Estruturas Hidráuicas I

Aula 5

Extravasores 4

Soleiras Labirinto & Piano Keys

Bom dia a todos.

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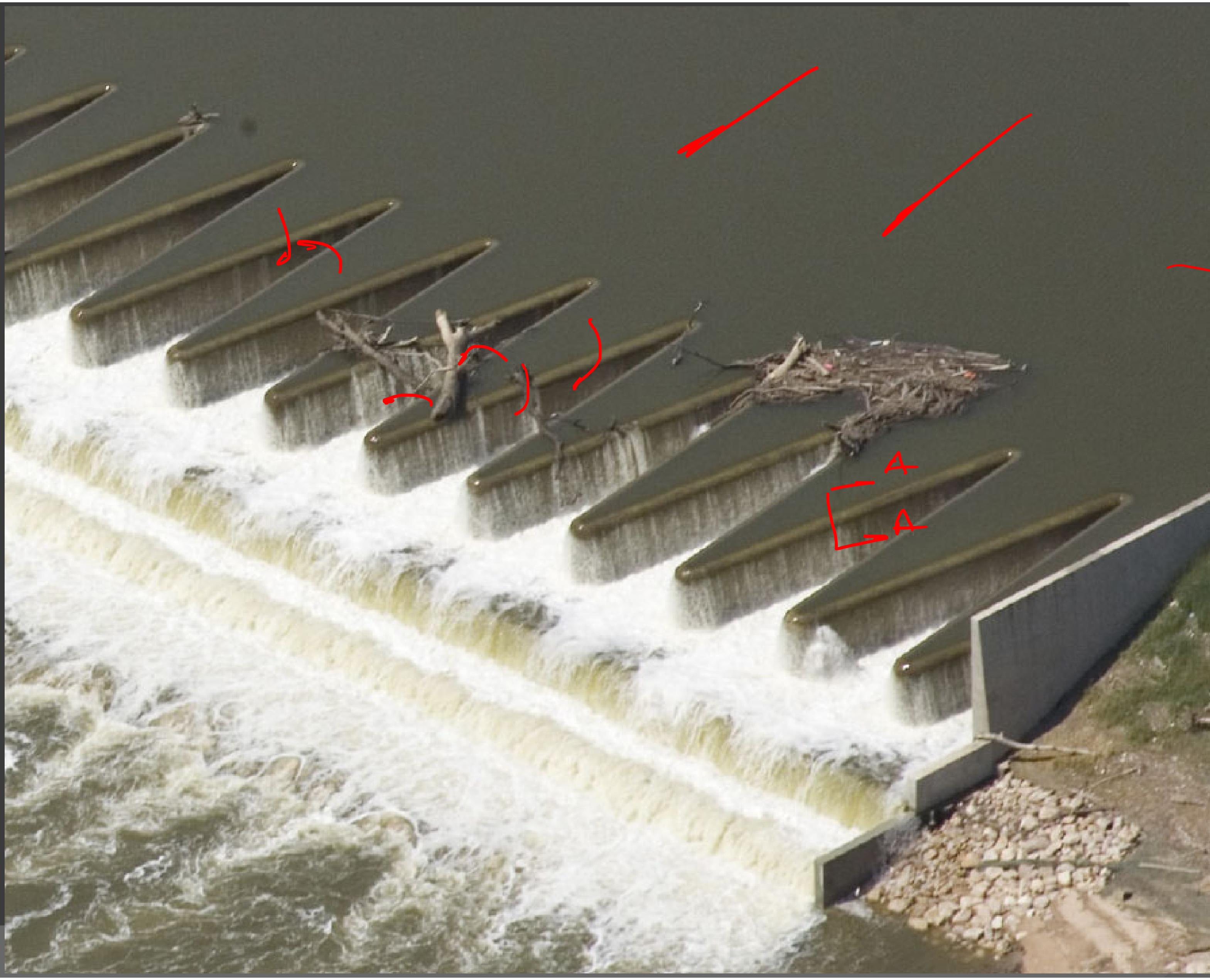
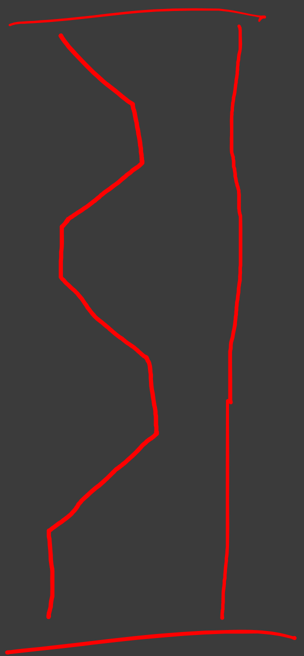
Bibliografia

- ANDERSON, R.; TULLIS, B. Comparison of piano key and rectangular labyrinth weir hydraulics. **Journal of Hydraulic Engineering,** v. 138, n. 4, p. 358-361, 2011. ISSN 0733-9429.
- CROOKSTON, B.; TULLIS, B. Hydraulic design and analysis of labyrinth weirs. I: Discharge relationships. **Journal of Irrigation and Drainage Engineering,** v. 139, n. 5, p. 363-370, 2012a. ISSN 0733-9437.
- ______. Hydraulic design and analysis of labyrinth weirs. II: Nappe aeration, instability, and vibration. **Journal of Irrigation and Drainage Engineering,** v. 139, n. 5, p. 371-377, 2012b. ISSN 0733-9437.
- CROOKSTON, B.; TULLIS, B. P. Discharge efficiency of reservoir-application-specific labyrinth weirs. **Journal of Irrigation and Drainage Engineering,** v. 138, n. 6, p. 564-568, 2011. ISSN 0733-9437.
- CROOKSTON, B. M. **Labyrinth weirs**. 2010. 222 (PhD). Utah State University, Logan, Utah.
- FALVEY, H. T. **Hydraulic design of labyrinth weirs**. ASCE Press (American Society of Civil Engineers) Reston, VA, 2003. ISBN 0784406316.
- KOHN, E. **VERTEDOR DO TIPO LABIRINTO**. 2006. (Dissertação de Mestrado). Escola Politécnica, Universidade de São Paulo, São Paulo.
- LEITE RIBEIRO, M. et al. Discharge capacity of piano key weirs. **Journal of Hydraulic Engineering,** v. 138, n. 2, p. 199-203, 2011. ISSN 0733-9429.
- LEMPÉRIÈRE, F.; OUAMANE, A. The Piano Keys weir: a new cost-effective solution for spillways. **International Journal on Hydropower & Dams,** v. 10, n. 5, p. 144-149, 2003. ISSN 1352-2523.
- PAXSON, G.; SAVAGE, B. Labyrinth spillways: comparison of two popular USA design methods and consideration of non-standard approach conditions and geometries. Proc. Int. Junior Researcher and Engineer Workshop on Hydraulic Structures, Montemor-o-Novo, Portugal, 2006. p.37-46.
- ROSELLI, R. G. **Extravasor labirinto em aproveitamentos hidrelétricos**. 2012. (Dissertação de mestrado). Escola Politécnica, Universidade de São Paulo, São Paulo.
- TULLIS, J. P.; AMANIAN, N.; WALDRON, D. Design of labyrinth spillways. **Journal of hydraulic engineering,** v. 121, n. 3, p. 247-255, 1995. ISSN 0733-9429.


