



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Drainage Engineering (BTAI3103)

Module 4

Surface and Subsurface Drainage Systems (Lecture-08: Investigation of Drainage Design Parameters)

**DEPARTMENT OF AGRICULTURAL ENGINEERING, SoABE
CENTURION UNIVERSITY OF TECHNOLOGY AND MANAGEMENT
PARALAKHEMUNDI, ODISHA**



Centurion
UNIVERSITY
*Shaping Lives...
Empowering Communities...*

Drainage Coefficient

- Drainage coefficient is defined as the amount of surplus water to be removed from the agricultural land in 24 hours so that the plants are not stressed due to surplus water.
- Alternatively, it is also defined as the depth of water to be removed in 24 hours from the entire drainage area. A commonly used unit of drainage coefficient is cm/day or mm/day.
- It is the key parameter needed for the hydraulic design of drainage systems.
- In agriculture lands, open ditches or drains are the most commonly used surface drainage structures.



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Drainage Coefficient

The rate at which the open drains should remove water from a drainage area depends on:

- (i) rainfall,
- (ii) size of the drainage area,
- (iii) characteristics of the drainage area, and
- (iv) nature of the crops grown and
- (v) the degree of protection required for them from waterlogging



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Problem: A watershed of 1500 hectares is discharging through a drain at an average ratio of $2.5 \text{ m}^3/\text{s}$. Calculate the drainage coefficient. If the drainage coefficient is 3 cm, what would be the discharge through the drain?

Solution:

$$\begin{aligned}\text{Drain discharge in 24 hours} &= 2.5 \times 60 \times 60 \times 24 \text{ m}^3/\text{day} \\ &= 216000 \text{ m}^3/\text{day}\end{aligned}$$

$$\begin{aligned}\text{Drainage Coefficient} &= \frac{216000}{1500 \times 10^4} = 0.0144 \text{ m per day} \\ &= 1.44 \text{ cm/day}\end{aligned}$$

If the drainage coefficient is 3 cm, the rate of flow through the drain (Q) will be:

$$Q = \frac{3 \times 1500 \times 10^4}{100 \times 24 \times 60 \times 60} = 5.21 \text{ m}^3/\text{day}$$



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Hydraulic Conductivity

- Saturated hydraulic conductivity is a quantitative measure of a saturated soil's ability to transmit water when subjected to a hydraulic gradient.
- Hydraulic gradient describes the effectiveness of the driving force behind water movement and is defined as:

$$i = \frac{\Delta H}{l}$$

where ΔH is the difference or change in total water potential between points in the soil and l is the distance between the points. For this technical note, hydraulic head represents soil water potential.



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Hydraulic Conductivity

- Hydraulic methods of K determination can be divided into two groups:
 - laboratory methods and
 - field methods.



Centurion
UNIVERSITY

Shaping Lives...
Empowering Communities...

