# Table of contents

# 1. CROP WATER REQUIREMENT:

Various steps for planning the irrigation system for an area

1. Area identification, GCA, CCA, NCCA.
2. Alignment of canals, distributaries and water-course
3. Deciding the cropping pattern.
4. Important definitions
5. Estimation of crop water requirements.

## 1.1. AREA IDENTIFICATION:

### 1.1.1. Gross Command Area (GCA)

It is the area which is bounded within irrigation boundary of a project, which can be economically irrigated without considering the limitation of the quantity of irrigation water. It also includes the area which cannot be cultivated e.g. villages, roads, utility etc.

It is total area used for design consideration. This may be cultivated or non-cultivated area depending upon the condition and topography.

### 1.1.2. Culturable Command Area (CCA)

It is the effective area which is culturable or the area that is cultivated out of total command area.

### 1.1.3. Non Culturable Command Area (NCCA)

It is the area which is not cultivated.

**CCA=GCA-Non Culturable Command Area**

### 1.1.4. Chak Bandi

It is to divide the whole CCA into command area of each outlet.

## 1.2. ALIGNMENT OF IRRIGATION CHANNELS:

The alignment of irrigation channels can be divided into two parts, namely

**(a)** Alignment of canals and distributory.

**(b)** Alignment of water course.

### 1.2.1. Alignment of canals and distributory

**i)** The canals and distributaries should be aligned in such a manner that the entire tract (land) should be irrigated by flow-irrigation. In order to achieve this objective and also to cut down cost in construction channels should be aligned along ridges. If this fact is overlooked the channel will run through filling which will not only entitle higher cost but will also jeopardize the area with water logging.

**ii)** Unless otherwise specified by higher authority, the contour plan with scale 2" to a mile and having contour at 5' interval should be used for studying the alignment of canals and distributory. The contour plan should be studied thoroughly and different proposals should be marked on plan and their merits and demerits should be weighted. The most economical and practical should be adopted.

**iii).** Care should, however be taken that the irrigation channel do not cross the drainage system of the area.

**iv).** Obstacles, such as roads, towns, railway lines, canals etc should be avoided.

**v).** An irrigation channel should not as far as possible cut an area which is irrigated by wells.

**vi).** The main as well as branch canals are carrier canals, and so no direct irrigation should be done from them.

**vii).** The main channel should be split into moderate sized branch canals and the splitting point should be so located that maximum area is irrigated economically.

**viii).** The distributaries should be so aligned that length of a water course taking off from it should in no case exceed **two miles**.

**ix).** Effort should be made to keep the channel straight. When it is not possible, the minimum radii of curves should be kept as follows;

| **Capacity of Channel (Cusecs)** | **Minimum Radii of curves (feet)** |
|---|---|
| Over-3000 | 5000 |
| 3000-1000 | 3000 |
| 1000-500 | 2000 |
| 500-100 | 1000 |
| 100-10 | 500 |
| Less than 10 | 300 |

**x).** As maintenance cost of a distributory is inversely proportional to its discharge, large sized distributaries are better than small ones.

### 1.2.2. Alignment of water course

**i).** The alignment of a water course unless otherwise directed by the higher authorities, should be studied on a plans having a scale of 8" to a mile and showing spot levels at every corner of 500 ft.

**ii).** A water course should be minimum in length.

**iii)**. As far as possible a water course should be aligned within one square. i.e 25 acres **(990x1100), 1 hectare = 2.47 acres iv).** In order to reduce absorption losses, a water

course should irrigate on its both sides.

**v).** Ordinarily only one **nakka** is sanctioned for each watercourse. But where the configuration of ground does not admit of one nakka, a second may be provided.

## 1.3. DECIDING THE CROPPING PATTERN

### 1.3.1. Cropping pattern

It means how many crops and how much area for a crop is being cultivated.

### 1.3.2. Cropping Intensity/cultivation intensity

It is the %age of area of a particular crop with respect CCA.

### 1.3.3. Factors Effecting Cropping Pattern:

- Climate
- Soil Characteristics
- Hydrology
- Water Allowance
- Crop Water Requirements
- Intensity of Cropping and Irrigation
- Farmer's Requirements for Food, Fodder Clothes Etc.

## 1.4. IMPORTANT DEFINITIONS

### 1.4.1. Crop Water Requirement:

It is the total amount of water required by the crop in a given period of time for normal growth, under field conditions. It includes evaporation and other unavoidable losses. It is normally expressed in terms of depth of water and associated with the area of crop.

***Crop water requirement = Consumptive use + Seepage Losses in the field + Others (water need for land preparation)***

### 1.4.2. Consumptive Use:

It is the amount of water required by a crop for its vegetated growth to evapotranspiration and building of plant tissues plus evaporation from soils and intercepted precipitation. It is expressed in terms of depth of water.

Consumptive use varies with temperature, humidity, wind speed, topography, sunlight hours, method of irrigation, moisture availability.

### 1.4.3. Estimation of Consumptive Use:

1. Direct method
2. Pan evaporation method
3. Empirical method

### 1.4.4. Factors influencing crop water requirements

**i.** Effect of Major Climatic Factors on Crop Water Needs

| Climatic factor | Crop water need | |
|---|---|---|
| | **High** | **Low** |
| Sunshine | Sunny (no clouds) | cloudy (no sun) |
| Temperature | hot | cool |
| Humidity | low (dry) | high (humid) |
| Wind speed | windy | little wind |

**ii.** Influence of crop type on crop water needs

The influence of the crop type on the crop water need is important in two ways.

1. The crop type has an influence on the daily water needs of a fully grown crop; i.e. the peak daily water needs of a fully developed maize crop will need more water per day than a fully developed crop of onions.
2. The crop type has an influence on the duration of the total growing season of the crop. There are short duration crops, e.g. peas, with a duration of the total growing season of 90-100 days and longer duration crops, e.g. melons, with a duration of the total growing season of 120160 days. There are, of course, also perennial crops that are in the field for many years, such as fruit trees.

### 1.4.5. Conveyance Losses:

Take place from barrage to the field (outlet). So design should be according to requirement of water plus losses.

Major loss of water in an irrigation channel is due to absorption, seepage or percolation and evaporation. In earthen channels losses due to seepage are much more than the losses due to evaporation. The absorption losses depend upon following:

- Type of soil
- Subsoil water
- Age of canal
- Position of FSL w.r.t to NSL

- Amount of Silt carried by canal
- Wetted perimeter

### 1.4.6. Crop Period:

It is the time normally in days that a crop takes from the instance of its sowing to harvesting.

### 1.4.7. Base Period:

is the time in days between the first watering and last watering to the crops before harvesting.

**Note:** Base Period is normally less than the crop period depending upon the type of crop.

### 1.4.8. Delta of a crop:

Total depth of water required by the crop in unit area during base period. In other words it is the total depth of water required for maturing the crop.

***Volume = Depth x Area.***

Now to get the total amount of water for crops (i.e water for Kharif and Rabi crops) add water for each crop individually as

***Q=Volume/Time***

### 1.4.9. Rabi Season (October to March):

| **Crop** | **Consumptive Use (cm)** |
|---|---|
| Wheat | 37 |
| Gram | 30 |
| Barley | 30 |
| Potato | 60-90 |
| Sugar cane | 90 |
| Fodder | 40 |
| Oil seed | 45 |
| Berseen | 70 |

### 1.4.10. Kharif Season (April to September):

| **Crop** | **Consumptive Use (cm)** |
|---|---|
| Cotton | 25-40 |
| Maize | 45 |
| Rice | 125-150 |
| Sugar Cane | 90 |

### 1.4.11. Indicative Values of the Total Growing Period

| Crop | Total growing period (days) | Crop | Total growing period (days) |
|---|---|---|---|
| Barley/Oats/ Wheat | 120-150 | Millet | 105-140 |
| Bean, green | 75-90 | Onion, green | 70-95 |
| Citrus | 240-365 | Pepper | 120-210 |
| Cotton | 180-195 | Rice | 90-150 |
| Grain/small | 150-165 | Sorghum | 120-130 |
| Lentil | 150-170 | Soybean | 135-150 |
| Maize, sweet | 80-110 | Squash | 95-120 |
| grain | 125-180 | Sunflower | 125-130 |

### 1.4.12. Duty of a Crop:

It is the area irrigated in hectors by one cumecs or area irrigated in acres by one cusecs.

### 1.4.13. Full Supply Factor:

From the statistical records for different projects in operation, duty is determined. The Base periods are Rabi (Winter Crop) and Kharif (Summer Crop). By comparing the tract (land) to be irrigated with those already under irrigation and by studying other relevant factors which affect the duty, a fair guess of it for new project is made. The term duty is only used for existing or running projects, but in a proposed project it is known as full supply factor.

