Water distribution
Basic concepts

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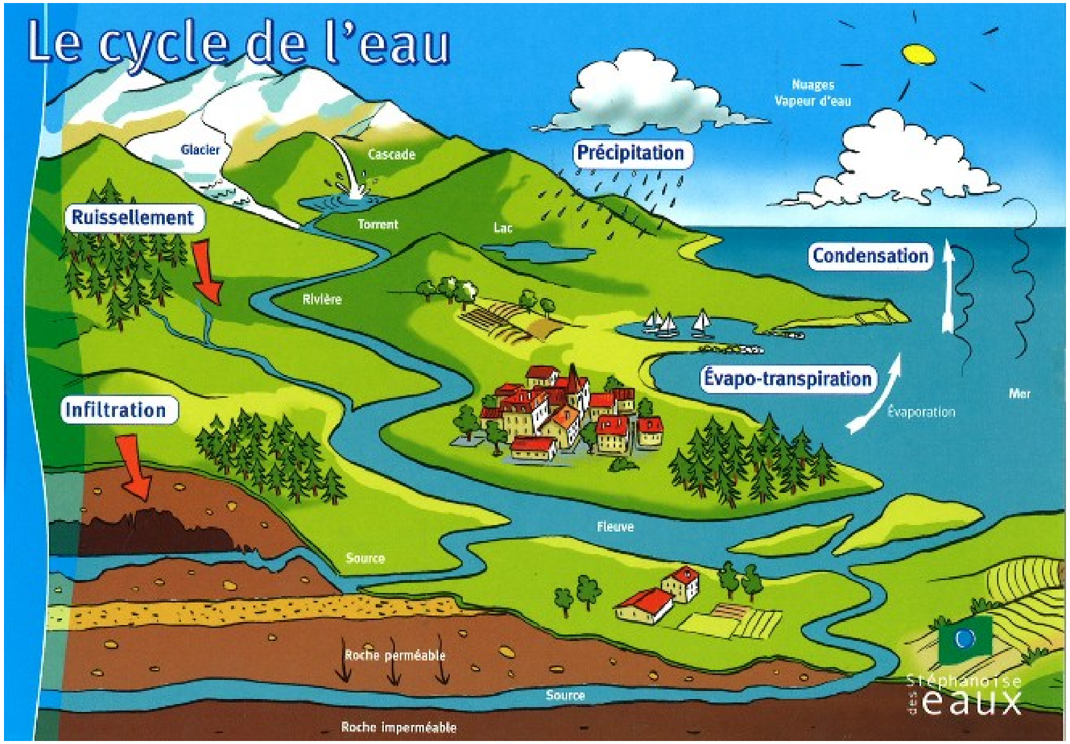
2018

Where does water come from ?

- Hydrology
  - Natural equilibrium
    - Quantity
    - Quality



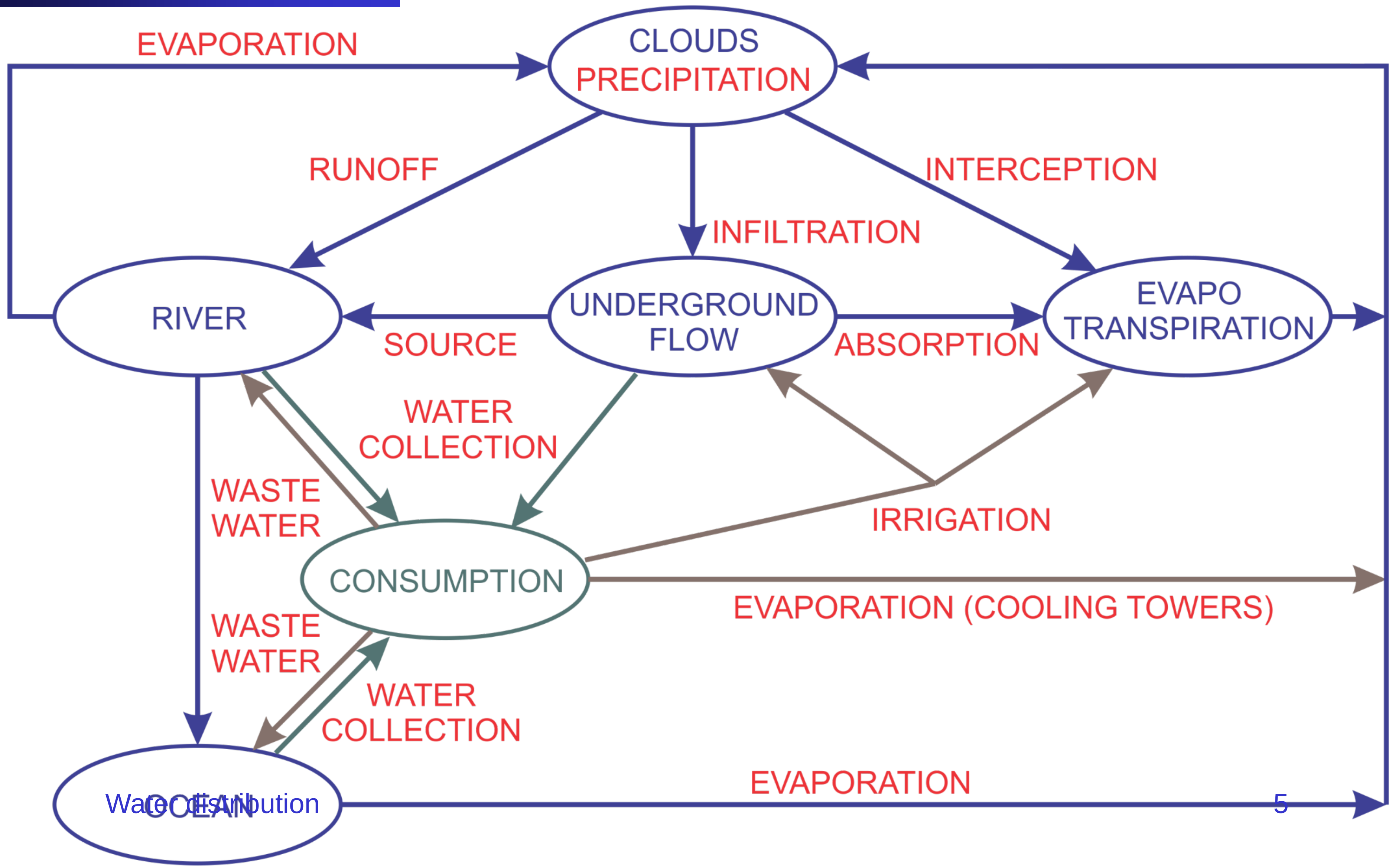
Water in the ecosystem

- 1 400 000 000 km^3
  - Salt water 97.30 % 1 362 200 000 km^3
  - Fresh water 2.70 % 37 800 000 km^3

Water in the ecosystem

- 1 400 000 000 km^3
  - Salt water 97.30 % 1 362 200 000 km^3
  - Fresh water 2.70 % 37 800 000 km^3
- 37 800 000 km^3 fresh water
  - Unusable 99.64 %
    - Frost water 29 181 600 km^3
    - Too deep groundwater 8 647 000 km^3
  - Usable 0.36 %
    - Lakes, marshes 132 000 km^3
    - Atmosphere 15 120 km^3
    - Waterways 3 780 km^3

The hydrological cycle



Use of water

- Water as a liquid
  - Transport
  - Energy
  - Industry
  - Wastewater drainage
- Water with all its properties
  - Water supply
  - Agriculture

Transport

- Navigation
  - Maritime
  - Fluvial
    - Canals
    - Rivers
- Floating of timber
- Transport by pipes

Wandre bridge
Meuse

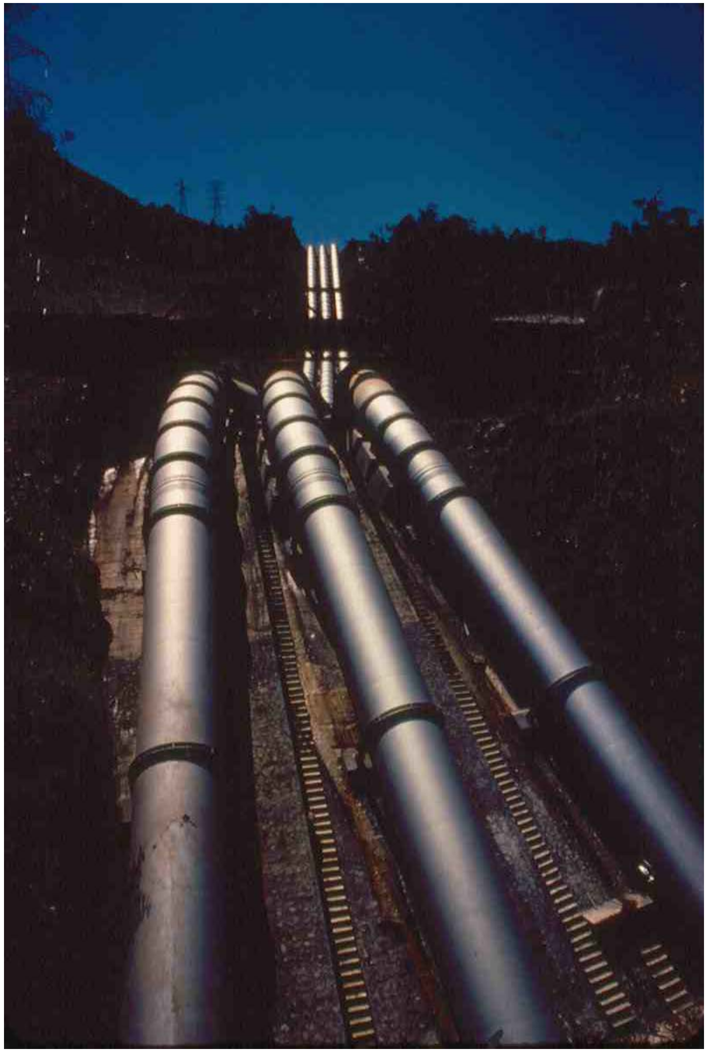
Energy: hydropower

- 15 % of the world's electricity production

Hoover Dam
Colorado, USA

Hydropower – water intake

- Pennstocks



San Francisco
Colombie

Hydropower – water intake

- Water hammer

Bear Creek
CA - USA

Water distribution

Industry

- Paper: 1 kg paper = 40 … 500 litres
- Steel industry: 1 kg steel = 300 … 600 litres
- Chemistry: 1 litre fuel = 200 litres
- Agro-food industry: 1 kg sugar = 300 … 400 litres

