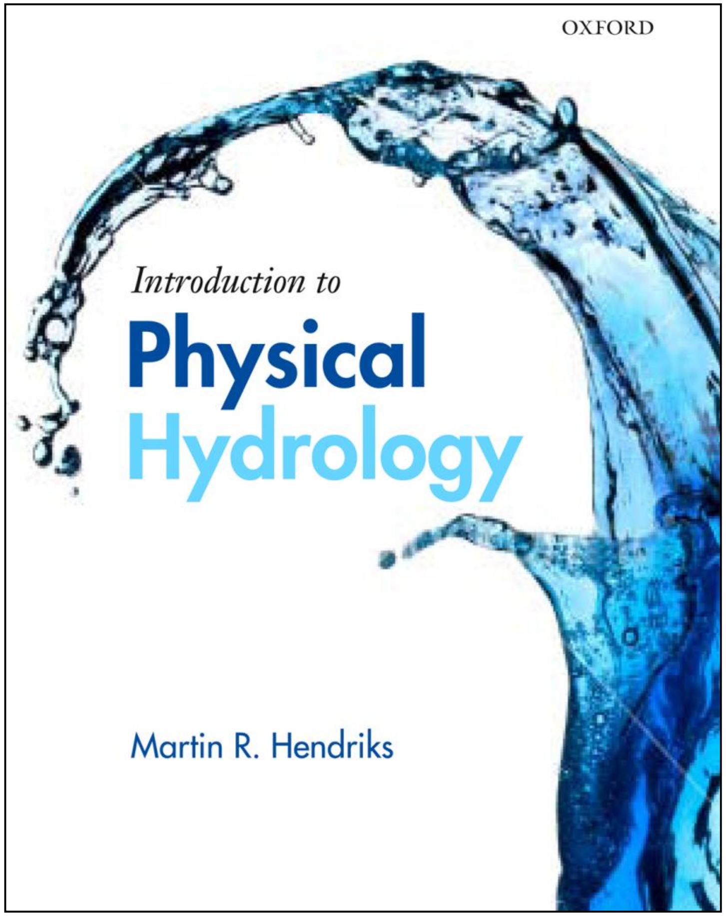
Soil water / Unsaturated Zone Hydrology



Paperback | 351 pages
Follow the book's didactic concept!

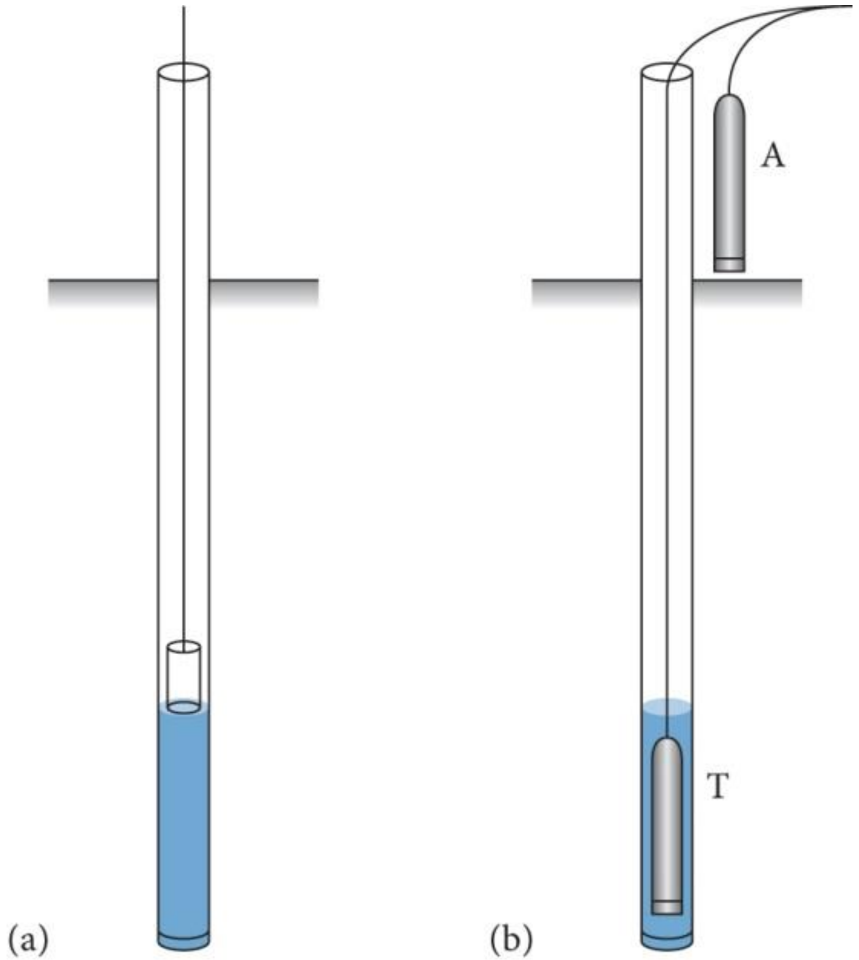
- Hydrological cycle
- Drainage basin
- Water balance

- Energy equation
- Flow equation
- Continuity equation

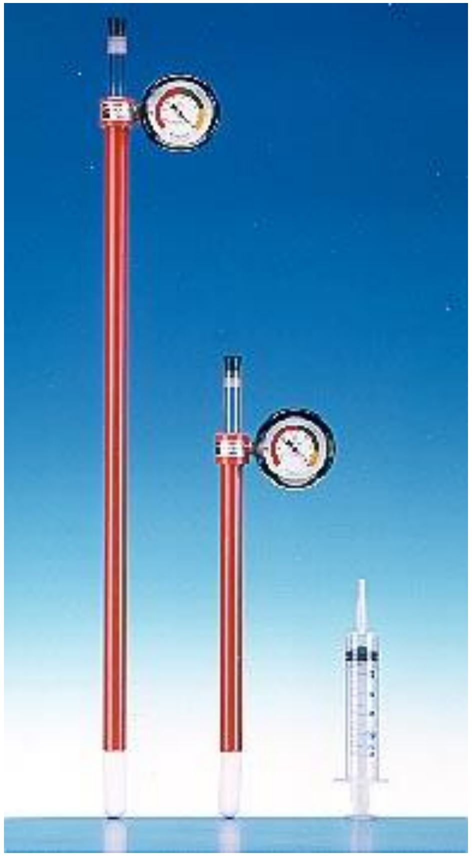
1. Introduction
2. Atmospheric water
3. Groundwater
4. **Soil water**
5. Surface water

