هندسة الري والبزل

Irrigation And Drainage Engineering

Lecture Notes 2022-2023

تعريف الري Irrigation definition

- الرّيُّ هو العلم الذي يهتم بتزويد المساحات الزراعية بالمياه اللازمة للاستخدامات الزراعية بطريقة محسوبة بدقة على أساس المناخ والطبوغرافيا وطبيعة التربة (درجة الحامضية، تدرج الحبيبات،...). وإمداد التربة بالماء يحافظ علي محتوى الرطوبة اللازم لنمو النبات، ويغسل التربة من الأملاح الزائدة، للحفاظ علي تركيز ملوحة مقبول في منطقة جذور النبات. (يمكن زراعة الأراضي المالحة بالأرز، الذي يحتاج لكميات مياه كبيرة فيتم في نفس الوقت غسل التربة من الأملاح).

تعريف الري Irrigation definition

المياه التي تضاف إلى كتلة التربة أثناء الري يتم الاحتفاظ بها في مسام التربة وتسمى مياه التربة (أو رطوبة التربة).

تتسبب مياه التربة في ظهور التربة رطبة استنادا إلى كمية الرطوبة التي تحتفظ بها كتلة التربة.

العوامل المسؤولة عن نمو المحاصيل هي

(أ) معدل دخول المياه إلى التربة.

(ب) المياه التي تحتفظ بها التربة.

(ج) توافر المياه لجذور النباتات.

الغرض

- تربية محصول لا ينمو فيه شيء بخلاف ذلك (مثل المناطق الصحراوية)
- زراعة محصول أكثر ربحية (على سبيل المثال، البرسيم مقابل القمح)
- زيادة غلة و/أو جودة محصول معين (مثل الفاكهة)
- زيادة قيمة جذابة من المناظر الطبيعية (على سبيل المثال، العشب، الزينة)
-

أنواع الري

1.**الري الطبيعي :** وهو وصول المياه بطريقة طبيعية للنبات دون تدخل بشري
2.**الري الصناعي:** تدخل الإنسان وإعادة توزيعه للمياه باستخدام الطرق المختلفة .

الطرق الشائعة للري

الري السطحي ويقسم إلى الري بالديم والري بالواسطة
الري بالرش
الري بالتنقيط

أقسام ماء الري

ينقسم الماء المستخدم في عملية الري إلى الأقسام التالية:
جزء يمتص بواسطة جذور النباتات
جزء يتبخر من سطح الأرض.
جزء تحتفظ به التربة حسب قوامها.
جزء يتسرب من خلال حبيبات التربة إلي المياه الجوفية.

فوائد ماء الري

يقوم الماء بدور العامل المذيب للمواد الغذائية التي تحتويها التربة وحملها لجذور النبات.
يساعد على نشاط بكتريا التربة التي تعمل علي تحليل المواد العضوية الموجودة في التربة فيمكن للجذر امتصاصها.
يساعد على حفظ درجة حرارة التربة لتكون مناسبة لنمو النباتات.
يحمل الأملاح الزائدة والمواد الضارة بالنبات إلى باطن الأرض وإلى المصارف.

أسباب زيادة الغلة (الأنتاجية)/الجودة

- انخفاض الإجهاد المائي
- إنبات أفضل ومستقر
- ارتفاع عدد النباتات
- استخدام الأسمدة بشكل أكثر كفاءة
- أصناف محسنة

فوائد الري الأخرى

- التخلص من الأملاح
- حماية ضد الصقيع
- تبريد النبات/التربة
- الأضافات الكيميائية
- مكافحة تآكل الرياح
- التخلص من النفايات

أنواع مياه التربة وتوافرها

ويمكن تصنيف المياه الموجودة في التربة تحت ثلاث مراحل:

المياه الهيجروسكوبية hygroscopic water:

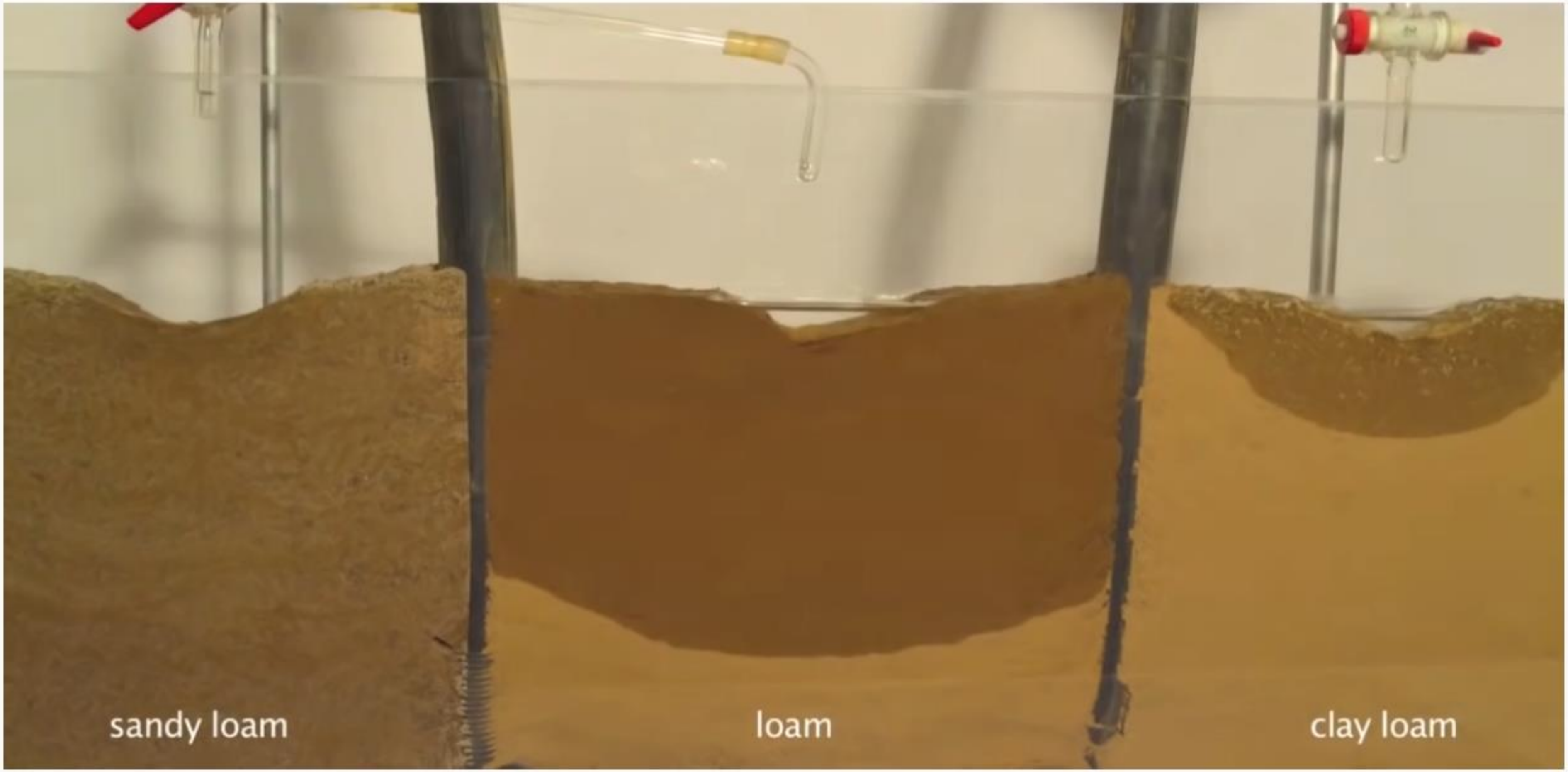
وهي المياه الممسوكة بقوة من قبل حبيبات التربة بحيث يتعذر على النبات الأستفادة منها.

مياه الشعيراتcapillary water:

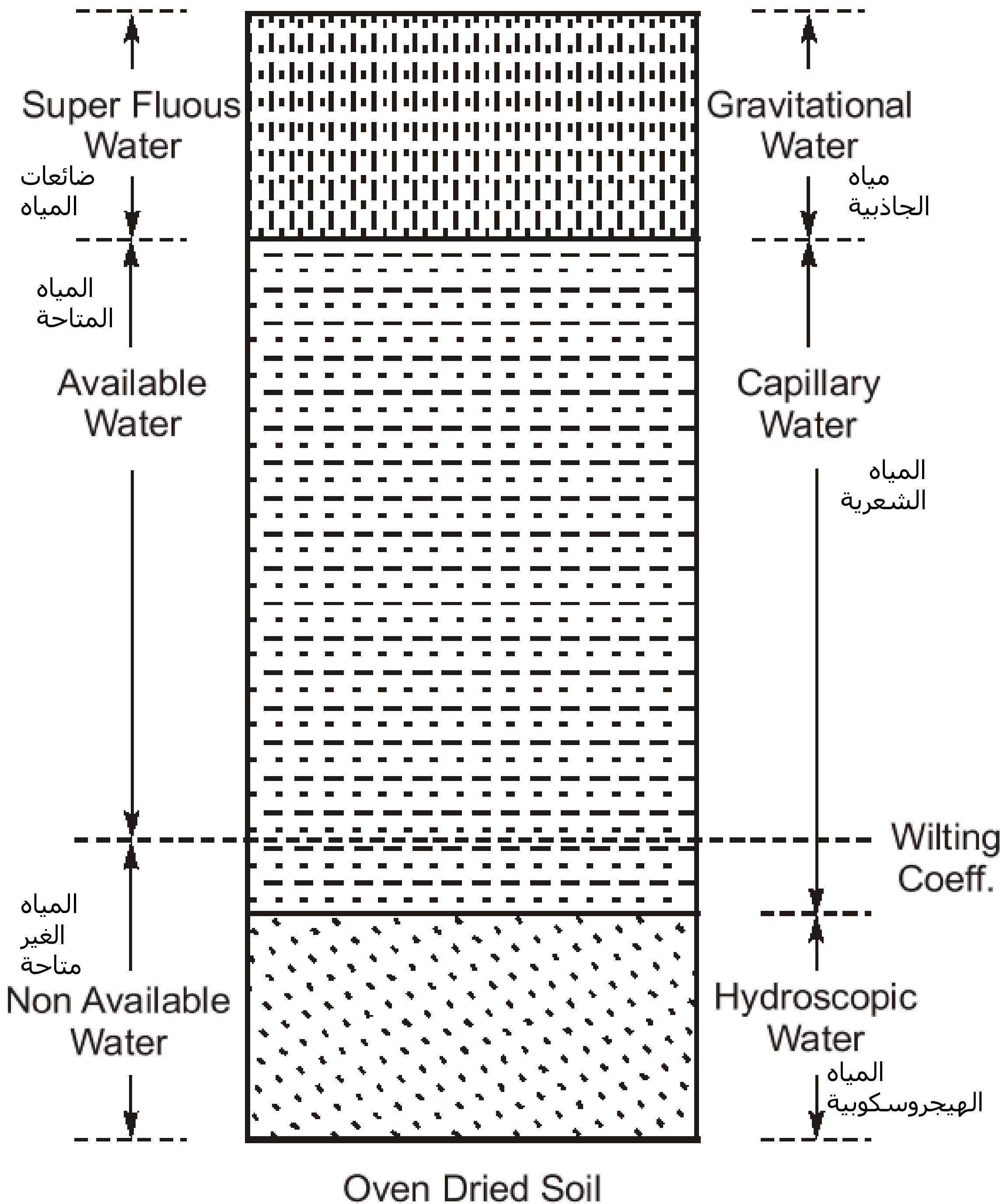
وهي المياه التي تملأ الفراغات والفجوات بين حبيبات التربة الدقيقة وغالبا ماتكون قوة مسكها من قبل حبيبات التربة صغيرة بحيث يمكن للنبات أن يستفاد منها في عملية النمو وتأمين أحتياجاته المائية.

مياه الجاذبية gravitational water:

وهي المياه التي تتواجد في الفجوات الكبيرة نسبيا مثل تلك الموجودة في التربة الرملية وهي غالبا ماتكون حرة وغير ممسوكة بحيث تتحرك الى الأسفل من دون أن يستفاد منها النبات .



Water movement in the soil


Super Fluous Water
ضائعات المياه
Gravitational Water
مياه الجاذبية
المياه المتاحة
Available Water
Capillary Water
المياه الشعرية
Wilting Coeff.
المياه الغير متاحة
Non Available Water
Hydroscopic Water
المياه الهيجروسكوبية
Oven Dried Soil

توتر رطوبة التربة/ إجهاد رطوبة التربة

تعرف رطوبة التربة بأنها القوة لكل وحدة من المناطق التي يجب أن تمارس من أجل استخراج المياه من التربة.

وعادة ما يعبر عن توتر رطوبة التربة من حيث الغلاف الجوي.

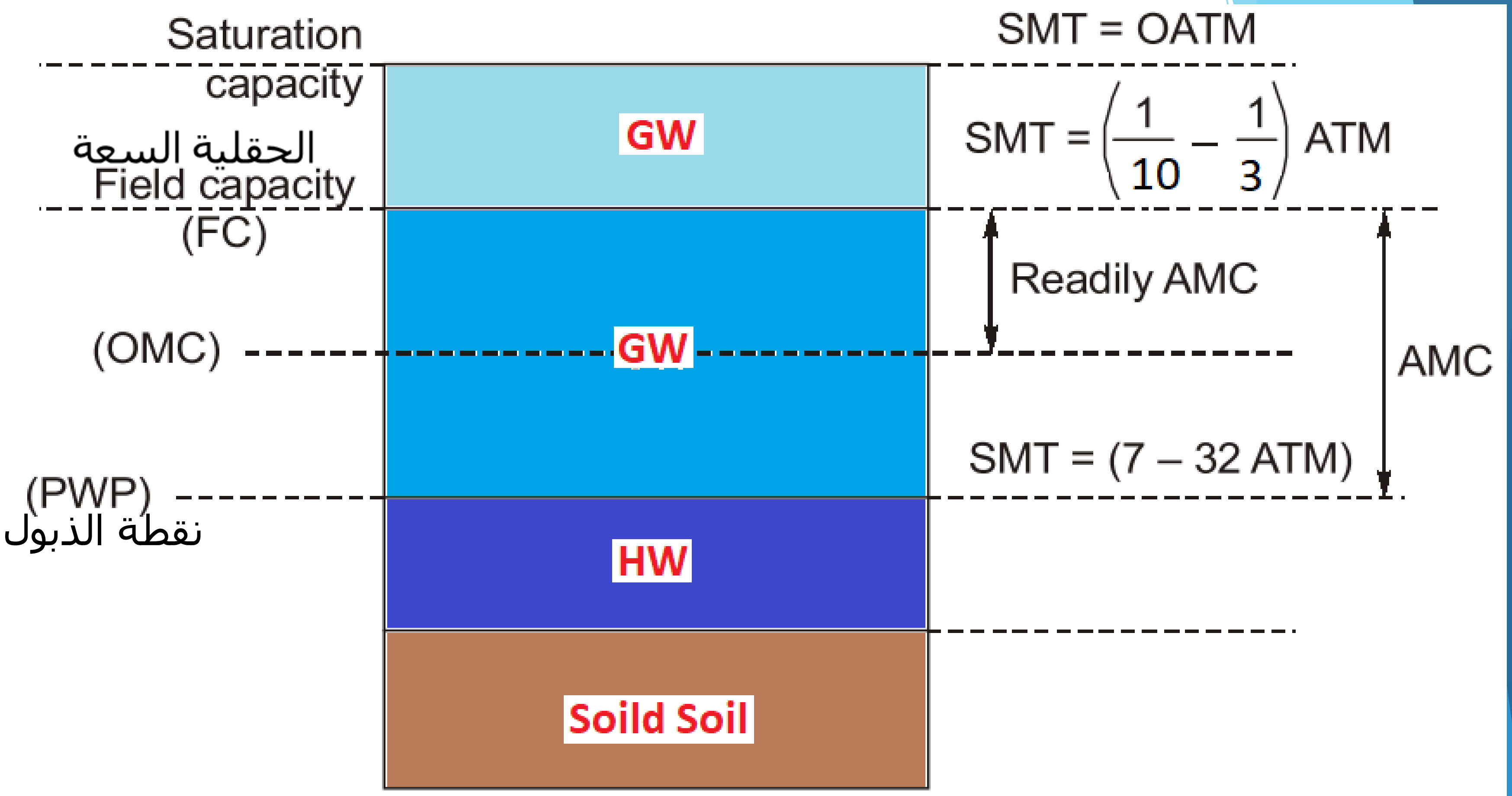
بالنسبة لتربة معينة، فإن توتر رطوبة التربة يتناسب عكسيا مع محتوى الماء.

إذا كنا نعرف SMT (توتر رطوبة التربة) ومحتوى الرطوبة المختلفة ثم يمكننا تحديد كمية المياه المتاحة للنباتات وما هي كمية المياه التي يجب إضافتها إلى التربة لغرض الري.

الضغط (OPتوتر رطوبة التربة) و (SMTإجهاد رطوبة التربة في مجموع التناضحي).

تسمى القوة التي يتحرك بها الماء عبر غشاء الخلية الضغط التناضحي.

Soil Moisture Constants



القدرة على التشبع —— يتم تعريفه على أنه محتوى المياه الكلي.
هو صفر. SMT• في القدرة على التشبع
السعة الحقلية :هي أقصى قدر من المياه التي يمكن أن تحتفظ بها التربة ضد الجاذبية. ذلك يعتمد على المسامية والشعيرات الدموية.

$$FC = \frac{\text{Weight of water retained in certain volume of soil}}{\text{Weight of same volume of dry soil}}$$

(محتوى الرطوبة في القدرة الميدانية يشمل المياه المجهرية والمياه الشعرية.
في مجال القدرات يتراوح بين (1/10 ضغط جوي - 1/3 ضغط جوي) SMT•
PWPنقطة الذبول / نقطة الذبول الدائمة
في هذا المحتوى الرطوبة أوراق النبات سوف تذبل.والمحتوى المائي في هذه النقطة يكون قليل ولن يستطيع النبات من الستفادة منه بسبب قوة الشد بين الماء وحبيبات التربة ويجب أن لايصل المحتوى المائي للتربة الى نقطة الذبول بل يجب التعويض بالكميات الضافية من المياه قبل ذلك.
يعتمد برنامج عمل البرنامج على طبيعة التربة.
هو الحد الأدنى من المياه الشعرية والحد الأعلى من المياه الهيغروسكوبية. PWP
هو في نطاق (7-32) ضغط جوي، ولكن لغرض الحساب نأخذ متوسط قيمة SMT، PWP• في 15 ضغط جوي لجميع التربة.

Available Moisture Content (AMC)

- وهي المياه المتاحة لنمو المحصول. ويسمى أيضا كأقصى قدرة تخزين للتربة.

Readily Available Moisture Content (RAMC)

- هذا الجزء من المياه المتاحة / الرطوبة التي يتم استخراجها بسهولة أكبر من قبل المحطة ويسمى هذا الحد **OMC (Optimum Moisture Content).**

في غياب البيانات المتاحة يمكننا أن نفترض RAMC = 75% من محتوى الرطوبة المتاحة.

رطوبة التربة بالقرب من نقطة الذبول PWP لا يمكن استخراجها بسهولة من جذور النبات.

نقص رطوبة التربة/ نقص السعة الحقلية Field capacity

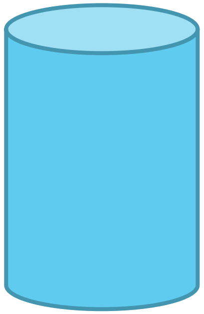
نقص رطوبة التربة هو كمية المياه التي سيتم إضافتها إلى التربة بحيث الرطوبة المحتوى الذي تم رفعه إلى سعة الحقل.

كيف يمكن توقع الرسم البياني بين محتوى الرطوبة ومعدل النمو؟

Depth of Water Held in Root Zone

For ease in calculation water present in the voids of the soil needs to be expressed as depth of water.

Let root zone depth = *dm*



Specific weight of dry soil = γ_d

cross-section area of soil considered=A

equivalent depth of water present in voids of the soil = *Dm*

$$FC = \frac{\text{Weight of water retained in certain volume of soil}}{\text{Weight of same volume of dry soil}}$$

$$= \frac{A \times D \times \gamma_w}{Ad \times \gamma_d}$$

$$D = \frac{\gamma_d}{\gamma_w} \cdot d \cdot FC$$

It is the depth of water stored in the root zone for full field capacity.

But this entire depth of water can't be extracted by the plants, hence available moisture content will be given as:

$$\text{Available depth of water} = \frac{\gamma_d}{\gamma_w} \cdot d \cdot (FC - PWP)$$

$$\text{Not available water} = \frac{\gamma_d}{\gamma_w} d(PWP)$$

$$\text{Equivalent depth of water readily available, RAMC} = \frac{\gamma_d}{\gamma_w} d(FC - OMC)$$

$$F_W = \frac{RAMC}{(Cu/day)} = \frac{\text{Maximum allowable deficiency}}{\text{Consumptive use per day}}$$

Example - 2.1 Depth of water in root zone at field capacity and permanent wilting point are 0.5 m per metre depth of soil and 0.2 m per metre depth of soil. Find field capacity and permanent wilting point Take $\gamma_d = 13.73$ KN/m^3.

Solution:

Given: $d_{w_1} = 0.5\,m$; $d_{w_2} = 0.2\,m$; Depth of soil, $d = 1$ m ; $\gamma_d = 13.73$ kN/m^3

$$\text{Field capacity (FC)} = \frac{\text{Weight of water retained in root zone corresponding to FC}}{\text{Weight of dry soil}}$$

$$FC = \frac{\gamma_{w\times(d_{w1}\times 1)}}{\gamma_d \times (d\times 1)} = \frac{9.81\times 0.5\times 1}{13.73\times 1\times 1} = 35.72\%$$

$$PWP = \frac{\gamma_w \times (d_{w_1} \times 1)}{\gamma_d \times (d\times 1)} = \frac{9.81\times(0.2\times 1)}{13.73\times(1\times 1)} = 0.1429 = 14.29\%$$

Alternate solution:

$$PWP = \frac{1}{2.5}\times F.C = \frac{35.72}{2.5}\% = 14.29\%$$

Since depth of water in root zone at F.C is 2.5 times that at PWP.

Example - 2.2 A loam soil has field capacity of 25% and wilting coefficient of 10%. The dry unit weight of soil is 1.5 gm/cc. If the root zone depth is 60 cm, determine storage capacity of the soil. Irrigation water is applied when moisture content falls to 15%.

Solution:

Given: F.C = 25% = 0.25 ; P.W.P. = 0.10 ; Dry density, ρ_s = 1.5 gm/cc ; Root zone depth, d = 60 cm

Moisture holding capacity of soil in root zone depth, d is given by

$$= \frac{\rho_d}{\rho_w} \times [\text{F.C.} - \text{PWP}] = \frac{1.5}{1} \times 60\,[0.25 - 0.1] = 13.5 \text{ cm}$$

When moisture content falls to 15%, the deficiency of water depth created will be given by

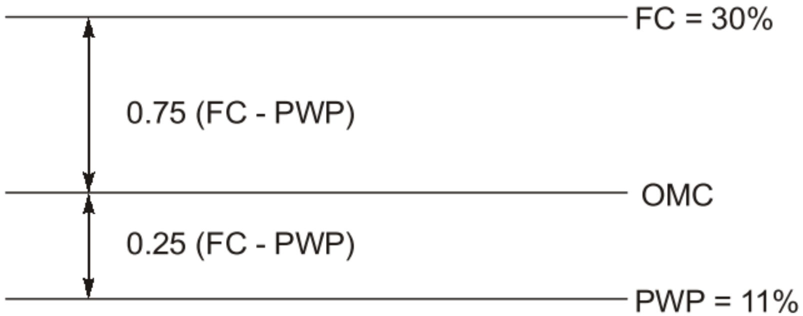
$$= \frac{\rho_d}{\rho_w} \times d\,[\text{F.C.} - \text{Fall in moisture content}]$$

$$= \frac{1.5}{1} \times 60\,[0.25 - 0.15] = 9 \text{ cm}$$

Hence, 9 cm depth of water is the net irrigation requirement.

Example - 2.3 For best growth of a particular crop, F.C = 30%, PWP = 11%, γ_d = 1300 kg/m^3. Effective depth of root zone = 800 mm, C_u per day = 12 mm. Moisture content must not fall below 25% of water holding capacity between field capacity and permanent wilting point. Determine frequency of irrigation.