### 1.4.14. Intensity of Irrigation:

It percentage of culturable area irrigated during a base period or annually.

### 1.4.15. Water Allowance:

This is the amount or discharge in cusec required to irrigate 1000 Acres of an area.

$$\textit{Water Allowance} = \Sigma Q x 1000 / CCA$$

### 1.4.16. Discharge Statement:

This gives the information of discharge at every point/section of the canal.

**1.4.17. Water Conveyance Efficiency:**
It is the ratio of the water delivered to the farmer by conveyance system to the water introduced into the canal at source.

**1.4.18. Potential Evapotranspiration ( $ET_o$)**
The highest rate of evapotranspiration (ET) by a short and actively growing crop or vegetation with abundant foliage(leafage) completely shading the ground surface and abundant soil water supply under a given climate.

**1.4.19. Reference Crop:**
An idealized grass crop with crop height of 0.12 m, albedo (reflected/incoming solar radiations on earth) of 0.23, and a surface resistance of 69 $sm^{-1}$.

**1.4.20. The 'bulk' surface resistance**
It describes the resistance of vapour flow through the transpiring crop and evaporating soil surface. Where the vegetation does not completely cover the soil, the resistance factor should indeed include the effects of the evaporation from the soil surface. If the crop is not transpiring at a potential rate, the resistance depends also on the water status of the vegetation

An extensive surface of short green grass cover of uniform height, actively growing, completely shading the ground and no water shortage resembles the reference crop.

**1.4.21. Actual crop Evapotranspiration ($ET_{crop}$):**
Rate of evapotranspiration by a particular crop in a given period under prevailing soil water and atmospheric conditions.

Usually calculated by multiplying the Crop Coefficient (Kc) for the period with $ET_{rc}$ : thus

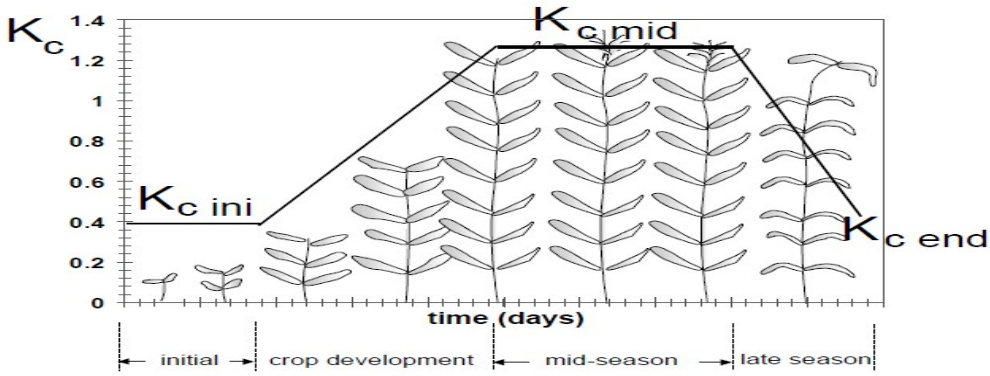
$$ET_{crop} = K.\ ET_{rc}$$

**1.4.22. Crop Coefficient (Kc):**
it is the ratio b/w the reference crop Evapotranspiration to the actual crop evapotranspiration.

Kc = ETo / ETc

It determined experimentally for various crops, Etc is determined by Lysimeter technique and ETo by USWB class A evaporation pan.

Kc is different for different crop and for different crop growth stages. Mainly affected by crop type, soil type and climate of the area.




*Rabi Discharge*= *Qr* = ΣVr / rabi period (days)   ($ft^3$/sec)

*Rabi Discharge*= *Qk* = ΣVk / kharif period (days)   ($ft^3$/sec)

***Design discharge* = larger of Qr ans Qk**

## 1.5. ESTIMATION OF CROP WATER REQUIREMENTS:

Gross Command Area = 521843.08 acres

Non Culturable Command Area = 178.51 acres

Culturable Command Area = 477732.29 acres

| Given Data | | | |
|---|---|---|---|
| **Months** | **Epan** | **Ep** | **20% effective Ep** |
| | **cm** | **cm** | **cm** |
| **January** | 1.5 | 2.5 | 0.5 |
| **February** | 1.8 | 3 | 0.6 |
| **March** | 4.5 | 4.4 | 0.88 |
| **April** | 17.1 | 2 | 0.4 |
| **May** | 24 | 2.5 | 0.5 |
| **June** | 22.5 | 4 | 0.8 |
| **July** | 19.5 | 20 | 4 |
| **August** | 11.1 | 16 | 3.2 |
| **September** | 12.3 | 6 | 1.2 |
| **October** | 7.5 | 1.5 | 0.3 |
| **November** | 7.2 | 0.8 | 0.16 |
| **December** | 4.2 | 1.2 | 0.24 |

| Required Discharge in Both Seasons | | | |
|---|---|---|---|
| **Season** | **Volume*** | **Time** | **Qr** |
| | **$ft^3$** | **Sec** | **ft3/s** |
| **Rabi Season** | 15406457616 | 15811200 | 974.40 |
| **Kharif Season** | 42280956432 | 15724800 | 2688.81 |
| *Acre -ft to ft3 conversion = 1 Acre ft = 43560 ft3 | | | |

| Description | Values | Units |
|---|---|---|
| Total Days in Rabi Season | 183 | Days |
| Total Days in Kharif Season | 182 | Days |
| Design Discharge | 2688.81 | Cusecs |
| Field losses (5%) | 134.44 | Cusecs |
| Total Discharge required | 2823.25 | Cusecs |
| Water Allowance* | 5.91 | Cusecs/1000Acres |
| Water course capacity, $Q_d$ | 3 | Cusecs |
| CCA of each Outlet** | 507.61 | Acre |
| Number of Outlets*** | 941 | |

$$* \ Water\ Allowance = \frac{Q_D \times 1000}{CCA}$$

$$** \ CCA\ of\ outlet = \frac{Q_d \times 1000}{WA}$$

$$*** \ No.\ of\ outlets = \frac{Total\ CCA}{CCA\ of\ each\ outlet}$$

### 1.5.1. No. of outlets:

Total area to be irrigated by minor canal having length of water course = 2 km on one side = 11576.87 acres

As,

5.91 cusecs is required for 1000 acres

5.91/1000 cusecs is required for 1 acre

5.91*11576.87/1000 cusecs will be required for 11576.87 acres

Hence, for **11576.87 acres, 68.42 cusecs** discharge will be required.

As,

3 cusecs discharge is served by 1 outlet

1 cusec discharge will be served by 1/3 outet

68.42 cusecs discharge will be served by 1*68.42/3 outlets

Hence, for **68.42 cusecs discharge, 23 outlets** are required on one side.

# 2. CAPACITY STATEMENT:

## 2.1. DIVIDE THE WHOLE AREA INTO OUTLET COMMAND AREAS, LOCATION OF EACH OUTLET IN THE SCHEME. SHOW ALIGNMENT OF CANALS AND WATER COURSES.

According to the CCA of each outlet, divide the whole irrigation scheme into no. of blocks (small areas) and the show the proposed alignment of canals and watercourses on the contour map of the area keeping in mind the following points:

- The area commanded by each outlet should be irrigated under gravity flow.
- The length of water courses should not be more than 3Km or 2 miles.
- Minimum idle length of canals in the system.

Based on these conditions, the area allocated for each outlet may be altered and hence the no. of outlet calculated at the start will be different from what are being actually provided in the distribution scheme.

## 2.2. DESIGN DISCHARGE FOR OUTLETS

Discharge of each outlet is calculated based on its actual area served plus the conveyance losses in the water course (take 10-15%).

**Conveyance Losses:** Take place from barrage to the field. So design should be according to requirement of water plus losses.

Major loss of water in an irrigation channel is due to:

**Seepage** (absorption or percolation), mainly absorption losses, vary from 2-50% of canal diversions

**Evaporation**, vary from 2-3%

In earthen channels losses due to seepage are much more than the losses due to evaporation. The absorption losses depend upon following:

- Type of soil
- Subsoil water
- Age of canal
- Position of FSL w.r.t to NSL
- Amount of Silt carried by canal
- Wetted perimeter

According to **irrigation branch of West Pakistan**:

$$K = 5.0Q^{0.625}$$

K= absorption loss per million square feet of wetted perimeter

Q= Discharge in channel.

