SAARC ENERGY CENTRE
Energy for Peace & Prosperity

Online training of SAARC Professionals on Small, Mini and Micro Hydro Power Generation (Sept 13 - 17, 2021)

Selection and Dimensioning of major Components of SMMHP plants

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Contents and structure

Weir

Water intake

Water conveyance

Learning objectives are to understand the function of the main components and the criteria of selcting one certain solution. Additionally this understanding should enable the participants to do a first approximate dimensioning of some components respectively to be able to evaluate an already existing design of these components.

Weirs

Aim and basics

- Weirs basically increase the water level mainly to allow or to ease the water abstraction.
- Only in few cases the backwater area serves for limited storage purpose (daily storage).
- Basement and frame of any type of weir is a fixed and solid weir body with different shaping and made of various material.
- In case of a gated weir the basement is completed by any type of gate described later on.
- The simple static criteria of dimensioning is the difference in height between top water and tail water level.
- The hydraulic design criteria is the maximum value of flow to be discharged.

Weirs

Aim and basics

Differentiation into **fixed crest weirs** und **gated weirs**

> Fixed crest weirs do not allow for any regulation of the head water level.
>
> Gated weirs can provide this advantage.

Any type of weir needs a cut-off wall upstream and downstream and a stilling basin downstream to avoid erosion.

Construction material fixed weirs: rock, concrete, wood and any combination).

Construction material gated weirs: steel, wood, rubber

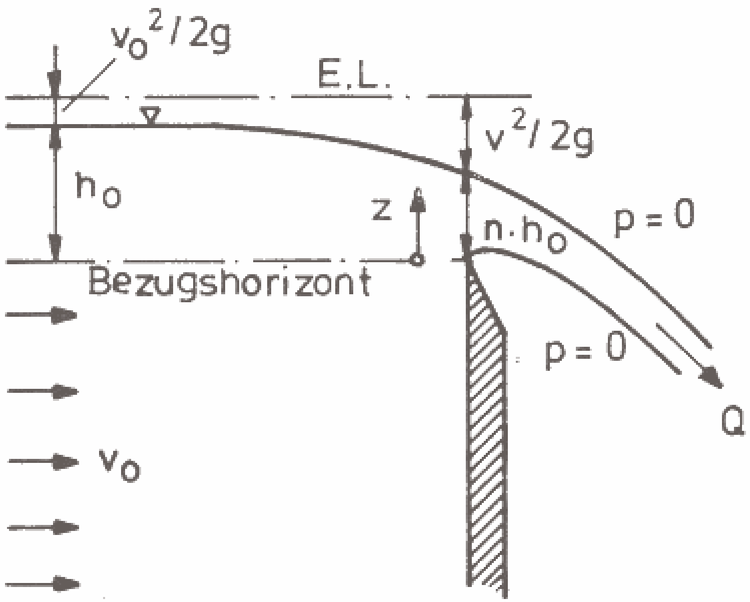
Weirs

Criteria to decide

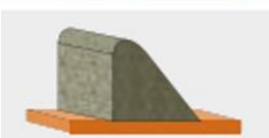
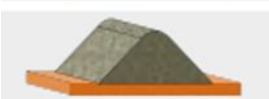
1: cost

2: Hydromechanical criteria: Poleni Formula

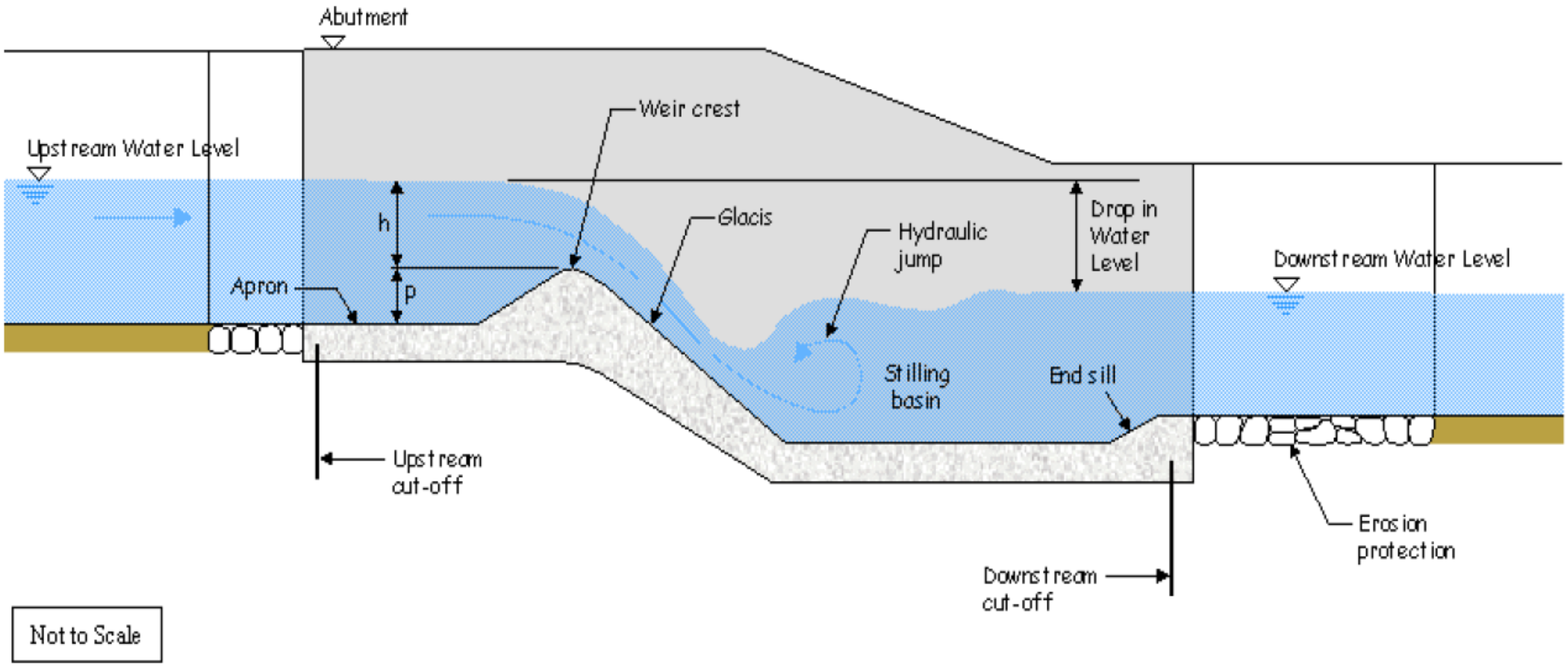
$$Q = \frac{2}{3} \cdot \mu \cdot b \cdot \sqrt{2g} \cdot h_o^{3/2}$$