- Agrofuel
  1 litre ethanol from corn
  = 1200…3400 litres water

Wastewater drainage

Wastewater drainage

Wastewater drainage

Wastewater drainage

Water supply

- Water intake
- Adduction
  - Ducts
  - Channels

Pont du Gard
France

Irrigation

- Haiti


Artibonite


Dory

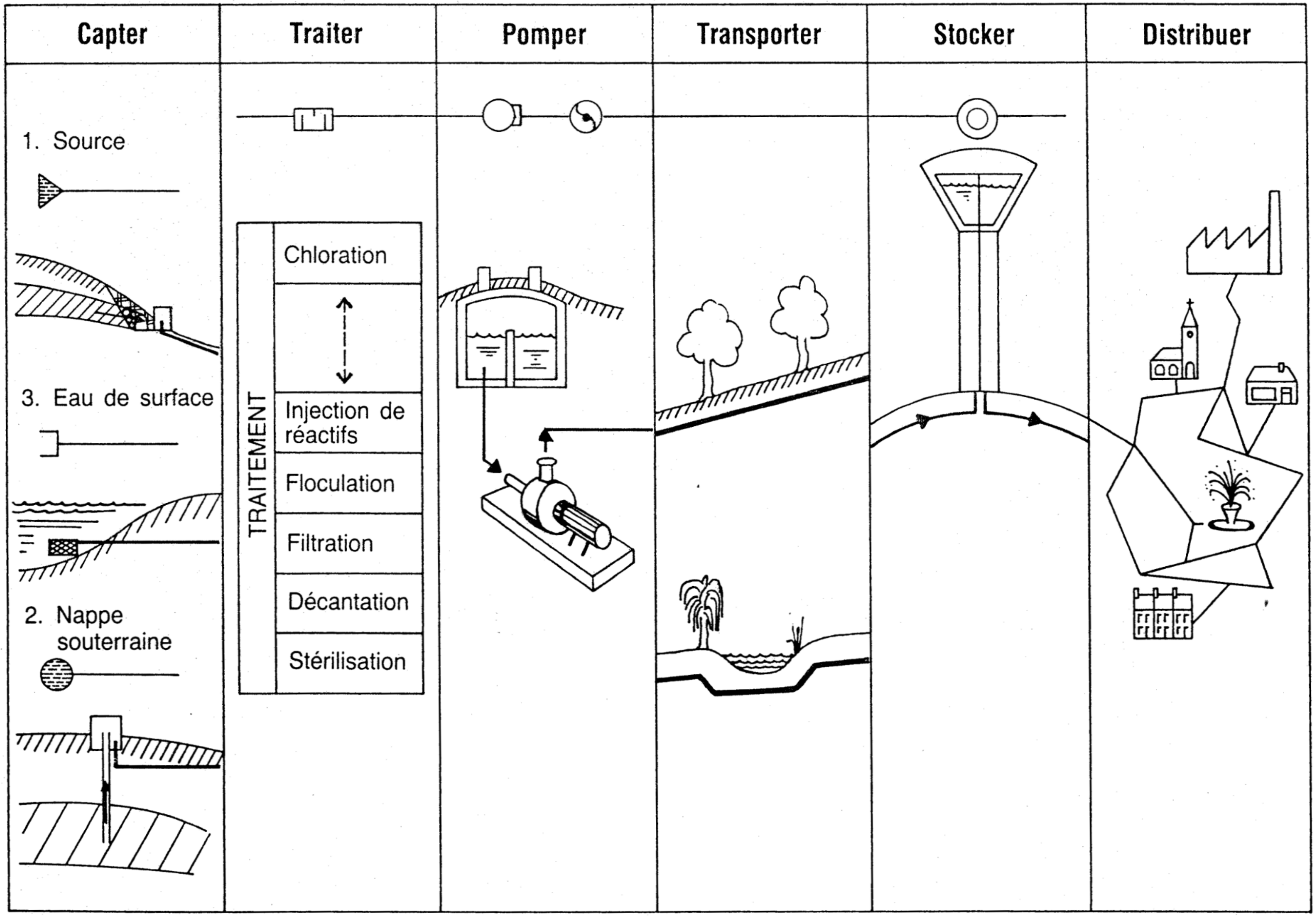
For the present work

- Water distribution
  - Drinkwater: pressurized flow
  - Irrigation: free-surface flow
- Wastewater drainage
  - Free-surface flow

Pressurized flow

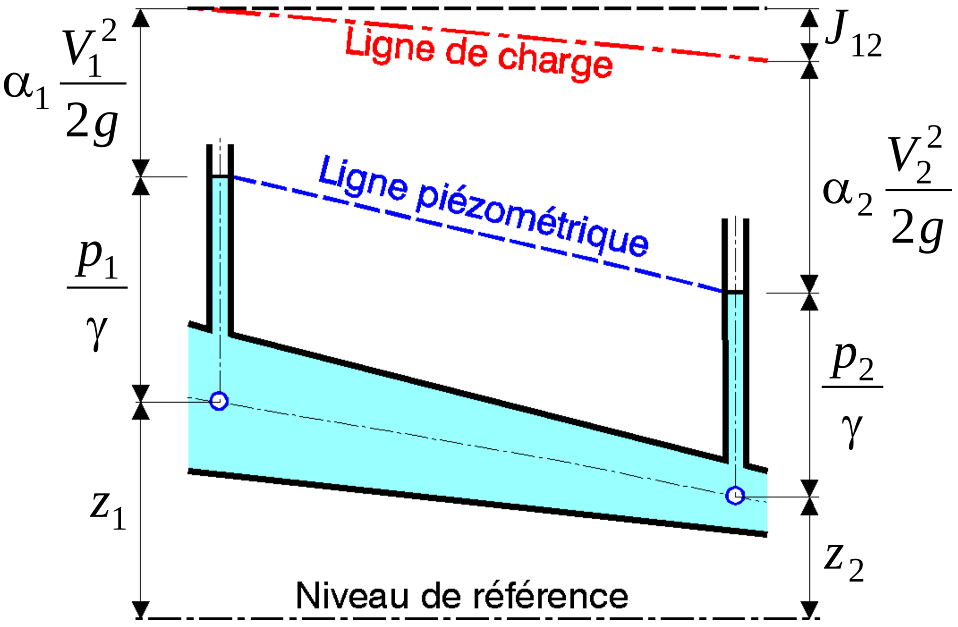
- Basic concepts
- Example of calculation
- Definition of the water demand

Water distribution



Pertes de charge

- Bernoulli equation



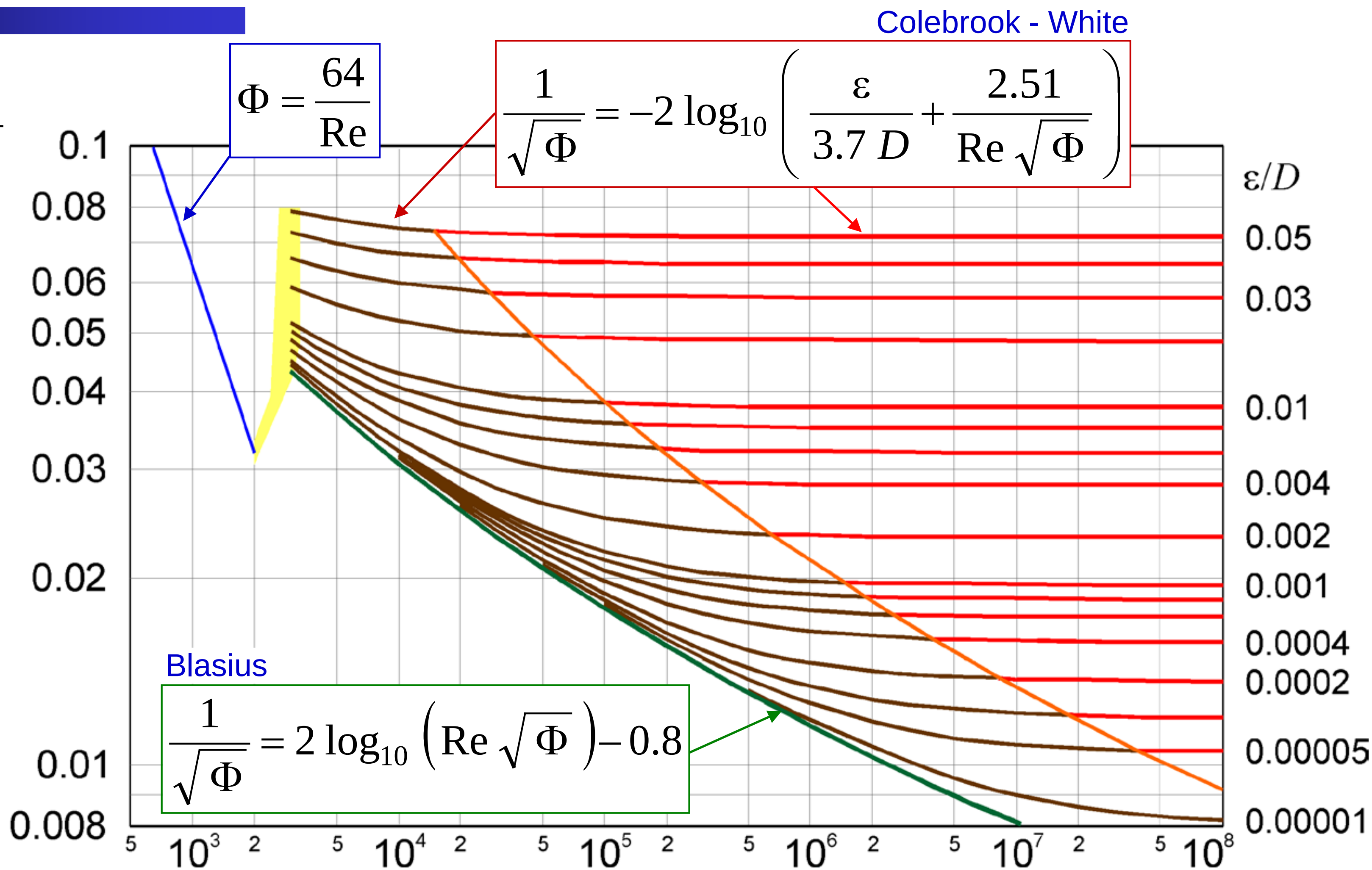
$$z_1 + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + J_{12}$$

- Headlosses: Darcy

$$J = \frac{V^2}{2g} \frac{L}{D} \Phi\left(\mathrm{Re}, \frac{\varepsilon}{D}\right)$$

Moody-Nikuradse

$$\Phi = \frac{J}{\dfrac{V^2}{2g}\,\dfrac{L}{D}}$$



$$\mathrm{Re} = \frac{V\,D}{\nu}$$

Pertes de charge générales

- Rugosité

Matériau	Rugosité ε (mm)
Ciment	0.30 … 3.0
Fonte	0.25
Fonte asphaltée	0.12
Acier riveté	0.90 … 9.0
Acier galvanisé	0.15
Tube cintré en acier	0.046
Tube étiré	0.0015

