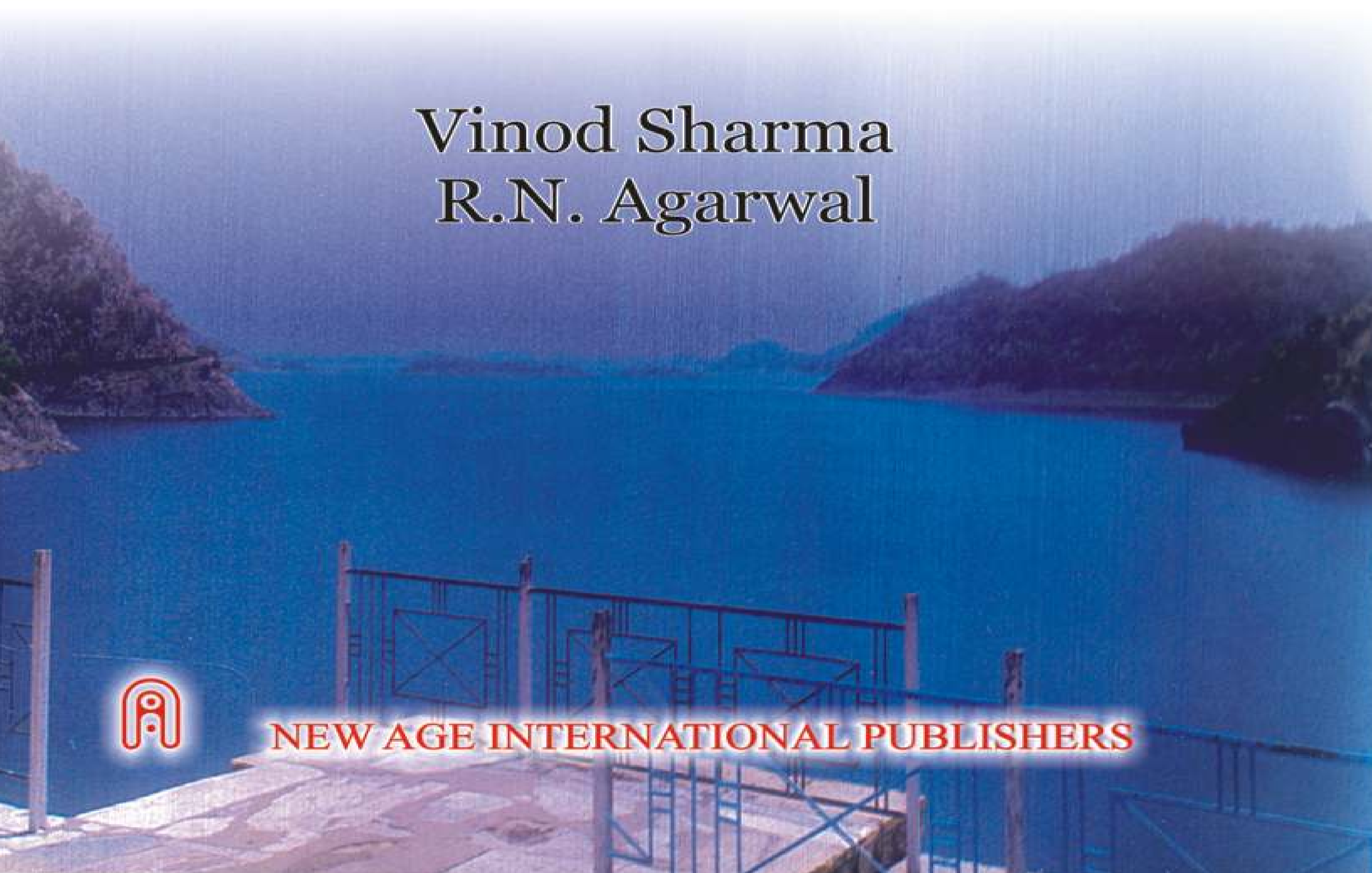
PLANNING IRRIGATION NETWORK

and OFD works

Vinod Sharma
R.N. Agarwal



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To

Our fellow engineers in
WAPCOS-CAD/IGNP

Heartiest thanks to my co-author for
his keen interest and efforts made in
bringing out this book.

R.N. Agarwal

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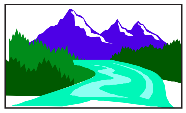

Epilogue

Water is life
Conserve water

Planning of an Irrigation project, particularly mega projects like IGNP. Sardar Sarover requires prime importance. Such projects are meant for hundreds of years to come. The impact of such projects on environment, economic, social, institutional on the area covered is drastic and in short span of implementation there would be a sea change in life style of the inhabitants.

We, the Irrigation engineers owe particular responsibilities towards the nation, to bring maximum area under irrigation. The lands are limited and cultivable area has almost reached a plateau. So to feed the increasing population with limited lands, sustainable irrigation is a must.

Any ill planning may create havoc. Where as proper long term based planning may be sustainable and keep the area blooming for the times to come.

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Preface

This small book is the out come of the problems faced by the authors during their working in the field in various capacities, as well as difficulty faced by farmers. Department find it in dilemma, when farmer brought their genuine demand for commanding of their lands by canal system.

Authors feel perturbed, why farmers and nation should suffer for the lapses in planning in canal network, OFD works by the department. In IGNP some six lacs ha area which could have been covered by flow canals has been left out. This is attributed to non-existence of any survey, planning policy, Execution of canal system, and on farm development (OFD) works uncoordinated.

This has prompted the authors to bring out some book on Survey and Planning, Canal network and OFD works. The aim is not fault finding but to stress that Survey and Planning are the keys for the optimum use of national resources and sustainable irrigation. Hitherto Survey and Planning is totally neglected.

Authors are greatly indebted for inspiration received from our fellow Engineers in IGNP, CAD & WAPCOS.

The authors greatfully acknowledge the help taken from many standard works on irrigation, studies and other national and international publications.

We wish to express our sincere thanks to M/s New Age International (P) LTD Publishers particularly Saumya Gupta for having expressed his confidence in publishing this book.

The authors would feel gratified to receive comments from our fellow practicing engineers for whom this book is meant as a reference book.

Bikaner

VINOD SHARMA
R.N. AGARWAL

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Abbreviations

A.P.M.	Adjustable Proportional Module
B.M.	Bench Mark
BIS	Bureau of Indian Standards
C.C.A.	Culturable Command Area
C.C.	Cement Concrete
C.I.	Cast iron
Cusec	Cubic feet per second
Cumec	Cubic meter per second
DT	Double tertiary
ET	Evapotranspiration
FAO	Food and Agriculture Organization
FSD	Full Supply depth
FSL	Full Supply Level
FB	Free board
FTL	Full Tank Level
FS	Full Supply
GTS	Great Trignometerical Station
GCA	Gross Command Area
HC	Hydraulic conductivity
Ha	Hectare
IGNP	Indira Gandhi Nahar Pariyojana
KWH	Kilo watt hours

OFD	On farm development
OT	Off-take
PPM	Parts per million
PCC	Pre cast concrete
SOI	Survey of India
ST	Single tertiary
USBR	United States Bureau of Reclamation
VSR	Village Service Area
WSS	Water surface slope
WP	Wetted perimeter
WAPCOS	Water and Power Consultancy Services.

Contents

1

Irrigation Terminology

1.1 Irrigation

Irrigation refers to application of additional water for crop maturity over and above the rainwater or available soil moisture contents. Irrigation requirement would be different for different crops, depending upon the rains, soil, moisture available, period of maturity, type of crops such as food gains, orchards, nurseries, etc.

Thus, irrigation may be defined as the science related with artificial application of water to the crops as per crop requirement from pre sowing to maturity. The application may be by gravity flow (border flooding, check flooding, basin flooding, furrow irrigation) pressure flow-porous hose method (drip irrigation and sprinkler irrigation).

1.2 Sources of Irrigation Water

Irrigation water may be underground water, storage water (tanks), diversion works, etc. Ground water is used for irrigation by lifting through open wells, tube wells. Application of ground water for irrigation is individualistic and depends upon ground water table, recharge, fillable porosity of soil, available mechanical means, etc. Being individualistic in nature mainly applied for small holdings, though the source and method is highly dependable, but due to involvement of lifting it is very costly. The cost of lifting is directly proportional to the depth of water. As a thumb rule cost of lifting is about Rs 6.0 lac. per annum per cubic metre per metre lift @ Rs 4 per unit of electric (one KWH.)

1.3 Diversion Works

Diversions are constructed on perennial streams and water is directly taken to the field through canal network. Irrigation through direct diversion is less dependable and not much in practice.

1.4 Storage Works

Storage works may be major, medium, minor. Major and medium storage works are generally multipurpose in nature. They envisage control of floods, production of hydropower as well as providing water for irrigation and drinking. Therefore regulation of such project is done synchronizing all the three, the flood, power requirement and to meet the irrigation and drinking water requirements. (Drinking water includes industrial and other requirements)

1.5 Quality of Irrigation Water

Contaminated water or water containing impurities may not be suitable for plant growth. Although this would depend on soil being irrigated, a particular impurity may be harmful for irrigation on a particular soil, but the same may be tolerable for irrigation on some other soil.

Mainly water with salt concentration is generally not suitable. The salt concentration is expressed by P.P.M. (parts per million) or one milligram per liter. Tolerance is as under:

Table 1.1 Quality of Irrigation Water

0 to 700 ppm	Tolerable for all plants
700 to 2000 ppm	Harmful to some plants
2000 ppm and above	Injurious to all plants

Salt concentration is also measured by electrical conductivity of water. Electrical conductivity is expressed in micro-mho per centimeter at 25 degree centigrade.

The suitability is as under:

Table 1.2 Suitability of Irrigation Water

100 to 250 micro-mho's at 25 degree C	Called low conductivity water suitable for all crops
250 to 750 micro-mho's at 25 degree C	Medium conductivity water suitable for normal salt tolerant crops.
750 to 2500 micro-mho's at 25 degree C	High conductivity water, may be used for high salt tolerant crops.
2500 and above micro-mho's degree C	Very high conductivity water, may generally not suitable for irrigation, unless treated before use.

Relation between PPM and Micro mho's 1 PPM = 0.640 Micro-mho's = 640 milli mho's

1.6 Surface Irrigation

Means application of water to the crop through gravity flow. Surface irrigation may be

1. Flow irrigation, lift irrigation.
2. Perennial irrigation, non-perennial irrigation.

Flow irrigation: Where the water has travelled to the fields by flow from main source i.e., dam, barrage, diversion works, tanks, etc.

Lift irrigation: Where the water has been lifted so as to travel to the fields, such as lift canals, tube wells, dug wells, etc.

Perennial irrigation: Means the water is available round the year for irrigation but may be short in requirement.

Non-perennial irrigation: Means the water is available for a particular period in a year for irrigation, but at some time may be available for the whole year.

1.7 Sub Surface Irrigation

Means application of water below surface in the root zone. This may be done by laying open jointed conduits below the soil so as to supply water to the crops by capillary.

1.8 Free Flooding

In this method small ditches are excavated in the field on contour or on water shed lines of the field. Water from these ditches flows across the field. No attempt is made to control the flow by means of levees. Resulting low water, use efficiency although land-leveling cost is low. As shown in Fig. 1.1

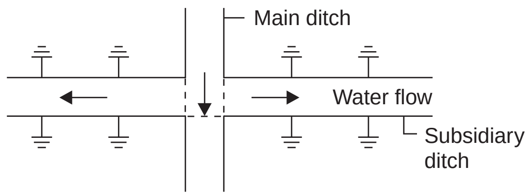


Fig. 1.1 Free Flooding

1.9 Border Flooding

In this method land is divided into a number of strips with low levees. The lands are confined in strips, depending upon the soil texture and water available. Generally strips may be 10 to 15 meters in width and 100 meters in length. In plain area, this method is mostly adopted with strip of 10 meter wide and 50 meter in length. The grade of strip is generally kept as 0.5% but depends upon the soil texture.

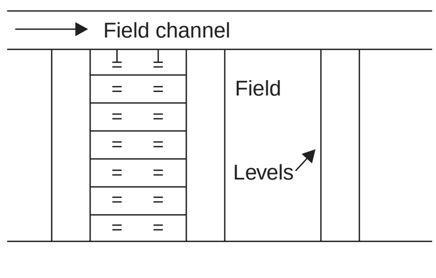


Fig. 1.2 Border Flooding

1.10 Check Flooding

In this method ordinary flooding is practiced along with check levees to control the flooding. Check levees are constructed according to the field topography.

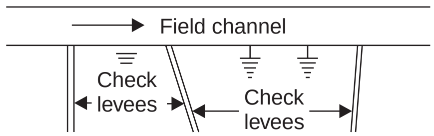


Fig. 1.3 Check Flooding

1.11 Basin Flooding

This method is adopted in orchards for watering plants. Ditches are constructed connecting each tree basin.

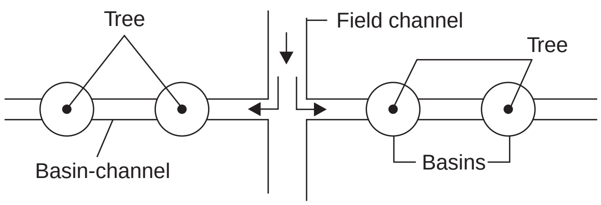


Fig. 1.4 Basin Flooding

1.12 Furrow Irrigation

In this method furrow (narrow ditches) are excavated between rows of plants to irrigate. In this method only a part of the surface is covered by water ranging from 1/2 to 1/5. Spacing of furrow depends upon plants spacing. Furrow's may be 8 to 30 cm. deep and 100 to 150 m long, 1.0 to 1.2 m wide.

1.13 Drip Irrigation

In this method water is pumped into porous flexible pipes laid below the surface near root zone. Water percolates through pores to meet the plants requirement. This is a highly efficient method of using water. Initial cost is high and maintenance also requires skilled persons.

1.14 Sprinkler Irrigation

In this method water is applied in the form of artificial rains over the crops, by means of pumps, pipes and stands. Sprinkler irrigation is an efficient, method of using water. It is as high as 80 % compared to gravity application, but its initial cost is high. For progressive farmers and where water is scarce, sprinkler method of water application is very effective and essential. In drip and sprinkler methods, doses of fertilizer can be applied very efficiently without any extra expenditure. On lift canals water must be applied through sprinkler or drip method.

1.15 Crops

This is the Field/Farm produce natural or cultivated crops for human and animal life. Every crop requires water right from pre-sowing to maturity. If timely rains are there during its growth no irrigation is required as the case in England and some other countries. But in tropical countries irrigation is a must, due to insufficient erratic rainfall and high evapotranspiration.

1.16 Kharif Season

Kharif season is from 15th April to 14th October and the main crops of kharif season are rice, bajra, jowar, maize, tobacco, groundnut, etc.

1.17 Rabi Season

Rabi season is from 15th October to 14th April. The main crops of the Rabi season are wheat, barley, gram, mustard, potato, etc. These dates are not rigid. Separation of season is mainly in Northern India as there are definite summer, winter, and rainy seasons. In South India, there is no such seasonal distinction.

1.18 Cash Crops

Cash crops refers to the crops, which need processing, marketing before consumption. Crops like jute, tea, cotton, tobacco, and sugar-cane, etc. i.e., excluding food crops, which are consumed without processing.

1.19 Arid Region

The region where water is scarce and rains are scanty. The hot dry climate persist and where irrigation is a must for agriculture is termed arid region.

1.20 Semi-Arid Region

The region where water availability is low due to low rain fall and climate is dry hot, is called the semi arid region. However, inferior crops (water stress) can be raised there without irrigation in good rainy season.

1.21 Effective Rainfall

Effective rainfall is that part of the rainfall which is available to meet the evapotranspiration needs of the crop. All rainfall is not effective, part may be lost by surface run off, deep percolation or evaporation. In case of heavy and high intensity rains only a part enter and stored in the root zone. Where as frequent light rains on the ground cover foliage are nearly 100% effective stored in the root zone. Effective rainfall may be estimated on average monthly ETo as given below. Average Monthly Effective Rainfall is related to Average Monthly ET crop and mean monthly rainfall.

Table 1.3 Effective Rainfall (Monthly mean rain fall (mm))

Av. Monthly ETc	*12.5*	*25*	*37.5*	*50*	*62.5*	*75*	*87.5*	*100*	*112.5*	*125*	*137.5*	*150*
25	8	16	24	–								
50	8	17	25	32	39	46	–	–	–	–	–	–
75	9	18	27	34	41	48	56	62	69	–	–	–
100	9	19	28	35	43	52	59	66	73	80	87	94
125	10	20	30	37	46	54	62	70	76	85	92	98
150	10	21	31	39	49	57	66	74	81	89	97	104
175	11	23	32	42	52	61	68	78	86	95	103	111
200	11	24	33	44	54	64	73	82	91	100	109	117
225	12	25	35	47	57	68	78	87	96	106	115	124
250	13	25	38	50	61	72	84	92	102	112	121	132

Where net depth of water that can be stored in the soil at the time of irrigation is greater than 75 mm, the correction factor to be used is

Effective Shortage	20.0	25.0	37.5	50.0	62.5	75.0	100	125	150	175	200
Correction Factor	0.73	0.77	0.86	0.93	0.97	1.0	1.02	1.04	1.06	1.07	1.08

Example: Mean Monthly rainfall 50 mm

ET Crop(Avg. monthly) 100 mm

Effective storage 50 mm, correction factor 0.93

Effective rainfall $35 \times 0.93 = 32.55$ mm

1.22 Crop Water Requirement

The total quantity of water, a crop requires at different intervals of time from pre-sowing to harvesting is called the crop water requirement of that crop. Different crops will have different water requirements depending on climate, type of soil, method of cultivation, useful rainfall, etc. Crop water requirement is defined as the depth of water needed to meet the water loss through evapotranspiration (ET Crop) of a disease free crop growing in large fields under non restricting soil conditions including soil water and fertility and achieving full production potential under growing conditions (FAO-24).

ETo is defined as the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, completely shading the ground and not short of water (FAO-24)

Crop Co-efficient (Kc) – Crop water requirement depends upon crop characteristics and is called crop Co-efficient (Kc)

$$ETc = Kc \times ETo$$

Table 1.4 ETc of Some Important Crops of North India (Station: Bikaner)

CROP	PERIOD	ETc
Groundnut	16th June to 23rd Oct.	488 mm
Wheat	16th Nov. to 4th April	343 mm
Mustard	16th Oct to 4th March	259 mm
Jowar	16th July to 17th Nov.	365 mm
Bajara	16th July to 8th Oct.	322 mm

Table 1.5 Monthly ETo Using Modified Penman Method (adjusted ETo) of Some Districts of Rajasthan

Month	*Ganga-nagar*	*Churu*	*Bikaner*	*Jodhpur*	*Phalodi*	*Barmer*	*Jaisal-mer*
Jan.	66	76	83	118	104	115	106
Feb.	91	105	107	136	128	137	129
March	148	173	179	199	218	205	207
April	187	220	214	242	251	246	237

Contd.

Table 1.5 (Contd.)

Month	*Ganga-nagar*	*Churu*	*Bikaner*	*Jodhpur*	*Phalodi*	*Barmer*	*Jaisal-mer*
May	226	269	274	317	342	301	332
June	218	261	278	325	338	271	353
July	218	224	243	223	260	209	265
Aug.	192	196	208	190	215	187	229
Sept.	180	194	206	204	222	193	237
Oct.	144	162	169	183	201	186	195
Nov.	89	105	107	138	133	134	129
Dec.	66	79	83	118	105	116	108
Total	1825	2067	2151	2393	2517	2300	2527

1.23 Crop Period

The time period between sowing and harvesting is called Crop Period. The time between first watering to a crop at its sowing to its last watering before harvesting is called Base Period. Generally Crop Period, Base Period and Growth Period are taken as synonymous.

1.24 Cropping Calendar

Refers to the sowing time, base period, harvesting time, etc. Cropping calendar as adopted in West Rajasthan for irrigated crops are as under:

Table 1.6 Cropping Calendar (Irrigated Crops) Northern India

S No.	*Name of Crop*	*Crop Period (days)*	*Harvesting Period*
1.	Bajara and Jowar	80–90	Aug. to 15th Nov.
2.	Jeera, Castor and Sunflower	90–100	Aug. to 15th Nov.
3.	Gowar	120–130	15th Sep. to Oct.
4.	Zaid pulses	60–70	15th May to June

Contd.

Table 1.6 (Contd.)

S No.	*Name of Crop*	*Crop Period (days)*	*Harvesting Period*
5.	Kharif Pulses	70–120	15th Sept. to Oct.
6.	Arhar	120–140	Oct. to Dec.
7.	Groundnut	120–140	7th Nov. to Dec.
8.	Cotton (Arabian)	160–200	Oct. to Jan
9.	Cotton (Indian)	170–200	Sept. to Dec.
10.	Til	90–200	Oct. to Nov.
11.	Chilies (dry)	15th June to 15th Nov.	Oct. to Nov.
12.	Zaid Fodder	100–120	50-60 Days
13.	Khariff Fodder	160–170	15th July to Oct.
14.	Wheat	130–140	20th March to 10th April
15.	Barley	120–130	March to early April
16.	Gram	125–140	25th Feb. to 31st March
17.	Mustard	125–140	15th Feb. to 31st March
18.	Onion	150–160	April to May
19.	Grafted Ber	May to June	Feb. to April
20.	Citrus	May to June	Dec. to April

1.25 Delta of a Crop–Duty of Water

The total depth of water required by a crop from sowing to maturity is called its delta. For example: A crop requires 7.0 cm. of water 6 times from sowing to maturity. The delta of the crop would be 7 × 6 = 42 cm. This includes soil moisture and useful rainfalls. In actual the requirement would be less, due to rainfall and soil moisture contribution. Delta of some crops is as under:

Table 1.7 Delta of Some Important Crops

Crop	D *in Cm*
Sugarcane	150–180
Rice	120

Contd.

Table 1.7 (Contd.)

Crop	D *in Cm*
Tobacco	75
Garden Fruit	60
Cotton	50
Vegetable	45
Wheat	30
Maize	25
Fodder	25

Duty of Water

The duty of water is the relationship between the volume of water and area under crop matured. Suppose, one cubic metre water flowing per second runs for B days (base period) and matures 200 ha, then duty of water is defined as 200 ha per cumec to the base of B days.

Total volume = Discharge × Base period

$= 60 \times 60 \times 24 \times B$ Cum

Area $= 100 \times 100 \times A$ Sqm

$$\text{Delta in metre} = \frac{60 \times 60 \times 24 \times B}{100 \times 100 \times A} \text{ m}$$

$$= \frac{8.64\,B}{\text{A}} \text{ m}$$

where *B* is the base period *A* is the area in ha matured.

1.26 Water Allowance

Water allowance is defined as antonymous of duty and is expressed in cusec/1000 acres or in cumec/100 ha. at outlet head, distributory head or main canal head as the case may be. Water allowance is fixed on canal basis but some time water allowance is also fixed on region basis, taking into account all the variable factors for cropping pattern on that canal or region.

On IGNP following water allowances are fixed on different Canal systems:

1. Stage-1 (0 to 189 Km)	24.5 lit/sec/100 ha	3.50 cusec/1000 acres
2. Kanwar Sain Lift	27.3 lit/sec/100 ha	3.90 cusec/1000 acres
3. Sahwa Lift Canal	14.04 lit/sec/100 ha	2.00 cusec/1000 acres
4. Stage-II IGNP	21.0 lit/sec/100 ha	3.00 cusec/1000 acres

5. Gajner, Kolayat, Phalodi, and Bangarsar Lift canal. 14.0 lit/sec/100 ha (2.00 cusec/1000 acres)

In fact availability of water plays an important part to decide the water allowance. Further, water allowance may be reviewed with the development of irrigation and means of application of water in the area. Procedure for calculating water allowance is given in table *1.8

Note

Δ = Delta in metres

W/R = Total water required in ha metres

Mean discharge include conveyance losses

Discharge has been calculated assuming 30 days in a month.

From the table above, total water required is 45.19 ha-metre in a year. Discharge required at outlet head.

$$= \frac{45.19 \times 100 \times 100}{360 \times 24 \times 60 \times 60} \text{ Cumec/100 ha}$$

= 0.0145 Cumec/100 ha

= 14.5 liter/sec/100 ha.

Generally water allowance varies from 14 to 35 liter/sec/100 ha with 100% irrigation intensity. A water allowance of 15 to 20 liter/sec/100 ha is found to be most reasonable. Weather soils are sandy mixed with alluvial, alluvial, clayey, black-collon, etc. The climatic conditions may have some effect on crop production, but not much. A water allowance more than 20 liter/sec/100 ha may not be justified in any circumstances.

Following should be born in mind

1. Our water resources are limited, only 30% land is under canal irrigation, that too is not assured.
2. Our water requirement would go on increasing with each passing day due to increase in population and industrial requirement.
3. Whatever may be the cropping calendar suggested by the department, farmers would follow their own cropping pattern, depending on demand and supply of the produce.
4. It has been experienced that with 15 to 20% water stress, yield affected is just 5%.
5. More the water less the efficiency, resulting increase in water table, creating water logging conditions.

Table 1.8 Sample Calculations for Water Allowance/Capacity Factor

Area under each crop month	*Wheat 27 ha*	*Rabi oil seed 7 ha*	*Grasses 18 ha*	*Misc. 5 ha*	*W.R. ha–m (A)*	*Rice 1 ha*	*Fooder 24 ha*	*Sugar 1 ha*	*Cotton 12 ha*	*Misc. 5 ha*	*Water Req. ha–m (B)*	*Total W.R. ha–m (A + B)*	*Mean Q/100 ha cumec/ 100 ha*
	Rabi Area–ha					*Kharif Area–ha*							
April Δ *WR*	–	–	–	–	–	–	–	0.225 0.225	0.075 0.90	0.04 0.20	1.325	1.325	0.0051
May Δ *WR*	–	–	–	–	–	–	–	0.225 0.225	0.15 1.80	0.075 0.375	2.40	2.40	0.0092
June Δ *WR*	–	–	–	–	–	0.3 0.3	0.075 1.80	0.225 0.225	0.15 1.80	0.075 0.375	4.50	4.50	0.0173
July Δ *WR*	–	–	–	–	–	0.45 0.45	0.075 1.80	0.15 0.15	0.15 1.80	0.075 0.375	4.575	4.575	0.0176
Aug. Δ *WR*	–	–	–	–	–	0.45 0.45	0.075 1.80	0.15 0.15	0.15 1.80	0.075 0.375	4.575	4.575	0.0176
Sep. Δ *WR*	–	0.075 0.525	0.04 0.72	0.075 0.375	1.62	0.45 0.45	0.075 1.80	0.15 0.15	0.15 1.80	0.04 0.20	4.40	6.02	0.0232
Oct. Δ *WR*	0.04 1.08	0.15 1.05	0.075 1.35	0.15 0.75	4.23	0.375 0.375	–	0.15 0.15	0.075 0.90	–	1.425	5.655	0.0218

Contd.

Table 1.8 (Contd.)

Area under each crop month	*Wheat 27 ha*	*Rabi oil seed 7 ha*	*Grasses 18 ha*	*Misc. 5 ha*	*W.R. ha–m (A)*	*Rice 1 ha*	*Fooder 24 ha*	*Sugar 1 ha*	*Cotton 12 ha*	*Misc. 5 ha*	*Water Req. ha–m (B)*	*Total W.R. ha–m (A + B)*	*Mean Q/100 ha cumec/ 100 ha*
	Rabi Area–ha					*Kharif Area–ha*							
Nov. Δ	1.075	0.075	0.075	0.075				0.15					
WR	2.025	0.525	1.35	0.375	4.275	–	–	0.15	–	–	0.015	4.425	0.0176
Dec. Δ	0.04	0.075	0.04	0.075				0.075					
WR	1.08	0.525	0.72	0.375	2.70	–	–	0.075	–	–	0.075	2.775	0.0107
Jan. Δ	0.04		0.075	–				0.075					
WR	1.08		1.35		2.43	–	–	0.075	–	–	0.075	2.505	0.0097
Feb. Δ	0.075		0.04	–									
WR	2.025		0.072		2.745	–	–	–	–	–		2.745	0.0106
Mar. Δ	0.011		0.04	–									
WR	2.97		0.72		3.69	–	–	–	–	–		3.69	0.0142
Total	0.38	0.375	1.385	0.375		2.025	0.30	1.575	0.90	0.38			0.1746/12
	10.26	2.625	6.93	1.875	21.69	2.025	7.20	1.575	10.80	1.80	23.50	45.19	= 0.0145

Δ = Delta, WR = Water required, Area = hactare

1.27 Water Shed

It may be broadly defined as the area between two drains or streams. There may be a main water shed having subsidiary water sheds dividing the drainage between the two streams on the either side:

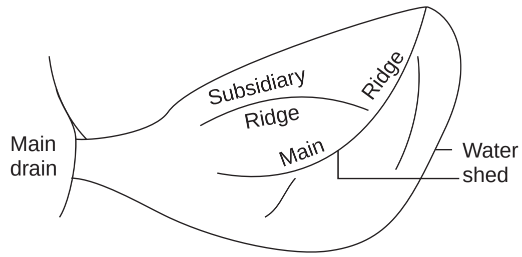


Fig. 1.5 Water Shed

As shown in the figure there is main water shed having four to six subsidiary watersheds. Every water shed in itself is a ridge connecting with the main water shed. There may be an isolated water shed surrounded by stream although this water shed is also bodily connected with the main water shed.

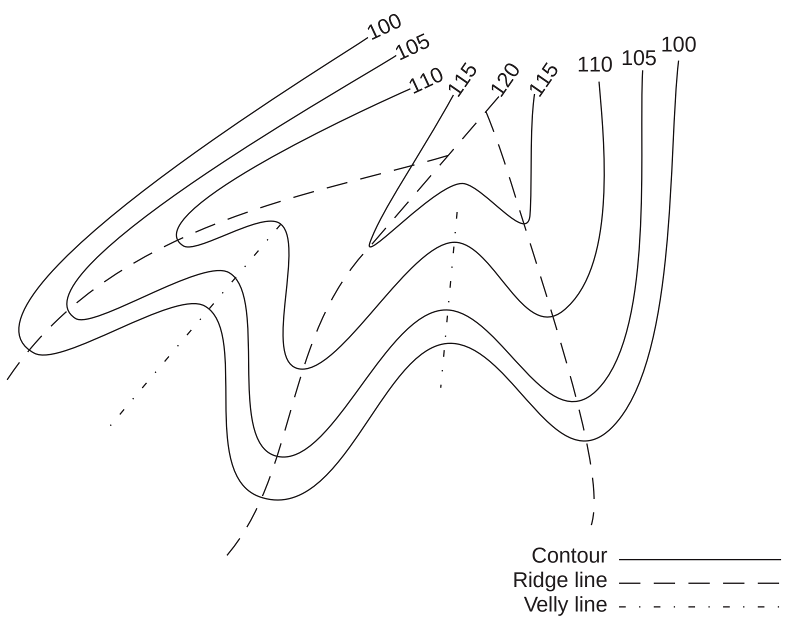


Fig. 1.6 Water Shed/Sub-Water Shed

1.28 Water Shed Canals

The canal which is aligned along any natural water shed is called water shed canal. In plain area, it is often necessary and economical to align channels on the water sheds of the area. In Punjab and Rajasthan mostly canals are water shed canals. In IGNP some 5000 km canal net work to irrigate 10 lac. ha area has been aligned on water sheds. However, where water sheds are close, canal should be aligned across the water sheds.

