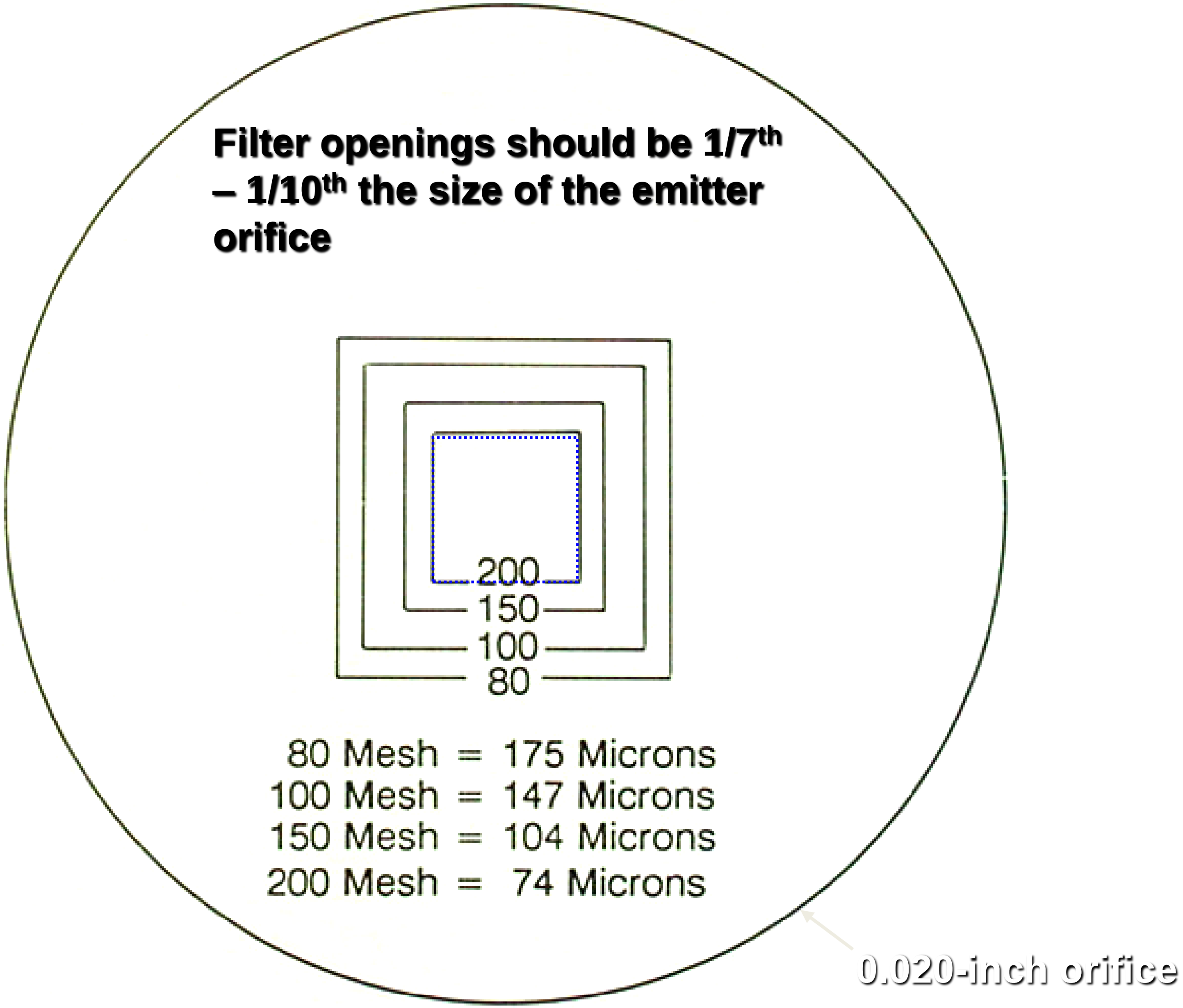
Other Design and Management Issues

- Clogging
  - Physical (mineral particles)
  - Chemical (precipitation)
  - Biological (slimes, algae, etc.)
- Filtration
  - Settling basins
  - Sand separators (centrifugal or cyclone separators)
  - Media (sand) filters
  - Screen filters

There are many different types of filtration systems.

The type is dictated by the water source and also by emitter size.

Filtration Requirements for Drip Emitters



Plugging Potential of Irrigation Water for Microirrigation

Table 14.1. Plugging Potential of Irrigation Water for Microirrigation (Bucks et al., 1979).

Potential Problem	Unit of Measure	Minor	Moderate	Severe
Physical				
Suspended Solids	ppm	< 50	50 - 100	> 100
Chemical				
pH	-	< 7	7 - 8	> 8
Salts	ppm	< 500	500 - 2000	> 2000
Manganese	ppm	< 0.1	0.1 - 1.5	> 1.5
Iron	ppm	< 0.1	0.1 - 1.5	> 1.5
Hydrogen Sulfide	ppm	< 0.5	0.5 - 2.0	> 2.0
Biological				
Bacteria Populations	Number/ml	<10,000	10,000-50,000	>50,000

- Chemical treatment
  - Acid: prevent calcium precipitation
  - Chlorine
    - control biological activity: algae and bacterial slime
    - deliberately precipitate iron
- Flushing
  - after installation or repairs, and as part of routine maintenance
  - valves or other openings at the end of all pipes, including laterals
- Application uniformity
  - manufacturing variation
  - pressure variations in the mainlines and laterals
  - pressure-discharge relationships of the applicators

Schematic of Subsurface Drip Irrigation (SDI) System

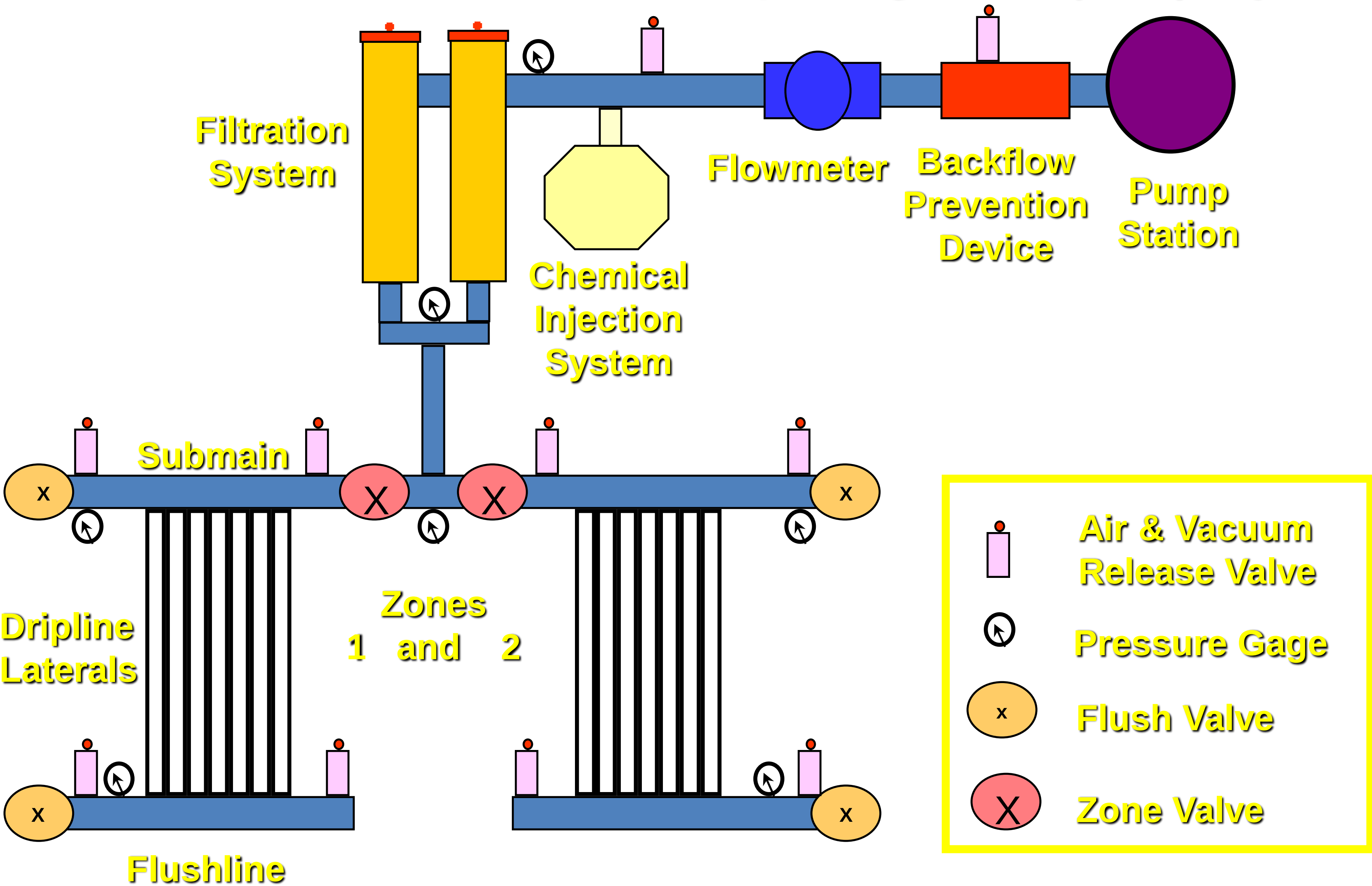
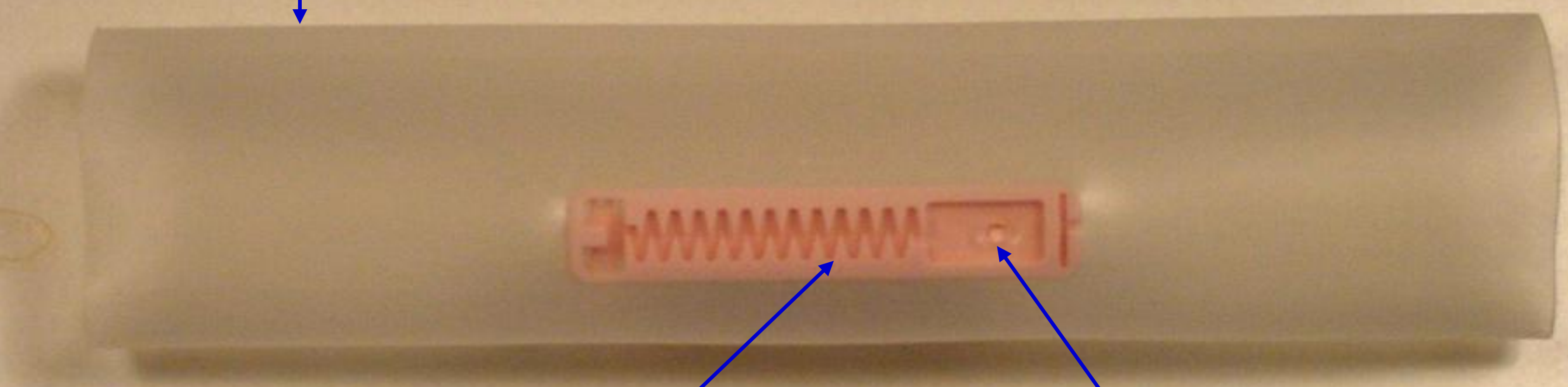


Diagram courtesy of Kansas State University

Netafim Typhoon® Drip Irrigation Tubing (Clear Demo Tubing)



