

River ecomorphodynamics and bioengineering

(ENV-418, A.Y. 2025-26)

4ETCS, Master option

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Platform of Hydraulic Constructions



Exercises L11

Exercise

- Influence on calibration curves relationship between water level and flow rate
- Generally, to determine the flow rate of a watercourse, the water level is measured in a section with quasi-uniform flow.

$$Q = \frac{1}{n} A R^{2/3} S_0^{1/2}$$

A red circle highlights the variable n in the denominator, with a red arrow pointing downwards from it.

où A= wet section
R= hydraulic radius
S₀=slope
n=1/k= Manning coefficient

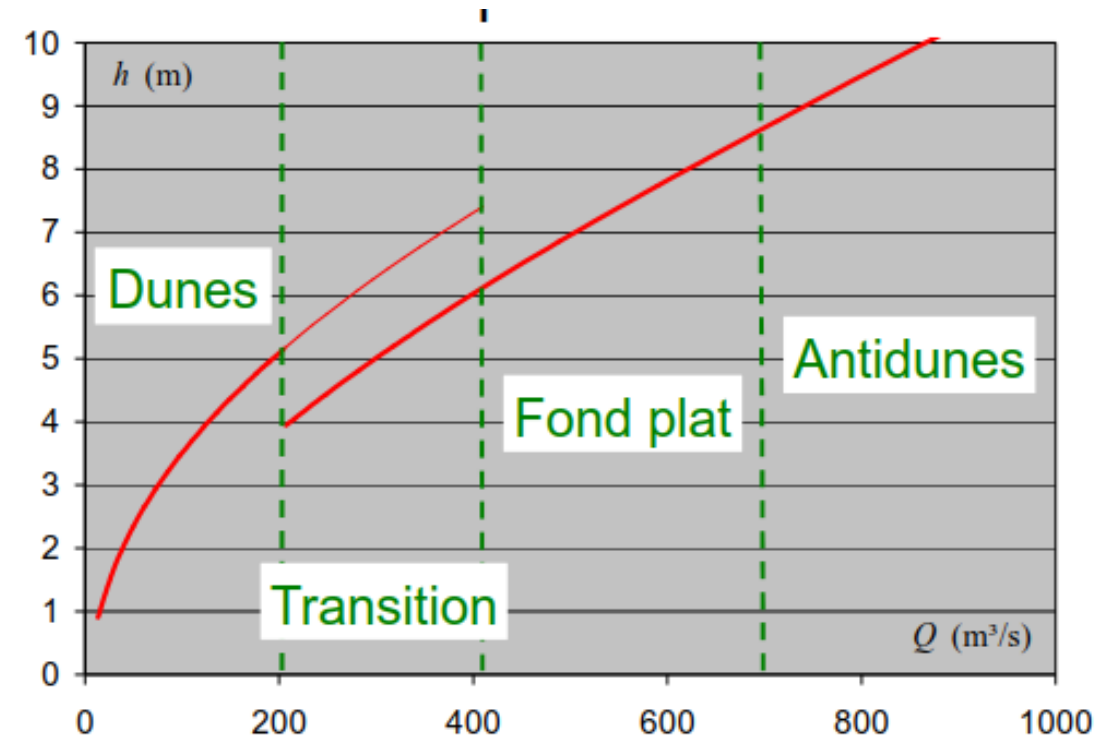


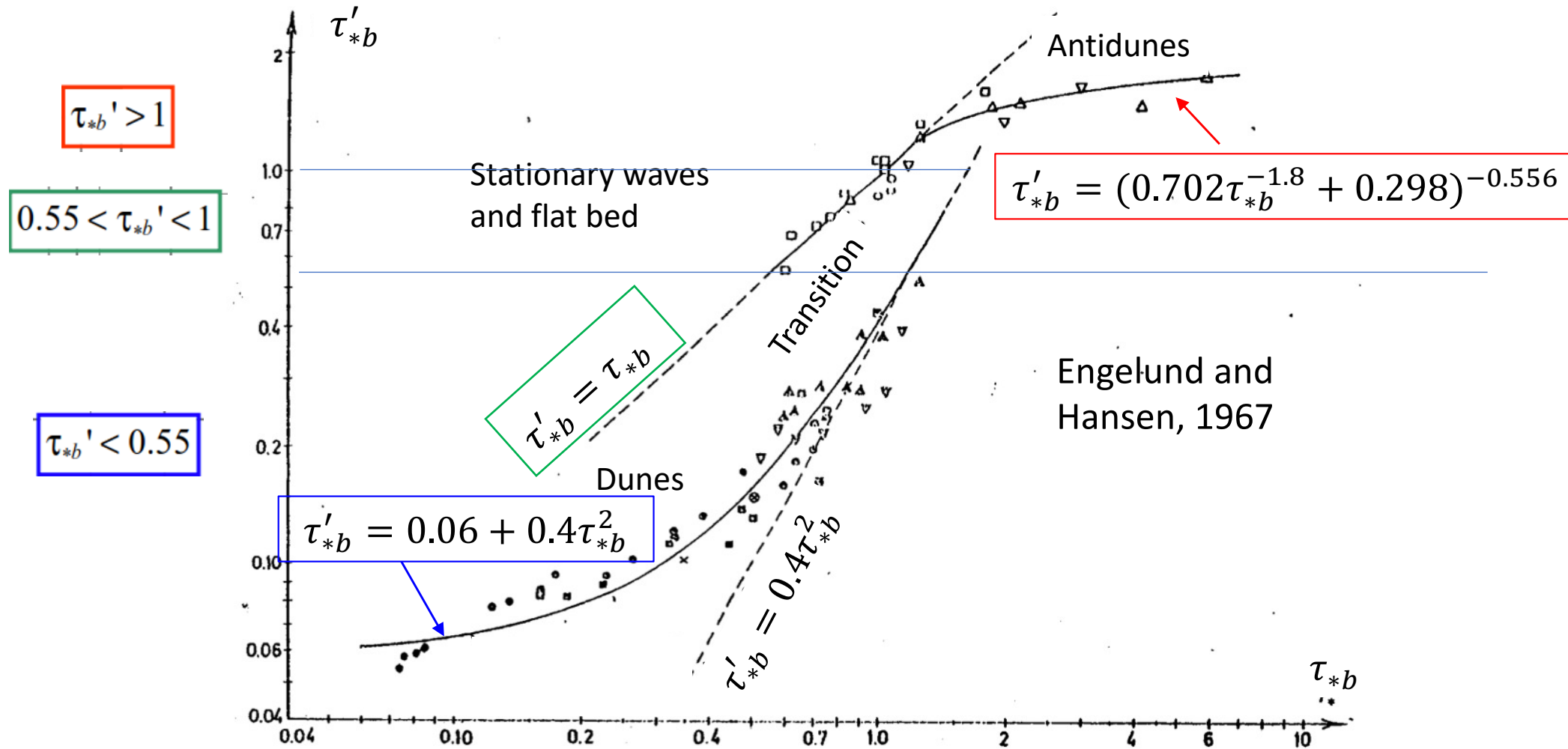
Problem: n is influenced by bedforms and may change depending on discharge