Hydraulic Conductivity

□ Laboratory methods

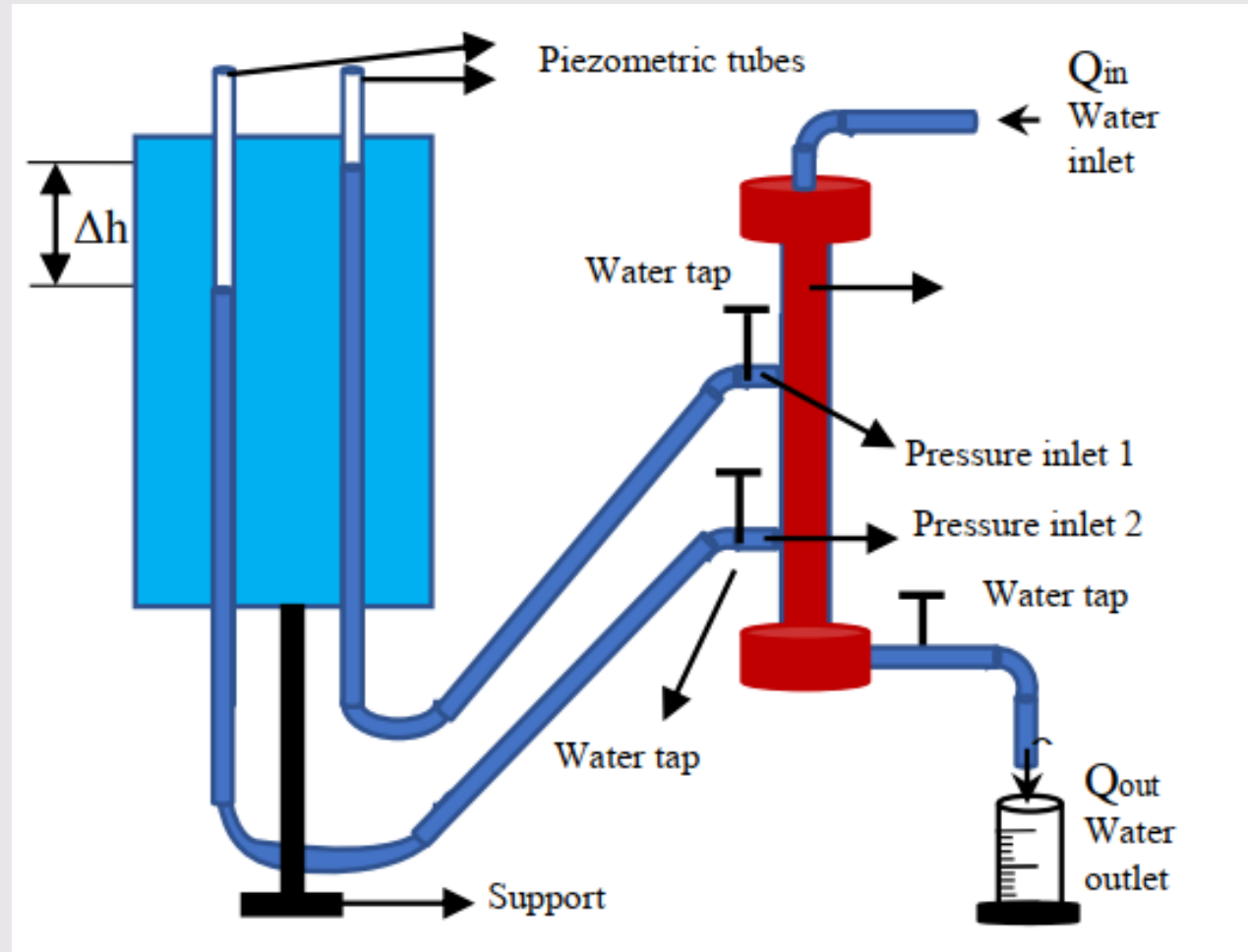


Fig. Constant-head permeameter



Centurion
UNIVERSITY

Shaping Lives...
Empowering Communities...