Pertes de charge

- Pertes de charge générales : Darcy

$$J_{gen} = \frac{V^2}{2g}\frac{L}{D}\Phi\left(\mathrm{Re}, \frac{\varepsilon}{D}\right)$$

$$\boxed{J_{gen} = Q^2\ K\, L}$$

$$K = \frac{\Phi}{2g\, D\, A^2}$$

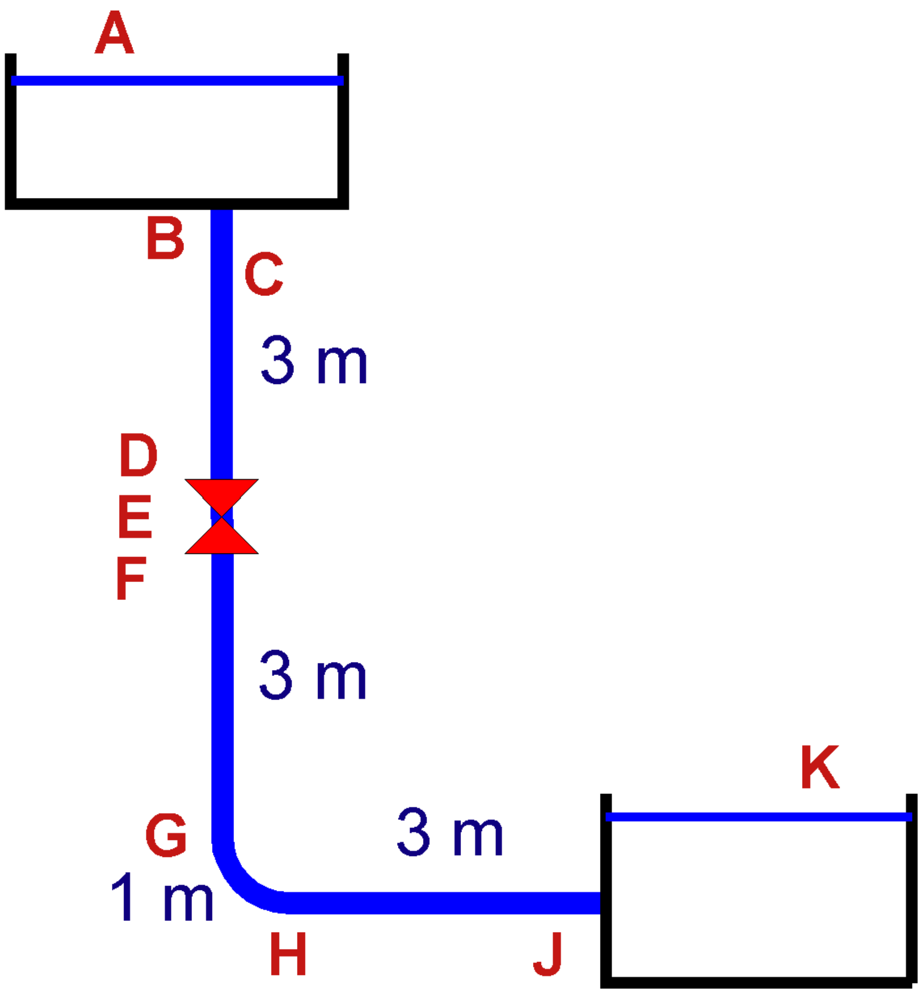
- Pertes de charge locales

$$J_{loc} = \zeta \frac{V^2}{2g}$$

$$\boxed{J_{loc} = Q^2\ K'\, N}$$

$$K' = \frac{1}{2g\, A^2}$$

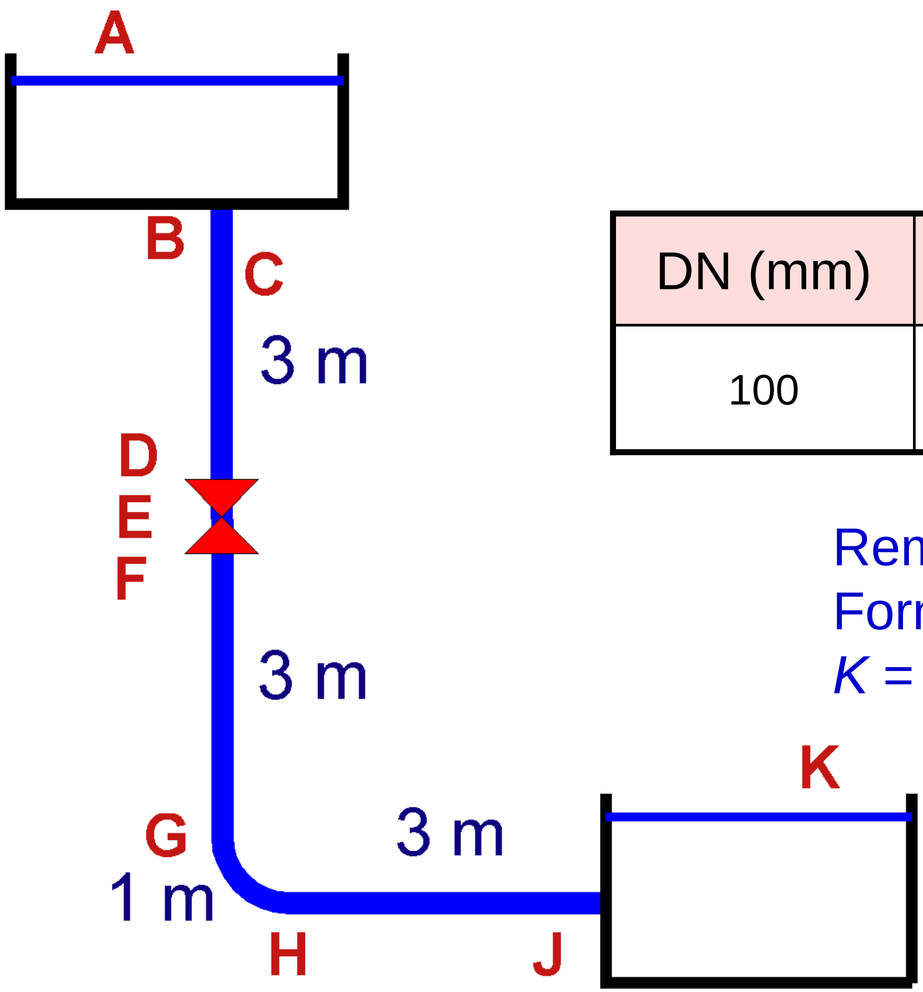
Conduite simple



	z (m)
A	7.800
B	6.637
C	6.637
D	3.637
E	3.637
F	3.637
G	0.637
H	0.000
J	0.000
K	0.800

D = 100 mm
ε = 0.25 mm (fonte neuve)

Conduite simple

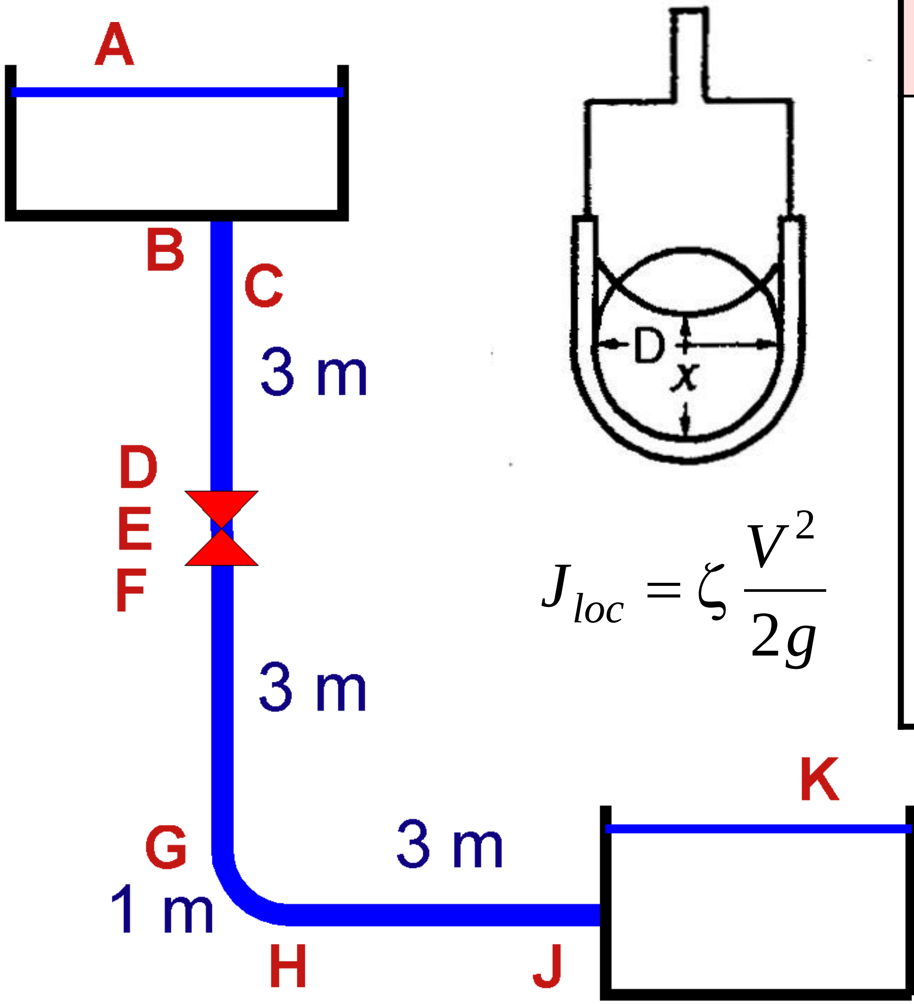


DN (mm)	K (m $^{-6}$ s ^{2})	K' (m $^{-5}$ s)
100	205.5	826.3

Remarque :
Formule utilisée = Colebrook – White
$K = 211.1\ m^{-6}s^{2}$

$D = 100$ mm
$\varepsilon = 0.25$ mm (fonte neuve)

Conduite simple



$$J_{loc} = \zeta \frac{V^2}{2g}$$

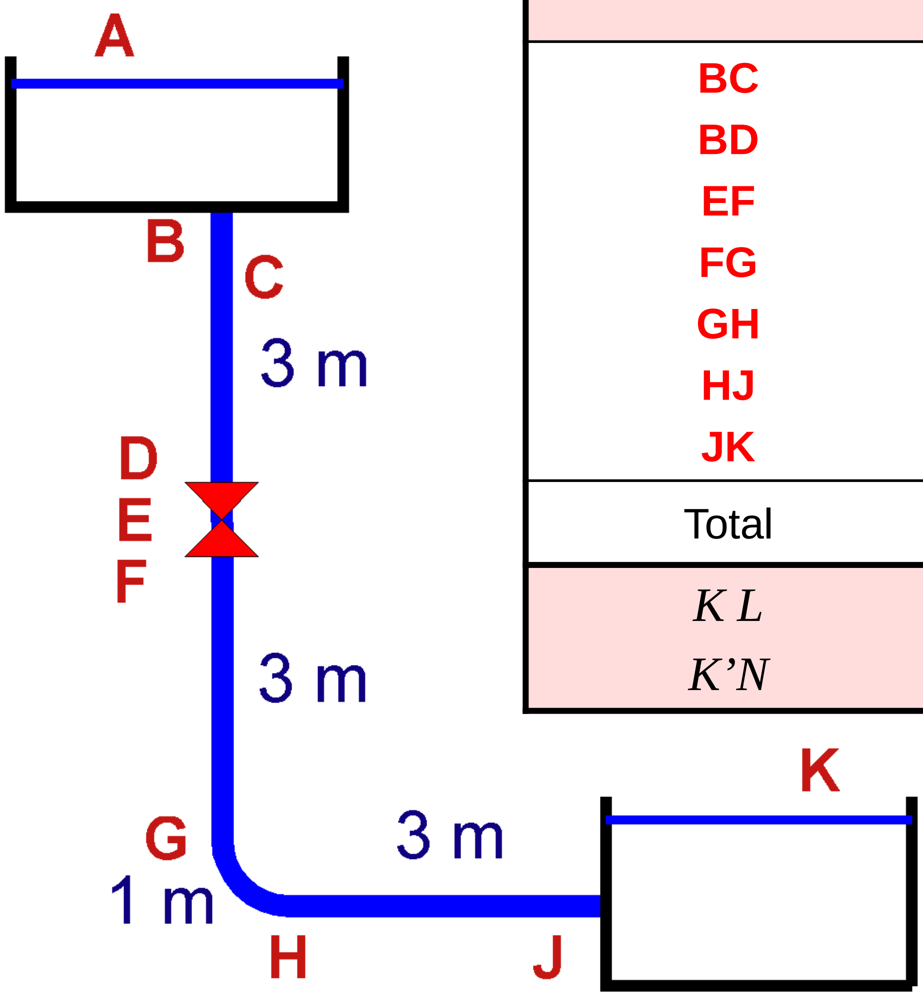
x/D	ζ
0.181	41.21
0.208	31.35
0.250	22.68
0.333	11.89
0.375	8.63
0.500	3.27
0.583	1.55
0.667	0.77
1.000	

D = 100 mm

ε = 0.25 mm (fonte neuve)

