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IRRIGATION ENGINEERING

[BTAI 2201]

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Border Specifications & Stream Size

Width of a border usually varies from 3 to 15 m depending on the size of the irrigation stream & degree of land leveling. If the size of the irrigation stream is small, width can be reduced. Reduction of width less than 3 m is not economical.

Length of the border strip depends on how quickly it can be wetted over its entire length. This, however, depends on (i) infiltration of rate of the soil (ii) longitudinal slope of the field and (iii) available size of the stream. In general, length of the border strip varies from 60 to 120 m for sandy or sandy loam soil, 100 to 180 m for medium loam soil and 150 to 300 m for clay or clay loam soil.

Borders usually have too little or no cross slope. However, they have some longitudinal slopes which is given as :

0.25 to 0.60 percent for sandy loam to sandy soils.

0.20 to 0.40 percent for medium loam soil and

0.05 to 0.20 percent for clay to clay loam soil.

Hydraulics of Border Irrigation



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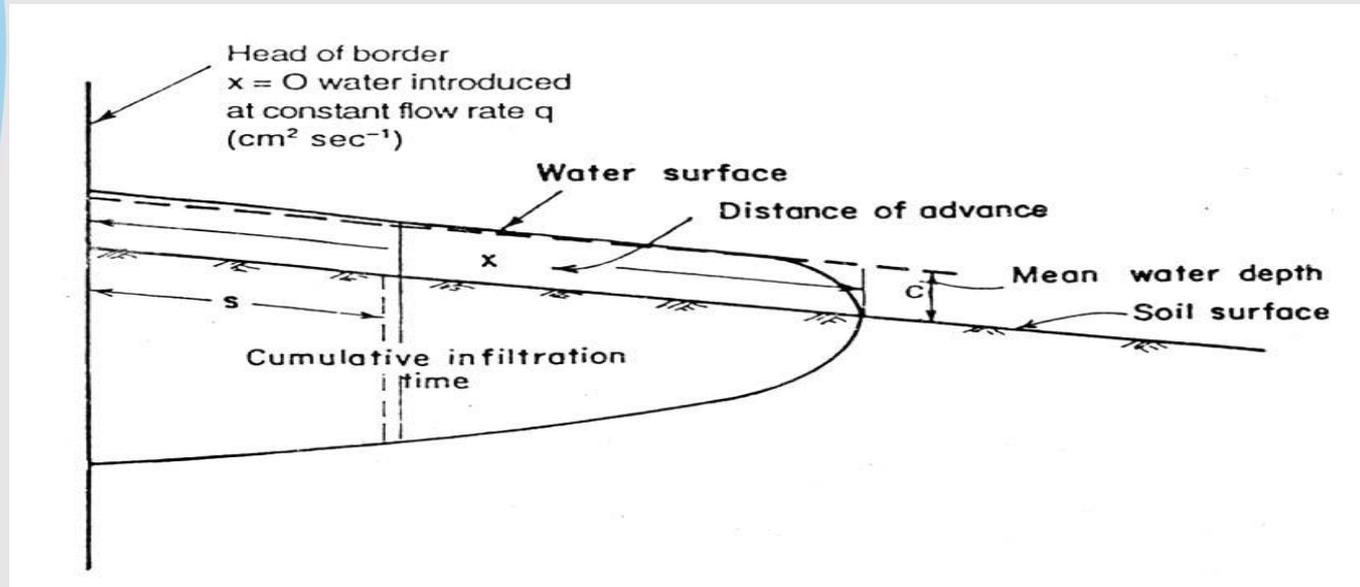
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Hydraulic of border strip can be studied by classical open channel hydraulics approach. Prominent variables that influence hydraulics of border irrigation are stream sizes, slope of land, infiltration of soil, & resistance to flow offered by the soil & vegetative cover



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Let q = Constant rate of flow per unit width at the upstream end of the border,
 $\text{cm}^3/\text{min}/\text{cm}$ of border strip

t = Time for which water is applied, min

d = Average depth of water applied, cm

x = Distance, the water front has advanced in time t , cm

t_s = Time when distance covered $x = s$, min

y = Accumulated infiltration depth at point $x = s$, when $t = t_s$



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Now at instantaneous time “dt” the distance of water advancement is “ds”.

The total water admitted in “t” per unit width of border strip = $q.t$

Volume of water stored on surface of border strip per unit width = $d.x$

Volume of water infiltrated per unit width at instantaneous time “dt” is “ $y.ds$ ”.

Total volume of water infiltrated over distance x is

$$= \int_0^x y.ds$$

Using volume balance approach, we get $q.t = d.x + \int_0^x y.ds$ (Eq. 8.1)



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The accumulated infiltration at any time t is found to be as: $y = b + at^\alpha$ (Eq.8.2)

where, y is accumulated infiltration at time t , cm; t is elapsed time, min and a , b and α are characteristics constants. Value of α is $0 \leq \alpha \leq 1$

Putting the value of y in Eq.8.2 in Eq. 8.1,

$$q.t = d.x + \int_0^x (at^\alpha + b) ds$$

Using convolution theorem of Laplace transformation & gamma function, solution of above eqn. gives water front advancement x as:



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$$x = \frac{q.t}{b+d} \left[\frac{1}{\Gamma 2} - \frac{\beta^1 t^\alpha}{\Gamma(2+\alpha)} + \frac{\beta^2 t^{2\alpha}}{\Gamma(2+2\alpha)} - \frac{\beta^3 t^{3\alpha}}{\Gamma(2+3\alpha)} + \dots \right]$$

when $\frac{\beta^1 t^\alpha}{\Gamma(2+\alpha)} < 1$

$$x = \frac{q.t}{b+d} \left[\frac{1}{\beta t^\alpha \Gamma(2-\alpha)} - \frac{1}{(\beta t^\alpha)^2 \Gamma(2-2\alpha)} + \frac{1}{(\beta t^\alpha)^3 \Gamma(2-3\alpha)} + \dots \right] \quad (8.5)$$

when $\frac{\beta^1 t^\alpha}{\Gamma(2+\alpha)} > 1$.

$$\beta = \frac{\alpha \Gamma(\alpha + 1)}{b + d}$$

$\Gamma(n+1) = n \Gamma(n)$, $\Gamma(1) = 1$, $\Gamma(2) = 1$, $\Gamma(n) = (n-1)!$, $\Gamma(4) = 3! = 6$ etc.