Hydraulic Conductivity

□ Laboratory methods

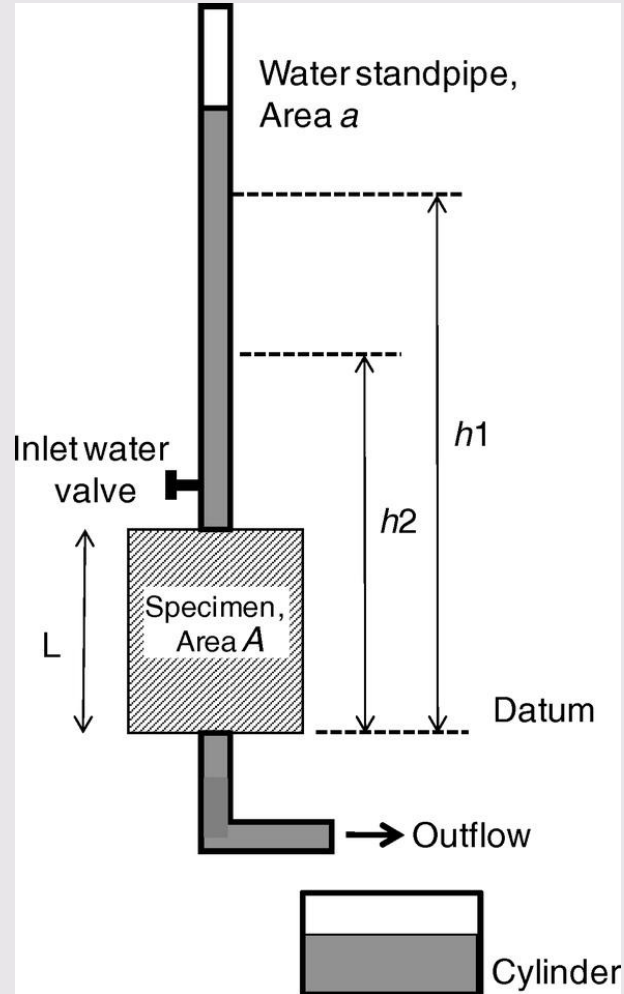


Fig. Falling head permeameter



**Centurion
UNIVERSITY**

*Shaping Lives...
Empowering Communities...*

Hydraulic Conductivity

□ Field methods

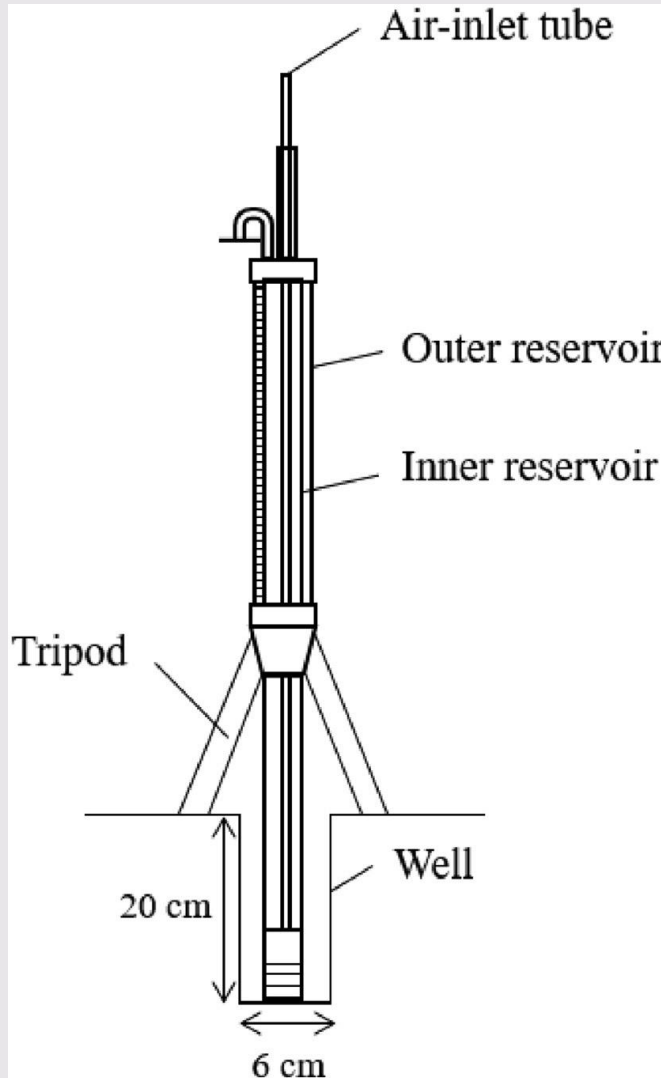


Fig: Guelph



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Drainable Porosity

- The term ‘drainable porosity’ is defined as the volume of water drained by gravity per unit volume of the saturated soil.
- It is also called ‘effective porosity’ or ‘specific yield’ or ‘storage coefficient’, especially in groundwater hydrology or hydrogeology.
- Since the release of water from a saturated soil under gravity is not instantaneous rather a slow process, the drainable porosity is a function of time and water table depth.
- However, most drain design methods adopt an average and constant value of drainable porosity because of simplicity in design computations.



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Drainable Porosity

- Drainable porosity can be measured in the laboratory or in the field.
- In the laboratory, drainable porosity can be measured using Hanging Water-Column apparatus which is suitable for a tension range of 0-150 cm.
- Hanging Water-Column apparatus consists of a glass funnel with a porous plate, a burette, and a flexible transparent tube connecting the glass funnel and the burette.



Centurion
UNIVERSITY

Shaping Lives...
Empowering Communities...

