Micro - Mini Hydro Power Output and Household Verification Guidelines

Alternative Energy Promotion Centre

Khumaltar, Lalitpur, Nepal

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Acknowledgment

The Rural Energy Fund (REF) has great pleasure to bring this "Micro - Mini Hydro Power Output and Household Verification Guidelines." This updated guideline is intended for the use of inspectors conducting micro – mini hydro power output and house hold verification in the field. The guideline will prove equally useful to the developer, consultants, institutions engaged in conducting feasibility study for micro –mini hydro. Similarly, organizations involved in community mobilisation and dissemination of the micro –mini hydro technology will be benefited.

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REF appreciates cooperation from all stakeholders in the micro hydro development and confident that it will continue to receive similar cooperation in future in achieving technical excellence and financial sustainability of micro hydro benefiting the rural Nepal. REF welcomes pointing out of error and other issues related to this document.

This document is organised in two parts. First part deals with theoretical background and other aspects of the field verification. Second part is field manual for verification inspectors and given in Appendices.

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Acronyms

AC	Alternating Current
ADL	Additional Dump Load
AEPC	Alternative Energy Promotion Centre
DC	Direct Current
DCS	Development and Consulting Services
DFS	Detail Feasibility Study Report
DHM	Department of Hydrology and Meteorology
ELC	Electronic Load Controller
ESAP	Energy Sector Assistance Programme
GON	Government of Nepal
GPS	Global Positioning System
ICIMOD	International Centre for Integrated Mountain Development
IGC	Induction Generator Controller
kVA	Kilovolt Ampere
kW	Kilowatt
MCB	Miniature Circuit Board
MCCB	Moulded Current Circuit Breaker
MHP	Micro-Mini Hydro Project
MIP	Medium Irrigation Project
MOEST	Ministry of Environment Science and Technology
NMHDA	Nepal Micro hydro Power Development Association
POV	Power Output Verification
REDP	Rural Energy Development Programme
RMS	Root Mean Square
WECS	Water and Energy Commission Secretariat

CHAPTER - 1

INTRODUCTION

1.0 Background

The Rural Energy Fund's Guideline for Power Output Verification has already become standard practice in the past 6 years whereas prior to that no common agreed practice existed for power output measurement by manufacturers and installation companies during the testing and commissioning of a Micro Hydropower Plant.

The Rural Energy Fund's Guideline for Power Output Verification has resolved the then existed lack of uniformity in the method of measurement of power output of a micro hydro plant and procedures were set and practiced invariable within the AEPC projects as well as other projects in the country. The guideline has been successful in introducing practice of measuring kilo Watt instead of kilo Volt Ampere (kVA) and also collecting data for ascertaining efficiency and feedback to the manufacturers. This has changed the past trend of plants actually producing less power than designed capacity. Prior to the implementation of guideline the efficiency of the plant (water to wire) was generally not measured during commissioning. Area velocity method used to be the most widely used methodology for flow measurement whose accuracy is very poor. The use of salt dilution and weir method, which is more reliable, has been introduced and practiced widely, now.

In the current government subsidy policy, the amount of subsidy is based on the actual power output of a micro hydro plant (MHP) as well as the number of households connected by the plant. Besides, all plants have to conform to minimum quality of installation standards as defined in the Reference Micro-hydropower standards up to 100 kW. Furthermore, the subsidy policy has also been extended to the mini hydro range. Thus, mini hydropower plants in the range between 100 kW to 500 kW can also now be eligible for subsidy support. These power plants will also have to adhere to a new reference standard (for mini hydro) which is currently being prepared.

Ensuring the efficiency, reliability, and value for money of the plant in the long run are important aspects in the micro and mini hydro (MH) development. This guideline describes the procedure for verification of number of households served and power output produced for hydropower schemes in the range above 5 kW and upto 500 kW. It has been updated from Interim Rural Energy Funds Guideline for Power Output Verification to meet the additional needs of the revised subsidy policy. For *Picohydro* installation (up to 5 kW), a brief procedural methodology has been prescribed where certain steps and parameters measurement have been made optional.

Prior to a decision being made on the amount of subsidy to be disbursed for a micro or mini hydro plant, site verification on the basis of this guideline is required to ascertain the following:

a) The power output of the micro or mini hydro plant is at minimum in accordance with the installed capacity adequate to supply the stated number of households for 11 months a year.

b) All equipment and accessories confirm to the standards that were specified in the contract agreement.

c) The performance of the individual components and the performance of the complete system are in accordance with the required standards.

d) The households that were initially proposed to be connected eventually receive electricity services from the power plant.

It should be noted that this “Micro-Mini Hydro Power Output and House Hold Verification (POV)” guideline is intended to be used to determine the following:

i) The plant is able to generate the installed capacity safely, continuously and reliably at the design discharge fixed during the feasibility study, and

ii) The actual power curve as compared to design/submitted during final approval by the installer/manufacturing company shall be within permissible tolerance limit.

The POV guideline is not intended to be used during the testing and commissioning phase of the power plant. A separate guideline has been developed for this purpose. Thus, this POV guideline excludes all standard testing and commissioning activities required for micro and mini hydropower plants.

During the power output verification process, river discharge and the diverted flow (and if feasible the design flow) to the power plant will also be measured so that the river hydrology and generating equipment performance can be verified.

Household verification is an important aspect in the micro hydro development to ensure the efficiency, reliability, and financial viability of the plant in the long run, especially since the subsidy system is presently tied up with the number of households connected to the power plant.

CHAPTER - 2
POWER VERIFICATION

2.0 Method Adopted by AEPC for Power Output Verification in MHP plant

Two methods are recommended for power output measurement, the method using power measurement kit (with additional dump load) and measurement by true RMS clamp-on-power meter and any one of the method can be adopted. While the measurement by use of additional dump load is simple, some experience will be required for use of true RMS clamp-on power meter. *The general instructions, step-by-step procedure and data sheet for power output measurement and flow measurement is given in Appendices A-E.*

2.1 Measurement by Power Measurement Kit (up to 100 kW)
(For project With Electronic Governing Devices)

Main principle: Most of the isolated micro-hydro plants in Nepal use thyrister controlled load controller, which are based on the phase angle control (larger power plants in the mini hydro range also often have hydraulic/flow governing system). The generator output current, in such cases has distorted waveform and the power factor keeps varying too. Only a true RMS meter can measure the power output in the case of distorted waveform. Alternatively, by devising a method to get a unity power factor, power measurement with ordinary voltmeter and ammeter can also be made. This is achieved by providing an additional resistive dump load other than the ballast. The ballast voltage is maintained at zero all the time and all the generated power is diverted to the dump load by regulating the flow of water. Under this condition, i.e., when the ballast voltage is zero, we have a unity power factor which results in no distortion in the waveform of the current output from the generator. Ammeter and voltmeter measure the current and the voltage in each phase respectively, and frequency is measured using frequency meter. The power for each phase is calculated by the power equation, $P = V*I$. The total power in three-phase system is given by adding power in each phase.

