10 FLOW MANAGEMENT

10.1 The Intake

The intake of pico hydro schemes can be a simple and inexpensive arrangement. Non-permanent solutions are favoured over elaborate weirs due to their lower cost and greater flexibility. The effect of floods must always be considered when designing the intake.

Pipe intake – for ample flows

Boulders used to divert part of a river flow into a simple canal or submerged length of pipe as shown in Figure 10-1 are often sufficient. With such simple and inexpensive solutions, storm damage can be repaired with local materials. Though careful construction is required to prevent frequent repair being necessary. The pipe must sometimes be quite long to ensure that the entrance is higher up than the exit to the canal. Flexible pipe is easier to use than rigid pipe and it should be anchored in the flow with large stones. The entrance should be raised slightly off the bed of the river or stream. This will prevent silt or debris from blocking the entrance.

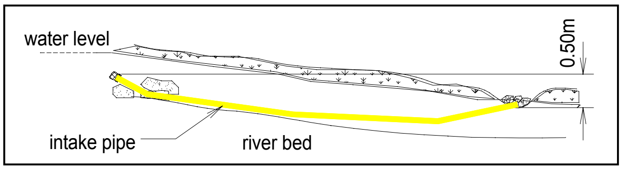


Figure 10-1 The simplest intake design is a pipe anchored in the flow

Weir intake – for low flow sites

A small weir can be constructed out of concrete to ensure that all the available water is diverted during the dry season. This may be a practical solution at some sites. The flexible pipe, which removes the water, is set into the weir. The foundations and the sides of the weir should be joined to solid rock to prevent water from leaking round and eventually undermining the structure.

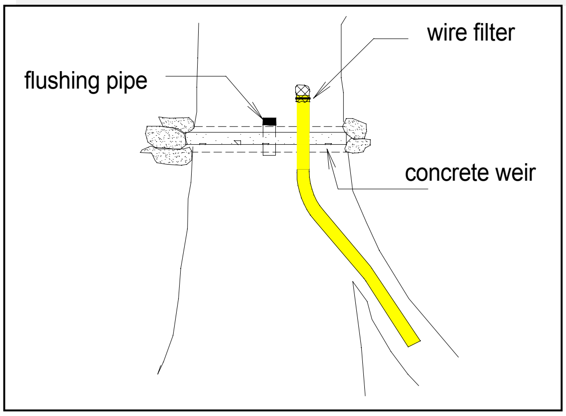


Figure 10-2 An intake using a small concrete weir is useful if the flow is very low during the dry season

Construction of Small Concrete Weirs

The proportions for small concrete or masonry weirs should follow approximately those given in Figure 10-3. Often large stones cemented together can be used for the construction of the weir. The strength of the structure is significantly improved by using a gabion. This is a wire cage that holds the structure together. It is particularly useful where strong flows are expected. The wire mesh is usually made from 2 or 3mm diameter wire with a mesh size of 50mm to 100mm.

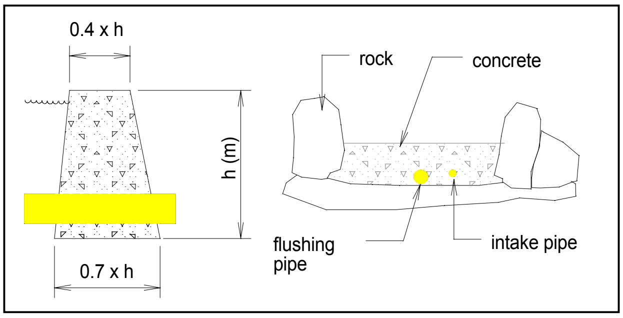


Figure 10-3 The construction of a weir should follow the above proportions.

Figure 10-4 A concrete weir can be used to form a small reservoir (Nepal).

Filters

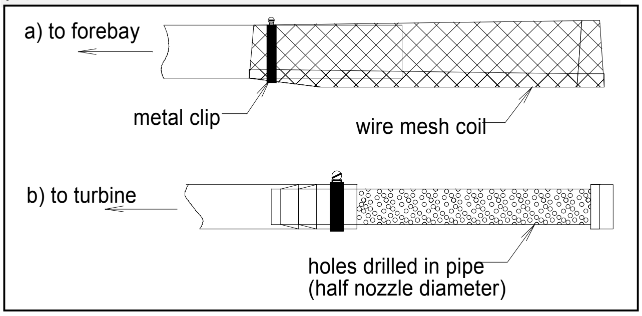


Figure 10-5 Filter designs for a) intake and b) penstock

Filters are required to prevent pipes that are used for pico hydro installations from becoming blocked with materials such as silt, wood and leaves. There are two situations where a filter is required:

1. the intake pipe leading to a canal, forebay or reservoir as illustrated above.
2. the entrance to the penstock pipe (see Section 11).

