Evaporation, Transpiration and Infiltration
Lecture 4, 04/11/2013

Arturo Leon, Oregon State University (Spring 2013)
Adapted from textbook and notes of Philip B. Bedient, David Maidment and Areeya Rittima

2

Evaporation: Measurement

Class A Evaporation Pan

Evaporation Pan Method, E = Kp.Ep

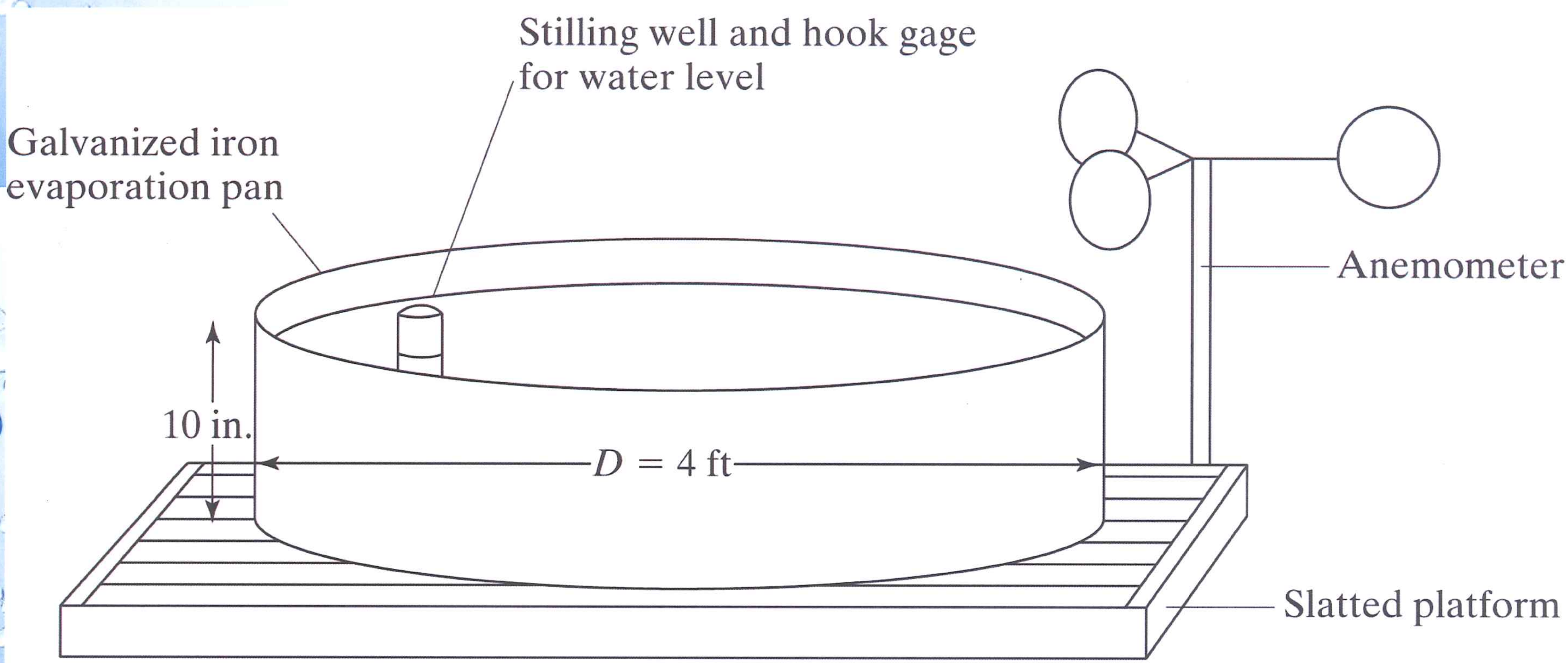
E = Evaporation Rate (mm/day)

Kp = Pan Coefficient (0.64-0.81. The average is about 0.70)

Ep = Measured Evaporation (mm/day)

3

Standard class A evaporation pan with cup anemometer and rain gage



Factors that Influence Evaporation

The two main factors influencing evaporation from an open water surface are :

1) The supply of energy to provide latent heat of vaporization.

↓

Solar radiation is the main source of heat energy

2) The ability to transport vapor away from evaporative surface.

↓

depends on → wind velocity over the surface
specific humidity gradient in the air above it

Evapotranspiration

The processes of evaporation from land surface and transpiration from vegetation are collectively termed **"Evapotranspiration"**.