Vanne : $x/D = 0.25$ $\zeta = 22.68$

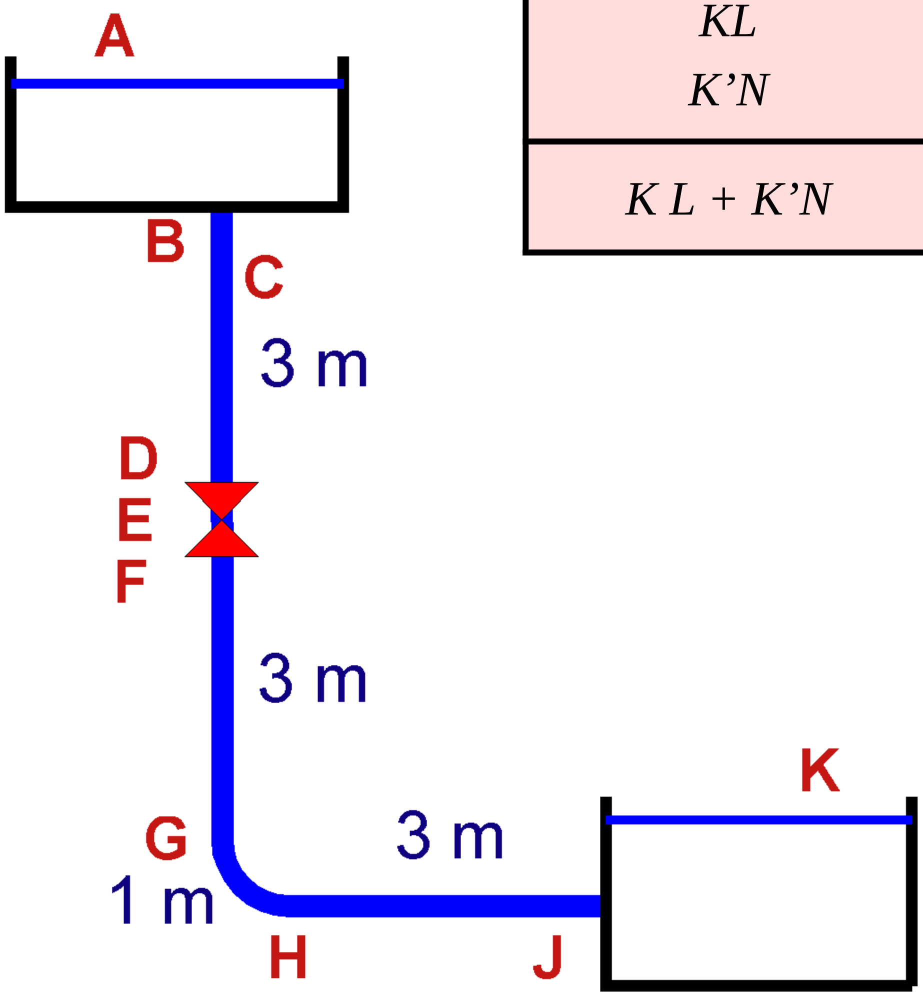
Conduite simple



	L (m)	N
BC		0.49
BD	3.00	
EF		22.68
FG	3.00	
GH	1.00	0.13
HJ	3.00	
JK		1.00
Total	10.00	24.30
$K\,L$	2 111	
$K'N$		20 076

D = 100 mm
ε = 0.25 mm (fonte neuve)
Vanne : x/D = 0.25 ζ = 22.68

Conduite simple



KL *K'N*	2 111	20 076
K L + K'N	22 187	

$J = 7.00$ m

$Q = 0.0178$ m^3/s

$V = 2.26$ m/s

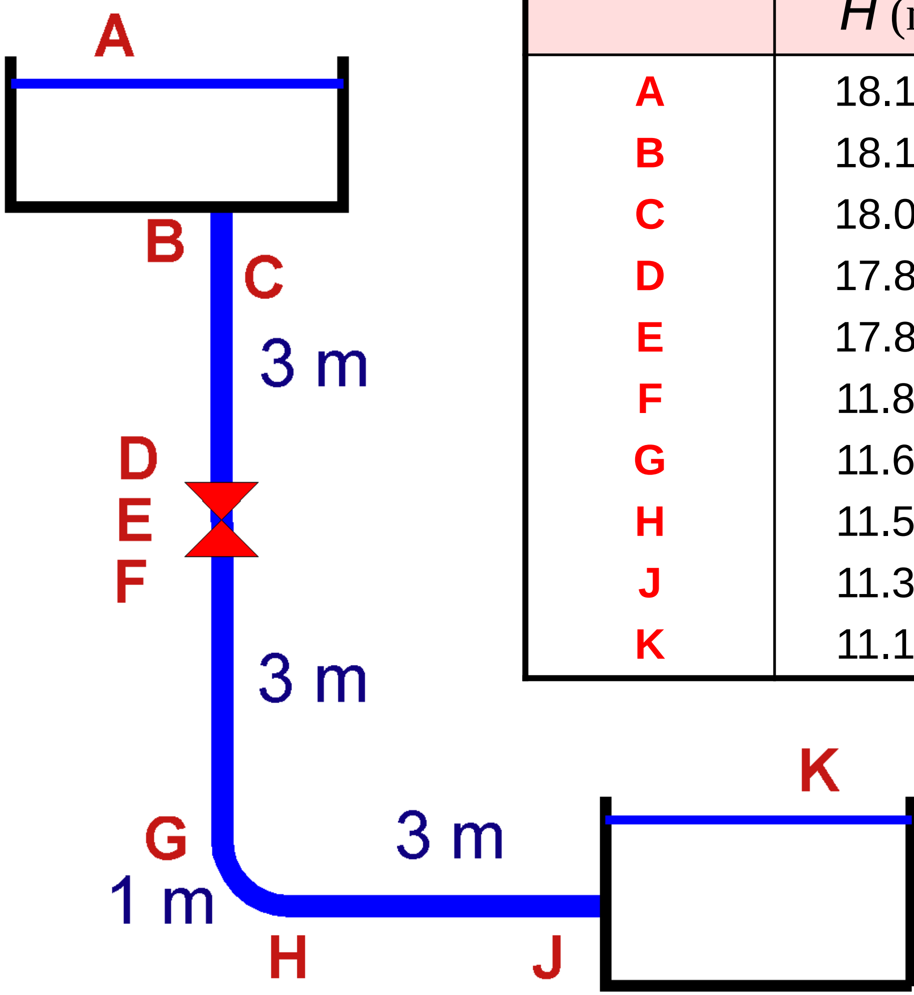
Re = 226 156

$D = 100$ mm

$\varepsilon = 0.25$ mm (fonte neuve)

Vanne : $x/D = 0.25$ $\zeta = 22.68$

Conduite simple



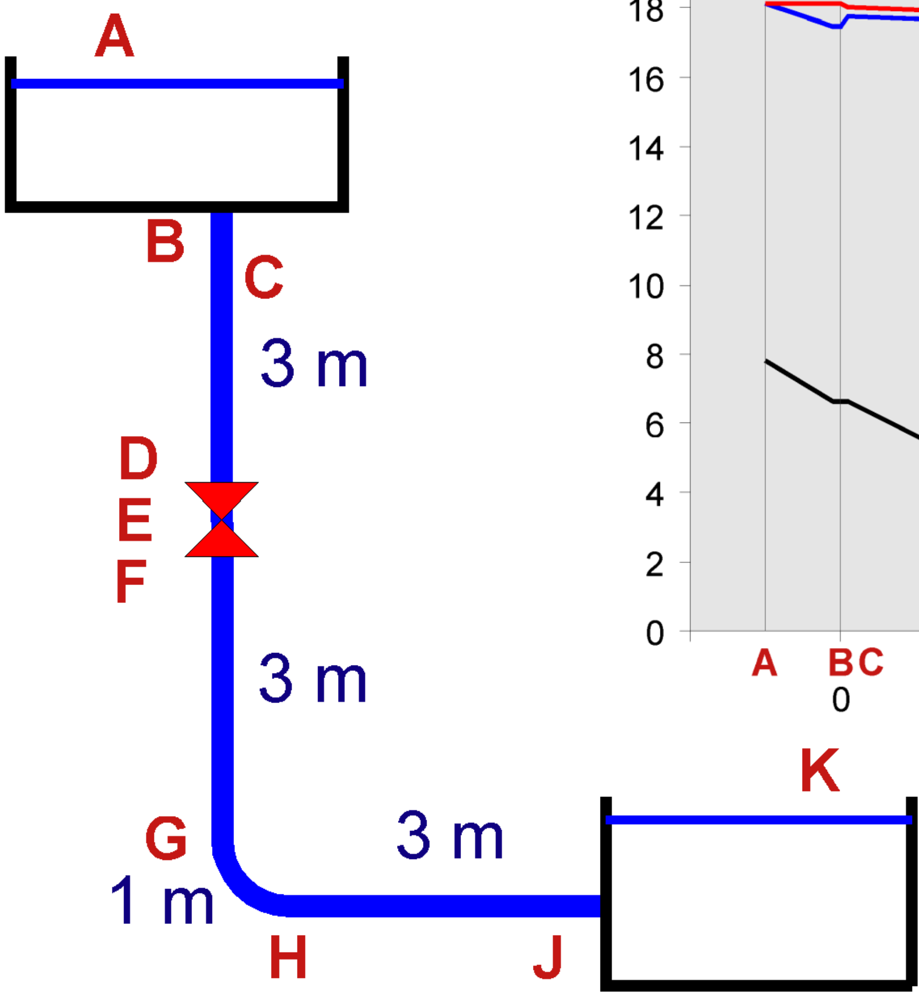
	H (m)	z (m)	p/γ	$V^2/2g$
A	18.132	7.800	10.332	0.000
B	18.132	6.637	10.817	0.678
C	18.005	6.637	11.108	0.261
D	17.806	3.637	13.908	0.261
E	17.806	3.637	5.548	8.621
F	11.893	3.637	7.996	0.261
G	11.693	0.637	10.796	0.261
H	11.593	0.000	11.332	0.261
J	11.393	0.000	11.132	0.261
K	11.132	0.800	10.332	0.000

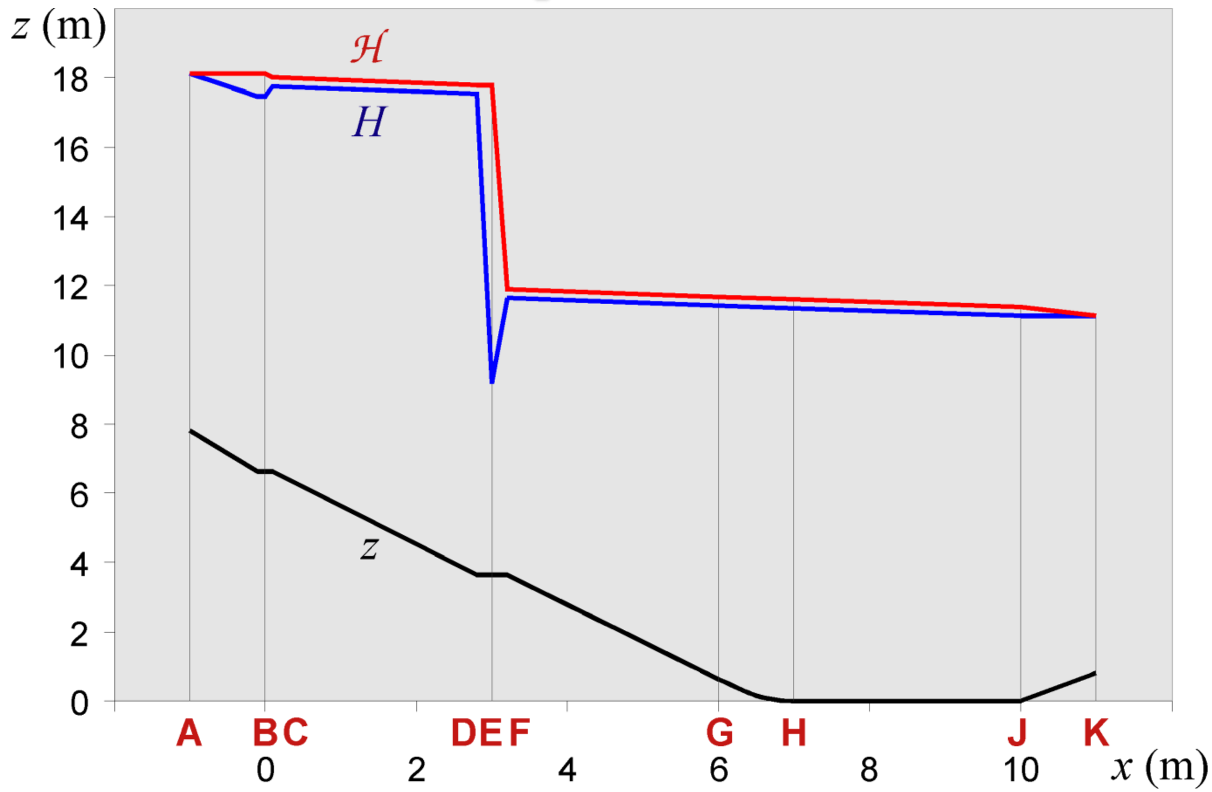
D = 100 mm

ε= 0.25 mm (fonte neuve)