- The presence of bedforms influences the rating curve;
- As Q grows, the disappearance of dunes causes a smaller water depth
- Dunes may form earlier when flow is inverted
- This may originate hysteresis in the rating curve behaviour
- Careful channel design must be made!
- Serious problems for navigation!



To assess the rating curve we can use Engelund and Hansen decomposition





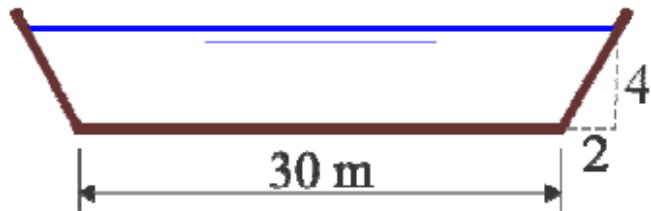
Procedure

Soit:

- $S_0=0.01\%$ (pente)
- $L=30\text{m}$ (largeur)
- $p=0.5$ (pente des berges)
- $n_w=0.014$ (rugosité des berges)
- $d_{65}=0.35\text{mm}$ (diamètre des sédiments)

Pour rappel:

- $\gamma_s=25996.5 \text{ N/m}^3$ ($=\rho_s g$)
- $\gamma=9810 \text{ N/m}^3$ ($=\rho g$)



R'_b (m)	0.8
τ'_{*b}	
u'_{*b} (m/s)	
U (m/s)	
τ_{*b}	
R_b (m)	
n_b	
R_w (m)	
h (m)	
A (m ²)	
Q (m ³ /s)	

