نظم الري والبزل

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دكتوراه (أدارة تربة ومياه) كلية الزراعة – جامعة البصرة 2022م

ماجستير هندسة الري والصرف الحقلي –كلية الزراعة –جامعة عين شمس 2015 م

المحاضرة الثالثة

علاقة الماء بالتربة
والنبات

Soil Water Relationships
علاقة التربة والمياه

Soil Properties

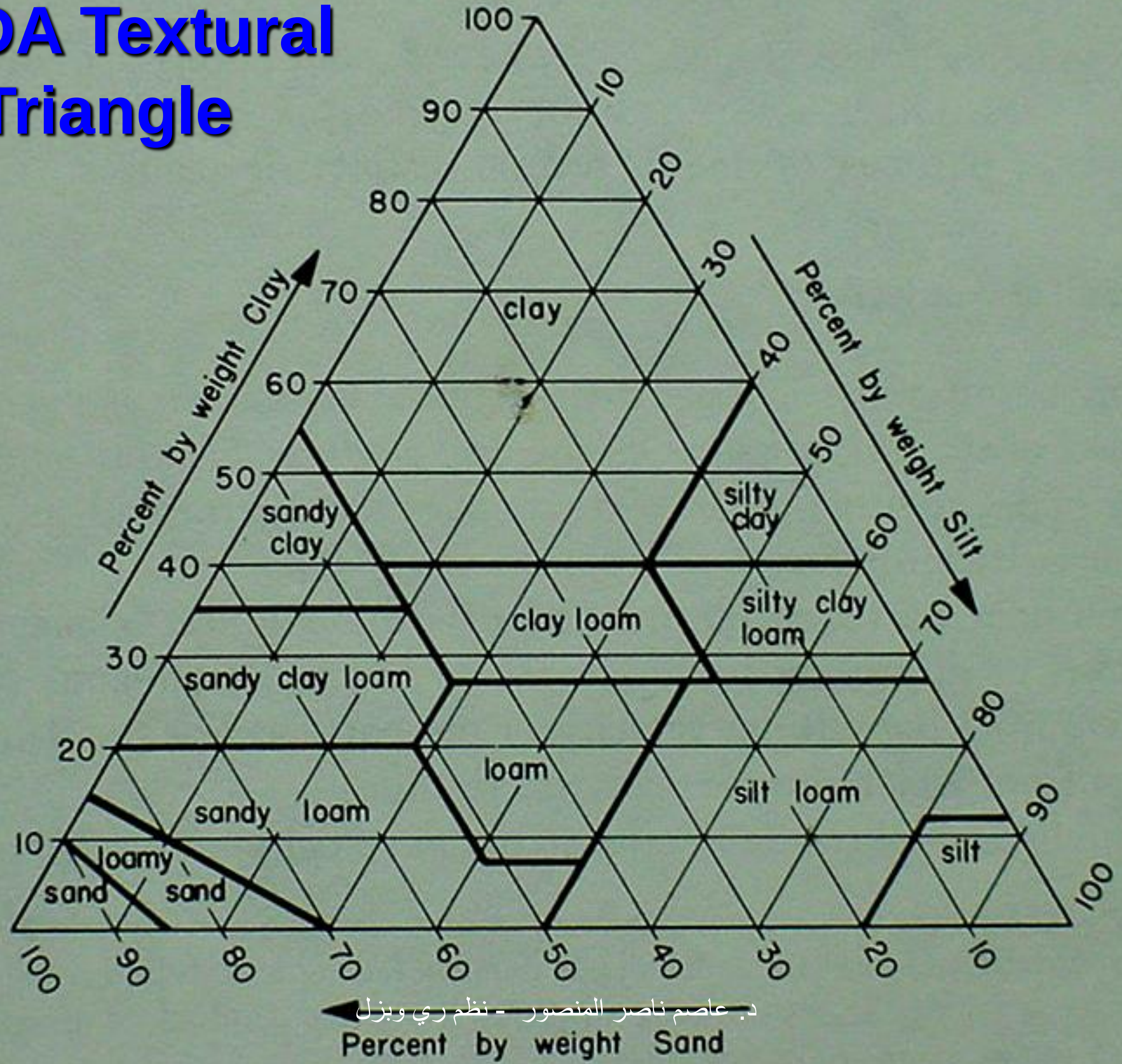
- Texture
  - Definition: relative proportions of various sizes of individual soil particles
  - USDA classifications
    - Sand: 0.05 – 2.0 mm
    - Silt: 0.002 - 0.05 mm
    - Clay: <0.002 mm
  - Textural triangle: USDA Textural Classes
  - Coarse vs. Fine, Light vs. Heavy
  - Affects water movement and storage

النسجه
التعريف: االتوزيع النسبي لأحجام مختلفة من جزيئات التربة الفردية
تصنيفات وزارة الزراعة الأمريكية
الرمل: 0.05 – 2.0 مم
الطمي: 0.002 – 0.05 مم
الطين: <0.002 مم
مثلث النسجه: فئات الملمس لوزارة الزراعة الأمريكية
الخشن مقابل الناعم، الخفيف مقابل الثقيل
يؤثر على حركة المياه وتخزينها

- Structure
  - Definition: how soil particles are grouped or arranged
  - Affects root penetration and water intake and movement

بناء الترب
التعريف: كيفية تجميع جزيئات التربة أو ترتيبها
يؤثر على اختراق الجذور وامتصاص المياه وحركتها

USDA Textural Triangle



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- Bulk Density (ρ_b)

$$\rho_b = \frac{M_s}{V_b}$$

  - ρ_b = soil bulk density, g/cm^3
  - M_s = mass of dry soil, g
  - V_b = volume of soil sample, cm^3
- Typical values: 1.1 - 1.6 g/cm^3

- Particle Density (ρ_p)

$$\rho_p = \frac{M_s}{V_s}$$

  - ρ_P = soil particle density, g/cm^3
  - M_s = mass of dry soil, g
  - V_s = volume of solids, cm^3
- Typical values: 2.6 - 2.7 g/cm^3

- Porosity (ϕ)