Solution :



$$OMC = PWP + 0.25\,(FC - PWP) = FC - 0.75\,(FC - PWP)$$

$$FC - OMC = 0.75\,(FC - PWP)$$

$$\therefore \quad RAMC = \frac{\gamma_d}{\gamma_w} d \cdot (FC - OMC)$$

$$RAMC = \frac{1300}{1000} \times 0.8 \times 0.75(0.3 - 0.11) = 0.1432 \text{ m}$$

$$\therefore \quad \text{frequency of irrigation (FW)} = \frac{RAMC}{C_u \text{ per day}} = \frac{143.2 \text{ mm}}{12 \text{ mm}} = 12.35 \text{ day}$$

$$\therefore \quad \text{frequency of irrigation} = 12 \text{ day}$$

Example - 2.4 The following data were recorded from an irrigation field:

Field capacity = 20%

Permanent wilting point = 10%

Permissible depletion of available soil moisture = 50%

Dry unit weight of soil = 15,000 N/m^3

Effective rainfall = 25 mm

Based on above data, the net irrigaton requirement per metre depth of soil will be

(a) 25 mm (b) 50 mm

(c) 75 mm (d) 125 mm

[UPPSC 2004]

Solution: (b)

Let depth of root zone = 1000 mm

Given : $FC = 20\%$, $\gamma_d = 15$ kN/m^3; PWP = 1%, $P_{eff} = 25$ mm

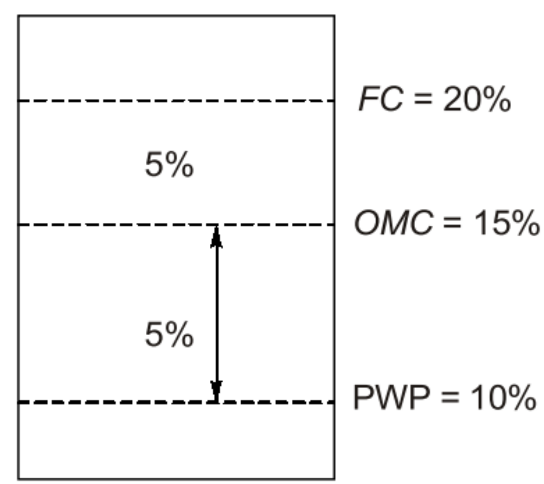
Permissible depletion of available soil pressure = 50%

$$\text{Optimum Moisture Content}, OMC = 0.5(20-10)+10 = 15\%$$

$$\text{Readily Available Moisture Content}, RAMC = \frac{\gamma_d}{\gamma_w} d(FC - OMC)$$

$$= \frac{15}{10} \times 1000(0.20-0.15)$$

$$= 75 \text{ mm}$$



$$\text{Consumptive irrigation required} = C_u - P_{effective\ rainfall}$$

$$\text{CIR} = 75 - 25 = 50 \text{ mm}$$

$$\therefore \quad \text{NIR} = CIR + \text{Leaching required}$$

$$\textbf{NIR} = \mathbf{50 + 0 = 50 \text{ mm}}$$

Calculating the appropriate depth of irrigation

1. Determine what field capacity is (see table below)أوجد السعة الحقلية
2. Determine what permanent wilting point is (see table below)أوجد نقطة الذبول الدائمة

Take a silt loam (the majority of soil types in N. Otago) for example where:

ΘFC = 31 % (determined from soil drying or tables)السعة الحقلية للطمى هي

ΘWP = 11 % (determined from soil drying or tables) نقطة الذبول الدائمة للطمى هي

Texture	FC (%)	PWP (%)	Texture	FC (%)	PWP (%)
Sand	10	5	Silt loam	31	11
Loamy sand	12	5	Silt	30	6
Sandy loam	18	8	Clay loam	36	22
Sandy clay loam	27	17	Silty clay loam	38	22
Loam	28	14	Silty clay	41	27
Sandy clay	36	25	Clay	42	30

3. Calculate total amount of water available to plants within the soil profile, حساب إجمالي كمية المياه المتاحة للنباتات داخل عمق التربة this is the ‘total available

water (TAW)’ and is calculated by:

TAW = ΘFC - ΘWP = 31-11 = 20%.

4. Determine the soil depth to which the water is appliedتحديد عمق التربة التي يتم تطبيق الماء عليه

, for instance in Pallic soils this beis may determined based on the depth of the topsoil 400 mm, or in other soils the rooting depth of the crop.Assuming a rooting depth of grass to be 0-300 mmعلى افتراض عمق تأصيل العشب ليكون 0-300 ملم

TAW = 20 % (from 3)

TAW = 0.20 x 300= 60 mm

5. Irrigation point (IP) is the moisture content at which irrigation should be applied. This is generally taken as a half way point between ϴFC and ϴWP.) نقطة الريIP) هي محتوى الرطوبة الذي ينبغي أن يطبق فيه الري. ويعتبر ذلك عموما نقطة في منتصف الطريق بين ϴFC و ϴWP.

IP = TAW /2 + Θ_{WP} = 20/2 +11 = 21

When soils reach 21 % (i.e. the IP) then we must re-fill to Θ_{FC} (which is 31 %).

This is achieved by adding 10 % more moisture.

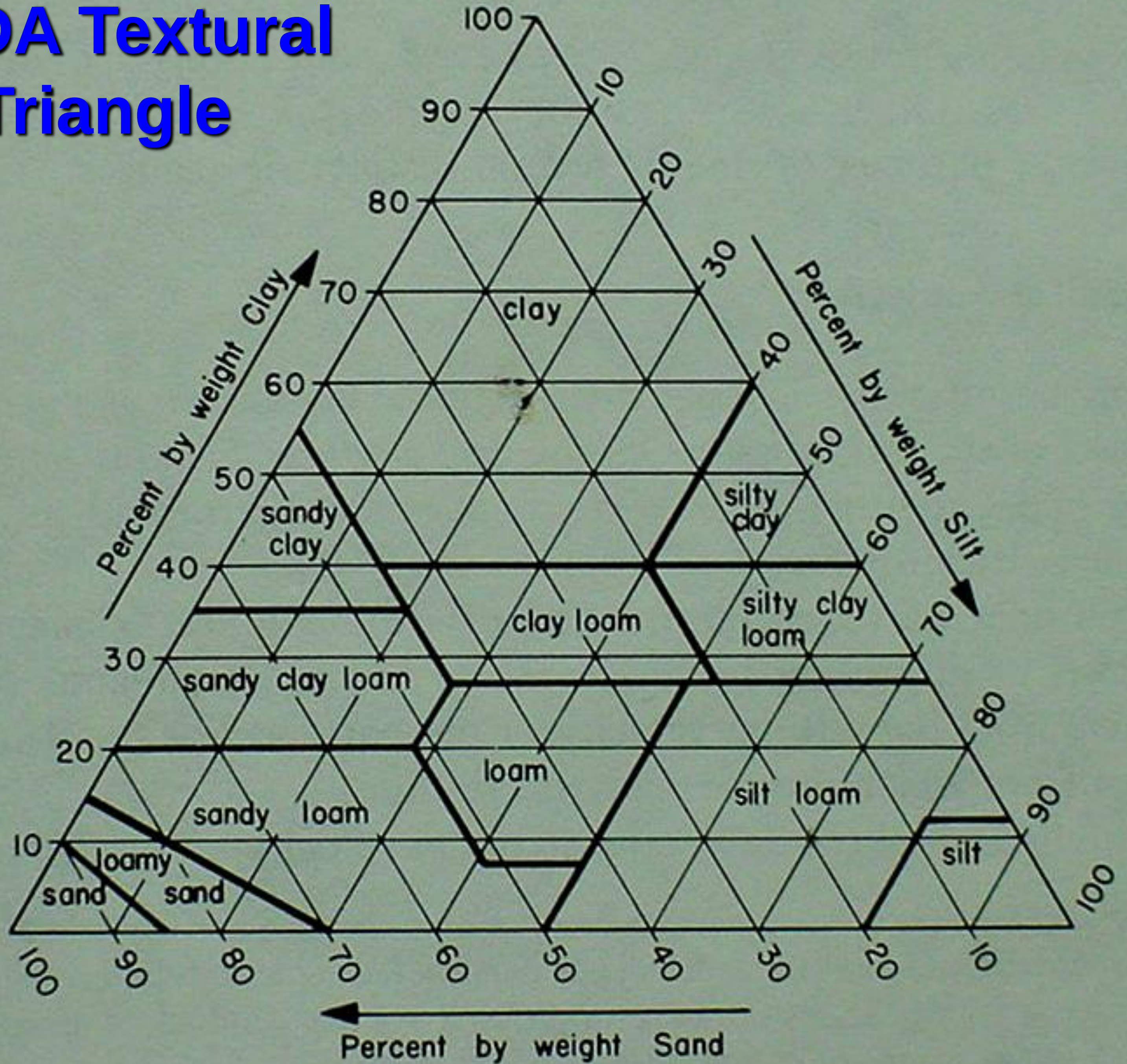
10 % of 300 mm = 30 mm

1 L applied over 1 m_2 = 1 mm, so 30 mm over 1 ha (10 000 m_2) = 300 000 L or 300 m^3.

Soil Properties

- Texture
  - Definition: relative proportions of various sizes of individual soil particles نسب مختلف أحجام جزيئات التربة الفردية
  - 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
- Structure
  - Definition: how soil particles are grouped or arranged
  - Affects root penetration and water intake and movement

USDA Textural Triangle



- Bulk Density (ρ_b)

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

  - ρ_b = soil bulk density الكثافة الكتلية للتربة, g/cm^3
  - M_s = mass of dry soil الكتلة الجافة, g
  - V_b = volume of soil sample حجم التربة, cm^3
- Typical values: 1.1 - 1.6 g/cm^3

- Particle Density (ρ_p) كثافة جزئية التربة

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

  - 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 (≥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, $\theta_V = \phi$
  - $\theta_V = As\ \theta_m$
  - 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

Volumetric Water Content & Equivalent Depth

Typical Values for Agricultural Soils

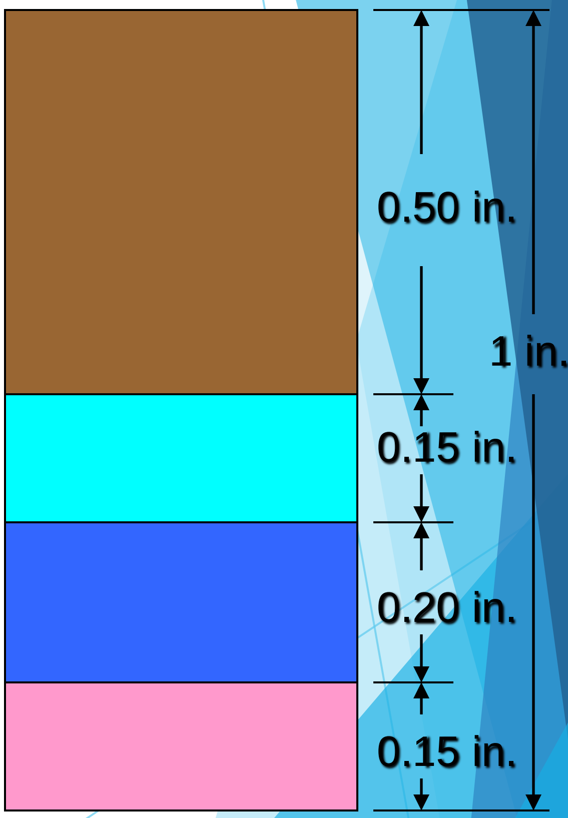
Soil Solids (Particles): 50%

Total Pore Space: 50%

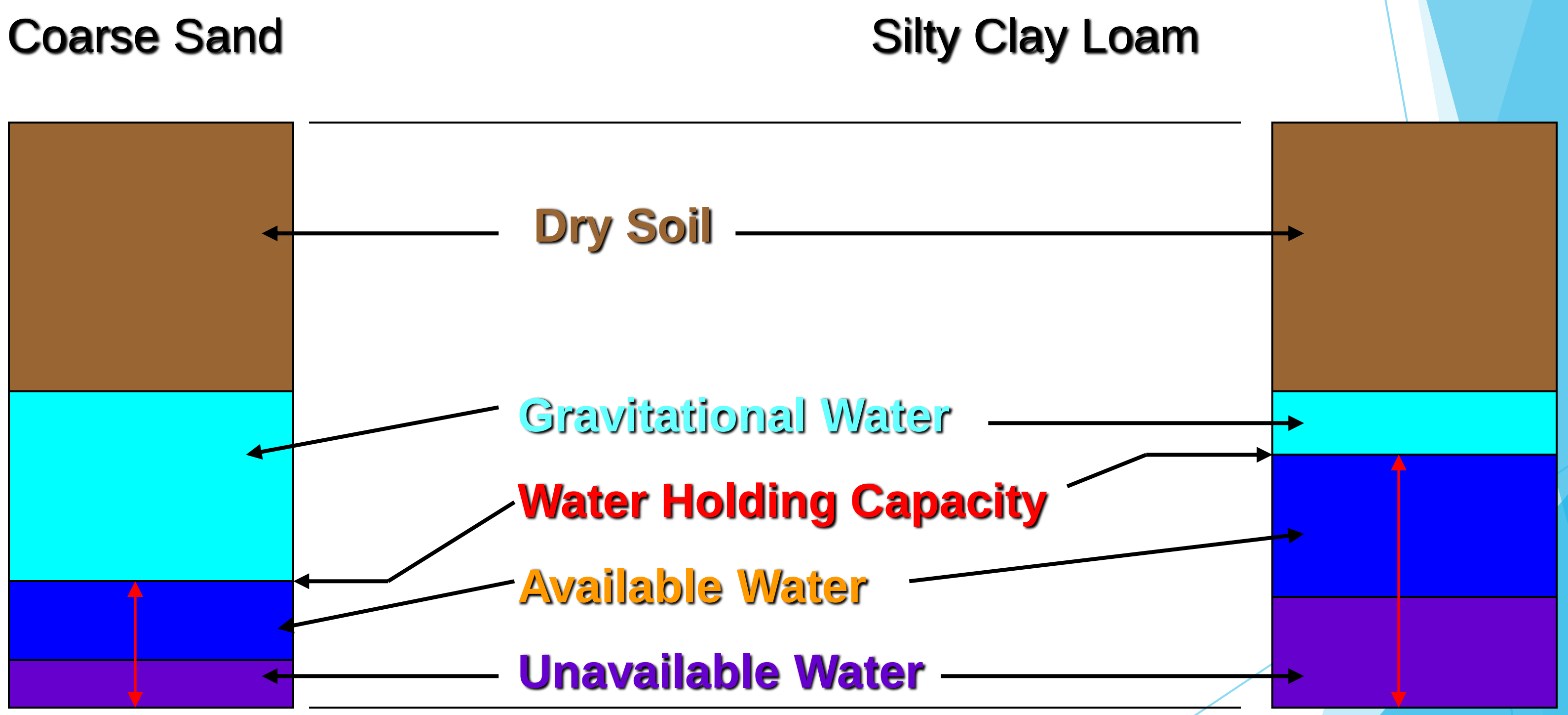
Very Large Pores: 15%
(Gravitational Water)

Medium-sized Pores: 20%
(Plant Available Water)

Very Small Pores: 15%
(Unavailable Water)



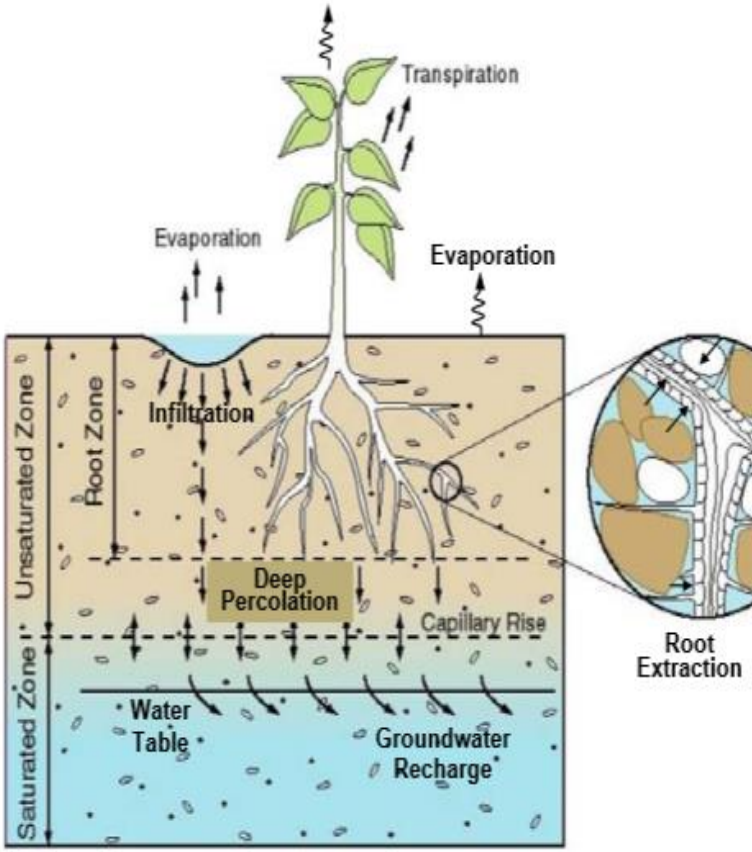
Water-Holding Capacity of Soil
Effect of Soil Texture



Equivalent depth of water (d)

- d = volume of water per unit land area
- $d = \frac{(\theta_v\, A\, L)}{A} = \theta_v\, L$
- d = equivalent depth of water in a soil layer
- L = depth (thickness) of the soil layer

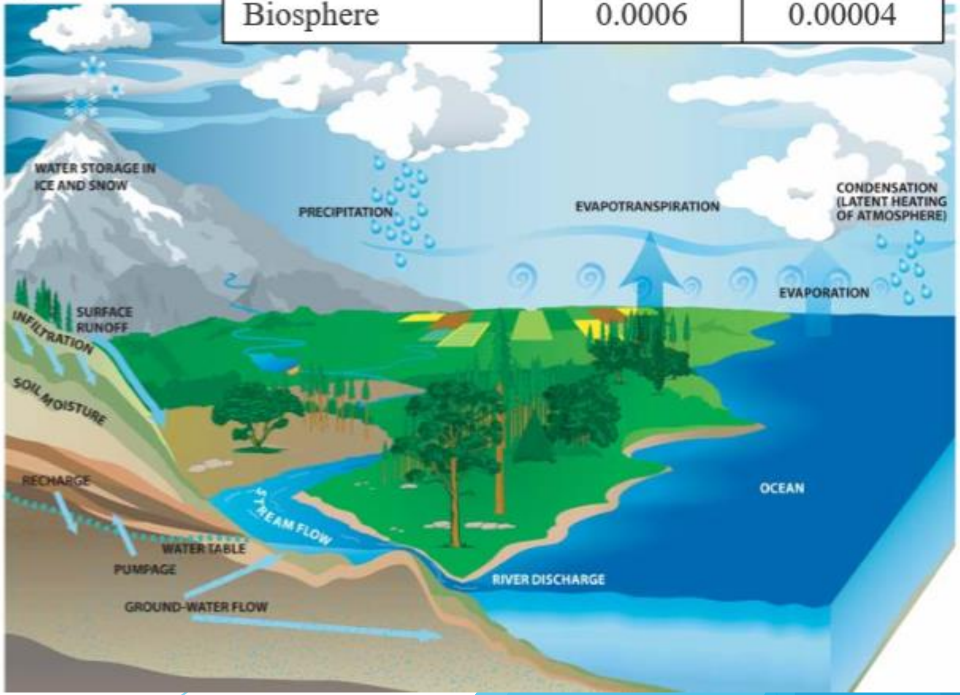
The Hydrological Cycle and Water Balance



The Hydrological Cycle

- The *hydrological cycle* describes terrestrial pathways and transformation of water.
- Evaporation, precipitation, and infiltration replenish soil water storage and recharge groundwater - key life supporting processes.
- The hydrologic cycle is "driven" by solar radiation.
- More than 97% of earth's water is found in oceans; soil water storage is less than 0.005% !
- Residence times in various "hydrological compartments" vary considerably: >10,000yr ice caps; >1000yr deep ground water; <1 yr surface soil water.

Reservoir	Volume (km^3 $x10^8$)	% of Total
Oceans	1370	97.25
Ice Caps & Glaciers	29	2.05
Groundwater	9.5	0.68
Lakes	0.125	0.01
Soil Moisture	0.065	0.005
Atmosphere	0.013	0.001
Streams & Rivers	0.0017	0.0001
Biosphere	0.0006	0.00004

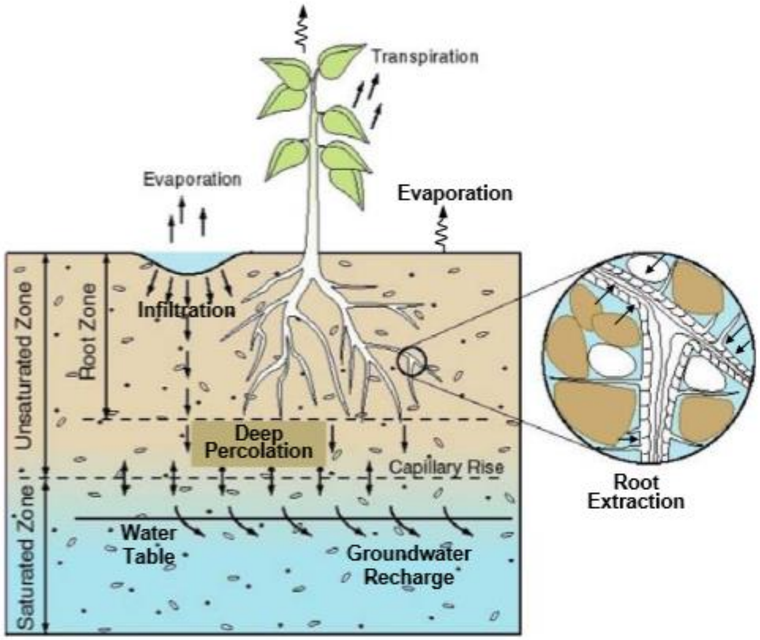


The Water Balance Equation

The primary use of soil water content information is for evaluation of the ***water balance equation*** given as:

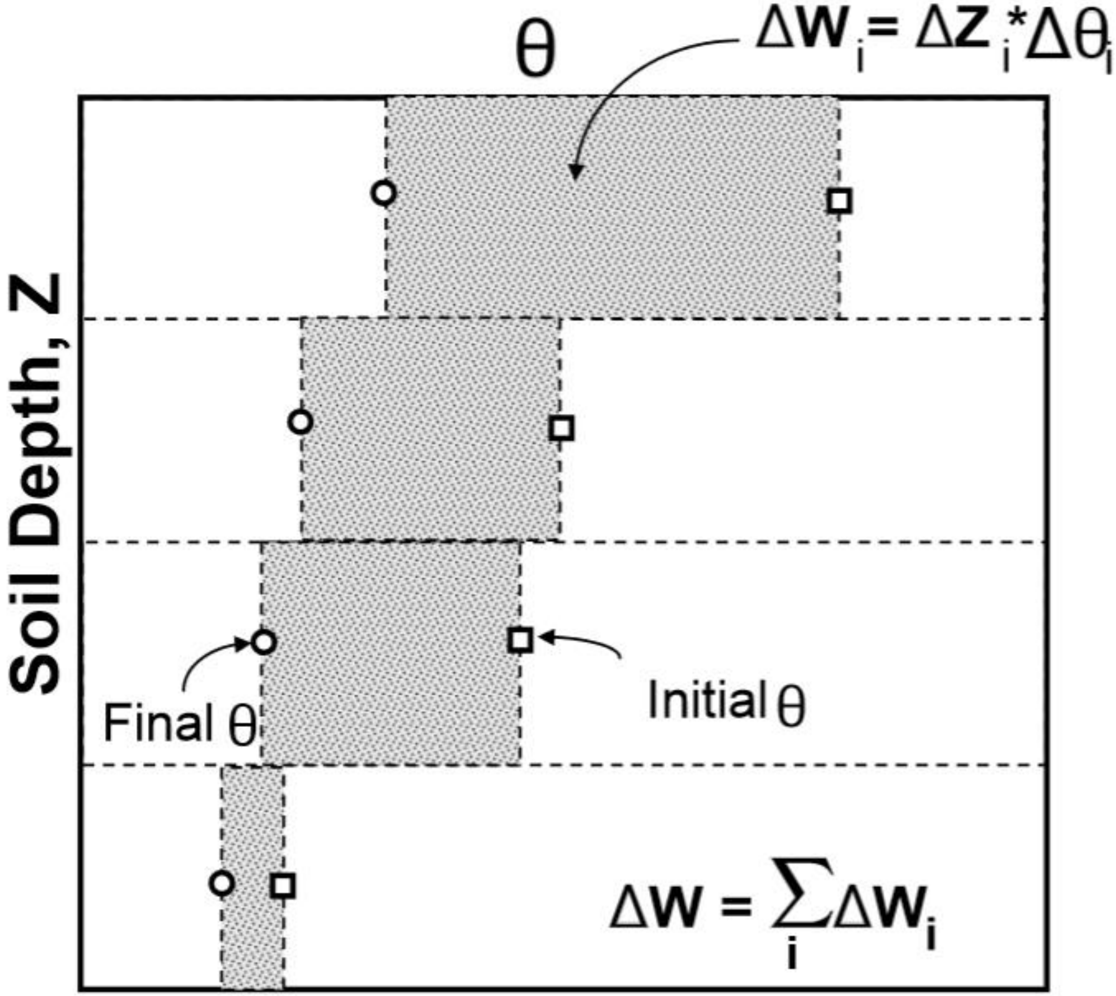
$$P + I = ET + DR + RO - \boxed{\Delta W}$$

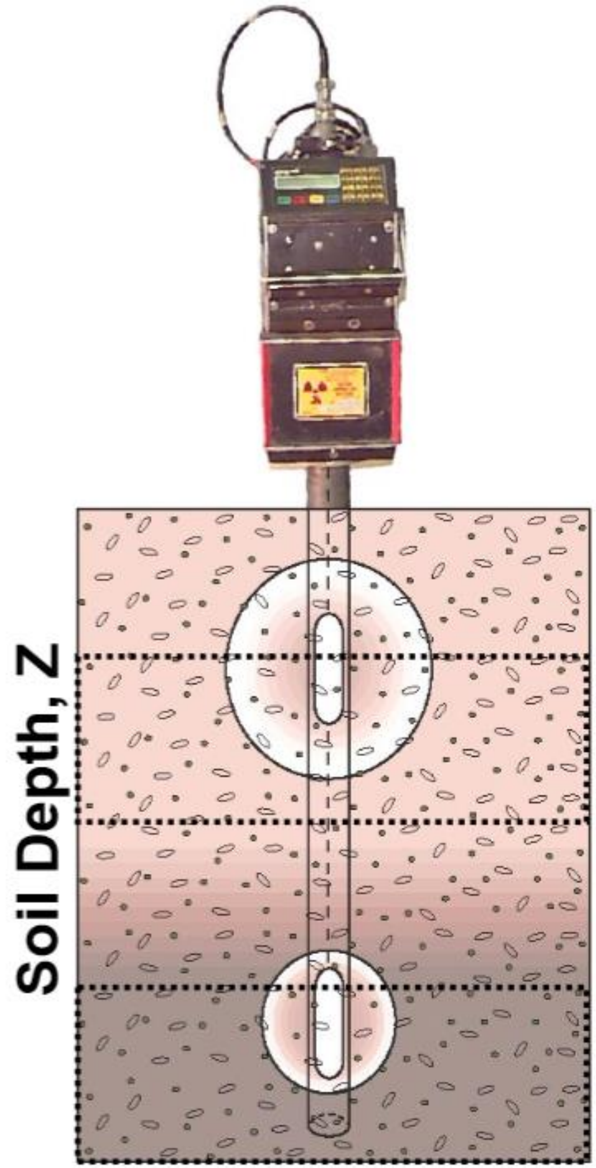
P .... Precipitation
I .... Irrigation
ET .... Evapotranspiration (Soil and Plant)
DR......... Drainage
RO .... Surface Runoff
ΔW .... Change in Water Storage within the Soil Profile (Soil Water Depletion)



- **The concept is based on conservation of mass, balancing inputs and outputs from a soil profile (inputs are taken as positive, outputs negative sign).**
- **Soil water storage W is defined as the <u>equivalent depth</u> of water stored in a certain soil depth.**
- **Changes in storage are calculated for a given time interval (day, year): $\Delta W = W_{initial} - W_{final}$.**
- **Under typical conditions ΔW is fairly significant over short period of times (weeks to months), but generally evens out to zero over one to several years.**

Changes in Soil Water Storage





The Water Balance Equation: Example

Example: Soil Water Balance

Problem Statement:

Estimate the drainage of water below a 2.0 m monitoring depth for the non-vegetated location of a recent chemical spill. Assume that the volumetric soil water content was monitored with a neutron probe having the soil-specific calibration equation:

$$\theta_v = -0.0130278 + 0.207666 \times CR$$

The measured neutron count ratios (CR) for 20 cm depth increments at the beginning and the end of the monitoring period are given as:

Depth [m]	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4	1.4-1.6	1.6-1.8	1.8-2.0
CR-Start	1.50	1.60	1.63	1.72	1.55	1.49	1.28	0.97	0.87	0.96
CR-End	0.90	1.10	1.62	1.68	1.56	1.47	1.30	1.05	0.90	1.10

The cumulative precipitation during the measurement interval was 42 cm, the surface runoff was 3 cm, and the cumulative Evapotranspiration (ET) was 36 cm.