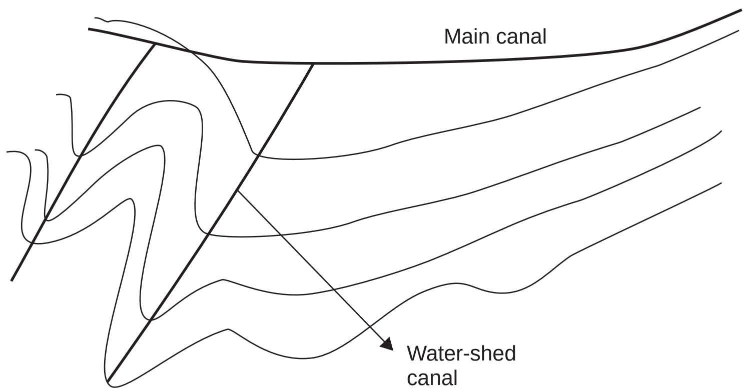


Fig. 1.7 Water Shed Canals

In general water shed canals or ridge canals are suitable and are economical where wide flat patches are available between two ridges. This facilitates planning of water course and chaks. In alluvial soils, a water course of nearly 35 liter/sec capacity may be most suitable for optimum application efficiency. In this part of western Rajasthan, most of the water course are 4 to 5 Km in linear length. Thus, an area of 8 to 10 Km wide flat is necessary in between two canals. This aspect has been dealt in detail under Canal Planning.

1.29 Contour Canal

Is the canal, which runs along contour so as to maintain a requisite maximum FSL. Normally feeder canals and main canals off taking up stream of berrage/dam are kept as contour canals irrigation on one side only because area on the other side is high. IGMN is a contour canal irrigating area, on its right side except few patches on left side by gravity.

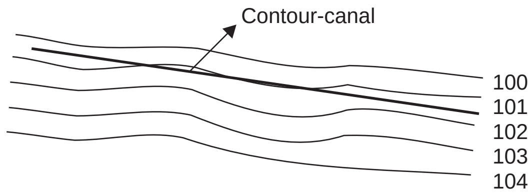


Fig. 1.8 Contour Canal

1.30 Feeder Canal

It is that portion of a canal which links head works to main canal. In general no off-take or irrigation is done from this part of the canal.

1.31 Main Canal

As the name indicates it runs at the highest water shed or contour as the case may be. Generally the water surface slope of the main canal is kept flatter as far as possible to irrigate the maximum area. No direct irrigation is practiced from main canal. Main canal is designed as per capacity factor worked out from the flow series of the main source of supply. Suppose a canal has been designed with capacity factor of 0.65 having carrying capacity as 500 cumec, that means average water availability is 325 cumec at head.

1.32 Branch Canal

The canal off taking from main canal with substantial discharge is termed as branch canal. As per convention, any canal off taking from main canal having discharge of 10 cumec and above is designated as branch canal.

As a principle no outlet is provided in branch canal as in the case of main canal. The reason being, main canal runs round the year. Like wise branches also run most of the year whereas distributories, minors and sub minors runs under rotation. Although in general a branch is taken as a unit while preparing roster for rotation. But sometimes distributories are also taken as a unit in preparation of rotation roster. So, any outlet provided in main canal and branch canal would function round the year, as no regulation arrangement is provided at outlet head. Even if any regulation arrangement at outlet head is provided in case of main canal and branches that is likely to be tampered with and made non-effective. Hence, no outlet should be provided on branch canal and main canal.

1.33 Distributories–Minors–Sub Minors

Canal O.T. from branch canal or main canal having discharge between 1.5 cumec to 10.0 cumec is designated as distributory and is the main conduit to distribute the water in the fields. Minor canals O.T. from distributory, branch canal/main canal having discharge above 1.00 cumec. but less than 1.5 cumec are termed as minor canals.

Sub Minors: Canal O.T. from minors is termed as sub minors having discharge of less than 1.00 cumec.

The above classifications of branches, distributories, minors, subminors are not rigid. On small and medium irrigation projects branches, distributories and minors may be designated on the basis of area served. Some time on medium irrigation project a canal serving area of 10,000 ha is termed as Main Canal and no out let is provided, although discharge may be 3 to 3.5 cumec depending upon the water allowance.

(Irrigation Project with CCA of more than 10,000 ha are classified as major projects and projects with CCA of more than 2,000 ha and up to 10,000 ha classified as a medium project. Minor projects has CCA less than 2,000 ha source—IES)

1.34 Water Courses

Small canals providing water to the field are termed as field channels or Water-courses and are the nerve system. Thus utmost care should be exercised in planning water course i.e., OFD works below outlets.

1.35 Outlets

The device/opening in canals for supplying irrigation water in Water-course is called outlet. Outlets may be non modular, semi modular, modular or open flumes. Outlets are generally non regulatory. They function automatically as the supplies are available in parent channel.

1.36 Intensity of Irrigation

Intensity of Irrigation means percentage of CCA proposed to be irrigated out of total CCA in one cycle of cropping period i.e., Rabi, Kharif and other seasonal crops. For example, Out of 100 ha CCA cropping pattern is as under:

1. Rabi	40 ha

2.	Kharif	45 ha
3.	Orchards etc.	2 ha

Intensity is 87%

Due to mechanization of sowing, harvesting and thrashing of crops, lands are generally not kept fallow. As a result intensity of irrigation is more than 100% subject to availability of water. In IGNP Stage–1 planned irrigation intensity is 110 % but actual intensity is nearly 180%, whereas in Stage–II planned irrigation intensity is 90 % and actual irrigation intensity is less than 50% due to insufficient water supply.

Some important factors that effects the fixing of intensity of irrigation are as under:

1. Water availability and its nature
2. Ground water conditions
3. Cropping pattern
4. Climatic conditions
5. Topography
6. Soil
7. Water application method

Although on a canal project, cropping pattern and intensity of irrigation are pre-determined canal wise or region wise but these are never followed. The water use cropping pattern and intensity depend upon cultivators, how judiciously they apply/use water in raising their crops. With the same quantity of water one may get 75% intensity whereas other might get more than 100%. Although other factors are same. Land shaping, proper grading method of water application such as sprinkler, drip may increase the intensity of irrigation substantially. Some times conjunctive use of ground water with canal water is done to raise the crops, thereby the intensity is increased. On irrigation projects initial irrigation intensity remains low, but with passage of time, intensity goes on increasing.

1.37 Drainage

Drainage arrangement must be planned with the planning of an irrigation project for sustainability. An irrigation project can survive only with an efficient system of drainage. Inefficient drainage may cause havoc in the irrigated area and may create water logging conditions leading to destruction of land and life inhabited in the area. On IGNP some 10,000 ha area is already water logged. This is due to high water allowance 5.23 cusec per

1000 acres coupled with storage of Ghaggar floodwater in depressions. As no natural drain is there, but hard pan is there at shallow depth. All these combine doubt the sustainability of this gigantic irrigation project, drainage does not mean constructing drains. This refers to drainage of seepage water below root zone so as to keep equilibrium in ground water level.

Drainage is a pre-requisite in an irrigated area as the water application efficiency seldom reach more than 50% implying whatever water is applied to the fields 50% goes in deep percolation-evaporation which in turn raises the water table. It is estimated that in IGNP Stage–II on full development nearly 0.58 m depth of water would be applied annually, along with 0.225 m rain water with 50% efficiency, 0.40 m water would go in deep percolation taking fillable porousity as 20% water would rise at the rate of 2.0 m per annum.

In IGNP there is no natural drainage, further most of the area under lain by hard formation at varying depth, worst part of the situation is that water holding capacity of the soil at present is very low. Infiltration rate varies from 11 cm/hour to 20 cm/hour indicating that the soils are sandy aeolion deposits. It is true that with the passage of time, water holding capacity of the soils would increase substantially, with the addition of green manure, silt carried by canal water and it is also true that with, land grading and shaping and with better water management, field application efficiency would increase substantially resulting increase in cultivated area. But, by the time water table may reach in some area at point of no return. Initially the intensity of irrigation is hardly 20% with the use of 40% water. The water use efficiency is hardly 10% to 15%. Thus, resulting rapid increase in water table and creation of water logging in some area where barrier is at shallow depth. So, initially water in the canals should be released on the basis of actual area under irrigation.

The solution of drainage problem may be Individual based and Institutional based: individual based may be (i) drip irrigation/sprinkler irrigation (ii) conjunctive use of ground water and (iii) Bio-drainage

Sub-surface drainage/surface drainage seems to be neither feasible nor economical. Further it is difficult to maintain them. In water shed areas generally natural drains are there, out falling in the main drain that serves the purpose of drainage.

Conjunctive use: Various agencies has advocated the conjunctive use of ground water but with caution. The pumping of underground water in to canals is a highly sensitive issue as the ground water is brackish of high E.C. value ranging up to 25,000 m mhos. Where as the E.C. of canal water is with in 250 m mhos. Blending ground water with canal water requires utmost care. Any contaminated water pumped into canal may create serious health problem, for human, cattle and crops as well. Further, pumping ground water of higher E.C. would affect the crop production at tail or even turn the tail soils unfit for cultivation due to application of saline water. It is practically difficult to check the quality of water being pumped into canal at every point and at every short interval of time. Before implementation of such a risky proposition a thorough study is needed. However, individual may blend or directly use ground water when canal supplies are short.

Reduction in water allowance: In north west Rajasthan most of the area served by canal, with water allowance of 24.5 lit/sec/100 ha to 17.5 lit/sec/100 ha (3.5 cusec/1000 acres to 2.5 cusec/1000 acres). The region where water allowance is more than 24.5 lit/sec/100 ha water table is rising exponentially.

On IGNP a decision to opt 14 lit/sec/100 ha water allowance on lift canals has been taken. As written earlier, most of the area under flow on right side of canal is lower than the FSL of IGMC, even then the CCA is just 60% of GCA and less than 50% of geographical area. The present basis of determination of CCA (Refer chapter 7–11) is going to create big demand from cultivator for uncommand to command. The present CCA of 7.0 lac. ha is bound to increase more than 8.5 lac. ha in flow area in stage IInd of IGNP. Moreover, the fundamental objective of mega projects is extensive irrigation, which should not be lost by sight. As the cultivators are not using the canal water judiciously as they do not take canal water like any other inputs for their crop production. Recently, CADA has started drip/sprinkler irrigation incentive schemes. Under the scheme a subsidy of Rs 50,000 is given to construct a tank of 8.0 lac. liter capacity with pumping and for other sprinkler set requirements. An interesting phenomenon was noticed during scrutiny of applications. Most of the applicants requested to construct the diggies/tanks ranging from 15 lac. liter to 50 lac. liter capacity, although the subsidy was limited to Rs 50,000 indicating that basis of 21 lit/sec/100 ha (3 cusec/1000 acres) water allowance is higher. As more and more area is to be brought under command by the farmers and big hike in canal water requirement would be there. A water allowance of 17.5 lit/sec/100 ha would be more realistic.

Although this water allowance of 17.5 lit/sec/100 ha giving delta of 0.375 meter plus 0.225 meter rainfall with an efficiency of 60%, 0.30 meter water would go in deep percolation there by raising the sub soil water table by 1.5 meter per year (assuming fillable porousity at 20% average).Even then drainage may be required at one stage, if water balance is not maintained.

Drip irrigation/Sprinkler irrigation: The adoption of drip irrigation/sprinkler irrigation can minimize the requirement of drainage as well as optimum use of scarce water resources. For this farmers have to be trained and educated with respect to land, shaping and leveling for optimum use of water, in crop production. All these would result in an increase in crop production. In the initial stage there may be problems of funds, but in overall this proposition is better with respect to sub-surface and surface drainage.

Bio-drainage: This has proved to be very effective. A lot of area, which was water logged, was dried through plantation on many projects.

In fact, water logging at some places along with the Main Canal and Branch Canals is due to miss-management of the Canal water. It is mainly due to running of unchecked direct outlet/syphones from these canals.

Bio-drainage is effective, productive, remunerative and also improves environment as well.

As per Rajasthan Colonization (General Colony) Conditions, additional covenants for Tenancies 20 (9) Plantation of trees. "An allottee is to plant 125 plants per square (Murraba) and shall ever maintain that number in good condition". If these plants are grown and maintained as per requirement of law water balance can be attained and drainage may be postponed indefinitely. Suppose there are 125 plants in a square (250 × 250 m) and each plants exposes a canopy of 25 sqm (after three or four year).

Water applied per annum = 250 × 250 × 0.8 × 0.48

in one square = 24000 cum

(Assuming Δ = 0.48, efficiency = 80%)

Water going under deep percolation = 24000 × 0.3

(30%) = 7200 Cum

Likely moisture loss by plants = 25 × 125 × 1.78 Cum

(Assuming ETc as 1780 mm)

= 5562 Cum

Net deep percolation = 7200 – 5562

= 1638 Cum/Square/Annum

$$= \frac{1638 \times 100}{250 \times 250} \text{cm/annum}$$

= 2.6 cm/annum.

Assuming 20% fillable porosity, the rise in water table would be 13.0 cm per annum.

(As per LAHIRI & KUMAR Approximate annual moisture loss stand of Prosopis cineria is 44.29 cum per tree, on this analogy moisture loss by 125 tree is approximately 5536 cum)

1.38 Conjunctive Use of Ground Water

As stated earlier pumping ground water into canal may create problems of far-reaching consequences. It should be better to study all the aspects before implementation. However, if ground water is used by individual farmer, it would be more economical—and less risky. As per logs of deep bore holes in western Rajasthan reveals that static water is at 100 m b.g.l. (below ground level) at most of the places. In between are layers of sand-sandkankar, sand witched between clay and kankar layers of varying thickness. On an average more than 50 m sand and kankar layer is there in 100 meters, the porosity of these layers of sand/sand kankar formation is more than 20%. On an average, that is to say nearly 10 meters of water column can be stored in these layers and which can be used by individual farmers. This can be done by constructing a deep well by the individual farmer in his field at the lowest place and connecting this well through a network of small underground drain constructed 1.5 m b.g.l. The arrangement can be in such a way that well masonry be honeycombed and upper 1.5 m be covered with a vent hole. Pumping arrangements may be there as per requirement.

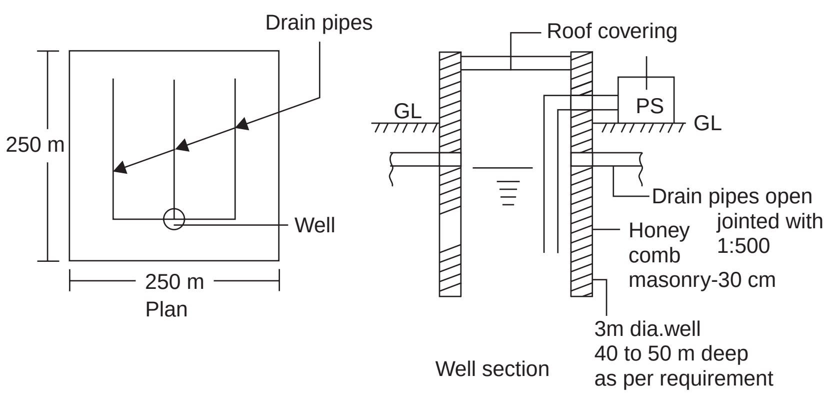


Fig. 1.9 Conjunctive Use of Ground Water

1.39 Hydrological Barrier

Less previous layer/barrier layer are synonymous. An irrigation project greatly depends upon the soil formation of the area under command. Where the barrier layer is within 1.5 m below the surface, practicing agriculture is difficult. A minimum 1.5 m depth is required for free airation of the root-zones for most of the crops. Any accumulation of the water within root zone (1.5 m) would hamper the growth of the plants resulting poor or no crop production at all. With the induction of canal water in the command water table starts rising. The reason being deep percolations of a part of applied water. The efficiency in gravity flow, application seldom reaches above 30 to 40 %.

The water application efficiency may be defined as consumptive use of water by the crop to the water applied to the crop.

$$\text{Efficiency} = \frac{\text{Consumptive use of water by the crop}}{\text{Water applied to the crop}} \times 100$$

When water is applied to a crop more than 30 to 40% of the applied water goes in deep percolation. This water going in deep percolation raises the sub soil water level. Unless remedial measures are not taken timely, area may become water logged and soil salt may come on surface, resulting the area unproductive and waste.

The remedial measure may be in the forms of:

1. Judicious application of water to the crops.
2. Sprinkler application of water to the crops.
3. Drip water application.
4. Drainage of sub soil water Bio-drainage.

In case of 1 and 2 above water logging period be graced for some time, but cannot be delayed altogether. In the case of 3 above, water balance can be maintained but the application of water through drip is very costly and requires skilled manpower. So use of drip irrigation is not picking up universally.

So in all cases drainage of sub soil water is a must for sustained irrigation practice. Construction of drainage is highly expensive as well as land wasting proposition for disposal of drained water. Therefore, before taking any irrigation project, soil characteristics from agriculture point of view as well as from barrier layer, be well ascertained for sustainability of the project.

Generally, area may be classified in two categories from storage point of view of the deep percolating water. This classification is based on the co-efficient of permeability of the soil formation. This co-efficient of permeability is also known as Hydraulic Conductivity. The classification is based where the hydraulic conductivity is less than 0.2 m/day and where the hydraulic conductivity is more than 0.2 m/day. Water allowance–cropping pattern may be suggested on this basis. Drainage too may be suggested on the above basis. Broadly a layer having hydraulic conductivity less than 0.2 m/day is termed as hard pan or hard layer. Not much emphasis is given on the thickness of the soil lense. More the thickness more the resistance, less the permeability, whereas less the thickness less the resistance, more the permeability, comparatively. Further a dry formation over lain by saturated formation creates high negative pressure resulting flow in the barrier layer. The sucking pressure or negative pressure may be as high as 10 m/sq. cm or so. Further hydraulic conductivity increase with the passage of time, when soil over the barrier remains saturated.

So the definition as adopted above for land use pattern would need changes from time to time. Further the area, which may have any barrier layer at shallow depth, may not act as a barrier in the time to come. It may always be kept in mind, any irrigation project is not confined for a period of 20 to 30 years, particularly major and medium irrigation projects extend for more than 100 years. So our planning may be on the basis of likely change in the coming years, not only its meteorological changes, but likely water availability, crop water requirement, land availability, consumptive use, etc.

The definition as propagated by USBR is more realistic. Barrier layer is one, which has a hydraulic conductivity value one-fifth or less than that of the weighted average hydraulic conductivity of the layers above it. Below table shows the barrier layer computation.

Table 1.9 Barrier Layer Computation

Sr. No.	*Depth in Feet*	*Kp Hydraulic conductivity, in/h*	*Kp weighted hydraulic conductivity in/h*	*Kp × 5 compared with Kp of layers above*	*Remark*
A	4–9	1.2	1.2		
	9–14	0.5	0.85	0.5 × 5 = 2.5 > 1.2	
	14–15	0.2	0.79	0.2 × 5 = 1.0 > 0.85	
	15–20	0.1	0.56	0.1 × 5 = 0.5 < 0.79	Barrier

Contd.

Table 1.9 (Contd.)

Sr. No.	*Depth in Feet*	*Kp Hydraulic conductivity, in/h*	*Kp weighted hydraulic conductivity in/h*	*Kp × 5 compared with Kp of layers above*	*Remark*
B	4–9	1.6	1.6		
	9–14	0.5	1.05	0.5 × 5 = 2.5 > 1.6	
	14–15	0.2	0.98	0.2 × 5 = 1.0 < 1.05	Barrier
	15–20	0.1	0.70		
C	4–6	0.1	0.01		
	6–13	1.5	1.20	1.5 × 5 = 7.5 > 0.01	
	13–17	0.2	0.89	0.2 × 5 = 1.0 < 1.2	Barrier
	17–20	0.1	0.74		
D	4–9	1.9	1.90		
	9–14	0.5	1.20	0.5 × 5 = 2.5 > 1.90	
	14–15	0.2	1.10	0.2 × 5 = 1.0 < 1.2	Barrier
	15–20	0.1	0.80		

(1 inch/hour – 0.61 m/day)

From the analysis of four areas where H.C. was observed at different depth of formation, it reveal that barrier layer may be one having H.C. of 0.06 m/day at one place, and at another place barrier layer may be one having H.C. as 0.12 m/day. In the third case the upper formation having hydraulic conductivity, as 0.06 m/day is not a barrier layer, this is attributed to the thickness of the layer. So the two deciding factors are the hydraulic conductivity of the upper formation and depth of the formation having low hydraulic conductivity.

1.40 Water Harvesting

There is nothing like water harvesting. This is a misnomer. In fact this implies collection of rain water for drinking and agriculture purposes. This collection of rain water is practicised from time immemorial life can not be sustained without water.

The collection of rain water was based

1. Individual
2. Institutional–community

Individual

Persons with resources use to construct under ground tanks in their own houses. Rain water was collected in these tanks from roofs as well as from surroundings.

Institutional–Community Based

Larger tanks, well and bands were constricted to meet this drinking water requirement of the community at large, as well to meet the requirement of cattle and house hold chores.

In the past this practice was viable as overall water requirement for drinking, house hold chores was very less. Eight to ten liter water was more than sufficient per head. Further population intensity was also very low. Industrial water consumption was nominal. Further most of the settlements were near the streams-rivers or where water table was near the surface.

But in the present circumstances this system of water collection may not be viable due to heavy water requirement for individual as well as for community as a whole and industries.

Roof top water harvesting—In the middle of year 2000 Central Ground Water Board has mooted a project "Simple solution of water scarcity, Roof top rain water harvesting". A sum of Rs 25 crore were get earmarked for this project to be given as subsidy. The idea might have been conceived to grab this amount by influential persons having spacious bangalows, as this amount was to be given as subsidy. The ground reality is in towns, cities and metros most of the people are living in multi story building–further a big population is living in Jhuggis and on footpaths. So there is no roof–no water harvesting. Even in spacious bangalows such a scheme if implemented to collect the rain water, the cost per liter may be around Rs 4.0 per liter (Source–simple solution not so simple R.N. Agarwal) with the added risk, if any rodent get way into the tank, that would be suicidal for the user's and may cost dearly.

With the passage of time water–requirement would go on increasing and as a long term solution, medium and large dams be constricted to store the water. Inter linking of rivers seems to be the only alternate in India, to avoid any rain water going waste in the form of floods due to heterogeneous monsoon rainfall.

1.41 Village Service Area (VSA) Irrigation Practice

Propagated in some area. VSA irrigation practice envisages construction of a miner–canal for each village, to serve an area of around 500 ha, having 5 to 10 outlets. This canal is proposed to be maintained by water users association, including collection and deposition of revenue, setting water disputes, etc. The idea is to make farmer's participation in water management. Such a practice can be implemented on small local bands. But implemen-tation of such a practice on medium and large projects may be suicidal.

1. The alignment of canals must be planned based on topography, to irrigate maximum are with least length of canal, implying least conveyance losses. Where as, if VSA practice is adopted, canal length may be too high per ha of CCA served. It may be noted that canal losses accounts more than 15% of the head discharge (In case of lined canal system). If for every village of nearly 500 ha a minor/canal is constricted, the losses may be more that 20% and capital cost of construction may increase by 25%, as there would be so many minors/canals parallel to the distributary. Further it may be kept in mind capital cost of construction is a one tim factor, but conveyance losses would be for all times to come.
2. Taluka Village boundary has no sanctity at all. What to talk of taluka or village, state boundaries, district boundaries goes on changing. In case of Gujrat—Gujrat come into existence only in May 1960 after re-organisation of Bombay state. At that time there were 9 or 10 districts, in 1975 there were 19 districts, and now in 2004 the number of districts has gone to 25. Similar is the case with talukas and villages. With every settlement survey new village comes into existence. So village boundary ha no sanctity.

   Canals must be planned and designed according to the topography with the cardinal principle–least length of canal to serve maximum area.
3. The system as adopted in northern India is a unique example of the joint state/farmer's management of irrigation system where in a state is responsible to manage water upto outlet head and farmers are to manage further distribution below outlet. This system is working very satisfactorily from last hundred years. (See Warebandi)
4. In village service area—there is every apprehension that might is right may play the guiding factor.

2

Survey Requirement of Canal Projects

2.1 Introduction

The aim of irrigation project is to bring water by gravity/lift flow from its source (Dam, Diversion head works, river, etc.) through a system of canals (Main Canal, Branch Canal, Distribution system) to the fields and subsequently through water-course to cultivator's field. For this, detailed contour maps are invaluable, firstly for the general feasibility planning of the project as a whole, secondly for estimation of individual component of the canal project.

The irrigation channels are necessarily located on the watersheds of the country traversed so that water may reach the desired fields with ease and with minimum expense. To finalize the alignment of Main Canal down to minors and sub minors, complete mapping cover of the area is a must. These maps should preferably have the village and cadastral boundaries marked over accurately to assess the land acquisition. Stony waste, forest, grazing reserve should also be marked distinctly.

The survey maps should be prepared after framing a definite survey policy. Keeping in view the three-stage requirement of a canal project, i.e.,

- Planning as a whole and then whole to part.
- Execution of individual component—Main Canal, Branch Canal, Distributary, etc.
- OFD works and field application of water.

IGNP covers nearly 35,000 Sq. Km of Thar Desert of Western Rajasthan. The desert area is highly undulating, cup shaped surrounded by high dunes. To plan a canal network in such an undulating area requires survey maps of high precision depicting all the topographical features.

2.2 Impact of Irrigation Projects

An irrigation project may be including a dam, barrage, diversion head works canal network. These should be planned on a long-term basis of not less than 100 years. Impact of likely change in environment, ecology, inhabitation, and economy must be studied in detail and a forecast blue print should be prepared. As the cost of construction of irrigation project involves crores of rupees. Any ill affect may create problem and jeopardize the whole planning and expenditure.

In a canal project, following are likely ecological and environmental changes, which must be studied and forecasted and incorporated in the planning.

(A) With the invent of canal water in the area the most important change envisaged is in topography and in meteorology. As the lands are limited, farmers tend to level their fields to bring maximum area under command and to have maximum use of available water. Land leveling not only increases command but also greatly benefits in water application through gravity flow. In arid zone particularly in Western Rajasthan where the lands are cup shaped, initially 5 to 10% intensity of irrigation may be there due to undulation. This intensity of irrigation goes on increasing with the increase in land leveling and land shaping. In Bhakra and Gang Canal area, which were once highly undulating arid zones and were parts of great Thar desert, is now completely leveled in a span of 20 to 25 years. The intensity of irrigation, which was just 5% in the beginning, has now reached to more than 100% against the envisaged 65 %. At some places the intensity is more than 150% as the farmers are using ground (tube well) water to augment the canal supplies.

So, while planning canal network the aspect of change in topography must be kept in mind.

(B) The second important change is in meteorological environment change. There is a sea change in rainfall, humidity, sand storms in Western Rajasthan over a period of last 10 years with the invent of canal water. These changes have direct bearings on the crop water requirement. With the passage of time crop would require less water and farmers would also get ground water at shallow depth to augment the canal water supplies. This ground water not only augments the canal water supplies but also an assured supply in case of any failure in canal supplies.

1. With the induction of additional water in the area of command, ground water table would start rising and a stage may come, when ground water may rise affecting plants root zone (generally root zone is taken as 1.2 m to 1.5 m below ground level). A balance is to be maintained to check the rise in water table. This may necessitate drainage system in the area of command.
2. With the increase in agriculture production, agriculture based industries are likely to come up, needing more water for industries.
3. With the availability of assured water, mineral and other medium and major industries may come up requiring more water.
4. With the induction of water, water bound diseases may crop up.
5. With the development of the area, there is every chance for the destruction of the flaura and fauna of the command area.

2.3 Survey Maps

Survey of India develops aerial survey maps with the help of ground controls. These maps are general-purpose topographical maps depicting broad features. These maps are on 1:250000 scale called one-degree maps. One map covers nearly 12300 sq km area surrounded by one-degree longitude by one-degree latitude. The area covered depends upon the location, near the equater, maximum area is covered where as near the poles, minimum area is covered.

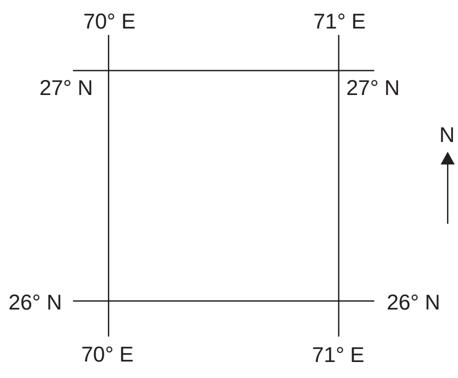


Fig. 2.1 One Degree Map

These maps of 1:250000 scales can be used as guide maps for the area. These are available with SOI for the whole country and can be obtained on specific request. Some times these maps are termed as 1/4'' maps. These one-degree maps are further developed into fifteen-minute maps on 1:50000 scales. These maps are updated as per the requirement of concerned department. These maps can be used for broad feasibility and reconnaissance survey of the area. These are also available with SOI as well as with authorized SOI distributors.

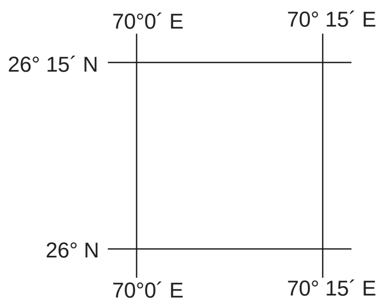


Fig. 2.2 15 Minute Maps

Accurate survey maps not only ensure correct planning construction, or position of structures but also ensures correct estimation of the project. For a minor irrigation scheme, locally surveyed maps serve the purpose, if required additional survey can be carried out as per requirement. But for mega project like IGNP covering more than 3.5 million ha area with a canal network of more than 7500 Km, commanding more than 1.5 million ha area, a definite survey policy is a must, otherwise whole planning would crumble. (Refer Chapter 3).

For such a gigantic canal system covering highly undulating and hostile warm desert, survey policy must be based to cater the requirement of the three stages as narrated i.e., Planning stage, Execution stage and finally OFD water application stage. In addition to this, pre-planning survey requirement may be different for different areas.

2.4 Rectangulation Survey

One of the methods, which have been very successful for major canal projects, is Rectangulation Survey. This process was usefully adopted on Gang Canal, Bhakra Canals and Sind Canals (now in Pakistan).

Rectangulation is a process of dividing portion of land into sub rectangle square of fixed size by accurate method and demarcating their corners with permanent marks. The process is useful not only in providing suitable rectangles for distribution of land on consolidation of holdings but also in providing a suitable frame work for surveying, leveling and preparation of contour maps. Some of the main advantage from irrigation settlement and revenue point of view are:

1. It provides field of regular size and shape for allotment.
2. Ensures economical and efficient use of water.
3. Simple and easy way of preparation of irrigation record.
4. Ensures economical planning of canal system and water-courses.

2.5 Implementation of Irrigation Projects

The Major and medium canal projects are implemented in three tier:

1. Planning of canal network with chak planning.
2. Construction of canal network, and
3. Construction of OFD works.

These three phases are although inter-linked, but in fact, they are equally independent in nature. The survey map requirements with details are different for the different phases.

The three stages of implementation of a gigantic canal project, the survey requirements are different. At planning stage the requirement is for the project as a whole right from the beginning to tail, all maps should be as per minimum requirement of canal planning, not only the details be depicted on the maps, but the requirement of suitable scale should also be ensured.

It should be borne in mind, survey is a specialized, time consuming, labour oriented job unless the survey map requirement of the project is ascertained before-hand, a lot of money and time may go waste in repetitive surveys in the field as well as in preparation of survey maps. This also creates confusion and leads to wrong planning and construction.