$$\phi = \frac{\text{volume of pores}}{\text{volume of soil}}$$

$$\phi = \left(1 - \frac{\rho_b}{\rho_p}\right) 100\%$$

- Typical values: 30 - 60%

Water in Soils

- Soil water content

$$\theta_m = \frac{M_w}{M_s}$$

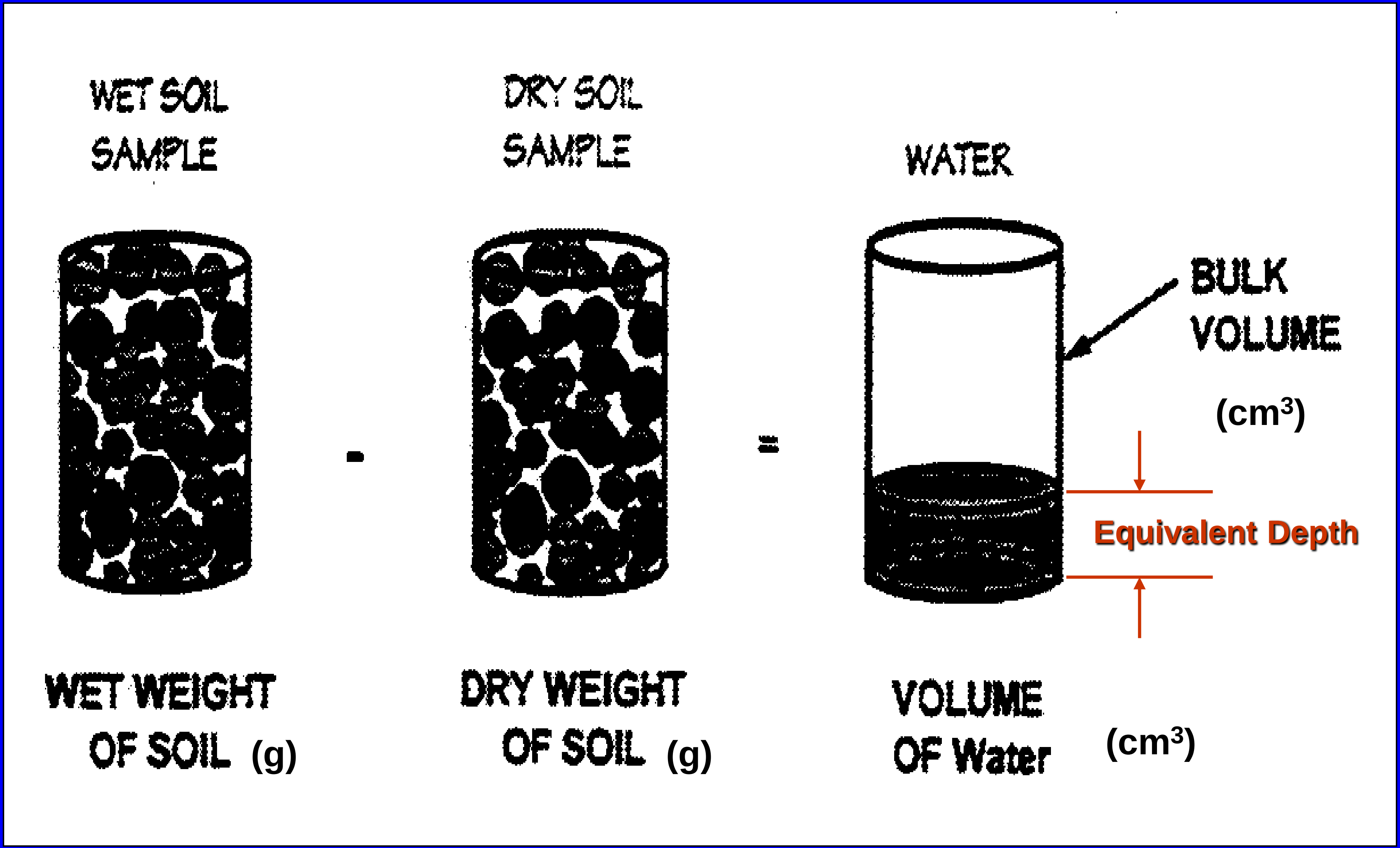
  - Mass water content (θ_m)
  - θ_m = mass water content (fraction)
  - M_w = mass of water evaporated, g ($\geq$24 hours @ 105^{o}C)
  - M_s = mass of dry soil, g

- Volumetric water content (θ_v)

$$\theta_v = \frac{V_w}{V_b}$$

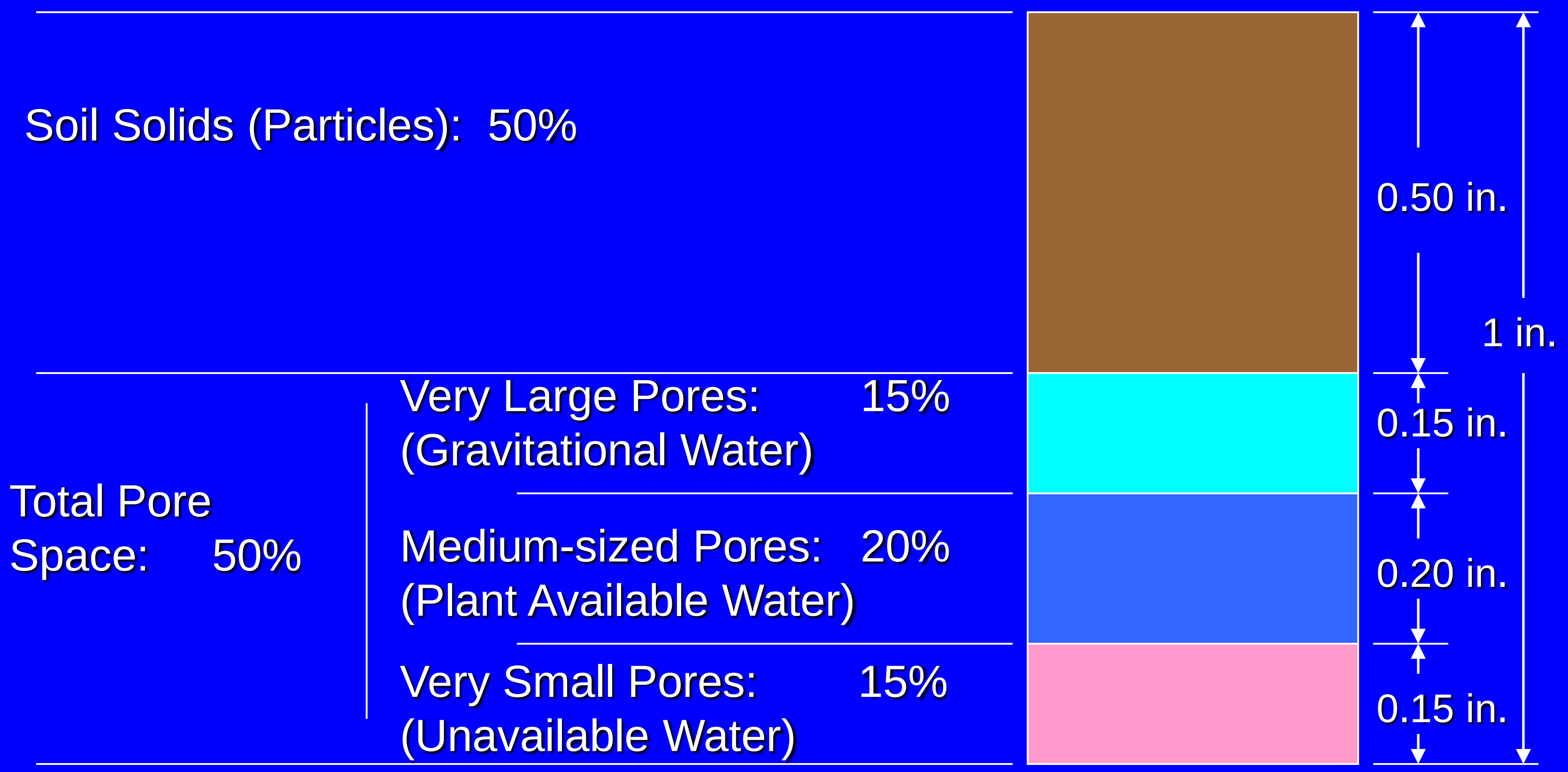
  - θ_v = volumetric water content (fraction)
  - V_w = volume of water
  - V_b = volume of soil sample
  - At saturation, $\theta_v = \phi$
  - θ_v = As θ_m
  - As = apparent soil specific gravity = ρ_b/ρ_w (ρ_w = density of water = 1 g/cm^3)
  - As = ρ_b numerically when units of g/cm^3 are used
- Equivalent depth of water (d)
  - d = volume of water per unit land area = (θ_v A L) / A = θ_v L
  - d = equivalent depth of water in a soil layer
  - L = depth (thickness) of the soil layer

