

Chester County Engineers Webinar May 7, 2020

HOW WATER MOVES THROUGH SOIL

OUTLINE

- ✕ Soil water characteristics and behavior
- ✕ Types of soil water movement
- ✕ Factors affecting pore size and water movement
- ✕ NC State University Dye Tracer Study

SOIL WATER CHARACTERISTICS AND BEHAVIOR

Structure and Related Properties of Soil Water

- ✗ Polarity $+H-O-H+$
- ✗ Hydrogen Bonding
- ✗ Cohesive forces vs. Adhesive forces
- ✗ Surface tension

CAPILLARY FUNDAMENTALS AND SOIL WATER

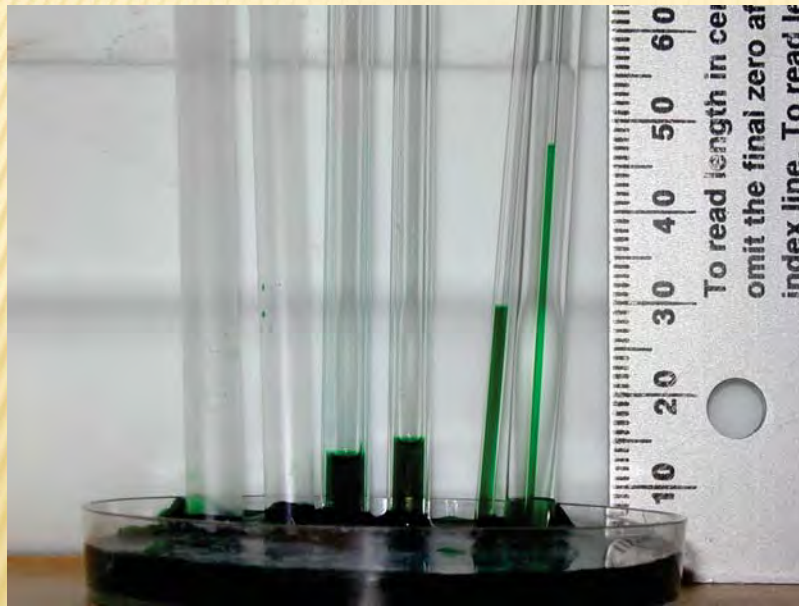
Capillarity is due to two forces:

1. The attractive force of water for solids on the pore linings or un-like surfaces= adhesion
2. The surface tension of water which is due to attraction of water molecules to each other=cohesion

Capillary force is due to big pores and little pores

Why does water rise higher in a small glass tube vs a large glass tube when place in the same bowl of water?

CAPILLARITY



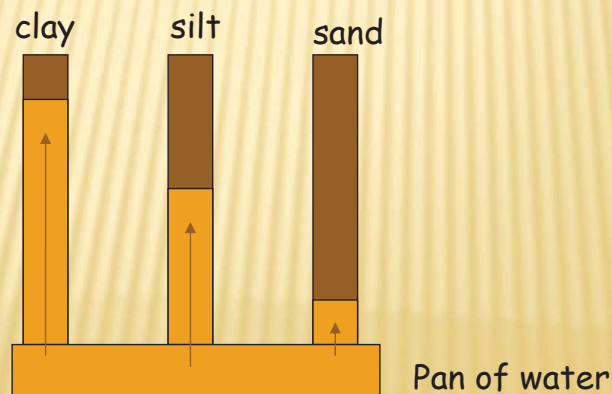
Height water will rise in cylinder depends on diameter of tube; due to **adhesion** of water and tube

Plastic

Glass

CAPILLARITY

- ✗ the smaller the pore space, the higher capillary water will rise in profile
- ✗ Smaller pore space, tighter water is held to particle surfaces against gravity (i.e., higher field capacity)



SOIL WATER ENERGY CONCEPTS

Forces Affecting Free Energy of Soil Water

1. Matric Force: mainly adhesion
2. Osmotic Force: movement of ions across a membrane
3. Gravity Force: movement downhill by gravity