**According to lacey:**

$$Q_A = 0.0133\ L\ Q^{0.5625}$$

QA= Absorption loss

L= Length of channel in thousand feet

Q= discharge in channel

## 2.3. MEASUREMENT OF SEEPAGE LOSSES:

***Direct Methods***

- ***Ponded Test method***
- *Canal is made full*
- *Inflow and outflow is stopped*
- *Losses measure through change in level at regular interval (e.g. daily)  Have to close the canal, and not recommended for Main Canals*

- ***Inflow outflow method***

- *Water budgeting is done*
- *Flows are measured at upstream, downstream end and diversions*
- *Seepage = Inflows – Outflows*
- *Relatively Quick, Simple, but depends on accuracy of discharge measurement (Notch Coefficent? Current Meter?)*

***Indirect Methods***

- ***Steady state method***

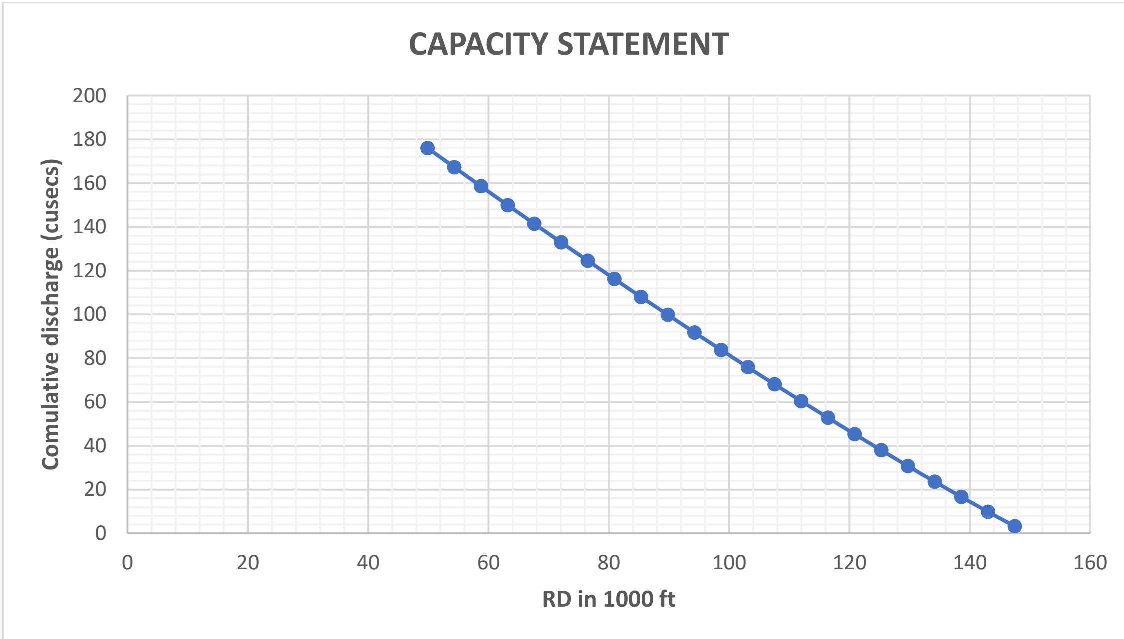
- *Knowledge of soil permeability and water table level is required*
- *Flow net is drawn based on water table around canal*
- *Seepage losses are calculated, using Darcy Forumlae*
- *$Q = K\ i\ A$*

- *Q=Seepage flow*
- *K= Permiability*
- *i = Head Loss Gradient =* $H_L/L$
- *A = Area of flow*
- *Q/A= discharge velocity (not actual velocity, that depends on capillary* ***area)***

- ***Canal closure method***

- *Water table levels are measured before, during and after canal closure*
- *flow net is drawn using the observed water tables and observed water levels in canal.*
- *seepage at various canal supply is calculated*

| CAPACITY STATEMENT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Water allowance= | | | 5.91 | Cusecs | | | | | Length of each water course= | 2 Km | 6561.67ft |
| Water course capacity = | | | 3 | Cusecs | | | | | | | |
| Land irrigated by 3 cusecs= | | | 507.61 | acres | | | | | | | |
| Sr No. | RD | | | OutLet Number | Length of outlet | Culturable Command Area | Outlet discharge | Cumulative discharge | Reach Loss=0.0133LQ^0.5625 | Total Discharge | Cummulative Discharge |
| | ft | | in 1000 ft | | 1000 ft | Acre | Cusecs | Cusecs | Cusecs | Cusecs | Cusecs |
| 1 | 49901.575 | 499+01 | 49.90 | $L_1$ | 6.5617 | 507.61 | 3 | 135 | 1.378 | 4.378 | 175.930 |
| 2 | 49901.575 | 499+01 | 49.90 | $R_1$ | 6.5617 | 507.61 | 3 | 135 | 1.378 | 4.378 | 175.930 |
| 3 | 54337.275 | 543+37 | 54.34 | $L_2$ | 6.5617 | 507.61 | 3 | 129 | 1.343 | 4.343 | 167.175 |
| 4 | 54337.275 | 543+37 | 54.34 | $R_2$ | 6.5617 | 507.61 | 3 | 129 | 1.343 | 4.343 | 167.175 |
| 5 | 58772.975 | 587+72 | 58.77 | $L_3$ | 6.5617 | 507.61 | 3 | 123 | 1.307 | 4.307 | 158.489 |
| 6 | 58772.975 | 587+72 | 58.77 | $R_3$ | 6.5617 | 507.61 | 3 | 123 | 1.307 | 4.307 | 158.489 |
| 7 | 63208.675 | 632+08 | 63.21 | $L_4$ | 6.5617 | 507.61 | 3 | 117 | 1.271 | 4.271 | 149.874 |
| 8 | 63208.675 | 632+08 | 63.21 | $R_4$ | 6.5617 | 507.61 | 3 | 117 | 1.271 | 4.271 | 149.874 |
| 9 | 67644.375 | 676+44 | 67.64 | $L_5$ | 6.5617 | 507.61 | 3 | 111 | 1.234 | 4.234 | 141.332 |
| 10 | 67644.375 | 676+44 | 67.64 | $R_5$ | 6.5617 | 507.61 | 3 | 111 | 1.234 | 4.234 | 141.332 |
| 11 | 72080.075 | 720+80 | 72.08 | $L_6$ | 6.5617 | 507.61 | 3 | 105 | 1.196 | 4.196 | 132.863 |
| 12 | 72080.075 | 720+80 | 72.08 | $R_6$ | 6.5617 | 507.61 | 3 | 105 | 1.196 | 4.196 | 132.863 |
| 13 | 76515.775 | 765+15 | 76.52 | $L_7$ | 6.5617 | 507.61 | 3 | 99 | 1.157 | 4.157 | 124.471 |
| 14 | 76515.775 | 765+15 | 76.52 | $R_7$ | 6.5617 | 507.61 | 3 | 99 | 1.157 | 4.157 | 124.471 |
| 15 | 80951.475 | 809+51 | 80.95 | $L_8$ | 6.5617 | 507.61 | 3 | 93 | 1.117 | 4.117 | 116.157 |
| 16 | 80951.475 | 809+51 | 80.95 | $R_8$ | 6.5617 | 507.61 | 3 | 93 | 1.117 | 4.117 | 116.157 |
| 17 | 85387.175 | 853+87 | 85.39 | $L_9$ | 6.5617 | 507.61 | 3 | 87 | 1.076 | 4.076 | 107.922 |
| 18 | 85387.175 | 853+87 | 85.39 | $R_9$ | 6.5617 | 507.61 | 3 | 87 | 1.076 | 4.076 | 107.922 |
| 19 | 89822.875 | 898+22 | 89.82 | $L_{10}$ | 6.5617 | 507.61 | 3 | 81 | 1.034 | 4.034 | 99.770 |
| 20 | 89822.875 | 898+22 | 89.82 | $R_{10}$ | 6.5617 | 507.61 | 3 | 81 | 1.034 | 4.034 | 99.770 |
| 21 | 94258.575 | 942+58 | 94.26 | $L_{11}$ | 6.5617 | 507.61 | 3 | 75 | 0.990 | 3.990 | 91.703 |
| 22 | 94258.575 | 942+58 | 94.26 | $R_{11}$ | 6.5617 | 507.61 | 3 | 75 | 0.990 | 3.990 | 91.703 |
| 23 | 98694.275 | 986+94 | 98.69 | $L_{12}$ | 6.5617 | 507.61 | 3 | 69 | 0.945 | 3.945 | 83.723 |
| 24 | 98694.275 | 986+94 | 98.69 | $R_{12}$ | 6.5617 | 507.61 | 3 | 69 | 0.945 | 3.945 | 83.723 |
| 25 | 103129.98 | 103+129 | 103.13 | $L_{13}$ | 6.5617 | 507.61 | 3 | 63 | 0.897 | 3.897 | 75.834 |
| 26 | 103129.98 | 103+129 | 103.13 | $R_{13}$ | 6.5617 | 507.61 | 3 | 63 | 0.897 | 3.897 | 75.834 |
| 27 | 107565.68 | 107+565 | 107.57 | $L_{14}$ | 6.5617 | 507.61 | 3 | 57 | 0.848 | 3.848 | 68.039 |
| 28 | 107565.68 | 107+565 | 107.57 | $R_{14}$ | 6.5617 | 507.61 | 3 | 57 | 0.848 | 3.848 | 68.039 |
| 29 | 112001.38 | 112+001 | 112.00 | $L_{15}$ | 6.5617 | 507.61 | 3 | 51 | 0.797 | 3.797 | 60.342 |
| 30 | 112001.38 | 112+001 | 112.00 | $R_{15}$ | 6.5617 | 507.61 | 3 | 51 | 0.797 | 3.797 | 60.342 |
| 31 | 116437.08 | 116+437 | 116.44 | $L_{16}$ | 6.5617 | 507.61 | 3 | 45 | 0.743 | 3.743 | 52.749 |
| 32 | 116437.08 | 116+437 | 116.44 | $R_{16}$ | 6.5617 | 507.61 | 3 | 45 | 0.743 | 3.743 | 52.749 |
| 33 | 120872.78 | 120+872 | 120.87 | $L_{17}$ | 6.5617 | 507.61 | 3 | 39 | 0.685 | 3.685 | 45.263 |
| 34 | 120872.78 | 120+872 | 120.87 | $R_{17}$ | 6.5617 | 507.61 | 3 | 39 | 0.685 | 3.685 | 45.263 |
| 35 | 125308.48 | 125+308 | 125.31 | $L_{18}$ | 6.5617 | 507.61 | 3 | 33 | 0.624 | 3.624 | 37.893 |
| 36 | 125308.48 | 125+308 | 125.31 | $R_{18}$ | 6.5617 | 507.61 | 3 | 33 | 0.624 | 3.624 | 37.893 |
| 37 | 129744.18 | 129+744 | 129.74 | $L_{19}$ | 6.5617 | 507.61 | 3 | 27 | 0.557 | 3.557 | 30.645 |
| 38 | 129744.18 | 129+744 | 129.74 | $R_{19}$ | 6.5617 | 507.61 | 3 | 27 | 0.557 | 3.557 | 30.645 |
| 39 | 134179.88 | 134+179 | 134.18 | $L_{20}$ | 6.5617 | 507.61 | 3 | 21 | 0.484 | 3.484 | 23.531 |
| 40 | 134179.88 | 134+179 | 134.18 | $R_{20}$ | 6.5617 | 507.61 | 3 | 21 | 0.484 | 3.484 | 23.531 |
| 41 | 138615.58 | 138+615 | 138.62 | $L_{21}$ | 6.5617 | 507.61 | 3 | 15 | 0.400 | 3.400 | 16.563 |
| 42 | 138615.58 | 138+615 | 138.62 | $R_{21}$ | 6.5617 | 507.61 | 3 | 15 | 0.400 | 3.400 | 16.563 |
| 43 | 143051.28 | 143+051 | 143.05 | $L_{22}$ | 6.5617 | 507.61 | 3 | 9 | 0.300 | 3.300 | 9.763 |
| 44 | 143051.28 | 143+051 | 143.05 | $R_{22}$ | 6.5617 | 507.61 | 3 | 9 | 0.300 | 3.300 | 9.763 |
| 45 | 147486.98 | 147+486 | 147.49 | $L_{23}$ | 6.5617 | 507.61 | 3 | 3 | 0.162 | 3.162 | 3.162 |
| 46 | 147486.98 | 147+486 | 147.49 | $R_{23}$ | 6.5617 | 507.61 | 3 | 3 | 0.162 | 3.162 | 3.162 |