The Water Balance Equation: Example

Solution:

(1) Change in soil water storage

Depth	θ_{vS}	θ_{vE}	θ_{vS}- θ_{vE}	ΔW_i
0.0-0.2	0.298	0.174	0.124	24.92
0.2-0.4	0.319	0.215	0.104	20.77
0.4-0.6	0.325	0.323	0.002	0.42
0.6-0.8	0.344	0.336	0.008	1.66
0.8-1.0	0.309	0.311	-0.002	-0.42
1.0-1.2	0.296	0.292	0.004	0.83
1.2-1.4	0.253	0.257	-0.004	-0.83
1.4-1.6	0.188	0.205	-0.017	-3.32
1.6-1.8	0.168	0.174	-0.006	-1.25
1.8-2.0	0.186	0.215	-0.029	-5.81
			SUM	**36.96**

(2) Drainage below 2.0 m

$$\text{DR} = 420 - 30 - 360 + 37 = 67 \quad [\text{mm}]$$

We can solve this problem by applying the climatic water balance equation:

$$P + I = ET + DR + RO - \Delta W$$

where P is precipitation, I is irrigation, ET is evapotranspiration, DR is drainage, RO is surface runoff, and DW is change in soil water storage. We rearrange the equation to solve for drainage:

$$DR = P + I - ET - RO + \Delta W$$

Since there was no irrigation during the measurement interval, the only unknown is the change in soil water storage DW.

The change in storage can be derived from neutron probe measurements. We first calculate the volumetric water content for each depth increment at the beginning and at the end of the measurement period using the calibration equation. We then take the difference between these θ_v values and calculate the change in storage (it is equal to the change in the equivalent depth of water) for each increment.

$$\Delta W_i = \Delta \theta_i \times D_i$$

The summation over the entire monitoring depth gives the change in soil water storage. [make sure you use the proper sign]

Equivalent Depth of Soil Water D_e

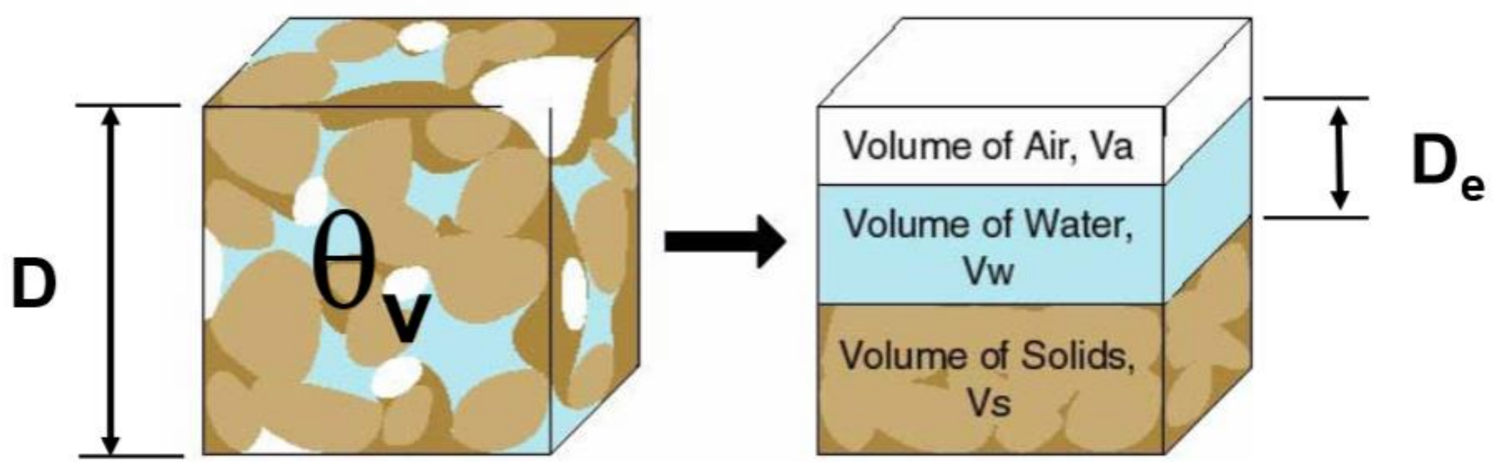
In the context of the water balance equation it is useful to recall the concept of *equivalent depth of soil water* D_e relating volumetric water content to water depth similar to climatic quantities (precipitation, irrigation, evapotranspiration) commonly expressed in equivalent units of water volume per unit soil surface area (or length).

$$D_e = \theta_v \cdot D$$

Where D is the soil depth increment having uniform water content θ_v

D_e is the volumetric water content in a given depth increment expressed as soil water storage (Length)

D_e is very useful in water balance calculations.



The Water Balance Equation: Example

Example: Equivalent Water Depth and Redistribution of Rainfall

Problem Statement:

Calculate the depth that a soil profile, initially at uniform wetness of θ_v=0.17m^3m^{-3}, would be wet to saturated water content of θ_s=0.49 m^3m^{-3} following 120 mm rainfall. Next, calculate depth of soil profile wetting to field capacity water content of θ_{FC}=0.24 m^3m^{-3} following internal redistribution of the added water.

Solution:

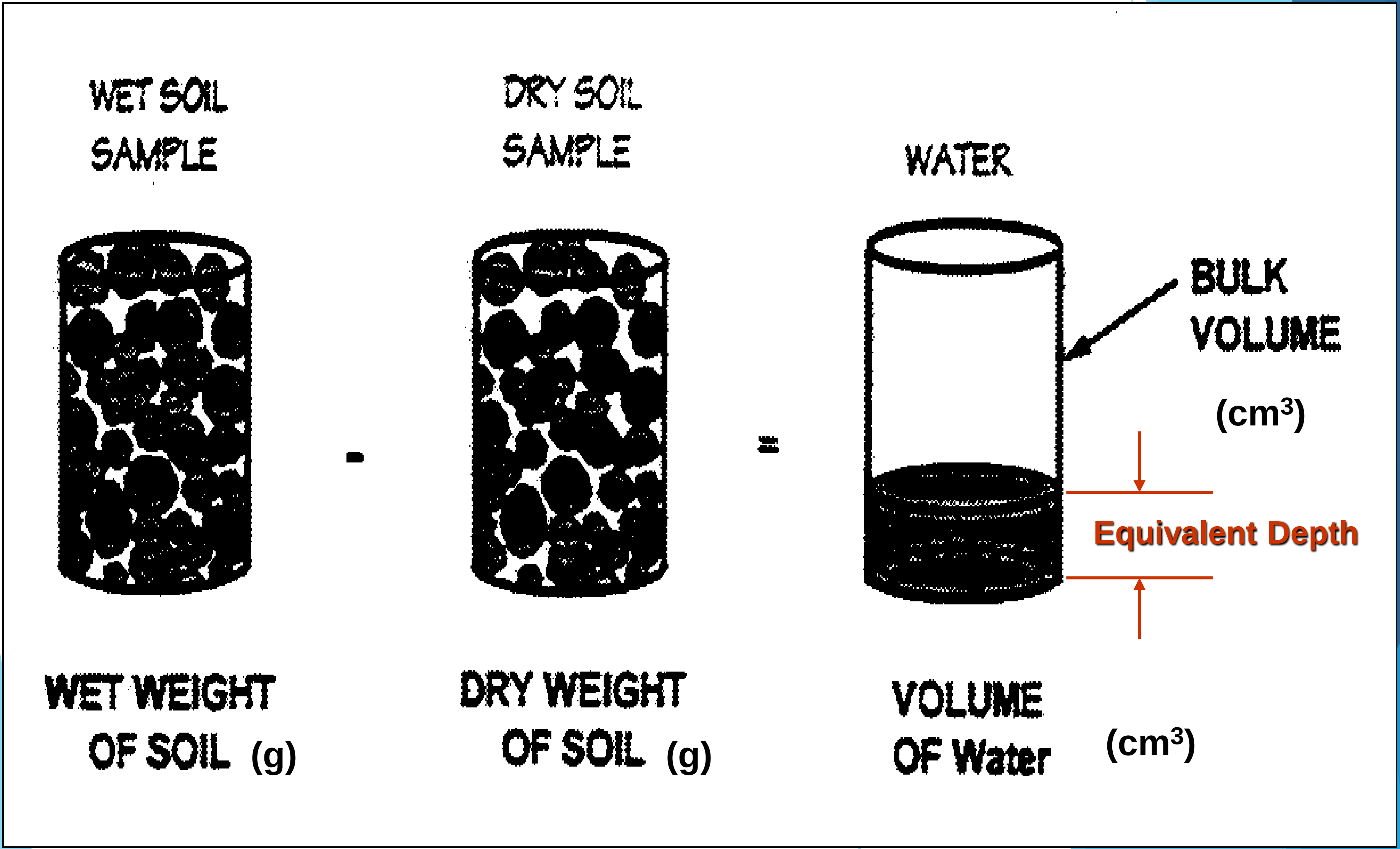
We employ the relationship $D = D_e/\Delta\theta_v$, solving for the soil depth (D) wetted from initial θ_v=0.17 m^3m^{-3} to saturation water content θ_v=0.49 m^3m^{-3} by 120 mm depth equivalent water (D_e). We must consider the initial water content because all pore space is not available for occupancy by the invading water.

$$D_1 = \frac{120\,\text{mm}}{(0.49 - 0.17)} = 37.5\ \text{cm}$$

Next, we calculate redistribution to field capacity using the same relationship:

$$D_2 = \frac{120\,\text{mm}}{(0.24 - 0.17)} = 171.4\ \text{cm}$$

Volumetric Water Content & Equivalent Depth



- Field Capacity (FC or θ_{fc})
  - –Soil water content where gravity drainage becomes negligible
  - –Soil is <u>not</u> 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 الميدانية (FC أو FC) محتوى مياه التربة حيث يصبح تصريف الجاذبية ضئيلا التربة ليست مشبعة ولكن لا تزال حالة رطبة جدا يعرف تقليديا بأنه محتوى المياه المقابلة لإمكانات مياه التربة من -1/10 إلى -1/3 شريط نقطة الذبول الدائمة (WP أو wp) محتوى مياه التربة الذي لا يمكن للنباتات التعافي من الإجهاد المائي (ميت) لا يزال بعض الماء في التربة ولكن ليس بما فيه الكفاية لتكون من استخدامها للنباتات تعرف تقليديا بأنها محتوى المياه المقابلة ل-15 أشرطة من SWP

Available Water

- Definition
  - Water held in the soil between field capacity and permanent wilting point
  - "Available" for plant use
- Available Water Capacity (AWC)
  - AWC = θ_{fc} - θ_{wp}
  - Units: depth of available water per unit depth of soil, "unitless" (in/in, or mm/mm)
  - Measured using field or laboratory methods (described in text)
  - تعريف المياه الموجودة في التربة بين القدرة الحقلية ونقطة الذبول الدائمة "متوفر" للاستخدام النباتي سعة المياه المتاحة (AWC) AWC = □fc - □wp الوحدات: عمق المياه المتاحة لكل وحدة عمق التربة، "بدون وحدة" (في/ في، أو مم / ملم) تم القياس باستخدام أساليب ميدانية أو مختبرية (موضحة في النص)

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)

Gravity vs. Capillarity

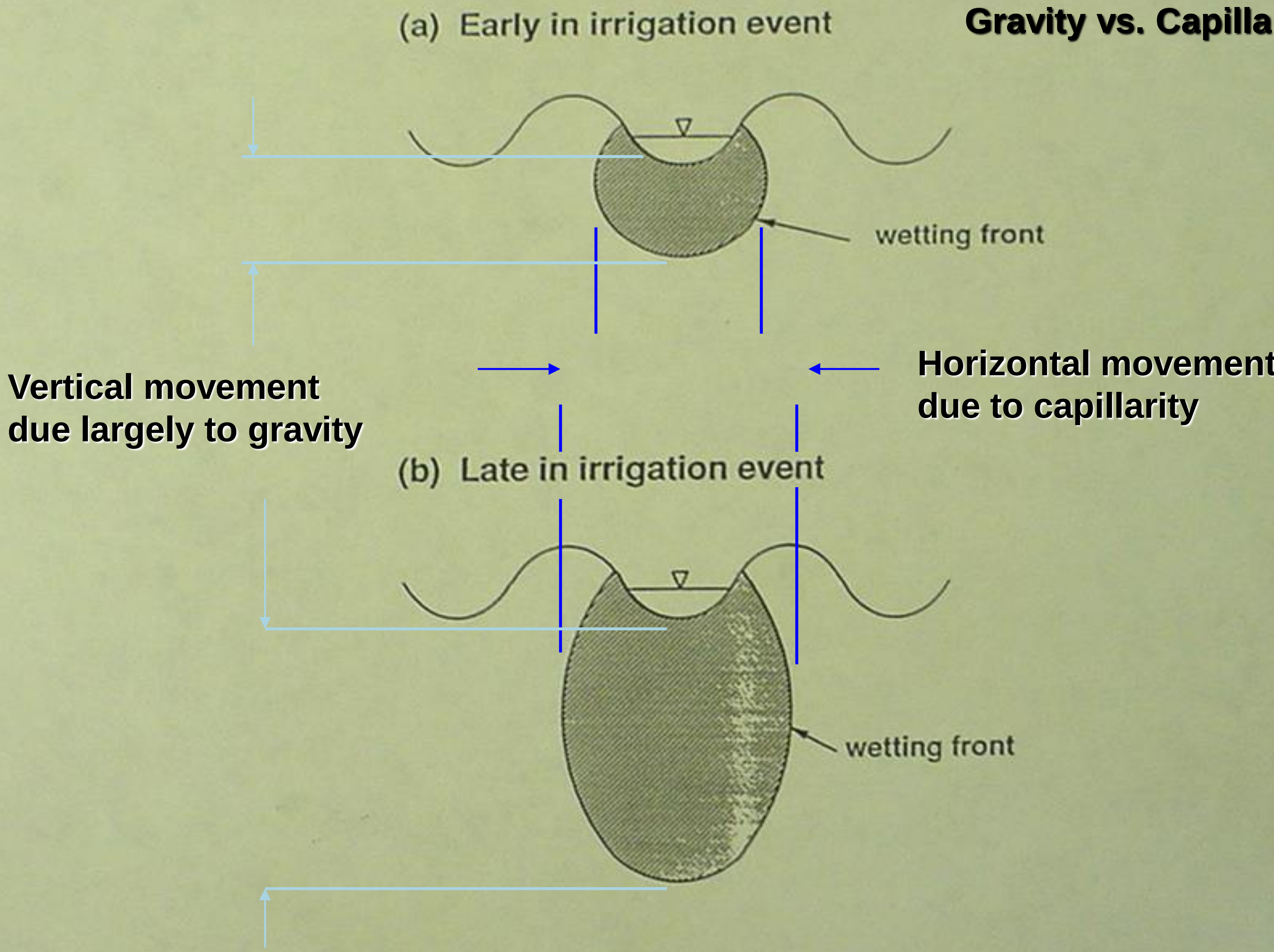


Figure 2.8. Wetting patterns early and late in furrow irrigation water application.

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
  - وصف
  - قياس حالة الطاقة لمياه التربة
  - مهم لأنه يعكس كيف يجب أن تعمل النباتات الصلبة لاستخراج المياه
  - وحدات القياس عادة ما تكون أشرطة أو أجواء
  - إمكانات مياه التربة هي الضغوط السلبية (التوتر أو الشفط)
  - تتدفق المياه من إمكانات أعلى (أقل سلبية) إلى إمكانات أقل (أكثر سلبية)

Soil Water Potential

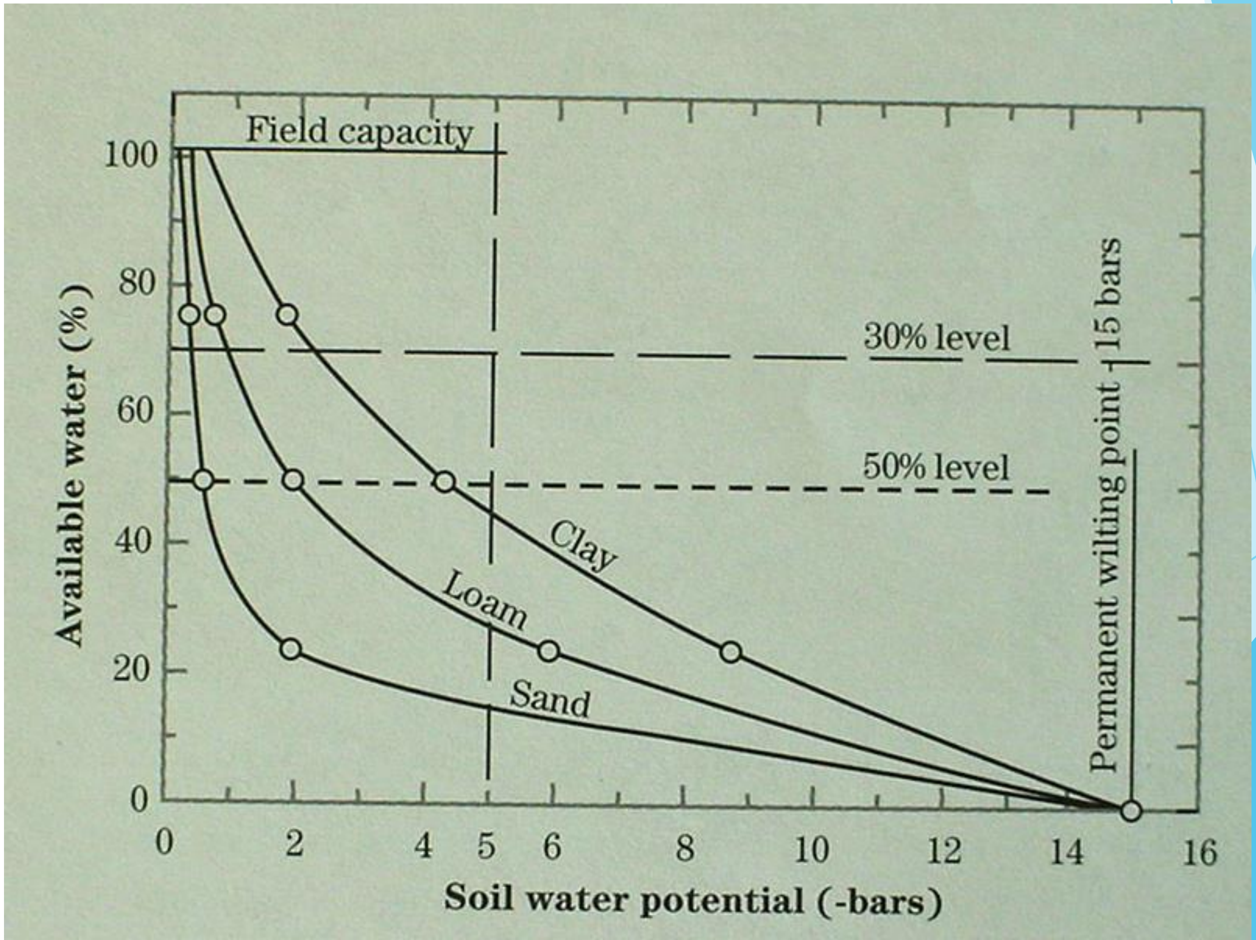
- Components

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

  - 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

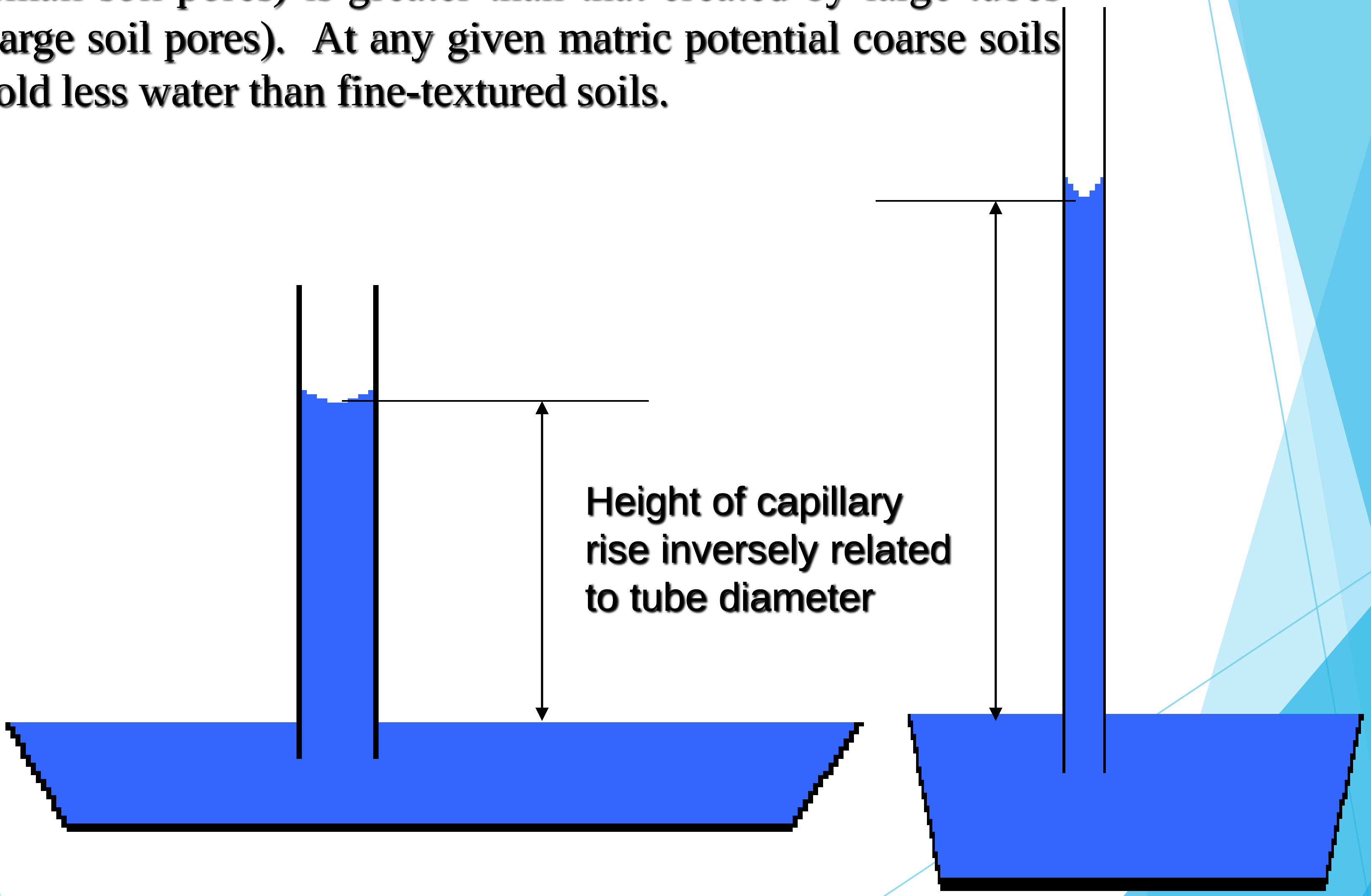
Soil Water Release Curve

- Curve of matric potential (tension) vs. water content
- Less water → more tension مياه أقل يؤدي الى ضغط مسك أكبر
- At a given tension, finer-textured soils retain more water (larger number of small pores) لنفس قيمة ضغط المسك تحتفظ التربة الناعمة مثل الطين بكمية مياه أكبر



Matric Potential and Soil Texture

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



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

Influencing Factors

- Soil texture
- Initial soil water content
- Surface sealing (structure, etc.)
- Soil cracking
- Tillage practices
- Method of application (e.g., Basin vs. Furrow)
- Water temperature


K

AWC = FC - WP

-0.33 bar - (- 15 bar)

% water by vol at Field Capacity = %FC = 55%

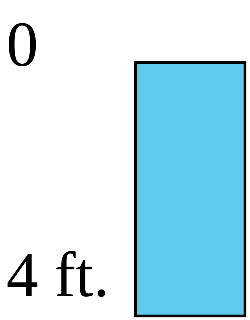
%water by vol at Wilt Point = % WP = 30%

% FC - % WP = % AWC

55%-30% = 25% & (% water x inch soil = inch water)

For 4 feet of soil 25% AWC means that .25 x 48 inch.