In order to estimate the water to wire efficiency, it is essential to measure the head and the flow. The head should be measured by pressure gauge meter fixed at the last section of the penstock connected with the turbine manifold and flow by weir placed at the tailrace or using salt dilution method. The flow can also be measured by using ultrasonic flow meter.

2.2 Measurement by True RMS Clamp-On Power Meter (up to 100 kW)
(With Electronic Governing Devices)

The current output of a generator with ELC or IGC has distorted waveform and varying power factor, in which case, only a true RMS meter can measure its current accurately. Such a meter does also measure voltage, power (kW), power factor, KVA, and frequency. So, the power measurement is simple. Total power = sum of the power in the each phase. The meter calibrates itself every time the meter is switched on. It is important that the meter is switched on in an area away from the influence of magnetic field (such as outside the powerhouse for it to allow accurate calibration). The meter should also be calibrated every six month with a calibration meter from a responsible institution .laboratory such as Nepal Bureau of Standards. The same method could be adopted in case of micro hydro project with electronic governing system other than ELC or IGC.

In order to estimate the water to wire efficiency, it is essential to measure the head and the flow. The head should be measured by pressure gauge meter fixed at the last section of the penstock connected with the turbine manifold and flow by weir placed at the tailrace or using salt dilution method. The flow can also be measured by using ultrasonic flow meter.

2.3 Measurement for project with mechanical governing system (up to 500kW).

If the micro - mini hydro power project is an isolated project (not connected to grid) with the governing system of which is done by flow control governor, the provision of dump load (more than 10% of the design capacity) will be compulsory. The main objective of the dump load is to allow POV of the project using the True RMS clamp on power meter only.

In order to estimate the water to wire efficiency, it is essential to measure the head and the flow. The head should be measured by pressure gauge meter fixed at the last section of the penstock connected with the turbine manifold and flow by weir placed at the tailrace or using salt dilution method or current meter. The flow can also be measured by using ultrasonic flow meter.

2.4 Requirement of Frequency and Voltage for Power Measurement

While measuring the power output for verification, the voltage should be maintained at 220V (+/- 10%) and frequency should be maintained at 50Hz (+/- 5%).

CHAPTER – 3

FLOW VERIFICATION

3.0 Verification of Low-Flow and Flow Measurements

3.1 The approach

The approach taken for flow prediction and verification of micro-hydropower schemes in this guideline is summarised below. The details are provided in the subsequent sections.

- The 11-month exceedance[1] flow (i.e. about 92% exceedance flow) is used as low flow. This is the second lowest monthly flow, which is exceeded during 11 months of the year. In other words, a minimum of 11-month exceedance flow should be available (statistically) for power generation in the river 11 out of 12 months in any year. This allows for some flexibility in sizing of schemes if the consumers are willing to use less power for one month. Since the current subsidy system is based on number of household to be electrified, in the event that the design flow is increased or the 11 month exceedance flow is reduced to ten months or lower, the following would apply:

Subsidy would be calculated based on number of households that could be electrified with 11 month exceedance flow if the actual numbers of households electrified are higher

- A 15% deduction[2] should be adopted of the low flow for seepage and for environmental reasons during the pre-feasibility/feasibility study since weirs in micro-hydro schemes are mostly temporary or semi-permanent. Even when permanent weirs are installed, the foundation is not extended to sufficient depth such that seepage is minimal. Hence, the design flow of a micro-hydro scheme should not exceed 85% of the 11-month exceedance flow. If river discharge during low flow periods is not a constraint for power production (i.e., there is always more than the required design flow to produce the installed power), then design discharge less than 85% of 11-month exceedance flow can be used. However, 85% of 11-month exceedance flow should not be exceeded while determining the design flow.

- Low flow of the source river at the intake should be determined during the pre-feasibility study stage and refined during the feasibility stage. Since it will always not be possible to measure flows during the 11 month exceedance flow period, correlation based on hydrological analysis will be required. Such correlation work is meaningful only if the spot measurements are done during the low flow periods. Therefore, flow measurements should be done between **November and May**. This should not be a problem since generally; site visits

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[1] 12 months exceedance in case of REDP Projects

[2] 25% in case of REDP Projects

for feasibility studies are not undertaken during monsoon periods due to technical and logistic difficulties (i.e., transport, survey, safety of equipment, availability of manpower etc.).

- For hydropower with flow greater than 30lps, the POV team should measure the flow in the river close to the intake area. Similarly, the flow to the turbines would be measured as part of the power output verification activity at the powerhouse. Thus the flow available in the river and the diverted flow into the system would be known. Based on the measured flow in the river, the 11 month exceedance flow should be determined as follows:

For catchment area less than 100 km^2, the MIP method should be adopted as described in detail in Appendix C2.2.

For catchment area larger than 100 km^2, along with the MIP method, HYDEST (see Appendix C2.1) should also be used to determine the 11 month exceedance flow and the mean monthly flows. The lower values derived from the above two methods should be adopted for mean monthly flows and the 11 month exceedance flow.

The 11 month exceedance flow determined using the above method should be compared with previous flow measurements undertaken during the detailed feasibility studies as shown in Appendix B

- A "conductivity meter" should be used for the river flow measurement in range of 30lps to 1.5 m^3/s flows since it is more accurate than other methods for small rivers and does not involve subjective judgement (such as in the float or area velocity method) of the hydraulic/hydrological parameters. For river with flow less than 30 lps can be measured by other engineering methods of flow measurement like Bucket or Weir method.

- For rivers with flows larger than 1.5 m^3/s, the conductivity meter will generally not be very useful. Larger rivers have milder slopes and there will be more likelihood of stagnant pools along the river stretch which will hinder the mixing of the salt. Furthermore, the amount of salt required will be higher as the flow increases and larger distance will be required (between point of measurement and placement of salt) which together make the use of this method impractical. Thus, for river flows larger than 1.5 m^3/s a current meter should be used. Note that even for lower flows, if the water depth is sufficient and the river section is suitable for use of current meter, this equipment can be used for flow measurements (Appendix B).

- The triangular and rectangular weirs should be verified by standard laboratories and certificates obtained from the laboratory before dispatching them to the site during the verification. Such a weir would be stored at site by the plant owner and used during commissioning for flow verification. Similarly, the conductivity meter also should be calibrated by a standard laboratory once a year so that salt constant can be independently verified for the equipment.

- The Consultant/Inspector who verifies the low flow during POV should be different than the one that did the pre-feasibility/feasibility study (i.e., to minimise bias).

- Two standard hydrological analysis methods commonly used in micro-hydro schemes, namely WECS/DHM and MIP methods are proposed. If the catchment area is more than 100 km^2 and during the pre-feasibility study it was not possible to undertake spot measurements, then the flows derived from the WECS/DHM methods should be used to size the design flow. However, during the feasibility stage, for micro hydropower, the low flows thus derived must be verified by one spot measurement and then crossed checked using the MIP method. For mini hydropower, at least 4 low flow spot measurements between 1.0 month – 1.5 month interval has been proposed in the (mini hydro) design guidelines and the average values are to be used for mean monthly and 11 month exceedance flows. If there are significant differences between the two methods, then the lower values calculated from the two methods should be used. For catchment areas less than 100 km^2, the only option is to use the MIP method in all cases (i.e., pre-feasibility, feasibility and commissioning stages).