A
A

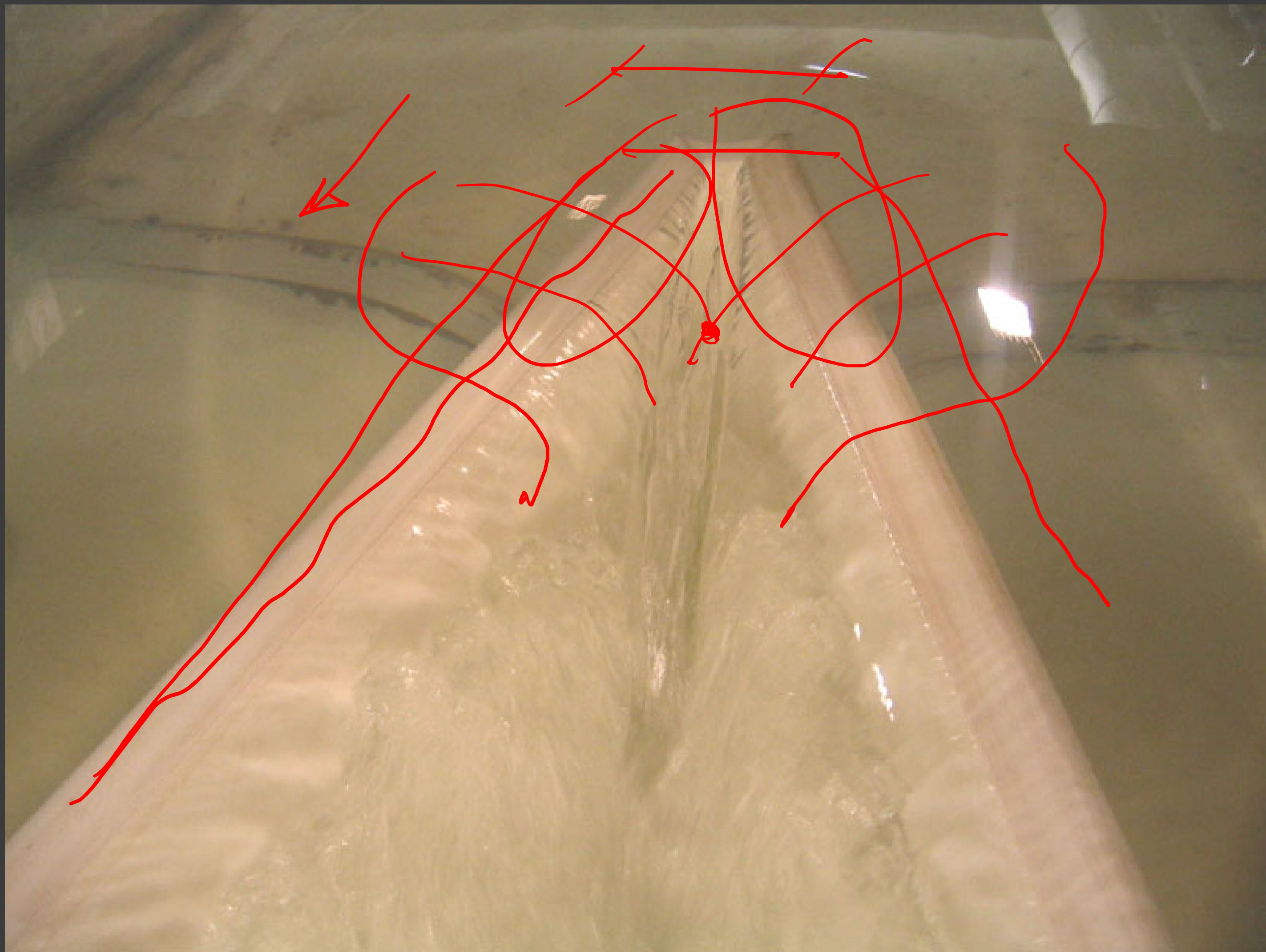
ZIG ZAG



$$Q = \frac{2}{3} C_D L_{util} \sqrt{2g}\, H^{3/2}$$

maior

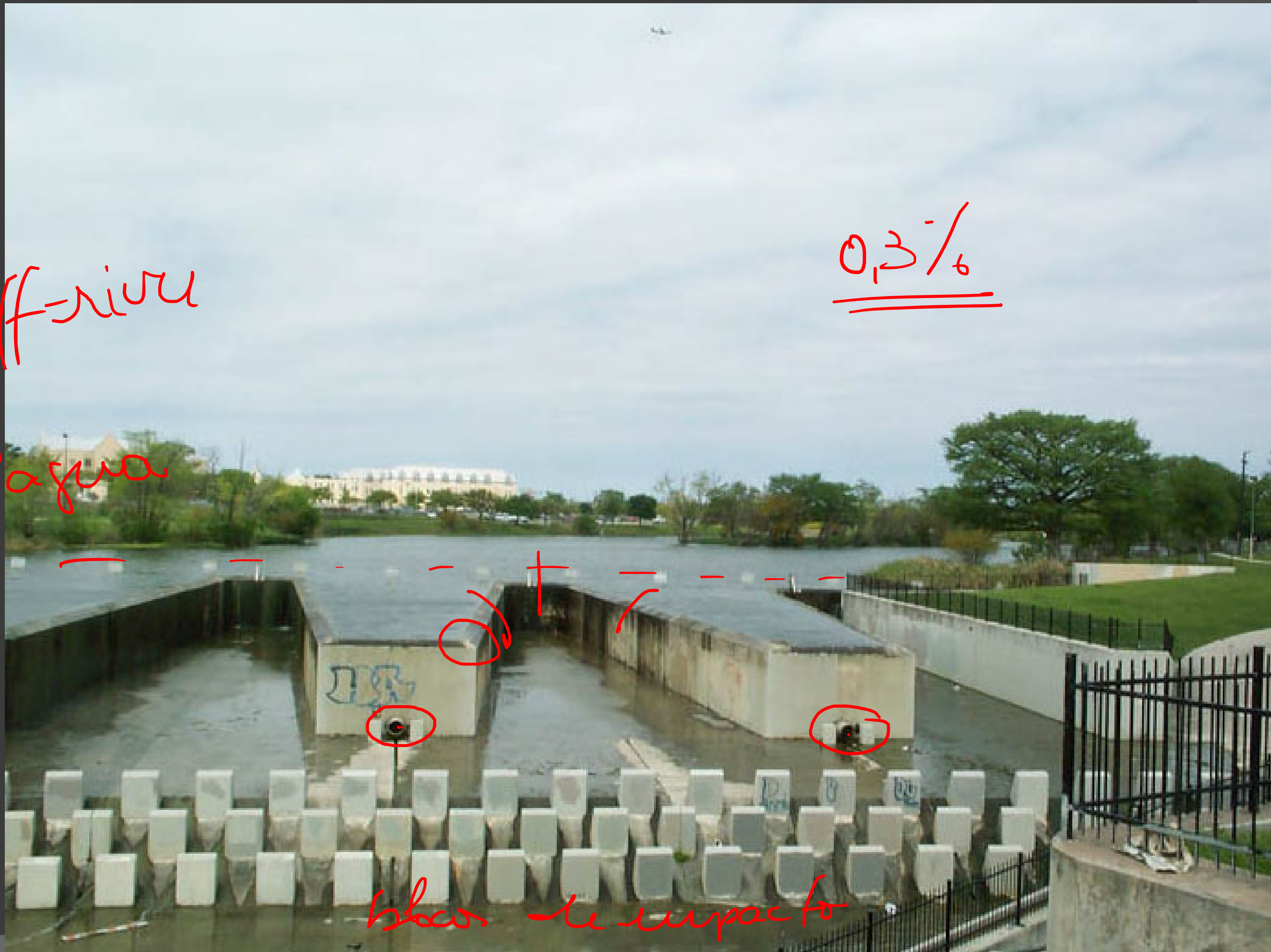
muito menor




B

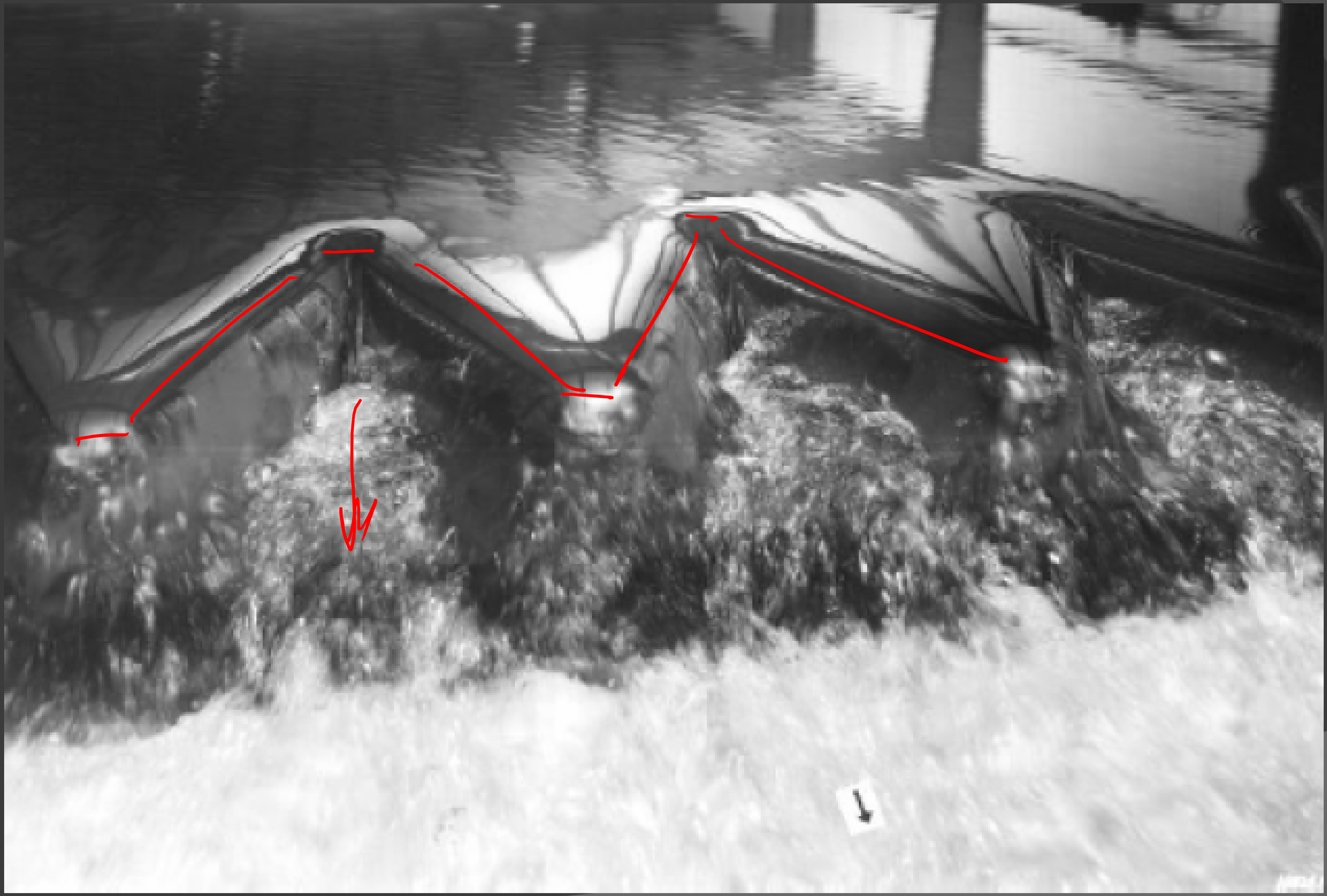
run-off-river

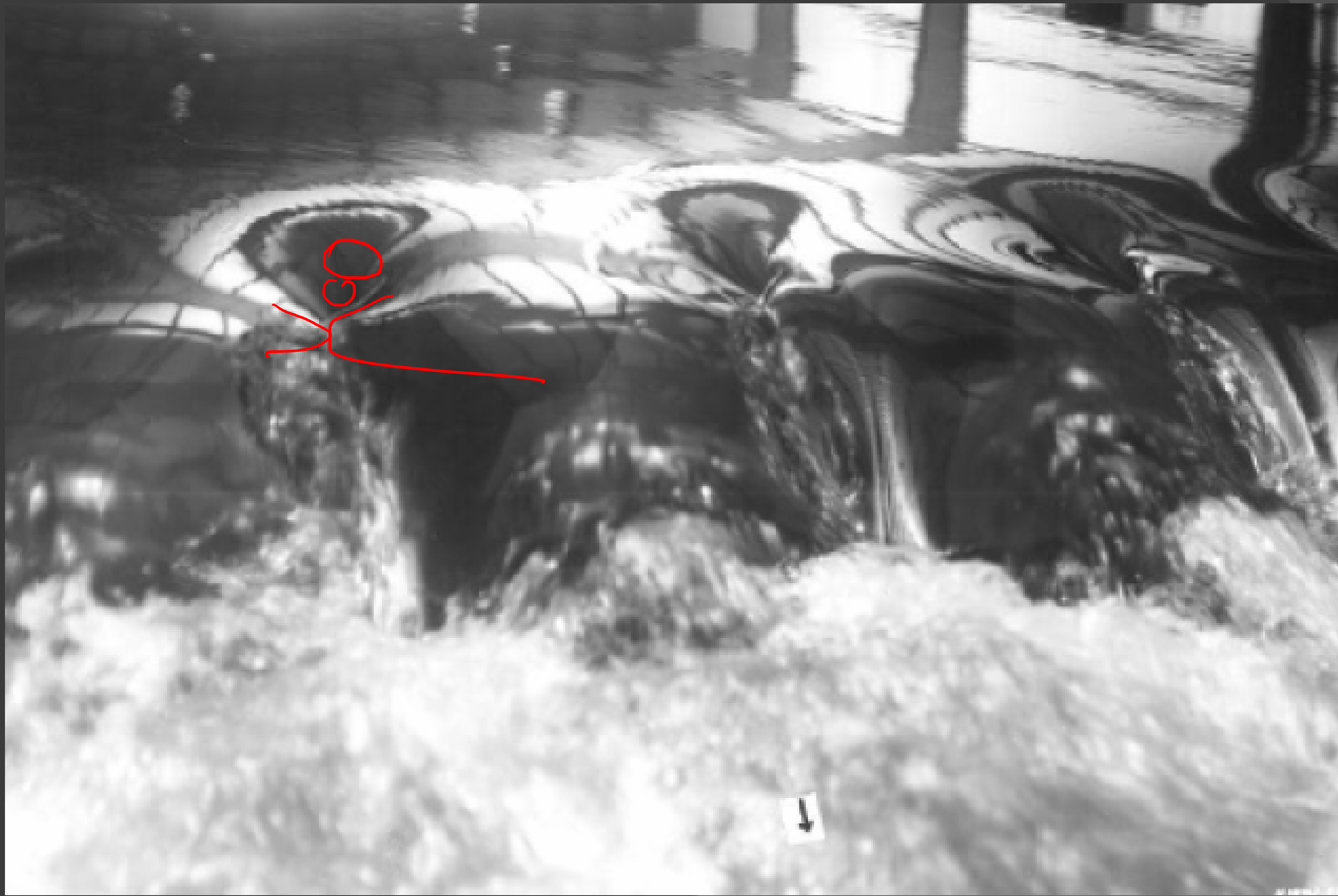
fio d'água

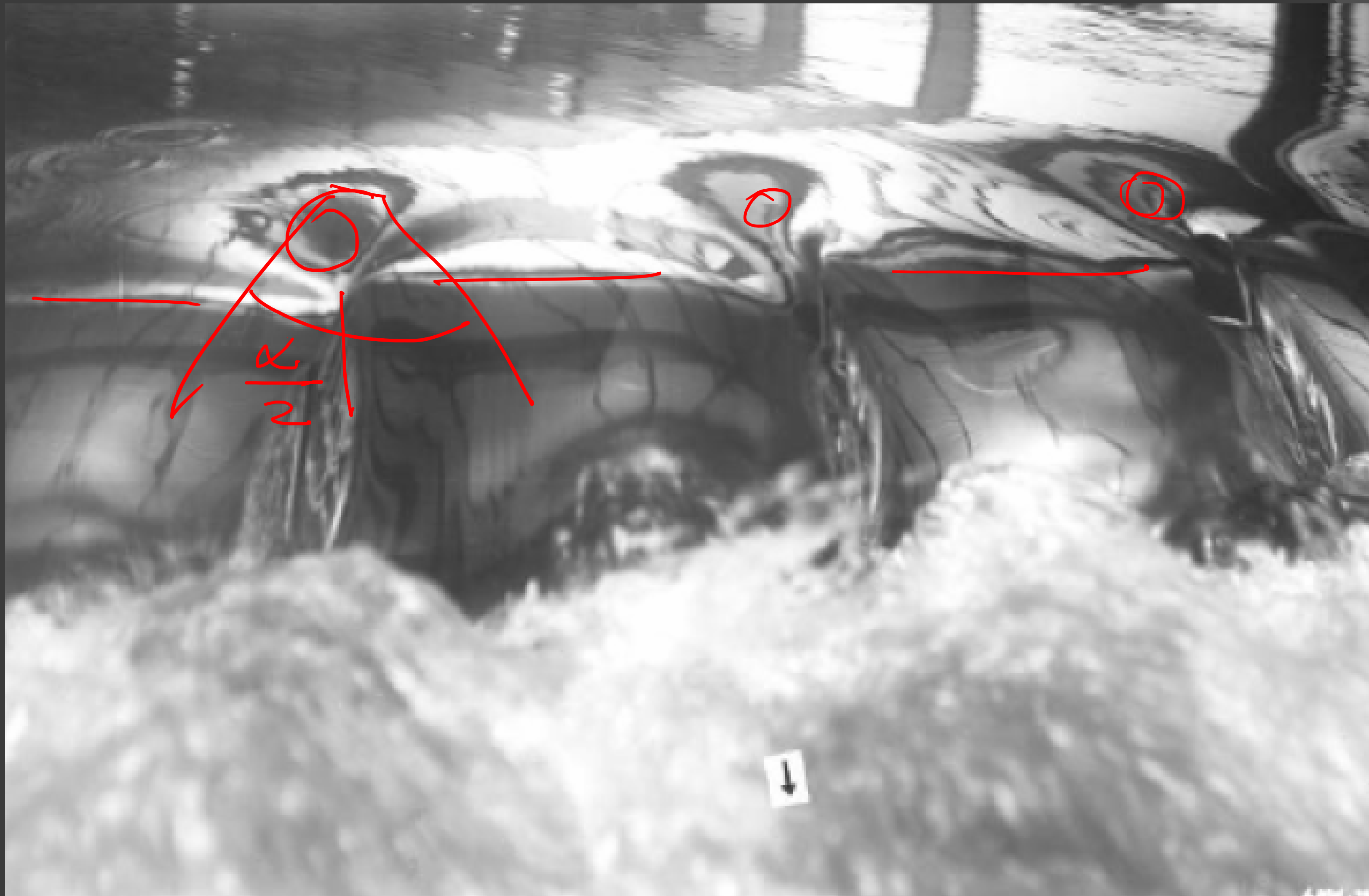


0,3%

bloco de impacto

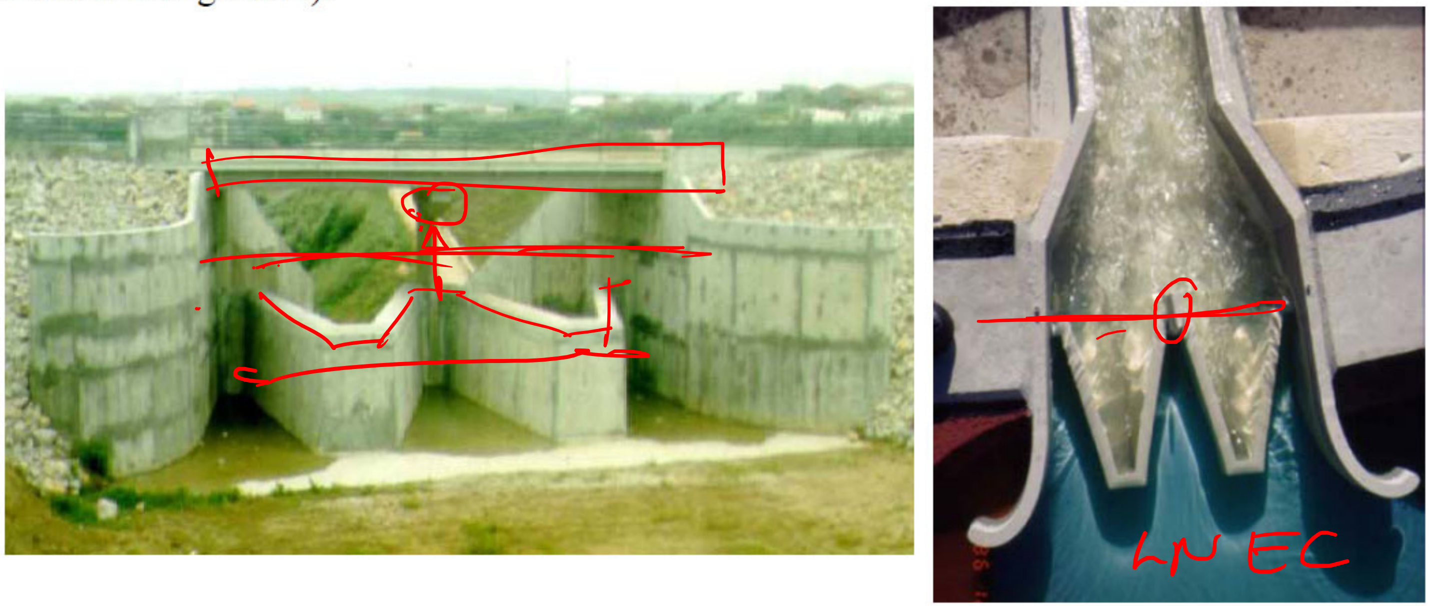






α/2

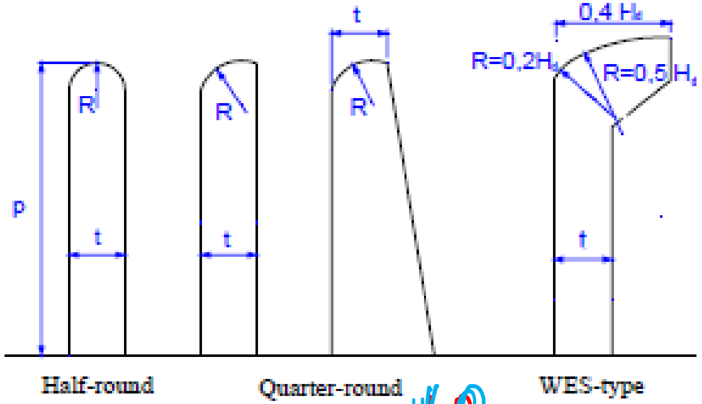