= 12 inches of water stored in 48 inches of soil.

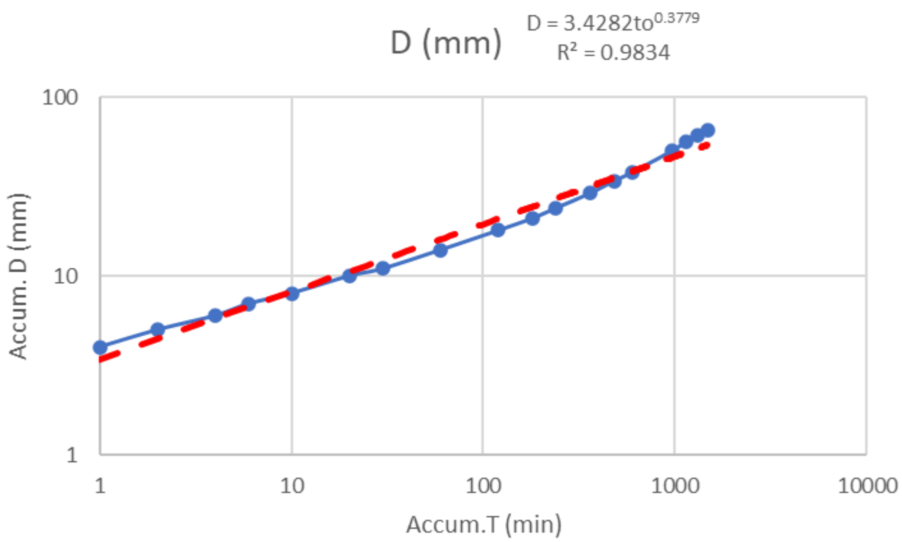


= 12 inches of water available/ 4 feet

Table 4 EXAMPLE CYLINDER INFILTROMETER DATA

Time Readings		Gauge Readings	
Clock	Cumulative	Gauge	Cumulative
hrs	min	mm	mm
0800	0	187	0
0801	1	183	4
0802	2	182	5
0804	4	181	6
0806	6	180	7
0810	10	179	8
0820	20	177	10
0830	30	176	11
0900	60	173	14
1000	120	169	18
1100	180	166	21
1200	240	163	24
1400	360	158	29
1600	480	153	34
1800	600	149	38
2400	960	137	50
0300	1140	131	56
0600	1320	126	61
0840	1480	122	65



$$D = Kt_o^m = 3.4282t_o^{0.3379}$$

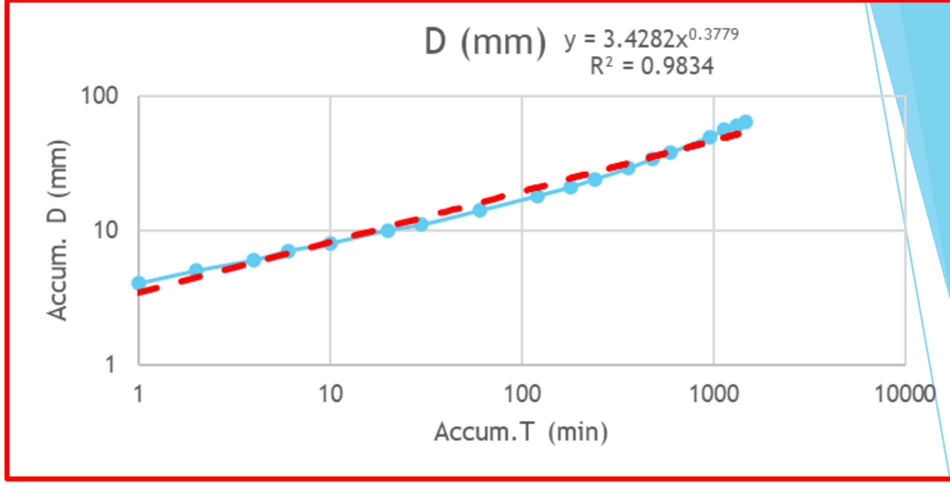
$$\frac{dD}{dt} = I = Kt_o^m = m.K.\,t_o^{m-1} = 0.3379 \times 3.4282t_o^{-0.6621}$$

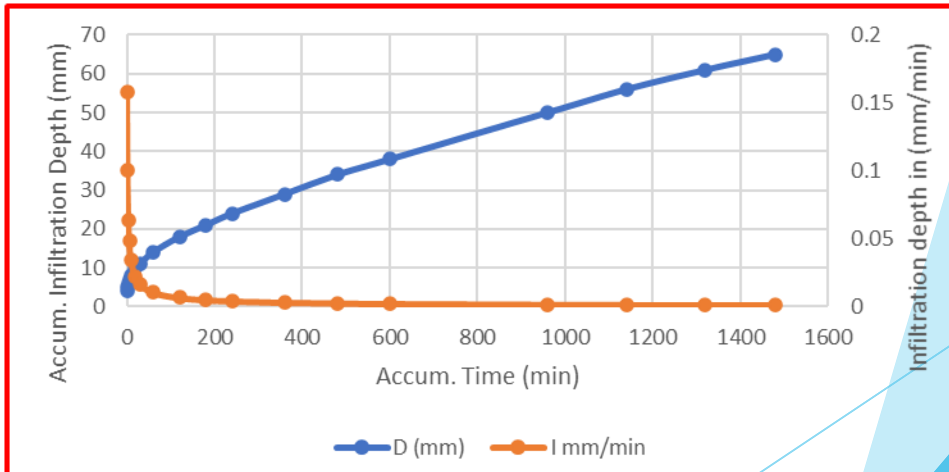
$$I = 1.1583t_o^{-0.6621}$$

$$D = Kt_o^m = 3.4282t_o^{0.3379}$$

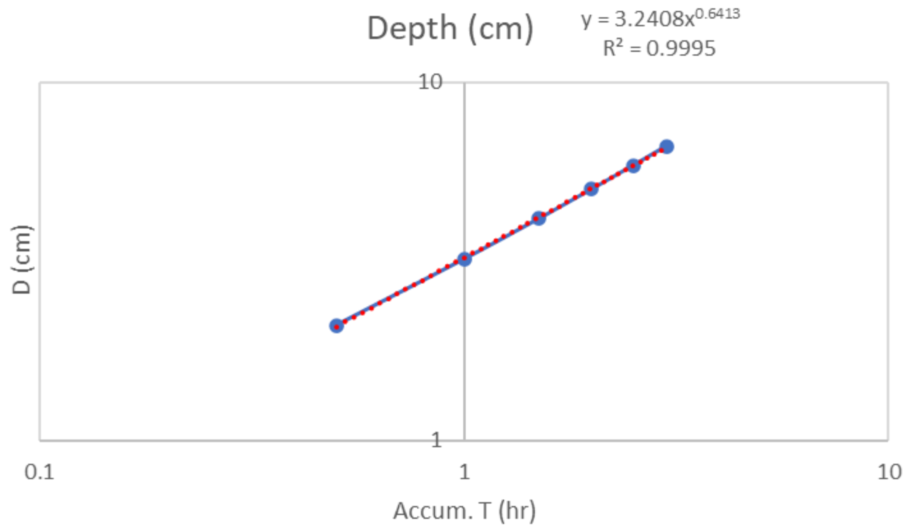
$$I = 1.1583t_o^{-0.6621}$$

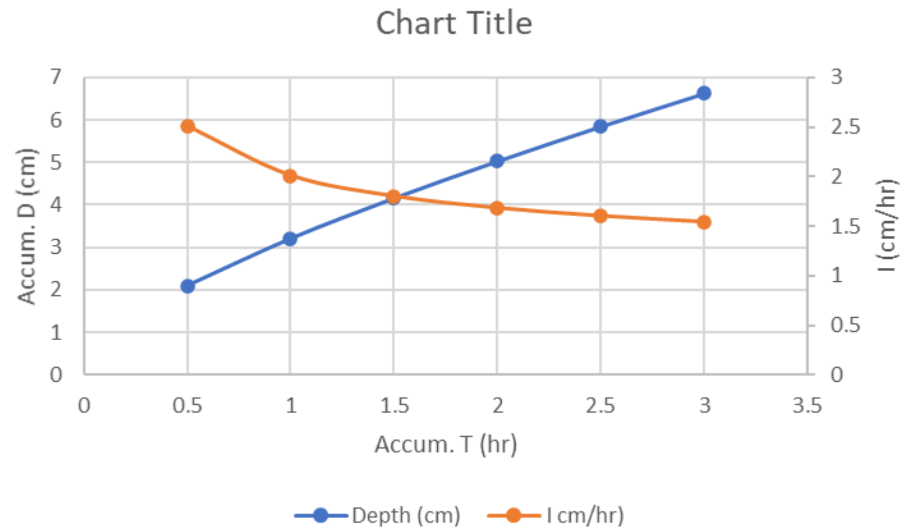
T (min)	D (mm)	I mm/min
1	4	0.1583
2	5	0.10003891
4	6	0.06322036
6	7	0.04833558
10	8	0.03446521
20	10	0.02178056
30	11	0.01665248
60	14	0.01052366
120	18	0.00665051
180	21	0.0050847
240	24	0.00420284
360	29	0.00321331
480	34	0.00265602
600	38	0.00229122
960	50	0.00167849
1140	56	0.00149797
1320	61	0.00135941
1480	65	0.00126023

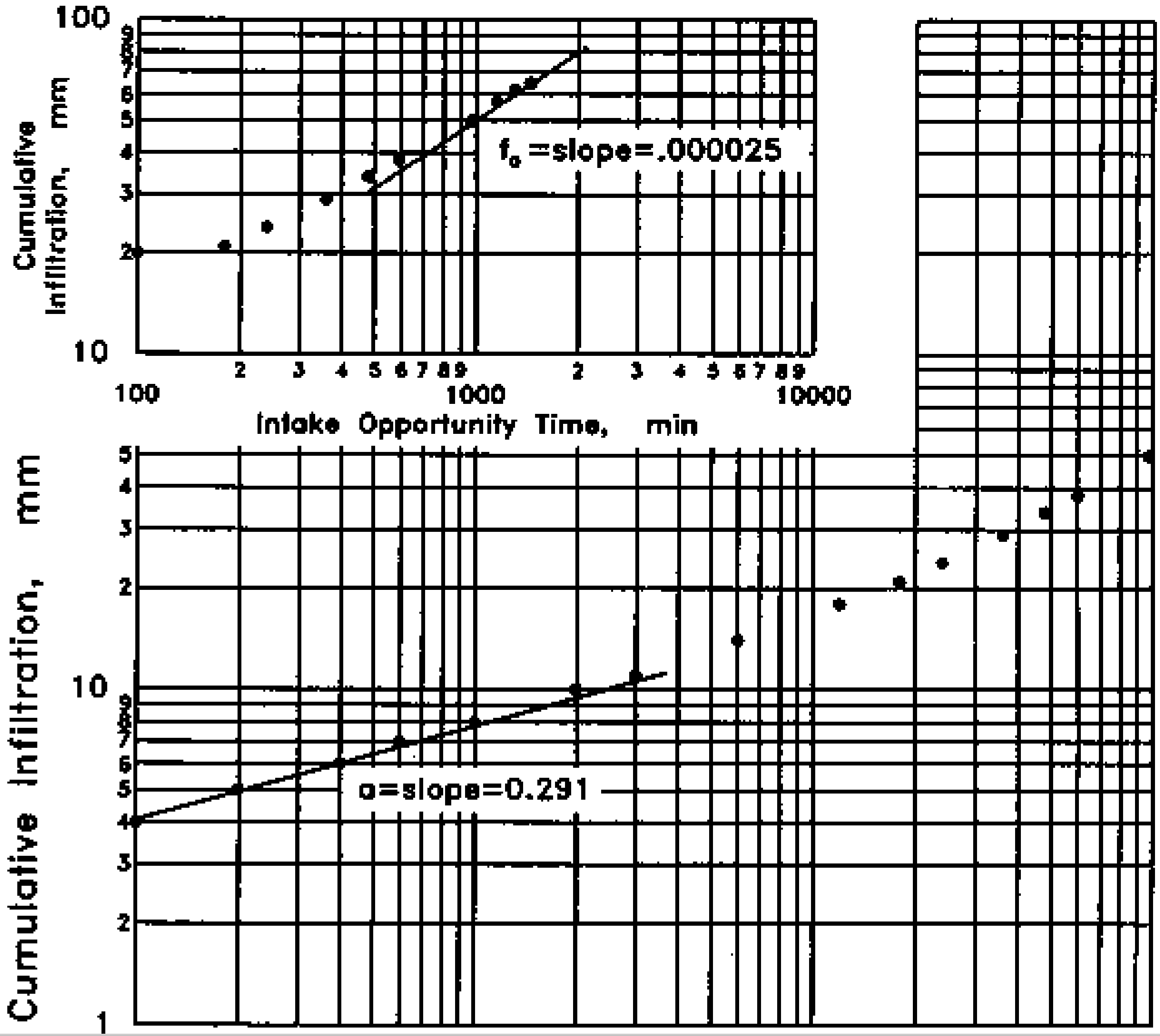




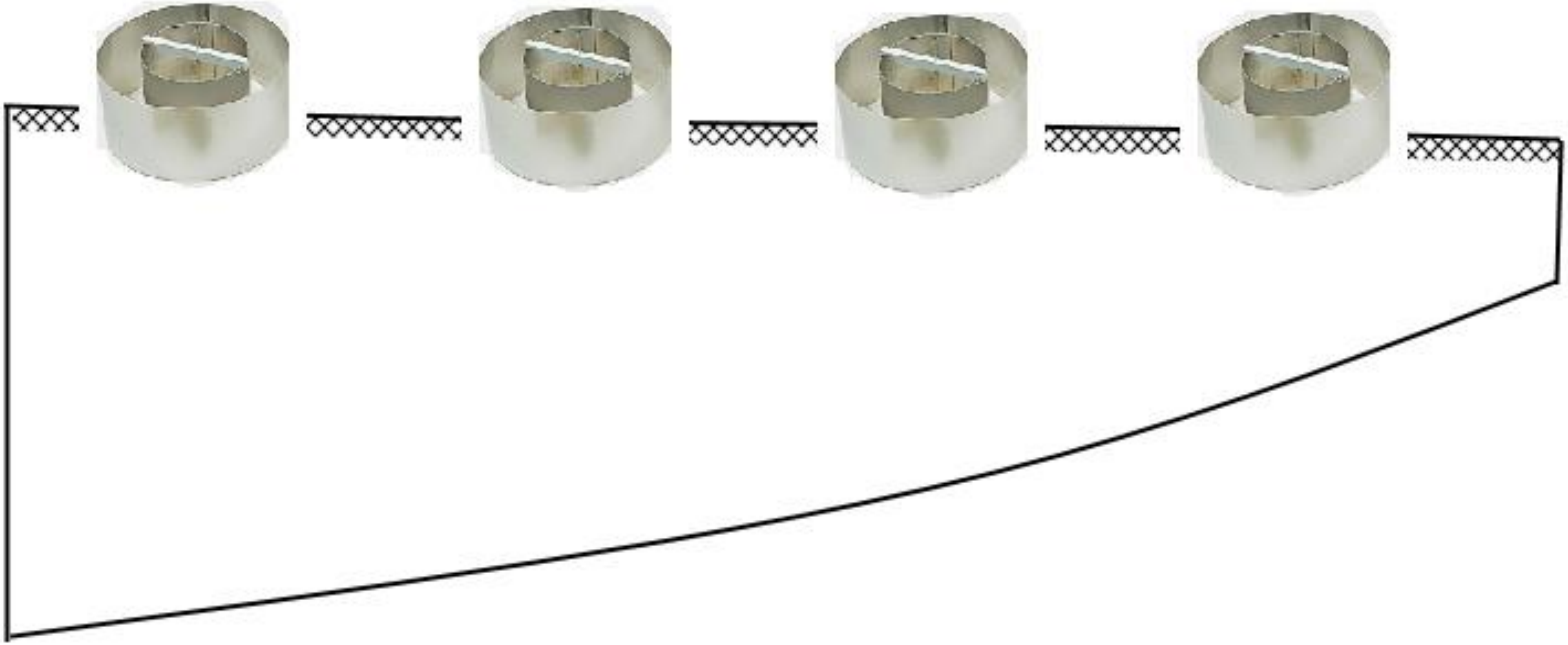
T (hr.)	Depth (cm)	I cm/hr)
0.5	2.1	2.51
1	3.21	2.01
1.5	4.16	1.8
2	5.03	1.68
2.5	5.85	1.6
3	6.63	1.54



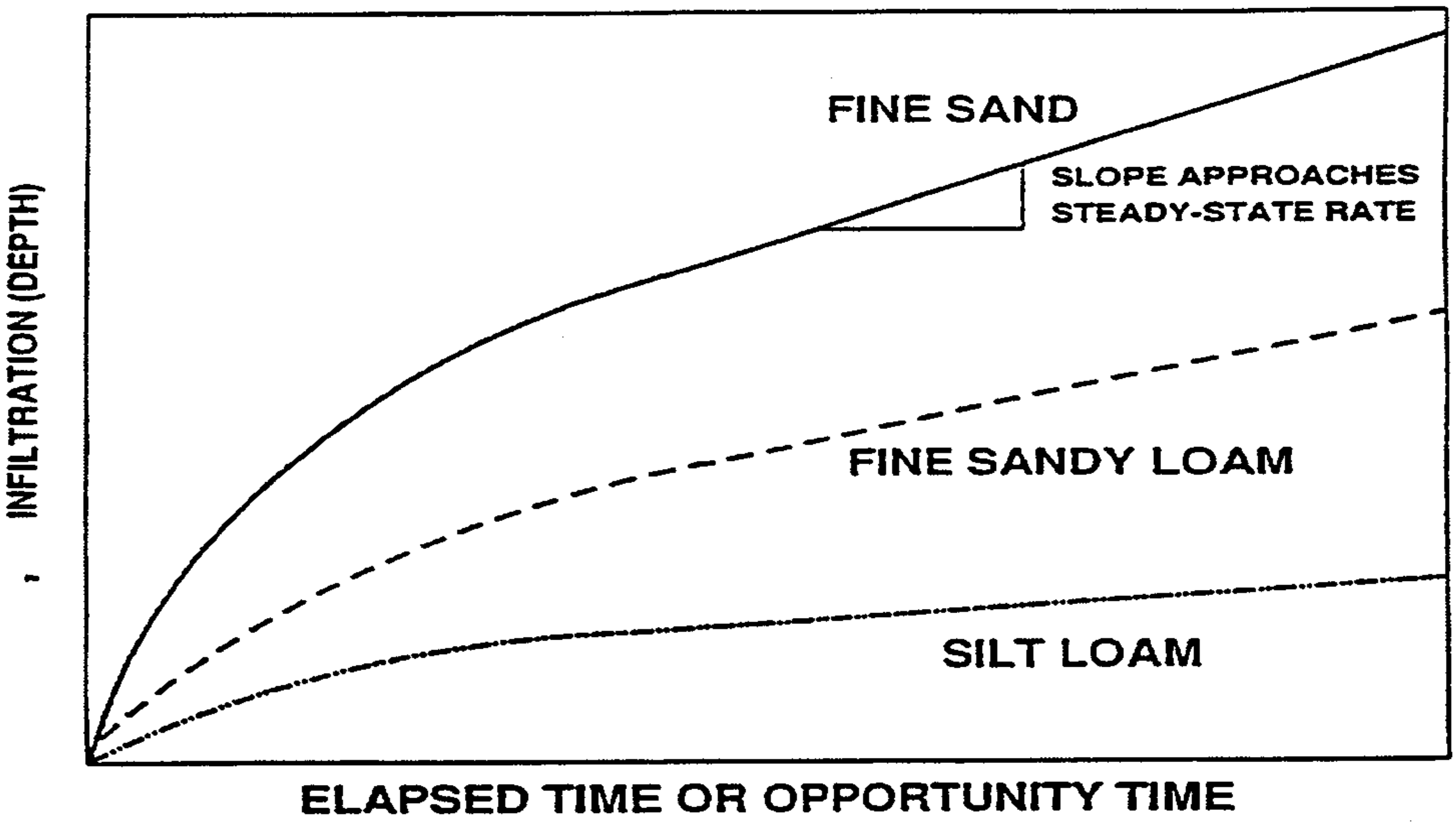



Cumulative Infiltration, mm
100
10
f_o =slope=.000025
100
1000
10000
Intake Opportunity Time, min
Cumulative Infiltration, mm
10
1
a=slope=0.291

- log(9.50) = **a** log (20)
  log(3.975) = **a** log (1) and by simultaneous solution:
- Thus,
- **Z** = 0.003975 $r^{.291}$ + 0.000025 r