CAPACITY STATEMENT
Comulative discharge (cusecs)
200
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
RD in 1000 ft

# 3. DESIGN OF OUTLETS, DESIGN OF CANALS IN REACHES, DESIGN OF WATER COURSES.

## 3.1. DESIGN OF CANALS IN REACHES:

***Important points:***

- Slope of irrigation channel should not be more than the slope of the tract.
- The water level in the main canal is controlled by the water level in branch canals; while the water level in branch canal is controlled by water level in distributaries, and water level in distributaries is controlled by water level required in water courses. Ultimately the water level in water courses is controlled by the elevation of the field to be irrigated. If the slope of the tract is more than the design slope of the channel, in that case fall should be provided at appropriate sites.

### LACEY'S REGIME THEORY

Based on his work, Lacey presented the following relationships:

FPS Units

- Perimeter: $P = 2.67\sqrt{Q}$
- Slope: $S = \left(0.0005423 f^{5/3}\right)/Q^{1/6}$
- Velocity:

$$V = 1.154(fR)^{1/2}$$
$$V = 16\left(R^{2/3}S^{1/3}\right)$$

$$a = \left(z - 2\sqrt{1+z^2}\right), b = P, c = -A$$

$$D = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$B = \left(A - zD^2\right)/D$$

## 3.2. DESIGN OF WATERCOURSES:

- Design it as Lines and Rectangular using Manning's formula:

$$Q = 1.49/n\ AR^{2/3}S^{1/2}$$

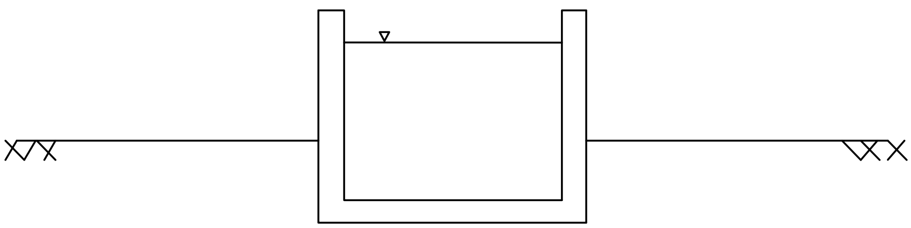
- Slope of water course = 1:5000 (Normally) varies from 1:3000~1:4000. Min 1:10000
- B = 2D, Velocity = 1 ft/sec, n = 0.013
- Calculate the depth of water in watercourse

## 3.3. TYPICAL CROSS-SECTIONS OF CANALS AT START, MID, END, CROSS-SECTION OF WATER COURSE.

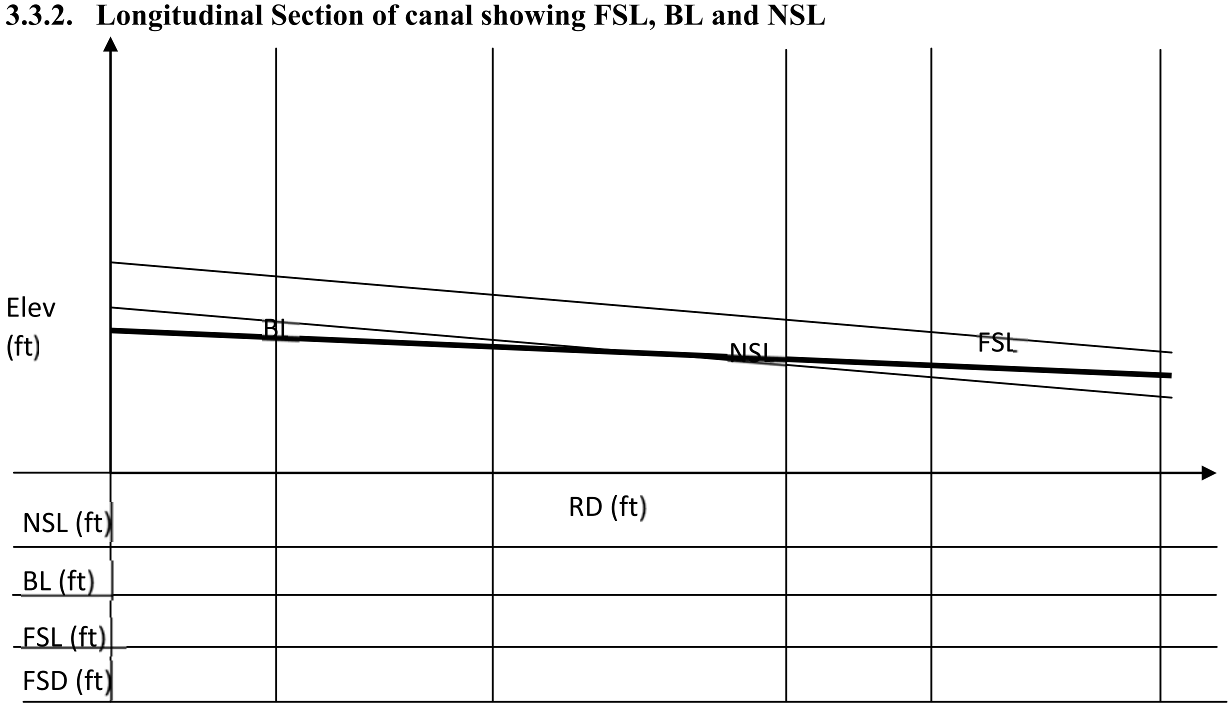
***Typical Cross-sections of canals at start, mid, end:***

Draw the typical canal cross-sections (3 in no.) showing the bed level, NSL, Full Supply Level, FSD, Bed width, canal banks, side roads, spoil bank etc.

