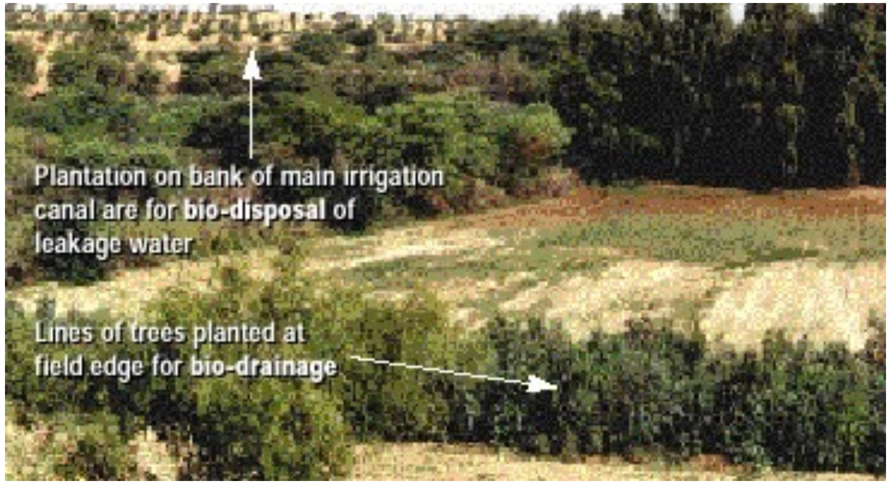
Irrigation and Drainage Engineering

(Soil Water Regime Management)



(ENV-549, A.Y. 2024-25)

4ETCS, Master option

Lecture 10-1. Drainage of agricultural soils: other techniques and design of subsurface drainage

Prof. Paolo Perona
Platform of Hydraulic Constructions

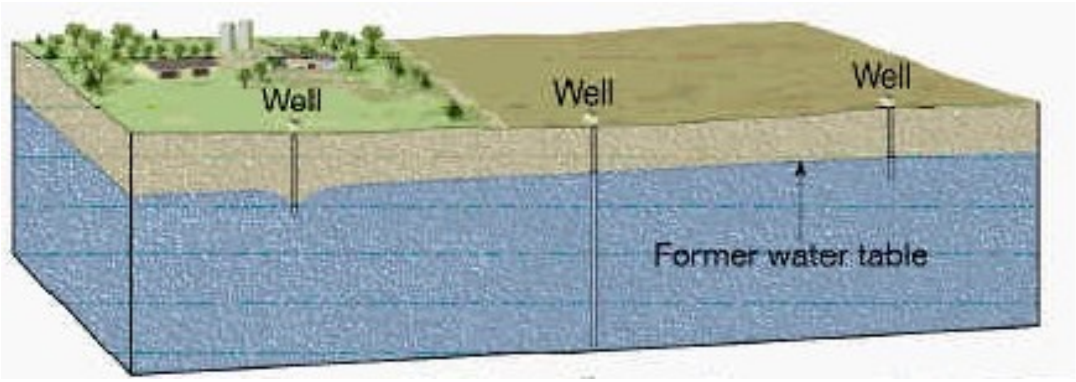
Other techniques for lowering the water table (marginal)

