**Infiltration**

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1. **Introduction**

A watershed is the topographic area that contributes all the water that passes through a given cross section of a stream, it is also called drainage basin, river basin, or catchment area, depending on scale. The boundary that delimits a watershed is called a divide. A watershed is treated as a unit for hydrologic investigations as its topographic divide typically defines hydrologic boundaries that enable water budgets to be computed. Consequently, one of the main building blocks of a small catchment study is the water balance, which is calculated using the water balance equation for any time period of length t:



Where P is precipitation (rain and snow), is ground-water inflow, also called infiltration, Q is stream or river outflow, ET is evapotranspiration by soil and vegetation, is ground-water outflow, and is the change in all forms of storage (water, snow and ice) over the time period.





Fig. 1 Schematic diagram of a watershed.

As the water balance equation shows, infiltration is one of main components of the hydrologic cycle, it defines how water fluxes at the soil surface enter the soil. Infiltration is measured as an ‘infiltration rate’, the rate at which soil is able to absorb rainfall or irrigation, and thus determines the soil water content, which is a critical factor for vegetation. Besides, it also controls the amount of outflow and ground water level, influencing the general water circulation pattern in the watershed.

Key Reference:

*Dingman, S.L., 2008. Water in Soils: Infiltration and Redistribution in Physical Hydrology, pp243~251.*

**Practice:**

To describe the infiltration process, we need to assess the following variables:

(1) Water-input rate (w(t)) , which is the rate at which water arrives at the surface due to rain, snowmelt, or irrigation [L / T].

(2) Infiltrability (infiltration capacity) (f\*(t)), which is the maximum rate at which infiltration can occur [L / T], this value is not constant, but changes during the infiltration event.

(3) Depth of ponding (H(t)), which is the depth of water standing on the surface [L].

(4) Soil moisture content, which is the quantity of water contained in soil, it is expressed as a ratio, which can range from 0 (completely dry) to the value of soil’s porosity at saturation (θ);

(5) Soil porosity (φ), a measure of the void space in soil, it is a fraction of the volume of voids over the total soil volume, a value between 0-1, or as percentage between 0-100%.

(6) Hydraulic conductivity (K), is a property of soil that describes the ease with which water can move through pore spaces or fractures.

(7) Pressure head (), is used to represent the internal energy of a fluid due to pressure exerted on its container, mathematically expressed as: (where is fluid pressure [M / [L T2]], is the specific weight [M / T2], is the density of fluid [M / L3], and g is the acceleration due to gravity.



Question 1

Note that dimensions are given for each variable, the fundamental dimensions are length, time, mass and electrical charge. Water input rate has the dimensions of length per time; can you think of the units that the weather forecast would present this variable in?

Question 2

Infiltration is driven by gravity and pressure forces on water arriving at the surface. For a constant precipitation rate on a dry soil (when the soil is unsaturated), lasting for a long time, will the infiltration rate change with time? If not, how will it change and why?

Question 3

For a very dry soil, and a low precipitation rate, the soil moisture profile goes through three stages 1) unsaturated; 2) partially saturated; and 3) fully saturated. Please describe the relationships between f(t), w(t) and f\*(t) for each case? How about the value of H(t) at each stage?

Question 4

Infiltration rate can be measured in several ways; one of devices used is called a ring infiltrometer, which directly measures infiltrability over a small area (0.02-1m2). The area is defined by an impermeable boundary, usually a cyclindrical ring extending several centimeters above the surface, and sealed at the surface or extending several centimeters into the soil.



Fig. 2 Ring infiltrometer

The Excel ‘Infiltration.xlsx’ file worksheet ‘Infiltration measurement’ shows the equation used in this field method.

*4A*  Explore average infiltration rate changes with precipitation duration. Calculate f(t) and show infiltration rate for each time interval, make a plot. What does this result in? What would happen if the ring was removed and part of the water was ponded and part of it runs off? (See worksheet for example values).

*4B*  Practice 2 calculates the average infiltration rate with increasing water input rate, calculate the value of f(t) and plot a graph of f(t) as a function of P, what did you get? Is there a constant slope? What does that mean and why?

Question 5

Hydraulic conductivity is an important parameter in the infiltration process, It depends on the intrinsic permeability of material and on the degree of saturation. Try to think about which factors will influence the hydraulic conductivity of soil (list at least 4) and how they work.

Question 6

A simple way to calculate infiltration uses ‘Richards equation’. The Excell worksheet named ‘Infiltration Model’ allows you to calculate the vertical flow rate for two different types of soil and with varying pressure heads. Please plot graphs of vertical flow rate changes as a function of K and Ψ. Compare the results, and quantify the role of K and Ψ in the infiltration process (Hint: you can do it by calculating the slope of the trend line, in addition search online to find realistic ranges for K and Ψ)

*Reference:*

*Hydraulic Conductivity measurement: http://www.connectedwater.gov.au/framework/hydrometric\_k.php*

*Static Pressure and Pressure Head in Fluids: http://www.engineeringtoolbox.com/static-pressure-head-d\_610.html*