Fig. 1 - S. Domingos labyrinth spillway, Portugal (1991): a) prototype; b) physical model (courtesy of A. Pinto de. Magalhães).



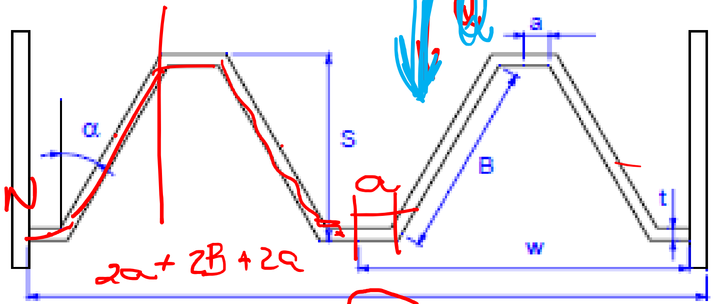
a)　　b)

disipación

Escalón



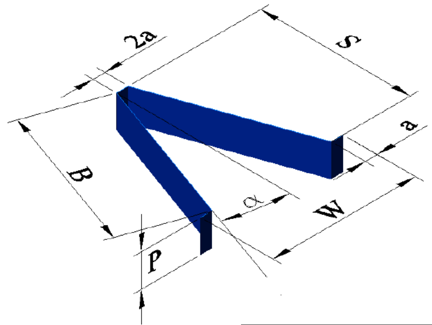
3D

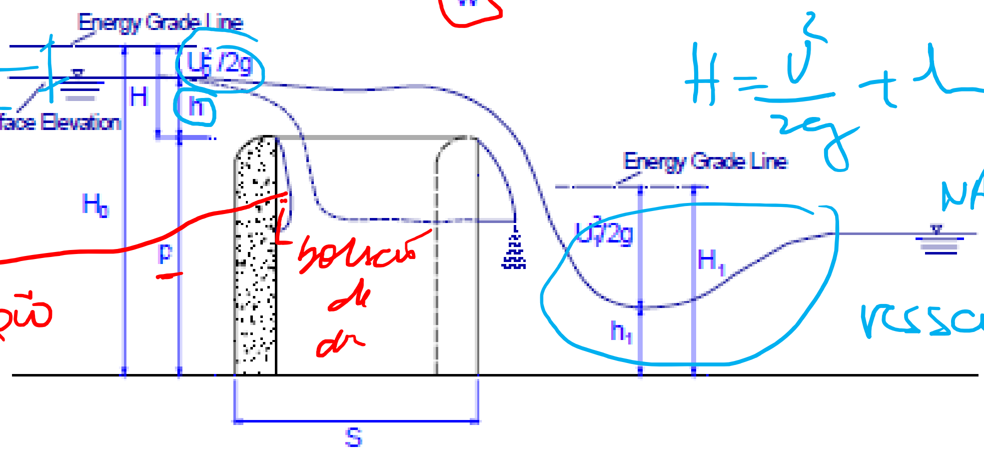


$L_{geo} = (Ha + 2B)N$

$2a + 2B + 2a$

Q





carga cinética

$H = \frac{v^2}{2g} + h$

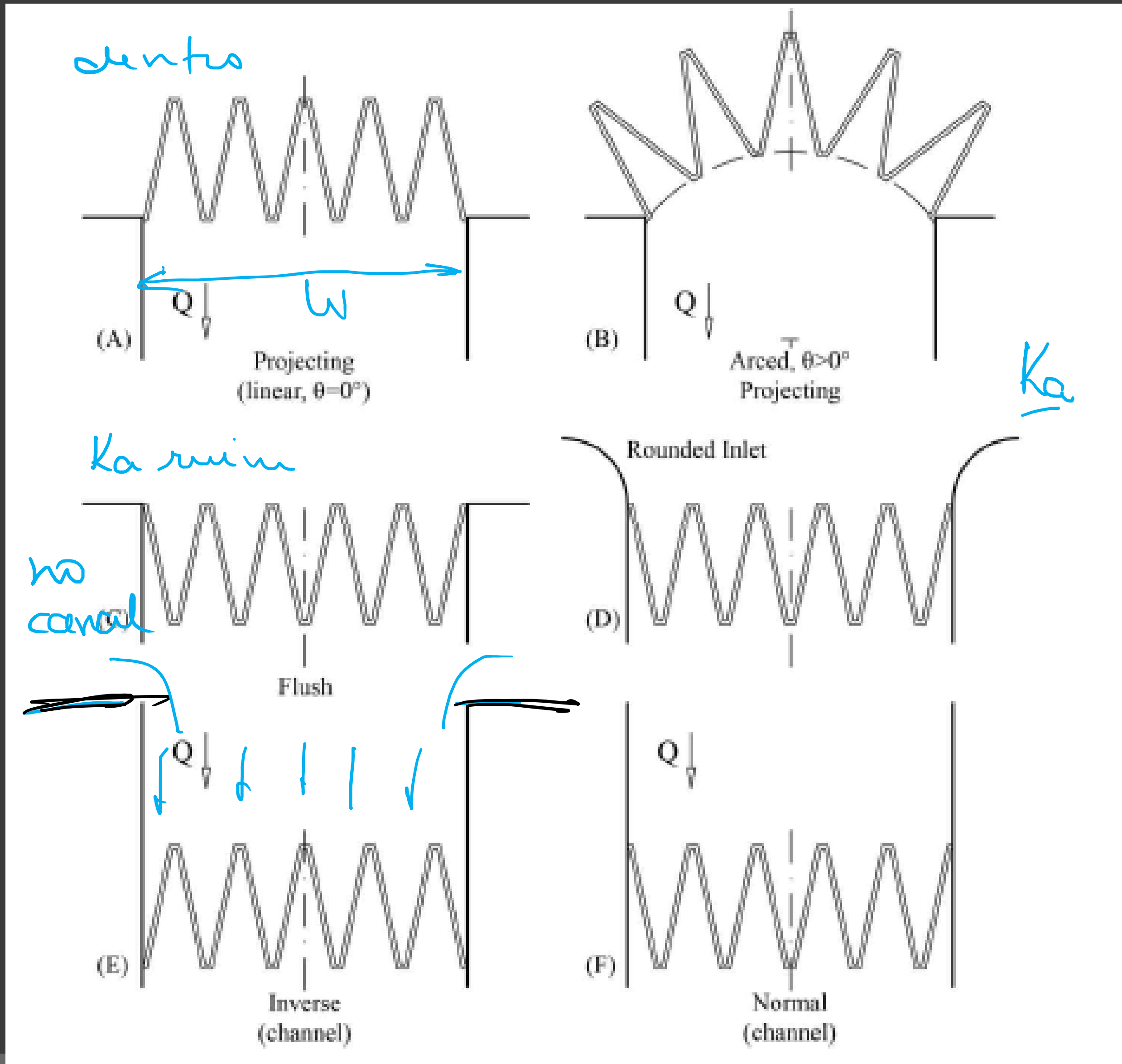
NA_j

ressalto ?