HOW DO WE MEASURE SOIL WATER

- ✕ Wells
- ✕ Piezometers
- ✕ Tensiometers

TYPES OF SOIL WATER MOVEMENT

- ✖ Saturated Flow
- ✖ Unsaturated Flow
- ✖ Vapor Flow

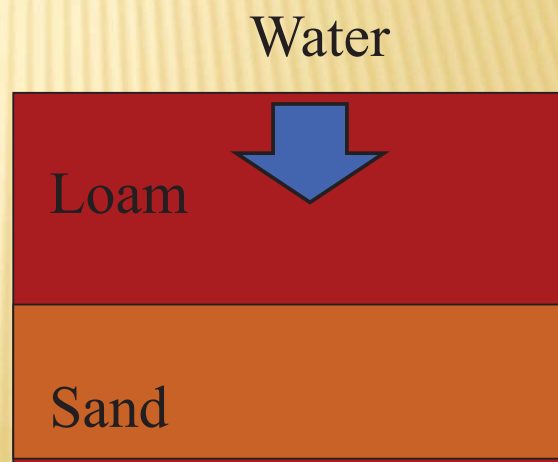
SATURATED FLOW

- ✖ Occurs when all of the pore space is filled with water and gravity is the main directional force
- ✖ Water flows downhill only under saturated flow
- ✖ Is not conducive to waste water treatment
- ✖ It's measurement is called hydraulic conductivity and determined by Darcy's law or K_{sat} . It measures one-dimensional flow. A percolation test is not measuring K_{sat} . It measures a drop of water in a hole
- ✖ How is K_{sat} measured?
 - Field: double ring and single tube methods
- ✖ Is HC faster with saturated or unsaturated flow?

UNSATURATED FLOW

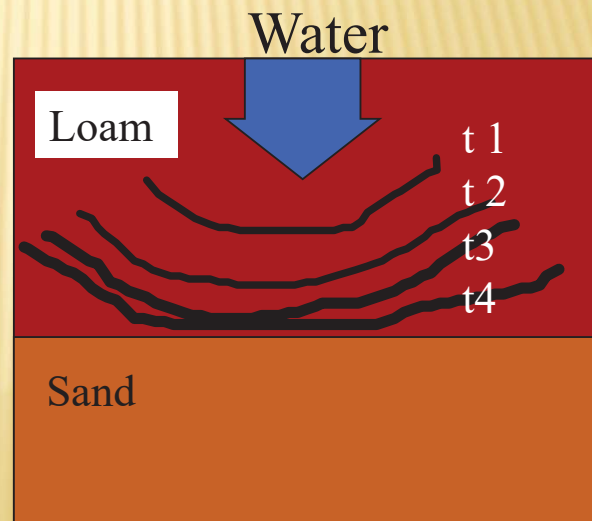
- ✖ Moves from low tension to high tension
- ✖ Moves from big pores to little pores
- ✖ Macro pore flow is sometimes called by-pass flow or a “flush” event
- ✖ Microspore flow holds the water and contaminants in the soil for renovation by micro organisms.
- ✖ Waste water treatment requires unsaturated flow.
- ✖ Remember: Soils Suck... they hold water against the force of gravity by unsaturated flow.

WATER MOVEMENT



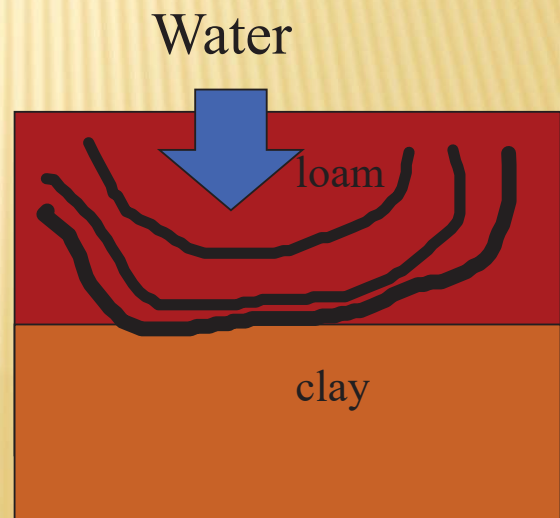
WATER MOVEMENT

- ✗ Water front does not move into sand until loam is saturated



WATER MOVEMENT

- ✗ Water front moves into clay upon contact with clay, but because it moves slow water builds up above the clay layer.