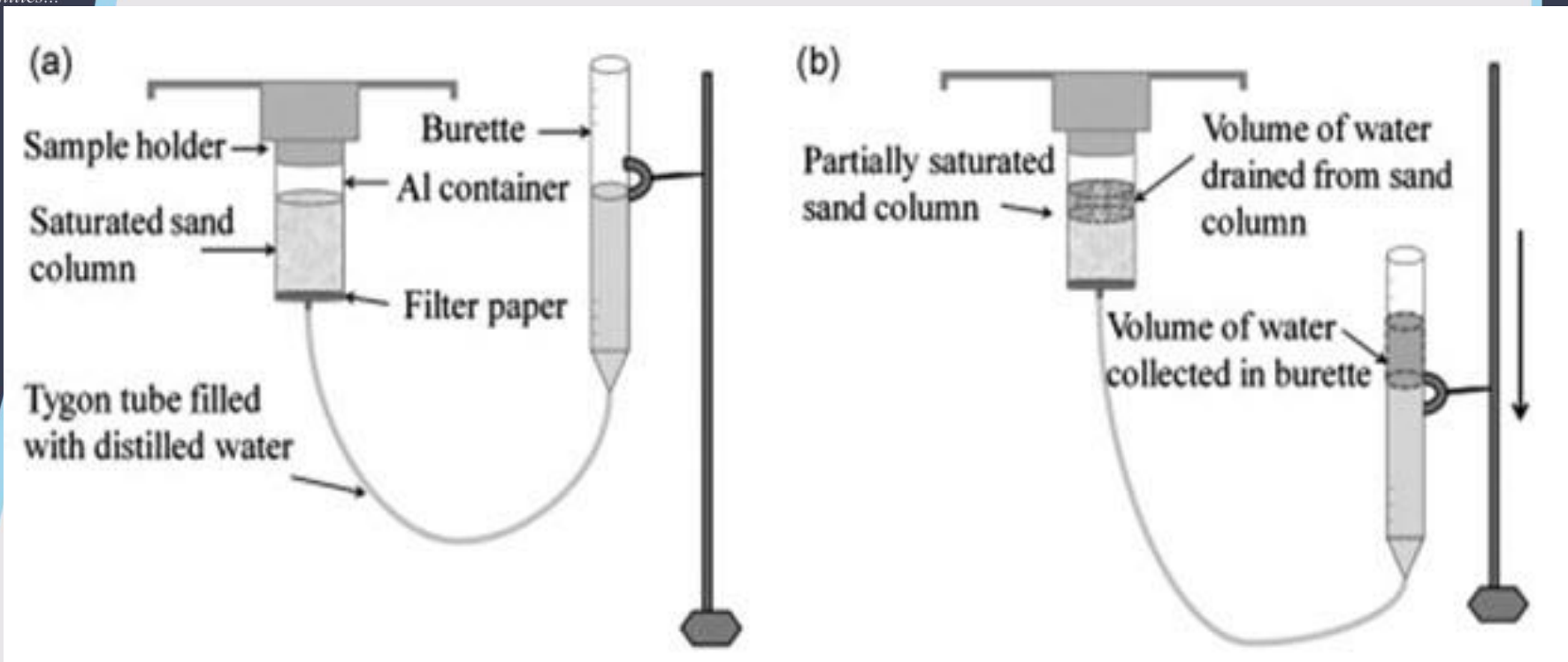


Fig. Hanging-Water Column apparatus: (a) Initial saturated sand column; (b) Lowered burette (Source: Kang et al., 2012)



Centurion
UNIVERSITY
*Shaping Lives...
Empowering Communities...*

Determination of Drainable Porosity

- Undisturbed soil sample is taken from the field and it is saturated in the laboratory with the help of Hanging Water-Column apparatus.
- The water level in the burette is maintained at the same level as the top of the porous plate.
- Thereafter, the burette is lowered by a certain distance (usually in steps of 10 cm), which imparts a suction to the saturated soil sample, and hence water starts draining slowly. The drained water raises the water level in the burette.
- At a given suction, this rise in water level is adjusted by readjusting the burette height such that the originally applied suction is closely maintained.



Centurion
UNIVERSITY
*Shaping Lives...
Empowering Communities...*

Determination of Drainable Porosity

- When there is no further rise in water level in the burette, the elevation difference between the top of the porous plate and the water level in the burette are noted down, which gives the value of average suction applied to the soil sample.
- The difference between the initial and the final burette readings gives the volume of water drained from the soil sample due to the applied suction.
- This process is repeated by lowering the burette in steps of 10 cm initially and more lately until the desired suction (corresponding to the maximum possible depth of the subsurface drain or any other criteria) is obtained.



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Determination of Drainable Porosity

- Generally, applying a suction of greater than 2 m is not required for drainage related studies.
- Based on the cumulative volume of water drained, drainable porosity is calculated by dividing the volume of water drained with the volume of the soil sample.



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Problem: In a subsurface drainage network, 10 lateral drains laid at a spacing of 40 m and each 150 m long, join a collector drain. The average discharge at the outlet of the collector drain was 10 L/s when the water table dropped from ground surface to 40 cm below the ground surface in 3 days. Find the average drainable porosity of the soil.

Solution

$$\text{Total area drained} = 10 \times 150 \times 40 = 60,000 \text{ m}^2$$

$$\text{Volume of soil drained} = 60,000 \times 0.4 = 24,000 \text{ m}^3$$

$$\begin{aligned} \text{Volume of water drained in 3 days} &= \frac{10 \times 3600 \times 24 \times 3}{1000} \\ &= 2592 \text{ m}^3. \end{aligned}$$

$$\text{Therefore, Drainable Porosity} = \frac{2592}{24000} = 0.108 \text{ or } 10.8\%,$$

Ans.



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

Note:

- The above calculated value of drainable porosity is the average of the top 40 cm soil layer and also an average over the time period of 3 days.
- As the water table is gradually declining, the discharge rate will also gradually decline.
- If the information on the discharge for shorter durations and the corresponding water table decline were available, the drainable porosity calculated for the shorter duration would have been different.
- Furthermore, the computed value of drainable porosity is also approximate as the entire depth of 40 cm of the soil has been assumed to have experienced a uniform water table decline of 40 cm.
- However, in a subsurface drained field, the water table is curved between the adjacent parallel drains.
- Therefore, the drained soil volume is not uniform throughout the drained field.



Centurion
UNIVERSITY

*Shaping Lives...
Empowering Communities...*