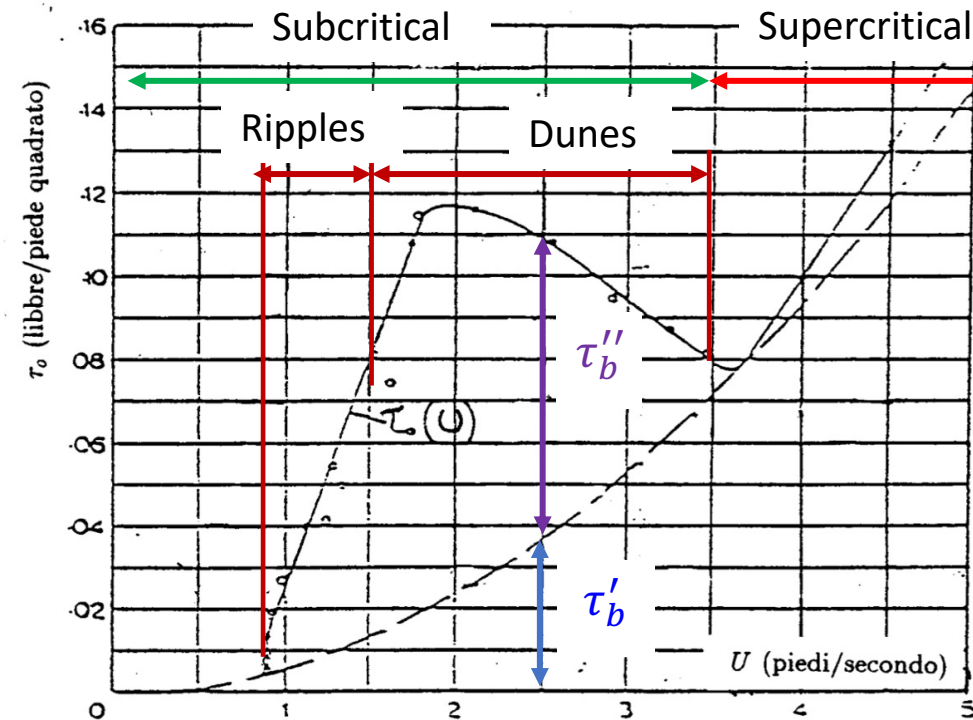
We assess the role of friction and that due to bedforms

Known the total tension, we decompose it into friction (τ'_b) and bedform (τ''_b) contributions

$$\tau_b = \gamma R_b S_f = \tau'_b + \tau''_b = \gamma (R'_b + R''_b) S_f$$

$$\tau_{*b}' = \frac{\tau'_b}{(\gamma_s - \gamma) d} = \frac{\gamma R'_b S_f}{(\gamma_s - \gamma) d}$$

$$\tau_{*b}'' = \frac{\tau''_b}{(\gamma_s - \gamma) d} = \frac{\gamma R''_b S_f}{(\gamma_s - \gamma) d}$$



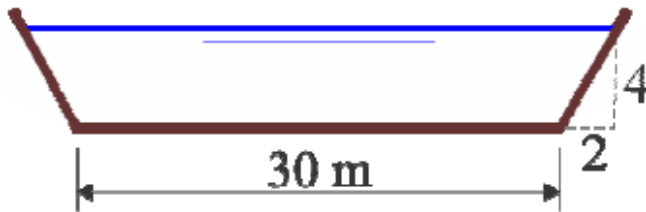
Source: Raudkivi, 1970

Soit:

- $S_0=0.01\%$
- $L=30\text{m}$
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Pour rappel:

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In order to calculate U we need to know u'_{*b}

$$U = \frac{u'_{*b}}{\kappa} \ln \left(a e^{-\chi} \frac{R'_b}{k_s} \right)$$

$$\begin{aligned} \kappa &= 0.4 \\ k_s &= d_{65} \\ a &= 29.964 \\ \chi &= 1.418 \end{aligned}$$

R'_b (m)	0.8
τ'_{*b}	
u'_{*b} (m/s)	
U (m/s)	
τ_{*b}	
R_b (m)	
n_b	
R_w (m)	
h (m)	
A (m ²)	
Q (m ³ /s)	

$$\tau'_{*b} = \frac{\gamma R'_b S_0}{(\gamma_s - \gamma)d}$$

$$u'_{*b} = \sqrt{g R'_b S_0}$$

$$U = \frac{u'_{*b}}{\kappa} \ln \left(a e^{-1} \chi \frac{R'_b}{k_s} \right)$$

$$\kappa = 0.4$$

$$k_s = d_{65}$$

$$a = 29.964$$

$$\chi = 1.418$$

$$\tau'_{*b} < 0.55$$

$$\tau'_{*b} = 0.4 \tau_{*b}^2 + 0.06$$

R'_b (m)	0.8
τ'_{*b}	0.139
u'_{*b} (m/s)	
U (m/s)	
τ_{*b}	
R_b (m)	
n_b	
R_w (m)	
h (m)	
A (m ²)	
Q (m ³ /s)	