Weirs

	Overflow coefficient μ	
	wide, sharp-edged, horizontal	0,49–0,51
	broad, well rounded edges, horizontal	0,50–0,55
	wide, completely rounded weir crown, reaches f.i by a deflected flap	0,65–0,73
	sharp-edged, ventilated overflow jet	~ 0,64
	Round crown, vertical upstream and sloping downstream side	0,73–0,75
	Roof-shaped, rounded weir crown	0,75–0,79

Weirs



Abutment
Weir crest
Upstream Water Level
h
p
Apron
Glacis
Hydraulic jump
Drop in Water Level
Downstream Water Level
Stilling basin
End sill
Upstream cut-off
Erosion protection
Downstream cut-off
Not to Scale

Weirs

Weirs

Gated weirs

- In recent times preferably used
- They are in principle constructed cross to the river course.
- They consist of a fixed part (foundation) and a movable gate.
- The types of gates are manifold and have different fields of application.

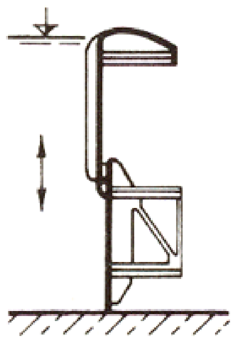
Main **selection criteria** are:

- the relation width : height
- save operation during floods
- bed load drifting features

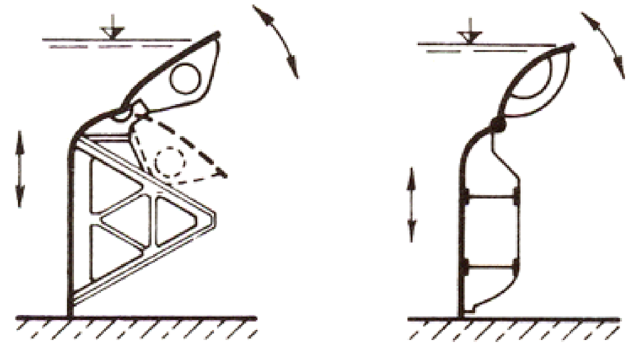
Seen from the hydraulic point of view the water can be discharged above or below the gate.

