CHAPTER VIII.

THEORY AND PHYSICS OF SEEPAGE LOSSES FROM UNLINED CHANNELS.

8.0 Determination of seepage losses in irrigation channel i one of the most complicated problems that have faced the Hydrauli Engineers from the earliest times and that perhaps explains why s little advance has been made therein upto the recent times. Laboratory tests while lending themselves to other cases, seem to fail when applied to seepage losses,because the most important factor viz. nature of subsoil strata, cannot be reproduced in the laboratory. The evaluation of seepage lossesfrom the canals with reasonable precision, is of the utmost importance for the Punjab State as it has invariably resulted in a rapid rise of spring levels causing acute waterlogging conditions in the canal irrigat tracts. It has been observed that a fairly high percentage of water let off at the head of a canal seeps into the subsoil throu unlined canals, branches and distributaries. On an average, out of the total quantity of water that enters a canal at the head, 17% is lost by way of absorption and evaporation in the main cana and branches, 8% in the distributaries and minors and 30% in the water courses. This means that for 100 cft. of water received ir the field, 182 cft. of water is released at the head.

In the subsequent pages, total amount of water which s into the subsoil from all major unlined canal systems in the Punjab State has been worked out to assess the gravity of proble The study has revealed that as much as 2,546 cusecs are being lost every day on this account.

8.1 Colonel Dyas (1863) and T.Higham(1874) were the earliest investigators in this line. They were, however, content to know that absorption losses in the Main Line of the Upper Bari Doab Canal were 20% and 12% respectively of the discharges in the Main Canal. Kennedy(1883) worked out absorption losses as different rates of sinkage per hour for main line, branches, distributaries and water courses. His results when reduced to cusecs per million sq. feet of wetted area were 9.75, 2.2, 3.3, and 9.4 respectively. Woods tried to be more scientific and produced the formula

$$q = C a d$$

where q is absorption in cusecs/10^6, C is a constant varying from 1.20 to 1.33, a is the reduced wetted perimeter of the channel section and d is the depth. Later, T.Higham(65) gave the following formula for determination of loss by seepage in Punjab Canals

$$P = C \frac{\sqrt{d}\ WL}{10^6}$$

where P = loss by seepage in cusecs for a length of canal

C = a constant usually taken as 3.5

d = depth of water in canal in feet.

W = width of water surface in canal in feet.

L = Length of canal section in ft.

Measurements on some of the older canals in Punjab gave an average loss of 8 cubic feet per second for each million square feet of wetted area, which is equivalent to a loss of 0.7 cubic feet of water per square foot of wetted area or a depth of loss of 8.4 inches.

Wilsdon(66) was perhaps the first to make a real start in the scientific investigation of this subject. His Lyallpur experiments gave a clear picture of what actually happens in the soil when water is lost from a canal by absorption through unsaturated soil (which has a moisture content of less than 23%) and by percolation through saturated soil (which has a moisture content of more than 23%). The term seepage losses stood both for absorption and percolation. Incidently investigations by Wilsdon proved that Wood's formula (K = Cad) was incorrect as the absorption losses were not at all directly proportional to depth. F.F.Haigh (67) of the Punjab Irrigation suggested the following formula based on observations and past experiences

$$K = 5.0 \quad Q^{0.0625} \qquad \text{(Unlined Channels)}$$

This formula was based on the usual experience that absorption losses were found at 6 cusecs per million sq. feet of wetted area for a channel of 20 cusecs and 8 cusecs per million for a channel of 2,000 cusecs or more. It has since been modified as follows in the Central Designs Office Irrigation Works, Punjab.

$$K = 4.0 \quad Q^{0.0625}$$

based on the correct interpretation of Mr. Haigh's results of 148 experiments.

The above rates of seepage losses represent average loss per square foot of wetted perimeter. The intensity of loss is, however, maximum at the bottom and decreases uniformly on the sides. If the intensity of loss is assumed to vary with the square foot of the depth as indicated by the results given above, then the total seepage loss from the two side slopes is equal to 4/3 times the length of the side slope, multiplied by the maximum intensity on the bottom. (This has been theoretically verified in subsequent pages). For ordinary proportions of bed width to depth the error resulting by applying the average loss per square foot to the entire wetted perimeter to obtain the total seepage loss will be small compared to the accuracy with which the loss can be estimated for different materials. The values given above can, therefore, be applied to any cross section and the loss expressed in cubic feet per second per mile with the help of the formula

$$S = 0.061 \text{ x } \left(1 + \frac{4}{3} \operatorname{cosec} \theta \right) \sqrt{\frac{Q\,s}{\sqrt{(i + \operatorname{Cot} \theta)}}}$$

Where Q = Discharge in cusecs.

S = total seepage losses.

s = Average seepage intensity.