Vanne : x/D = 0.25 ζ = 22.68

Conduite simple



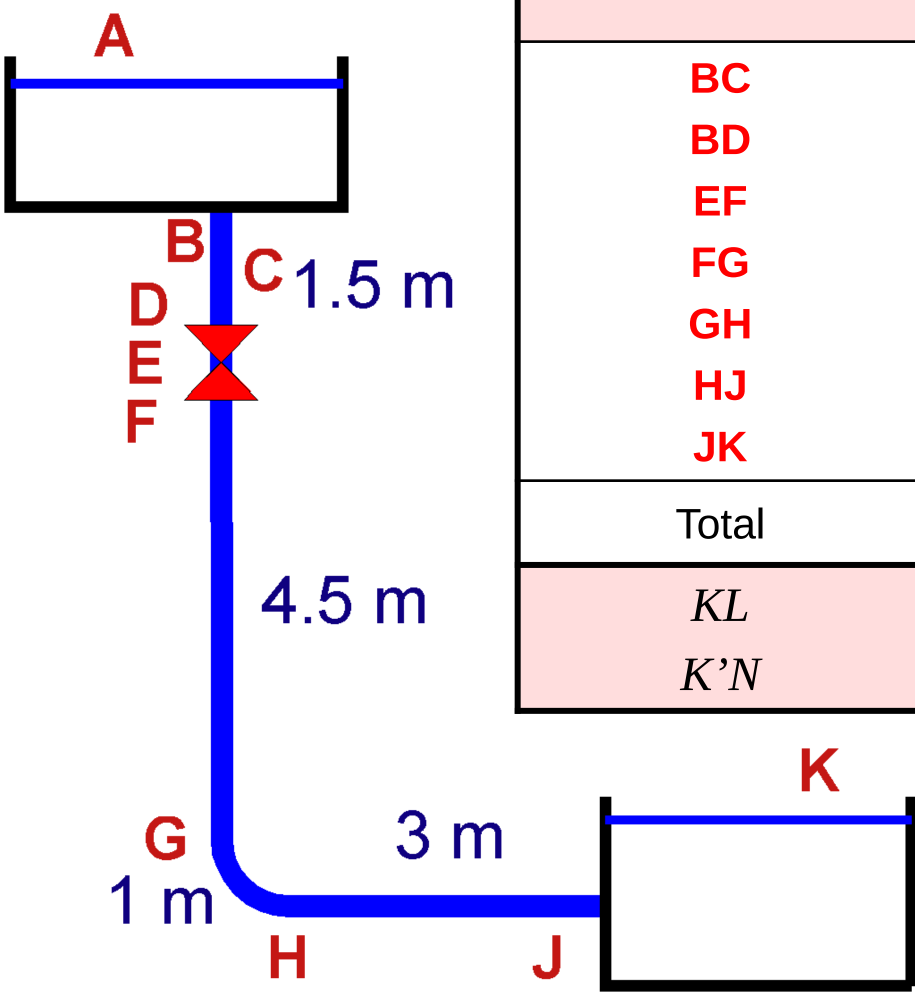


D = 100 mm

ε= 0.25 mm (fonte neuve)

Vanne : $x/D = 0.25$ $\zeta = 22.68$

Conduite simple



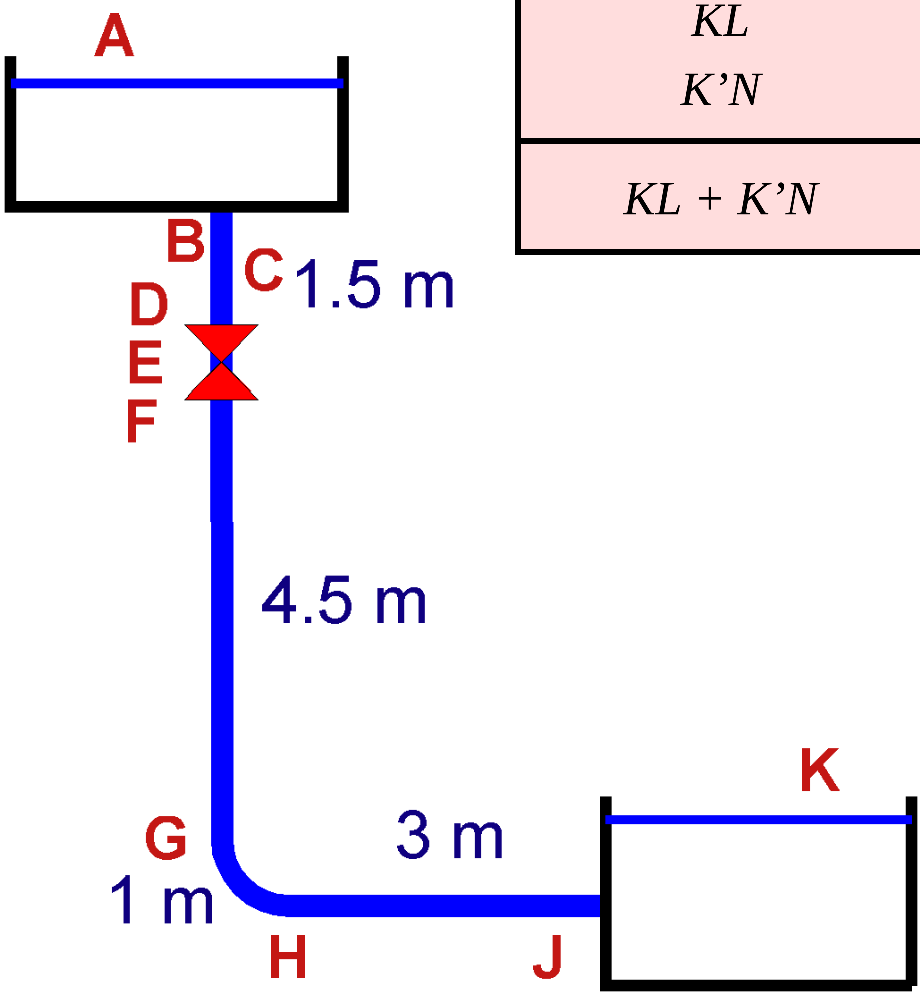
	L (m)	N
BC		0.49
BD	1.50	
EF		22.68
FG	4.50	
GH	1.00	0.13
HJ	3.00	
JK		1.00
Total	10.00	24.30
KL	2 111	
$K'N$		20 076

D = 100 mm

ε = 0.25 mm (fonte neuve)

Vanne : x/D = 0.25 ζ = 22.68

Conduite simple



KL	2 111	
$K'N$		20 076
$KL + K'N$	22 187	

$J = 7.00$ m

$Q = 0.0178$ m^3/s

$V = 2.26$ m/s

Re = 226 156

$D = 100$ mm

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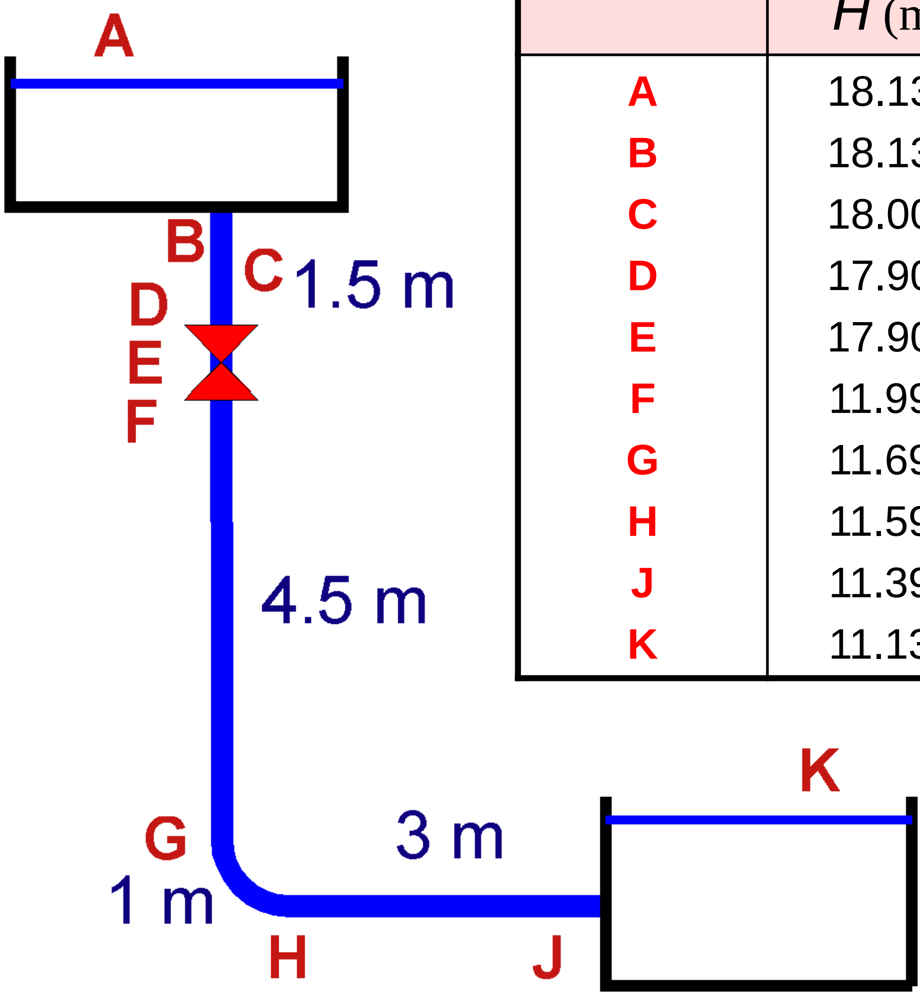
Conduite simple