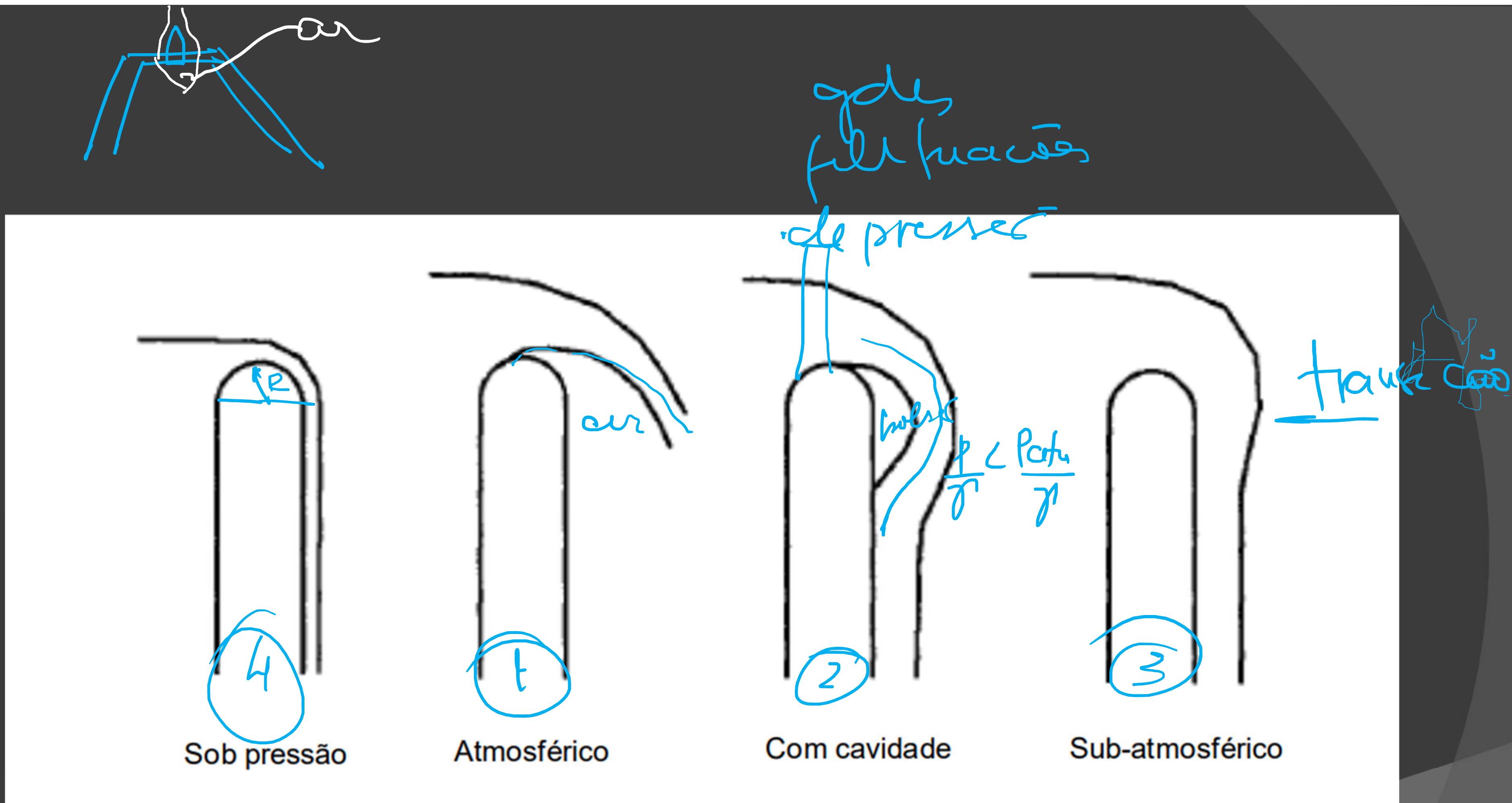
aeração

bolsão de ar

Note:



dentro
W
Q
(A)
Projecting
(linear, θ=0°)
Q
(B)
Arced, θ>0°
Projecting
Ka
Ka ruim
Rounded Inlet
no canal
(D)
Flush
Q
Q
(E)
Inverse
(channel)
(F)
Normal
(channel)


ar
gotas
filtrações
de pressão
ar
4
1
2
3
transição
Sob pressão
Atmosférico
Com cavidade
Sub-atmosférico

Capacidade de Descarga

0,667

$$C_Q = \frac{2}{3} C_D$$

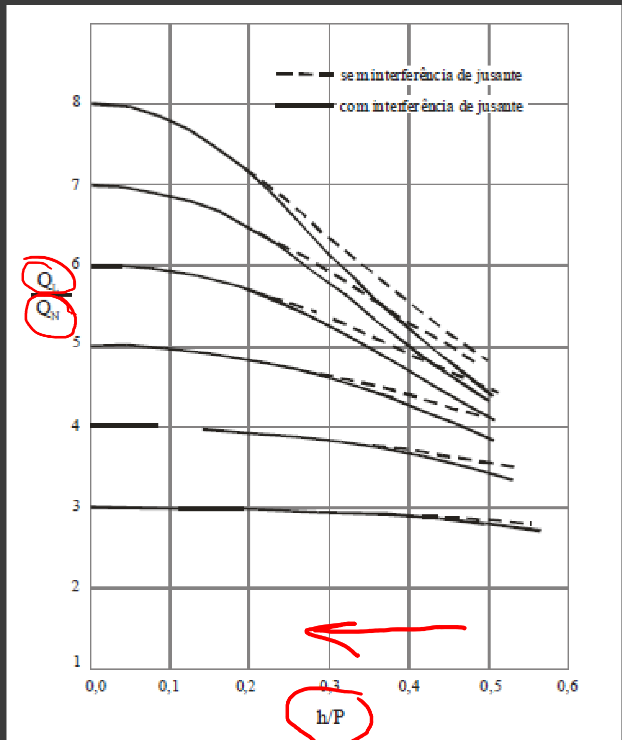
$$C_D = f(\alpha_1, \alpha_2, \alpha \ldots)$$

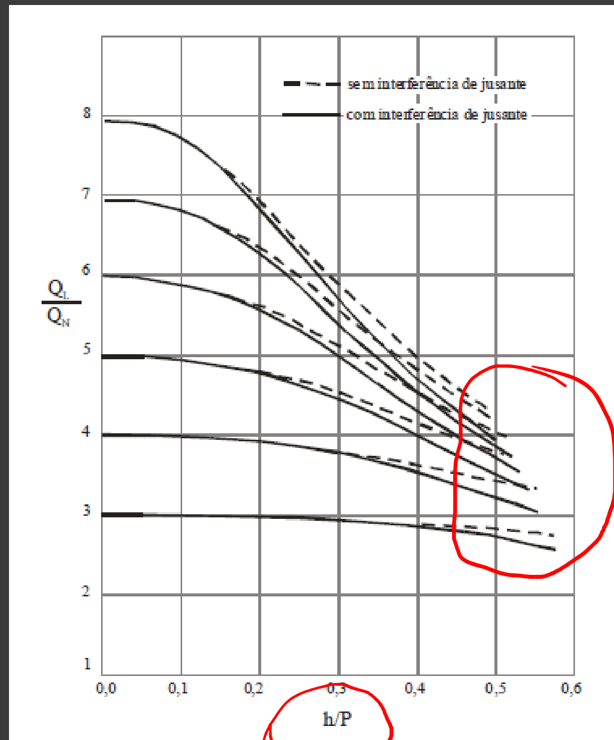
quando aprox altura H

$$Q_N = C_{HT} L H^{\frac{3}{2}}$$

$$C_{HT} = 3{,}22 + \frac{h}{P}$$

~190S

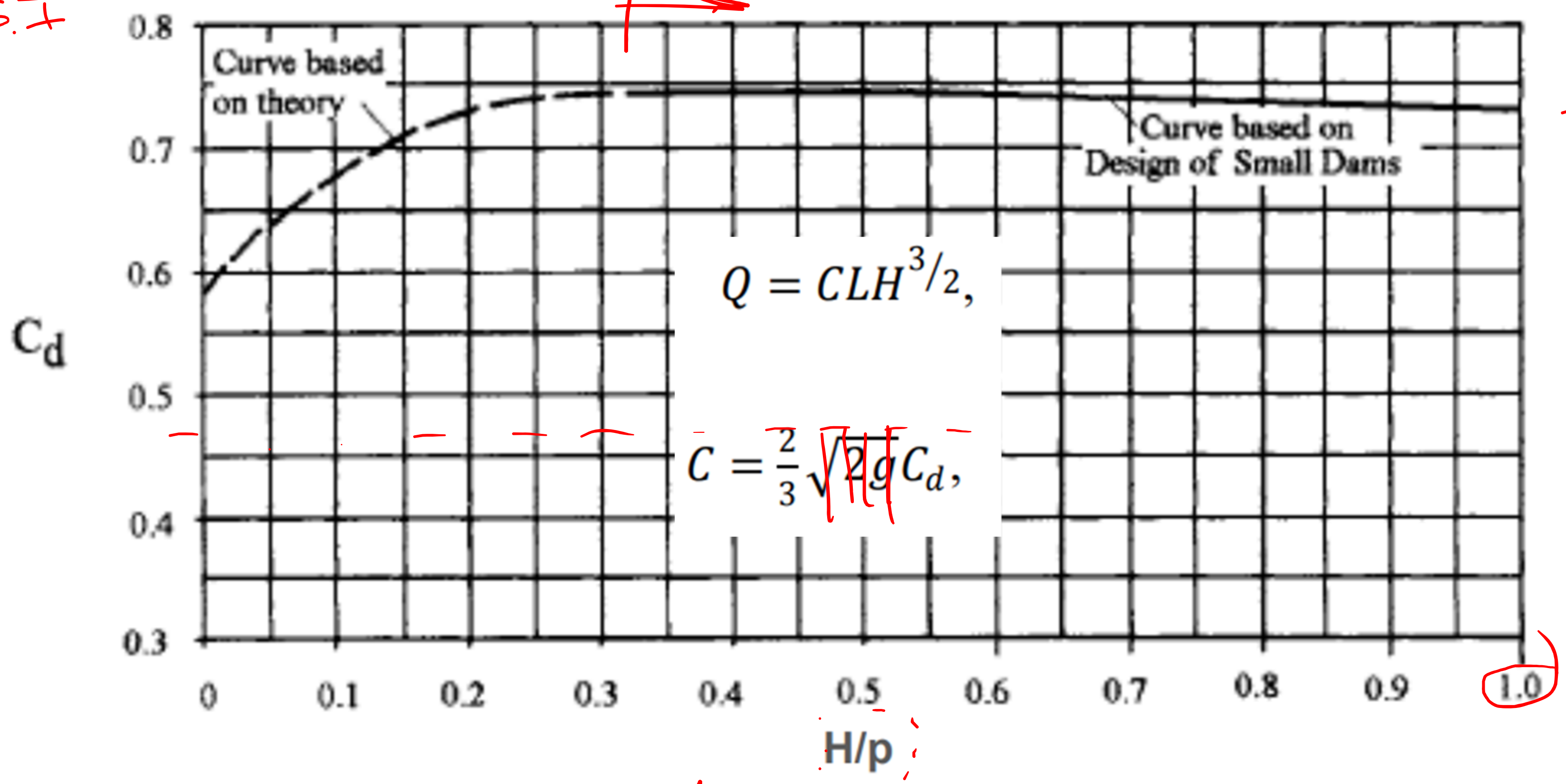




Hayland & Taylor

Capacidade de descarga (USBR Small Dams)

