Labyrinth & piano key (PK) weirs for effective discharge

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Motivation:

A dam should safely bypass the design flood (conditions)

in this project:

To enhance spillway discharge capacity

(not touching on energy dissipation)

Why labyrinth and PK weirs?

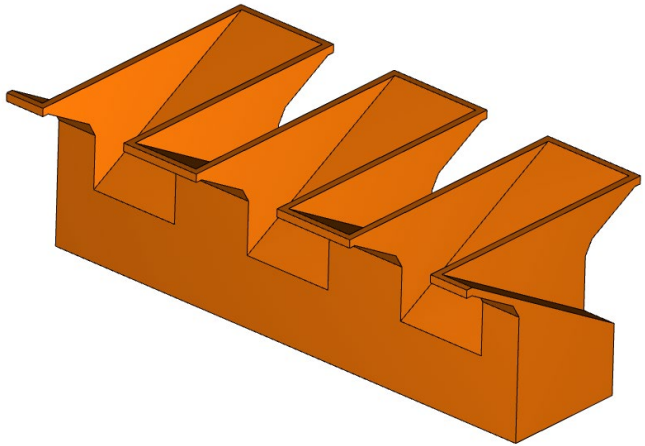
Depending water head, 2–5 times the capacity of a conventional linear weir, leading to a much lower reservoir water level. No gate required.

Purposes

- Literature review to map state-of-the-art within research/design of labyrinth & PK weirs;
- To disseminate the knowledge;
- To propose improvements for more laboratory model tests

Contents

1. Introduction
2. Labyrinth weir
3. Piano key (PK) weir
4. other aspects
4. Conclusions



Spillway discharge with free surface

$$Q = CBH^{1.5}$$

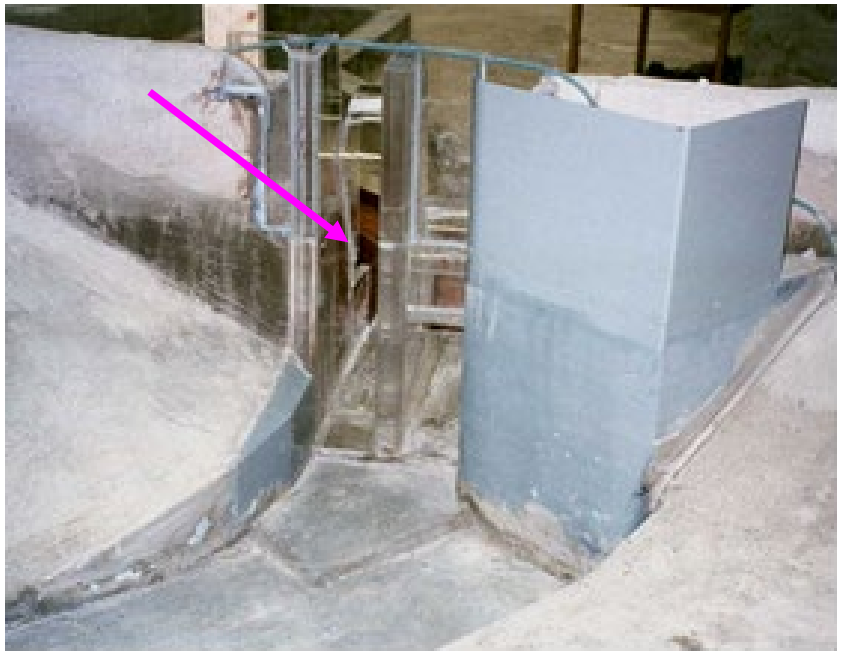
C = discharge coefficient

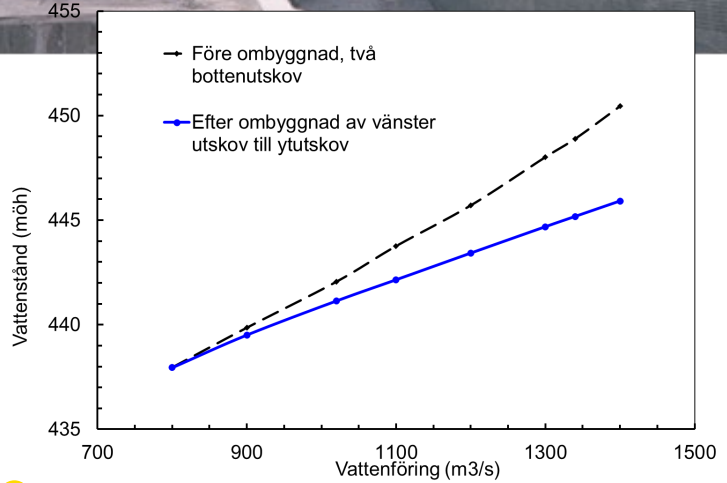
H = water head

B = overflow width

Ajaure

From bottom outlet to overflow type, $H^{0.5} \rightarrow H^{1.5}$





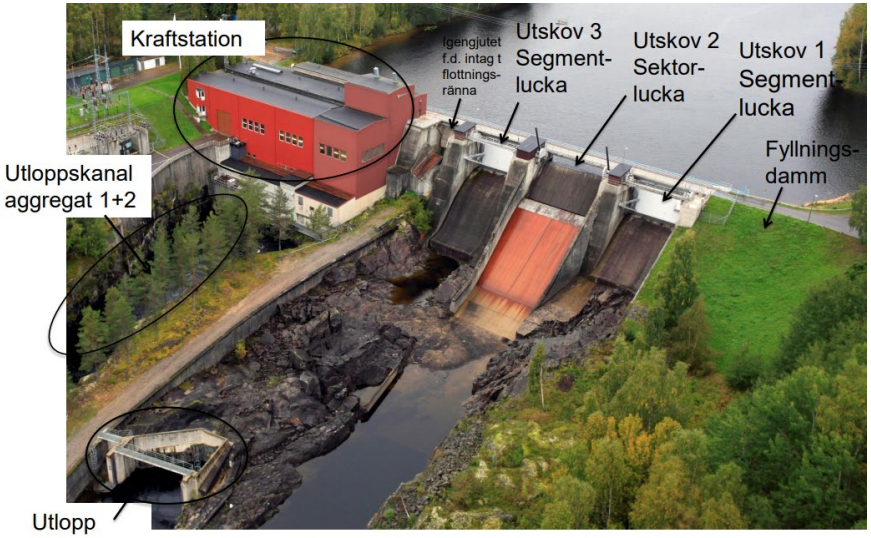
The reduction by 3.7 m at the design flood 1340 m3/s