$$8 \quad Q = AU$$

$$\tau_{*b} = \frac{\gamma R_b S_0}{(\gamma_s - \gamma)d}$$

$$U = \frac{1}{n_b} R_b^{2/3} S_0^{1/2}$$

$$U = \frac{1}{n_w} R_w^{2/3} S_0^{1/2}$$

$$A = A_b + A_w$$

$$= R_b P_b + R_w P_w$$

À titre d'exemple, la rugosité sans tenir compte des formes:

$$n'_{b,Raudkivi} = \frac{d_{65}^{1/6}}{24} = 0.011$$

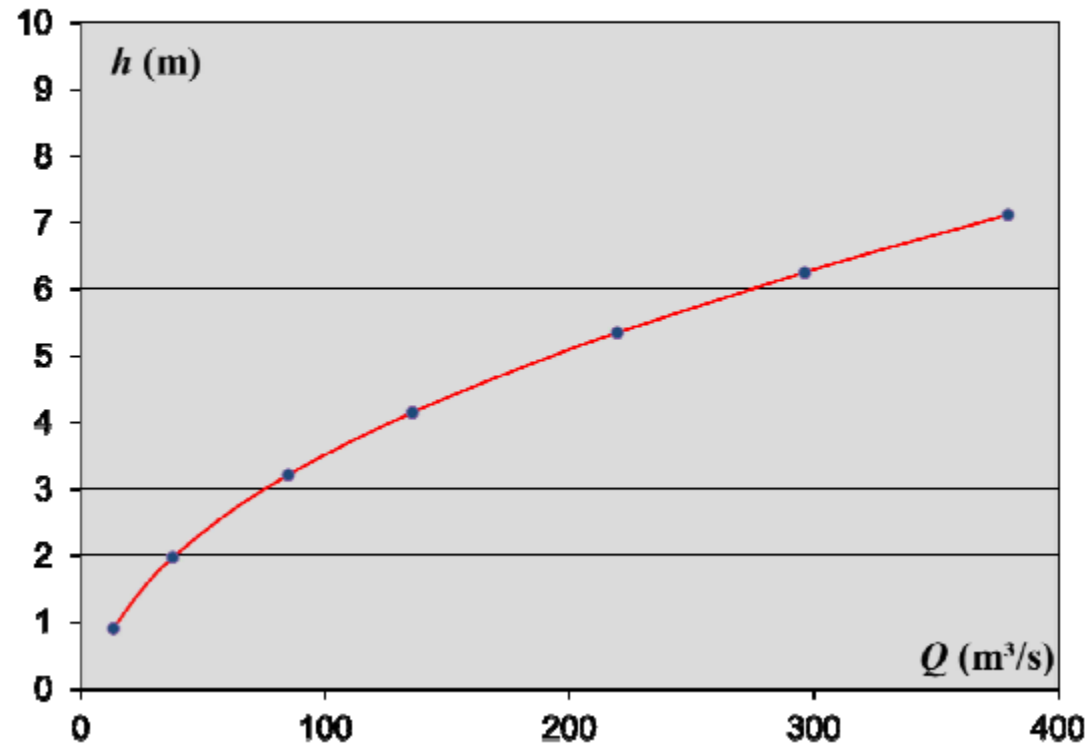
$$\frac{R_w}{R_b} = \left(\frac{n_w}{n_b} \right)^{3/2}$$

$$A = h(L + ph)$$

$$P_b = L$$

$$P_w = 2h\sqrt{1+p^2}$$

- Résultat dans la zone des dunes



R'_b (m)	h (m)	Q (m ³ /s)
0.400	0.903	13.298
0.600	1.967	37.678
1.000	3.204	84.847
1.400	4.142	135.639
2.000	5.340	219.318
2.500	6.246	295.986
3.000	7.107	379.089

