INFILTRATION OF WATER INTO SOIL

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A better understanding of the intake rate of water into soils is helpful in planning irrigation practices and evaluating depth of wetting of soils following irrigations.

Studies, in general, have shown that the intake rate decreases with time, and that it can be expressed very well by the simple empirical exponential equation

$$I = Kt^n \qquad (1)$$

where: I = intake rate at any time t

K = a constant, representing the instantaneous intake rate at time t = 1, and

n = an exponent which for most soils is negative with values between 0 and -1.

(An exception to the above occurs with difficulty wettable soils which will be discussed by Dr. John Letey following this presentation.)

The accumulated depth of water, D, that enters the soil in any time, t, can be determined by integrating equation (1) between the limits of t = 0 and t = t. Thus for equation (1)

$$D = \int_0^t I\,dt = \int_0^t Kt^n dt = \frac{Kt^{n+1}}{n+1} \qquad (2)$$

Measurements of the inflow and outflow from a given length of furrow can be used for determining the instantaneous rate of water intake into the soil. These rates for different periods of elapsed time can be plotted on log-log paper to determine the infiltration equations, and from this the equation for accumulated water intake.

Measurements of the drop in water surface in basins or ring infiltrometers give the accumulated intake for a given increment of time. Successive measurements can be plotted on log-log paper to determine the equation for accumulated intake. By differentiating this equation, an equation for infiltration rate can be determined.

Example 1. - The intake rate, I, in inches per hour was found to follow the equation

$$I = 0.3t^{-0.6}$$

where t is in minutes, determine the accumulated intake equation.

$$D = \frac{1}{60} \frac{Kt^{n+1}}{n+1} = \frac{0.3}{60x0.4} t^{0.4}$$

$$D = 0.125\ t^{0.4}$$

Example 2. - The accumulated intake equation was found to follow the equation

$$D = 0.030t^{0.65}$$

where D is in inches and t is in minutes. Determine the equation for infiltration rate.

$$I = \frac{dD}{dt} = 60 \frac{d\ (0.030t^{0.65})}{dt}$$

$$I = 60x0.030x0.65t^{0.65-1}$$

$$I = 1.17t^{-0.35}, \text{ in inches per hour.}$$

Terminology

Furrow intake measurements give the inflow and outflow as measured at different points along a representative section of a furrow. The flows are usually measured in gallons per minute. Inflow minus outflow is equal to the amount of water infiltrating into the furrow at any instant. The intake can be expressed in gallons per minute for a particular length of furrow. It has become common practice to convert these

measurements to gallons per minute per 100 feet of furrow. This figure divided by the wetted width of the furrow measured in feet gives a value which is nearly equal to the infiltration rate in inches per hour. This is normally called the furrow intake rate. If the gallons per minute per 100 feet of furrow is divided by the spacing of the furrows, measured in feet, a value is obtained for the equivalent field intake rate in acre-inches per acre per hour. The "basic intake rate" is usually defined as the rate at which water will enter the soil after a period of several hours, when the change in rate becomes very slow.

The following Table 1, 3 and 4 give examples of equations for infiltration rates and accumulated intake for a number of California soils. Table 2 illustrates how these equations can be put to practical use.