Gate 5 m wide by ~18 m high

Stenkullafors

Threshold lowering by 4.3 m

Skallböle



Sill in opening 2
lowered by 5.5 meter

	Vid nivå DG +50,44
Före ombyggnad	940 m^3/s
Efter ombyggnad	1575 m^3/s

Valldalen, Norway

120 m long crest

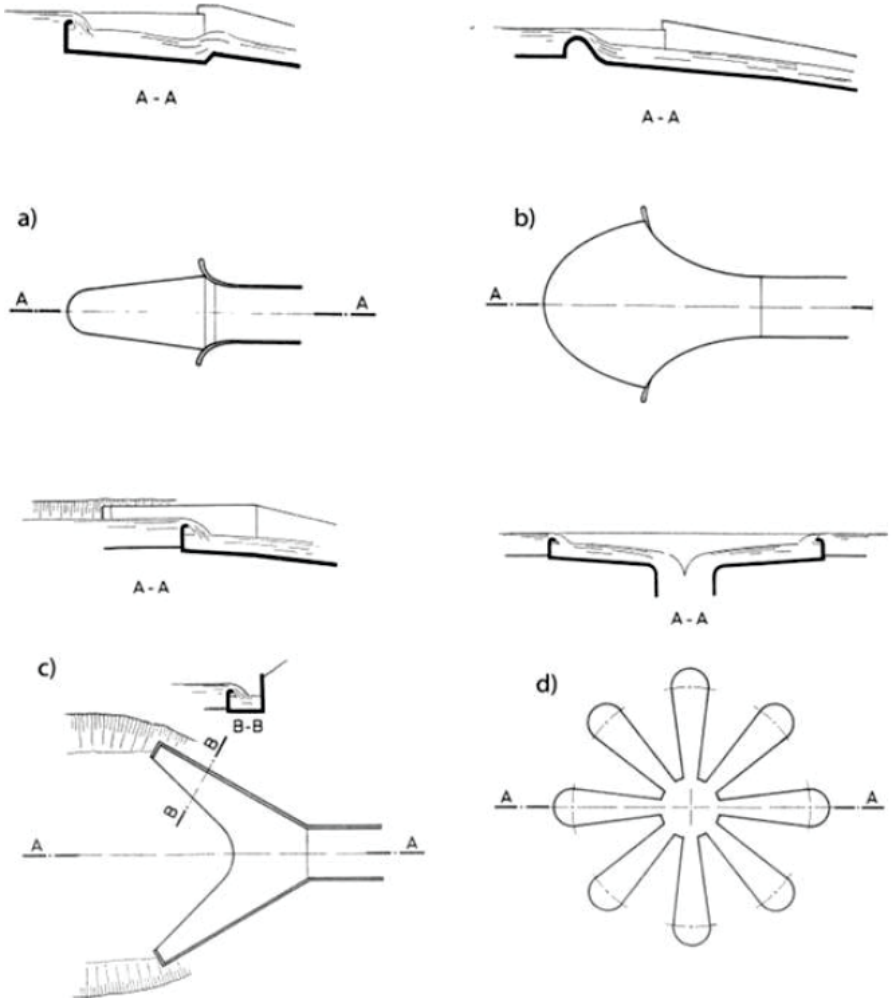
Kárahnjúkar, Iceland

Duckbill

Garden Route dam, SA

Daisy flower

Different layouts



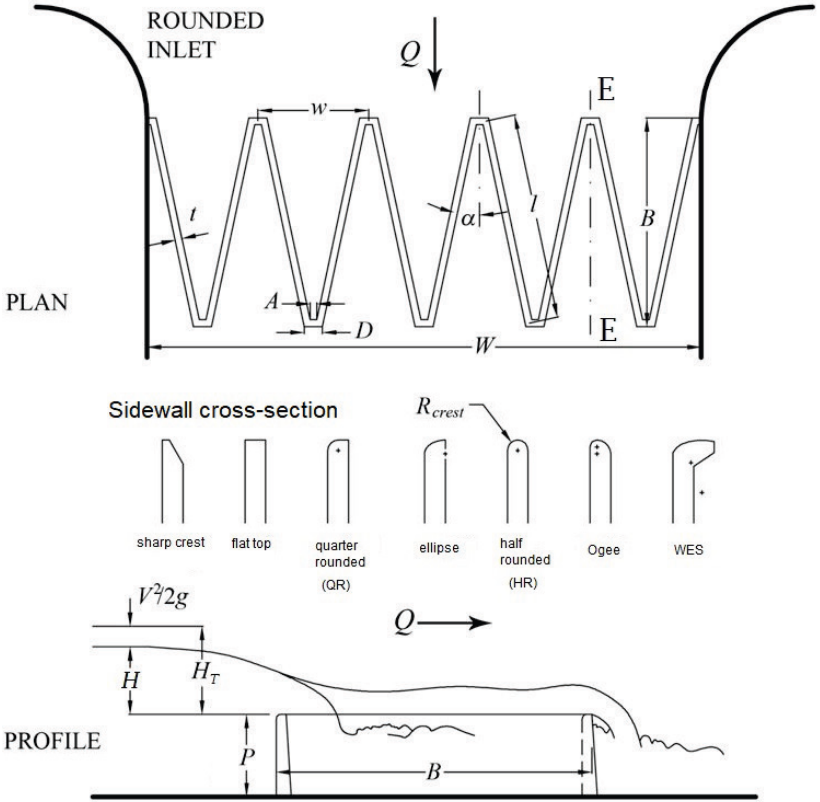
Labyrinth spillway

Standley Lake facility, Westminister, Colorado

Lake Brazos, Waco, Texas

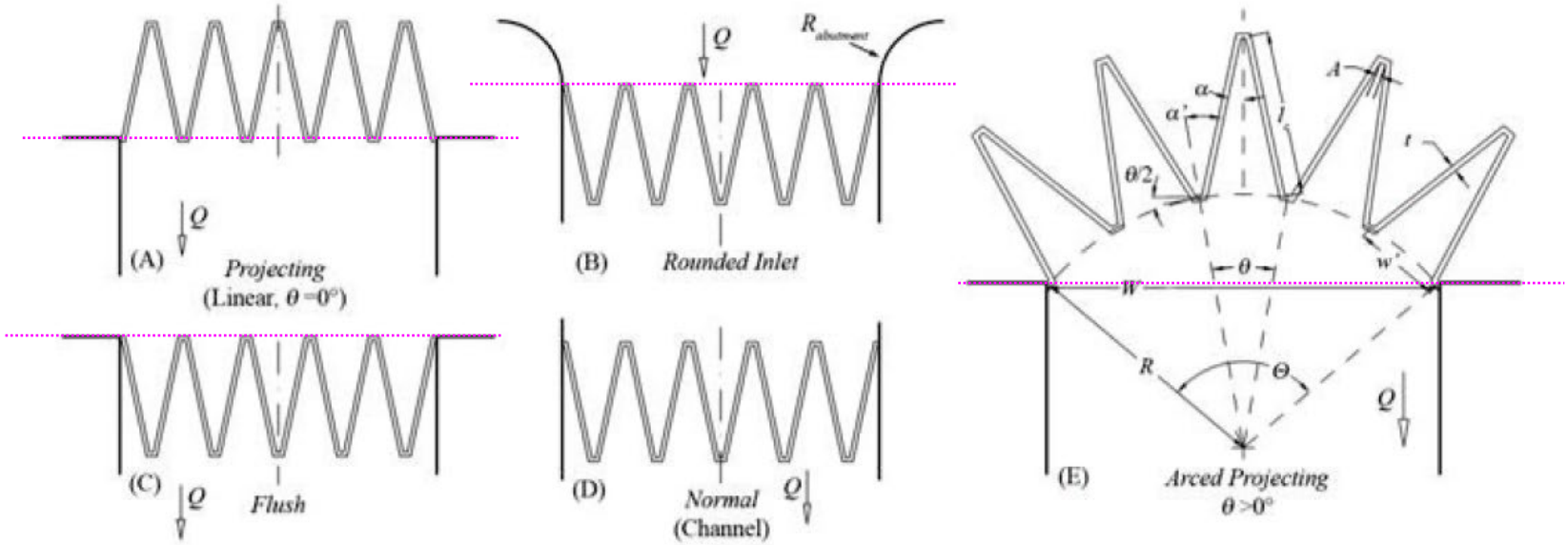
Lake Isabella Dam

Parameters

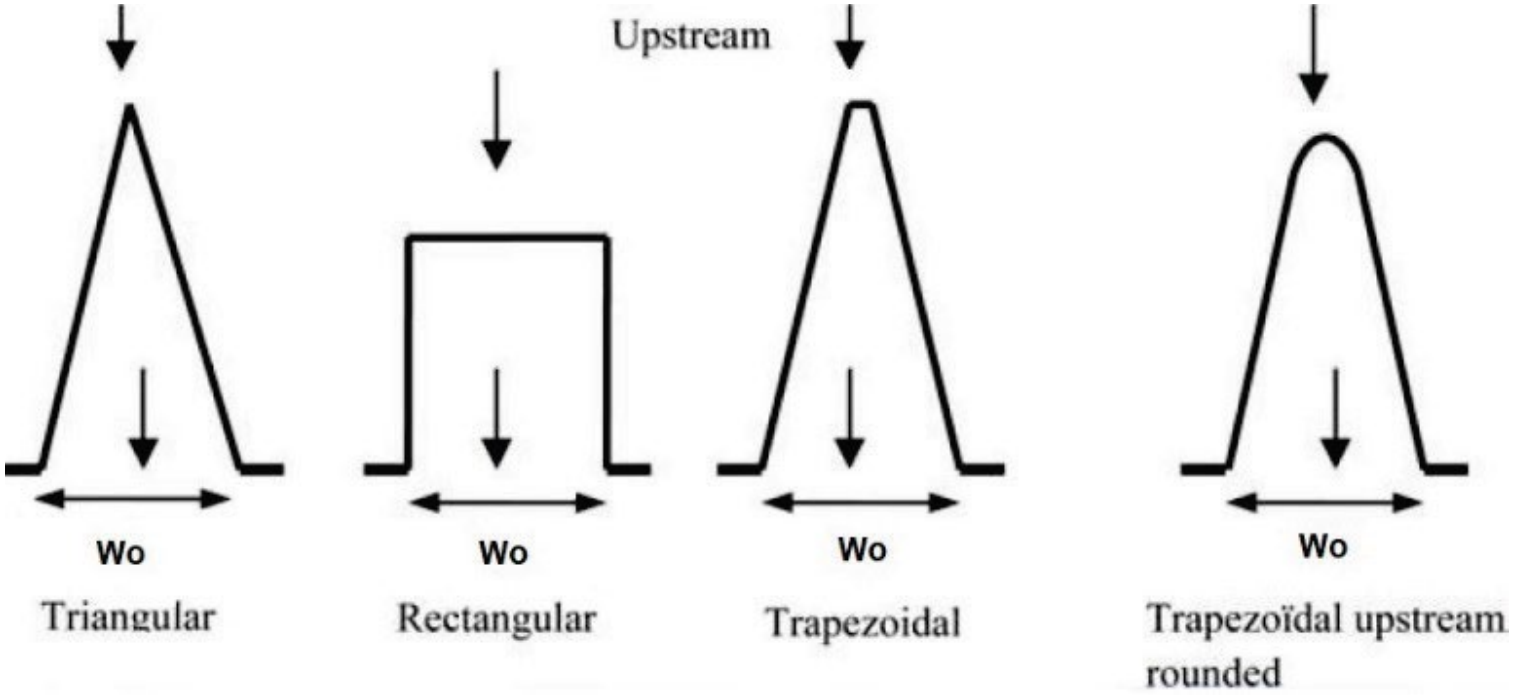