- Since hydrological analysis such as flow verification is not an exact science and furthermore there will be some instrumentation errors, a maximum tolerance of: $\pm$ 10% should be allowed on the design low flow used during the feasibility stage, the commissioning stage and POV stage.

3.2 Low Flow Estimation for Ungauged Rivers for MHP

There are two methods that can be used in estimating low flows in micro-hydropower schemes as follows:

- Water and Energy Commission Secretariat (WECS)/Department of Hydrology and Meteorology (DHM) method
- Medium Irrigation Project (MIP) Method

3.2.1 WECS/DHM Method

The WECS/DHM method has been developed for predicting flow characteristics of ungauged rivers of the country. It is based on hydrological theories, empirical equations and statistics. This method is generally fairly accurate for predicting river flows for catchment areas larger than 100 km^2. For smaller catchment areas, its accuracy is questionable since only 4 data points with less that 100 km^2 catchment areas have been used in the database. Therefore, for catchment areas less than 100 km^2 this method is not recommended. This method may be required only in exceptional case, when a large stream is used to divert part of the low flow. In this case, accuracy of low flows does not become crucial since only a portion of the low flow is required (i.e. not the entire 85% of low-flow).

In this method the total catchment area, areas between 5000 m to 3000 m elevations and elevation below 3000 m are required as input. Catchment area above 5000 m is assumed to be insignificant for flow contribution. Such higher elevation is assumed to lie in permanent snow cover zone and contribute nominal flows. Flow contribution per unit area (km^2) from 5000 m to 3000 m and from lower elevations (i.e. below 3000 m) is assumed to be in different proportion during flood events. Catchment area below 3000 m elevation is assumed to contribute more flows per km^2 area during floods than areas between 5000 m to 3000 m. However, for long term average monthly flows, all areas below 5000 m are assumed to contribute flows equally per km^2 area.

Once, the catchment area and elevation are taken into account, the next step is to determine the monsoon wetness index of the centre of the catchment basis. This can be read from a standard “monsoon wetness index” map prepared by WECS/DHM as discussed later. For higher accuracy, monsoon wetness index for different elevations or portions of the catchment area (by dividing the catchment in different sections) can be used in case the area is large. Generally, catchment areas are not so large in micro-hydro schemes since small tributaries are used as the source river. Furthermore, generally, the catchment areas in micro-hydropower schemes are less than 100 km^2 in which case the MIP method should be used.

Apart from low flow characteristics, the WECS/DHM method also estimates flood flows and extreme low flows for various return periods (1:2, 1:20, 1:50, 1:100 years). Since the scope of this guideline is limited to determining low flows, only the long-term average monthly flows are discussed. For details regarding determination of extreme events (low and flood flows for various return periods) reference should be made to the WECS/DHM manuals.

3.2.2 MIP Method

In the MIP method, hydrologically, Nepal has been divided into seven zones. For each hydrological zones, non-dimensional and unit hydrographs in terms of average monthly flows per km^2 of catchment areas have been prepared. Once the catchment area of a micro-hydro scheme has been calculated and the hydrological zone identified, long term average monthly flows can be determined by multiplying the unit hydrograph (of the concerned region) with the measure catchment area. Finally, the calculated monthly flows are refined based on actual site measurements during the low flows.

In both of these methods the first step is to determine the catchment area of the drainage basin. This process is presented below:

3.3 Catchment Area Calculation

A hydrological catchment is a drainage area in which all rainfalls within that area are contained and drained through gullies, streams and rivers. Catchment areas can be calculated from topographical maps (maps that show contours) once the intake locations are identified by using GPS. In Nepal, three types of topographical maps are available as follows[3]:

- 1:25,000 recently produced by the Survey Department Nepal Government in cooperation with the Government of Finland. These maps are generally referred to as Finnmaps. Among the maps available in the country, Finnmaps are the most accurate ones. However, these maps are not yet available for some areas of the country.

- District maps at 1:125,000 scale: these are available for all districts of the country.

- Maps at 1:150,000 along popular trekking routes such as the Annapurna area, Sagarmatha National park etc.

Step-by-step description of catchment area calculation:

i) Obtain a topographical map of the area of concern. Note that a higher scale map is usually more accurate. Since map scales are given in ratios, the smaller the denominator the larger the scale. For example a 1:25,000 is a higher scaled map (i.e. more detailed) than 1:50,000 one. If available, Finnmaps should be chosen over other maps since these are most recent. In the event that a photocopied map is used, it must be ensured that the photocopy is done at the same scale, i.e., the map is neither enlarged nor reduced from the original. Enlarged or reduced maps

[3] Maps with maximum resolution should be as per availability

distort the map-scale and therefore the catchment area calculations will be less accurate.

ii) Identify the intake of the micro-hydro scheme on the map.

iii) Then from the intake, draw a line along the ridges (i.e. catchment boundary) on the topographical map and thus mark the catchment. Note that the ridgeline contours curve in the opposite direction compared to the stream contours. If the topographical map has adequate details (i.e., good relief and low contour intervals,), then by encircling the boundaries of the tributaries that merge with the source river upstream of the intake area will be close enough to the ridgelines. Ridgelines are also sometimes shown in maps (such as in case of Finnmaps) and in such cases the catchment area from the intake can simply be connected to the intake.

iv) Once the catchment upstream of the intake has been circled in the map, the next step is to calculate the area. This can be done in two ways. The catchment can be divided into triangles and squares and then their areas can be calculated. The other method is to trace the catchment area in a transparent graph paper. Then the area can be calculated by counting the number of squares in the graph paper inside the catchment boundary. In this method, if more than half the square is within the catchment area it is rounded to 1 and if on the other hand more than half is outside, it is ignored.

v) Finally, the area thus calculated in the map is converted into actual catchment area by multiplying the map area by the square of the denominator of the map scale.

For example, if the area calculated in the map is 10 cm^2 and the map scale is 1:20,000 then, the actual catchment area becomes 10 cm^2 x $(20,000)^2$ = 4,000,000,000 cm^2 or 4,000,0000,000/(100x100) = 400,000 m^2 or 400,000/(1000x1000) = 0.4 km^2. Note that since area is length squared, conversion form one unit to another (i cm to m, m to km etc) requires the division (or multiplication if conversion is towards the lower units, i.e., km to m, m to cm etc.) by the square of the conversion factor as in the above example.

3.4 Detailed procedures and equipment description

Further details of MIP and HYDEST method, flow measurements using conductivity and current meters including principles and worked out examples are presented in Appendix B.

3.5 Flow Insufficiency due to Abnormal Condition

Hydrological cycles can vary from year to year, i.e., some years can have higher than average flows and other years can have lower than average flows such as during draughts. Furthermore, the regions where abnormal flows occur can have spatial and temporal variation. Thus, if the POV period is suspected to be a draught year (i.e., a number of power plants in the region have flow insufficiency) and AEPC realized the fact (as per data/information available in national level) then installer company will apply for consideration on flow insufficiency due to abnormal condition. In such condition REF will make final decision on power output.