### 3.3.1. Cross-section of water course:



### 3.3.2. Longitudinal Section of canal showing FSL, BL and NSL



Longitudinal Cross-section should include the following:

- Natural Surface Level
- Bed Level of Canal
- Full Supply Level
- Full Supply Depth
- Location of canal falls (if any)

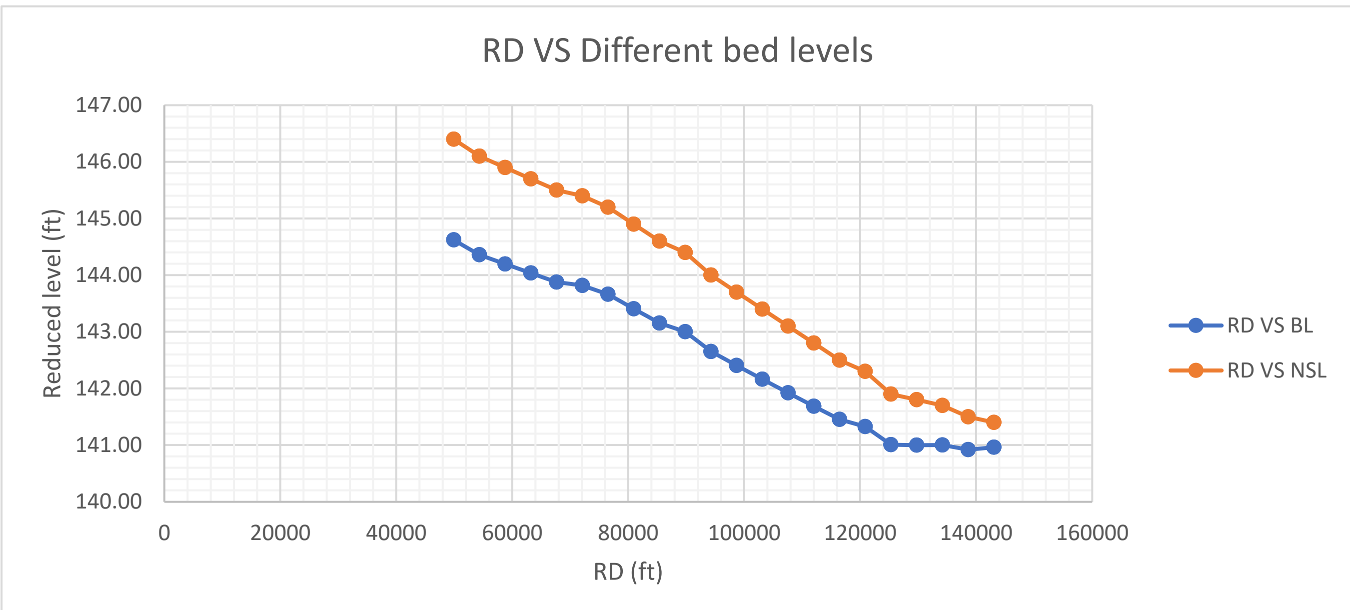
| MINOR CANAL DESIGN | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S= | | 0.0004 | | | | | | | | | | | | | |
| Side slope= | | 0.5H:1V | | | | | | | | | | | | | |
| Z= | | 0.5 | | | | | | | | | | | | | |
| **Sr No.** | **RD** | **OutLet Number** | **Discharge** | **Wetted Perimeter** | **Silt factor** | **Hydraulic Radius** | **Velocity** | **Area** | **a** | **b** | **c** | **Depth** | | **Design depth** | **Width** |
| | **-** | **-** | **Cusecs** | **ft** | | **ft** | **ft/s** | **ft$^2$** | **-** | **-** | **-** | **ft** | **ft** | **ft** | **ft** |
| 1 | 499+01 | $L_{1}$ | 175.930 | 35.415 | 1.397 | 2.399 | 2.113 | 84.968 | -1.736 | 35.415 | -84.968 | 2.777 | 17.622 | 2.777 | 29.204 |
| 2 | 499+01 | $R_{1}$ | 175.930 | 35.415 | 1.397 | 2.399 | 2.113 | 84.968 | -1.736 | 35.415 | -84.968 | 2.777 | 17.622 | 2.777 | 29.204 |
| 3 | 543+37 | $L_{2}$ | 167.175 | 34.522 | 1.390 | 2.363 | 2.091 | 81.568 | -1.736 | 34.522 | -81.568 | 2.740 | 17.145 | 2.740 | 28.394 |
| 4 | 543+37 | $R_{2}$ | 167.175 | 34.522 | 1.390 | 2.363 | 2.091 | 81.568 | -1.736 | 34.522 | -81.568 | 2.740 | 17.145 | 2.740 | 28.394 |
| 5 | 587+72 | $L_{3}$ | 158.489 | 33.613 | 1.383 | 2.325 | 2.069 | 78.160 | -1.736 | 33.613 | -78.160 | 2.702 | 16.659 | 2.702 | 27.570 |
| 6 | 587+72 | $R_{3}$ | 158.489 | 33.613 | 1.383 | 2.325 | 2.069 | 78.160 | -1.736 | 33.613 | -78.160 | 2.702 | 16.659 | 2.702 | 27.570 |
| 7 | 632+08 | $L_{4}$ | 149.874 | 32.687 | 1.375 | 2.287 | 2.046 | 74.742 | -1.736 | 32.687 | -74.742 | 2.663 | 16.165 | 2.663 | 26.732 |
| 8 | 632+08 | $R_{4}$ | 149.874 | 32.687 | 1.375 | 2.287 | 2.046 | 74.742 | -1.736 | 32.687 | -74.742 | 2.663 | 16.165 | 2.663 | 26.732 |
| 9 | 676+44 | $L_{5}$ | 141.332 | 31.742 | 1.367 | 2.247 | 2.022 | 71.314 | -1.736 | 31.742 | -71.314 | 2.623 | 15.661 | 2.623 | 25.877 |
| 10 | 676+44 | $R_{5}$ | 141.332 | 31.742 | 1.367 | 2.247 | 2.022 | 71.314 | -1.736 | 31.742 | -71.314 | 2.623 | 15.661 | 2.623 | 25.877 |
| 11 | 720+80 | $L_{6}$ | 132.863 | 30.776 | 1.358 | 2.205 | 1.997 | 67.875 | -1.736 | 30.776 | -67.875 | 2.581 | 15.146 | 2.581 | 25.004 |
| 12 | 720+80 | $R_{6}$ | 132.863 | 30.776 | 1.358 | 2.205 | 1.997 | 67.875 | -1.736 | 30.776 | -67.875 | 2.581 | 15.146 | 2.581 | 25.004 |
| 13 | 765+15 | $L_{7}$ | 124.471 | 29.788 | 1.350 | 2.163 | 1.972 | 64.422 | -1.736 | 29.788 | -64.422 | 2.538 | 14.620 | 2.538 | 24.113 |
| 14 | 765+15 | $R_{7}$ | 124.471 | 29.788 | 1.350 | 2.163 | 1.972 | 64.422 | -1.736 | 29.788 | -64.422 | 2.538 | 14.620 | 2.538 | 24.113 |
| 15 | 809+51 | $L_{8}$ | 116.157 | 28.776 | 1.340 | 2.118 | 1.944 | 60.956 | -1.736 | 28.776 | -60.956 | 2.493 | 14.082 | 2.493 | 23.201 |
| 16 | 809+51 | $R_{8}$ | 116.157 | 28.776 | 1.340 | 2.118 | 1.944 | 60.956 | -1.736 | 28.776 | -60.956 | 2.493 | 14.082 | 2.493 | 23.201 |
| 17 | 853+87 | $L_{9}$ | 107.922 | 27.737 | 1.330 | 2.072 | 1.916 | 57.474 | -1.736 | 27.737 | -57.474 | 2.447 | 13.530 | 2.447 | 22.266 |
| 18 | 853+87 | $R_{9}$ | 107.922 | 27.737 | 1.330 | 2.072 | 1.916 | 57.474 | -1.736 | 27.737 | -57.474 | 2.447 | 13.530 | 2.447 | 22.266 |
| 19 | 898+22 | $L_{10}$ | 99.770 | 26.669 | 1.320 | 2.024 | 1.886 | 53.974 | -1.736 | 26.669 | -53.974 | 2.398 | 12.964 | 2.398 | 21.307 |
| 20 | 898+22 | $R_{10}$ | 99.770 | 26.669 | 1.320 | 2.024 | 1.886 | 53.974 | -1.736 | 26.669 | -53.974 | 2.398 | 12.964 | 2.398 | 21.307 |