$$Q = f(H_T, H_d, L, \alpha, l, w, P, B, t, g, \nu, inströmning, krönform, ytråhet\ m.m.)$$

Layout

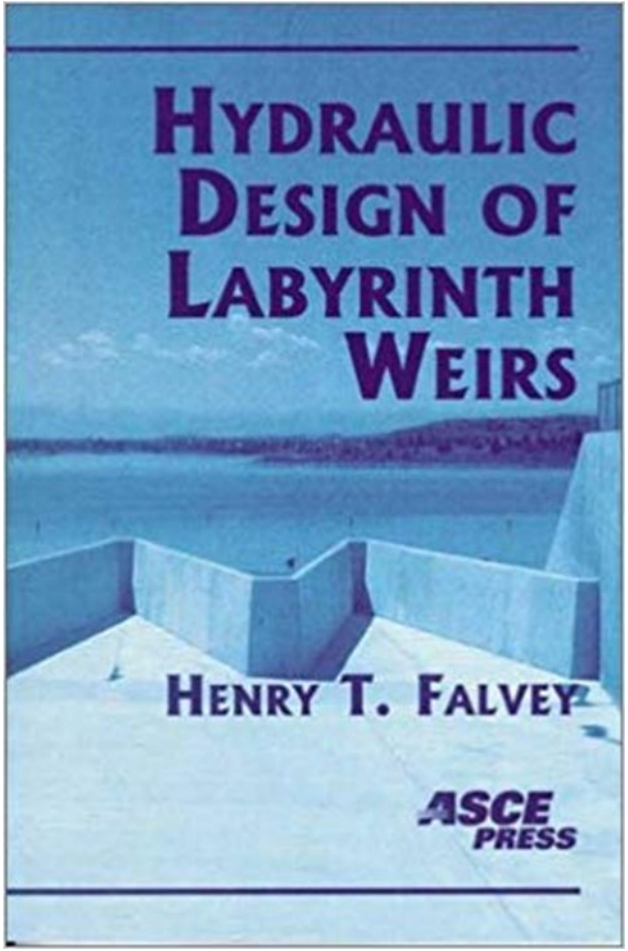

Q
(A)
Projecting
(Linear, θ =0°)
Q
R abutment
(B)
Rounded Inlet
(C)
Q
Flush
(D)
Normal
(Channel)
Q
α
α'
A
l
t
θ/2
θ
w'
w
R
Θ
Q
(E)
Arced Projecting
θ >0°

Apex forms


Upstream
Wo
Triangular
Wo
Rectangular
Wo
Trapezoidal
Wo
Trapezoïdal upstream rounded

Reference:

Falvey's bok 2003

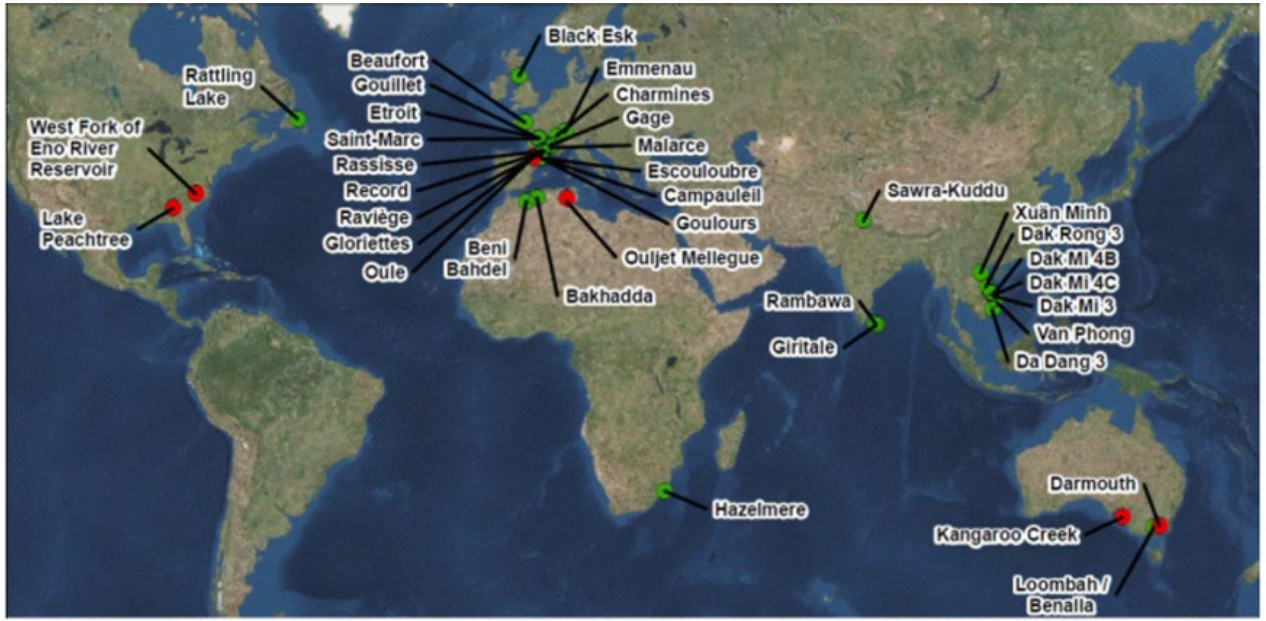


PK Weir

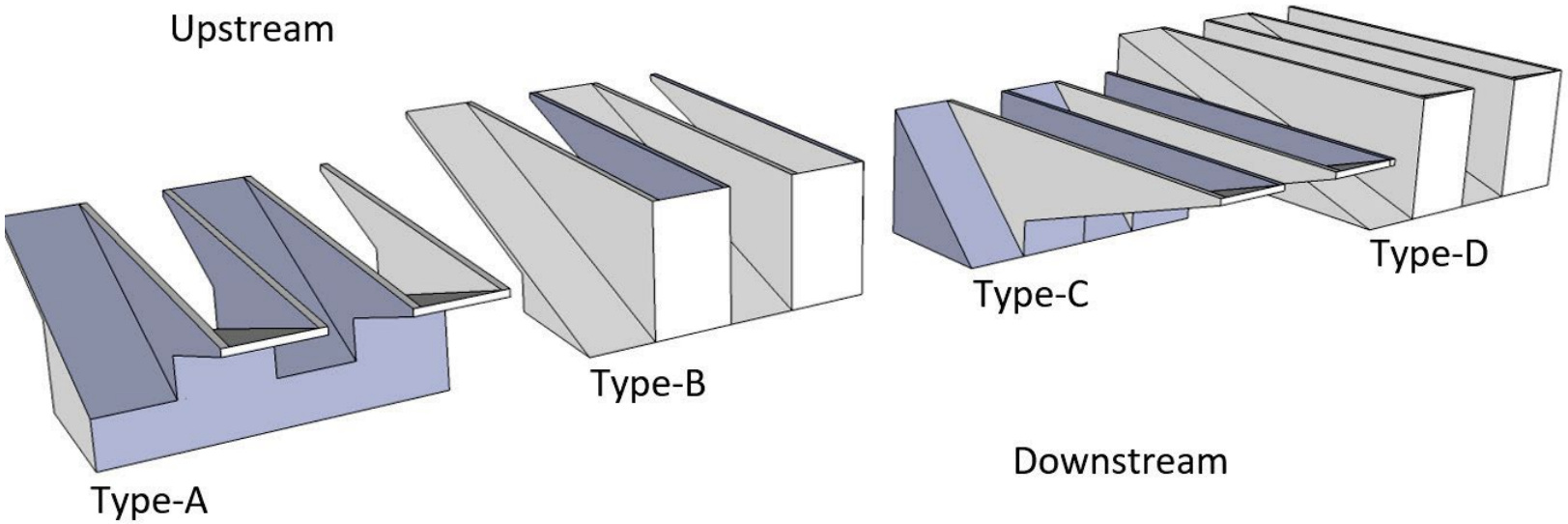
Existing PK weirs

First concept proposed **2003** by Lempérière och Ouamane;