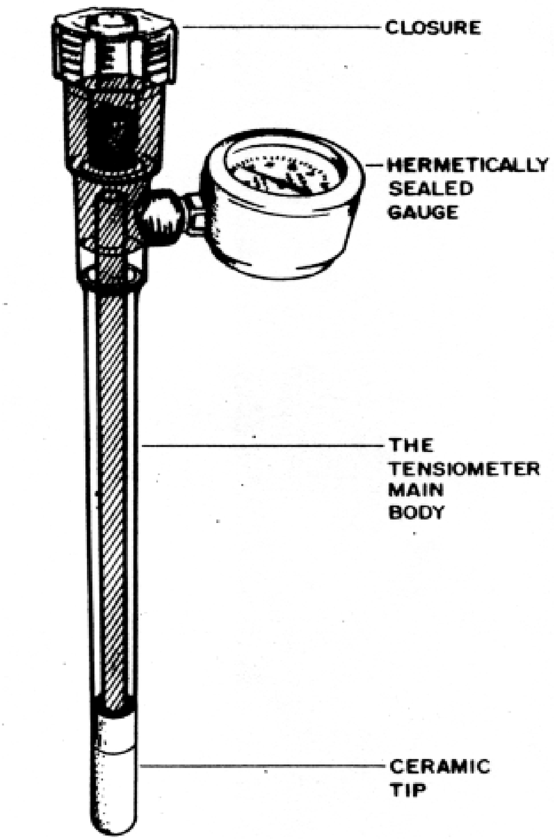
Exercises

Piezometers

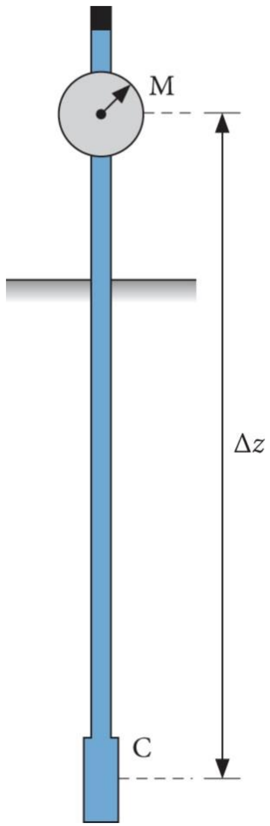


Tensiometers





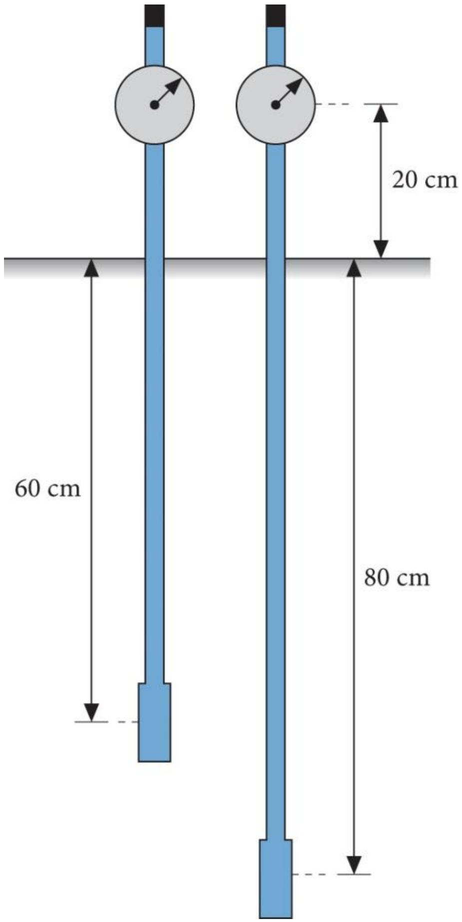
Tensiometer



$$p_{C} = p_{M} + \rho g \Delta z$$

$$\psi_{C} = \psi_{M} + \Delta z$$

Two tensiometers



$\Psi_C = \Psi_M + \Delta z$

$\Psi_M = -110$ cm

$\Delta z = 60 + 20 = 80$ cm

$\Psi_C = -110 + 80 = -30$ cm

Land surface: $z = 0$

$h = z + \Psi_C$

$h = -60 + (-30) = -90$ cm

$\Psi_C = \Psi_M + \Delta z$

$\Psi_M = -110$ cm

$\Delta z = 80 + 20 = 100$ cm

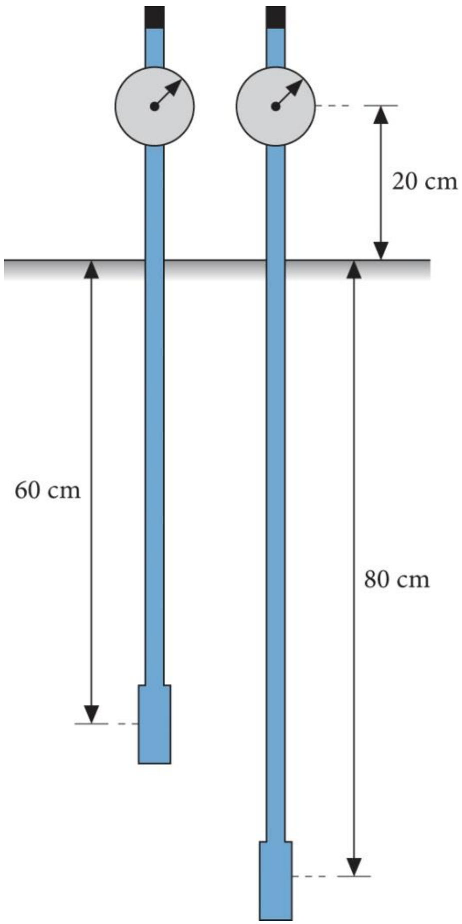
$\Psi_C = -110 + 100 = -10$ cm

Land surface: $z = 0$

$h = z + \Psi_C$

$h = -80 + (-10) = -90$ cm

Upward flow



$\Psi_C = \Psi_M + \Delta z$

$\Psi_M = -130$ cm

$\Delta z = 60 + 20 = 80$ cm

$\Psi_C = -130 + 80 = -50$ cm

Land surface: $z = 0$

$h = z + \Psi_C$

$h = -60 + (-50) = -110$ cm

$\Psi_C = \Psi_M + \Delta z$

$\Psi_M = -110$ cm

$\Delta z = 80 + 20 = 100$ cm

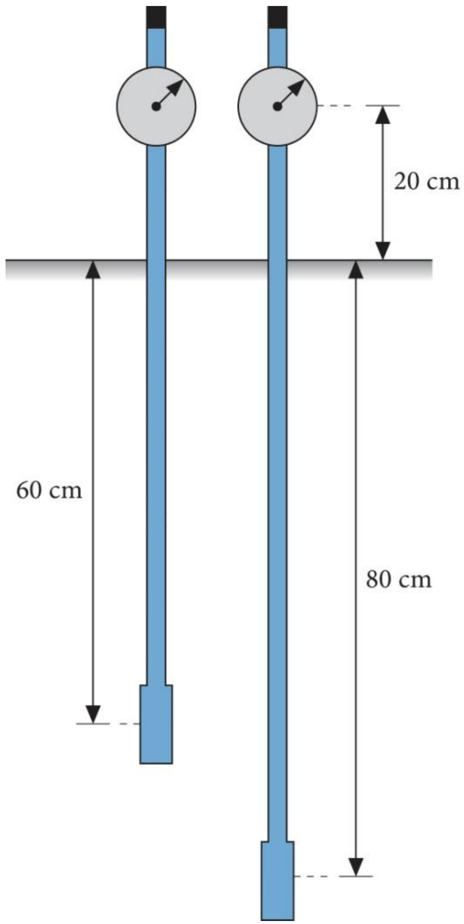
$\Psi_C = -110 + 100 = -10$ cm

Land surface: $z = 0$

$h = z + \Psi_C$

$h = -80 + (-10) = -90$ cm

Downward flow



$\Psi_C = \Psi_M + \Delta z$

$\Psi_M = -110$ cm

$\Delta z = 60 + 20 = 80$ cm