S.I



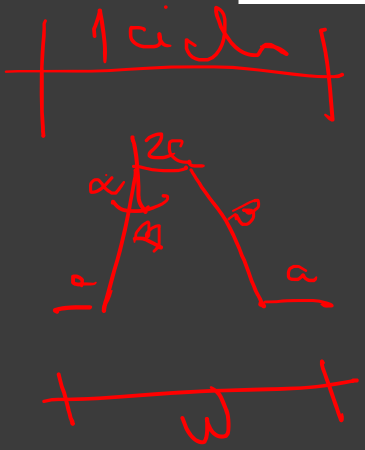
$$Q = CLH^{3/2},$$

$$C = \frac{2}{3}\sqrt{2g}\,C_d,$$

cuidado → SI SUI

Capacidade de Descarga

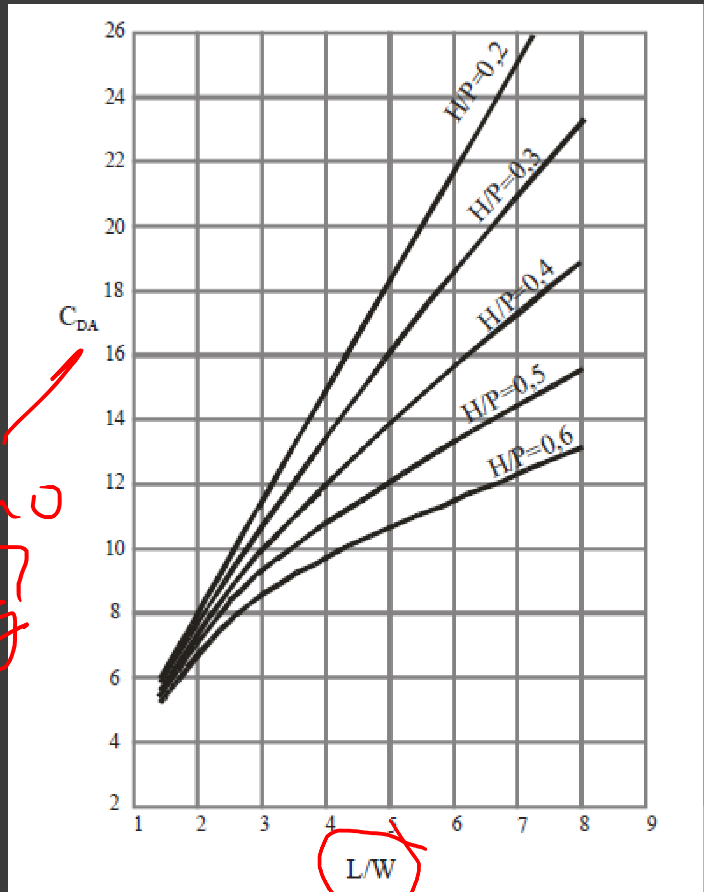
$$C_{DA} = \frac{Q_L}{W \cdot H_0^{1,5}}$$



Darvas

temo

$\frac{2}{3}\sqrt{2g}$



L = ?

W = ?

L = 4a + 2B

Capacidade de Descarga

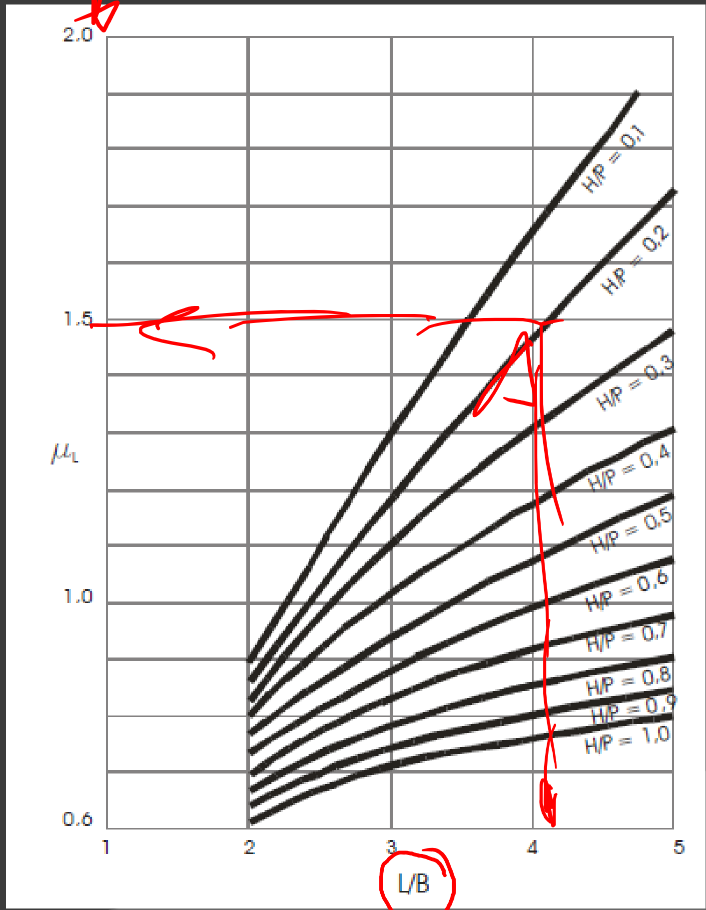
$$\mu_L = \frac{Q}{L.\sqrt{2.g}\,H^{1,5}}$$

Magalhães & Lorena

LNEC

W

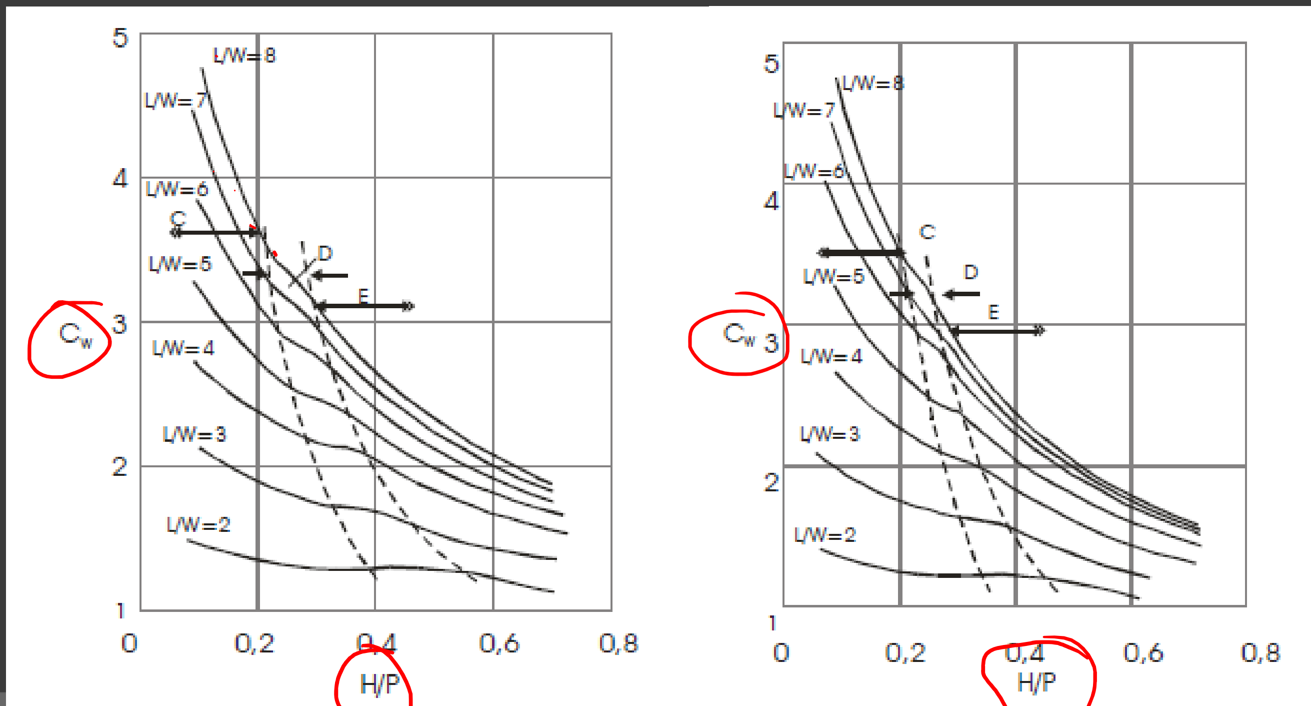
para o USBR



Capacidade de Descarga

$$Q = C_w \left(\frac{\frac{W}{P}}{\frac{W}{P} + k} \right) W.H.\sqrt{g.H}\text{ , válida para } W/P \geq 2$$

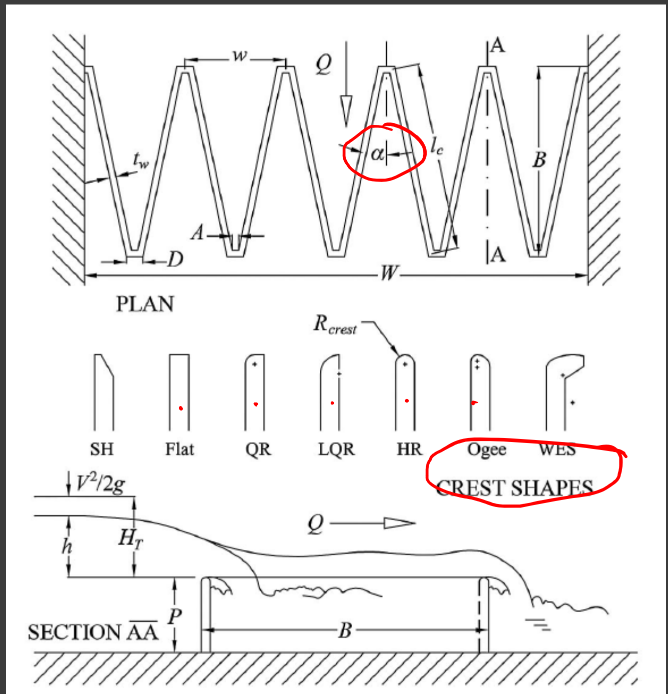
Lux & Hinchliff

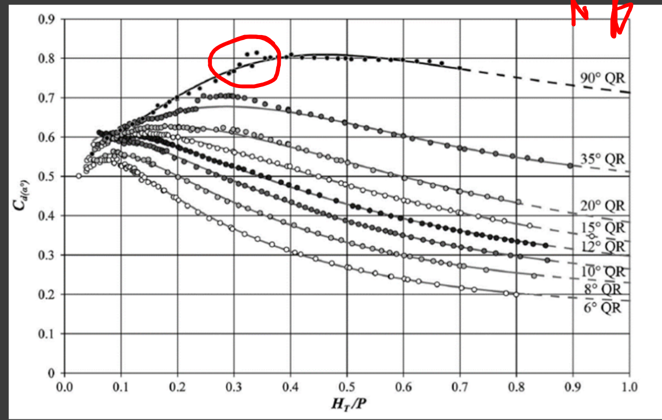


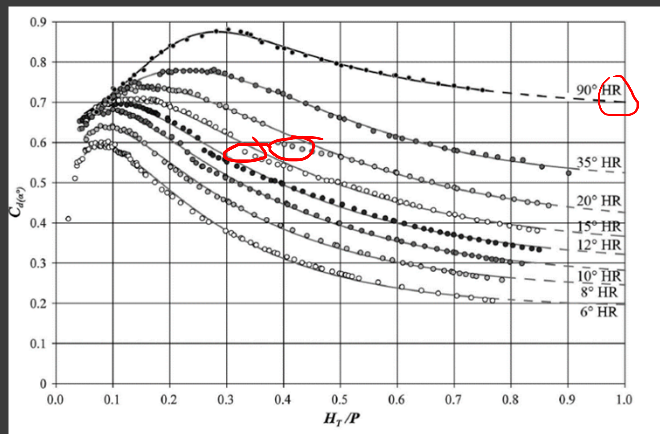
Capacidade de Descarga – Crookston & Tullis

