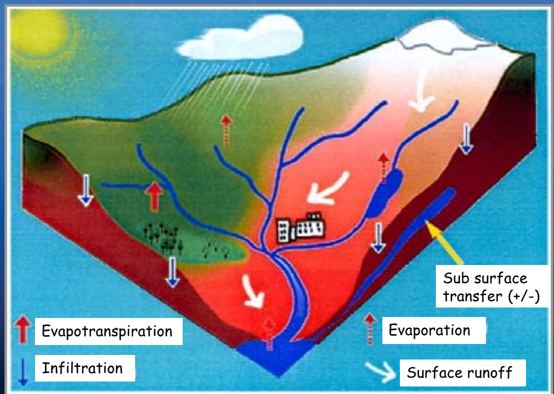
Small hydro projects
Flow and Head measurment methods

B. ROQUEMAUREL - *SERT*
May 2007

① The hydrological cycle



② Why head and flow measurment

Gross power :

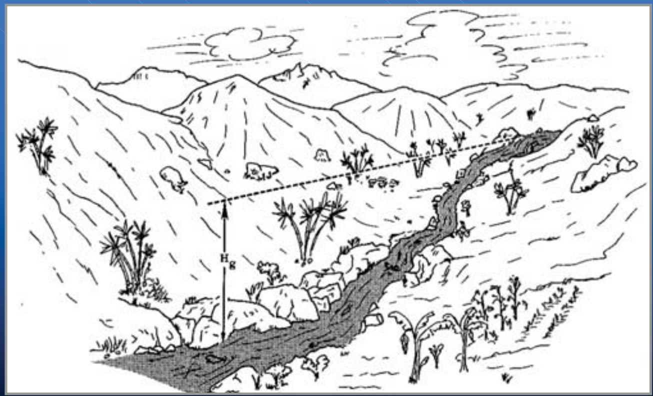
$$P_g = 9.81 \times Q \times H_g$$

Q : flow (discharge) in cubic meters per second (m^3/s) - 1 m^3/s = 1000 l/s

H_g : gross head in meters (difference between upper and lower level)

P : gross power in kilowatts (kW)

Example : H_g = 90 m
Q = 6 l/s = 0.006 m^3/s
P_g = 9.81 x 0.006 x 90 = 5.3 kW



Net power (electrical power) :

P_{elec} = **Gross Power x global efficiency**
(9.81 x Q x H_g) x e

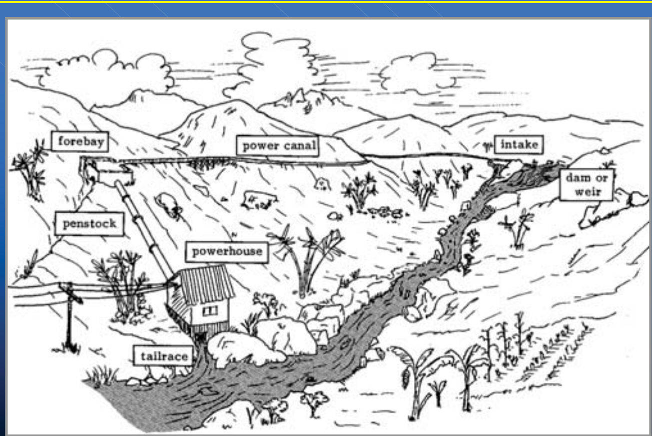
Q : flow (discharge) in cubic meters per second (m^3/s) - 1 m^3/s = 1000 l/s

H_g : gross head in meters (difference between upper and lower level)

e : global efficiency (all losses : in canal, penstock, turbine …) # 0.50

P_{elec} : net power (electrical power) in kilowatts (kW)

Example : H_g = 90 m & Q = 6 l/s = 0.006 m^3/s
P_g = 9.81 x 0.006 x 90 = 5.3 kW
P_{elec} = 5.3 x 0.5 = 2.65 kW