VAPOR FLOW

Two types of vapor flow

1. Internal: within the soil pores
2. External: loss of water to the soil surface by evaporation

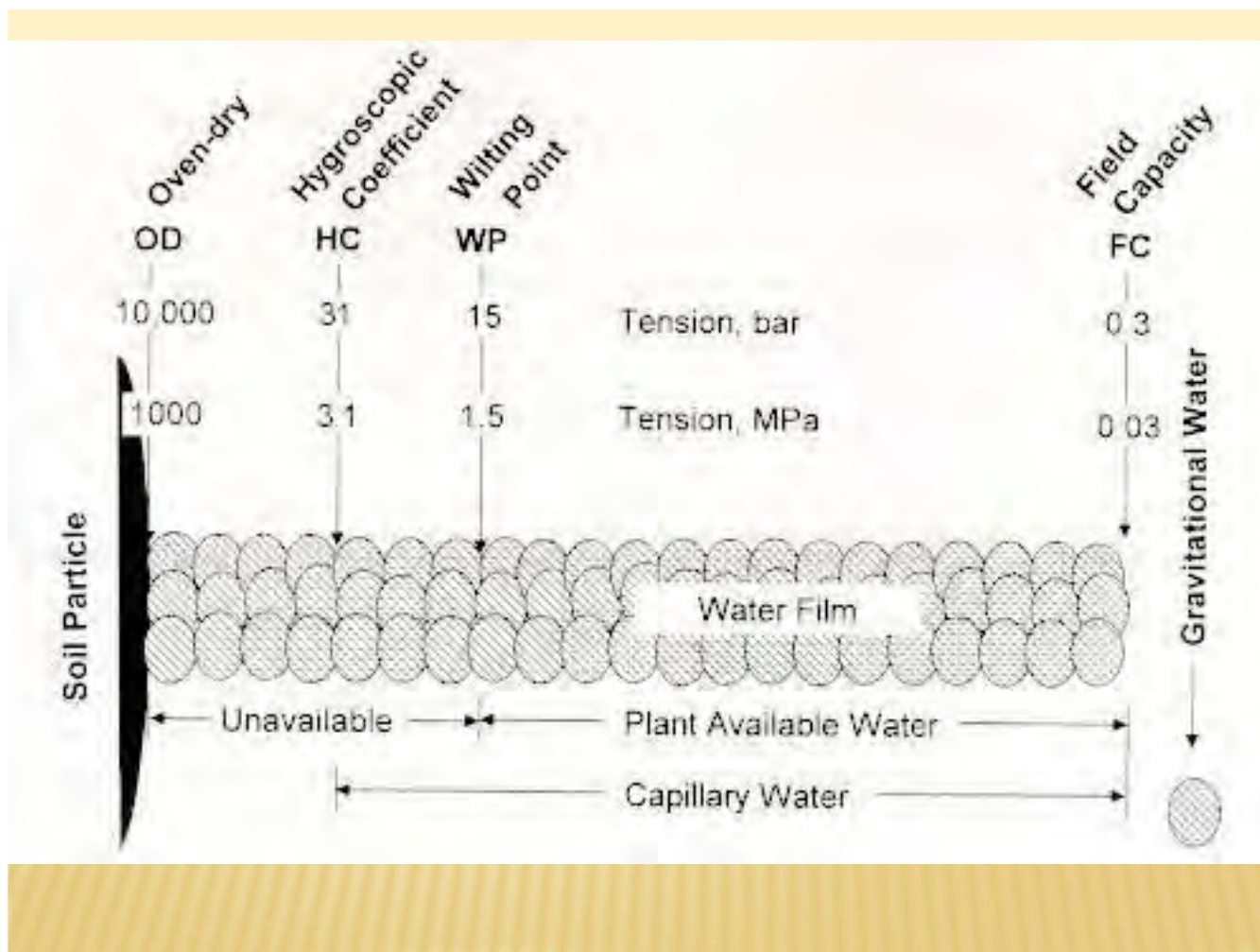
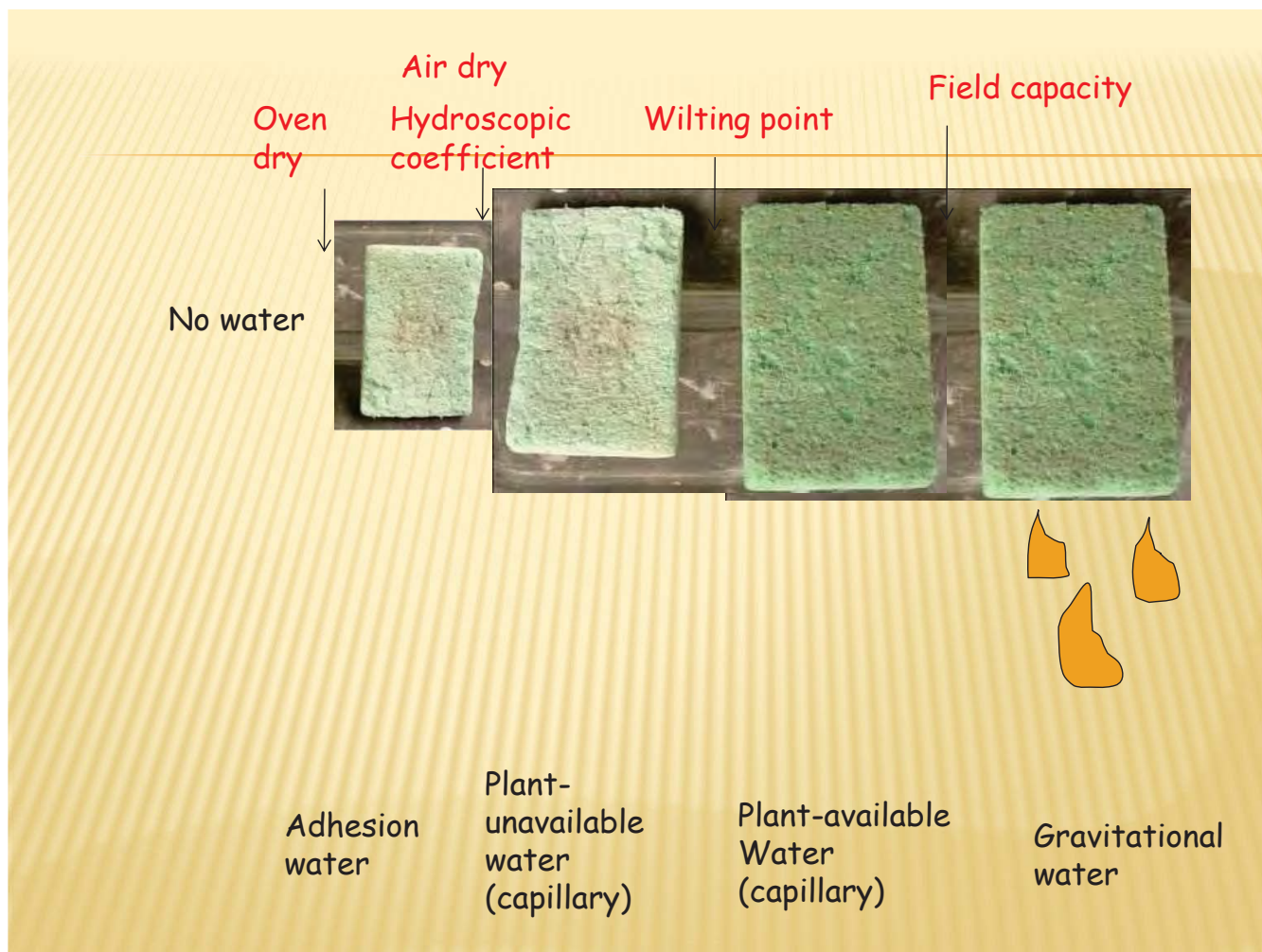
SOIL WATER CAPACITY