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

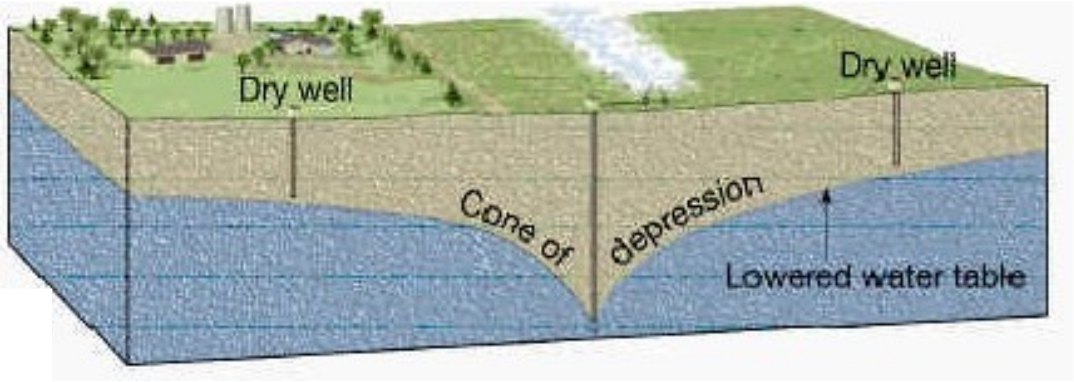
Drainage by pumping from wells

This involves lowering the water table by pumping into a network of wells evenly distributed in space, so that their cones of depression overlap.

This method is mainly used when the water table needs to be lowered significantly, in particular to prevent salinisation of the soil by capillary rise (capillary salinisation).



Before intensive pumping

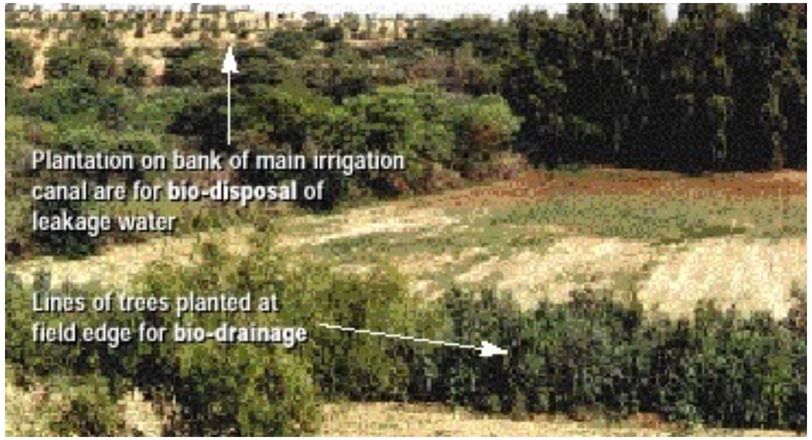


After intensive pumping

Bio-drainage and bio-removal of seepage water

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Planting rows of trees (eucalyptus, acacia, etc.) or other halophytic plants around agricultural fields to remove excess water from the soil and lower the water table*.



Planting trees along canals with large losses to dry out the soil and limit deep percolation.

Avantages :

- low investment costs for beneficiaries
- no need for external equipment or facilities
- natural process, easy to combine with an integrated rural development approach

Inconvenients

- effectiveness and continuity
- inaccurate control of the water table
- not very active in eliminating salts accumulated in the root zone

*This is the principle of the project EIRA, which happens in a hot-dry climate and highly bracksh water conditions.

Design parameters for subsurface drainage networks

Network characteristics, such :

- spacing of drains or ditches
- Depth of the drains
- flow rates to be evacuated
- size of drains, ditches and collectors
- etc.