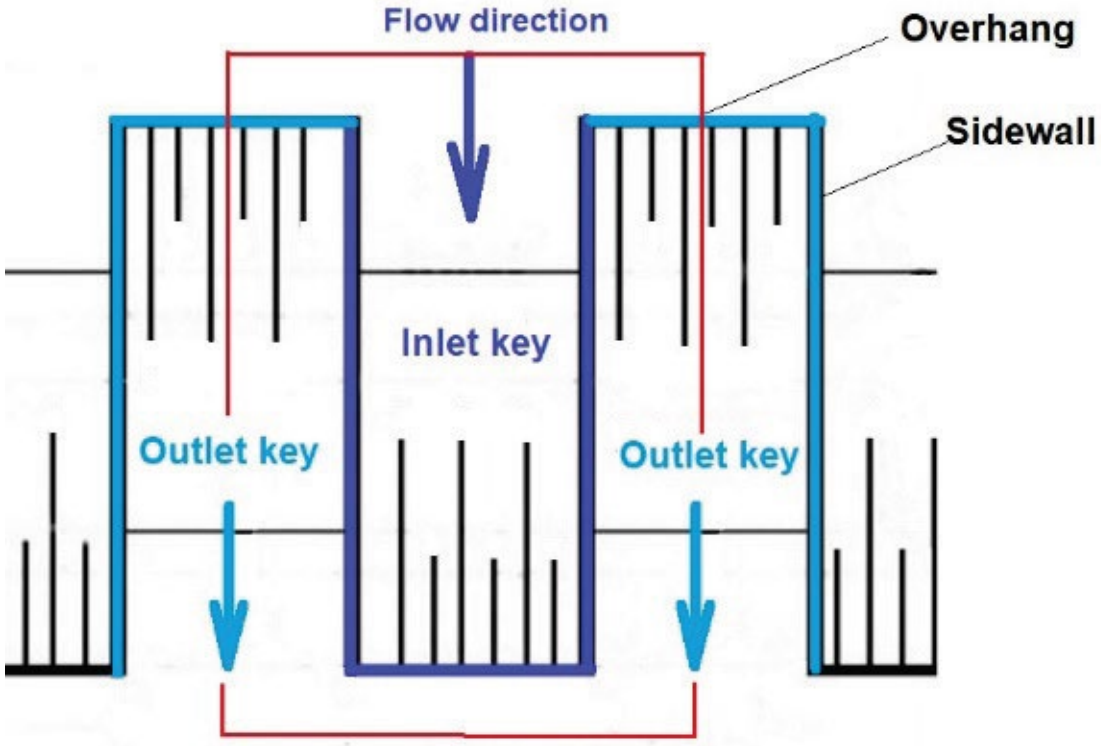
First prototype **2006** by EDF (Goulours dam). EDF has built 10+ such weirs.