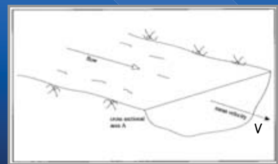
③ Flow measurment

- Measurment of volume and time

$$Q = \frac{\text{volume } (m^3)}{\text{time (seconds)}}$$

- Measurment of surface and water velocity

Q = A x V



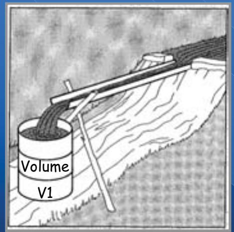
A : cross sectional area (m^2)
V : average water velocity (m/s)
Q : flow (m^3/s)

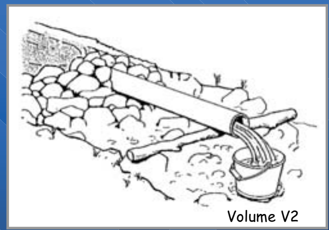
Example 1 : V = 0.8 m/s and A = 3.2 m^2 ➩ Q = 3.2 x 0.8 = 2.56 m^3/s

Example 2 : volume = 80 liters & time = 4 seconds ➩ Q = 80/4 = 20 l/s = 0.020 m^3/s

3.1 Measurment of volume and time

Method : recording of the time required to fill a volume

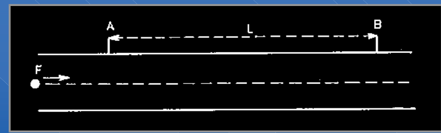




Example 1 :
volume V1 = 200 liters
If t = 4 secondes
Q = 50 l/s = 0.050 m3/s

Example 2 :
volume V2 = 20 liters
If t = 5 secondes
Q = 4 l/s = 0.004 m3/s

3.2 Measurment of average velocity and cross sectional area



Method : recording of the time (t) required to a floating object F (filled bottle, piece of wood…) to cover a known distance L (between points A and B – straight portion of the stream, uniform flow and width as possible) :

- the surface water velocity is Vs = L/t
- the approximate average velocity of the stream is

V = 0.8 x L/t L in meters t in seconds V in m/s

- measurment of the cross sectional area of the flow at both ends (A and B) the average cross sectional area is

$A = (S_A + S_B) / 2$ Sa and Sb in m^2

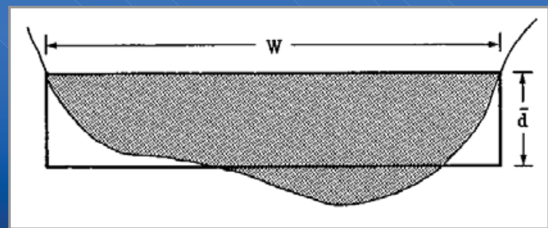
- calculation of the average flow : Q = A x V A in m2 V in m/s

Example : L = 12 m and t = 16 s (several measures)
➩ L/t = 12 / 16 = 0.75 m/s
➩ V = 0.8 x L/t = 0.8 x 0.75 = 0.6 m/s

Sa = 1.6 m^2 and Sb = 1.4 m^2
➩ $A = (S_A + S_B) / 2 = (1.6 + 1.4) / 2 = 1.5\ m^2$

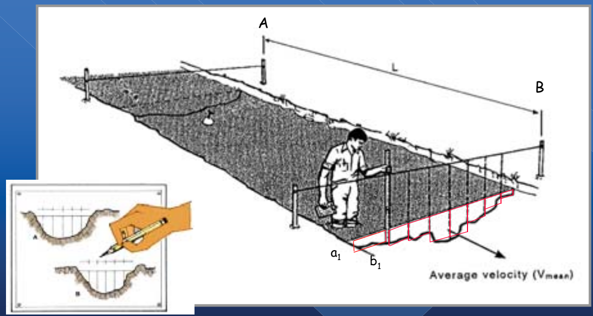
➩ Q = A x V = 1.5 x 0.6 = 0.9 m^3/s (900 l/s)

Measurment of cross sectional area - simple



Area A = W x d W : width in m
d : everage depth en m
A : area in m^2

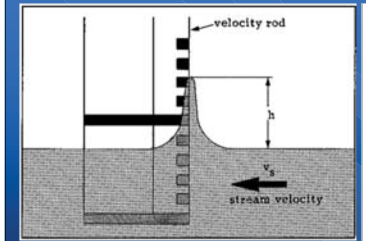
Measurment of cross sectional area – detailed