$\Psi_C = -110 + 80 = -30$ cm

Land surface: $z = 0$

$h = z + \Psi_C$

$h = -60 + (-30) = -90$ cm

$\Psi_C = \Psi_M + \Delta z$

$\Psi_M = -130$ cm

$\Delta z = 80 + 20 = 100$ cm

$\Psi_C = -130 + 100 = -30$ cm

Land surface: $z = 0$

$h = z + \Psi_C$

$h = -80 + (-30) = -110$ cm

The soil as

https://cf.shopee.sg/file/2b9171463a8d68c8fcda8c987d683ff7

https://images-na.ssl-images-amazon.com/images/I/41QvgogjXbL.jpg

a dry filter paper

a dry sponge

The soil as

https://cf.shopee.sg/file/2b9171463a8d68c8fcda8c987d683ff7

https://images-na.ssl-images-amazon.com/images/I/41QvgogjXbL.jpg

a wet filter paper

a wet sponge

Field capacity
Veldcapaciteit

The soil as

https://cf.shopee.sg/file/2b9171463a8d68c8fcda8c987d683ff7

https://images-na.ssl-images-amazon.com/images/I/41QvgogjXbL.jpg

a filter paper

dry soils
small pores
water held at high suctions
large negative matric potentials

a sponge

wet soils
large pores
water held at low suctions
small negative matric potentials

Terminology revisited

h = total potential (cm) = hydraulische potential (cm)

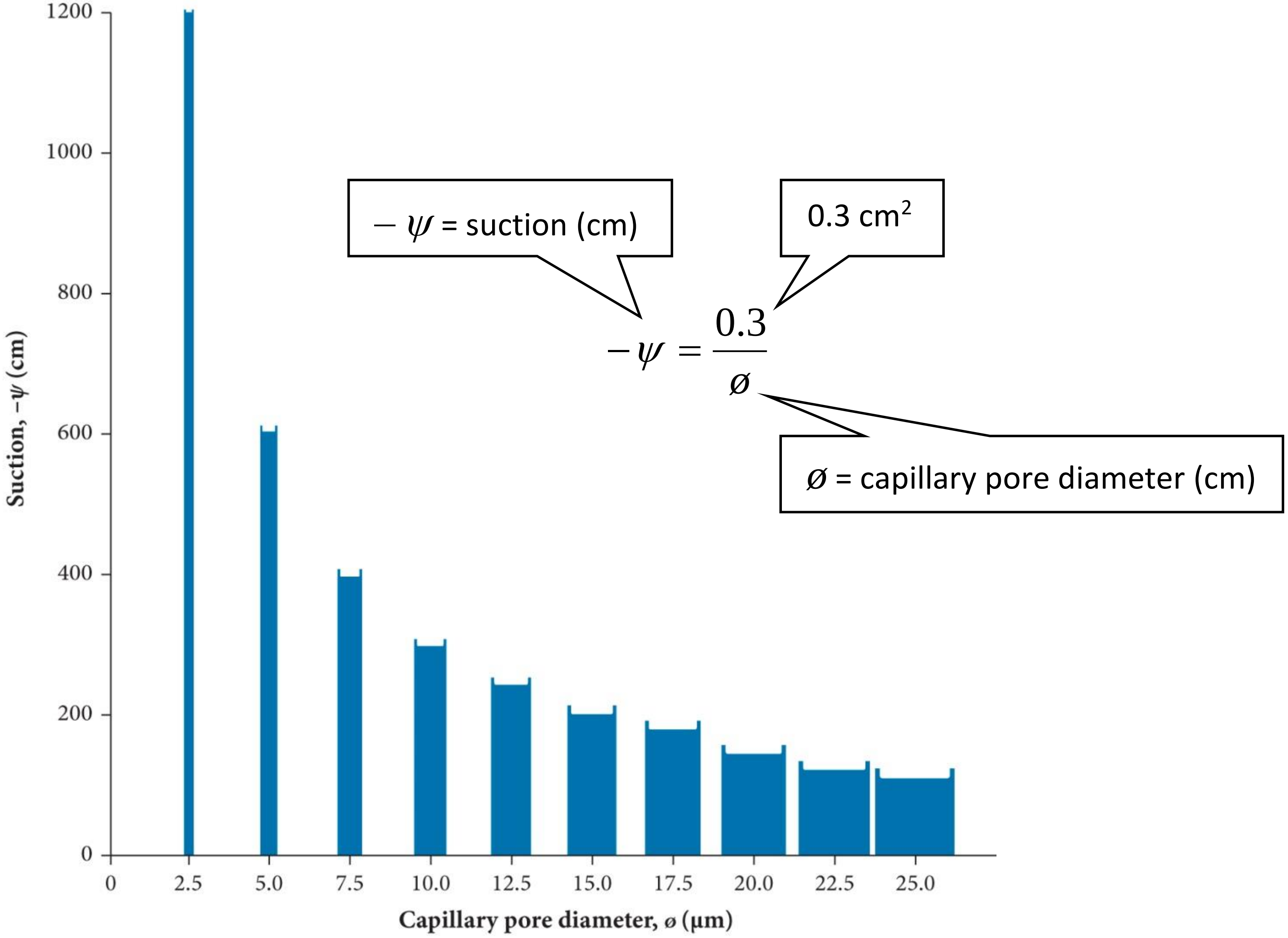
z = gravitational potential (cm) = zwaartekrachtspotentiaal (cm)

