Introduction to Micro-Hydro

Sun, Wind, Water

- Solar Electricity
  - Simple
  - Reliable
  - No moving parts
  - Low maintenance
  - resource is available to most people
- Wind Electricity
  - requires tall towers
  - Requires regular maintenance
  - Complements PV
  - Resource available to few people
- Hydro Electricity
  - Most cost effective
  - reasonable maintenance
  - constant output
  - resource available to fewest people

Hydro Power

- Full Scale Hydro (> 10 MW)
  - Large towns and extensive grid supplies
- Mini-Hydro (300 kW to 10 MW)
- Micro-Hydro (50 W – 300 kW)
  - ideal for remote areas away from the grid
  - group of houses to small factories (mini-grid)
  - AC or DC
  - Cost ranging between $2,000 - $10,000
- Pico-Hydro (< 50 W)

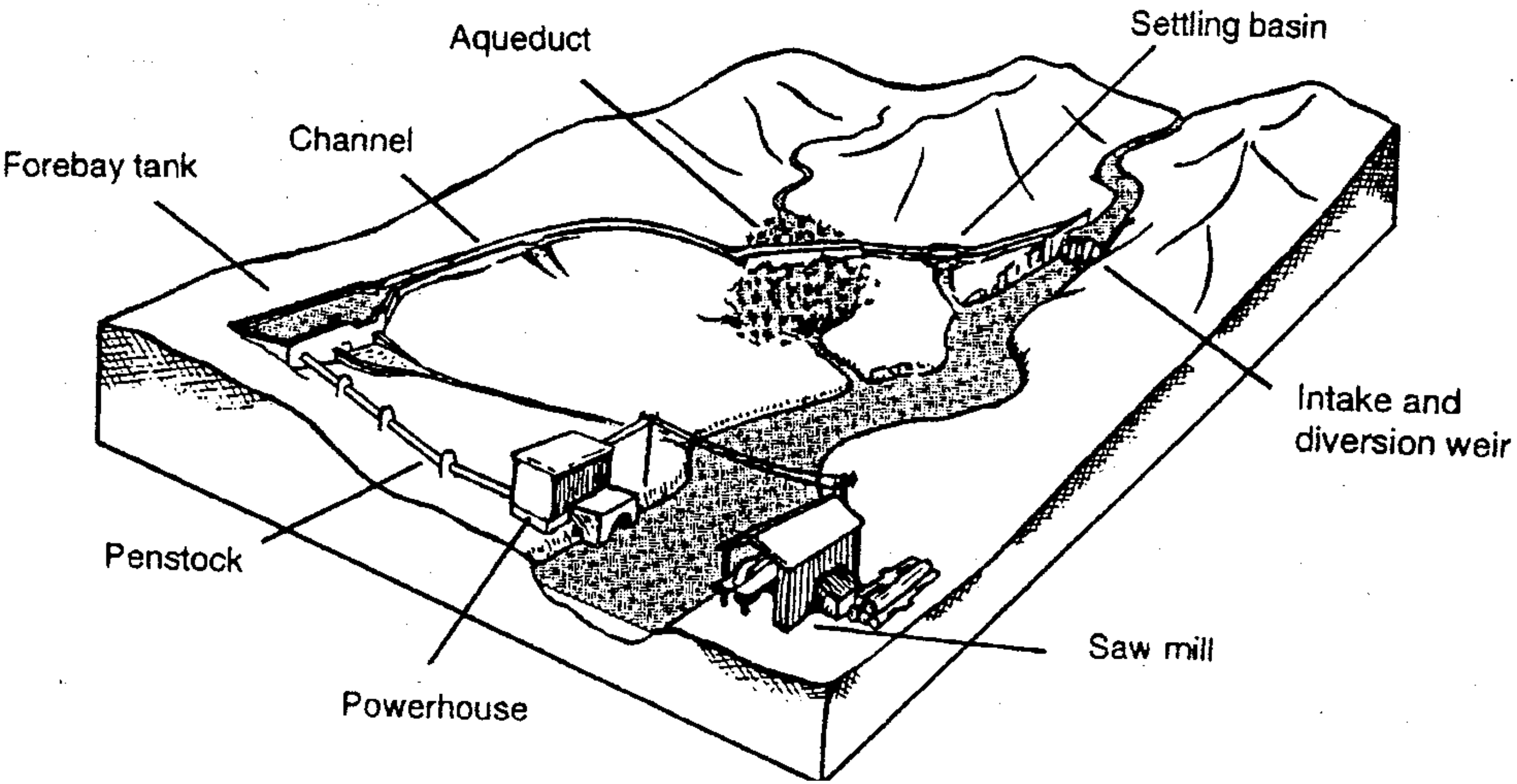
Micro-Hydro

- Advantages
  - uses portion of stream flow
  - environmentally benign
  - AC or DC
  - Flow as low as 5 gpm, head as low as 2 ft
  - No fuel required
  - Available energy is predictable
  - Available to meet continual demand
  - Low maintenance and operating costs
  - Long lasting and reliable
  - Can be connected to the utility grid