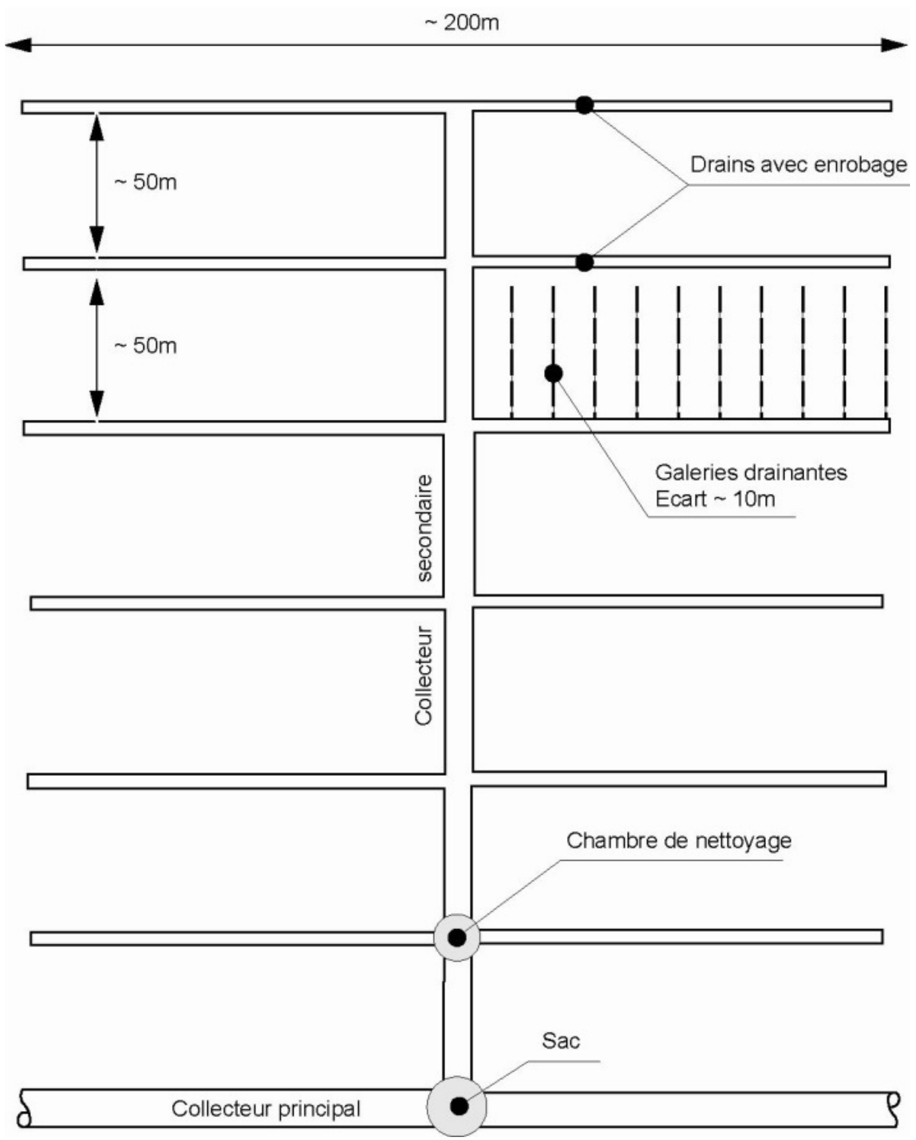
are defined on the basis of various parameters, in particular :

1) permissible submersion time

2) characteristic drainage rate

3) desirable depth of water table

4) soil characteristics



1) Permissible submersion

Depends on:

- the time of submergence
- the type of plant

Values typically considered:

✓	**Market vegetables**	**1 day**
✓	**Cereals**	**3 days**
✓	**Meadows**	**7 days**

2) Characteristic drainage rate

Under steady-state conditions, the drainage network is sized to evacuate the critical rainfall event i_c with a duration equal to the Admissible Submersion Duration (ASD) and a given return period (generally 5 years).

The characteristic flow rate qc that the drains must be able to evacuate is calculated from the intensity ic of the critical rainfall:

$$q_c = (1 - e)\, i_c$$

e: runoff coefficient

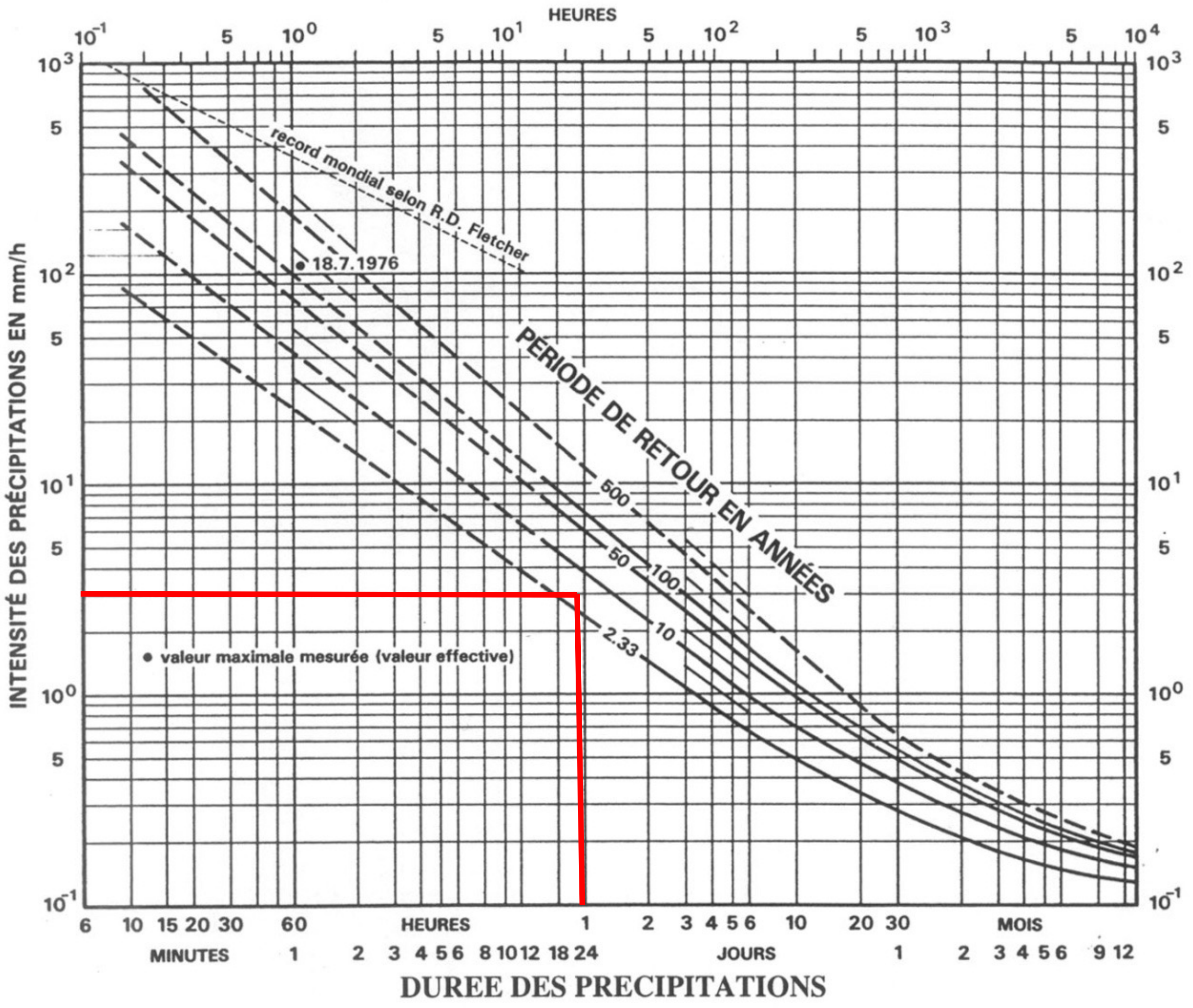
1 - e: coefficient of restitution

Example of intensity-duration-frequency curves

Station of Marcelin sur Morges (1926 – 1977)

if ASD = 1 jour → $i_c \cong 3$ mm/h = 8.3 l/s ha

Pour 1 – e = 0.6 → $q_c =$ 5 l/s ha



("Précipitations extrêmes dans les Alpes suisses et leurs régions limitrophes"; FNP Birmensdorf)