Cumulative Infiltration Depth vs. Time
For Different Soil Textures



Infiltration Rate vs. Time
For Different Soil Textures

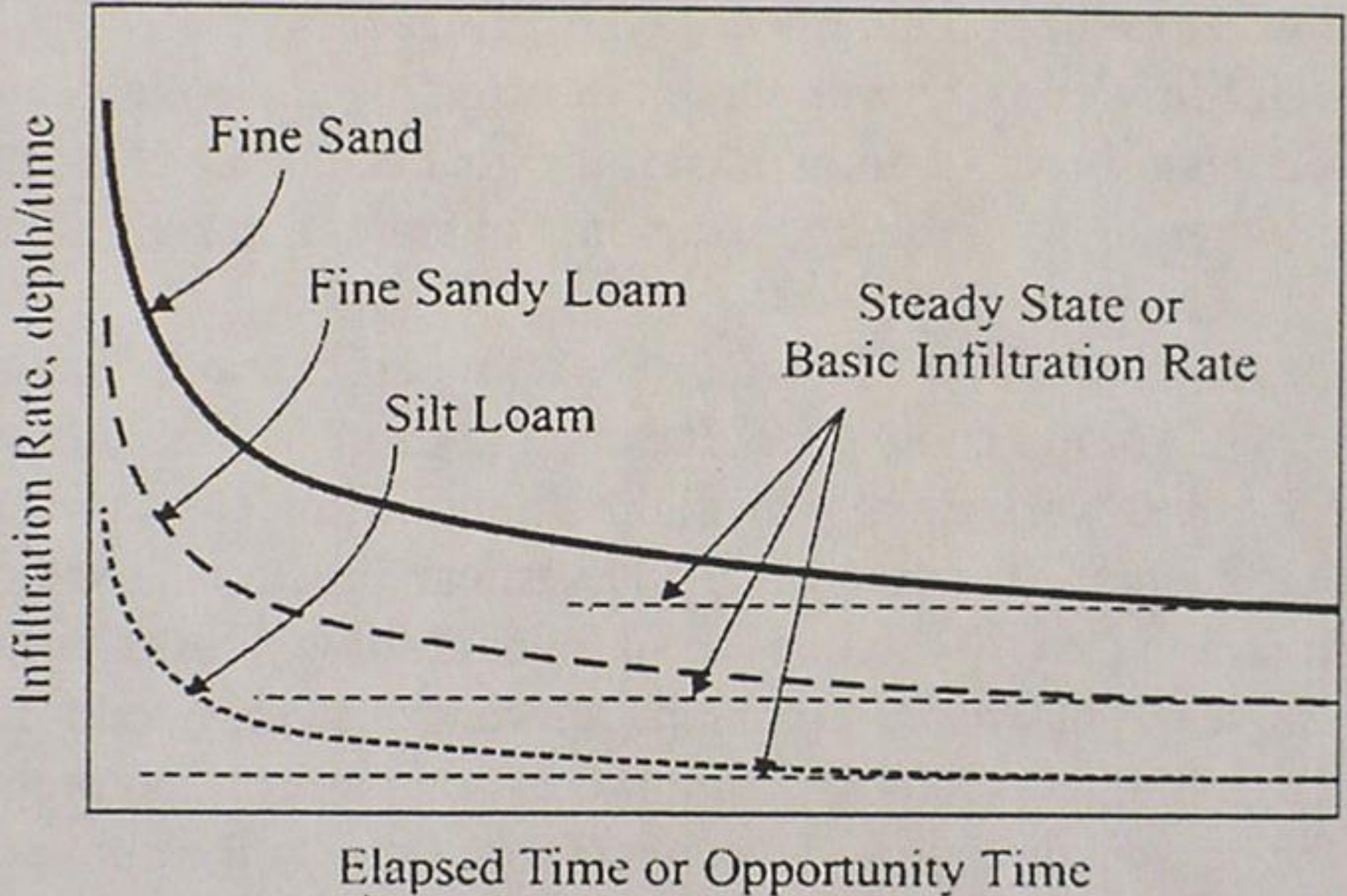


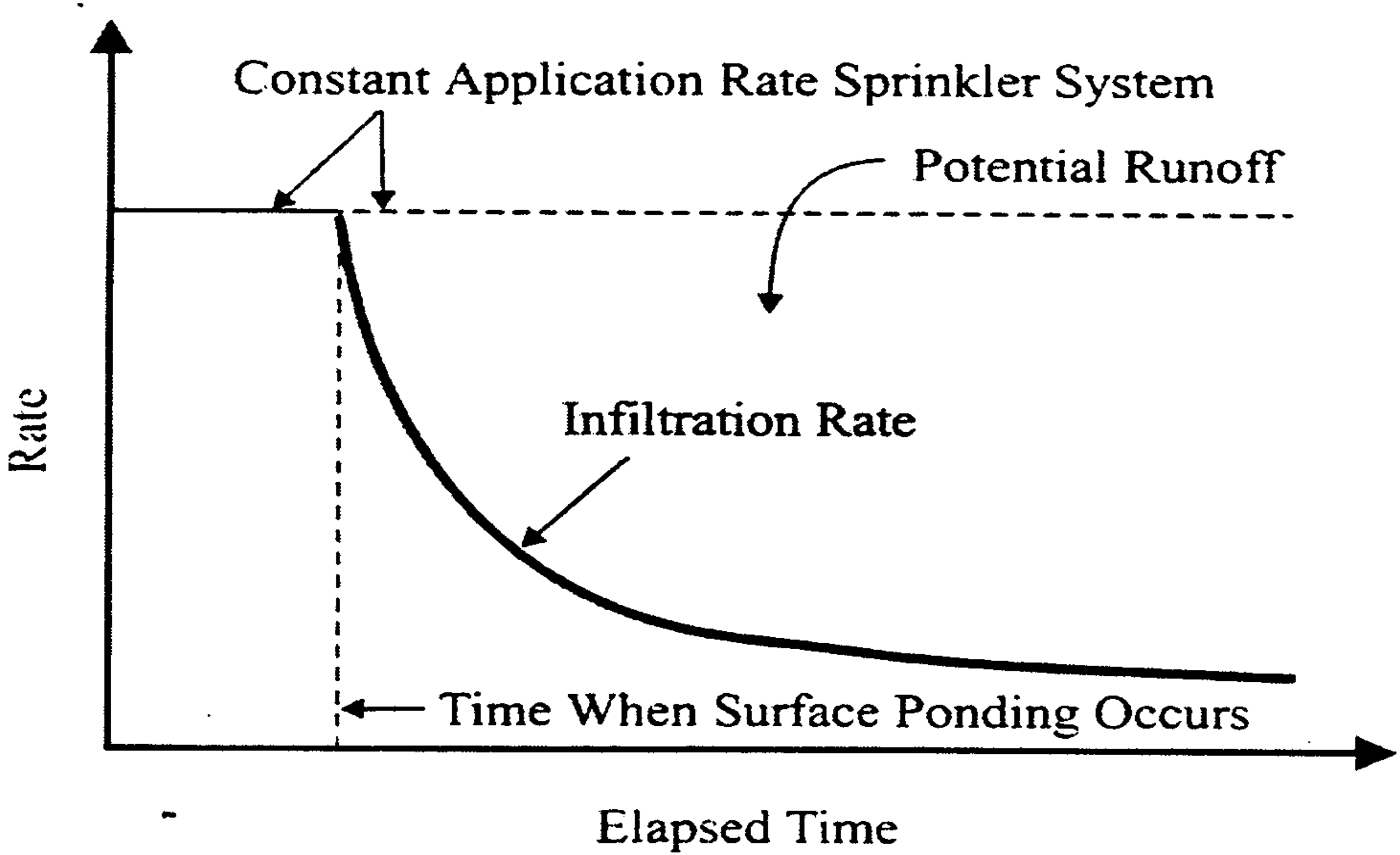
Figure 2.9. Infiltration rate vs. opportunity time.

Water Infiltration Rates and Soil Texture

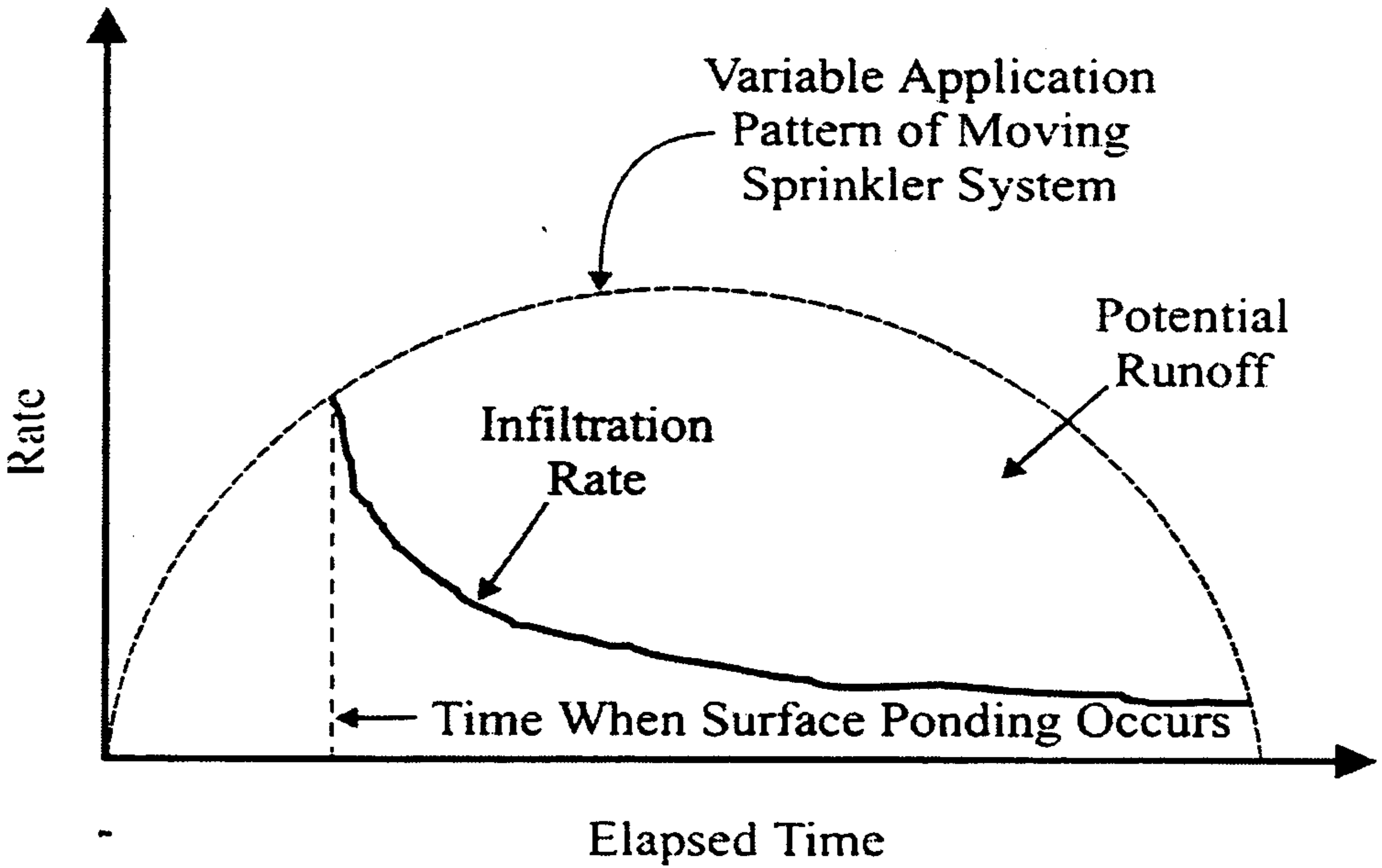
Table 2.4. Basic infiltration rates for stationary sprinkler systems. (Adapted from Pair, 1983.)

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



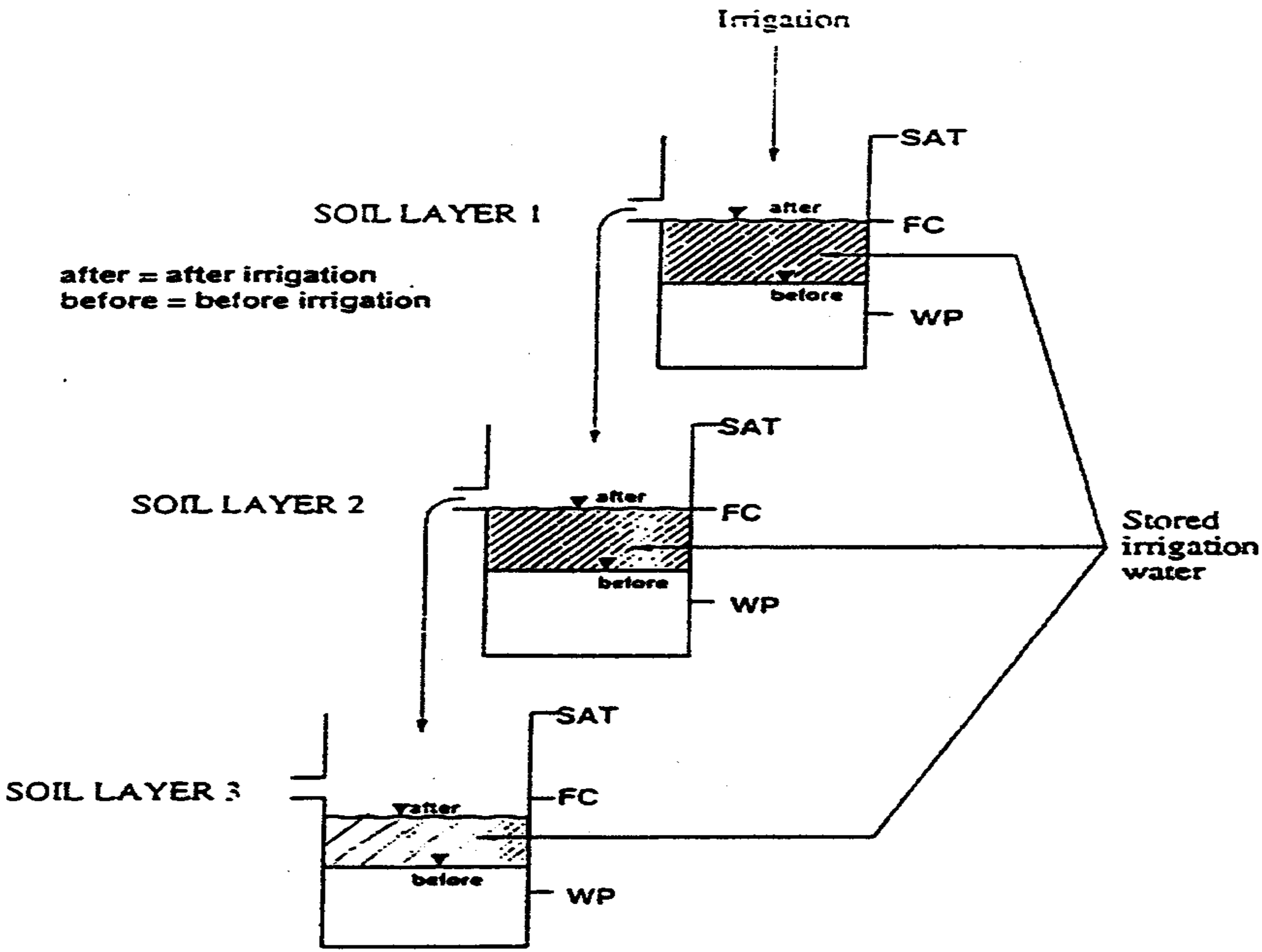
Soil Infiltration Rate vs. Variable Irrigation Application Rate



Depth of Penetration

- 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

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).

Example 3.10 *Find the capacity o f a soil for the following data:*

Root zone depth = 2m

Existing water content = 5%
Dry density o f soil = 1.5 g/ m3
Water applied to the soil = 500 m3
Water loss due to evaporation etc.= 10%
Area o f plot =1000 sq.meters.

Solution.

Total water applied = 500 m3

Loss of water =10%

∴ Water used in the soil

$$= 500 \times \frac{90}{100} = 450 \ m^3$$

$$= 450 \times 10^6 \ g$$

Total dry weight of the soil

$$= 1000 \times 2 \times 1.5 \times 10^6 \ g$$

∴ % of water added

$$= \frac{450 \times 10^6}{1000 \times 2 \times 1.5 \times 10^6} \times 100$$

$$= 15 \ \%$$

∴ New water content

$$= 5\% + 15\% = 20\%$$

∴ Field capacity = 20 %

Example 3.11. *After how many days will you supply water to soil (clay loam) in order to ensure efficient irrigation of the given crop, if*

(*i*) *Field capacity of soil = 27%*

(*ii*) *Permanent wilting point = 14%*

(*iii*) *Density of soil =1.5 g/cm^3*

(*iv*) *Effective depth of root zone =75 cm*

(*v*) *Daily consumptive use of water for the given crop =11 mm.*

Solution.

Available moisture = Field capacity − permanent wilting point

= 27 − 14 = 13%

Let the *readily available moisture* be 80% of the available moisture.

∴ Readily available moisture = 13 × 0.8 = 10.4%

∴ Optimum moisture

$$=27-10.4=16.6\%$$

Hence when irrigation water is applied, moisture is raised from 16.6 to 27%.

∴ Depth of water stored in root zone, during each watering

$$=\frac{\gamma_d}{\gamma_w}\text{ [Field capacity} - \text{Optimum water content]}$$

$$=\frac{\gamma_d}{\gamma_w}\left[0.27-0.166\right]\text{ metres}$$

$$=\frac{1.5\times 0.75}{1}\times 0.104=0.117\text{ m}$$

$$=11.7\text{ cm}$$

Thus, depth of water available for evapo-transpiration

$$=11.7\text{ cm}$$

Daily consumptive use of water

$$=1.1\text{ cm}$$

∴ Watering frequency

$$=\frac{11.7}{1.1}\approx 10\text{ days.}$$

Hence, water should be applied after every 10 days.

Example 3.12 *A loam soil has field capacity of 22% and wilting coefficient of 10%. The dry unit weight of soil is 1.5 g/cm³. If the root zone depth is 70 cm, determine the storage capacity of the soil. Irrigation water is applied when moisture content falls to 14%. If the water application efficiency is 75% determine the water depth required to be applied in the field.*

Solution

Maximum storage capacity = Available moisture

$$= \frac{\gamma_d}{\gamma_w} [\text{Field capacity} - \text{Wilting coefficient}]$$

$$= \frac{1.5 \times 0.70}{1} [0.22 - 0.10] \text{ metres}$$

$$= 0.126 \text{ m} = 12.6 \text{ cm}$$

Depth of irrigation water

$$= \frac{\gamma_d}{\gamma_w} [\text{Field capacity} - \text{Optimum m.c.}]$$

$$= \frac{1.5 \times 0.7}{1} [0.22 - 0.14] \text{ metres}$$

$$= 0.084 \text{ m} = 8.4 \text{ cm}$$

Field irrigation requirement

$$= \frac{8.4}{0.75} = 11.2 \text{ cm.}$$

Sample Problem: Gravimetric determination of soil water

- Wt. of cylinder + oven dry soil = 240g
- wt. cylinder at field capacity =350g
- wt cylinder at wilt point = 300
- Wt cylinder on June 1 = 320
- volume cylinder = 200 cc
  - Or Wet------------FC----------field June 1----wp----------air dry

    350 320 300
- BD = 240/200 = 1.2 g/cc
- % water by wt. at FC = ((350-240)÷240)x100 = 45.8%
- % water by vol at FC = ((350-240) ÷200) x100 = 55%
- and (%water by wt.) X (BD) = % water by Vol
- Or 45.8 X 1.2 = 55%
- % water by vol at WP = ((300-240) ÷200) x100 = 30%

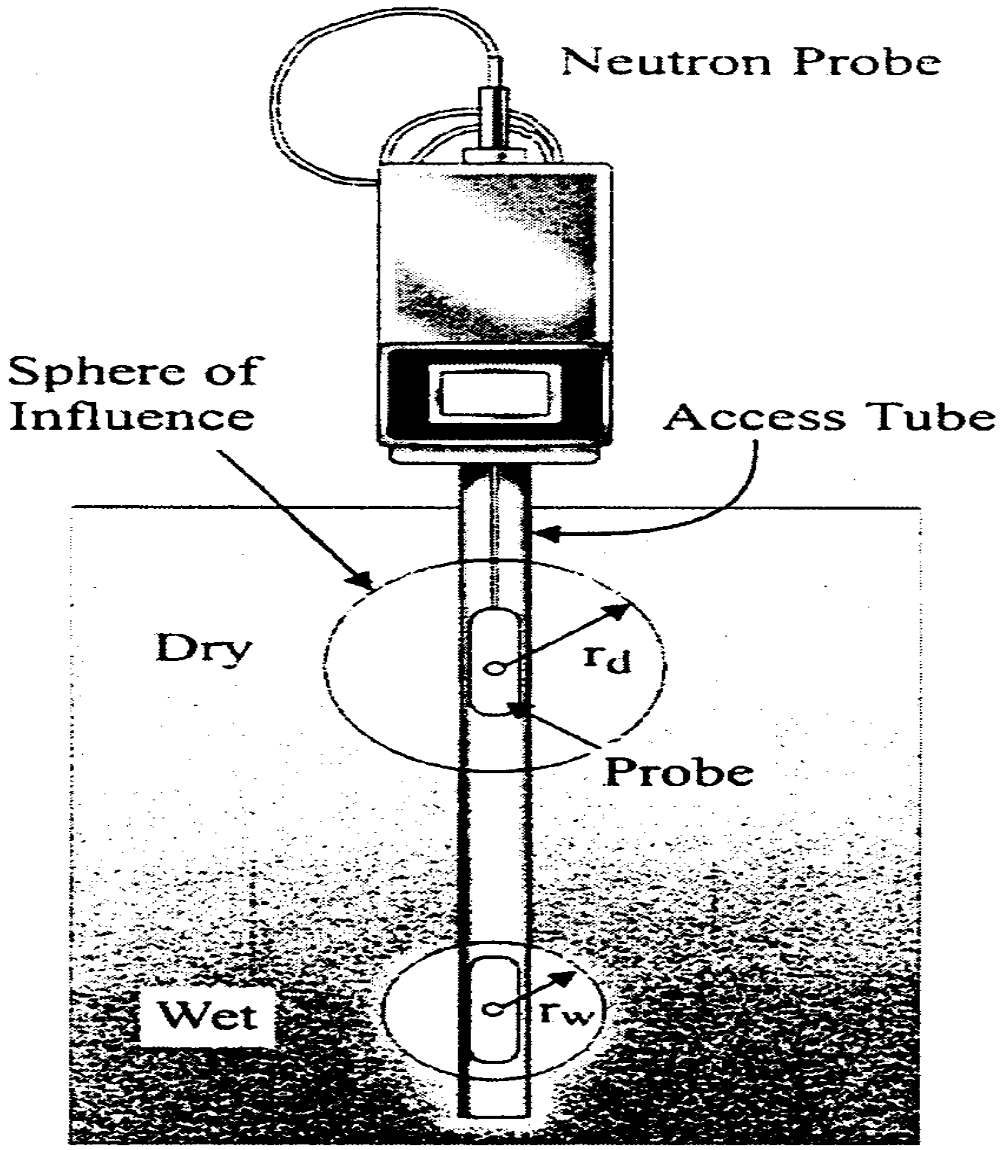
Soil Water Measurement

- Gravimetric
  - Measures mass water content (θ_m)
  - Take field samples → weigh → oven dry → 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

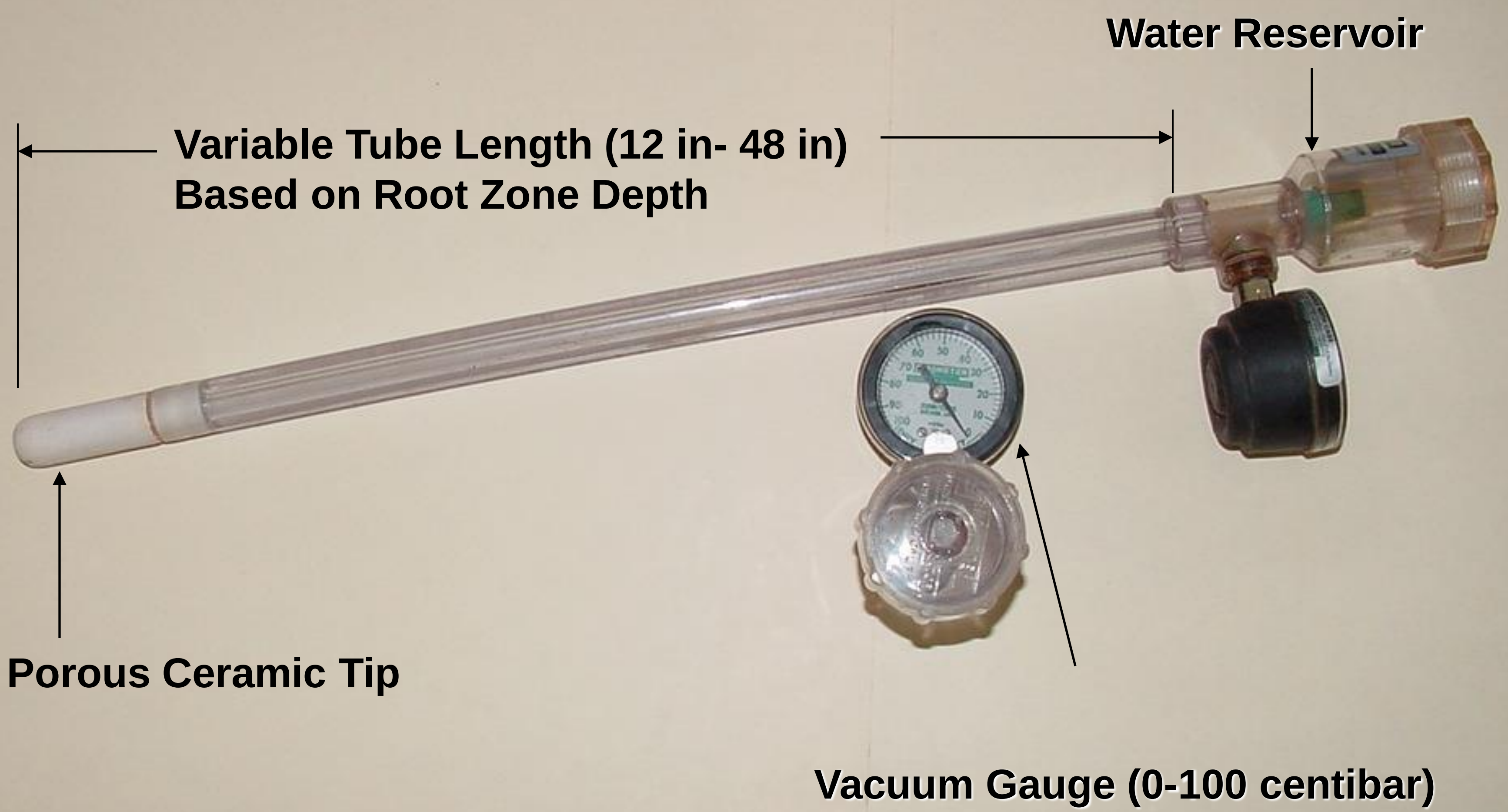
Soil Water Measurement
Neutron Attenuation