Netafim Typhoon® Drip Irrigation Tubing

Wetting Pattern of a Subsurface Drip Lateral

Photo Courtesy of Kansas State University


Plowing in drip tubing

Surface wetting from drip

Drip tubing end after being sheared by the trencher

Flush Risers on Distal End of Research Plots

Irrigation Water Requirement

Evapotranspiration

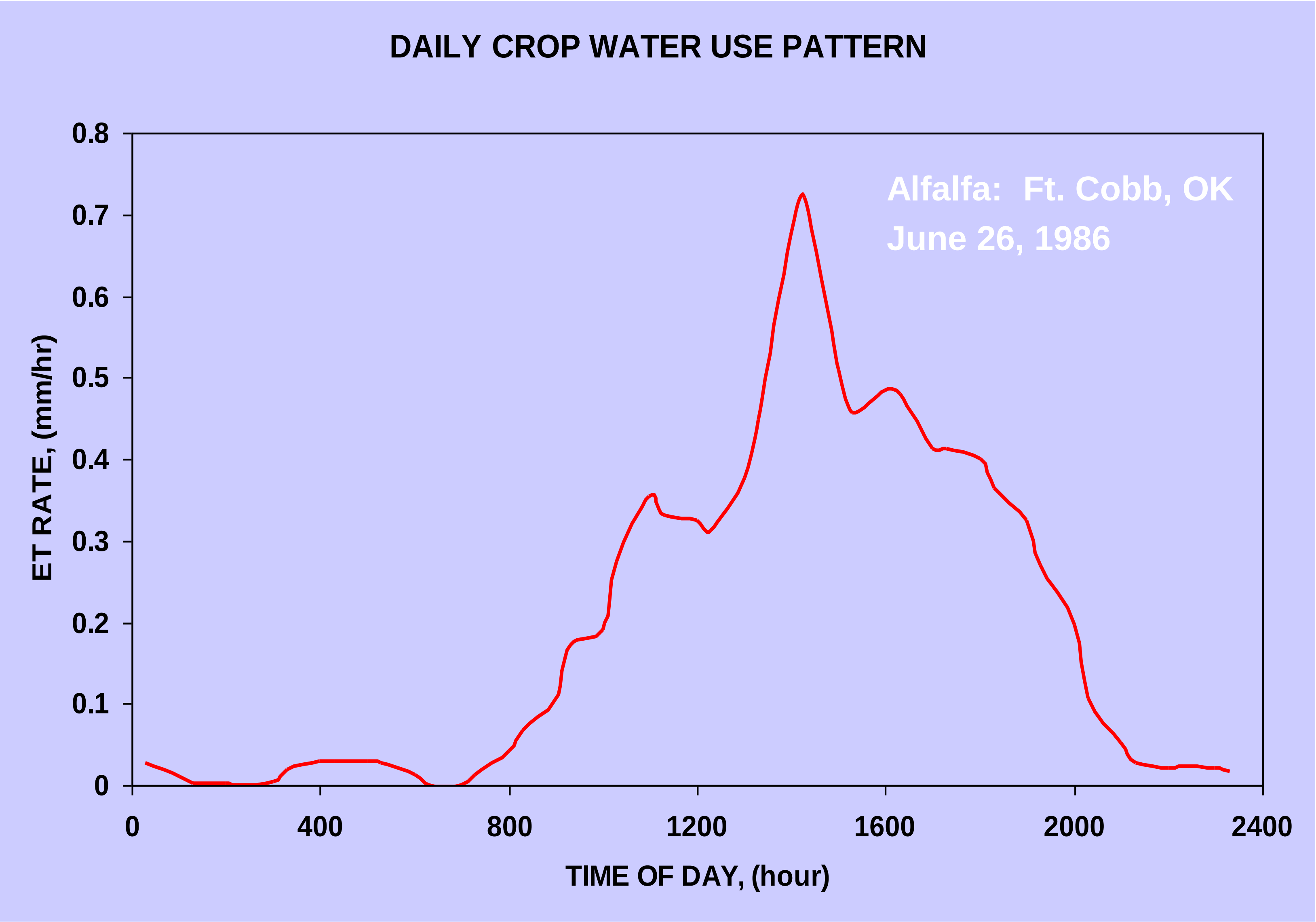
- Terminology
  - Evaporation
    - Process of water movement, in the vapor form, into the atmosphere from soil, water, or plant surfaces
  - Transpiration
    - Evaporation of water from plant stomata into the atmosphere
  - Evapotranspiration
    - Sum of evaporation and transpiration (abbreviated "ET")
  - Consumptive use
    - Sum of ET and the water taken up the plant and retained in the plant tissue (magnitude approximately equal to ET, and often used interchangeably)

Magnitude of ET

- Generally tenths of an inch per day, or tens of inches per growing season
- Varies with type of plant, growth stage, weather, soil water content, etc.
- Transpiration ratio
  - Ratio of the mass of water transpired to the mass of plant dry matter produced (g H_2O/g dry matter)
- Typical values: 250 for sorghum
  500 for wheat
  900 for alfalfa

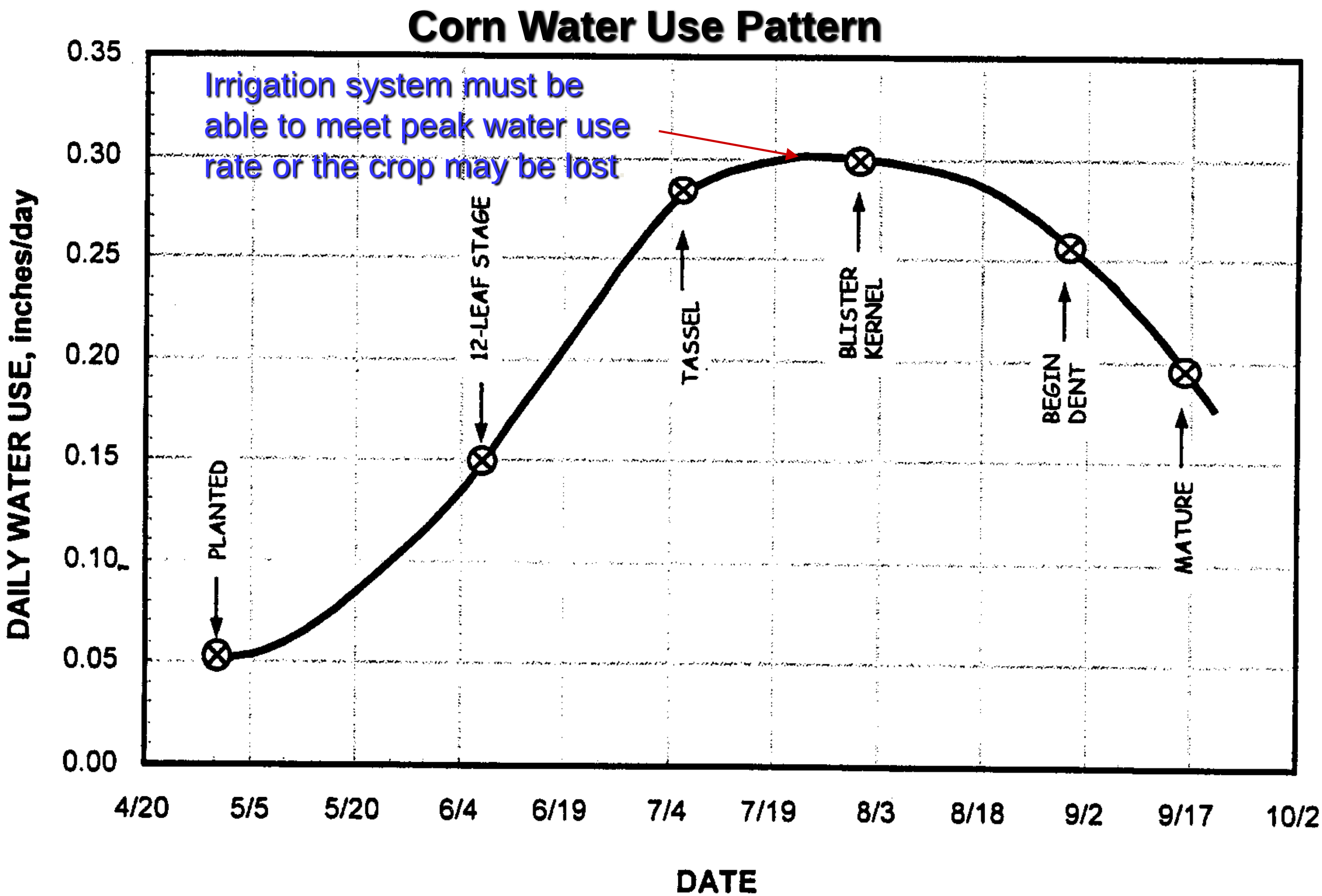
Plant Water Use Patterns

Daily Water Use: peaks late in afternoon; very little water use at night



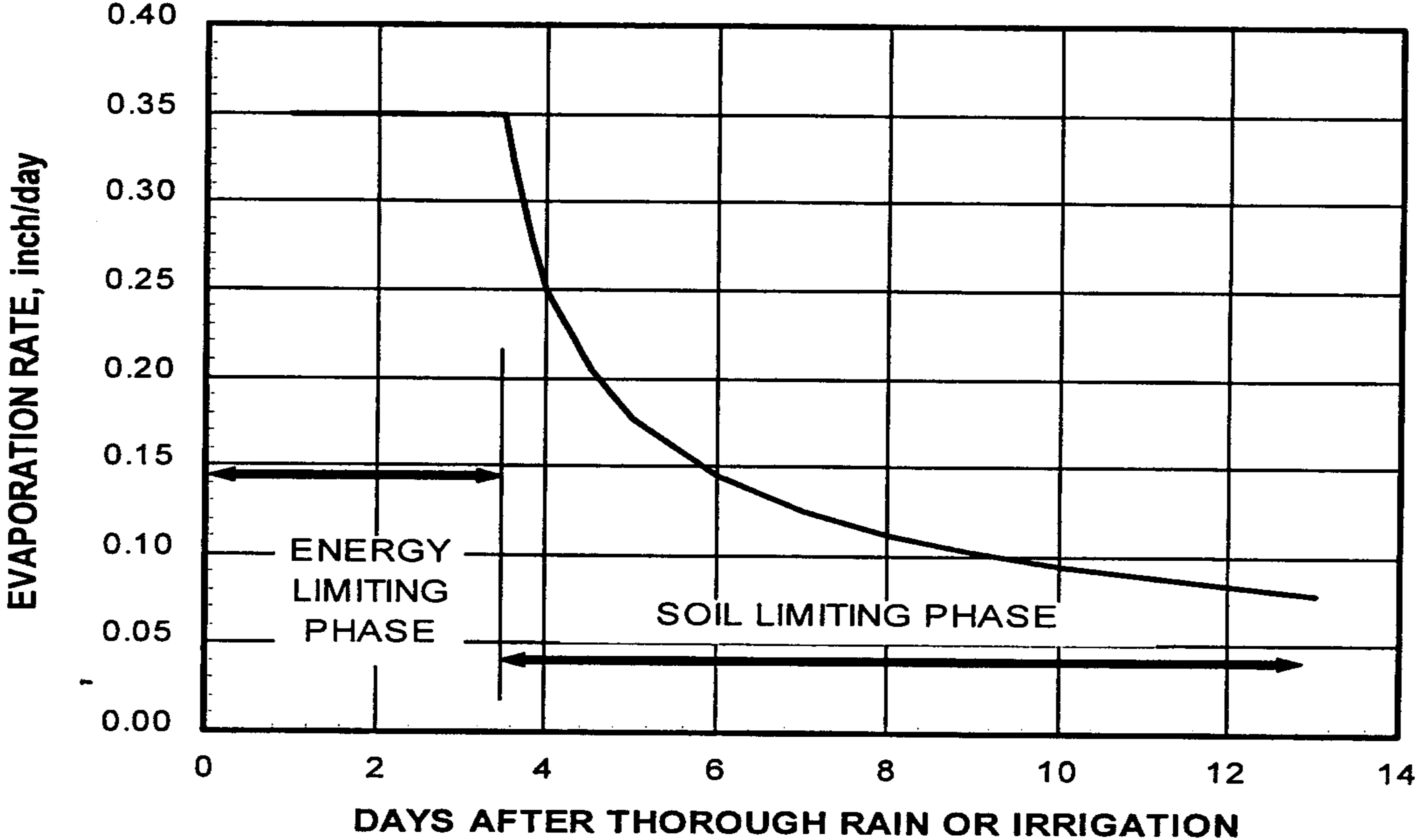
Plant Water Use Patterns

- Seasonal Use Pattern: Peak period affects design



Evaporation Rate and Time Since Irrigation

Energy or Water Availability as the Limiting Factor in ET Rate



Evapotranspiration Modeling

- Estimation based on:
  - climate
  - crop
  - soil factors

$$ET_c = K_c \, ET_o$$

- ET_c = actual crop evapotranspiration rate
- ET_o = the evapotranspiration rate for a reference crop
- K_c = the crop coefficient