B -

α crest







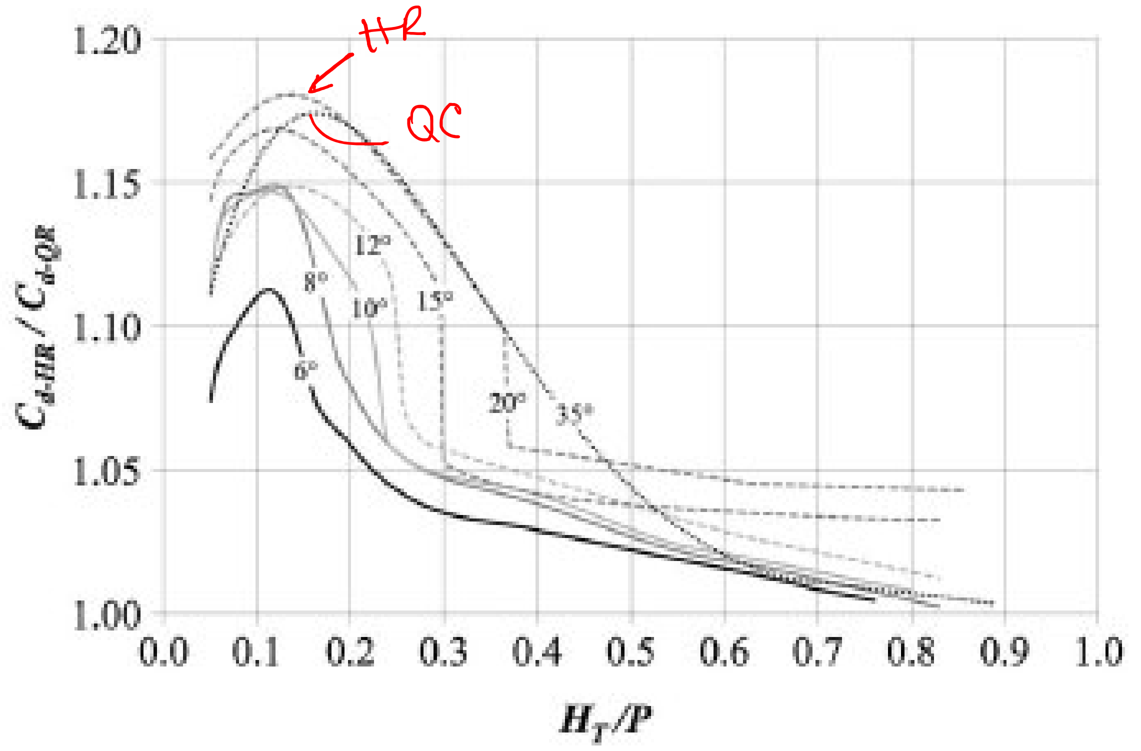


Fig. 4. Comparison of half-round and quarter-round crest shape on hydraulic performance of labyrinth weirs

Paredes Convergentes

fator?
gráfico

$$\mu_w = \frac{Q}{W\sqrt{2g}H^{1,5}}$$

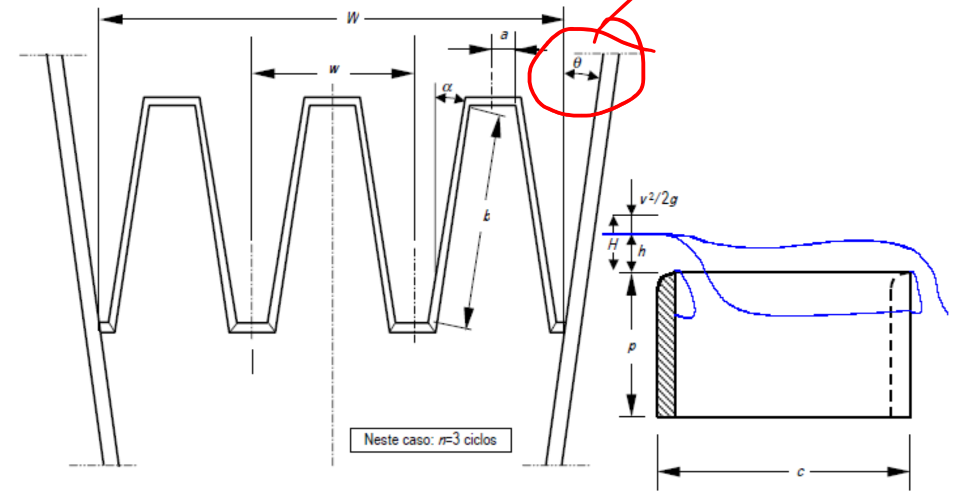
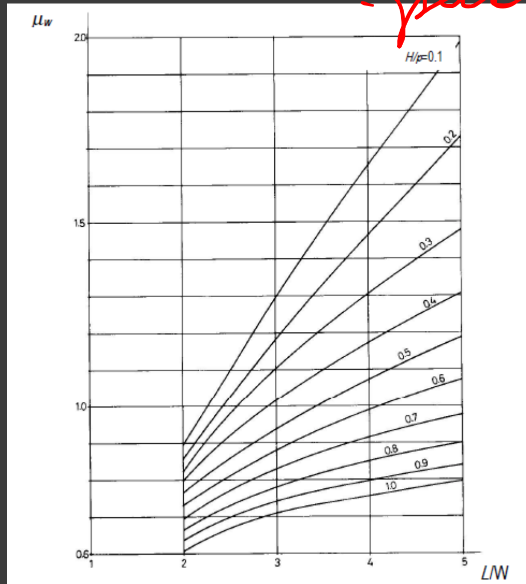


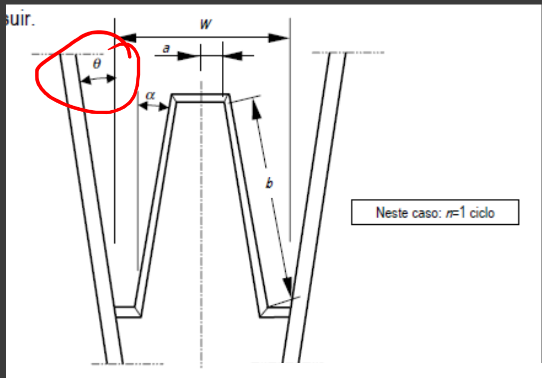
Figura 1 - Definição esquemática de uma soleira em labirinto e identificação das principais variáveis envolvidas na determinação da sua capacidade de vazão.

paralele



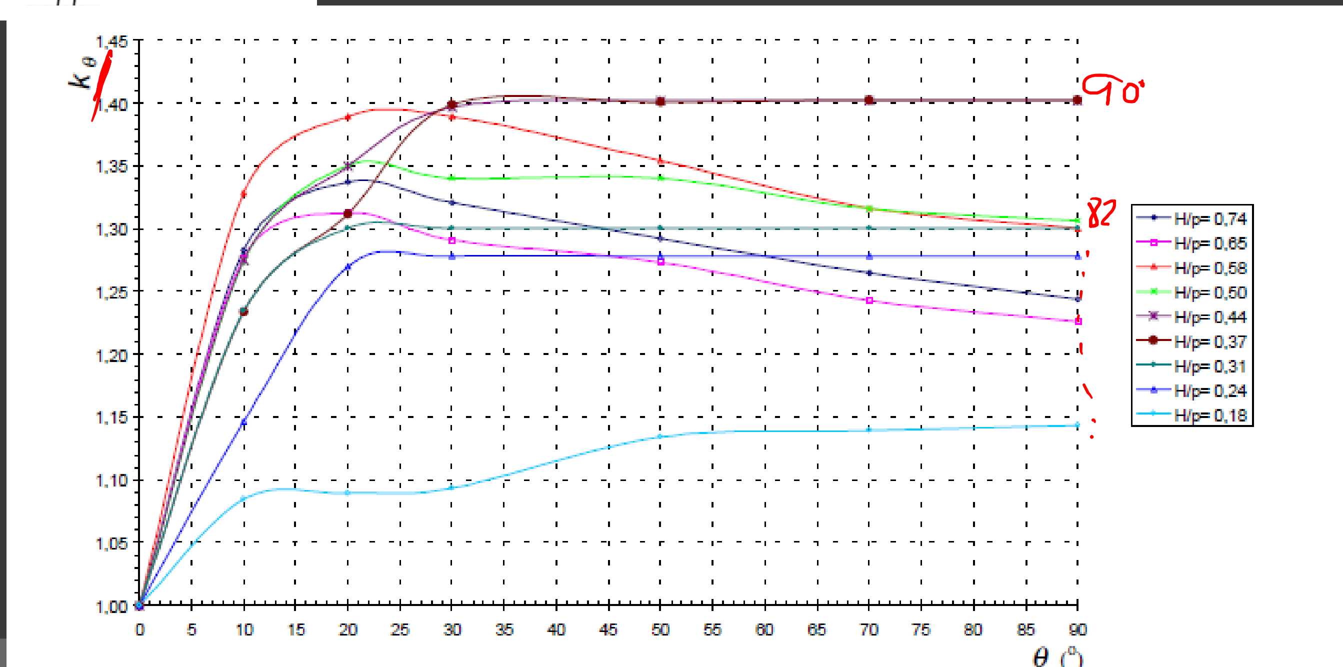
Falcão & Ramos

Paredes Convergentes

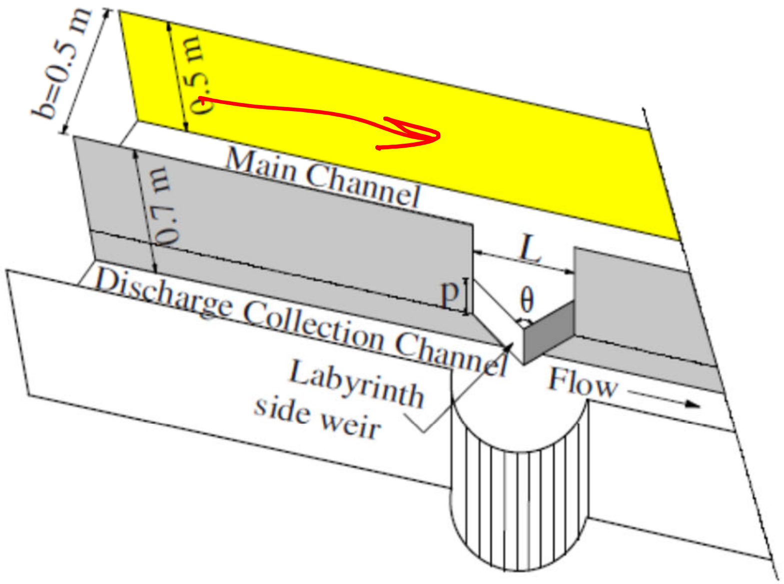


(2/3)

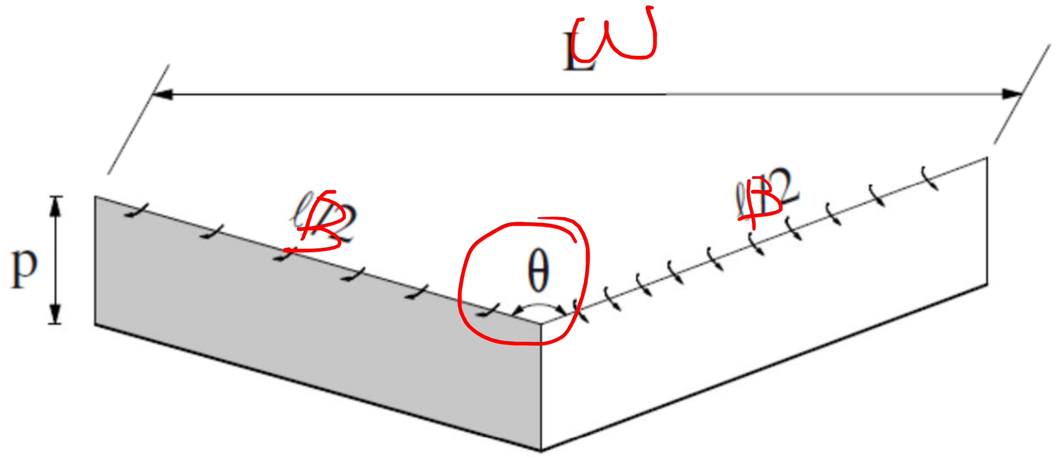
$$Q = K_\theta \mu_W W \sqrt{2g} H^{1,5}$$