In India, Survey of India is prime organization entrusted with the job of topographical survey. SOI conducts topographical surveys as per the States' policy of country as a whole. This is generally aimed surveys and their development with ground control and conventional surveys in the field. Recently a new technique based on remote sensing photography is being practiced. This is done with the help of satellite. The imageries prepared by remote sensing method give reasonably fair pictures of the area. These imageries can be used for assessment of forest and other natural resources. As far canal planning is concerned, the imageries have a very limited role to play. These imageries are certainly very useful to compare pre-project and post-project scenario of the region. But the accuracy is $\pm$ 10% although that depends upon the agency interpolating the imageries.

In a canal project like IGNP, where extensive irrigation is the basic theme, proper survey maps are must, to have optimum use of the scarce water. In major canal project, where extensive irrigation is practiced, canal planning has two aspects. Firstly, to cover the maximum command area, at least cost of canal construction. Secondly, the outlet size and position should be such that the OFD works may cost minimum. The outlet size is directly related with the area commanded under the outlet. Here, this area is termed as ‘Chak’. Thus, at planning stage the two aspects, minimum canal length to cover the maximum area, and the chak size, so that the cost of OFD works is minimum is kept in view. The two aspects are vital not only from the cost of canal net work and OFD works but also from the saving of seepage loss from the canals and OFD works as well. Seepage losses are directly proportional to the length of canals, and OFD works.

2.6 IGNP Survey

In IGNP rectangulation survey method is adopted on the pattern of Gang Canal and Bhakra Canal. In this system area is first divided into blocks of 25 mile × 15 mile representing one block and is designated with one alphabet along with a numeric such as A1, A2, A3 or B1, B2, B3, and so on. This block is further divided into 10 sub blocks of 7.5 mile × 5 miles and is designated with No. 1 to 10 of that block. The topographical surveys of block 7.5 mile × 5.0 mile is depicted on one sheet measuring $20'' \times 30''$ (Scale 1:15840) and are marked as A2 1. A2–2 … A2–10. This sub block of 7.5 mile × 5.0 miles is further divided in square of 1000 acres measuring 1 ¼ × 1 ¼ mile. Thus every sheet covers 24 squares ($6600' \times 6600'$) of 1000 acres. Each block is further sub rectangulated in 64 squares measuring $825' \times 825'$. For OFD works planning each sub block of $825' \times 825'$ is further divided into $165' \times 165'$ square and surveyed. This square of $165' \times 165'$ is locally termed as one bigha (0.625 acre) (1 standard acre = 43560 sq.ft.). FPS system was prevalent before switching over to MKS system).

The rectangulation (25 mile × 15 mile, 7.5 mile × 5 mile and 1 1/4 mile × 1 1/4 mile) and topographical survey including rails, roads, quarries, villages, ponds, rivers, forest lands, etc. was done by SOI and sheets were prepared on 1: 15840 scale. The sequence of sheet is as under:

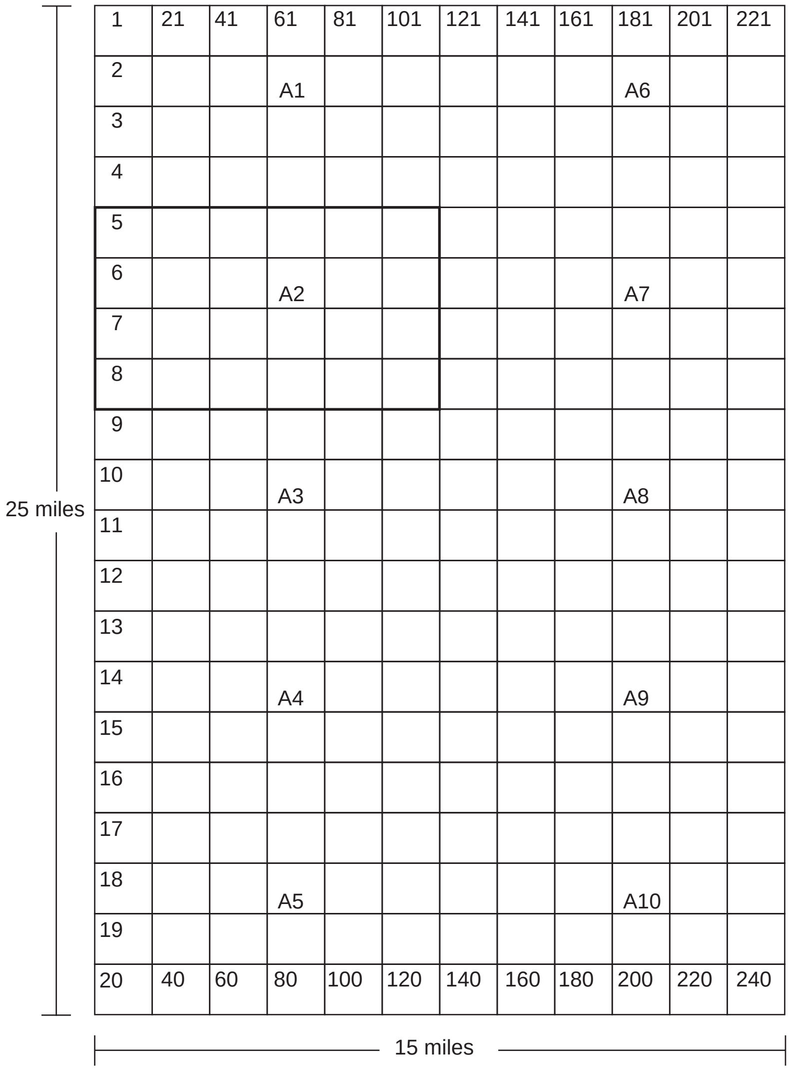
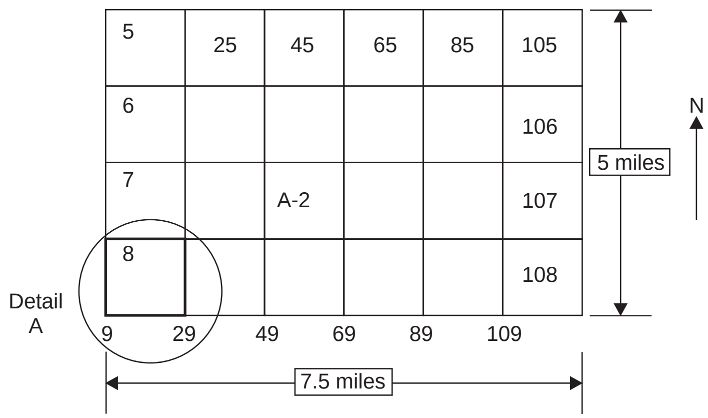
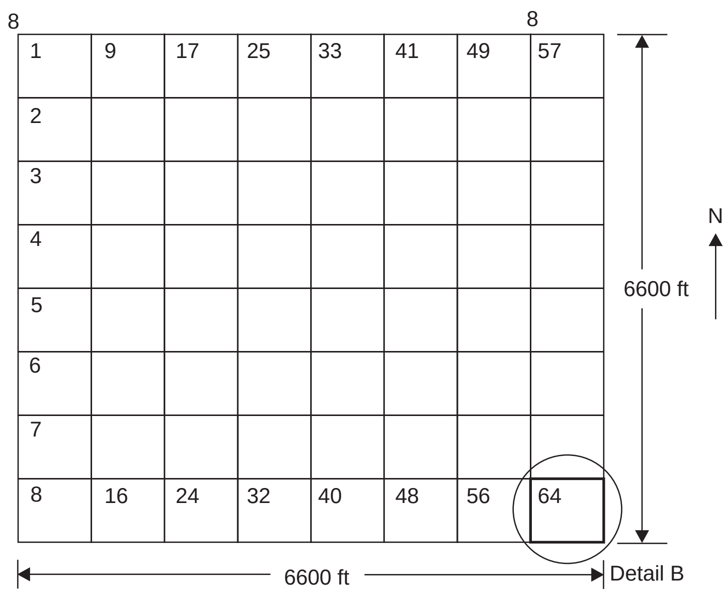


Fig. 2.3 Arrangement of Survey Sheets



G.T. Sheet 7.5 × 5 Miles
Showing 1000 Acres Block



Detail A

Block 1000 Acres showing sub Sq 825 × 825 – 1 to 64

Fig. 2.4 Rectangulation and Sub-rectangulation

Stones are fixed at the north-west corner of each sheet, block and square (murraba). Number's are marked with paint or engraved such

$A-2\frac{8}{64}$, indicating sheet No. A-2, block No. 8, and square No. 64. Thus stone at north-west corner represent that square.

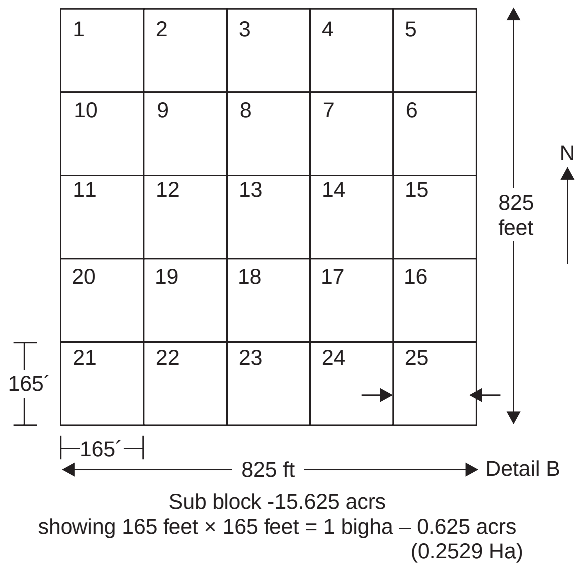


Fig. 2.5 Bighas in a Sub-rectangle

In rectangulation survey whole area is divided in squares of $6600' \times 6600'$ (1000 Acrs), then $825' \times 825'$ (15.625 Acrs) and finally in $165' \times 165'$ (0.625 Acrs). This system is best suited for new canal projects as well as CAD projects, as stated earlier. Presently survey and sheets are referred in Mks, keeping the size same.

On Sardar Sarover Narmada Project which is one of the biggest canal project of the world. Survey has been done on the same pattern as stated above by SOI. Survey sheets were prepared on the same scale of 1:15840. Each sheet covering an area of 12542 ha (30991.7 acres) measuring 15000 × 10000 yards. Nearly 780 sheets were prepared covering 98000 sq km area.

2.7 Survey Requirements

Initial Planning: Planning canal network and chaks are complimentary but the survey requirement for these may be different. For planning canal network, two types of survey maps may be there. One for planning the system as a whole. These survey maps may be on 1:50,000 scale with contour intervals of 2.5 m to 5.0 m including other ground features such as road, rails, village, forest may be marked. These maps broadly depict the topographical features and greatly help in canal network planning systems as a whole. From these maps of 1:50,000 to 1:1,00,000 scale one can easily understand the broad topographical features and can define and identify likely vallies and ridges while planning canal network. These maps of 1:50,000 to 1:1,00,000 scale gives the birds eye view of the whole area under planning.

However, these maps of 1:50,000 to 1:1,00,000 scale may not be used for detail planning of individual canal. Detail canal planning involves, canal planning as well as individual chak planning. For detail canal planning maps on 1:50,000 to 1:1,00,000 scale may be misleading.

Detailed Planning: For detail planning of canal network survey maps should be on 1:10000/1:7500 scale depicting complete topographical details, as well as furnishing the requirement of construction phase. At planning stage some of the information as depicted on 1:10000/1:7500 scale may not be required, such as location of Bench-marks, trees, pond, kutcha tracks, etc. But these may be necessary for the detail planning stage as well as construction stage.

As these maps of 1:10,000 scale or 1:7,500 scale are the base maps for individual canal system planning, so all the details required for canal construction may be surveyed and depicted on these maps. During detailed planning of canal system, the two aspects, least canal length for maximum area with chak size so that cost of OFD works may be minimum be kept in mind. For correct assessment of the CCA as well as for detail planning of alignments, contour interval of 0.5 to 1.0 m should be there, rather it would be better if contour interval is lowered up to 0.25 m.

As stated earlier in general survey sheet of 1:15840 or 1:15,000 scale (4″ : 1 mile) are got prepared by SOI. These sheets neither serves the first phase of broad planning being too small (one sheet covers nearly 10,000 ha area) and becomes difficult to have an over view of the whole planning nor serves the requirement of detail chak and canal planning being scale is too large and contour interval of generally 2.5 m to 0.5 m resulting resurvey of the whole area at the OFD and construction stage.

Presently, in most of the major and medium canal projects, three stage field surveys are being carried out. First by SOI. Topographical survey sheets are prepared, which includes triangulation of the area, fixing block stones at suitable grid, spot level contouring (based on plane table and calinometer). The contour interval is kept 0.5 m to 2.5 m in plane area, 5 m to 10 m in undulating area. Primary, secondary D.T./S.T.. B.Ms are also fixed at suitable locations along tracks. Survey of important features of permanent nature is also carried out. Important information regarding village, tehsil, and district boundaries are taken from revenue authorities for incorporation in the maps.

Besides the above survey sheet prepared by SOI on 1:15840 or 1:15,000 scale, following surveys of the whole area is done by the department or through other agencies:

Sub Rectangulation of the whole area with $825' \times 825'$ squares (called Murabba), fixing stones and numbering at each corner.

The sub rectangulation fixing stone and their numbering is the requirement for construction and also the requirement for Colonization and Revenue Departments. In case where rectangulation survey is not carried out, survey in individual holding of the village is carried out.

Before construction canal alignment, survey is carried out for the preparation of longitudinal section of the canals. Battery of B.Ms is further fixed along the alignment of canal for execution of canal and hydraulic structures.

Further, whole area is again surveyed to meet the requirement of OFD works. Maps are prepared for the individual chak/village (area under one outlet) on 1:5000 or 1:1000 scale.

The present three-phase survey on mega projects, not only costs dearly but also creates problem of overlapping, and non-matching besides consuming lot of time and manpower.

On mega projects survey sheets prepared by SOI on 1:15840/1:15000 scale is not suitable for broad base planning, being too big in size and in numbers. In IGNP there are some 350 sheets.

So, one cannot have the over view of the general topography of the area. It also becomes very difficult to handle such a large number of maps. These survey sheets are also not suitable for detailed chak/canal planning as the contours are on the basis of spot levels (calinometer heights) and not on the basis of grid levels. As there are no grid levels it becomes difficult to ascertain correct CCA, resulting re-survey of the whole area at the time of execution of OFD works.

The survey sheets of 1:15840 or 1:15000 scale does not cater the requirement of canal construction stage. As canal alignment has to be marked in the field and levels are observed at suitable interval with fixing of BM's.

Conclusion

For detail planning the maps should be on 1:10000/1:7500 scales. Contour interval should be 0.5 m to 2.5 m in plain area and 5 m to 10 m in undulating area. Stones should be fixed at suitable location and be D.T. leveled. Levels should be depicted on survey sheets. Other ground features like road, rail, tank, holding village, tehsil district boundary should be shown.

From these maps for broad planning another maps of 1:50,000 or 1:1,00,000 scale must be prepared depicting contours at 5.0 m and 10 m interval along with important features. One time survey would serve the purpose of three-phase implementation of canal project.

3

Planning Canal Network

3.1 Introduction

Planning canal network on a system with extensive irrigation approach, requires high sense of accuracy. On IGNP, particularly in Stage II, which covers nearly 25 lac ha of Western Rajasthan adjoining Indo–Pak, border. The area is very harsh topographically, environmentally and socio-economically. The main problem is the scarcity of water, which can be judged from the fact that the area has the lowest precipitation of the country 125 mm to 200 mm per annum. (All India average of last 20 years is 430 mm) The ground water is 50 to 100 m deep and that too is brackish except a few perched rainwater pocket-bodies.

In view of the above situation, there is utmost need for the well planned and proper use of IGNP water which has traveled a distance of about 1000 Km to quench the thirst of great Indian Thar Desert. Every drop of this Himalayan water is scarce. Therefore, planning envisage optimum use of every drop of the scarce water.

Planning a canal system, depend inter alia on topography, hydrology, soil, climatology of the area, but topography plays an important role as far as gravity flow planning of canal network is concerned. While planning canal network general criterion kept by the planner in mind is to negotiate the heavy cutting and heavy filling. Heavy cutting and filling can be avoided either by increasing the canal length, at the cost of command area. Generally, the latter is sacrificed by providing falls.

3.2 Length of Canal Per Hectare of CCA

Capital cost of execution, is a one time factor however, maintenance cost, operational cost, along with seepage and evaporation losses are recurring for all the time to come. All these costs are directly related with length of canal system.

Therefore, planning of such a big system like that of IGNP needs utmost care. Some important points affecting the overall cost of the project should be decided at hand before finalizing the canals individually and as well as system as a whole. As already stated one of the important factors is the length of the system.

As the length of canal system is directly related to the cost, hence, utmost exercise should be done to reduce the length of the canal system.

Length of the system mainly depends upon the following two factors:

1. Shape and size of chaks.
2. Percentage of CCA/GCA

Shape of the chak mainly depends upon the topography, but it may depend upon the intensity of irrigation that is water allowance. In stage II of IGNP mostly the soils are sandy, thus, a chak of discharge less than 50 liter/sec is not preferred. In stage II where the water allowance is 0.209 lit/sec/ha average chak size comes to 240 ha. Whole area of IGNP is divided into sub. squares of 251.46 × 251.46 m (825 × 825 ft). Whatever may be the shape of the chak, length of water-course remains the same for a particular size (as shown in Fig. 3.1). But from operational and maintenance point a chak of 2.4 km length is quite satisfactory. Assuming both side chak of average 240 ha and length of 2.4 km then length of canal is 1.0 km.

$$\text{Length of canal per ha of CCA comes to } \frac{1000}{480} = 2.08 \text{ m/ha}$$

Length of the system also depends upon the percentage of CCA on the system.

Therefore length of system is:

1. Directly proportional to the size of the chak i.e. CCA.
2. Inversely proportional to the percentage of CCA and GCA.

Therefore

$$\text{Length per ha of the system} = K \frac{2.08 \times \text{GCA}}{\text{CCA}}$$

Where 'K' constant of proportionality which depends upon length of channels, off take angle, topography, curves, etc. Value of 'K' comes 1.05 to 1.15.

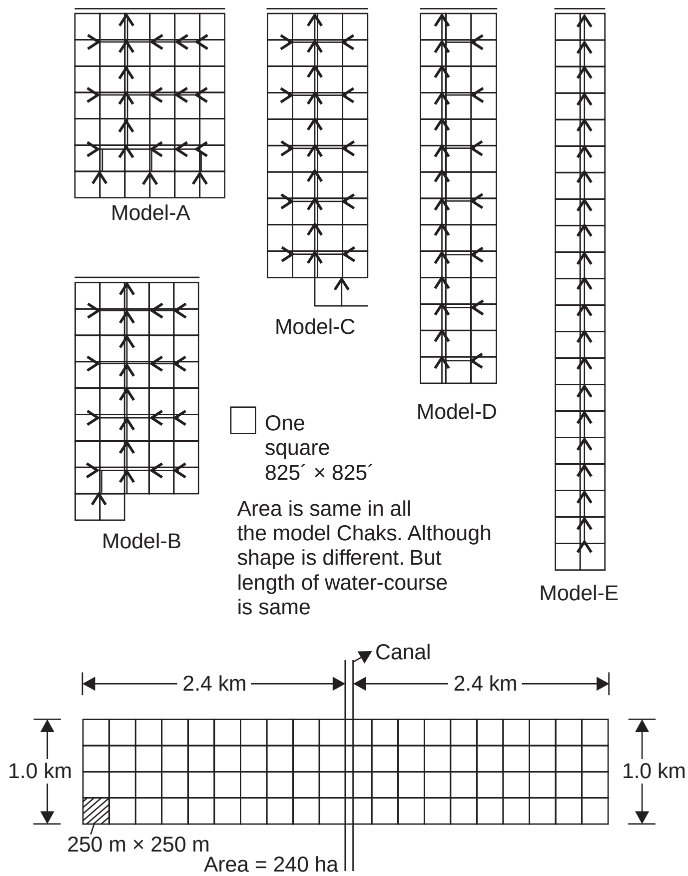


Fig. 3.1 Canal Length per Ha of CCA

Assuming 60% CCA of GCA

Length of canal per ha of CCA = 1.1 × 2.08/0.60 = 3.81 m.

Length of the channels per ha of CCA as per 1987 Project report of IGNP stage II is as under:

Table 3.1 Length of Canals per Ha of C.C.A.

Name of System	*Length (Km)*	*Length per ha of CCA*	*Length as per Relation*	*Excess Length*
Dattor Disty Sys.	137.75	7.55	6.43	17%
Barsulpur Br. Sys.	224.26	4.78	3.85	24%
Charanwala Br. Sys.	410.03	4.23	4.17	15%
Shahed Bubal Shakha System	397.11	3.89	3.30	18%
Sagrmal Gopa Shakha Tail System	1547.35	4.59	4.14	11%
Total	3085.47	4.59	4.0	15%

Above table reveals that nearly 15% extra canal length has been planned and executed.

Sometimes, it is argued that higher length of canal system per ha of CCA gives saving in the length of water-courses, this is not correct. Whatever may be the shape and size of the chak, length per ha of water-course will remain the same under similar conditions.

The general rule hitherto, followed by the planners of the canal system is to run the branch canals, distributaries, minors on the ridges, whereas water-courses are aligned on the slope of ridges. Secondly, as far as possible, small-scale sheets of 1:5000 to 15,000 scale are used while planning the canal system.

These two rules might be applicable for small systems covering area up to 5000 ha or so, but cannot be applied on mega projects like IGNP covering some 25,000 sq. km.

In view of the above for an efficient canal system with the utmost economy in construction, operation and to cover the maximum CCA the following points should be followed.

1. For planning as a whole system topographical sheets of scale 1:50,000 should be used with contour mark at 2 m to 5 m intervals. However, for individual system sheets of scale 1:5000 to 10,000 having contour 0.25 m to 1 m interval can be used.
2. Distributories and minors should be aligned across the ridges, where the distance between the ridges is up to 4.0 km and water-course should be aligned along ridges. However, where

distance between the ridges is more than 4.0 km, minors and sub minors can also be aligned along the ridges.

Although there cannot be a rigid rule to follow while planning big canal system, yet before giving final shape percentage of CCA with GCA and corresponding length per ha should invariably be checked for economy. It would not be out of place to mention that abnormal cutting and filling is not desirable for construction and operation point of view, but at the same time, CCA should not be sacrificed on the pretext of heavy cutting and filling. A positive view should be kept in this regard looking to the future developments in the land use techniques.

For reasonable maintenance and operation of canal system following cutting and filling may be workable and adopted.

Table 3.2 Cutting and Filling in Canals

Channel size	*Depth of Cutting (m)*	*Ht of filling (m)*
Up to 1 cumec	3.00	3.00
1–5 cumec	4.00	4.5
6–10 cumec	5.00	7.5
Above 10 cumec	7.5	10.0

The above cutting/filling has been proposed keeping in view that cost of earth works is 10 percent of lining cost in general. With the above norms the earthwork cost would be around 30 percent of lining.

3.3 W.S.S. in Canals

To save the earthwork i.e., to avoid heavy cutting and filling, falls are provided and CCA is sacrificed. Providing falls not only affects CCA but also increases the cost as well as increase in seepage losses of precious water. These seepage losses further increase the water table at a high rate. This increase in water table may be suicidal where hard pan-impervious layer is encountered at shallow depth.

Table 3.3 Conveyance Losses V/V Water Surface Slope, Side Slope 2:1

Discharge 4.25 cumec (150 Cusec)

W.S.S	*FSD (m)*	*Velocity (m/sec)*	*W.P.(m)*	*Increase in W.P. (%)*	*Increase in Losses (%)*
1:2000	1.34	0.95	6.62		
1:3000	1.45	0.82	7.15	8.0	8.0
1:4000	1.53	0.73	7.54	13.9	13.9
1:5000	1.60	0.68	7.87	18.9	18.9
1:6000	1.65	0.63	8.14	23.0	23.0
1:7000	1.70	0.60	8.38	26.6	26.6

From above Table 3.3 it reveals that in case where tail FSL is maintained by providing flatter w.s. slope from 2000 to 7000 by inserting falls there would be increase in lining cost by 26.6% and decrease in velocity by 37%. Similarly in case of 2000 to 6000 the increase in lining cost would be 23% and decrease in velocity by 34%.

Saving in the cost of earthwork by increasing the cost of lining is in no way justified, technically, economically and in the greater national interest.

General apprehension is that in deep cutting and high filling, maintaining channels would be difficult. This apprehension is not sustainable. There is no doubt, at present climatic conditions are very harsh on the western end of the IGNP. Storms are frequent in this area. But this phenomenon would not last more than 10 to 15 years. But on other mega projects, this problem may not be there.

It may be added here, with the invent of IGNP water around Bikaner, climatic condition in this region has changed drastically. Storm frequency–intensity has come down to 25 to 30% as compared to what was prevailing pre-project era.

Providing flatter slopes and falls to save earthwork is detrimental as reduction in velocity up to 30% may not be able to keep the sediments in suspension. Further, higher velocity would be beneficial in running the canals particularly to feed the tail ends.

Economically doing more earthwork means more land shaping and saving lining means conserving the national resources.

The another important aspect of providing steeper slopes is saving in precious canal water. As revealed from Table 3.3, losses have increased up to 26% in case where the W.S.S has been provided to 1:7000 in place of 1:2000. As the seepage and evaporation losses are directly proportional to the WP. any increase in WP. means increase in losses of water. Flatter slope can be provided by inserting falls at suitable locations. In case of 1:7000 W.S.S. in place of 1:2000 every Km needs 0.36 m falls. In a canal length of just 10 Km there would be a fall of 3.6 m. The cost of the fall would further increase the cost of construction along with wastage of national resources.

3.4 Side Slope

Table 3.4 Conveyance Losses V/V Side Slope, W.S.S 1:5000, N = 0.018

Discharge 4.25 Cumec (150 Cusec)

Side Slope	*FSD (m)*	*Velocity (m/sec)*	*W.P. (m)*	*Increase in W.P. (%)*	*Increase in losses (%)*
1:1	1.8	0.733	6.426		
1.5:1	1.7	0.705	7.10	10.4	10.4
1.75:1	1.65	0.69	7.47	5.2	16.25
2:1	1.60	0.676	7.87	5.35	22.47

The most economical canal section would be one having vertical side with bed width double the FSD.This is based on the principle that least perimeter gives the maximum area. But providing vertical sides is not structurally safe and feasible for higher discharge. The maximum safe depth with vertical sides of 11 cm thick brick is 0.33 m. Owing to this limitation side slope is provided to make the canal section structurally safe. Side slopes are provided on the basis of angle of repose of the soil, where canal is being constructed. In general side slope of one vertical to two horizontal is being provided. This side slope of 2:1 is in no way justified on canals below 3 cumec (100 cusec).

As already mentioned, canal losses are directly proportional to the wetted perimeter. Any increase in wetted perimeter increases the losses in the same proportion along with the construction cost. The cost is capital and non-recurring. Whereas losses are recurring till the canals are there. These losses of precious water may be 10 to 15 times the capital cost of the lining. So any increase in lining means increasing losses for all the times to come.

On IGNP Stage II out of 6100 Km canal system, 90% (5500 Km) canal system accounts for less than 3 cumec canals. These canals could have been safely constructed with 1.5:1 and 1:1 side slopes (see Table 3.5).

Canals with

1. Discharge 1.5 cumec to 3 cumec 20% — Side slope 1.5:1
2. Discharge 0.75 cumec to 1.5 cumec 30% — Side slope 1:1
3. Discharge up to 0.75 cumec 50% — Side slope 1:1

Table 3.5 Saving in Conveyance Losses

Side Slope 2:1, W.S.S 1:5000
Losses @ 0.61 cumec per MSqm of W.P

Sr. No.	*Average Discharge*	*Length (Km)*	*W.P. (m)*	*Total (W.P) (MSqm)*	*Losses (cumec)*
1.	2.25 cumec	1100	6.2	6.82	4.16
2.	1.12 cumec	1680	4.77	8.01	4.89
3.	0.35 cumec	2750	3.08	8.47	5.17
				Total	14.22 502 cusec

WSS 1:5000
Losses @ 0.61 cumec per MSqm of W.P.

Side Slope 1.5:1		*Length (Km)*	*W.P. (m)*	*Total (W.P) (MSqm)*	*Losses (cumec)*
1.	2.25 cumec	1100	5.59	6.15	3.75
Side Slope 1:1					
1.	1.12 cumec	1650	3.90	6.44	3.93
2.	0.35 cumec	2750	2.52	6.93	4.23
				Total	11.91 cumec 420.60 cusec

(MSqm of W.P. = 10^6 sqm of wetted perimeter)

Saving in losses comes to 2.21cumec (Above 16%)

As detailed in table above by providing side of 1:1 in small channels up to 1:5 cumec and 1:5:1 in medium sized channels having discharge between 1.5 to 3.0 cumec lining cost can be reduced by 16 to 22% and saving in losses can be effected up to 19%. Saving of 2.21 cumec of water may irrigate some 9500 ha area.

The side slopes should be selected on the principle that there should be no stresses on lining. Lining should be laid as far as possible on the natural slope of the sub grade and angle of repose of the sub grade. On IGNP a side of 2:1 is being adopted for all channels. The type of lining being adopted single/double clay tile lining, single brick lining, PCC slab lining, cast in situ CC lining. This practice of adopting 2:1 side slope for channels having discharge up to 4.0 cumec, does not seems to be rational. The channels having discharge up to 1:5 cumec or FSD up to 0.5 m should be with 1:1 side slope. Channels having 3.0 cumec or FSD up to 1.0 m may be with 1.5:1 side slope.

Table 3.6 Wetted Perimeter V/V Side Slopes

Discharge	*Side Slope*	*W.S.S.*	*W.P.*
1.5 cumec	1:1	1:5000	4.35
1.5 cumec	1.5:1	1:5000	4.80
1.5 cumec	2:1	1:5000	5.32
3.0 cumec	1:1	1:5000	5.64
3.0 cumec	1.5:1	1:5000	6.23
3.0 cumec	2:1	1:5000	6.91

From the above table it is clear that the increase in W.P. from side slope 1.5:1 from 1:1 is 10%. Similarly in 2:1 side slope from 1.5:1 is 11%. In general a side slope as given below would save 10% of the lining cost from prevailing practice of 2:1 side slope:

Table 3.7 F.S.D. V/V Side Slope

Discharge range	*FSD(m)*	*Side Slope*
Up to 1.0 cumec	0.5	0.75:1
1.0 to 1.5 cumec	1.0	1:1
1.5 to 3.0 cumec	1.5	1.5:1
3.0 to 4.0 cumec	1.75	1.75:1
Above 4.0 cumec	1.75 above	2:1

IGNP is a contour canal commanding area on the right side of flow except few patches on the left side. The area right up to the Indo-Pak border is proposed to be commanded by IGMC. The area served is dunny with large inter-dunnal flats. It is worth noting that most of the high dunes are lower than the FSL of Main Canal. Even than command is less than 60% of GCA and 40% of geographical area.

Same figures of IGNP Stage II need to be mentioned here under:

Table 3.8 G.C.A./C.C.A. Percentage

Sr. No.	*System*	*GCA*	*CCA*	*Percantage*
1.	Direct minor/outlets	44547	28203	63.30%
2.	Direct Distributory	111869	71001	63.50%
3.	Dattor Distributory	51184	18235	35.60%
4.	Birsalpur Branch	78866	46884	59.40%
5.	Charanwala Branch	176518	96820	54.80%
6.	Shaheed Birbal Shakha	147174	102029	69.30%
7.	Sagarmal Gopa Shakha and Tail System	609022	336947	55.30%
	Total	1219180	700119	57.42%

(***Source***: *IGNP Approved Project Report*, 1987)

It is worth mentioning nearly 6,00,000 ha area has been left out of GCA, a substantial part of which could have been commanded. Now, this left over area is being proposed to be commanded by providing additional high-level canals from Main Canal, branches and by extending canal system. Even then some 4,00,000 ha area would remain out of GCA.