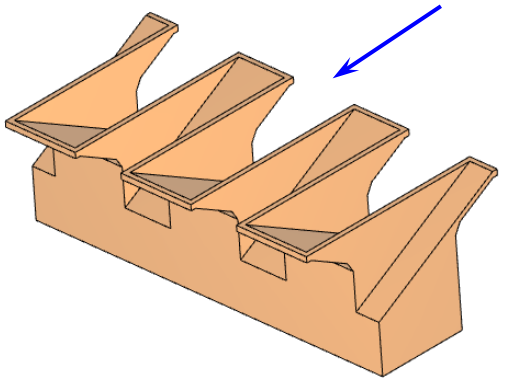


Four basic types

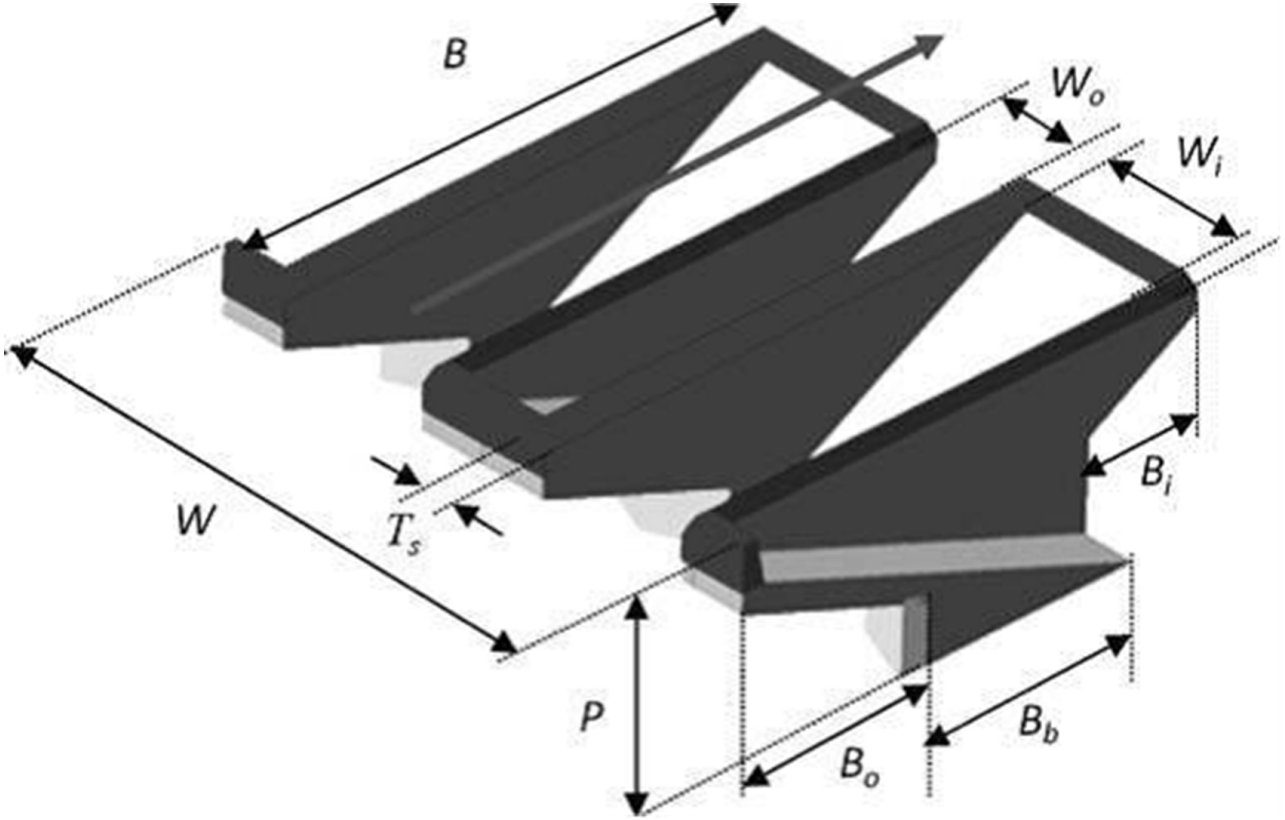


Weir cycle

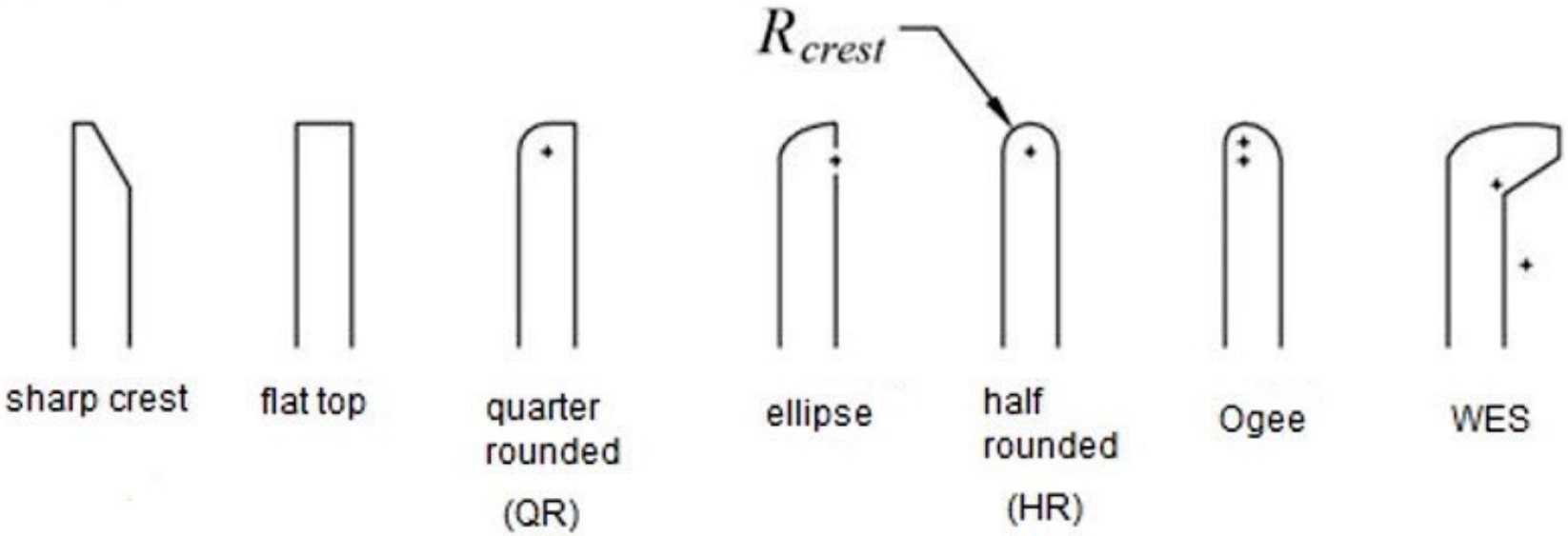

Flow direction
Overhang
Sidewall
Inlet key
Outlet key
Outlet key



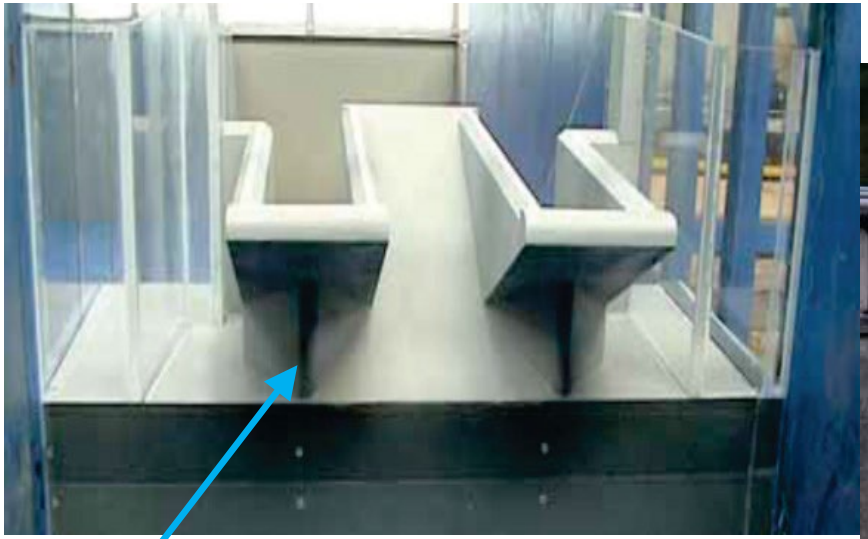
Weir parameters



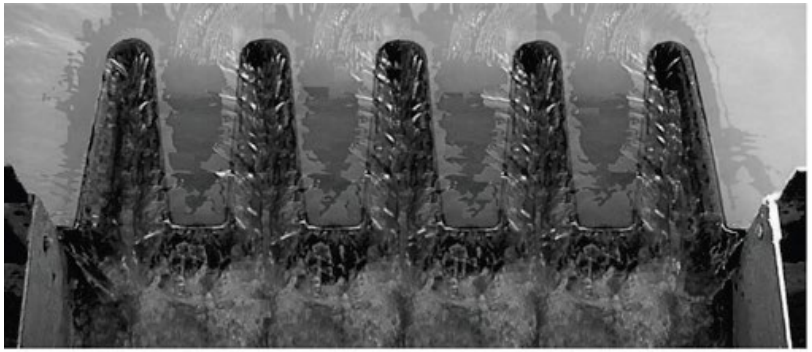
Wall crest shapes



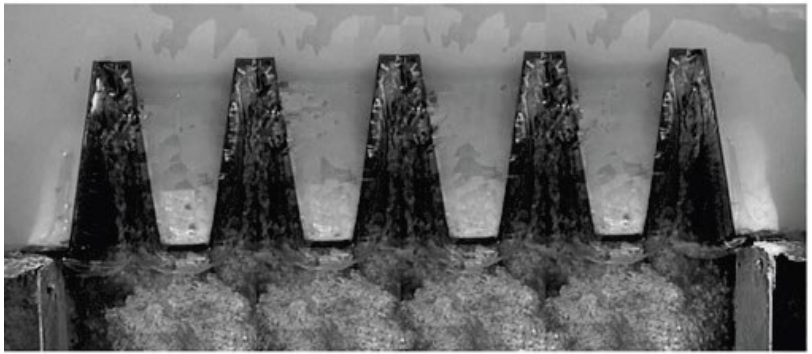
Nose form



Apex form

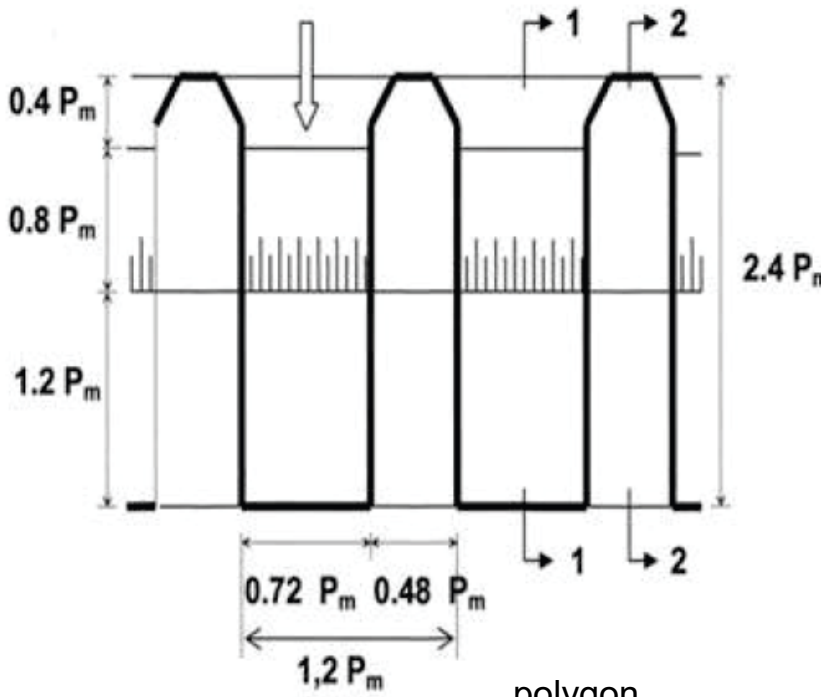


Labyrinth weir model with rounded front wall.



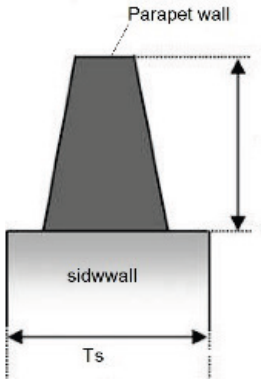
Model labyrinth weir with flat front wall.