Evapotranspiration is influenced by

1) the supply of energy to provide the latent heat of vaporization

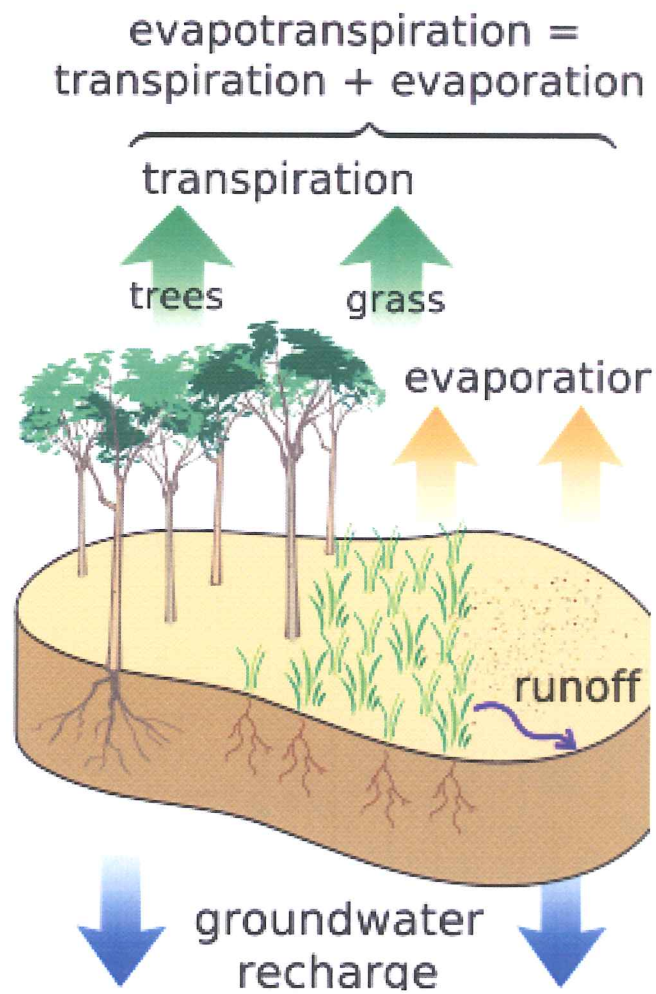
→ Energy Supply

2) the ability to transport the vapor away from the evaporative surface

→ Vapor Transport

3) the supply of moisture at the evaporative surface

→ Moisture



Evapotranspiration (Cont.)

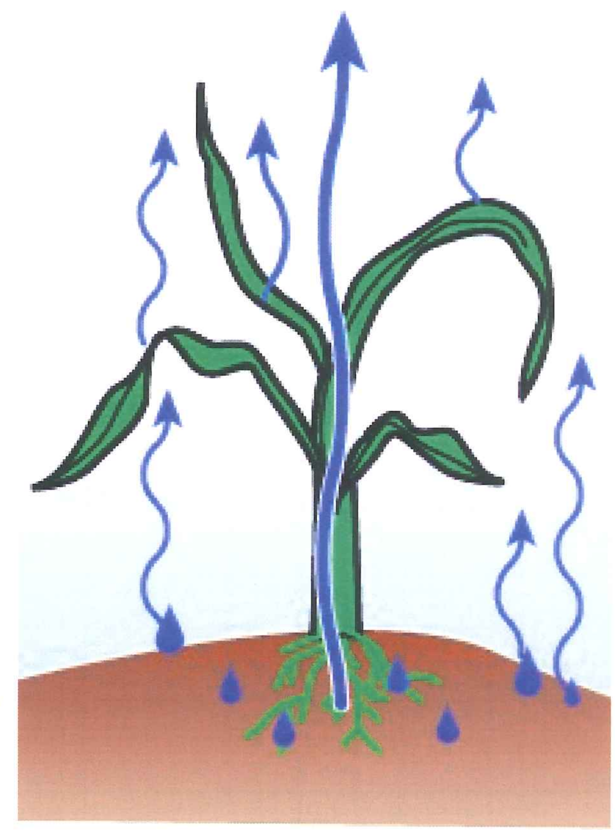
6

Water evaporates from any moist surface into the air unless **the air is saturated**.

Field capacity of the soil: Moisture content above which water will be drained by gravity.

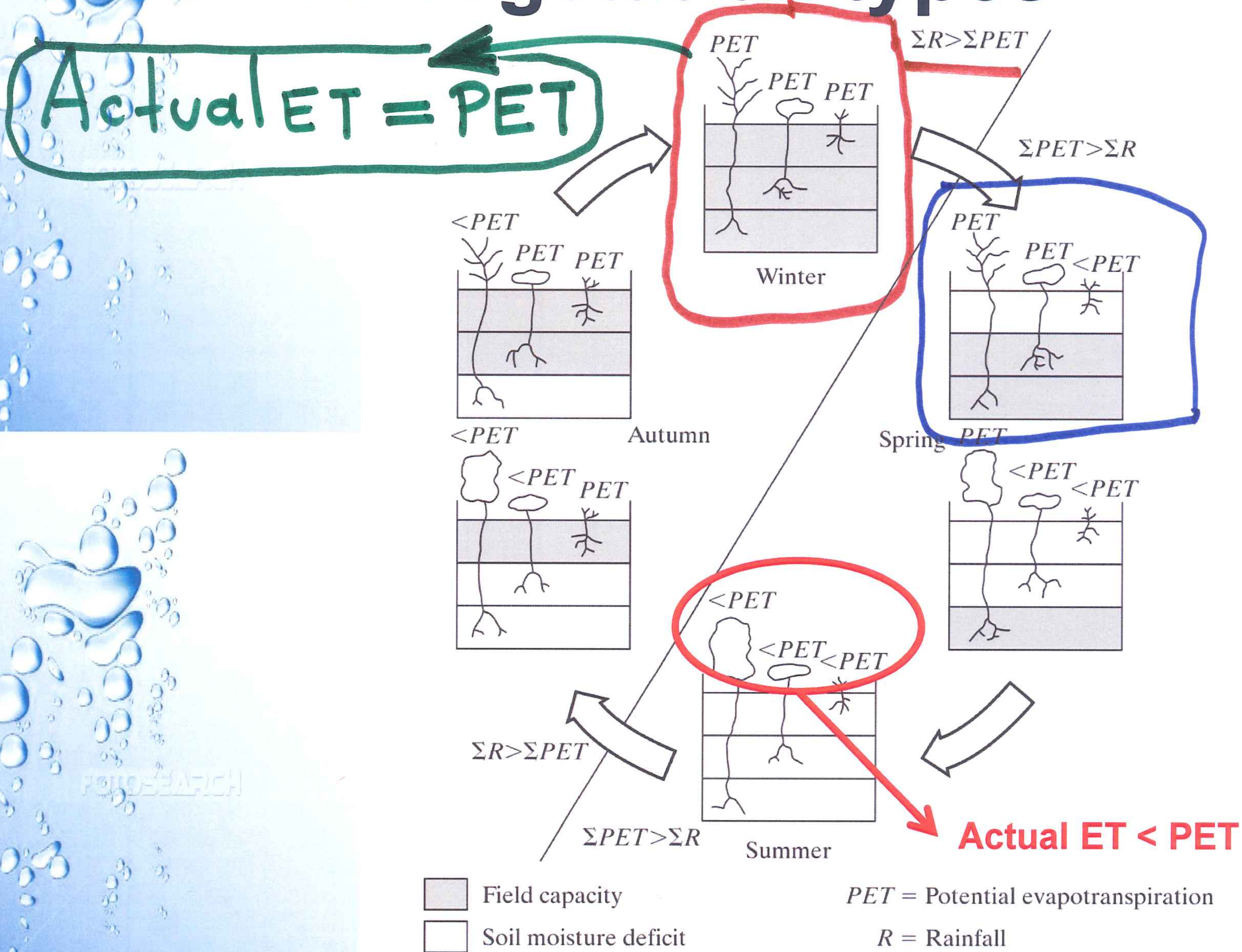
Wilting point of the soil: Moisture content below which plants cannot extract further water.

