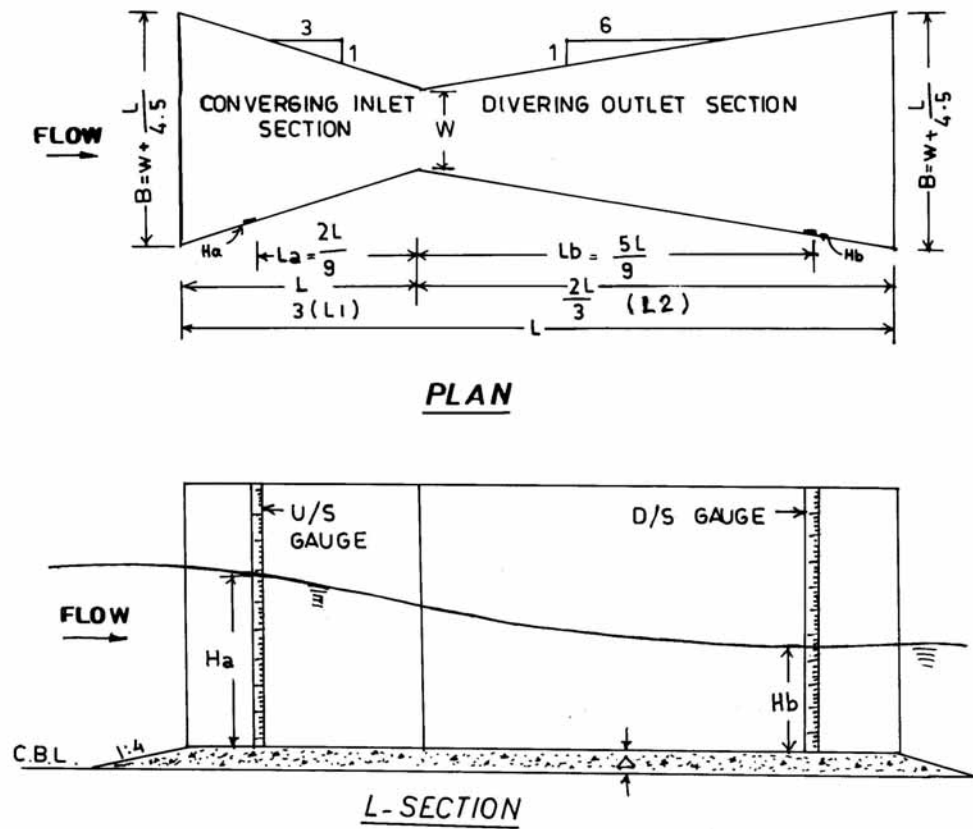


FIG. 2 : SKETCH OF CUT-THROAT FLUME .

Figure-6.2 : SKETCH OF CUT-THROAT FLUME

The discharge equation under free flow conditions is as below:

$$Q = C H_a^n$$

Where,

Q is discharge in m³/sec.

H_a is upstream gauge reading in m.

C is discharge coefficient and n is exponent depending upon flume length.

The value of discharge coefficient C is calculated as:

$$C = K.W^{1.025}$$

TABLE - 6.3
Free Flow Discharge Table for 10x90 cm and
20x90 cm Cut-Throat Flumes

Upstream Head Ha (cm)	Discharge (l.p.s.)	
	10 x 90 cm	20 x 90 cm
5.0	1.5	3.0
5.5	1.8	3.6
6.0	2.1	4.2
6.5	2.4	4.8
7.0	2.7	5.6
7.5	3.1	6.3
8.0	3.5	7.1
8.5	3.9	8.0
9.0	4.3	8.6
9.5	4.8	9.8
10.0	5.3	10.7
10.5	5.8	11.7
11.0	6.3	12.8
11.5	6.8	13.9
12.0	7.4	15.0
12.5	8.0	16.2
13.0	8.5	17.4
13.5	9.2	18.7
14.0	9.8	19.9
14.5	10.5	21.3
15.0	11.1	22.6
15.5	11.8	24.1
16.0	12.5	25.5
16.5	13.3	27.0
17.0	14.0	28.5
17.5	14.8	30.1
18.0	15.6	31.7
18.5	16.4	33.3
19.0	17.2	35.0
19.5	18.0	36.7
20.0	18.9	38.5

TABLE - 6.3 (Contd...)

Upstream Head Ha (cm)	Discharge (l.p.s.)	
	10 x 90 cm	20 x 90 cm
20.5	19.8	40.3
21.0	20.7	42.1
21.5	21.6	44.0
22.0	22.5	45.9
22.5	23.5	47.8
23.0	24.5	49.8
23.5	25.5	51.8
24.0	26.5	53.9
24.5	27.5	55.9
25.0	28.5	58.1
25.5	29.6	60.2
26.0	30.7	62.4
26.5	31.8	64.6
27.0	32.9	66.9
27.5	34.0	69.2
28.0	35.2	71.5
28.5	36.3	73.9
29.0	37.5	76.3
29.5	38.7	78.8
30.0	39.9	81.3
30.5	41.2	83.8
31.0	42.4	86.3
31.5	43.7	88.9
32.0	45.0	91.5
32.5	46.3	94.2
33.0	47.6	96.9
33.5	48.9	99.6
34.0	50.3	102.3
34.5	51.7	105.1
35.0	53.0	107.9
35.5	54.4	110.8
36.0	55.9	113.7

K is coefficient depending upon length of flume and W is throat width in m.

For 90cm long flume value of exponent n and coefficient K are 1.843 and 3.89 respectively. Value of n and k for other length of flume are available, but are not given here.

For free flow condition, discharge equation for 10x90 cm flume will become.

$$Q = 0.3672 H_a^{1.843} \quad (\text{M.K.S. units})$$

Discharge equation for 20x90 cm flume under free flow condition will be:

$$Q = 0.7473 H_a^{1.843} \quad (\text{M.K.S. units})$$

For better accuracy, upstream head h_a should be restricted to 0.4 L i.e. 36 cm.

Free flow discharge tables for 10x90 cm and 20x90 cm cut-throat flume are given in Table-6.3.

Regarding gauge locations, in Cut-throat flume u/s gauge is located in converging section at a distance equal to $2L/9$ measured along the axis of the flume from the throat. The d/s gauge is located in the diverging section at a distance $5L/9$ from the throat.

Computation of Discharge for Submerged Flow Condition:

Discharge equation for submerged flow condition ($H_b/H_a \times 100 > \% St$) through a Cut-throat flume is

$$Q_s = \frac{C_s(H_a - H_b)^n}{(-\log_{10} S)^{n_s}} \quad (\text{M.K.S.})$$

Where,

Q_s = discharge under submerged flow condition in M^3/s ,

C_s = Submerged flow discharge coefficient,

H_a = U/s head in m

H_b = D/s head in m

n = free flow exponent depends upon flume length L ,

S = Actual submergence in fraction

$$= \frac{H_b}{H_a}, \text{ and}$$

N_s = Submerged flow exponent depends upon flume length L ,

$$C_s = K_s W^{1.025} \quad (\text{M.K.S.})$$

Where,

K_s = Submerged flow coefficient depends upon flume length L and,

W = Throat width in m.

Submerged flow discharge equation for a given Cut-throat flume of size $W \times L$ can be developed similar to as for free flow conditions. However, it is observed experimentally that accuracy of flow measurement by using Cut-Throat flume is doubtful under submerged condition and hence not discussed in detail in this Publication. It is also advised to avoid submerged flow condition in Cut-throat flumes as far as possible. Example 1 explains how to establish submerged flow discharge equation for a given flume size $W \times L$ and then to compute discharge for observed gauge readings i.e. H_a and H_b .

Example 1:

Establish submerged flow discharge equation for 20 x 90 cm Cut-throat flume and compute discharge if measured gauge readings are as below:

$$H_a = 20.0 \text{ cm}$$

$$H_b = 16.0 \text{ cm.}$$

Solution:

Flume size under consideration is 20 x 90 cm. For flume length 90 cm,

$$n = 1.843$$

$$n_s = 1.483$$

$$K_s = 2.15$$

$$W = 20 \text{ cm} = 0.2 \text{ m.}$$

$$C_s = K_s W^{1.025} = 2.15 \times 0.2^{1.025} = 0.413$$

Submerged flow discharge equation for flume size 20 x 90 cm is:

$$Q_s = \frac{0.413 (H_a - H_b)^{1.843}}{(-\log_{10} S)^{1.483}} \quad (\text{M.K.S.})$$

Calculation of discharge if $H_a = 20.0 \text{ cm}$ and $H_b = 16.0 \text{ cm}$

$$S = \frac{16.0}{20.0} = 0.8 \quad (\text{Submerged flow condition})$$

Put values of H_a , H_b and S in the submerged flow discharge equation, $H_a = 20.0 \text{ cm} = 0.2 \text{ m}$. $H_b = 16.0 \text{ cm} = 0.16 \text{ m}$.

$$Q_s = \frac{0.413 (0.2 - 0.16)^{1.843}}{(-\log_{10} 0.8)^{1.483}} = 0.0349 \text{ m}^3/\text{s}$$

$$Q_s = 34.9 \text{ l.p.s.}$$

Upper Limit for U/s Head H_a and Submergence S :

For flow measurement through a Cut-throat flume, the u/s head H_a should not exceed $0.4 \times L$ and submergence should not be more than 95%.

Selection, setting and location of Cut-Throat Flume for Free Flow Condition:

Setting of Cut-Throat Flume for Free Flow Condition:

It is convenient to use Cut-throat flumes for free flow condition. Setting (Δ) of the flume means the height of sill (leveled floor of the flume) above the canal bed level. Setting (Δ) is calculated for the maximum discharge, Q_{max} , supposed to flow in the canal. Setting involves the selection of appropriate flume size also.

Steps involved in computation of setting (Δ) are:

- i) Select the flume size
- ii) For Q max and selected flume size, find H_a required for free flow condition from discharge table.
- iii) Find max. value of H_b for free flow to occur i.e. $H_b = \text{free flow submergence limit} \times H_a$.
- iv) At this limiting condition, the water surface at d/s gauge location coincides with the normal depth line i.e. Y_n i.e. full supply depth in channel
- v) Then setting $\Delta = Y_n - H_b$
- vi) Depth of flow in the u/s of the flume, D will be :
 $D = H_a + \Delta$
- vii) Afflux caused by the flume Δh will be;
 $\Delta h = D - Y_n$.
- viii) For afflux Δh , check whether sufficient free board is available or not in the u/s of the flume if sufficient free board is not available select the bigger size flume and repeat the steps.

As it is likely that flume may settle down in due course of time, or there may be vegetation growth and silting in the d/s side (which may increase the submergence) it is the practice to set the flume little bit higher than the setting (Δ) worked out.

Location of the Flume:

- i) The flume should not be placed too near the off – taking point because the afflux caused due to the installation/construction of flume may decrease the driving head at head regulator or out-let head. In any channel the distance of Cut-throat flume from off-taking point should be calculated taking into account the afflux, back water length and allowable decrease in driving head.

The length of backwater profile can be computed by direct step method given in any standard book on Open Channel Flow. However, an approximate method for computation of length of backwater profile in small canals is given below:

$$L = \frac{K \cdot X}{S}$$

Where,

- L = length of backwater profile = distance of flume from off-taking point in m.
 K = a coefficient = 1.5 to 1.9
 X = depth u/s of flume – allowable depth d/s of off-taking point in m
 S = bed slope of the canal.

Allowable depth d/s of off-taking point can be determined by knowing the water surface level u/s of off-taking point and minimum driving head required between parent channel and off-taking channel.

(Ref. P.W.D. Hand Book, Volume II (1960). Govt. of Maharashtra, Page 685)

At the planning stage, if topography allows, afflux due to flume can be accommodated at d/s of flume by lowering the bed level of field channel. This will allow to install the flume not far away from the outlet.

- ii) Flume should be installed/constructed in a sufficient straight reach.

Example 2:

Set a cut-throat flume 10 x 90 cm to measure a discharge of 30.0 l.p.s. flowing in a field channel with normal depth 18.0 cm. Make a comparative study with flume size 20 x 90 cm also.

Solution:

$$Q = 30.0 \text{ l.p.s.} \quad \text{and } Y_n = 18.0 \text{ cm. (i.e. normal full supply depth)}$$

- i) from free flow discharge table 3 for flume size 10 x 90 cm and discharge 30.0 lit/sec,

$$H_a = 26.0 \text{ cm}$$

- ii) For flume length 90 cm submergence transition.

$$St = 65.3\% \quad \text{or} \quad 0.653$$

- iii) Maximum value of d/s head H_b for the free flow condition to exist.

$$H_b = St \times H_a = 0.653 \times 26.0 = 17.0 \text{ cm.}$$

- iv) Height of sill (flat bottom) above canal bed,

$$\begin{aligned} \text{setting } \Delta &= Y_n - H_b \\ &= 18.0 - 17.0 = 1.0 \text{ cm.} \end{aligned}$$

- v) Depth u/s of flume,

$$D = H_a + \Delta = 26.0 + 1.0 = 27 \text{ cm.}$$

- vi) Afflux $\Delta H = D - Y_n = 27.0 - 18.0 = 9.0 \text{ cm.}$

The comparative study of 10 x 90 cm and 20 x 90 cm flume sizes for free flow condition in the field channel under consideration is made in the table below:

Steps	Particulars	Flume size	
		10 x 90 cm	20 x 90 cm
i)	U/s head H_a	26.0 cm	17.5 cm
ii)	Transition Submergence St (fraction)	0.653	0.653
iii)	D/s head H_b $= St \times H_a$	17.0 cm	11.5 cm
iv)	Setting Δ $= Y_n - H_b$	1.0 cm	6.5 cm
v)	U/s depth D $= H_a + \Delta$	27.0 cm	24.0 cm
vi)	Afflux ΔH $= D - Y_n$	9.0 cm	6.0 cm

Important Points:

- i) Cut-throat flumes have the advantage over Parshall flumes in the layout of the structure i.e. the floor is flat bottom which facilitates the construction or fabrication simple. Cost of the flumes also reduces considerably.
- ii) As the angle of convergence (3 : 1) and divergence (6 : 1) are same for all flume sizes, even if in the construction the throat width is different than designed, there is a flexibility of using the same flume with modified discharge tables.

4.0 Replogle Flume:

Replogle flume is broad crested weir, having a sill and ramp with slope 3:1 (3 Horizontal to 1 vertical). Profile and cross section of Replogle flume are given in Figure-6.3. The sides of the channel are also the sides of the flume. In the Figure, different abbreviations used are follows:

d = constructed depth of channel: D_1 = upstream water depth, F_1 = actual free broad, Y_1 = gauge reading, L = sill length, ΔY_1 = Loss of head caused by the flume, S = sill height, d_m = normal depth of flow, $3 \times S$ = Three times the sill height (ramp length), B_1 = channel bottom width, B_3 = Channel width at sill level or sill width and Z = channel side slope.

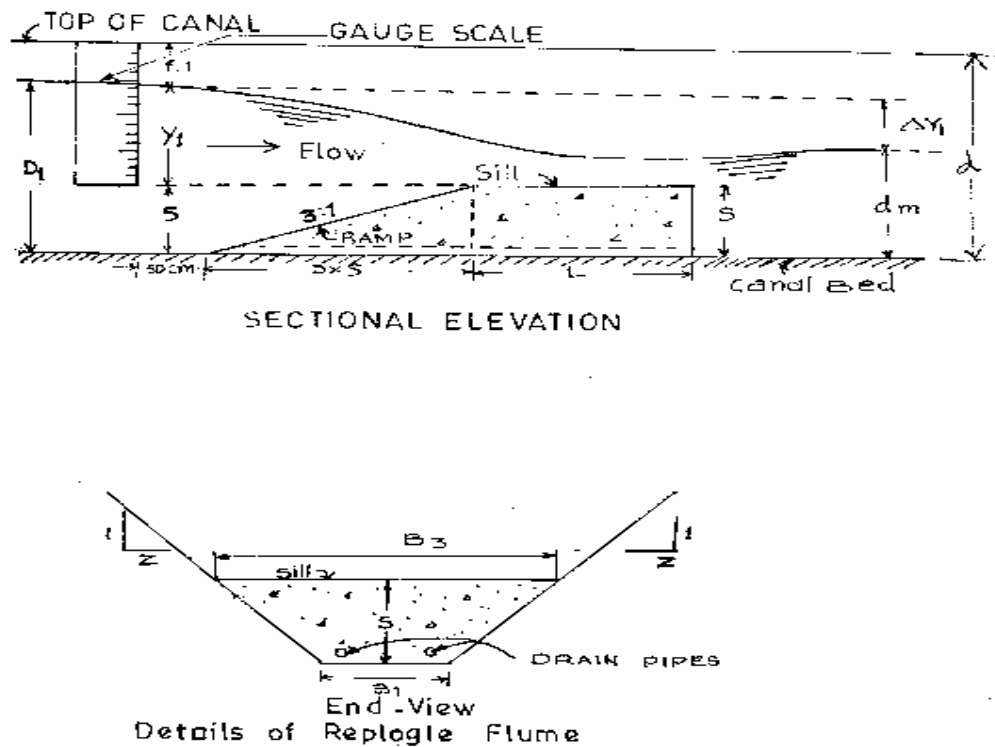


Figure-6.3 : DETAILS OF REPLOGLE FLUME

The gauge is located at a distance of 30 cm upstream of the ramp and its Zero must coincide with the sill level.

The discharge equation, which consists critical flow area and critical depth is complicated due to the trapezoidal shape of flow area and hence is not given here. However, in Table-6.4, discharge are given for corresponding gauge (Y_1) for three sets of sill heights (S) and sill lengths (L) for a channel with bottom width of 30 cm and side slopes 0.5 : 1, 1 : 1, 1.5 : 1 and 2 : 1.

Modular Limit:

The sill height (S) is the most important design dimension for which the flume is very sensitive. Replogle flume operates satisfactorily upto 85% submergence i.e. the downstream water head should not be more than 85% of the upstream water head, both measured above the sill level. In other words loss of head ΔY_1 should be least 15% of the gauge reading Y_1 . Care must be taken that the sufficient free board is available to accommodate upstream depth D_1 ($d_1 = s + Y_1$) for the maximum designed discharge.

TABLE - 6.4**Discharge Table for Replogle Flumes in Field Channels**

Discharge Q (l.p.s.)	Gauge Reading Y_1 (cm)			
	Channel Side Slope			
	0.5 : 1.0	1.0 : 1.0	1.5 : 1.0	2.0 : 1.0
6	3.8	3.0	2.5	2.2
8	4.5	3.6	3.1	2.7
10	5.2	4.2	3.5	3.1
12	5.9	4.7	4.0	3.5
14	6.5	5.2	4.4	3.8
16	7.0	5.6	4.8	4.2
18	7.6	6.0	5.1	4.5
20	8.1	6.5	5.5	4.8
22	8.6	6.8	5.8	5.1
24	9.0	7.2	6.1	5.4
26	9.5	7.6	6.5	5.7
28	9.9	7.9	6.8	5.9
30	10.4	8.3	7.0	6.2
32	10.8	8.6	7.3	6.4
34	11.2	8.9	7.6	6.7
36	11.6	9.3	7.9	6.9
38	12.0	9.6	8.1	7.2
40	12.3	9.9	8.4	7.4
42	12.7	10.2	8.6	7.6
44	13.1	10.4	8.9	7.8
46	13.4	10.7	9.1	8.0
48	13.8	11.0	9.4	8.2
50	14.1	11.3	9.6	8.5
52	14.4	11.5	9.8	8.7
54	14.7	11.8	10.1	8.8
56	15.1	12.0	10.3	9.0
58	15.4	12.3	10.5	9.2
60	15.7	12.5	10.7	9.4

Advantages:

- Simple in construction and cheap in cost
- No upstream approach transition is required as the section of the flume is same as the section of the channel
- Modular limit (free flow limit) is higher (upto 85%) the Parshall flume and Cut-throat flume.

Replogle Flume for Field Channels:

Recommended size of Replogle flume for the measurement of discharge in field channels (Bottom width $B_1 = 0.3$ m) is with sill S as 0.2 m and sill length L as 0.5 m. The discharge table, for channel side slopes 0.5:1.0, 1.0:1.0, 1.5:1.0, 2.0:1.0 and is given in Table-6.4.

Construction:

Replogle flume can be constructed either in masonry or in concrete. But care must be taken to provide accurate side slopes throughout the length of flume, finishing, curing, etc. the sill height (S) should not change more than 1 percent.

Wall Mounted Gauge scale is mounted on the sidewall of the channel at the prescribed location. As sidewalls of the channel are inclined, scale should be either calibrated to read vertical depths, or correction factor should be applied.

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CHAPTER – 7

LINING

1. Preliminary:

The field channels are the last link in the water delivery system of an irrigation network. They constitute the micro distribution system, which operates below the outlet, installed on a minor, distributory or a direct outlet on branch / main canal in some cases. The field channel, thus, distributes the water to each field in the command of the chak. The distribution network of field channels, therefore, governs the quantity of irrigation supplies to each beneficiary.

2. The factors influencing the conveyance efficiency of field channel:

The conveyance efficiency of the field channel at turnout is the percentage ratio of water delivered at turnout (W_t) to water delivered at irrigation outlet (W_o).

It is, thus, obvious that various causes occurring from irrigation outlet to turnout, which affect the quantity of flow from irrigation outlet to turnout, would constitute factors influencing the conveyance efficiency. These are enlisted as below:

$$E_d = \frac{W_t}{W_o} \times 100$$

- a. Bed gradient, alignment and length of F.C.
- b. Discharge characteristics of the outlet i.e. Gate controlled outlet, standard regulated outlet, etc.
- c. Head losses due to pipe crossings on F. C.
- d. Seepage losses through F. C.
- e. Location of turnout with reference to drop structures on F.C.
- f. If the initial length of field channel from the irrigation outlet to the first service point (turnout) i.e. the water course, is in deep cutting in fine texture expansive soil (B. C. soil), the side slopes often collapse and create an obstruction to the flow in the field channels. If the watercourse, therefore, is not maintained regularly, the water delivery in the field channel and subsequently through turnouts is badly hampered, causing decrease in conveyance efficiency of the field channel. This affects the utility of O.F.D. works and reliability of irrigation supplies to the beneficiaries, particularly at tail end.

3. Need for lining:

Experience in irrigation projects in the country as well as outside, shows that the percentage of water lost in small irrigation channels is generally higher than the losses in the large canals. They constitute a substantial portion of irrigation water. The longer the length of unlined watercourse, the more are the losses, because watercourse is running for the full flow period of rotation. The longer unlined length of field channel between division box to the first turnout on either side will also result in substantial seepage losses. The principal considerations, for providing lining to the field channels in the first instance, are, therefore, reduction of seepage losses and achieve improvement in conveyance efficiency of F.C.

There are numerous of other benefits, which may be achieved to the maximum extent through F. C. lining in full length, which cannot be determined directly, but they are nevertheless important. Some of them are listed below:

a. Improved water supply in the command:

Reduction of seepage, thereby making more water available for irrigation and thus improving rate of water supply in the command, and the beneficiaries at tail end of command in particular.

b. Reduction in filling time:

With lined F. C., conveyance efficiency is improved which helps to reduce the filling time for a field i.e. time to irrigate the crops in the field. This in turn provides increased delivery period to the other fields and tail-end farmers may also get full supply of water, in a given duration of time.

c. Elimination of possible breaches:

The chances of accidental breaching of F.C. are almost negligible in case of lined channel, thereby reducing the likely damages to standing crops and farm soils.

d. Eradication of weed problem:

Waterweeds grow luxuriously in unlined F. C. channel beds and banks. Besides using water for their plant life, these promote siltation of channel and reduction of water velocity. This green grass attracts grazing animals which deteriorate the F.C. section due to trampling. Lining of F. C. may help to eradicate the weed problem and other allied problems.

e. Minimizing of waterlogging in adjacent lands:

Reduction of seepage losses help to reduce the menace of waterlogging and salinity to some extent, in adjacent lands.

f. Reliability of water supply:

The lined watercourse with appropriate mode of construction and the construction materials, helps to reduce the sliding of side slopes of F. C. This in turn helps to ensure structural integrity of the watercourse and hence the reliability of water supply.

In clayey soils like black cotton soils, the unlined channels are not stable and quickly get de-shaped. It is expected that in such soils, lining will help in ensuring the structural integrity of channel and in allowing water to be distributed in a more equitable and rational fashion.

g. Improvement of operational efficiency:

All the above (a) to (f) benefits allow improvement of operational efficiency also.

3.1 Requirements of lining:

Requirements of a good lining are impermeability, structural stability, durability, hydraulic efficiency, and economy.

a. Impermeability:

A good lining should restrict the seepage losses to a value of about 0.6 cumecs/Mm². Generally the seepage loss is more dependent upon the type of jointing than the material of the lining.

b. Structural stability:

The lining will be subjected to external pressure due to sub-soil water and saturated back fill and should be able to withstand the same. It should also be strong enough to withstand trampling by livestock. Lining with rigid materials like concrete, bricks, stone, etc. is strong against trampling by livestock, but it is susceptible to cracks because of back pressure. Lining with soil, soil cement, PVC, etc. is relatively flexible, but cannot withstand trampling by livestock.

c. Hydraulic efficiency:

Smoothen the lining, smaller the coefficient of rugosity(N), and higher the hydraulic efficiency. The coefficient of rugosity is a function of condition of surface. If the surface conditions deteriorate with time or due to less maintenance, the value of N changes. The coefficient of rugosity, however, also depends upon the manner in which the lining is laid, particularly the joints. For small channels, like field channels, the workmanship of construction affects the coefficient of rugosity to large extent.

The value of rugosity coefficient can range from 0.022 for well-laid concrete pipes to 0.03 for stone masonry. The values of coefficient of rugosity for grass lining is 0.035 and for the unlined field channel in murum, it is 0.04. Since, the hydraulic efficiency is very sensitive to coefficient of rugosity, the lining shall be as smooth as possible.

d. Durability:

Lining should be durable. It should withstand the erosive effect of high velocity of water, weather conditions, changes in moisture, weed growth, rodents and trampling by livestock. If the lining is not durable, the cost of maintenance may become recurring and prohibitive. Ease of maintenance and repairs will also be a factor for consideration, along with its durability.

e. Economy:

Cost of lining will depend upon the availability of construction materials at reasonable leads, availability of skilled and unskilled labour and also availability of machinery and equipment for construction.

Types and techniques of lining:

There are various types of Field Channel lining based on the construction material used for lining the cross section. Generally, the various types of lining for field channels can be classified into two categories:

A. Soft surface lining:

- a. Bentonite lining
- b. Soil cement slabs lining
- c. PVC lining
- d. Murum lining
- e. Grass lining

B. Hard surface lining:

- a. UCR stone masonry lining
- b. Brick lining
- c. Shahabad stone tile lining
- d. Concrete lining
 - i. Cast in situ concrete lining.
 - ii. Pre-cast cement concrete slabs.
 - iii. Pre-moulded, precast concrete sections
 - Trapezoidal concrete sections in PCC
 - RCC concrete half-round pipes.