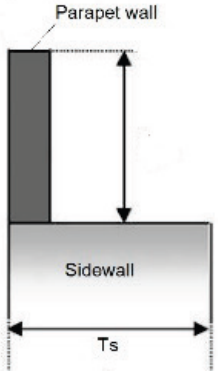
´trapezoid

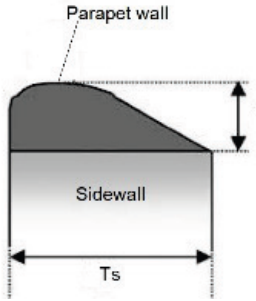


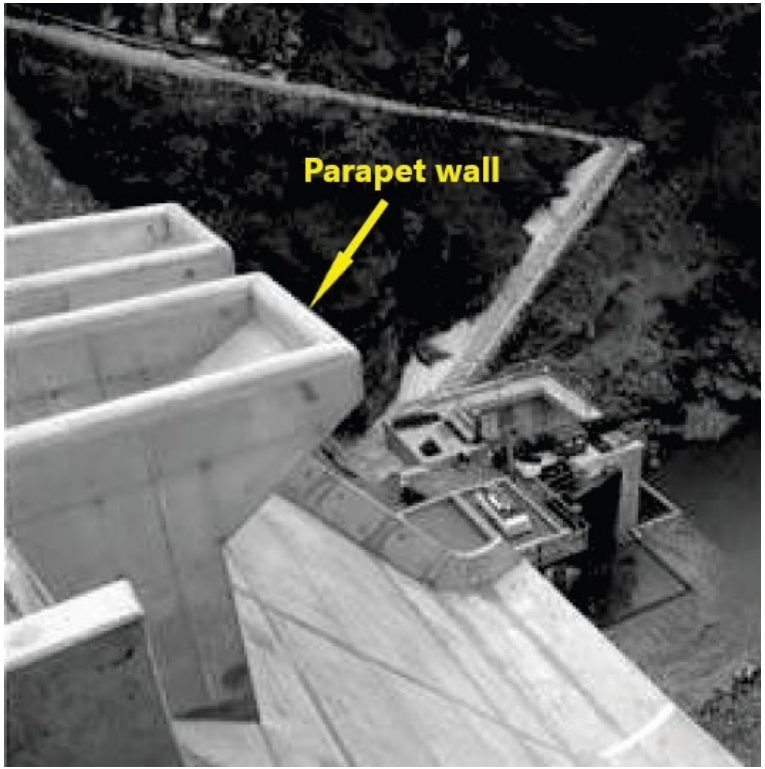
polygon

Parapet wall

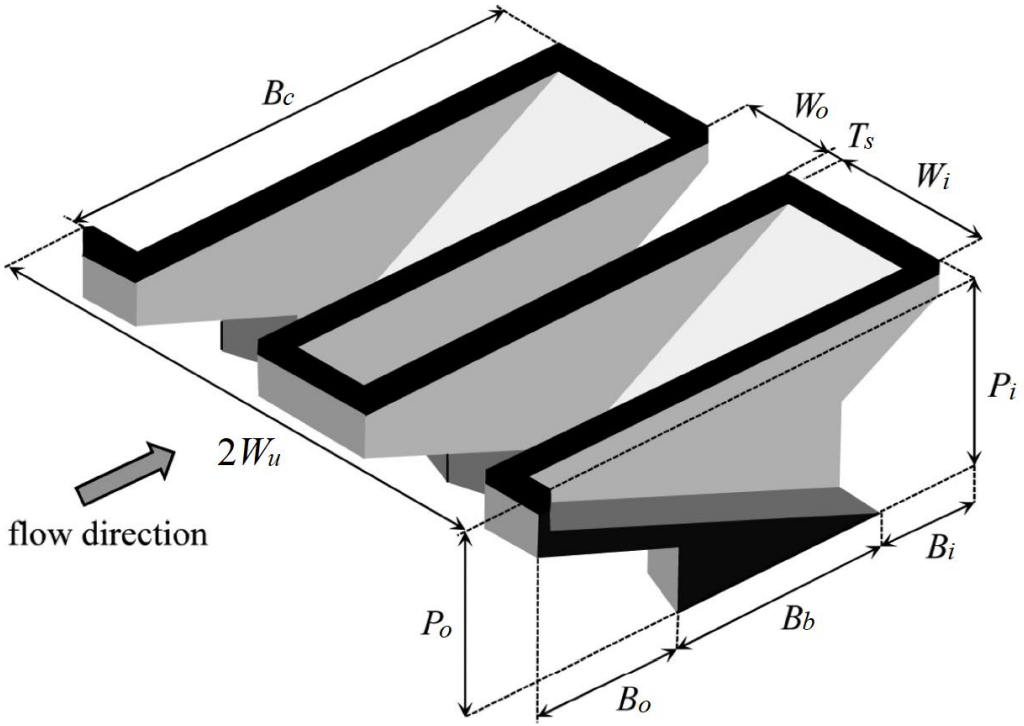








Geometrical relations



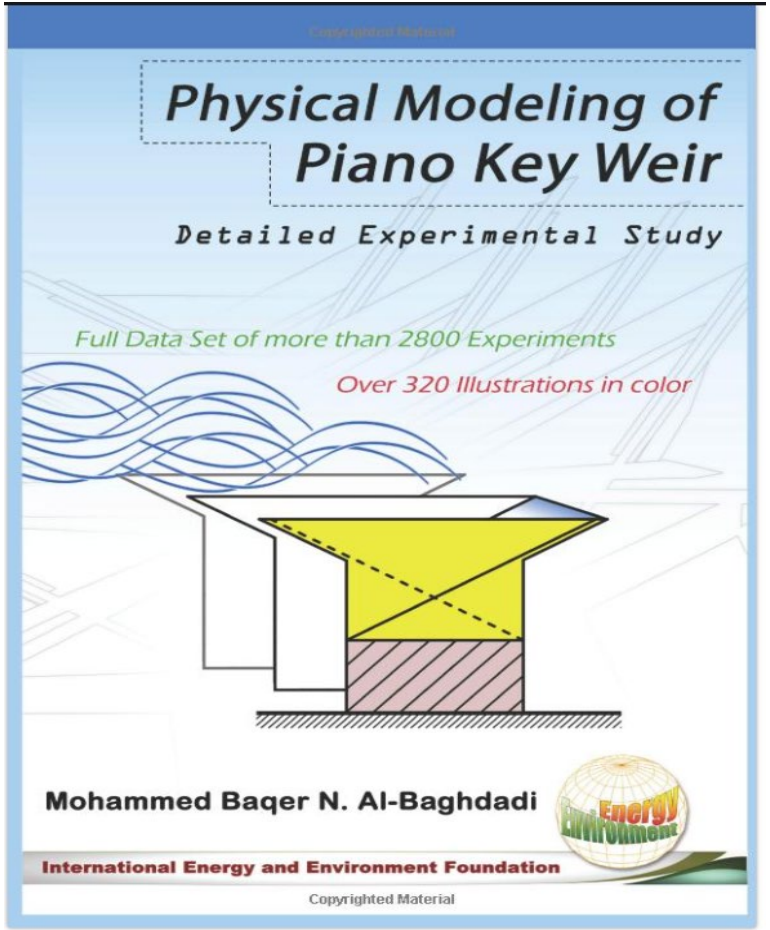
L/W

Wi/Wo

P/Wu

Ts

Ref


Physical Modeling of
Piano Key Weir
Detailed Experimental Study
Full Data Set of more than 2800 Experiments
Over 320 Illustrations in color
Mohammed Baqer N. Al-Baghdadi
Energy
Environment
International Energy and Environment Foundation
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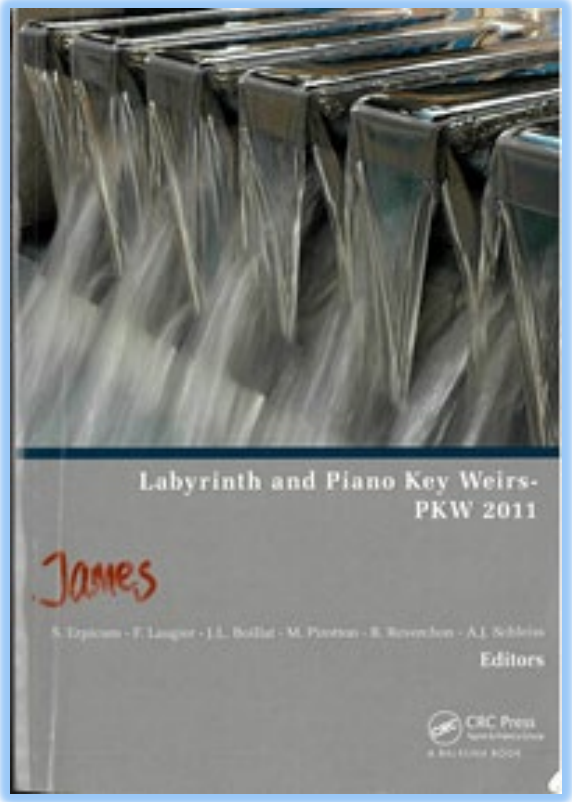