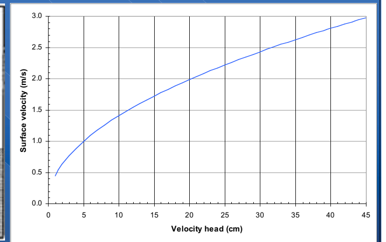


$S_B = a_1 \times b_1 + a_2 \times b_2 + a_3 \times b_3 + \ldots\ldots$

Other method to measure velocity :

- Measurment of « velocity head »





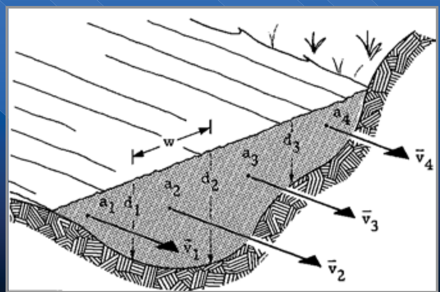
Examples :

h = 5 cm ⇨ $V_{surface}$ = 1 m/s ⇨ V_{stream} = 0.8 x 1 = 0.8 m/s
h = 20 cm ⇨ $V_{surface}$ = 2 m/s ⇨ V_{stream} = 0.8 x 2 = 1.6 m/s
h = 40 cm ⇨ $V_{surface}$ = 2.8 m/s ⇨ V_{stream} = 0.8 x 2.8 = 2.4 m/s

- Measurment of water velocity with a propeller (« current meter »)

The rotation speed of the propeller is a function of the incident water velocity of the stream.

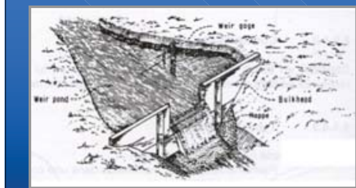
Method : measurment of water velocity for several partial areas ; calculation of the flow of each partial areas. The total flow is Q = a1 xV1 + a2 x V2 + ...