Potential Evapotranspiration (PET) is the maximum evapotranspiration that occurs if the water supply to both the plant and soil surface is unlimited.



Idealized annual soil moisture cycle for three vegetation types

7

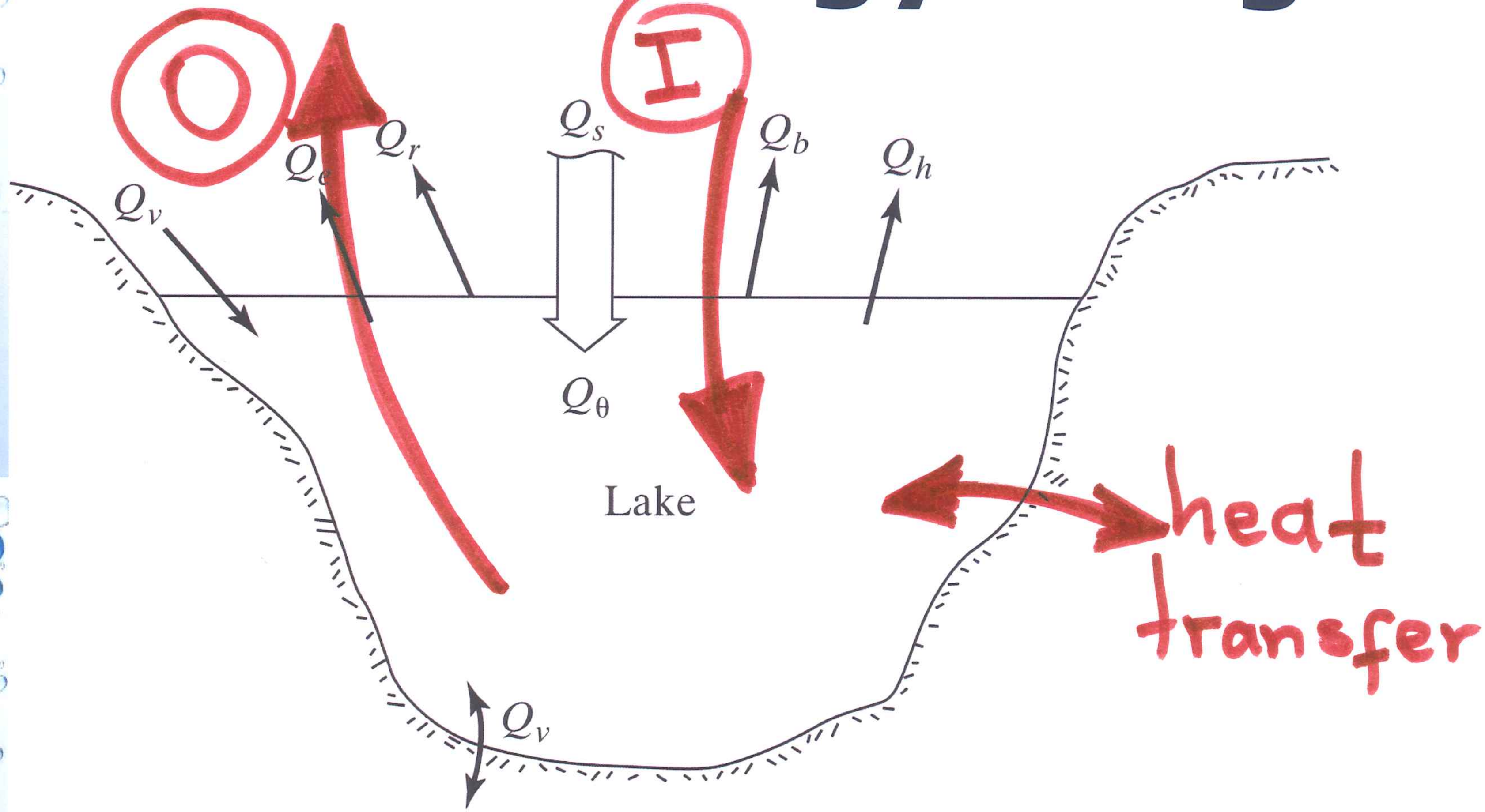


8

Methods for determining evaporation

- Water budget $\Sigma I - \Sigma O = \Delta s / \Delta t$
- Mass transfer
- Energy Budget (Penman Method)
- Combined Method (energy budget and mass transfer)
- Pan evaporation