4.1 Soft Surface lining :

Bentonite lining is not suitable for field channel lining. The soil-cement slabs had been used in Jayakwadi Project on experimental basis and it had been observed that, this type of lining is not strong, durable and impermeable. The L.D.P.E. or PVC lining had also been tried on Bhima Project, but the experience revealed that this type of lining is not strong to resist trampling and get punctured. For murum lining, the proper CNS material is not available economically in Maharashtra. Hence, murum lining is not provided. The grass lining is considered the most economical soft surface lining. It is necessary to promote and implement grass lining to field channels in situations where field channels cannot be lined in full length with masonry, bricks, concrete or RCC half round spun pipes. Hence, details of installing the grass lining to field channels are presented in this manual.

4.1.1 Grass lining:

Grass lining is perhaps the cheapest type of lining where the main purpose of lining is to retain the channel section. Such cases arise in case of soft soils, especially black-cotton soils. The deterioration of section can be prevented by providing grass lining for bottom width and sides of the section. Immediately after the field channel section is cut in ground or built in embankment, spreading variety of grass is planted on bottom and sides. Watering for a few weeks makes grass to root in properly and spread in due course on remaining moisture after rotation.

In “The Evaluation report of O.F.D. structures (1988) prepared by The Directorate of Irrigation Research and Development, Pune (DIRD, Pune), it is reported that, “In Japan nowhere concrete is used for lining and grass is grown on prefabricated, foldable bamboo mats. This is initially done at one central place and then these are transported for laying to the site in position.” Please see Fig. 7.1.

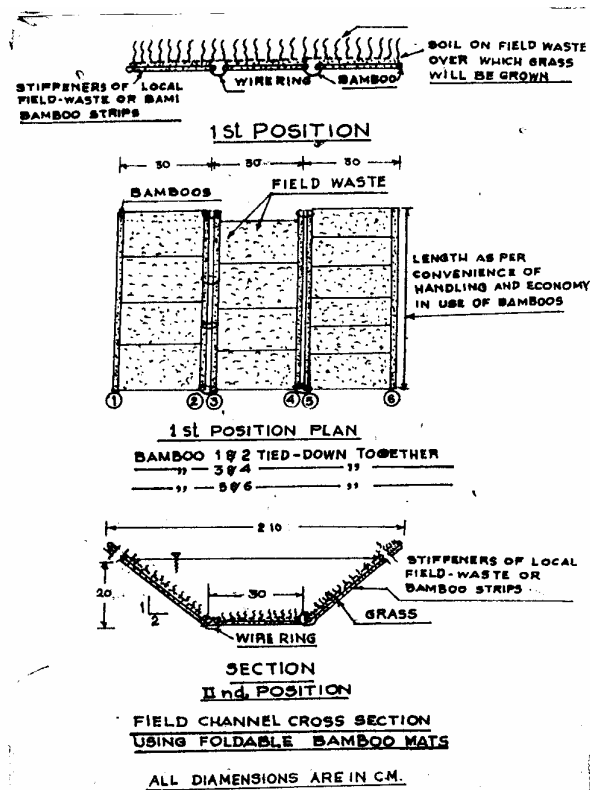


Fig. 7.1
Sketch for Grass Sodding Technique on foldable bamboo mats.

From the preliminary experiments done by DIRD, Pune, it is seen that the cost of this type of lining, is almost one third of the cost of concrete lining. This type of lining, however, could not be used on mass scale because of non-availability of foldable grass mats in large quantity.

The Chief Administrator, CAD, Aurangabad had taken-up grass lining on experimental basis by issuing a technical circular vide CS/CAD/Mudaka/2795 dt. 23.6.88 on this issue. It has been mentioned in this circular that local variety of creeping grass known as "Harali" occurs naturally in the field channels along with other types of weeds and grasses. It is further directed that during maintenance of field channel, the vertically growing grass may be uprooted because it obstructs the flow, but the creeping grass "Harali" may be allowed to grow. Such grass may be used to plant on other lengths of field channels where "Harali" does not appear naturally. It has been further advised to contact agricultural experts to know about other variety of creeping grasses like Blue grass.

It has been, however, observed that grass lining invites cattle and the field channel section gets disturbed due to trampling of cattle. Secondly, farmers nearby also do not allow to grow weeds in field channel under apprehension of spreading of weeds through water in their fields, thereby increasing their costs on weed removal from farms and fields.

The grass lining is worth attempting in the field channel, lengths, where costly concrete / masonry lining cannot be provided for want of funds or due to

limitation of cost norms for field channel lining. The grass lining helps to maintain F.C. cross section as well as F.C. Alignment at low cost.

4.2 Hard surface lining:

4.2.1. Murum / CNS backing, The Basic need for good quality of Hard Surface lining in soft soils:

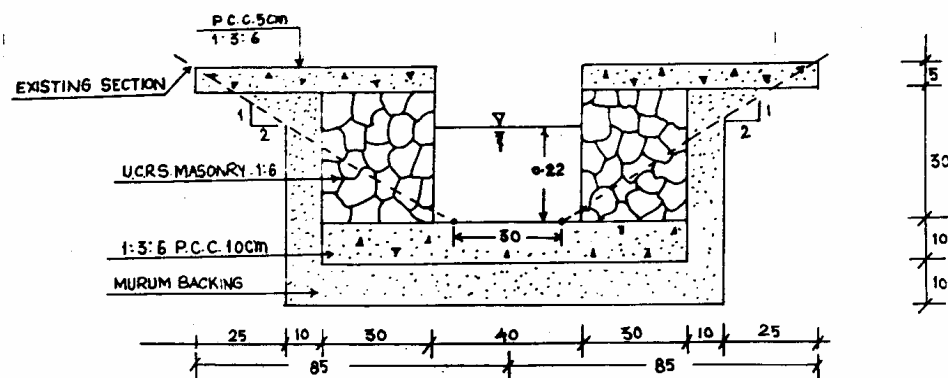
For any type of hard surface lining to the field channel, passing through soft soils, especially black-cotton soils which exhibit typical behavior in wet & dry conditions, the bedding & sides are required to be prepared by providing properly compacted murum / CNS layer of at least 20 to 30 cms thick. For any other type of hard soils, soft murum bedding is provided to create an even surface so that proper bed gradient can be achieved in finished surface of lining. In embankments also, it is necessary that earthwork behind & below the lining is properly compacted so that lining does not crack due to uneven settlement. It is desirable to place the lining in embankment portion after one year has passed on, after the construction of embankment.

4.2.2 Types of hard surface lining:

a. UCR Stone masonry lining:

For the UCR Stone masonry lining, the cross section of field channel is usually of rectangular shape, with plain cement concrete at bottom and vertical masonry sides. The field channel cross section provides for a free board of 7 to 10 cms above water level. The rectangular cross section with bottom width of 40 cms is kept from the workability of masonry construction and ease for maintenance, point of view. It may be easily cleaned using *phawara* which has 20 to 25 cms wide blade.

The bottom is provided in 10 cm thick plain cement concrete (1 : 3 : 6) slabs, as the bed of the field channel has to be structurally stable, durable & impermeable. The U.C.R. (1:6) stone masonry constructed for vertical sides of the field channel, has thickness of 30 cms for the view point of workability of masonry construction. Please see Fig. 7.2, which show the typical cross sections of field channel with Masonry lining.



ALL DIMENSIONS ARE IN C.M.

Fig. 7.2
Typical cross section of field channel lining 0.3m thick UCRS
Masonry for vertical sides and PC concrete bedding

In fig. 7.2 masonry lining with 1:3:6 P.C.C. bed has been provided. This type of UCR stone masonry lining has been tried in the Mula Pilot Project (1980) and subsequently many other places in irrigation projects. Though the cost of this type of lining is comparatively high, it is reported to be performing well. Secondly, the recurring costs on repairs to lining are very low, when coping of 1:3:6 P.C.C. is provided over masonry vertical sides including top of murum backing. This type of lining has been provided to water courses in pilot distributories in Pilot Project of Dynamic Regulation on Majalgaon Project (1998). Their hydraulic performance is satisfactory because of stable bed gradient & maintenance free cross section. UCR stone masonry can be constructed & maintained if required, by local masons. Hence, UCR masonry lining may be selected for full length of water course in the chaks because they perform hydraulically better and provide reliable water supply with easy maintenance. UCR stone masonry can also be provided F.C. lining in selective lengths of F.C. The performance of F.C. lining with UCR Stone Masonry in selective lengths is equally good. Hence, this type of lining is widely used in some projects.

b. Brick lining:

Brick lining may be used for lining to field channel / water course if the bricks are available nearby the command of distributory / minor, wherein construction of field channel lining is to be taken up. The availability of construction material i.e. bricks, near the working site would economize on lead charges. Brick lining besides being durable is fairly impermeable. Secondly, it can be constructed and maintained by local masons.

The brick lining may be done in trapezoidal section or rectangular section. The trapezoidal section is found to be vulnerable to damage due to trampling of cattle. The top layer of bricks in both cases gets loosened gradually and then the brick lining starts deteriorating. A typical cross section of field channel with brick lining is shown in Fig. 7.3. Here, half brick lining is used for sides. In brick lining, instead of half brick thick lining for sides, full brick thick lining may be done and restricted to 6 to 7 brick courses as shown in fig. 7.4. This type of lining increases the

thickness of brick lining and makes it stronger, but the number of joints increase in such cases. The quantity of bricks also increases. Where there is shortage of bricks, the bed may be laid with 10 cms thick 1:3:6 cement concrete.

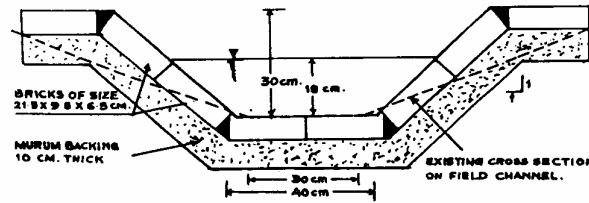


Fig. 7.3
Cross Section showing field channel lining using bricks with half brick thickness.

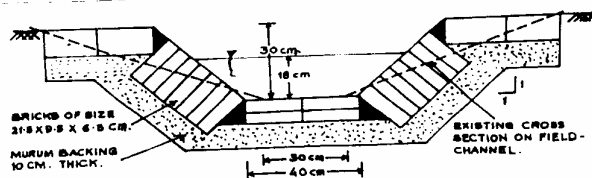


Fig. 7.4
Field Channel with Brick Lining using bricks with full brick thickness.

Brick lining has been tried on Mula and Bhima Projects. The length laid in Bhima Project was 1500 m of rectangular section and 1400 m of trapezoidal section. The seepage losses were observed to be about 1.8 Cumecs/Mm² in rectangular type and range from 2.3 Cumecs/Mm² to 2.8 Cumecs/Mm² in the trapezoidal type.

In Maharashtra, the availability of bricks is not wide spread, except near urban areas. The bricks are mostly used for housing purpose. The availability of bricks in villages is scarce. The bricks used in side lining are likely to be loosened by miscreants, purposefully and theft for other uses in the villages. The brick lining may, therefore, be used judiciously.

c. Shahabad stone lining:

Shahabad stone lining has been tried on Bhima Project. There is a high risk of Shahabad stone slabs being stolen. Hence, these may be used with caution.

d. Concrete Lining:

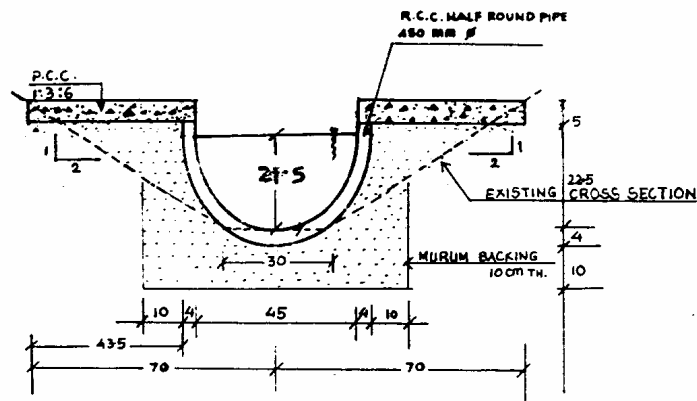
Concrete has been considered for field channel lining in four different forms, viz.

1. Cast in situ concrete lining.
2. Precast cement concrete slabs (P.C.C. Slabs).
3. Premoulded plain concrete trapezoidal section:
4. Precast reinforced half round spun pipes:

The concreting operation in situ for field channels, where work is done at isolated patches in remote areas, rigorous quality control is difficult to achieve. Hence, cost in situ concreting is generally avoided. Precast cement concrete slabs and premoulded plain concrete trapezoidal sections have been tried in Bhima Project, Mula Project and Jayakwadi Project. It has been experienced that these types of linings function well, but the breakage of slabs / trapezoidal sections is prohibitive. Hence, premoulded slabs and trapezoidal sections are not in use as F.C. lining. The precast reinforced half round spun pipes are used as FC lining on large scale in many projects because this type of lining is observed to be strong, durable and easy for construction. Hence, details of F.C. lining with precast reinforced half round spun pipes are given in this manual.

4.2.2.1. F. C. Lining using precast reinforced half round spun pipes:

Of all cross sections of a given area, the semi circle has the smallest wetted perimeter. It is the cross section giving the highest hydraulic efficiency. Structurally also, a semi circular is better than a trapezoidal section because stress concentrations are likely to be few. Looking to larger percentage of breakage of premoulded P.C.C. sections, nominal hoop reinforcement of 4 mm dia at 25 cm centre-to-centre and longitudinal reinforcement of 6 mm dia, 5 Nos. along semicircle is introduced in precast concrete half round pipes. From the easy handling point of view, the length of single pipe is kept as 1.25 M. This can be easily lifted and placed by two persons, lifting each piece of pipe from two ends. This type of lining has fewer joints as compared to P.C.C. slabs because of larger length (1.25 M) of single pipe. A typical cross section of field channel lining with half round spun pipes is shown in Fig. 7.5. A semicircular pipe with 45 cms diameter and 4 cm thickness is used with nominal reinforcement as discussed above.



All dimensions are in cm

Fig. 7.5

Typical cross section of field channel lining with half round spun pipe 45 cm dia.

The main shortfall of this type of lining is, however, that it has very little free board. The height of half round pipe lining is 22.5 cm (i.e. radius of pipe) only, whereas the height of flow for discharge of 30 lit/sec with normally occurring bed gradient and rugosity coefficient 'N' as 0.022 is 18 to 21 cms. Thus, free board is hardly 4.5 to 1.5 cms. It is observed from design calculations that for bed gradient, 1:800, the depth of flow is 22.5 cms. Hence, it is obvious that for any field channel with a bed gradient flatter than 1:800, the depth of flow will surpass the edges of half round pipe. Hence, even if a little larger discharge than 30 lit/sec is accidentally let out in the field channel, the water overtops the periphery of half round pipe and water seeps by the sides of pipe. The edges of half round pipe lining are also likely to be overtopped near the division box, due to small free board which may not accommodate the rise in water level caused due to some backwater effect and whirling action when the field channel flow turns at right angle in the division box. Such over topping is also likely to occur in the half round pipe lining near the measuring device, like Parshal flume, if appropriate type of Parshal flume is not used. Since the free board is too small, even minor obstructions like inadvertently occurring soil clods and silt mounds may result in rise of water level and cause overtopping of half round pipe lining. The change in rugosity conditions of pipe, change the hydraulic conditions and hence change in depth flow. It is observed from design calculations, that change in coefficient of rugosity from 0.022 to 0.025 for half round pipe with bed gradient 1:550 causes the rise in depth of flow from 0.2m to 0.215m. for a discharge of 30 lit/sec. It is thus, obvious that pipes shall be kept smooth and clean.

Moist / wet conditions in the murum backing are likely occur when lining is overtopped in various situations as discussed above and disturb the bed gradient of that segment of pipe. Thus, the sanctity of design bed gradient is likely to be lost due to such mishaps. Hence, it is essential to have a P.C.C. coping of 5 to 10 cm thick over edges of pipe, covering the murum backing at the top. This would not only protect the murum backing, but would provide additional free board and prevent thefts because there is a high risk of theft of half round pipes. The stolen pipes are seldom taken to home by farmers. The stolen pipes are put by farmers in minor or distributory and used as temporary crossing at convenient locations for their movement of bullocks, agricultural equipments, etc. from one field to other field.

Such misuse of pipes disrupts the flow conditions in the parent minor or distributory and the field channel is also left to get deteriorated. Hence, optimum provision of crossings in the distributory network is essential to avoid loss of half round pipe lining. This may sound stretching imagination, but the experience teaches this lesson. The other difficulty in case of half round pipe lining is that it is difficult to lay RCC half round pipes along curves, because these pipes are available in straight lengths of 1.25m length. Hence, UCR Stone Masonry (1:6) lining is generally proposed on curves and half round pipes for the straight legs of the curve. To reduce the cost of lining, dry rubble pitching on curves may also be a good alternative.

The cost of half round spun pipe is higher than any other type of concrete lining, but the minimum wastage in breakage compensates the higher cost and secondly, the seepage losses through joints are also minimum. This type of lining has been extensively used in Bhima, Jayakwadi and Mula Projects. In Bhima Project, the seepage losses were observed to be only 0.5 cumecs/Mm².

4.3 Selection of type of lining:

Selection of type of lining has to be done very judiciously, because it involves large financial investments in its construction. Secondly, the type of lining has to be such that the recurring costs of maintenance and repairs has to be minimal. Thirdly, the nature of repairs has to be such that it can be easily done using local materials and local skills. Thus, the type of lining selected should be effectively economical, hydraulically efficient and structurally stable to achieve the maximum conveyance efficiency with minimum water losses through seepage.

From the earlier discussions on various types of lining, it appears that no single type of lining may be used for the complete length of the field channel in a chak. In a given chak, a combination of two or three types of lining may prove to be effectively economical and efficient in long run. The DIRD, Pune conducted a survey of observations of the lining of field channels in various commands with different materials. The analysis of performance data done by DIRD, Pune is given in Table 7.1.

TABLE 7.1
Performance analysis of field channel lining with different material in various commands done by DIRD, Pune

Sr. No.	Type of Lining	Total length observed (m)	Condition		
			Average Length	Good Length	Bad Length
			(m) / %	(m) / %	(m) / %
1.	PCC Slabs	7064	4945 / 70	282 / 4	1837 / 26
2.	Per-moulded trapezoidal PCC Sections	8192	3522 / 43	4587 / 56	83 / 1
3.	UCR Stone Masonry	415	182 / 44	233 / 56	Nil
4.	Half round spun pipe	1096	230 / 21	822 / 75	44 / 4

It can thus be seen that the percentage failure is much less in field channel lining with half round spun pipes and premoulded trapezoidal P.C.C. sections whereas it is Nil for U.C.R. stone masonry lining. It has, however, been observed that percentage breakage of premoulded trapezoidal sections during transport and actual construction is prohibitive. Hence, the choice remains between U.C.R. masonry lining and half round spun pipes lining. These may be used in combination with grass lining, murum lining etc. on the merits of site conditions and cost norms, as discussed below:

- b. The U.C.R. stone masonry lining may be used for complete length of water course which is generally not longer than 5 to 10 M, because the location of outlet is so selected that it opens out in its command within shortest distance, i.e. with shortest length of water course.
- c. The half round spun pipe lining may be used on selective lengths at vulnerable sections of field channel where lining is necessary for retaining the structural integrity of the channel section, i.e. at high banking section, on curves, upstream and down stream of OFD structures, where the field channel is passing through soft soils like B.C. soils.
- d. U.C.R. Stone masonry may be used instead of half round spun pipe lining, on selective length at vulnerable sections of field channel if it is less costlier, at particular location due to ready availability of construction materials like rubble, sand, water at shorter lead distances.
- e. For the remaining length of field channel, grass lining with naturally growing local grass may be developed so as to stabilize the cross section.
- f. If good quality of murum is available at short leads from excavated materials of distributory / main canal, murum lining may be tried.

4.4 Extent and location of lining:

The extent of field channel lining in a given chak has always been a point of debate. There is one school of thought, which questions the utility of field channel lining in improving the functioning of irrigation activities in the chak and insist to the extreme point that no lining may be provided to the field channels. It is important to note here that the irrigation activities in the chak are related to reliable water supply in assured quantity, which in turn depends on the well being of field channel net work in the chak and the well being of field channel net work is governed by protective works like field channel lining. The well being of field channel lining is in turn, dependant

on the type of lining, extent of lining and location of lining and quality of construction of lining. Thus, field channel lining at appropriate locations with proper design and good quality is essential to improve irrigation management in the chak. The extent of field channel lining would depend on the type of soil through which it is passing and financial norms.

4.4.1 To decide extent of field channel lining in pervious soils:

If the field channel is passing through pervious soils like murum and other light soils, the field channel cross sections do not get disturbed much, but the seepage losses would be prohibitive. This would mean a loss of precious resource like water and also increase in rotation period. Hence, it is necessary to provide field channel lining in pervious soil, but the extent to which such lining is required has to be judiciously decided. WALMI, Aurangabad has explained the principle to decide the extent of lining in its publication No. 12 (March 1989). To understand the principle to decide the extent of field channel lining in pervious soils to achieve reduction in seepage loss, an example is illustrated herewith.

Step 1: Prepare a schematic diagram of the field channel distribution with division boxes and all turnouts upto last turnout as shown in Fig. 7.6.

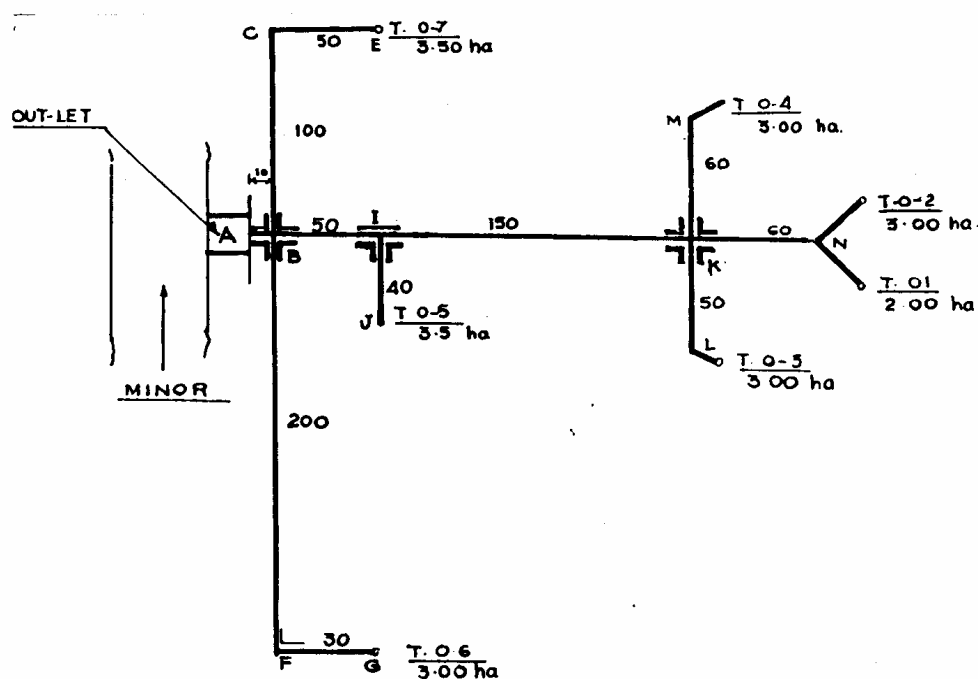


Fig. 7.6
Schematic diagram of hypothetical chak for calculations of losses in F.C.

Step 2: Mark the length of each segment of field channel and the area under each turnout to be irrigated.

- Step 3: It is assumed that irrigation is being done with R.W.S. and for the sake of simplicity, it is assumed that 1.0 ha can be irrigated in 10 hours.
- Step 4: To prepare a statement showing percentage losses in each segment of field channel.

In a given chak, the discharging capacity of field channel is constant, i.e. 30 ltr./sec and the flow section of the field channel does not vary appreciably. Hence, the field channel losses will be effectively proportional to the product of the length of segment of field channel and the running time of flow through that segment.

i.e. Seepage losses $\propto$ Length of segment $\times$ running time.

Using this principle, a statement showing percentage losses in each segment of field channel is prepared as worked out from the schematic diagram. The irrigation is considered from tail to head.

Table 7.2 shows the statement of percentage losses in each segment of field channel.

- Step 5: To plot a curve showing percentage losses in field channel against the percentage length of field channel.

The percentage losses obtained in Table 7.2 are arranged in decreasing order in Table 7.3. The corresponding length of segment is denoted against the corresponding percentage losses. The percent length of each field channel segment is worked out. The cumulative percentage losses and the cumulative percentage of total length is obtained. A curve as shown in Fig. 7.7 is prepared.

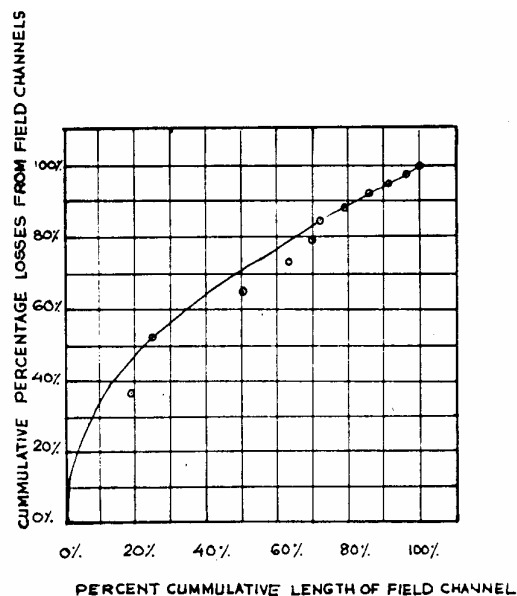


Fig. 7.7

Graph showing % losses against % length

Table 7.2

Statement showing percentage losses in each segment of field channel.

Segment of F.C.	Length (M)	Running time in Hours for Turnouts (10 Hrs/Ha.)								Product of Length & Running time (M.-hrs)	% losses in each segment (% w.r.t. total M-hrs.)
		1	2	3	4	5	6	7	Total		
1	2	3	4	5	6	7	8	9	10	11	12
AB	10	20	30	30	30	35	30	35	210	2,100	4.60
BC	100	0	0	0	0	0	0	35	35	3,500	7.66
CE	50	0	0	0	0	0	0	35	35	1,750	3.83
BF	200	0	0	0	0	0	30	0	30	6,000	13.13
FG	30	0	0	0	0	0	30	0	30	900	1.97
BI	50	20	30	30	30	35	0	0	145	7,250	15.86
IJ	40	0	0	0	0	35	0	0	35	1,400	3.06
IK	150	20	30	30	30	0	0	0	110	16,500	36.11
KL	50	0	0	30	0	0	0	0	30	1,500	3.28
KM	60	0	0	0	30	0	0	0	30	1,800	3.94
KN	60	20	30	0	0	0	0	0	50	3,000	6.56
Total										45,700	100.00

Table 7.3

Table showing percentage losses in field channel against percentage length of field channel.

Segment	Losses in the segment (Percent)	Cumulative percentage of losses	Length of segment in (M)	Percentage of total length	Cumulative % of total length
1	2	3	4	5	6
IK	36.11	36.11	150	18.75	18.75
BI	15.86	51.97	50	6.25	25.00
BF	13.13	65.10	200	25.00	50.00
BC	7.66	72.76	100	12.50	62.50
KN	6.56	79.32	60	7.50	70.00
AB	4.60	83.92	10	1.25	71.25
KM	3.94	87.86	60	7.50	78.75
CE	3.83	91.69	50	6.25	85.00
KL	3.28	94.97	50	6.25	91.25
IJ	3.06	98.03	40	5.00	96.25
FG	1.97	100.00	30	3.75	100.00
Total :			800		

Step 6:

Analyse the information in Table 7.3 and the curve in Fig. 7.7. It can be seen from the curve that even if 20 percent length of field channel is lined, the percentage seepage losses are reduced to 45 to 50 percent. If the lining is restricted to 15 to 20 percent,

the percentage losses saved are 40 to 45 percent. The saving in losses does not increase substantially by lining F. C. lengths beyond 75 to 80 percent of total length.