| 21 | 942+58 | $L_{11}$ | 91.703 | 25.568 | 1.309 | 1.973 | 1.855 | 50.453 | -1.736 | 25.568 | -50.453 | 2.347 | 12.380 | 2.347 | 20.319 |
| 22 | 942+58 | $R_{11}$ | 91.703 | 25.568 | 1.309 | 1.973 | 1.855 | 50.453 | -1.736 | 25.568 | -50.453 | 2.347 | 12.380 | 2.347 | 20.319 |
| 23 | 986+94 | $L_{12}$ | 83.723 | 24.431 | 1.297 | 1.920 | 1.821 | 46.909 | -1.736 | 24.431 | -46.909 | 2.294 | 11.778 | 2.294 | 19.301 |
| 24 | 986+94 | $R_{12}$ | 83.723 | 24.431 | 1.297 | 1.920 | 1.821 | 46.909 | -1.736 | 24.431 | -46.909 | 2.294 | 11.778 | 2.294 | 19.301 |
| 25 | 103+129 | $L_{13}$ | 75.834 | 23.251 | 1.284 | 1.864 | 1.786 | 43.338 | -1.736 | 23.251 | -43.338 | 2.238 | 11.155 | 2.238 | 18.247 |
| 26 | 103+129 | $R_{13}$ | 75.834 | 23.251 | 1.284 | 1.864 | 1.786 | 43.338 | -1.736 | 23.251 | -43.338 | 2.238 | 11.155 | 2.238 | 18.247 |
| 27 | 107+565 | $L_{14}$ | 68.039 | 22.024 | 1.270 | 1.804 | 1.747 | 39.736 | -1.736 | 22.024 | -39.736 | 2.178 | 10.508 | 2.178 | 17.153 |
| 28 | 107+565 | $R_{14}$ | 68.039 | 22.024 | 1.270 | 1.804 | 1.747 | 39.736 | -1.736 | 22.024 | -39.736 | 2.178 | 10.508 | 2.178 | 17.153 |
| 29 | 112+001 | $L_{15}$ | 60.342 | 20.741 | 1.255 | 1.740 | 1.706 | 36.098 | -1.736 | 20.741 | -36.098 | 2.115 | 9.832 | 2.115 | 16.012 |
| 30 | 112+001 | $R_{15}$ | 60.342 | 20.741 | 1.255 | 1.740 | 1.706 | 36.098 | -1.736 | 20.741 | -36.098 | 2.115 | 9.832 | 2.115 | 16.012 |
| 31 | 116+437 | $L_{16}$ | 52.749 | 19.392 | 1.239 | 1.672 | 1.660 | 32.415 | -1.736 | 19.392 | -32.415 | 2.047 | 9.123 | 2.047 | 14.815 |
| 32 | 116+437 | $R_{16}$ | 52.749 | 19.392 | 1.239 | 1.672 | 1.660 | 32.415 | -1.736 | 19.392 | -32.415 | 2.047 | 9.123 | 2.047 | 14.815 |
| 33 | 120+872 | $L_{17}$ | 45.263 | 17.963 | 1.220 | 1.597 | 1.610 | 28.680 | -1.736 | 17.963 | -28.680 | 1.973 | 8.374 | 1.973 | 13.552 |
| 34 | 120+872 | $R_{17}$ | 45.263 | 17.963 | 1.220 | 1.597 | 1.610 | 28.680 | -1.736 | 17.963 | -28.680 | 1.973 | 8.374 | 1.973 | 13.552 |
| 35 | 125+308 | $L_{18}$ | 37.893 | 16.436 | 1.198 | 1.514 | 1.554 | 24.879 | -1.736 | 16.436 | -24.879 | 1.892 | 7.576 | 1.892 | 12.206 |
| 36 | 125+308 | $R_{18}$ | 37.893 | 16.436 | 1.198 | 1.514 | 1.554 | 24.879 | -1.736 | 16.436 | -24.879 | 1.892 | 7.576 | 1.892 | 12.206 |
| 37 | 129+744 | $L_{19}$ | 30.645 | 14.781 | 1.173 | 1.420 | 1.490 | 20.993 | -1.736 | 14.781 | -20.993 | 1.801 | 6.712 | 1.801 | 10.752 |
| 38 | 129+744 | $R_{19}$ | 30.645 | 14.781 | 1.173 | 1.420 | 1.490 | 20.993 | -1.736 | 14.781 | -20.993 | 1.801 | 6.712 | 1.801 | 10.752 |
| 39 | 134+179 | $L_{20}$ | 23.531 | 12.952 | 1.142 | 1.312 | 1.413 | 16.994 | -1.736 | 12.952 | -16.994 | 1.699 | 5.761 | 1.699 | 9.153 |
| 40 | 134+179 | $R_{20}$ | 23.531 | 12.952 | 1.142 | 1.312 | 1.413 | 16.994 | -1.736 | 12.952 | -16.994 | 1.699 | 5.761 | 1.699 | 9.153 |
| 41 | 138+615 | $L_{21}$ | 16.563 | 10.866 | 1.103 | 1.181 | 1.317 | 12.832 | -1.736 | 10.866 | -12.832 | 1.579 | 4.680 | 1.579 | 7.335 |
| 42 | 138+615 | $R_{21}$ | 16.563 | 10.866 | 1.103 | 1.181 | 1.317 | 12.832 | -1.736 | 10.866 | -12.832 | 1.579 | 4.680 | 1.579 | 7.335 |
| 43 | 143+051 | $L_{22}$ | 9.763 | 8.342 | 1.046 | 1.008 | 1.185 | 8.407 | -1.736 | 8.342 | -8.407 | 1.438 | 3.367 | 1.438 | 5.127 |
| 44 | 143+051 | $R_{22}$ | 9.763 | 8.342 | 1.046 | 1.008 | 1.185 | 8.407 | -1.736 | 8.342 | -8.407 | 1.438 | 3.367 | 1.438 | 5.127 |
| 45 | 147+486 | $L_{23}$ | 3.162 | 4.748 | 0.935 | 0.719 | 0.946 | 3.411 | -1.736 | 4.748 | -3.411 | 1.399 | 3.001 | 1.388 | 4.126 |
| 46 | 147+486 | $R_{23}$ | 3.162 | 4.748 | 0.935 | 0.719 | 0.946 | 3.411 | -1.736 | 4.748 | -3.411 | 1.399 | 3.001 | 1.388 | 4.126 |

