CONDUCTING A PRE-FEASIBILITY STUDY FOR CONSTRUCTION OF MINI HYDRO PLANTS

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INTRODUCTION

There were several mini-hydro electric schemes in tea estates about 30-40 years ago but most of them were abandoned after 1952. However, with the recent escalation in the price of oil with concomitant increase in the cost of electricity it would be possible to renovate some of the old plants and construct new ones. Today in Sri Lanka's tea plantation sector it is the normal practice to obtain the services of competent consulting firms to carry out all the work connected with mini-hydro schemes. Basically, this work involves feasibility studies, preparing specifications for tender documents, construction and supervision, commissioning, etc. However, if one has a basic knowledge of mini-hydro work it should be possible to undertake this work by doing a pre-feasibility study.

Theoretical Hydro power potential

The power available in a waterfall is porportional to the product of water flow (Q) and the vertical drop (H) and can be calculated as follows:

$$\text{Output power} = \frac{Q \times H}{11.8} \text{ kilowatts, where}$$

Q = Flow in cu.ft/sec.
H = Head in feet

$$= \frac{Q \times H}{102} \text{ kilowatts, where}$$

Q = Flow in litres per second
H = Head in metres

This is the maximum power available to the turbine shaft if the turbine efficiency is 100 %. But the turbine efficiency may vary from 60 % to 90 %, and the actual power available to the shaft is 60 % to 90 % of the above. Taking the efficiency of belt drive at 95 % and the efficiency of alternator at 80 % the electrical power available may fall as low as 50 % of the above.

Selection of site for dam and power house

To harness maximum power out of the Mini Hydro Scheme it is important to decide on those sites that have a maximum of both Q and H. As H is the vertical drop from dam to the power house, it is important to have the dam as further up stream as possible, and the power house as lower down stream as possible. But when the stream becomes less in slope it is not economical to go further up or down to maximise H as the cost involved in open channel, penstock, etc is not justifiable. Attempts should be made to reduce the length of penstock by selecting the proper site as penstocks are relatively expensive.

Two other important matters to be considered are, the soil strength and possible diversion of other small streams. Mini Hydro Power houses are normally built in a bank of the stream a few feet above maximum flood level.

Measurement of Head

After deciding on a site for the dam and power house, the vertical height difference has to be measured. There are many expensive survey instruments to measure this very accurately but the "road tracer" available in most tea estates can be used to get a fairly accurate figure. Since the road tracer can measure the gradient of a particular line of sight with the horizontal, the vertical height can be calculated once the distance between two points is known. If two places are not visible from one another, or the maximum gradient available in the road tracer is not enough to measure the gradient then the above measurements have to be repeated a few times in a convenient low gradient path between the power house and the dam.

The road tracer adjusted to get the horizontal view can also be used to measure the vertical height from the power house to the dam. The person who uses this has to walk from the power house towards the dam sighting through the pipe. He has to walk to the spot sighted through the pipe and then take another sight and so on until he reaches the site of the dam. The number of such steps multiplied by the height of the road tracer pipe above the ground gives the water head.

Measuring water flow

Due to various reasons the measurement of flow is not as easy as measuring the vertical height. Unlike the head, the flow is a varying quantity, its measurements are not straightforward and a large amount of data has to be collected before one could arrive at a figure for the flow. However it is important to obtain the values for the lowest and highest seasonal flows, and the average dependable flow per month. There are several methods available to measure the flow, and three of these methods are given below. You may choose any method you wish depending on the accuracy you require and the availability of time.

Weir Method

This is a very accurate method to measure the flow in medium sized streams. The weir is built as a dam across the stream which causes all the water to flow through a rectangular notch (say ABCD where AB is the horizontal length and BC is the vertical length) of known dimensions. The notch should be able to accommodate maximum possible flow, and its width to height ratio should be at least 3:1 (AB/BC greater than 3) and be perfectly level and sharp edged. Depending on the flow, depth of the water above the bottom of the weir (CD) varies and a table can be given to find the flow once the flow height is known. As the level of the water tends to fall near the crest of the weir, it is necessary to measure the flow from a point six foot up stream from the weir.

Depth of weir in inches	Cubic feet per minute per inch length	Depth of weir in inches	Cubic feet per minute per inch length
1	0.4	10	12.7
1.5	0.7	10.5	13.7
2	1.1	11	14.6
2.5	1.6	11.5	15.6
3	2.1	12.0	16.7
3.5	2.6	12.5	17.7
4	3.2	13	18.8
4.5	3.8	13.5	19.9
5	4.5	14	21.1
5.5	5.2	14.5	22.1
6	5.9	15	23.3
6.5	6.6	15.5	24.5
7	7.4	16	25.7
7.5	8.2	16.5	26.9
8	9.1	17	28.1
8.5	10.0	17.5	29.4
9	10.8	18	30.6
9.5	11.7	18.5	31.9

This table gives the flow in cubic feet per minute per inch length of the weir. The total flow can be found by multiplying the flow by the length of weir notch.