θ = Inclination of the side to horizontal.

$i = \frac{B}{D}$, where B is Bed width and D is Depth of the channel.

For unlined channels, a side slope of $1\frac{1}{2}$ to 1 is generally taken in the Punjab.

8.2 THEORETICAL DETERMINATION OF SEEPAGE LOSSES

From an investigation of the characteristics of the Zhukovsky's function

$$\theta = iZ + \frac{W}{K} = A\, e^{w/\alpha}$$

(where $w = \phi + i\psi$, α is a parameter and A is a real constant velocity along the perimeter of a ditch can be worked out as

$$V = \frac{k}{\sqrt{1 + \left[\pi H/(B + 2H)\right]^2 - \frac{2\pi H}{B+2H} \operatorname{Cos} \frac{\pi}{B+2H}}} \quad \text{...(8.1}$$

where B is the surface width, H is the maximum depth of the ditch and k is the permeability.

Vedernikov (68) developed a much more direct method of solution for determining seepage from ditches, canals etc. of a trapezoidal section using the method of inversion. He takes the quantity of seepage in the form

$$q = k\ (B + AH)$$

Where A is given by the relationship

$$A = \frac{2}{\tan \sigma\, II} \quad \frac{f_2(\alpha,\beta) - f_1(\alpha,\beta)/\mathrm{Cos}\, \sigma\, II}{J_2\,(II/2) - f_2\,(\alpha,\beta)}$$

Taking a series of values for α and β, he obtained the correspondence between A and B/H as given in Fig. 8.1. In this figure, m = Cot is the side slope of the ditch.

Noting that the velocity at infinity equals the coeffici of permeability, we find that the width of the flow at infinity is

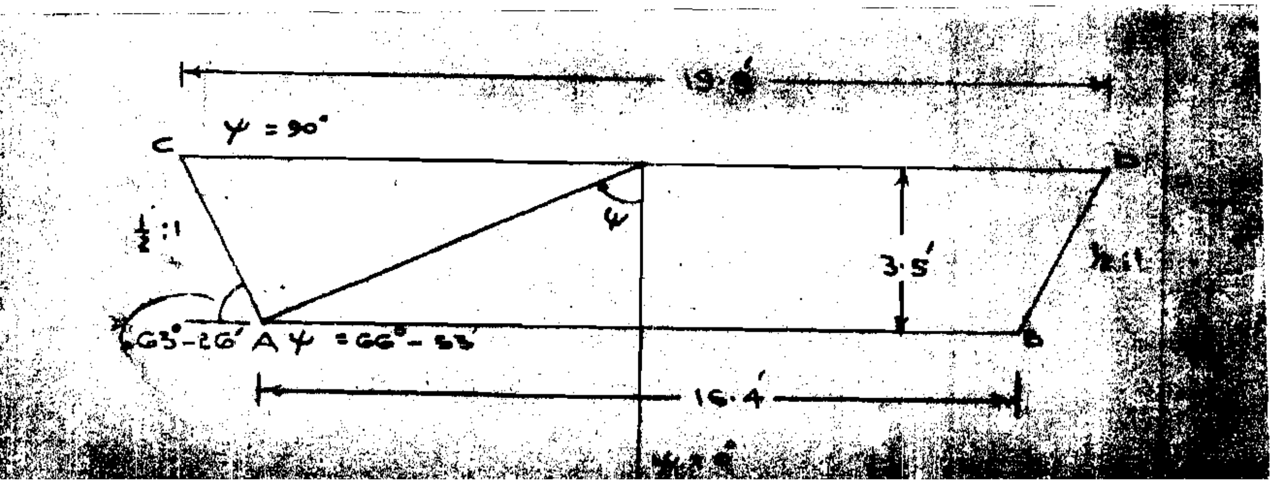
$$L = (B + AH)$$

Thus for a trapezoidal section, the equipotential lines rapidly approach the horizontal. Hence the solution of this section may also be considered to provide a sufficiently valid approximation for seepage into deep horizontal filters.

8.3 COMPARATIVE APPLICABILITY OF TWO METHODS.

FIRST METHOD.

In order to investigate the comparative applicability of two methods illustrated above, let us take the section of the ditch or canal as below:-



B = Water Surface width = 19.9 ft.

H = 3.5 ft.