# 4. COMMAND STATEMENT:

It is prepared to ensure that the slope of an irrigation channel is capable of commanding the area to be irrigated.

- From head to tail (when the water at the head of canal is fixed)
- From tail to head (when the topography of the area is dominating and water level at the head can be adjusted)

| COMMAND STATEMENT | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sr. # | RD | | OutLet Name | Length of Water Course | Tail Level of W.C | Water Level in Water Course | Slope | Change in length | Head Level | Water Level in minor | Depth of Water in minor | Required bed level in Canal | Natural Soil Level |
| | - | ft | - | ft | - | ft | - | ft | ft | ft | ft | ft | ft |
| 1 | 499+01 | 49901.6 | L1 | 6561.69 | 143.78 | 144.03 | 0.0004 | 2.62 | 146.40 | 147.40 | 2.78 | 144.62 | 146.40 |
| 2 | 499+01 | 49901.6 | R1 | 6561.69 | 143.78 | 144.03 | 0.0004 | 2.62 | 146.40 | 147.40 | 2.78 | 144.62 | 146.40 |
| 3 | 543+37 | 54337.3 | L2 | 6561.69 | 143.48 | 143.73 | 0.0004 | 2.62 | 146.10 | 147.10 | 2.74 | 144.36 | 146.10 |
| 4 | 543+37 | 54337.3 | R2 | 6561.69 | 143.48 | 143.73 | 0.0004 | 2.62 | 146.10 | 147.10 | 2.74 | 144.36 | 146.10 |
| 5 | 587+72 | 58773 | L3 | 6561.69 | 143.28 | 143.53 | 0.0004 | 2.62 | 145.90 | 146.90 | 2.70 | 144.20 | 145.90 |
| 6 | 587+72 | 58773 | R3 | 6561.69 | 143.28 | 143.53 | 0.0004 | 2.62 | 145.90 | 146.90 | 2.70 | 144.20 | 145.90 |
| 7 | 632+08 | 63208.7 | L4 | 6561.69 | 143.08 | 143.33 | 0.0004 | 2.62 | 145.70 | 146.70 | 2.66 | 144.04 | 145.70 |
| 8 | 632+08 | 63208.7 | R4 | 6561.69 | 143.08 | 143.33 | 0.0004 | 2.62 | 145.70 | 146.70 | 2.66 | 144.04 | 145.70 |
| 9 | 676+44 | 67644.4 | L5 | 6561.69 | 142.88 | 143.13 | 0.0004 | 2.62 | 145.50 | 146.50 | 2.62 | 143.88 | 145.50 |
| 10 | 676+44 | 67644.4 | R5 | 6561.69 | 142.88 | 143.13 | 0.0004 | 2.62 | 145.50 | 146.50 | 2.62 | 143.88 | 145.50 |
| 11 | 720+80 | 72080.1 | L6 | 6561.69 | 142.78 | 143.03 | 0.0004 | 2.62 | 145.40 | 146.40 | 2.58 | 143.82 | 145.40 |
| 12 | 720+80 | 72080.1 | R6 | 6561.69 | 142.78 | 143.03 | 0.0004 | 2.62 | 145.40 | 146.40 | 2.58 | 143.82 | 145.40 |
| 13 | 765+15 | 76515.8 | L7 | 6561.69 | 142.58 | 142.83 | 0.0004 | 2.62 | 145.20 | 146.20 | 2.54 | 143.66 | 145.20 |
| 14 | 765+15 | 76515.8 | R7 | 6561.69 | 142.58 | 142.83 | 0.0004 | 2.62 | 145.20 | 146.20 | 2.54 | 143.66 | 145.20 |
| 15 | 809+51 | 80951.5 | L8 | 6561.69 | 142.28 | 142.53 | 0.0004 | 2.62 | 144.90 | 145.90 | 2.49 | 143.41 | 144.90 |
| 16 | 809+51 | 80951.5 | R8 | 6561.69 | 142.28 | 142.53 | 0.0004 | 2.62 | 144.90 | 145.90 | 2.49 | 143.41 | 144.90 |
| 17 | 853+87 | 85387.2 | L9 | 6561.69 | 141.98 | 142.23 | 0.0004 | 2.62 | 144.60 | 145.60 | 2.45 | 143.15 | 144.60 |
| 18 | 853+87 | 85387.2 | R9 | 6561.69 | 141.98 | 142.23 | 0.0004 | 2.62 | 144.60 | 145.60 | 2.45 | 143.15 | 144.60 |
| 19 | 898+22 | 89822.9 | L10 | 6561.69 | 141.78 | 142.03 | 0.0004 | 2.62 | 144.40 | 145.40 | 2.40 | 143.00 | 144.40 |
| 20 | 898+22 | 89822.9 | R10 | 6561.69 | 141.78 | 142.03 | 0.0004 | 2.62 | 144.40 | 145.40 | 2.40 | 143.00 | 144.40 |
| 21 | 942+58 | 94258.6 | L11 | 6561.69 | 141.38 | 141.63 | 0.0004 | 2.62 | 144.00 | 145.00 | 2.35 | 142.65 | 144.00 |
| 22 | 942+58 | 94258.6 | R11 | 6561.69 | 141.38 | 141.63 | 0.0004 | 2.62 | 144.00 | 145.00 | 2.35 | 142.65 | 144.00 |
| 23 | 986+94 | 98694.3 | L12 | 6561.69 | 141.08 | 141.33 | 0.0004 | 2.62 | 143.70 | 144.70 | 2.29 | 142.41 | 143.70 |
| 24 | 986+94 | 98694.3 | R12 | 6561.69 | 141.08 | 141.33 | 0.0004 | 2.62 | 143.70 | 144.70 | 2.29 | 142.41 | 143.70 |
| 25 | 103+129 | 103130 | L13 | 6561.69 | 140.78 | 141.03 | 0.0004 | 2.62 | 143.40 | 144.40 | 2.24 | 142.16 | 143.40 |
| 26 | 103+129 | 103130 | R13 | 6561.69 | 140.78 | 141.03 | 0.0004 | 2.62 | 143.40 | 144.40 | 2.24 | 142.16 | 143.40 |
| 27 | 107+565 | 107566 | L14 | 6561.69 | 140.48 | 140.73 | 0.0004 | 2.62 | 143.10 | 144.10 | 2.18 | 141.92 | 143.10 |
| 28 | 107+565 | 107566 | R14 | 6561.69 | 140.48 | 140.73 | 0.0004 | 2.62 | 143.10 | 144.10 | 2.18 | 141.92 | 143.10 |
| 29 | 112+001 | 112001 | L15 | 6561.69 | 140.18 | 140.43 | 0.0004 | 2.62 | 142.80 | 143.80 | 2.11 | 141.69 | 142.80 |
| 30 | 112+001 | 112001 | R15 | 6561.69 | 140.18 | 140.43 | 0.0004 | 2.62 | 142.80 | 143.80 | 2.11 | 141.69 | 142.80 |
| 31 | 116+437 | 116437 | L16 | 6561.69 | 139.88 | 140.13 | 0.0004 | 2.62 | 142.50 | 143.50 | 2.05 | 141.45 | 142.50 |
| 32 | 116+437 | 116437 | R16 | 6561.69 | 139.88 | 140.13 | 0.0004 | 2.62 | 142.50 | 143.50 | 2.05 | 141.45 | 142.50 |
| 33 | 120+872 | 120873 | L17 | 6561.69 | 139.68 | 139.93 | 0.0004 | 2.62 | 142.30 | 143.30 | 1.97 | 141.33 | 142.30 |
| 34 | 120+872 | 120873 | R17 | 6561.69 | 139.68 | 139.93 | 0.0004 | 2.62 | 142.30 | 143.30 | 1.97 | 141.33 | 142.30 |
| 35 | 125+308 | 125308 | L18 | 6561.69 | 139.28 | 139.53 | 0.0004 | 2.62 | 141.90 | 142.90 | 1.89 | 141.01 | 141.90 |
| 36 | 125+308 | 125308 | R18 | 6561.69 | 139.28 | 139.53 | 0.0004 | 2.62 | 141.90 | 142.90 | 1.89 | 141.01 | 141.90 |
| 37 | 129+744 | 129744 | L19 | 6561.69 | 139.18 | 139.43 | 0.0004 | 2.62 | 141.80 | 142.80 | 1.80 | 141.00 | 141.80 |
| 38 | 129+744 | 129744 | R19 | 6561.69 | 139.18 | 139.43 | 0.0004 | 2.62 | 141.80 | 142.80 | 1.80 | 141.00 | 141.80 |
| 39 | 134+179 | 134180 | L20 | 6561.69 | 139.08 | 139.33 | 0.0004 | 2.62 | 141.70 | 142.70 | 1.70 | 141.00 | 141.70 |
| 40 | 134+179 | 134180 | R20 | 6561.69 | 139.08 | 139.33 | 0.0004 | 2.62 | 141.70 | 142.70 | 1.70 | 141.00 | 141.70 |
| 41 | 138+615 | 138616 | L21 | 6561.69 | 138.88 | 139.13 | 0.0004 | 2.62 | 141.50 | 142.50 | 1.58 | 140.92 | 141.50 |
| 42 | 138+615 | 138616 | R21 | 6561.69 | 138.88 | 139.13 | 0.0004 | 2.62 | 141.50 | 142.50 | 1.58 | 140.92 | 141.50 |
| 43 | 143+051 | 143051 | L22 | 6561.69 | 138.78 | 139.03 | 0.0004 | 2.62 | 141.40 | 142.40 | 1.44 | 140.96 | 141.40 |
| 44 | 143+051 | 143051 | R22 | 6561.69 | 138.78 | 139.03 | 0.0004 | 2.62 | 141.40 | 142.40 | 1.44 | 140.96 | 141.40 |
| 45 | 147+486 | 147487 | L23 | 6561.69 | 138.68 | 138.93 | 0.0004 | 2.62 | 141.30 | 142.30 | 1.33 | 140.88 | 141.30 |
| 46 | 147+486 | 147487 | R23 | 6561.69 | 138.68 | 138.93 | 0.0004 | 2.62 | 141.30 | 142.30 | 1.33 | 140.88 | 141.30 |



# 5. PREPARATION OF WARABANDI FOR AN OUTLET CHAK:

## 5.1. DEFINITION AND BRIEF DESCRIPTION:

The term Warabandi means “turns” (*wahr*) which are “fixed” (*bandi*).