Weirs

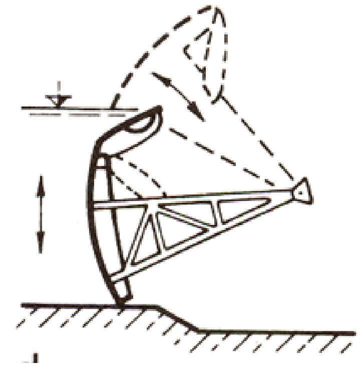
Overview gated weirs



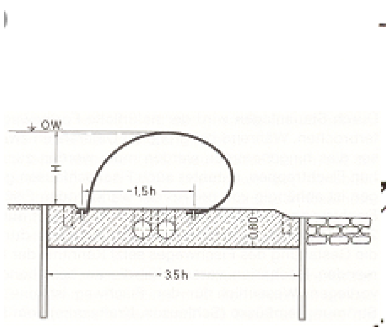
Vertical gate



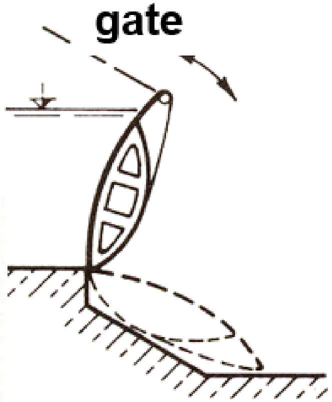
Vertical gate comb. with flap gate



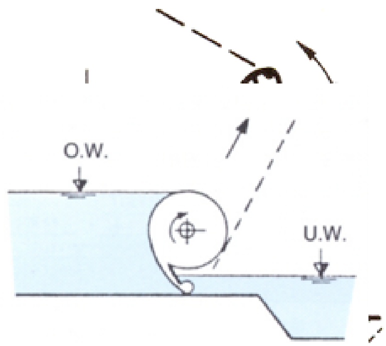
Radial gate comb. with flap gate



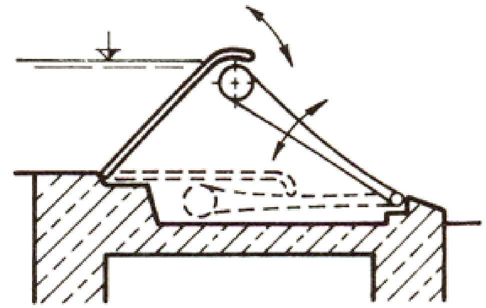
Rubber dam



Flap gate



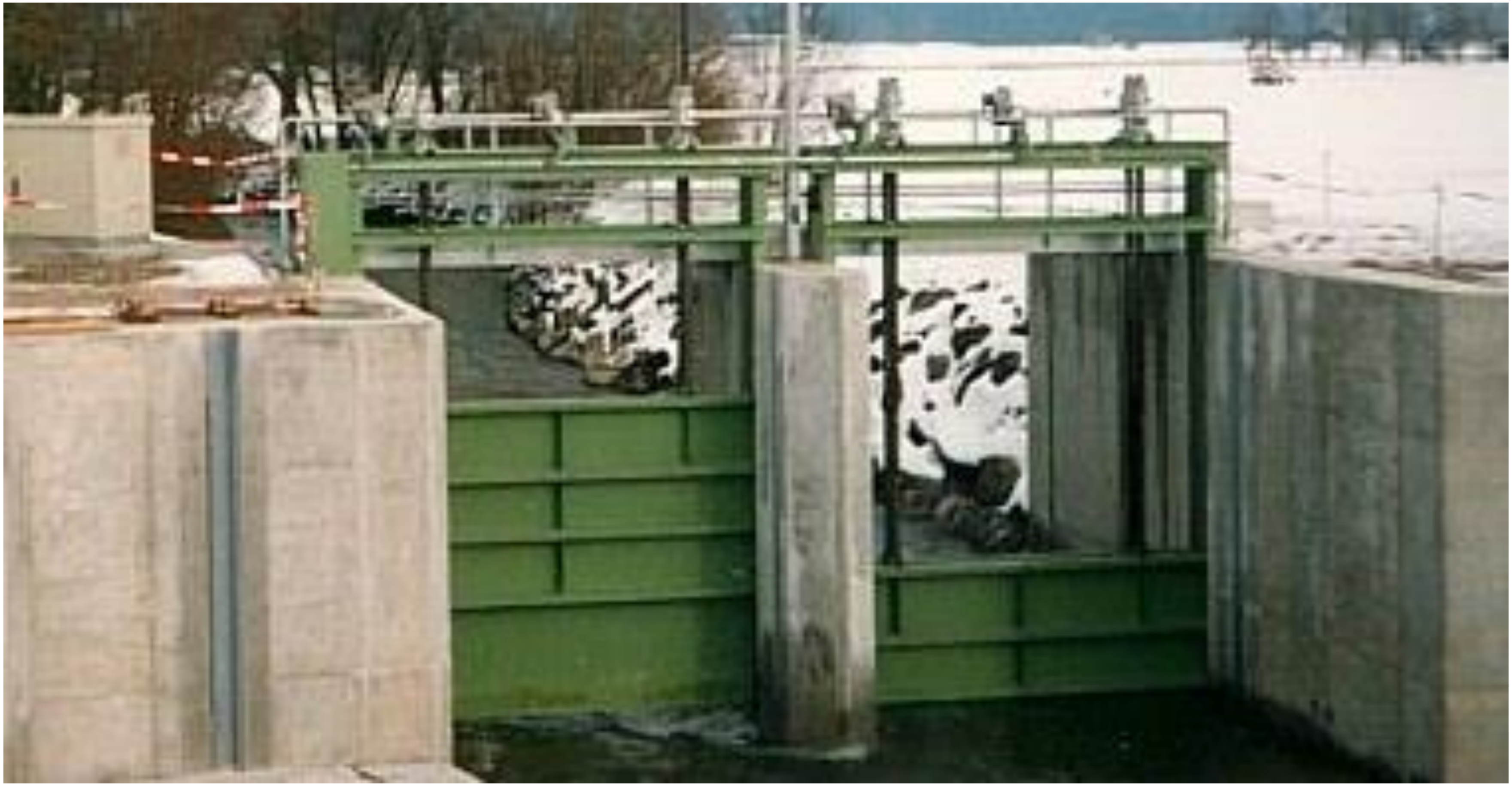
Drum gate



Double flap gate or roof weir

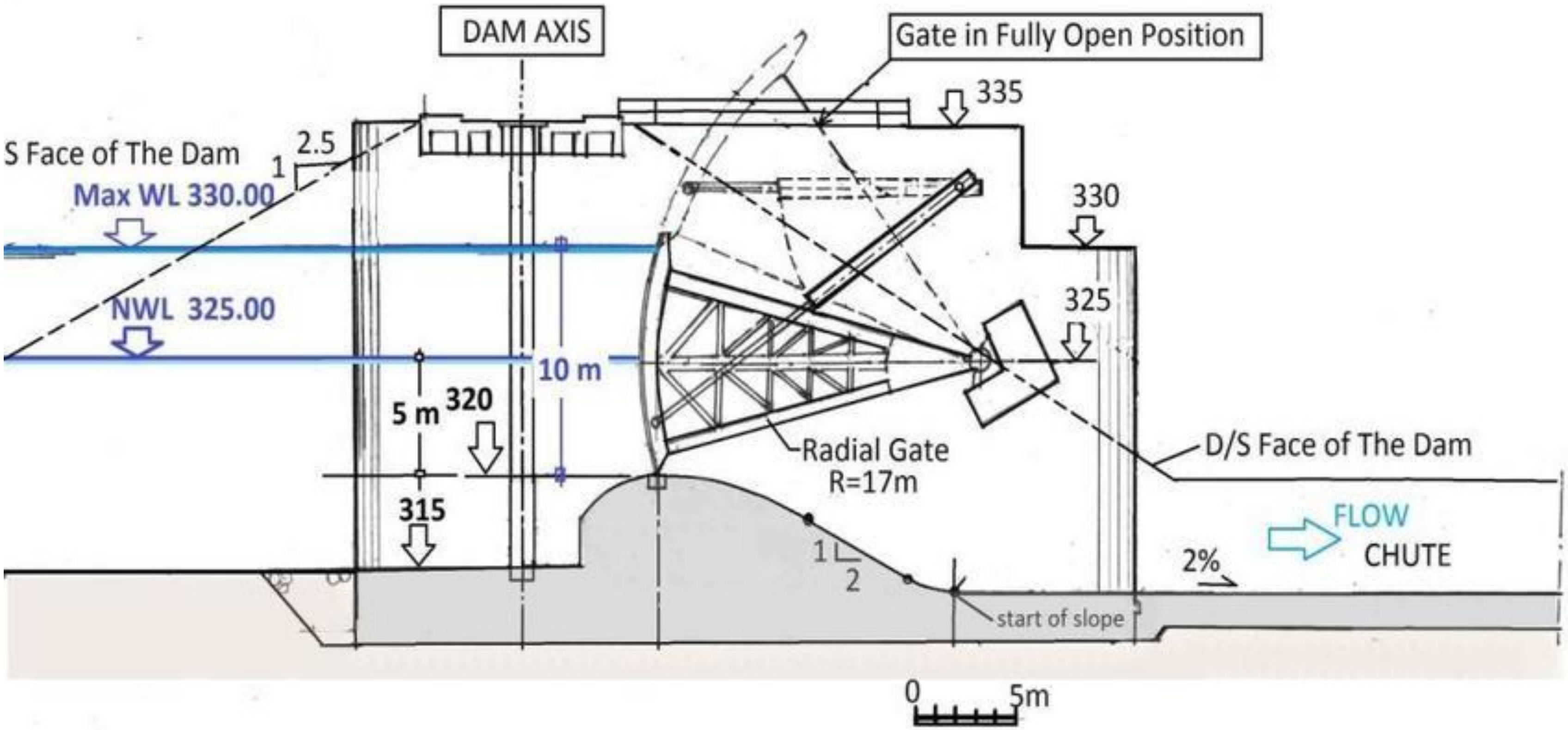
Weirs

Vertical gate



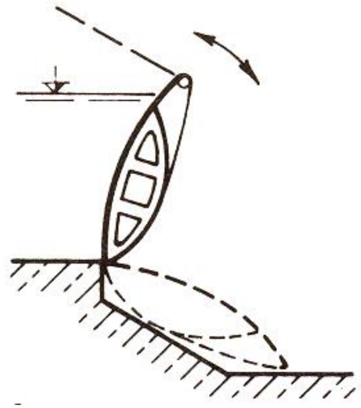
Weirs

Radial gate



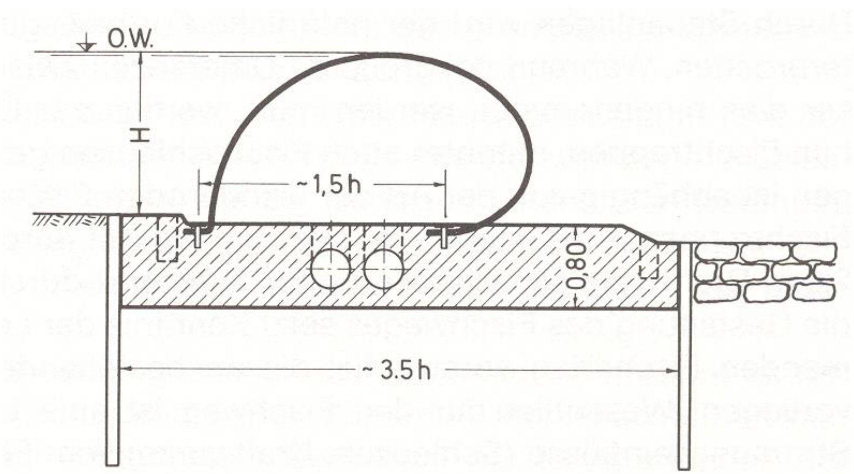
Weirs

Flap gate



Weirs

Rubber dam



Water intake

Subsurface intake

- ➢ Direct connection via penstock with turbine.
- ➢ Applied at lakes and storage basins
- ➢ Water remains under pressure

Open flow intake

- ➢ Water gets into the water conveyance structure (open channel, tunnel etc.) →