TABLE 1

West Side Field Station
Panoche Clay Loam

Infiltration in 40' x 47' Basins
t in minutes

	To Fill		Equations	
	Time min.	Infil. in.	Acc. Infil. in.	Infil. Rate in. per hr.
Basin 2				
June 19	16	3.17	$D = 0.090t^{0.54}$	$I = 2.92t^{-0.46}$
July 11	12	.03	$D = 0.042t^{0.63}$	$I = 1.60t^{-0.37}$
Aug 22	12	2.58	$D = 0.036t^{0.63}$	$I = 1.36t^{-0.37}$
Basin 4				
June 19	16	1.57	$D = 0.080t^{0.49}$	$I = 2.36t^{-0.51}$
July 11	14	2.15	$D = 0.093t^{0.52}$	$I = 2.90t^{-0.48}$
Aug 22	14	2.41	$D = 0.027t^{0.67}$	$I = 1.09t^{-0.33}$
Basin 6				
June 19	14	1.54	$D = 0.068t^{0.53}$	$I = 2.16t^{-0.47}$
July 11	10	.45	$D = 0.023t^{0.80}$	$I = 1.10t^{-0.20}$
Aug 22	15	2.70	$D = 0.066t^{0.76}$	$I = 3.02t^{-0.24}$
Basin 8				
June 19	18	1.43	$D = 0.036t^{0.65}$	$I = 1.40t^{-0.35}$
July 11	14	.13	$D = 0.046t^{0.63}$	$I = 1.74t^{-0.37}$
Aug 22	16	2.13	$D = 0.030t^{0.67}$	$I = 1.21t^{-0.33}$
Basin 10				
June 19	21	1.44	$D = 0.084t^{0.55}$	$I = 2.78t^{-0.45}$
July 11	16	.53	$D = 0.032t^{0.67}$	$I = 1.29t^{-0.33}$
Aug 22	16	2.74	$D = 0.026t^{0.67}$	$I = 1.05t^{-0.33}$
Basin 12				
June 19	23	1.45	$D = 0.011t^{0.95}$	$I = 0.63t^{-0.05}$
July 11	16	.45	$D = 0.018t^{0.71}$	$I = 0.77t^{-0.29}$
Aug 22	17	2.73	$D = 0.037t^{0.61}$	$I = 1.36t^{-0.39}$
Basin 14				
June 19	20	.96	$D = 0.044t^{0.66}$	$I = 1.75t^{-0.34}$
July 11	19	.40	$D = 0.027t^{0.74}$	$I = 1.20t^{-0.26}$
Aug 22	17	2.86	$D = 0.027t^{0.71}$	$I = 1.15t^{-0.29}$

	To Fill		Equations	
	Time min.	Infil. in.	Acc. Infil. in.	Infil. Rate in. per hr.
Basin 16				
June 19	17	.81	$D = 0.008t^{0.85}$	$I = 0.41t^{-0.15}$
June 11	18	1.14	$D = 0.044t^{0.62}$	$I = 1.64t^{-0.38}$
Aug 22	17	3.13	$D = 0.024t^{0.67}$	$I = 0.97t^{-0.33}$
Basin 18				
June 19	16	1.35	$D = 0.030t^{0.69}$	$I = 1.24t^{-0.31}$
July 11	18	.10	$D = 0.025t^{0.72}$	$I = 1.08t^{-0.28}$
Aug 22	19	1.81	$D = 0.023t^{0.70}$	$I = 0.97t^{-0.30}$
Basin 20				
June 19	21	3.42	$D = 0.020t^{0.66}$	$I = 0.81t^{-0.34}$
July 11	20	-.03	$D = 0.040t^{0.58}$	$I = 1.39t^{-0.42}$
Aug 22	19	2.29	$D = 0.030t^{0.62}$	$I = 1.12t^{-0.38}$

Table 2

WEST SIDE FIELD STATION

Panoche Clay Loam

Time hrs.	$D = 0.030t^{0.65}$ Acc. Infiltration in.	$I = 1.17t^{-0.35}$ Infil. Rate in. per hr.
1	.43	.28
3	.88	.19
6	1.38	.15
12	2.16	.12
18	2.81	.10
24	3.39	.09
36	4.41	.08
48	5.32	.07
72	6.92	.063
96	8.34	.056

Table 3

Tulare County
Crop Rotation Plots
Chino loam
18" Infiltrometer Tests
Aug. 21-22, 1962

	Acc. Infil.	Infil. Rate
Replication I		
South	$D = 0.050t^{0.54}$	$I = 1.62t^{-0.46}$
Middle	$D = 0.071t^{0.54}$	$I = 2.30t^{-0.46}$
North	$D = 0.145t^{0.44}$	$I = 3.82t^{-0.56}$
Replication II		
South	$D = 0.045t^{0.73}$	$I = 1.97t^{-0.27}$
Middle	$D = 0.14\ t^{0.60}$	$I = 5.04t^{-0.40}$
North	$D = 0.24\ t^{0.50}$	$I = 7.20t^{-0.50}$
Replication III		
South	$D = 0.094t^{0.61}$	$I = 3.44t^{-0.39}$
Middle	$D = 0.12\ t^{0.60}$	$I = 4.42t^{-0.40}$
North	$D = 0.072t^{0.59}$	$I = 2.52t^{-0.41}$
Replication IV		
South	$D = 0.070t^{0.67}$	$I = 2.82t^{-0.33}$
Middle	$D = 0.040t^{0.67}$	$I = 1.61t^{-0.33}$
North	$D = 0.033t^{0.64}$	$I = 1.31t^{-0.36}$