3.6 POV of power plants with sufficient flows

In certain schemes, the diversion flow for power generation can be less than 11 months flow such as due to limited demand for electricity and/or relatively low population in the distribution area. In such cases, it would be cost and time effective to undertake POV at any time of the year (i.e., not only during the dry seasons). Thus, if can be demonstrated in the feasibility study that the design flow for power generation is less than half the 11 months exceedance flow, POV can be performed during any time of the year.

CHAPTER – 4

POWEROUTPUT VERIFICATION FOR PICO HYDRO

Power Output Verification for Pico Hydro Set

The same principle applies for verifying the power output of Pico Hydro Set as described for micro hydro plant (> 5 kW). However, the sizes of the additional dump load will be different. The additional dump load will have air heaters of the sizes 250 W, 500 W, 1 kW, 2 kW and 4 kw. The combination will allow for measurement of installations of various sizes - 250 W, 500 W, 750 W, 1kW, 1.25 kW, 1.5 kW, 1.75 kW, 2 kW, 2.25 kW, 2.5 W, 2.75 kW, 3 kW, 3.25 kW, 3.5 kW, 3.75 kW, 4 kW, 4.25 kW, 4.75 kW, 5 kW, 6 kW, using the same kit. True RMS meter can also be used for power output verification but the power measurement kit using additional dump load will be a cheaper option.

The flow measurements as well as other requirements are as per the reference standards of AEPC 11 month exceedance.

The list of equipment required and step-by-step procedure for power output verification for Pico Hydro Set is given in Appendix D.

CHAPTER – 5

HOUSE HOLD VERIFICATION

This chapter describes the procedure for verification of number of households served by the hydropower schemes in the range of up to 5 kw (pico hydro) and 5 kW to 500 kW (Micro – mini hydro).

Household verification is an important aspect in the micro hydro (MH) development to ensure the efficiency, reliability, and financial viability of the plant in the long run, especially since the subsidy system is presently tied up with the number of households connected to the power plant. The household connection verification should be carried out as described in this guideline.

The experience to date is that due to various reasons, all community members that wanted to be connected to the electricity services from the proposed power plant during the pre-feasibility and detailed feasibility study stages, do not actually get connected when the power plant is commissioned or even afterwards for various reasons.

In order to address the above non connection issue, the following household connection verification procedure shall be adopted:

a. Prior to the field visit, the POV team will first review all records regarding household connection as follows:

- The number of households proposed to be connected by the power plant in the detailed feasibility study

- The number of households and their details submitted to REF during subsidy application

- The number of households connected during the testing and commissioning period as mentioned in the Testing and Commissioning Report.

Based on the review of the above documents, the POV team shall assess the household connection status of the hydropower scheme by the time power output verification takes place. The team will also hold discussion with the installation company, project developer and local community regarding reasons for non-connection if exist. A standard form is provided in Appendix E – form No. 10a-10d to record these findings.

b. During the site visit the POV team needs to determine the following:

- The number of households that is connected to electricity services.

- The number of households that can be connected by service wire (Transmission line accessible), length of service wire not exceeding 50 metres, for the households that were initially in the list of households in REF's subsidy application form (SAF) to be connected to electricity services.

- Others: Neither connected to electricity services nor could be connected by service wire (Transmission Distribution not extended) but was initially in the list of households to be connected to electricity services.

Standard forms Form No. 10a-10d are provided in Appendix E to record the above information. The forms 10b-10d should be countersigned by the ward or VDC representative and the plant owner or representative of the user's committee.

c. The procedure for verifying household connections as defined above shall be as follows:

- The installer/manufacturing company duly filled up the prescribed household connection certification format and submit it to REF. This format should be certified by the representative of micro hydro developer, installer and the local government (VDC Chairman/Secretary).

During the POV procedure, POV team will verify above certification based on random service main pole check. Service main pole check will include pole serial numbers, household connected and other details provided in the households connection certificate. At least 5 percent of the total service main poles will be randomly verified during the POV. Standard forms 10b to 10 d in Appendix E should be used to record the information.

In the event as specified are not found the households verification considered to be failed. In such case, POV team will verify each and every service main poles to ascertain the total number of households connection. In case of false certification, record of such event of Installer Company will be maintained by REF and will be used in installer company pre-qualification assessment.

At the year end check 100 percent of the planned households will have to be connected. In cases of few houses are not connected for various reasons up to 10% of the planned number of households will be considered possible to be electrified in near future with justification.

CHAPTER – 6

PERSONNEL, EQUIPMENT, TRAINING

6.1 Team composition and Requirement

AEPC should have certified pool of inspectors for verifying power output of a micro hydro plant. Such certification will be based on academic background, experience and attendance of mandatory training course organized by AEPC. There will be a Team leader and the qualification and experience required for such inspectors will be,

a. for project up to 40 kW

Basic Academic Qualification : Electrical Diploma or above

Experiences : 2 Years

Note: If the person is from mechanical or civil background but has experiences of more than 5 years working in the hydropower sector is also eligible for POV Inspector,

b. for project up to 100 kW

Basic Academic Qualification : Electrical Engineering (B.E. or above)

Experiences : 2 Years

Or

Basic Academic Qualification : Electrical Diploma (or above)

Experiences : 4 Years

c. for project up to 500 kW

Basic Academic Qualification : Electrical Engineering (B. E. Or above)

Experiences : 3 Years

Note: If the person is from mechanical or civil background but has experiences of more than 5 years working in the hydropower sector is also eligible for POV Inspector.

Key skills required

- Conceptual knowledge related to head, flow, power, and the entire micro hydro power systems (civil, mechanical and electrical)
- Practical skills of measuring head (using abney level, water filled tube, pressure meter) and flow (using weir, salt dilution gauge), power output by different methods.
- Practical knowledge of operation of civil structures, electro-mechanical installations, protective systems of the plant and safety requirements.
- General knowledge of GON policy for micro and mini hydropower, other procedural guidelines of AEPC and working modality of AEPC.

Essential personal quality

Dependable with proven track record of professional integrity.

6.2 Team Composition for POV

A. Up to 40 kW

Team Leader – 1- Electrical Overseer

Assistant – 1 – Civil/Mechanical Overseer

B. 40 kW -100 kW

Team Leader – 1- Electrical Engineer or Senior Electrical Overseer

Assistant – 1 – Civil/Mechanical Overseer

C. 100 kW -500 kW

Team Leader – 1- Electrical Engineer

Assistants – 1 – Civil Engineer/Overseer with>5 years experiences/ and or

– 1 – Mechanical Engineer/Overseer with > 5 years experience

6.3 Equipment

It is recommended that all equipment used for power output verification be maintained at the AEPC store. The equipment will be loaned to inspectors at the time of power output verification. This will also ensure the standards and uniformity of the equipment used. The description and general specification of the equipment will be as mentioned in Appendix A.