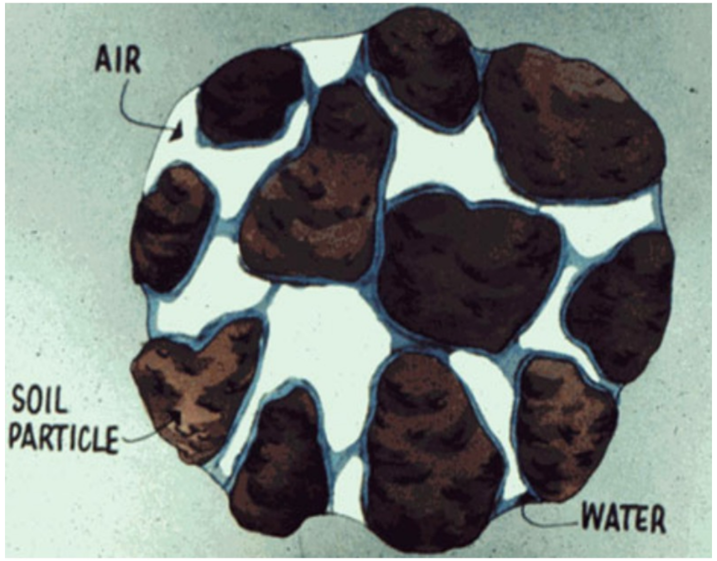
3) Desirable depth of the water table

In general, the drains are placed in such a way that during the critical rainfall (permanent regime) or after a given period of time (variable regime), the water table is at the following minimum depths:

- **0.2 to 0.3 m for grassland**
- **0.5 m for cultivated land**
- **0.8 m for orchards**

4) Soil characteristics

- hydraulic conductivity at saturation
- drainage porosity
- zonation of the soil profile (zonal soils)
- granulometry of the different horizons
- chemical characteristics (pH, iron content, etc.).



Source: Waller & Ytayew, 2017

Depth of the drains

Selection criteria:

- hydraulic efficiency: a priori, interest in increasing depth
- economic considerations

Local conditions:

- water level at outlet
- soil conditions
- risk of excessive drying out of the soil
- available machinery
- risk of root clogging and frost

Typical depths: 0.8 to 1.2 m

Drainage systems to control salinity: frequently much greater depths

Drainage and irrigation

Objective: **prevent salinisation of the soil by capillary rise**

Particular aspects :

- maintaining the water table at a sufficient depth
- as a first approximation, in arid zones: **drainage system capacity = quantity of water not used by plants = irrigation system losses**

$$V_D = V_{ir} - V_{utile}$$

Or : $$E = \frac{V_{utile}}{V_{ir}}$$

whence:

$$V_D = V_{ir}\left(1 - E\right)$$

V_D: volume of water to be evacuated by the drainage network
Vir: total volume of irrigation water injected into the network
Vutile: volume of irrigation water used by plants

E: overall irrigation efficiency; $E = e_t\, e_p$

Transport efficiency: $e_t = (V_{ir}-V_t)/V_{ir}$ V_t : transport losses, V_{ir} : total delivered water volume

Plot efficiency: $e_p = V_{utile}/(V_{ir}-V_t)$ $V_{utile,}$ or V_{veg} : is the volume used by vegetation

➔ $E = e_t \ e_p$

- **Water volume V_t lost during the transport**

$V_t = V_{ir} - e_t V_{ir} = V_{ir}\,(1-e_t)$

Vol. injected

Vol. arriving at the plot

- **Water volume V_p lost at the plot :**

$V_p = e_t V_{ir} - e_p e_t V_{ir} = V_{ir}\, e_t(1-e_p)$

Vol. arriving at the plot

Vol. actually used by vegetables: V_{ir} E

Maximum flow of water transmissible through the soil

In the case of a permanent upward flow from a water table located at depth D, Darcy's equation :