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

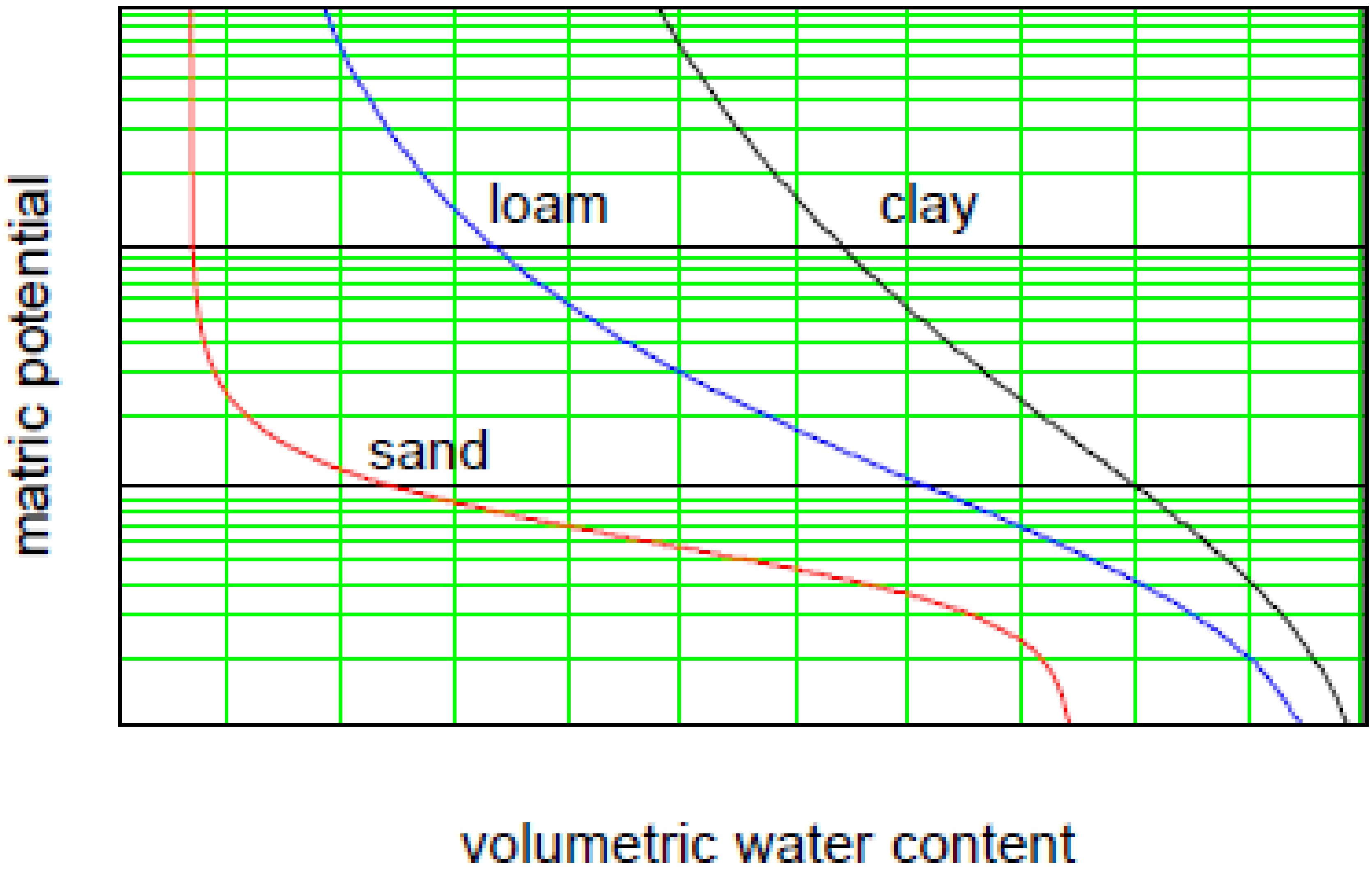
Tensiometer for Measuring Soil Water Potential

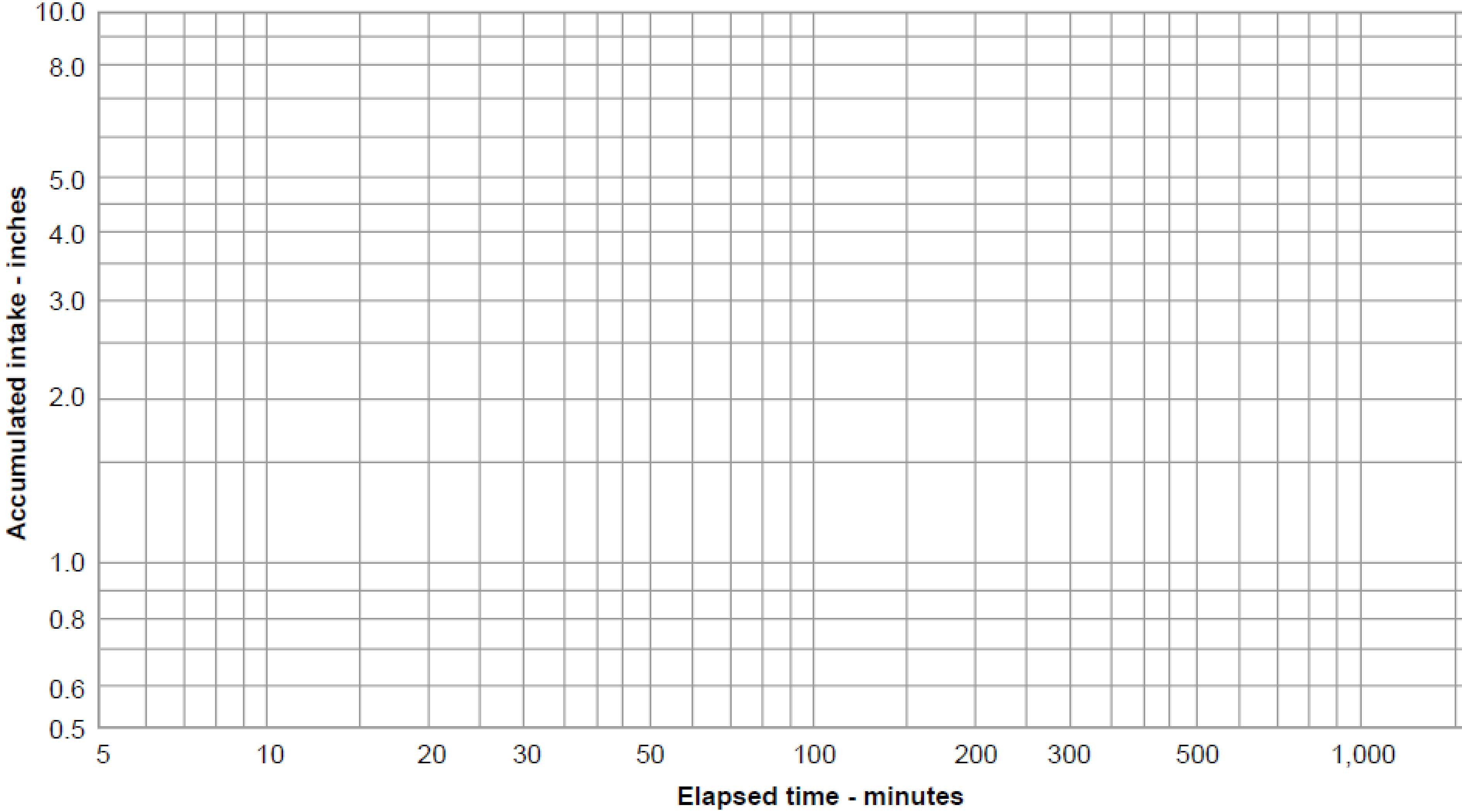


Electrical Resistance Blocks & Meters

S. No.	Description	Determination No.		
		I	II	III
1	Weight of empty container (W_1) in g	20.12	20.08	20.00
2	Weight of container + Wet soil (W_2) in g	44.12	44.11	46.10
3	Weight of container + Dry soil (W_3) in g	41.18	41.16	43.01
	CALCULATION:			
1	Weight of water $= W_2 - W_3$	2.94	2.95	3.09
2	Weight of solid $= W_3 - W_1$	21.06	21.08	23.01
3	Water content $w = \frac{W_2 - W_3}{W_3 - W_1} \times 100\%$	13.96	13.99	13.43
	Average value		13.79%	

Soil Water Characteristic Curves





Accumulated intake - inches
10.0
8.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
5
10
20
30
50
100
200
300
500
1,000
Elapsed time - minutes

Surface Irrigation

①

Ex: The following particulars are used for furrow irrigation:

Inflow = 0.8 L/sec

advance function $X = 9.5\, t^{0.555}$

Equivelant Infiltration function $I_e = 90\, t^{-0.5}$

I_e = mm/hr , t (min)

Net depth of irrigation = 60 mm

furrow interval = 1 m

Determine:

1- equivelant depth of infiltration function:

$$\frac{dd}{dt} = 90\, t^{-0.5} \Rightarrow \int dd = \int 90\, t^{-0.5}\, dt$$

$$d = 90\, \frac{t^{-0.5+1}}{-0.5+1} \Rightarrow d = 180\, t^{0.5} = \frac{180}{60}\, t^{0.5}$$

$$d = 3\, t^{0.5}$$

2- Determine the following when the length of furrow 125 m and 250 m

i- time of irrigation

from infiltration function with NDI = 60 mm

the T_n = 400 min

advance time for L = 125 m , T_{125} = 104 min

at L = 250 ⇒ T_{250} = 362 min

$T_a(125)$ = 504 min , $T_a(250)$ = 762 min

ii- gross depth of irrigation

$$D_g = 60 \times q \times T_a / (S_f \times L) \quad \text{where } S_f = 1.$$

$D_g(125)$ = 194 mm , $D_g(250)$ = 146 mm

(2)

iii- average depth of Equivalent infiltration

$$D = 3\, t^{0.5}$$

$$D_{125} = 3\,(504)^{0.5} = 67\ mm$$

$$D_{250} = 3\,(762)^{0.5} = 83.0\ mm$$

average depth of surface flow

$$Da = (Do + D_L)/2$$

$$Da_{125} = \frac{67+60}{2} = 63.5\ mm \quad 64$$

$$Da_{250} = \frac{83+60}{2} = 71.5\ mm \quad 71$$

iv : average of surface runoff

$$D_r = D_g - D_a$$

$$D_{r_{125}} = 194 - 64 = 130 \text{ mm}$$

$$D_{r_{250}} = 146 - 71 = 75 \text{ mm}$$

v : Average deep percolation depth :

$$D_p = D_a - D_n$$

where

D_a : average of infiltration depth

D_n : net depth of irrigation

$$D_{p_{125}} = 64 - 60 = 4 \text{ mm}$$

$$D_{p_{250}} = 71 - 60 = 11 \text{ mm}$$

vi : Irrigation efficiency

$$E\% = \left(D_n / D_g \right) \times 100$$

$$E_{125} = \frac{60}{194} \times 100 = 31\%$$

$$E_{250} = \frac{60}{146} \times 100 = 41\%$$

3- Determine final average flow

The reduce of the time of flow based upon the time of irrigation (Ta) and the of advance water to the end of furrow. and then the reduction time may be one of the following

$T_c = T_a/2$, $T_a/3$, $T_a/4$ and under the condition

$T_c \geq T_L$

$T_c = \frac{1}{2} T_a = \frac{1}{2} \times 762 = 381 \text{ min} > T_{250} = 362 \text{ min}$

which obtained from infiltration function. ok

4- If the available quantity 24 L/sec. Determine the time required to irrigate the complete field

The length of field (furrow) is 250 m and the number of furrows which irrigated at the same time

$$\text{No. of furrows} = \frac{24}{0.8} = 30$$

$$\text{No. of furrows in the field} = \frac{600 \times 250}{1 \times 250} = 600 \text{ furrows}$$

Time required to irrigate the field =

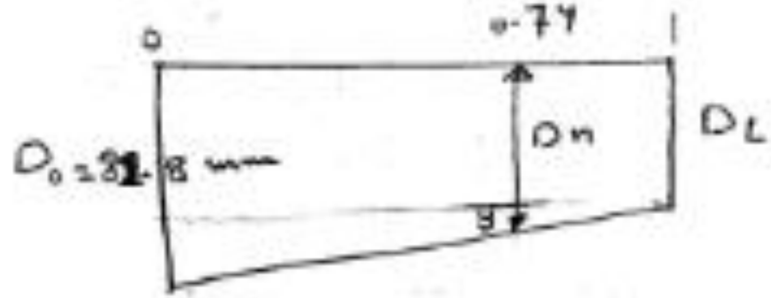
$$\frac{\text{total No. of furrows}}{\text{No. of furrows irrigated at the same time}} \times T_a \times \frac{24}{\text{No. of hours working daily}}$$

$$= \frac{600}{30} \times \frac{762}{24 \times 60} \times \frac{24}{24} = 10.58 \text{ days}$$

5- If the $D_L = 60$ mm and adequacy of irrigation is 74 %

Determine time interval of irrigation if the consumptive use is 6 mm / day and then irrigation efficiency.

$$\frac{D_o - D_L}{1} = \frac{y}{1-0.74}$$



$$\frac{82.8 - 60}{1} = \frac{y}{0.26}$$

$$Dn = 66 = 5.928 + 60$$

$$\text{irrigation interval} = \frac{D_n}{C.U} = \frac{66}{6} = 11 \text{ days}$$

Ex: Available water for furrow field is 25 L/sec, the no. of furrows is 1200 and the average flow for each furrow 1 L/sec and the time of irrigation 5 hours and advance time to the end of furrow is 90 minutes. Determine the total volume of water and the time required to irrigat the whole field.?

volume of water required for each furrow

$$q \times T_a = \frac{1}{1000} \times 5 \times 3600 = 18\ m^3$$

$$\text{total volume for field} = 18 \times 1200 = 21600\ m^3$$

$$\text{No. of furrows irrigated at the same time} = \frac{25}{1} = 25 \text{ furrows}$$

$$\text{Time required to irrigate the whole field} = \frac{1200}{25} \times \frac{5}{24} = 10 \text{ days}$$

Ex: A field of border irrigation system recive its quantity of water (Q_a) 3 days per week. The number of borders = 144. the time required to irrigate each border = 2 hours, the dimensions of border (6m x 360 m), the consumption use of water 10 m/day the efficiency = 70 %. Determine Q_a

$$NDI = II \times CU = 7 \times 10 = 70 \text{ mm}$$

$$GDI = NDI / E = 70 / 0.7 = 100 \text{ mm}$$

$$Q_u \times (60 \times T_a) = (L \times 1) \times (GDI / 1000)$$

$$Q_u = 5 \text{ LPS} / 1\text{m}$$

$$Q / \text{border} = 5 \times 6 = 30 \text{ LPS}$$

Determination the no. of border which irrigated at the same time

Time required to irrigate the entire field = (Total no. borders/N) T_a

$$3 \times 24 \times 60 = (144 / N) \times (2 \times 60) \Rightarrow N = 4$$

$$Q_a = Q / \text{border} \times N = 30 \times 4 = 120 \text{ LPS}$$

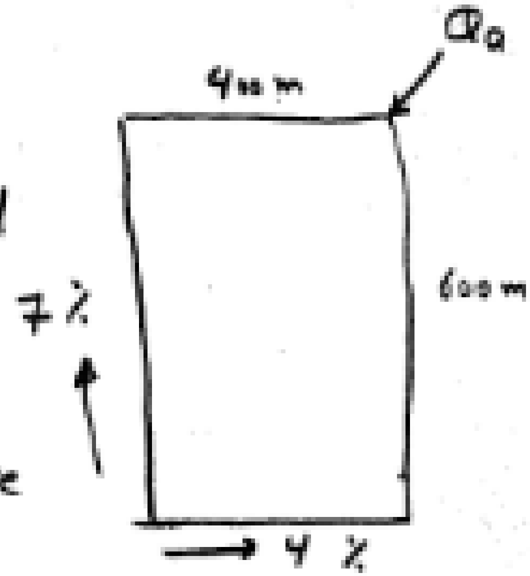
Ex: root zone = 1 m , field holding capacity = 1.26 mm / cm ,
depletion ratio = 50 % , n = 0.25 , Ta = 1 hr / border , L = 200 m ,
irrigation efficiency = 70 % .

calculate :

1- width and number of borders
(width of machine 2.5 m)

2- Available irrigation Qa and time required
to irrigate the whole field.

3- Time of recession .



The width of border according to the slope
is 15 m

the width of machine which compatible
with the width of borders (5 , 7.5 , 10 , 12.5 , 15) m

max. width according to the cross width required determine the depth
flow depth and Average flow for unit width (Qa) through the
Determination the total irrigation depth .

(6)

1-) $NDI = RZD \times WHC \times \%\ Depletion$

$= 1 \times 100 \times 1.26 \times 0.5 = 63\ mm$

$GDI = NDI / E = 63 / 0.70 = 90\ mm$

$Q_u \times (60 \times T_a) = (L \times 1) \times (GDI / 1000)$

$\frac{Q_u}{1000} \times (60 \times 60) = 200 \times (90 / 1000)$

$Q_u = 5\ LPS / 1m$

$d = 1.585 (n\, Q_u)^{0.6} / S_i^{0.3}$

$= 1.585 (0.25 \times 5)^{0.6} / (0.007)^{0.3} = 8\ cm$

$W_{max} = \frac{d}{400\, C_s} = \frac{8}{400 \times 0.004} = 5\ m$

this value of border width is suitable with the machine width ii)

$$\text{No. of borders} = \frac{\text{length of the field in the direction of slope}}{\text{length of border}} \times \frac{\text{width of the field in the direction of } C_s}{\text{border width}}$$

$$No. = \frac{600}{200} \times \frac{400}{5} = 240$$

Assume the no. of borders which irrigated in same time = 2

so the time required to irrigate the whole field.

$$T = \frac{240 \times 1}{2} = 120 \text{ hrs} = 5 \text{ days}$$

discharge required (Q_u) for each border ⇒

$$Q_{border} = Q_u \times W = 5 \times 5 = 25 \text{ LPS}$$

$$Q_a = Q_{border} \times N = 25 \times 2 = 50 \text{ LPS}$$

iii)

$$T_L = \frac{d^2}{1200 \times Q_u \times S_1} = \frac{8^2}{1200 \times 5 \times 0.007} = 1.52 \text{ min}$$

⑦

EX: The following data are for advance and recession water for border has 300 m long , 5 m wide . The average inflow 18.5 m/sec , slope = 0.7% , n = 0.2 , the infiltration function $D = 5\,t^{0.6}$

X (m)	0	30	60	90	120	150	180	210	240	270	300
$T_{advance}$	0	5	13	23	35	48	62	77	94*	114	160
$T_{recession}$	95	98	102	109	116	129	143	155	167	174	200

i- Draw the curves of advance and recession

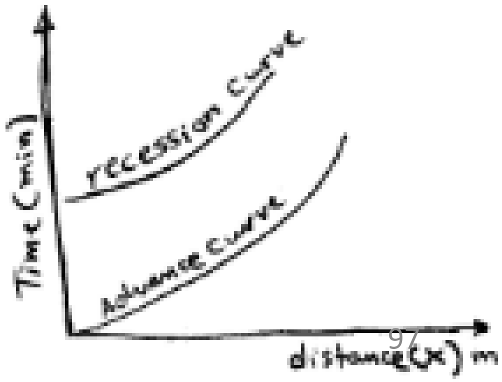
ii- Calculate the infiltration depth for each point

iii- If the net depth of irrigation 65 mm . Find the adequacy and efficiency of irrigation

iv- what is the value of irrigation efficiency if the adequacy of irrigation = 100 % for irrigation NDI = 45 mm

v- Estimate max. depth of flow .

i-



ii- $t_i = t_r - t_a$

X	0	30	60	90	120	150	180	210	240	270	300
ti	95	93	89	86	81	81	81	78	73	60	40
D	77	76	74	72	70	70	70	68	66	58	46

iii- adequacy : Since all infiltration depths upto distance of 240 m are approximately equals or more than NDI, therefore the adequacy of irrigation is as following:

$$\frac{240}{300} \times 100 = 80\%$$

To determine the irrigation efficiency, the gross depth of irrigation it must be found by following formula for complete width:

$$Q_u \times (60\, T_a) = (L \times 1) \times (GDI/1000)$$

$$\frac{18.6}{1000} \times (60 \times 94) = 5 \times 300 \times \frac{GDI}{1000} \Rightarrow GDI = 70\ mm$$

(8)

The average useful depth of infiltration :

$$\left[(240 \times 65) + \left(30 \times \frac{65+58}{2}\right) + \left(30 \times \frac{58+46}{2}\right)\right] / 300 = 63\ mm$$

The irrigation efficiency $IE = \frac{NDI}{GDI} \times 100 = \frac{63}{70} \times 100\% = 90\%$

iv- For NDI of 45 mm the irrigation efficiency is as follows :

$$IE = \frac{NDI}{GDI} = \frac{45}{70} \times 100 = 64\%$$

v- The max. depth of flow in border:

$$d = 1.585\,(n\,Q_u)^{0.6} / S_i^{0.3} \quad , \quad Q_u/m = \frac{18.6}{5} = 3.72\ L/s/m$$

$$d = 1.585\,(0.2 \times 3.72)^{0.6} / (0.007)^{0.3} = 5.88\ cm$$

Ex: The following particulars given to design the border irrigation system:

root zone depth (RZD) = 1.2 m

water holding capacity (WHC) = 1.3 mm/cm

Consumption use (CU) = 10 mm/day

machine width = 2.5 m

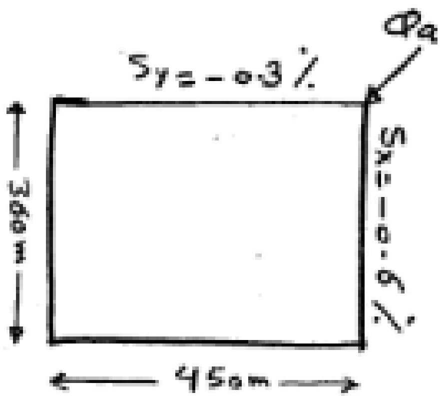
Manning's coefficient $n = 0.15$

function of infiltration depth $D = 10\,t^{0.5}$

where D in mm and t in minutes

Number of daily operation hours = 16 hours

neglect the time of recession (T_r)



Determine:

i- No. of borders

ii- discharge available required for field (Qa)

iii- Irrigation interval II and the time required to irrigate the whole field.

iv- The flow depth in border

v- No. of border which irrigated at the same time per day.

vi- The magnitude of recession time which was neglected.

Solution :

The irrigation slope = −0.6 % , The cross slope = −0.3 %

It is required to determine the long and width of each border;

when $T_L = 0$ So the $T_a = T_n$

$NDI = RZD \times WHC \times \%\ Depletion$

assume the % Depletion 50 %

$NDI = 1.2 \times 100 \times 1.3 \times 0.5 = 78\ mm$

$CU = \frac{NDI}{II} \Rightarrow II = \frac{NDI}{II} = \frac{78}{10} = 7.8\ days$

it is better to approximate the value of II into integer number so II will be 8 days and then the new value of NDI must be determined as:

$$NDI = II \times CU = 8 \times 10 = 80 \text{ mm}$$

check the value of depletion

$$\% \text{ Depletion} = \frac{NDI}{RZD \times WHC} = \frac{80}{1.2 \times 100 \times 1.3} = 51.3\% \quad \text{ok}$$

from the function of infiltration depth, Tn can be found as:

$$D = 10 t^{0.5}$$

$$80 = 10 T_n^{0.5} \Rightarrow T_n = \left(\frac{80}{10}\right)^2 = 64 \text{ min}$$

The Irrigation efficiency it can be found by change the depth infiltration depth into rate infiltration function and by using special table (will given).

$$\frac{dD}{dt} = I_b = 0.5 \times 10 \, T_n^{-0.5} = 5 T_n^{-0.5} \quad \text{mm/min}$$

$$I_b = 300 \, T_b^{-0.5}$$, where $T_b = |600 \times n|$ and

n is the power of basic infiltration function

$T_b = 1600 \times 0.5 / = 300$ min

$I_b = 300\ (300)^{-0.5} = 17.32$ mm/hr

The corresponding value of IE from table is 65%

$GDI = \frac{NDI}{E} = \frac{80}{0.65} = 123$ mm

assume the length of border equal the length of field in the direction of irrigation which is 360 m.

$$\frac{Qu}{1000} \times (60 \times Ta) = L \times 1 \times \frac{GDI}{1000}$$

$$\frac{Qu}{1000} \times (60 \times 64) = 360 \times 1 \times \frac{123}{1000} \Rightarrow Qu = 11.5 \text{ LPS/1m}$$

11

Check the value of Q_u

$Q_{u-max} = 0.175 \times (0.006)^{-0.75} = 8.12$ Lps / 1m

$Q_{u-min} = 5.95 \times 10^{-3} \times 360\ (0.006)^{0.5} / 0.15 = 1.11$ Lps / 1m

note:

$Q_{u\,max} = 0.175\ S_i^{-0.75}$

$Q_{u\,min} = 5.95 \times 10^{-3}\ L\ S_i^{0.5} / n$

The value of Q_u / m = 11.5 Lps / 1m > $Q_{u\,max}$, so, it is required to decrease the length of border, assume the the length of border is 180 m in the direction of irrigation

$$\frac{Q_u}{1000} \times (60 \times 64) = 180 \times 1 \times \frac{123}{1000}$$

$Q_u = 5.76$ Lps / m which is more than $Q_{u\,min}$ and less than $Q_{u\,max}$.