From the table it is clear that overall CCA is 57.42% of GCA. As mentioned above, it reveal from survey sheets that most of the high dunes are lower than the FSL of Main Canal falling in the geographical area.

The low percentage of CCA indicates that cutting and filling has been avoided by providing falls at the cost of CCA as it is evident from the table below:

Table 3.9 Drops in F.S.L.

Canal	*Length (Km)*	*Drop in FSI (m)*	*% of CCA*
Dattor Distributory	25.40	14.30	35.60 %
Birsalpur Branch	27.70	39.30	59.40%
Charanwala Branch	81.90	37.80	54.80%
Direct Distributories	65.50	55.00	63.50%

Drop in water level could have been 5 m, 5.4 m, 16.4 m and 13.1 m respectively with a slope of 1:5000.

3.5 Lined Canals

Lining of canal is done mainly to minimize the seepage losses. But the corresponding benefits make the lining economical and advantageous in the long run. Some other benefits are:

1. Reduced seepage checks rise of sub soil water table, in turn reduce the land damage due to water logging.
2. Due to higher velocity there is saving in cross sectional area and land width.
3. Improvement in command.
4. Practically no maintenance cost.

Seepage losses in unlined canals varies from 5.0 cumec to 10.0 cumec per million sq. meter of the wetted perimeter. In initial stage the losses may be even more. Further, in sandy soils as in the case of Western Rajasthan, seepage losses may be further on higher side. Whereas seepage losses in lined canals (single tile lining) varies from 0.4 cumec to 0.6 cumec per million square meter of the wetted perimeter. Thus, in lined canals losses are just 8 to 6% of the unlined canals.

On major and medium canal system with unlined channels the losses accounts for 45 to 50% of the feeder head discharge. If there is a head discharge of 100 cumec, losses may account from 45 cumec to 50 cumec whereas in lined canals the losses may be not more than 6 to 8 cumec. Thus substantial water can be saved by lining, which can be used for irrigating the extra lands.

Higher velocity reduces the sectional area resulting narrow land width for canal construction, the saving in land width may be up to 50% as compared to unlined canal width. Further in lined canals, higher velocities up to 2.5 m/sec (7.5 ft/sec) can be provided whereas in unlined canals, velocity of more than 0.6 m/sec may not be feasible. Thus, a substantial saving in cost may be effected in length and structures by lining the canals. Lined canals are practically maintenance free. Whereas, unlined canals require frequent maintenance of canals as well as structures there on.

The economy of lining a canal depends upon availability of lining material, skilled and unskilled labour, construction machinery and time available. But the important point is lining should be structurally durable and should be maintenance free as far as possible. Lining is not designed for taking any load, but only to withstand erosion and wave pressure. The sub grade should be compacted so as to withstand water pressure. As mentioned earlier, the main aim of lining is to minimize seepage losses. So, this aspect may not be lost from the sight while selecting type of lining. Experiments have shown that most of the seepage loses are through joints. So as far as possible, there should be minimum joints, and joints should be well packed and staggered.

Although permeability of lining depends upon depth of water in canal, thickness of lining, sub soil water table and moisture of sub grade, dry the sub grade more the seepage. Velocity in a lined canal is inversely proportional to the rugosity co-efficient, directly proportional to the hydraulic means depth and water surface slope. Thus, the greater the rugosity, co-efficient lowers the velocity. Lower the hydraulic mean depth lower the velocity. Lower the WSS (flatter) lower the velocity. Conversely to increase the velocity, hydraulic mean depth should be greater and water surface slope should also be greater (Steeper) as far as possible matching the country slope.

3.6 Economical Section

As far as cost of lining is concerned, most economical rectangular section is one where bed depth ratio is 2, i.e., bed width = 2 × depth, implying area = $2d \times d = 2d^2$ (see Fig. 3.2)

$$\text{Wetted perimeter} = d + 2d + d = 4d$$

$$\text{Hydraulic mean depth} = \frac{2d^2}{4d} = 0.5\,d$$

Small channels upto 0.5 cumec discharges are constructed with sides vertical. But keeping sides vertical for channels above 0.5 cumec may not be structurally safe.

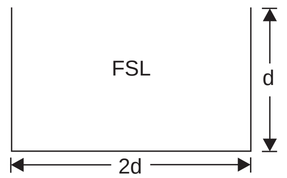


Fig. 3.2 Rectangular Economical Section-Canal

Side slopes of canal lining are based on sub grade. Side slopes as recommended by I.S. 10430–1982:

1. Very light loose sand to average sandy soil	2:1 to 3:1
2. Sandy	1:1 to 2:1
3. Graved Sandy soil	1:1 to 2:1
4. Clay soil	1:1 to 1.5:1
5. Rock	0.25:1 to 0.5:1

Hydraulic efficiency also termed as discharge carrying capacity of a canal varies inversely with the rugosity co-efficient of canal lining:

$$Q = A \times V \qquad A \text{ is constant}$$

$$V \propto R^{2/3} \cdot S^{1/2}$$

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

Where N is the rugosity co-efficient

R = Hydraulic mean depth = Area/ WP

S = Water surface slope (1:S).

$$\text{Hydraulic depth} = \frac{\text{Area}}{\text{Top width}}$$

$$\text{Faurde's no} = \frac{V}{\sqrt{gd}}$$

When $F > 1$

Velocity is supper critical

and when $F < 1$

Velocity is sub critical.

Trapezoidal economical section

$$A = (b + sd)d$$

$$WP = b + \sqrt{s^2 + 1} \times 2d$$

$$R = \frac{(b + sd)\,d}{b + \sqrt{s^2 + 1} \times 2d} = \cdot 5d$$

$$b + sd = 0.5b + \sqrt{s^2 + 1} \cdot d$$

$$\frac{b}{d} = \frac{\left(\sqrt{s^2 + 1} - s\right)}{\cdot 5}$$ (where s = side slope H:V)

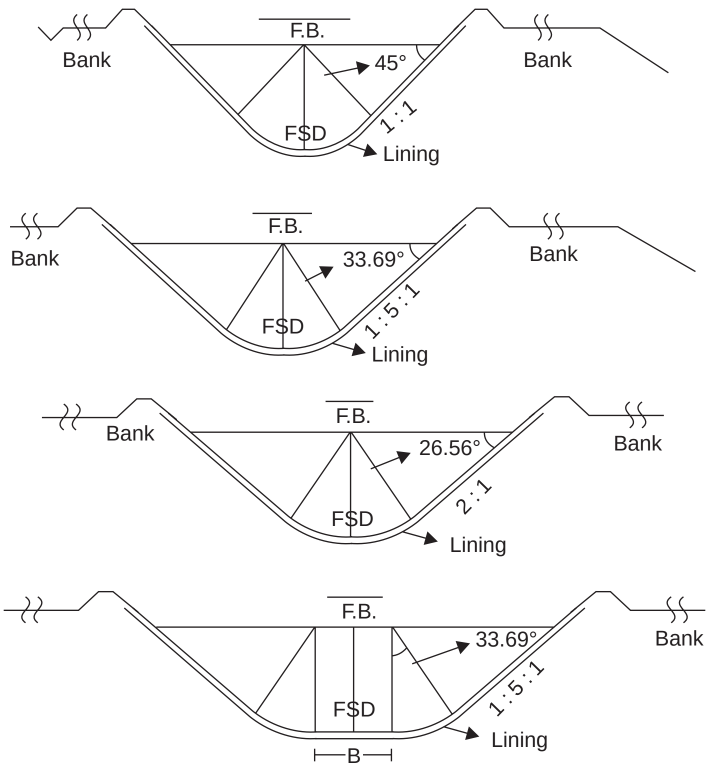


Fig. 3.3 Semi Circular Canal Section (Mehboob Sections)

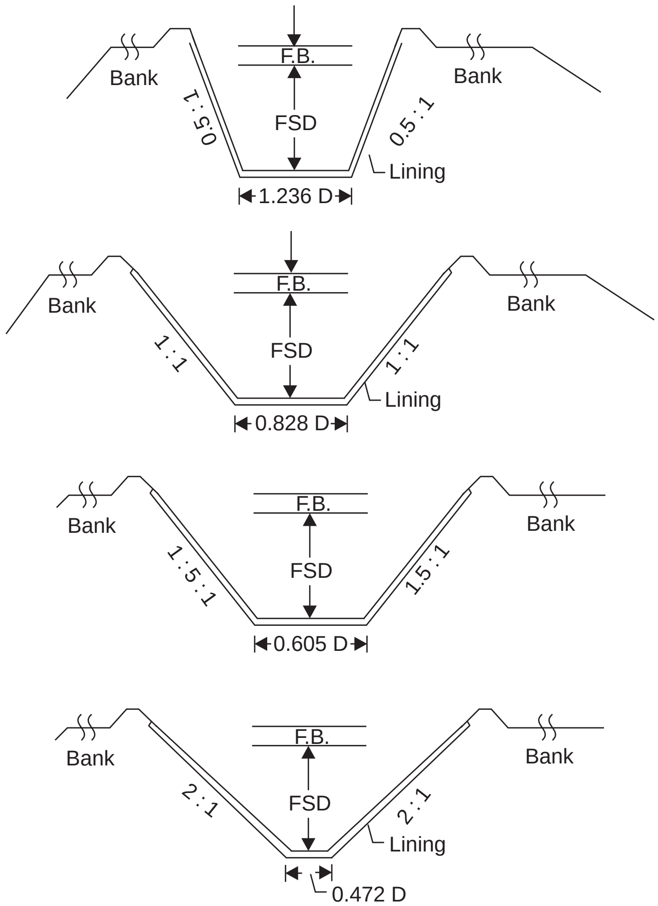


Fig. 3.4 Sharp Corner-Economical Sections

Lining may be

1. Pre cast cement conc. block—30 × 45 × 5 cm or any suitable size—Mix 1:3:6
2. Cost in situ in panels of 10 m, 5 to 7 cm thick with bottom sleeper— Mix × 1:3:6
3. Tile or brick lining in 1:5 cement–sand, mortar

3.7 Rugosity Co-efficient

There is nothing like absolute, smooth. Hence, the value of *N* is always less than one.

Value of *N* as per I.S. Code 10430-1982 is as under:

Concrete:

1. Formed no finish/PCC tiles/Slabs	0.018–0.020
2. Trowel finish	0.015–0.018
3. Grout finish (Shot concrete finish)	0.018–0.022
Brick-tile lining	0.018–0.020
Dressed stone masonry	0.019–0.021
Coarsed rubble masonry	0.018–0.020
R.R. Masonry	0.020–0.025
Masonry plastered	0.015–0.017
Dry boulder lining pitching	0.020–0.030

Value of '*N*'(rugosity co-efficient) goes on increasing with the passage of time due to deterioration in lining, weed growth, etc.

3.8 Manning Formula for Design of Lined Canals

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

Where

R = Hydraulic Mean Depth

S = Bed Slope = Water Surface Slope

N = Rugosity Co-efficient

Design of Canal section (rounded corner)

Let discharge be Q cumec

Assume bed width b

FSD d

Table 3.10 Design of Lined Canals

Side Slope	*Area*	*W.P.*	ϕ
1:1	$1.785\ d^2 + bd$	$3.57\ d + b$	45°
1.5:1	$2.088\ d^2 + bd$	$4.176\ d + b$	33.69°
2:1	$2.4636\ d^2 + bd$	$4.9272\ d + b$	26.56°

$$R = \frac{\text{Area}}{\text{WP}}$$

$$V = \frac{R^{2/3}\ S^{1/2}}{N} \text{ (MKS)} \qquad Q = A. \times V$$

3.9 Mehboob Section

Is the canal section where bed width is kept as zero. For least perimeter hydraulic mean depth i.e., area/WP comes to 0.5*d* where d is the FSD. This is the case where bed width is equal to twice the FSD (B/D ratio is 2). This is applicable in rectangular section. But keeping the side slope vertical is not structurally feasible and safe for higher discharge. On this analogy, Mehboob section is most economical wherein for most economical all side slopes hydraulic mean–depth remains 0.5*d*.

Table showing different parameter at different side slopes is given below. The WSS is assumed as 1:5000 (Rounded Corners)

Table 3.11 F.S.D. Co-efficient for Economical Canal Section

Sr. No.	*Side Slope*	*Area*	*W.P.*	*FSD Co-efficient*
1.	1:1	1.785 d^2	3.57 *d*	$(Q/0.8835)^{0.375}$
2.	1.25:1	1.925 d^2	3.85*d*	$(Q/0.9528)^{0.375}$
3.	1.5:1	2.088 d^2	4.176 *d*	$(Q/1.0336)^{0.375}$
4.	1.75:1	2.269 d^2	4.538 *d*	$(Q/1.123)^{0.375}$
5.	2:1	2.4636 d^2	4.927 *d*	$(Q/1.219)^{0.375}$

Mehboob section has been adopted at some projects upto a discharge of 200 cumec. The different sections is shown in the Fig. 3.3.

8 (a) In case of sharp corner B.D ratio be as under for economical section. Section has been shown in the Fig. 3.4.

Table 3.12 B/D Ratio for Economical Canal Section

Side slope	*B.D ratio*
1/2:1	1.236
1:1	0.828
1.25:1	0.70
1.5:1	0.605
1.75:1	0.53
2:1	0.472

3.10 F.B. in Canals

F.B. is provided to accommodate any sudden increase in discharge as well as to sustain waves due to winds or otherwise. As a thumb rule derived on the basis of waves height on different width of channel.

F.B. as per I.S. Code 10430–2000 is as under:

Discharge> 10 cumec	0.75 m
5 to 10 cumec	0.60 m
1 to 5.0 cumec	0.50 m
Discharge< 1.0 cumec	0.30 m
F.B. in water-courses	0.15 m

F.B. as adopted in IGNP:

Discharge> 10 cumec	0.75 m
5 to 10 cumec	0.60 m
1.42 to 5 cumec	0.50 m
1 to 1.42 cumec	0.45 m
Below 1.0 cumec	0.30 m

As the cost of lining is substantial, in small channels less than 1.0 cumec discharge, no F.B. in lining be constructed, instead of this masonry dowel can be constructed. Masonry dowel may be as under:

Discharge> 10 cumec	0.45 × 0.45 m
5 to 10 cumec	0.30 × 0.45 m
2.5 to 5 cumec	0.30 × 0.30 m
1.0 to 2.5	0.15 to 0.30 m
Less than 1.0 cumec	0.15 × 0.23 m

3.11 Bank Width

Table 3.13 Bank Width for Canals

As adopted on IGMP

Discharge Range	*Inspection*	*Non-Inspection*
Below 0.30 cumec	0.91 m	0.91 m
0.30 to 1.42 cumec	5.18 m	1.22 m
1.42 to 3.0 cumec	5.18 m	1.52 m
3.0 to 10.0 cumec	5.18 m	1.82 m
Above10.0 cumec	7.62 m	5.18 m

As recommended by B.I.S. Code 10480:–1982.

Table 3.14 Bank Width as Recommended by BIS-10430–2000

Discharge Range	*Inspection*	*Non-Inspection*
0.15 to 1.5 cumec	4.0 m	1.5 m
1.5 to 3.0 cumec	4.0 m	2.0 m
3.0 to 10.0 cumec	4.0 + Dowel m	2.5 m
10.0 to 30.0 cumec	5.0 + Dowel m	4.0 m
Above 30.0 cumec	8.0 + Dowel m	5.0 m

3.12 Curves

To negotiate heavy cutting and filling, road crossing and for any other obstructions, curves are being provided. The curve should not be sharp. The deflection should not be more than 60 (but in no case should be obtuse). As far as possible radii of curvature should be maximum, so as to have a smooth transition. The following radii is recommended by IS 5968–1987.

$$\left(1^\circ = \frac{180 \times 100}{\pi \times 3.281}\,\text{m}\right)$$

Table 3.15 Radius of Curvature on Canals

Discharge (cumec)	*Degree of Curve*	*Radius in (m)*	*Recommended by BIS 5968–1987*
Upto 0.30	35	50	50
0.30 to 3.0	35 to 17.50	50 to 100	50–100
3.0 to 10.0	17.50 to 12.0	100 to 145	100–150
10.0 to 40.0	12.0 to 9.0	145 to 195	150–200
40.0 to 70.0	9.0 to 6.0	195 to 290	200–300
70 to 140	6.0 to 4.0	290 to 435	300–450
140 to 200	4.0 to 2.5	435 to 700	450–600
200 to 280	2.5 to 2.0	700 to 870	600–750
280 and above	2.0	200	900

3.13 Land Width for Canals

Land width acquired for canal construction is of two-types, Temporary acquisition. Permanent acquisition. Permanent acquisition is for all the times to come and is likely to be under the canal and its appurtenant works, whereas temporary land acquisition is only for the construction phase to facilitate the construction work. Although land acquisition plans are prepared and based on cutting/filling and cross section applicable. The land plan is generally prepared on the basis of cross section taken at 100 m intervals. In undulating area cross section should be taken at 50 m intervals. As a guide line on an average following permanent land width is generally taken for acquisition:

Table 3.16 Land Width for Canals

Canal (Lined)	*Discharge range*	*Land width (m)*
Branches	Above 10 cumec	50
Distributory	5 to 10 cumec	40
Distributory	1.42 to 5 cumec	30
Minor/sub minors	Less than 1.42 cumec	25
Road along canals	–	20

3.14 Land Width for Afforestation

Afforestation along canal are necessary to check the rise of water table due to seepage. Afforestation also checks the blown sand falling in the canals, particularly in Western Rajasthan where sand storms are frequent with high wind velocities. Afforestation acts as a barrier and reduces the wind velocities and sand from accumulating in the canals. Following land widths has been recommended for afforestation:

Table 3.17 Land Width for Afforestation

Canals	*Land width*	*Remarks*
1. Main Canals	200 m left side 100 m right side	1000 m u/c Govt. Land 500 m u/c Govt. Land
2. Branches	100 m left side 50 m right side	500 m u/c Govt. Land 500 m u/c Govt. Land
3. Distributories	50 m both sides	

Contd.

Table 3.17 (Contd.)

Canals	*Land width*	*Remarks*
4. Minors, subminors and lift canals	25 m both sides	
5. Road side Plantations	20 m both side	

(u/c—uncommand)

Afforestation along canals not only protect the banks from erosion/damage, but also improves the ecology of the area, at no cost. Practically no watering is required except in the first year of planting.

Further it has been estimated, that canal construction cost can be recovered in a span of 15 to 20 year's if proper plantation and its maintenance is done along the canals.

3.15 Canal Outlets

It is a small structure built at the head of the water-course to link with the canal, it is also termed as module. The requirement of a good outlet is:

1. It should be strong enough so as not be tampered with by the beneficiaries.
2. It should be simple in construction and should have no moving part.
3. It should work efficiently with small working heads.

Type of outlets/modules

1. Non-modular: Where the discharge of the outlet depends upon the difference of head between the canal and water-course.

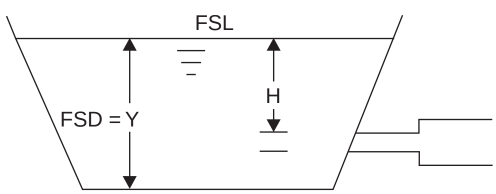


Fig. 3.5 Non-Modular Outlet

2. Semi-modular (flexible module): Where the discharge of the outlet depends upon the water head in the canal and is independent of water head in the water-course.

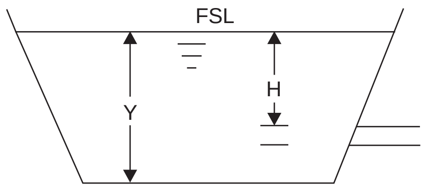


Fig. 3.6 Semi-Modular Outlet

3. Rigid modular: Where the discharge of the outlet is independent of fluctuation of water level in canal and water-course, such as Gibb's module.
4. Flexibility/ modulity: It is defined as the ratio of rate of change of discharge in outlet to the rate of change of discharge in canal and is denoted by F.

$$F = \frac{M}{N} \times \frac{Y}{H}$$

Where,

M = outlet index (discharge of outlet = $CH^{1/2}$)

N = distributory index (discharge of disty.= $CH^{5/3}$

Y = FSD in distributary

H = Head acting on the outlet

For outlet to be proportional, flexibility should be unity:

$$F = \frac{M}{N} \times \frac{Y}{H} = 1$$

or

$$\frac{M}{N} = \frac{H}{Y} = \frac{\text{Outlet Index}}{\text{Canal Index}}$$

Setting is defined as the ratio of Head over outlet to the FSD in canal

$$\text{Setting} = \frac{H}{Y} = \frac{\text{Outlet Index}}{\text{Canal Index}}$$

Outlet index is generally 1/2

Canal index is generally 5/3

$$\text{Setting} = \frac{1/2}{5/3} = \frac{1}{2} \times \frac{3}{5} = 0.3 = H/Y$$

H = 0.3Y.

An orifice type out let on trapezoidal canals shall be proportional, if the outlet is fixed at 0.3 times the depth, below the FSL or head over the orifice should be 0.3 FSD.

For weir type outlets on trapezoidal canal shall be proportional if the weir is fixed at 0.9 times the depth, below the water surface (for weir type outlet $N = 3/2$)

$$\text{Setting} = \frac{3}{2} \times \frac{3}{5} = 0.9$$

Hyper proportional are those outlets where setting is less than M/N

$$\text{Setting} = \frac{H}{Y} < \frac{M}{N}$$

That is head on the outlet is less than the required head. In other words, setting is at less than 0.3 times the depth, below the FSL.

Sub proportional are those outlets where setting is more than M/N

$$\text{Setting} = \frac{H}{Y} > \frac{M}{N}$$

Where setting is more than 0.3 times the depth, below the FSL.

(Head is more than required)

Sensitivity: It is defined as the ratio of the rate of change of discharge through the outlet, to the rate of change of water level in the distributary.

$$S = \frac{\text{Rate of change of discharge through outlet}}{\text{Rate of change of FSL in the distributary}}$$

$S = 5/3\ F$ (F = Flexibility)

Minimum modular head: Is defined as the head required to pass the design discharge.

Efficiency of an outlet: It is defined as the head required to pass the designed discharge. Less the head required more is the efficiency conversely, more the head required less is the efficiency.

3.16 Pipe Outlets

(A) Submerged

$Q = Cd \times A \times (2gh)^{1/2}$

Q = discharge of the outlet

Cd = Co-efficient of discharge = 0.8

A = Area of pipe

h = working head = Head loss

Example:

Q =.057 Cumec (2 cusec)

FSL in distributary = 100.0 m

FSL in water-course = 99.7 m

FSD in distributary = 1.0 m

$h = 100 - 99.7 = 0.3$ m

$Q = 0.057 = 0.8 \times A \times (2g \times 0.3)^{1/2}$

$$A = \frac{0.057}{1.94} = 0.029 \text{ sq. metre}$$

$D = 0.19$ m provide 20 cm pipe.

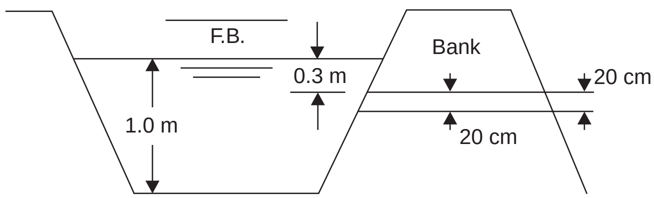


Fig. 3.7 Submerged Pipe Outlet

(B) Free Fall Outlet

In case of free falling outlets discharge depends only on depth of water on the centre line of pipe. In case of free falling outlet co-efficient of discharge is taken as 0.62.

$Q = \text{Cd. A } (2gh)^{1/2}$

Example:

$Q = 0.057$ cumec

FSL in Dy. = 100.00 m

FSL. in W/c = 99.00 m

FSD in Dy. = 1.0 m

Cd = 0.62

As the head is not known, pipe dia. is assumed as 25 cm.

$$A = \frac{3.14 \times d^2}{4} = 0.196/4 = 0.049 \text{ Sq m.}$$

$Q = 0.057 = 0.62 \times 0.049 \times (2 \times 9.81 \times h)^{1/2}$

$H = 0.18$ m =18 cm.

Provide 25 cm diameter pipe

Pipe setting = 100 – 0.18 – 0.25/2 = 99.695 m

3.17 Crumps APM

The most commonly used outlet is crumps, Adjustable Proportional Module (Crumps APM). This is made of a C.I. block having base of Roof block and check plate for adjusting the opening. This block is fixed in masonry and cannot be tampered with. However, whenever needed masonry is dismantled, the roof block is readjusted for the changed discharge and re-fixed in the masonry.

The detail of the outlet is given in below.

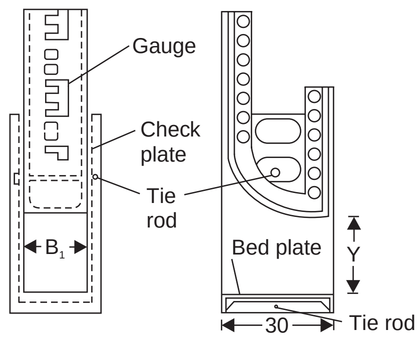


Fig. 3.8 Details of Roof Block

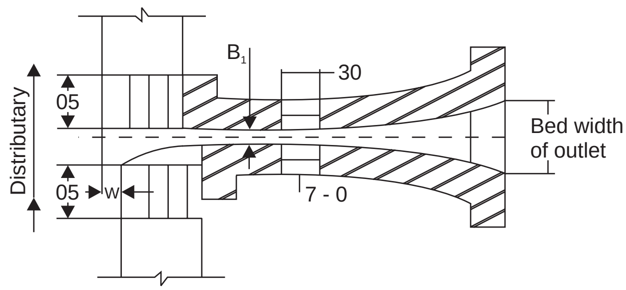


Fig. 3.9 Plan

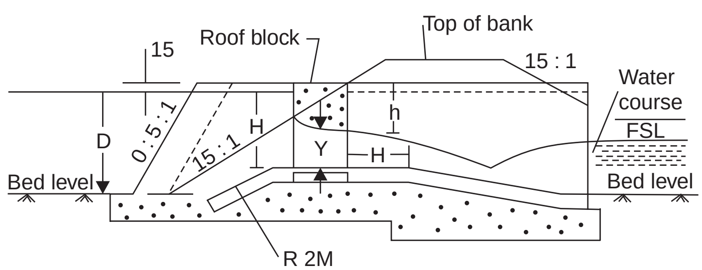


Fig. 3.10 Longitudinal Section

Discharge is given by the formula

$$q = Cd\ (B_t \cdot y) \cdot (2gh)^{1/2}$$

where q = required discharge to be passed

Cd = co-efficient of discharge

B_t = Throat width

y = Height of the opening

h = Head over the roof block

Co-efficient of discharge varies with discharge in parent channel, throat width (B_t).

In general co-efficient of discharge is taken is 0.85 for throat width from 0.20 m to 0.3 m.

The formula becomes

$$q = 0.85 \times (2g)^{1/2}\ (B_t \times y)\ h^{1/2}$$

$$= 3.76\ (B_t \cdot y)\ h^{1/2}$$

The ratio h/D should be around 0.33 for proportional distribution of bill. (h/D = head over roof block/F.S.D in canal)

The ratio h/D should be around 0.9 for modular working (refer flexibility/modulity).

Setting of the outlet.

The base plates and roof blocks are manufactured in standard sizes. Base plate is manufactured in standard width of 6.2, 7.6, 9.9, 15.4, and 30.5 centimeters. Whereas, check plates holes are spaced at 2 cm centre to centre, rounding height, next higher hole opening is taken.

Practical approach: It has always been a problem with the irrigation engineers to feed the tail chak of a canal system. Tail chaks seldom get their due share of water. The reason being non-practical approach, that is providing modular working head on outlets, i.e., keeping h/D ratio is 0.9 or less. For further details regarding working head (h) refer Chapter 6.

4

Planning Lift Canal System

4.1 Introduction

Planning of lift canal system is an altogether different from flow canal system planning. In flow canal system canals are planned according to the country topography and system is planned according to intercrossing watersheds. In flow system only the main canal or feeder canal runs along the contour and system runs as per country slope-topography. Though branch-distributaries and minors, off taking at suitable points command on both sides. The main consideration is that with minimum run of water, maximum area is commanded.

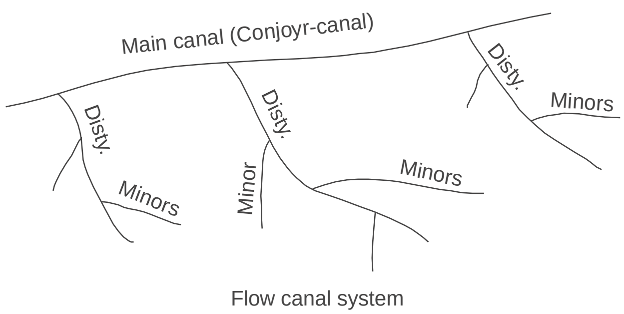


Fig. 4.1 Flow Canal System

In the case of lift canal main canal runs against rising country slope and every canal off taking from the main lift canal is a contour canal. Thus, every canal off taking from lift main canal commands area only on one side practically, except minor patches on the other side.

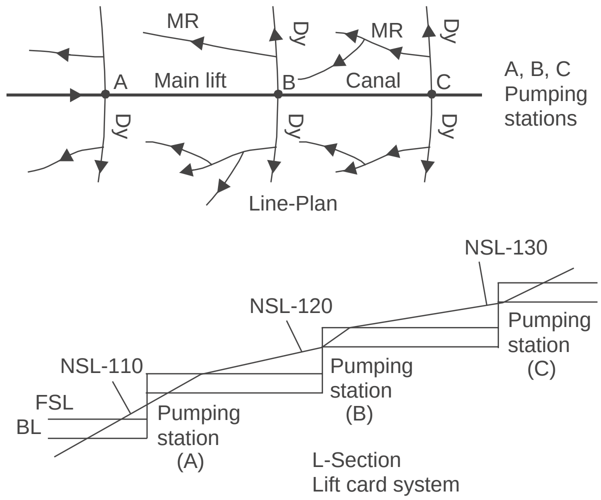


Fig. 4.2 Lift Canal System

In lift system, to have a balance between canal system, construction and operation of pumping station is a vital proposition. As shown in Fig. 4.2, canal system runs from pump station to pump station. Water is lifted to a certain height according to the topography of the main lift canal, but that may not be the requirement of the off taking channel.

4.2 Lift Main Canal

In case of lift main canal, proposition is reverse to the flow main canal. Lift main lift canal is never kept on contour neither it is advisable to keep the same on contour. As the lift main canal has to irrigate the area on both sides, lift main canal is so aligned that it centrally divides the command, so that O.T. canals which in turn are contour canals may have minimum run to irrigate the area on both sides of lift main canal.

4.3 Differential Lifting: A Concept

In lift, system; generally lifting is done in main lift canal so that there should be minimum number of pumping stations. This is to reduce the construction cost. No doubt, construction of P.S. is a time consuming, expensive and requires expertise in design and planning. But, the concept of differential lifting may be highly economical in the long run, particularly in India, where power is scarce and costly. It has been estimated that power charges for lifting of one cumec of water by one meter, annually comes to Rs 25,000/- with 50% capacity factor, excluding the cost of P.S. maintenance etc. So, the concept of differential lifting needs attention. This has been explained under model differential lift planning.