4.4.2 To determine the need and extent of field channel lining in Black Cotton Soils:

Maharashtra has the highest percentage of area of Black Cotton Soils in the country. The gross total Black Cotton soil area of India is 72.9 Million ha. and out of this total, Maharashtra has a share of 29.9 Million ha. In many of the irrigation projects in Maharashtra, the project command area constitutes Black Cotton soil area to the extent of 40% to 60%. In Jayakwadi Project, the project command has Black Cotton soils (deep & medium) to the extent of 65 percent. The issue of OFD works and field channel lining particularly in Black Cotton soils need to be treated with careful thinking.

Black Cotton soils are impervious in wet conditions. The seepage losses through field channel in wet conditions are hardly 1 to 2 percentage. Hence, it is sometimes thought that lining is not required in Black Cotton soils. But on careful thinking, it can be seen that lining to field channels in B.C. soils is required as protection to the field channel section and OFD structures.

It is a well-known fact that Black Cotton soils are expansive soils which increase in volume in wet conditions and shrink in dry state, to develop cracks in the soil. The field channel sections, therefore, cannot retain the shape. The water flow through field channel may create wet conditions around the foundation and upper parts of the OFD structures on field channel. The expansive nature of Black Cotton soils in wet condition causes distress in such OFD structures and cracks appear in the structures. The structures being small, such development of cracks initiate deterioration. The unequal settlement of structures in such state causes dislocation and distortion in design alignment and setting of the structures. It can, thus, be seen that field channel lining in Black Cotton soils is very much required to retain the field channel section on curves, design alignment and setting of the OFD structures.

Since the purpose of providing lining to field channels in Black Cotton soils is to protect and prevent behavioural failures to achieve structural integrity, only the vulnerable segments of field channels are identified for selective lining. Such vulnerable locations are enlisted as below:

i. High embankments:

For embankments of height 0.5 m and more, lining is required to be provided in full length of banking section. Field channel section in banking may be required to be protected from outside at some locations where the field channel is located on contour on a sloping field. Such protection may be achieved by providing dry rubble pitching to banking from outside.

ii. Curves:

On curves, the protection with lining for a length of 3.75 m (i.e. three pieces of half found spun pipes) on either side of the curve, in addition to full length of curve is sufficient,

iii. Field channel segments on upstream & down stream of OFD structures.

Field channel segments of 3.75 m length (i.e. three pieces of half round spun pipes) on upstream and 2.5 m (i.e. two pieces of half round pipes) down stream of drop structures, division boxes, crossing and measuring device is sufficient. Lining may not be provided on upstream and down stream of turnouts.

iv. Water course in deep cutting:

The field channel section in cutting with a cutting depth more than 0.5 m is likely to be disturbed due to side collapses. The design bed gradient is also distorted due to such collapses. These factors affect the water delivery schedule badly. Hence, it is essential to protect complete length of watercourse with lining to achieve credibility of water delivery in the field channel disnet of the chak, thereby increasing the utility of OFD works.

5.0 Design of Lined field channel section:

Lined field channels are designed on the same principles as unlined, except that the coefficient of rugosity 'N' changes, with the type of lining. The Govt. of Maharashtra in Irrigation Department has issued a technical circular for revised design of canals vide Govt. circular No. MIS 1094/(156/94) MP (A) dt. 18/02/1995. In this circular, the coefficient of rugosity for lined and unlined canals have been specified, based on the discharging capacity of canal. The field channels are too small irrigation channels to compare with canals. The construction of field channels being of small in quantity and scattered in nature, as compared to construction of canals, the construction finishes are not fine enough. Hence, the values of coefficient of rugosity 'N' for lined and unlined field channels are considered as per "Manual of design for OFD works (1982)". These values of N are given in Table 7.4.

Table 7.4
Recommended values of N for field channels.

Sr. No.	Types of surface lining	N
01.	Half round RCC spun pipes	0.024
02.	Pre-moulded PCC trapezoidal sections or PCC soil cement slabs or Shahabad stone or concrete cast in situ	0.025
03.	UCR Masonry	0.03
04.	Murum / CNS lining	0.03
05.	Grass lining	0.04
06.	Hard murum / rock cutting	0.04

The bed gradient of field channel is, generally, not changed in the lined segment of field channel, when lining is done in selective lengths.

The bed width of the lined section in UCR Stone masonry is kept sufficiently wide from the workability point of view during construction and also for easy maintenance. Generally, this is kept as 0.4m.

The side slopes may be kept vertical for UCR Stone masonry or these may be sloping at 1:1 or 1:1½ if trapezoidal section is adopted for brick masonry lining or UCR Stone masonry lining.

The water depth of flow is determined for a discharge of 30 lit/sec. using Manning's formula. Table 7.5 illustrates the depth of flow for a discharge of 30 lit/sec., various bed gradients and different types of lining. This is only for quick estimation. The detailed design of cross section shall be done for the actual bed gradient, side slopes and lining material. The type design of lined cross section with RCC half round spun pipes and with UCR Stone masonry is presented in Annexure 7.1 & 7.2 respectively.

6.0 Preparation of plans and estimates:

For realistic plans & estimates of F.C. lining, following aspects shall be studied and be incorporated appropriately in the estimate:

- a. The plans and estimates for the construction of field channel lining shall be prepared on the basis of work done plans and L-sections of OFD works of the chak. If these are not available, the factual plans and L-sections be prepared by ground verification & resurvey.
- b. From the layout map of the field channel disnet, following information is prepared:
 - i. Type of soil in various segments of field channel and requirement of field channel lining depending on type of soil.
 - ii. The statement showing location and type of structures.
 - iii. The statement showing location and length of curves.
 - iv. The statement showing location and length of field channel segments in banking with height of banking more than 0.5 M.

From above details, estimate the length of F.C. lining as discussed in 4.4.1 and 4.4.2

- c. Identify the field channel segments for which lining is essential, from outside as protection against runoff from heavy rains etc.
- d. The availability of construction materials, i.e. Rubble, murum, sand, cement and water is assessed. The shortest leads are identified and lead chart is prepared.
- e. The stacking place for half round pipes in the chak may be identified so as to avoid rehandling and transportation.
- f. Work out the rate of construction per meter length of lining with R.C.C. half round spun pipes and UCR Stone masonry, taking into consideration the realistic leads as identified in (d) above. In the rate analysis of items of construction, following points may be looked into and account for carefully,

- i. Excavation of section in wet condition or in dry condition as per the actual case.
(Do not forget to deduct the existing F.C. section from the box out required for F.C. lining.)
- ii. Back filling for murum backing watering and due compaction, etc.
- iii. Construction of masonry 1:6 proportion, if masonry lining is to be provided.
- iv. Cement pointing (1:3) to joints.
- v. P.C.C. of 1:3:6 mix proportion for coping including curing etc.

6.1 Economizing the cost of lining:

- a. For F. C. passing through pervious soils:
When the field channel is passing through pervious soils, the objective of lining is essentially to reduce the seepage losses. It has been observed (please refer to para 4.4.1, Fig.7.7) that field channel lining with just 20 percent of total length of field channel reduces the seepage losses to the extent of 45 to 50 percent or so, which is a reasonable reduction. Hence, field channel lining to the extent of only 20 percent of total length of F.C. may be considered. Thus, if total length of F.C. in a chak is 900 M. to 1000 M, the field channel lining may be done only for 80 M to 100 M of length in selective segments of field channel which run for longer periods in given RWS schedule. If the cost of lining is exceeded even with 20 percent of F.C. lining, it may further be reduced to 15 percent deleting the field channel segments which comparatively run for shorter periods. For judicious selection of field channel segments in such cases, it is necessary to carry out detailed study as mentioned in Para 4.4.1.
- b. For F. C. passing through Black Cotton Soils:
For field channels passing through black cotton soils, the objective of F.C. lining is “protective and preventive” to achieve the structural integrity and increase credibility of delivery of water supply in the field channel disnet of the chak. Hence, F.C. lining lengths are identified accordingly with special attention to vulnerable locations as discussed in Para 4.4.2. The field channel length is worked out with these guidelines and the cost of lining is estimated. If this estimated cost is higher than the cost norms, the lining is limited to 20 percent of total length of field channel. As per Govt. Circular No. LNP.1083/(366/82)/CAD(Engg.) dt. 23-09-1983, in no case, should the provision of lining be allowed to exceed 20% of field channel length without prior approval. If the cost norm is still exceeded, the field channel lining on upstream of the structures may be reduced to 2.5 M (i.e. two pieces of half round pipe) instead of 3.75 M (i.e. three pieces of half round pipes).
If the estimated cost is still exceeding the cost norms, the priorities in decreasing order are given as below:

- Full Length of water course.
- Lining field channel segments with height of banking more than 0.5m.
- Upstream and downstream of curves.
- Lining upstream and down stream of drop structure.
- Upstream and downstream of measuring device.

The cost of lining is, thus, related to number of drop structures and other OFD structures. Hence, the planning of OFD works has to be integrated and futuristic, keeping the view of curtailment of costs on lining.

For remaining length of field channel in black cotton soil, murum lining may be done if the murum from excavated stuff of distribution or main canal is available nearby the construction site of OFD works. Grass lining may also be developed if locally growing grass is suitable.

c. To merge OFD structures with F. C. lining:

At some locations, 0.3 m and 0.6 m drop structures can be eliminated by a chute with lined section using RCC half round spun pipes or UCR Stone masonry (1:6). This cost can further be reduced if grouted stone pitching rapid or dry rubble chute is provided with a small well in the F.C. bed at the end of chute / rapid to dissipate the energy and avoid erosion due to high velocities generated on chute / rapid. Thus, the cost of 0.3m drop structure is eliminated by merging it with lining.

At Division boxes also, the branching corners may be covered by grouted stone pitching (1:6) and branching lengths may be protected by dry rubble pitching upto 3.5m on field channel segments on either sides. Thus, the cost of division box may also be eliminated by merging it with lining. It is, however, necessary to plan the F. C. lining with the planning and layout of field channels and OFD structures, so that relevant structures may be eliminated and be merged with lining.

d. The type of lining:

The competitive cost economics may also be studied for RCC half round spun pipes lining and UCR Stone Masonry lining. Such hard surface lining shall be very judiciously provided as these are very costly. Grass lining with local grass and murum lining may also be used in combinations with hard surface lining.

Table 7.5
Table of depth of flows for 30 lit/sec flow for various bed gradients and different types of F. C. lining

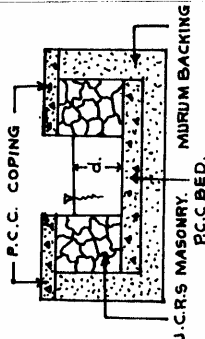
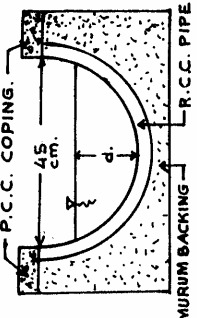
Sr. No.	Type of Lining	Cross Section	Bed gradient (S)	Coefficient of Regosity (N)	Depth of water flow (d) meters	Velocity (V) meters/sec.	Discharge (Q) cumecs.
1	U.C.R. Masonry		1:1000	0.030	0.2900	0.2541	0.02950
			1:950	0.030	0.2840	0.2595	0.02940
			1:900	0.030	0.2750	0.2639	0.02900
			1:850	0.030	0.2700	0.2702	0.02920
			1:800	0.030	0.2650	0.2770	0.02940
			1:750	0.030	0.2570	0.2836	0.02920
			1:700	0.030	0.2500	0.2912	0.02910
			1:650	0.030	0.2450	0.3004	0.02940
			1:600	0.030	0.2400	0.3107	0.02980
			1:550	0.030	0.2300	0.3203	0.02950
			1:500	0.030	0.2200	0.3312	0.02920
2	RCC Half round pipes		1:350	0.022	0.1800	0.5119	0.03000
			1:400	0.022	0.1850	0.4849	0.02890
			1:450	0.022	0.1900	0.4630	0.02950
			1:500	0.022	0.1950	0.4446	0.02930
			1:550	0.022	0.2000	0.4288	0.02920
			1:600	0.022	0.2050	0.4165	0.02940
			1:650	0.022	0.2100	0.4034	0.02930
			1:700	0.022	0.2150	0.3931	0.02940
			1:750	0.022	0.2200	0.3836	0.02960
			1:800	0.022	0.2250	0.3750	0.02980

Table 7.5
Table of depth of flows for 30 lit/sec flow for various bed gradients and different types of F. C. lining

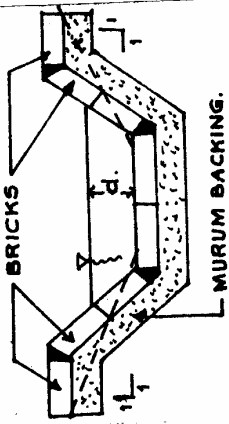
Sr. No.	Type of Lining	Cross Section	Bed gradient (S)	Coefficient of Regosity (N)	Depth of water flow (d) meters	Velocity (V) meters/sec.	Discharge (Q) cumecs.
3	Brick lining		1:650	0.030	0.1900	0.0320	0.02890
			1:700	0.030	0.1950	0.2955	0.02850
			1:750	0.030	0.2000	0.2890	0.02890
			1:800	0.030	0.2050	0.2834	0.02930
			1:900	0.030	0.2100	0.2704	0.02890
			1:950	0.030	0.2150	0.2662	0.02940
			1:1000	0.030	0.2175	0.2610	0.02930

Table 7.5

**Table of depth of flows for 30 lit/sec flow for various bed gradients
and different types of F. C. lining**

Sr. No.	Type of Lining	Cross Section	Bed gradient (S)	Coefficient of Regosity (N)	Depth of water flow (d) meters	Velocity (V) meters/sec.	Discharge (Q) cumecs.
1	U.C.R. Masonry		1:1000	0.030	0.2900	0.2541	0.02950
			1:950	0.030	0.2840	0.2595	0.02940
			1:900	0.030	0.2750	0.2639	0.02900
			1:850	0.030	0.2700	0.2702	0.02920
			1:800	0.030	0.2650	0.2770	0.02940
			1:750	0.030	0.2570	0.2836	0.02920
			1:700	0.030	0.2500	0.2912	0.02910
			1:650	0.030	0.2450	0.3004	0.02940
			1:600	0.030	0.2400	0.3107	0.02980
			1:550	0.030	0.2300	0.3203	0.02950
			1:500	0.030	0.2200	0.3312	0.02920
			1:450	0.030	0.2150	0.3466	0.02980
			1:400	0.030	0.2050	0.3620	0.02960
			1:350	0.030	0.1950	0.3806	0.02970
2	RCC Half round pipes		1:350	0.022	0.1800	0.5119	0.03000
			1:400	0.022	0.1850	0.4849	0.02890
			1:450	0.022	0.1900	0.4630	0.02950
			1:500	0.022	0.1950	0.4446	0.02930
			1:550	0.022	0.2000	0.4288	0.02920
			1:600	0.022	0.2050	0.4165	0.02940
			1:650	0.022	0.2100	0.4034	0.02930
			1:700	0.022	0.2150	0.3931	0.02940
			1:750	0.022	0.2200	0.3836	0.02960
			1:800	0.022	0.2250	0.3750	0.02980
3	Brick lining		1:650	0.030	0.1900	0.0320	0.02890
			1:700	0.030	0.1950	0.2955	0.02850
			1:750	0.030	0.2000	0.2890	0.02890
			1:800	0.030	0.2050	0.2834	0.02930
			1:900	0.030	0.2100	0.2704	0.02890
			1:950	0.030	0.2150	0.2662	0.02940
			1:1000	0.030	0.2175	0.2610	0.02930

e. Provision for murum backing:

The provision for murum backing shall be made only for F C passing through black cotton soils only. The thickness of murum backing may be reduced to a minimum of 10 cms to economize the costs if murum is available at longer leads.

7 Construction of field channel lining:

DIRD, Pune has advised in the “Evaluation Report of OFD Structures (March 88)” that lining to field channels should be taken up after passing of water in the channels for three irrigation seasons or after passing at least one Monsoon Season after the construction of field channels to allow settlement of bank work before lining. During this period, the local grass would also grow on sides and bed of field channel and stabilise the section to some extent. Such field channel segments may be excluded from construction of lining. The local grass can be advanced to grow at other locations also. Thus, economy of lining to field channel may be achieved.

Sometimes, the construction of F. C. lining is taken up along with construction of OFD works. This may be done only when the irrigation water is likely to flow in the very next irrigation season after the construction of F C lining. If this does not occur within a reasonable time after construction of the OFD works and the FC lining, these get deteriorated with time due to non use. Such OFD works do not serve the intended purpose. Thus, utility of OFD works and expenditure incurred on them is lost because of un-timely phasing of construction of OFD works. Hence, it is essential to phase the construction of OFD works and FC lining with the appropriate time of onset of irrigation in the command. It is advisable to take up the construction of F.C. lining & OFD works in the command where formation of WUA is in progress or WUA has already been formed. It is also necessary to take necessary steps under section 3 of the Maharashtra Irrigation Act 1976 to modify command at earliest as a concurrent activity to the construction of OFD works & FC lining. This would help to construct the OFD works, the disnet of field channels with active participation of farmers and test, functioning of OFD works and F C lining etc. with their cooperation which in turn would increase the credibility and utility of OFD works to the members of WUA.

7.1 “Do’s and Don’t’s in the construction of field channel lining:

The construction of field channel lining is a skillful job, which needs to be performed keenly and precisely. The construction of field channel lining without sanctity of quality would be wasteful expenditure and create difficulties in the water delivery system. Hence, it is necessary to take care during construction about certain points. These are enlisted as below:

- a. From the work done plans & L-sections of field channels, the design bed gradient of field channel segment wherein the lining is to be constructed is determined and verified on grounds. It is necessary to maintain the design bed gradient as actual, on ground even after the field channel lining is actually constructed. The mark out for excavation and other activities is given accordingly, using proper survey equipments.
- b. The half round spun pipes shall be inspected thoroughly at casting yard. Any pipe length with cracks shall be discarded and rejected. Any pipe length with rough inner surface, reinforcement protruding out from surface etc. shall be discarded and rejected.

While unloading the half round spun pipes from truck/tractor on site, it is necessary to place waste rubber tyres of truck/tractors on ground, so that pieces of lining do not get damaged due to impacts on ground.

It is also necessary to take care while stacking the half round spun pipes. The pipes shall be stacked such that these are not over stressed in the stack and crack under the self load of pipes.

- c. The murum backing shall be done with proper compaction and required thickness. This forms a good sub-grade for hard surface lining. Unless, therefore, the sub-grade is compacted properly and its surface also prepared well, the lining is susceptible to dislocation and also to fail under severe changes in moisture and pressure.
- d. The ideal method for the preparation of murum backing is the construction of field channel lining would be “The fill, roll and cut method”. In this method, design box cut is completely filled with murum and rolled with watering for good compaction. After rolling and compaction, the desired cross section with designed bed gradient is cut out. The main difficulties in implementing this method in actual practice are standing crops, absence of approach roads for transporting the rollers to the interior of command area on actual site of field channels. The additional cost / m for “fill, roll & cut” method is about Rs. 30/m. Hence, it is preferable to adopt conventional method of construction using hand rammers with manual labours, for compaction of murum backing.
- e. The joints in half round pipes/masonry shall be cement pointed with rich mortar (1:3) and flush with the bed, so that water flow shall not disturb the joints and the bed gradient. Any obstructions like rough surface due to left over mortar used for pointing or any protruding portion of cement pointing may increase the rugosity coefficient and may cause rise in the water level. Hence, bed surface shall be kept as smooth as possible.

- f. Where lining is done in selective and limited segments, there are number of junctions between the lined portion and the earthen channel. Hydraulically also, the behaviour of flow would be different in lined portion as compared to that in unlined portion because of difference in rugosity coefficient. It is, therefore, advised to provide an improvised transition at all such junctions. Since the shape of the section from trapezoidal in earthen channel to semicircular or rectangular in lined position is occurring, such transition is very much necessary.
- g. The coping over top edge of the lining shall be provided in 1:3:6 P.C.C. to avoid water seepage in the sub grade and reduce the risk of failure as explained in (c) above.
- h. The concrete or mortar shall not be prepared by mixing on natural ground, due to which the quality gets deteriorated by mixing earth and other deleterious materials in concrete or mortar. Galvanized iron sheet 1.5m × 1.5m shall be used as platform for mixing. The iron sheet may be provided with wired handle so that it can be dragged easily from one spot to other.
- i. For the good quality, impermeability and strength of OFD structures and FC lining, curing of concrete and mortar shall not be ignored. Curing shall not be ignored even for jointing and pointing of half round pipes. Negligence in curing of joints in half round pipes and pointing in UCR Stone Masonry make the lining weak. Trampling by livestock cause cracks in the weak mortar joints and deterioration commence. Curing of F. C. lining in selective lengths is a difficult task, because these works are scattered and too small in quantity. If lining is done just ahead of commencement of rotation, the problem of curing is erased out to some extent, because of availability of water. Generally, moist curing by sprinkling water by employing labours is done, by concerned contractor.

Curing can be achieved by applying curing compounds. ConCure-WB is a waterbased curing compound hence it is non-toxic and non-flammable. It is a colourless, ready to use solution. It is a single application spray, applied to fresh concrete. It is suitable for canal linings. It can cover an area of 4.5 SqM. to 5.5 SqM. in one liter. It is available in a pack of 20 liters or a drum of 210 liters. The curing compound ConCure-WB is not yet used in irrigation projects for curing of OFD works in Maharashtra, but it may be tried on pilot basis in some projects.

- j. To avoid jointing and pointing of pipes, self fit half round spun pipes with tongue and groove joints are preferable. Such pipes are, however, difficult for laying without skillful hands. The manufacturing defects in tongue and groove joints make it more difficult for laying them in line and grade. Hence, unless good quality of such pipes are available, and skilled labour is at hand, these may not be used.
- k. The RCC half round spun pipes shall be carefully placed in line, grade and alignment. It is not possible to place the pipes properly on curves, it may be replaced by UCR Stone Masonry (1:6) to achieve proper hydraulic conditions and stability on curves.
- l. The bed gradients in the lined field channel segments be checked after one rotation and corrected if required.

7.2 Tolerance:

a. The following tolerances may be accepted in the preparation of the sub grade.

- | | | |
|------|------------------------------------|---|
| (i) | Departure from establish alignment | 40mm on straight section
100mm on tangents
200 mm on curves |
| (ii) | Departure from established grade | 40 mm |

The same tolerance as for preparation of sub grade mentioned above will be accepted for final surface.

8.0 Completion Report and Record of Drawings:

The completion report shall consist of following details:

a. Design Report:

It shall cover the extent and location of lining proposed and the justification thereof. It shall also discuss the reasoning for selection of type / types of lining based on soil types and other constraints. The hydraulic design of lined field channel section for the bed gradients existing in the chak shall be annexed.

b. Work done Report:

It shall cover the discussions and details of deviations from the provisions in the design and estimate with justifications thereof.

c. Work done record drawing:

The extent, location and type of lining shall be shown on work done maps (1:1000 or 1:1250) with OFD structures. The details of F C lining shall be presented in a tabular form as shown in Table 7.6.

Table 7.6

Table showing work done details of F C lining in the chak

Sr. No.	Nomenclature of F C	Location of F C lining Ch. (m)	Length of F C lining (m)	Bed gradient of F C	Type of lining	Cross section of F C lining	Depth of flow (m)	Velocity (m/sec.)
1.	F C – 1							
2.	F C – 2							
		Total length of F C Lining						
		% of F. C. lining						

The overall pertinent details as per requirements of permanent record drawing shall also be mentioned. e.g. estimated cost, work done cost, M B No., F B No., Date of completion of F C lining work, etc. The record drawing shall be canvas mounted and preserved in foldable binding. A true copy of this drawing is handed over to Water Users' Association, for upkeep and maintenance of OFD works and FC lining works.

9.0 Maintenance and Repairs:

Field channel lining is a part of OFD works. The Government of Maharashtra in Irrigation Department (vide Govt. Circular No. CDA-1079/1893-CAD-II dated 05th June 1979) has issued a directive that lining shall be provided to field channel portions as a part of community item of land development work. The Government has directed (vide GR dated 21 March 1978) that the maintenance of these works shall be with the beneficiaries and for this purpose all the relevant provisions in Maharashtra Irrigation Act, 1976 shall be applicable.

The Government of Maharashtra in Irrigation Department has made mandatory to form Water Users' Co-op Societies (vide GR (Marathi) 1001/(442/2001)/ dt. 23.7.2001) and hand over the command area to the society along with the responsibility of irrigation management, maintenance and repairs to the irrigation works., As per the relevant clauses in the Maharashtra Farmers' Participatory Irrigation Management Act – the water users' co-op Association is responsible for maintenance and repairs of field channels, field drains and allied works on them. It is further laid down in this Act and the relevant clauses in the agreement between WUA and Govt., that if the Water Users' Association does not undertake these maintenance and repair works, Government has right to stop the water supply to such defaulter society or the Government shall carry out necessary maintenance and repairs on behalf of the society and the expenditure thereon shall be recovered from the society.

The irrigation managers shall be making use of above legal provisions to upkeep the field channel lining and allied aspects of lining in the disnet of field channels.

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11. Govt. of Maharashtra, Irrigation Department, Godavari Marathwada irrigation Development Corporation, Aurangabad, RSR 2000 – 01.
12. B & C RSR 2000 – 01.

Design of Field channel section With RCC half round spun pipe lining

1.0 Given:

- a) Diameter of pipe (D): 45 cms i.e. $R = 22.5$ cms.
- b) Coefficient of Rugosity (N): 0.022
- c) Discharge through channel (Q): 30 lit / sec i.e. 0.03 cumecs.
- d) Bed gradient (i): 1 : 700

2.0 Calculate depth of flow and velocity:

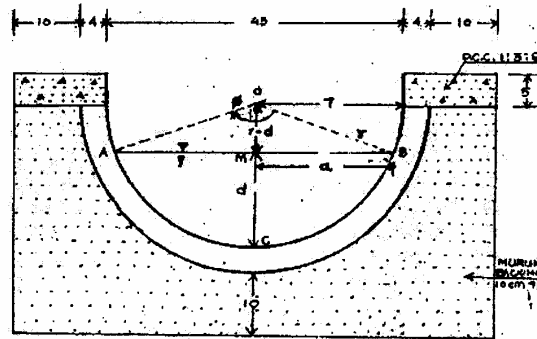


Figure 7.8

Typical cross-section of field channel with RCC half round pipe lining.

To calculate velocity of flow, Manning's formula is used.

$$V = \frac{R^{2/3} \times i^{1/2}}{N} \text{ m/sec}$$

Where,

R = Hydraulic mean depth = $\frac{A}{P}$

P = Wetted perimeter
= Arc length ACB (L)

$$= \frac{\phi \pi r}{180} \dots \dots \dots \left[\phi = 2 \cos^{-1} \frac{r-d}{r} \right]$$

r = Radius of pipe

d = Depth of flow.