Container Method

This method is suitable for small streams. The stream is temporarily diverted so as to fill a container (e.g. a barrel) of known volume. In most small streams a suitable place with a gentle fall can be found to keep a barrel to fill without any diversion. The time taken to fill the container is measured and the flow calculated.

Float Method

This method is not as accurate as the other two. In this method the average velocity of water is calculated by measuring the time taken by a float to travel a known distance along the stream.

To obtain better results from this method a straight smooth section of the river of at least 30 feet in length is necessary. The depth of the river has to be measured at several places and the average taken. The cross-sectional area is found by multiplying the average depth by the average width of the river. Having ascertained the velocity and the cross-sectional area the flow is found by multiplying the two.

Estimation of power potential and reliability

The power available from the Mini Hydro plant is the product of vertical height and water flow which is a varying quantity. In order to obtain dependable power from the plant it is important to have a reliable flow, throughout its life span. Therefore it is best if the above flow measuring experiments are continued for at least one year in order to determine the annual variation. However, it is not practicable to continue these measurements for several years before a Mini Hydro plant is built and following two methods are available to find reliability of the flow for several years.

a) Using rainfall data

In most places of Sri Lanka rainfall records are available for more than seventy years. If the rainfall is recorded while the flow is measured it is not difficult to derive the daily run-off from rainfall during the wet dry season. But due to infiltration and evaporation it may be difficult to obtain an accurate correlation in time with seasonal changes. However, measuring the variation of flow in drought season and comparing it with drought period obtained from rainfall data, it may not be difficult to find the lowest flow available in past years.

b) Using flow data available in any stream in same hydrographic area

If there is a Hydrographic station which has been measuring the flow of a stream for quite sometime this data can be converted to calculate the flow of the stream concerned, if both are in the same Hydrographic area. In this method it is assumed that flow in a stream is proportional to the catchment area and hence the ratio of two flows is same as the ratio of their respective catchments. Therefore, if the flow in a particular stream is Q_1 with catchment area A_1, the flow of a stream of catchment area A_2 will be $Q_1 \times \frac{A_2}{A_1}$.

The catchment area of two streams (A_1 and A_2) can be approximately found using a one inch to one mile Survey Department contour map of the area. Further, the catchment area of the stream where flow data is available (A_1) can be obtained from the same hydrographic station. However the accuracy of the catchment area obtained from one inch map may not be sufficient when the catchment area of the stream concerned (A_2) is fairly small and in such a situation some survey measurements are necessary to get an accurate figure. Knowing A_1, A_2, and flow data Q_1, the flow in the stream concerned can be calculated for the years in which data Q_1 is available.

Most economical size of the plant

As the flow of a stream is a varying quantity the amount of power which can be harnessed from Mini Hydro plant also varies. To decide on the most economical size of the plant several additional factors have to be considered. When high flow is available in the stream for a few days, yearly, it is possible to harness this high amount of power by having suitable high power equipments. However, by adopting this practice the equipment would be grossly under utilized most of the time and would not prove to be economical. On the other hand by installing the smallest plant which is capable of running throughout the year even using the lowest flow available, the plant will be fully utilized but this would be wasteful of most of the energy potential. Hence the most economical size of the plant has to be decided only with a knowledge of such factors as prices of different sizes of plants and material, present and future cost of electricity, variation reliability of flow, bank interest rates, etc. Such decisions have to be taken by personnel competent in this field.

Economical Utilization of power

The other important factor in Mini Hydro set up is the economical utilization of power. This also depends on so many factors and one of which is the amount of power available from a Mini Hydro plant. For example if the power available is less than 10 KW it is not economical to use it for running of the factory but may be suitable for domestic purposes. On the other hand if the power available is quite sufficient to run a tea factory (about 300 KW) then this power can be easily utilized at minimum cost. If the power available is not enough to run your factory but above 10 KW, then this could be utilized to run a portion of the factory machinery. Again, the most economical connection depends on many factors such as distance from Mini Hydro plant to the distribution board, cost of switch gear and cables and daily electrical demand variation of the section of the factory concerned.

When Mini Hydro power is used to run a portion of the factory, the motors which demand power for longer periods, such as withering motors can be chosen as loads. As for deciding the most economical size of the plant, the most economical way of utilizing this power has to be decided by competent personnel in this field.