ψ = matric potential (cm) = matrixpotentiaal (cm) = vochtspanning (cm)

$-\psi$ = suction (cm) = zuigspanning (cm)

$pF = \log(-\psi)$ with $-\psi$ in cm!

Suction and capillary pore diameter

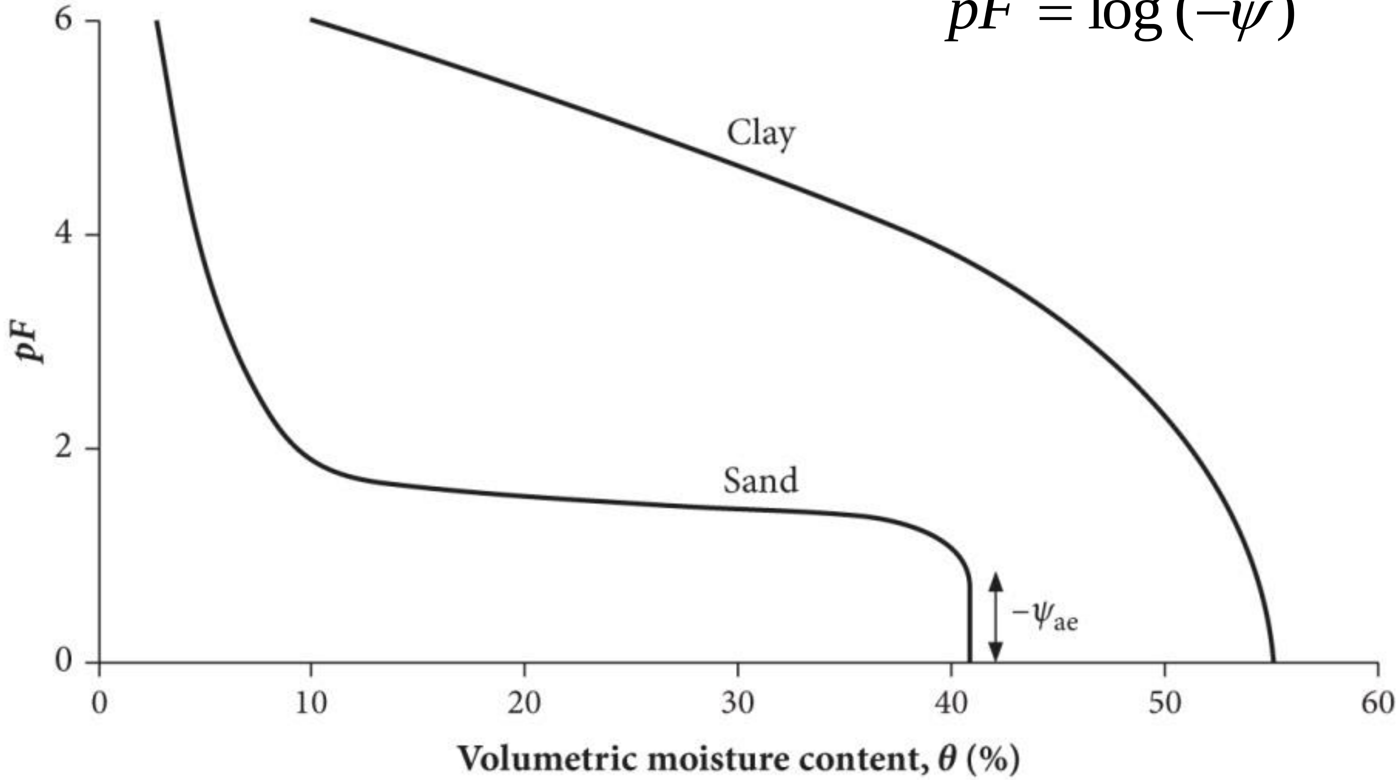


$pF = \log(-\psi)$

Soil moisture characteristic

Soil moisture retention curve or *pF* curve

$$pF = \log(-\psi)$$



$-\psi_{ae}$ = air-entry suction

Soil moisture characteristic

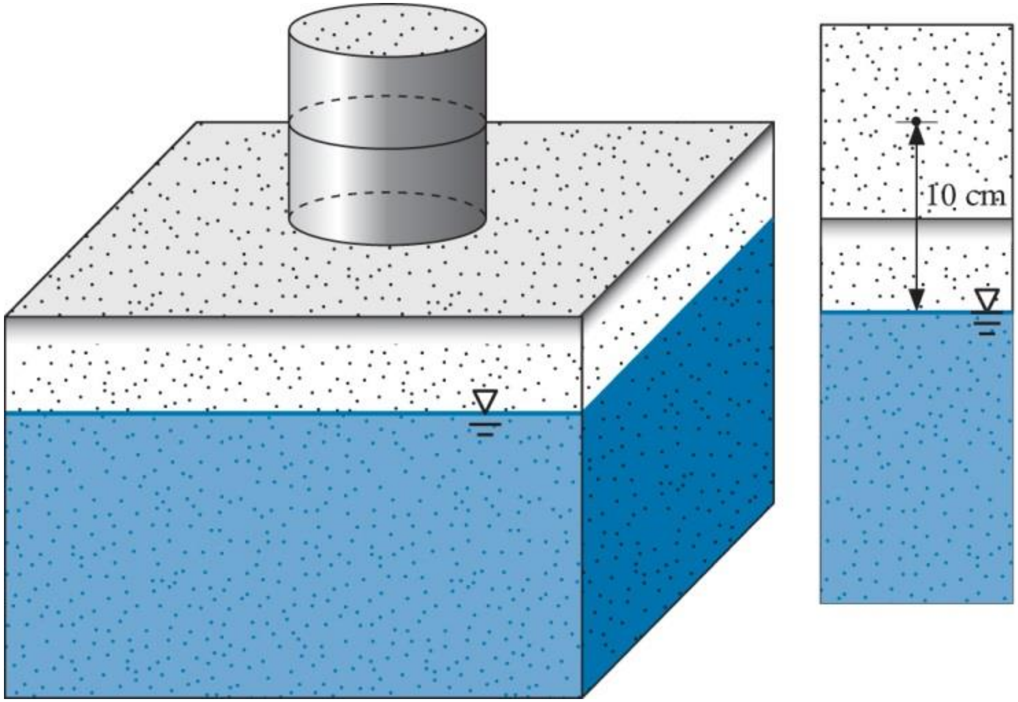