Micro-Hydro

- Disadvantages

  - certain flow, head and output characteristics are required
  - very site specific
  - seasonal variations in flow
  - Lack of knowledge and skills to sustain technology
  - Not all sites where there is potential energy available will allow micro-hydro to be developed in a cost effective fashion. Fixed costs


Settling basin
Aqueduct
Channel
Forebay tank
Intake and diversion weir
Penstock
Saw mill
Powerhouse

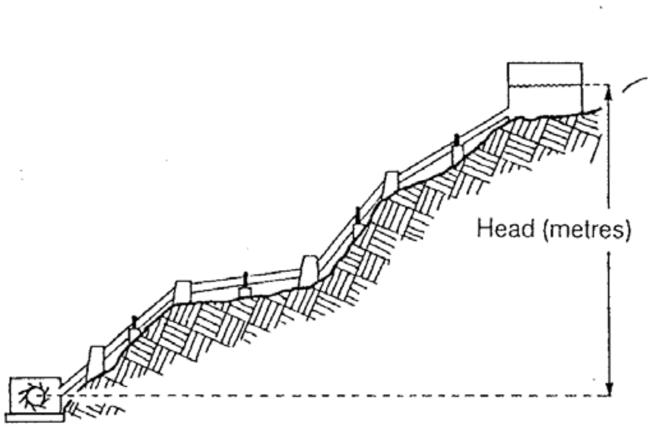
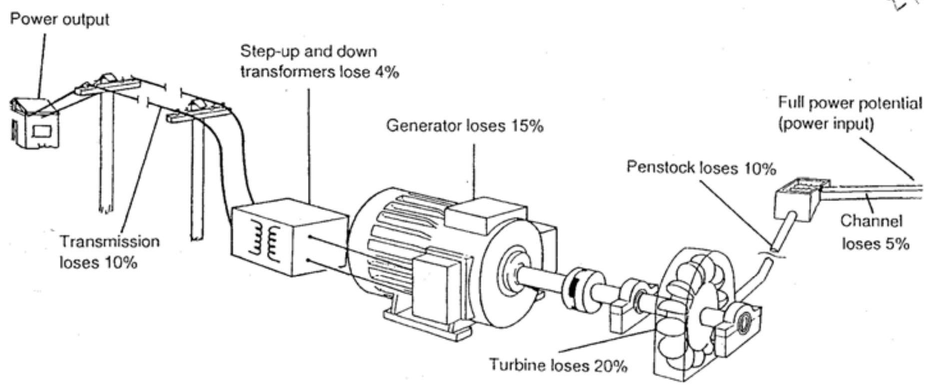


Fig 1.3.1 Head is the vertical height through which the water drops.



$$
\begin{aligned}
\text{Power output} &= e_{\text{civil works}} \times e_{\text{penstock}} \times e_{\text{turbine}} \times e_{\text{generator}} \times e_{\text{line}} \times \text{power input} \\
&= e_o \times \text{power input} \\
&= 0.95 \times 0.9 \times 0.8 \times 0.85 \times 0.96 \times 0.9 \times \text{power input} \\
&= 0.5 \times \text{power input}
\end{aligned}
$$

Energy released by a falling body of water of mass, m, over a height, h (static head)

$E = mgh = \rho Vgh$ (Joules)

Power associated with falling body of water

$P = dE/dt = \rho g h dV/Dt = \rho g h Q$ (Watts)

where Q flow rate in m^3/s entering the turbine

Include friction losses in penstocks and channel, etc..