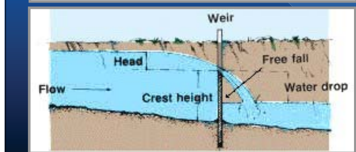


3.3 Weir method

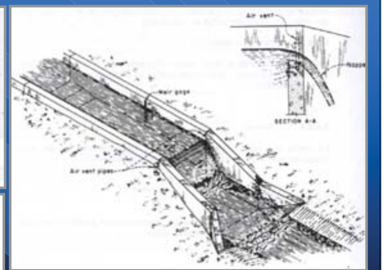
3.3.1 Rectangular weir

With lateral contractions

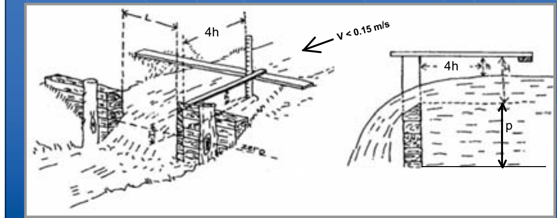




Without contraction



Rectangular weir WITH lateral contractions

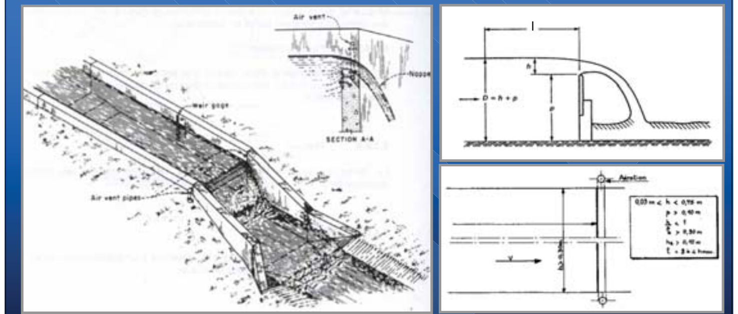


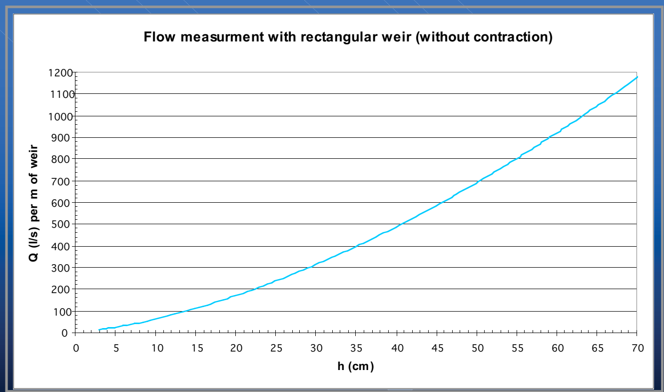
Conditions of use :
- p > 2h
- V < 0.15 m/s

H-h (cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Q (l/s) per meter of weir	5.2	9.5	15	20	27	33	41	49	57	65	74	84	93	103	113	124
H-h (cm)	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Q (l/s) per meter of weir	135	146	157	169	181	193	205	217	230	243	256	269	283	296	310	324
H-h (cm)	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Q (l/s) per meter of weir	338	352	367	381	396	411	426	441	456	472	487	503	518	534	550	566

Example : L = 1.80 m H-h = 30 cm ⇨ Q = 1.8 x 283 = 509 l/s

Rectangular weir WITHOUT lateral contractions

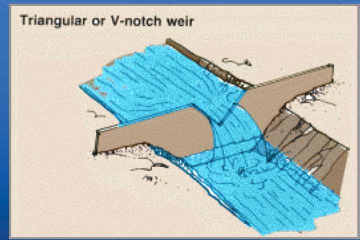


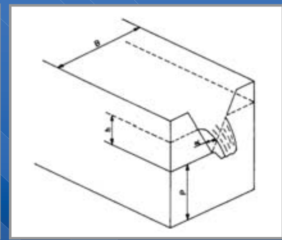


Rectangular weir without contraction - Flow = f(h) per m of weir

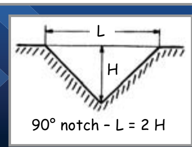
h(cm)	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5
Q(l/s) per meter of weir	9.9	12.3	15.0	17.8	20.8	23.9	27.2	30.6	34.2	37.9	41.7	45.6	49.7	53.9	58.1	62.5	67.1	71.7
h(cm)	12	12.5	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5	20	20.5
Q(l/s) per meter of weir	76.4	81.2	86.2	91.2	96.3	102	107	112	118	123	129	135	141	147	153	159	165	171
h(cm)	21	21.5	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5
Q(l/s) per meter of weir	177.9	184.3	190.9	197.5	204.2	211	218	225	232	239	246	253	261	268	276	283	291	299
h(cm)	30	30.5	31	31.5	32	32.5	33	33.5	34	34.5	35	35.5	36	36.5	37	37.5	38	38.5
Q(l/s) per meter of weir	306	314	322	330	338	347	355	363	371	380	388	397	406	414	423	432	441	450
h(cm)	39	39.5	40	40.5	41	41.5	42	42.5	43	43.5	44	44.5	45	45.5	46	46.5	47	47.5
Q(l/s) per meter of weir	459	468	477	487	496	505	515	524	534	543	553	563	573	583	593	603	613	623
h(cm)	48	48.5	49	49.5	50	50.5	51	51.5	52	52.5	53	53.5	54	54.5	55	55.5	56	56.5
Q(l/s) per meter of weir	633	644	654	664	675	685	696	707	717	728	739	750	761	772	783	794	806	817
h(cm)	57	57.5	58	58.5	59	59.5	60	60.5	61	61.5	62	62.5	63	63.5	64	64.5	65	65.5
Q(l/s) per meter of weir	828	840	851	863	874	886	898	910	921	933	945	957	969	982	994	1006	1018	1031
h(cm)	66	66.5	67	67.5	68	68.5	69	69.5	70	70.5	71	71.5	72	72.5	73	73.5	74	74.5
Q(l/s) per meter of weir	1043	1056	1068	1081	1094	1106	1119	1132	1145	1158	1171	1184	1197	1210	1224	1237	1250	1264