Photos soil core sample ring:
Forschungszentrum Jülich GmbH

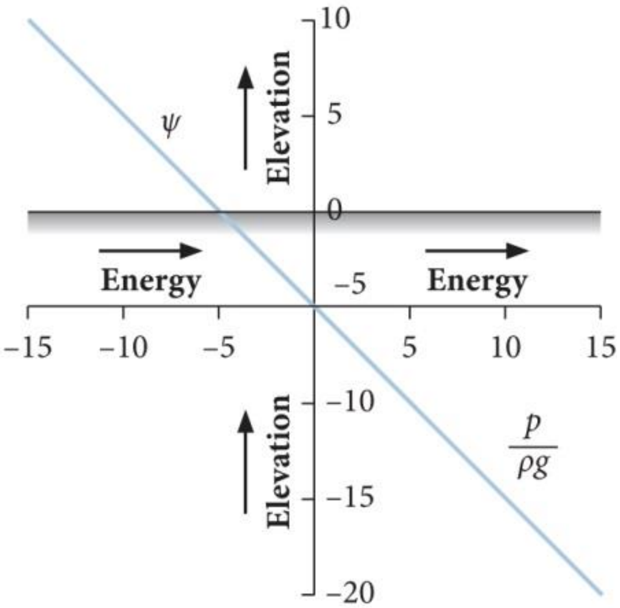
$$pF = \log(-\psi)$$

Soil moisture characteristic

Soil moisture retention curve or *pF* curve

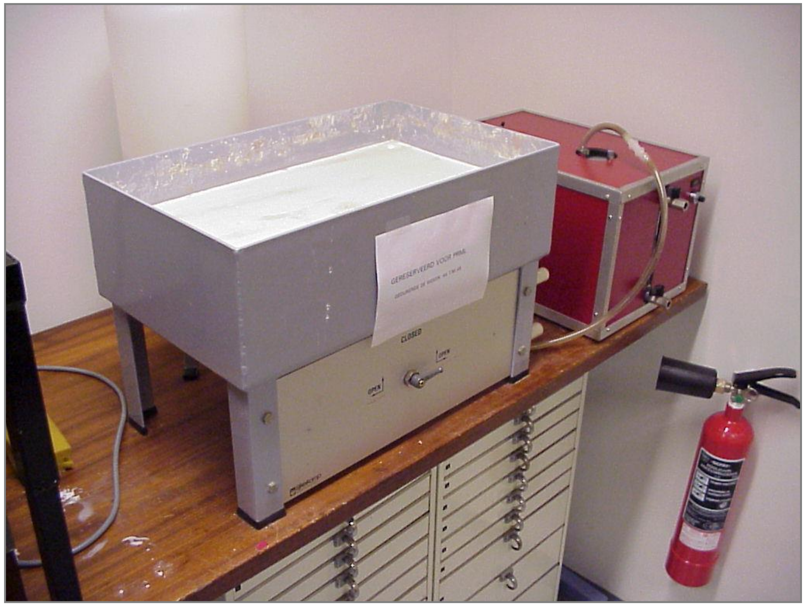
$$pF = \log(-\psi)$$





Establishing a *pF* curve

- Sand-pit: *pF* 0 – 2 (ring)
- Kaolinite tank: *pF* 2.0 – 2.7 (ring)
- High-pressure press: *pF* 2.7 – 4.2 (loose sample)
- *pF* 6 ~ air dry