Saturated soil: flow by gravity

Field capacity: point at which soil is still un-saturated but is almost saturated and gravity is not affecting the water flow

Wilting coefficient: water held so tightly that it is unavailable for plant uptake

Hygroscopic coefficient: down to water film of a few molecules



RELATIONSHIP TO WASTE WATER RENOVATION

- ✖ Saturated flow allows for transport of contaminates through the soil by macro pore flow
- ✖ Flush events occur after a significant rainfall. This aspect was demonstrated by research at DVC
- ✖ Unsaturated flow is what we try to achieve when siting an on-lot sewage disposal system. This allows for renovation of the waste water in micro pores by physical, chemical and biological processes.

FACTORS AFFECTING PORE SIZES AND WATER MOVEMENT IN SOIL

- ✖ Texture
- ✖ Soil Structure
- ✖ Consistency
- ✖ Slope

TEXTURE

- ✖ Coarse fragments : greater than 2mm
- ✖ Sand: 2 mm to .05 mm
- ✖ Silt: .05 to .002 mm
- ✖ Clay: less than .002 mm

- ✖ Texture is the % sand , silt, and clay
- ✖ Textural class is a grouping of textures into 12 textural classes.
- ✖ **Source of primary porosity**

SOIL STRUCTURE

Source of secondary porosity

Type, grade and size

Type:

1. Granular
2. Blocky (angular and sub-angular)
3. Platy
4. Prismatic or columnar
5. Wedge or lenticular
6. Structure less (massive, single grain or rock fabric)

Grade is the durability of the structure which is produced by organic acids.

Size affects the number of ped faces or pores between the structural units

SOIL CONSISTENCY

Dependent on moisture content

DRY: hard or soft

MOIST: friable or firm

WET: sticky and plastic

Consistency affects the density of the ped and therefore the pore size and its affect on water movement

SLOPE

Only a factor in saturated flow

Moves water from high gradients to low gradients
on the ground surface or sub-surface by
saturated flow

Water moves down hill and pay day is on Friday!
Is this always true???

LANDSCAPE LOADING

Landscape loading uses soil morphology and the principals of soil water movement to determine the length and width of an absorption area (Tyler 2000).

5 gallon bucket of water tipped over and measure the distance for infiltration vs. a long rain gutter with 5 gallons of water

Which one will infiltrate in the shortest distance?

This is landscape loading!

REVIEW OF SOIL WATER MOVEMENT

- ✖ Saturated vs unsaturated flow
- ✖ Saturated flow by gravity
- ✖ Unsaturated flow from low to high tension
- ✖ Saturated flow uses the macro pores
- ✖ Unsaturated flow uses the micro pores

EXAMPLES

Sand over clay:

with unsaturated flow will water enter the clay?

Clay over sand:

with unsaturated flow will water enter the sand?

Will a buried drain collect water by saturated or unsaturated water flow?