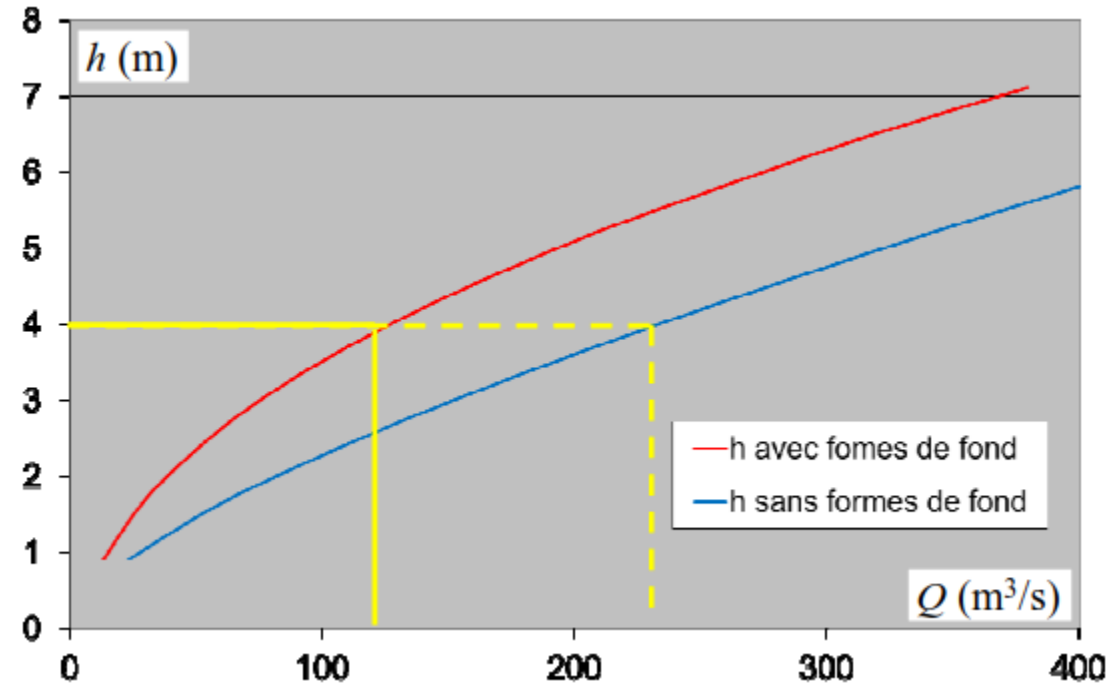
Hydraulique Fluviale

- Effets des formes de fond

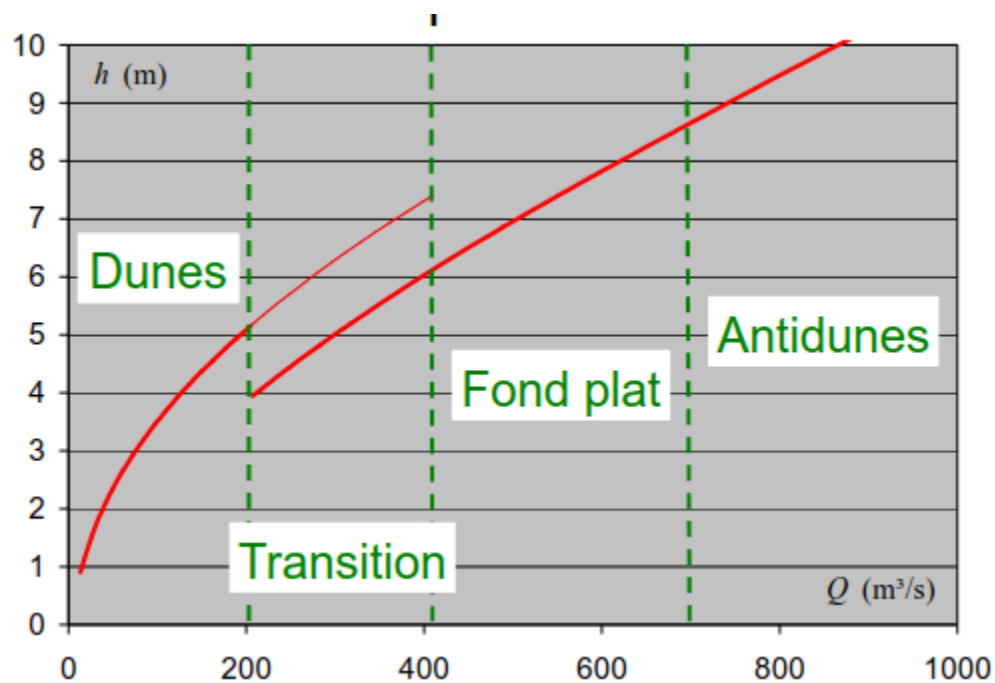
Pour $h = 4$ m:

$Q = 127 \text{ m}^3/\text{s}$
avec formes de fond

$Q = 233 \text{ m}^3/\text{s}$
sans formes de fond



- Résultats complets



Exercise 2

The river Thur near Altikon before restoration (Figure 1) had a channelized width of $B_0=50$ m and slope $s=0.3\%$. The mean annual river discharge is 47 m³/s. Flows with return period of 2, 10 and 100 years, at the gauging station located 15 km downstream the restored reach, are estimated respectively 570 m³/s, 820 m³/s and 1070 m³/s.