A Lake's Energy Budget



$Q_N = (Q_s - Q_r - Q_b)$

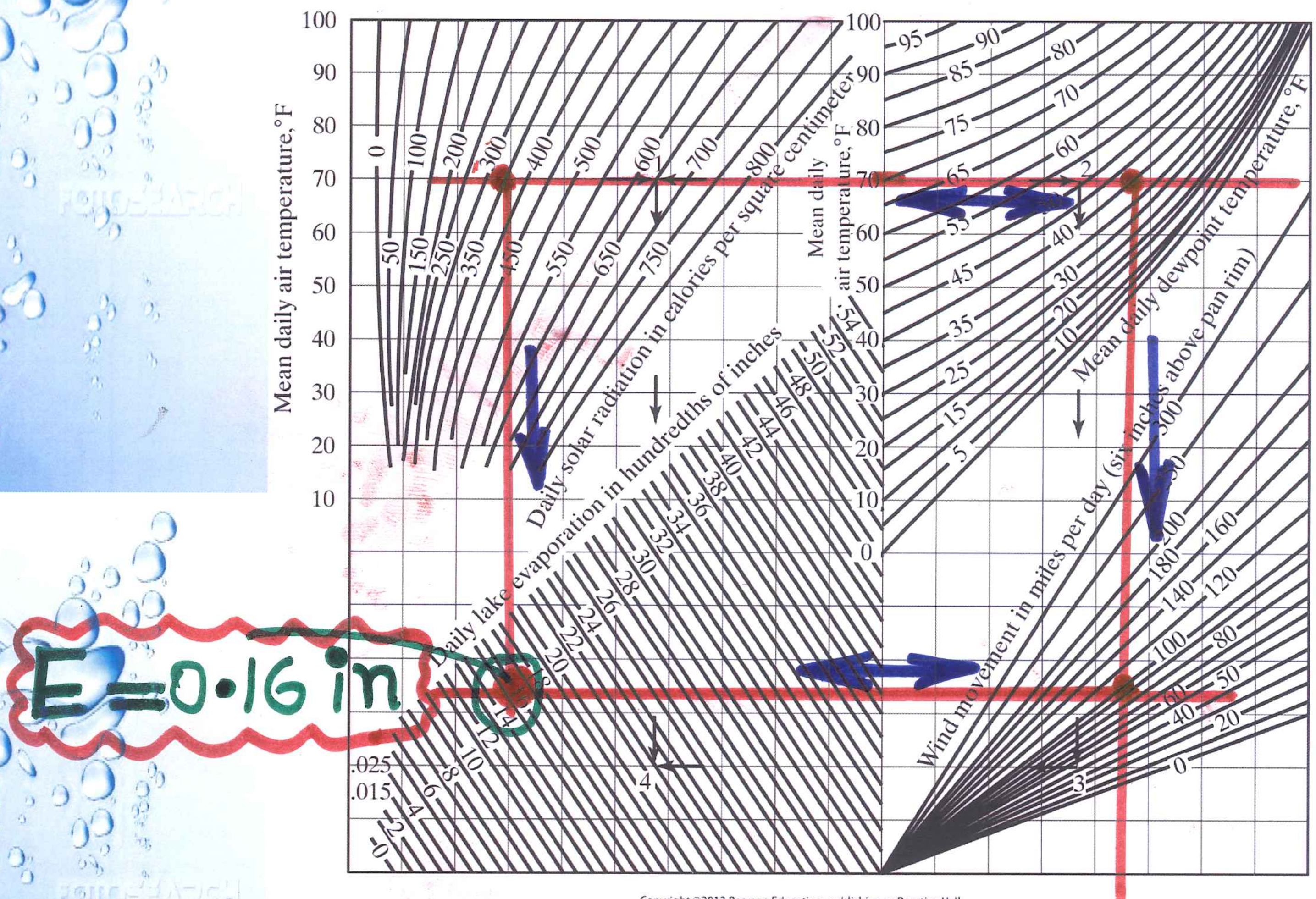
where Q_s = shortwave solar radiation

Q_r = reflected shortwave radiation

Q_b = longwave radiation back to atmosphere

Shallow Lake Evaporation (Graphical Regression based on the Penman Equation)

10



The **dew point** is the temperature below which the water vapor in a volume of humid air at a given constant barometric pressure will condense into liquid water at the same rate at which it evaporates. Condensed water is called dew when it forms on a solid surface.