A line diagram for such an arrangement is given below:

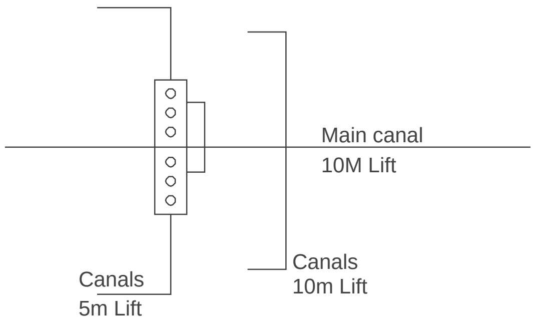


Fig. 4.3 Differential Pumping-Layout

In lift irrigation, where water application is through sprinkler/drip system, FSI, at Naka point or turn out should be kept same as that in water-course at Naka point, as there would be no gravity flow of water in application.

4.4 A Case Study

BISRASAR DISTRIBUTARY O.T. at Km 53 down stream P.S. II. where lift is 15 m. U/S FSL, 199.04 m, D/S FSL, 214.04 m.

The detail of this system, as planned see Fig. 4.4. It would be noted that FSL at tail of the minors O.T. from this distributory is 205.9, 202.38, 198.37, 200.00 and 198.95 i.e., except in the first two minors, FSL, at tail in other minors is lower than the U/S FSL. i.e., before lifting. In other terms first we have lifted some 1.916 cumec water by 15.0 meter and then by providing steeper slopes of 1:2500, 1:2650, 1:2750, 1:750 and 1:1600 we have wasted this gained potential energy.

To serve the same area under Bisrasar Dy, differential lifting was studied. At the same pumping station II, a lift of 7.5 m was provided for 1.916 cumec discharge, whereas 15.0 m lift was provided for the remaining discharge in main canal.

The comparative position with regard to single lift of 15 m planned and differential lifting of 7.5 m for the distributing discharge and 15 m for the remaining main canal discharge is given in Table 4.1. Fig. 4.4 shows planning of distributory after singh lift of 15 m, where as Fig. 4.5 shows proposed planning after differential lift of 7.5 m for distributory 15 m in main canal at this same pumping station.

Table 4.1 Comparative Statement (Case Study-Differential Lifting)

Index	*As already Planned*	*As per proposed Differential lift planning*
1. FSL at head FSL at head of O.T Dy (7.5 m lift)	213.04 –	213.04 205.54
2. FSL at tail minor FSL at Tail minor with 7.5 m lift	198.95 –	199.67 198.86
3. Total length of system	69.95 Km	65.50 Km
4. GCA (ha)	24568	24568
5. CCA (15 m lift) (ha) CCA (7.5 m lift) (ha)	20356 –	12078 7739
	20356	19817
6. m/ha of canal length 6(a) Lining Sqm/ha	3.436 m/ha 10.725 Sqm/ha	3.305 m/ha 10.44 Sqm/ha
7. Percantage Losses	7.6%	7.3%
8. Total WP	222394 Sqm	206967 Sqm
9. Discharge with 15 m Lift	1.916 cumec	1.142 cumec
10. Discharge with 7.5 m lift	–	0.717 cumec
Total	1.916 cumec	1.859 cumec
11. Head Regulator's	4 Nos	4 Nos
12. Nos of Chack 13. Saving in losses 14. Saving in power	55 Nos 1.916 – 1.859	52 Nos =0.057 cumec 439664 KWH

From the comparative statement as given above, it is clear that, with differential lifting of 15 m and 7.5 m instead of single 15 m lift, there would be a substantial saving in power consumption. (Approx. Rs 20 lacs per annum.)

Conclusion

1. *Canal length*: In Single lift of 15 m, m/ha comes to 3.436 m where in differential lift of 7.5 m and 15 m, m/ha of canal

length comes to 3.305 m. Similarly, in the earlier case lining sqm/ha is 10.725 sqm, where as in the later case this comes to be 10.44 sqm, saving of 4.6%.

2. *Losses*: In single lifting of 15 m losses come to 7.6% of head discharge, whereas in differential lifting these come to 7.3% of head discharge.
3. CCA: There is a decrease in CCA marginally. It is likely that CCA with differential lift may be around 19817 ha against, 20356 ha in case of single lift. However, this CCA of 539 ha can be well commanded by the canal portion planned earlier So, the CCA practically would remain the same.
4. *Power*: Likely power consumption charges with 50% canal running with 15 m lifts would be as under:

$$= \frac{1.916 \times 15 \times 1000 \times 9.81}{0.85 \times 0.8 \times 0.9 \times 1000} = 460.68 \text{ Kw/Sec}$$

(Electrical efficiency	85%
Mechanical efficiency	80%
Operational efficiency	90%)

$$\text{Annual Cost @ Rs 4/- KwH} = \frac{460.68 \times 365 \times 24 \times 4}{2} = 80{,}71{,}113$$

Say 50% running 80,71,000/-

Likely power consumption with differential lift of 7.5 m and 15 m respectively

$$7.5 \text{ m Lift} = \frac{7.5 \times 0.717 \times 1000 \times 9.81}{0.85 \times 0.8 \times 0.9 \times 1000} = 86.2 \text{ Kw/Sec}$$

$$\text{Annual Cost @ Rs 4/-} = \frac{86.2 \times 365 \times 24 \times 4}{2} = 15{,}10{,}224$$

50% running

$$15.0 \text{ m Lift} = \frac{15 \times 1.142 \times 1000 \times 9.81}{0.85 \times 0.8 \times 0.9 \times 1000} = 274.58 \text{ Kw/Sec}$$

$$\text{Annual Cost @ Rs 4/- KwH 50\% Running} = \frac{274.58 \times 365 \times 24 \times 4}{2}$$

$$= \text{Rs } 48{,}10{,}641$$

Total Cost = Rs 1510224 + 4810641 = 63,20,865

Say = Rs 63,21,000

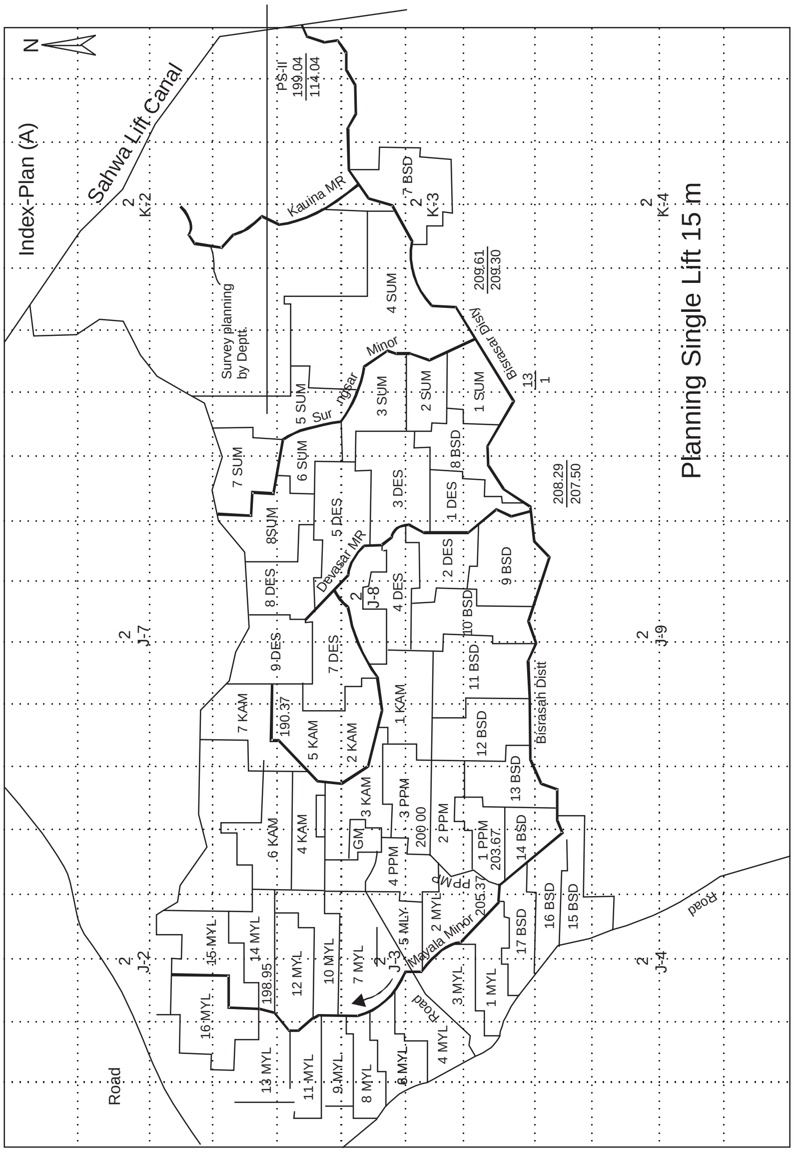


Fig. 4.4 Case Study Planning Single Lift

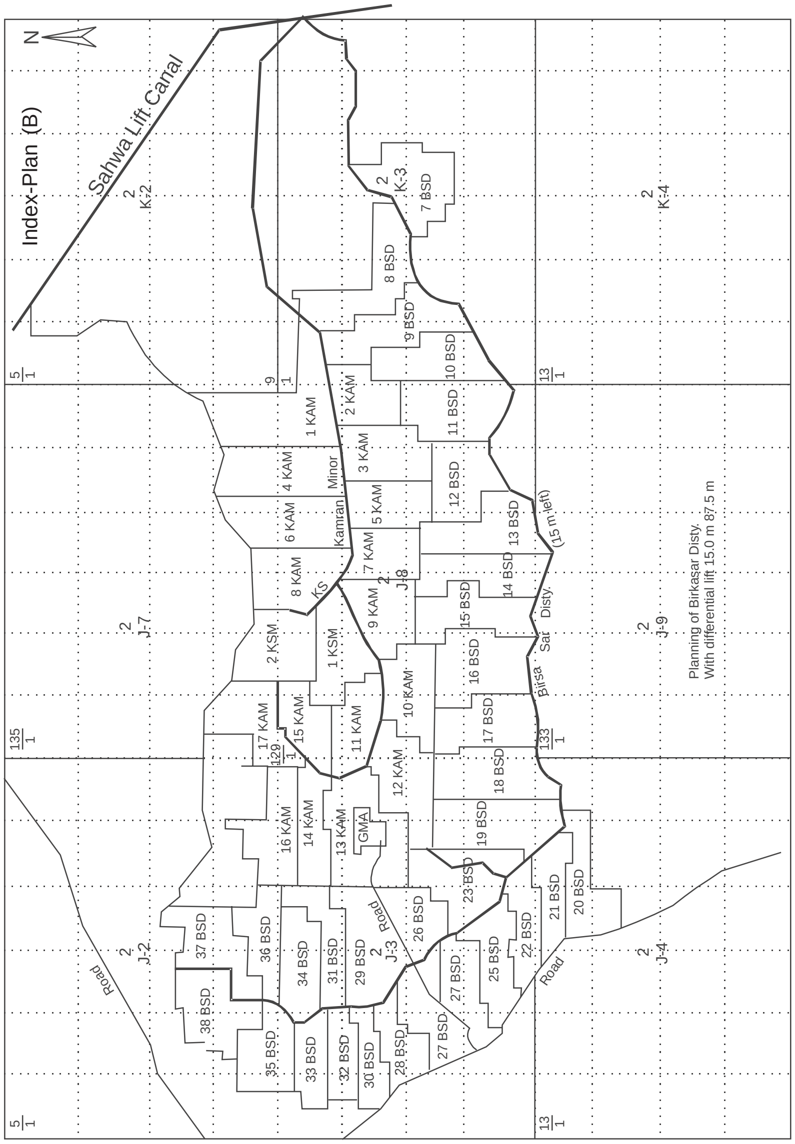


Fig. 4.5 Case Study Planning Differential Lift

Saving per year = Rs 80,71000 – 63,21,000
= 17,50,000

Lining: In case with single lift of 15 m total lining comes to 2,22,394 Sqm, with differential lift, total lining comes to 206967 Sq m. Saving in lining Cost @ Rs 150/- per Sq m = 15427 × 150 = Rs 23,14,050.

So, while planning lift canal system a judicious thought is to be given while providing lift. No doubt the cost of pumping station, construction and maintenance is high, but one should not forget that the power consumption cost is recurring and may surpass the cost of construction in few years.

It is advocated that steeper slopes should be given so that there may not be any silting in canals. Where the water has already travelled a distance of about 400 km, water is likely to be silt free except in rainy season. In Western Rajasthan there may be problem of blown sand in the initial stage of operation, but with the development, the sand problem may not be there, as we have experienced in Bhakhra and Ganga Canal Area. So, it is always advisable to provide reasonable slope of 1:5000 or so, to save the energy. Energy saved is energy produced. India is struggling hard to meet its power requirement. Shortage of power is one of the reasons for under development of the country even after 50 years of Independence.

5

OFD Works Terminology

5.1 Chak

It is the group of holdings getting water from a single outlet. Where the area is not rectangulated, chak may be termed as the total area getting water from a single outlet. In rectangulated area square is taken as a unit, where as in unrectangulated area may vary from 4 to 5 ha. The importance of unit (square-sub chak) lies in the fact that each unit gets a turn out from the water-course.

5.2 Square (Murraba)

In Punjab, Haryana and north-western Rajasthan land has been rectangulated and sub rectangulated. Each rectangle in fact, is a square covering 1000 acres measuring 6600’ × 6600’. Similarly, each sub rectangle is a square covering 15.625 acres measuring 825’ × 825’. This has greatly facilitated in planning chaks, water-courses and canals. This system of rectangulation and sub-rectangulation is termed as the best one for an irrigation system from the point of view of technical, administrative and revenue collection.

Bigha

A bigha covers 0.625 acres and measures 165’ × 165’ and is 1/25th in area of square. Square and bigha both are units of area for revenue in FPS system. These are multiple of Gunter chain (66’). One hundred Gunter chain by one hundred Gunter chain measures 1000 acres. The area of ten squares of one Gunter chain (66 feet) equals to one standard acre. But this varies from place to place at some places one acre equal to 132 × 132 feet.

5.3 Outlet (Mogha)

An outlet is a structure at the head of the water-course; through which designed discharge is passed in the water-course. Thus, the connection of water-course with the canal is through outlet.

Outlet may be pipe outlet, an APM (Adjustable Proportional Module) or an open flume. In the early stage of construction when a part canal system is complete, to utilize the created irrigation potential, pipe outlets are provided, but at the later stage when the supplies are regular, pipe outlets are replaced with the APMs (For details refer Canal Outlets).

As far as possible temporary outlet in the initial stage be fixed at the same location and of the same size as per design discharge, otherwise this may create problem when permanent outlet is constructed.

5.4 Water-Courses

Water-course is the channel connecting farmer's land with the canal supply. A water-course may be main water-course, laterals water courses. Water-courses are designed on the basis of area served and water allowance applicable on the canal system. At some places water-course is also termed as sub minor.

Carrying capacity of a water-course is derived from water allowance applicable on that project/canal.

Water allowance varies from project to project, or even there may be different water allowance on a project, based on regions.

The carrying capacity of a water-course should be around 35 to 50 liters/sec for flow irrigation i.e., where the water is applied through gravity. In case of lift irrigation where water is deemed to be applied through sprinkler or drip system, the carrying capacity of water-course could be 21 to 35 liters/sec.

Water-courses should be aligned on ridge as far as possible. In case where the area is sub-rectangulated water-courses runs on square line as far as possible. Similarly, where the area is not sub-rectangulated, water-courses run on holding lines to avoid bifurcation of holding. But cardinal principle water-courses must run on ridge line should not be sacrificed.

5.5 Naka (Turnout)

Nakas are the outlets of the water-courses. Each square/sub chak is provided with a separate Naka. A separate Naka is provided even if the command in the square (Murabba)/sub chack is less than one ha. If a square sub chak is bifurcated then two Nakas are to be provided for the bifurcated square (as shown in Fig. 5.1 and 5.2).

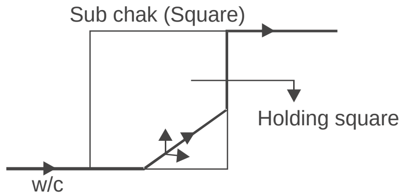


Fig. 5.1 Bifurcating-Holding

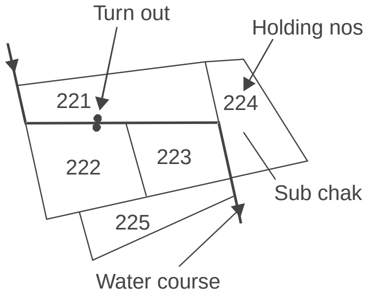


Fig. 5.2 Bifurcating-Sub-Chak

At one time, only one Naka of the water-course remains in operation, that means at one time only one square or part of square is being feeded from the water-course. That is why Naka is also termed as turn out. Only turn by turn one Naka is operated, rest remain out of turn. Naka should be provided on the following considerations:

1. It should be at the centre of the holding.
2. It should be at a point where the NSL is just at FSL or bit higher.
3. It should not be provided at points where heavy cutting or filling is encountered.

The reason for providing Naka at centre point saves water running in the field channels, during application in the individual bigha/survey numbers/

holding. As the field channels are unlined, more run in field channels result in heavy seepage losses.

5.6 Field Channels

It is a kutcha channel constructed and maintained by the cultivators in their individual field for irrigating water from Naka point of the water-course. To save water losses in the kutcha field channel, portable semi circular PVC sections may be used. It may be noted that, maximum water losses are on account of seepage in the unlined field channels. The kutcha field channel losses are about eight to ten times of the losses of the lined water-course for the same time of run.

5.7 Gross Command Area

It is the total area of the chak, which includes lands under infrastructure, rails, abadis, public roads, etc. culturable and unculturable area. Gross command area is equal to culturable command area plus uncultivable area.

The gross command area is the geographical area confined by the boundary of the chak and includes all land whatsoever.

5.8 Culturable Command Area

It is the cultivable portion of the gross command area, whether culturable or non culturable. Precisely, culturable command area is that part of the gross command area in a chak which is usable for crop cultivation. Some lands may be culturable or cultivable but may not be otherwise usable for crop cultivation.

6

Chak Planning

6.1 Introduction

Chak Planning is done in two stages: First at the canal planning level and second at the OFD works planning level. Chak is defined as a group of holdings getting irrigation water from an outlet provided specifically to that group of landholders. Planning of chak is very important to economise planning of canal system as well as for proper economical irrigation of the area under service.

Before planning chaks on a canal network, whether the area is rectangulated or not, following parameter's must be well decided.

1. Area of a sub chak-Area under a turn out.
2. Stream size with maximum linear length.

The water requirement of other departments such as Agriculture, Abadi planning. Animal husbandry. Agro forestry, etc. may also be ascertained with location of requirement. So that due provision may be kept at appropriate location of their water requirement.

6.2 Area of Sub Chak

One important aspect of chak planning is the block size, which is to be served with a separate Naka. In Punjab, Haryana, Western Rajasthan, as stated earlier whole area is rectangulated and sub rectangulated. Each sub rectangle is of 825' × 825' (15.625 acres or 6.323 ha in area). Each sub rectangle (also termed as murraba or square in local language) is sub chak with a separate turn out implying any holding comprising a square would get a separate turn out, although the square may be held by more than one person. On major and medium irrigation projects sub chak size may be 3 ha to 8.0 ha. Smaller is the sub chak size more is the length of water-course and number of turnouts. On IGNP-Bhakra and Gang Canal system average length of water course per ha of CCA comes to be nearly 25 metre.

6.3 Stream Size-Water Carrying Capacity

The size of the stream feeding the chak has to be decided before chak planning. The size of the stream feeding the chak depends upon CCA under the chak and water allowance. So, the size of the sub chak and CCA must be decided with the maximum-minimum limits. Similarly, the maximum linear length of the water-course run must be decided. The linear length of water course is directly related with the canal system. More the linear length of the water-course, less would be canal system length. Similarly, bigger the stream size, more the cost of construction of water-course.

In the former case, where the linear length of the water-course is 4 Km, the requirement of the canal system per ha would be less as compared to the latter case where the linear length of the water-course is 3 km, percentage of CCA/GCA in both the cases is same.

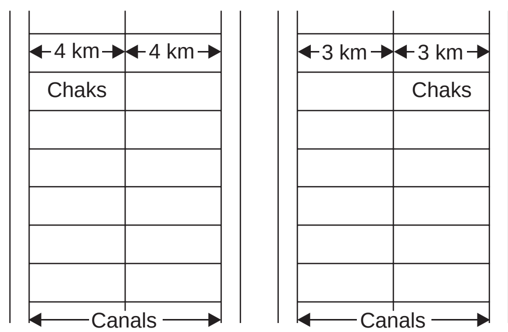


Fig. 6.1 Metre per Ha of Canal

From the above illustration it is clear that keeping m/ha of the water-course same, the cost of water-course lining can be reduced by 5% to 10% by proper planning. Similarly, by proper planning of chaks with respect to linear length of water-course, canal system can be reduced substantially. Although there are some vital factors affecting the canal system and water-course, but the important factor directly affecting the cost of lining of water-course is chak size, bigger the chak size more the cost of lining of water-course.

Size of the chak is decided upon rate of infiltration of soil. As the application of irrigating water is through gravity in the field, so rate of infiltration plays an important part in traveling water in the plot under water application. Where soils are sandy, area is highly undulating, the water holding capacity is very low. A stream size of 56 liter to 70 liter/second (2 to 2.5 cusec) is generally advocated for efficient flow of water in a plot of 50 m × 10 m under water application.

In fact the size of 56 liter to 70 liter/second (2 to 2.5 cusec) has done more harm than good. Proper application of water in a plot mainly depends on the proper grade of the fields and not merely on rate of infiltration as generally assumed. Further, rate of infiltration, is inversely proportional to the water holding capacity of the soil. Less the water holding capacity more the rate of infiltration. Water holding capacity of the soil depends upon soil texture and biomass present in the soil. The bio-mass in a soil goes on increasing with the cultivation and passage of time. Similarly texture of the soil goes on improving with the cultivation, due to addition of silt brought by canal water, addition of fertilizer, chemicals and green manure. So it may not be correct, to assume merely that water application is mainly dependent on rate of infiltration of soil. Besides, proper grade of the plot is very important for water application. In sandy soil a grade of 0.3 to 0.5% was found to be reasonable but this can be improved to 0.2 to 0.3% by applying a light roller on the plot surface before pre-sowing watering. It has been observed that application of light roller has reduced the application time by 1/3rd. In a plot size of 10 meter by 50 meter with stream size of 56 lit/sec. It takes nearly 20 minutes to apply the water with a grade of 3% When the same plot was given a light roller application, the time of application was reduced to 13 to 15 minutes. It should always be kept in mind that infiltration rate of the soil goes on decreasing and water holding capacity goes on increasing with the passage of time. So the stream size may be kept with long term planning in mind and practical approach should be adopted. Bigger the stream size more the cost of water-courses lining and allied structures. A chak size of 40 liter/second to 50 liter/second is more suitable. On Gang Canal System and Bhakra Canal System, average stream size comes to 42 liter/second (1.5 cusec). This would effect saving to the range of 10 to 15% which is quite substantial.

6.4 Initial Chak Planning

Chak planning at the first stage should be done with great care. Whole planning of canal system depends on this chak planning. The cardinal principle is whole to part and then part to whole. Individual chak should not be planned. Otherwise this may lead to canals either leaving the area from command or taking the area, which may have better command from adjoining canal system.

This initial planning is the foundation for whole canal planning. There may be chances where a canal is constructed without any command or a canal may be constructed, which may have just 20 to 30% CCA at final stage or even may not have any command.

On major and medium irrigation projects, Survey of India (SOI) prepares survey sheets on 1:15000 scale. Contours are drawn on spot level basis. Planning of chak/canal is done on the basis of contour on these sheets. This scale is not suitable for chak planning, however, these sheets are reasonably suitable for canal planning. As canal planning/chak planning goes on side-by-side and both planning are complementary, utmost care must be exercised while planning. Chak on Survey Sheets scale 1:15000 in conjunction with canal. This not only saves the canal lengths but also serves/helps in proper designing of canal section and assessing CCA.

Initially canals and chaks boundaries are marked on Survey Sheets scale 1:15000 tentatively. Thereafter-longitudinal profile of canal section is prepared on the basis of contours marked on survey sheets (as shown in Fig. 6.3)

Tentative FSL line is drawn taking maximum cutting and filling into consideration as well as requirement of FSL at different location of outlet head. As shown in the Fig 6.2. First mark the maximum level required in each chak or area under each outlet. (maximum level is some time called as critical level however this is misnomer.) Now there are many options in this particular case but only two options would be discussed here to understand the planning.

1. As regards meeting the requirement of maximum level in general a slope of 1:2500 may be provided, resulting FSL at tail as 94.0 m as shown with dotted line. But this would increase the earthwork substantially and the canal would be in cutting. To avoid this situation a WSS of 1:6000 with two falls at Km 6.5 and 10.5 would save the earth work considerably, but would increase the cost of lining by at least 15%.

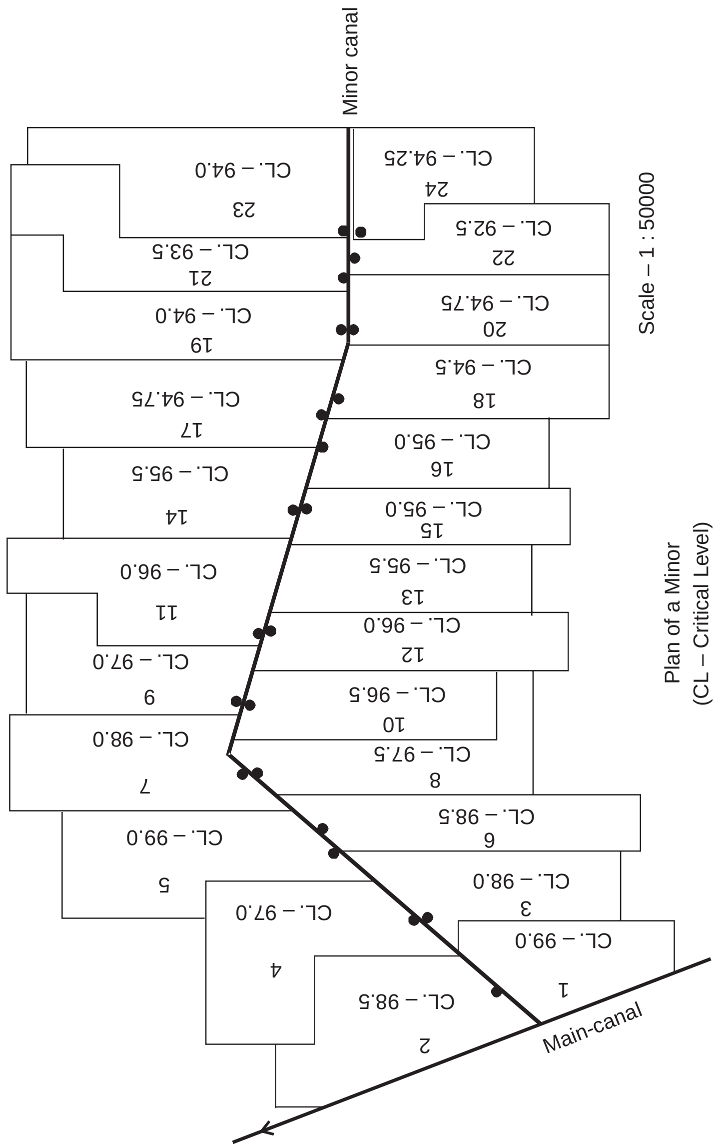


Fig. 6.2 Plan of a Minor

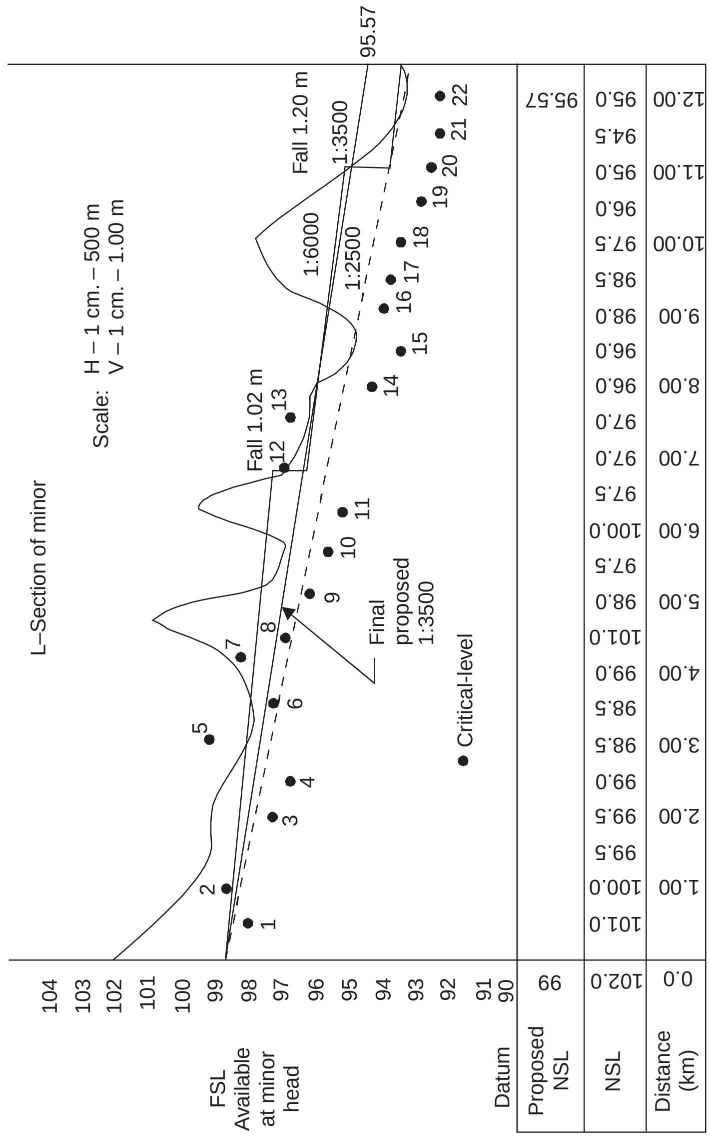


Fig. 6.3 L-Section of Minor

2. So a compromise is to be made, whether earthwork is to be increased with losing command under chak No. 5, 7, 12 and 13 substantially and marginally in chak No. 2. Alternate increase in lining and structures cost and marginally losing the command in chak No. 5 and 7.

From the two options, it emerges that a slope of 1:3500 would be most economical and beneficial. This would inspire the farmers for shaping their lands and bringing maximum area under command. In the present case, there is an ample scope for land leveling. Unless the FSL is kept high, land leveling may not be economical.

6.5 Planning Whole to Part–effect of Unco-ordinated Planning

In chak planning the principle of whole to part and then part to whole should be strictly followed. Otherwise there may be instances where some area would be left uncommand on periphery of one chak while the same is commendable from the adjoining chak. Even this may happen in the case of canals. One area may be left uncommand at the periphery of one canal system but may be commandable from adjoining canal system.

Planning in part may lead to high cost of canal construction as well as losing the command. Few examples-case studies-needs to be mentioned.

1. The distance between Godu minor (Charanwala Branch system) and Ranjeetpura Distributory near at head of Ranjeetpura Distributory is hardly 3 km against the minimum of 8 km. The FSL in Godu minor is 8 to 10 metre higher than the FSL in Ranjeetpura Distributory. The chaks of Ranjeetpura distributory were planned and OFD works executed without considering FSL available in Godu minor, resulting reverse flow to the fields and a big part of the area was rendered uncommanded on the periphery of left side chaks of Ranjeetpura Distributory. During chak planning of Godu minor it was noticed that there was practically no need to construct Ranjeetpura Distributary. The area under Ranjeetpura Distributary could well be commanded from Godu minor. But till that time water-courses of the chaks of Ranjeetpura Distributory in head reach were already constructed. A good part of the left over uncommanded area of these chaks was later commanded from Godu minor, leaving still a good part uncommanded, otherwise

commandable. Even area on right side of Ranjeetpura Distributary, which was left uncommanded could have been commanded from Godu minor. As shown in the sketch below, shaded area was left uncommanded from Ranjeetpura Distributary, but was later commanded from Godu minor.