Evapotranspiration Modeling

- Reference Crop ET (ETo)
  - ET rate of actively growing, well-watered, "reference" crop
  - Grass or alfalfa used as the reference crop (alfalfa is higher)
  - A measure of the amount of energy available for ET
  - Many weather-based methods available for estimating ETo
    - (FAO Blaney-Criddle; Jensen-Haise; Modified Penman; Penman-Montieth)
- Crop Coefficient (Kc)
  - Empirical coefficient which incorporates type of crop & stage of growth (Kcb); and soil water status-- a dry soil (Ka) can limit ET; a wet soil surface (Ks) can increase soil evaporation
  - Kc = (Kcb x Ka) + Ks
  - Kc values generally less than 1.0, but not always

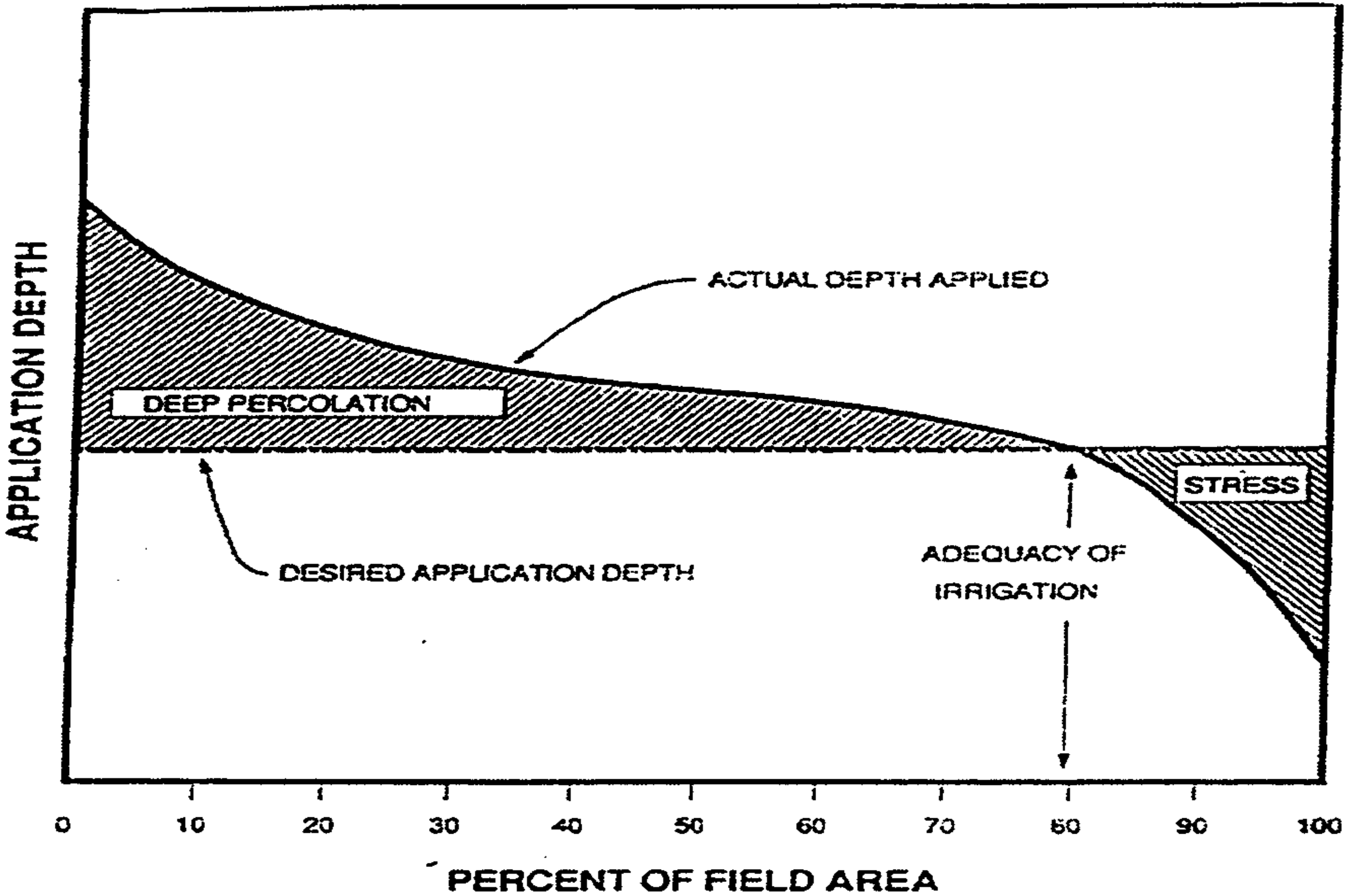
Efficiencies and Uniformities

- Application efficiency (E_a)

$$E_a = \frac{d_n}{d_g}$$

  - d_n = net irrigation depth
  - d_g = gross irrigation depth
  - fraction or percentage
- Water losses
  - Evaporation
  - Drift
  - Runoff
  - Deep percolation

Water Losses



Adequacy

- Because of nonuniformity, there is a tradeoff between excessive deep percolation and plant water stress
- Adequacy: the percent of the irrigated area that receives the desired depth of water or more
- Figure 5.3
  - Plotting the percentage of area in the field that receives a given depth of irrigation water or more gives a distribution uniformity curve
  - Irrigating for a longer or shorter time moves the curve up or down
  - System modifications may be required to change the shape of the curve

Figure 5.3a

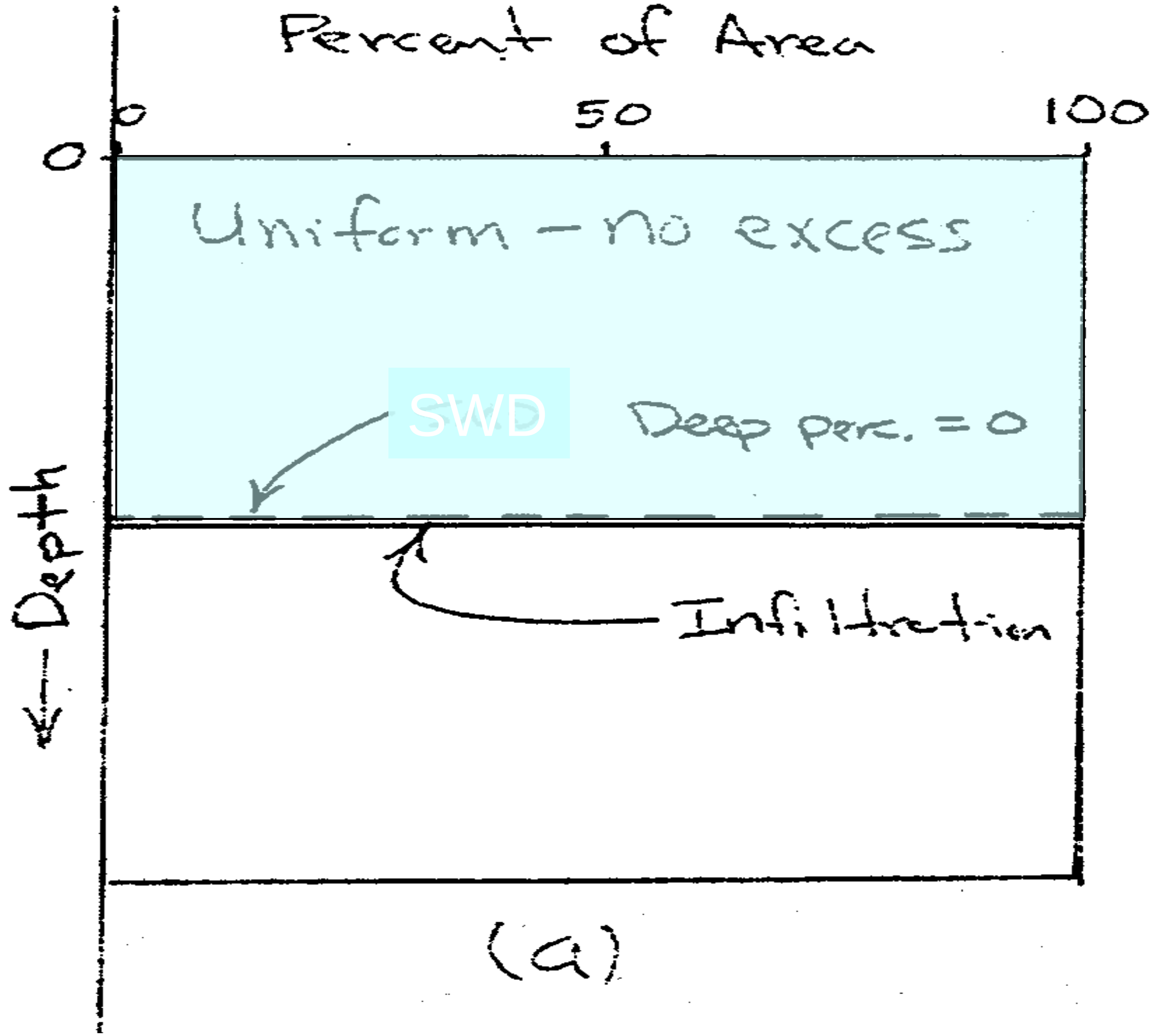
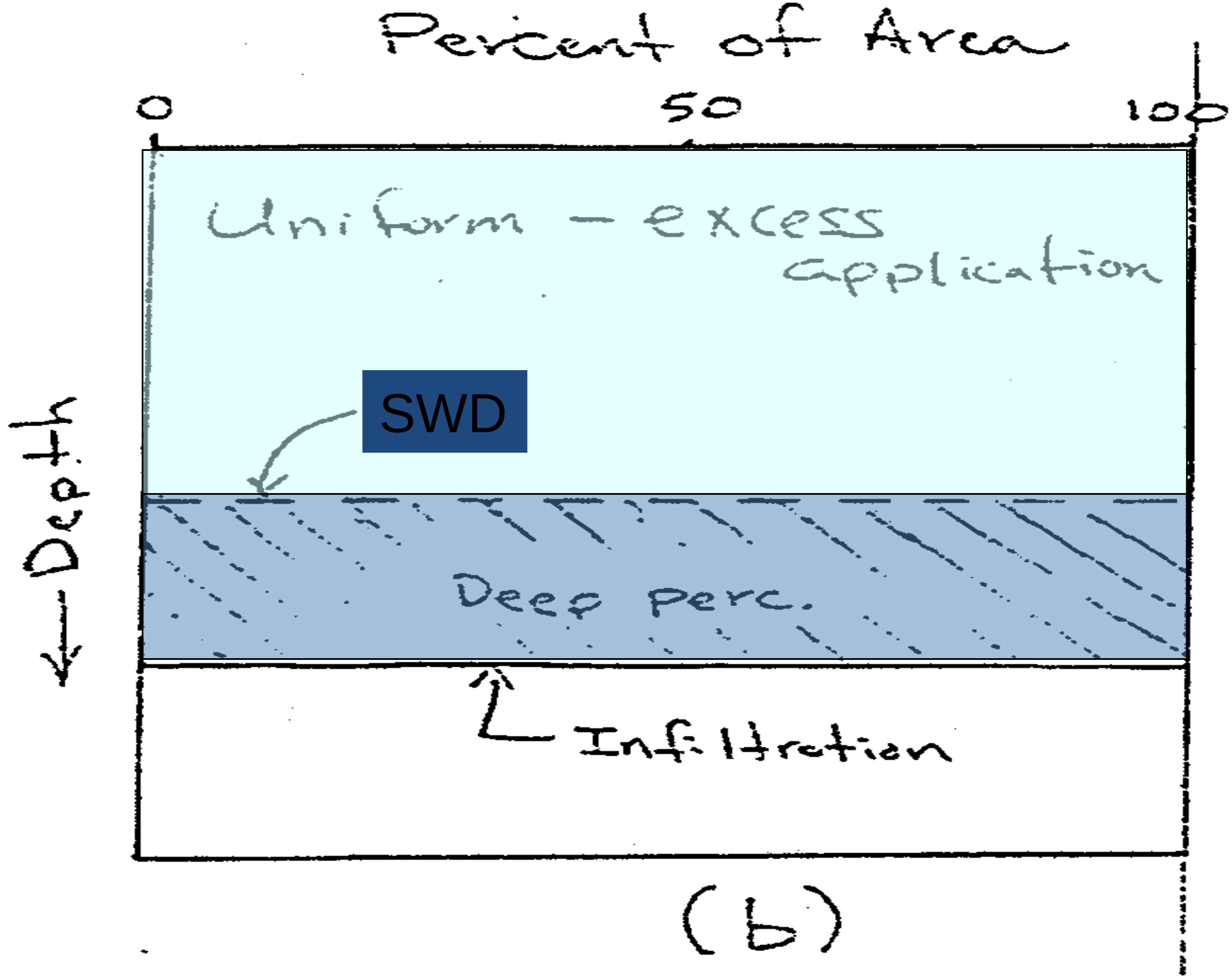
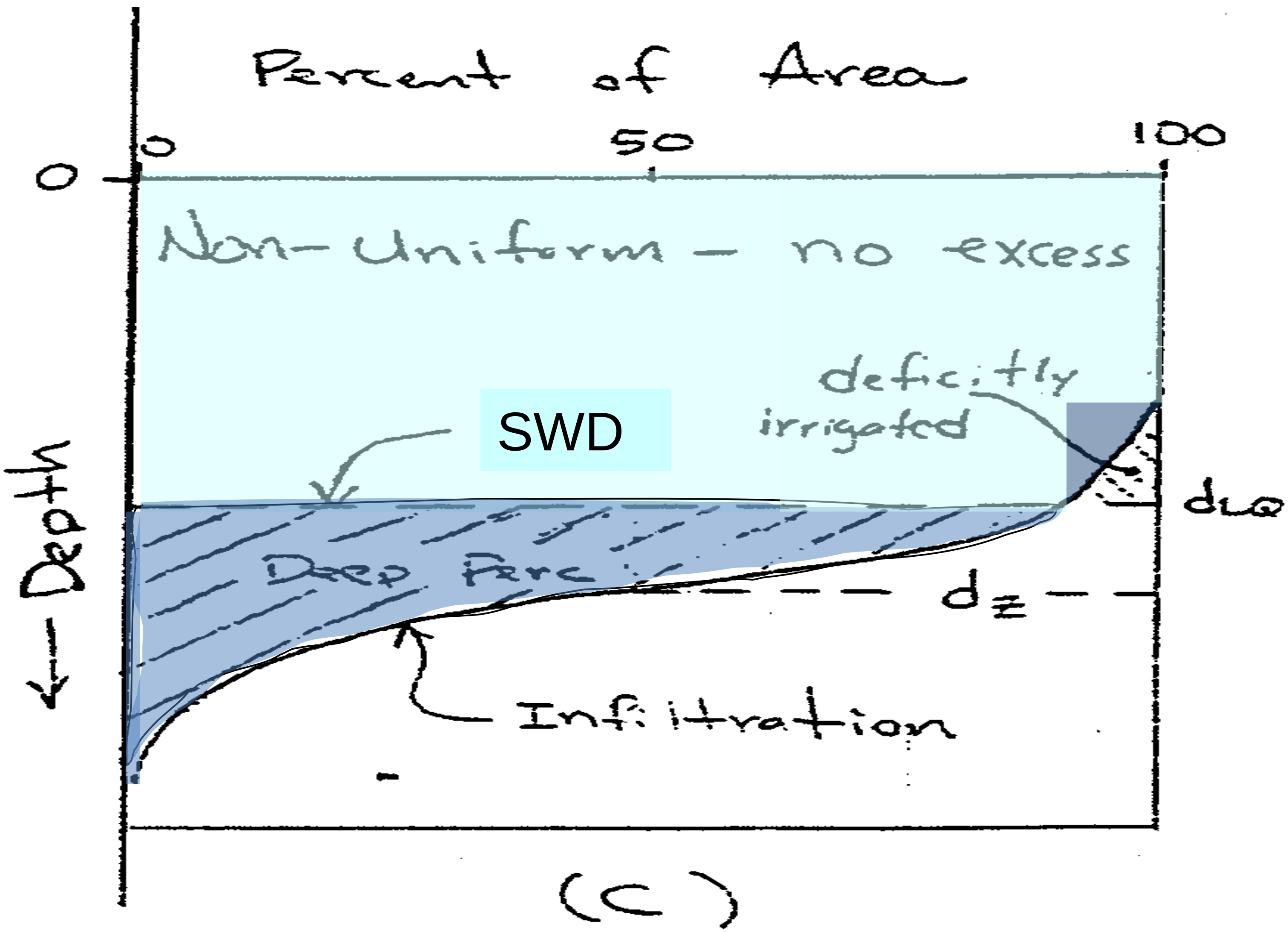