How does this affect a drain design?

CONCLUSION

Saturated water flow is by gravity

Unsaturated flow moves by tension...from low to high
Soils Suck!

Field capacity is the amount of water held by a given soil against the force of gravity...that point right before saturated flow

Wastewater renovation is best at unsaturated flow

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DISCUSSION

- ✗ Is water movement faster with saturated or unsaturated flow?
- ✗ What affect does buried organic material have on unsaturated water flow?
- ✗ What affect would a pocket of shale with voids have on unsaturated water flow? On saturated flow?
- ✗ Does fine texture soil over coarse texture soil create a water table?
- ✗ Any other questions?

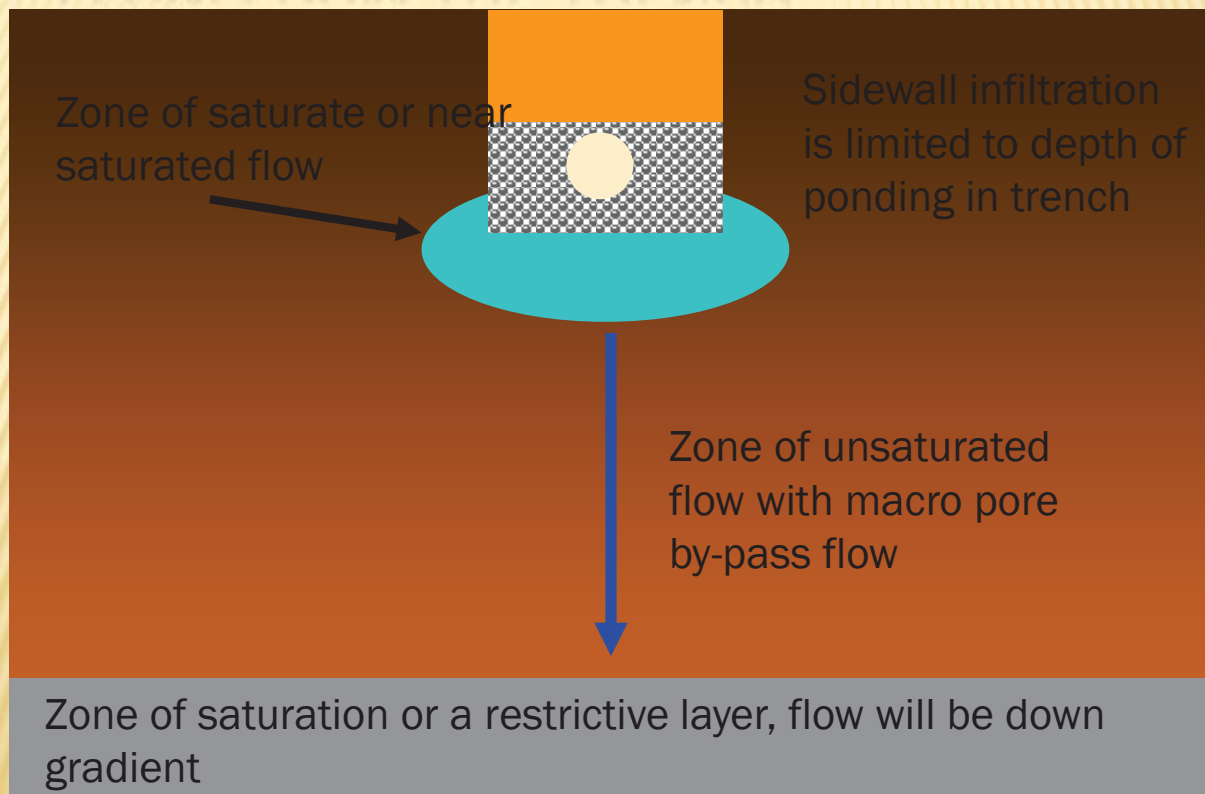
WASTEWATER FLOW FIELD STUDIES

NC Carolina State University

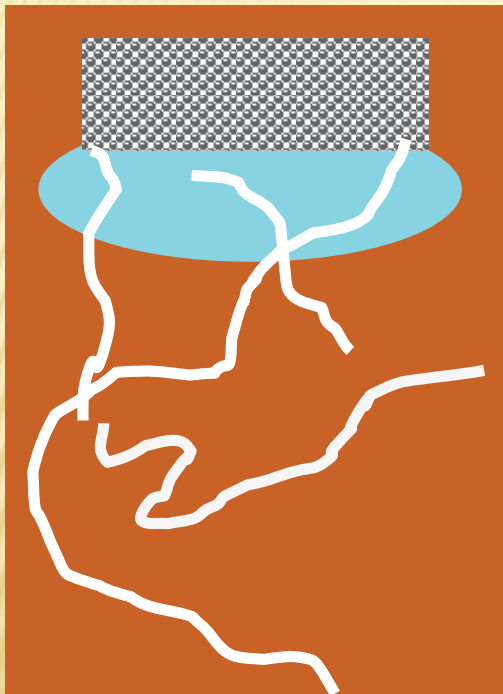
Dye Tracer Study

2000

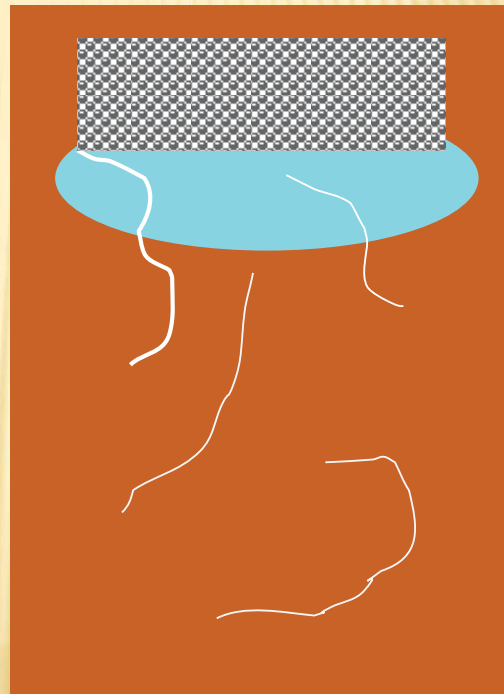
FLOW FROM THE TRENCH



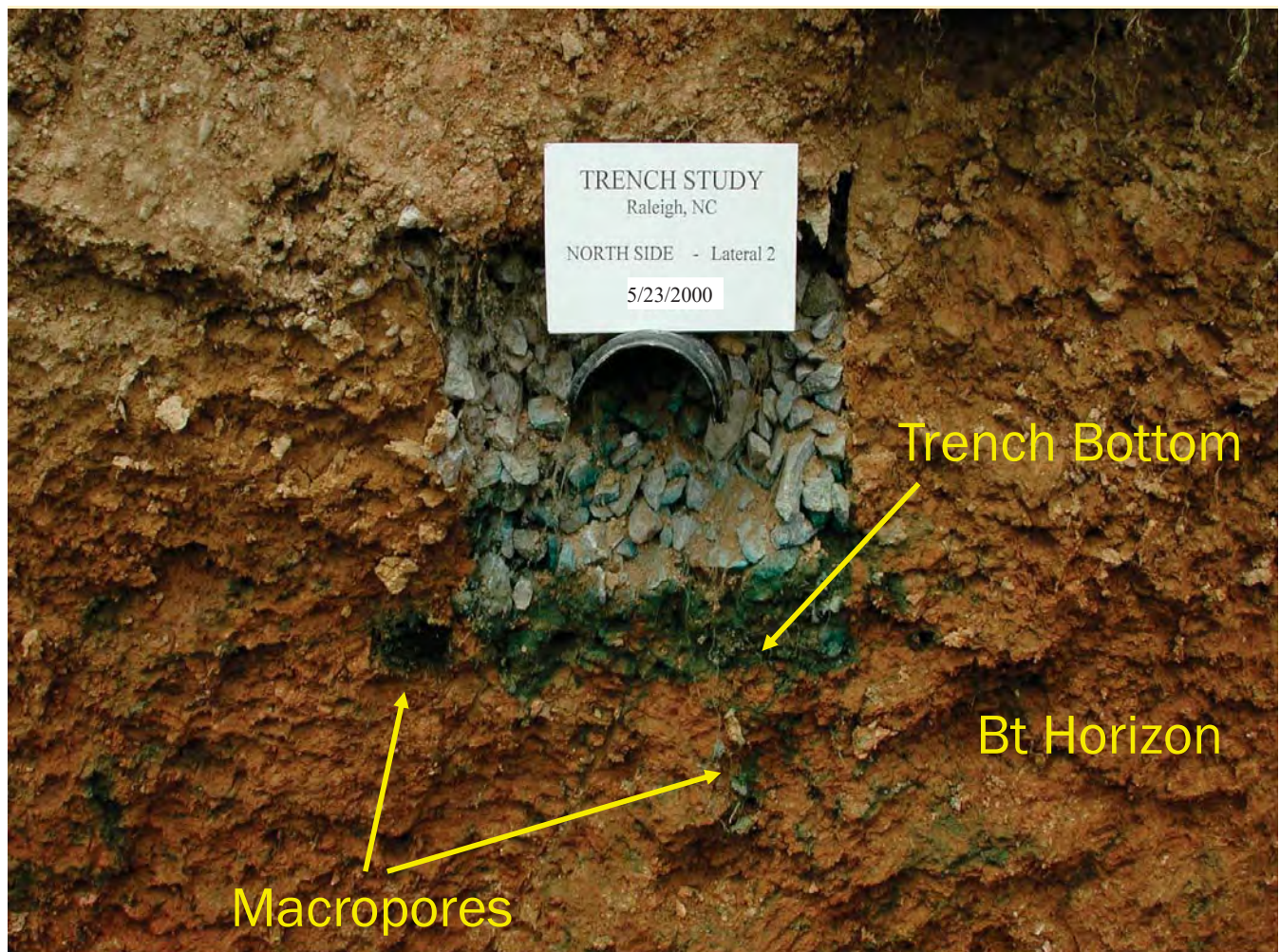