The specifications of the equipment are as per:

- Power output verification kit Appendix A – A1
- AC/DC True RMS Clamp-on Power Meter supplied to RS by LEM UK, LH1050, stock no 246-8947 or of similar specification.
- General-purpose pressure indicator available from Fluke
- Weir (as specified in the Guidelines for Flow Prediction) calibrated from a responsible institutions in standard laboratory
- Ultrasonic flow verification meter

For Low flow predictions following equipments are also required:

- Conductivity meter with accessories (as specified in the Guidelines for Flow Prediction
- Current meter with accessories if records from previous measurements indicate river flows to be high (1.5 m3/s or higher), conductivity meter is not practical given the site conditions and/or this equipment was used earlier (e.g., feasibility study).

6.4 Training, Evaluation and Selection of Inspectors

It is suggested that a training based on the approved procedures be provided to most potential candidates selected by and based on the evaluation and certificate will be provided as power output and house hold verification inspector. The certification should be valid only for a year and based on their performance it can be renewed by AEPC every year. AEPC will have the right to withdraw certification of inspectors any time should there be any evidence that show lack of integrity of the inspector.

It is expected that generally two to three persons, one inspector and other assistant will be required to carry out power output and house hold verification depending up on the size of Micro- Mini hydro Power Project; the assistant however may not need to be certified by AEPC

6.5 HRD Programme for Inspectors

It is suggested that AEPC select potential inspectors and invite them to attend an orientation programme on power output and house hold verification as per AEPC guidelines. Based on the evaluation, participants can be certified as inspectors to verify power output and house hold connection for all AEPC supported MHP plants as per requirement. The potential inspectors should already have sufficient knowledge and skills of power output verification. The purpose of the training programme would be to orient them with the AEPC guidelines for power measurement.

In addition to regular training, in order to maintain the pool of Inspectors, AEPC will conduct exam for Power Output Verification Inspectors on yearly basis. The Inspectors selected by this process should also attend the short orientation training provided by AEPC.

Course Content: as per the guidelines for power output verification and guidelines for low flow prediction.

Orientation Method: both classroom and practical (simulation or on a real site)

Duration: 7 days for main training and 2 days for short orientation training.

Participant selection: by AEPC based on the TOR given for inspectors

Instructors: one each from each of the discipline (electrical, mechanical and civil)

Evaluation: practical and interview by AEPC and instructors

Certification of inspectors: to be provided by AEPC evaluation/certification team

CHAPTER – 7
CONCLUSION AND RECOMMENDATION

7.1 Conclusions

With a standard Power Output Verification guideline which is in accordance to the current government policy, use of pre qualified and experienced verification team that has been provided with adequate training it should be feasible to assess the real situation at site regarding the status of household connections, power output and water to wire efficiencies at part flows and low flows (including the 11 month exceedance flow). The experience in using the previous guideline has also clearly demonstrated that it is possible to assess the status of the plant in terms of power output including efficiencies and low flows for up to 100 kW installed capacity power plants. This updated guideline has attempted to increase the range up to mini hydro (i.e., up to 500 kW installed capacity) and to assess whether all households that were envisioned to be connected have actually been connected during the verification site visit. This guideline will also provide feedback to the installers and manufacturers regarding the status and system efficiencies of their equipment so that they can continue improving the quality standards which would have a positive impact in the sector.

7.2 Recommendations

Based on the methodology proposed in this guideline, the following recommendations are made:

a. The proposed equipments for power and flow verification are expensive and can not be generally afforded by individual consultants. Thus, if the practice of using independent consultants is to be continued, it is recommended that the equipment be provided (such as on a rental basis) by AEPC.

b. For larger plants AEPC should maintain a series of dump loads (of various kW) which should be returned (for use in another site) after completion of the verification process

c. The pre-qualification status of the POV consultant should be renewed each year based on their performance. Training should be provided periodically so that adequate human resources are available the verification activities.

The most preferred method of power output verification of a micro hydro plant is by using true RMS clamp-on power meter which can be cross verified by use of additional dump load or vice versa. The additional dump load which has18 kW load can be used for scheme up to 17 kW and extra dump load can be added for schemes of larger size. The true RMS meter has an accuracy of $\pm$ 2.5% in measuring the power output. The accuracy of power measurement using additional dump load and clamp meter can be within about ±3%. The use of ADL has advantage over True RMS meter method of measurement, that a full load rejection test can be performed with it.

AEPC should select potential inspectors for power output verification and after evaluation certify 30 (10Existing +20 new) inspectors who should be the only person for power output verification. The equipment for power output verification should be purchased and maintained by AEPC. They should be calibrated every six month in a standard laboratory. The inspectors for power output verification should use only this equipment maintained at AEPC. To take in to account of the errors in the instruments and measurement process following tolerances limit will be allowed:

Sizes in kW →	<20	>20
Tolerance Limit in ±%	±10%	±5%

The above tolerance limit is applicable for determining the power output curve. The nature of the actual power output curve shall be within the band of above tolerance limit.

The actual power output of a plant should be made public (by AEPC through its newsletter); those conforming to design size should be given recognition to encourage better accuracy of the plant output.

For power measurement for Pico Hydro Set additional dump load method is recommended. The measurement of head and flow will not be mandatory in order to keep the procedure simple. If this measurement is necessary, such as when there is a dispute, the flow should be measured by either bucket method or weir method and the net head by pressure gauge meter fixed at the penstock pipe near the turbine manifold.

If the POV is not acceptable the first time, the party challenging the results should bear the cost of second POV, i.e., the installation company would bear the POV human resources cost if it does not accept the findings whereas if the first POV has not been as per the required standards (e.g., malfunction of equipment etc) or there are logistic, measuring equipments problems then AEPC will have to bear the costs.

8.0 REFERENCES

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9.0 APPENDICES

APPENDIX - A	GENERAL DESCRIPTION AND SPECIFICATION OF EQUIPMENT
APPENDIX - B	FLOW MEASUREMENT METHODS AND EXAMPLES
APPENDIX - C	FLOW ESTIMATION METHODS AND EXAMPLES
APPENDIX - D	GENERAL INSTRUCTION FOR POWEROUTPUT VERIFICATION
APPENDIX - E	FORMS AND FORMATS