$P_{net} = e_o P = e_o \rho g h Q$ (Watts)

Since $\rho g = 10\ kN/m^3$ for water, a **quick estimate** of P_{net} can be determined by taking $e_o = 0.5$. Thus,

$P_{net} = e_o P = 0.5 \times 10 \times h \times Q$ (kWatts)

Site Assessment

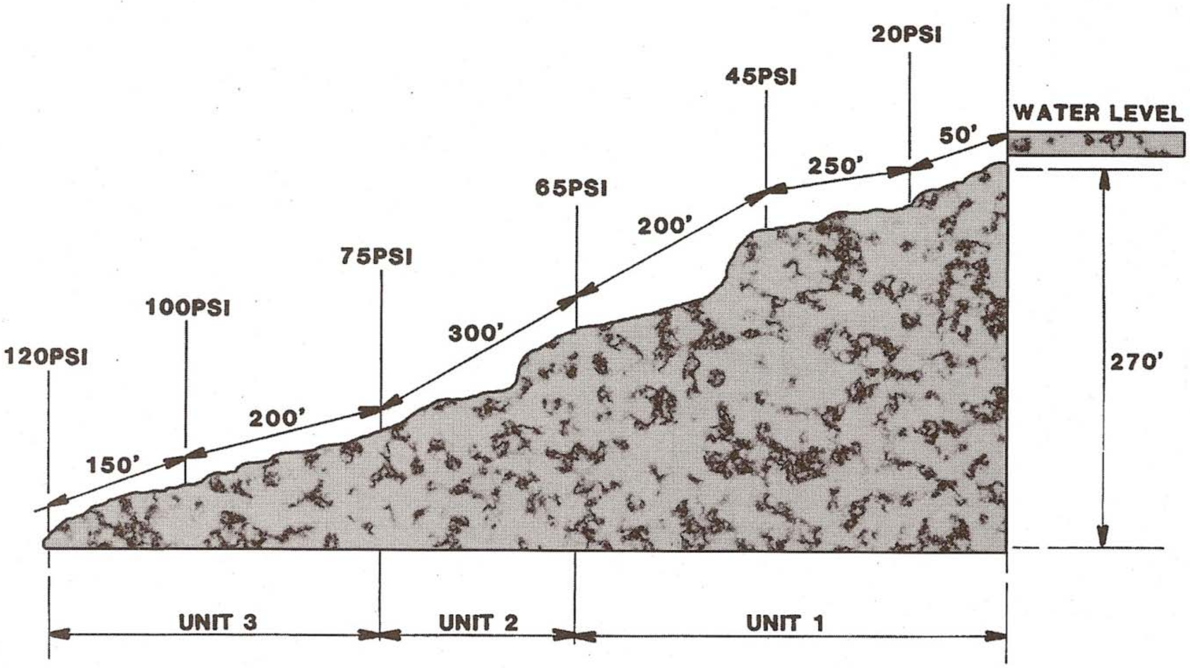
- **Flow**
  - The flow is the quantity of water available to the turbine
  - The design flow will be a percentage of measured stream flow
  - Design flow determines penstock size
  - Design flow determines nozzle size
- **Head**
  - Determines the turbine speed
- **Penstock** length, diameter and material characteristics
- **Intake** and **Power house** locations
- **Geological Study**
- **Loads** – required power, potential power

Measuring Head

Convert head into pressure: 1 psi = 2.31 ft of head for water. An accuracy of ± 3% is required.

- Topographic map
- Hose and Pressure gage
- Water-filled tube
- Level
- Inclinometer, sighting meters
- Altimeters

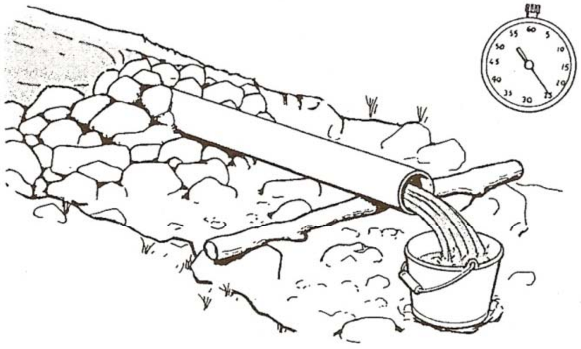
Stream Profile



A stream profile measures the vertical drop and the distance over the ground that your pipeline might take.
Credit: Corri Loschuck.

