

CEE6400 Physical Hydrology

Infiltration example problem

Consider a soil of given type (e.g. **silty clay loam**) and given an input rainfall hyetograph, calculate the infiltration and the runoff. Initial soil moisture content 0.3. Rainfall rate 2 cm/hr, for 3 hours.

This is an event based calculation of runoff

Solution outline

1. Determine soil properties from texture (Table 1 p 4:18)

These are the parameters of the problem (time invariant quantities that describe behavior in a particular situation).

K_{sat}	
n	
Ψ_a	
b	

2. System state described by initial condition and the depth of water that has infiltrated up to any point in time

$\theta_o = 0.3$	$F = 0$ cm at $t=0$ cm (will change during course of the event)
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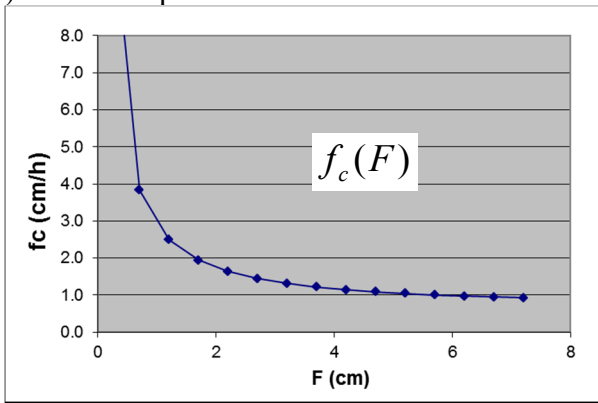
3. Establish Infiltrability – Depth approximation. In Green-Ampt approach this is based on hydraulic gradient over the depth of penetration of wetting front, Darcy's equation and suction in advance of a wetting front (Infiltration18.pptx, slide 13)

$$f_c = K_{sat} \left(1 + \frac{|\Psi_f| \Delta\theta}{F} \right) = K_{sat} \left(1 + \frac{P}{F} \right)$$

$ \Psi_f = \frac{2b+3}{2b+6} \Psi_a $ equation 44	
$\Delta\theta = n - \theta_o$	
P	