	H (m)	z (m)	p/γ	$V^2/2g$
A	18.132	7.800	10.332	0.000
B	18.132	6.637	10.817	0.678
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D	17.905	5.137	12.508	0.261
E	17.905	5.137	4.148	8.621
F	11.993	5.137	6.596	0.261
G	11.693	0.637	10.796	0.261
H	11.593	0.000	11.332	0.261
J	11.393	0.000	11.132	0.261
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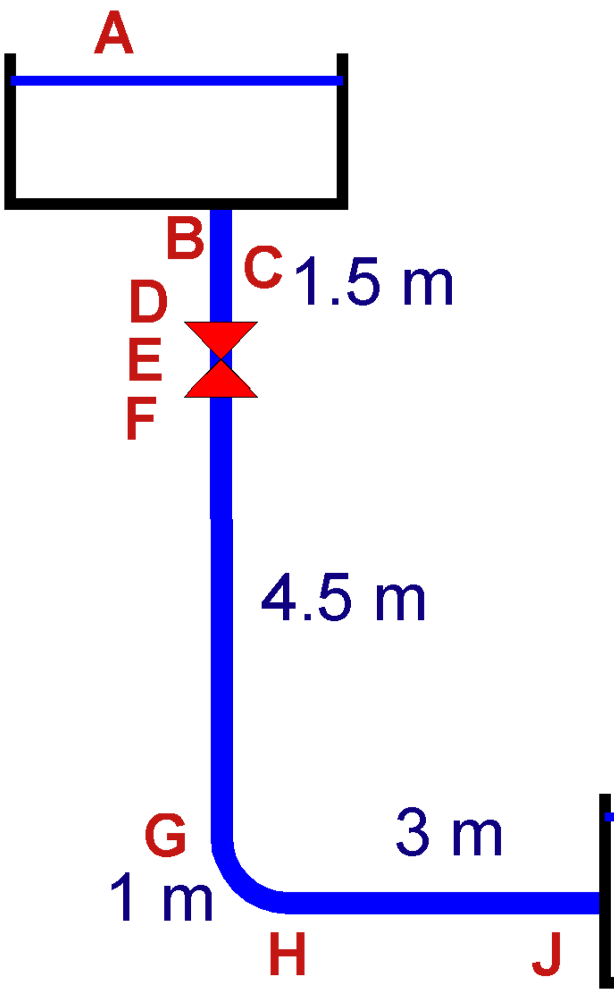
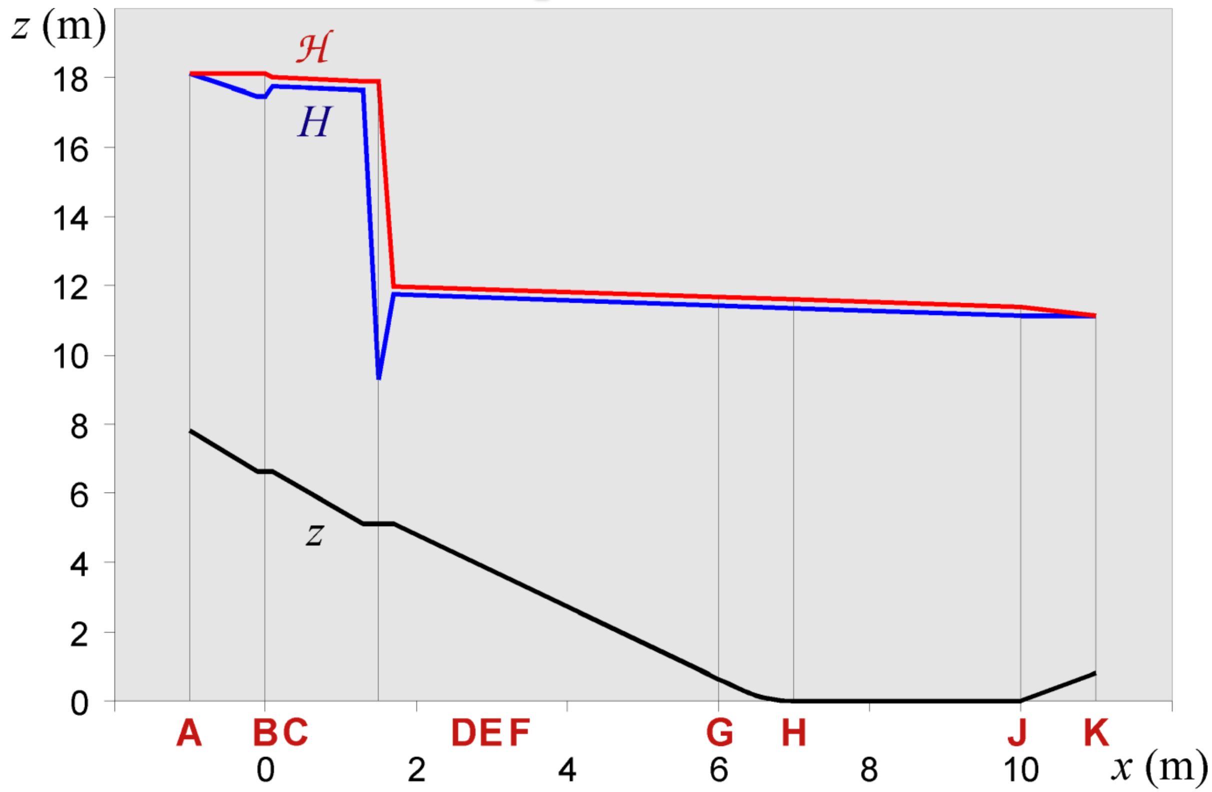
Conduite simple





$D = 100$ mm

$\varepsilon = 0.25$ mm (fonte neuve)

Vanne : $x/D = 0.25$ $\zeta = 22.68$

Consommations (normes françaises)

- Communes rurales (< 2000 habitants)

125 … (200) litres / jour / habitant

Besoins domestiques		60 litres/jr/hab.
Elevage	Cheval ou bovidé Porc Mouton	50 litres/jr 20 litres/jr 5 litres/jr
Arrosage des jardins		3.6 … 9 litres/jr
Exploitation agricole	Fromagerie Cidrerie Vinification Brasserie Sucrerie	5 litres par litre de lait 4 litres par litre de cidre 2 litres par litre de vin 5 litres par litre de bière 100 litres par kg de sucre

Consommations (normes françaises)

- Communes urbaines (> 2000 habitants)
  - < 20000 habitants : 125 … 200 litres / jr / hab.
  - 20000 à 100000 hab. : 200 … 300 litres / jr / hab.
  - > 100000 hab. : 300 … 400 litres / jr / hab.

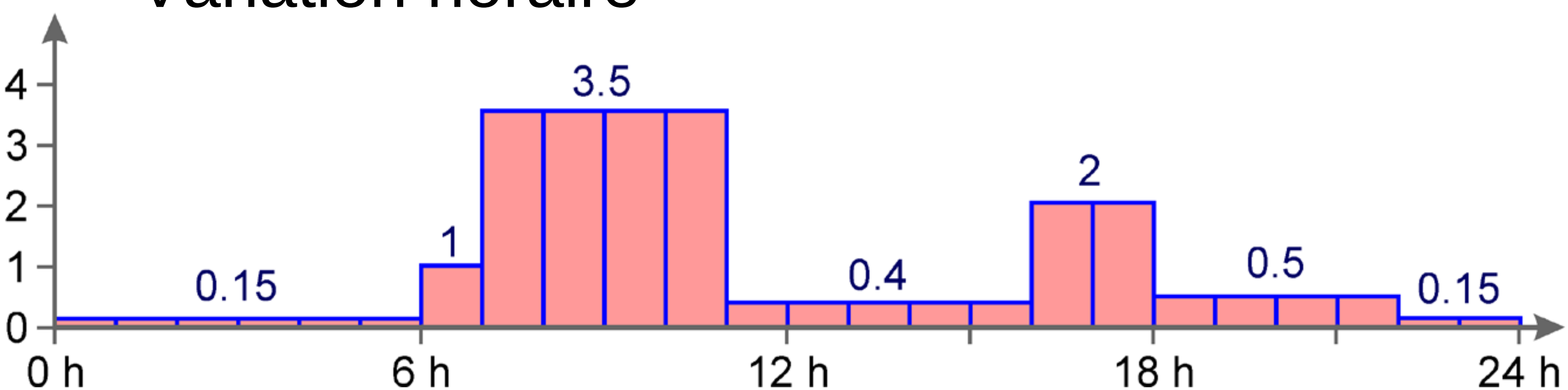
Ecole	100 litres/jr par élève
Sanatorium	250 litres/jr par lit
Hôpital	500 litres/jr par lit
Colonie de vacances	100 litres/jr par personne
Urinoir	20 litres/jr par place
Lavoir	1200 litres/jr par place
Bain-douche	200 litres/jr par poste
Abattoir	500 litres/jr par tête de bétail
Nettoyage des marchés	5 litres/m^2 par jour de marché
Lavage des caniveaux	25 litres/m par jour

Consommations (normes françaises)

- Pertes : 25 … 35 … 50 %
- Incendies : 60 m^3/h pendant 2 heures
- Marge : + 20 … 30 % sur 25 ans

Coefficient de pointe

- Estimation moyenne : $p = 2.$
- Estimation différenciée
  - En tête de réseau : $p = 2.$
  - Aux points de distribution : $p = 3.$
- Estimation globale $p = 1.5 + \frac{2.5}{\sqrt{Q_{moy}}}$ Q_{moy} en litres/s
- Variation horaire



Consommations (normes OMS)

- Eau potable : ≥ 1 à 2 litres/jour par personne
- Eau pour l'hygiène et la nourriture :
  52 à 54 litres/jour par personne

Haïti Accès à l'eau et à l'assainissement		Population urbaine (46 % de la population)	Population rurale (54 % de la population)	Population totale
Eau	Accès Domicile	52 % 24 %	56 % 3 %	54 % 14 %
Assainissement		57 %	14 %	30 %

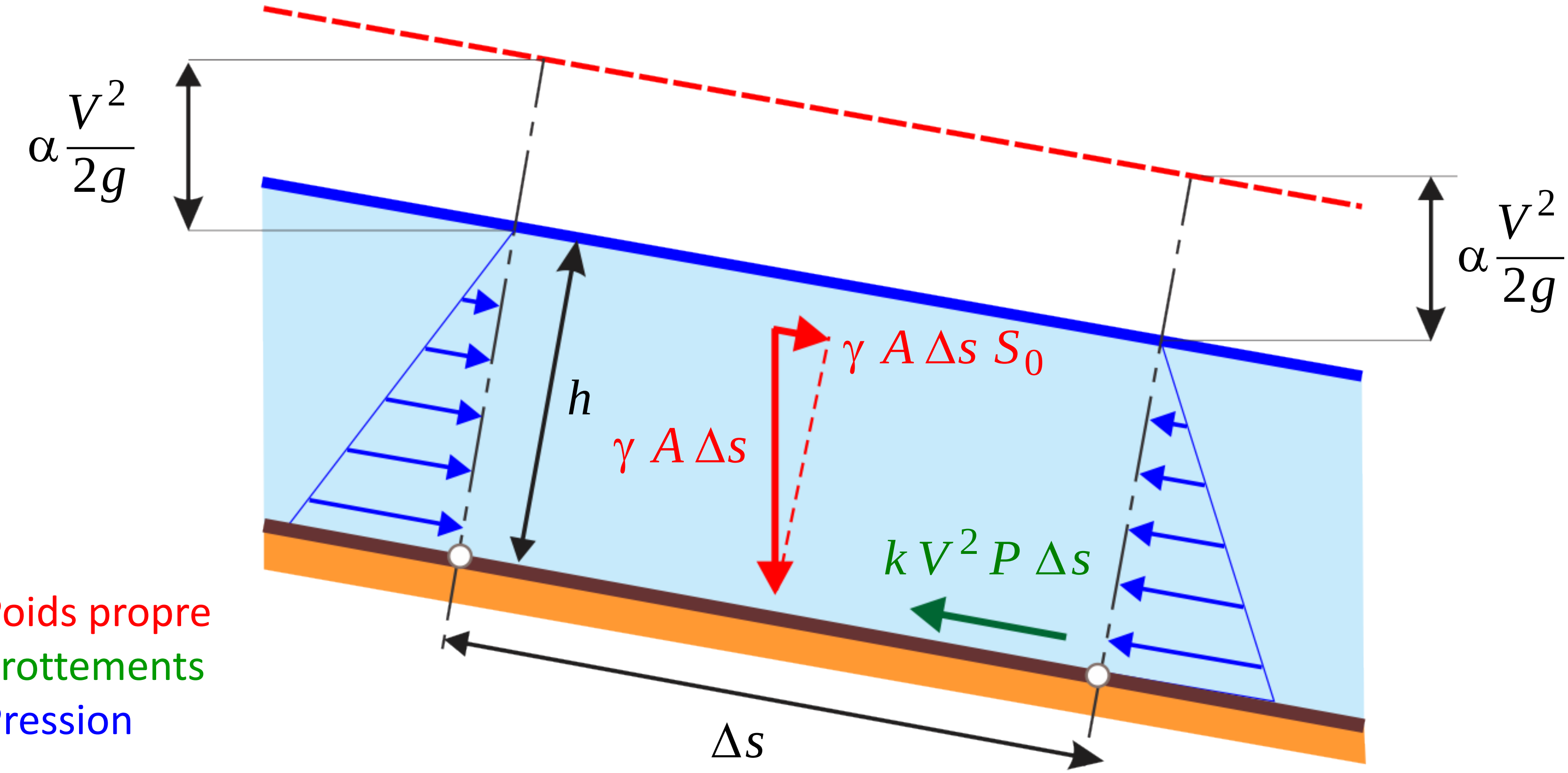
WHO/UNICEF Joint Monitoring Program, 2004