Percent of Area
0
50
100
0
Uniform - no excess
SWD
Deep perc. = 0
Infiltration
← Depth
(a)

Fig 5.3b



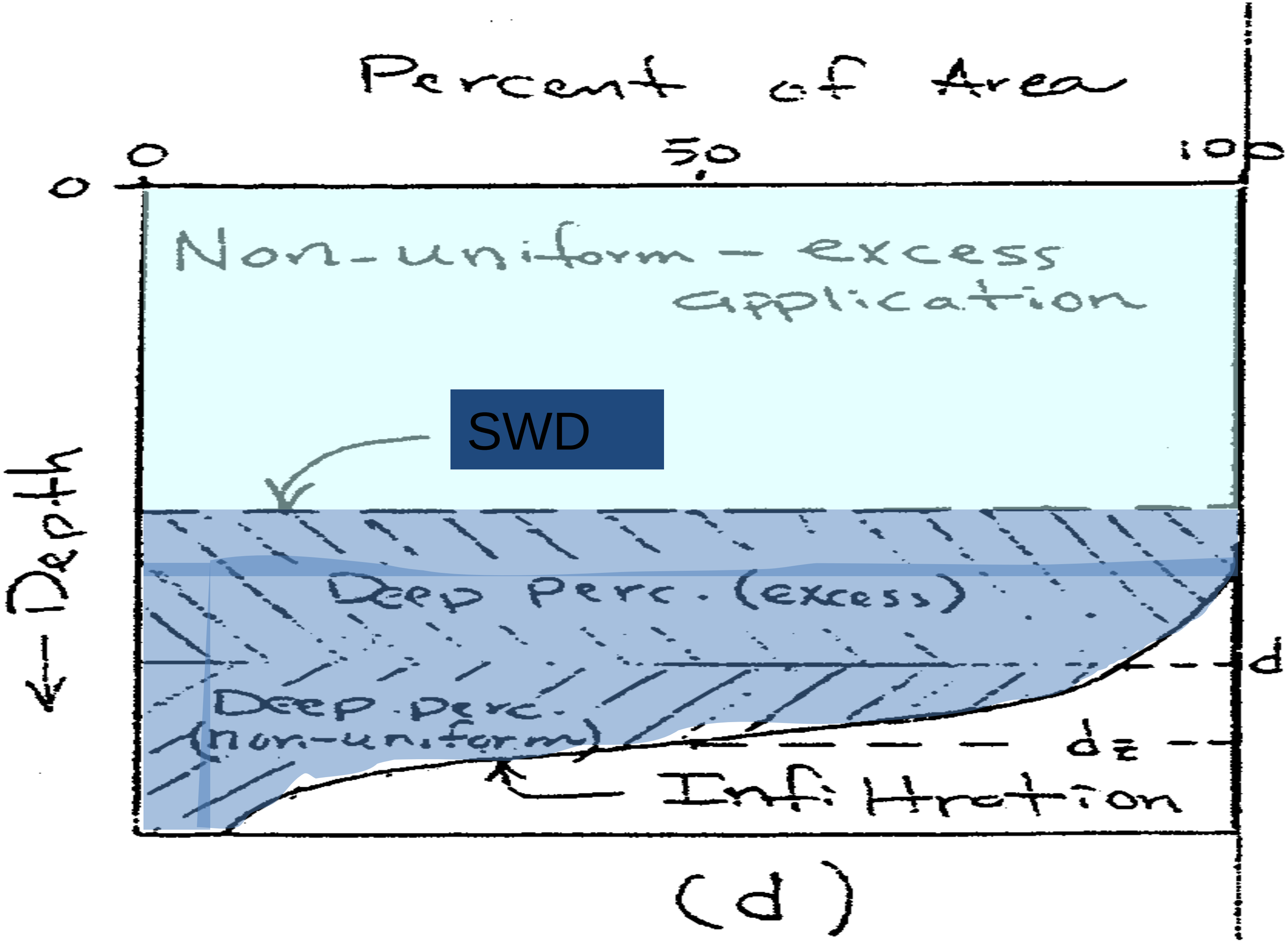
Percent of Area
0
50
100
Uniform – excess application
SWD
Deep perc.
Infiltration
Depth
(b)

Figure 5.3c



Percent of Area
0
50
100
0
Non-Uniform – no excess
deficitly irrigated
SWD
Depth
Deep Perc
dz
Infiltration
(c)

Figure 5.3d



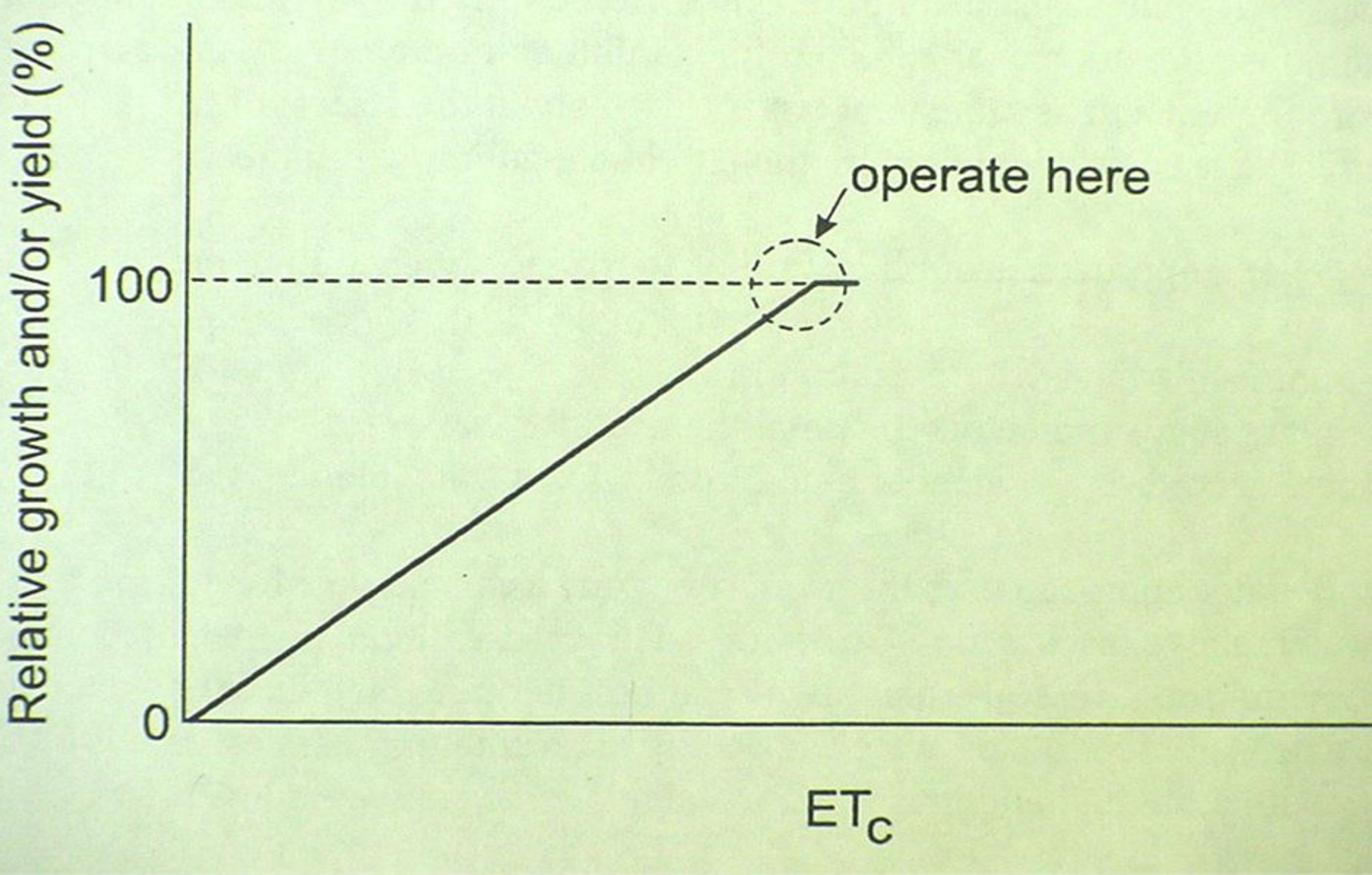
Percent of Area
0
50
100
0
Depth
Non-uniform - excess application
SWD
Deep Perc. (excess)
Deep Perc. (non-uniform)
d
dz
Infiltration
(d)