APPENDIX - A

GENERAL DESCRIPTION AND SPECIFICATION OF EQUIPMENT

APPENDIX - A

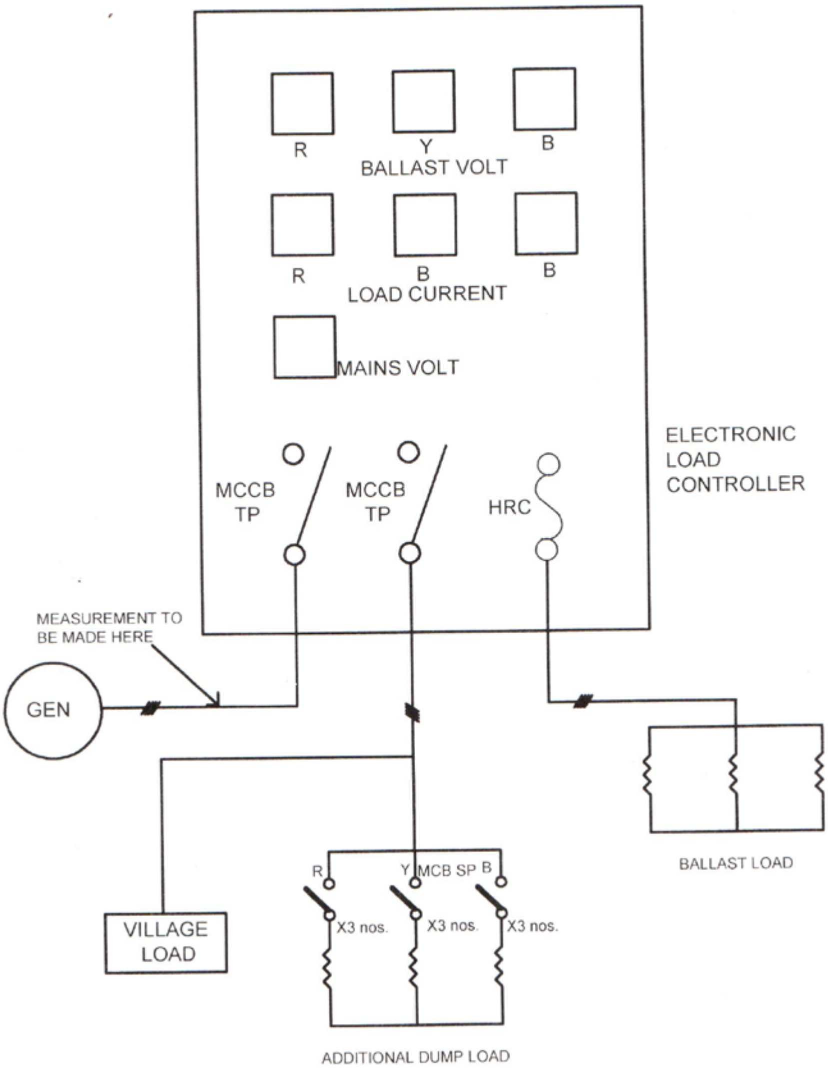
GENERAL DESCRIPTION AND SPECIFICATION OF EQUIPMENT

A1 Power Measurement Kit

The main component of this kit is the additional dump load. See photo A1: 18 kW Additional Dump Load with MCBs and Frequency Meter and Fig A1: circuit diagram for three phase additional dump load.

Construction: the main parts of the additional dump load are the immersion heater, step switches (MCBs), frequency meter and the tank, which are all assembled as one portable unit (dimension 9"X9"X21" and about 12 kg in wt.). The heaters are each 2 kW and therefore, 2 kW load can be increased in each step. The total load in each phase is 6 kW and the total heater power is 18 kW. The other equipment required is a clamp meter, a 20 litres bucket, a screwdriver, wrenches, cable, and a calculator.

Photo A1: 18 kW Additional Dump Load with MCBs and Frequency Meter



CIRCUIT DIAGRAM OF ADL AND POWER
MEASUREMENT TEST SETUP FOR MHP

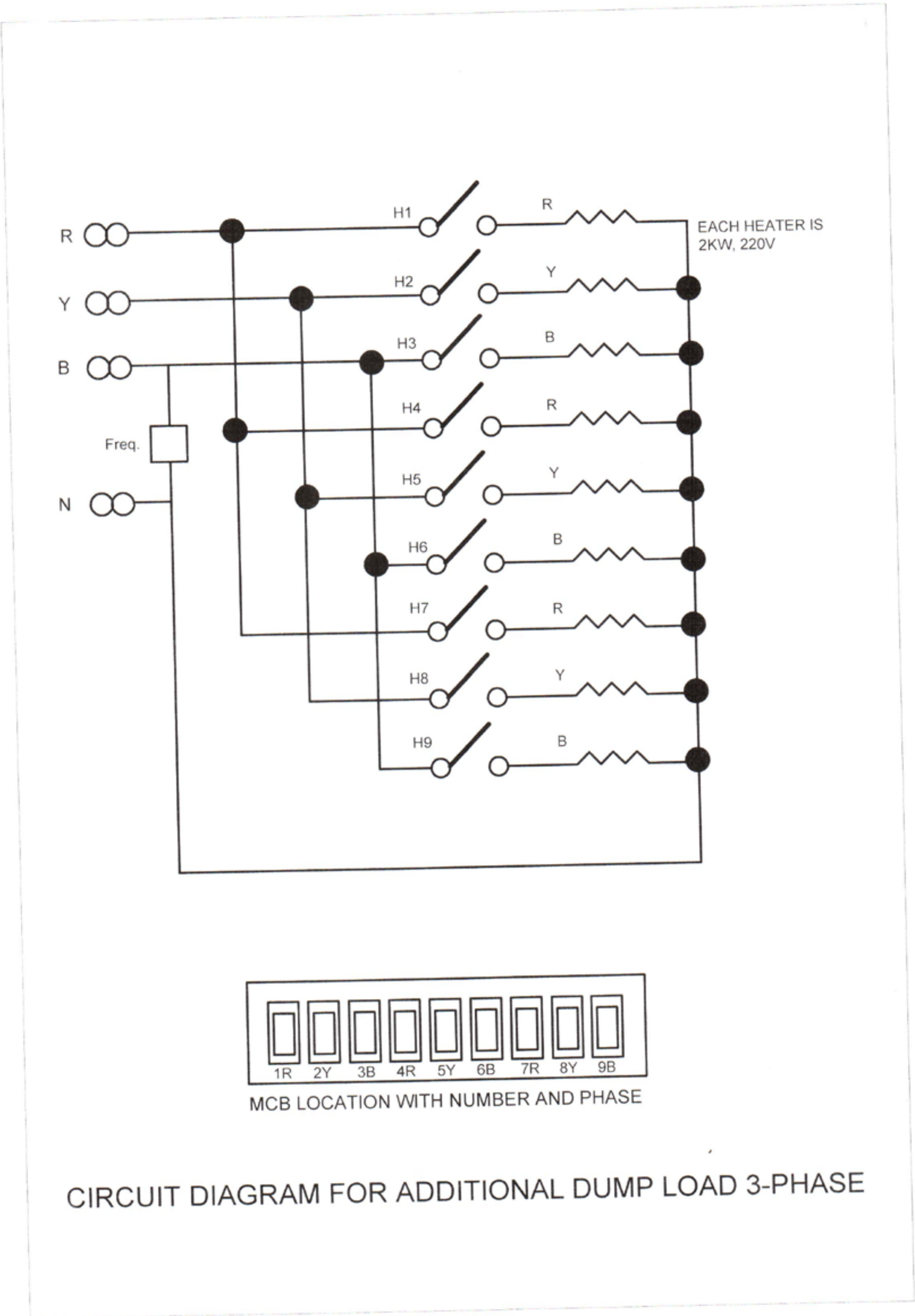


Figure A1: Circuit diagram for three phases additional dump load.