In 2002, a 2 km long river reach has been restored, its left hand side bank left free to erode the embankments. In a few years alternate bars developed as in figure 2 below. The sediment bar grain size distribution is shown in Figure 3



Figure 1. The Thur river in 2000



Figure 2. The Thur river in 2005

In the 2009 configuration a discharge of 250 m³/s would inundate all bars and the channel would be full for a channel breadth of about 85 m.

Questions:

- 1) Use the Chow relationships or similar to obtain the equivalent Manning roughness coefficient and calculate the average water depth and velocity for the discharge of 250 m³/s
- 2) Is the wavelength of the developed alternate bar pattern in agreement with your expectations and is that pattern the expected one for the actual d_{50} (use Figure 3)?
- 3) Verify if the bed shear stress exceeds the critical one for the abovesaid discharge of 250 m³/s. Calculate which flow rate would determine critical bedload transport conditions for the average d_{50} and the averaged d_{84} obtained from the GSDs of Figure 3

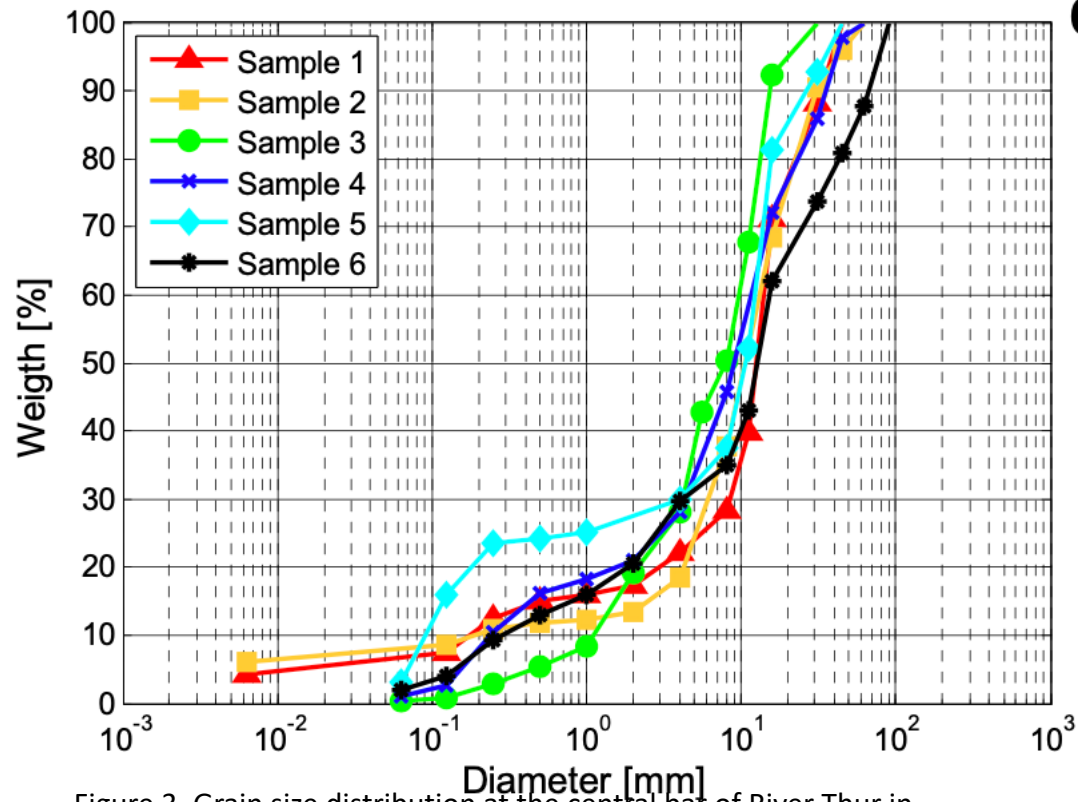


Figure 3. Grain size distribution at the central bar of River Thur in 2009 (Pasquale et al., HESS, 2011).