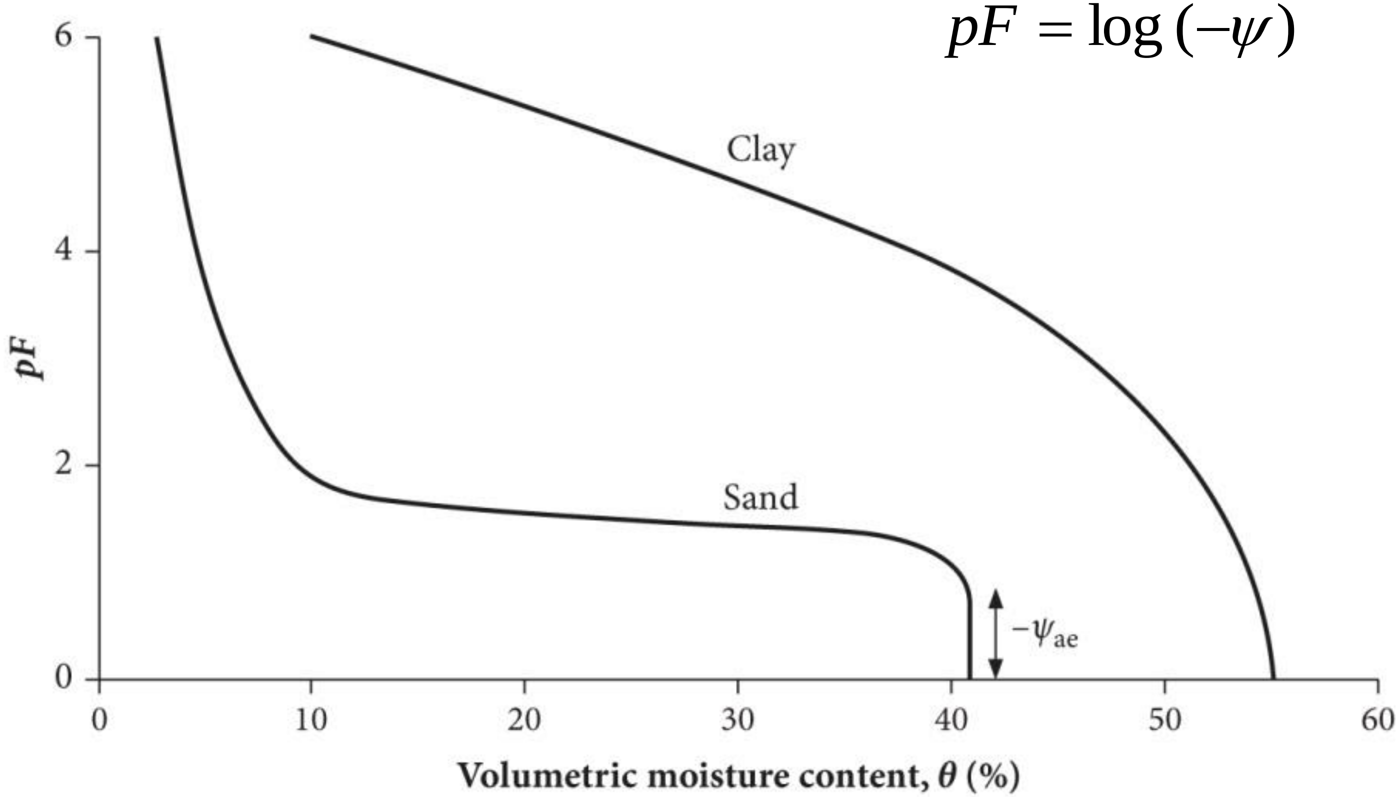


$pF = \log(-\psi)$

Soil moisture characteristic

Soil moisture retention curve or *pF* curve

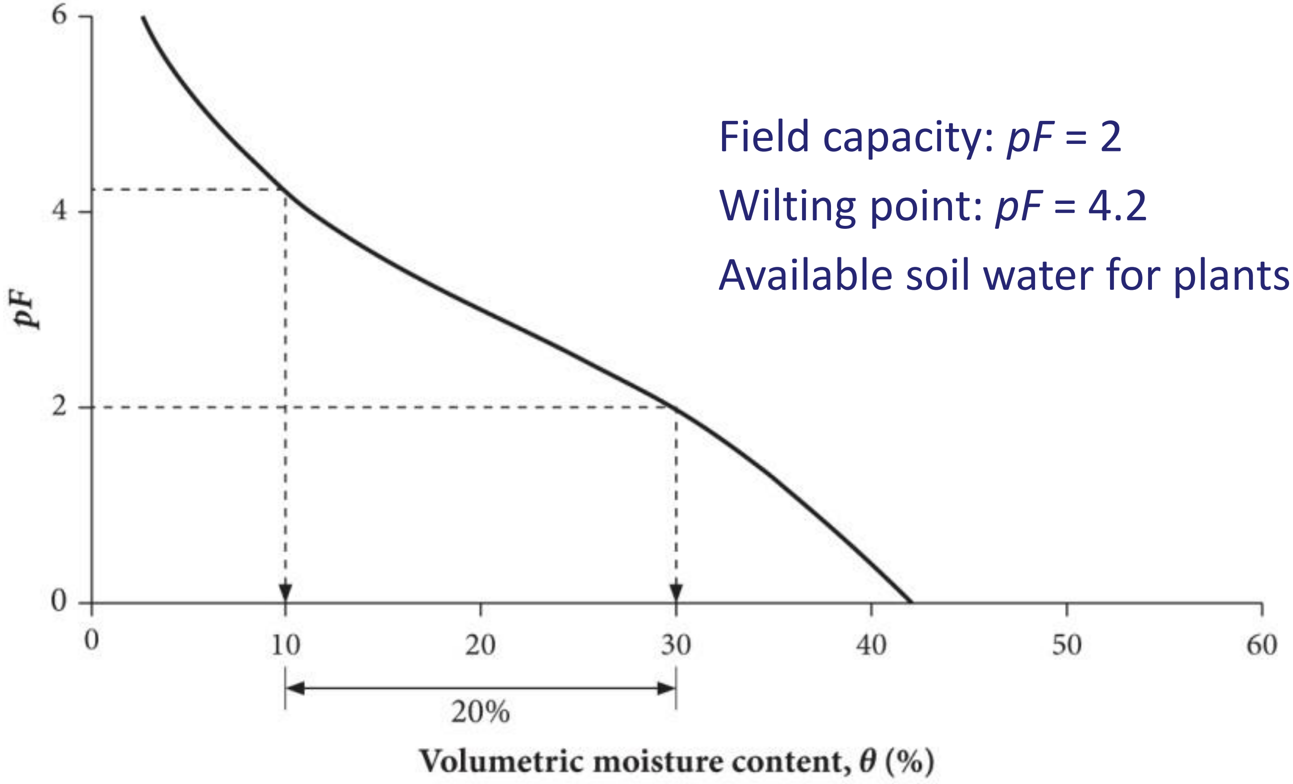
$$pF = \log(-\psi)$$



$-\psi_{ae}$ = air-entry suction

Available soil water for plants

Approximation



Field capacity: $pF = 2$