A = Area of Segment ACB

$$= \text{Area of sector O.ACB} - \text{Area of triangle OAB}$$

$$= 0.5 r L - 2[\text{Area of Triangle OMB}]$$

$$\begin{aligned}
&= 0.5 r L - 2 \left[\frac{1}{2} (r-d) \cdot (a) \right] \\
&= 0.5 r L - [(r-d) \cdot (a)] \\
&= 0.5 r L - \left[(r-d) \cdot \sqrt{r^2 - (r-d)^2} \right] \\
&= 0.5 r L - \left[(r-d) \cdot \sqrt{(D-d) \cdot d} \right]
\end{aligned}$$

Discharge through field channel,

$$Q = A \times V$$

Assume depth of flow (d) = 0.215 m & Let bed gradient 1 : 700

$$\begin{aligned}
\therefore \quad \phi &= 2 \cos^{-1} \left(\frac{r-d}{r} \right) \\
&= 2 \cos^{-1} \left(\frac{0.225 - 0.215}{0.225} \right)
\end{aligned}$$

$$\begin{aligned}
&= 174.9053 \text{ degrees} \\
P &= \text{Wetted perimeter} \\
&= \text{Arc length AcB (L)}
\end{aligned}$$

$$\begin{aligned}
&= \frac{\phi \pi r}{180} \\
&= \frac{174.9053 \times \pi \times 0.225}{180} \\
&= 0.6868 \text{ m}
\end{aligned}$$

$$\begin{aligned}
A &= \text{Area of water flow} \\
&= 0.5 r L - \left[(r-d) \cdot \sqrt{(D-d) \cdot d} \right] \\
&= 0.5 \times 0.225 \times 0.6868 - \left[(0.225 - 0.215) \sqrt{(0.45 - 0.215) \cdot (0.215)} \right] \\
&= 0.07501 \text{ Sq. M.}
\end{aligned}$$

$$\text{Hydraulic Mean Depth } R = \frac{A}{P} = \frac{0.07501}{0.6868} = 0.1092 \text{ m.}$$

By Manning's Formula,

$$\begin{aligned}
V &= \frac{R^{2/3} \times i^{1/2}}{N} \text{ m/sec} \\
V &= \frac{0.1092^{0.666}}{0.022} \times \frac{1}{\sqrt{700}}
\end{aligned}$$

$$V = 0.3930 \text{ m/sec.}$$

$$\begin{aligned}
Q &= A \times V \\
Q &= 0.07501 \times 0.393
\end{aligned}$$

$Q = 0.02948$ cumecs i.e. 0.03 cumecs.

3.0 For other bed gradients, the depth of water flow is calculated. Please see Table 7.7.

Table – 7.7

Table showing depth of flow (for $Q=0.03$ cumecs, $N = 0.022$) through RCC half-round spun pipe (Diameter 0.45 m) with different bed gradients.

Sr. No.	Bed Gradient	Depth of flow (m).	Velocity M/sec.	Discharge Cumecs.
1	1:350	0.180	0.5115	0.03
2	1:400	0.185	0.4849	0.0298
3	1:450	0.190	0.463	0.0295
4	1:500	0.195	0.4446	0.0293
5	1:550	0.200	0.4248	0.0292
6	1:600	0.205	0.4165	0.0294
7	1:650	0.210	0.4034	0.0293
8	1:700	0.215	0.3931	0.0294
9	1:750	0.220	0.3836	0.0296
10	1:800	0.225	0.3750	0.0298

From this Table 7.7, it is observed that the depth of flow varies in the range 18 cm at bed-gradient 1 : 350 to 21.5 cm at bed-gradient 1 : 700. Thus, the free board is reduced to 1.0 cm or even less for bed gradients flatter than 1:700. Hence, the lining is likely to be overtopped. Hence additional freeboard by providing a P.C.C. coping is very much essential, to avoid the overtopping & creating moist, wet conditions around pipe, which may cause uneven settlement of pipes.

□ □ □ □

Design of Field channel section With UCR Stone masonry lining

1.0 Given:

- a. Bed width (B) : 0.4m, side : vertical,
- b. Rugosity coefficient $N = 0.03$
- c. Discharge through channel : 30 lit/sec i.e. 0.03 cumecs.

2.0 Calculate depth of flow and velocity:

To calculate velocity of flow, Manning's formula is used.

$$V = \frac{R^{2/3} \times i^{1/2}}{N} \text{ m/sec}$$

Where,

- R = Hydraulic mean depth = $\frac{A}{P}$
P = Wetted perimeter
= $B + 2d$ (d = depth of flow)
A = $B \times d$
i = Bed gradient of field channel.

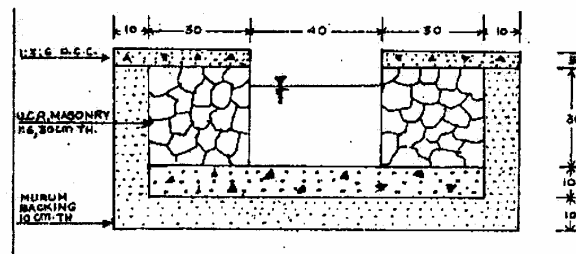


Figure 7.9

Typical cross section of field channel with UCRS Masonry (1:6) lining on vertical sides and concrete bedding with 1:3:6 PCC.

Assume depth of flow (d) = 0.275 m

Let bed gradient $i = 1:900$

$$\begin{aligned} A &= 0.4d \\ &= 0.4 \times 0.275 = 0.110 \text{ Sq. M.} \end{aligned}$$

$$\begin{aligned} P &= 0.4 + 2d \\ &= 0.4 + 0.56 = 0.95 \text{ m} \end{aligned}$$

$$\text{Hydraulic mean radius } R = \frac{A}{P} = 0.1157 \text{ m}$$

$$V = \frac{R^{2/3} \times 1^{1/2}}{N} \text{ m/sec}$$

$$V = \frac{(0.1157)^{0.6666}}{0.03} \times \frac{1}{\sqrt{900}}$$

$$V = 0.2639 \text{ m/sec.}$$

$$Q = A V$$

$$= 0.110 \times 0.2639$$

$$= 0.0294 \text{ cumecs}$$

$$= 0.03 \text{ cumecs approximately}$$

3.0 For other bed gradients, the depth of water flow is calculated. Please see Table 7.8.

Table – 7.8

Table showing depth of flow (for Q=0.03 cumecs, N = 0.03) through F.C. lined with UCRS
Masonry on vertical sides & concrete bedding.

Sr. No.	Bed Gradient	Depth of flow (m).	Velocity M/sec.	Discharge Cumecs.
1.	1 : 1000	0.290	0.2541	0.0295
2.	1 : 950	0.284	0.2592	0.0294
3.	1 : 900	0.275	0.2639	0.0290
4.	1 : 850	0.270	0.2702	0.0292
5.	1 : 800	0.265	0.2770	0.0294
6.	1 : 750	0.257	0.2836	0.0292
7.	1 : 700	0.250	0.2912	0.0291
8.	1 : 650	0.245	0.3004	0.0294
9.	1 : 600	0.240	0.3107	0.0298
10.	1 : 550	0.230	0.3203	0.0295
11.	1 : 500	0.220	0.3312	0.0292
12.	1 : 450	0.215	0.3466	0.0298
13.	1 : 400	0.205	0.3620	0.0296
14.	1 : 350	0.195	0.3806	0.0297

From this Table 7.8, it is observed that the depth of flow varies in the range 0.195m for bed gradient 1 : 350 to 0.29m for bed gradient 1 : 1000. Thus, if the vertical sides of the field channel section are kept 0.3m high with a 0.05m thick coping of 1:3:6 PCC. The depth of flow can be well contained with sufficient free board. The section with coping will have sufficient strength to face the trampling of cattle and humans.

□□□□

CHAPTER - 8

LAND FORMING FOR IRRIGATION

1.0 Definition:

It is the process of developing surface relief of the land to a planned grade to provide better aeration and efficient water application on farm.

2.0 Objectives:

The main objectives of land forming are:

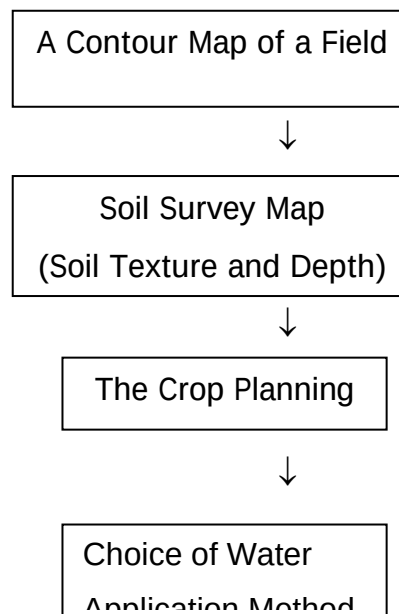
- i) To provide better aeration and congenial soil environment to the crops,
- ii) To provide efficient water application,
- iii) Removal of excess rainwater without causing any soil erosion.

3.0 The Need:

The present field application efficiency in command areas varies from 40% to 60%. This is because of adoption of improper method of irrigation and lack of land forming. Therefore, it is necessary to do required land forming and adoption of scientific irrigation methods.

4.0 The Planning Process:

The logical sequence of land forming planning process is as follows:





Choice of Land
Forming Technique

The Crop Planning:

The land forming i.e. slope to be provided will depend on type of crop to be irrigated and proper irrigation method to apply the water efficiency. Therefore, crop planning is important before land forming work is taken up.

5.0 Topographic Map and Soil Survey:

A compass traverse survey is necessary to delineate the boundaries of the fields owned by an individual farmer. A block contour survey with grid size of 10 x 10 m is done for planning and design of Land Forming works. The contours are marked at the vertical interval of 0.2 m, upto 1% land slope and 0.3 m for slopes more than 1% (Figure-8.1).

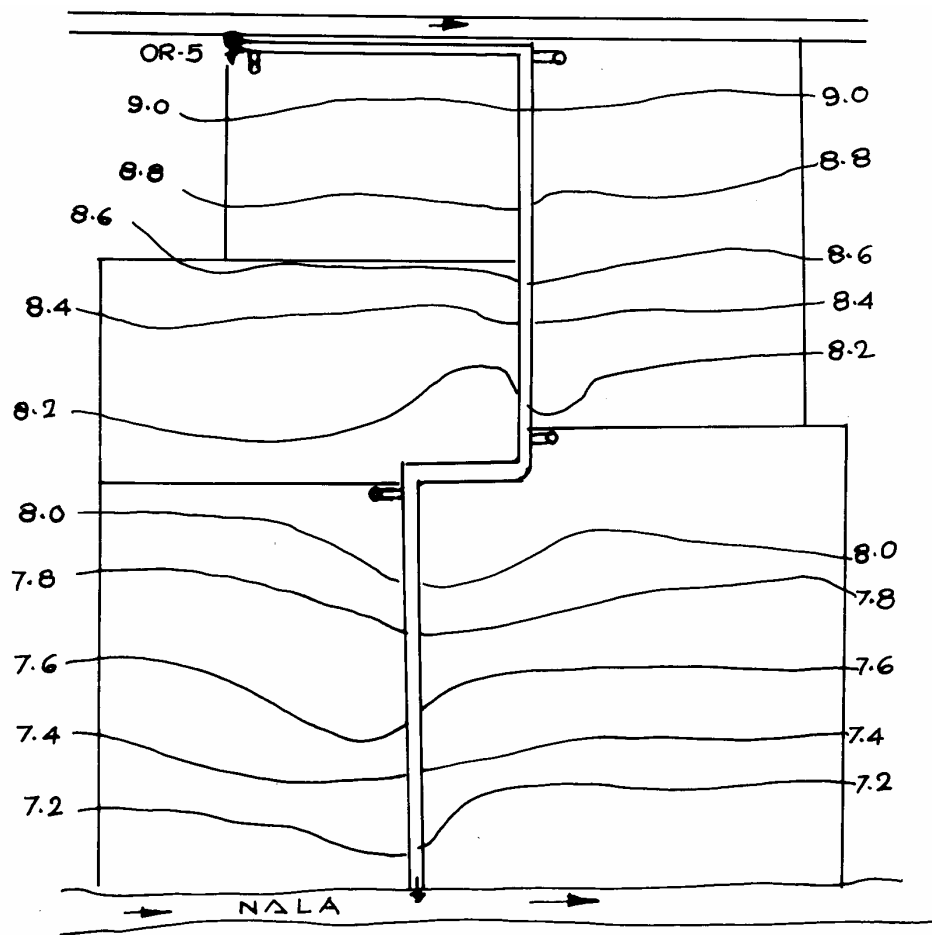


FIG. 8.1: A Contour Survey map of a Chak.

Soil survey of each individual field is carried out to determine the soil texture by surface feel method and soil depth using screw Auger. The soil survey map is prepared as indicate in Figure-8.2.

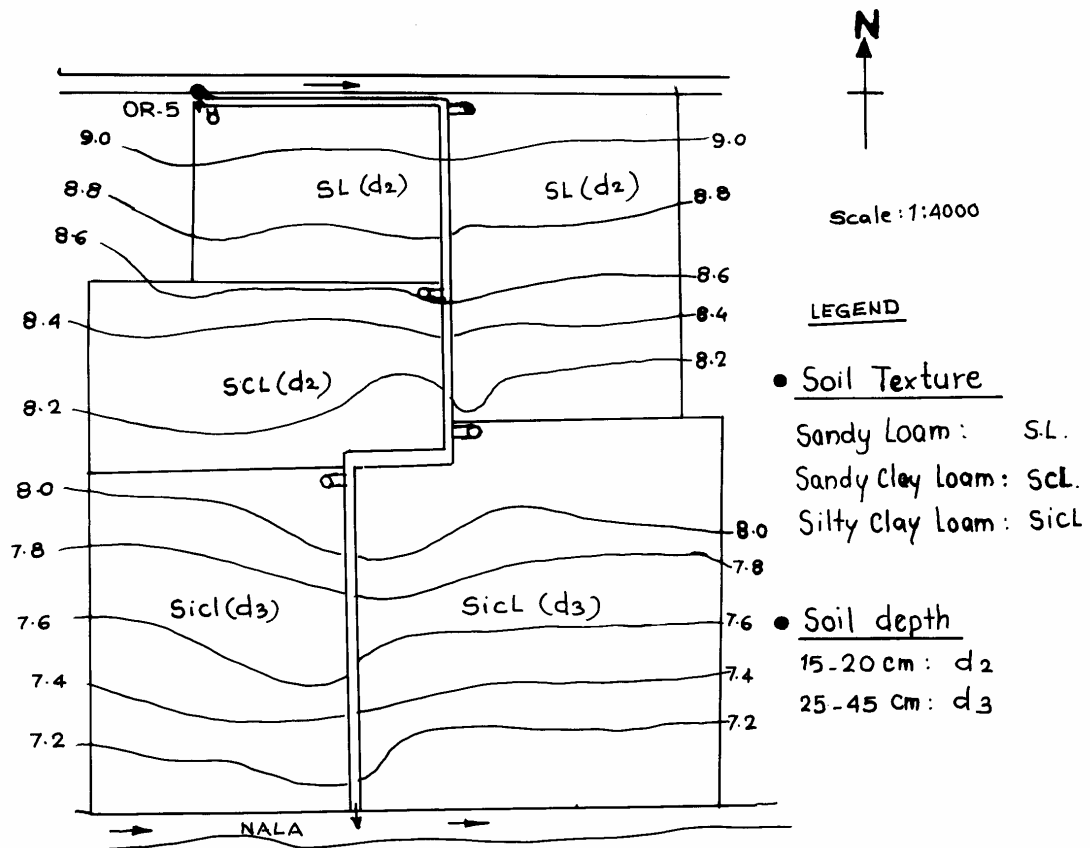


Fig.8.2: A Soil Survey map of a Chak.

Choice of Water Application Method:

6.0 Basin Irrigation:

The area surrounded by the dyke/small soil bund is called as basin. The length : width ratio is less than 10 :1. The water is being ponded on the entire area of the basin. This method is used mainly for leafy vegetables and paddy. The shape of the basin is either square or rectangular. The size varies from 2 x 3 m, to 4 x 6 m for vegetable crops and paddy basin size varies from 0.2 to 0.5 ha. The ideal land slopes should be zero in all the directions. The permitted discharge to irrigate the basin varied from 5 to 30 l.p.s. The basins should be irrigated one by one to achieve 90% irrigation efficiency (Figure-8.3). The farmer's practice is to irrigate 4 to 6 basins simultaneously with 20 to 30 l.p.s. discharge in the canal command. Since the quantity of water is not properly monitored in each basin, the irrigation efficiency may go down to 40%. Therefore, it is suggested to irrigate one basin at a time with the available discharge. Higher the applicate rate quicker will be water spread over the basin area and hence maximum will be the irrigation efficiency of basin irrigation. A precise land forming construction (zero

slope in all direction) is the basic requirement for efficient basin irrigation.

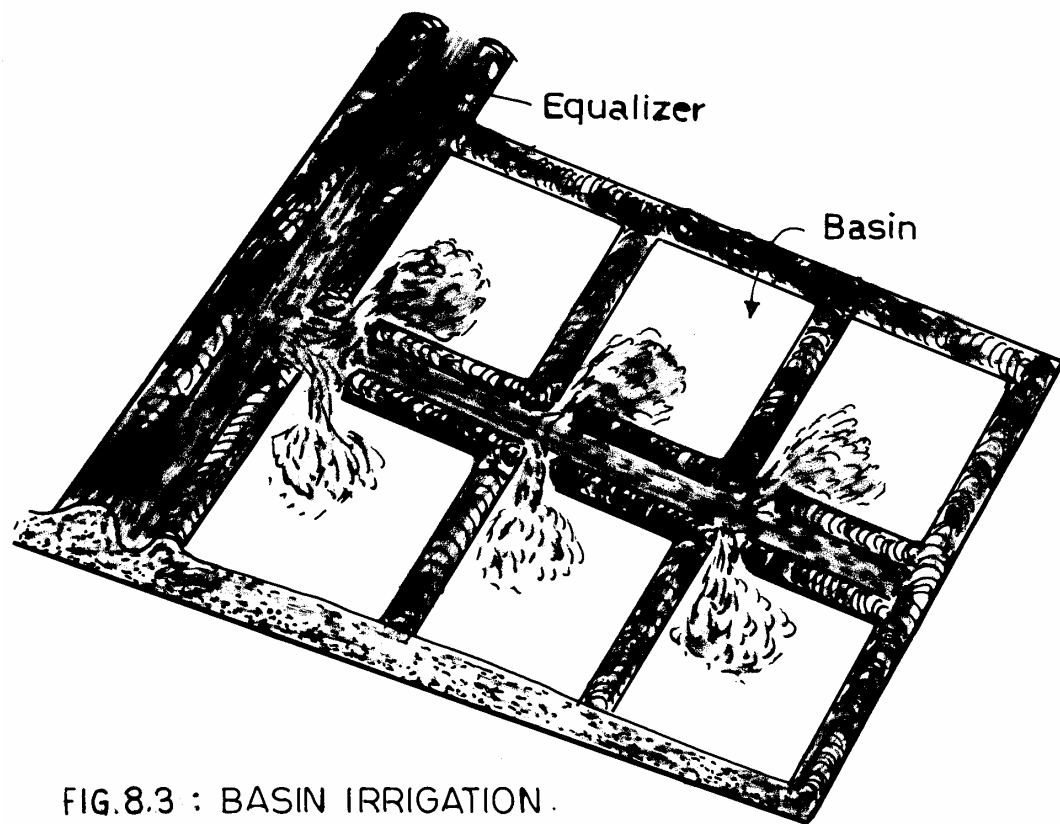


FIG.8.3 : BASIN IRRIGATION .

7.0 Serpentine Furrow cum Basin Irrigation:

Serpentine Furrow cum Basin Irrigation is a quite old and traditional surface irrigation practice used for sugarcane crop in the canal command as well as under the command of well irrigation of individual farmer (Figure-8.4).

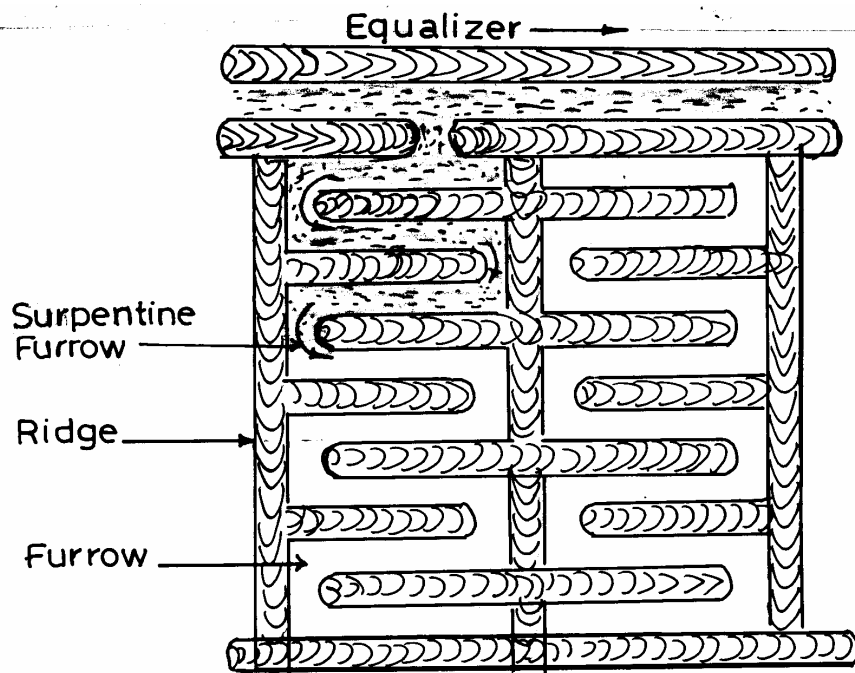


FIG.8.4 : SERPENTINE FURROW CUM BASIN IRRIGATION .

The main attractions to use this method are:

- i) The land forming construction is not required to prepare the Serpentine Furrow cum Basin Irrigation layout.
- ii) Water is released at the highest spot in the field. From the highest spot water moves in the serpentine furrow towards the lower end of the field. The farmer has to let out water at the highest spot to continue irrigation for about 12 hours. The farmer has to change the water let out point in the morning and in the evening while going home. Thus irrigation continues overnight (for 12 hours). This night irrigation becomes easy.
- iii) Once the layout is prepared human efforts are not required to irrigate the field. The presence of farm labour is also not required.

The main disadvantages of this method are:

- i) 200 to 300 millimeters of water is applied in one rotation where only 100 millimeters are required.
- ii) This is well known as idle man's method of irrigation
- iii) Water application efficiency in the field is less than 50%.
- iv) Leeching of nitrogenous fertilizers in each rotation can pollute ground water.

This method of irrigation in the canal command must be replaced by straight ridges and furrows method. The straight furrows must be oriented approximately

parallel to contour. For this purpose a precise land forming construction is required to attain the uniform slope along the straight furrow length.

8.0 Straight Ridges and Furrow Irrigation:

The straight ridges and furrows (Figure-8.5) can be prepared using a bullock drawn ridger or a two or three bottom tractor drawn ridger. The width of furrow can be as small as 60 cm and as big as 1.0 m. However, the width of broad bed and furrow may vary from 1.5 to 2.5 m. in fine textured soil. The design parameters such as furrow discharge per unit width of furrow, furrow slope, length, width etc. are given in Table-8.1.

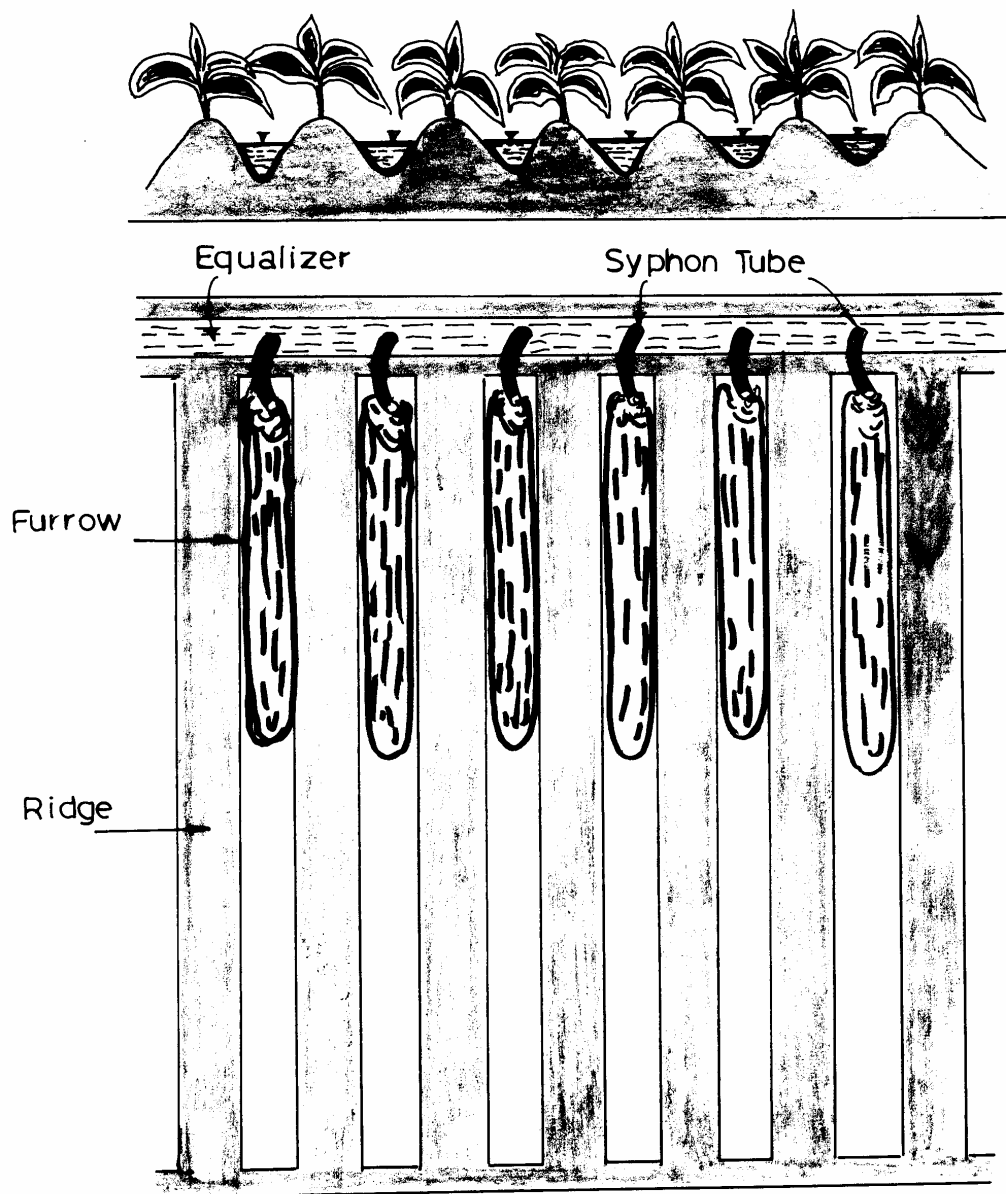


Fig 8.5: STRAIGHT FURROW SURFACE IRRIGATION SUITABLE FOR SUNFLOWER, COTTON, MAIZE, PIGEON, PEA, ETC:

The desired discharge in each individual furrow can be released using gated pipes or syphon tubes. Thus measured quantity of water can be applied in this method. The attainable efficiency can be as high as 90% if surge irrigation technique is used. The automation of surge irrigation is now possible with solar powered surge irrigator (Figure-8.6). This would be the most useful devise to irrigate sugarcane crop in the canal command. Better aeration and the suitable soil moisture status (i.e. moisture content upto field capacity) are the inherent characters of this method. Straight furrows can also be used for draining out excess rainwater without causing any soil erosion. Earthingup operation of sugarcane crop is possible with bullock drawn ridger in straight furrows which will save appreciable amount of farm labour.