Pan Coefficients for Evapotranspiration Estimates

11

Evap Lake ≈ 0.7 Epan

Evapotranspiration (ET) using the Pan Evaporation Method ET = Kp.Ep

ET = Evapotranspiration Rate (mm/day)
Kp = Pan Coefficient (see table 2.2)
Ep = Measured Evaporation (mm/day)

Table 2–2 Pan Coefficients for Evapotranspiration Estimates

Type of Cover	Pan Coefficient	Reference
St. Augustine grass	0.77	Weaver and Stephens (1963)
Bell peppers	0.85–1.04	
Grass and clover	0.80	Brutsaert (1982, p. 253)
Oak–pine flatwoods (east Texas)	1.20	Englund (1977)
Well-watered grass turf		Shih et al. (1983)
Light wind, high relative humidity	0.85	
Strong wind, low relative humidity	0.35	
Everglades agricultural areas	0.65	
Irrigated grass pasture (central California)	0.76	Hargreaves and Samani (1982)

Example of Pan Evaporation (Problem 2.29)

A class A pan is maintained near a small lake to determine daily evaporation (see table). The level in the pan is observed at the end of everyday. Water is added if the level falls *near* 7 in. For each day the difference in height level is calculated between the current and previous day, and the precipitation value is from the current day. Determine the daily lake evaporation if the pan coefficient is 0.70.

Day	Rainfall (in.)	Water Level (in.)	Evapor PAN (in)	Evap. Lake (in)
1	0	8.00	0	0
2	0.23	7.92	0.23+8−7.92	0.217
3	0.56	7.87	0.61	0.427
4	0.05	7.85	0.07	0.049
5	0.01	7.76	0.10	0.07
6	0	7.58		
7	0.02	7.43		
8	0.01	7.32		
9	0	7.25		
10	0	7.19		
11	0	7.08*	0.11	0.077
12	0.01	7.91	0.01+8−7.91	0.070
13	0	7.86		
14	0.02	7.8		

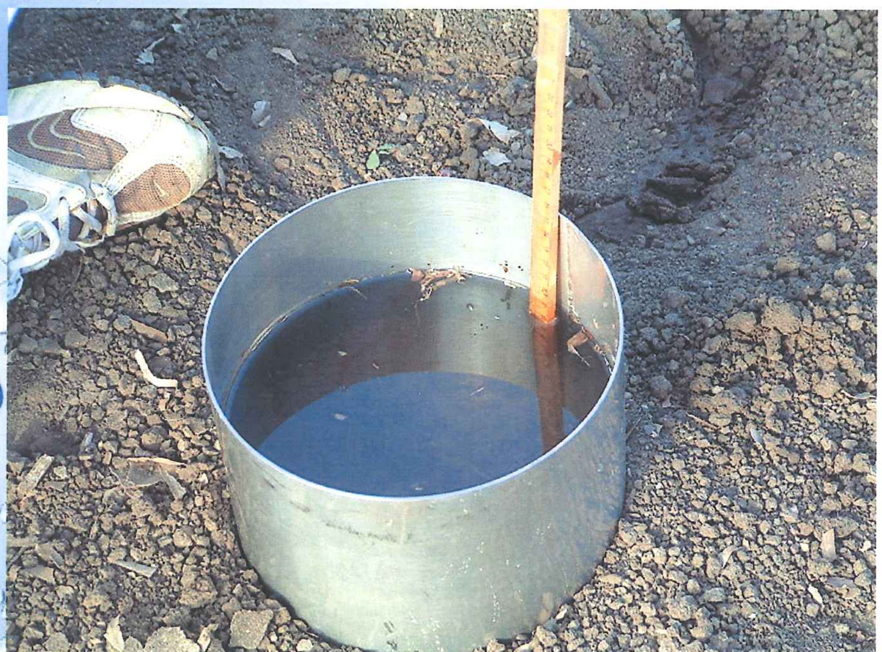
*Refilled at this point to 8 inches

13

Infiltration: Measurement

Types of Infiltrometers

Single Ring



Double Ring

http://en.wikipedia.org/wiki/Infiltrometer

(14)