Volumetric Water Content & Equivalent Depth



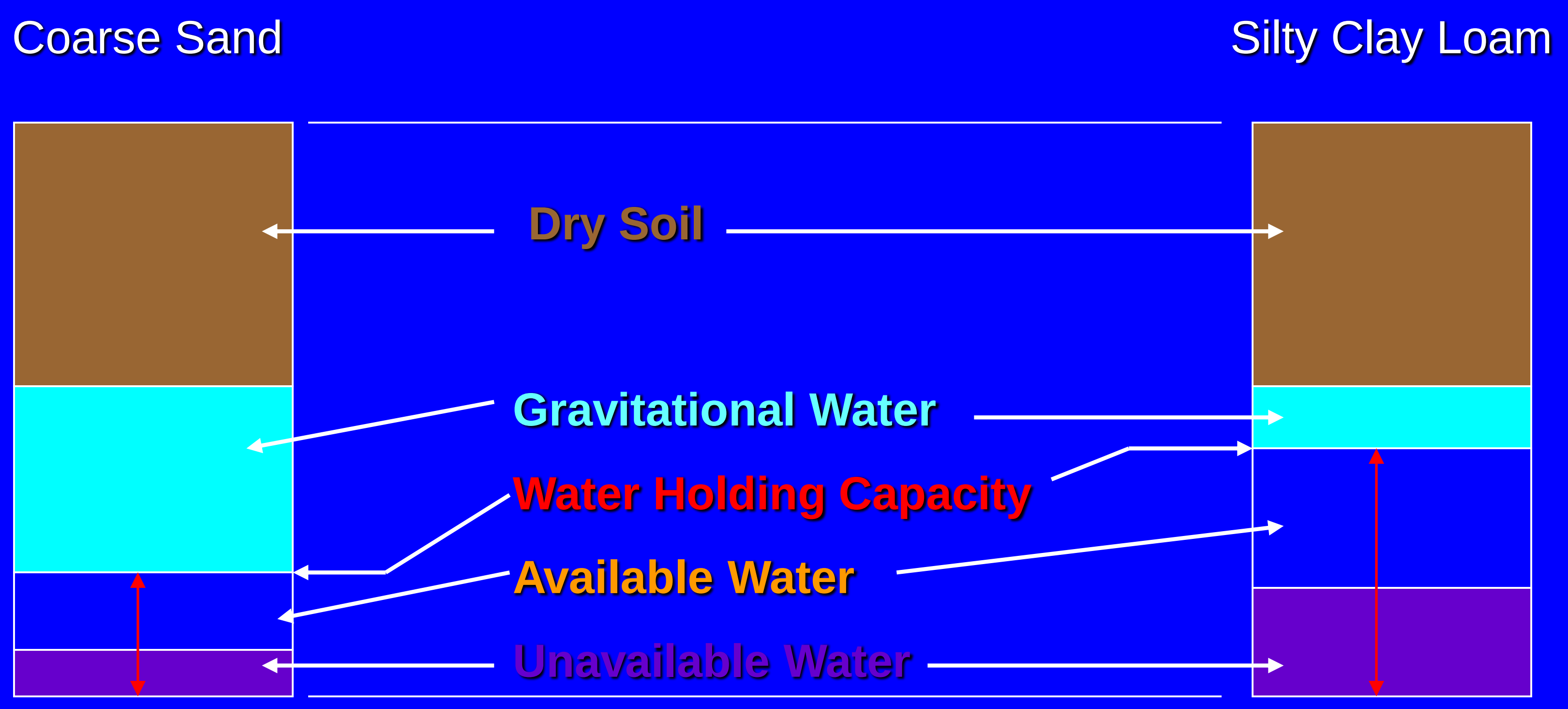
Volumetric Water Content & Equivalent Depth

Typical Values for Agricultural Soils



Water-Holding Capacity of Soil

Effect of Soil Texture



Soil Water Potential

- Description
  - Measure of the energy status of the soil water
  - Important because it reflects how hard plants must work to extract water
  - Units of measure are normally bars or atmospheres
  - Soil water potentials are negative pressures (tension or suction)
  - Water flows from a higher (less negative) potential to a lower (more negative) potential