A2 AC/DC True RMS Clamp-on Power Meter

This meter ensures accurate AC/DC power measurements for single phase and balanced/unbalanced three phase systems even with distorted waveforms.

Main features (LH1050 from RS catalogue):

- Measures voltage, current, frequency, power, VAR, and power factor
- True RMS for accurate measurement of ac and dc distorted signals.
- Bar - graph for dual display of V/Hz, A/Hz and PF/W
- Built in three-phase power capability for balanced loads.
- Digital output for PC logging with optional WinLog software and interface

Technical Specification

Current ranges	400 A		1000 A	
Resolution	0.1 A		1 A	
Accuracy	± 1.5% of reading (5 digits)			
Voltage ranges	400 V		600 V	
Resolution	0.1 V		1 V	
Accuracy	± 1% of reading (5 digits)			
Watts	4 kW	40 kW	400 kW	600kW
Resolution	1 W	10 W	100 W	1 kW
Accuracy	± 2.5% of reading (5 digits)			
Power factor	0.3 cap to 0.3 ind			
Resolution	0.01	Accuracy	± 3 deg	
Frequency	30 Hz to 1kHz	Resolution	0.01	
Accuracy	40-70 Hz ± 0.5%			
	30-1000 Hz ± 1%			

Photo A2: True RMS Clamp-On Power Meter

A3 Digital pressure gauge

This consist of a pressure module (to be fitted on the penstock pipe) which converts the water pressure in the pipe into electrical signal and the pressure can be read in FLUKE DMM117 (See Photo A3).

Pressure Indicator (FLUKE DMM 117)

Photo A3 -1 –Digital Multimeter (DMM) used as Pressure Indicator

Fluke DMM 117 can be used as pressure indicator. PV 350 Digital Pressure Vacuum Module is connected with the digital multimeter which indicates pressure in kPa.

General Features

Fluke 117 Electrician's Multimeter

Auto Volt automatic ac/dc voltage selection,

Low input impedance: helps prevent false readings due to ghost voltage

Large white LED backlight to work in poorly lit areas

True-rms for accurate measurements on non-linear loads

Measures 10 A (20 A overload for 30-seconds)

Resistance, continuity, frequency and capacitance

Min/Max/Average with elapsed time to record signal fluctuations

Specifications

Maximum voltage between any terminal and earth ground 600 V

Operating Temperature -10 °C to + 50 °C

Storage Temperature -40 °C to + 60 °C

Battery type 9 volt Alkaline, NEDA 1604A/ IEC 6LR61

Battery Life 400 hours typical, without backlight

Accuracy Specifications

DC volts

Range/Resolution: 6.000 V / 0.001 V

Range/Resolution: 60.00 V / 0.01 V

Range/Resolution: 600.00 V / 0.1 V

Range: 600.0 V

Resolution: 0.1 V

AC millivolts1 true-rms

Range: 600.0 mV

Resolution: 0.1 mV

AC volts1 true-rms

Range/Resolution: 6.000 V / 0.001 V

Range/Resolution: 60.00 V / 0.01 V

Range/Resolution: 600.0 V / 0.1 V

Ohms

Range/Resolution: 6.000 kΩ / 0.001 kΩ

Range/Resolution: 60.00 kΩ / 0.01 kΩ

Range/Resolution: 600.0 kΩ / 0.1 kΩ

Range/Resolution: 6.000 MΩ / 0.001 MΩ

Capacitance

Range/Resolution: 1000 nF / 1 nF

Range/Resolution: 10.00 μF / 0.01 μF

Range/Resolution: 100.0 μF / 0.1 μF

Range/Resolution: 9999 μF / 1 μF

Range/Resolution: 100 μF to 1000 μF

AC amps true-rms (45 Hz to 500 Hz)

Range/Resolution: 6.000 A / 0.001 A

Range/Resolution: 10.00 A / 0.01 A

DC amps

Range/Resolution: 6.000 A / 0.001 A

Range/Resolution: 10.00 A / 0.01 A

Hz (V or A input) 2

Range/Resolution: 99.99 Hz / 0.01 Hz

Range/Resolution: 999.99 Hz / 0.1 Hz

Range/Resolution: 9.999 Hz / 0.001 Hz

Range/Resolution: 50.00 Hz / 0.01 Hz

Digital Pressure Module (PV 350)

Photo A3-2 – Digital Pressure Module

The Fluke PV 350 sets the standard for pressure/vacuum troubleshooting, turning the digital multimeter into a complete measuring system. The system has been designed as a compact module that plugs into standard diameter banana jacks on the front of any DMM.and it provides high accuracy, high resolution digital pressure and vacuum measurements.

Technical Specification

Pressure

Pressure ranges	0-3500kpa (0-35Kg/cm)
Accuracy	$\pm$ 1 % of reading

Vacuum

Range	0 – 76cm Hg
Accuracy	$\pm$1% of reading

A4 Ultrasonic Flow Meter

The first choice for flow measurement should be to use calibrated weir fixed at the tailrace and plan for installation of weir has to be made during the feasibility study of the scheme. If a weir is installed at the headrace, it has to take into account of the loss of water from the spillway, which may not be easy to quantify the amount of spilled out water. However, not all MHP may have an appropriate tailrace (a minimum of 2 meter flat stream length) where a weir can be installed. In such case, ultrasonic flow meter should be used for flow measurement.

In the ultrasonic method, flow measurements are made by penetrating the penstock pipe with ultrasound wave. Time differences, frequency variations, or phase shifts of the ultrasonic signals caused by the flowing liquid are subsequently evaluated. The measurement of flow is based on the principle that sound waves travelling in the direction of flow of the fluid require less time than when travelling in the opposite direction. The difference in transit times of the ultrasonic signals is an indication for the flow rate of the fluid. Since ultrasonic signals can also penetrate solid materials, the transducers can be mounted onto the outside of the pipe. Fast Digital Signal Processor signal analysis guarantees reliable measuring results even under difficult conditions. See Photo A4