For the first case, the size of the holes in the filter is not important. The only thing to consider is how to prevent the pipe from becoming blocked. One method of building a suitable filter is to use a tube of wire mesh. The tube can be fixed to the pipe with a metal clamp such as a jubilee clip.

In the second situation, when the filter is positioned at the entrance to the penstock, it is important that the holes in the filter are smaller than the nozzle at the other end. Actually, they should be about half the diameter of the nozzle to be sure that any particles that enter the pipe can not cause a blockage at the other end. (If the nozzle becomes blocked then there is a danger that the penstock will burst due to the sudden pressure.) A filter with small holes can be made out of a piece of plastic or metal pipe that is capped at one end. Lots of holes are made using a correctly sized drill. It is important that the total area of the number of holes drilled is more than the area of the pipe to make sure that enough water can be drawn in. The filter is threaded or clamped over the pipe to ensure a tight seal.

10.2 Canals

Figure 10-6 Canal installed in a difficult location supplying a small hydro scheme for local electrification (Peru)

A canal can be a low cost method of conveying water from a source some distance to a more favourable intake position. For some sites, this can really improve the economic viability by reducing the length of penstock and cable required. At other sites a canal is an expensive addition and can often require regular maintenance due to leaks, soil erosion and landslides.

Using a canal and deciding on the route it should take, are decisions that must be considered carefully. The following factors are important:

- Local experience and history with building and managing similar water systems such as irrigation canals.
- The availability of cheap / free labour to dig and maintain the canal
- Soil type, lining requirements and cost of transporting materials such as cement.
- The cost of other options such as a longer penstock / longer distribution cable compared to the cost of a canal. The use of low-pressure pipe to convey water to the intake may also be a lower cost alternative.
- Could a new canal serve a dual purpose, irrigating land during the dry season in addition to supplying the turbine?
- Are there any existing (or abandoned) irrigation canals that could be directly used or improved or extended if necessary?

If the canal is lined with concrete or stones and cement, then its strength and reliability will be improved. However, such a lining will increase the cost considerably. In many remote areas this will not be practical because of the difficulty of transporting building materials. Lining a canal also increases its efficiency. Water can travel at higher speed without causing the sides to erode so for a particular volume flow rate, the dimensions can be reduced (see Table 10-1).

Canal design

The flow of water in a canal depends on:

- The speed or velocity of the water
- The cross-sectional area of water

The equation for flow rate is

$$Q = vA$$

where:
Q = flow rate (m^3/s)
(multiply by 1000 for flow in litres per second)
v = velocity (m/s)
A = Cross-sectional area of water (m^2)

1. The **velocity** of water flowing in a canal (v) depends on the slope of the canal and the 'roughness' of the material which has been used to line it.

There is an **upper limit** to the velocity for different building materials. Above this value the sides can quickly become eroded.

Canal material	**Max. velocity to avoid erosion in shallow canals**
Sandy soil	0.4 m/s
Clay soil	0.6 m/s
Concrete / masonry	1.5 m/s

Table 10-1 Velocity limits for shallow canals (<0.3m deep)

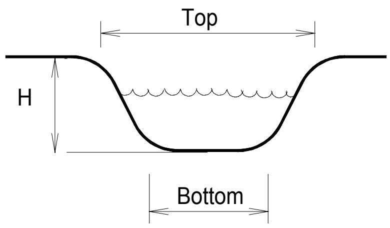
From Table 10-1 it is apparent that for earth lined canals, the maximum velocity of the water is much less than for those with a durable lining. If the water contains silt then there is also a **lower limit** to the velocity of 0.3 m/s. This is to prevent the silt being deposited and blocking the canal. If the water is clear then the lower limit is not important. A low velocity means that the drop required over the length of the canal is small. For this reason, the canal dimensions given in Table 10-2 have been calculated using a design velocity of 0.3 m/s. This allows the head loss in the canal to be reduced and maximises the head available for the penstock.

In the following examples of canal dimensions a roughness of 0.07 has been assumed. This is suitable for a shallow canal with some vegetation. The roots of vegetation growing along the canal cause some friction but they are useful because they support the sides.

2. Design of canal cross-sectional area (A)

Naturally, the canal cross-sectional area must be bigger than the cross-sectional area of water needed to give the flow required. The extra height (called the freeboard allowance) is usually about 30%. This reduces the risk of the canal walls being damaged by overfilling.