Measuring Flow

- Bucket Method



- Float Method
- Weir Method
- Salt Dilution Method
- Flow meter

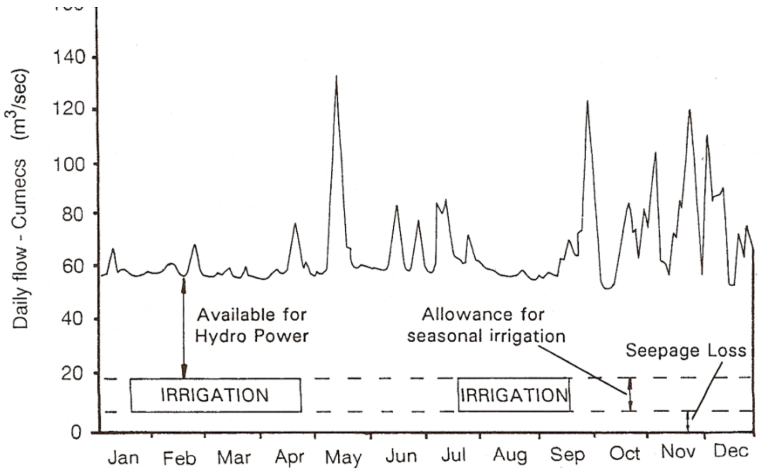
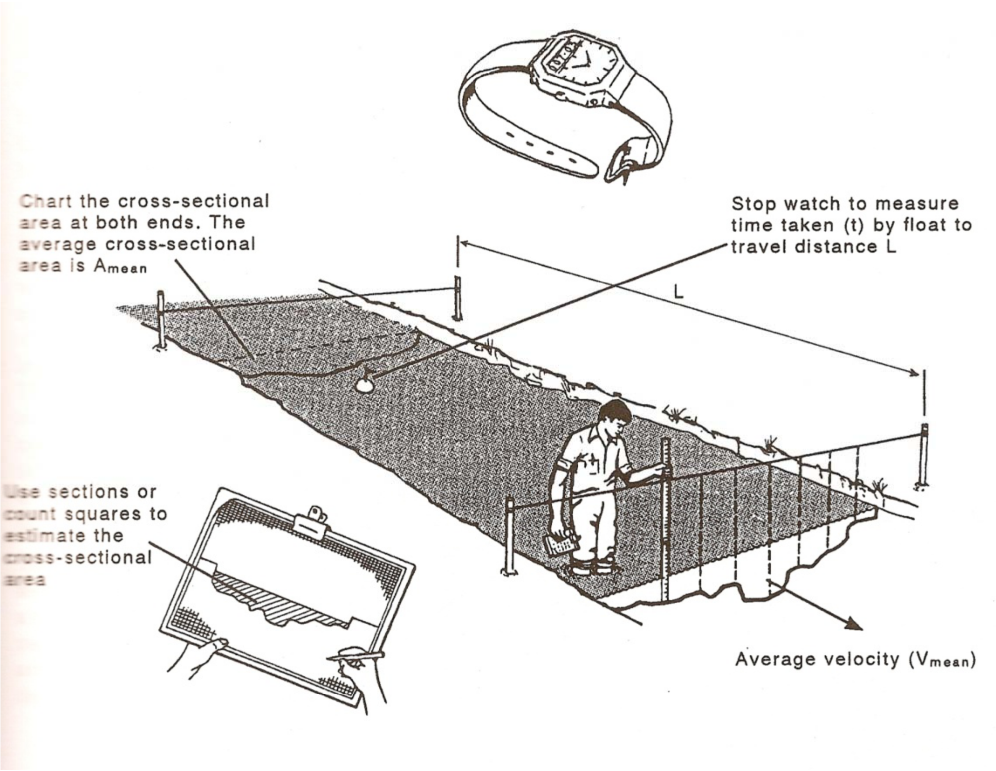


Fig 2.2.11 The annual hydrograph shows flow in a particular river or average flow in all rivers monitored in a region. The irrigation or industrial demand for water can be included on the hydrograph.