Fig. 8.6: Solar powered Surge Irrigator with gated pipes.

The uniform land slope along the furrow length is the basic requirement for efficient furrow irrigation. The straight furrows are oriented approximately parallel to contour or across the main land slope. The ups and downs along the furrow length can be even out in the process of land forming construction.

Majority of the arable crops such as Cotton, Sugarcane, Maize, Tur, Gram, Safflower, Brinjal, Chilies, Quali flower cabbage, fruit crops etc. can be irrigated by broad bed and furrows (Figure-8.7) or straight furrows (Figure-8.5).

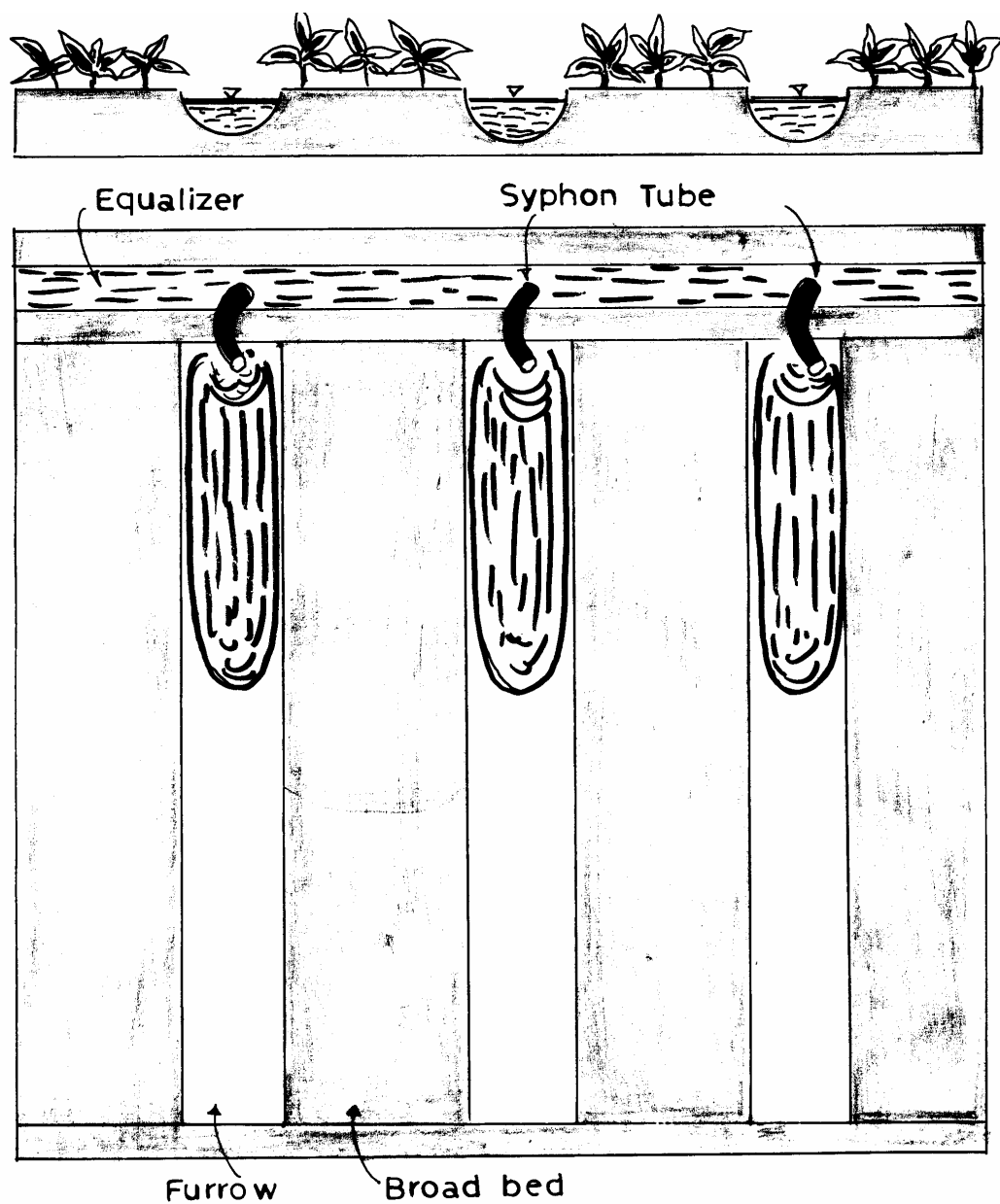


Fig.8.7: BROAD BED AND FURROW SUITABLE FOR GROUNDNUT, POTATO , GINGER, GARLIC, ONION ETC.

Table-8.1 : Design Parameters of Straight Furrow Irrigation

Sr. No.	Soil Texture	Furrow Slope, %	Furrow Width, m	Furrow Length, m	Flow rate l.p.s.	Cut off length %	Depth applied mm (Inches)
1	Coarse	0.05 – 0.1	0.6 – 0.75	60-90	3-4.5	100	75-100 [3-4]
		0.1 – 0.2	0.6 – 0.75	60-90	3-4.5	95	75-100 [3-4]
		0.2 – 0.3	0.6 – 0.75	60-75	1.5-3	90	50-75 [2-3]
2	Medium	0.05 – 0.1	0.75 – 0.90	100-150	3-4	100	75-90 [3-3.5]
		0.1 – 0.2	0.75 – 0.90	60-100	1.5-3	95	60-75 [2.5-3]
		0.2 – 0.3	0.75 – 0.90	50-75	1.5-2.5	90	50-75 [2-3]
3	Fine	0.05 – 0.1	0.9 – 1.0	100-200	2.5-3.5	95	75-100 [3.0-4]
		0.1 – 0.2	0.9 – 1.0	50-100	1.5-2.5	90	60-75 [2.5-3]

Table-8.2 : Design Parameters of Border Irrigation

Sr. No.	Soil Texture	Border Slope, %	Cross Slope, %	Border width, m	Border Length m	Flow rate Lps	Cut off length %	Depth applied mm (Inches)
1	Coarse	0.2–0.4	0– 0.1	4-5	60-90	8-11	100	100-125 [4-5]
		0.4–0.6	0.1–0.4	2-3	60-75	5-6.5	95	75-100 [3-4]
		0.6–1.0	0.4–0.6	1-2	30-50	4-6	90	50-75 [2-3]
2	Medium	0.2–0.3	0.0–0.1	4-5	75-150	4-6	100	100-125 [4-5]
		0.3–0.5	0.1–0.4	2-3	60-75	2.5-4	95	75-100 [3-4]
		0.6–0.8	0.4–0.6	1-2	30-50	2.5-3.5	90	50-75 [2-3]
3	Fine	0.1–0.2	0.0–1.0	4-5	100-200	3-5	95	100-125 [4-5]
		0.2–0.3	0.2–0.3	2-3	50-100	2.5-4	90	75-100 [3-4]
		0.3–0.6	0.3–0.4	1-2	30-50	2.5-4	85	50-75 [2-3]

Note: The desired cross slope should be less or equal to 0.2%. However, under economic constraints it may be upto 0.6%.

9.0 Border Irrigation:

Borders can be prepared using a bullock drawn bund former. The length : width ratio of border is more than 10. There is ponding on a partial length of border. The width, slope, length of border discharge released in the border, as per the soil texture are given in Table-8.2. Surge irrigation technique can also be used in border irrigation. Automated border irrigation is also possible with surge irrigator. A measured quantity of water can also be applied using either siphon tubes or gated pipes (Figure-8.6).

Wheat, lucern, gram, etc. are the crops which are irrigated by border irrigation (Figure-8.8).

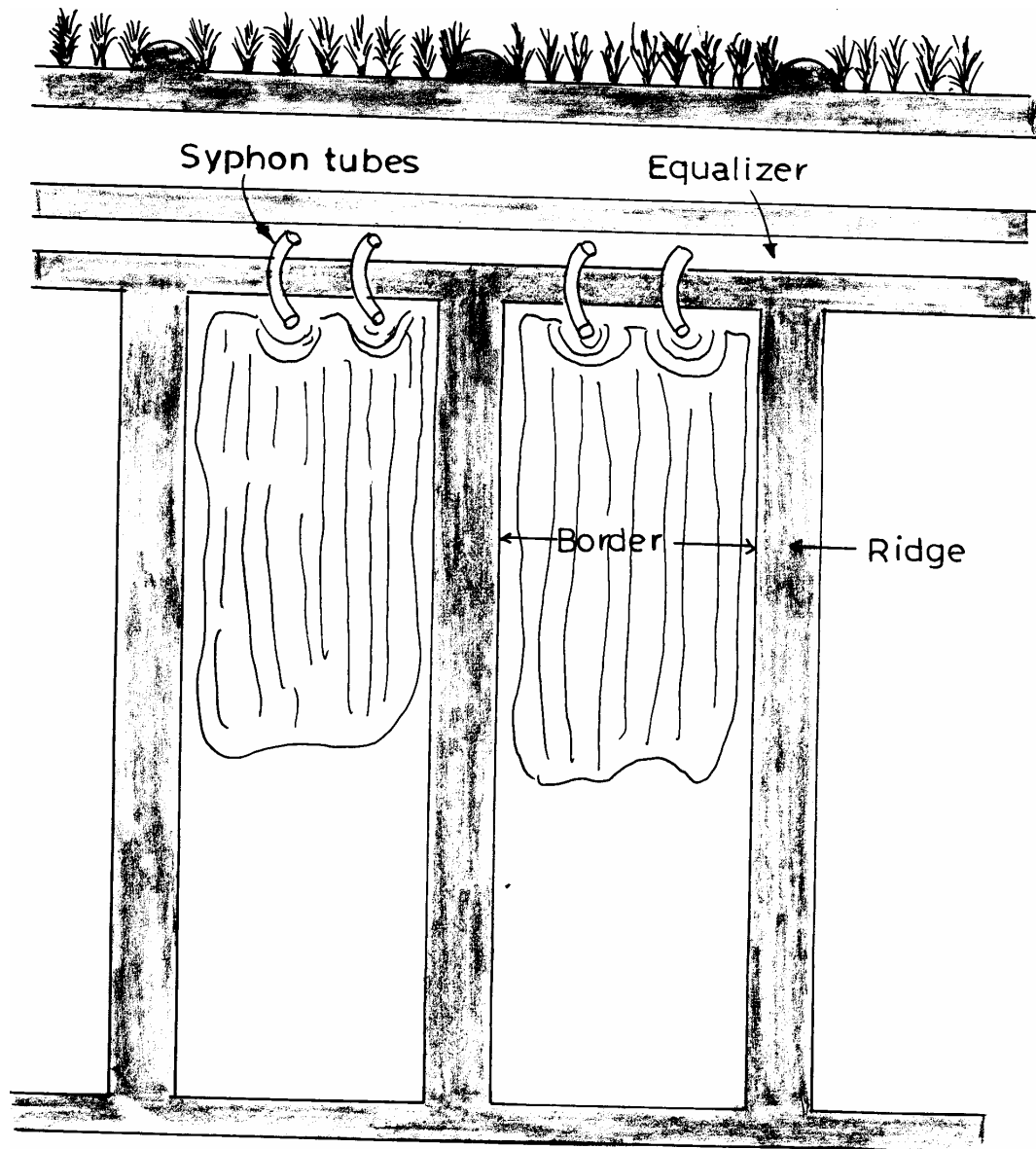


Fig.8.8: BORDER IRRIGATION USED FOR WHEAT, LUCERN, CORIENDER ETC.

10.0 Land Forming Techniques:

Land Smoothing:

It is the process of forming uniform slope in the direction of irrigation without changing the natural land slope. The soils at elevated spots or mounds are cut and put in the depressions to make the uniform slopes, (Figure-8.9). This technique is mainly used for straight furrow irrigation.

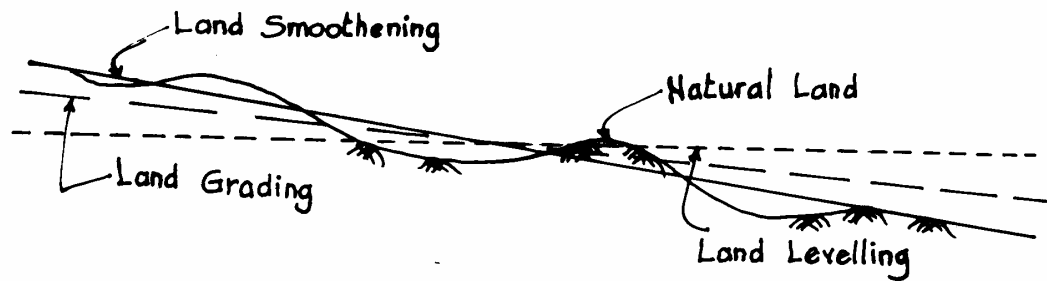


Fig.8.9: Land farming Techniques

Land Grading:

It is process of developing desired land slope in the direction of irrigation by changing natural land slope (Figure-8.9). It is used for both furrow and border irrigation.

Land Leveling:

It is the process of giving zero slope in the direction of irrigation and as well as in cross direction (Figure-8.9). This technique is mainly used for basin irrigation where low land paddy is grown and field-to-field irrigation is practiced.

11.0 Land Forming for Irrigation – A Step-by-step Procedure

Step-I:

A block contour survey with a grid size of 10x10 m is conducted. A contour plan is prepared with 0.2 m contour interval and 1 : 1000 scale. The soil depth is determined by a hand screw auger. The soil texture is found out by surface feel method. A contour plan is shown in Figure-8.10.

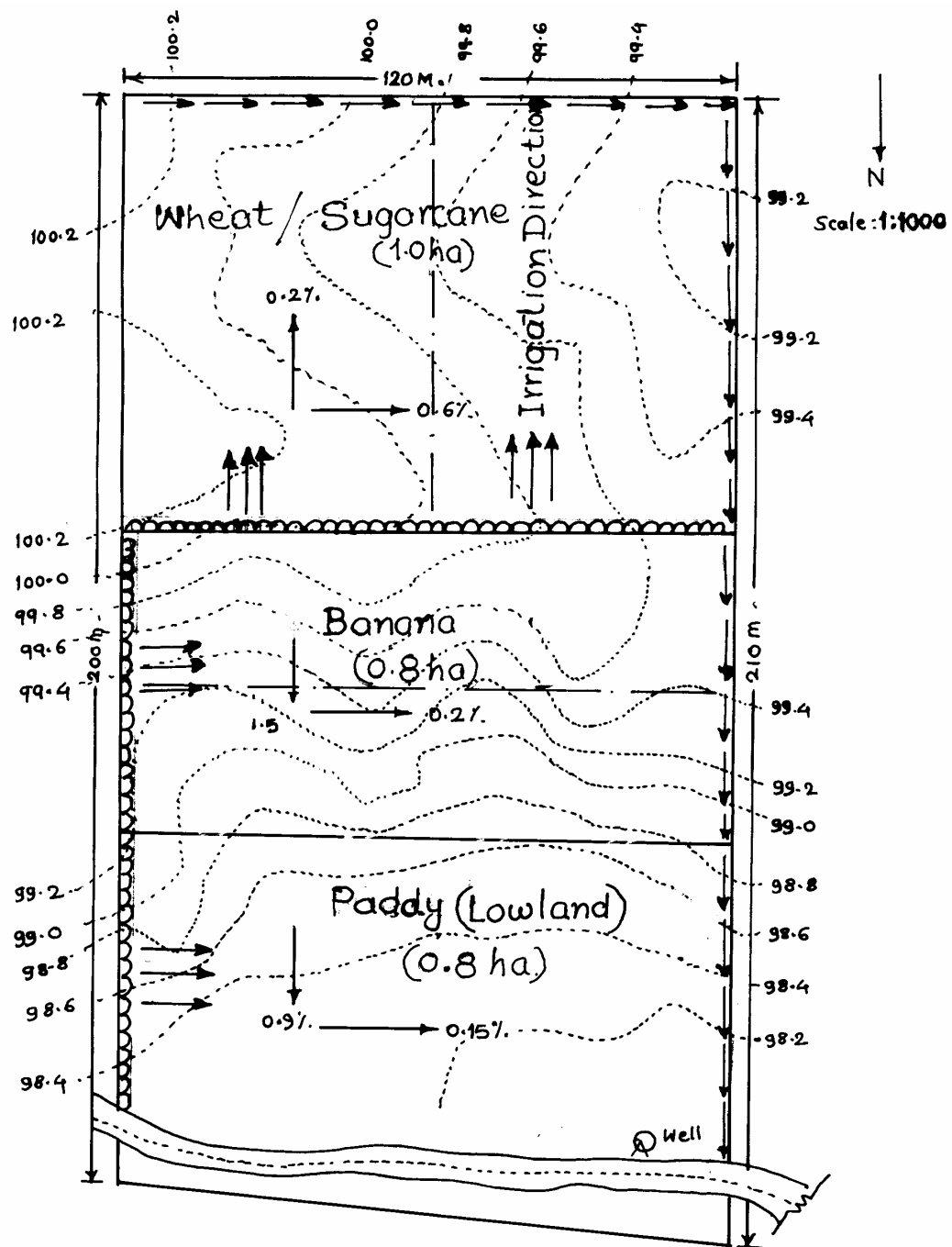


Fig: 8.10:A CONTOUR MAP.

Determine Soil depth, and Soil texture in the Field. For Example:

Soil depth : 0.9 to 1.2 m
 Soil Texture : Sandy clay loam (Medium texture)

Step-II: Decide the Crop Planning as per the Water Availability:

Crop Planning: (Figure-10)

Sugarcane / wheat	:	1.0 ha
Banana	:	0.8 ha.
Low land paddy	:	0.8 ha.

Step-III: Selection of Irrigation Method:

Sugarcane	:	Straight ridges and furrows
Banana	:	Straight ridges and furrows
Wheat	:	Border Irrigation
Low land Paddy	:	Basin Irrigation

Step-IV : Select the land forming technique suitable for Water Application Method:

Selection of land forming technique:

Straight ridges and furrows	:	Land smoothing
Border Irrigation	:	Land grading
Basin Irrigation	:	Land leveling.

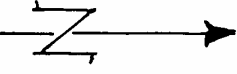
Step-V : Irrigation Direction and Alignment of Equalizer:

The irrigation direction should be approximately parallel to contour. The direction of interculture operation during the rainy season should also be parallel to contour. This will help to control soil erosion in the Kharif season. If there is long dry spell one or two protective irrigations can be given in the Kharif season. If heavy rainfall occurs excess rain water can be driven out of the field through the straight furrows without causing any soil erosion. The equalizer with siphon tubes or gated pipe can be arranged across the contour to irrigate straight furrows. A farm drain must be provided parallel to the equalizer alignment located at the other end of the field (Figure-10). The criteria for subdivision of field for land forming are given in Table-3.

Step-VI A : Design Procedure for Land Smoothing:

Crop	:	Sugarcane; A contour plan (Figure-8.10)
Method	:	Land smoothing

- Divide the field into sub fields as per criteria given in Table-8.3, (Figure-8.10)
- Decide irrigation direction as indicated in Figure-8.10
- Indicate alignment
- Indicate Farm drain
- Calculate the natural land slope of the field in the direction of irrigation, (Figure-8.11).


 Scale 1:500
 * centroid R.L.: 10.03.

Land Slope $\rightarrow 0.33\%$
 Irrigation Slope $\rightarrow 0.2\%$

Land Slope 0.72% $\rightarrow$
 Cross Slope 0.70% $\rightarrow$

A	10.24	10.32	10.22	10.34	10.20	10.25	10.18	10.10	10.16	10.04	10.14	10.12	10.20	10.10	10.21
	(9)	(8)	(12)	(12)	(6)	(7)	(11)	(11)	(11)	(11)	(11)	(11)	(9)	(2)	(2)
	-8	-8	-12	-12	-5	8	+12	+12	+12	+12	+12	+12	-8	-1	-1
B	10.10	10.19	10.08	10.20	10.06	10.11	10.04	10.09	10.03	10.02	10.05	10.05	10.05	10.03	10.05
	(10)	(3)	(13)	(10)	(6)	(14)	(5)	(10)	(5)	(11)	(11)	(11)	(2)	(12)	(12)
	-9	-2	-12	-9	-5	15	+6	+11	+6	+12	+12	+12	+3	-11	-11
C	10.03	10.16	10.01	10.10	10.09	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
	(14)	(14)	(10)	(10)	(2)	(7)	(4)	(7)	(4)	(4)	(20)	(12)	(12)	(13)	(13)
	-13	-13	-9	-9	-1	+8	+15	+8	+15	+15	+21	+12	+12	-12	-12
D	10.20	10.20	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05	10.05
	(25)	(12)	(12)	(12)	(9)	(4)	(21)	(4)	(21)	(21)	(17)	(5)	(5)	(21)	(21)
	-24	-11	-11	-11	-7	+5	+22	+5	+22	+22	+18	-4	-4	-20	-20
	9.96	10.20	9.94	10.05	9.92	9.99	9.30	9.85	9.88	9.66	9.86	9.68	9.84	9.82	9.72

Fig.8.11: A Part plan of Sugarcane field indicating cutting & filling depths. (Land Smoothing technique)

Ground level (GL) at A – GL at A' = $10.32 - 10.21 = 0.11$
 GL at B – GL at B' = $10.19 - 10.07 = 0.12$
 GL at C – GL at C' = $10.20 - 9.72 = 0.48$

Mean elevation difference ÷ Distance * 100 = Slope %
 $0.11 + 0.12 + 0.48 = 0.71 \div 3 \div 70 * 100 = 0.33\%$

Calculate the land slope across the irrigation direction:

GL at A – GL at C = $10.32 - 10.20 = 0.12$
 GL at A' – GL at C' = $10.10 - 9.85 = 0.25$
 GL at D – GL at D' = $10.21 - 9.72 = 0.49$

Mean Elevation Difference ÷ Distance * 100 = $0.286 \div 40 * 100$
 = 0.716%

Table-8.3 : Criteria for Sub Division of Field for Land Forming

Sr. No.	Land slope along Field Channel or Equalizer Align. In %	Width of sub field along the field channel align., m.
1.	0 – 0.5	90 – 120
2.	0.5 – 1.0	60 – 90
3.	1.0 – 2.0	30 – 60
4.	2.0 – 3.0	15 – 30
5.	3.0 – 4.0	10 – 15

Note: The width of sub field can be as small as 30 m. to optimize the depth of cutting.

Table-8.4 a : Desired slope criteria for Land Smoothing Technique

Sr. No.	Soil Texture	Irrigation Slope, %	Cross Slope, %
1.	Coarse	≤ 0.3	≤ 3.0
2.	Medium	≤ 0.3	≤ 3.0
3.	Fine	≤ 0.2	≤ 3.0

(Mainly used for Straight Ridges and Furrows)

Table-8.4 b : Desired slope criteria for Land Grading Technique

Sr. No.	Soil Texture	Irrigation Slope, %	Cross Slope, %
1.	Coarse	≤ 0.6	≤ 0.2
2.	Medium	≤ 0.4	≤ 0.2
3.	Fine	≤ 0.3	≤ 0.2

(Mainly used for Border Irrigation)

Table-8.5 : Cut-Fill Ratio (Compaction Factor)

Sr. No.	Soil Texture	Cut-Fill Ratio
1.	Coarse	1.1 – 1.2
2.	Medium	1.2 – 1.3
3.	Fine	1.3 – 1.5

- The desired slopes for Straight Furrow Irrigation are given in Table-8.4.

The desired irrigation slope : 0.3 % (Figure-8.11)

The desired cross slope : 0.7 % (Figure-8.11)

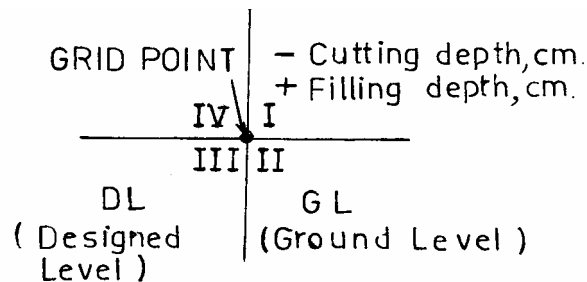
- Locate the centroid of the field at indicated in Figure-8.11

Find out the center point between A & C and name as 'O'.

Find out the center between C & C' and name as 'O' '.

Extend the straight lines from 'O', and 'O' '. The junction of these straight lined as indicated in Figure-8.11 is the centroid of this field.

- Calculate the Mean of all ground elevations in the field. The mean elevation of the field is 10.3 m. This mean elevation is considered as designed elevation at the centroid. Calculate the designed elevation at each grid point considering designed irrigation and cross slope. The ground elevation (GL), the designed elevation (DL) are written in the second and third quadrant at each grid point as indicated below. The cutting depth is



indicated by minus sign and + sign indicate filling depth in centimeters (Figure-8.11).

$$\begin{aligned}
 \text{Cut-Fill Ratio} &= \frac{\Sigma (\text{cutting depth at each grid point})}{\Sigma (\text{Filling depth at each grid point})} \\
 &= 172 \div 182 = 0.945
 \end{aligned}$$

This cut-fill ratio is very close to 1.0. However the desired cut-fill ratios varies from 1.1 to 1.5 as shown in Table-8.5. Since desired cut-fill ratio for medium texture soil is 1.1 to 1.3; the plane at the centroid is required to be lowered by one centimeter. It means the designed elevation at the centroid is reduced by one centimeter. Thus the depth of

cutting at each cutting grid point is increased by one centimeter and simultaneously the filling depth is reduced by one centimeter at each filling grid point. These new cutting and filling depths are shown in the circle at each grid point. The modified cut-fill ratio would be:

$$\text{Cut-Fill Ratio} = \frac{172+21 \text{ cm}}{182-19 \text{ cm}} = \frac{193}{163} = 1.184 \cong 1.2$$

Since this cut-fill ratio is in desired limit the land forming smoothening is quite satisfactory.

- Calculate cost per ha @ Rs. 10/- per cubic meter of cutting volume of soil

$$\text{Cost per ha} = 1.93 * 100 * 10 \div 0.4 = \text{Rs. 4825/-}$$

Step-VI B : Design Procedure for Land Grading:

Crop : Wheat
Soil : Medium Texture, soil depth : 0.9 to 1.2 m.