Irrigation Scheduling

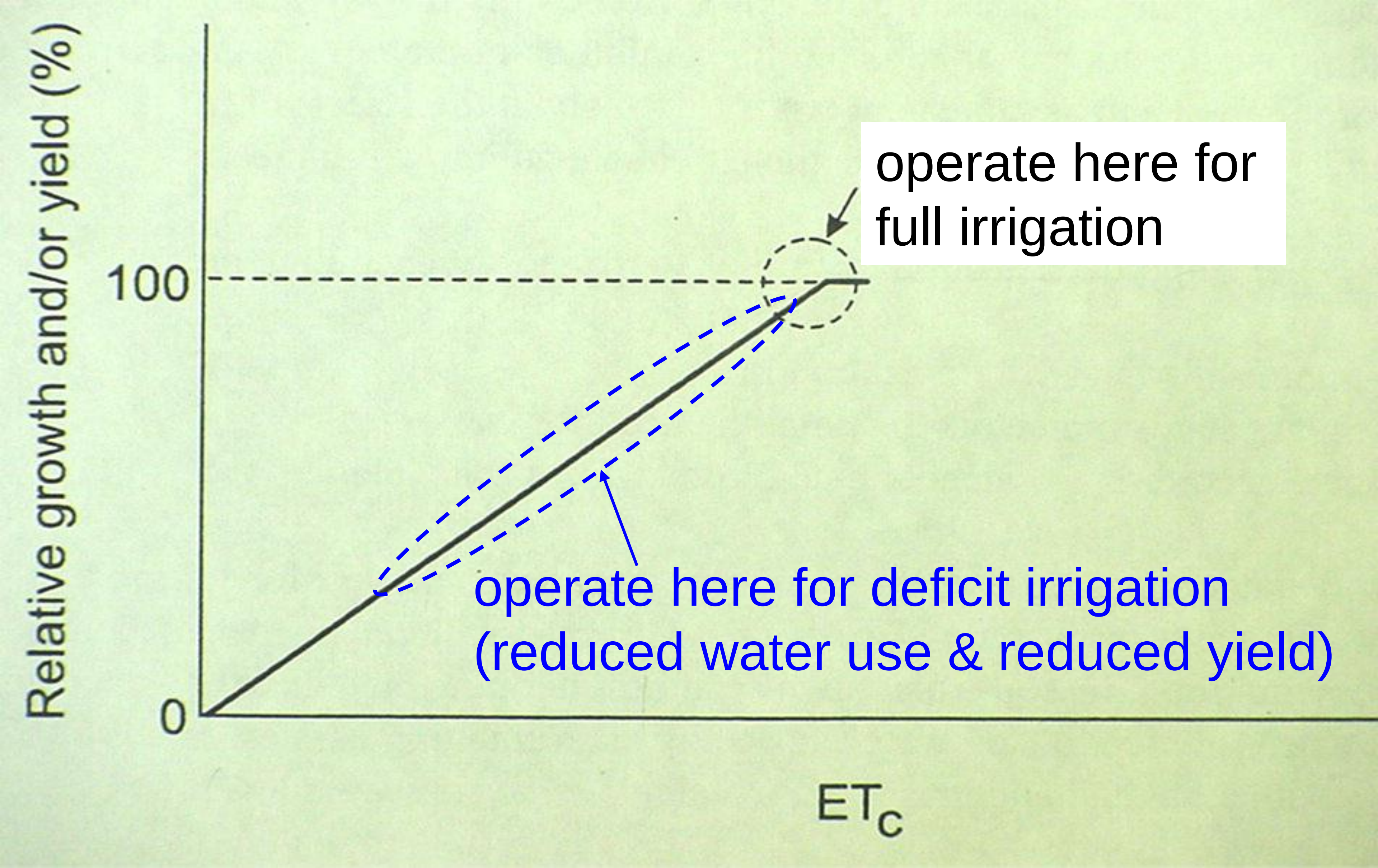
General Approaches

- Maintain soil moisture within desired limits
  - direct measurement
  - moisture accounting
- Use plant status indicators to trigger irrigation
  - wilting, leaf rolling, leaf color
  - canopy-air temperature difference
- Irrigate according to calendar or fixed schedule
  - Irrigation district delivery schedule
  - Watching the neighbors

Yield/Appearance vs. ET_c

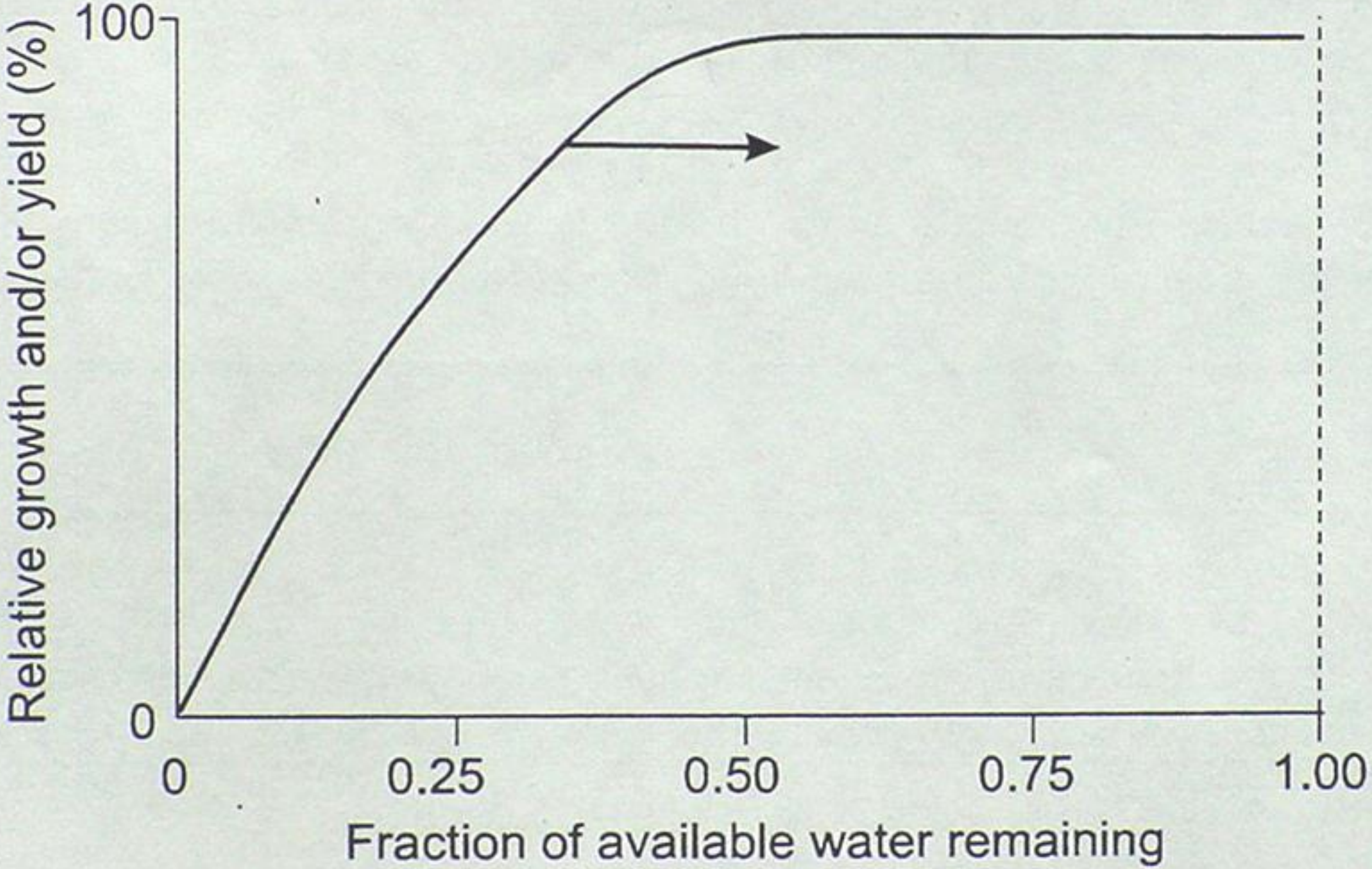


Deficit Irrigation



Growth/Yield vs. fr

(Figure 6.2)



Possible Irrigation Scheduling Management Objectives

- Maximum yield/biomass production
- Maximum economic return
- Functional value of plants (e.g., athletic fields)
- Aesthetic value of plants (e.g., landscapes)
- Keeping plants alive

Plant Root Zones

- Depth used for scheduling vs. maximum depth where roots are found
- Influenced by soil characteristics
  - Soil texture
  - Hardpan
  - Bedrock
- Perennial vs. annual plants

Table 6.2. Range of maximum effective rooting depths for fully grown plants.

Crop	Maximum Effective Depth, ft	Crop	Maximum Effective Depth, ft
Alfalfa	3.0 - 10	Onions	2.6 - 6.6
Banana	1.3 - 2.6	Other small grains	3.3 - 5.0
Barley	3.3 - 4.3	Palm trees	2.3 - 3.6
Beans	1.3 - 2.6	Peas	2.0 - 3.3
Cabbage	2.0 - 3.3	Peppers	1.7 - 3.3
Carrots	1.6 - 3.3	Pineapple	1.0 - 2.0
Celery	1.0 - 1.7	Potatoes	1.3 - 2.6
Citrus	3.3 - 5.9	Safflower	3.3 - 6.6
Clover	2.0 - 3.0	Sisal	1.7 - 3.3
Cotton	3.3 - 6.6	Sorghum	3.3 - 6.6
Cucumber	2.3 - 4.0	Soybeans	2.6 - 5.0
Dates	5.0 - 8.3	Spinach	1.0 - 1.7
December orchards	3.3 - 9.9	Strawberries	0.7 - 1.0
Flax	3.3 - 5.0	Sugarbeet	2.6 - 6.6
Grapes	3.3 - 6.6	Sugarcane	4.0 - 6.6
Grass	1.7 - 5.0	Sunflower	3.3 - 8.3
Groundnuts	1.7 - 3.3	Sweetpotatoes	3.3 - 5.0
Lettuce	1.0 - 1.7	Tobacco	1.7 - 3.3
Maize	3.3 - 6.6	Tomatoes	2.3 - 5.0
Melons	3.3 - 5.0	Vegetables	1.0 - 2.0
Olives	2.6 - 6.6	Wheat	3.3 - 6.6

Modified from Doorenbos and Pruitt (1977).