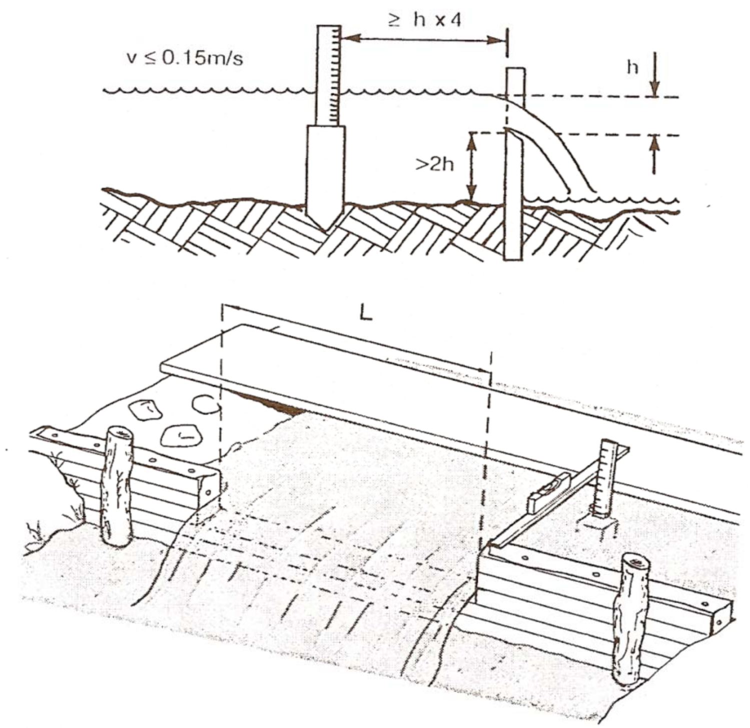
Float Method

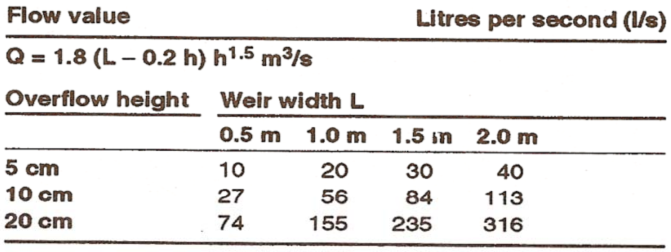


Flow = Area x average velocity

Area = Stream Width x Average Depth

Weir Method



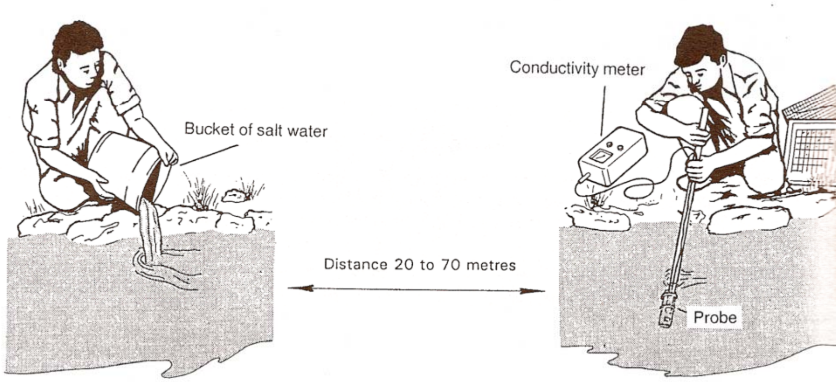


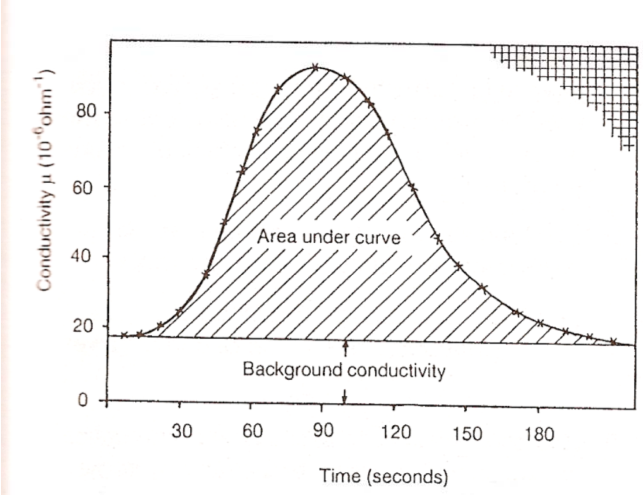
Flow value — **Litres per second (l/s)**

$Q = 1.8\,(L - 0.2\,h)\,h^{1.5}\ m^3/s$

Overflow height	**Weir width L**			
	0.5 m	**1.0 m**	**1.5 m**	**2.0 m**
5 cm	10	20	30	40
10 cm	27	56	84	113
20 cm	74	155	235	316

Salt Dilution Method





$Q = M/kA$

M: mass of salt (g)
A: area under curve ($\Omega^{-1}s$)
k: Conversion factor ($g\Omega/l$)

Geography

- A penstock route must be considered
- Identify possible sites for intake and power house when measuring head
- Note soil/rock types, erosion, geologic conditions
- Consdier future changes in river pattern

Intake and Powerhouse

- Flood conditions must be planned for
- Composition and nature of stream bed determines erosion and future path changes
- Natural features can protect civil works
- Location to avoid competing with other users
- Access for construction and maintenance

Locating the Intake

- Choose a site with a stable streambed (constant flow stream, bedrock, small gradient)
- The inside of bends accumulate sediment
- The outside of bends are subject to erosion and flood damage
- Place intake along straight section