- Decide irrigation direction as indicated in Figure-10.
- Indicate the alignment of equalizer and Farm drain
- Calculate the land slope in the direction of irrigation
Land slope = 0.33%
(The same procedure as in land smoothening technique)
- Calculate land slope across irrigation direction
Land slope = 0.72%
- The desired slope criteria for border irrigation are given in Table-8.4 b
The desired irrigation slope : 0.3%
The desired cross slope : 0.2%.
- The division of field into subplots is necessary to optimize on the cutting depth of soil. The criteria for sub division of field are given in Table-8.5. The field is divided into subplots as indicated in Figure-8.10. Each subplot is considered as an independent field and the earthwork quantity for land grading work is estimated. The step-by-step procedure is given below:
 - ◆ Locate the centroid of the subplot
 - ◆ Calculate the mean of all ground levels i.e. 10.03 m.
 - ◆ Consider this mean ground level as the designed elevation at the centroid.
 - ◆ Calculate the designed elevations at all the grid points. Indicate the cutting and filling depths (Figure-8.12).


 Scale 1:500
 Centroid R.L.: 10.03

Land Slope $\rightarrow 0.33\%$
 Irrigation Slope $\rightarrow 0.3\%$

Land Slope 0.72% $\uparrow$
 Cross Slope 0.20% $\uparrow$

-15	-20	-14	-2	+1	-12	-21	-25
10.17	10.32	10.14	10.34	10.11	10.25	10.10	10.21
-4	-12	-2	+4	+4	-5	+4	-11
10.15	10.19	10.12	10.24	10.09	10.11	10.06	10.05
-6	-10	-4	+15	+6	+10	+0	-15
10.13	10.19	10.10	10.20	10.07	10.11	10.04	10.07
-5	-2	-5	+13	+19	+24	+5	-11
10.11	10.16	10.08	10.10	10.05	10.00	9.99	9.98
-11	+1	+4	+15	+31	+26	+3	+16
10.09	10.20	10.06	10.05	10.03	9.99	9.97	9.98

Fig.8.12: A Part plan of Sugarcane field indicating cutting & filling depths. (Land Grading Technique.)

- ◆ Calculate cut fill ratio.

$$\text{Cut-Fill Ratio} = \frac{\text{Sum of cutting depth}}{\text{Sum of filling depth}} = \frac{212 \text{ cm}}{201 \text{ cm}} = 1.05$$

- ◆ Lower the plane at the centroid by one cm and recalculate the cut fill ratio.

$$\text{Cut Fill Ratio} = 234 \div 182 = 1.278 = 1.3$$

- ◆ Calculate cost per ha. @ Rs. 10/- per cubic meter of cutting volume of soil

$$\text{Cost per ha} = 2.34 * 100 \div 0.4 * 10 = \text{Rs. 5850 per ha}$$

Step-VI C : Design Procedure for Land Leveling:

Crop : Low land Paddy
Soil : Medium textured, soil depth : 0.9 to 1.2 m.

- The desired slope in the direction of irrigation is zero %, the desired cross slope is also zero%
- Calculate the mean elevation of the field:

Mean GL = 8.54 m.
- Since the zero slope is to be given, the mean GL value is written as desired level at all the grid points in the field (Figure-8.13).

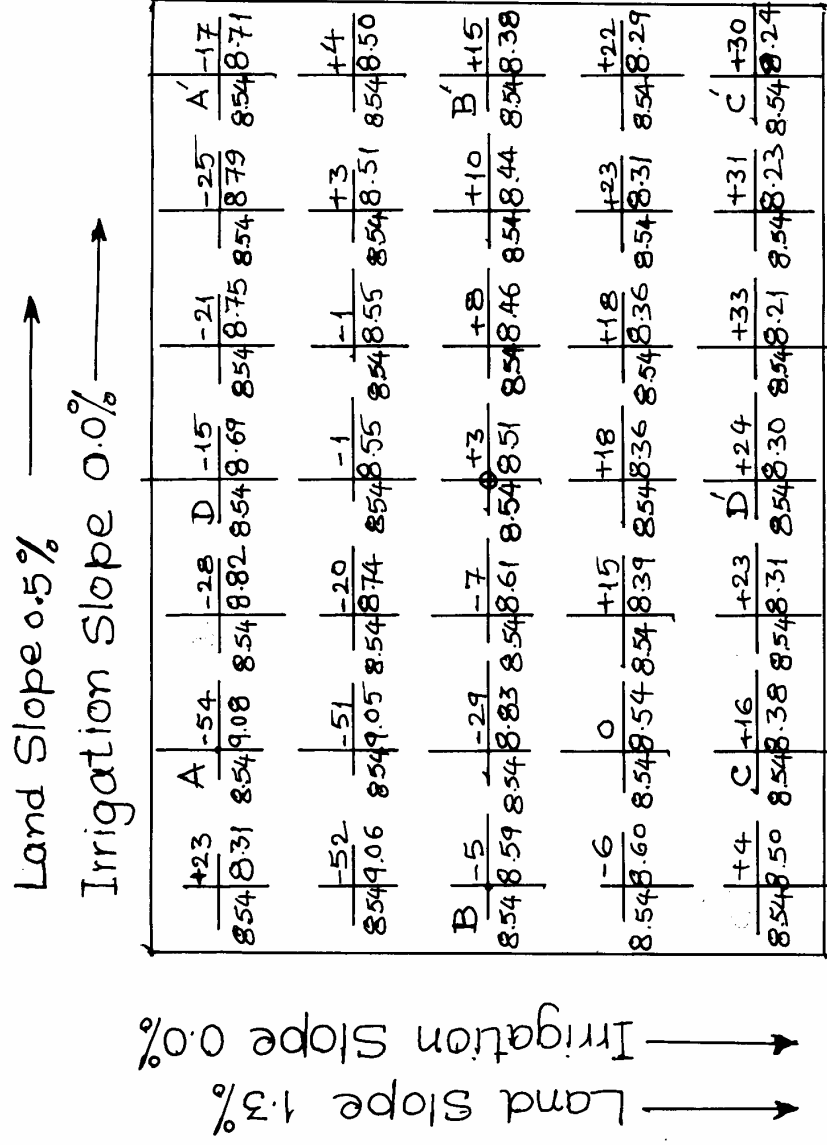


Fig.8.13: A Plan of a Paddy Field indicating cutting & Filling depths (Land Levelling Technique.)

- Land slope in the direction of Irrigation : 0.5%
- Cross slope : 1.3%
- Calculate the cutting and filling depths at each grid point as indicated in Figure-13, calculate cut fill ratio.

$$\text{Cut Fill Ratio} = 332 \div 323 = 1.03$$

- Lower the desired plane by one cm. to increase the cutting depth at each grid point.

$$\text{Cut Fill Ratio} = 348 \div 304 = 1.15$$

- Calculate the cost per hectare @ Rs. 10/- per cubic meter of cutting volume of soil.

$$\text{Cost} = 3.48 * 100 * 10 \div 0.35 = \text{Rs. 9943 per ha}$$

There is minimum soil handling and minimum disturbance of soil fertility status in this technique. Most of the aerable row crops such as cereals, oil seeds, vegetables, fibre crops, sugarcane, banana and other fruit crops can be irrigated by straight furrows. Therefore, wherever possible land smoothening technique should be adopted for making straight furrows which are oriented parallel to contour.

The land grading technique can be used for preparing border to irrigate Rabi and Hot weather seasonals such as wheat, lucern etc. Land grading technique may be used on relatively flatter lands to retain the soil fertility.

Similarly the land leveling technique preferably should be used for low land paddy on flat topography in high rainfall zone. As far as possible the land grading and land leveling technique should not be used on steep topography (i.e. slopes more than 1%).

Step-VII : Construction of Land Forming Works:

The grid survey layout is marked in the field. The wooden pegs or iron Bars of about 0.3 to 0.5 m are used for marking cutting and filling depths. At the cutting point a small pit is dug. The peg is inserted in the pit at the desired depth such that the cutting depth from the ground surface is measured down to the top of the peg (Figure-8.14). The green ribbon is tied on the peg to indicate the filling depth. This filling depth is calculated as cut fill ratio multiplied by the actual filling depth at each grid point to take care the soil compaction factor.

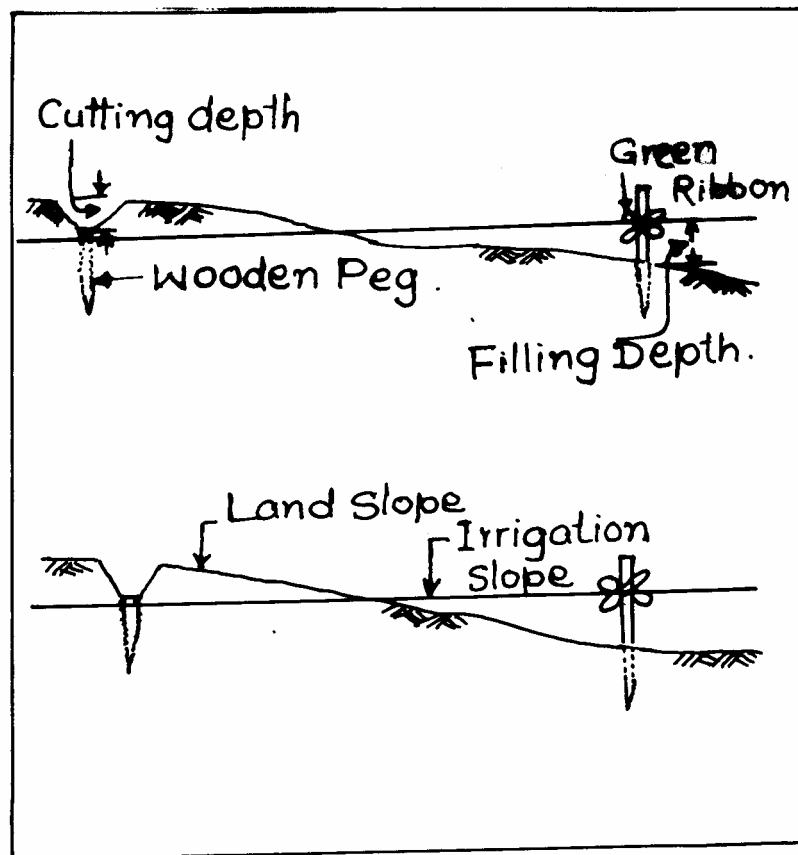


Fig.8.14 Method of Marking Cutting and Filling depths.

The rear mounted tractor drawn scraper, buck scraper, front mounted tractor drawn scraper or a chain tractor i.e. bulldozer are the equipments used for land forming work. Leger land leveling equipment is also used for precise land forming construction.

Step-VIII : Evaluation of Land Forming Work:

The mean deviation between the existing land plane and the desired land plane is called as Land Forming Index (LFI). It is calculated as follows:

$$\text{L.F.I.} = \frac{\sum | \text{Ground Elevation} - \text{Desired Elevation} |}{\text{Total No. of Grid points in the field}}$$

It is expressed in centimeters. The quality of land forming work is judged on the basis of criteria given below.

If $\text{LFI} \leq 1.0 \text{ cm}$ → Land forming work is Excellent

If LFI is 1 to 5 cm → Land forming work is Satisfactory

If $LFI \geq 5 \text{ cm}$ → Poor quality Land forming work.
Need improvement

Example:

Existing L.F.I. for land grading work

$$= \frac{212 + 201}{40} = 10.3 \text{ cm}$$

Since L.F.I. is greater than 5 cm the land forming work is required.

REFERENCES:

1. On-farm Development Works including Micro Distribution Network and Land shaping for Irrigation, WALMI, Publication No.12
2. Holsambre D.G., 1997, "Irrigation Management Techniques in Sugarcane Farming Systems", Jr. of IWRS, Vol. 17(3) No.1

CHAPTER - 9

DRAINAGE

1. Drainage of irrigated lands is the removal of excess rain water or irrigation water either from the soil surface or from the subsoil strata.

2. The Need for Drainage:

- (1) Removal of excess rain water without causing soil erosion
- (2) Providing balanced environment of soil, air and water to the plant to obtain good crop yield.
- (3) To provide workable soil conditions for farm operations.
- (4) To leach out undesirable salts from the soil profile
- (5) To prevent water-logging, soil salinity and health hazards
- (6) To minimize plant diseases, which are more active under high water table conditions. Fungus growth is particularly prevalent
- (7) To avoid comping up of salt in the root zone which may convert productive land into unproductive land

3. Drainage Measures:

Preventive and curative measures are taken to tackle drainage problems. The preventive measures are cheaper and cost effective than the curative measures.

3.1 Preventive Measures:

- 1) Provide adequate natural drainage facilities to prevent soil erosion
- 2) Land formation for efficient irrigation
- 3) Adopt contour strip cropping
- 4) Use of contour furrows, straight graded furrows, border and chek basin method of irrigation
- 5) Prevent the use of serpentine furrows cum basin irrigation
- 6) Use drip or sprinkler irrigation techniques for high value crops
- 7) Line the irrigation canals to prevent seepage and water logging
- 8) Use groundwater for irrigation.

3.2 Curative Measures:

- 1) Provide adequate surface drainage network
- 2) Provide adequate sub surface drainage network
- 3) Provision of Interceptor drains and pumping of ground water, tree plantation, nalla and river training etc.

4. Surface Drainage:

4.1 Surface drainage is the orderly removal of excess water from land surface, through constructed or improved natural channels and supplemented by proper grading of land surfaces.

A field drain is a graded channel that collects the excess water from a field or a holding of an individual farmer (Figure-9.1).

A link drain or collector drain is a drain which collects water from field drains and carries it to the main drains. (Figure-9.1)

A main drain is the principal drain for an area. (Figure-9.1)

(The words 'Surface drain' include both field drain and a link drain. A field drain is a community item whereas a link drain is a Government owned work).

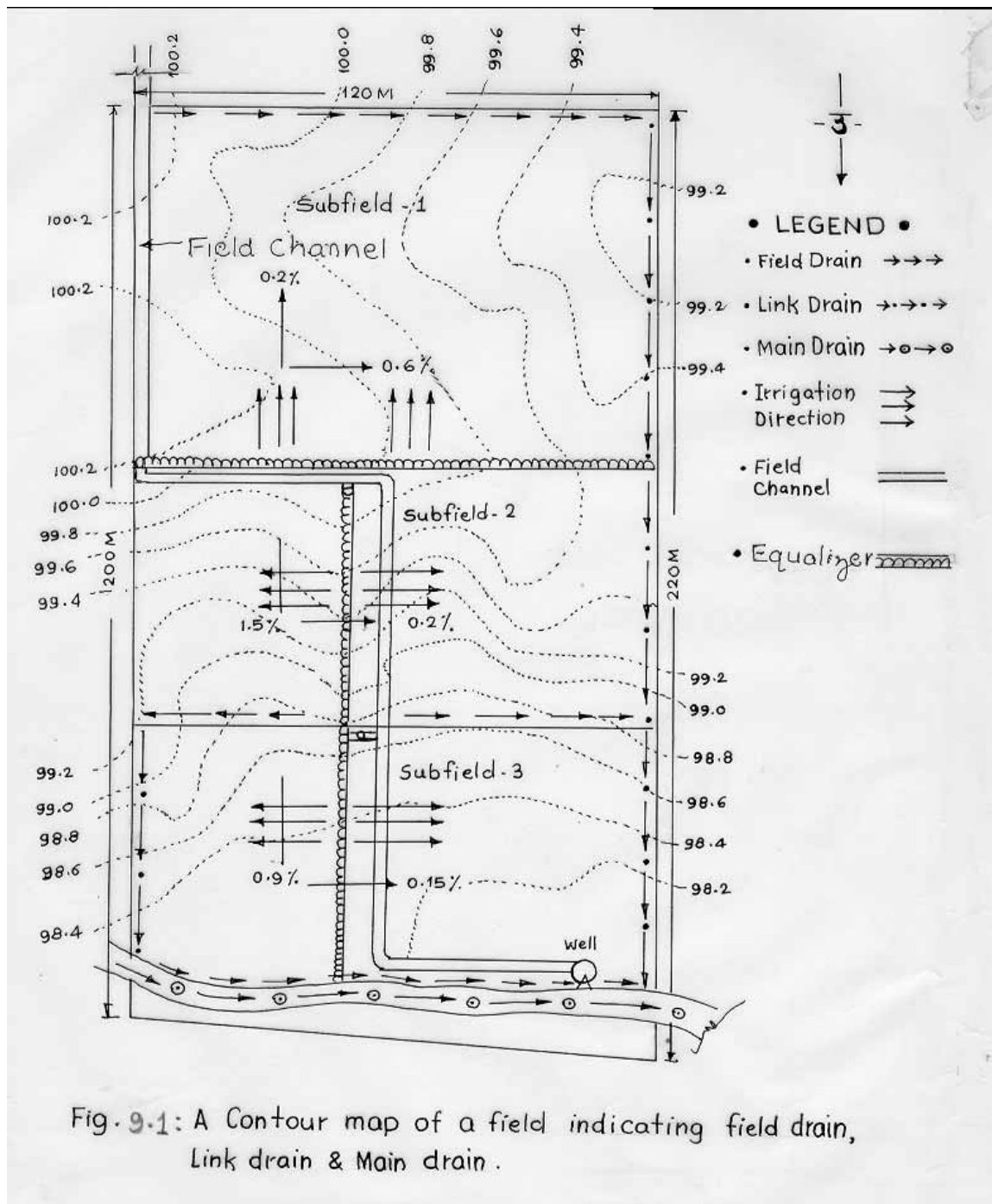


Fig. 9.1: A Contour map of a field indicating field drain, Link drain & Main drain.

4.2 Planning & Design of Surface Drainage System:

4.2.1 A topographic map of grid size 20 m x 20m and contour of 0.2 to 0.4m is required for planning of surface drains.

4.2.2 Two different approaches are used while designing the surface drainage network.

A) Design of surface drains for flat topography:

Wherever the average land slope is less or equal to 1%, it is considered as flat topography. The surface runoff depends upon the soil intake rate and vegetation cover

on the soil. In flat topography the excess rainfall can be disposed off the field with in the permissible limit of ponding. A period of 3 days ponding is allowed for paddy, sugarcane and Banana, 1½ days for other food crops and one day for vegetables. With all these considerations the design capacities are given in the table 9.1.

Table 9.1 : Design Capacity of Surface Drains

Sr. No.	Zone	Maximum 24 hrs rainfall mm	Soil Type	Runoff coefficient	Design Runoff mm	Ponding Time days	Design capacity lps/ha
1	Heavy rainfall	250	Paddy fields & clayey soils	0.5	125	3	5
				0.5	125	1½	10
				0.5	125	1	10
2	Heavy rainfall	250	Medium & coarse soils	0.25	62	3	2.5
				0.25	62	1½	5
				0.25	62	1	7.5
3	Other area	100	Clayey Soils	0.5	50	3	2
				0.5	50	1½	4
				0.5	50	1	6
4	Other areas	100	Medium & coarse soils	0.25	25	3	1
				0.25	25	1½	2
				0.25	25	1	3

A broad based field drains generally known as waterways can be constructed in flat land. These drains do not require any maintenance and the crops can be grown in the water ways (Figure 9.2).

The link drain should have a minimum bottom width of 0.5m and depth 0.6m. The bed gradient should be 0.1 to 0.3%. A typical cross section of link drain is indicated in Figure 9.3.

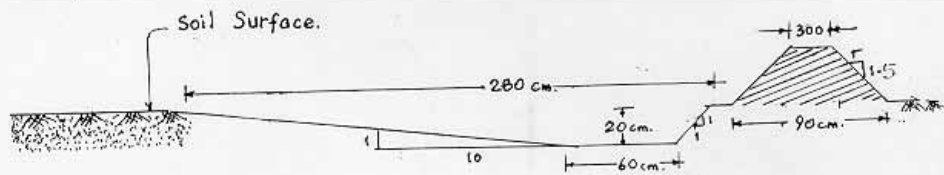


Fig.9.2 : -A TYPICAL SECTION OF FIELD DRAIN.

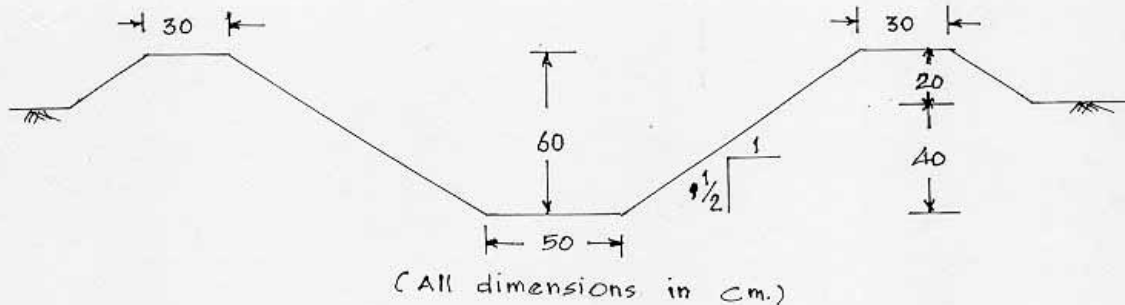


Fig.9.3 : CROSS SECTION OF DRAIN.

The alignment of main drain is located in the natural nala. The trapezoidal cross section of main drain is designed for the bed gradient similar to the link drain and the side slope should be $1\frac{1}{2} : 1$; $2 : 1$ and $2\frac{1}{2} : 1$; in coarse, medium and fine texture soil. The roughness coefficient may be taken as 0.04.

B) Design of Surface Drains for Steep Topography;

The average agricultural land slope greater than 1% is considered as steep topography which is prone to soil erosion due to excess rainfall. A rational formula is used to calculate the peak rate of runoff.

$$Q_{\text{peak}} = 10 C I A.$$

In which Q_{peak} is the peak rate of runoff in $\text{m}^3/\text{hr.}$, 'C' is the runoff coefficient, I is the rainfall intensity with 10 years recurrence interval of one hour storm i.e. mm/hr (see table 9.3). A is the area of drainage basin or catchment area in ha. The generalized runoff coefficient for small watershed up to 20 ha based on field experience are given in Table 9.1.

The side slopes, bed gradients and the roughness coefficient values are given in Table 9.2.

Table 9.2 : The generalized paramers used for the design of Field, drain, and main drain. (Generally the trapezoidal section is used for the drains)

Sr. No.	Soil Texture	Bed Slope %	Side Slope H : V	Manning's 'n' value
1	Coarse	≤ 0.4	1.0 : 1.0	0.04
2	Medium	≤ 0.3	1.5 : 1.0	0.045
3	Fine	≤ 0.2	2 : 1	0.05

Table 9.3 : One hour rainfall intensities with 10 years return period for the districts of Maharashtra State

Sr. No.	District Place	Rainfall Intensity mm/hr	Sr. No.	District Place	Rainfall Intensity mm/hr
1	Akola	70	15	Nagpur	80
2	Amrawati	70	16	Nasik	60
3	Ahmednagar	55	17	Osmanabad	55
4	Aurangabad	55	18	Parbhani	70
5	Beed	55	19	Pune	60
6	Bhandara	80	20	Ratnagiri	85
7	Buldhana	65	21	Raigarh	85
8	Chandrapur	70	22	Sangali	80
9	Dhule	55	23	Satara	80
10	Jalgaon	60	24	Solapur	60
11	Jalna	55	25	Sindudurg	85
12	Kolhapur	80	26	Thane	80
13	Latur	55	27	Wardha	70
14	Nanded	70	28	Yavatmal	70

Design Procedure:

Field Drains:

The main objective of field drains, is to control soil erosion due to excess rainfall. The trapezoidal section is designed for the drains. The field drains are constructed with the formation of bund as indicated in Figure 9.4. The field drain is oriented approximately parallel to contour.

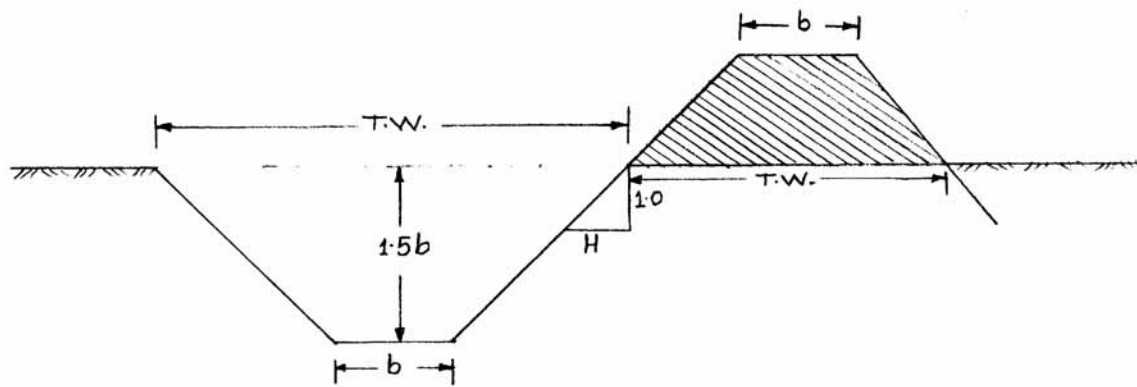


Figure 9.4: A typical cross section of field drain in steep topography

- Calculate the peak rate of runoff using rational formula, use 'I' value from Table 9.3 of the nearest location.
- Assume drain depth 1.5 times the bottom width of the drain
- Calculate cross section area and hydraulic radius in terms of bottom width 'b'.
- Use Manning equation and other parameters from Table 9.2 to calculate the bottom width of drain.
- Calculate top width and construct the bund as indicated in Figure 9.4.

Link Drains:

These drains are constructed to link the farm drain. The design procedure is same as that of field drains. The excavated material is dumped on both sides of the drain.

Main Drain:

The main drain is divided into two to four reaches depending on the length of the drain and the catchment area. A separate trapezoidal cross section is designed for the reaches of the main drains. The similar procedure is adopted for designing the cross section of the main drains.

4.3 Tolerances for drain earth work are specified below :

Bed level	..	..	± 0.1 m
Sides	..	..	± 0.2 m

4.4 Grass sodding:

Grass sodding with selected grass is required for controlling erosion. Where the gradients are steep, grass sodding should be provided. The erosive grades will vary with soils. Generally gradients steeper than 0.3 percent in clayey soils need protection.

Sodding need be provided only for the portion below the design water level. (i.e. generally below ground).

4.5 Rapids:

In steep topography, where the ground slopes are steeper than gradients permissible for the drains, falls are required at intervals, to bring down the water from a higher level to a lower level. However, unlike on field channels regular drop structures are not necessary for field drains, because -

- (i) the usual gradients adopted for field drains are flatter than for field channels and the velocities are low;
- (ii) the design discharges of field drains are required to be passed only once in a while.

In areas other than ravine areas and black cotton soils areas, instead of drop structures, rapids in stone/boulder pitching are found to work satisfactorily. A rapid can be designed for a fall upto 1 m. (Figure-9.5).