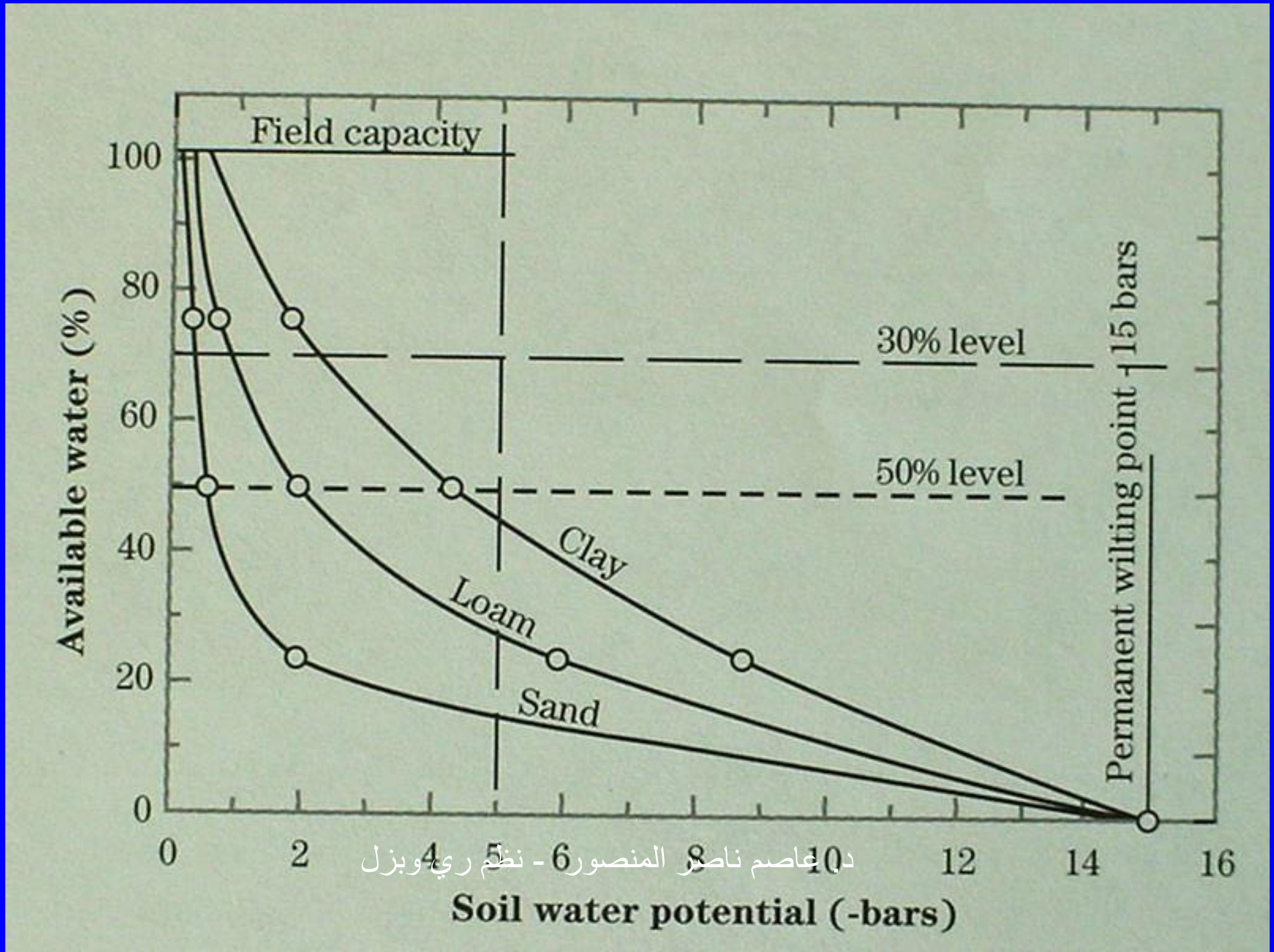
Soil Water Potential

- Components

$$\psi_t = \psi_g + \psi_m + \psi_o$$

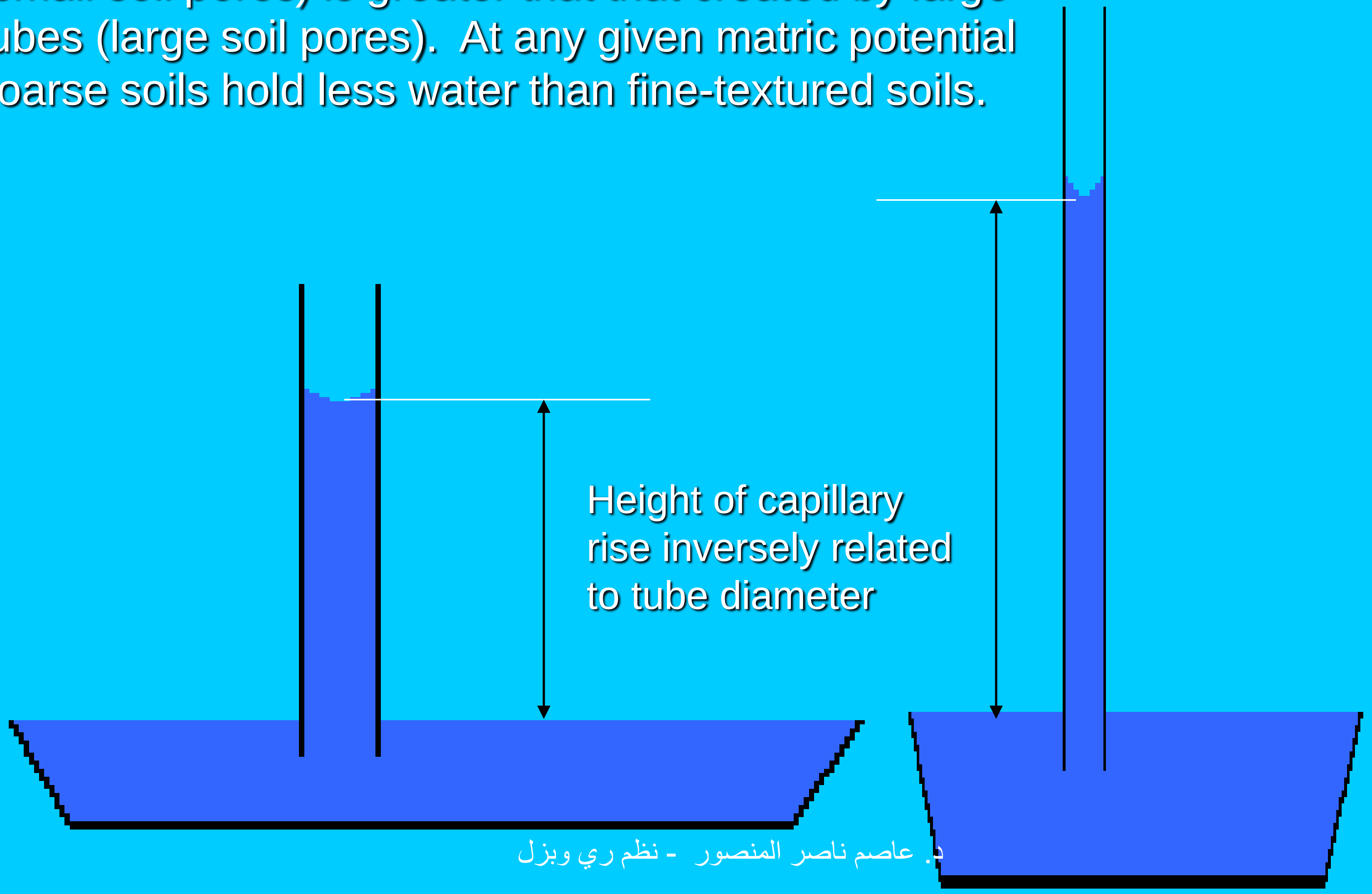
  - ψ_t = total soil water potential
  - ψ_g = gravitational potential (force of gravity pulling on the water)
  - ψ_m = matric potential (force placed on the water by the soil matrix – soil water “tension”)
  - ψ_o = osmotic potential (due to the difference in salt concentration across a semi-permeable membrane, such as a plant root)
  - Matric potential, ψ_m, normally has the greatest effect on release of water from soil to plants

- Soil Water Release Curve
  - Curve of matric potential (tension) vs. water content
  - Less water → more tension
  - At a given tension, finer-textured soils retain more water (larger number of small pores)



Matric Potential and Soil Texture

The tension or suction created by small capillary tubes (small soil pores) is greater that that created by large tubes (large soil pores). At any given matric potential coarse soils hold less water than fine-textured soils.



- Field Capacity (FC or θ_{fc})
  - –Soil water content where gravity drainage becomes negligible
  - –Soil is not saturated but still a very wet condition
  - –Traditionally defined as the water content corresponding to a soil water potential of -1/10 to -1/3 bar
- Permanent Wilting Point (WP or θ_{wp})
  - –Soil water content beyond which plants cannot recover from water stress (dead)
  - –Still some water in the soil but not enough to be of use to plants
  - –Traditionally defined as the water content corresponding to -15 bars of SWP

السعة الحقلية (FCأو fc)
محتوى الماء في التربة حيث يصبح تصريف الجاذبية ضئيلاً
التربة ليست مشبعة ولكنها لا تزال في حالة رطبة للغاية
تُعرف تقليديًا بأنها محتوى الماء المقابل لإمكانية مياه التربة من -1/10 إلى -1/3 بار

نقطة الذبول الدائمة (WPأو wp)
محتوى الماء في التربة الذي لا يمكن للنباتات بعده التعافي من الإجهاد المائي (الميت)
لا يزال هناك بعض الماء في التربة ولكن ليس بالقدر الكافي ليكون مفيدًا للنباتات
تُعرف تقليديًا بأنها محتوى الماء المقابل لـ -15 بار من SWP\

Available Water جاهزية الماء

- Definition
  - Water held in the soil between field
  - capacity and permanent wilting point
  - “Available” for plant use
- Available Water Capacity (AWC)
  - AWC = $\theta_{fc} - \theta_{wp}$
  - Units: depth of available water per unit
  - depth of soil, “unitless” (in/in, or mm/mm)
  - Measured using field or laboratory methods

التعريف : هو المياه المحتجزة في التربة بين السعة الحقلية ونقطة الذبول الدائم"المتاحة" لاستخدام النبات

السعة المائية المتاحة (AWC)AWC = □fc - □wp

الوحدات: عمق المياه المتاحة لكل وحدة عمق من التربة، "بدون وحدات" (بوصة/بوصة، أو مم/مم)

يتم قياسها باستخدام طرق الحقل أو المختبر

Soil Hydraulic Properties and Soil Texture

Table 2.3. Example values of soil water characteristics for various soil textures.*

Soil texture	θ_{fc}	θ_{wp}	AWC
	- - - - - - - - - -	in/in or m/m	- - - - - - - - -
Coarse sand	0.10	0.05	0.05
Sand	0.15	0.07	0.08
Loamy sand	0.18	0.07	0.11
Sandy loam	0.20	0.08	0.12
Loam	0.25	0.10	0.15
Silt loam	0.30	0.12	0.18
Silty clay loam	0.38	0.22	0.16
Clay loam	0.40	0.25	0.15
Silty clay	0.40	0.27	0.13
Clay	0.40	0.28	0.12

* Example values are given. You can expect considerable variation from these values within each soil texture.

- Fraction available water depleted (f_d)

$$f_d = \left(\frac{\theta_{fc} - \theta_v}{\theta_{fc} - \theta_{wp}} \right)$$

  – (θ_{fc} - θ_v) = soil water deficit (SWD)
  – θ_v = current soil volumetric water content

- Fraction available water remaining (f_r)

$$f_r = \left(\frac{\theta_v - \theta_{wp}}{\theta_{fc} - \theta_{wp}} \right)$$

  – (θ_v - θ_{wp}) = soil water balance (SWB)

- Total Available Water (TAW)

  $TAW = (AWC)(R_d)$

  – TAW = total available water capacity within the plant root zone, (inches)
  – AWC = available water capacity of the soil, (inches of H_2O/inch of soil)
  – R_d = depth of the plant root zone, (inches)
  – If different soil layers have different AWC's, need to sum up the layer-by-layer TAW's

  $TAW = (AWC_1)(L_1) + (AWC_2)(L_2) + \ldots (AWC_N)(L_N)$

  - L = thickness of soil layer, (inches)
  - $_{1,\ 2,\ N}$: subscripts represent each successive soil layer

  [Error on page 26 of text: change *SWD* → *TAW*]