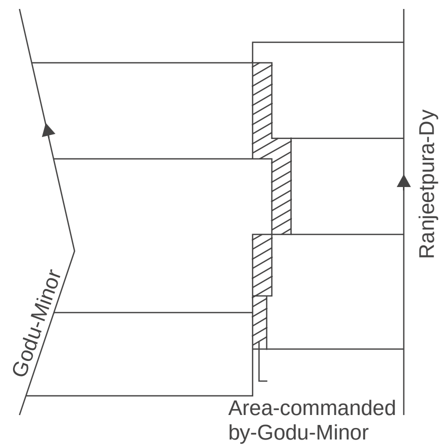


Fig. 6.4 Case Study-Uncommand-Command

2. The tail of Bikampur minor (A direct minor from IGMC) is hardly 1 km away from Khara minor near tail end. The FSL in Bikampur minor is nearly 10 m higher than the FSL in Khara minor. The chaks of Khara minor were planned earlier on the basis of FSL available in Khara minor, without considering FSL available in Bikampur minor. The principle, whole to part of planning was not exercised, resulting a big chunk of area rendered uncommanded. When the chaks of Bikampur minor were planned it was noticed that most of the area rendered uncommanded by Khara minor can be commanded by Bikampur minor. Tail portion of Khara minor, already constructed is now being used as water-courses and some portion stands defunct.
3. There is one direct minor of Kheruwala Distributary, which was constructed to serve 3 chaks of nearly 800 ha area but the same is defunct. This canal was constructed at a cost of some 50 lac rupees but it can not be used even to serve a single chak. An examination of contour sheet reveal that most of the area on both sides of this canal is higher than the FSL available. So, this canal will never be operational as such.

4. There is one Lareka sub minor of Round Distributary system. This sub minor was constructed to irrigate 3 chaks of nearly 720 ha. This minor is now used as a water-course, as the area which can be served by this minor is just 250 ha. of one chak.
5. There is one Surasar subminor which was planned and constructed to serve four chaks of 830 ha, is now being used as water-course to serve only one chak of 281 ha against four chaks of 830 ha planned.
6. There is one Kalran minor having 21 chaks off taking from Tibrewala minor. At the tail Kalran minor below chak 16KLR, the distance between these two canals is just 3 km. The FSL in Tibrewala minor is 2.5 m higher than the FSL in Kalran minor. On detail examination of contour plan reveal that most of the area planned to be served by Kalran minor below chak 16KLR is going to be uncommanded. So the tail of Kalran minor was kept at 16KLR and the remaining canal was rendered defunct. The area of chak 17 KLR to 21 KLR nearly 1300 ha is now proposed to be commanded by Tibrewala minor.

This is all due to neglecting the cardinal principle of canal planning, from whole to part and than part to whole.

As stated earlier IGNP is a gigantic canal project serving 35000 sq km of Thar desert, minor mistakes are bound to be there, this is by no way sustainable excuse. We engineers owe the responsibility that each drop of water must be used properly. If planning is done from whole to part and then part to whole such situation can be avoided.

There should be definite survey planning policy. It must be realised that proper systematic survey planning is the foundation for big projects. The impact of neglecting vital aspects of survey and planning is that nearly 6.0 lac ha area is left uncovered between the canals on IGNP. This left over area has to be covered later or sooner, and construction of canal system for this left over area would be a very costly proposition.

Due to lack of proper survey planning policy, a big part of area North-West of Sagarmalgopa Shakha opposite 73.0 km is left uncovered. This area is about 3.0 lac ha. Although this area is undulating but there are very good flat patches. As this area is nearly 50 m lower than the available FSL in canal, more area can be brought under command, if proper planning is exercised.

At present no cross drainage works have been planned, there are three CD works now planned on Sagarmalgopa Shakha. But no planning has been done to train this drain flow. OFD works have been planned and executed just downstream of these cross drainage works. Any flow passing through these CD works is bound to cause heavy damage to OFD works as well as crops habitats.

Working Head

Working head provided in O.T. channels is generally taken as 1/3rd FSD of parent channel plus 0.30 m. This practice is aimed at that O.T. channels may function even when the supplies in the parent channel is less than the full supply discharge. As far as adoption of the above practice in canals having discharge of more than 10 cumecs can be justified, as some O.T. channels may be running under 2nd or 3rd priority due to less supplies. But in case of small channels which either runs full or remain closed, may create problems for tail enders. It is generally felt that tail enders are most sufferers owing to this practice. The head reach channels draw more water then their due share where as tail ends get less supplies.

Further providing more working head is directly lowering the FSL in O.T. channel and decommanding the area. So while planning, efforts should be made. So that there should be equitable distribution of water and no area goes uncommand only on the basis of higher working head. In case of off taking distributories and minors the working head should be one third FSD of the parent channel plus maximum 0.1 m to 0.3 m.

At some projects it has been noticed that canals are kept in cutting, further bed level of off taking channel is kept the same as of parent channel (GRBC—North Karnataka). This is against the principle of canal planning, and may render a big part of the area uncommand.

7

Detail Chak Planning

7.1 Introduction

Under utilization of irrigation potential, particularly under major and medium irrigation projects, was a concern with the State and Central Government. The gap between irrigation potential created and utilized basically attributed to delays in the development of On-farm works. To reduce the gap particularly between the irrigation potential created and utilized command area, development programme was initiated in 1974–75. Under this programme inter-alia it was decided, as far as possible water-course should be made lined. The object was two-fold:

1. To motivate the farmers to use the canal water for cultivation who are weak and unable to construct/maintain water-course.
2. The losses in katcha water-courses are too high; farmers were unable to take water upto their field.

On IGNP, a Committee has reported that losses in unlined water-courses vary from 45.0 cusec/M.sft of W.P (Chak 6-NUD) to 28.0 cusecs/M.sft of W.P (Chak 1-CD). Water losses were observed in 38 water-courses mostly by ponding method. Looking to these high losses, lining of water-course is must.

In IGNP where the works were taken up in two stages, Stage 1 upto KM 189 and Stage II below KM 189.0. In Stage I most of the water-courses were trapezoidal in section but in Stage II it was decided to construct the rectangular water-courses. The reason being in Stage II of IGNP, climatic conditions are more harsh, soils are sandy, storm intensity and frequency is more. It is likely that soil erosion under the inclined lining, in case of trapezoidal section may damage the lining in a big way. Further, due to non-availability of good clay for tiles has attributed to the construction of rectangular brick section, water-course.

7.2 Adoption of FSL at Naka Point

It is vital and should be decided with utmost care. The FSL at Naka point for a sub chak/square (Murabba) should be governed by the critical NSL of that square. Critical NSL in a square is that which is most judicious up to that NSL area should be commanded. Critical NSL point is based on the following consideration:

1. Land leveling upto critical level would be within the economical limits.
2. Construction and maintenance of field channels upto critical level in the square would be within the economical limits of the farmer.
3. Critical point is the governing point in a square in the determination of CCA in that square/sub chak and FSL and Naka point for that square.
4. A slope of 1.5 to 2.0 cm per 50 m (bigha length) are added in the critical level depending upon the soil texture to arrive at the requisite FSL at the Naka point.

Example:

Let critical N.S.L. is 101.0 m and lies 350 m away from Naka

Total run of water 350 m

Add: $1.75 \times 350/50$ cm in critical NSL

Required FSL at Naka point = 101.0 + 0.12 = 101.12 m

7.3 Grades in Water-courses

Grades in water-courses are very important factors in planning water-courses, particularly in case of lined water-courses. Cost of lining is inversely proportional to the water surface slope (WSS). Flattrer WSS results in bigger water courses section which in turn increases the lining cost. While steeper slopes results in smaller water course section which decreases the cost of lining.

As regards velocity is concerned, in lined water-courses, it may be upto 2 m/sec (Refer I.S.code 10.130—1982 para 6.8.12). Critical Velocity

Ratio (CVR) is not applicable in lined sections. But CVR should not be less than one resulting in silting. Hence, CVR should be higher than unity. Therefore, grades should be such as generating velocity, greater than one meter per second. The service area of IGNP Stage II is sandy and storms are frequent, accumulation of sand in water course is a common occurrence. Every year a huge expenditure is incurred on sand clearance. The past experience/study conducted has shown that quantity of silt is nominal. Most of the accumulation/blockage is due to blown sands. Thus, in case of water-course, to keep this blown sand in suspension, maximum velocity should be aimed. Area may not be decommanded merely on this account, a balance is required to be maintained.

It should be noted that there would be drastic changes in the climate with the induction of canal water in the area. It has been observed that intensity of sand storms has reduced to 30% in just 10 years or so after the induction of canal water in this area.

In steeper terrain to avoid falls and to economize the section, higher velocities may be provided.

7.4 Outlet Size

Outlet size refers to the discharge of the outlet, which is directly proportional to the CCA of chak. Here chak does not mean geographical size of chak. As per study conducted and on the basis of experiments it was found that a discharge of around 50 liter/sec. (1.75 cusec) is most suited in application in the field in sandy soils. If discharge is less than 50 liter/sec. (1.75 cusec) there would be over irrigation in the head reach of strip (generally 16.5 m × 50 m) whereas under irrigation in the tail part of the strip.

In IGNP the chak size is so kept that discharge of outlet should generally be between 42 to 70 liter/sec (1.50 to 2.5 cusec). Outlet with discharge below 42 liter/second and above 70 liter/sec, are considered in special cases. In case of higher discharge common feeder water-course in some length and then bifurcating the same by providing proportional distributor is preferable.

Over irrigation and under irrigation is attributed to the velocity of flow in a 16.5 m wide strip. However, if strip size is kept 10 m by 50 m and farmers are educated for maintaining proper grade and land shaping a discharge of 42 liter/sec. (1.5 cusec) ± 10% is most economical. In due course of time when the soils are stabilized and grades are made proper, a discharge of around 42 liter/sec. (1.5 cusec) is ideal for economy and for efficient utilization of water. The lining cost is directly proportional to the discharge when other parameters remains the same, with every 7 liter/sec increase in discharge, cost of lining of water course increases by 5%.

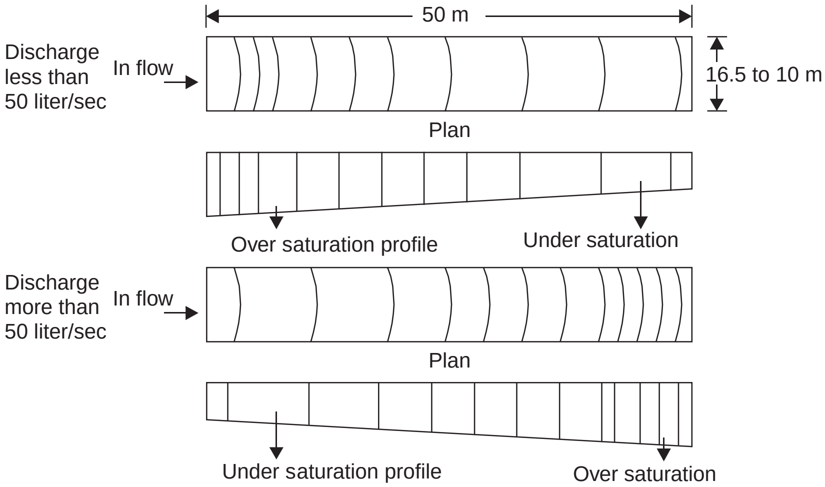


Fig. 7.1 Over Saturation and Under Saturation Profile

Meteorological datas of the last five years related to IGNP areas indicate noticeable change in humidity, wind intensity velocity and precipitation. Changing environment and increase in biomass in the soil is likely to result in lower ETo, which in turn shows reduction in crop water requirement.

The soils under Gang Canal system were initially almost similar to that of IGNP, the average size of outlet is 1.84 cusec. All water-courses are unlined and length per ha of water-course is 25 m/ha. Assuming 20% losses, the discharge comes to 1.45 cusec. The details of the chaks reveal that more than 70% chaks are of less than 2.0 cusec discharge as tabulated below:

Table 7.1 Discharge Range of Chaks-Gang Canal System

Discharge Range (cusec)	*No. of chaks*	*Percentage of total chaks*
0.5 to 1.0	75	6%
1.01 to 1.50	300	25%
1.51 to 2.00	484	40%
2.01 to 2.50	310	26%
2.51 to 3.00	22	2%
Above 3.00	14	1%

So, there is no justification in keeping the chak size greater than 235 ha CCA with stream size 50 lit/sec. (1.75 cusec) when the water courses are lined. In the adjoining Gang canal system chak size 257.6 ha on an average, with discharge of 52 lit/sec, even when the water courses are unlined. In IGNP stage II where water courses are lined a discharge range of 30–50 lit/sec, is most suitable. This would save 10% of lining cost. Further small discharge can be better managed by the farmers as well and prompt them for better water management.

7.5 Working Head

Working Head is the difference in water level in the parent channel and water level at the head of outlet. More precisely, working head is the difference in the FSL of parent channel and FSL at the head of water-course. Working head, provided at the outlets head plays an important role not only in the proper running of water-course but for the proper functioning of parent channel as well.

Working head serves three main functions:

1. Release of design discharge from the outlet.
2. Equitable distribution of water to all the chaks on that channel.
3. Withdrawal of the share of silt/sand from the parent channel.

In case of Main Canals and Branch Canals, as far as possible, no outlet should be provided, but in case, an outlet is essential to be provided, it should be fixed in such a way that working head should not be more than d/3 of the parent channel, that is Main Canal and Branch Canal. In case of Distributories and Minors, working head should be provided as under:

Table 7.2 Working Head

Reach	*Working head*
1. Head one third reach	$d/3$ or 30 cm which ever is more
2. Middle one third reach	$2d/3$ or 30 cm which ever is more
3. In case of tail reaches	d or 30 cm which ever is more d = FSD in parent channel.

Suppose there are 20 outlets on a canal length which covers first 6 to 7 outlets is head one third reach, the length of canal covering next 6 to 13/14 outlets is the middle one third reach and remaining is the tail one third reach.

It is a common complaint that water seldom reaches tail ends, this is attributed to higher working head on the outlets in the head reaches resulting withdrawal of higher discharge by the outlets of the head reach.

Higher working head also leads to decommand of the area. Therefore, working head should be provided considering the problem of the tail reach, as well as likely area going to be decommanded. Working head should be provided to pass the requisite discharge even by providing higher section of APM/pipe or open flume outlet. The performance of an outlet is judged by its flexibility and proportionality (refer Chapter 3).

Thus, head over crest of the outlet should not be more than 1/3rd of FSD for orifice outlets fixed on trapezoidal channels. In other words, a pipe or orifice type outlet will be proportional if the outlet is fixed at 0.3 FSD below the water surface. In general most of the outlets are of orifice type and channels are trapezoidal in section. Hence, head over crest of the outlet should not be more than 0.3 FSD, in turn working head should not be more than 0.3 FSD but in case of small channels, a working head of 30 cm or less may be provided. The aim is, equitable distribution of water and withdrawal of due share of silt by all the outlets. In case of laterals on a water-course no working head be provided.

7.6 Cutting and Filling in Water-course

Cutting and filling in water-course depends upon topography. In IGNP cutting and filling is restricted to 2.5 m and 1.5 m respectively, is not justifiable. To have the maximum command with the available FSL, in the channels, a compromise in cutting and filling is must. But it is also not desirable to have abnormal cutting and filling which may create problem of maintenance. Heavy cutting and filling in a developing terrain may be problematic in the initial stage of running, but in long run isolated cutting and filling can be beneficial to the farmers.

Laying alignment of water-courses along fringe of cutting would certainly increase in lined length and bifurcation of holding, which is in no way justifiable economically as well as in the interest of the farmers. Bifurcation of squares/holdings restricts the cultivators from land leveling of his holdings.

As shown in Fig. 7.2, to avoid cutting at point 0 the alignment of water-course has been shifted along contour of 123.0 meter. But this would restrict the land holder to level his land falling under higher contour. In this way 2 bigha land would permanently go under uncommand, which could be easily levelled.

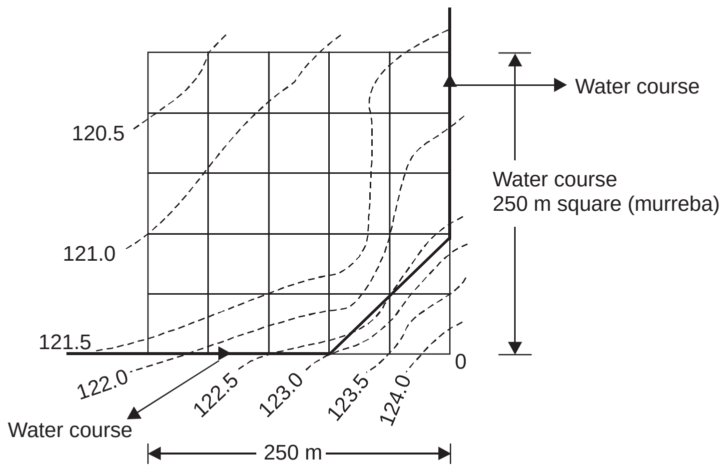


Fig. 7.2 Alignment of Water Course

It should also be kept in mind that unless the farmer in the above case does not level his field, he may not be able to utilize the land and water economically. For proper application of water land leveling and land shaping is a must with a proper grade, otherwise there would be over watering at some places and under watering at other places. This would result in poor crop production.

In Western Rajasthan where most of the area is cup shaped can well be leveled, but bifurcation of holding would restrict the cultivator. However, in case where heavy cutting is involved, otherwise bifurcation would be there, it is better to provide covering over water course in cutting and avoid bifurcation. However, covering in long reaches of 250 m or more may not be desirable. This may create choking problem. Before covering, proper arrangements are made to flush out any accidental choking.

7.7 (a) Naka Point/Turn Out

Nakas are the outlets of the water-course. In the case of outlet of a channel, all the outlets are in operation, whereas in the case of water-course only one Naka is in operation at a time. Only one Naka is provided for each square/sub chak may be more than one holder in that square/sub chak. In compelling circumstances such as bifurcation of square/sub chak by water-course pucca road, two Nakas are provided. Even in that case too, only one Naka would be operative although the two Nakas are meant for the same square sub chak. Location of Naka should be at the highest NSL matching with FSL. It is not necessary that Naka should be on the bigha line or holding line. It may be provided at any suitable point.

(b) Location of Naka Point/Turn Out

Location of Naka plays an important role in saving of seepage losses in the field channel. More is the water run in the field channel, more are the losses.

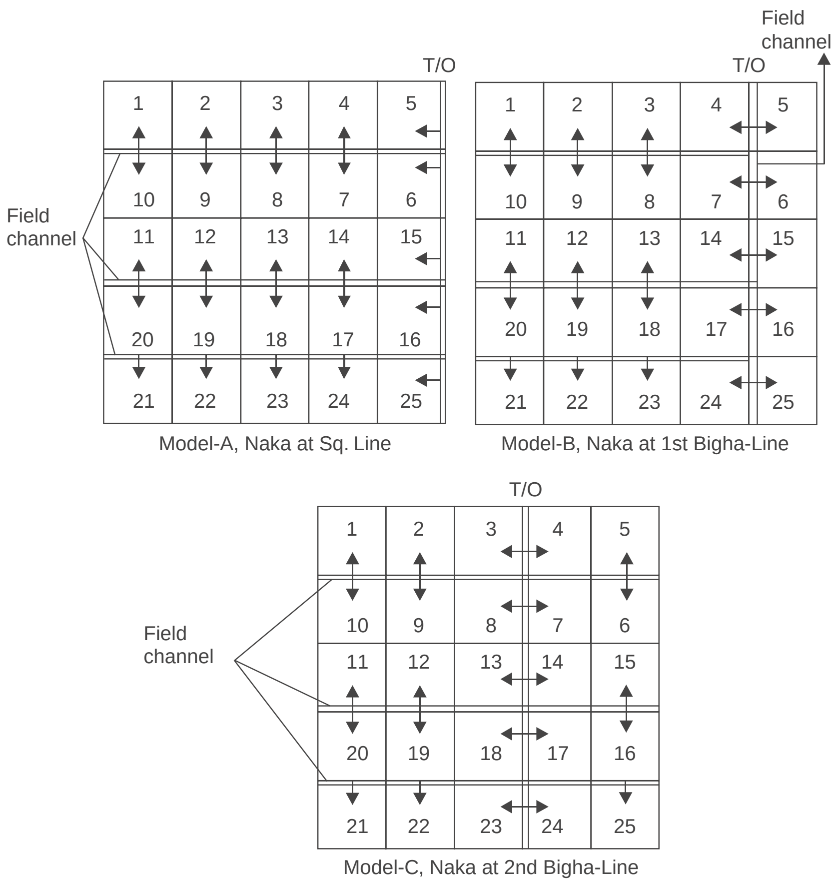


Fig. 7.3 Location of Naka Point

Table 7.3 Water run in Bigha Length

For Bigha No.	*Model A*		*Model B*		*Model C*	
1 and 10	2 × 5.5	11	2 × 4.5	9	2 × 3.5	7
2 and 9	2 × 4.5	9	2 × 3.5	7	2 × 2.5	5
11 and 20	2 × 7.5	15	2 × 6.5	13	2 × 5.5	11
12 and 19	2 × 6.5	13	2 × 5.5	11	2 × 4.5	9
21	1 × 8.5	8.5	1 × 7.5	7.5	1 × 6.5	6.5
22	1 × 7.50	7.5	1 × 6.5	6.5	1 × 5.5	5.5
3	1 × 3.5	3.5	1 × 2.5	2.5	1 × 0.5	0.5
8	1 × 3.5	3.5	1 × 2.5	2.5	1 × 0.5	0.5
13	1 × 5.5	5.5	1 × 4.5	4.5	1 × 2.50	2.5
18	1 × 5.5	5.5	1 × 4.5	4.5	1 × 2.50	2.5
23	1 × 6.5	6.5	1 × 5.5	5.5	1 × 4.5	4.5
4	1 × 2.5	2.5	1 × 0.5	0.5	1 × 2.5	2.5
7	1 × 2.5	2.5	1 × 1.5	1.5	1 × 1.5	1.5
14	1 × 4.5	4.5	1 × 2.5	2.5	1 × 2.5	2.5
17	1 × 4.5	4.5	1 × 3.5	3.5	1 × 3.5	3.5
24	1 × 5.5	5.5	1 × 4.5	4.5	1 × 5.5	5.5
5	1 × 0.5	0.5	1 × 0.5	0.5	1 × 2.5	2.5
6	1 × 1.5	1.5	1 × 1.5	1.5	1 × 2.5	2.5
15	1 × 2.5	2.5	1 × 2.5	2.5	1 × 4.5	4.5
16	1 × 3.5	3.5	1 × 3.5	3.5	1 × 4.5	4.5
25	1 × 4.5	4.5	1 × 4.5	4.5	1 × 5.5	5.5
Total		120.5		98.5		88.5
Weighted avg.	$\frac{120.5 \times 50}{25}$		$\frac{98.5 \times 50}{25}$		$\frac{88.5 \times 50}{25}$	
	241 m		197 m		177 m	

Conclusion

1. In case of unlined water-courses the most suitable location for Naka is as per Model 'B' i.e., the Naka should be at first bigha lines. The reduction of field channel is estimated as 5%. Because the water-course is unlined i.e., overall water run in unlined channel would be 98.5 bigha length of unlined water-course.
2. In case of lined water-course the most suitable location of Naka is as per Model 'C' i.e., the Naka should be located at 2nd bigha line. The reduction in seepage losses in field channel is estimated as 23%.In case where some length of water-course is kept unlined for economical reasons, Nakas and other

structures should be provided at appropriate locations keeping in mind, the safety of structures and irrigability of the land.

7.8 Masonry Structures

As far as possible structures should be so designed that there is no head loss, implying section of the culverts, syphon should be slightly bigger than the water-course. Generally, pipe syphons and pipe culverts are constructed using ACC hume pipes. Use of ACC hume pipes are economical, easy to lay and construct. It is always preferred to use pipe section of higher dia so that flow is free and there is no head loss.

Head loss in hume pipes can be computed using Hazin & Williams formula wherein

$$V = \frac{Q}{A}, \quad A = \frac{\pi D^2}{4},$$

$$\text{WP} = \pi D, \quad R = \frac{\text{Area}}{\text{WP}} = \frac{D}{4}$$

V = Velocity = m/sec, Q = discharge in cumec

A = Area = Sqm, R = Hyraulic Mean depth = m

$$H_L = \frac{V^{1.85}}{1145.8\ R^{1.17}}$$

with the above equations head loss cm/m for discharge range 28 liter to 96.3 lit/sec. using pipe 30 cm to 70 cm dia is tabled below:

Head Loss per metre length of pipe in cm

Table 7.4 Head Loss per Metre Length of Pipes-Different Dia

Discharge Lit/Sec	*Pipe dia*				
	30 cm	*45 cm*	*50 cm*	*60 cm*	*70 cm*
28	0.33	0.05	0.03	0.01	–
31	0.40	0.06	0.03	0.01	–
34	0.47	0.06	0.04	0.02	0.01
37	0.54	0.08	0.04	0.02	0.01
40	0.62	0.09	0.06	0.02	0.01
43	0.70	0.10	0.06	0.02	0.01

Contd.

Table 7.4 (Contd.)

Discharge Lit/Sec	*Pipe dia*				
	30 cm	*45 cm*	*50 cm*	*60 cm*	*70 cm*
45	0.79	0.11	0.07	0.03	0.01
48	0.89	0.12	0.07	0.03	0.01
51	0.99	0.14	0.08	0.03	0.01
54	1.09	0.15	0.09	0.04	0.01
57	1.20	0.17	0.10	0.04	0.01
60	1.31	0.18	0.11	0.04	0.02
62	1.43	0.20	0.12	0.05	0.02
65	1.55	0.22	0.13	0.05	0.02
68	1.68	0.23	0.14	0.06	0.02
71	1.81	0.25	0.15	0.06	0.03
74	1.96	0.27	0.16	0.06	0.03
77	2.08	0.29	0.17	0.07	0.03
79	2.24	0.31	0.19	0.08	0.03
82	2.38	0.33	0.20	0.08	0.03
85	2.54	0.35	0.21	0.09	0.03
88	2.70	0.37	0.22	0.09	0.03
91	3.03	0.40	0.24	0.10	0.03
93	2.66	0.42	0.25	0.10	0.03
96	3.20	0.44	0.27	0.11	0.03

From the table above it would be noticed that in case of 57 liter/sec discharge and pipe of 45 cm dia the head loss in 20 m length of hume pipe is 3.4 cm (0.17 × 20). If the pipe is of 60cm dia losses is less than one cm (0.04 × 20) which can be neglected. However, where pipe section is small, losses must be accounted being substantial.

Pipe, syphon, pipe culverts, which are economical in construction, should be provided. The drawings for pipe syphon and pipe culverts are given at Annexure. As far as possible section of pipe should be such that there is no head loss.

7.9 Economical Length of Lining in Water-course

Refers to the extent of living which may be done in a water course, so that objective of living is achieved, as explained under.

Suppose, there are 58 squares in a chak, all fully commanded. Therefore, water is to be equally shared by all the squares. Let the turn of each square in a cycle of 7 days flow be *X* hours and losses in each square length of water course be 'K'. table given below shows losses in water course/laterals/last length during one cycle of watering.

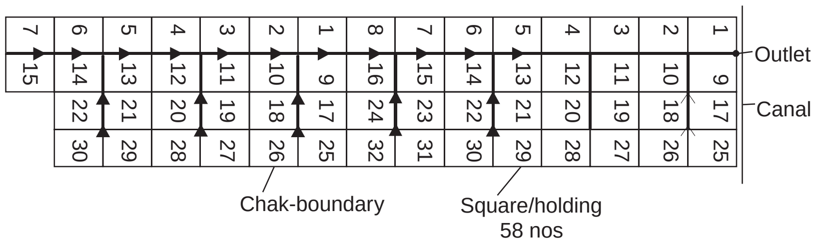


Fig. 7.4 Chak Plan

Table 7.5 Losses in Water Course During One Cycle of Watering

Turn of square No.	*Losses in main W/C length × K*	*Losses in lateral Length × K*	*Total Losses*
7, 15	13K	0 + 1K	14K
29, 30	13K	1K + 1K	15K
21, 22	13K	1K	14K
6, 14	13K	–	13K
5, 13	12K	–	12K
4, 12	11K	–	11K
19, 20	11K	1K	12K
27, 28	11K	1K + 1K	13K
3, 11	10K	–	10K
2, 10	9K	–	9K
17, 18	9K	1K	10K
25, 26	9K	1K + 1K	11K
1, 9	8K	–	8K
8, 16	7K	–	7K
23, 24	7K	1K	8K
31, 32	7K	1K + 1K	9K
7, 15	6K	–	6K
6, 14	5K	–	5K

Contd.

Table 7.5 (Contd.)

Turn of square No.	*Losses in main W/C length × K*	*Losses in lateral Length × K*	*Total Losses*
21, 22	5K	1K	6K
29, 30	5K	1K + 1K	7K
5, 13	4K	–	4K
4, 12	3K	–	3K
19, 20	3K	1K	4K
27, 28	3K	1K + 1K	5K
3, 11	2	–	2K
2, 10	1K	–	1K
17, 18	1K	1K	2K
25, 26	1K	1K + 1K	3K
1, 9	–	–	–
Total 58	202K	14K + 8K	224K

Total length of w/c = 28 sq. length
Length of last laterals = 8 sq. length
Total losses = 224K
losses in last lateral = 8K
losses in last laterals = (8/224) × 100 = 3.6%
Cost of laterals = (8/28) 100 = 28.6%

That means to save 3.6% of total losses, 28.6% cost has been incurred, which is not justified. At the same time losses in unlined water courses are 4 to 5 times more than lined water courses. Keeping last laterals unlined losses would be 256K (in lined length 216 k, in unlined length 8 k × 5). Likely, increase in losses 32/224 × 100 = 14%. Saving in lining cost 28.6%, which is justified.

To mitigate the hardship of farmers served by last unlined length, the turn out time has to be increased to compensate the seepage losses in the unlined length. This increase in running time of unlined length would in turn decrease, in running time in lined length.

Although, this would depend on chak to chak, but in case where small laterals are there, lining more than 50% is unjustified and there is no justification in lining the length preceding small patches.

On the basis of table, saving in losses by lining different length of water courses has been observed as follows:

Table 7.6 Percentage Saving in Losses V/V Percentage Lining

Percentage saving in losses	*Percentage length lined*
55 %	25 %
80 %	50 %
91 %	75 %

Thus, if 75% length of water-course is lined, practically objective of lining is achieved.

Small patches served by unlined water course, the lined length preceding the unlined length for small patches should be left unlined as shown below.

Suppose there are only 10 bighas, which can be commanded in square No. 12 and 20 and for this kutcha water-course was proposed from square No. 18 to 19. Pucca water-course is being provided from square 17 and 18 to serve square 11 and 19. However, if water-course between squares 17 to 18 is kept unlined, our objective of lining is almost achieved even with 50% lining.