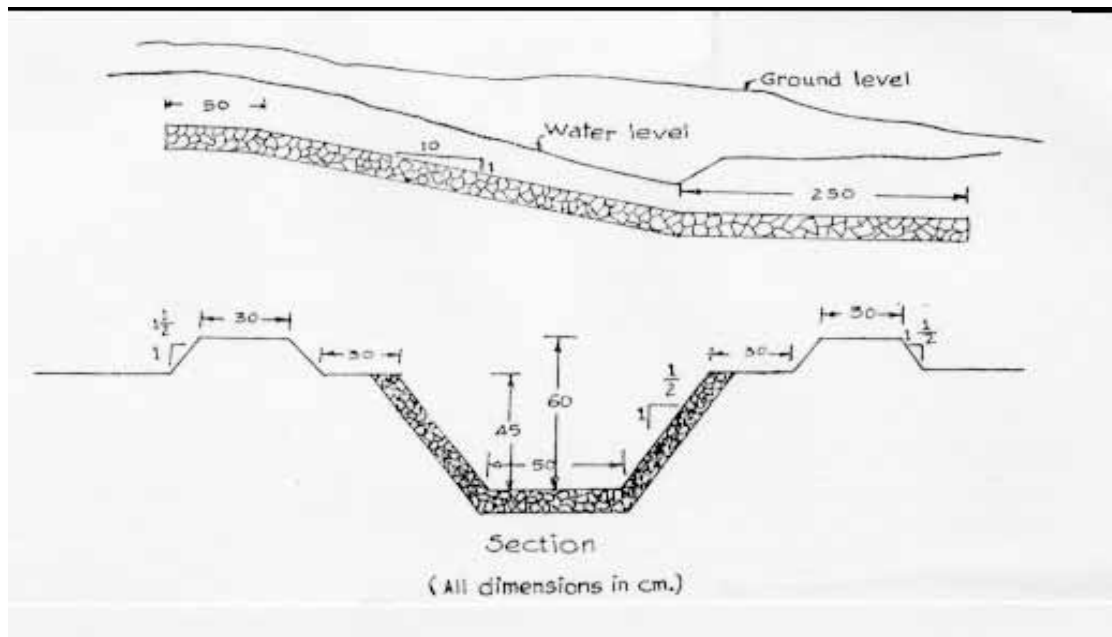


Figure-9.5 : Rapid (in dry rubble)

Rapid will have a length of 13 m. including 10 m. of the rapid proper, 2.5 m. protection on the downstream and 0.5 m. on the upstream. The slope of the rapid will be suitably adjusted according to the required fall (1 in 10 for a 1 m. fall; 1 in 11 for a 0.9 m. fall; 1 in 50 for a 0.2 m. fall etc.)

In ravines and black cotton soil areas, regular drop structures as in the case of field channels may be provided.

4.6 Outfall:

Where the link drain meets the main drain (nalla) there has to be a proper outfall. This junction is designed as a fall structure.

The design water level in the drain should be at least 0.5 m (desirably 1.0 m) above the normal water level in the main drain (nalla). At the junction point of a field drain and a link drain also, particularly where the field drain's proportionate distribution of rate of flow is high, it is desirable to keep the outfall point of the field drain at least 15 centimeters above the bed level of the link drain.

4.7 Crossings:

Where a surface drain crosses an existing road or cart track, a crossing arrangement has to be provided. The bed gradient of the drain should be maintained and siphoning should be avoided.

The arrangement recommended for a field channel crossing is suitable for a surface drain crossing also.

5.0 Subsurface Drainage:

5.1 Sub surface drainage has prime importance in on-farm water management. Sub surface drainage has to be dealt with carefully in association with on-farm water distribution, surface drainage and crop management.

In this context sub surface drainage is related to on-farm development works, but it is to be clearly understood that any construction of drainage scheme for sub surface drainage is not part of any on-farm development work as envisaged in this manual.

Irrigation Engineer in-charge of on-farm irrigation management must be aware of following aspects of sub-surface drainage.

- a) The need of sub surface drainage in irrigated area
- b) The impact of inadequate subsurface drainage
- c) Identification of damaged irrigated lands due to inadequate subsurface drainage
- d) Remedial measures to restore irrigated lands influenced by water logging and salinity due to inadequate sub surface drainage
- e) Legal aspects of drainage with special reference to Maharashtra Irrigation Act 1976.

5.2 The need of sub surface drainage in irrigated area:

The soils may be well drained and non saline under "natural conditions" i.e. under "rainfed agriculture". These soils, however, may not have adequate drainage properties to cater for "irrigated agriculture". When the rainfed lands are brought under irrigation, it is necessary to establish good drainage system for additional sub soil water and soluble salts which come along with canal irrigation water, extensive use of fertilizers and intensive cropping. If this fact is not recognized in on-farm water management, the ground water table rises from a considerable depth to within a few meters from ground encompassing the root zone in a short span of time after

commencement of canal irrigation. During early years of development of irrigation project, water is frequently plentiful and there is tendency to use it in excess. This hastens the rise of water table and creates conditions conducive to water logging. Water logging gives birth to salinity.

As the water table rises and the water logging conditions are evident, salts concentrated beneath the root zone are dissolved and carried to the root zone or to the surface at sometimes through water by capillary action. The irrigable soils, thus, become waterlogged and become saline either partially or fully. The application of irrigation water, too, may contribute to problem of salinity, because some times canal irrigation waters have more concentration of salts than natural rain water. To avoid waterlogging and salinity, in irrigated area, need of sub surface drainage is evident.

5.3 The impact of inadequate subsurface drainage

- a) The high concentration of salts in the root zone interfere with the movement of soil water into the roots and plants begin to wither and either yield low or loose productivity.
- b) In waterlogged soils, the air content within soil is very low, because most of the pores are filled with water. The exchange between the air in the soil-pores and the air in the atmosphere above is very much restricted by waterlogged conditions. The oxygen deficiency create anaerobic conditions in soil, which result in toxic concentrations of sulphides and organic gasses. Crop growth is impaired due to toxic conditions in soil and yield gets affected due to such unhealthy conditions in the soil.
- c) Excess water on or in the soil adversely affects the soil workability. There are fewer workable days on poorly drained land which has become waterlogged. Essential farm operations i.e. seed bed preparations, planting, weeding, harvesting etc. may be critically delayed. Modern mechanized farming is much more affected than traditional bullock driven farming operations.
- d) The environmental implications of waterlogging and salinity are slow but widespread and devastating. These are as below.
 - i) Soil modifications
 - ii) Socio-economic impact
 - iii) Public health disorders
 - iv) Effect on flora and fauna.

5.4 Identification of damaged irrigated lands due to inadequate subsurface drainage

The waterlogging and salinity have an environmental impact which create disorders as discussed in para 5.3 above. Hence, it is essential to identify the damaged irrigated lands at the nick of time. The identification of damaged irrigated lands is done in three ways, as described below.

- a) Visual observations of soil moisture conditions, unhealthy crop conditions and other vegetative growth like, bulrush, pankanis etc. in the area
- b) Observations of water levels in the wells in the area during post-monsoon and EC values.
- c) Laboratory tests of soil samples and water samples to determine pH and EC.

The Directorate of Irrigation Research and Development, Pune and the six research divisions viz. I.R.D., Pune, I.R.D., Nasik, I.R.D., Akola, I.R.D.A., Aurangabad. I.R.D., Kalwa and Jayakwadi Land Drainage Division, Aurangabad have been assigned to identify and demarcate the damaged area each year, on the basis of above observations and laboratory tests. The irrigation engineers in-charge of irrigation subdivision / irrigation section and canal inspectors, measurers may report to Irrigation Research Divisions or subdivisions whenever they apprehend the possibility of waterlogging on the basis of visual observations. This would assist the realistic identification of damaged area.

5.4.1 Criteria for classification of damaged area:

The damaged area is basically classified as,

- a) Waterlogged area and
- b) Saline area.

In Maharashtra, the waterlogged and saline area are further classified as,

- a₁) Fully waterlogged area
- a₂) Slightly or partially waterlogged area
- b₁) Fully saline area, and
- b₂) Slightly or partially saline area.

The D.I.R.D., Pune and six Research Divisions mentioned above, are the only competent authorities to certify the damaged area as above on the following norms,

- a₁) Fully waterlogged area: The area where the water table is at ground surface.
- a₂) Slightly or partially waterlogged area: The area where the water table is upto 1.2m below the ground surface.
- b₁) Fully saline area with sodic soils: The EC value of soil is more than 3 Mmhos/cm and pH value is more than 8.5 . The salt incrustation is abundantly seen on the surface of soil and crop growth is stunted or no crop at all.
- b₂) Slightly saline area: The EC value of soil is between 1 to 3 Mmhos/cm and pH value is between 7.5 to 8.5. The soil incrustation is slightly seen

on the surface of the soil in water delivery channels and crop growth is slightly stunted, crop foliage is not bright green and the crop yield is low.

6. Remedial Measures to restore irrigated lands influenced by waterlogging and salinity:

Remedial measures are of two type, viz.:

- a) Preventive Measures.
- b) Curative Measures

6.1 Preventive Measures:

Preventive measures are the measures which can be implemented by irrigation engineers incharge of irrigation sub division and irrigation section. The canal inspectors and measurers may be encouraged to create awareness about these measures amongst farmers.

Preventive measures are as below:

- a) Prescribing the area of perennial crops through fixing X-limit
- b) Other preventive measures related to crop and water management in association with maintenance of water distribution system and natural drainage system.

6.1.1 Prescribing the area of perennial crops through fixing X-limit:

Based on large field research (1916-1937), the concept of X-limit as envisaged in Technical Paper No. 56 (T.P. 56) by Mr. W.A. Evershed and Sir C.C. Inglis is adopted by Irrigation Department for prescribing the area of perennial crops. The basic data regarding water and land use in the command area in association with season wise details of crops and water supplied to crops, along with detailed command maps have to be supplied by field irrigation engineers to D.I.R.D. Officers. The X-limit for each outlet i.e. prescription of maximum permissible area under sugarcane and other perennial crops is decided by D.I.R.D. Officers. This forms a guiding limit for sanction of area under perennial crops in the command area under outlet. The Government has laid down directives that no curative measures in the form of construction of drainage schemes be taken at Government cost where the X-limit has been exceeded and its implementation is emphasized.

The Maharashtra Water and Irrigation Commission has recommended in its report (June 1999) to replace the norm of X-limit by some other norm based on more scientific outlook considering soil classification, drainage properties, rainfall etc. Hence, the norm of X-limit may be revamped in near future. But the importance of prescribing perennial crops to avoid waterlogging and salinity, cannot be ruled out.

6.1.2 Other Preventive Measures:

- a) These are related to timely maintenance of water distribution system and OFD works, drainage schemes in existence and natural drainage channels in association with land formation, crop and water management and use of modern water saving irrigation techniques such as sprinklers, drips, etc.
- b) It is necessary to connect the borrow pits, along side of main canal and distributories, to nearby natural nalla. This would avoid continuous addition of seepage water into agricultural lands nearby the disnet and prevent water-logging.

6.2 Curative Measures, Agency and Norms:

To design and implement curative measures for improvement of waterlogged and saline lands in irrigated area, DIRD, Pune has been assigned the responsibility of preparation and execution of drainage scheme. A drainage scheme for improvement of waterlogged and saline area is taken up by DIRD, Pune at Government cost only when,

- a) The damaged area persists continuously for three years inspite of timely maintenance of natural drainage channels in the concerned command area
- b) The X-limit prescribed by DIRD, Pune is not exceeded
- c) In case of Water User's Associations, appropriate crop and water management in association with water saving techniques shall have been adopted to control the ground water table as per provisions in the agreement with Water User's Association.
- d) The farmers benefited through such drainage scheme shall permanently hand-over and transfer the rights and ownership of their land without any land compensation, which is required by Irrigation Department for construction of drainage scheme.

6.2.1 Types of Curative Measures, by DIRD, Pune:

DIRD, Pune designs and prepares the drainage schemes for lowering subsurface water levels through effective subsurface drainage using guidelines and principles enunciated in Technical Paper No. 56 (T.P. 56) titled "Land Drainage in the Deccan Canal Areas" by Mr. Evershed and Sir C.C. Inglis. The T.P. 56 prescribes a classical technique of drainage for,

- a) Shallow, Medium soils, and
- b) Deep black cotton soils.

a) Drainage Scheme for Shallow, Medium soils:

For shallow, medium soils open drains are excavated in definite - pattern with main drain and laterals to cater for lowering the subsoil water in waterlogged and saline area. These drains are taken deep enough to strike previous layer (Murum layer). The water seeping into ground is tapped through the previous layer and then collected in open drains (Main drain and Lateral drains). These open drains are then connected to a carrier drain which merely carries the water to out-fall drain and into natural nalla. This technique has been quite successful in most of the command areas where a murum layer can be struck at about a depth of 2m to 3m.

The cross section for open drains is suitably designed with adequate side slopes and bed with 0.6m to 1.0m. The bed gradient is suitably adopted for non erosive - non silting purposes. Though, the discharge received from subsoil water seeping through previous layer is very low, the open drain has to cater the surface runoff from local catchments from rains. Hence, the depth of cross section is decided on the basis of striking the pervious layer and overall stability of cross section is decided on the basis of type of soil strata and surface runoff.

The maintenance of the open drains (Main drain, Lateral drains and carrier drain in association with natural drain) is very much important for efficient functioning of drainage scheme. The previous layer shall be kept clearly open in the drain. Exhorbidant growth of pankanis and silting of drains or any dampings in the drain by farmers, seal the previous layer, which mars the very purpose of drainage scheme. Hence, on-farm irrigation engineers incharge of irrigation sub-division / irrigation section shall make farmers aware and see that sub drainage system is timely maintained through participatory interactions.

b) Drainage Scheme for Deep Black Cotton Soil:

In deep black cotton soils, the previous layer is at a depth more than 3m to 4m. It is not desirable to construct open drains, in such case. Hence, sub-artesian bores are constructed as prescribed in T.P. 56. These are bores at the bottom of drain to tap the lower pervious strata. Since, these drains are vertical and look like a chimney in the cross section, these are also called as "Chimney Drains". The DIRD, Pune has constructed such "Chimney Drainage Schemes" in some of the irrigation projects, e.g.

- a) Aral drainage scheme in Purna Irrigation Project
- b) Kedgaon drainage scheme on new Mutha Right Bank Canal in Mula Project
- c) Mahakala drainage scheme on Paithan Left Bank Canal in Jayakwadi Project

- d) Kawsan drainage scheme on Paithan Right Bank Canal in Jayakwadi Project.

6.2.2 Other Techniques of Underground Drainage Schemes:

DIRD, Pune has designed and studied various types of drainage schemes on prototype drainage works in deep black cotton soils in actual command areas of various projects. Viz.

- a) Pipe drainage schemes
- b) Rubble drainage schemes
- c) Tile drainage schemes
- d) Earthenware pipe drainage scheme
- e) Brick drainage scheme
- f) Brick and tile drainage scheme.

The determination of drain spacing is determined by using suitable equations. Hooghoudt or Glover Dumm equation is used for Medium and coarse textured soils. For fine texture soils Fukuda equation is most suitable. The depth of underground drain pipes is decided on the basis of root zone depth and the requirements of uninterrupted depth for farming operations. The diameter of pipe is determined on the basis of hydraulic requirements using Darcy-Weisbach formula or Chezy-Manning equation. The bed gradient is generally "non silting" but it is prudent to "over design" the pipe to allow for subsequent partial silting and for miss-alignment during construction.

7. Legal Aspects of Drainage:

- (A) The Maharashtra irrigation Act-1976 has several legal provisions to deal with construction and maintenance of drainage works and natural drains in the command area of irrigation projects. These are enlisted as below,
 - a) In part-I, clause 2, (9) defines "drainage work"
 - b) In part-III, clause 19, clause 20 and clause 21, provides for prohibition and removal of obstructions to drainage
 - c) In part-III, clause 22 provides for taking up drainage schemes for public health, or for reclamation of land, or for the improvement of proper cultivation or irrigation of any land or that protection from floods or other accumulations of water, or from any erosion by river.
- (B) In the jurisdiction of a Water User's Association, there is freedom of cropping pattern. Hence, it may be possible to impose restriction of cropped area under perennials, through X-limit. But the agreement with Water User's Association provides for responsibility of Water User's Association to control the ground water level below 3.0m from ground level. If the ground water level rises within 3.0m from ground level, the irrigation engineer shall curtail the sanctioned water quota to Water User's

Association accordingly to assist Water User's Association to maintain ground water level within norms.

The irrigation engineers in charge of irrigation sub-division / irrigation section shall study the legal provisions in Maharashtra Irrigation Act 1976 and also the provisions in the Maharashtra Farmers' Participatory Irrigation Management Act 2002 and provisions in the agreement with Water User's Association for efficient upkeep of surface as well as subsurface drainage in association with efficient irrigation water distribution and management.

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CHAPTER – 10

NON CONVENTIONAL ON FARM DEVELOPMENT WORKS

1.0 Introduction:

Conventionally, the irrigation water is supplied by gravity through a network of open channels, from main canal to field channels. In uneven topography with rolling ground or in hilly areas with steep slopes, high rainfall zone, heavy seepage losses and smallholdings, it may not be practicable from the hydraulics and maintenance point of view to reach by gravity flow through conventional open channels for each farm holding. Sometimes the natural ground slope is not favourable for economical land forming and irrigate through conventional irrigation methods. In such situations, non-conventional type of distribution systems and irrigation methods are required to be practiced. This type of situation exists particularly in Konkan and eastern part of Vidarbha region. A few of such systems and methods are mentioned as below,

- a) Piped distribution system
- b) Half round R.C.C. pipes supported on R.C.C. pedestals
- c) Developing interface in gravity irrigation network to adopt pressurized irrigation methods.

2.0 Piped Distribution System:

In the piped distribution system, the irrigation water is conveyed through closed conduits flowing full having non-silting velocity and internal pressure within permissible limits. Special control structures, such as float valves, air vent, hydrants etc. are used in irrigation pipeline to maintain congenial and permissible hydraulic conditions, in order to control water flow and protect the pipeline from damages.

2.1 On Farm irrigation Pipeline Distribution:

There are three types of on-farm irrigation pipelines,

- a) Completely surface system, where water enters the distribution pipeline at the supply well/reservoir or open channel turnout and the water distributed to the field through network of pipes with gated outlet at each field.
- b) A combination of buried and surface pipeline through one or more risers (hydrants), and
- c) A completely buried pipeline system generally used for border or basin irrigation. Water is released into the field from risers (hydrants) on the buried pipeline.

The piped distribution system is useful for diversification of crop pattern in Paddy growing areas where field-to-field irrigation is practiced in addition to saving of water and minimizing maintenance problems. Generally, in Paddy growing areas, Paddy over Paddy is grown, which consumes more water, affects soil

fertility and structure and reduces crop yield. Therefore, pipelines with hydrants will facilitate growing other crops (other than Paddy) for the individual farmer.

2.1.1 Pipeline Material:

Various materials suitable for pipeline have been developed starting from Bamboo pipeline to cast iron, steel, asbestos, cement, R.C.C., polyethylene low density / high density, fiber glass etc. Recently, in P.V.C. pipes, riblock variety is preferred. The ribbed profile and the wall stiffeners strengthen the pipe by creating high section modulus than plane P.V.C. pipe of equivalent amount of materials. In Konkan region, RIBLOCK PVC pipes have been used on Punade Minor Irrigation scheme, Tal. Uran, Dist. Raigad. It is found that the RIBLOCK pipes are lightweight, easy to handle, easy to fix and join and are quite leak proof. Hence, RIBLOCK PVC pipes may be used for on-farm irrigation pipelines. These are, however, low pressure pipes with limiting pressure of 1 Kg/cm² i.e. only upto 10 m water head.

2.1.2 Pipeline distribution system : Planning, design and construction.

The investment costs for construction of on-farm irrigation pipelines are heavy. Hence, to get appropriate returns from the scheme through benefits to farmers and revenue collection, it is essential that planning, design and construction of piped distribution system is done meticulously. The availability of hydraulic head is also a major factor affecting cost.

2.1.2.1 Planning:

To have the effective, non-problematic pipeline system, the information required for planning and designing play an important role. There are two aspects of planning:

- a) Collection of data
- b) Survey and mapping.

(a) Collection of Data:

- i) Data such as control levels of existing water distribution system, details of structures, roads, farm boundaries, major trees, wells etc. which are influencing factors for alignment and laying of pipes shall be precisely obtained.
- ii) Soil Data:

Information regarding existing soil and its characteristic is essential. This information shall include, type of soil (clay/silt/loam/murum/ S.R. / H.R.), and soil pH. The soil pH can affect the choice of material of pipe; pH<5 would preclude use of iron and concrete pipe. The cover over top

of pipe determines the soil load on pipe. The existing ground water table, soil specific characteristics like drainability, shear strength, compressibility, infiltration rate provide important parameters to decide structural stability of pipeline. Hence, these should be collected and analyzed to prevent unequal settlement of pipeline, shearing of pipeline at joints etc.

(b) Survey and Mapping:

The individual field under the command of each outlet of minor are surveyed by plane table to ascertain exact area of land holdings. The plans are prepared to the scale of 1:1000 for small command area. For the larger command, plane table survey may be too clumsy; hence, field corner level surveys are found to be adequate. The contours shall be plotted at 0.5m to 1 m interval, depending on steepness of terrain.

2.1.2.2 Designing the piped distribution system:

Design of piped distribution system envisages following aspects,

- A) Selection of pipe material
- B) Layout of piped distribution network
- C) Hydraulic design of piped distribution network.

(A) Selection of pipe material:

The type of pipe material depends on soil properties of existing strata wherein the piped distribution networks rests. The PVC Riblock pipes generally cater to the requirements of stability and strength. These are lightweight, easy to handle, easy to fix and join and are quite leak proof. Hence, RIBLOCK PVC pipes shall be used for main line and laterals.

(B) Layout of piped distribution network:

Important consideration to determine the alignment of pipeline,

- i) The main pipeline and laterals are aligned in such a way that they cover maximum area in minimum length.
- ii) The alignment of pipeline should be so decided that it generally passes through the centre of the chak. If the pipeline is on the ground, it should not bisect the

fields. It may go along the farm boundaries in such cases.

- iii) As far as possible, the pipeline alignment shall avoid bends. Curves are permitted with a maximum deflection of five degrees in mortar joints and a maximum of three degrees in rubber gasket pipe.
- iv) If the pipeline is a buried system, the depth and location of pipe below ground should be such that it does not hinder the farming activities. The maximum depth of cover for low head pipe shall be 1.2m.
- v) Pipelines should be straight and have uniform gradient from reach to reach or between stands.

The network of pipeline is so laid out that as far as possible each individual land holder or group of 4 to 5 landholders, if holding is very small, will get one turnout for obtaining water from the pipeline.

The pipe distribution system comprises of intake chamber at outlet on Minor / Distributory to connect main pipeline and laterals are provided to irrigate all the field in the chak. (Figure-10.1).

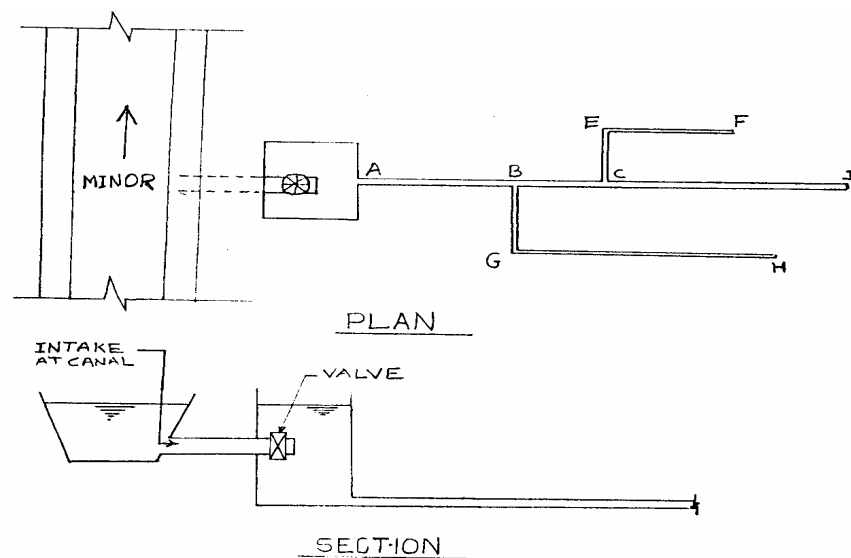


Fig : 10.1 Piped Distribution System

The intake chamber helps the water to enter the pipeline system gravitationally. It also helps as silt chamber to arrest the grit/silt etc. For controlling the flow of water, sluice valves shall be provided at the entry of chamber. Similarly, along the main pipeline itself sluice valves shall be required to be provided at suitable distances to stop the flow in case of emergency. Since the sluice valves are expensive, these may be replaced by fabricated MS Tee valves, which are simple to manufacture and cost about one third of the cost of a sluice valve.

In the conventional network of open field channels, turnouts are provided at each property head to facilitate irrigation of individual land holding. In piped distribution system Hydrants (risers) are installed on the laterals. It is desirable to provide separate hydrant for individual holding. However, because of smallholdings in Konkan area, one hydrant may be provided for 1 ha. area. In order to achieve equity in distribution, proper clubbing and scheduling of hydrants is necessary. Generally in such case universal hydrant is provided. The universal hydrant can rotate in 360°. From this hydrant, small field channels shall be constructed by individual farmer upto their fields. Providing drains at the end of lateral is necessary. In the case of emergency, arrangements to empty the system as per requirement through drains are very much essential and shall be provided.

For continuity of uniform flow and for better operation, installation of the air relief valves, pressure relief valves, thrust blocks and check valves shall be provided as per hydraulic requirement of the system. Vent stands are used to relieve pressure, release air and prevent vacuum. Vents shall be provided at following locations.

- i) At the downstream end of each lateral
- ii) At the points where there are changes in grade of (more than ten degrees) in downward direction of flow
- iii) At the summits in the pipeline.

A float valve shall be provided in the initial reach of each lateral. There shall be drain valve at lowest levels on bends in elevation for main pipeline. These shall be anchor block/thrust block of PCC with nominal reinforcement of every bend in plan of main pipe/lateral to take care of thrust etc.

(C) Hydraulic design of piped distribution system:

Hydraulic design of piped distribution system consists of following,

- i) Design discharge and velocity for the piped distribution system
- ii) Design pressure
- iii) Design Diameter, and

i) Design discharge and Velocity:

i) Design Discharge;

The discharge of the FC is 30 lps in conventional OFD works. However considering small land holdings, the chak size will have to be restricted to minimize the number of beneficiaries as well as safe handling of discharge. It is, therefore, better to provide outlets of 15 to 20 lps capacity. The permissible chak size, therefore, shall be worked out considering this discharge. Generally the permissible chak size in hilly areas having small land holdings may be between 10 to 15 20 ha of CCA.

ii) Design Velocity:

The pipeline system is liable to clogging / choking due to the sedimentation. Hence, minimum permissible velocity should be fixed to safeguard against silting. A separate water desilting box or a sand trap is necessary when incoming stream carries appreciable amounts of silt. Generally, this is provided on mainline as an inlet structure.

The velocity in a pipeline when operating at system capacity, should not exceed the permissible velocity recommended by the pipe manufacturer.

The velocity in the pipe can be calculated using the modified Hazen Williams formula, which is derived from Daray-Weisbach and Colebrook-White equations. The modified Hagen Williams formula is derived as,

$$V = 143.534 C_R * r^{0.6575} * S^{0.5525} \text{ (meters/sec)}$$

Where,

V = velocity of flow in M/sec.

C_R = Pipe roughness coefficient = 1 for PVC Pipes

r = hydraulic mean radius

S = friction slope

Generally, minimum velocity shall be 0.6 m/sec.

II) Design Pressure:

In the pipe system, internal pressure is developed in the pipe due to hydraulic head. The design pressure. In the main line are in the range from 5 m to 25m. Therefore, in general, PVC Class 2.5 pipes can be used conveniently. However, in hilly terrain, if operating pressures are in excess of 2.5 Kg/cm² are not unusual.