- ➢ Applied along rivers and open water ways
- ➢ Water remains in many cases at free surface

Combined works

open flow intake → open channel

→ penstock → turbine

Water intake

General design criteria

- Size of river
- Type of river (no bedload, heavy bedload)
- Cross section of the river (wide, v-shaped, …)
- Floating debris transport
- Flushing options

General dimensioning

- According to rated flow (+20%)
- Consideration of all kind of friction loss
- Minimising loss of head
- Flow velocity at the intake structure (0,6 – 0,8m/s)

Water intake

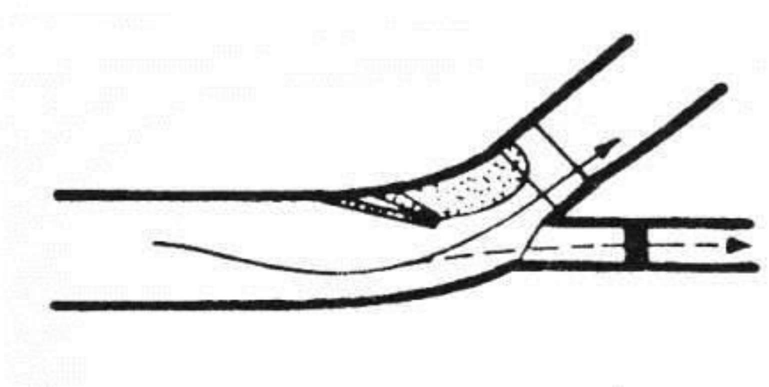
Detailed design criteria open flow

- Applied preferably in low head plants
- Located – if possible - in river bend
- Strong secondary flow at the outer side of the bend avoids the capture of bed load
- Rated discharge Q_A < 50 % of critical discharge Q_{kr}

