Appendix 2: *Determining Available Head & Flow*

Measuring Head: *Closed Diversion Systems*

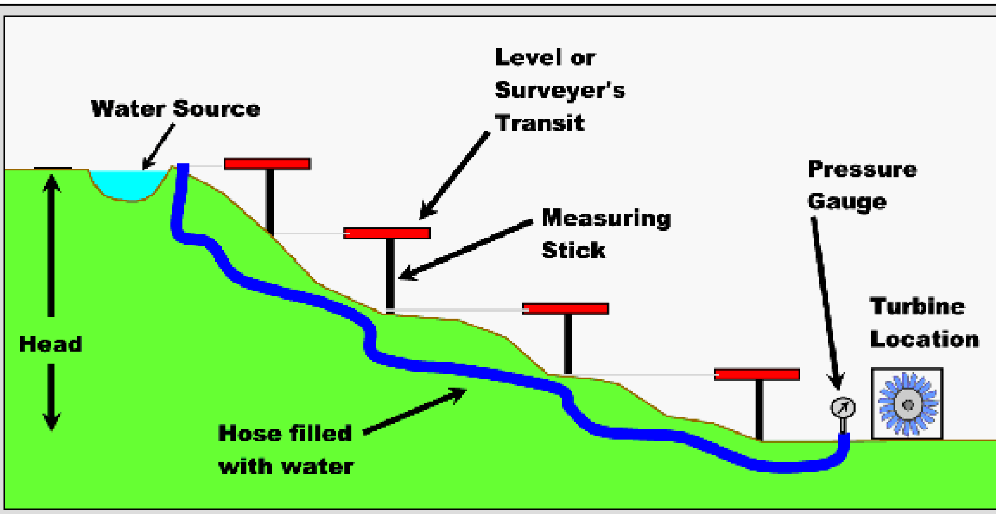
Selecting The Water Source Site

There may be several potential water source points, particularly if the water source is a river or stream. Each one will have a different elevation and linear distance from the hydro turbine. In selecting the best site, several factors to consider are water availability, site access, topography of the site, elevation (potential static head), linear distance from the turbine, head pressure required for the turbine, and the volume of water required for the turbine. The best site will usually be the one that has the best cost-benefit ratio (the least cost per kWh of electricity produced). The site with the highest elevation may not be the best, as that site may also have the highest incremental cost of diverting and transporting the water to the turbine.

Measuring The Available Head

Head is a vertical distance. It's starting point is where the water begins to impact the pressure at the hydro turbine and it's ending point is where the water ceases to affect the pressure at the hydro turbine. With closed diversion systems, head is the change in elevation from the water surface at the inlet to the closed diversion system and the elevation at the turbine nozzle. Head is the most important factor in determining if your site is adequate for an impulse type turbine. There are a couple of commonly used methods of measuring head for a closed diversion system:

1. Use a transit or level and a measuring stick of known length to measure the vertical elevation change in successive steps down the slope. The cumulative total of the vertical measurements is the head in feet.
2. Assemble a temporary piping system (a series of connected garden hoses works well for this) and, with a water pressure gauge, measure the static pressure (in pounds per square inch or PSI) at the lower end of the hose system with the hose filled with water. Convert the static pressure to vertical feet of head, using the formula 0.43 PSI = 1.0 foot of head. This method can also be done in successive steps to measure total head over a longer distance. This method is quite accurate.



Determining head for a closed diversion system

Note: The expected error range of ± 50 ft on GPS altitude readings prevents GPS from being an accurate method for determining head.

Measuring Head: *Open Diversion Systems*

Selecting The Water Source Site

Water source site selection and head calculation for open diversion systems requires a different approach. The minimum head requirements for reactive turbines and open diversion systems are much less than the requirements for impulse turbines and closed diversion systems, and they are much easier to attain.

All of the water source site selection criteria for closed diversion systems also apply to open diversion systems. However, the cost-benefit analysis for open diversion systems focuses on water volume, instead of water pressure, as the benefit.

Measuring The Available Head

With open diversion systems, you are not as concerned with high heads (high pressures) as with large volumes of water. The turbine (usually a reaction turbine) is submerged in the water at the end of the open diversion system.

With impulse turbines the water exits the closed diversion system at the turbine so we are only dealing with the head prior to the turbine, or pressure head. With reaction turbines there can also be a closed system for the water exiting the turbine, creating suction head.

The pressure head for open diversion systems is the vertical distance between the water surface above the turbine and the turbine impellers. This distance is usually less than ten feet and is easily measured. If a draft tube is used (see page 8), there is also suction head for these turbines. The suction head must also be measured. The total head is the pressure head (prior to the turbine) plus the suction head (after the turbine).

Measuring Flow

Note: The term 'Flow' as used in conjunction with micro hydro represents volume, not speed. It is the volume of water, stated as Cubic Feet Per Second (ft^3/s) or gallons per minute (GPM), that flows past a specific point in a specific amount of time.