Soleira lateral labirinto (zig-zag)



(a)



(b)

J. Irrig. Drain Eng., 2010, 136(1): 37-46

M. Emin Emiroglu[1]; Nihat Kaya[2]; and Hayrullah Agaccioglu[3]

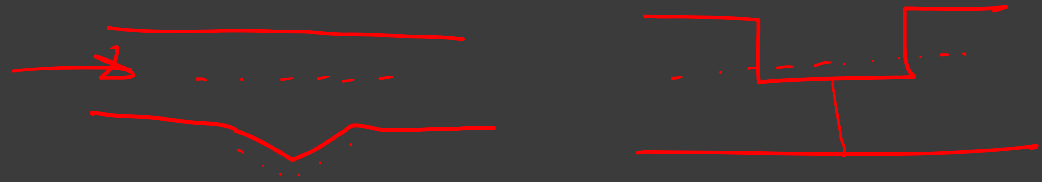
Capacidade de descarga – soleira lateral regular

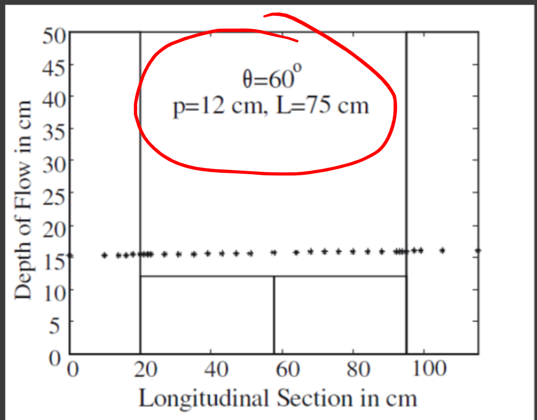
(do século passado)

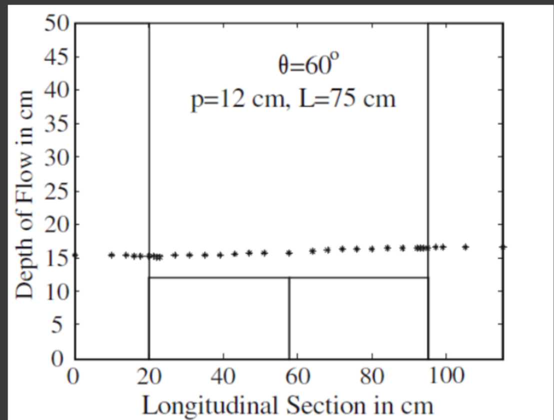
Table 1. Side-Weir Discharge Coefficient Equations Presented in the Literature for Straight Channels

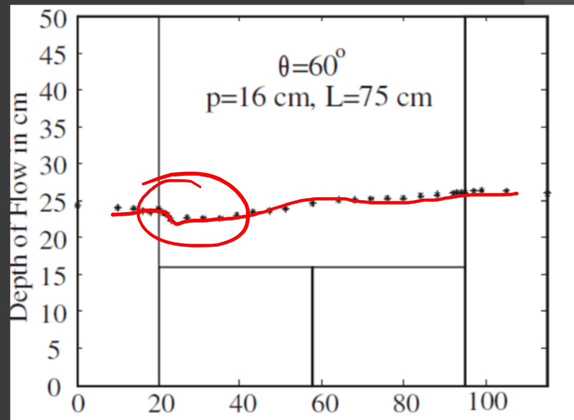
Reference	Discharge coefficient	Froude number	L/b	p/h_1
Subramanya and Awasthy (1972)	$C_d=0.864\{1-F_1^2/2+F_1^2\}^{0.5}$	0.02–0.85	0.2–1.0	0.2–0.96
Yu-Tech (1972)	$C_d=0.415-0.148F_1$	—	—	0.2–0.5
Nandesamoorthy and Thomson (1972)	$C_d=0.288\{2-F_1^2/1+2F_1^2\}^{0.5}$	—	—	(p=0.0–0.6 m)
Ranga Raju et al. (1979)	$C_d=0.54-0.40F_1$	0.10–0.50	0.10–0.70	(p=0.2–0.5 m)
Hager (1987)	$C_d=0.485\{2+F_1^2/2+3F_1^2\}^{0.5}$	0.0–0.87	3.33	(p=0.0–0.2 m)
Cheong (1991), for trapezoidal channel	$C_d=0.30-0.14F_1^2$	0.28–0.78	0.50–1.64	0.42–0.85
Singh et al. (1994)	$C_d=0.33-0.18.F_1+0.49p/h_1$	0.23–0.43	0.25–0.50	0.42–0.85
Borghei et al. (1999)	$C_d=0.7-0.48F_1-0.3p/h_1+0.06L/b$	0.1–0.9	0.67–2.33	(p=0.01–0.19 m)

Linhas d´’agua e perfis de velocidade

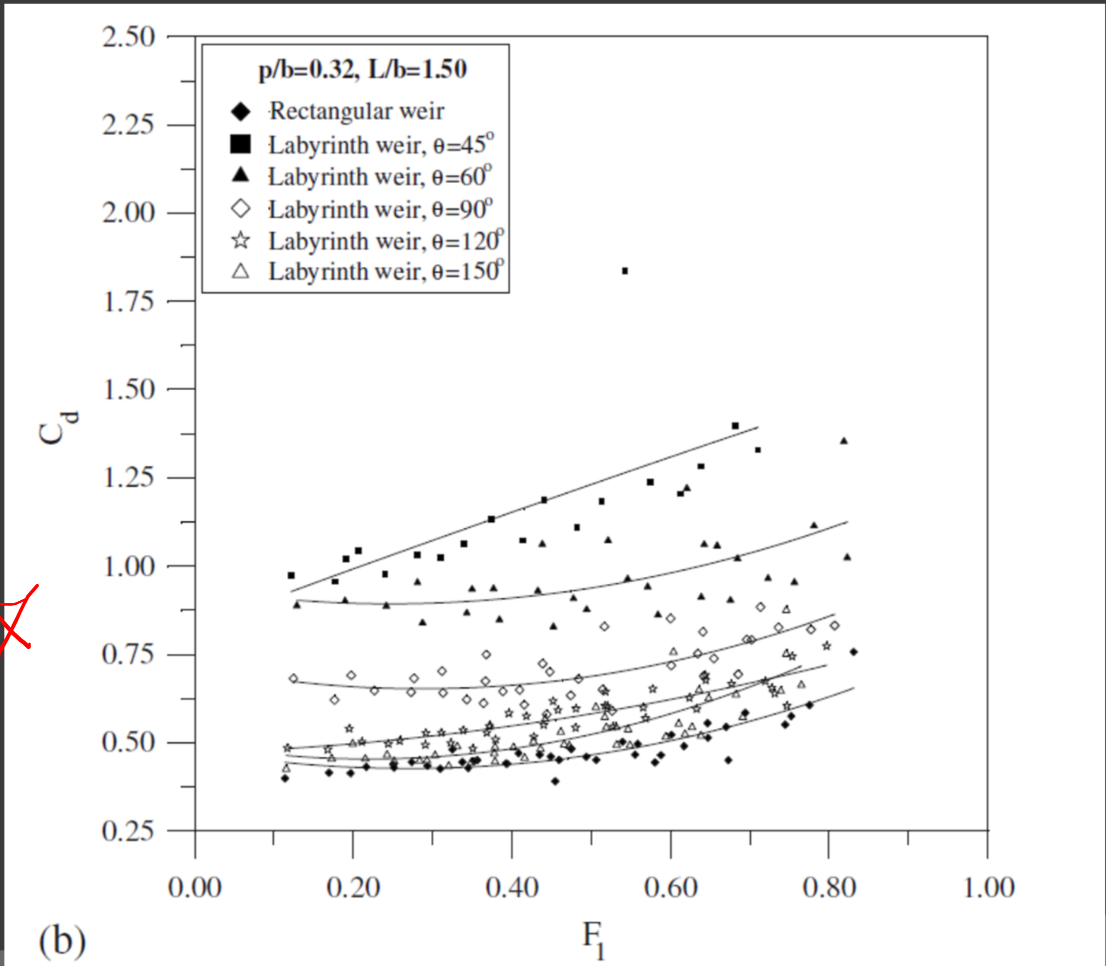


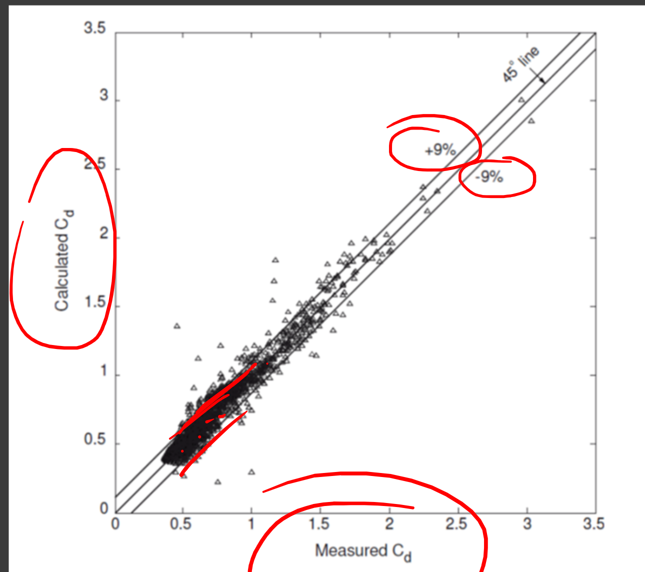






Efeito do Número de Froude





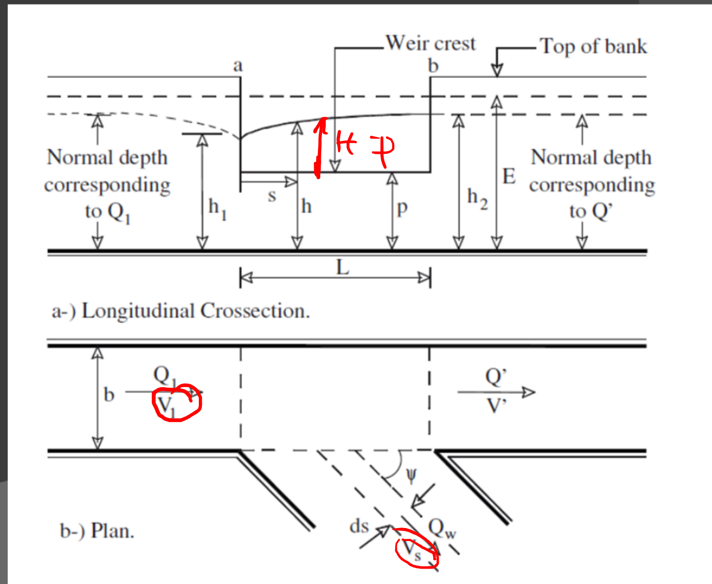
Capacidade de descarga combinada

$$-\frac{dQ}{ds}=\frac{2}{3}C_d\sqrt{2g}[h-p]^{3/2}$$

$$C_d=f\left(F_1=\frac{V_1}{\sqrt{gh_1}},\frac{L}{b},\frac{L}{h_1},p/h_1,\psi\right)$$

$$\sin\psi=\sqrt{1-\left(\frac{V_1}{V_s}\right)^2}$$

$$C_d=\left[18.6-23.535\left(\frac{L}{b}\right)^{0.012}+6.769\left(\frac{L}{l}\right)^{0.112}-0.502\left(\frac{p}{h_1}\right)^{4.024}+0.094\sin\theta-0.393F_1^{2.155}\right]^{-1.431} \qquad (6)$$