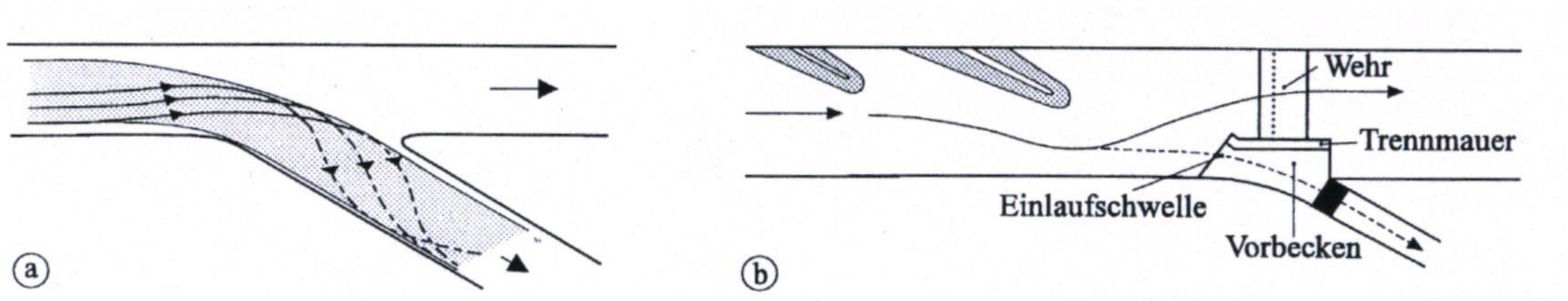
  (Q_{kr} = discharge when bed load transport starts up)
- Increase of Q_A possible by construction of a cantilever sill (>1m)
- Floating items and suspended load mainly at outer side of the bend
- Bed load transport preferably at the inner side of the bend

Water intake

In a bended river reach

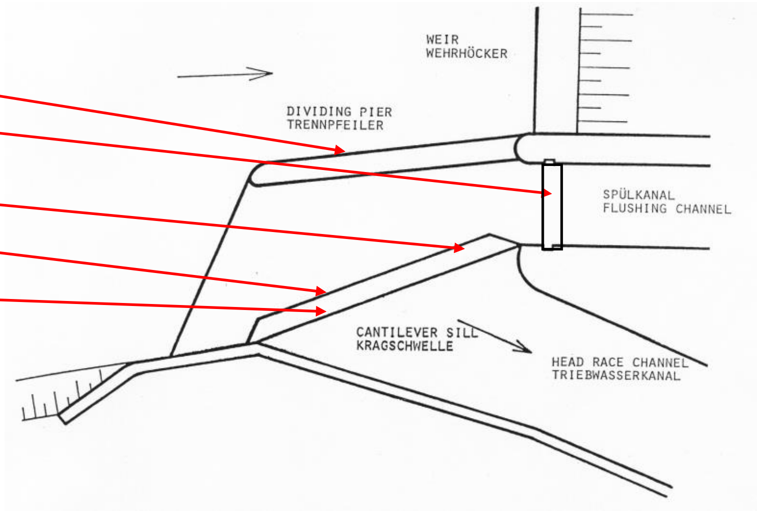


In a straight river reach



Water intake

- Construction works to reject solid material
  - Dividing pier
  - Flushing channel
  - Intake sill
  - Skimming wall (floating tree)
  - Trash rack

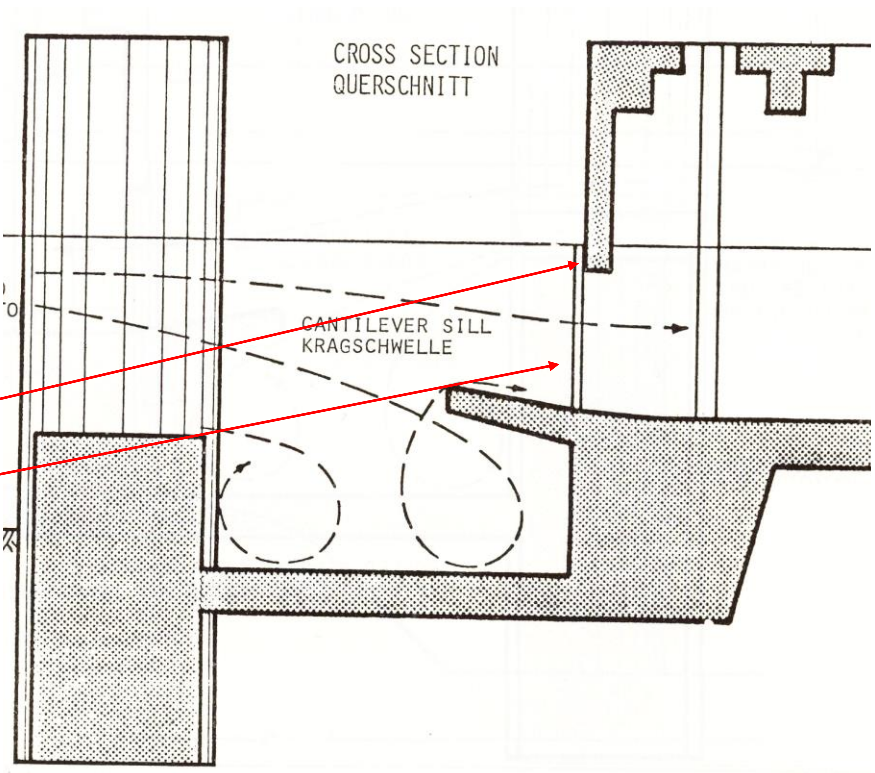


- Construction work to manage solid material
  - settling basin
  - Flushing gate
  - Trash rack cleaning

Water intake

- Flushing gate
  - In the section of the weir
  - Bottom of flushing gate significantly lower than bottom of intake
  - Intake sill

- Special design: cantilever sill
  - Initiating additional secondary flow direction



Water intake

Trash rack

- Coarse rack
  - 200 mm to 500 mm clearance, bars diameter 35 – 60mm
  - Predominantly manual cleaning
- Fine rack
  - Some rack elements
  - Trash rack cleaning machine (Chain, rope, hydraulic)
  - Hydraulic optimised cross section of bars → minimising head loss
  - Clearance 10 - 12 mm (small Pelton turbine) up to 150 mm (large Kaplan turbines)
  - Fishery demands maximum 20 mm clearance (protection of fish)
  - Flow velocity preferably 0,60 – 0,80 m/s (minimising head loss)
  - Static consideration: full water pressure in case of complete jam