Method 1:

The simplest way to measure flow is via a four-step process:

1) Measure the speed of the water (in feet per second)
2) Determine the cross-sectional area of the water source (in square feet) by measuring and multiplying the average water depth (in feet) X the average water width (in feet)
3) Calculate the flow (in cubic feet per second) by multiplying the water speed X the cross-sectional area.
4) Convert the flow in cubic feet per second to flow in gallons per minute by multiplying by the flow in ft^3/s X 450.

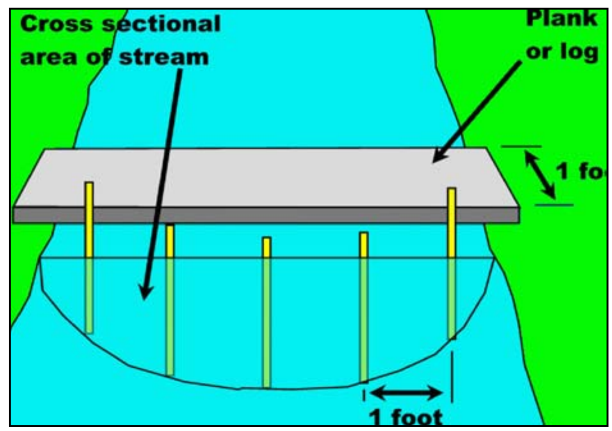
Water Speed

Determining the water speed is easy. Pick a representative segment of river or stream close to the expected water diversion point. Place two stakes 50 feet apart along the bank, marking the upper and lower limits of this segment. Drop a ping-pong ball (or other lightweight, floating object) into the current opposite the upper stake. Time (a wrist watch with a second hand works great!) how long it takes for the ping-pong ball to travel the 50 feet.

Take this measurement several times and calculate the average time (add all times and divide by the number of trials). This is the speed of the water through the segment *at the surface*. Not all water moves as fast as the surface because there is friction at the bottom and along the banks. To calculate the overall average speed of the water, multiply the surface speed X .80.

Cross-Sectional Area

Now we can measure and calculate the cross-sectional area of a 'slice' of the water. In the segment used above for determining water speed, select a spot that will provide a representative water depth and width for the 50 ft segment.



Measure and record the water depth at one foot increments along a cross section (water-edge to water-edge) of the river or stream at this spot. Laying a log or plank across the river or stream from which you can take these measurements is convenient.

You can also wade (or boat) across but take care that you are measuring the actual water depth and not the depth of water affected by your presence in the water. Calculate the average depth of the water (as explained above during water speed).

Measure and record the width of the river or stream (in feet and from water-edge to water-edge). Multiply the average depth **X** the width. You now have the cross-sectional area (in square feet) of that 'slice' of the river or stream.

Calculating Flow

You can now use the following equation to calculate your Flow.

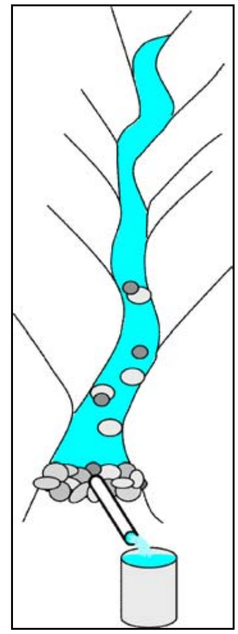
Water Speed (ft/sec) X Cross Sectional Area (sq ft) = Flow (cu ft per second)
Flow (cubic feet per second) X 450 = Flow (gallons per minute)

Calculate the flow in cubic feet/second first by multiplying the average speed (in feet per second) **X** the cross-sectional area (in square feet). Then convert the flow from cubic feet per second to gallons per minute (GPM) by multiplying the cubic feet per second **X** 450.

Method 2:

Sometimes with small, intermittent, or steeply dropping streams, it is difficult to accurately measure the average depth, width, and/or water speed. This is fairly common with water sources for impulse turbines, since they can operate with low water volumes. In these instances, it is possible to temporarily 'gather' the water by using sand bags, rocks, wood, etc. to create a temporary dam.

Insert a short length of pipe in the middle of this dam, preferably the same diameter of pipe that you later plan to use for your diversion system pipeline. The inlet to this pipe must be completely submerged in the water behind the temporary dam.



Fill a container of known volume (in gallons) with the water exiting the pipe, timing (in seconds) how long it takes to fill. Like above, conduct this measurement several times and calculate the average. Using the 60 seconds = 1 minute relationship, calculate how many gallons would exit the pipe in one minute. You now have your flow in GPM.

Example:

The container holds 5.5 gallons

The average time to fill the container is 15 seconds

$$5.5 \text{ gallons} \times \frac{60 \text{ seconds}}{15 \text{ seconds}} = 20 \text{ gal./minute (GPM)}$$

<u>Seasonal Changes In Water Availability</u>

When taking flow measurements for both closed and open diversion systems, evaluate any seasonal deviations in the source water level, such as low water during dry spells or flooding, and take these into account when determining the potential flow, diversion system size, and hydro turbine output.

Remember, though, that the requirement is to keep the pipe full or keep enough water in the diversion canal to supply the turbine. Any flow capacity at the water source that is in excess of the turbine requirement, even during dry spells and low water, is immaterial.