Measurement of Infiltration using a Double Ring Infiltrometer

http://www.youtube.com/watch?v=YawF0W8PBA0

15

Horton's Infiltration Concept
f(t) = Rate of water loss into soil

$f = f_c + (f_o - f_c) \exp(-kt)$

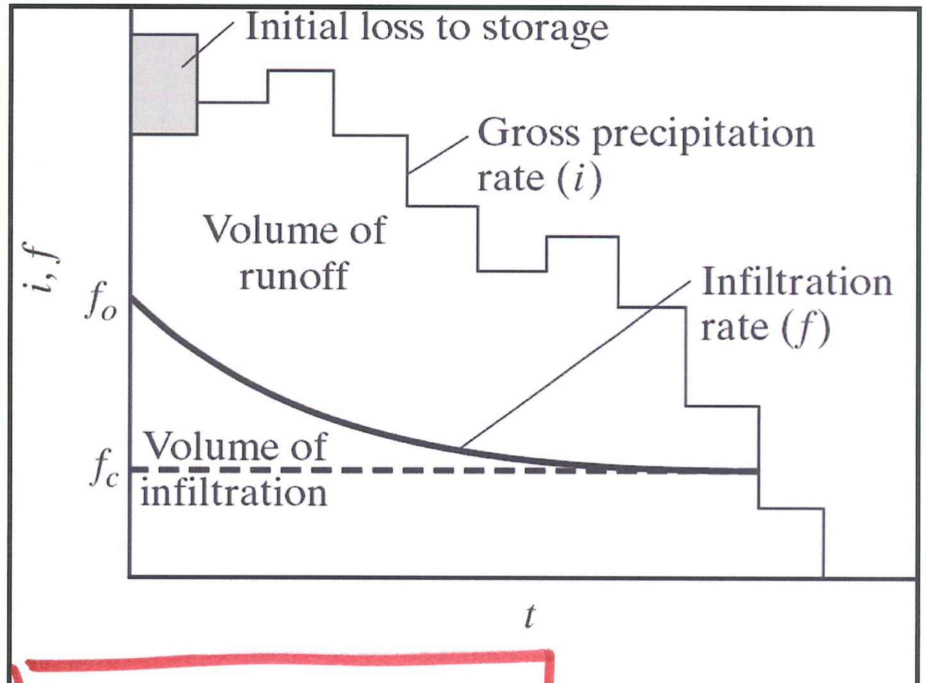
f_c = *final capacity*

f_o = *initial capacity*

K = decay rate

Can integrate to get

F(t) = Vol of infiltration

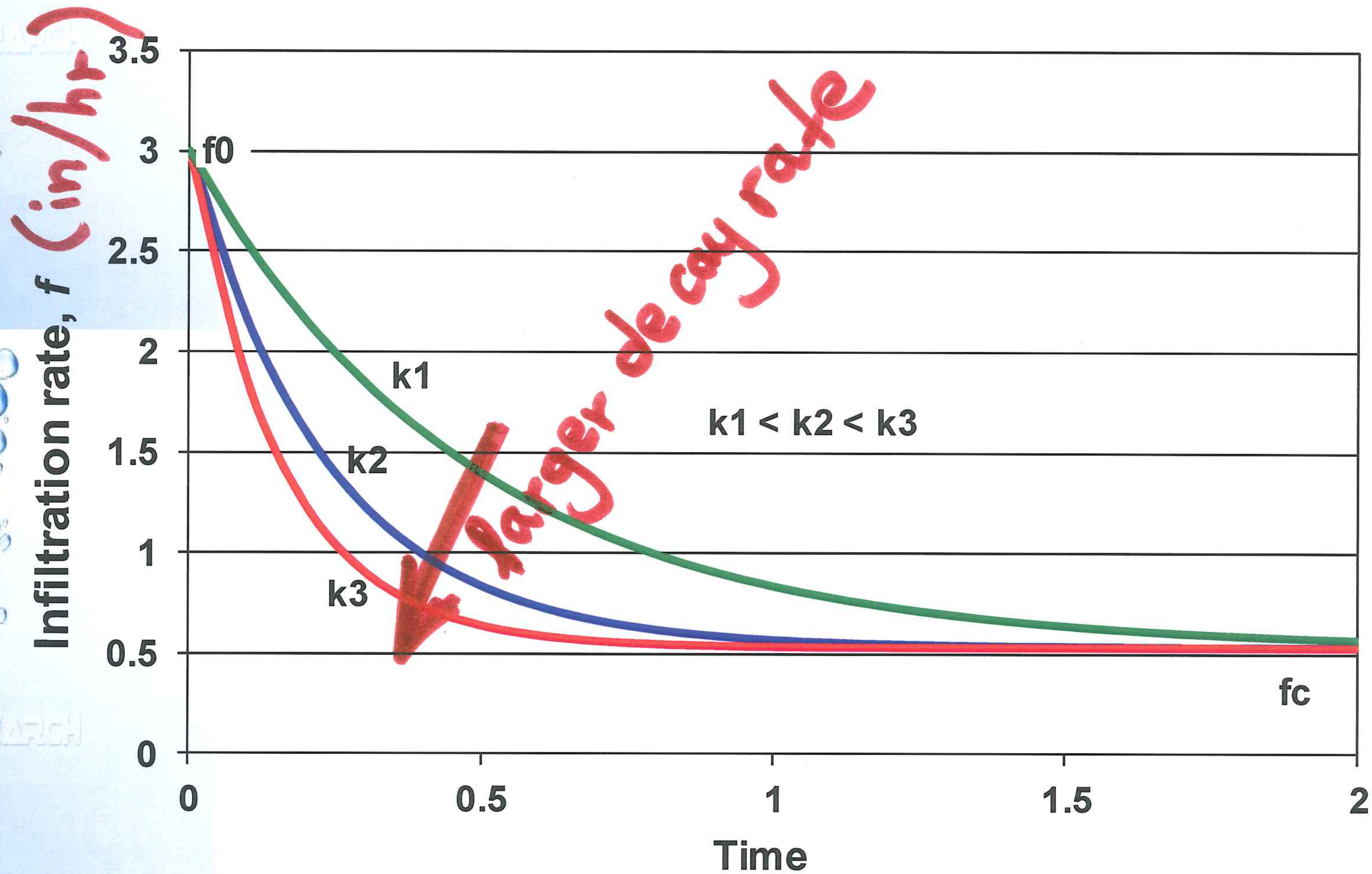


$$F = \int_0^T f\,dt$$

F = Cumulative Infiltration

16 a

Hortonian Infiltration



16b

Typical Values of the Parameters of f_0, f_c, and k of the Horton Model

final capacity

initial capacity

Table 2–3 Typical Values of the Parameters of f_0, fc, and k of the Horton Model

Soil Type	f_c (in./hr)	f_0 (in./hr)	k (hr^{-1})
Alphalpha loamy sand	1.40	19.00	38.29
Carnegie sandy loam	1.77	14.77	19.64
Dothan loamy sand	2.63	3.47	1.40
Fuquay pebbly loamy sand	2.42	6.24	4.70
Leefield loamy sand	1.73	11.34	7.70
Tooup sand	1.80	23.01	32.71

After Rawls et al., 1983.