Warabandi is a rotational method for equitable distribution of the available water in an irrigation system by turns fixed according to predetermined schedule specifying the day, time and duration of supply to each irrigator in proportion to size of his land holding in the outlet command. (Singh 1981, Malhotra 1982)

The warabandi water allocation method practiced in Pakistan’s large-scale canal irrigation systems offers some empirical evidence of the relative neglect of water rights as a major issue in agricultural production. In the current practice of warabandi, the actual water distribution is found to deviate substantially from the design stage expectations. The implications of this gap between the design and practice of warabandi are yet to be fully explored.

Malhotra (1982)points out the warabandi is not just distribution of water flowing inside a water course according to a roster but is an integrated water management system extending from source to the farm gate.

The warabandi is a continuous rotation of water in which one complete cycle of rotation that lasts seven days or in some instances, ten days and each farmer in the water course receives water during one turn in this cycle for an already fixed length of time.

The cycle begins at the head and proceeds to the tail of the water course, and during each time turn, the farmer has the right to use all the flowing water in water course. Each year, preferably at canal closer, the warabandi cycle is rotated by twelve hours to give relief to the farmers who had their turns during the night in the preceding year schedule.

## 5.2. WARABANDI MANAGEMENT SYSTEM:

In the large canal irrigation systems in Pakistan, which are jointly managed by government agencies and farmers, warabandi rules and traditions act as the binding glue for an agency-farmer interface. A Central Irrigation Agency/department manages the primary main canal system and its secondary level

“distributories” and “minor” canals and deliver water at the head of tertiary level “watercourse” through an outlet called “mogha” which is designed to provide a quantity of water in proportion to CA of water course.

The agency has to ensure a uniform flow in watercourse so that it continuously receives its allotted water duty. Farmer within the watercourse are expected to manage the on-farm water distribution of water according to warabandi schedule officially "sactioned" or established solely on the basis of mutual agreement by the farmers. Once the arrangement of turns has been agreed upon, the agency does not interfere unless a dispute arises among the farmers and it is brought to official notice. . The dispute is resolved through an adjudication process (a legal process) according to prescribed rules.

The warabandi system in Pakistan includes the following **functions and characteristics**, among other things;

1. The main canal distributing points operate at supply levels that would allow distributory canals to operate at no less than 75 percent of full supply level.
2. There is rotation of distributaries, in some instances, when the supply in the main canal system falls further.
3. Only "authorized" outlets draw their allotted share of water from a distributary at the same time and
4. Outlets are ungated and deliver a flow of water proportion to the area commanded. Cooperative behavior among agency staff and water users is an overriding requirement to follow an agreed set of rules.
5. Water users have to maintain the watercourse in good condition.
6. The operating agency has to ensure proper hydraulic performance of the conveyance system.

## 5.3. OBJECTIVES OF WARABANDI:

As an integrated water management system, warabandi is expected to achieve two main objectives,

1. High efficiency
2. Equity in water use.

Water use efficiency is to be achieved through the imposition of water scarcity on each and every user, and equity in distribution through enforced equal share of scarce water per unit area among all users.

## 5.4. TYPES OF WARABANDI:

### 5.4.1. Official Warabandi:

Warabandi schedule officially determined and recorded in official document.

**Note:** None of the watercourses in the study sample followed the official Warabandi schedules in actual practice. (D. J. Bandaragoda)

### 5.4.2. Agreed Warabandi:

Agreed Warabandi is a derivative of the official Warabandi and is mutually agreed upon by the people for their convenience. For instance, a big landowner may divide his water turn into several component turns with the consent of other farmers. This new schedule is not reflected in the official schedule.

The reported reasons for these modifications were:

- Changes in water supply
- Changes in the physical layout of the watercourse
- Changes in landownership
- Other power relationships among the water users

### 5.4.3. Actual Warabandi

Field observations of the actual application of water turns by farmers showed that even the agreed warabandi was not strictly followed, and frequent changes took place on timing and duration of turns almost on a daily basis. While the reasons for introducing some flexibility in developing a more functional warabandi on mutual agreement can be easily understood, the divergence between the official warabandi schedules and what is actually practiced in the field is unexpectedly large.

## 5.5. TWO TYPES OF WARABANDI ARE FREQUENTLY MENTIONED IN PAKISTAN.

### 5.5.1. Kachcha (ordinary or unregulated) Warabandi:

The warabandi which has been decided by the farmers solely on their mutual agreement, without formal involvement of any government agency, is known as *kachcha* (ordinary or unregulated) warabandi,

### 5.5.2. Pucca Warabandi:

The warabandi decided after field investigation and public inquiry by the Irrigation Department when disputes occurred, and issued in officially recognized warabandi schedules, is called *pucca* warabandi.

Kachcha warabandi became increasingly unpopular as it was prone to exploitation by large landowners. Wherever this pressure could be challenged openly, disputes were registered with the canal authorities, and after prescribed adjudication processes, the kachcha warabandi was converted to official pucca warabandi schedules. The reason for having kachcha warabandi still in operation in some areas of southern Punjab and Sindh is attributed to the more skewed distribution of land favoring larger landowners in these areas. In central Punjab, the majority of watercourses have pucca warabandi.

## 5.6. BENEFITS OF WARABANDI:

- Increased cropping intensity
- Irrigation discipline
- Common issues are settled
- Greater economy and dependability
- Simplicity of implementation
- Productivity increment of irrigated agriculture.

## 5.7. FORMULATION OF WARABANDI:

The warabandi schedule is framed under Section 68 of the Canal and Drainage Act (VIII of 1873) in which rights to form and maintain water distribution schedules for watercourses are vested (having the rights of ownership) with the Canal Officers of the Irrigation Department. Several amendments and departmental rules were added later.

Theoretically, in calculating the duration of warabandi turn given to a particular farm plot, some allowance is added to compensate for the time taken by the flow to fill that part of watercourse leading to farm plot. This is called ***Khal bharai (filling time).*** Similarly, in some cases, a farm plot may continue to receive water from a filled portion of the watercourse even when it is blocked upstream to divert water to another farm or another part of the watercourse command. This is called ***Nikal (Drainage time)*** and is deduced from the turn duration of that farm plot.

The calculation of Warabandi schedule starts with determining by observation, the total of such filling times ($T_F$) and total of such drainage time ($T_D$). Thus for a weekly Warabandi rotation, the ***unit irrigation time ($T_U$) in hours per hectare/acre*** can be given by

$$\mathbf{T_U = (7x24-T_F+T_D)/CCA = (168-T_F+T_D)/CCA}$$

Where: CCA = Command area of an outlet/watercourse

$T_F$ = Total filling time = $\sum T_f$

$T_D$ = Total drainage time = $\sum T_d$

The value of $T_U$ should be same for all the farmers in the water course.

A ***farmer's Warabandi turn time*** is given by:

$$\mathbf{T_t = T_u x A + T_f - T_d}$$

Where: A= farm area/ area of farmer.

$T_f$ and $T_d$ are filling and drainage time respectively for a farm area.

Only some of the farms in a watercourse may be entitled to filling time or drainage time, or both. The warabandi schedule is prepared on the basis of different turn times calculated for each farm plot on the basis of these values, whenever they occur, and the area of each farm plot.

## 5.8. *WARABANDI SCHEDULE:*

It should be prepared for any one outlet in the irrigation scheme. Divide the whole CCA of outlet into sub areas of 25 acres (01 square = 1100 ft x 990 ft) preferably.

CCA = Outlet Command area

Q = Outlet discharge

V = 1 ft/sec

Time of filling/emptying the watercourse=L/V

$$T_U= (168-T_F+T_D)/CCA$$

$$T_t=T_U x A+T_f-T_d$$

## 5.9. COMMENTS ON WARABANDI FROM FIELD EXPERIENCE:

1. Time required for filling and drainage of watercourse is calculated by considering the velocity of water equal to 1m/sec (3.281 ft/sec). In actual practice, 5 minutes are added or subtracted per side of an acre (220 ft or 198 ft) for the same purpose.

2. The above said affair is the base FOR most of the disputes arising in the Warabandi after its implementation. As the actual time required by the watercourse for filling is more than 5 minutes per side of acre and the actual time required for the watercourse to be emptied is less. So in general, *drainage time is very much liked by the irrigators and filling time is avoided.*

3. Conventionally distribution of water is started from head of the watercourse (Head Moga) to tail of the water course with the consideration that at the same point, the land on left side is irrigated first and the land on right side is irrigated latter on. Due to this, at the same nakka points, the land owners having land on left side have to take water filling from the previous nakka (in previous Muraba) which is disliked by the irrigators widely due to above said reason. The solution of the problem which have successfully been implemented in the filed is that when such problem arises, the warabandi should be fixed turn by turn between the two irrigators, irrigating from the nakkas at the same place.

4. "Nikal" is the water left in the water course when the last irrigator irrigates his land. Although drain water subtraction is taken place but on most of the outlets, this dispute arises between the irrigators having their lands at the tail of the watercourse.