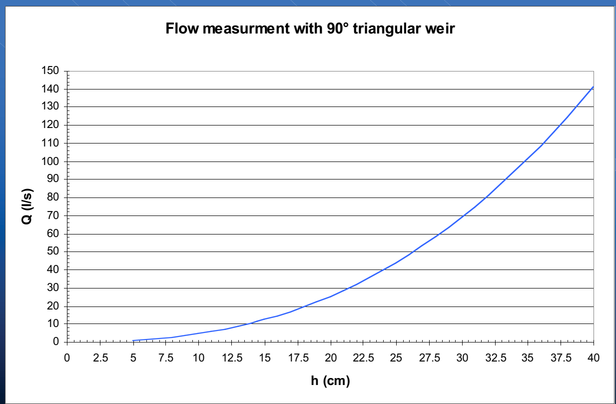
3.3.2 Triangular weir (α = 90° - L = 2H)





Conditions of use : 0.05 m < h < 0.40 m
p > 0.45 m
B > 1.2 m
B > 5 h



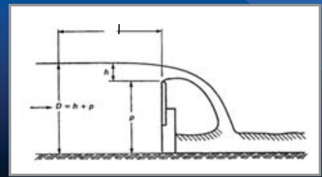


Triangular weir – Flow = f(h)

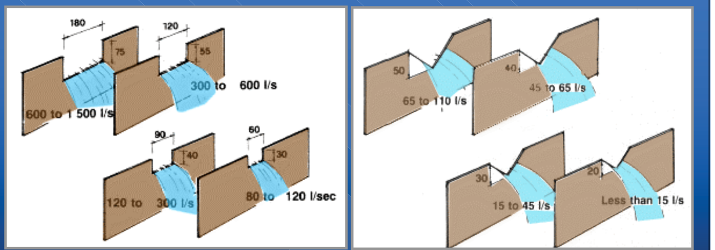
h (cm)	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5
Q (l/s)	0.8	1.0	1.2	1.5	1.8	2.1	2.5	2.9	3.4	3.9	4.4	5.0	5.6	6.3
h (cm)	12	12.5	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5	18	18.5
Q (l/s)	7.0	7.7	8.5	9.3	10.2	11.2	12.1	13.2	14.3	15.4	16.6	17.9	19.2	20.5
h (cm)	19	19.5	20	20.5	21	21.5	22	22.5	23	23.5	24	24.5	25	25.5
Q (l/s)	21.9	23.4	24.9	26.5	28.2	29.9	31.6	33.5	35.4	37.3	39.3	41.4	43.6	45.8
h (cm)	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5
Q (l/s)	48.0	50.4	52.8	55.3	57.8	60.4	63.1	65.9	68.7	71.6	74.6	77.6	80.7	83.9
h (cm)	33	33.5	34	34.5	35	35.5	36	36.5	37	37.5	38	38.5	39	39.5
Q (l/s)	87.2	90.5	93.9	97.4	101	105	108	112	116	120	124	128	132	137

3.3.3 Which type of weir for flow measurment ?

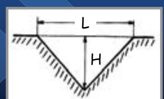
Flow to be measured		Type of weir	Head of water (h)		Remarks
mini	*maxi*		*mini*	*maxi*	
0.8 l/s	140 l/s	triangular (90° notch)	5 cm	40 cm	p > 45 cm and D > 85 cm
5 l/s	250 l/s	rectangular with lateral contractions - 0.50 m width	3 cm	50 cm	p > 40 cm and D > 80 cm
50 l/s	500 l/s	rectangular with lateral contractions - 1.0 m width	10 cm	45 cm	p > 40 cm and D > 80 cm
100 l/s	1000 l/s	rectangular with lateral contractions - 1.0 to 2.0 m width	15 to 10 cm	65 to 45 cm	D > 1.30m to D > 0.90 m
10 l/s	65 l/s	rectangular without lateral contractions - 1.0 m width	3 cm	10 cm	p > 10 cm
10 l/s	180 l/s	rectangular without lateral contractions - 1.0 m width	3 cm	20 cm	p > 20 cm
10 l/s	330 l/s	rectangular without lateral contractions - 1.0 m width	3 cm	30 cm	p > 30 cm
10 l/s	500 l/s	rectangular without lateral contractions - 1.0 m width	3 cm	40 cm	p > 40 cm
10 l/s	1000 l/s	rectangular without lateral contractions - 1.0 m width	3 cm	60 cm	p > 60 cm