$$z = \int_0^{\psi} \frac{K(\psi)}{e + K(\psi)} \, d\psi$$

can be integrated directly for certain analytical expressions of $K(\psi)$*, such as that of Gardner (1958)

$$K(\psi) = \frac{a}{\psi^m + b}$$

a, b et m : soil constants

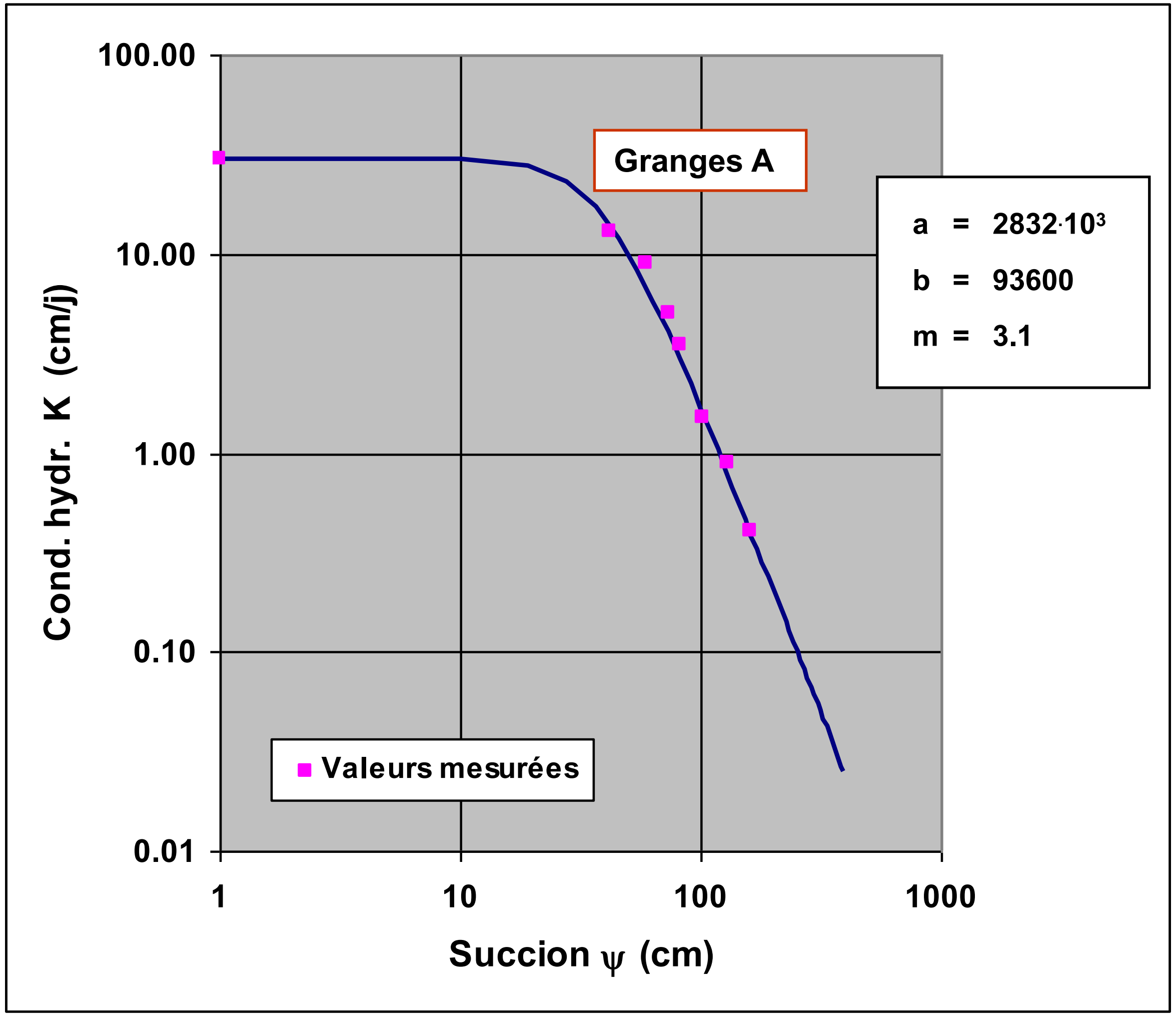
The maximum flow e_{max} that the soil can transmit to the surface from a water table located at a depth D is given by :