Turf & Shrub Rooting Depths

Table 6.3. Effective root depths for turfgrass and shrubs.

Turfgrass	0.5 - 2.0 foot
Shrubs	2.0 foot

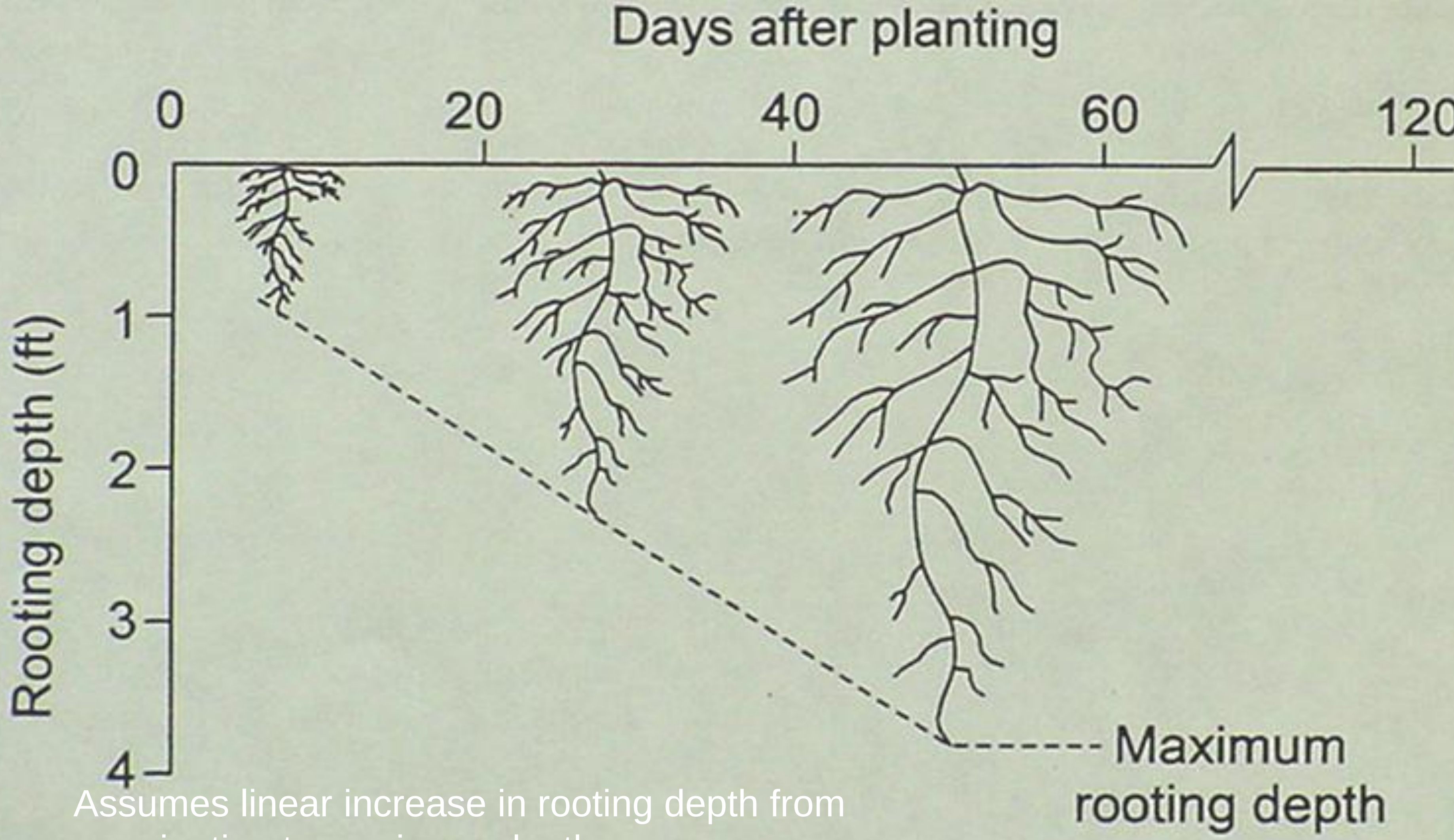
Turfgrass Root Depth

Potential Rooting Depth for Turfgrass Species

(Dr. L. Wu, U. C. Davis, 1985)

Shallow (1-8 inches)	Medium (8-18 inches	Deep (18-60 inches)
Poa annua	Kentucky bluegrass	Zoysiagrass
Creeping bentgrass	Red fescue	Bermudagrass
Colonial bentgrass	Ryegrass	Tall fescue
	St. Augustinegrass	

Root Development of Annual Plants



Assumes linear increase in rooting depth from germination to maximum depth

Figure 6.3. Development of a corn plant's root zone.

Example 6.2

Determine the root zone depth for corn at early tassel assuming that depth at germination is 6 inches, maximum rooting depth is 4 feet, full depth occurs 90 days after germination, and early tassel occurs 50 days after germination.

<u>Given:</u>

D_{ag} = 50 days,
D_{tm} = 90 days,
R_{dmin} = 0.5 feet, and
R_{dmax} = 4.0 feet.

<u>Find:</u> R_d at early tassel.

Use Equations 6.6 and 6.7

$$R_f = \frac{50\ days}{90\ days} = 0.56$$

R_d = 0.5 ft + (4.0 ft - 0.5 ft) 0.56 = 2.5 feet

4-3-2-1 Rule-of-Thumb

- Divide the crop root depth into quarters
- Upper ¼ provides 40% of water uptake
- 2nd ¼ provides 30% of water uptake
- 3rd ¼ provides 20% of water uptake
- Lowest ¼ provides only 10% of water uptake
- Applies only when most of root zone irrigated to field capacity
- Dictated by distribution of root mass

Maximum vs. Effective Rooting Depth

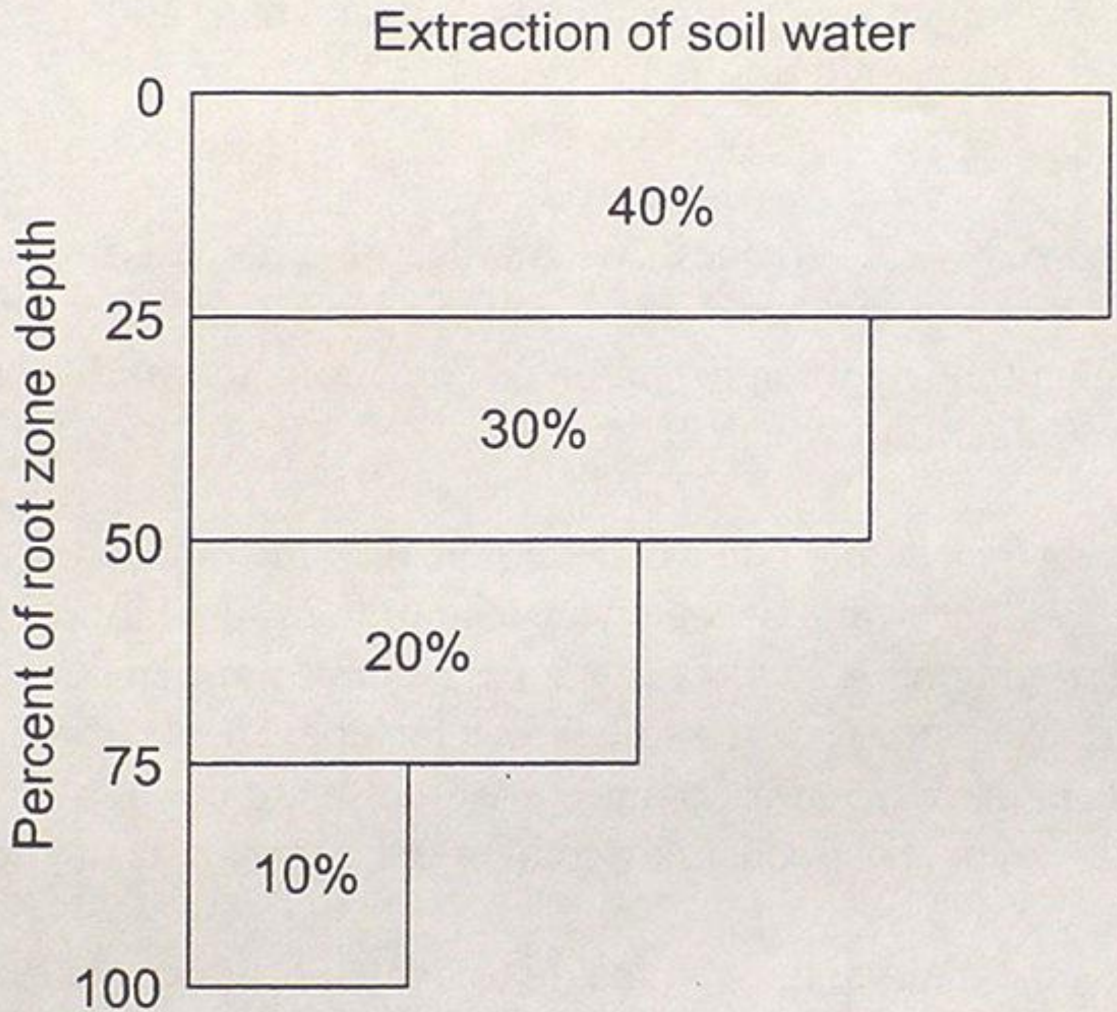


Figure 6.4. Average moisture extraction from the plant root zone, the 4-3-2-1 rule.

Irrigation Timing

- Maximum irrigation interval, (days)

$$T_{max} = \frac{AD}{ET_c}$$

AD=Allowed Deficient

- Actual irrigation interval, (days)

$$T = \frac{d_e}{ET_c}$$

d_e = effective depth of irrigation, (in. or mm)

Latest Date

$$LD = \frac{AD - SWD}{ET_c(\,forecast\,)}$$

- LD = maximum number of days before irrigation should occur
- AD=Allowable Deficient
- SWD=Soil Water Deficient
- ET_c(forecast) can be based on long-term averages or last few days