Would be preferred for installing wetlands or infiltration ponds

decay rate

Horton's Infiltration: Problem 2.33

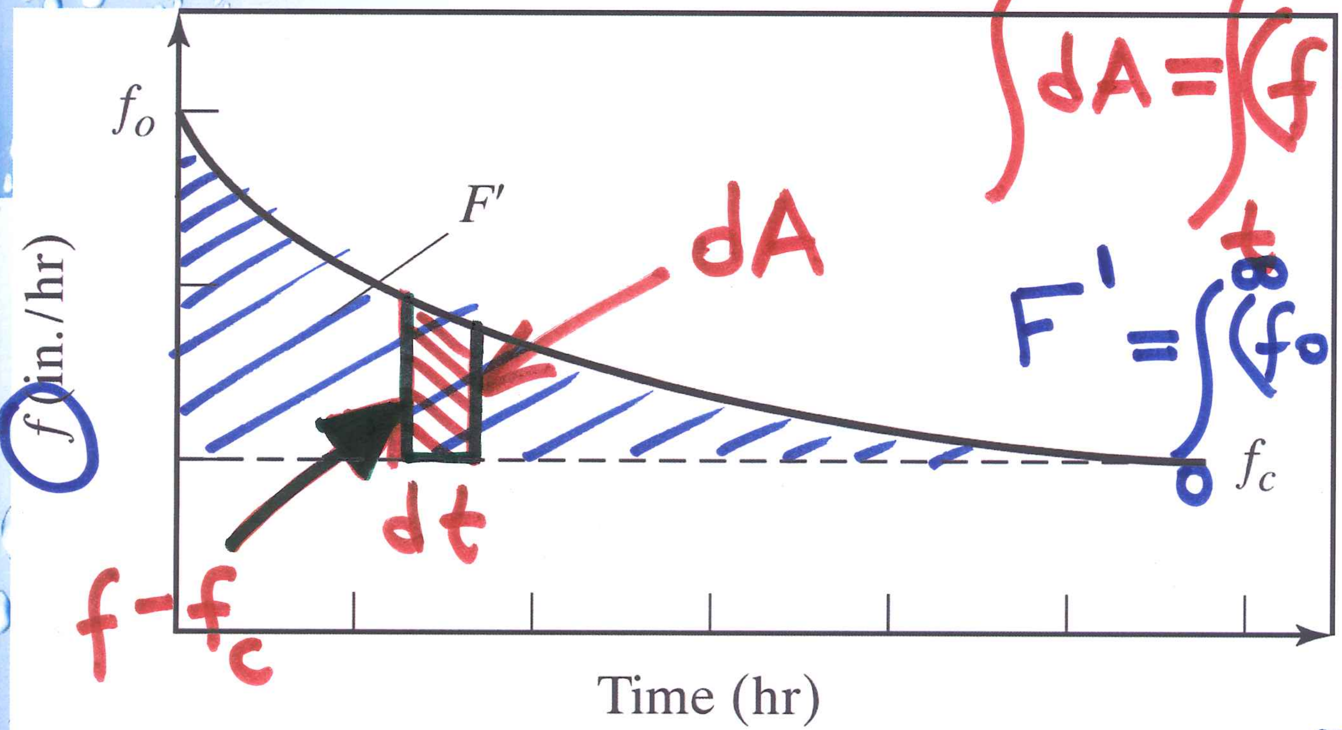
16 (c)

A plot of the infiltration curve obtained using Horton's equation is shown in Fig.

P2–33. Prove that $k = \frac{(f_o - f_c)}{F'}$ if F' is the area between the curve and the f_c line.

Find the area by integration over time, as time approaches infinity.