Locating the Powerhouse

- Must be above flood height
- To maximime head, place the turbine belwo the powerhouse floor
- Locate powerhouse on inside of bends
- Use natural features for protection
- Tailrace oriented downstream
- May be some distance from the stream

$P = \rho g h Q$ (Watts)

- SI Units: h (m), Q (m^3/s), $\rho g = 10\ kN/m^3$

  Rule of Thumb

  P (Watts) = F_c x Head (m) x Flow (m^3/s)

  with
  F_c = 4.9 for a 50% overall efficiency
  F_c = 3.9 for a 40% overall efficiency

$P = \rho g h Q$ (Watts)

- Imperial Units: h (ft), Q (ft^3/min), ρg = 62.4 $lbft^3$

  P (Watts) = Head (ft) x Flow (ft^3/min)/709

  Rule of Thumb

  P (Watts) = Head (ft) x Flow (gpm)/ F_c

  with
  F_c = 9 for a 59% overall efficiency
  F_c = 10 for a 53% overall efficiency
  F_c = 13 for a 41% overall efficiency

Civil Works

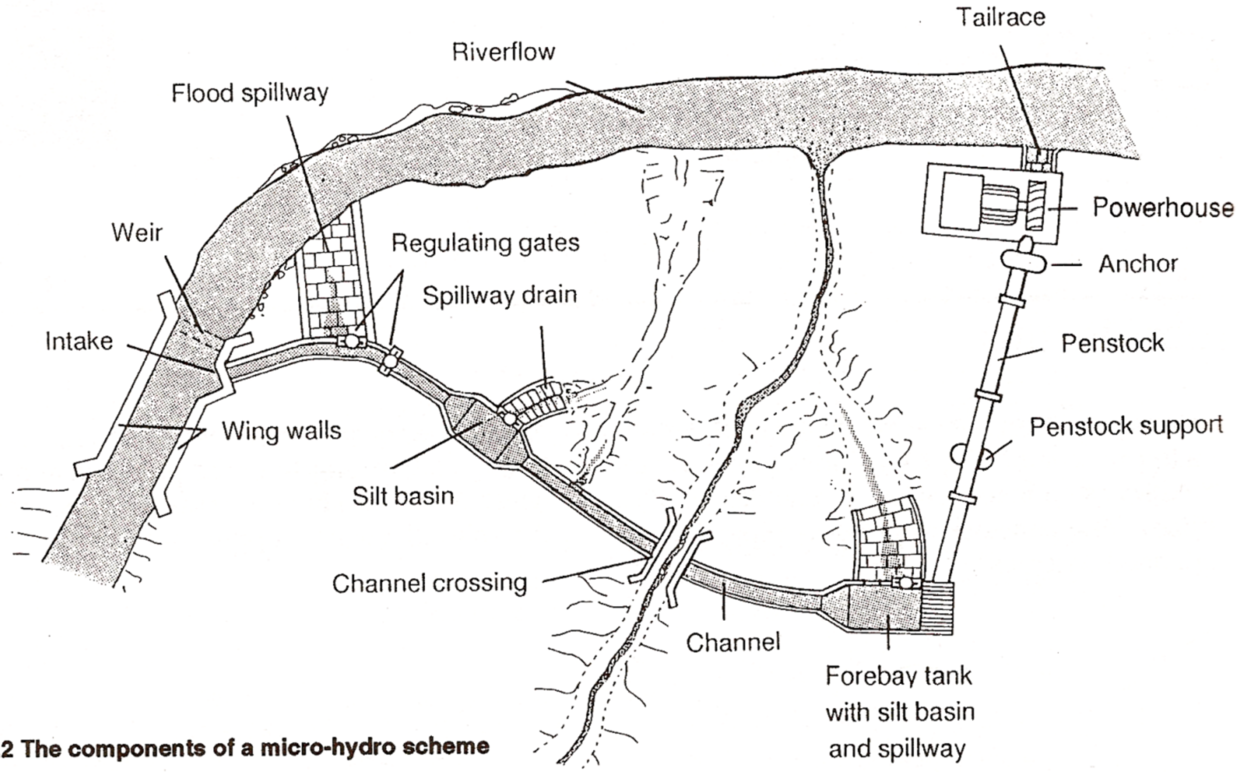
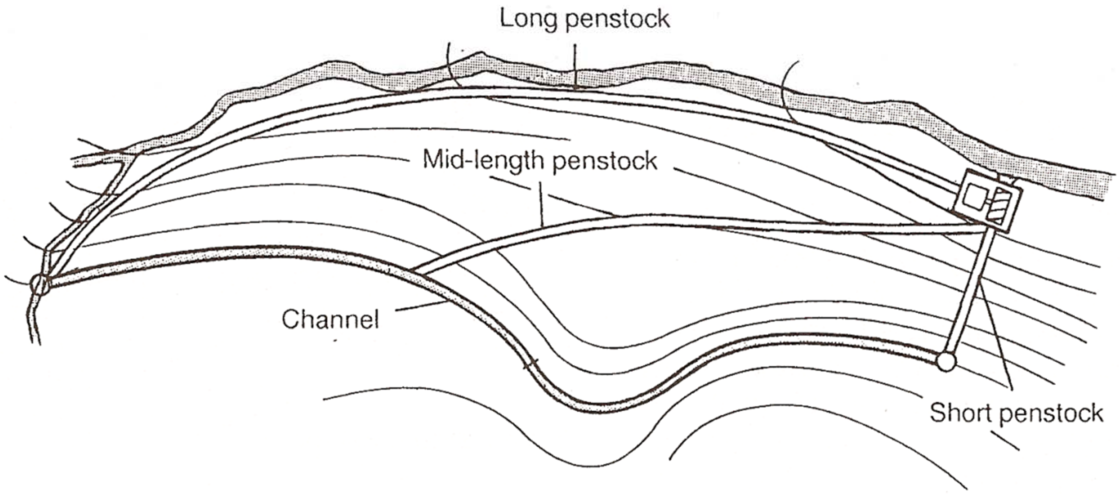
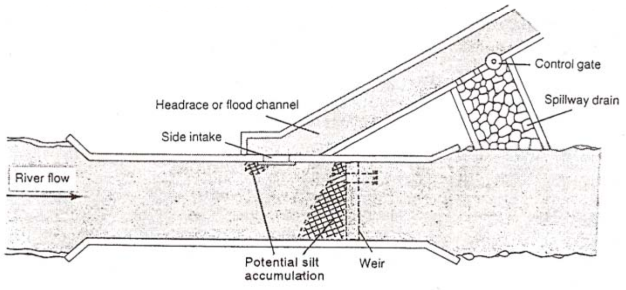