To find the width of border it is required to find value of d:

$$d = 1.585\ (n \cdot Q_u)^{0.6} / S_i^{0.3}$$

$$d = \frac{1.585\ (0.15 \times 5.76)^{0.6}}{(0.006)^{0.3}} = 6.74 \text{ cm}$$

$$W_{max} = \frac{d}{400 \times C_s} = \frac{6.74}{400 \times 0.003} = 5.6 \text{ m}$$

The Wmax according to slope of field in direction of irrigation

is : $W_{max} = 15$ m

According to the machine width which equal is 2.5 m, so,

W = 5 , 7.5 , 10 , 12.5

there for the suitable value of W = 5 m

$$\text{No. of borders} = \frac{\text{length of field in irrigation direction}}{\text{length of border}} \times \frac{\text{field width}}{\text{border width}}$$

$$= \frac{360}{180} \times \frac{450}{5} = 180 \text{ borders}$$

determination of Q_a : it is required to find the number of borders which irrigated at the same time (N) so that the time required to irrigate whole field must be less than the irrigation interval II .

$$\frac{\text{No. of borders}}{N} \times \frac{\text{irrigation time of one border}}{\text{No. of daily operation hours}} \leq 8 \text{ days}$$

$$\frac{180}{N} \times \frac{\frac{64}{60} \text{ hrs}}{16 \text{ hrs/day}} \leq 8$$

$N = 1.5$. say $N = 2$

$$Q_{border} = Q_u \times W = 5.76 \times 5 = 11.5 \text{ LPS}$$

$$Q_a = Q_{border} \times N = 11.5 \times 2 = 23 \text{ LPS}$$

$$\text{Time required to irrigate the whole field} = \frac{\frac{180}{2} \times \frac{64}{60}}{\frac{16 \text{ hrs}}{\text{day}}} = 6 \text{ days} \leq 8 \text{ days}$$

depth of flow = 6.74 cm

The no. of borders are 180 and the time required for irrigation is 6 days and this mean 30 borders will irrigated per day.

vi –

$$T_L = \frac{d^2}{1200\, Q_u\, S_i} = \frac{(6.74)^2}{1200 \times 5.76 \times 0.006} = 1$$

Design of sprinkler irrigation –

Steps are as follow –

1. **Inventory of Resources and Conditions.**

A. **Map of the area.** It is essential that a map of the area concerned is prepared and drawn to scale with sufficient accuracy to show all dimensions so that **lengths of main and laterals can be scaled** there from. It should **be a contour map** or, at least, should show all relevant elevations with respect to water source, pump location, and critical elevations in the fields to be irrigated. The elevation map **provides information about pressure developed for pump**.

B. **Water supply—source, availability and dependability.-** The quantity available should also **meet the seasonal and annual requirements of the crops** and the area to be irrigated. The water should be chemically suitable for irrigating the crops and soils of the area. It should not have any corrosive effect on the equipment. The water should be relatively clean **and free of suspended impurities** so that the sprinkler lines and nozzles are not clogged.

C. **Climatic conditions.** - The consumptive use of a crop depends upon the climatic parameters such as temperature, radiation intensity, humidity and wind velocity. Sprinkler system is **designed for the daily peak rate of consumptive use of the crops irrigated by it.**

A peak demand in the range **of 2 to 10 mm depth per day** is equivalent to a continuous flow of 0.23 to 1.16 litres/second/hectare.

sprinkler spacing, operating pressure, and nozzle sizes that will most nearly provide the optimum water-application rate with the greatest degree of uniformity of distribution.

A. Location and nature of water supply. –

- **The layout** of the mains will depend on the location of the well. It is advantageous if **the pump for the well designed to lift the water and provide necessary pressure** to overcome the friction loss in the pipelines and to operate the sprinklers.
- Sometimes it may be necessary to adopt a sprinkler irrigation system with an already laid underground pipeline water distributuion system or field channels.
- In case of **underground pipelines a portable pumping set** can be used with the suction attached to the hydrants mounted on the pipe outlet
- In case of field channels running **, the channel can be run down the centre of the field** the laterals will then be only half as long so that smaller length laterals could be used, but the channel may interfere with tillage operations and may result in some reduction in the net area cropped.
- Another alternative is to have **a permanent pumping plant at the source** and distribute the water in buried pressure pipelines. These pipelines will usually run down the centre of the field so that the outlets offer little hindrance to tillage and other farm operations.

B. Orientation of laterals.-

- To obtain a reasonable degree of uniformity in the discharge of each sprinkler, the mains should be located in the general direction **of the steepest slope**, with **the laterals at right angles**
- If the lateral **slopes upgrade** appreciably, it is **difficult** to design for a reasonable **length.** If it slopes **downgrade, the length can be longer than usua**l, but rarely does the slope remain uniform for each setting.
- A **main** located along the **middle of a field**, a given lateral will normally be moved to successive positions up one side and then down the other.

(a) Length of Main pipe,

$$L_m = \frac{\text{width of field}}{2}\ \text{m}$$

(b) Frictional loss for assumed diameter of pipe,

$$h_m = \frac{825 f Q^2 L_m}{d_m^5}$$

Q = discharge lit/sec
dm = Assumed diameter of pipe, cm
f = frictional coefficient

(c) Length of lateral pipe,

$$L_f = \frac{\text{length of field}}{2} m$$

(d) Diameter of lateral pipe

$$d_f = \left[\frac{825fsq^2}{h_s}\frac{1}{r}\right]^{\frac{1}{5}}$$

Where, d; = diameter of Lateral pipe, cm
f = coefficient of friction
q = discharge of one sprinkler =Total discharge(Q)/Nos of sprinkler
ha = operating pressure in terms of height or head of wat
(1 kg/cm2 = 10 m of water)
1/R = value for Nos of sprinklers from standard Table,
(for 13 sprinklers value of 1/R = 3068)
S = spacing of sprinkler, metre.

⇨

C. The **number of possible arrangements**

- ⇨ The arrangement selected should provide for a minimal investment in irrigation pipe, have low labour requirement.
- ⇨ The choice will depend to a large extent upon the types and capacities of the sprinklers and their operating pressures.

D. **Sprinkler Selection and Spacing.-**

- ⇨ The actual selection of the sprinkler is based largely upon design information furnished by the manufacturers of the equipment.
  - ⇨ The choice depends mainly on the diameter of **coverage required**, pressure available and sprinkler discharge.
  - ⇨ The best combination of sprinkler spacing and lateral moves, suiting the application rate for the soil and wind conditions should be selected.
  - ⇨ The required discharge of an individual sprinkler by the following formula:

$$Q = \frac{S_t \times S_m \times I}{360}$$

in which, Q = required discharge of individual sprinkler,

i. Sj = spacing of sprinklers along the laterals, metres
ii. Sm = spacing of laterals along the main, metres
iii. I = optimum application rate, cm/hr.

E. Height of sprinkler riser pipes.

- ⇨ Sprinklers are located at **maximum height of the crop**.
- ⇨ To avoid excessive turbulence in the riser pipes the minimum height of riser is 30 cm when the riser pipe is of 2.5 cm diameter and 15 cm when it is of 1.8 to 2 cm diameter.

4. Capacity of Sprinkler Systems.-

- ⇨ The required capacity of a sprinkler system depends on the size of the area to be irrigated (design area), the gross depth of water applied in each irrigation, and the net operating time allowed to apply water to this depth.
- ⇨ The capacity of the system may be calculated by the formula:

$$Q = 2780 \frac{AD}{FHE}$$

in which,
Q = discharge capacity of the pump, litres/sec
A = area to be irrigated, hectares
d = net depth of water application, cm
F = number of days allowed for the completion of one irrigation
H = number of actual operating hours per day
E = water application efficiency, per cent.

- ⇨ In equation it may be noted that F and H are of major importance in that they have a direct bearing on the capital investment per hectare required for equipment.
- ⇨ From the formula it is clear that the greater the product of these two factors (operating time) the smaller is the system capacity (and thereby the cost) for a given area.

6. Hydraulic Design of Sprinkler Systems.

- ⇨ The hydraulic design of sprinklers is aimed at obtaining a uniform irrigation coverage, the desired rate of application, the break-up of sprinkler drops necessary to Minimize structural deterioration of the soil surface, the efficiency desired to reduce the energy requirement in operating the system and to maximize area of coverage.
- ⇨ The main hydraulic principles involved in a sprinkler system design are given below.

A. Discharge of sprinkler nozzle. The discharge of a sprinkler

Example 2.2 Determine the required capacity of a sprinkler system to apply water at the rate of 1.25 cm/hr. Two 186 metres long sprinkler lines are required. Sixteen sprinklers are spaced at 12 metre intervals on each line. The spacing between lines is 18 metres.

Solution:

$$Q = \frac{S_t \times S_m \times I}{360}$$

$$= \frac{12 \times 18 \times 1.25}{360}$$

$$= \frac{0.75 \frac{\text{litres}}{\text{sec}}}{\text{sprinkler}}$$

System capacity = total discharge of all sprinklers

= 0.75 x 32

= 24 litres/sec.

Example 2.4 Determine the system capacity for a sprinkler irrigation system to irrigate 16 hectares of maize crop. Design moisture use rate is 5 mm per day. Moisture replaced in soil at each irrigation is 6 cm. Irrigation efficiency is 70 per cent. Irrigation period is 10 days in a 12-day interval. The system is to be operated for 20 hours per day.

Solution:

Given: A = 16, F = 10, H = 20, d = 6

System capacity

$$Q = 2780\,\frac{AD}{FHE}$$

$$= 2780 \times \frac{8 \times 2.85}{6 \times 15 \times 75}$$

$$= 9.4 \text{ liters / second}$$

Example 2.5 Determine the size of sprinklers, laterals, pump and power unit for the sprinkler system layout with the following conditions:

Hn = 35.3 m, Hj = 0.5 m, Hm = 2.2 m, Hs = 3.5 m, I = 1.25 cm / hr, maximum length of main = 60 m, Sj= 15 m, Sm = 20 m and allowable variation in pressure in the lateral is 20 per cent.

Solution:

1. Determine the sprinkler and the lateral capacities:

$$Q = \frac{S_t \times S_m \times I}{360}$$

$$= \frac{15 \times 20 \times 1.25}{360}$$

$$= 1.05 \frac{\text{litres}}{\text{sec}} /\text{sprinkler}$$

Area of sprinkler nozzle,

$$q = Ca\sqrt{2gh}$$

$$a = \frac{q}{c\sqrt{2gh}}$$

$$= \frac{1.04 \times 10^{-3}}{0.95\sqrt{2 \times 9.8 \times 30}}$$

$= 0.45 \times 10^{-4}\ m^2$

Diameter of sprinkler nozzle,d = 0.75 cm

2. Select 7.5 cm diameter lateral (assumed)
3. Select 10 cm diameter main(assumed)
4. Pump size –

$$H_t = H_n + H_m + H_j + H_s$$

$= 35.5 + 0.5 + 2.2 + 3.5$

$= 43.0$ m

$$H.P. = \frac{QH}{76E} = \frac{1 \times 10^{-3} \times 10^3 \times 45}{75 \times 0.7} = 9.43$$

Example 2.3 Allowing 1 hour for moving each 186 metre sprinkler line described in Example 2.1 how many hours would be required to apply a 5 cm irrigation to a square 16-hectare field? How many days are required assuming 10-hour days?

Solution: Irrigation time to apply 5 cm irrigation at the rate **of 1.25 cm/hour**= $\frac{5}{1.25}$= 4 hours

Time required for moving the lateral = 1 hour

Total time per setting = 4 + 1 = 5 hours

Area of field = 16 x 10,000 = 1,60,000

Length of field =$\sqrt{a}$ = $\sqrt{160000}$ = 400 m

The entire length of 400 m is covered by the two 186 m laterals.

The number of moves required= 400/18 =22.2 say 22 moves

Total time required for irrigation = 22 x 5 = 110 hours

= 110/10 = 11 days.

Drainage Engineering

https://www.slideshare.net/LATIFHYDER Wadho/drainage-engineering-drainage-and-design-of-drainage-systems

Need of Drainage

During rain or irrigation the fields become wet. The water infiltrate into the soil and is stored in its pores. When all the pores are filled with water, the soil is said to be saturated and no more water can be absorbed; when rain or irrigation continues, pools may form on the soil surface (as shown in Figure).

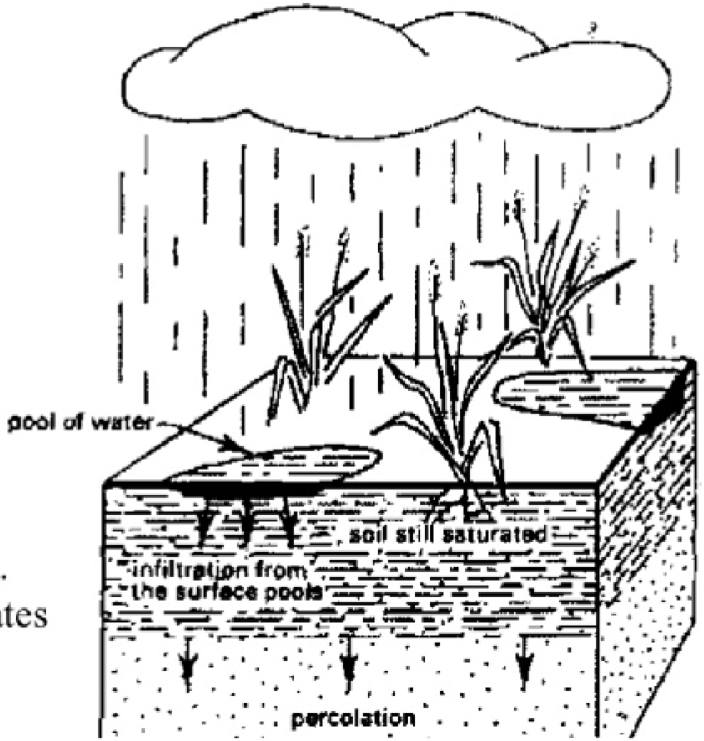
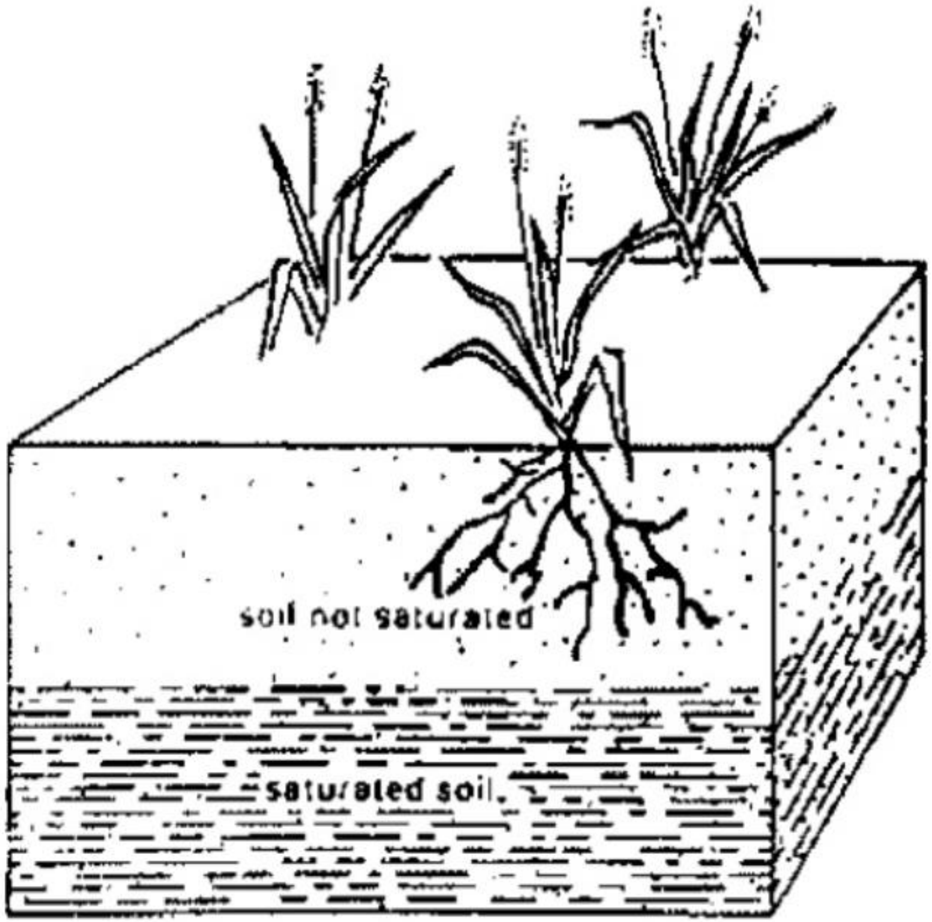
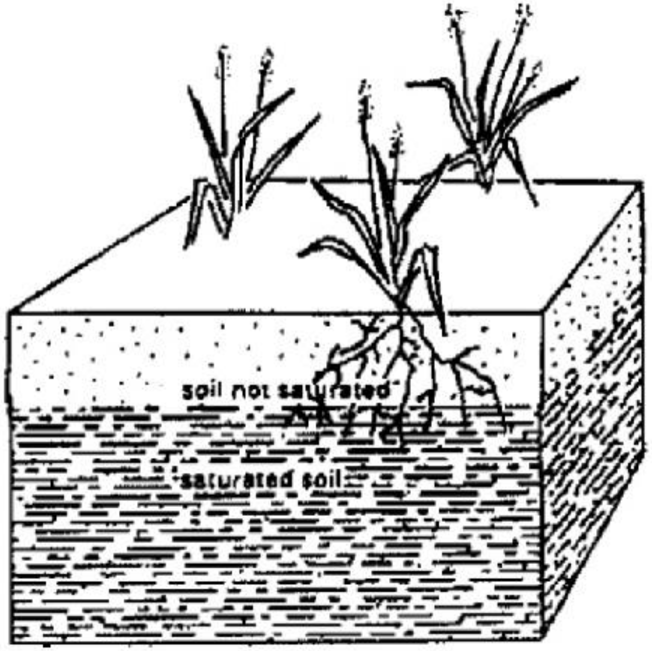


Figure. During heavy rainfall the upper soil layers become saturated and pools may form. Water percolates to deeper layers and infiltrates from the pools

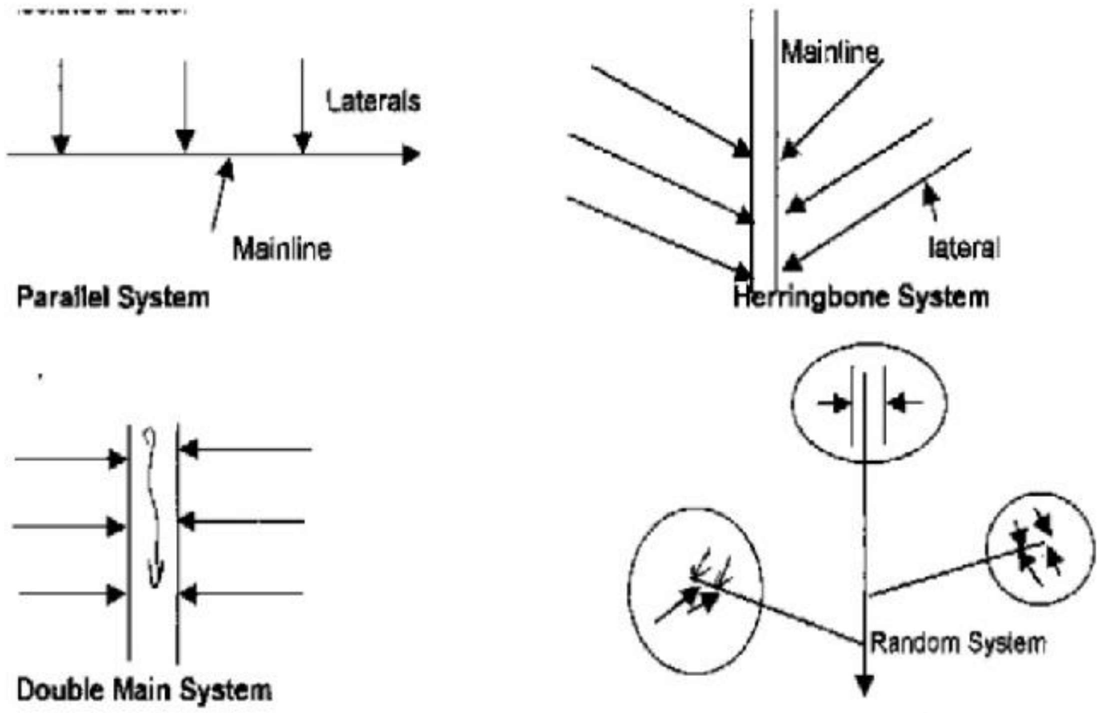
BEFORE HEAVY RAINFALL



Water in Soil After Heavy Rain



Arrangements of Sub-Surface Drains



Example

In the design of an irrigation system, the following properties exist:

- Soil field capacity = 28% by weight,
- Permanent wilting point = 17% by weight;
- Bulk density = 1.36 g/cm^3 ;
- Root zone depth = 1m = 1000 mm;
- Peak ET = 5 mm/day;
- Irrigation efficiency = 60%,
- Water conveyance efficiency = 80%,
- Water lost in canals contributing to seepage = 50%;
- Rainfall for january = 69 mm and
- Evapotranspiration = 100 mm;
- Salinity of irrigation water is 0.80 m mhos/cm while that acceptable is 4 mmhos/cm.

➢Compute the drainage coefficient.

Solution:

Readily available moisture (RAM) = ½ (FC - PWP)

= 1/2(28 - 17) = 5.5%.

In depth, RAM = 0.055 x 1.36 x 1000 mm

= 74.8 mm = Net irrigation

Shortest irrigation interval = RAM/peak ET

= 74.8/5 = 15 days

With irrigation efficiency of 60 %,

GIR = 74.8/0.6 = 124.7 mm. This is per irrigation.

(a) Water losses = GIR - Net irrigation

= 124.7 - 74.8

= 49.9 mm

Assuming 70% is deep percolation while 30% is wasted on the soil surface (Standard assumption),

Deep percolation = 0.7 x 49.9

= 34.91 mm

(b)Seepage

$$\text{Conveyance Efficiency} = \frac{\text{Water delivered to farm}}{\text{Water delivered at dam}}$$

$$= 0.8$$

Water delivered to farm = GIR = 124.7 mm

i.e. Water released at dam = 124.7/0.8 = 155.9 mm

Excess water or water lost in canal = 155.9 - 124.7

= 31.2 mm

Since half of the water is seepage (given), the rest will be evaporation during conveyance

Seepage = 1/2 x 31.2 mm

= 15.6 mm

Neglecting Leaching Requirement,

Total water input into drains

= Deep percolation +Seepage +Rainfall

= 34.91 + 15.6 + 34.5

= 85.01 mm

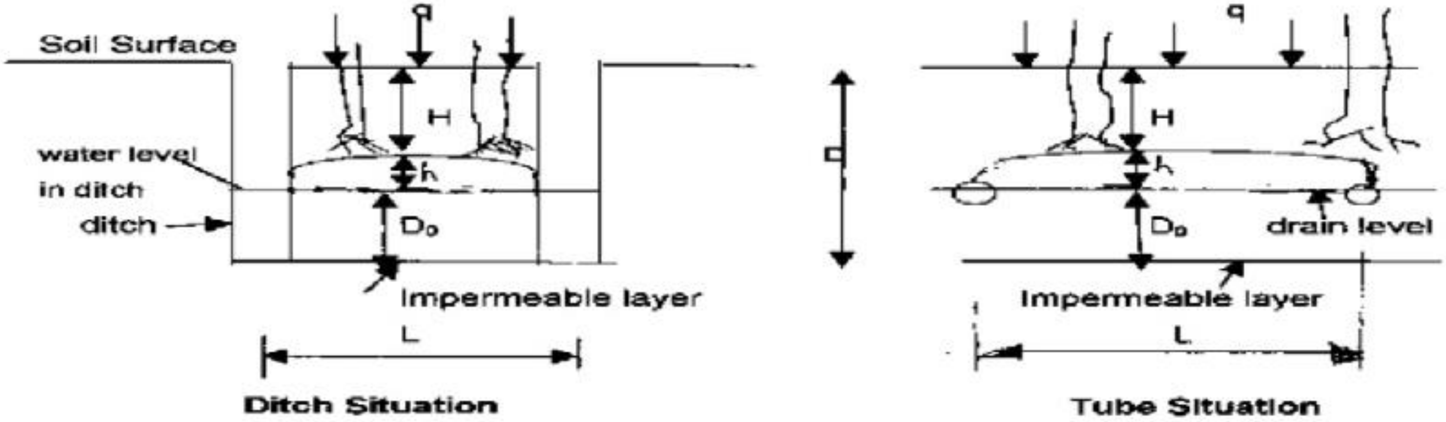
This is per 15 days, since irrigation interval is 15 days

Hence,

Drainage coefficient = 85.01/15 = 5.67

= 6 mm/day.

2. Drain Depth and Spacing



L = drain spacing;

h = mid drain water table height (m) above drain level;

Do = depth of aquifer from drain level to impermeable layer(m);

Q = water input rate(m/day) = specific discharge or drainage coefficient;

K = hydraulic conductivity(m/day);

H = depth to water table.