Size of rectangular (with contractions) and triangular weir and related flows

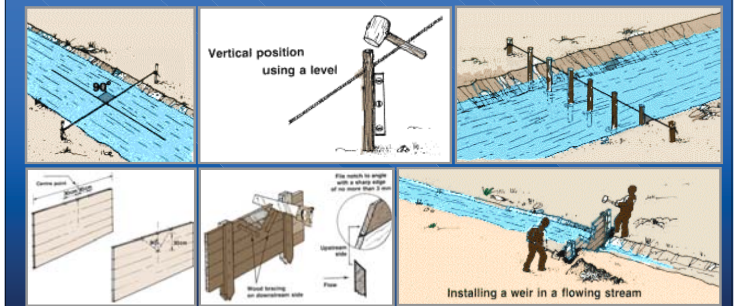


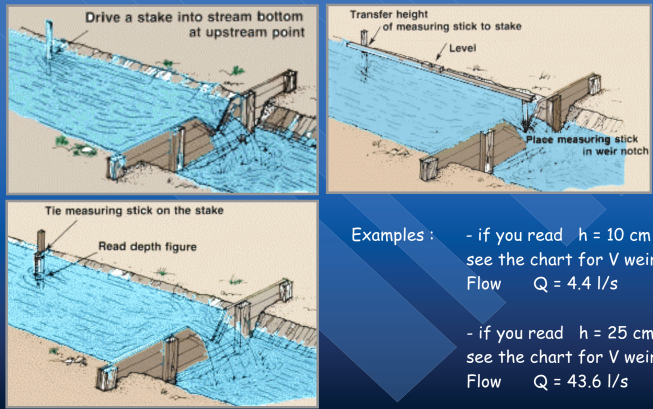
Dimensions in centimeters.



90° notch - L = 2 H

3.3.4 Weir construction (example of a triangular model)

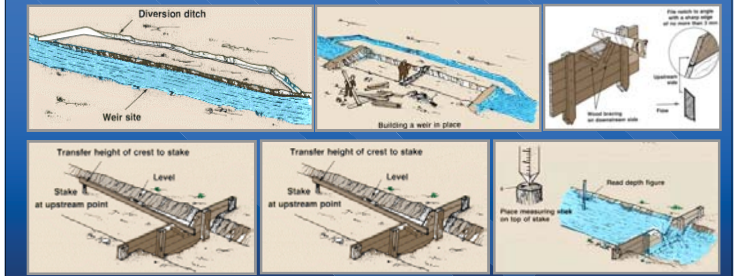




Examples : - if you read h = 10 cm
see the chart for V weir
Flow Q = 4.4 l/s

- if you read h = 25 cm
see the chart for V weir
Flow Q = 43.6 l/s

Other method to build a weir

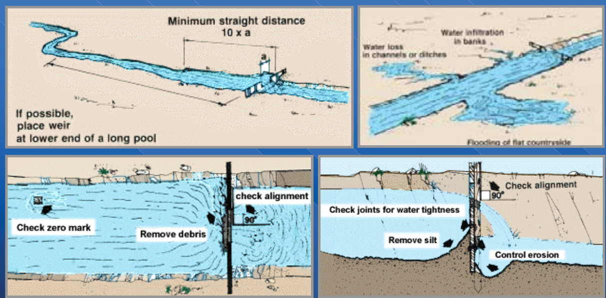


Examples : - if you read h = 15 cm
see the chart for V weir
Flow Q =

- if you read h = 30 cm

Flow Q =

Precautions

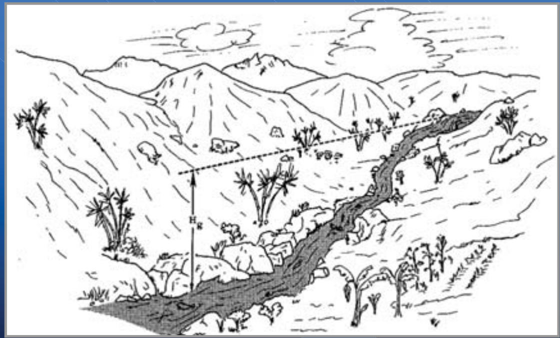


3.3.5 Data collection

Site :	N° :	Type of weir :	Dimensions :
Name of the stream :	Village :	Province :	Year of installation :

Date	Time	Value of h (cm)	Value of Q (l/s) (see the chart)	Name of the technician	Remarks (rainy day...