Fig 3.1.2 The components of a micro-hydro scheme

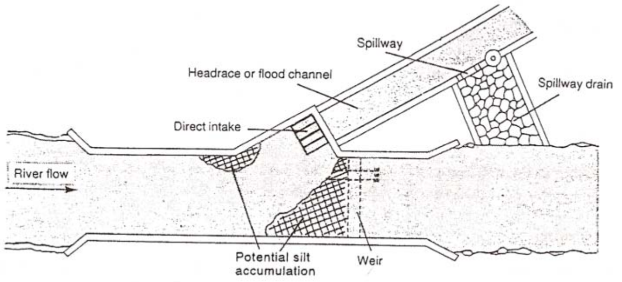
System Layout



Intake structures



b Sediment build-up downstream of this side intake can be removed manually instead during low flow periods when access is feasible. In many sites the side intake will remain clear of blockage by acting in the same way as a direct intake, that is, sucking all sediments through to the silt basin.



c A direct intake will automatically stay clear of blockage by encouraging the debris to flow through the intake rather than collect at the intake mouth.

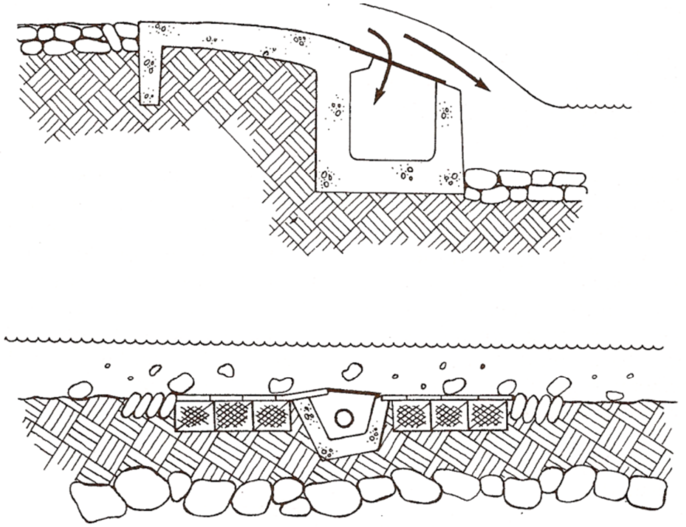


Fig 3.3.12 Trench intake. Fast flowing mountain streams are often laden with excessive silt loads and larger debris such as stones, grasses and branches. The intake rack shown here allows these objects to flow over it, the water velocity itself acting to keep the rack clean. Any debris which collects on the rack during low flow periods will be washed off in high flow periods. If such intakes are designed carefully, with correct mesh size, slope angle, evenness of slope, width, etc, they can operate in difficult conditions for years on end without attention.