DETAIL OF FLOW AWAY FROM TRENCH

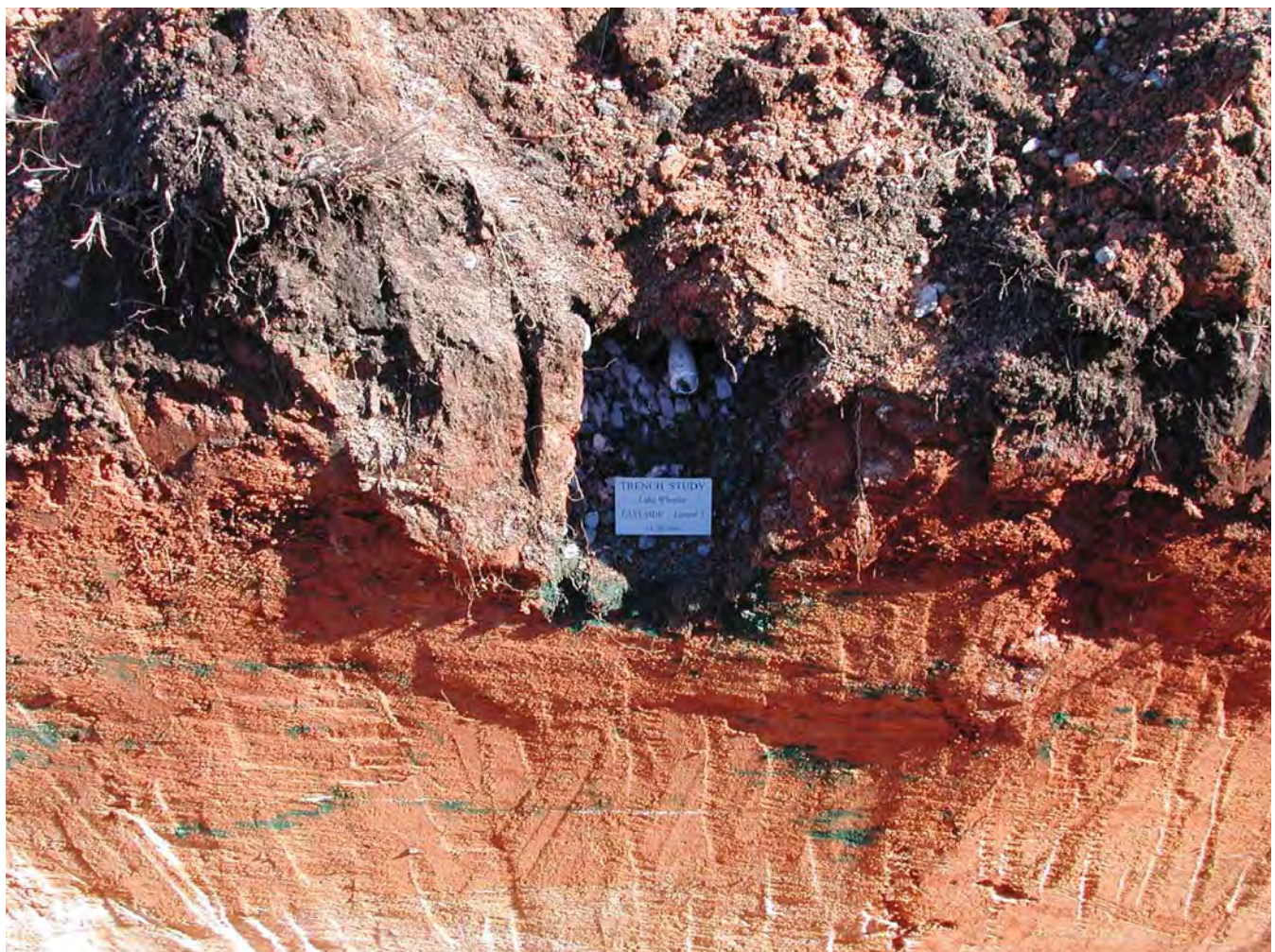
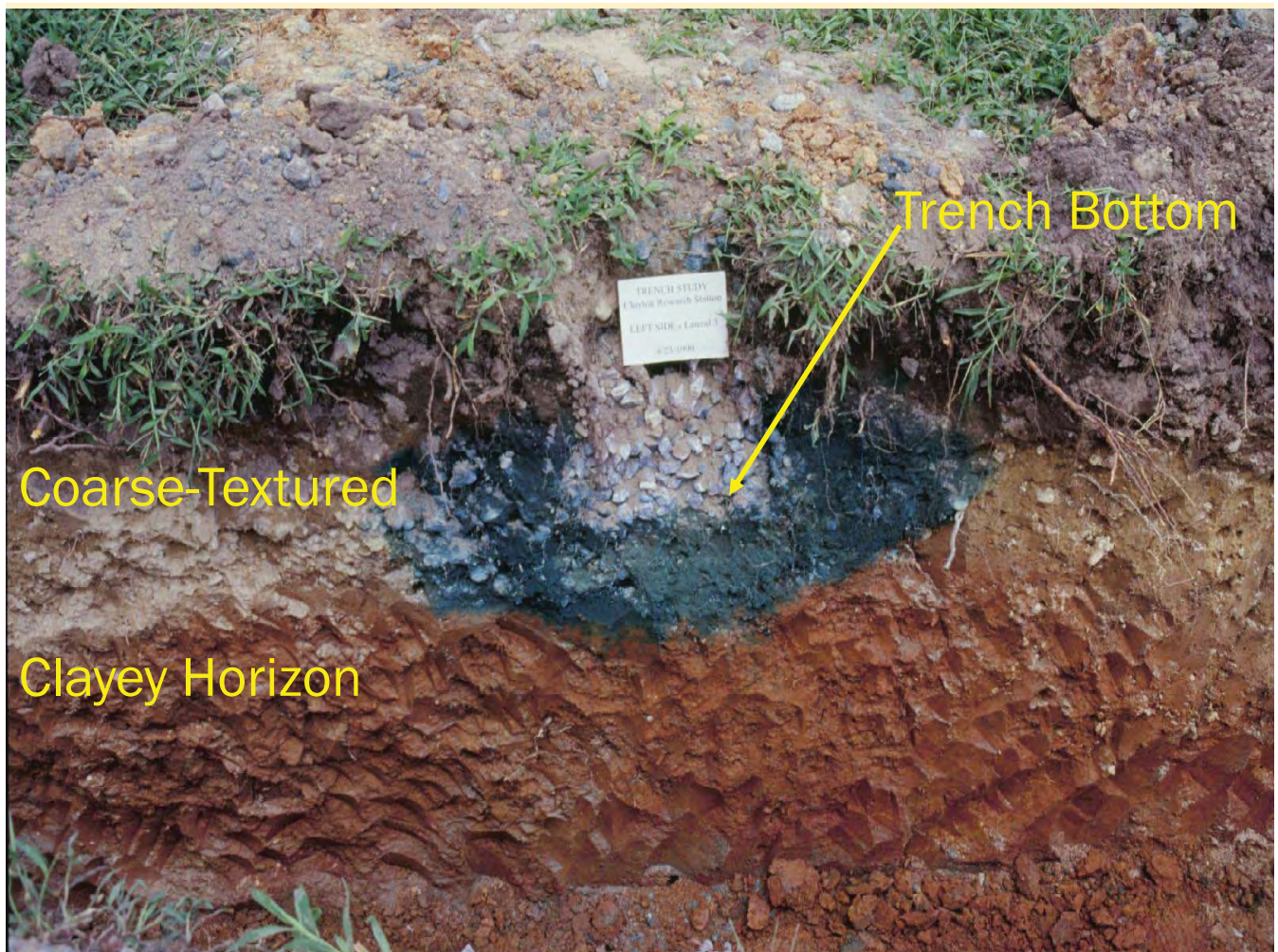


Faster flow away from trench



Slower flow away from trench









SUMMARY OF SOIL WATER FLOW

- ✖ Saturated vs. unsaturated flow
- ✖ Macropore vs micropore flow
- ✖ Structured vs non-structured soils
- ✖ Vertical vs horizontal flow-Landscape Loading
- ✖ Surface vs sub-surface installations and preferential flow patterns
- ✖ Flush events or by-pass flow

ACKNOWLEDGEMENTS

- ✕ Dr. David Lindbo, NC State University
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HOW WATER MOVES THROUGH SOIL

How Water Moves Through Soil Video

<https://video.search.yahoo.com/search/video?fr=mcafee&p=video+water+movement+through+soil+water#id=5&vid=567ff8b8aad88bf519e907cf21455b04&action=view> 31:17

Soil Water Sponge Demonstration Video

<https://video.search.yahoo.com/search/video?fr=mcafee&p=video+water+movement+through+soil+water#id=41&vid=3a497cf6acf5ef2d92471716902d4b37&action=view> 5:04

Questions ?