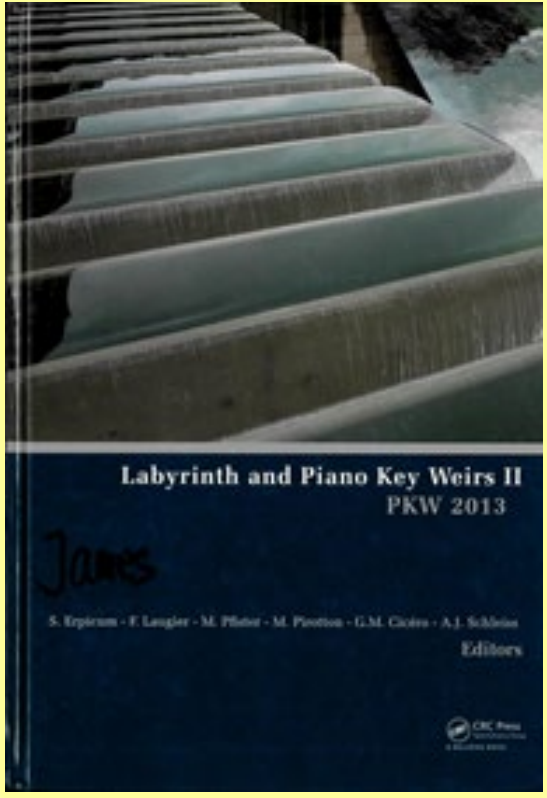
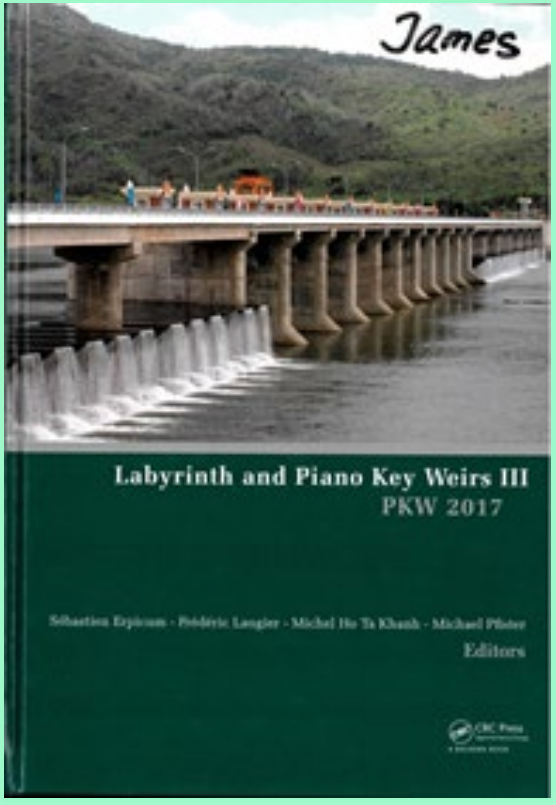

Labyrinth and Piano Key Weirs-
PKW 2011
James
Editors
CRC Press


Labyrinth and Piano Key Weirs II
PKW 2013
James
Editors


James
Labyrinth and Piano Key Weirs III
PKW 2017
Editors

Air entrainment & areation

Floating debris

Ice formation

Sediment

(a)

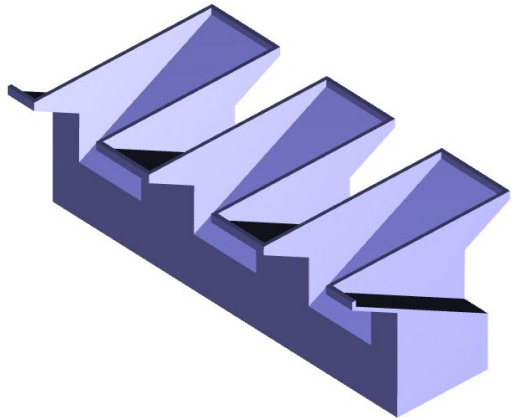
(b)

(c)

(d)

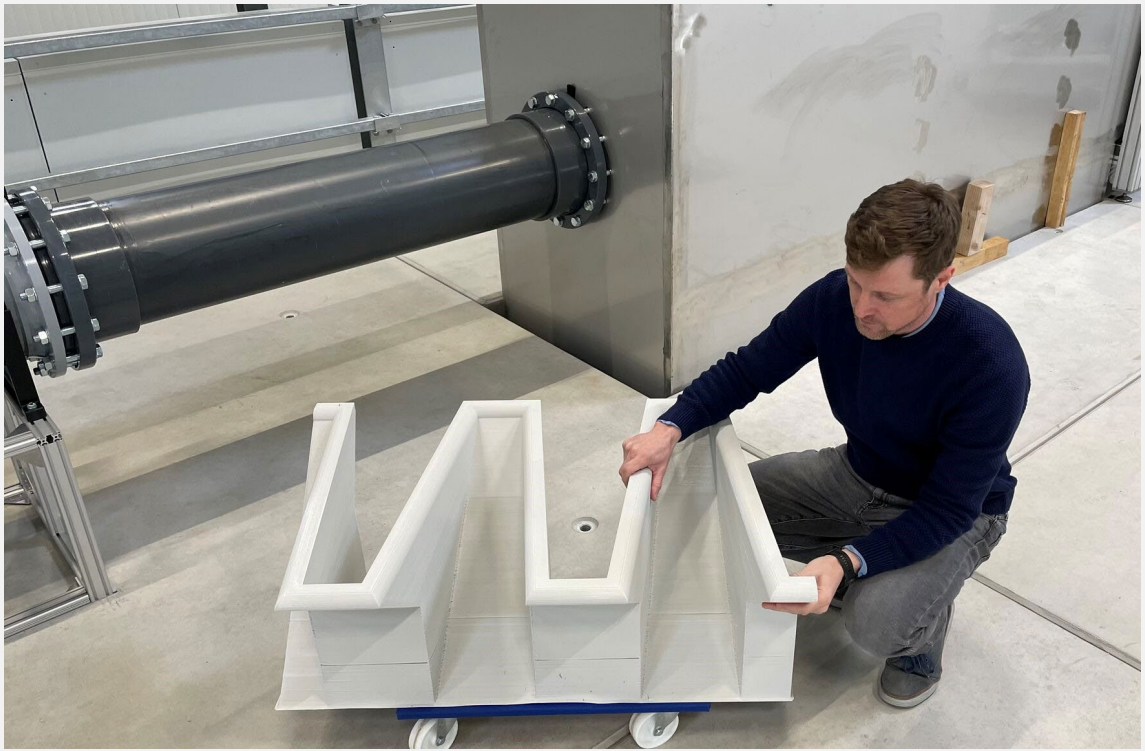
Conclusions

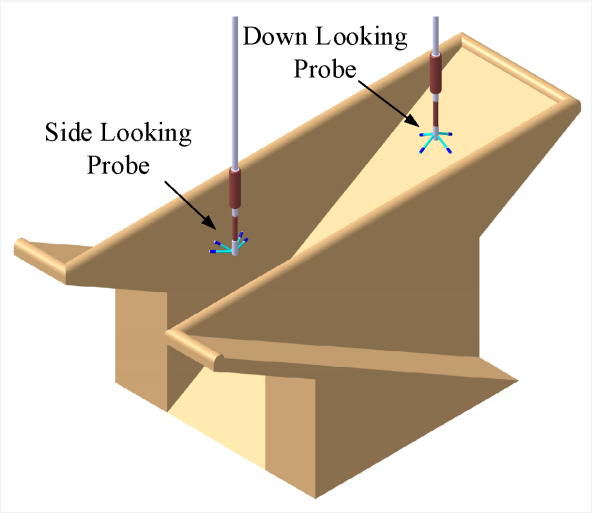
1. To streamline the crest in plan & augment crest length
2. To modify inlet and outlet keys to increase flow passage
3. parapet wall