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K	ईK	K	ईK	K	ईK	K	ईK	K	ईK
1.00	1.000000	1.205	0.916857	1.405	0.8870028	1.605	0.894088	1.805	0.932720
1.01	0.994325	1.21	0.915576	1.41	0.886764	1.61	0.894680	1.81	0.934076
1.02	0.988844	1.22	0.913106	1.42	0.886356	1.62	0.895924	1.82	0.936845
1.03	0.983549	1.23	0.910754	1.43	0.886036	1.63	0.897244	1.83	0.939690
1.04	0.978438	1.24	0.908521	1.44	0.885805	1.64	0.898642	1.84	0.942612
1.05	0.973504	1.25	0.906402	1.45	0.885661	1.65	0.900116	1.85	0.945611
1.06	0.968744	1.26	0.904397	1.46	0.885694	1.66	0.901668	1.86	0.948687
1.07	0.964152	1.27	0.902503	1.47	0.885633	1.67	0.903296	1.87	0.951840
1.08	0.959725	1.28	0.900718	1.48	0.885747	1.68	0.905001	1.88	0.955071
1.09	0.955459	1.29	0.899041	1.49	0.885945	1.69	0.906781	1.89	0.958379
1.10	0.951351	1.30	0.897471	1.50	0.886227	1.70	0.908639	1.90	0.961765
1.11	0.947395	1.31	0.896004	1.51	0.886591	1.71	0.910571	1.00	0.961766
1.12	0.943590	1.32	0.894640	1.52	0.887039	1.72	0.912581	1.92	0.968774
1.13	0.939931	1.33	0.893378	1.53	0.887567	1.73	0.914665	1.93	0.972376
1.14	0.936416	1.34	0.892216	1.54	0.888178	1.74	0.916826	1.94	0.976099
1.15	0.933040	1.35	0.891151	1.55	0.888868	1.75	0.919062	1.95	0.979880
1.16	0.929803	1.36	0.890185	1.56	0.889639	1.76	0.912375	1.96	0.983743
1.17	0.926699	1.37	0.889313	1.57	0.890489	1.77	0.923763	1.97	0.987684
1.18	0.923728	1.38	0.888537	1.58	0.891420	1.78	0.926227	1.98	0.991708
1.19	0.920885	1.39	0.887854	1.59	0.892428	1.79	0.928767	1.99	0.995813
1.20	0.918169	1.40	0.887264	1.60	0.893515	1.80	0.931384	2.00	1.000000



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In a border strip experiment the infiltration characteristic is given by the equation $y = 0.75 t^{0.5} + 0.7$. The irrigation applied for 2 hr with constant rate of flow per unit width of the channel at the upstream side is $q = 1.5$ lpm/cm of border strip. The mean depth of flow over the soil surface is 8 cm. Find out the distance of water front advance.



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Sol. Given that $q = 1.5 \text{ lpm/cm} = 1500 \text{ cm}^3/\text{cm}/\text{min}$,
Mean depth of flow $d = 8 \text{ cm}$ and
Time of irrigation $t = 2 \text{ hr} = 120 \text{ min}$
Accumulated infiltration-time relationship is

$$y = 0.75t^{0.5} + 0.7$$

Which gives values of $a = 0.75$, $b = 0.7$, $\alpha = 0.5$

$$\beta = \frac{\alpha \Gamma(\alpha + 1)}{b + d} = \frac{0.75 \times \Gamma(0.5 + 1)}{0.7 + 8} = \frac{0.75 \times 0.88622}{0.7 + 8} = 0.076$$

$$\frac{\beta^1 t^\alpha}{\Gamma(2 + \alpha)} = \frac{0.076 \times 120^{0.5}}{\Gamma(2 + 0.5)} = \frac{0.076 \times 10.954}{1.5 \times 0.88622} = 0.626 < 1$$

$$x = \frac{q \cdot t}{b + d} \left[\frac{1}{\Gamma 2} - \frac{\beta^1 t^\alpha}{\Gamma(2 + \alpha)} + \frac{\beta^2 t^{2\alpha}}{\Gamma(2 + 2\alpha)} \right]$$

$$= \frac{1500 \times 120}{0.7 + 8} \left[\frac{1}{1} - \frac{0.076 \times 120^{0.5}}{\Gamma(2 + 0.5)} + \frac{(0.076^2 \times 120)}{\Gamma(2 + 1)} \right] = 149 \text{ m.}$$



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RECESSION FLOW: After the irrigation stream is cutoff, the tail water recedes downstream. The rate of recession of tail water is determined by noting the time at which water just disappears from the upstream end & recedes downstream past border strip.

In plotting advance & recession curves, distance down the stream is plotted on x -axis & elapsed time in y -axis. In same graph, both advance & recession curves are drawn with same scale in an arithmetic graph paper.

Difference of time of recession & advance at any distance from upstream end of the border gives **infiltration opportunity time or time of ponding.**



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