The sides of an **earth canal** should slope outwards. This reduces the risk of the walls collapsing due to the erosion caused by the flow of water. It is possible to construct a canal with vertical walls if it is strengthened by lining the sides with stones and cement or with concrete. In this case the top and bottom dimensions are the same. However, masonry and concrete linings are expensive and are rarely cost-effective for pico hydro schemes.



In order to simplify the process of canal design, suitable dimensions for the cross sectional area are given for different flow rates in the following table. The head loss is the drop for 100m of canal. If the required length of canal is 200m then multiply the head loss by 2 and build with this drop over its length.

	Canal lining and minimum dimensions		
10 l/s	Sandy soil	Clay soil	Concrete/ masonry
Height H	13 cm	15 cm	15 cm
Top Width	59 cm	44 cm	29 cm
Bottom Width	6 cm	13 cm	29 cm
Head Loss (100m length)	1.6 m	1.3 m	1.4 m
20 l/s			
Height H	19 cm	22 cm	21 cm
Top	84 cm	62 cm	42 cm
Bottom	9 cm	18 cm	42 cm
Head Loss (100m length)	1.0 m	0.8 m	0.9 m
30 l/s			
Height H	23 cm	27 cm	25 cm
Top	103 cm	75 cm	51 cm
Bottom	11cm	22 cm	51 cm
Head Loss (100m length)	0.8 m	0.6 m	0.7m

Table 10-2 Suitable minimum canal dimensions for different flow rates and lining materials

Seepage

Earth lined canals loose a significant proportion of the water due to seepage. In sandy soil areas expect at least 5% to be lost through seepage per 100m (e.g. 0.5 l/s for a flow rate of 10 l/s)
Providing additional water is available, it is worth sizing the canal for a larger flow rate than that required by the turbine. Assume that an additional 10%-20% will be required. This will allow for some loss through small leaks as well as seepage. Sometimes water in the canal will also be used for a number of purposes such as irrigation or domestic supply. The requirements should be taken into consideration at the design stage.

Canal Construction.

The route taken by the canal must be carefully selected. If possible the following areas should be avoided:

- Excessively porous ground
- Rocky areas which prevent excavation
- Steep and unstable sections

Sealing the canal with clay or concrete in porous areas may be an option but large rocky outcrops should be avoided. Steep sections and storm gullies are also difficult but in many rural areas, ingenious solutions have been found. Canals have, been successfully constructed in some very difficult locations (see Figure 10-6 and Figure 10-9). These require careful planning, local motivation and persistence but not necessarily great expense.

Figure 10-7 A length of pipe can be used to bridge a difficult gulley with a small canal. The pipe is secured with rocks on either side.

When crossing a storm gulley, for example, it is particularly important to allow adequate drainage for rainwater that could otherwise destroy the sides of an earth canal. Short lengths of pipe (Figure 10-7) or small wooden aqueducts (Figure 10-8) can sometimes be used to bridge difficult sections of the route.

Figure 10-8 A wooden aqueduct can be used to transport water in the canal across uneven ground

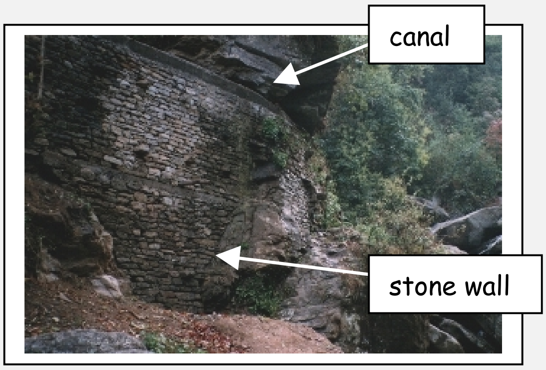


Figure 10-9 and Figure 10-10 show a raised canal that runs on a narrow ledge underneath a vertical rock face. The canal has a masonry lining and is supported by a high stone wall underneath.

Low Pressure Pipe

An alternative method to convey water to the intake is to use low-pressure, plastic pipe. This is available in some countries as drainage pipe. Low-pressure pipe is cheaper than penstock pipe because the walls are thinner. It will often be a cheaper alternative than a concrete lined canal.

Figure 10-11 Land drainage pipe

Some consideration needs to be given to the best diameter and the slope of the pipe since this will affect the flow rate and head loss. See Section 11.