F cm				
f_c cm/h				

$f_c(F)$ relationship serves as foundation for calculations that follow



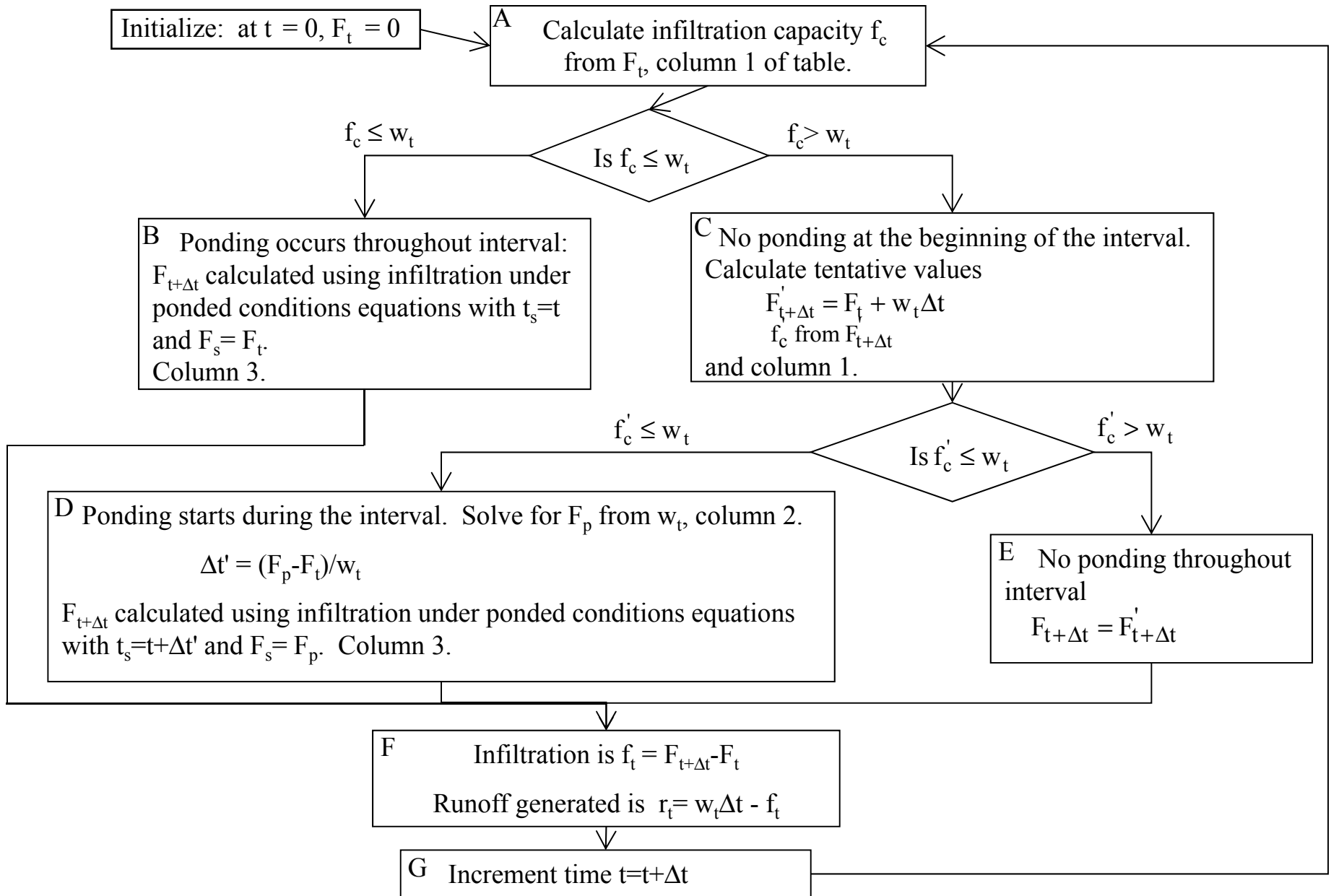
4. Ponding (saturation at the surface) first occurs when $f_c=W$ (water input rate or rainfall rate) This idea lets you solve for the depth of water that has to infiltrate before ponding occurs, F_p , and the time to ponding t_p for a particular input rate W .

F_p cm	
t_p h	

5. After ponding the rate of increase in F (remember, this is a state variable describing the state of the system) is limited by the infiltration capacity

$$\frac{dF}{dt} = f_c(F) = K_{sat} \left(1 + \frac{P}{F} \right)$$

Solving this gives an equation relating F and t for ponded conditions



Equations for variable surface water input intensity infiltration calculation.

	Infiltration capacity	Cumulative infiltration at ponding	Cumulative infiltration under ponded conditions
Green-Ampt Parameters K_{sat} and P	$f_c = K_{sat} \left(1 + \frac{P}{F} \right)$	$F_p = \frac{K_{sat} P}{(w - K_{sat})}$ $w > K_{sat}$	$t - t_s = \frac{F - F_s}{K_{sat}} + \frac{P}{K_{sat}} \ln \left(\frac{F_s + P}{F + P} \right)$ Solve implicitly for F
Horton Parameters k , f_o , f_1 .	$F = \frac{f_o - f_c}{k} - \frac{f_1}{k} \ln \left(\frac{f_c - f_1}{f_o - f_1} \right)$ Solve implicitly for f_c given F	$F_p = \frac{f_o - w}{k} - \frac{f_1}{k} \ln \left(\frac{w - f_1}{f_o - f_1} \right)$ $f_c < w < f_o$	Solve first for time offset t_o in $F_s = f_1(t_s - t_o) + \frac{(f_o - f_1)}{k} (1 - e^{-k(t_s - t_o)})$ then $F = f_1(t - t_o) + \frac{(f_o - f_1)}{k} (1 - e^{-k(t - t_o)})$
Philip Parameters K_p and S_p	$f_c(F) = K_p + \frac{K_p S_p}{\sqrt{S_p^2 + 4K_p F} - S_p}$	$F_p = \frac{S_p^2 (w - K_p / 2)}{2(w - K_p)^2}$ $w > K_p$	Solve first for time offset t_o in $t_o = t_s - \frac{1}{4K_p} \left(\sqrt{S_p^2 + 4K_p F_s} - S_p \right)^2$ then $F = S_p (t - t_o)^{1/2} + K_p (t - t_o)$