④ Measurment of head



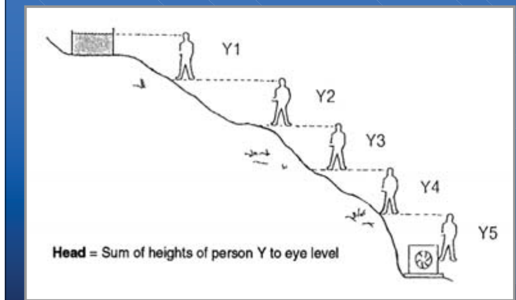
Gross head = difference of altitude between upper and lower level of water

4.1 Altimeter

Measure of the atmospheric pressure : its difference between upper and lower level gives H_g.

Important errors possible if weather conditions varies (temperature, atmospheric pressure…)

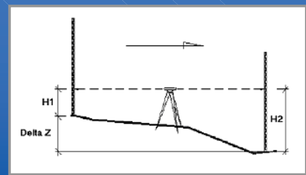
4.2 Clinometer



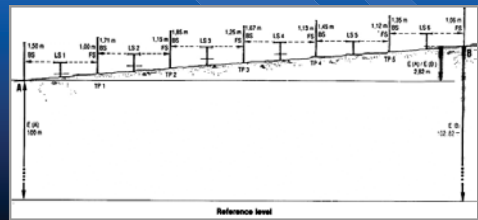
H_g = Y1 + Y2 + Y3 + ... And Y1 = Y2 = Y3 = Y = height of the eye of the person

H_g = n x Y (example : here Hg = 5 x Y)

4.3 Builders level

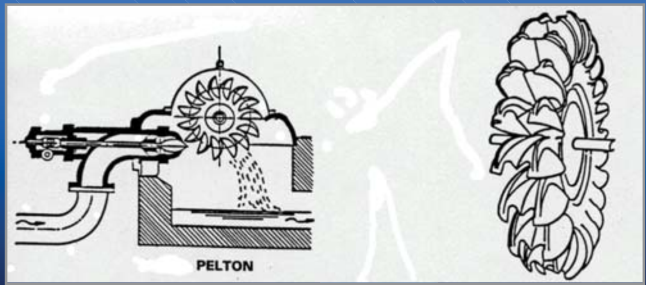


Hg = (H2 - H1) + (H3 - H2) + (H4 - H3) + ...