Gravity vs. Capillarity

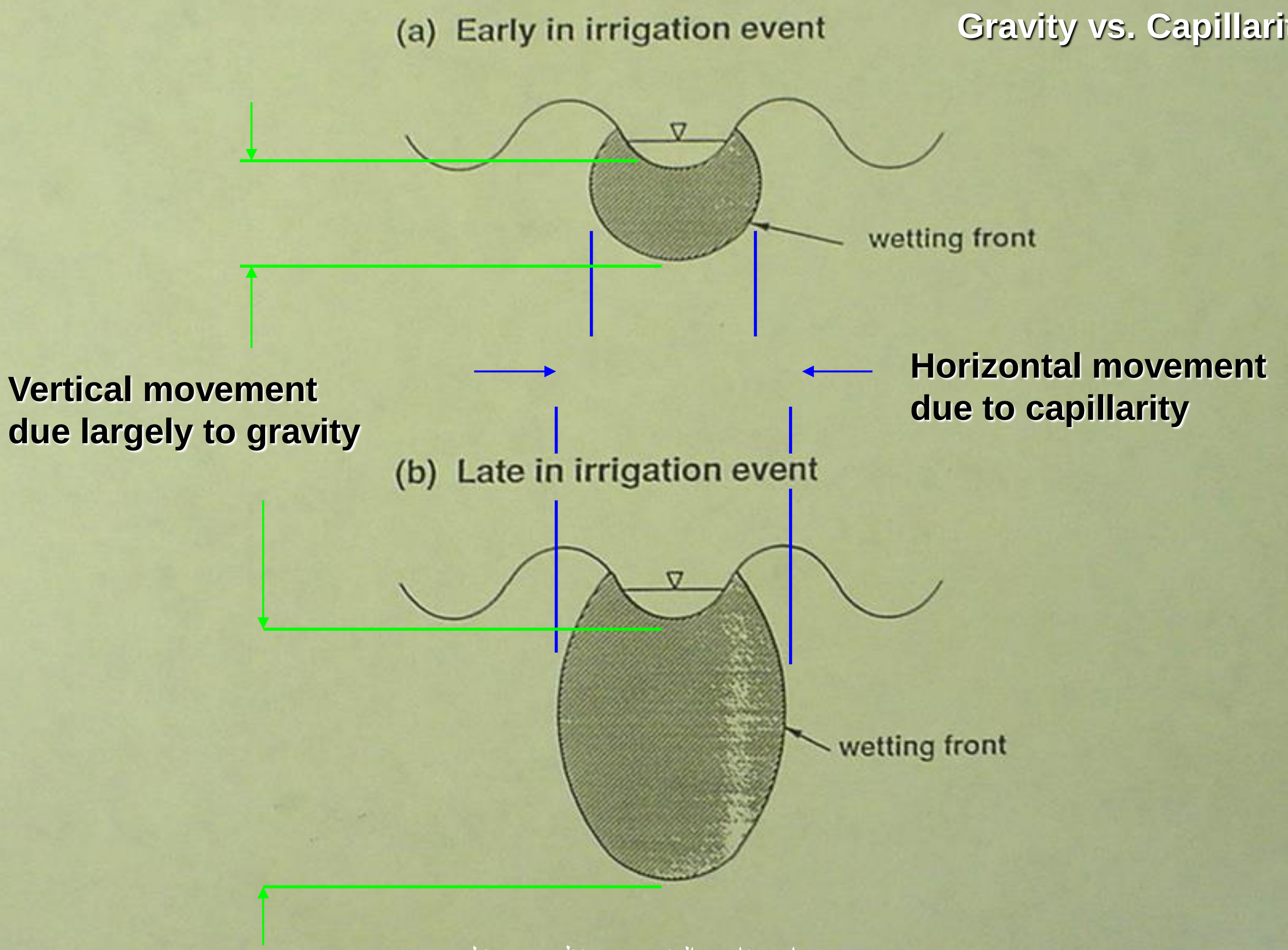


Figure 2.8. Wetting patterns early and late in furrow irrigation water application.

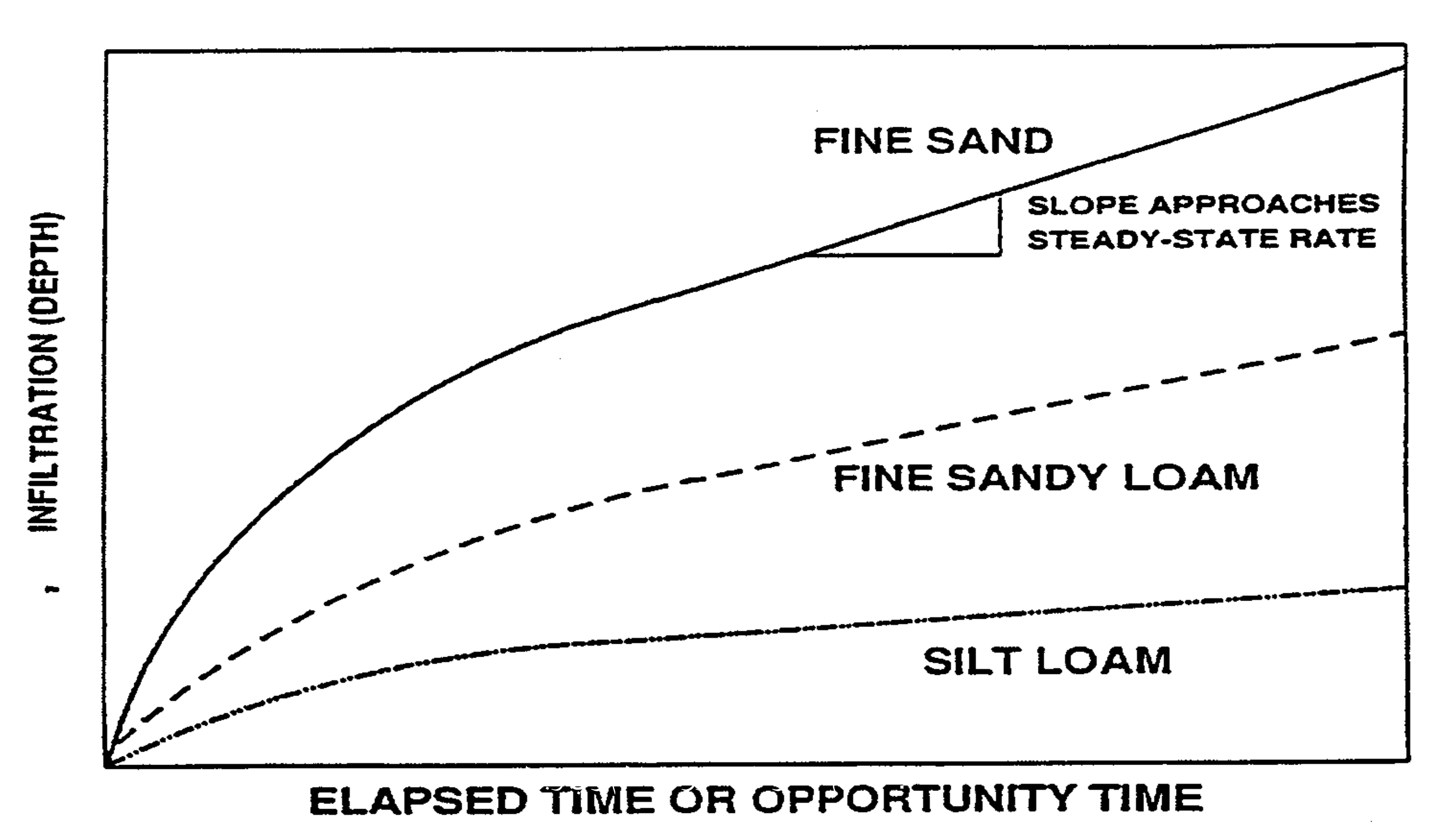
Water Infiltration رشح الماء

Def'n.: the entry of water into the soil

تعريف :هو دخول الماء خلال التربة

Influencing Factors	العوامل المؤثرة
• Soil texture	نسجة التربة
• Initial soil water content	المحتوى الابتدائي من الرطوبة في التربة
• Surface sealing (structure, etc.)	شكل سطح التربة
• Soil cracking	تشققات التربة
• Tillage practices	عمليات الحراثة
• Method of application (e.g., Basin vs. Furrow)	طريقة الاضافة
• Water temperature	درجة حرارة الماء

Cumulative Infiltration Depth vs. Time
For Different Soil Textures
زمن تجمع عمق الرشح لترب مختلفة