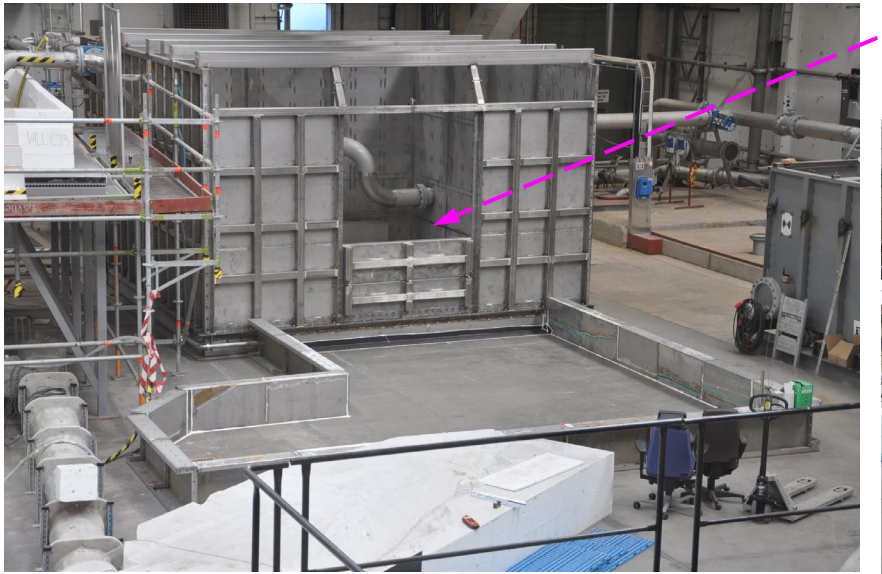
3D printed models

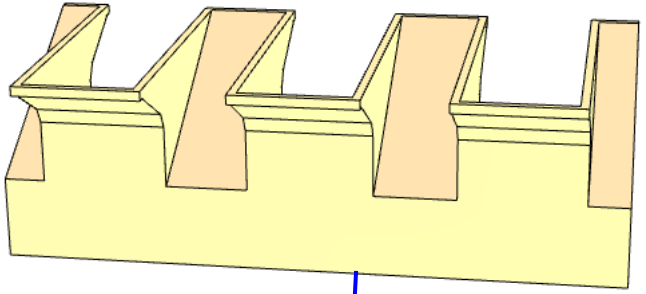
Each model of 3 units, 114 cm wide



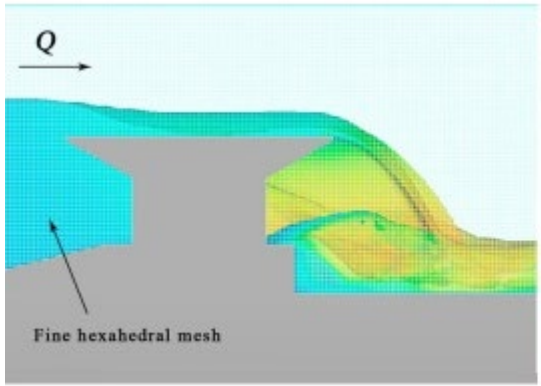


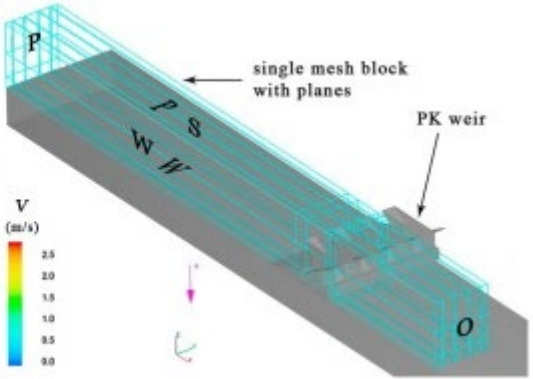
Physical models

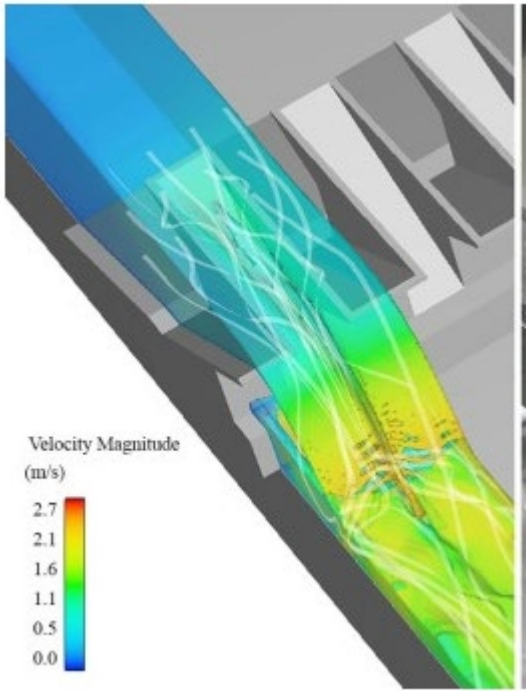




Why not CFD?





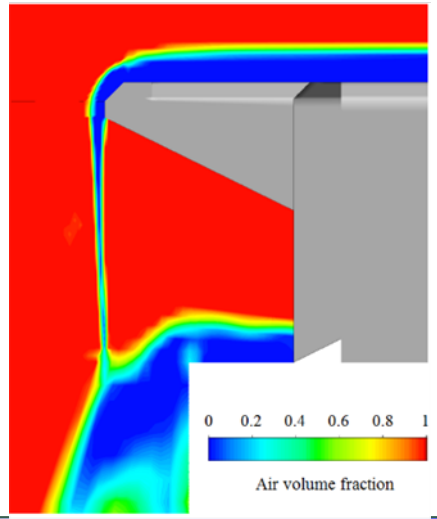


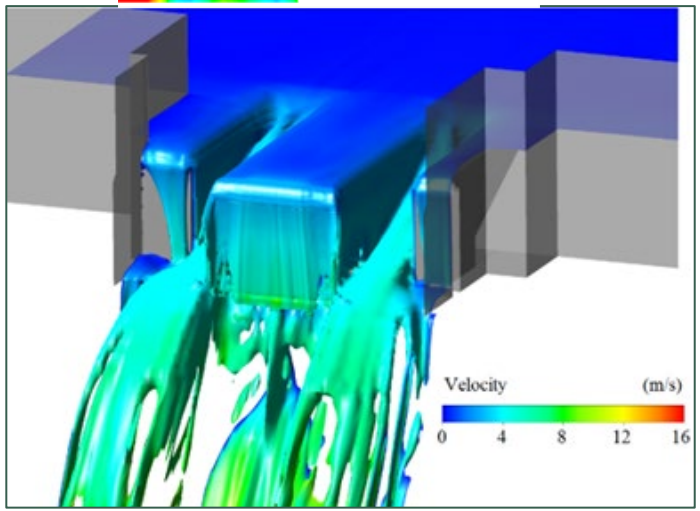
Large grid density

Result:

Dependence on turbulence mode + choice of two-phase model

EDF Escouloubre PK weir





Yang et al. (2022). Flood discharge of piano key weir, air-water flow features. 27th ICOLD Congress, May/June 2022, Marseille, France.

Is it the right name in Swedish?

Labyrinth weir (spillway)

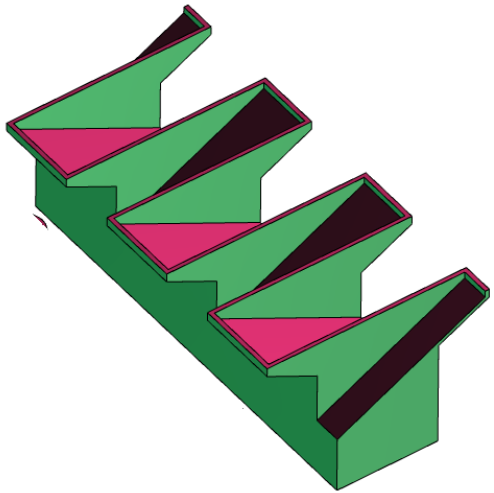
Labyrintöverfall (Labyrintutskov)

Piano key weir (spillway)

Pianotangentöverfall (pianotangentutskov)

Pianoutskov?

Thanks also to Carolina for providing the opportunity & coordinating the project.



Thanks for your attention!

Any questions?