Wilting point: $pF = 4.2$

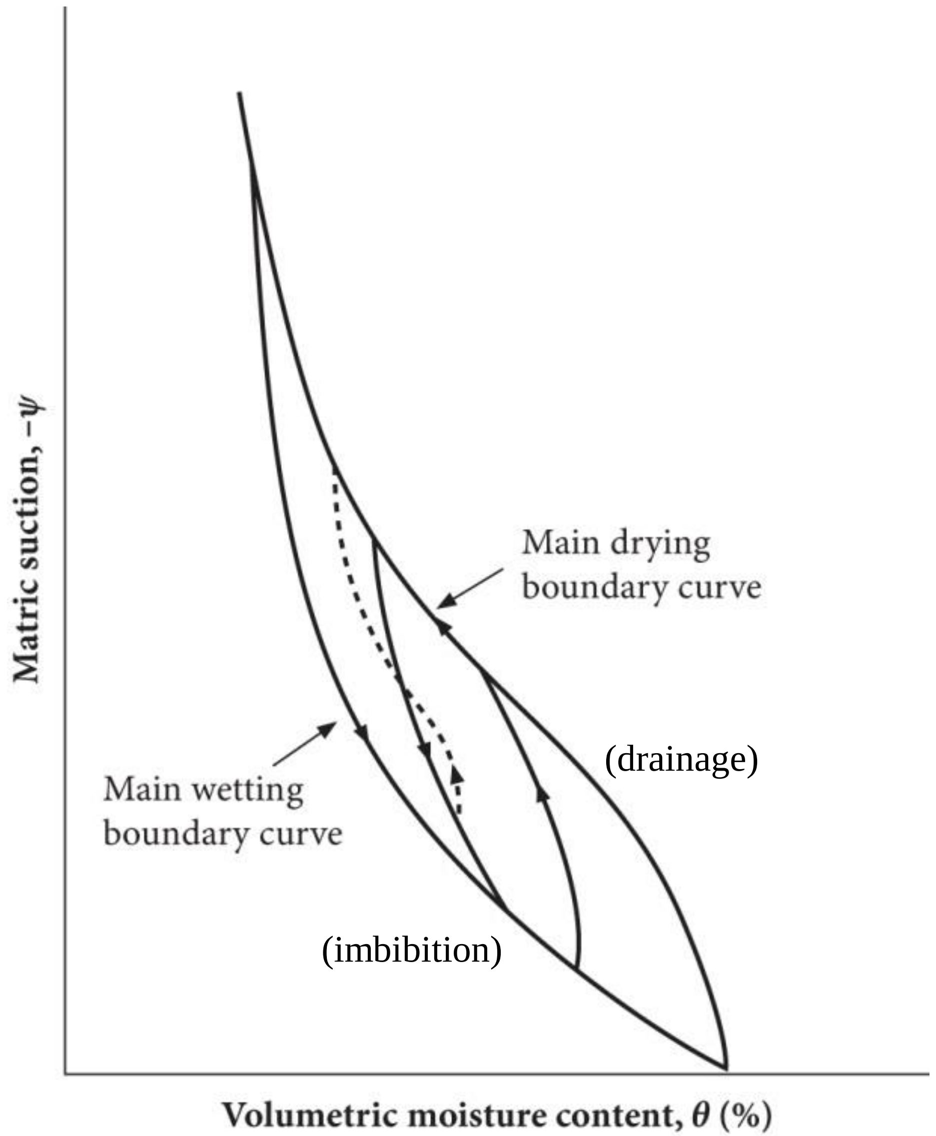
Available soil water for plants: $\theta_{pF=2.0} - \theta_{pF=4.2}$

$\theta_{pF=2.0} - \theta_{pF=4.2}$ = 20% = 20 cm water per 100 cm soil depth

If root zone is 40 cm deep, then

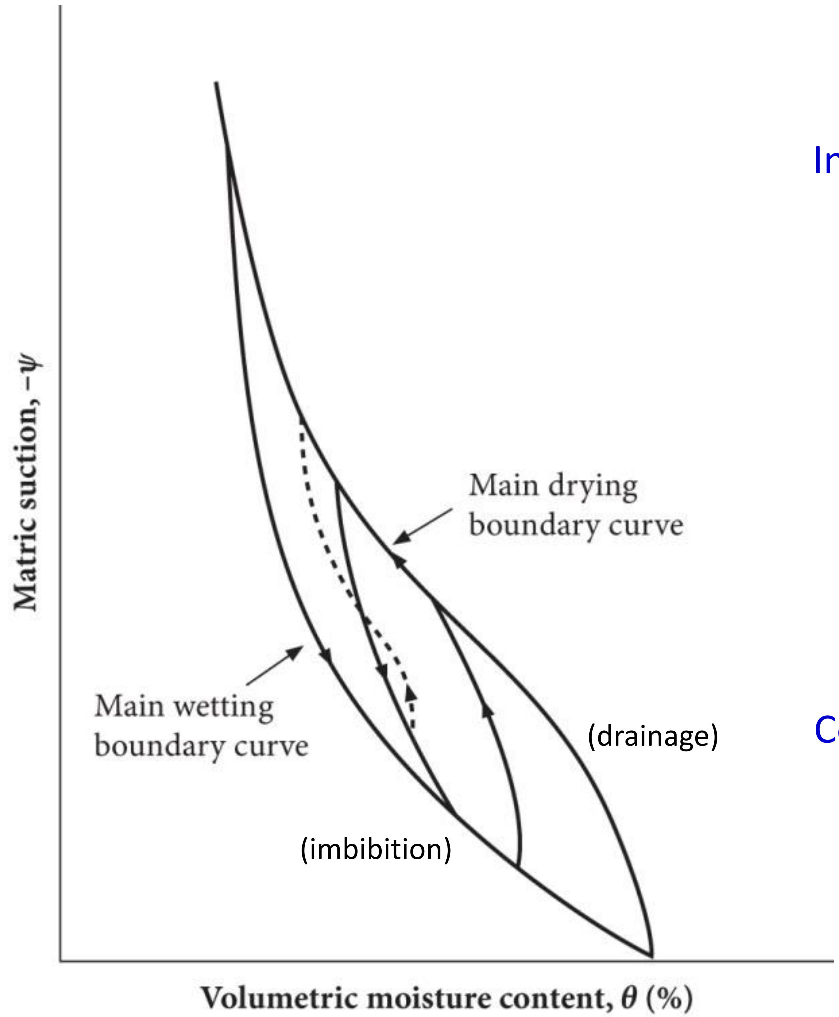
(40/100) x 20 cm = 8 cm water in the root zone