Latest Date

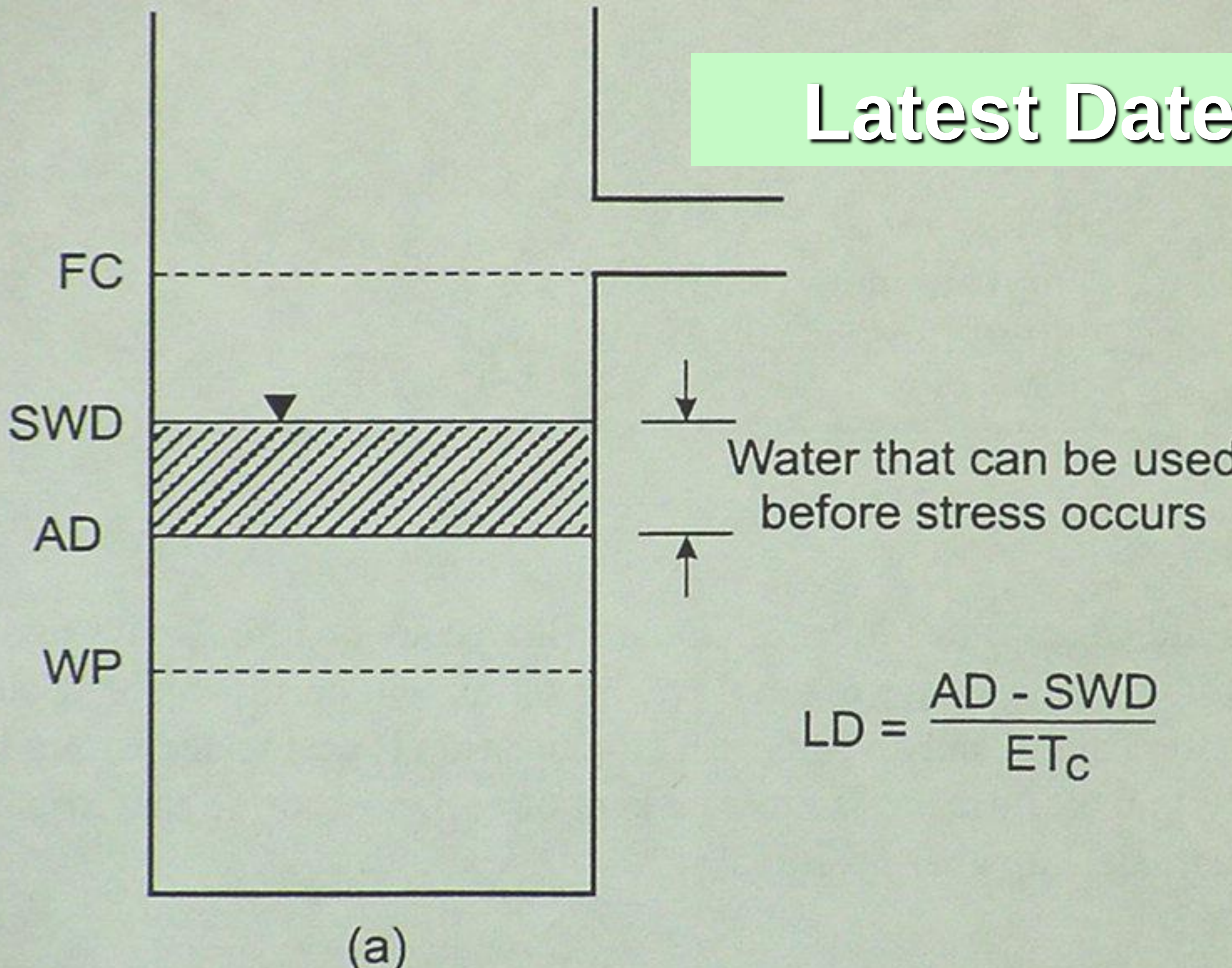


Figure 6.5. Illustration of LD concept.

Earliest Date

$$ED = \frac{r_a + d_{ep} - SWD}{ET_c(forecast)}$$

- ED = minimum number of days before irrigation should occur
- d_{ep} = planned effective depth of water
- r_a = rainfall allowance (allow room in the profile beyond d_{ep})

Earliest Date

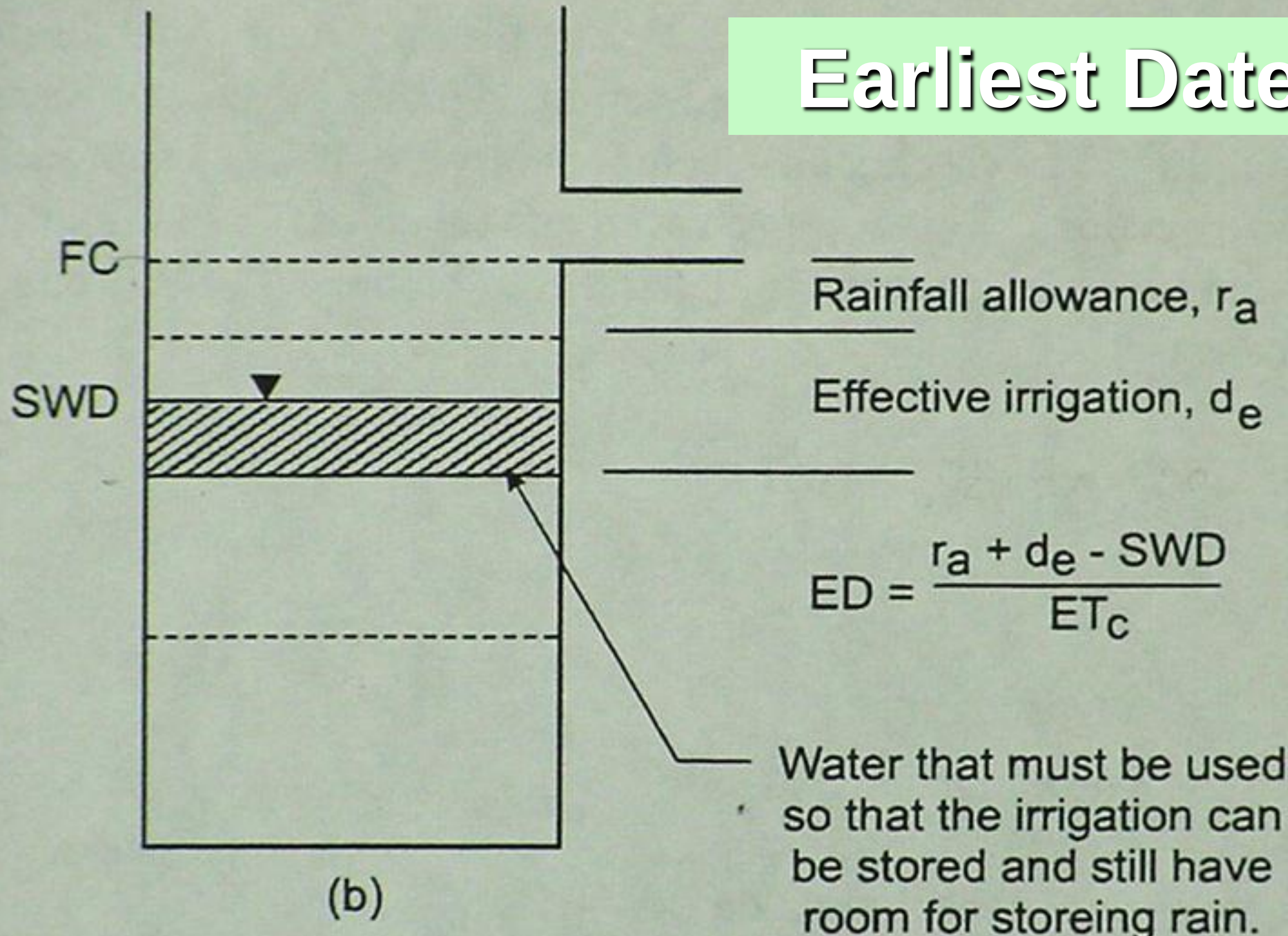
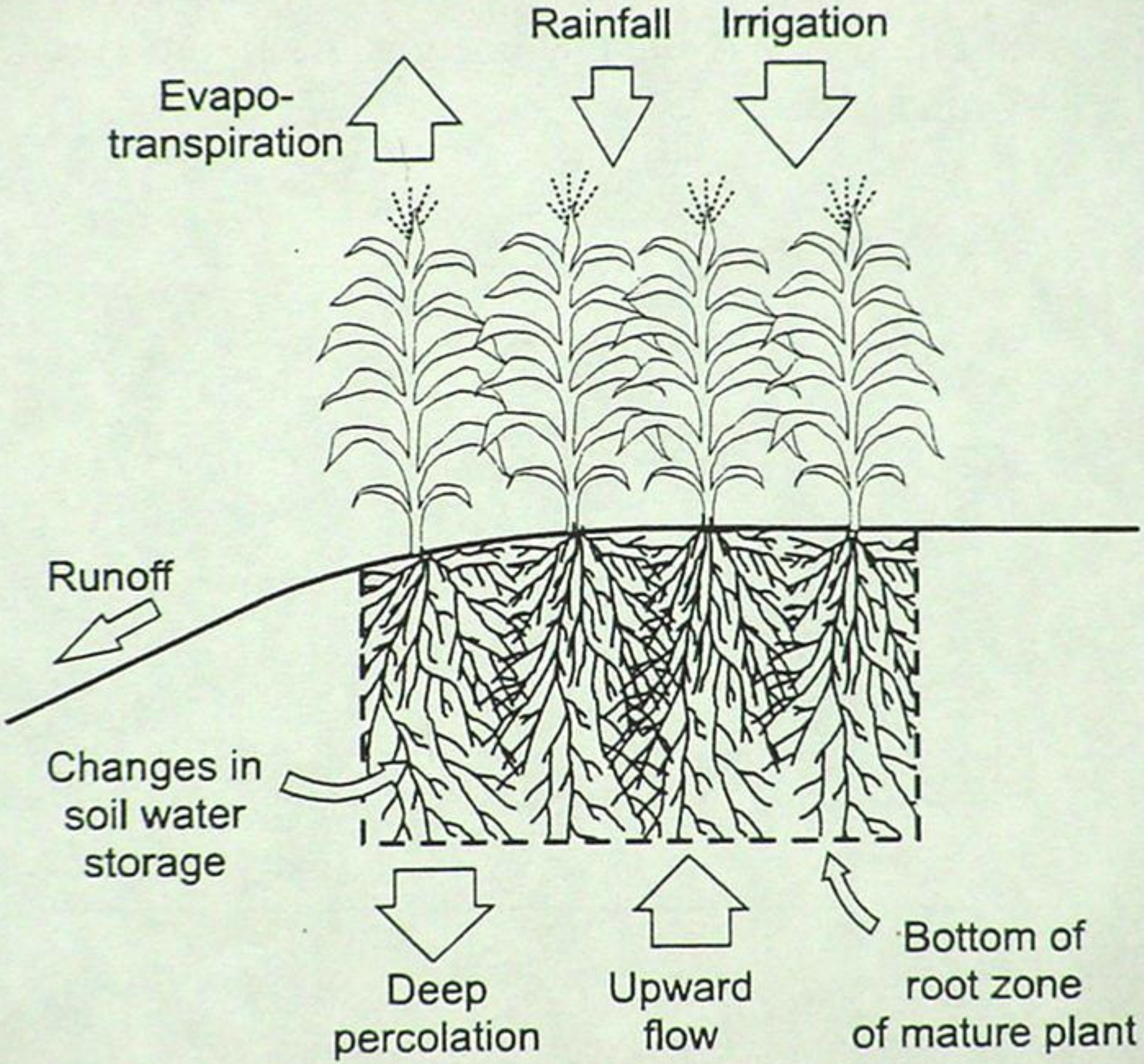


Figure 6.7. Illustration of ED concept.

Components of Crop Root Zone Water Balance



Soil Water Budget Calculations

$$SWD_i = SWD_{i-1} + ET_{c\ i-1} - d_{e\ i-1} - P_{e\ i-1} - U_{f\ i-1}$$

Subscripts: i = today i-1 = yesterday

(all quantities below in consistent depth units: inches, mm, etc.)

