Important to always include tailrace to reduce environmental impact due to erosion.

Story - 3" pipe from US does not fit 3" pipe in Mexico

Weir
- Back pressure
- Control flow

Gate
- Need to be able to turn it off for example for maintenance

Channel
- Can be made of pipe, or erodible open channel
  + easier to build, and fix
  - debris added
  - crack in contract

Settling Pool
- Large area for particles to settle out

Holding tank
- Gain head to drop water

Turbine
- Generates electrically by spinning wires w/magnets
  - in USA - always (almost)
- Mechanical energy → run a mill

El Leon: Microhydro example
- 100 families have their homes powered by microhydro.

Channel to a self cleaning filter which is still cleared once a week.

Everyone works 1hr/month on the system
Everyone works 1hr/mi
Penstock goes to powerhouse. Tail race goes to agriculture.
About 80 meters of head.

Types of systems

Pelton wheels - 2 inch diameter > greater than 10 ft.
Can change the number of nozzles spraying on the wheel. Their efficiency is aimed 65%.
The water leaving the generator still has energy so the tail race needs to protect the environment from unnecessary erosion.

Location

Important balance between efficiency and cost. There is loss due to friction in pipes and transmission versus the cost of pipes & transmission lines.

Environmental Impacts

Can design system so there are negative impacts.
- Avoid black pipes or bury pipes
  + Protect pipe
  - hard to find the leak
  use sand pipes to monitor pressure.

Small N. Calif. systems

Intakes
  - need low sediment if no settling or well "sand blast" rotation wheel generator.
  - pipes alone ground
  + easy to fix leak
  - easy to break
  - weak
Calculations

Mass Power is a function of flow rate (Q) & head (H)

\[ P = \frac{Q \cdot H \cdot e}{K} \]

- **K**: Conversion factor for (flow)(height) = power units
- **e**: Efficiency of turning
- **Qmax**: Max take (GPM)
- **Pmax**: Power (KW)
- **H max**: Max accessible height W/out lift (ft)
- **100%**: Efficiency (impossible)
- **e=1**: Efficiency (impossible)

IDEA: Have student feel the power of water by changing flow and head.

The higher you head then the smaller the pipe you can use because your pipe must accomodate Q = the flow.

Each of these (G & H = e) are linear in real life.

Calculations after field work

Flow rate is the same along the stream as long there are no tributaries or diversions.

- Dams of two people walking at
  1) same speed
  2) behind slower
  3) in front slower

This is a reasonable assumption.

...
This would mean a group. Imagine once every mung
was meeting (not every 98 & on). So lengthwise
water flows at same rate.

But in a cross-section the velocity of the
water varied due to
edge effects. Water flows slower on
gles—the nearer the edge—the slower
the water flows.

\[
Q_{\text{max}} = 1000 \text{ gallons/min (GPM)}
\]

\[
H_{\text{max}} = 15 \text{ feet (ft)}
\]

\[
R_{\text{un}} = 150 \text{ ft}
\]

\[
C_{\text{turbine}} = 0.88
\]

This estimate is the flow for the entire creek.

\[
P_{\text{max}_{10\%}} = \frac{Q_{\text{max}}(10\%)(H_{\text{max}})}{K} = \frac{(100 \text{ GPM})(15 \text{ ft})}{5310 \frac{\text{gal}}{(\text{min})(\text{KWW})}} = 6.282 \text{ KW}
\]

\[
P_{\text{net}_{10\%}} = \frac{Q_{\text{net}}(10\%)}{K}
\]

\[
P_{\text{net}_{10\%}} = \frac{Q_{\text{net}}(10\%)}{K}
\]

We know \( Q_{\text{net}} = Q_{\text{max}}(10\%) = 100 \text{ GPM} \)

To find \( H_{\text{net}} \) we need to figure out the friction losses
using tables.

Table 1 tells how much head is lost due to size of pipe
Table 2 tells how much head is lost due to a fitting

E.g. 45° elbow given 1 inch pipe is equivalent to
1 & 1/2 straight pipe.
Back to our imaginary system assume 3" pipe

<table>
<thead>
<tr>
<th>City</th>
<th>fitting</th>
<th>Equivalent length</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>90°</td>
<td>7.9</td>
<td>15.8</td>
</tr>
<tr>
<td>1</td>
<td>45°</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>gate valve top &amp; bottom</td>
<td>6.2</td>
<td>6.0</td>
</tr>
<tr>
<td>0</td>
<td>union</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>15</td>
<td>adapters</td>
<td>0.5</td>
<td>97.5</td>
</tr>
<tr>
<td>150</td>
<td>pipe</td>
<td>1.0</td>
<td>150</td>
</tr>
</tbody>
</table>

286 ft

We started w/ 150 ft but we have equivalent friction loss of 286 ft

PFHL (Pressure Foot Head Loss)
For 3" pipe is
\[
\frac{2.3 \text{ ft/1000 ft pipe}}{100 \text{ ft pipe}}
\]

\[
\text{Head loss} = H_{loss} = \text{Equivalent length} \times PFHL
\]
\[
= 286(\text{ft/pipe}) \times 2.3 \text{ft/1000 ft pipe}
\]
\[
= 6.58\text{ ft}
\]

\[
H_{net} = H_{max} - H_{loss} = 15\text{ft} - 6.58\text{ft} = 8.42\text{ft}
\]

\[
\text{P}_{\text{net}} = \frac{\text{Q} \times \text{H}_{\text{net}} \times e}{\text{K}} = \left(\frac{100 \text{gpm}}{\text{min}}\right) \left(\frac{8.43\text{ft}}{\text{min}}\right) \left(0.98\right)
\]
\[
= \left(\frac{100 \text{ gpm}}{\text{min}}\right) \left(\frac{8.43 \text{ ft}}{\text{min}}\right) \left(0.98\right)
\]
\[
= \frac{0.139 \text{ kW}}{100 \text{ gpm}}
\]

Can calculate loss from \(\text{P}_{\text{max}100%} = \text{P}_{\text{net}}\).
\[ = 0.139 \text{ kw} \]

\[ = 139 \text{ W.} \]

**Comments**

- Note that flow is 24hrs vs solar panels.
- Can do this calculation month by month for varied demand.
- Often batteries can not store over the seasonality of change in flow.

**Resource**

Be sure to check out interactive spreadsheet so you can do calculations assuming different configurations. Also, at the bottom of the interactive spreadsheet there is a graph which shows the impact of pipe size on different flows.

**Design**

Students can be invited to design a system given flow & financial constraints.