(Pressure in Kg/ cm² = Hydraulic Head in M/10)

In such cases, use of PVC Class 4 pipes shall be used or R.C.C. P2 Class pipes shall be used. The pressures in laterals are generally less than 1 Kg/cm², hence, PVC Riblock pipes or R.C.C. NP2 Class pipes shall be used. Pipelines using low head pipe, like PVC Riblock pipes, shall be designed such that the maximum static or working pressure of the system does not exceed the permissible pressure or head.

Air vents are also used at appropriate places in the pipe distribution network to relieve pressure, release air and prevent vacuum.

III) Design diameter:

The diameter of pipes shall be selected from the Nomographs tables, knowing the design discharge, friction losses, design velocity and design pressure. The Nomographs of pipes are supplied by the Manufacturer. Diameter of pipe is also related to effective head i.e. (Hydraulic gradient line – Ground level). The diameter of pipe is so decided that the effective head shall not be less than 0.6 m. In exceptional cases, the effective head to the extent of 0.3 m may be allowed. Friction losses in pipeline and losses due to bends, valves etc. shall be accounted for appropriately. To account for losses due to bends, Tees etc. equivalent length of 10.0 m of pipe is considered. The example for design of pipe diameter is given in Annexure 10.1.

For design period of 30 years, no reduction in capacity needs to be effected for asbestos cement pipes or PVC pipes irrespective of quality of water. However, care must be taken to ensure self cleansing velocity to prevent formation of slimes and consequent reduction in carrying capacity of these pipes with age. If CI pipes are used, the corrosion causes reduction in carrying capacity in addition to reduction due to deposition of sediments. Hence, a suitable allowance upto 15% may be considered to determine the diameter of pipe.

2.1.2.3 Construction of piped distribution system:

For the construction of piped distribution system, the level of accuracies and quality of construction shall be high and similar to open channel distribution in conventional OFD works. If no compromises are made on quality of pipe and appurtenant structures, quality of joints and connections and about laying the pipeline in proper grade and alignment, no pipeline shall leak and trouble shoot.

During the excavation and placement of pipeline, following guidelines shall be followed,

- a) Trenches should be reasonably straight and bottom of trench shall be free of undulations and humps. The width of the trench should be sufficient to permit laying of pipes correctly. There should be a minimum clearance of 150 mm on each side of pipe, for pipes upto 400 mm in diameter and clearance of 200 to 300 mm on each side for large pipes.
- b) The excavated material shall be deposited on one side of the trench with sufficient place to erect a tripod, if required for placement and the pipes to be placed in the trench shall be kept on other of the trench.

- c) In black-cotton soils the trenches shall be filled and comported with Murum to a depth of 40 cms to 50 cm below design bed gradient level.
- d) The seepage water, if any, occurring in the trench shall be drained away or controlled in a manner to prevent damages to pipe joints. When the pipes are laid, the trench shall be reasonably dry, firm and uniform in accordance with design bed gradient.
- e) Pipes shall be inspected before placement on site and lowered carefully without any damage. The interior of pipes shall be checked before lowering and kept free of any dirt, humps and lumps.
- f) Any pipe which is not in true alignment or which shows undue settlement due to self weight after laying or is damaged during placement, should be taken up and laid freshly.
- g) The pipeline shall be thoroughly and completely tested for pressure strength and leakages through joints before back filling the trenches. If it is necessary to partially backfill, the body of pipeline shall be covered but the joints and junctions shall be kept uncovered for inspection.

2.1.2.4 Operation and Maintenance of Piped Distribution Systems:

In view of Government Policy on Farmers' Participation in Irrigation Management, the schemes shall be handed over to the Water Users' Association for operation and maintenance.

To facilitate easy operation and maintenance, following data / documents shall be handed over,

- i) Detailed drawings of chak water delivery system
- ii) Information about control structures
- iii) Operating schedules and instructions for trouble free operation of the system
- iv) Spare parts list
- v) Pipe and valve specifications.

Before handing over the pipeline distribution system to Water Users' Association, it is suggested that training to selected members of WUA shall be arranged for repairs and maintenance of distressed pipelines.

3.0 On-Farm Distribution System using half Round R.C.C. Pipes supported on pedestals:

The chak water delivery system can also be implemented using half round R.C.C. pipes as water carriers, installed on concrete pedestals. This can be an alternative to piped irrigation system in hilly terrain with less steeper slopes. It is evident that this being an open channel system, the necessity of air relief valves, pressure relief valves, and other structures required for safety of piped distribution system is eliminated. The trench excavations are also eliminated. Hence, this may be an economical alternative in lesser hilly terrain.

The chak water delivery system through R.C.C. half round pipe carrier system has been tried in Goa State on Tillari Interstate irrigation Project. Topography in Goa State for the Tillari Project is similar to most of the parts in Konkan region i.e. Lateritic soil which has high seepage rate, high rainfall zone and hilly terrain with mild to steep ground slopes. Hence, this non conventional method may be tried on pilot basis in some of the projects in Konkan region and then replicated elsewhere with modifications and improvements based on experience on pilot project.

The general guidelines for chak water delivery system using R.C.C. half round pipes on concrete pedestals are broadly elaborated as follows:

- a) The area to be served in a chak shall be about 10 ha to 15 ha of CCA if holdings are very small.
- b) Maximum length of field channel in a chak may not exceed 500 meters, as far as possible.
- c) Field channels are taken along the farm boundaries or gut numbers to avoid division of land because most of the farmers are marginal farmers with very small land holdings to the extent of 0.2 ha to 0.5 ha per family.
- d) If the land holdings are too small, to the extent of less than 0.5 ha., two to three land holdings shall be grouped under one turnout. One turnout should not serve area more than 1 ha to 1.5 ha.
- e) The bed gradient for field channels with half round pipes on pedestals shall be uniform from reach to reach and shall be such as to avoid high velocities at turnouts. It may be in the range of 1:10 to 1:700.
- f) The outlet discharge may be between 20 to 30 Lps. The coefficient of rugosity shall be 0.022.
- g) The diameter of half round pipes shall be from 300 mm to 450 mm. The free board shall be as far as possible upto 15 cms to 20 cms. In exceptional cases, the diameter of half round pipe may be 600 mm.
- h) The concrete pedestals shall have firm foundation so that they do not show unequal settlement during operation. In black cotton soils, special

foundation treatment similar to that for conventional OFD structures shall be provided. The pedestals shall be in good concrete with nominal reinforcement to take care of temperature and atmospheric stresses. The concrete used for pedestals may be 1:3:6 or 1:2:4 as per the structural requirement of typical pedestal.

- i) The length of single piece R.C.C. half round pipe may be 2.5 m. but not more than 3.0 m.

The chak water delivery system with R.C.C. half round pipes on pedestals as discussed above, may be advantageous in Vidarbha region also, where conventional field channel system fails to serve the purpose due to heavy rains. The field channels excavated in black cotton soil do not remain in good shape and gradient due to heavy rainfall. The farmers are not willing to spend frequently on maintenance of field channels. Hence, the micro distribution network gets disrupted. In such cases, the non-conventional method of chak water delivery system with R.C.C. half round pipes carried on concrete pedestals with appropriate foundation treatment may be a good solution.

4.0 Developing an interface in gravity irrigation network to adopt pressurized irrigation system:

There are certain pockets in the command area of irrigation project where efficient irrigation through conventional gravity system is not possible unless the lands are brought to permissible slopes for flow irrigation using land-forming techniques. But the land forming techniques in some of the locations is not feasible either because of economical reasons or due to limited soil cover or on account of heavy earth movement causing detrimental effect on productivity of land. In such cases, pressure irrigation systems like drip irrigation, sprinkler irrigation may prove to be best solution. To make this solution feasible on gravity flow system an interface is required to be developed to adopt pressurized irrigation system.

A farm pond can serve as interface. It shall be constructed to cater the irrigation requirements of an individual farmer or for a group of 4 to 5 farmers, which will serve as intake chamber. The capacity of the pond will depend on irrigation interval of canal system. The farm pond shall be got excavated from the concerned beneficiaries. Adequate evaporation allowance shall be taken into account for determining the capacity of farm pond. The farm pond can be made leakproof adequately by using LDPE sheets or geotextiles of sufficient thickness and strength.

The individual farmer shall draw his irrigation supplies from respective farm pond using pump on the farm pond and a pipeline upto his farm to operate drip or sprinkler irrigation system.

Since the on-farm water management is to be handed over to Water Users' Associations, such non-conventional on farm water management techniques may be promoted so as to educate WUA to utilize the allocated water economically using drip and sprinkler irrigation systems, availing Government subsidies, if any.

5.0 Conclusions:

- a) Irrigation Engineer should make every endeavor to supply irrigation water to each individual farmer through efficient and economical on farm development works, suitable to topographical, climatologically and agricultural conditions.
- b) The non-conventional on farm development works shall be successful only if these are planned, designed and constructed with farmers' participation at all levels. These works shall also be such that on minimal training, the beneficiaries in WUA can manage, operate and maintain them with confidence within economical costs.
- c) Hence, non-conventional methods of on-farm development works may be taken up only after formation of WUA and through active interaction with them since planning upto and including construction.

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Annexure – 10.1

Design of Pipe Diameter

Design a PVC pipe irrigation system for 20 Lps discharge serving the chak having land slope (from minor to lower delivery point) of 2%. The full supply depth in the minor is 0.5 m above the ground at outlet location. (Refer Figure-10.1).

Length of each line and No. of turnouts is as below:

Line	Length	Number of Turnouts
ABGH	1000 m	8
ABCD	800 m	6
ABCEF	700 m	5

Solution:

Land slope i.e. 2% is used to find out the level difference between starting point A and other end points (Actually the actual level difference should be considered while design).

Fall available:

ABGH	20 m
ABCD	16 m
ABCEF	14 m

Total available head = available head at inlet + fall in line.

Line	Total available head (m)
ABGH	$0.5 + 20 = 20.5$ m
ABCD	$0.5 + 16 = 16.5$ m
ABCEF	$0.5 + 14 = 14.5$ m

To get the required flow from the minor total loss of head must be less than the total available head.

Total loss of head = Friction loss in line + Loss at structures.

Loss at structures can be assumed as:

– Inlet	0.02 m	$(0.5 V^2/2g)$
– Gate valve	0.01 m	$(0.2 V^2/2g)$
– Bends (2 to 3)	0.02 m	$(0.15 V^2/2g)$
– Tee (off takes) (8 x 0.01)	0.08 m	

–	Misc.	0.04 m

		0.17
	Say	0.2 m

(Source: irrigation from supply canals via buried pipe distribution system, FAO, January 1985. Head losses at structures are generally small as compared to friction loss in pipeline. In most cases a blanket allowance of say 7 to 10% of friction loss in pipeline may be taken as friction loss at structures).

Therefore friction loss allowable in each pipe line will be (Total loss – loss at Structures)

Line	Max. Allowable friction loss (m)
ABGH	20.3
ABCD	16.3
ABCEF	14.3

∴ Maximum allowable friction loss for 100 m length will be;

Line	Friction allowable loss (m/100 m)
ABGH	2.3 m
ABCD	2.4 m
ABCEF	2.04

Now from the friction loss nowographs / tables final out the dia. of pipe for 20 Lps discharge. The tables show that 12.5 or 15 cm diameter pipe are suitable. Therefore select 15 cm diameter pipe.

Check:

Assume that first Turnout is at 100 m distance. Whether it will get 20 lps discharge through pipe of 15 cm dia. or not?

Friction loss for 15 cm dia = 0.69 m / 100 m (from manufacturer's table)

Total loss = 0.69 + 0.02 + 0.01
= 0.72 m

Total head available for 100 m length
2 + 0.5 = 2.5 m

Total available head at the distance of 100 m i.e. 2.5 m is more than total loss of 0.72 m. Therefore 20 Lps can be passed through the turnout at this location.

CHAPTER 11

Record of On Farm Development Works

OFD works (Part-I) including selective lining of field channels are to be executed at Govt (Project) cost, but are to be handed over to the beneficiaries for further / permanent operation and maintenance. Recent Govt. Policy is of handing over of entire irrigation management including operation and maintenance to minor level Water Users' Associations (WUA). OFD works (Part-I) are to be handed over to such WUA. It is expected that such WUAs are involved right from the planning stage in execution of OFD works (Part-I).

O.F.D. works (Part-II) (Land forming) are to be executed by Govt. (Command Area Development Divisions) on behalf of the individual farmer at his own cost by obtaining his written consent and by following the provisions of BLIS Act 1942.

Before taking up execution of OFD works, detailed planning, general report and estimates must be completed. Record of execution of OFD works in the form of completion report is also to be prepared. After completion of works all these records will be handed over by the Command Area Development Division to the Irrigation Management Division for permanent record, with a copy provided to WUA concerned,

Details of record / documents to be prepared are given below.

A) GENERAL REPORT OF DESIGN AND ESTIMATES

1. After completion of the design, detailed plans and estimates will be prepared to include the following:

- (a) Design Report
- (b) Detailed Plans
- (c) Detailed Estimates including measurements, quantities, and abstracts.

The Plans and estimates will be in three parts :

- (i) Part-I Chak water delivery system and surface drains
(including water courses and link drains)
- (ii) Part-II Land shaping
- (iii) Part-III Lining

2. Part I Works

2.1 Design report for Part I works will cover the general procedure adopted for design, including the following:

- (i) Name of distributory / minor
- (iv) Data of roads, wells, major trees, orchards, etc.
- (iii) Determination of chak layout
 - a) Area
 - b) Field Channel length
 - c) Number of farmers
 - d) Natural drainage lines
 - e) Other limitations like village boundaries, roads, etc.
- (iv) Whether final locations of outlets differed from tentative locations and if so to what extent; whether these were agreed to by Construction Organisation; whether there was a joint inspection with Construction Organisation as well as with WUA members.
- (v) Finalisation of Field Channel Alignment
- (vi) Finalisation of L-Section of field channel

a Hydraulic details of field channel

Sr. No	FC Reach Ch to Ch	Length m	Soil type	Natural Ground slope	Design Bed gradient	Slide slope m.	Bed width m.	Velocity m/sec	Water depth m	Remarks
1	2	3	4	5	6	7	8	9	10	11

b Details of structures on F.C. and branches

Sr. No	Type of structure	Sill level of structure m	Bed level of F.C. m	Water Depth m	Remarks
1	2	3	4	5	6

- (vii) Surface drains—procedure adopted for design. Whether outfall is available. Conditions of main drain.

2.2 Detailed plans will include the following:

- (i) Map (1:8000) or (1:10000) showing tentative locations of outlets, as received from the Construction Organisation.
- (ii) Map (1:2000) or (1:2500) of distributory / minor / chak system,

contour interval of 0.3 m. showing the final locations of outlets, alignment of field channels, and boundaries of chaks; signed by Executive Engineer

- (iii) Map (1 : 1000) or (1 : 1250) of chak, contour interval of 0.2 m. to 0.3 m. showing final alignment of the field channels, locations of structures, proposed bed levels and water levels in the field channels at different points, bed level and water level in the minor at the outlet, and sill level and water level in the outlet, locations and sizes of drops, measuring device, division boxes, turnouts, crossings ; alignment of field drains and link drains locations and sizes of rapids; and location of outfalls; signed by Executive Engineer
- (iv) Longitudinal Section of the field channel showing design bed levels in the field channels, water levels, and top of bank levels; levels written separately at outlet, all structures and near property boundaries; locations of selective lining and reaches there of; cross sections adopted in different reaches and gradients; signed by Executive Engineer
- (v) Plans of different structures as adopted; if no changes are made from type plans, the plans may be signed by Deputy Engineer; if there are changes, then they should be signed by Executive Engineer

2.3 Estimate will contain the following:

- (i) Detailed measurements .
- (ii) Rates adopted & rate analysis, including lead chart of various construction materials.
- (iii) Abstracts for different sub-estimates;
- (iv) Overall abstract, signed by the Executive Engineer

3. Part II works

3.1 General Report will cover the general procedure adopted for design, including the following :

- (i) Name of distributory / minor, chak, holding;
- (ii) Planned method of irrigation; crops to be grown.
- (iii) How the detailed survey was carried out; grid size and justification thereof;
- (iv) Initial marking of compartments and the basis thereof, whether farmer agrees to the same
- (v) How the final marking of compartments was done; how the

widths were arrived at;

- (vi) Method adopted for the design (Centroid Method), and cut/fill ratios as adopted;
- (vii) Whether the farmer agrees to the final plan & written consent of the farmer / owner to bear the cost of execution along with the interest and other charges.

3.2 Detailed plans will include the following:

- (i) Map (1 : 1000 or 1250) of chak referred to in Part I
- (ii) Map (1 : 500 or 625) of holding showing location of turnout and planned water level at turnout; demarcation of shallow soils, medium soils and deep soils; levels at grid points; proposed compartments; small bunds with outlets and large bunds with outlets; signed by Deputy Engineer
- (iii) Map of each compartment (1:250 or 325) showing grid levels, centroid, average level of the compartment, formation levels, cuts and fills, signed by Deputy Engineer

3.3 Estimate will include the following :

- (i) Detailed calculations of cuts and fills;
- (ii) Measurements;
- (iii) Rates adopted rate analysis, including lead chart of various construction materials.
- (iv) Abstracts for different compartments;
- (v) Overall abstract:, signed by the Deputy Engineer.

4. Lining

4.1 Design report will cover the following :

- (i) Extent and location of selective lining, reachwise, proposed and the justification thereof.
- (ii) Type / type of lining adopted and the reasoning therefor.
- (iii) Hydraulic Design
- (iv) Details of selective lining on F.C. and branches:

Sr. No	F.C. Chainage m.	Length of lining m	Type of lining	Water depth (m)	Velocity (m/sec)	Reasons for selection of type of lining	Remarks
--------	------------------	--------------------	----------------	-----------------	------------------	---	---------

1	2	3	4	5	6	7	8

4.2 Plans will include the following:

- (i) Map of chak (1: 1000 or 1 : 1250) referred to in Part I showing, in addition, the extent and location of lining.
- (ii) Type sections of different linings proposed to be adopted.

4.3 Estimate will include the following:

- (i) Measurement
- (ii) Rates adopted and Rate analysis, including lead chart of various construction materials.
- (iii) Abstract of estimate; It will be signed by Executive Engineer.

(B) RECORD / DOCUMENTS FOR HANDING OVER.

OFD works Part I are to be handed over to WUA.

After completion of construction of OFD works, concerned section officer (SO) and Civil Engg Assistant of Command Area Development Division along with their counter parts in Irrigation Management Division and also office bearers of outlet committee / WUA, should carry out a joint inspection of all OFD works executed in the chak; a demonstration showing that water reaches to all parts of field channels should be arranged for satisfaction of WUA regarding proper execution of OFD works.

Actual handing over of OFD works should be within a month after joint inspection. A handing over note containing detailed information and necessary chak map should be prepared and should include a certificate of handing over which Sub-divisional Officer (DEPUTY ENGINEER), sectional officer & Civil Engineering Asstt of both Command Area Development Division and Irrigation Management Division and also office bearers of WUA One copy of the record should be sent to Revenue Department for taking necessary entries of executed Part-I works in 7/12 records of concern land holders.

A model 'Chak Handing Over Proformae' has been developed by D.I.R.D. Pune and has been included in this chapter for adoption by field officers with necessary modifications, as Annexure 11.1.

Proformae for Handing Over of O.F.D. Works

List of Offices involved in Handing over

Chak (outlet) No.----- Minor/ Distributory No. -----Canal-----
----- Project-----

(A) **Handing over Offices**
(Command Area Development)

	Office	Section	Name of Officer
i)	_____	_____	_____
ii)	_____	Sub-Division	_____
iii)	_____	Division	_____

(B) **Taking Over Office**
(Irrigation Management)

	Office	Section	Name of Officer
i)	_____	_____	_____
ii)	_____	Sub-Division	_____
iii)	_____	Division	_____

(C) Date of Joint Inspection _____

(D) Date of Final Handing over _____

CAD Wing

(Signature)

Name _____

Section Officer

_____ Section

Irrigation Management Wing

(Signature)

Name _____

Section Officer

_____ Section

CERTIFICATE

Handing over the chak

Outlet No.----- Dy / Minor No.-----of-----Canal
of-----project

The chak has an irrigable area of -----ha. The alignment of the field channel and branches as shown on the chak map is satisfactory. Water can be supplied to -----
- ha area of the chak with these channels.

This chak No.----- along with all OFD works has been handed over today
(Date-----) to the ----- Water Users' Association
for further operation and maintenance. The repairs will be carried by the (Name-----
-----) Water Users' Association.

CAD Wing

Irrigaion Management Wing

Signature

Signature

Signature

Sectional Officer (Irrigation)

Sectional Officer (Construction)

Chairman

-- ----- Section

----- Section

----- WUA

----- Sub-division

----- Sub-division

----- village

Salient Features

- 1 Name of Project _____
 - 2 Distributory / Minor No. _____
 - 3 Chainage _____
 4. Outlet No. & Side (Left / Right) _____
 - 5 Sill level of Outlet _____
 - 6 Total C.C.A. (ha.) _____
 - 7 Total developed area (Part-II) _____
 - 8 Total No.of beneficiaries (as per proforma) _____
 - 9 Details of OFD works _____
- (i) Field channel and branches _____

Sr.No.	Reach	Ch. to Ch.	Length (m.)

- (ii) Field drains

Sr. No.	Reach	Ch. to Ch.	Length (m.)

- (iii) Density of field channel in the chak

$$= \frac{\text{Total FC length}}{\text{CCA}} = \text{_____ (m/ha)}$$

- (iv) Density of field drains in the chak

$$= \frac{\text{Total Field Drain Length}}{\text{CCA}} = \text{_____ (m/ha)}$$

- (v) Details of structures :

	Structure	Total No	Ch.	Size	Type	Remarks
(a)	Drops / Falls on F.C.		1 2 . .			
(b)	Division Boxes		1 2 . .			

(c)	Turnouts		1. 2. . .			
(d)	Road Crossings		1. 2. . .			
(e)	Measuring Device	1				

(vi) Field channel Lining :

	Reach	Ch. to Ch.	Length	Type
(a)				
(b)				
(c)				

10. Land Slope in Chak.

Sr. No.	Slope group	Area (ha)
1	0 to 0.6 %	
2	0.6 to 1 %	
3	1 to 2 %	
4	2 to 3 %	
5	3 to 4 %	
6	Above 4 %	
	Total Area	

11 Details of Part-II Works executed (if any)

Sr. No.	S.No./ Gut No.	Total Area (ha)	Improved Area (ha)	No.of Compartments	Final grade / slope provided		Remarks
					Long.	Cross.	
1	2	3	4	5	6	7	8

12 Total expenditure of

(a) Part-I Works .. Rs. _____
(Including Lining)

- | | | | |
|-----|---------------------------|----|-----------|
| | (b) Selective Lining only | .. | Rs. _____ |
| | (c) Part-II works | .. | Rs. _____ |
| 13. | Per Ha. expenditure of | | |
| | (a) Part-I Works | .. | Rs. _____ |
| | (b) Selective Lining only | .. | Rs. _____ |
| | (c) Part-II works | .. | Rs. _____ |

CAD Wing

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

Irrigation Management Wing

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

List of Documents Handed over

		Supplied		Page No
1	Uptodate Map of chak No._____	Yes	No	
2	List of beneficiaries (Proforma-I)	Yes	No	
3	List of Members and office bearers of WUA (Proforma-III)	Yes	No	
4	True copies of Notifications issued under clause No.5-1 and 9-2 of BLIS Act 1942	Yes	No	
5	True copy of the letter sent to Revenue Department giving intimation about OFD works executed and for taking entries in 7/12 records of concerned land / holders.	Yes	No	
6	List of Page Nos. (concerned with OFD works) of relevant Field Book and Measurement Books (Proforma-(III) & (IV))	Yes	No	
7	Map of Minor / Distributory			

CAD Wing

Irrigation Management Wing

(Signature)

Section Officer

_____Section

_____Sub-Division

Date :

(Signature)

Section Officer

_____Section

_____Sub-Division

Date :

Points verified during Handing over

1	All relevant Documents / Maps have been attested before handing over	Yes	No	
2	Field channels / Field drains / Structures as shown on the chak Map actually match with field condition as per joint inspection (State variations if any)	Yes	No	
3	All the irrigable area and holdings in the chak can be fully irrigated with the planned and executed OFD works (State variations if any)	Yes	No	
4	Revenue Department has been intimated about execution of OFD works	Yes	No	
5	First Irrigation season and year _____	Yes	No	
6	Recovery statements for Part II works have been prepared and submitted to MLDC Pune.	Yes	No	

CAD Wing

Irrigation Management Wing

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date

:

CERTIFICATE
of
Handing over and Taking over

Certified that Chak No.-----on-----Minor-----
Distributory of----- Canal] -----Project has been
handed over / taken over physically alongwith all OFD works executed as shown in the
chak Map and salient features, today (on Date -----). All documents,
records, maps have been handed over / taken over and there are no complaints / short
falls about them. A joint inspectioin of chak and OFD works has been done alongwith
office bearers of the----- WUA of this project on Date-----
and they are satisified that water reaches to all Parts of the chak as per planning of OFD
works and also that all OFD works are in sound condition.

CAD Wing

Irrigation Management Wing

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

(Signature)

Chairman _____ WUA

Date :

(Signature)

Secretary _____ WUA

Date :

(Proforma-I)

List of Beneficiaries

Chak No _____ Project _____

Minor / Distributory No _____ Canal _____

Village _____ Taluka _____ District. _____

Sr. No.	Full Name	Gat / Survey No	Total Area as per 7/12 (ha)	CCA (ha)	Improved /Irrigable Area (ha)	Remarks
1	2	3	4	5	6	7

CAD Wing

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

Irrigation Management Wing

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

(Proforma-II)

List of Office bearers and members of WUA

_____ WUA

1 Chak / Outlet No. .. _____

2. Distributary / Minor No. .. _____

3 Canal .. _____

4 Project .. _____

5 Date of formation of WUA .. _____

6 Date of Registration of WUA .. _____

7 Name of Chairman .. _____

8 Name of Secretary .. _____

9 List of All members . .. _____

Sr. No.	Full Name	Post	Whether belongs to SC/ST/OBC	Whether small / marginal land holder	Whether in head reach	Whether in tail reach	Gat / S.No	Area (ha)	Remarks
1	2	3	4	5	6	7	8	9	10

CAD wing

(Signature)
Section Officer

_____ Section
_____ Sub-Division

Date :

(Signature)

Chairman _____ WUA

Date :

Irrigation Management Wing

(Signature)
Section Officer

_____ Section
_____ Sub-Division

Date :

(Signature)

Secretary _____ WUA

Date

:

(Proforma-III)

List of Field Books

Chak No _____ Canal

Distributory/Minor No _____ Project

Sr. No.	Field Book No	Year	Pages used		Remarks
			From	To	
1	2	3	4	5	6

CAD wing

Irrigation Management Wing

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

(Signature)

Section Officer

_____ Section

_____ Sub-Division

Date :

(Proforma IV)

List of Measurement Books

Chak No _____ Canal

Distributory/Minor No _____
Project _____

Sr. No.	Measurement Book No	Year	Pages used		Remarks
			From	To	
1	2	3	4	5	6

CAD wing
Wing

Irrigation Management

(Signature)
Section Officer
_____ Section
_____ Sub-Division

(Signature)
Section Officer
_____ Section
_____ Sub-Division

Date :

Date :