The values of y/k at various points on the side and bed are given by the equation (8.1)

$$\frac{y}{k} = \frac{1}{\sqrt{1 + \left\{\frac{\Pi H}{B+2H}\right\}^2 - \left(\frac{2\Pi H}{B+2H}\right)\left\{\cos\frac{\psi\Pi}{B+2H}\right\}}}$$

At

P , $\psi = 90^\circ$ $\frac{y}{k} = 0.93$

P_1 , $\psi = 85^\circ$ $\frac{y}{k} = 0.96$

P_2 , $\psi = 80^\circ$ $\frac{y}{k} = 0.99$

P_3 , $\psi = 75^\circ$ $\frac{y}{k} = 1.03$

P_4 , $\psi = 70^\circ$ $\frac{y}{k} = 1.06$

Q , $\psi = 66^\circ 53'$ $\frac{y}{k} = 1.08$

Q_1 , $\psi = 60^\circ$ $\frac{y}{k} = 1.15$

Q_2 , $\psi = 45^\circ$ $\frac{y}{k} = 1.30$

Q_3 , $\psi = 30^\circ$ $\frac{y}{k} = 1.49$

Q_4 , $\psi = 0^\circ$ $\frac{y}{k} = 1.70$

The average value of $\frac{y}{k} = 1.17$

Wetted Perimeter of the ditch = 24.4 ft.

Taking unit length of the canal section,

Wetted area = 24.4 X 1 = 24.4 sq. ft.

So the total quantity of seepage through the section is given by

$$\frac{y \times a}{k} = 1.17 \times 24.4$$

or $q/k = 28.5$

(b) SECOND METHOD.

Vedernikov method takes into consideration the value of A for calculation of q/k as shown in Fig. 8.1. Since the graph does not give values of A against values of B/H for $m = \cot\alpha = 0.5$ the same were extra - polated and are shown in the same figure from which A was found out to be 3.24 for B/H = 5.70

$$\text{Hence } q/k = B + A\,H = 19.9 + 3.24 \times 3.5$$

$$= 31.3$$

It will be seen that the values of q/k as calculated by different methods are very near to each ~~etorh~~ other. Taking the average of these two, the quantity of seepage is given by

$$\frac{q}{k} = 30.0$$

Assuming $k = \frac{1}{2} \times 10^{-5}$

$$q = \frac{30.0 \times \frac{1}{2} \times 10^{-5} \times 10^{6}}{24.4}$$

$$= \frac{150.0}{24.4} = 6.15 \text{ cusecs}$$

8.4 RATIO OF SEEPAGE FROM BED AND SIDES OF A CANAL SECTION.

It will be quite informative to investigate the ratio of seepage loss as it occurs from the bed and side of a canal section. This has been calculated from the First Method which is based on the Zhukovsky's Function

$$\theta = iz + \frac{\omega}{k} = A\,e^{w/\alpha}$$

Taking the same section of the Canal as before viz.

Side length = 4.0 ft.

Bed Width = 16.4 ft.

Side Slope = 1 V : ½ H

Maximum Intensity of seepage at bottom is given by

$$V/k = 1.7$$

as calculated by the equation (8.1) by taking $\psi = 0$ at the middle

Also the values of seepage from the sides can be calculated by finding the average value of V/k for sides and then multiplying by the length of sides.

For the above section, the average value of V/k at the sides comes out to be 1.01

$\therefore$ Seepage through both the sides comes out to be

$1.01 \times 8.0 = 8.08$

$\therefore$ $\text{Ratio} = \dfrac{8.08}{1.7 \times 4} = 1.2 = 6/5$

which shows that the total seepage through both sides of a canal section is equal to 6/5 times the maximum intensity of seepage at the bottom multiplied by the side length. This value is taken as 4/3 by some authors which appears some-what on the high side.

8.5 APPLICATION TO CANAL SECTIONS.

The methods given above can be applied to any canal section, hydraulic data for which are available, to determine seepage losses on a theoretical basis. Some of these canal sections are given in Table 8.1. The value of total seepage loss through the bed and the sides has been calculated by the application of the relationship

$$q = k (B + A H)$$

where values of A can be read against the corresponding values of $m = \text{Cot}\ \alpha$ and the ratio of the water surface width of water surface depth, B/H.

The value of seepage losses as calculated from the above formula for these sections are given in the same table and found to vary from 5.75 to 6.15 cusecs/10^6 sq. ft. of wetted area with an average of say 6 cusecs.

T A B L E 8.1

Statement showing calculations of Seepage Losses through the sections of various canals and Branches.

S.No.	Name of Canal	Bed width in ft.	Depth in ft.	Discharge in cusecs.	Total seepage in cs/10^6 sq. ft. of wetted area.
1.	Main Branch Upper (U.B.D.C.)	180	7.7	8050	5.80
2.	Sirhind Canal	230	13.4	12626	5.90
3.	Bhatinda Branch	136	6.3	2786	5.74
4.	Abohar Branch	84	7.85	2493	6.10
5.	Kotla Branch	114	7.0	2415	5.90
6.	Main Branch Lower (U.B.D.C.)	92	5.62	1585	5.90
7.	Kasur Branch	74	4.2	1190	5.85
8.	Sabraon Branch	47	4.8	578	6.14

N.B:- Side slope of each canal system has been taken as 1:1.