Infiltration Rate vs. Time

For Different Soil Textures

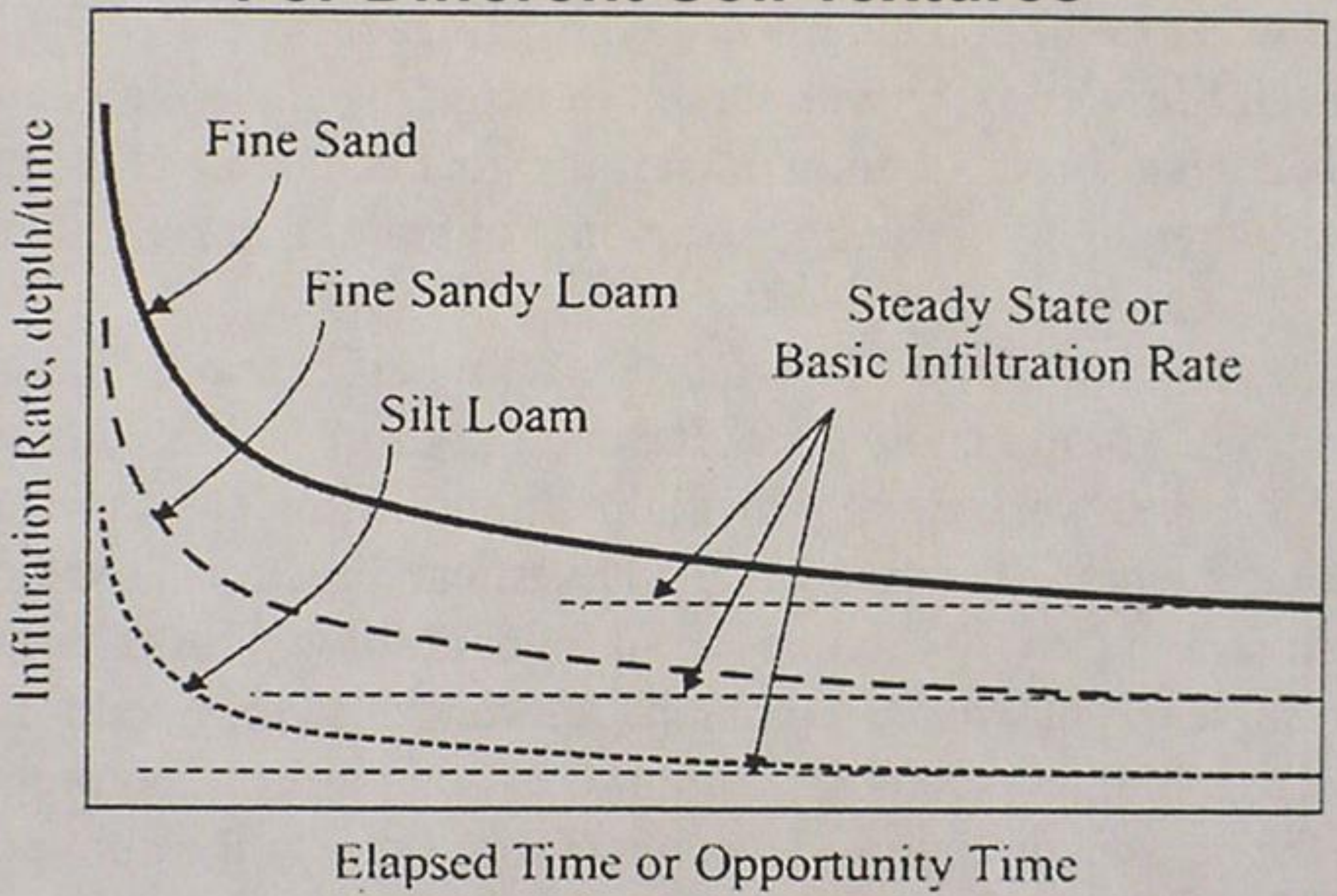


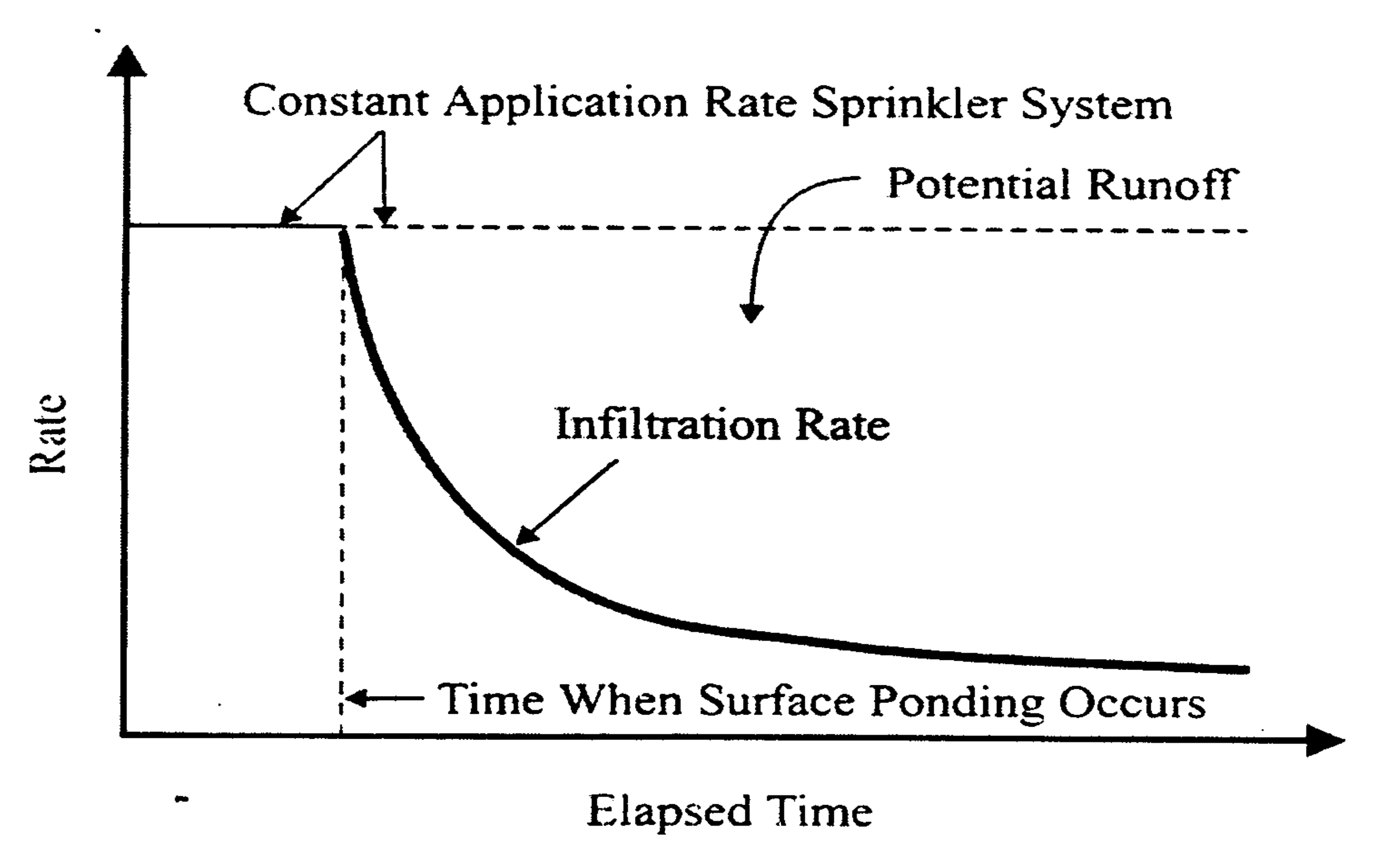
Figure 2.9. Infiltration rate vs. opportunity time.

Water Infiltration Rates and Soil Texture

Table 2.4. Basic infiltration rates for stationary sprinkler systems. (Adapted from Pair, 1983.)