Open-channel flow

- Reference flow for
  - Urban drainage
  - Irrigation
- Uniform flow
  - General case
  - Urban sewer

Uniform flow

- Equilibrium flow

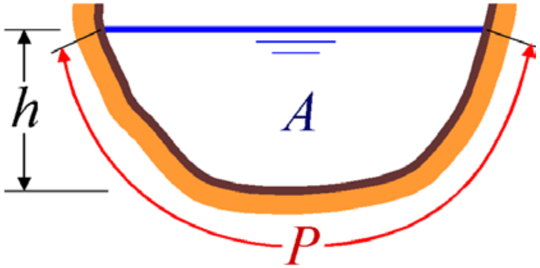


Poids propre
Frottements
Pression

Uniform flow

- Chézy

$$V = C\sqrt{R\,S_0} = C\sqrt{R\,S_f}$$



- Manning-Strickler

$$C = \frac{1}{n} R^{1/6} = K\,R^{1/6}$$

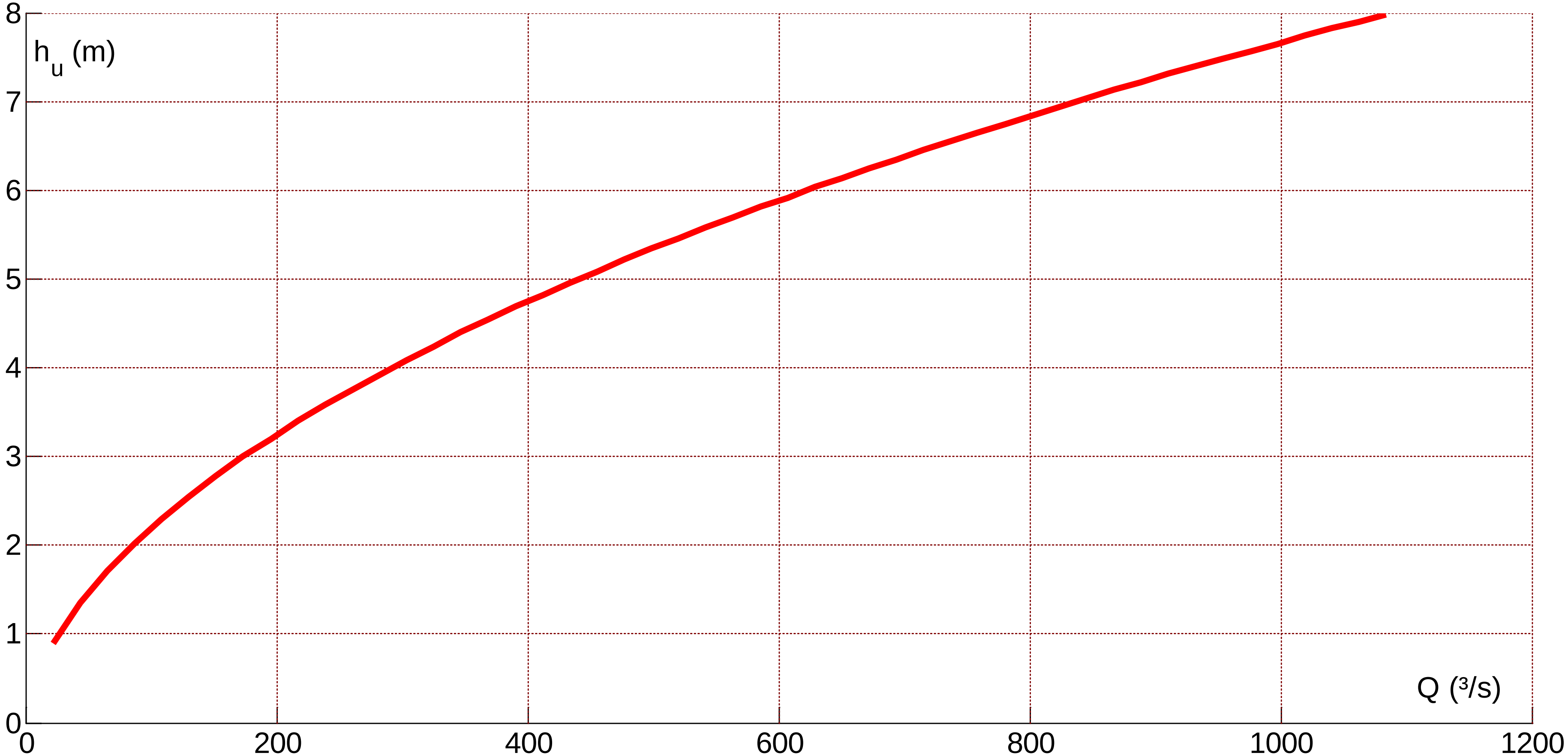
A aire mouillée
P périmètre mouillé
R = *A*/*P* rayon hydraulique