$$e_{max} = a \left(\frac{m + 0.5}{m - 1} \right) D^{-m}$$

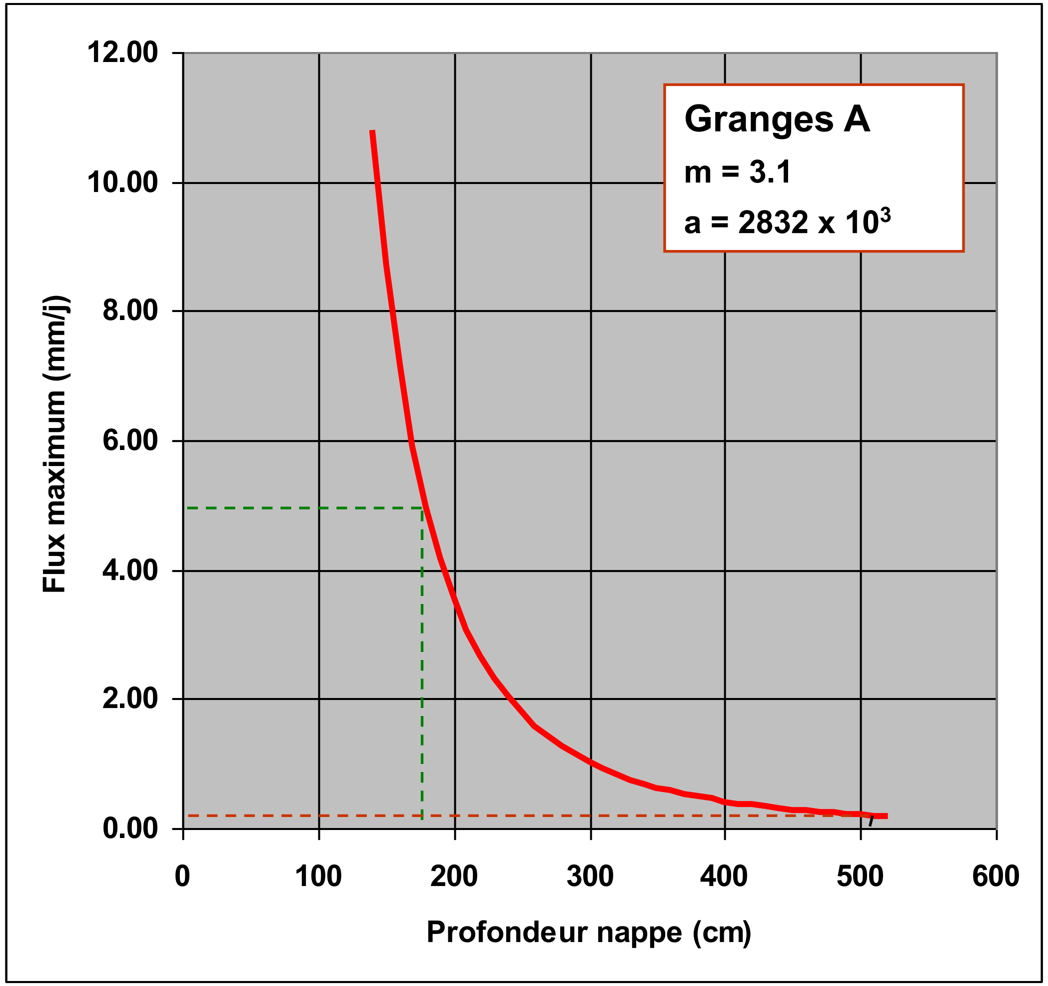
*$K(\psi)$ is the hydrualic conductivity and ψ is suction