10.3 Forebay Tanks

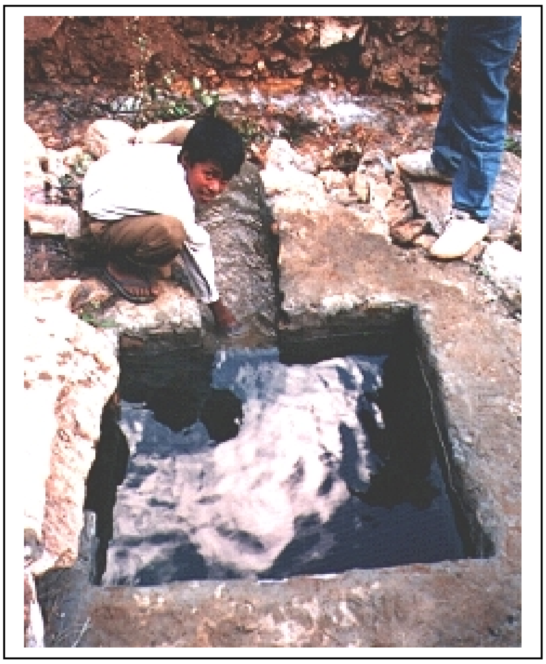


Figure 10-12 A small forebay is suitable where flow is sufficient throughout the year

The forebay tank provides a sufficient depth of water to ensure that the top of the penstock is always covered. In some cases the penstock is extended to the intake and then no forebay is required. A forebay is required where a canal is used or if water from more than one source is collected.

The design of the forebay may vary depending on factors such as:

- accessibility of location
- availability of building materials
- type of ground and soil
- cost of labour and local skills

However, it is highly recommended that all designs include an overflow facility and some means of draining to allow the tank to be cleaned.

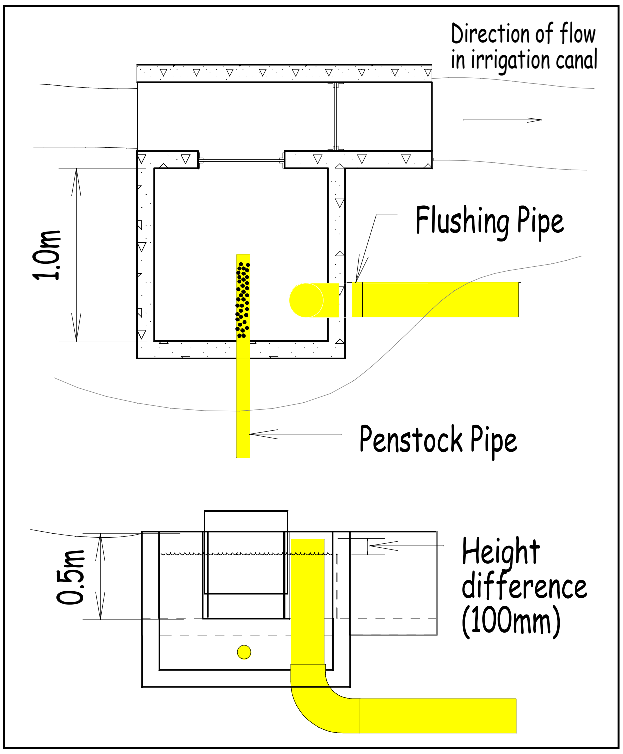


Figure 10-13 Suggested design of forebay tank fed from an irrigation canal.

Depth of Water

The depth of water in the forebay tank should be sufficient to cover the penstock by 4 times its diameter. The penstock should also be approximately one diameter clear of the bottom.

Example

What depth should the overflow in the forebay be set at if the penstock is 75mm in diameter?

Answer

Depth above penstock = 4x75 = 300mm

Depth below penstock = 75mm

Penstock diameter = 75mm

Therefore approximate depth of overflow

= 300+75+75 = **450mm**

Silt

Since the water in the forebay tank is slow moving, silt falls to the bottom where it forms a thick layer of mud. This can block the penstock if it is allowed to become too deep. Larger hydro schemes often have desilting basins to remove the silt. This is rarely necessary for pico hydro providing that a sluice gate or a flushing pipe is included (see Figure 10-13). This makes the job of cleaning out the silt much easier.

Overflow

If the forebay becomes full, the water must escape without causing damage. The overflow can be a notch or channel cut into the lowest wall of the forebay (see Figure 10-15). An alternative method is to use a pipe that combines the overflow and the flushing facility. This is illustrated in Figure 10-13. The vertical pipe can be removed from the elbow to flush out the tank. This example shows a forebay that is fed by an irrigation canal although the water could equally well be provided by a low-pressure pipe. The flow can be diverted into the forebay when required. Otherwise the water always continues to flow down the canal.

Whichever method is used, the overflowing water should be directed away from the forebay, preferably into another stream or a ditch.