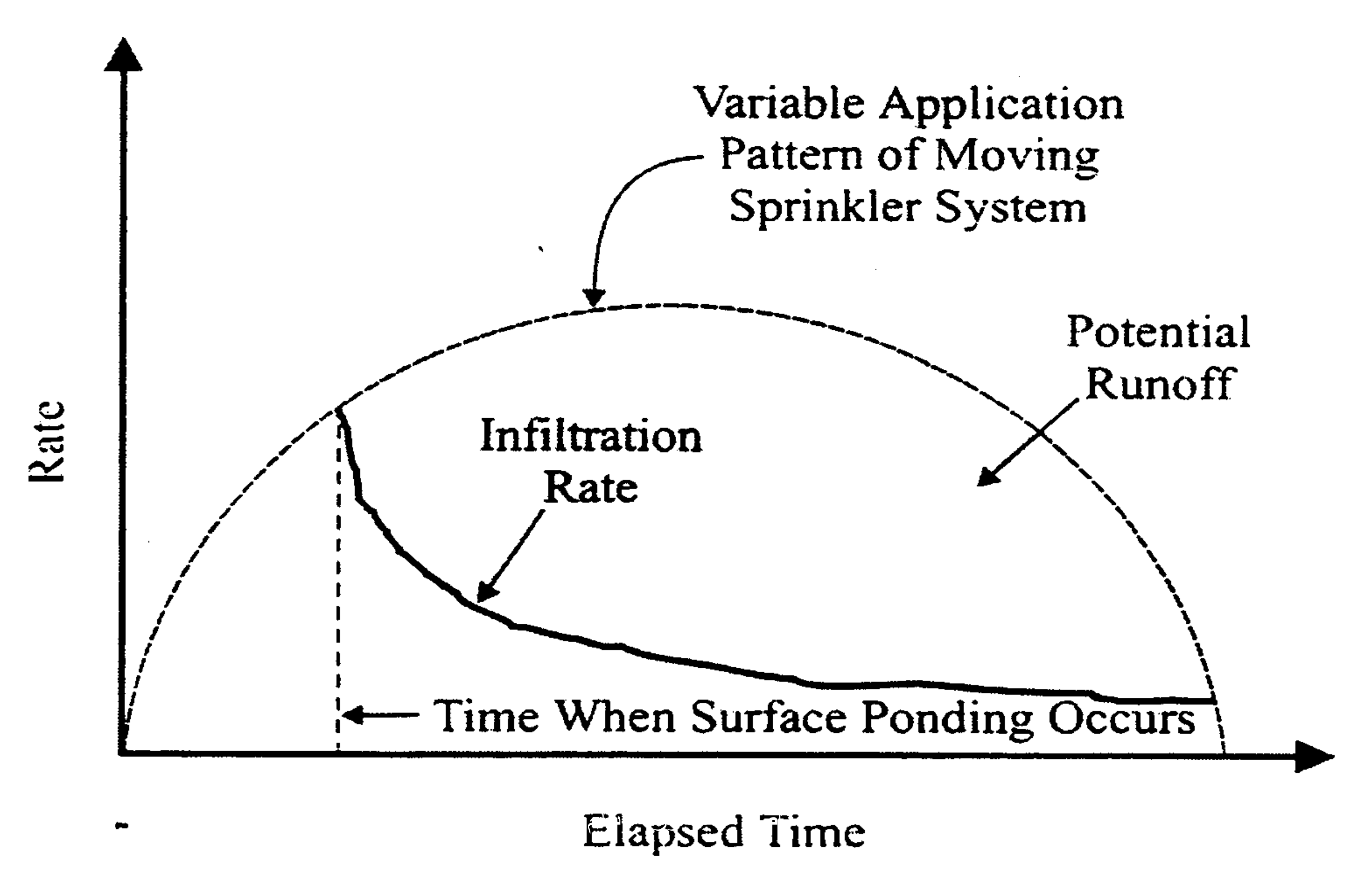
Soil Texture	Minimal Surface Sealing	Some Surface Sealing
	in/h	in/h
Coarse sand	0.75-1.00	0.40-0.65
Fine sand	0.50-0.75	0.25-0.50
Fine sandy loam	0.35-0.50	0.15-0.30
Silt loam	0.25-0.40	0.13-0.28
Clay loam	0.10-0.30	0.05-0.25

Soil Infiltration Rate vs. Constant Irrigation Application Rate



Soil Infiltration Rate vs. Variable Irrigation Application Rate

معدل رشح التربة مع عامل معدل اضافة الري



Depth of Penetration
عمق الاختراق

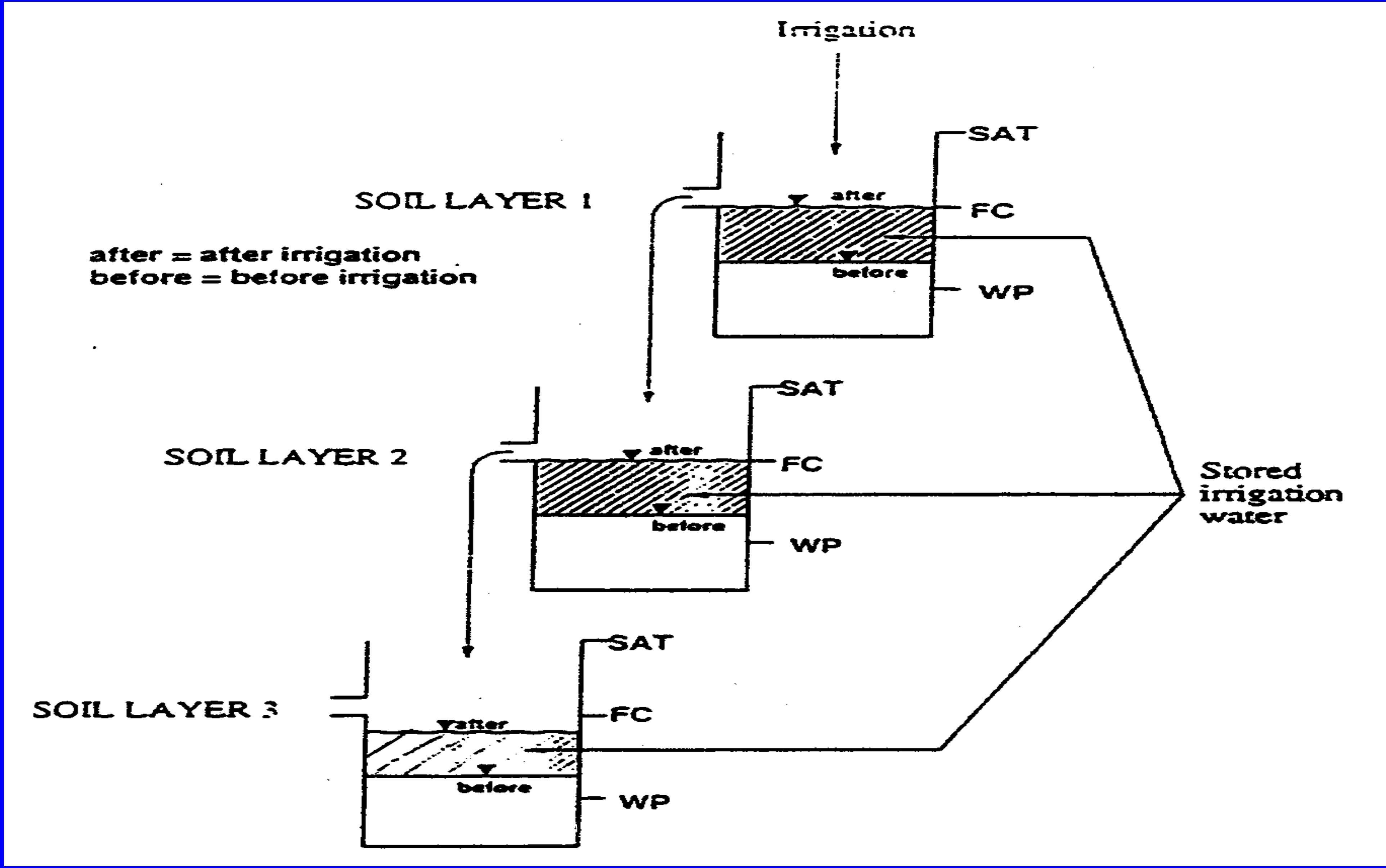
- Can be viewed as sequentially filling the soil profile in layers
- Deep percolation: water penetrating deeper than the bottom of the root zone
- Leaching: transport of chemicals from the root zone due to deep percolation

ممكن نستعرض بالتعاقب املاء التربة في الطبقات

الرشح العميق : اختراق الماء تحت منطقة الجذور الفعالة للنبات

الغسيل : نقل المواد الكيميائية من منطقة الجذور بواسطة الرشح العميق

Water Storage in Layered Soil Profiles



Example 2.4

Given a soil with the following characteristics, calculate the depth to which 4 in. of infiltrated water would penetrate.