Penstocks

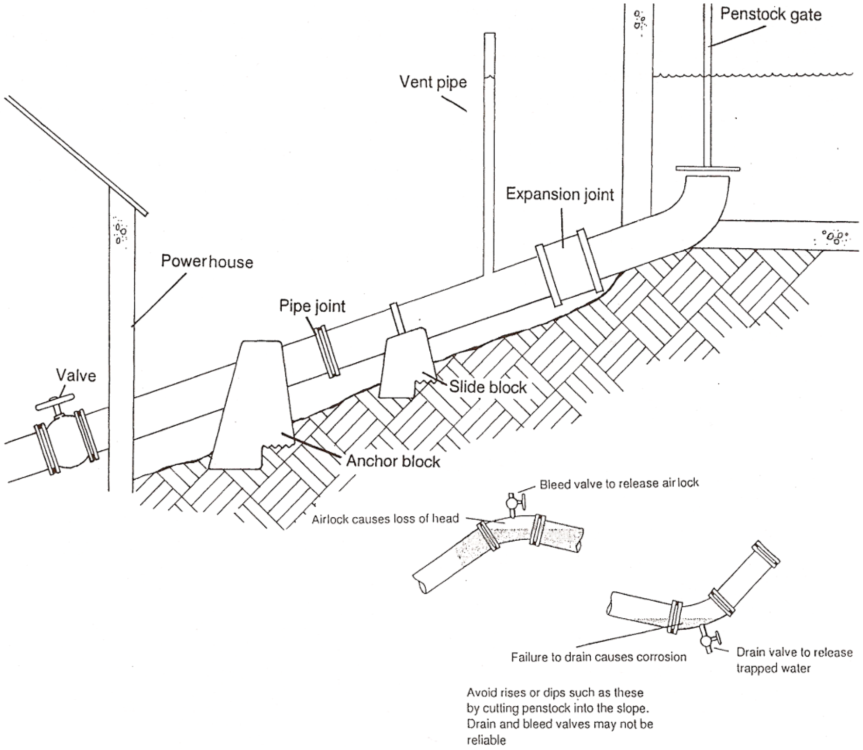
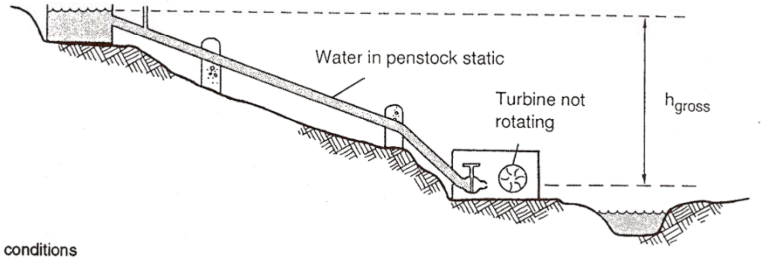
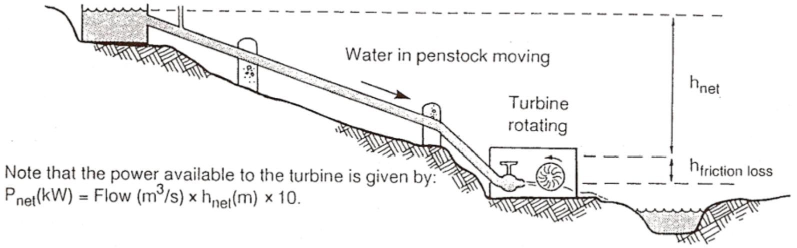


Fig 3.7.1 Components of penstock assembly. Penstocks must be laid in such a way as to prevent airlocks forming inside them. These airlocks act as obstructions in the penstock and cause a pressure drop across them. If a danger of airlocks exists because the ground rises and the penstock cannot be cut in, an air bleed valve must be fitted as shown. Similarly water drain valves may be needed. Always avoid the use of valves since after some years they can become unreliable.

Penstocks



a Static conditions



Note that the power available to the turbine is given by:
$P_{net}(kW) = \text{Flow}\ (m^3/s) \times h_{net}(m) \times 10$.

b Normal operating conditions