Forebay Construction

Providing that labour is available a small forebay, using stones and clay as a seal, is not expensive to construct. The intake to the penstock is easier to secure if stones are used in the construction of the walls. If the forebay frequently overflows then the clay will be quickly eroded and will require regular repair.

Cement and stones or concrete are used to construct forebays with a longer life and greater erosion resistance. A suitable method for cementing stones or bricks to line a forebay, canal or reservoir is shown in Figure 10-14

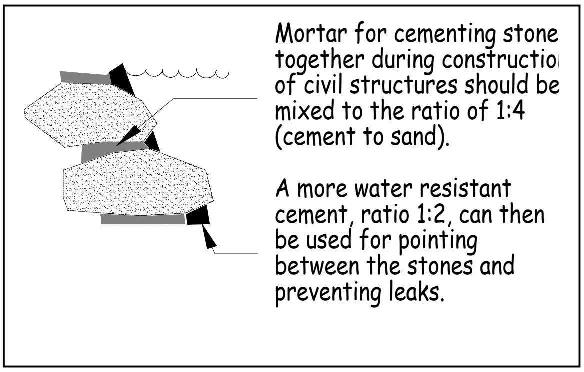


Figure 10-14 Masonry techniques for pico hydro civil structures

Figure 10-15 Construction of stone forebay (Kushadevi, Nepal)

Figure 10-16 The flow of water into the forebay is controlled by a sluice gate. An overflow is cut into the wall on the downhill side so that excess water is returned to the stream without undermining the masonry. A flushing pipe, sealed with a wooden bung has been incorporated at the lowest part of the tank.

10.4 Reservoirs

Figure 10-17 A small reservoir provides low-cost energy storage which can be useful during the dry season. (Sankhuwa Sava, Eastern Nepal)

The forebay can be enlarged to form a small reservoir if the flow during the dry season is insufficient to operate the turbine continuously.

For example, water is stored up during the day and night when the turbine is not in constant use and then released to provide power for evening lighting.

Water storage can add a useful degree of flexibility and security to the scheme if either of the following are true:

1) The water will be collected from more than one source, some of which is likely to be intermittent.

2) The water is or will soon be used for other purposes apart from hydro-power, such as irrigation.

The storage requirements are easily calculated if the flow required by the turbine and the lowest expected flow into the reservoir are known. The manufacturer should provide information about the flow requirements of the turbine. The reservoir should be sized according to the minimum expected flow. This must be measured during the driest part of the year using one of the techniques described in Section 0. Alternatively it must be estimated by relying on local knowledge.

Example Storage Capacity of a Reservoir

A 1.5kW turbine and generator have been selected for the site in Western Nepal described in the example on page 7-1. The head has been measured at the site and found to be 70 meters after friction losses in the penstock have been taken into account.

In order to generate this power with this head the turbine manufacturer recommends a flow of 5 litres per second. Measurements of the flow in the nearest stream to the village have been taken during the driest part of the year, after several weeks of no rain and found to be only 2 litres per second. This is also the lowest flow that has been observed in the stream according to local knowledge (thought to be reliable as far back as 10 years). During the rest of the year, however, a flow exceeding 5 l/s is available. Storage will be required for the dry periods to enable the scheme to supply electricity to the village for 5 hours of lighting in the evenings and for two hours of mechanical power to drive a saw in the workshop during the mornings.

How big does the reservoir need to be?

Flow in during driest period = 2 l/s
Flow into penstock = 5 l/s
Maximum period of operation = 5 hrs
Shortfall in supply during this period
= 5 - 2 = 3 litres per second

The reservoir must have enough capacity to supply an extra 3 litres per second during the period of operation.
Volume of water required as storage:

5hrs = 5 x 60 x 60
= 18000 seconds
Volume = 18000 s x 3 litres per second
= 54000 litres or = 54 m^3
(1 cubic metre = 1000 litres)

What dimensions should the reservoir be in order to store 54 m^3?

The reservoir will be allowed to fill up overnight so that the saw can be driven in the morning.

The ground is rocky at the proposed site of the reservoir and it is unfeasible to dig a reservoir that is more than 1.5 m deep.
Suitable dimensions would therefore be 1.5 metres depth x 6 meters width x 6 metres length.
1.5 x 6 x 6 = 54 m^3

An alternative solution for this village is to supply the reservoir with water from a spring that is some distance away. They can transport approximately 1 litre per second though a narrow but inexpensive pipe from the second source during the driest period. What is the new storage capacity required?

[Answer = 36 m^3 so suitable dimensions would be 1.5m x 6m x 4m]