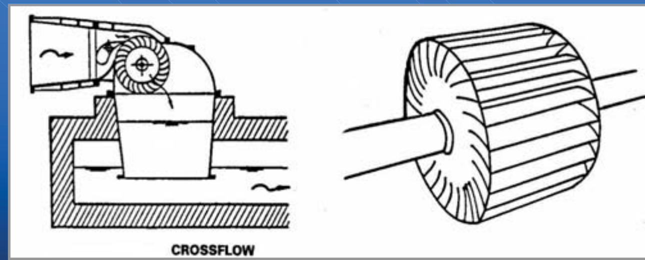
⑤ Turbines

5.1 Pelton



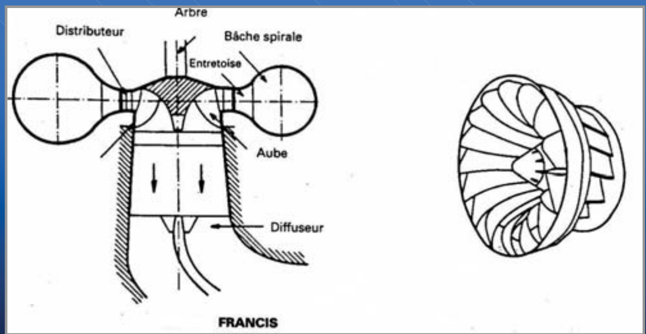
High and medium heads - Low discharges

5.2 Banki (or Crossflow)



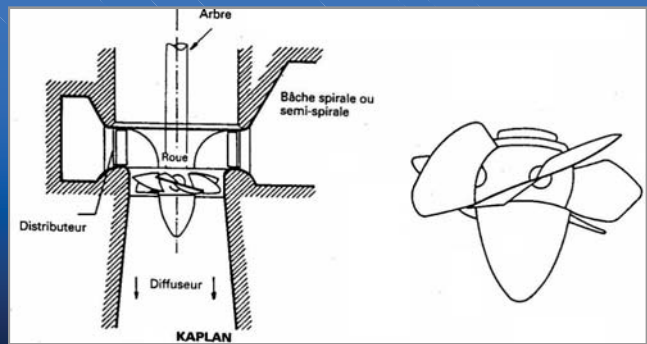
Medium and low heads – Medium and low discharges

5.3 Francis



Medium and low heads – Medium and high discharges

5.4 Kaplan



Low heads – high discharges


Example of projects
⑥ Example of projects
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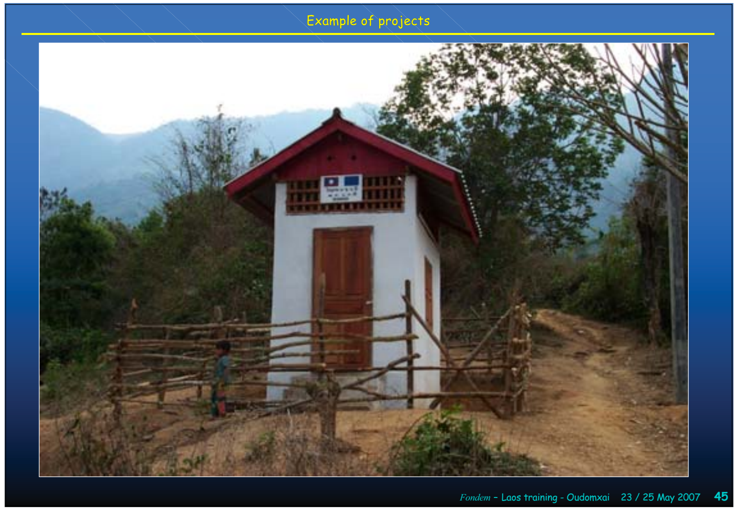
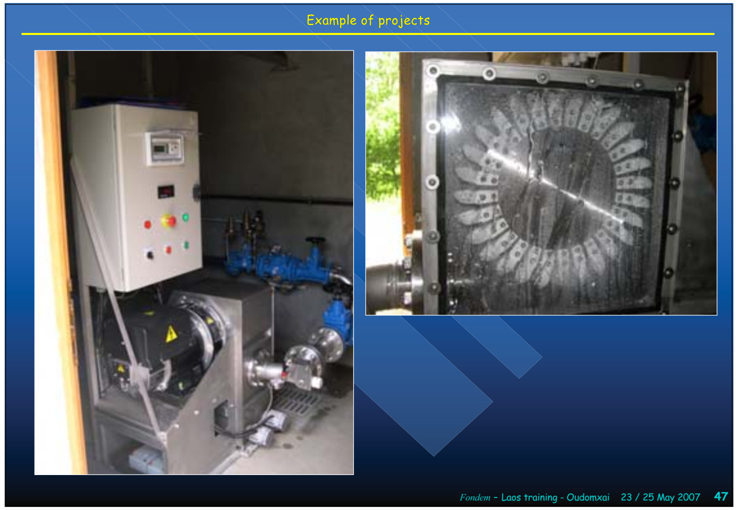
Example of projects
Fondem - Laos training - Oudomxai 23 / 25 May 2007 42


Example of projects
Fondem - Laos training - Oudomxai 23 / 25 May 2007 43


Example of projects
Fondem - Laos training - Oudomxai 23 / 25 May 2007 44


Example of projects
Fondem - Laos training - Oudomxai 23 / 25 May 2007 45


Example of projects
Fondem - Laos training - Oudomxai 23 / 25 May 2007 46


Example of projects
Fondem - Laos training - Oudomxai 23 / 25 May 2007 47


Example of projects
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Example of projects

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