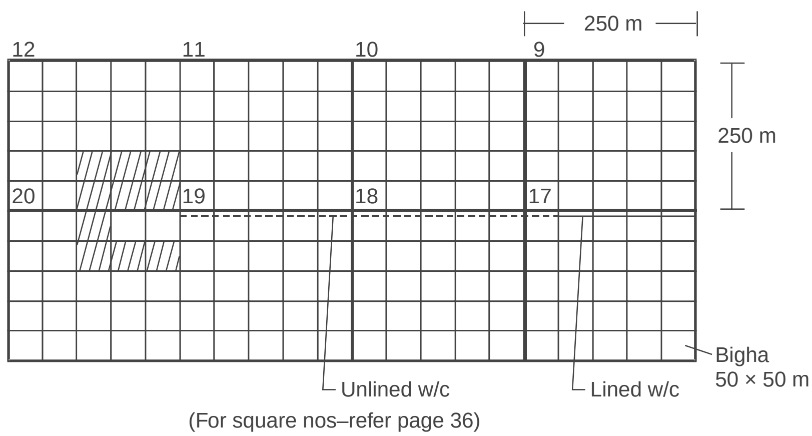


Fig 7.5 Water Course for Small Patches

7.10 Culturable Command Area

Culturable command area is the basis for the design of water-course rather it is the basis for the design of an irrigation project. It is also vital for deciding the chak size. 'Culturable Command Area' it is the portion of the gross command area, which is culturable and cultivable.

Uncommand has been defined as lands whose weighted average ground levels are higher than the FSL at the relevant point. This definition too is technically faulty. At present, CCA is determined taking bigha as a unit. When the average level of four corners of the bigha are higher than the FSL at Naka point, for that square it is termed as uncommand and rest are taken as command. This has created an odd situation, The culturable command area is just 60% of he gross command area and is less than 50% of the geographical area, whereas 95% of geographical area falling on the right side is lower than the available FSL. The reason is that no clear definition of CCA, no clear concept regarding cutting and falling to be provided in canal system and water course has been evolved. Faulty planning of distribution system has further aggravated the situation. While canal planning, CCA is assessed on the basis of murraba/sub chak as a unit, where as at OFD chak planning stage CCA is assessed on the basis of bigha (165 × 165’) as a unit or Revenue Survey numbers in case of non rectangulated area. There is no doubt that CCA must be determined on the basis of bigha/survey number levels, but taking square/sub chak as a unit.

The very important factor which has lost sight is without land leveling, and land shaping, application of water in the field by flow method is not feasible. It is also true that the land leveling may disturb the soil formation, but the land leveling has to be done may be at slow pace. Therefore, culturable command area must be decided on the basis of weighted average of cluster of bigha/survey number. An example is cited in Fig. 7.6.

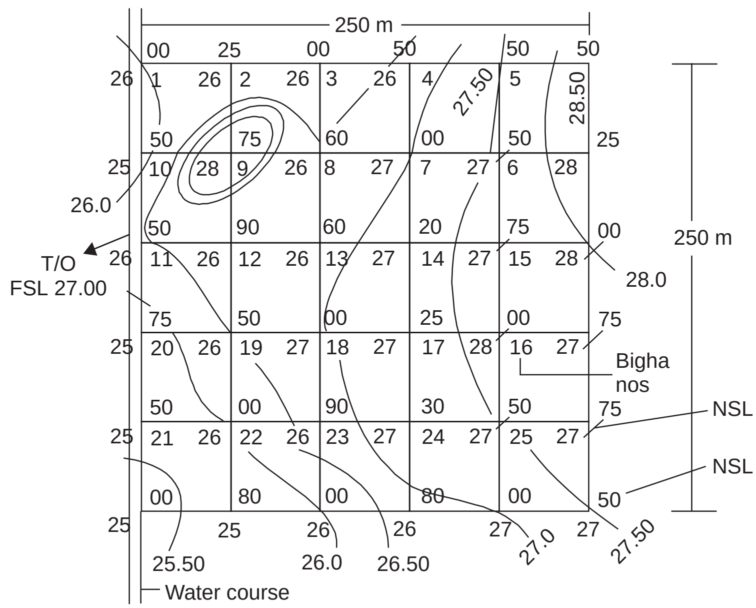


Fig. 7.6 C.C.A. on Weighted Average N.S.L.

The T/O is at bigha no 11 and FSL at T/O is 27.00.

If bigha is taken as unit, likely bighas going uncommand are 4, 5, 6, 7, 14, 15, 16, 17, 18, 24 and 25 total 12 bighas. The CCA is taken as 13 bighas. The average NSL of these 13 bighas taken as command is 26.5 which is 0.5 m lower than the FSL, at T.O (turn out). Whereas, the weighted average of all the 36 points is 26.86 m.

If proposed FSL is 27.25 m (0.75 m filling) at Naka point even then bigha number 5, 6,14, 15, 16,17 and 25 (7 bigha) on the basis of bigha as unit still remains uncommanded. Whereas these bighas should have been commanded on the basis of average NSL (26.86 m).

At present to command all the 25 bighas, the FSL at Naka point required is 28.0 m, thereby providing 1.50 m filling at Naka point. It is stressed that field channel cannot be maintained in a filling of 1.5 m. Water cannot be applied in a slope of 1:50. The maximum slope which can be provided, ranges between 0.04% to 0.08%, depend upon the soil texture porousity and holding capacity of soil. Even after land leveling in due course of time, water-course would be 1.14 m above average NSL in the above case, which is in no way justified, as well as very difficult to maintain.

On the basis of average NSL, FSL required is 26.86 + 0.21 (field channel slope in 7 bighas) is 27.07 m. This gives 0.57 m filling at Naka point whereas on the basis of weighted average NSL, FSL, required is 26.92 + 0.21 = 27.13 m. This gives 0.63 m filling at Naka point. FSL, in water-course would be 0.21 m above average NSL on land leveling against 1.14 m as per present practice. The present practice is not only decommanding the area and incurring 10%, extra cost on earth work and lining, as well as creating problems for future water requirements for the areas brought under command due to land leveling. Further, most of the water-course would be hanging and would be difficult to maintain in future.

The present practice discourage farmers land shaping and grading. Further, if CCA is determined on the basis of weighted average of square/ holding, then cases of uncommand to command will be less in future. Further, present practice is costing state heavily, because the lands which are in fact commandable are being given as uncommandable. To substantiate this view, analysis of three chaks is given below.

(a) Case Studies: Treating Command as Uncommand

Case 1. Name of chack 30 TBM (Tibrewala minor of Sadhana Dystributory system)

Table 7.7 Case I-Treating Command as Uncommand

Particulars	*As per Approved Planning*	*As Per Weighted Average*
1. FSL in minor	130.84 m	130.84 m
2. FSL in W/C	130.54 m	130.41 m
3. Working Head	0.30 m	0.43 m
4. GCA	248.70 ha	248.70 ha
5. CCA	218.09 ha	232.26 ha
6. Discharge	1.70 cusec	1.81 cusec
7. Length of lined W/C	3193.39 m	3193.39 m
8. Section of W/C	Vth type	Vth type
9. M/ha of lined W/C	14.64 m	12.84 m
10. Total E/W	21215.67 cum	19837.58 cum
	Increase in CCA 6.5%	
	Decrease in E/W 6.5%	

From the above table it is clear that 14.17 ha (232.26 – 218.09) area which is commandable has been allotted as uncommand land.

Case 2. Chak 3BSM (Baramsar Minor)

Area decommended in square where Naka FSL is higher than average NSL of square.

Table 7.8 Case II-Treating Command as Uncommand

Sq. No	*FSL of Naka (m)*	*Av. NSL of square (m)*	*Area decom-mended in square (Bigha)*	*FSL above average NSL (m)*
56/17	157.37	156.31	02	1.42
36	158.69	158.15	07	0.54
34	159.06	158.68	08	0.38
35	162.00	160.08	06	1.92
41	158.59	157.79	03	0.80
42	159.05	158.45	15	0.85
43	158.36	158.20	09	0.16

Contd.

Table 7.8 (Contd.)

Sq. No	*FSL of Naka (m)*	*Av. NSL of square (m)*	*Area decom-mended in square (Bigha)*	*FSL above average NSL (m)*
76/01	155.03	155.00	03	0.03
09	155.03	154.90	01	0.13
17	155.55	155.00	06	0.55
26	155.55	155.20	04	0.35
75/08	156.19	155.25	03	0.94
14	156.03	155.90	06	0.13
15	156.19	156.00	06	0.19
21	155.65	155.50	03	0.15
24	155.88	155.70	10	0.18
31	155.79	154.06	05	1.73
36	155.11	154.80	03	0.31
37	155.27	154.28	01	0.99
38	155.50	155.20	05	0.30
40	154.64	154.12	04	0.52
44	155.11	154.69	09	0.42
45	155.27	154.57	08	0.70
46	155.35	155.00	06	0.35
47	154.60	154.48	08	0.12
			Total 140	

Total area decommended = 140 Bighas
= 11.7%

Table 7.9 Case III-Treating Command as Uncommand

FSL higher than Av. NSL	*Area Decommanded Bigha*
More than 1.0 m	13
0.5 m. to 1.0 m	47
0.3 m. to 0.5 m	32
Less than 0.30 m	48
	Total 140

From the above table it reveal that even when the FSL at Naka point is 0.30 m higher than the Av. NSL of the square, even than the area has been decommanded in the square.

Case 3:

Table 7.10 F.S.L. Higher than Av. N.S.L.

Sq. No	*FSL of Naka*	*Av. NSL of square*	*Area decom-manded in square (Bigha)*	*FSL above average NSL*
55/12	158.14	157.34	7	0.80
13	158.14	157.32	7	0.82
14	156.14	159.76	4	0.60
15	156.26	154.74	3	0.52
19	157.86	156.94	6	0.92
21	158.02	157.87	6	0.15
22	156.34	156.18	9	0.16
23	156.26	155.14	3	1.02
25	157.80	156.53	2	1.37
30	157.60	156.56	2	1.04
35	156.72	156.21	6	0.21
36	157.75	157.23	7	0.52
37	157.75	157.00	1	0.75
43	156.72	156.41	5	0.21
52	157.38	157.03	3	0.35
53	157.38	156.58	1	0.80
58	157.90	157.33	14	0.57
59	157.10	156.96	7	0.14
60	157.10	156.94	10	0.16
62	157.50	157.82	11	0.08
3	157.84	157.78	8	0.06
4	157.84	157.76	4	0.06
5	156.84	156.24	1	0.60
13	156.34	156.31	2	0.03

Contd.

Table 7.10 (Contd.)

Sq. No	*FSL of Naka*	*Av. NSL of square*	*Area decom-manded in square (Bigha)*	*FSL above average NSL*
20	156.73	156.41	3	0.32
25	156.36	155.96	5	0.40
26	156.40	155.82	2	0.58
28	156.55	155.31	3	1.24
33	156.29	155.59	2	0.70
42	155.53	154.84	2	0.59
Total area decommanded: 145 bighas = 36.0 ha.				

Table 7.11 Area Decommended

FSL higher than Av. NSL	*Area Decommanded Bigha*
Above 1.0 m	10
0.5 m to 1.0 m	57
0.3 m to 0.5 m	11
Less than 0.30 m	67
	Total 145 bighas

From the above table it is clear that even when the FSL at Naka point is 0.30 m higher than the Av. NSL area has been decommanded.

(b) Area Under—Abadies, Mandies and Roads, etc.

Area under Abadi, Mandi, Roads, Agro-service centers i.e., area under infrastructures are termed as Gair Mumkin,(not possible to cultivate.) whereas nurseries are taken under CCA. In case of Abadis, water is provided aquivalent of 5 ha CCA for Abadi, covering upto 25 ha, thereafter one ha equivalent-water is provided for each additional 5 ha area. The same principle should be applied in case of area under Mandis. As far as Agro-Service Centre, if these are planned combined with Agro-Research Centre, then whole of the area of Agro-Research Centre should be taken as CCA, though it may be planned in uncommanded area. The water requirement of Agro-research centre would in no case be less than other commanded area. Water requirements of Agro-research centre would be more as the water is applied under ideal condition for optimization of production of the crops under research. Further, the Agro-research centre is to develop new varieties resulting more water use. Hence, requirement of water for Agro-service centre coupled with Agro-research centre should in no case be less than as provided for other command areas.

In case of forestland in a chak no provision of water should be kept for such lands. The requirement of forestry is only for first two years of planting, thereafter most of the water requirement by the trees is met by ground water.

Syphoning or pumping directly from canals is done for watering forest plantation along main canal and branches. This practice encourage wastage of precious water. The water to the plants should be applied through cartage from nearest canal.

7.11 Integrated Planning

This refers to planning of infrastructures along with OFD planning for early utilization of created irrigation potential

In the first phase attention must be paid to strengthen the existing infrastructure amenities particularly shelter accommodation, drinking water, primary education, dispensary and road links. These are the primary requirements for the inhabitants old or new.

In the second phase: Thrust must be on developing the new infrastructure in a planned way. These should be primary—Abadi and Mandi. In the former case one abadi with diggi, primary school be planned for 8 to 10 chaks, as far as possible centrally located. This primary abadi should be located in such a way that most of the surrounding area be uncommanded for rearing cattles and development of animal husbandry but must have 5 to 10 bighas in command and should be near to canal, well connected with Mandi-Abadi and Agro-research centre. The primary abadies should be planned taking into account the existing nearby Abadi and utilizing existing infrastructure maximum possible, provision for future development should also be there.

Mandi-Abadi with all amenities should be planned to cater the needs of a cluster of ten primary Abadies. In this way broadly one Mandi with abadi should be planned covering a geographical area around 350 to 400 sq Kms. All amenities should be planned in these Mandies, so that there is no movement of people to bigger towns.

As far as possible Mandies, Agro-service Centres, Agro-research Centers, etc. should be planned on uncommand lands. However, 1.25 ha to 2.5 ha area must be under command for constructing, drinking water supply, nurseries, etc. Road network should be planned in such a way that all existing roads may be fully utilized by the settlers, particularly, the roads constructed along canals should be well connected to the Mandi and Abadi roads. Diggies (water tank) should be constructed in each abadi and it must be ensured that diggi is fed through gravity flow from nearest canal with least length of water-course. The capacity of diggi should be for a month water supply requirement of the Abadi or Mandi-Abadi as the case may be.

7.12 Sprinkler-Drip Irrigation, Economic Use of Precious Water

To economise the use of water, sprinkler/drip irrigation should be encouraged through subsidies and other incentives. Recently Govt. has launched a programme to boost sprinkler/drip irrigation by providing subsidy upto Rs 50,000/- for constructing diggies of about 8.0 lac liter capacity by individual farmer.

The concept of sprinkler irrigation application of water would change the definition of command and uncommand. In case of flow irrigation area above FSL at Naka point is termed as uncommand, but in case of sprinkler and drip irrigation no area can be termed as uncommand. Looking to the low availability of water it has been decided by Government to reduce the water allowance to 8.75 lit/sec/100 ha (1.25 cusec/1000 acres) on Lift Canals It has also been decided that water would be given to only those cultivators, who has installed sprinkler/drip water application arrangements. This would completely change the earlier planning concept of OFD works. A new concept has to be evolved matching the availability of 8.75 lit/sec/100 ha water allowance. In flow (gravity) application stream size is kept around 56 liters and linear length around 4.0 km as the water allowance is 21 lit/sec/100 ha (3.0 cusec per 1000 acres). With the reduction of water allowance to 8.75 lit/sec/100 ha keeping a stream size of 56 liter is not practicable. This means keeping chak size of 647 ha CCA involving some 130 cultivators, their turn would be of just 1.30 hours in a weak cycle. To mitigate, it is opined that stream size should be around 21 liter to 35 liters. Assuming a discharge of 28 liter/sec and water surface slope of 1.2750 and linear length of water course to be 4.5 km, likely losses at the tail end at the rate of 0.61 cumec per M.sqm of W.P. would be

$$= \frac{0.963 \times 0.61 \times 4500}{10^6} \times 10^3 = 2.6 \text{ liter/sec}$$

Which comes nearly 9.4% of head discharge. This is with the assumption that water is flowing continuously. But in the case of water course only one Naka is operative at a time. So, the losses are bound to be much more than assumed. It has been observed that in brick lined water courses, where dry sand/earth filling is there, loss is almost 1.2 liter/ 1000 sqm of wetted perimeter. Thus, in the above case losses at tail would be around 18.8% of the head discharge. This would put tail end users in big disadvantage. In case where discharge is less than 28 liter/sec the linear length of water-course may not be more than 3.0 km. This would necessitate more channels per ha of CCA. Moreover, planning of chak should be, with the concept that first water is to be stored in a tank and thereafter it would be used for irrigation by means of sprinkler/drip system.

No part of the water-course be kept unlined where water allowance is 8.75 lit/sec/100 ha. In unlined water-course a discharge of 28 liter/ second would not travel a distance of more than 200 meters, hence the very purpose of constructing water-course would be frustrated.

In case where the water allowance is 8.75 lit/sec/100 ha, while planning chaks, importance must be given, where the tank is to be constructed by the farmer in his holding. The field channel length connecting tank should not be more than 25 to 50 m, otherwise field losses in the kutcha water-course would be so high that water may not reach the tank. Secondly, tank should be planned in such a way that minimum lift is required for sprinkler and drip application of water as the head loss in the sprinkler and drip irrigation is very high due to small section of distribution pipes and high velocity, more head loss, means more power required. In flow system falls can be affordable to lower the cost of earth work, whereas in case of sprinkler and drip irrigation application of water, providing falls may not be economical in the long run, as the application of water needs further lifting.

7.13 Unlined Water-course and F.B.

In case of lined water-course, a free board of 15 cm is being provided. For unlined water-course it should be 30 cm. In case of unlined water-courses, bank width should not be more than 45 cm at bank level in filling cases, whereas in cutting reaches, bank width or berm width should not be less than 100 cm and side slopes should be 2:1 to 3:1(H: V) so as to minimize the blown sand accumulation and choking. In case of unlined water-course, water surface slope should be not more than 1:4000 (i.e., 0.06 m per square of 250 m) thereby resulting CVR would be less than 1.0 implying that velocity would be silting. Table for design parameters for unlined section for different discharge grades is given below:

Unlined section for discharge range 14 liter/sec (0.5 cusec) to 116 liters/sec (4.1 cusec)

Assume N = 0.03 A = (B + S.S × D) D

W.S.S. = 1:5000 $WP = B + 2\left(\sqrt{S.S^2 + 1}\right) \times D$

S.S. = 2 : 1 (H : V) R = A/WP

$$V = \frac{R^{\frac{2}{3}} \times S^{\frac{1}{2}}}{N}$$

Table 7.12 Unlined Water Course Sections

Bed width in Metres

Depth	0.3	0.4	0.5
	Discharge in liters/sec.		
0.20	15.8	18.7	22.0
0.25	25.5	29.7	33.9
0.30	38.2	43.8	49.4
0.35	54.0	61.0	68.0
0.40	73.0	82.0	91.0
0.45	124.0	107.0	118.0
0.50	124.0	136.0	149.0

Assume N = 0.03

W.S.S. = 1 : 4000

S.S. = 2 : 1 (H : V)

Bed width in Metres

Depth	0.3	0.4	0.5
	Discharge in liters/sec.		
0.20	17.7	20.9	24.6
0.25	28.5	33.2	37.9
0.30	42.8	49.0	55.2
0.35	60.4	68.0	76.0
0.40	81.6	892.0	102.0
0.45	107.0	120.0	132.0
0.50	139.0	152.0	167.0

7.14 Bank Width in Lined Section in Filling

In case of filling bank width of 1.0 m at TBL is on higher side in lined water-course. The width of berm should be 1.0 m at bed level on both sides of water course.

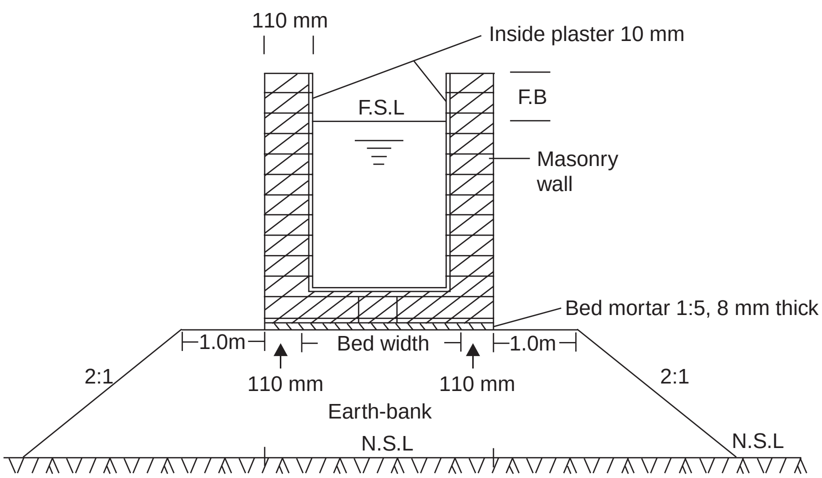


Fig. 7.7 Bank Width of Lined Water Course

There should not be any filling above bed level. The filling above bed level of lining is detrimental in two ways:

1. Defects in lining are covered/hidden, as the lining cannot be checked from outside whether joints are properly filled or not.
2. Increases in seepage loss due to negative pressure created by the dry earth filling.

The seepage loss due back fill would persist till the back fill is unsaturated. Back fill is not likely to attain saturation as the soils are of high infiltration rate and water table is too deep (more than 100 m). As per International Land Reclamation Institute page 223 para 23.1.1 in the zone above the ground water table the potential which is numerically equal to the hydro static pressure has a negative sign, it is convenient to express it in terms of tension or suction. In equilibrium situation the tension in a soil profile above a water table equals the height above that water table. In sandy soils the soil moisture is mainly built by capillary forces where as in clay soils by the lower water content range. The absorbed ions play an important part. Soil moisture tension/suction range extends from

0 (saturated soil) to about 10^6 cm water column (air dry soil). This imply that in air-dry soil tension/suction is upto 1000Kg/cm^2.

In this connection a simple experiment was done during Nov-Dec. 1992 and it was observed that losses have increased three times due to back fill (dry earth filling) as against no back filling.

In place of 20 cm thick selected soil cover on side slopes, Mulching should be done on side slopes to avoid erosion of banks. Mulching would be more effective if done before onset of rains, further Mulching should be done in systematic manner so that winds changing direction may not damage embankment. The distance between mulching rows should not be more than 1.0 m. Mulching is more effective and economical for embankment protections, as well as for stabilizing embankment soil.

7.15 Design of Lined Water-courses

For design of lined water-courses Mennings formula is adopted wherein

Q = Discharge in cumec

V = Velocity in m/sec

R = Hydraulic mean depth (m)

S = Water surface slope

$$Q = A \times V,\ V = \frac{R^{2/3} \cdot S^{1/2}}{N} \text{ (MKS)}$$

$$\left(V = 1.486 \quad \frac{R^{2/3} \cdot S^{1/2}}{N} \text{ in FPS system} \right)$$

N = Rugosity coefficient.

In FPS

Q = Discharge in cusecs

V = Velocity in ft/sec

R = Hydraulic mean depth (ft).

S = Water surface slope

N = Rugosity co-efficient

1.486 = Conversion factor = $(3.28084)^{1/3}$

The standard cross-sections are based on optimum use of bricks. Section are so designed that there is no wastage of brick in the construction. Conversely, the sections are in accordance with the use of full bricks and half-brick combination in bed and sides. There are 8 sections using two and a half bricks to four and a half bricks in bed, and four bricks to six bricks on side. The sections are as under with brick size 23 cm × 11 cm × 7 cm

Table 7.13 Brick Lined-Water Course Sections

Sections	*No. of bricks*		*B.W. (cm)*	*FSD (cm)*
	Bed	*Side*		
I	2.5	4	35	17
II	2.5	5	35	25
III	3.0	5	47	25
IV	3.5	5	59	25
V	4.0	5	71	25
VI	3.5	6	59	33
VII	4.0	6	71	33
VIII	4.5	6	83	33

A comprehensive discharge table covering all the eight sections with W.S.S 1:5500 to 1:330 generating velocity upto 0.762 m/sec (2.5'/sec) is as under:

Table 7.14 Discharge in Lined Water Courses

Slope Per 1000	*Section B.W × Depth in metres*							
	0.35 × 0.168	*0.35 × 0.248*	*0.47 × 0.248*	*0.59 × 0.248*	*0.71 × 0.248*	*0.59 × 0.326*	*0.71 × 0.326*	*0.83 × 0.326*
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
	Discharge in cumecs							
0.18	0.008	0.014	0.021	0.029	0.036	0.042	0.053	0.065
0.24	0.010	0.016	0.024	0.033	0.042	0.048	0.061	0.075
0.30	0.011	0.018	0.027	0.037	0.047	0.054	0.068	0.084
0.36	0.012	0.020	0.030	0.041	0.051	0.059	0.075	0.092
0.42	0.013	0.022	0.032	0.043	0.055	0.064	0.081	0.100
0.48	0.014	0.023	0.034	0.047	0.059	0.068	0.087	0.106
0.54	0.015	0.025	0.037	0.050	0.063	0.072	0.092	0.113

Contd.

Table 7.14 (Contd.)

Slope Per 1000	*Section B.W × Depth in metres*							
	0.35 × 0.168	*0.35 × 0.248*	*0.47 × 0.248*	*0.59 × 0.248*	*0.71 × 0.248*	*0.59 × 0.326*	*0.71 × 0.326*	*0.83 × 0.326*
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
	Discharge in cumecs							
0.60	0.016	0.026	0.039	0.052	0.066	0.076	0.097	0.119
0.66	0.016	0.027	0.040	0.054	0.070	0.080	0.102	0.125
0.72	0.017	0.028	0.042	0.057	0.073	0.083	0.106	–
0.78	0.018	0.029	0.044	0.060	0.076	0.087	0.111	–
0.85	0.019	0.031	0.046	0.062	0.078	0.090	0.115	–
0.91	0.020	0.032	0.047	0.064	0.081	0.093	0.119	–
0.97	0.020	0.033	0.049	0.066	0.084	0.096	–	–
1.03	0.021	0.034	0.050	0.068	0.086	–	–	–
1.09	0.022	0.035	0.052	0.070	0.089	–	–	–
1.15	0.022	0.036	0.053	0.072	0.091	–	–	–
1.21	0.022	0.037	0.055	0.074	0.094	–	–	–
1.27	0.023	0.038	0.056	0.076	–	–	–	–
1.33	0.024	0.038	0.057	0.078	–	–	–	–
1.39	0.024	0.039	0.059	0.079	–	–	–	–
1.45	0.025	0.040	0.060	0.081	–	–	–	–
1.51	0.025	0.041	0.061	0.083	–	–	–	–
1.57	0.026	0.042	0.063	0.084	–	–	–	–
1.64	0.026	0.043	0.063	0.086	–	–	–	–
1.70	0.026	0.043	0.065	0.088	–	–	–	–
1.76	0.026	0.044	0.066	0.089	–	–	–	–
1.82	0.027	0.045	0.067	–	–	–	–	–
1.88	0.027	0.046	0.068	–	–	–	–	–
1.94	0.028	0.046	0.069	–	–	–	–	–
2.00	0.028	0.047	0.070	–	–	–	–	–
2.06	0.029	0.048	–	–	–	–	–	–
2.12	0.029	0.048	–	–	–	–	–	–
2.18	0.030	0.049	–	–	–	–	–	–

Contd.

Table 7.14 (Contd.)

Slope Per 1000	*Section B.W × Depth in metres*							
	0.35 × 0.168	*0.35 × 0.248*	*0.47 × 0.248*	*0.59 × 0.248*	*0.71 × 0.248*	*0.59 × 0.326*	*0.71 × 0.326*	*0.83 × 0.326*
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
	Discharge in cumecs							
2.24	0.030	0.050	–	–	–	–	–	–
2.30	0.030	0.050	–	–	–	–	–	–
2.36	0.031	0.051	–	–	–	–	–	–
2.42	0.031	0.052	–	–	–	–	–	–
2.48	0.032	0.052	–	–	–	–	–	–
2.54	0.032	–	–	–	–	–	–	–
2.61	0.032	–	–	–	–	–	–	–
2.67	0.033	–	–	–	–	–	–	–
2.73	0.033	–	–	–	–	–	–	–
2.79	0.033	–	–	–	–	–	–	–
2.85	0.034	–	–	–	–	–	–	–
2.91	0.034	–	–	–	–	–	–	–
2.97	0.035	–	–	–	–	–	–	–
3.03	0.035	–	–	–	–	–	–	–

7.16 Losses in Lined Water-courses

Providing 8 mm thick mortar on sub grade below bed bricks is not technically justifiable. First there is nothing like sub grade in bed, that is sand watered and dressed to maintain slope and section of the water course. Spreading cement mortar over earth and then laying brick renders the bottom mortar ineffective due to suction of water from the mortar by sand and there is no way to cure this.

During test checking at some places particularly in filling reaches, it was observed that bottom mortar found to be just dry non-sticky under the bricks. It would be better if bed plaster is done in two layers of 8 mm and 10 mm. Although the second layer of plaster in bed would reduce the section height by 8 mm resulting decrease in X-sectional area but this can be adjusted within the freeboard of 152 mm. In side bed, plaster in two layers would certainly be more effective in checking the seepage, as substantiated by the experiments.

Table 7.15 Discharge Co-efficient for Brick Lined Water Course

Section	*Discharge (cumec)*
I	$0.6344\sqrt{S}$
II	$1.0531\sqrt{S}$
III	$1.5693\sqrt{S}$
IV	$2.1296\sqrt{S}$
V	$2.7103\sqrt{S}$
VI	$3.0930\sqrt{S}$
VII	$3.9487\sqrt{S}$
VIII	$4.8342\sqrt{S}$

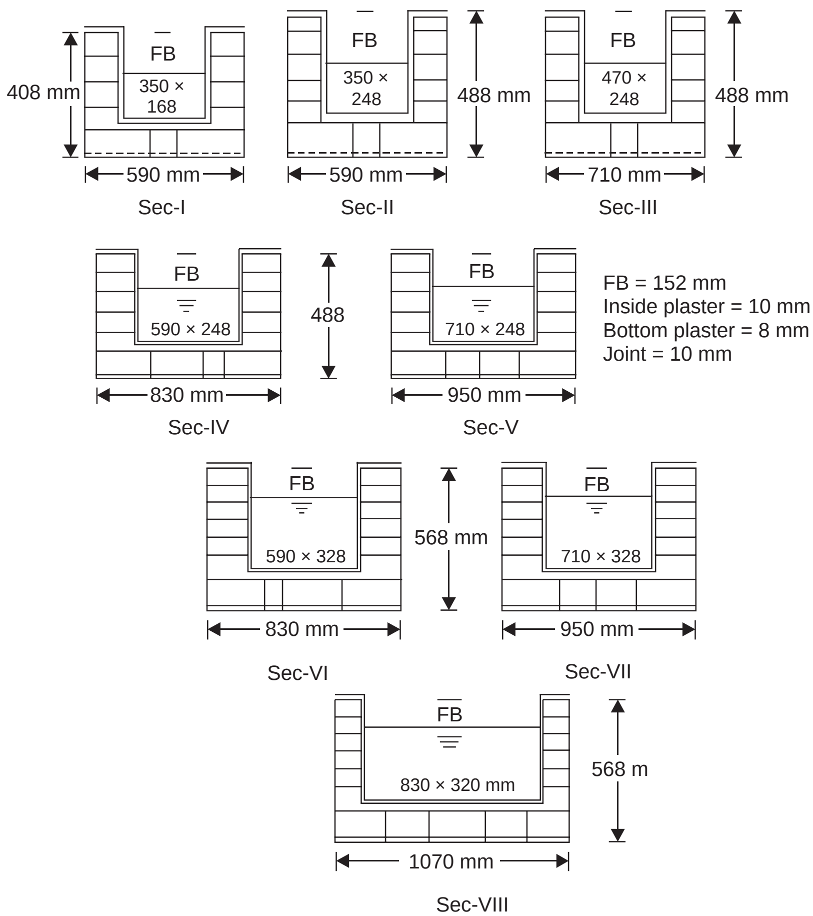


Fig. 7.8 Brick-Lined-Sections (Brick 23 × 11 × 7.0 cm)

Table 7.16 Losses in Water Course with Different Specification of Lining

Sr. No.	*Type of Lining*	*No. of Observations*	*Loss per M. sft of WP (cusec Av.)*
1.	Brick lined as per rectangular Section and specification	2000 (App)	0.50
2.	Brick Lined as per rectangular section without inside plaster	6	3.442
3.	Brick Lined as per rectangular section inside plaster but without side plaster.	9	3.190
4.	Brick Lined as per rectangular section without inside plaster but LDPE film at bottom	1	2.60
5.	Rectangular lined stone patties in Bed with brick masonary wall fully inside plastered	1	0.410
6.	Rectangular lined stone patties in bed with brick masonary wall inside plastered but no bed plaster.	1	0.810
7.	Trapezoidal section, ferro cement mortar lining	1	0.54
8.	RCC half rounded pipe water course	1	1.00
	Source - G.C. report)		

As per table above Sr. No. 2, losses in case of Rectangular brick lined water-course without inside plaster is 3.442 cusec/M.sft of W.P. whereas with inside plaster and without bed plaster losses is 3.19 cusec/M.sqft of W.P. This indicates that side plaster is not much effective in checking the seepage. In some cases inside bed and side plaster losses may come to 0.50 cusec/M.sft of W.P. It means that bed plaster is governing in checking the seepage in case of brick lined rectangular water-course. So, bed plaster should be in two layers of 8 mm and 10 mm. However, 8 mm mortar on sub grade may be dispensed with.