TABLE 4

Equations for Infiltration Rates and Accumulated Intake
of a Number of California Soils

(Measurements made by Lukas F. Werenfels
with 18-inch infiltrometer except where basin size is shown.)

Location	Soil Series	Type	Irrig. Method	Crop	Soil Management	Date	Number of runs (18"cyl)	D in inches t in min.	I = in/hr t = min.
Gridley	Gridley	l	flood	prunes	clean cult	Apr	6	$D = .075t^{.8}$	$I = 3.6\ t^{-.20}$
Fairfield	Esparto	si c	sprink	prunes	sod	Jan	6	$D = .14\ t^{.52}$	$I = 4.5\ t^{-.48}$
Davis	Yolo	l	flood	apricots	summer legume (Hubam)	Jan	8	$D = .25\ t^{.7}$	$I = 10.5\ t^{-.30}$
Davis	Yolo	l	flood	apricots	clean cult	Jan	8	$D = .10\ t^{.7}$	$I = 4.2\ t^{-.30}$
Davis	Yolo	l	flood	walnuts	non cult	Nov	6	$D = .15\ t^{.69}$	$I = 6.2\ t^{-.31}$
Davis	Yolo	l	flood	walnuts	clean cult	Nov	6	$D = .40\ t^{.69}$	$I = 16.6\ t^{-.31}$
Fresno	San Joaquin	s l	flood	figs	non cult	Jan	4	$D = .025t^{.80}$	$I = 1.2\ t^{-.21}$
Fresno	San Joaquin	s l	flood	figs	clean cult	Jan	4	$D = .052t^{.80}$	$I = 2.5\ t^{-.21}$
Clovis	Madera	l	non irri	figs	non cult	Jan	4	$D = .11\ t^{.7}$	$I = 4.6\ t^{-.30}$
Clovis	Madera	l	non irri	figs	clean cult	Jan	4	$D = .19\ t^{.7}$	$I = 8.0\ t^{-.30}$
Clovis	San Joaquin	s l	flood	figs	non cult	Jan	4	$D = .12\ t^{.8}$	$I = 6.0\ t^{-.20}$
Clovis	San Joaquin	s l	flood	figs	clean cult	Jan	4	$D = .40\ t^{.8}$	$I = 19.2\ t^{-.20}$
Camino	Aiken	c l	sprink	pears	clean cult	Oct	8	$D = .41\ t^{.78}$	$I = 19.2\ t^{-.22}$
Placerville	Aiken	c l	sprink	pears	sawdust mulch (traffic patt)	Jul	6	$D = .025t^{.60}$	$I = .90t^{-.40}$
Placerville	Aiken	c l	sprink	pears	sod (traffic pattern)	Jul	6	$D = .12\ t^{.35}$	$I = 2.5\ t^{-.65}$
Corning	Tehama	si l	flood	olives	sod wet	Oct	4	$D = .05\ t^{.65}$	$I = 1.9\ t^{-.35}$
Corning	Tehama	si l	flood	olives	sod dry	Oct	4	$D = .09\ t^{.40}$	$I = 2.2\ t^{-.60}$
Corning	Tehama	si l	flood	olives	sod dry	Sep	10 x 10 basin	$D = .037t^{.60}$	$I = 1.33t^{-.40}$
Gilroy	Rincon	c l	sprink	prunes	clean cult	Jul	6	$D = .05\ t^{.54}$	$I = 1.6\ t^{-.46}$
Red Bluff	Proberta	si l	flood	almonds	clean cult	Nov	20 x 20 basin	$D = .18\ t^{.44}$	$I = 4.8\ t^{-.56}$