Relation K(ψ) de Gardner:

$$K = \frac{2832 \cdot 10^3}{\psi^{3.1} + 93600}$$



$$e_{max} = a\left(\frac{m+0.5}{m-1}\right)D^{-m}$$



Relation entre le flux maximal transmissible par le sol e_{max} et la profondeur D de la nappe (site de Granges A)

Calculation of drain spacing, flow rates to be evacuated and water table equation

Approaches to the design of a drainage network

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

The design of the network differs according to the rainfall characteristics of the region:

TWO CASES WILL BE EXAMINED

- long, frequent rainfalls during the critical period (the soil does not have time to dry out completely between two rainy periods): plausible steady state hypothesis (permanent regime)

In this case, the aim is to keep the water table below a maximum level that must not be exceeded.

- intense, short-duration rainfall spaced relatively far apart in time: variable regime approach (transient regime)

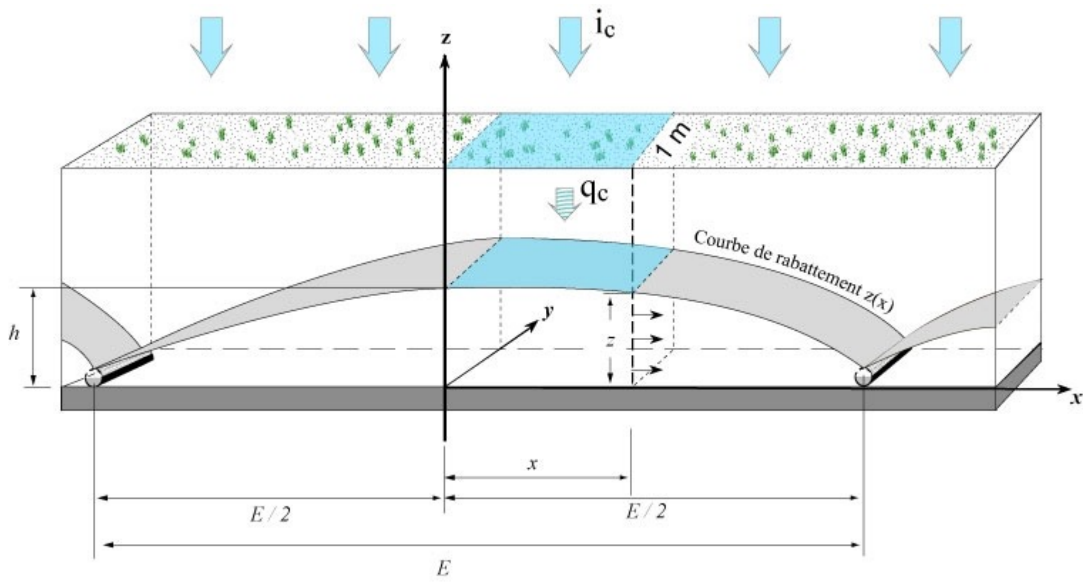
In this case, the aim is to obtain a sufficient lowering of the water table within a given time after the end of the rain.

Basis hypotheses

The behaviour of the water table is mainly influenced by :

- soil properties
- recharge: rainfall, etc.
- discharge routes (ET, etc.)
- depth and spacing of drains

En général, les méthodes de dimensionnement reposent sur 3 hypothèses :



- **two-dimensional flow**
- **uniform distribution of recharge (only precipitation is considered)**
- **negligible effects of discharge channels**

Calculation of the drain spacing

As far as both the permanent and transient regimes we will examine two characteristic cases:

- **Permanent regime:**
  - **drains laid over an impermeable layer**
  - **drains above an impermeable layer**
- **Transient regime:**
  - **drains laid over an impermeable layer**
  - **drains above an impermeable layer**