Design Water table depth (H):

This is the minimum depth below the surface at which the water table should be controlled and is determined by farming needs especially crop tolerance to water.

Typically, it varies from 0.5 to 1.5 m.

Design Depth of Drain

The deeper a drain is put, the larger the spacing and the more economical the design becomes.

Drain depth, however, is constrained by soil and machinery limitations.

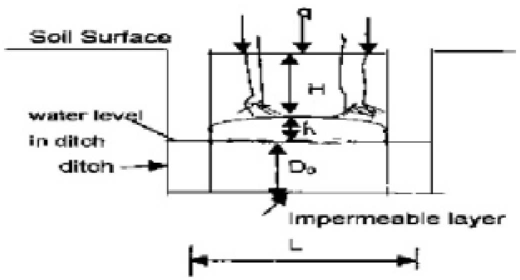
Table : Typical Drain Depths(D)

Soil Type	Drain Depth (m)
Sand	0.6
Sandy loam	0.8 - 1.0
Silt loam	0.8 - 1.8
Clay loam	0.6 - 0.8
Peat	1.2 - 1.5

Drain Spacing (L)

This is normally determined using the Hooghoudt equation. It states that for ditches reaching the impermeable layer:

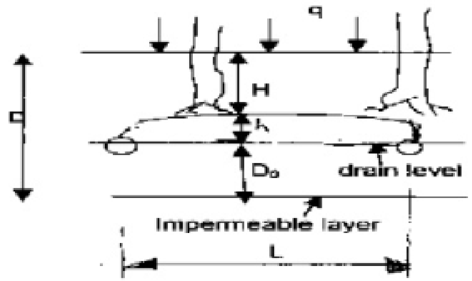
$$L^2 = \frac{8KD_o h}{q} + \frac{4Kh}{q}$$



Ditch Situation

For tube drains which do not reach the impermeable layer, the equation can be modified as:

$$L = \frac{8Kdh}{q} + \frac{4Kh^2}{q}$$



Tube Situation

Where

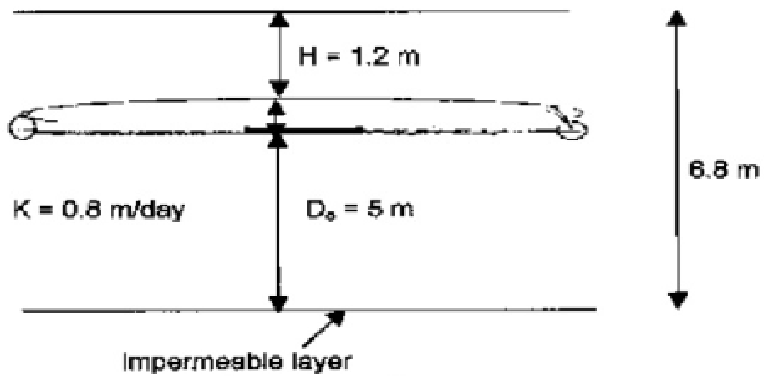
d = Houghoudt equivalent

The equation for tube drains can be solved using trial and error method or the graphical method.

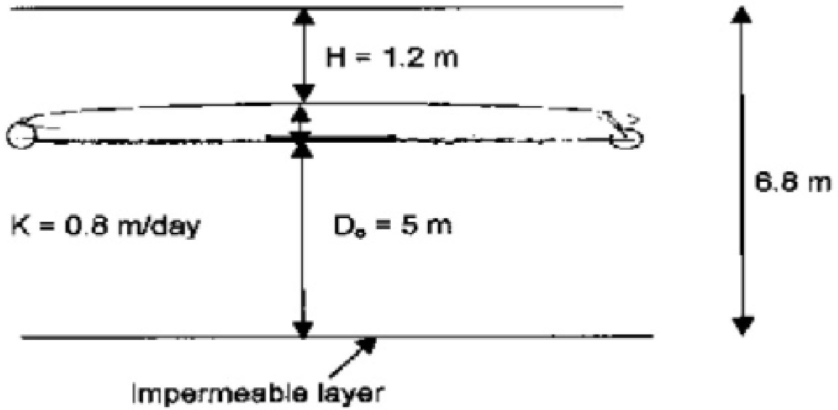
Example

For the drainage design of an irrigated area, drain pipes with a radius of 0.1 m are used. They are placed at a depth of 1.8 m below the soil surface. A relatively impermeable soil layer was found at a depth of 6.8 m below the surface. From auger hole tests, the hydraulic conductivity above this layer was estimated as 0.8 m/day. The average irrigation losses, which recharge the groundwater, are 40 mm per 20 days so the average discharge of the drain system amounts to 2 mm/day.

Estimate the drain spacing, if the depth of the water table is 1.2 m.



Solution:



Analytical solution

$$L^2 = \frac{8Kdh}{q} + \frac{4Kh^2}{q} = \frac{8\times0.8\times d\times0.6}{0.002} + \frac{4\times0.8\times0.6^2}{0.002}$$

$$= 1920\, d + 578 ----------(1)$$

<u>Trial One:</u> Assume L = 75 m

for L = 75 m and Do = 5 m, from Hooghout table, d = 3.49 m

From eq. (1), $L^2 = (1920 \times 3.49) + 576 = 7276.8$; $L = 85.3$ m

Comment: The chosen L is small since 75 < 85.3 m

<u>Trial Two:</u> Assume L = 100 m,

for L = 100 m and Do = 5 m, from table, d = 3.78 m

From (1), $L^2 = (1920 \times 3.78) + 576 = 7833.6$; L = 88.51m

Comment: Since 88.51 < 100, try a smaller L;

L should be between 75 and 100 m.

Table. Values of Equivalent depth of Houghoudt for $r_o = 0.1$ m, D and L in m

L →	5 m	7.5	10	15	20	25	30	35	40	45	50
D											
0.5 m	0.47	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.50	0.50
0.75	0.60	0.65	0.69	0.71	0.73	0.74	0.75	0.75	0.75	0.76	0.76
1.00	0.67	0.75	0.80	0.86	0.89	0.91	0.93	0.94	0.96	0.96	0.96
1.25	0.70	0.82	0.89	1.00	1.05	1.09	1.12	1.13	1.14	1.14	1.15
1.50	0.70	0.88	0.97	1.11	1.19	1.25	1.28	1.31	1.34	1.35	1.36
1.75	0.70	0.91	1.02	1.20	1.30	1.39	1.45	1.49	1.52	1.55	1.57
2.00	0.70	0.91	1.08	1.28	1.41	1.5	1.57	1.62	1.66	1.70	1.72
2.25	0.70	0.91	1.13	1.34	1.50	1.69	1.69	1.76	1.81	1.84	1.86
2.50	0.70	0.91	1.13	1.38	1.57	1.69	1.79	1.87	1.94	1.99	2.02
2.75	0.70	0.91	1.13	1.42	1.63	1.76	1.88	1.98	2.05	2.12	2.18
3.00	0.70	0.91	1.13	1.45	1.67	1.83	1.97	2.08	2.16	2.23	2.29
3.25	0.70	0.91	1.13	1.48	1.71	1.88	2.04	2.16	2.26	2.35	2.42
3.50	0.70	0.91	1.13	1.50	1.75	1.93	2.11	2.24	2.35	2.45	2.54
3.75	0.70	0.91	1.13	1.52	1.78	1.97	2.17	2.31	2.44	2.54	2.64
4.00	0.70	0.91	1.13	1.52	1.81	2.02	2.22	2.37	2.51	2.62	2.71
4.50	0.70	0.91	1.13	1.52	1.85	2.08	2.31	2.50	2.63	2.76	2.87
5.00	0.70	0.91	1.13	1.52	1.88	2.15	2.38	2.58	2.75	2.89	3.02
5.50	0.70	0.91	1.13	1.52	1.88	2.20	2.43	2.65	2.84	3.00	3.15
6.00	0.70	0.91	1.13	1.52	1.88	2.20	2.48	2.70	2.92	3.09	3.26
7.00	0.70	0.91	1.13	1.52	1.88	2.20	2.54	2.81	3.03	3.24	3.43
8.00	0.70	0.91	1.13	1.52	1.88	2.20	2.57	2.85	3.13	3.35	3.56
9.00	0.70	0.91	1.13	1.52	1.88	2.20	2.57	2.89	3.18	3.43	3.66
10.00	0.70	0.91	1.13	1.52	1.88	2.20	2.57	2.89	3.23	3.48	3.74
∞	0.71	0.93	1.14	1.53	1.89	2.24	2.58	2.91	3.24	3.56	3.88

Table. Values of Equivalent depth of Houghoudt for r_o = 0.1 m, D and L in m

L →	50	75	80	85	90	100	150	200	250
D									
0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1	0.96	0.97	0.97	0.97	0.98	0.98	0.99	0.99	0.99
2	1.72	1.80	1.82	1.82	1.83	1.85	1.00	1.92	1.94
3	2.29	2.49	2.52	2.54	2.56	2.60	2.72	2.70	2.83
4	2.71	3.04	3.08	3.12	3.16	3.24	3.46	3.58	3.66
5	3.02	3.49	3.55	3.61	3.67	3.78	4.12	4.31	4.43
6	3.23	3.85	3.93	4.00	4.08	4.23	4.70	4.97	5.15
7	3.43	4.14	4.23	4.33	4.42	4.62	5.22	5.57	5.81
8	3.56	4.38	4.49	4.61	4.72	4.95	5.68	6.13	6.43
9	3.66	4.57	4.70	4.82	4.95	5.23	6.09	6.63	7.00
10	3.74	4.74	4.89	5.04	5.18	5.47	6.45	7.09	7.53
12.5	3.74	5.02	5.20	5.38	5.56	5.92	7.20	8.06	8.68
15	3.74	5.20	5.40	5.60	5.80	6.25	7.77	8.84	9.64
17.5	3.74	5.30	5.53	5.76	5.99	6.44	8.20	9.47	10.4
20	3.74	5.30	5.62	5.87	6.12	6.60	8.54	9.97	11.1
25	3.74	5.30	5.74	5.96	6.20	6.79	8.99	10.7	12.1
30	3.74	5.30	5.74	5.96	6.20	6.79	9.27	11.3	12.9
35	3.74	5.30	5.74	5.96	6.20	6.79	9.44	11.6	13.4
40	3.74	5.30	5.74	5.96	6.20	6.79	9.44	11.8	13.8
45	3.74	5.30	5.74	5.96	6.20	6.79	9.44	12.0	13.8
50	3.74	5.30	5.74	5.96	6.20	6.79	9.44	12.1	14.3
60	3.74	5.30	5.74	5.96	6.20	6.79	9.44	12.1	14.6
∞	3.88	5.38	5.76	6.00	6.26	6.82	9.55	12.2	14.7

Table. Values of Equivalent depth of Houghoudt for $r_o = 0.1$ m, D and L in m

D ↓ / L →	5 m	7.5	10	15	20	25	30	35	40	45	50
0.5 m	0.47	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.50	0.50
0.75	0.60	0.65	0.69	0.71	0.73	0.74	0.75	0.75	0.75	0.76	0.76
1.00	0.67	0.75	0.80	0.86	0.89	0.91	0.93	0.94	0.96	0.96	0.96
1.25	0.70	0.82	0.89	1.00	1.05	1.09	1.12	1.13	1.14	1.14	1.15
1.50	0.70	0.88	0.97	1.11	1.19	1.25	1.28	1.31	1.34	1.35	1.36
1.75	0.70	0.91	1.02	1.20	1.30	1.39	1.45	1.49	1.52	1.55	1.57
2.00	0.70	0.91	1.08	1.28	1.41	1.5	1.57	1.62	1.66	1.70	1.72
2.25	0.70	0.91	1.13	1.34	1.50	1.69	1.69	1.76	1.81	1.84	1.86
2.50	0.70	0.91	1.13	1.38	1.57	1.69	1.79	1.87	1.94	1.99	2.02
2.75	0.70	0.91	1.13	1.42	1.63	1.76	1.88	1.98	2.05	2.12	2.18
3.00	0.70	0.91	1.13	1.45	1.67	1.83	1.97	2.08	2.16	2.23	2.29
3.25	0.70	0.91	1.13	1.48	1.71	1.88	2.04	2.16	2.26	2.35	2.42
3.50	0.70	0.91	1.13	1.50	1.75	1.93	2.11	2.24	2.35	2.45	2.54
3.75	0.70	0.91	1.13	1.52	1.78	1.97	2.17	2.31	2.44	2.54	2.64
4.00	0.70	0.91	1.13	1.52	1.81	2.02	2.22	2.37	2.51	2.62	2.71
4.50	0.70	0.91	1.13	1.52	1.85	2.08	2.31	2.50	2.63	2.76	2.87
5.00	0.70	0.91	1.13	1.52	1.88	2.15	2.38	2.58	2.75	2.89	3.02
5.50	0.70	0.91	1.13	1.52	1.88	2.20	2.43	2.65	2.84	3.00	3.15
6.00	0.70	0.91	1.13	1.52	1.88	2.20	2.48	2.70	2.92	3.09	3.26
7.00	0.70	0.91	1.13	1.52	1.88	2.20	2.54	2.81	3.03	3.24	3.43
8.00	0.70	0.91	1.13	1.52	1.88	2.20	2.57	2.85	3.13	3.35	3.56
9.00	0.70	0.91	1.13	1.52	1.88	2.20	2.57	2.89	3.18	3.43	3.66
10.00	0.70	0.91	1.13	1.52	1.88	2.20	2.57	2.89	3.23	3.48	3.74
∞	0.71	0.93	1.14	1.53	1.89	2.24	2.58	2.91	3.24	3.56	3.88

D ↓ / L →	50	75	80	85	90	100	150	200	250
0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1	0.96	0.97	0.97	0.97	0.98	0.98	0.99	0.99	0.99
2	1.72	1.80	1.82	1.82	1.83	1.85	1.00	1.92	1.94
3	2.29	2.49	2.52	2.54	2.56	2.60	2.72	2.70	2.83
4	2.71	3.04	3.08	3.12	3.16	3.24	3.46	3.58	3.66
5	3.02	3.49	3.55	3.61	3.67	3.78	4.12	4.31	4.43
6	3.23	3.85	3.93	4.00	4.08	4.23	4.70	4.97	5.15
7	3.43	4.14	4.23	4.33	4.42	4.62	5.22	5.57	5.81
8	3.56	4.38	4.49	4.61	4.72	4.95	5.68	6.13	6.43
9	3.66	4.57	4.70	4.82	4.95	5.23	6.09	6.63	7.00
10	3.74	4.74	4.89	5.04	5.18	5.47	6.45	7.09	7.53
12.5	3.74	5.02	5.20	5.38	5.56	5.92	7.20	8.06	8.68
15	3.74	5.20	5.40	5.60	5.80	6.25	7.77	8.84	9.64
17.5	3.74	5.30	5.53	5.76	5.99	6.44	8.20	9.47	10.4
20	3.74	5.30	5.62	5.87	6.12	6.60	8.54	9.97	11.1
25	3.74	5.30	5.74	5.96	6.20	6.79	8.99	10.7	12.1
30	3.74	5.30	5.74	5.96	6.20	6.79	9.27	11.3	12.9
35	3.74	5.30	5.74	5.96	6.20	6.79	9.44	11.6	13.4
40	3.74	5.30	5.74	5.96	6.20	6.79	9.44	11.8	13.8
45	3.74	5.30	5.74	5.96	6.20	6.79	9.44	12.0	13.8
50	3.74	5.30	5.74	5.96	6.20	6.79	9.44	12.1	14.3
60	3.74	5.30	5.74	5.96	6.20	6.79	9.44	12.1	14.6
∞	3.88	5.38	5.76	6.00	6.26	6.82	9.55	12.2	14.7

Trial Three: Assume L = 90 m,

$d = 3.49 + 15/25(3.78 - 3.49) = 3.66$ m

$L^2 = (1920 \times 3.66) + 576 = 7603.2$ m ; L = 87 m

Comment: Since $87 < 90$, try a smaller L;

L should be between 75 and 90.

Trial Four: Assume L = 87 m,

$d = 3.49 + 12/25(3.78 - 3.49) = 3.63$ m

$L^2 = (1920 \times 3.63) + 576 = 7545.6$; L = 86.87 m

Comment: The difference between the assumed and calculated L is <1, so : Drain Spacing = 87 m.

Graphical Solution

Calculate $\frac{4Kh^2}{q}$ and $\frac{8Kh}{q}$

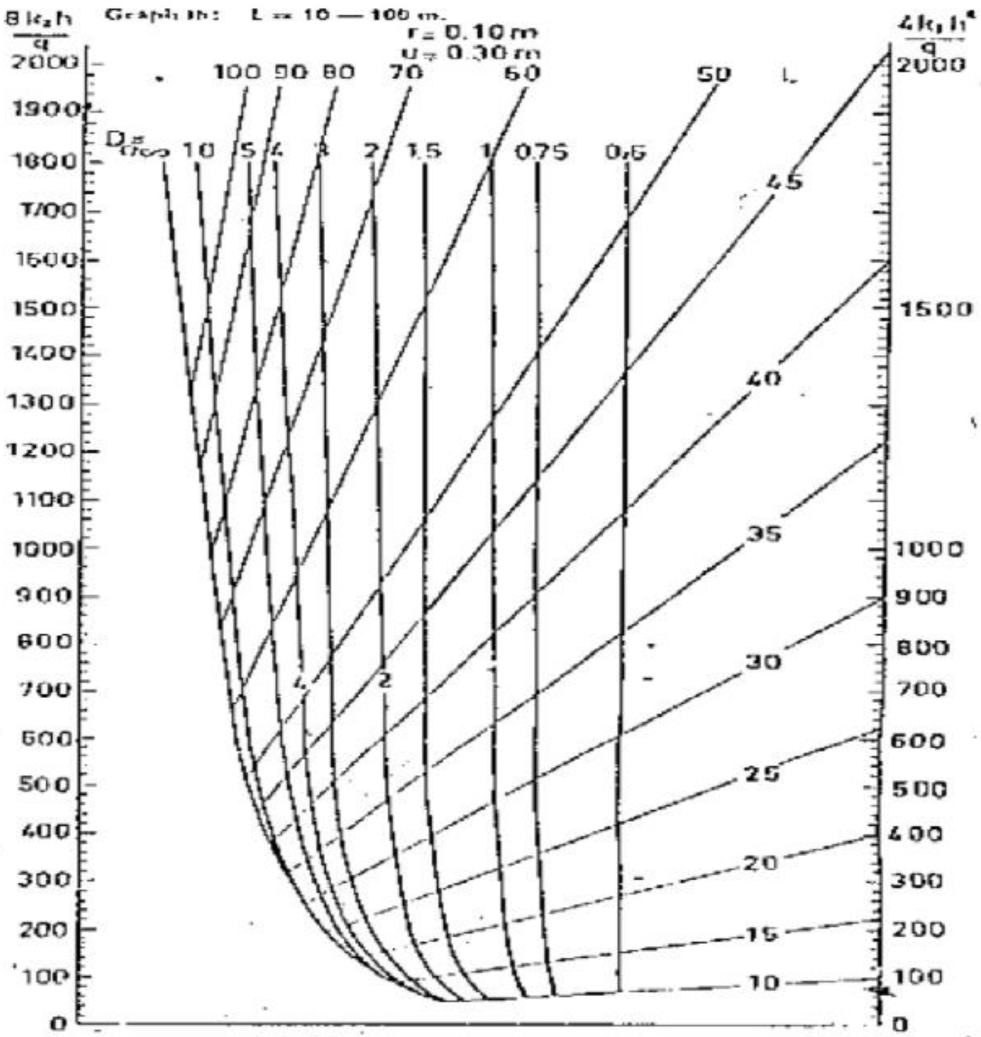
$$\frac{4Kh^2}{q} = \frac{4\times0.8\times0.6^2}{0.002} = 576$$

$$\frac{8Kh}{q} = \frac{8\times0.8\times0.6}{0.002} = 1920$$

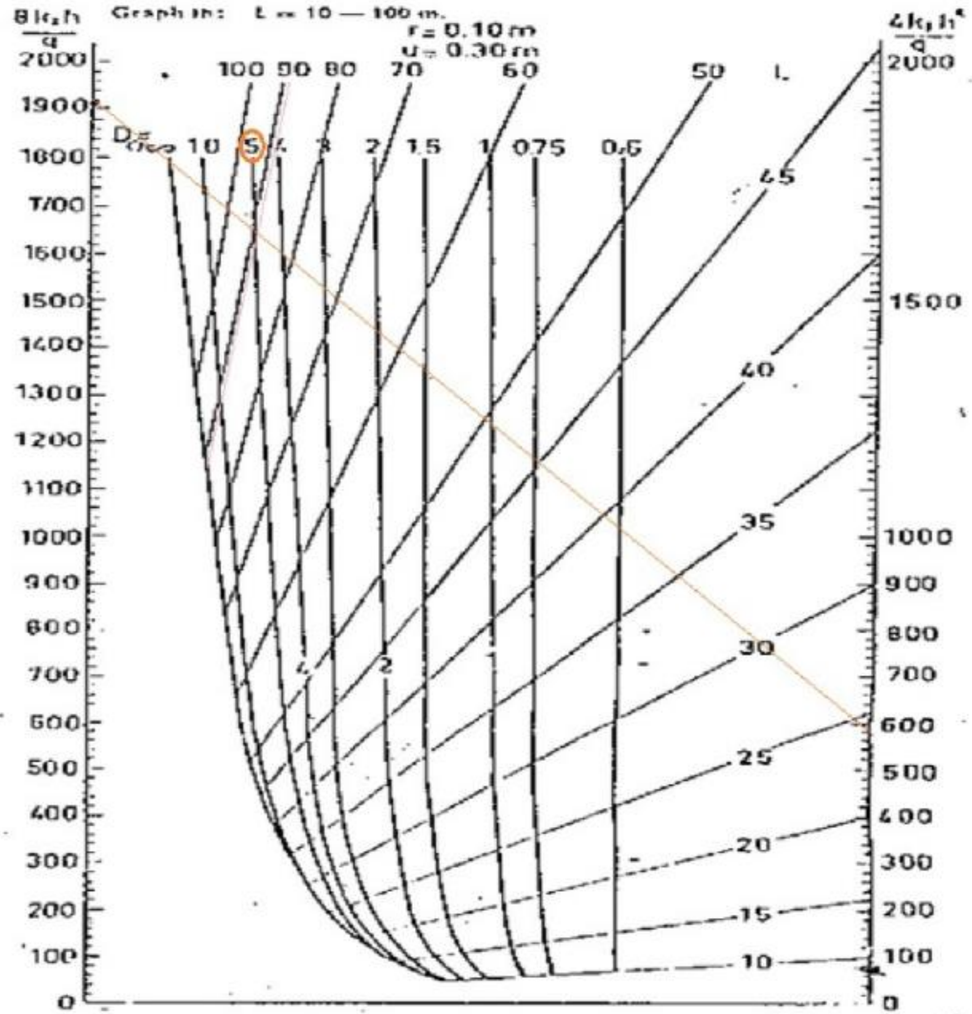
Locate the two points on graph given and join.

For a value of Do = 5 m; produce downwards to meet the line. Read off the spacing on the diagram

L = 87 m



r = 0.10 m
u = 0.30 m
100 90 80 70 60 50 L
10 5 4 3 2 1.5 1 0.75 0.5
45
40
35
30
25
20
15
10
2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 0
2000 1500 1000 900 800 700 600 500 400 300 200 100 0



8k₂h / q
Graph in: L = 10 — 100 m.
r = 0.10 m
u = 0.30 m
4k₁h² / q
100 90 80 70 60 50 L
D = d/ep 10 5 4 3 2 1.5 1 0.75 0.6
45
40
35
30
25
20
15
10
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0

3. Drain Diameters and Gradients

There are two approaches to design:

(a) Transport approach:

- Assumes that pipes are flowing full from top to end of field.
- Assumes uniform flow.
- Widely used in United States, Canada and Germany.
- Used to design collector drains.

(b) Drainage approach:

- Assumes that water enters the pipe all down the length as it is perforated.
- This is more realistic.
- Widely used in United Kingdom, Holland and Denmark.
- This is used to design lateral drainage pipes.

Parameters Required to use Solution Graphs

(a) Types of pipes: Pipes can be smooth or rough:

Clay tiles and smooth plastic pipes are smooth; while

Corrugated plastic pipes are rough.

(b) Drainable area: The area drained by one lateral. It is equal to the maximum length of a lateral multiplied by drain spacing.

The whole area drained by the laterals discharging into a collector represents the drainable area of the collector.

c)Specific discharge: Earlier defined. Same as drainage coefficient.

d) Silt safety factors: Used to account for the silting of pipes with time by making the pipes bigger. 60, 75 and 100 % pipe capacity factors are indicated. This means allowing 40, 25 and 0% respectively for silting.

e) Average hydraulic gradient(%): It is normally the soil slope.

Example:

The drainage design of a field is:

drain spacing = 30 m,

length of drain lines = 200 m,

slope = 0.10%,

specific discharge = 10 mm/day.

Estimate drain diameter. Assume 60% silt factor and clay tiles.

Solution:

Area to be drained by one lateral = 30m x 200m = 6000 m^2 = 0.6 ha

Slope = average hydraulic gradient = 0.10% ;

q = 10 mm/day

Using chart for smooth drains,

nearest diameter = **70 mm inside diameter.**