As per above report the least losses come in case of stone patties in bed with brick masonry wall fully inside plastered (0.416 cusec/M.sqft of W.P.), implying that practically all the losses are through bed. Hence, bed plaster in two layers is more beneficial in case of brick lining in bed and sides.

Table 7.17 Losses in Different Grades of Mortar Used in Masonary and Plaster

Sr. No.	*Description of Masonry in bed and side*	*Description of Masonry in side plaster*	*No. of Obser-vations*	*Total length*	*Seepage losses in cusec/ M.sft (Av.)*
1.	Brick masonry In 1:5 CM	1:4 CM	7	6189	0.778
2.	Brick masonry In 1:5 CM	1.5 CM	7	6352	1.13
3.	Brick masonry In 1:5 CM	1.6 CM	7	6632	0.667
4.	Brick masonry In 1:6 CM	1:4 CM	6	9661	0.409
5.	Brick masonry In 1:6 CM	1:5 CM	6	4910	0.417
6.	Brick masonry In 1:6 CM	1:6 CM	7	5200	0.579
	Source: Gill committee report. C.M. (Cement mortar)				

The provision of 10 mm thick cement plaster 1:4 cement sand mortar on inside bed and walls upto top needs review, in the light of the above table. In case of brick masonry in 1:5 cement sand mortar losses are 0.677 cusec/M.sqft with inside plaster in 1:6 cement sand mortar whereas in case of brick masonry 1:6 cement sand mortar losses are 0.409 cusec/ M.sqft. with inside plaster in 1:4 cement sand mortar. This indicates that mortar for plaster may be 1:4 or 1:6 cement sand is not of much importance.

It is implied that, most of the losses are through bed percolation. Therefore, plaster in bed should be in two layers. An experiment was conducted with the following proposition:

1. Rectangular brick lined section 1:6 cement mortar with inside bed plaster in two layers and side wall plaster up to top in 1:6 cement, sand mortar.	The losses were observed to be 0.30 cusec/M.sft of wetted perimeter.
2. Rectangular brick lined section, bed with brick on edge in 1:6 cement sand mortar inside bed and wall plaster upto top in 1:6 cement, sand, martar	The losses were observed to be 0.285 cusec/M.sft of wetted perimeter.

From the above two observations as well as reported in Gill Committee report, it is concluded that the main losses are through bed. In both the above cases 8 mm thick mortar on sub grade was not used. So, it is emphasized that to check the seepage either inside bed plaster should be in two layers or bed bricks should be on edge.

(ii) Providing Village Road Bridge

Where village road bridge is above 0.5 metre, from NSL it may not be convenient for plying of vehicular traffic, particularly for camel/bullock carts. Culvert on water courses are mostly used for cartage of farm produce by camel/bullock carts or by tractor-trolley. One metre high VRB would need long ramps for smooth plying. As these are kutcha tracks and difficult to maintain, it would be better to provide syphon culvert in case bank filling is more than 0.5 metre, using 0.6 m dia RCC pipe.

The cost in both the case practically remains the same. Initially construction cost of syphon culvert may be somewhat more, but keeping and maintaining the cushion over culvert and ramps would be a costly affair.

(iii) Providing Naka/Turn Out in Filling

In case the Naka is provided in filling for smooth passage of water from higher level to field level sloping apron with cistem for energy dissipation should be provided. The slope of the apron should not be less than 4:1 and cistem depth should be minimum 0.5 m below the ground level. However, practical approach depending upon the field conditions may be adopted. It may be kept in mind; Naka in filling is most vulnerable point in the maintenance of water-course. Most of the breaches/damage occurs at Naka point in fillings. Utmost care should be exercised for smooth transition of flow from water-course to field level.

Type Design of a Fall

A cushion type fall is suitable for water courses and small channels. The dimensions of basin are worked out by following empirical relations.

In the sketch—Element of a fall

D = Depth of flow (F.S.D)

H = Fall of drop

X = Depth of cushion sill below downstream F.S.L. in the field channel.

Y = Length of cushion

Z = Depth of cushion sill below upstream F.S.L. in the field channel.

With full supply depth in upstream field channel, D, and the height of drop, H, known. the X, Y, Z,. can be determined by following formula:

$$x = D + 0.82\ D^{1/2} \cdot H^{1/3}$$

$$Y = 4/3\ (ZD)^{1/2}$$

$$Z = X + H - D \text{ (all dimensions in m.)}$$

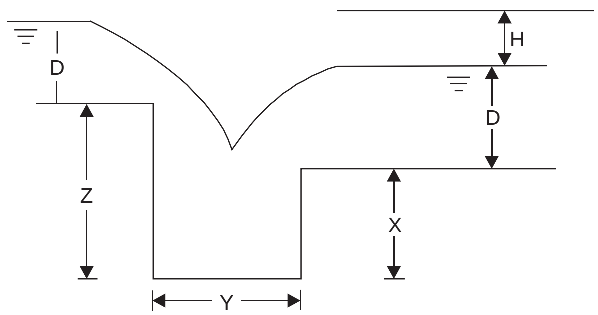


Fig. 7.9 Type Design of a Water Course Fall

The width of the cushion is kept more than the field channel width by about 10 to 20 Cm. The fall can be economically constructed in brick masonry stone masonry.

Example:

D = 0.246 m

H = Drop = 1.2 m

$X = 0.246 + 0.82\ (0.246)^{1/2}\ (1.2)^{1/3}$

$= 0.678$ m.

$Z = 0.678 + 1.2 - 0.246$

$= 1.632$ m

$Y = 4/3\ (1.632 \times 0.246)^{1/2} = 0.845$ m.

8

Planning OFD Works Under Lift Schemes

8.1 Introduction

Lift Irrigation schemes are executed under highly compulsive circumstances particularly, in the countries suffering power shortage. The capital cost of lift irrigation schemes is generally two to three times more than the flow irrigation schemes, but the maintenance/operation cost is 15 to 20 times more than the flow irrigation schemes. However, irrigation charges are generally same or just 5% to 10% more. So, execution of lift irrigation scheme is a very costly proposition, but where there is no alternative, such schemes are executed in the interest of public at large. But, before taking up such lift irrigation schemes, some hard policy decisions must be taken. Before start of such schemes, particularly with respect to the area to be covered under the scheme, water allowance to be provided, duty and delta and mode of application of water in the field and water charges to be levied.

As per recommendation of the Committee on water charges, water charges should in no case be less than the maintenance and operation charges of the lift scheme concerned. This implies that water charges recovered must be commensurate to meet the maintenance and operation charges. In lift irrigation scheme in addition to canal maintenance, pump house maintenance and operation charges are very high. The power availability in countries likes India is low, breakdowns are frequent, cost of power supply is too high, maintenance of pumps and transformer is also very high. Under these circumstances high importance must be paid to the planning of lift canals and related OFD works.

8.2 Water Allowance

In flow system water is generally applied in the field through gravity flow, but in case of lift irrigation as far as possible there should be restriction on this practice. Water should be applied either through sprinkler or drip system, and water allowance should be 40% to 60% to that of gravity flow application in the area. Intensive irrigation should be discarded and extensive irrigation should be patronized, as far as possible, particularly in area like Western Rajasthan where water is scarce and rains are scanty but land is in abundance.

8.3 Location of Service Tank

While planning OFD works, where water is to be applied through sprinkler/ drip system. The water course network should be planned in such a way that there should be no falls, no loss of potential energy should be there. Chaks should be carved in such a way that water course network should be minimum. It shall be born in mind that there would be no field channel, practically no land leveling and no land shaping. From water course, the supplies would be into water tank maintained by individual holdings. Cultivators should be educated to construct the tank (diggi) near the Naka point and full tank level must be same as that of water course at that Naka point.

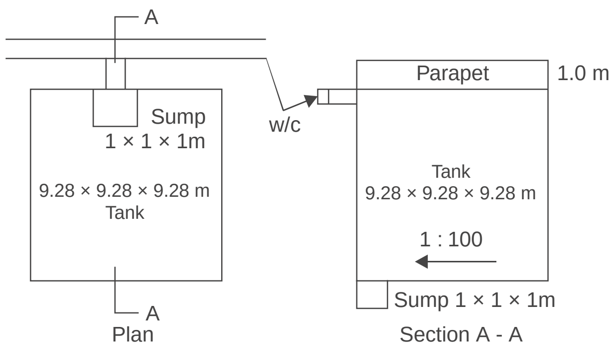


Fig. 8.1 Location of Storage Tank

The tank should be located as near the water course as possible so that there may be minimum losses in travelling water from water course to tank. Tank should be rectangular or circular with double the capacity of his turn, example

Suppose there are 50 holdings of 6.32 ha each and water allowances is 0.104 lit/sec/ha (1.5 cusec/1000 acres)

Discharge of the water course	= 32.86 liter/sec (50 × 6.32 × 0.104)
Turn time in a week	= 7 × 24/50 = 3.36 hours
Water available during turn	= 3.36 × 60 × 60 × 32.86 liter
	= 3,97,475 liters
	Say = 4,00,000 liter
Capacity of the tank at FTL should be	= 8,00,000 liter

Keeping such a capcity is to meet any eventuality and to keep cushion in application in turn, the tank should neither be shallow nor too deep. For 8,00,000 liter capacity a tank of 9.28 m × 9.28 m × 9.28 m. deep is most suitable. Parapet may be above this as per requirement. Shallow tank would increase the evaporation losses proportional to the surface area increased. Similarly, increase in depth would increase the pumping cost proportionately. Hence, the most suitable proposition would be cube shaped tank. In case of circular tank minor adjustment is there in dimensions. In this case a circular tank of 10.1 m inner dia with 10.1 m height upto FTL may be suitable.

8.4 C.C.A. Assessment

While assessing CCA under lift system, where application of water is with sprinkler or drip system, area upto 2 metre above FSL at Naka point may be termed as CCA. Practically whole area is under CCA, irrespective, of its elevation or undulation as the water application is through secondary lift for sprinkler or drip application. So, it depends upon the cultivator to raise/lift water for sprinkler or drip. But to have cut off, it is better either to term the area upto FSL as under CCA but to be on safer side the area upto 2.0 m higher than the FSL should be taken as under CCA. The conservative approach in CCA assessment would make cultivator conscious in using water as well as keeping water table in balance and proper benefit of inputs, fertilizer, etc. However, where area upto FSL in water course at Naka point is termed as CCA, then CCA must be ascertained on the basis of average weighted NSL of the square/sub chak coming under command.

In case of flow system OFD works are planned, keeping the FSL at outlet in consideration while in case of lift, where application of water is through sprinkler and drip, no such criteria is considered. The main consideration should be minimum length of water-course connecting all the holdings. Cutting/filling should be compromised upto some extent, so as the losses in water-course may be minimum, implying minimum length of water-course. Here every drop of water is after incurring heavy cost on lifting.

8.5 Slopes in Water-courses

Slope in water-course should be reasonably flat, as far as possible; there should be no fall. In case terrain requires some drop, better to provide steeper slopes to negotiate falls as far as possible, water courses should run at the heighest possible elevation.

8.6 Naka Point/Turn Out

In case of flow command, where water application in the field is through gravity flow, to have the minimum run in the field channel, turn out is provided at the middle of the sub chak, whereas in the case of lift system, where application is through sprinkler/drip, turn out should be provided at such a point that tank distance should be minimum, otherwise transit losses from water course to tank would be very high, unbearable, or the link of water course and tank, should be through open pipe or lined water course. The losses in unlined water course comes to 3.0 to 3.5 cumec per million sqm. of wetted perimeter. So, the location of turn out should be decided in conjunction with the location of tank or diggi for storage of water.

8.7 Adoption of FSL at Naka Point/Turn Out

In lift canals where water application is through sprinkler/drip system, FSL at Naka point or turn out should be kept same as that of FSL in water course at Naka point as there would be no gravity flow of water in application, rather the water would be lifted to higher elevation for field application. Hence, FSL at Naka point should be kept same as available in water-course.

9

Warabandi

9.1 Introduction

Warabandi is a system of distributing irrigation water based on equity and providing ample safeguards for the farmers at the tail of the conveyance system:

> "Warabandi is above all a management system and its principle management objective is to simultaneously achieve efficiency of water use by improving water scarcity, on each and every user. This acts as a deterrent to wasteful practices and resulted in maximum production per unit of the available water"
>
> MALHOTRA S.P.

This system is unique example of the joint State/Farmer management of Irrigation system wherein a State is responsible to manage water upto outlet head and farmers are to manage further distribution below outlet. Thus, both State and farmers have their well defined part in irrigation/ water management. As there is inbuilt mechanism for equity and efficiency, the system has a greater social acceptance and hence the process of development of irrigation on new projects is likely to be much easier in the case of warabandi system of water distribution. The success of such a system depends on dividing the irrigation time cycle more efficiently, equitably and the time interval between two turns is always constant, is repeated at regular intervals. Considering all these factors a seven-day rotation is most suited. Watering in a week is also suited for crops water requirement.

The distribution of water in warabandi system is a two tier operation, upper tier operated by State agency i.e., all distribution systems are operated with their full discharge. This reduces the running time as well as seepage losses to minimum. The distribution of water below outlet is the lower tier managed by institution of cultivators having their land under that outlet. State only interferes when the cultivator's institution fails to manage. The performance of the system is monitored at head and tail of the distribution channels.

9.2 Equitable Distribution of Water

Each cultivators right to receive water according to his land holdings is inherent under this system. Thus, each cultivator is entitled to receive water on a specific day and time as notified in the roaster including night time. There is no provision for compensation if any cultivator fails to avail his turn due to one or the other reason. The system is tightly managed and is against wastage.

The losses per cusec of water run through water course i.e., downside of outlet, is minimum for the efficient management below outlet is a must for the success of the water irrigation scheme. As the losses are directly proportional to the wetted perimeter. Table below shows the W.P. per cumec of water run in the lined system.

W.S. slope assumed is 1:5000, value of $N = 0.018$

S.S. – 2:1 (H;V). Mehboob section

Table 9.1 W.P. per cumec Run of Discharge in Branch, Disty., Minor and Water Course

Channel	*Discharge Cumec*	*W.P. (m)*	*W.P./Cumec run (m)*
1. Branch	15	12.63	0.842
2. Distributary	5	8.36	1.672
3. Minor	1.5	5.33	3.55
4. Water course*	0.06	1.40	23.3

*Rectangular section $b = 0.7$ m, $d = 0.35$ m

As the absorption losses are directly proportional to the wetted perimeter, the length of canal system must be kept minimum. Secondly, section parameters must be judiciously decided considering soil texture and topography. In general most of the channels are constructed with side slope 2:1 (H:V), whereas small channels upto (0.283) cumec can be made rectangular, which may reduce the wetted perimeter upto 13%. Similarly, channels upto 1 cumec may be constructed with side slope 1:1 and channels upto 2 cumec (70 cusee) may be constructed with 1:5:1 side slope. (Refer Chapter 3 losses V/V side slope)

Firstly, as soon as water leaves the canal and enters the water courses, losses increase tremendously. As the loss per cumec in water course is 8 to 20 times more than that in distributary and minors, water courses must be planned with minimum length and with suitable section. It is estimated that a water course of nearly 0.07 cumec discharge would be most suitable. As explained earlier this discharge is on higher side, a discharge range of 0.05 to 0.055 cumec would have been most suitable and would have saved the losses at least by 5 to 10%. This saving may account for upto 5 cumecs (Refer Table 3.5).

9.3 Roaster of Turns

In unlined water course it is very difficult to assess the exact seepage losses and time to fill the water course from outlet to first turn out, and then turn out to another turn out. To calculate the actual time available, for irrigation application by the cultivators in a week system is as under:

$$\text{Flow time for a unit are (F.T.)} = \frac{168 - \text{Time of filling} + \text{Time of emptying}}{\text{Total area}}$$

Flow time for a farmer = F.T. × Area of his holding

As an example—In a week time rotation = 7 × 24 = 168 hours

There are 44 holdings—comprising 278 ha CCA (687 acres)

Total length of water course 5250 m.

Maximum length from outlet is 13 square length is 3250 m as shown below:

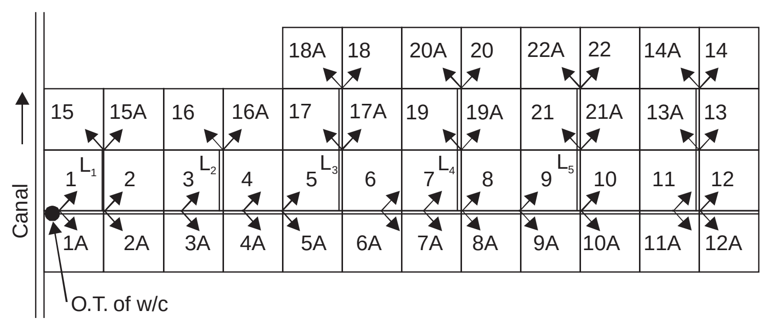


Fig. 9.1 Roster of Turn in a Chak

Total filling	1st Naka	100 m		
	2nd Naka	150 m	L1	250 m
	3rd Naka	350 m	L 2	250 m
	4th Naka	250 m		
	5th Naka	150 m	L3	500 m
	6th Naka	450 m		
	7th Naka	150 m		
	8th Naka	150 m	L4	500 m
	9th Naka	250 m		
	10th Naka	250 m	L5	500 m
	11th Naka	400 m		
	12th Naka	100 m		
	13th Naka	250 m		
	14th Naka	250 m		
	Total	3250 m		2000 m

Filling time comes to 10 to 15 minutes, per 250 m say Av. 12 minutes per 250 m

$$\text{Total filling time} = \frac{12 \times 5250}{250} = 252 \text{ minutes} = 4.2 \text{ hours}$$

Emptying length	15–250 m
for square	16–250 m
	18–500 m
	20–500 m
	22–500 m
	14–3250 m
Total =	5250

Let emptying time be 6.86 minutes per 250 m = 144 minutes = 2.4 hours

With the above proposition

$$\text{F.T.} = \frac{168 - 4.2 + 2.4}{44} = 3.777$$ hours per holding (assuming equal holdings)

The flow time for each cultivator as worked out above is not so simple. As soon as outlet starts working, turn starts from head to tail. The order of turn is as under:

1, 1A, 15, 15A, 2, 2A, 3, 3A, 16, 16A

4, 4A, 5, 5A, 17, 17A, 18, 18A, 6, 6A, 7, 7A,
19, 19A, 20, 20A, 8, 8A, 9, 9A, 21, 21A, 22, 22A,
10, 10A, 11, 11A, 12, 12A, 13, 13A, 14 and 14A.

In this case as soon as the turn of last holding ends, and first holding starts, water filled in the water course from 1st Naka to last holding goes to the last holding. Although the filling time was from the common pool time, however, emptying time is added in last turn.

The length of the upper portion of water course which has been filled with common pool time can be discharged into the last holding turn. Normally, the total time of filling this length should be recovered from him in lieu of his emptying time . But owing to the fact that he does not get all the water at a constant rate. As soon as 1st holding cuts off supplies from head, water starts receding at tail gradually becomes zero. Such a supply beyond a limit is not worth for field application that is why emptying time is kept 55 to 60% of filling line

The roster may be as under with reference to chak plan shown above, assuming each holding is of 6.32 ha CCA. The order of turn would be as under serially:

Table 9.2 Roaster of Turn in a Chak

S. No.	*Holding SQ. No*	*Turn Time (Hours)*	*Length of filling (m)*	*Time of filling (Hours)*	*Length of Emplying (m)*	*Time of Emplying (Hours)*	*Time allotted*
1	1	3.777	–	–	–	–	3.777
2	1A	3.777	–	–	–	–	3.777
3	15	3.777	500	0.40	–	–	4.177
4	15A	3.777	–	–	250	0.114	3.663
5	2	3.777	–	–	–	–	3.777
6	2A	3.777	–	–	–	–	3.777
7	3	3.777	350	0.28	–	–	4.057
8	3A	3.777	–	–	–	–	3.777
9	16	3.777	400	0.32	–	–	4.097
10	16A	3.777	–	–	250	0.114	3.663
11	4	3.777	100	0.08	–	–	3.857
12	4A	3.777	–	–	–	–	3.777
13	5	3.777	150	0.12	–	–	3.897

Contd.

Table 9.2 (Contd.)

	Holding SQ. No	Turn Time (Hours)	Length of filling (m)	Time of filling (Hours)	Length of Emplying (m)	Time of Emplying (Hours)	Time allotted
14	5A	3.777	–	–	–	–	3.777
15	17	3.777	500	0.40	–	–	4.177
16	17A	3.777	–	–	–	–	3.777
17	18	3.777	250	0.20	–	–	3.977
18	18A	3.777	–	–	500	0.228	3.549
19	6	3.777	200	0.16	–	–	3.937
20	6A	3.777	–	–	–	–	3.777
21	7	3.777	200	0.16	–	–	3.937
22	7A	3.777	–	–	–	–	3.777
23	19	3.777	350	0.28	–	–	4.057
24	19A	3.777	–	–	–	–	3.777
25	20	3.777	250	0.20	–	–	3.977
26	20A	3.777	–	–	500	0.228	3.549
27	8	3.777	–	–	–	–	3.777
28	8A	3.777	–	–	–	–	3.777
29	9	3.777	250	0.20	–	–	3.977
30	9A	3.777	–	–	–	–	3.777
31	21	3.777	500	0.40	–	–	4.177
32	21A	3.777	–	–	–	–	3.777
33	22	3.777	250	0.20	–	–	3.977
34	22A	3.777	–	–	500	0.228	3.549
35	10	3.777	–	–	–	–	3.777
36	10A	3.777	–	–	–	–	3.777
37	11	3.777	400	0.32	–	–	4.097
38	11A	3.777	–	–	–	–	3.777
39	12	3.777	100	0.08	–	–	3.857
40	12A	3.777	–	–	–	–	3.777
41	13	3.777	250	0.20	–	–	3.977
42	13A	3.777	–	–	–	–	3.777
43	14	3.777	250	0.20	–	–	3.977
44	14A	3.786	–	–	3250	1.486	2.291
		166.188	5250	4.20	5250	2.398	167.99

The difference of 168 – 167.99 = 0.01 hours = 36 seconds.

This 36 seconds time may be divided into land holder's not getting benefit of depletion. e.g. square No. 15, 16, 18, 20, 22 and 14.

It would be noticed that time of filling which is from the common pool is 4.2 hours, whereas time of depletion allowed is 2.40 hours. Thus, there is difference of one hour 48 minutes. There is always a scramble between the farmers which are getting depletion benefit.

From the chak plan dispute points are:

1. Whether holder of square 15 or 15A
   16 or 16A
   18 or 18A
   20 or 20A
   22 or 22A
   14 or 14A is to avail
   depletion benefit.
2. In case of 6A the holder get filling time as well as benefit of Naka location.
3. In case of 2A, 5A, 8A, 9A, 10A, 12A and 13A neither get filling time nor their Naka position is suitable. The least water run in the field channels is in the case when the Naka is at the middle of the holdings.
4. In case when the canal is running for full month there are no losses in upper reaches but in the lower reaches, the seepage losses are appreciable. No account is made for these losses.
5. The above chak plan is based on hypothetical assumption, there may be cases where the last holding may be smaller than the allotted time and may not be able to avail depletion time, in that case preceeding land holder has to avail part of the depletion time, with minor adjustment. The turn has to be started either from head or tail, where the tail Naka holder is not having sufficient CCA to absorb the allotted time, he is always benefited.
6. As an economy entire length of the water course is not lined, last lengths are kept unlined. In the present case, laterals feeding squares 15, 16, 18A, 20A, 22A and 14A may be kept unlined. Losses in these unlined length are too much and further they get receding water, which cannot be efficiently applied for.

However, the holder of land in the unlined water course are getting indirect benefit from seepage losses through unlined water course.

7. Time slips are distributed to all the land holders under each chak, indicating day/date-time of start and time of shut (AM/PM).

9.4 Change in Roaster

After every two crops or as decided by the farmers society the water rotation schedule is rotated by 12 hours to mitigate the hardship of night irrigators. Suppose, some one is getting his turn from 22 hours to 2 hours he would get turn at 10 hours to 14 hours with rotated turn.

In the following circumstances roster may need change:

1. Conversion of GCA into CCA
2. Sanction of extra irrigation time for gardens
3. Change in schedule—rotation by 12 hours
4. Any addition of extra CCA
5. Change in the size of outlet.
6. Deletion of time of defaulting water charges payment land holder's.

In IGNP, Gang Canal, Bhakhra Canals all the water courses are lined and holdings are in a regular sequence of squares and every square is provided with a turn out. So, the problem of consolidation/division is not there. Every square may be under more than one holder but would get only one Naka from the water-course to irrigate that square. Further distribution application of water is done as per roster.

Tail Cluster: Generally, there is more than one outlet at tail of minors/ distributaries. The cluster of outlet is always designed as proportional flow divider's with gauge. This is to facilitate observation whether the tail chaks are getting their authorised discharge or not. In fact, the efficiency of the system is judged from the fact whether tail chaks are getting their due share or not.

9.5 Rotational Running of Canals, Grouping of Canals

For equitable distribution of water to all the cultivators it is necessary that the distributaries must either run at full supply or remain closed and they must run round the clock for a cycle of 7 days period. However canal system are planned on the dependability liking of storage, works.

This dependability is arrived on the basis of availability of supplies observed/recorded in the last 40 to 50 years. A graph of the supplies is plotted in the descending order on time base as shown below:

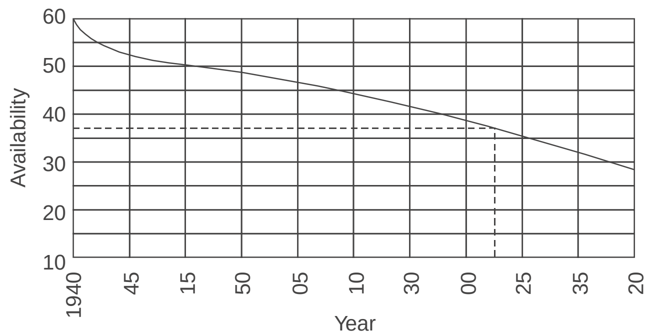


Fig. 9.2 Run Off (of storage site)—time Graph

Normally major and medium projects are planned with 75% dependability. A 50 years availability graph shows that maximum supplies at any time during these 50 years was 60 MCM and the least was 28 MCM. Out of 50 years, in 37.5 years at 75% of the time, the availability was 37 MCM. So, we plan the system for these supplies. But, this supply would not be available round the year constantly. Further in some years the supplies available would be more and in some years the supplies would be less. So, the canal system planned has to be run according to the supplies available. In general the capacity factor is kept 0.63 that means, system is likely to get 63% of the supplies but the system is planned for 100% supplies. In IGNP head discharge is 16500, with capacity factor of 0.63. That means canals would be generally getting discharge of 10500 cusecs, although the canal system has been planned and constructed for 16,500 cusecs. Whenever demand increase supply, some channels have to be closed as stated earlier for equitable distribution. Either a distributary has to run full or remain closed. So, this necessitate grouping of canals so that with the available supply a definite canal system may be run with full supply.

Generally, a branch with direct minors from Main Canal is clubbed in a group. Let there be three groups of canals. Their rotation is given below:

Table 9.3 Rotation of Canals in Groups

Period	*Cycle*	*Priority order for groups*		
		I	*II*	*III*
Rabi Crops:				
2nd Oct to 9th Oct	1	B	A	C
10th Oct to 17th Oct	2	C	B	A
18th Oct to 25th Oct	3	A	C	B
26th Oct to 2nd Nov	4	B	A	C
3rd Nov to 10th Nov	5	C	B	A
11th Nov to18th Nov	6	A	C	B
19th Nov to26th Nov		Balancing Period		
27th Nov to 4th Dec	1	B	A	C
5th Dec to 12th Dec	2	C	B	A
13th Dec to 20th Dec	3	A	C	B
21st Dec to 28th Dec	4	B	A	C
29th Dec to 5th Jan	5	C	B	A
6th Jan to 13th Jan	6	A	C	B
14th Jan to 21st Jan		Balancing Period		
22nd Jan to 29th Jan	1	B	A	C
30th Jan to 6th Feb	2	C	B	A
7th Feb to 14th Feb	3	A	C	B
15th Feb to 22nd Feb	4	B	A	C
23rd Feb to 2nd Mar	5	C	B	A
3rd Mar to 10th Mar	6	A	C	B
11th Mar to 18th Mar		Balancing Period		

Assuming that during the first cycle adequate supplies are available for channels of all the three groups. During 2nd, 3rd and 4th cycle supplies were in short supply sufficient to run 2.5 groups during 5th and 6th cycle, only two groups can be run.

If each group is further divided into two sub groups, the schedule for running each sub group would be as under:

Table 9.4 Schedule for Running each Sub-group of Canals

Cycle	*A1*	*A2*	*B1*	*B2*	*C1*	*C2 Run*	*No. of sub Groups*	*No. of Groups*
1.	Yes	Yes	Yes	Yes	Yes	Yes	6	3
2.	No	Yes	Yes	Yes	Yes	Yes	5	2.5
3.	Yes	Yes	No	Yes	Yes	Yes	5	2.5
4.	Yes	Yes	No	Yes	No	Yes	5	2.5
5.	No	No	No	Yes	Yes	Yes	4	2.0
6.	Yes	Yes	No	No	Yes	Yes	4	2.0
Total yes	4	5	4	5	5	6	29	14.5
Balancing	Yes	Yes	No	Yes	No	No	4	2.0
G. Total	5	6	5	6	5	6	33	16.5

In the balancing period, supplies are so rotated that there is a balance among all the three groups. Although there may be some disparity in such groups A1, B1 and C1 as compared to other sub groups of their groups. This is just an example. If the supplies are sufficient all the groups can be run, in case the supply are too short, one or one and other half group may run. So, this adjustment for equitable distribution has to be made at the end of each season.

For Rabi

Sowing season	Oct. to Nov.
Growing season	Nov. to Jan.
Maturing season	Jan. to March

For Kharif:

Sowing season	April to June
Growing season	June to August
Maturing season	August to Oct.

Although this depends upon region to region, in South India there is no such seasonal distribution.