Layer	Depth (in)	θ_{fc}	θ_v
1	0-12	0.34	0.20
2	12-30	0.40	0.33
3	30+	0.30	0.24

Using Equation 2.12:

SWD_1 = (0.34 - 0.20) 12 in. = 1.7 in.
SWD_2 = (0.40 - 0.33) 18 in. = 1.3 in.
3.0 in. (1.7 in. + 1.3 in.) is required to fill the first two layers

The remaining water is: 4.0 in. - 3.0 in. = 1.0 in.

To find the depth penetrated in the third layer (L_3), use the same equation, but solve for L_3 when SWD_3 = 1.0 in.:

$$L_3 = \frac{1.0}{(0.30-0.24)} = 16.7 \; in.$$

The depth from the surface penetrated by a 4-inch application is then:
12 in. + 18 in. + 16.7 in. = 46.7 in. (about 4 feet).

Soil Water Measurement
طرق قياس ماء التربة

- Gravimetric

الطريقة الوزنية

قياس المحتوى المائي ككتلة

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

- Feel and appearance

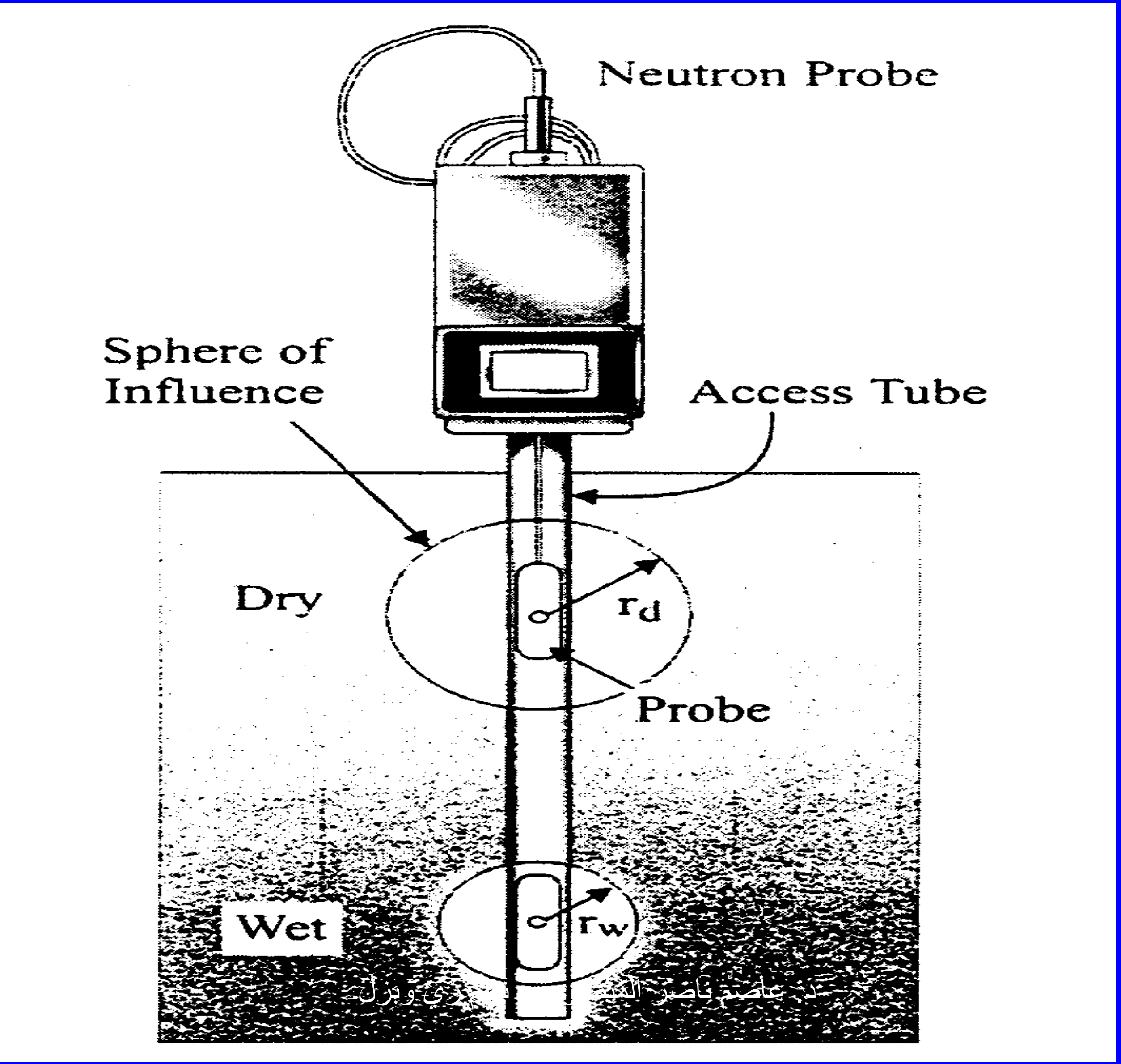
طريقة معرفة الرطوبة باللمس والمظهر الخارجي

  - 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

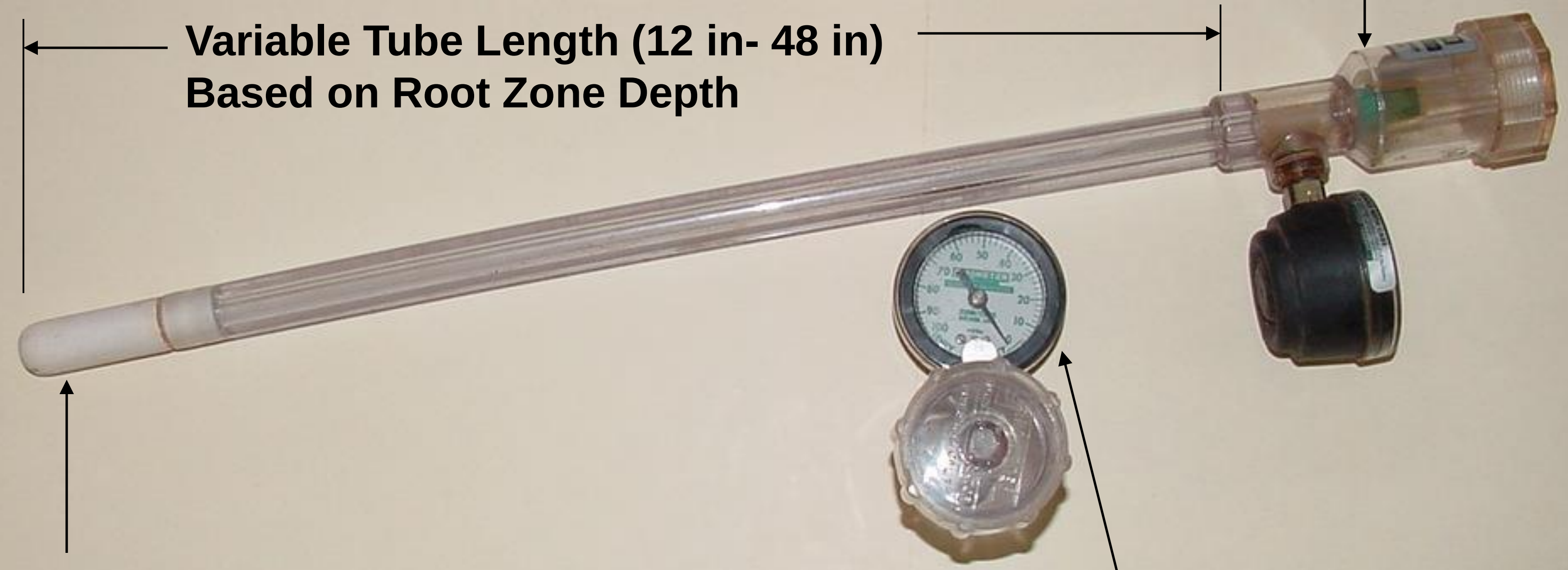
Soil Water Measurement
Neutron Attenuation



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