SWD= soil water deficit

ET_c = crop evapotranspiration

d_e = effective irrigation

P_e = effective precipitation

U_f = upward flow of water from a shallow water table

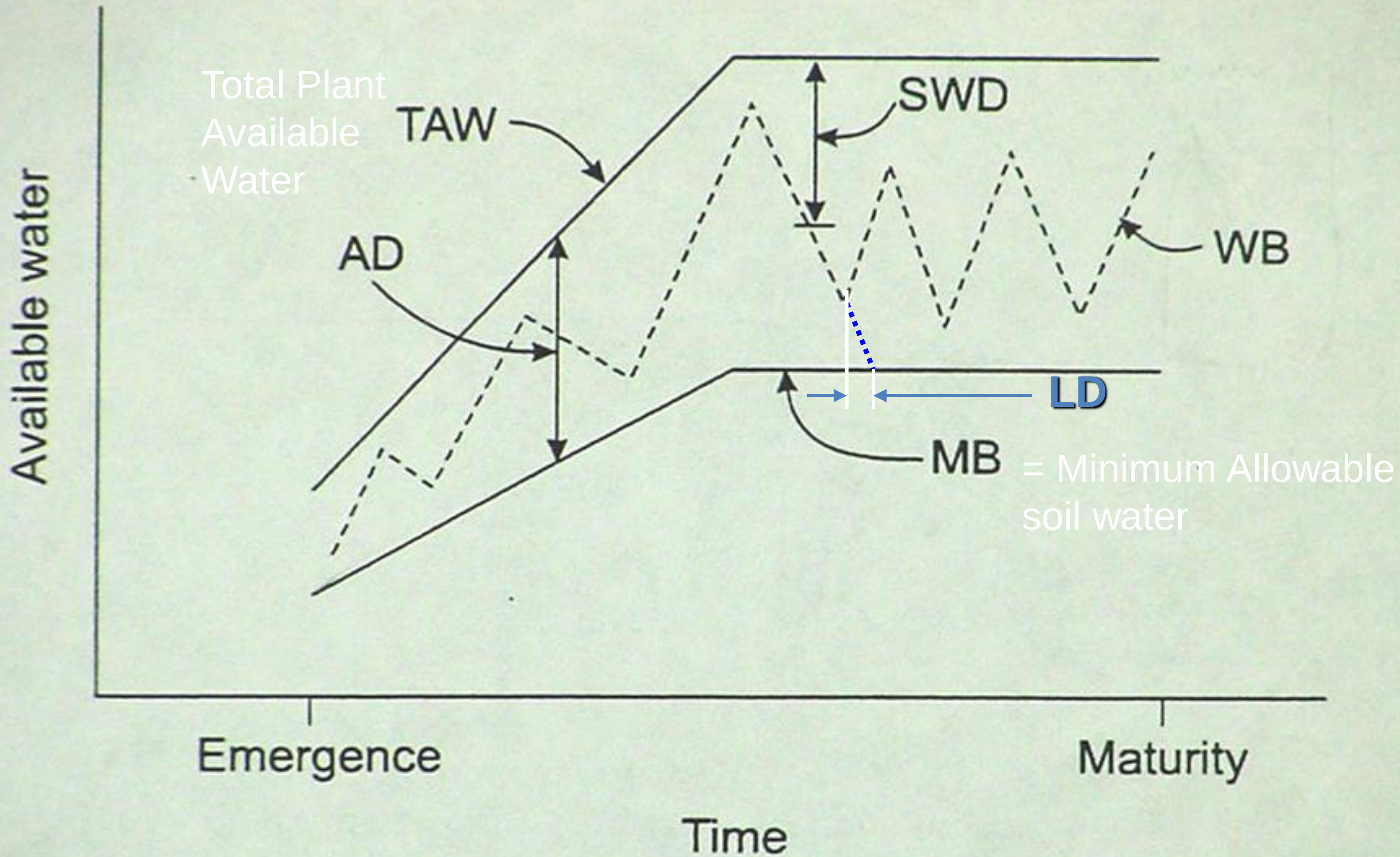


Figure 6.8. Illustration of key irrigation scheduling terms and their changes with time for annual crops.

Other Irrigation Scheduling Methods

- Soil Water Measurement
  - Determine SWD by measuring:
    - feel and appearance of soil
    - θ_m (gravimetric sampling)
    - θ_v (neutron scattering)
    - ψ_p (potential: w/ tensiometers or resistance blocks (must convert ψ_p to water content)
  - Need measurements at several locations
  - Need measurements throughout root zone depth
  - Difficult to predict Latest Date
  - Doesn't indicate how much water to apply

Other Irrigation Scheduling Methods

- Plant Status Indicators
  - Leaf water potential (energy status of leaf water)
    - Use pressure chamber or thermocouple psychrometer
    - Measured at mid-day; many samples needed
  - Foliage/Air temperature difference
    - Well-watered plants cooler than air
    - Use infrared thermometer
  - Leaf appearance
    - Color, wilting, etc.
    - Indicators show up too late
  - Irrigate at critical growth stages (e.g.: flowering)

Mesonet Irrigation Scheduler

- http://agweather.mesonet.org/index.php/data/section/crop

Soil Water Measurement

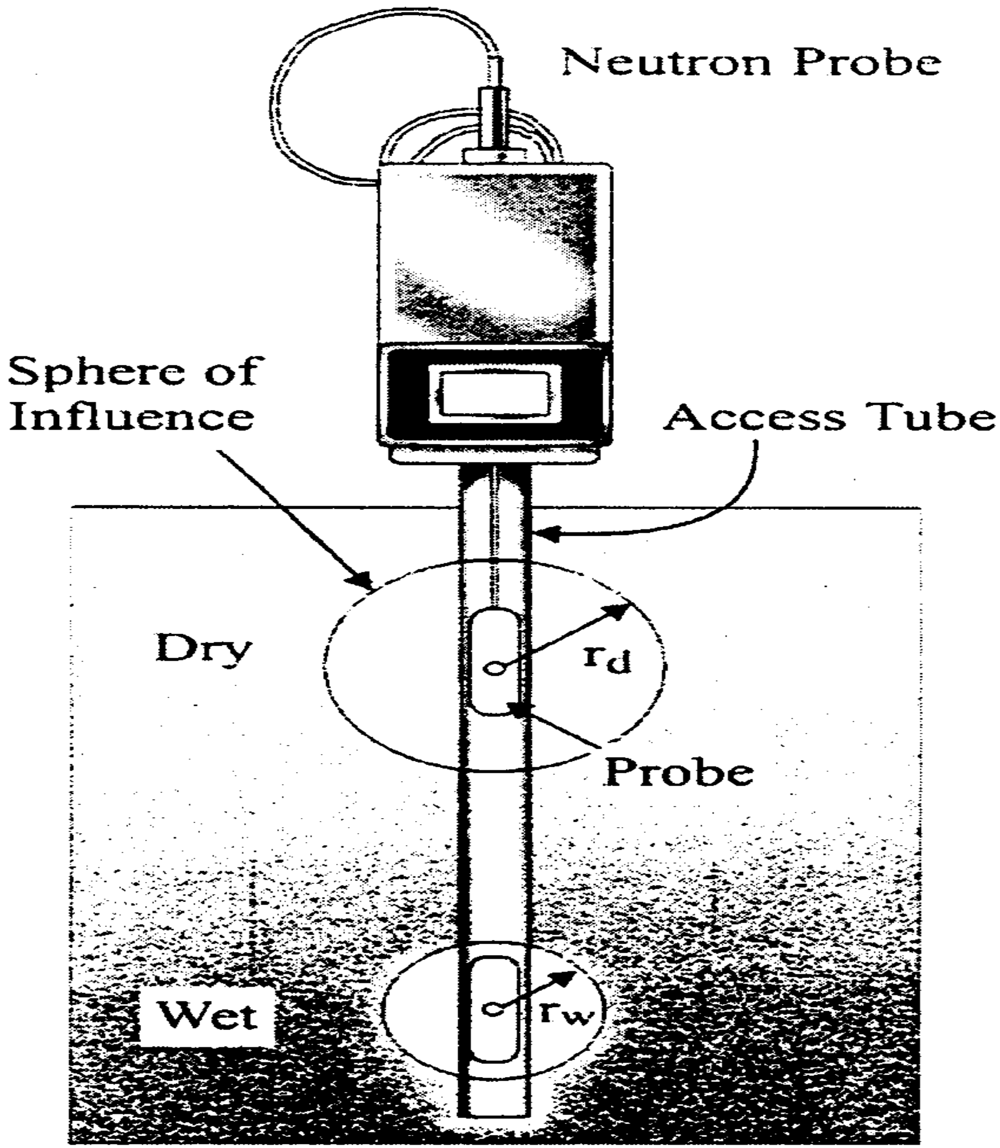
- Gravimetric
  - Measures mass water content (θ_m)
  - Take field samples $\rightarrow$ weigh $\rightarrow$ oven dry $\rightarrow$ weigh
  - Advantages: accurate; Multiple locations
  - Disadvantages: labor; Time delay

- Feel and appearance
  - Take field samples and feel them by hand
  - Advantages: low cost; Multiple locations
  - Disadvantages: experience required; Not highly accurate

Soil Water Measurement

- Neutron scattering (attenuation)
  - Measures volumetric water content (θ_v)
  - Attenuation of high-energy neutrons by hydrogen nucleus
  - Advantages:
    - samples a relatively large soil sphere
    - repeatedly sample same site and several depths
    - accurate
  - Disadvantages:
    - high cost instrument
    - radioactive licensing and safety
    - not reliable for shallow measurements near the soil surface
- Dielectric constant
  - A soil's dielectric constant is dependent on soil moisture
  - Time domain reflectometry (TDR)
  - Frequency domain reflectometry (FDR)
  - Primarily used for research purposes at this time

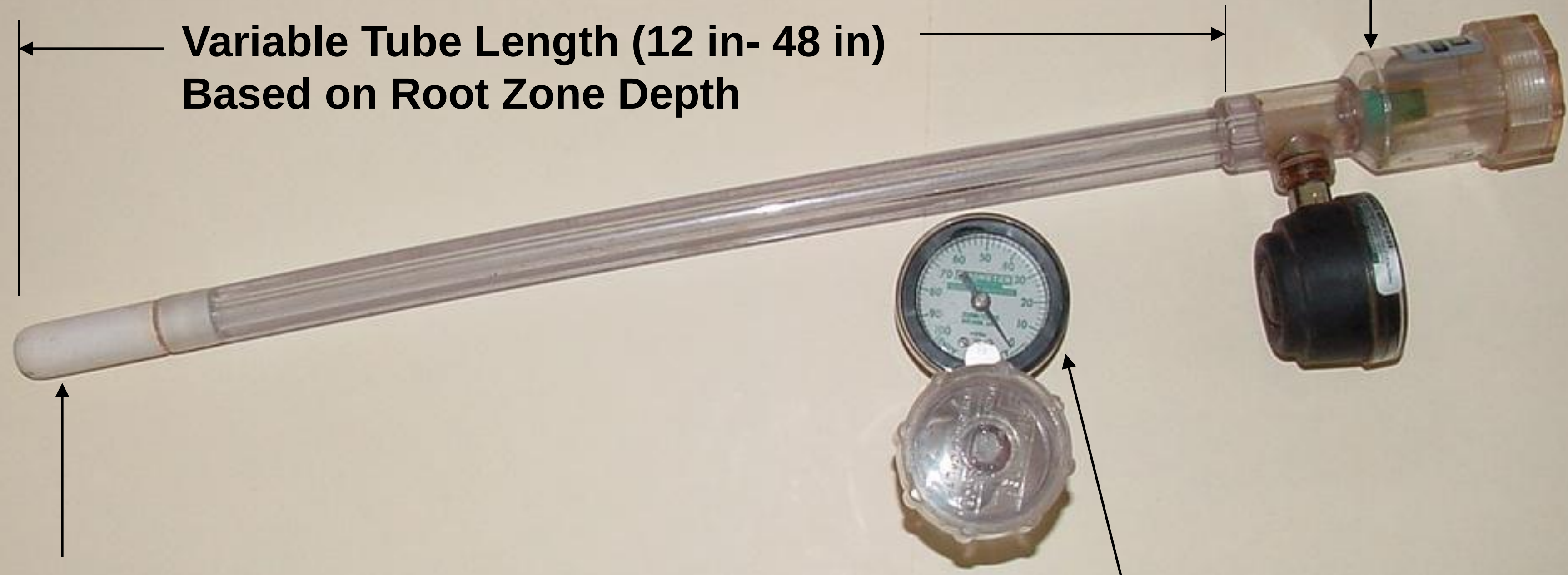
Soil Water Measurement
Neutron Attenuation



Soil Water Measurement

- Tensiometers
  - Measure soil water potential (tension)
  - Practical operating range is about 0 to 0.75 bar of tension (this can be a limitation on medium- and fine-textured soils)
- Electrical resistance blocks
  - Measure soil water potential (tension)
  - Tend to work better at higher tensions (lower water contents)
- Thermal dissipation blocks
  - Measure soil water potential (tension)
  - Require individual calibration

Tensiometer for Measuring Soil Water Potential



Electrical Resistance Blocks & Meters