It may not be out of place to mention here that generally seepage losses are assumed to be of the order of 8 cusecs per million square feet of wetted area which assumption is not prove to hold good on theoretical considerations.

Also the value of seepage loss from the sides can be calculated by finding the maximum seepage intensity at the central point of the bed by taking $y = 0$ in the equation (8.1), and multiplying in with the side length and the ratio 6/5.

8.6 TOTAL WATER LOSSES IN UNLINED CHANNELS.

A detailed study has been made to work out quantitatively the amount of water which goes into the subsoil by way of seepage through Main Line and Branches of all the major unlined canal systems of the State. Details about the Upper Bari Doab Canal, Main Line, are given in Table 8.2 by way of illustration, similar lengthy calculations for branches of this canal system and for other major canals having been ommitted for purpose of brevity. Absorption losses per unit area are worked out from the formula $K = [illegible]\ Q^{0.0625}$ evolved in the Central Design Office of the Punjab Irrigation Department as a result of observations and researches extending over a number of years. Total seepage losses on this canal system work out as under.

Canal system	Seepage (in cusecs/day).
Upper Bari Doab Canal (Main Line).	260
Main Branch Lower	166
Lahore Branch	108
Main Branch Lower	201
Kasur Branch Upper	33
Kasur Branch Lower	133
Sabraon Branch	104
	1005

Working on the same lines, extent of seepage losses on the

TABLE 5.2

Statement showing Seepage Losses on the Main Line of the Upper Bari Doab Cana

S.No.	REACH			OFF-TAKING CHANNEL			Total Q in reach.
	From	To	Length (in ft)	Name	RD.	Discharge 'Q' (Cusecs).	
1.	2.	3.	4.	5.	6.	7.	8.
1.	151800	134000	17800	M.B.Upper	151800 R	5791	
				K.B.Upper	151800 L	2713	
				Silt Ejector in KBU	16450 L	500	
				Moranwali Disty.	151800 L	47	
				Ghazikot Disty.	138925 L	30	
						9081 CS.	9081
2.	144000	114110	19890	Silt Ejector	134000L	1500	
				Nanu Nangal Disty.	128500R	18	
						1518 CS	10599
3.	114110	72720	41390	Bhatoa Disty	105000 R	81	
				Awankha Disty.	89000 R	16	
						97	10696
4.	72720	66758	5962	Silt Ejector	72720 L	1500	
						1500 CS.	12196
5.	66758	28500	38258	Faridanagar Feeder	66758 L	-1800	
				Dhimpur Silting Tank	64150	100	
				Gulpur Disty.	54400 R	363	
				Kalanaur Disty.) Sarna Disty)	39400 R	51	
						-1800) + 514) =1286	10910
6.	28500	28203	297	Faridanagar Feeder	28385 L	1800 cs.	12710
7.	28203	11000	17203	Salampur Feeder	28203 R	-3500 cs.	9210
8.	11000	0	11000	M.B.Link &	11000 L	10000 cs.	19210

P_w wetted perimeter.	Wetted area =Col.4xP_w = A.	$K = 4 A^{0,0625}$	Absorption losses = $\frac{K \times A}{10^6}$
9.	10	11.	12.
246	43,80,000	7.05	31 cs.
246	49,00,000	7.12	35 cs.
249	103,00,000	7.13	74 cs.
249	14,85,000	7.20	11.cs.
250	95,65,000	7.14	68 cs.
260	78,000	7.22	1 cs.
227	38,00,000	7.08	28 cs.
180	16,80,000	7.40	12 cs.
		Total	260 cs.

Sirhind Canal and the Western Yamuna Canal come to 720 cusecs and 608 cusecs respectively, while those for the Main Line and Main Branch of the Eastern Canal sum upto 213 cusecs. Thus on an avera a total of 2,546 cusecs of water is being lost every day through the unlined channels in the Punjab. Besides causing a recurring heavy loss to the State Exchequer by way of revenue, this staggering figure is responsible for rise in watertable of the various canal irrigated tracts to a large extent.

It is thus seen that the irrigating water is of no less importance for the free groundwater regime, causing sharp rise of the ground water levels during the watering time, which results in the fluctuations of the water table.

8.7 The percolation of the water of the main canal causes the formation of waves of fresh water on the water table, which spread in height and breadth in proportion to the growth of the percolating water; they then join the canal surface water and form lenses of fresh water floating on the salt ground water. The width of these lenses reaches 200-300 m.

If at a certain depth, there are rocks of good filtering capacity (sand, pebbles), the main canal water percolation is accompanied by a transfer of hydrostatic pressure along the free ground water table which quickly extends for several kilometres away from the canal and causes a rise of water level in the observation wells.

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