Roteiro de Cálculo

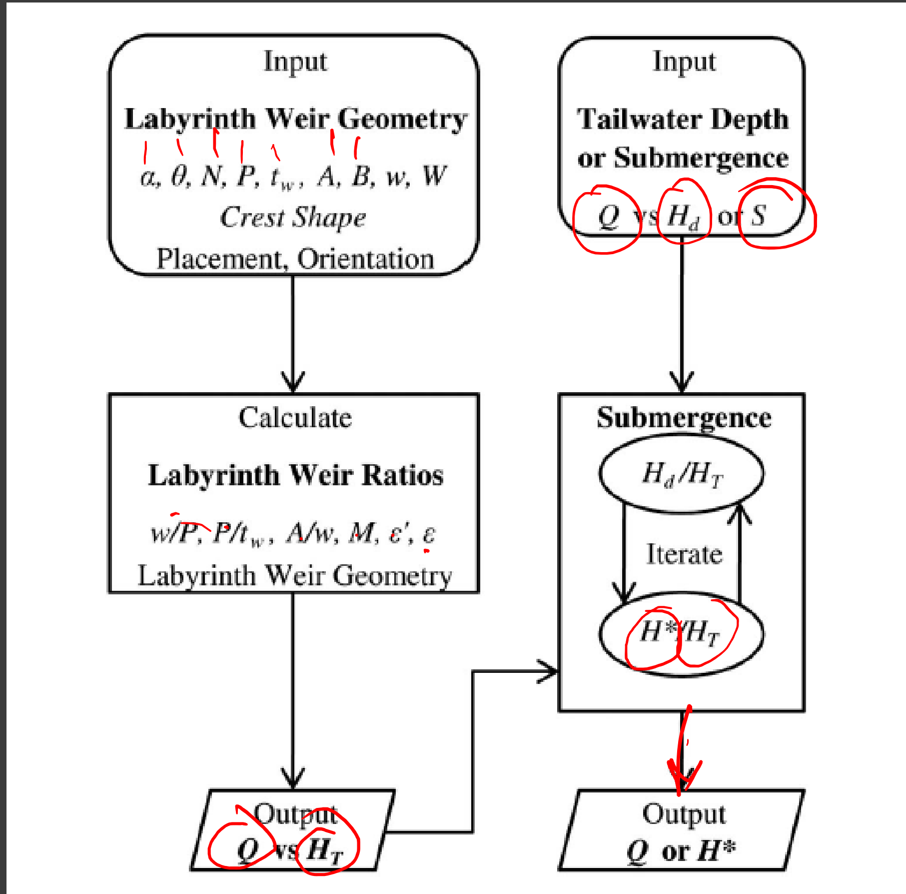
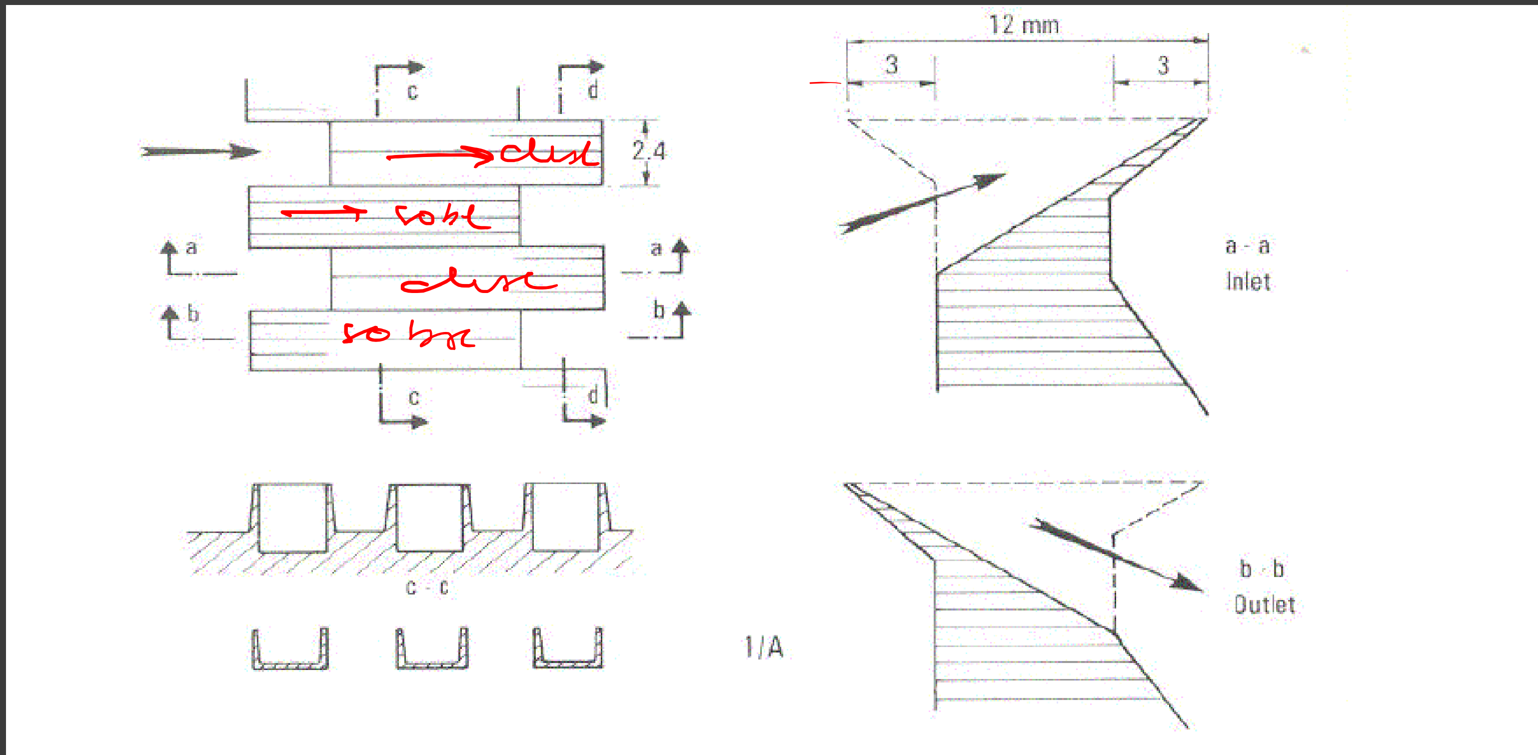


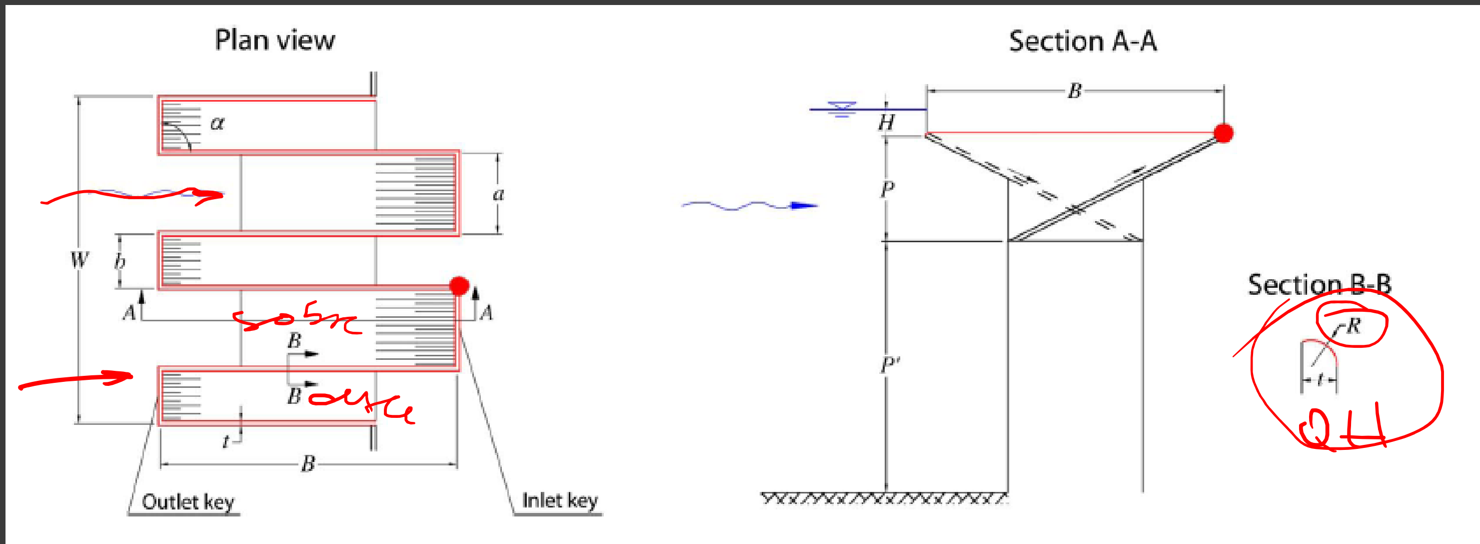
Fig. 7. Recommended procedure for analyses of labyrinth weirs

Soleiras Piano Keys

Piano Keys



Coeficiente de Descarga



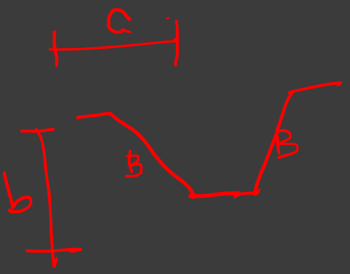
$$Q_{\mathrm{PKW}} = f(\rho, g, \nu, \sigma, H, L, P, P', W, a, b, B, s_{\mathrm{in}}, s_{\mathrm{out}}, \alpha, t, R)$$

$$C_{\mathrm{PKW}} = \frac{Q_{\mathrm{PKW}}}{L H^{\frac{3}{2}} \sqrt{2\,g}}$$

$\frac{2}{3} C_D$

$$C_{\mathrm{PKW}} = f\left(\frac{L}{W}, \frac{a}{b}, \frac{P}{a}, \frac{P}{P'}, \frac{t}{P}, \frac{t}{R}, \frac{H}{a}, s_{\mathrm{in}}, s_{\mathrm{out}}, \mathrm{F}, \mathrm{R}, \mathrm{W}\right)$$

Coeficiente de Descarga



$$\frac{L}{W} = \frac{a + b + 2B}{a + b}$$

$$r = \frac{Q_{PKW}}{Q_W} = \frac{C_{PKW} L H^{\frac{3}{2}} \sqrt{2\,g}}{C_d W H^{\frac{3}{2}} \sqrt{2\,g}}$$

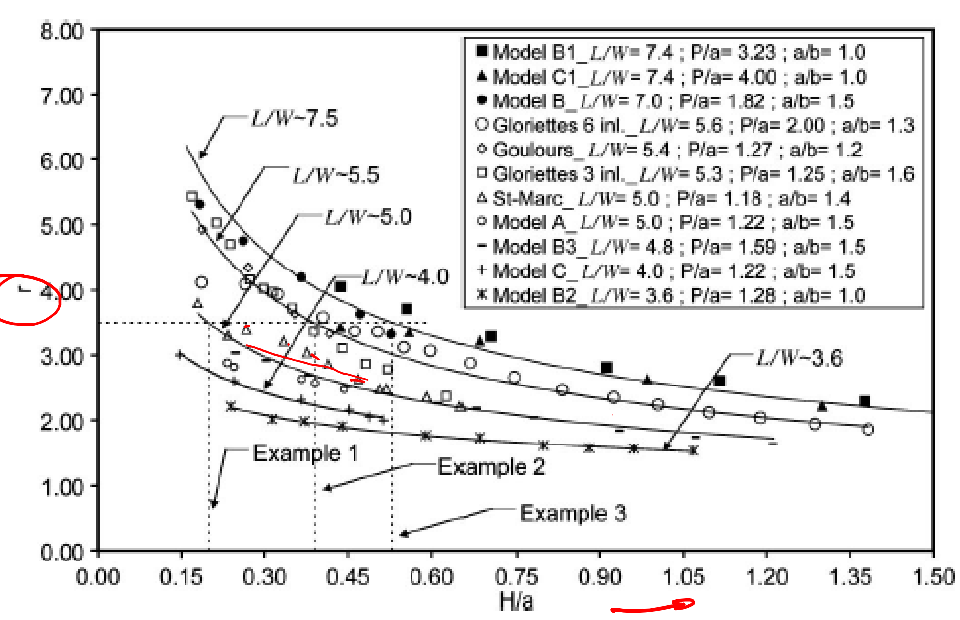


Fig. 3. Discharge enhancement ratio r as a function of H/a for different PK-Weirs and three solutions (L/W) for a given value of r

Redimensionar o vertedouro do exercício da aula 2 consierando uma necessidade de elevar a crista em 2m, reduzindo assim a carga máxima a ser observada para 1m. Dicas

Falcão & Ramos

B. Tullis

Exercício