Hysteresis

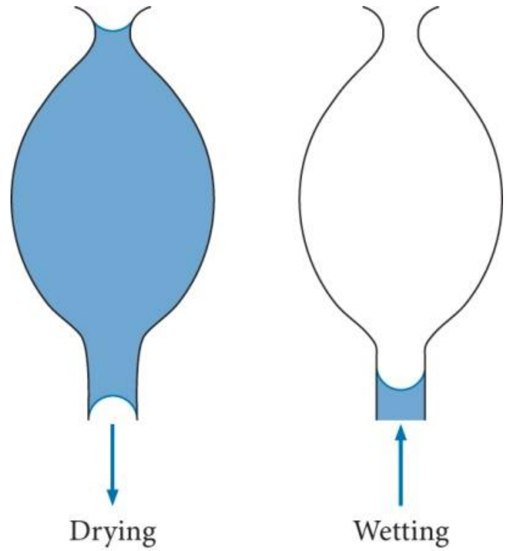


Matric suction, $-\psi$
Main drying
boundary curve
(drainage)
Main wetting
boundary curve
(imbibition)
Volumetric moisture content, θ (%)

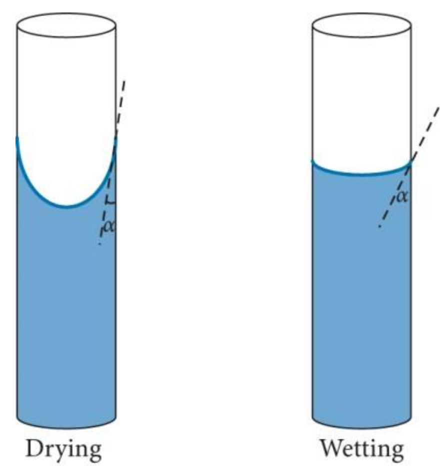
Hysteresis explained in part



Ink bottle effect

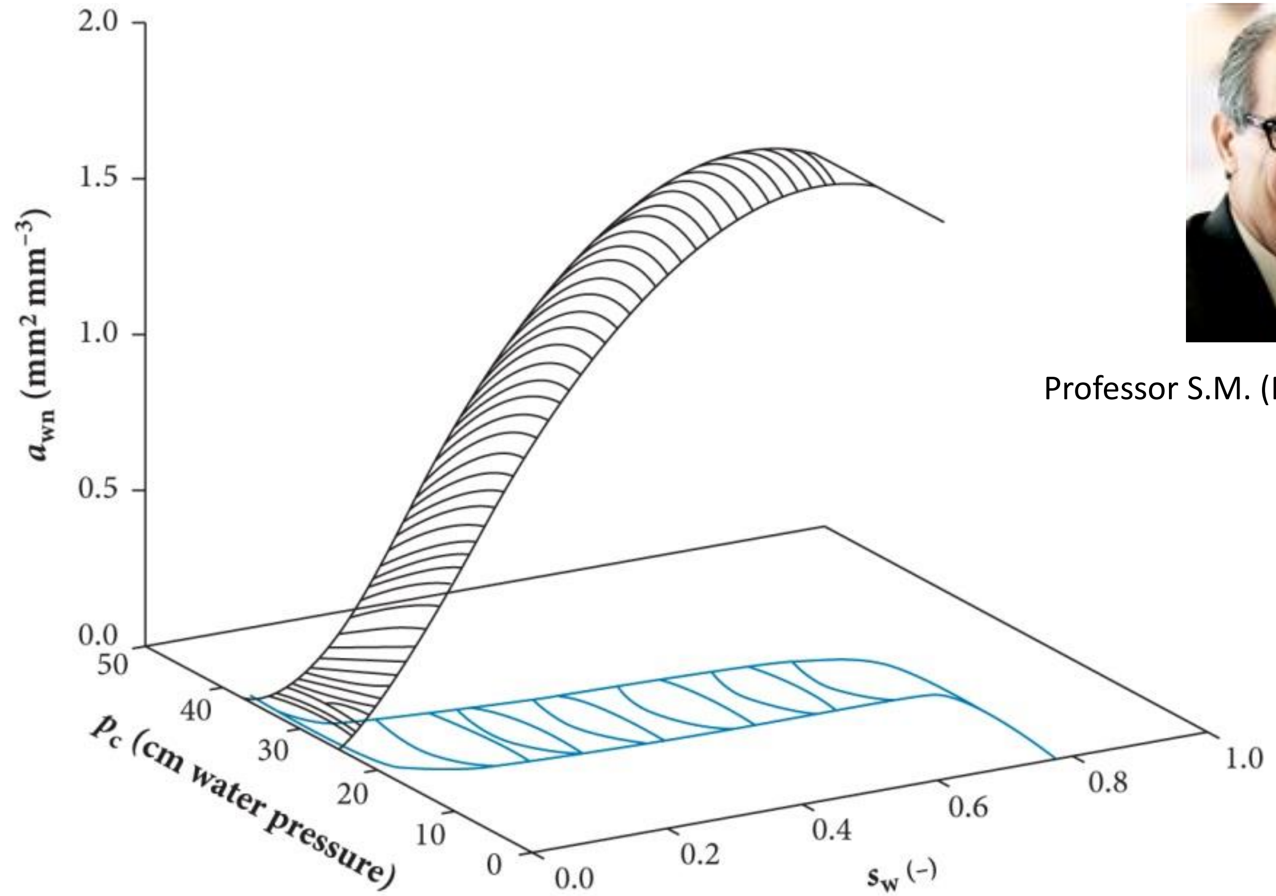


Contact angle effect



Hysteresis explained in full

a_{wn} = air/water interfacial area per volume of a soil (mm^2 mm^{-3})



After Held and Celia (2001)

Professor S.M. (Majid) Hassanizadeh

$$s_w = \frac{\theta}{n}$$

s_w = wetting phase saturation (-)

References

Held, R.J. and Celia, M.A. (2001). Modelling support of functional relationships between capillary pressure, saturation, interfacial area and common lines. Advances in Water Resources, 24, pp. 325-343.

Hendriks, M.R. (2010). Introduction to Physical Hydrology. Oxford University Press.