$$\boxed{V = \frac{1}{n} R^{2/3}\, S_0^{1/2} = K\,R^{2/3}\, S_0^{1/2}}$$

n en $\mathrm{m}^{-1/3}\,\mathrm{s}$
K en $\mathrm{m}^{1/3}\,\mathrm{s}^{-1}$

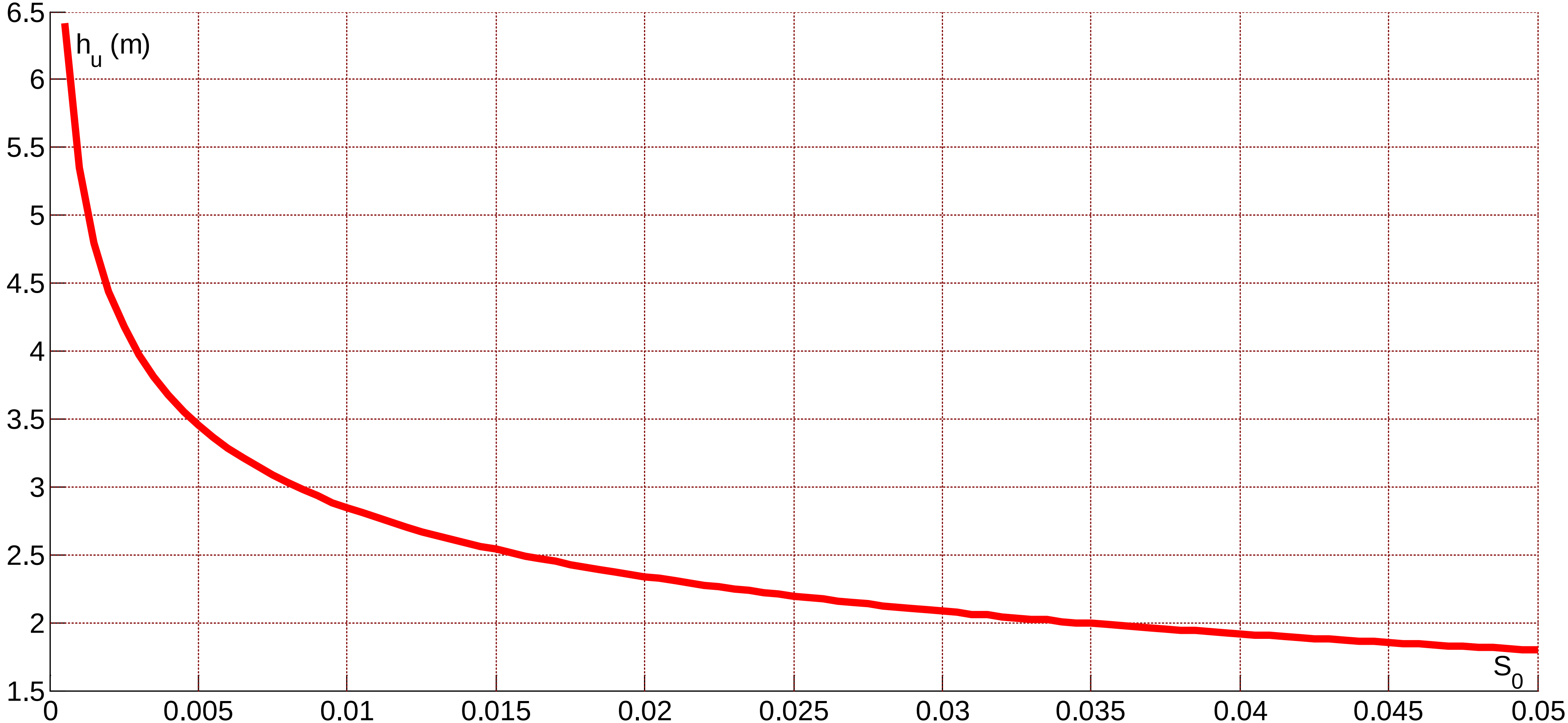
Uniform flow

- $h_u = f(Q)$



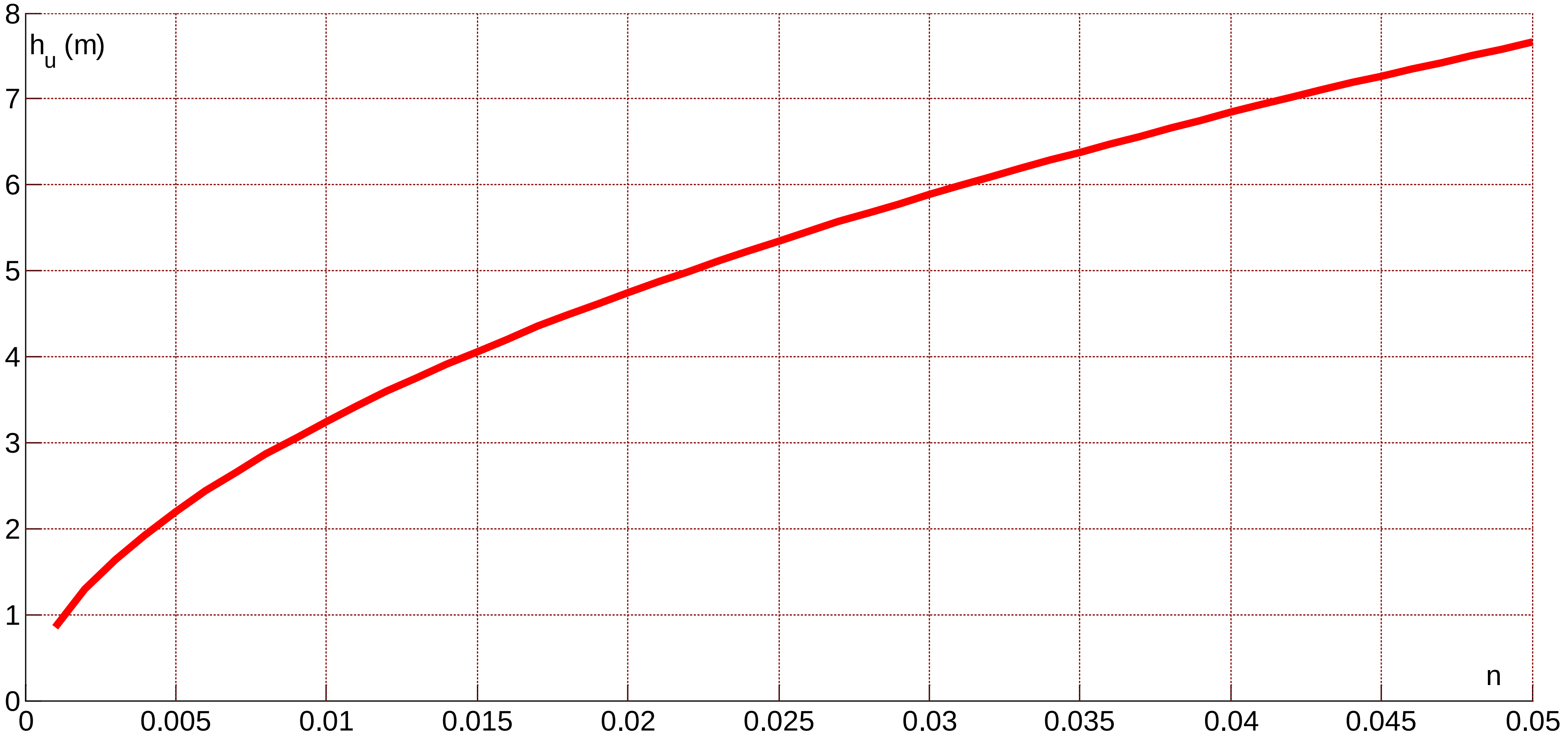
Uniform flow

- $h_u = f(S_0)$

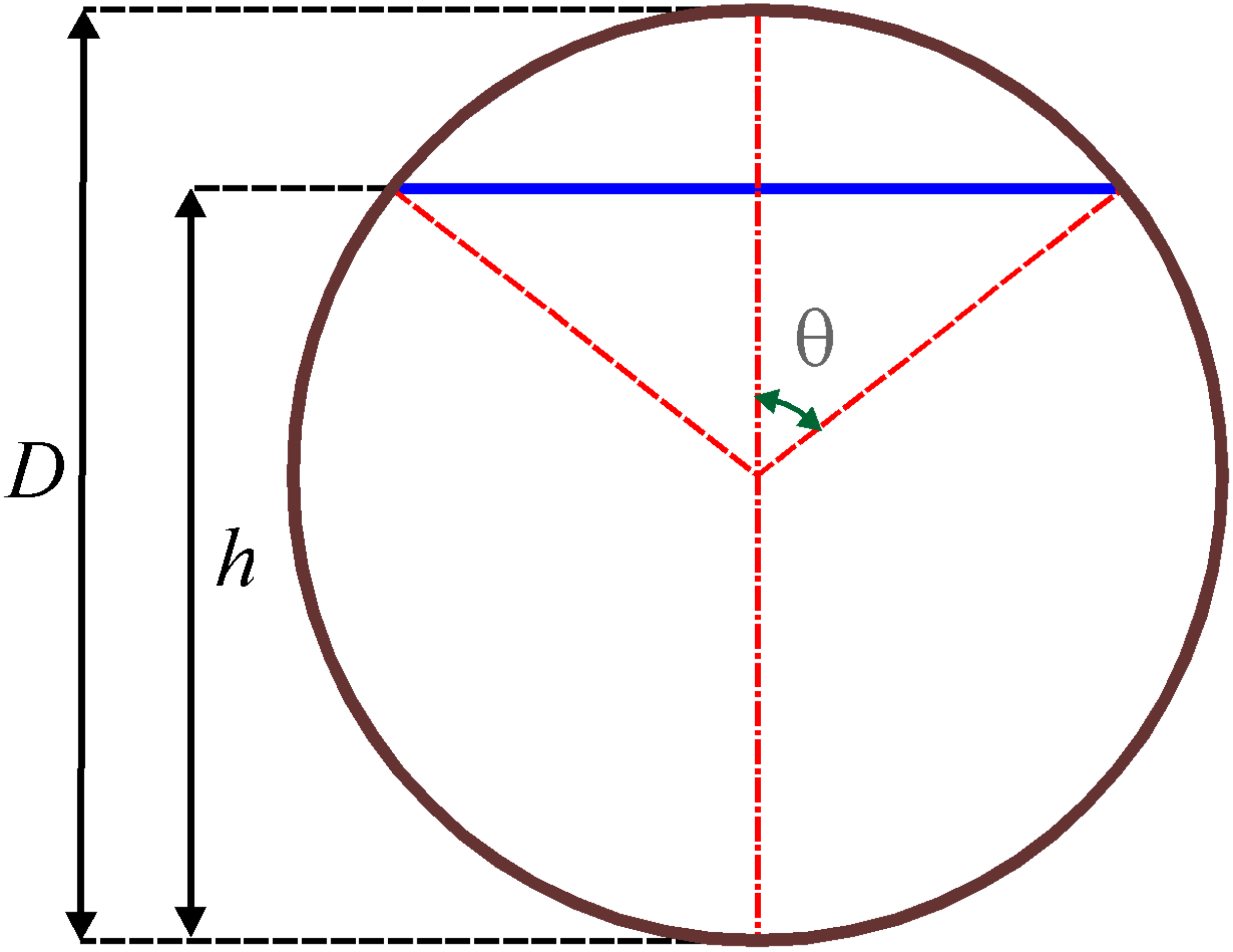


Uniform flow

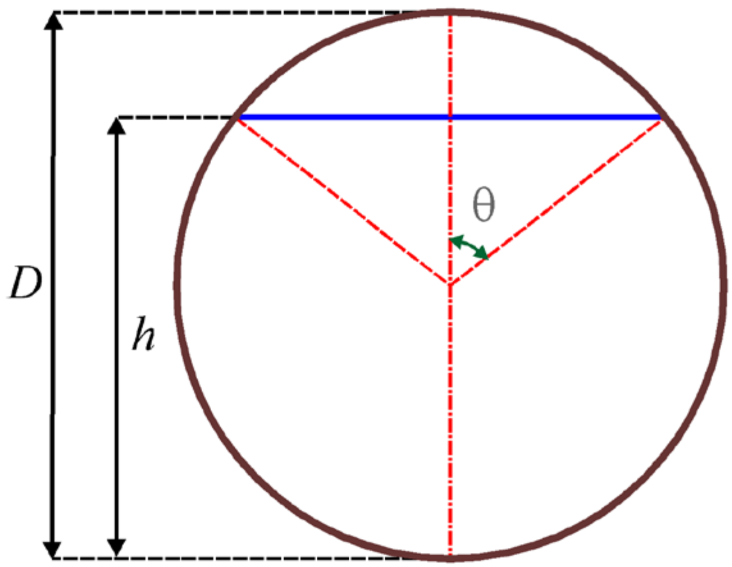
- $h_u = f(n)$

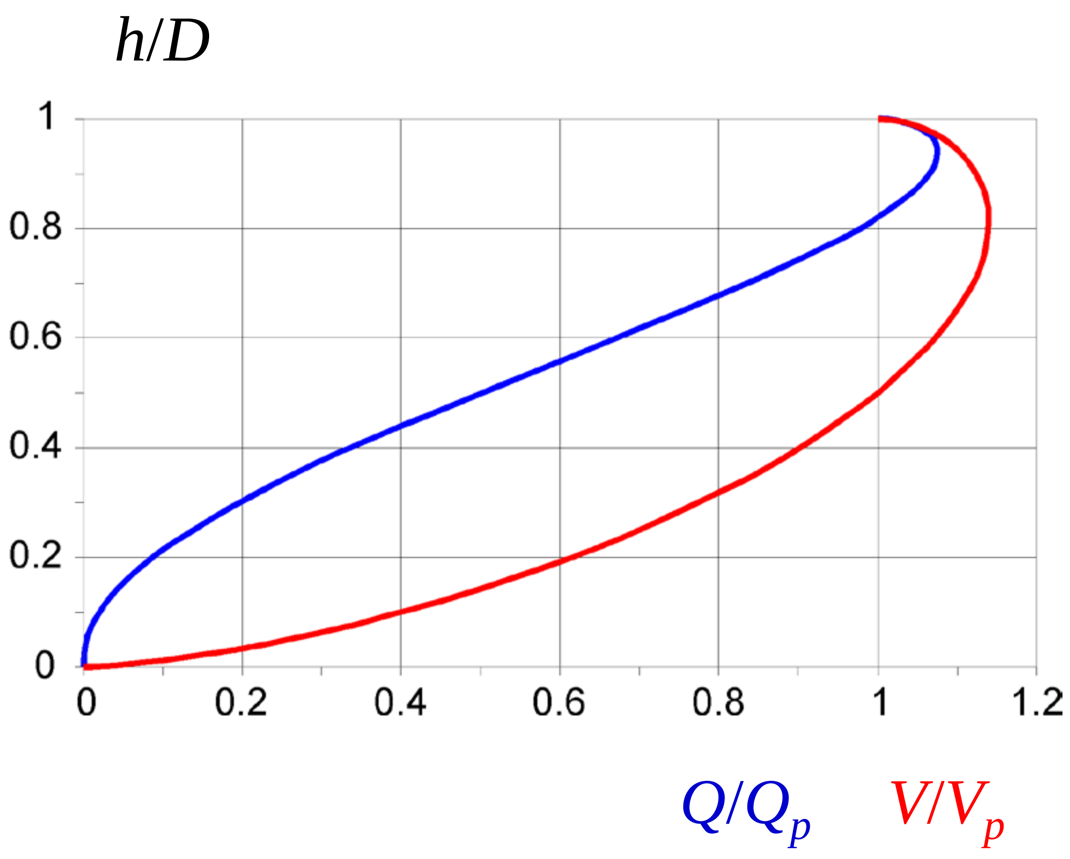


Urban drainage hydraulics



Urban drainage hydraulics





Constraints

- Velocity
  - Self-cleaning: $V \geq 0.60$ m/s for $Q = 0.1\ Q_{max}$
    $V \geq 0.30$ m/s for $Q = 0.01\ Q_{max}$
  - Attrition: $V \leq 2$ m/s
- Slope
  - Installation accuracy : $S_0 \geq 0.005$
  - Earthwork volume limitation: $S_0 \leq 0.04 \ldots 0.05$
- Diameter
  - Non obstruction : $D \geq 0.20$ m at the head of the network
    $D \geq 0.30$ m inside the network
- Inspection manholes: inter-distance 10 … 35 m

Avoid pressurized flow

- https://www.youtube.com/watch?v=10dSbmtq1cU