Water intake

Coarse rack

α ….. Incline of the rack
β ….. Form coefficient of bars
d ….. Diameter of bars
a ….. clearance in mm

$$h_R = \beta \sin \alpha \left(\frac{d}{a}\right)^{4/3} \frac{v_0^2}{2g}$$

Water intake

Fine rack

Water intake

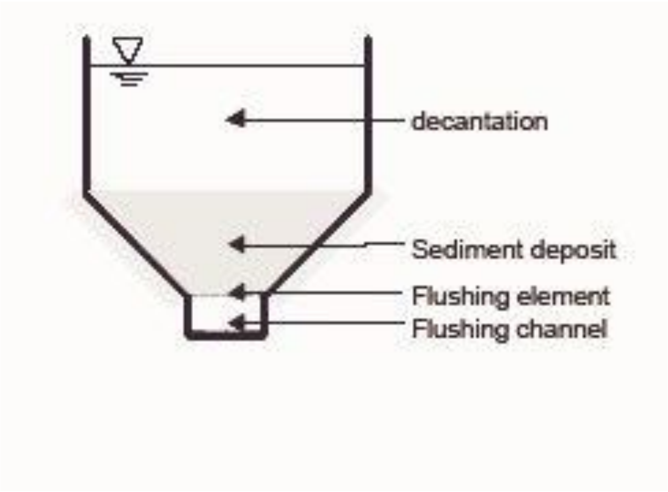
Settling basin

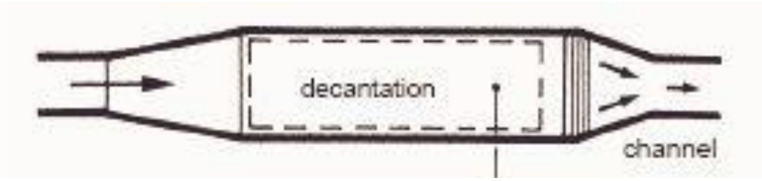
Main tasks:

- Avoid sedimentation in downstream reaches of waterway
- Avoid erosion on mechanical equipment

Principle:

- Reduction of flow velocity and turbulences (enlarging the cross section
- Sedimentation of solid material





Water intake

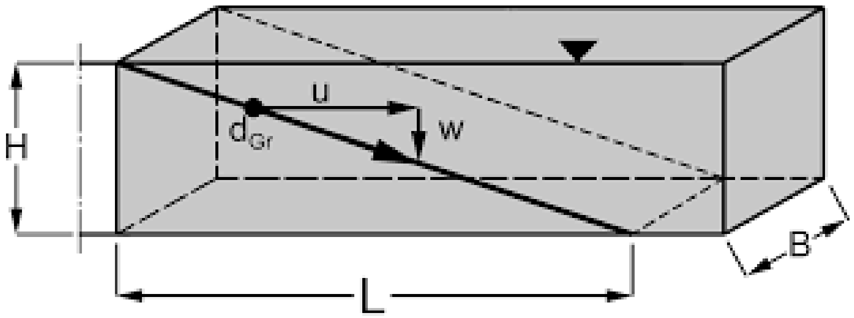
Settling basin

Design criteria

- ➢length → all material has enough time for sedimentation
- ➢Sinking time t_s relates to passing time t_p