$$f = f_c + (f_o - f_c)e^{-kt}$$



$$\int dA = \int (f - f_c)\,dt$$

$$F' = \int_0^\infty (f_o - f_c)e^{-kt}\,dt$$

$$F' = (f_o - f_c)\frac{1}{-k}e^{-kt}\Big|_0^\infty$$

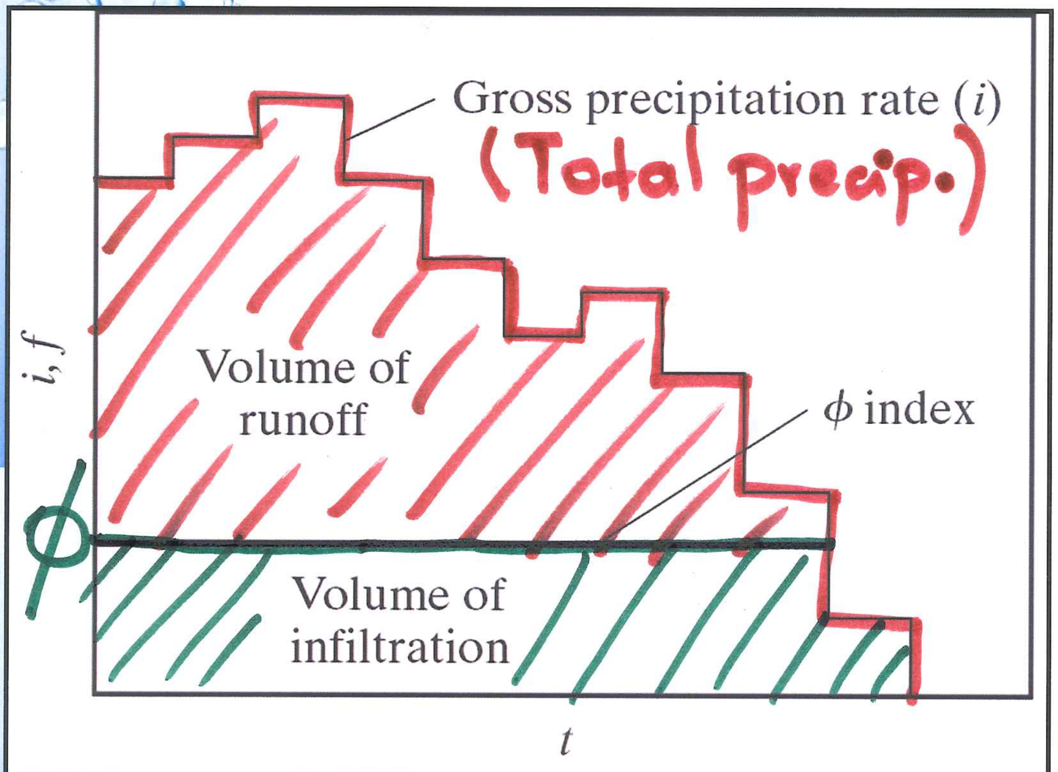
$$F' = (f_o - f_c)\left(0 - \left(\frac{-1}{k}\right)\right)$$

$$F' = \frac{(f_o - f_c)}{k}$$

$$k = (f_o - f_c)/F'$$

17

Φ index Infiltration Method

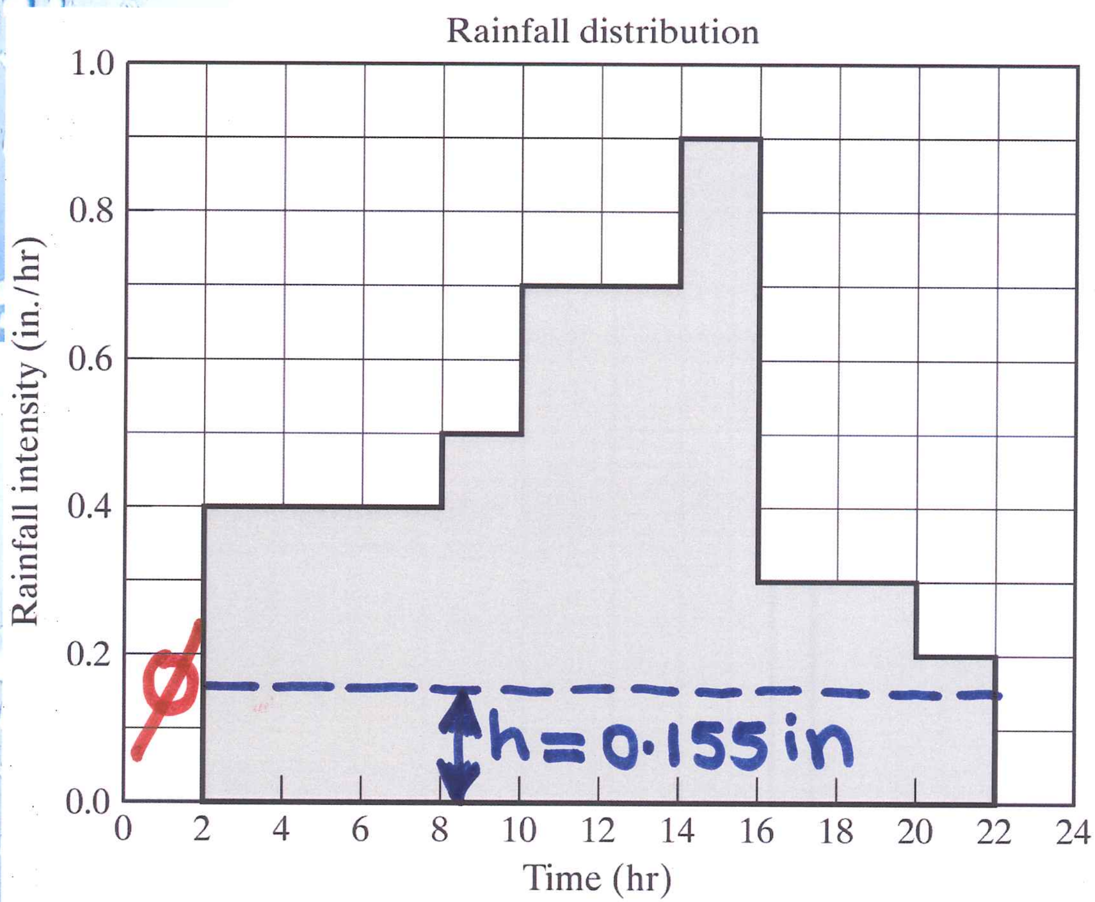


- Assumes constant infiltration over time of rainfall
- Volume above line is volume of direct runoff (DRO)
- Volume below line is F(t)
- Trial and error computed

18

Example of Φ Index: Problem 2.34

Determine the Φ index of figure 2.34 if the runoff depth was 6.5 in. of rainfall over the watershed area



Total rain depth

$= 9.6 \text{ in} \left(\sum i \cdot \Delta t\right)$

Runoff = 6.5 in

Infiltration = 9.6 − 6.5

= 3.1 in

20 h = 3.1 in

h = 0.155 in