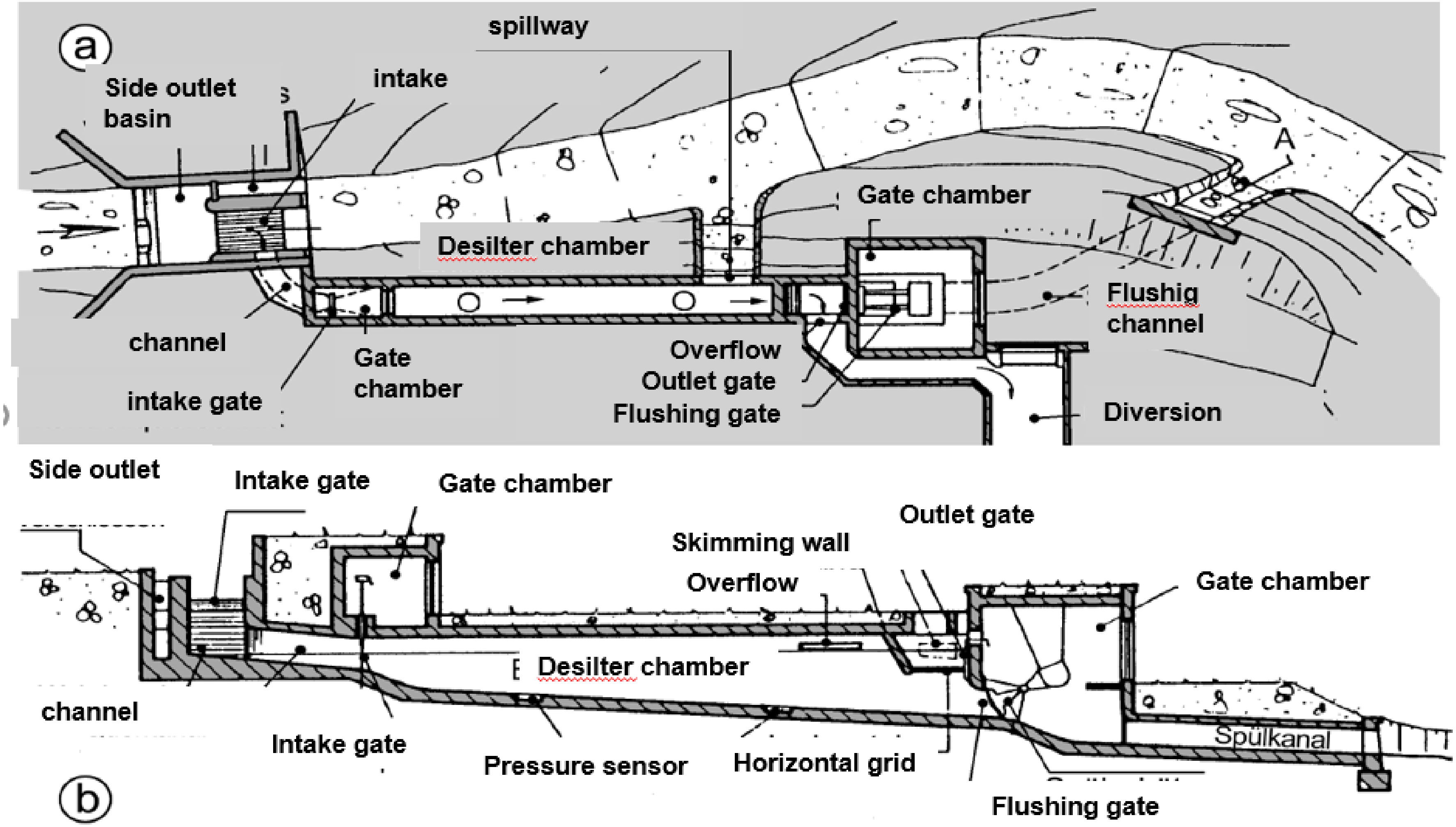
Design values

- ➢Rated discharge
- ➢efficiency
- ➢width < 1/8 of length L
- ➢width < 2 times depth h
- ➢Flow velocities: 0,3 to 0,5 m/s



Water intake

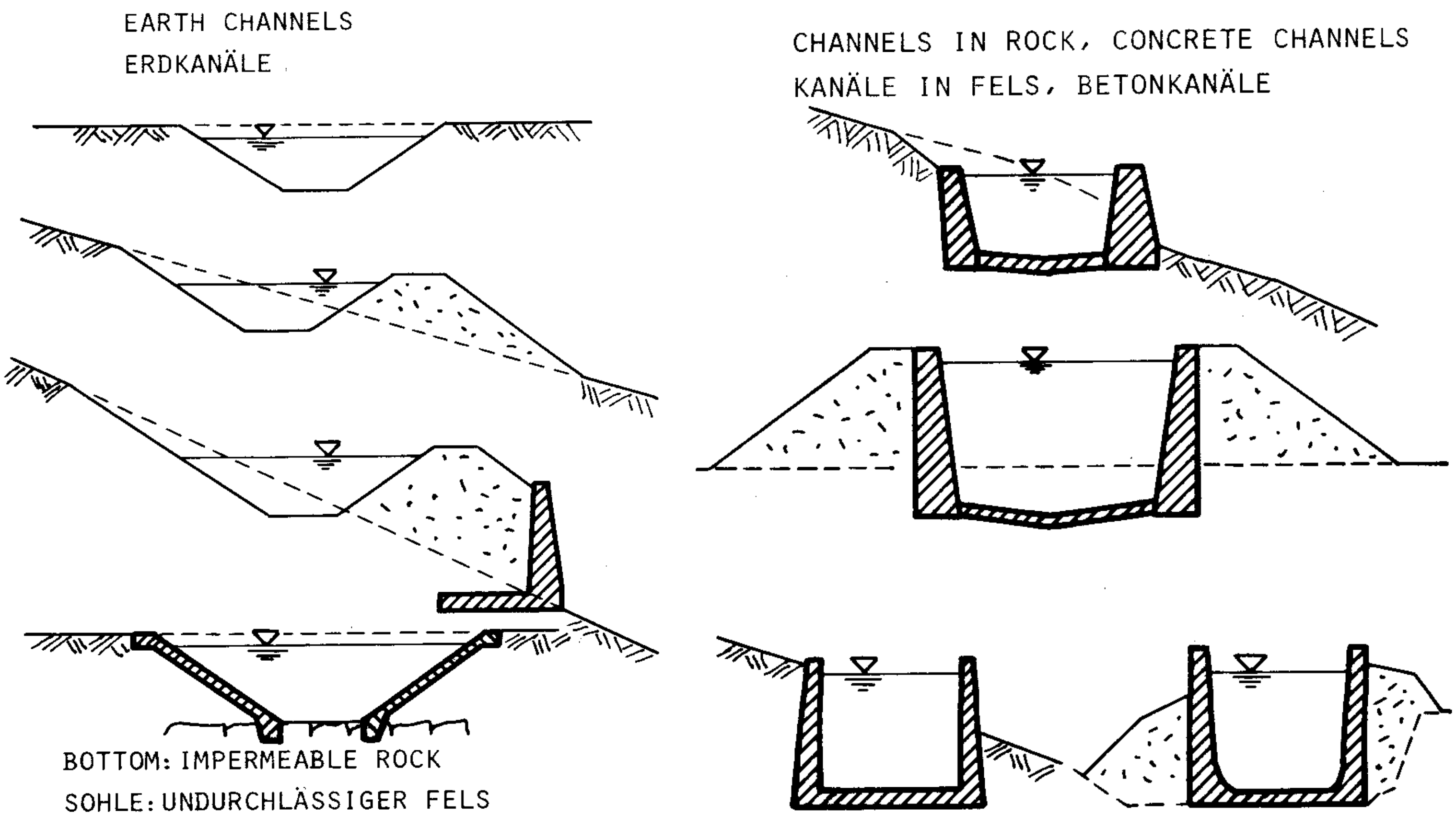
Settling basin



Water conveyance – open waterways

Open channel

Different options according to ground, topography, space available, size of cross section, costs, length



Water conveyance - open waterways

Dimensioning: cross section area according to flow velocity: < 1m/s but higher than 0,5m/s to avoid sedimentation

Water conveyance - pipes

Dimensioning following an optimisation process:

Cost of construction (pipe + pipe laying)

versus

Variation of revenue due to variation of friction loss

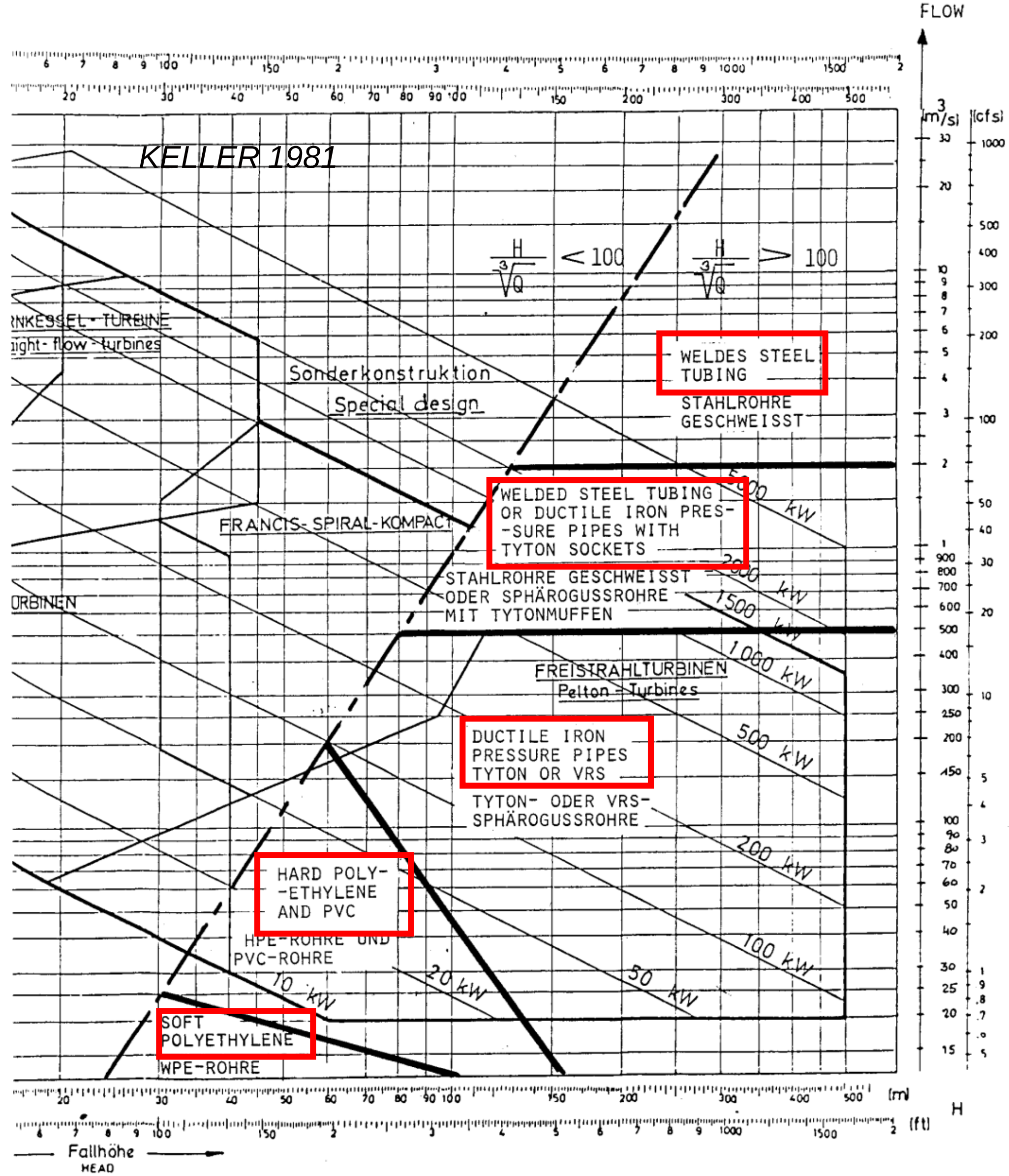
rated flow: $1 m^3/s$		**lenght: 1000m**	**k = 1mm**	**gross head = 135m**							
Dimension	area	flow velocity	head loss	net head	rated power	production	revenue	difference	cost of pipe	difference	payback
m	m^2	m/s	m	m	kW	MWh/a	€/a	€	€	€	a
0,6	0,283	3,54	23,70	111,30	890	4452	311 640		153 000		
								36 848		76 000	2,06
0,7	0,385	2,60	10,54	124,46	996	4978	348 488		229 000		
								14 868		77 000	5,18
0,8	0,503	1,99	5,23	129,77	1038	5191	363 356		306 000		
								6 748		144 000	21,34
0,9	0,636	1,57	2,82	132,18	1057	5287	370 104		450 000		
								3 276		225 000	68,68
1,0	0,785	1,27	1,65	133,35	1067	5334	373 380		675 000		
								1 820		360 000	197,80
1,1	0,950	1,05	1,00	134,00	1072	5360	375 200		1 035 000		

Water conveyance - pipes

Material of pipes

- Plastic (PE, GRP)
- Ductile cast pipes
- Steel
- Wood
- Concrete

Reaches of application



Water conveyance - pipes

soft polyethylene: discharge < 0,03 m^3/s; pressure < 10 bar

PVC: discharge 0,05 - 0,20 m^3/s; pressure < 16 bar

GRP: discharge 0,05 - 20 m^3/s , pressure <25 bar

Ductile cast pipes: 0.05 – 3 m^3/s, pressure < 100 bar

Steel pipes: almost unlimited

Water conveyance - pipes

GRP

Steel

Ductile cast iron

Water conveyance - pipes

Dimensioning

Static pressure curve & dynamic pressure curve (water hammer, negative pressure)

Water hammer:

Immediate closing of a gate → stop of flow, mass inertia → increased pressure

Depending on closing time, flow velocity & head

Critical closing time: v*L / g*H

The closing time is indirect proportional to the dimension of water hammer maxima: app. 102 v

Thank you