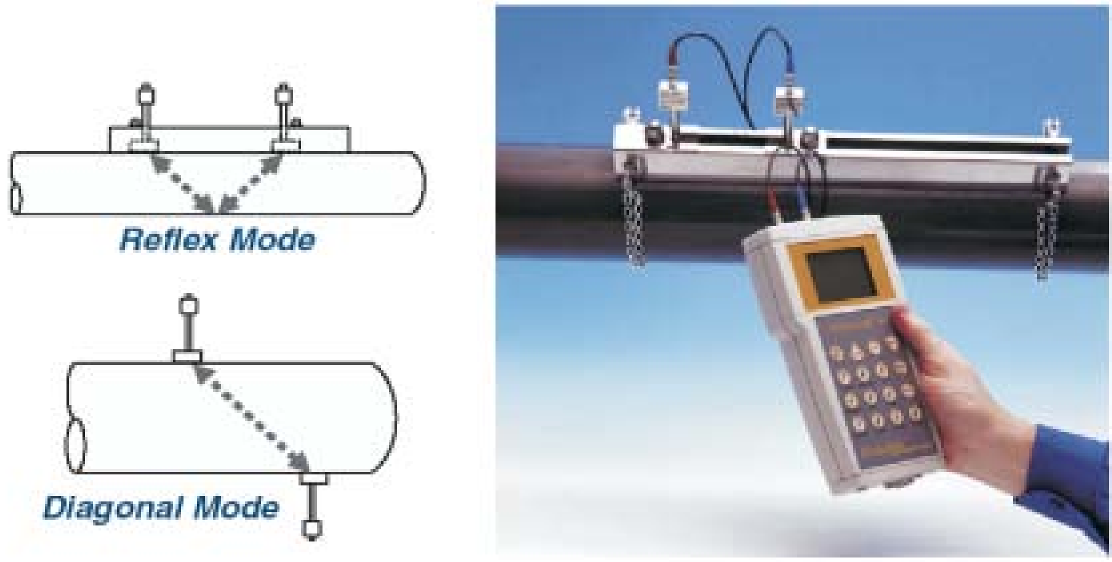


Photo A4: Clamp-on Digital Ultrasonic Sensors and Processing/Display Unit

For flow in a pipe, the easiest and most accurate method of measuring flow is by using ultrasonic flow meter. This meter reads the flow instantly by clamping the meter at the pipe section where the flow is to be measured. Details of flow measurement are given in a Chapter 3, separately where low flow prediction for micro hydro schemes are discussed. See Appendix B, for Procedure and Data sheet for Flow Measurement during Power Output Verification with this guideline.

A5 Current Meter

Current meter is a mechanical device with revolving cups or propeller attached to a shaft. When the current meter is placed in flowing water, these cups or propellers revolve due the flow velocity. The higher the flow velocity, the faster the cups or the propellers will revolve, i.e., the frequency of revolution increases. If the cross section area of the river is know at the discharge measurement point, and from the correlation between the revolution of the cups/propeller and the flow velocity, the average velocity can determined, then in principle the river discharge can be calculated.

Discharge measurement by conductivity meter is not practical for large rivers due to requirements of large volumes of salt required and more likelihood of intermittent stagnant pools along short stretch[4]. Thus, for rivers with (low) flows larger than 2.5 m^3/s, an alternative method of flow measurement (than conductivity meter) needs to be used. The current meter appears to be a suitable method of flow measurement for rivers with relatively higher flows where a conductivity meter is not practical.

As there is a direct correlation between the frequency of revolution and flow velocity, the flow velocity can be calculated from current meter using the correlation equation. This current meter is most suitable for flow measurement in the velocity range between 0.2 to 5 m/s where the accuracy can be as high as 98%.

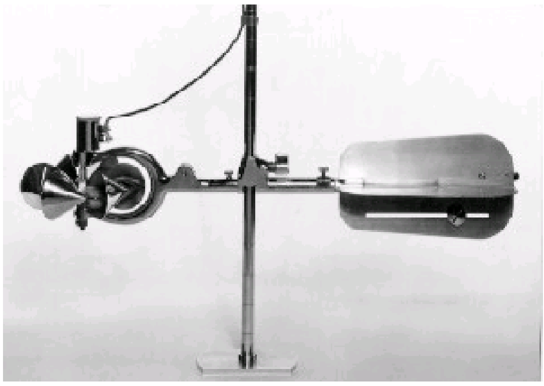


Photo A5 - 1: Cup current meter

[4] Large rivers have generally milder slope and low velocity and thus more likely to have stagnant pools at short lengths

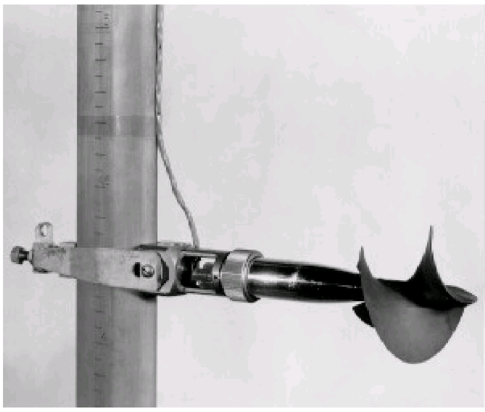


Photo A5-2: Propeller current meter

Photo A5-3: Mini Air current meter

Cup current meter (Shown in Photo A5-1) and Propeller current meter (Shown in A5-2) are widely used in river flow measurement. They are similar in principle but cup current meter has multiple cups and revolves in vertical axis whereas the propeller current meter has a propeller and revolves in horizontal axis. A Mini Air current meter actually designed for air speed measurement is shown in Photo A5-3. It automatically gives flow velocity can be used in small rivers.

The correlation equation for river flow velocity calculation is:

$v=a*N+b$

Where,

v= flow velocity

a and b = correlation coefficient supplied by manufacturer or calibrated in a standard Laboratory

N= Number of revolution per second

Specification:

Current meter shall be either of cup type or propeller type from well recognized manufacturers (those meeting ISO certification). Correlation equation with calibrated date should be available with the current meter and placed in the carrying box. Initials of an authorized person along with stamp of the calibrating agency should be put together along with the correlation equation. The calibration shall also specify the accuracy range for measurement which in any case shall be less than 5% to be accepted for use for flow measurement. `

The current meter set should include stop watch, graduated handle and mechanical, electrical or digital revolution counter. Direct velocity recording digital device can also be used in place of revolution counter. The rod and the propeller should be robust for use in small rivers. Submerged part of the electrical/digital counterpart should be water proof. Vanes and cups should be clean. Turbine shaft should be frictionless.

A6 Conductivity Meter

Flow measurement using conductivity meter is also known as the “Salt Dilution Method.” The method involves pouring a salt solution some distance upstream and measuring the change in conductivity as the salt wave approaches the gauging location. The salt solution changes the conductivity of the river (as the salt wave travels downstream) and this change in conductivity can be related to the river flow if base line conductivity of the river, the type, and amount of salt added and water temperature are known. As the salt wave passes the measurement location, the conductivity of the river returns to its original level (i.e. base line conductivity).

Photo A6 - 1Conductivity meter – HI 8733 (Recommended for POV Team)

Specification:

Range	0.0 to 199.9 µS/cm; 0 to 1999 µS/cm; 0.00 to 19.99 mS/cm; 0.0 to 199.9 mS/cm
Resolution	0.1 µS/cm; 1 µS/cm; 0.01 mS/cm; 0.1 mS/cm
Accuracy	±1% F.S. (excluding probe error)
Calibration	manual, 1 point
Temperature Compensation	automatic, 0 to 50°C (32 to 122°F) with ß adjustable from 0 to 2.5%/°C
Probe	**HI 76302W**, ATC, with 1 m (3.3') cable (included)
Battery Type / Life	1 x 9V / approx. 100 hours of continuous use
Environment	0 to 50°C (32 to 122°F); RH max 100%
Dimensions	164 x 76 x 45 mm (6.4 x 3.0 x 1.8")
Weight	250 g (8.8 oz.)

Photo A6-2 Conductivity meter – Hanna (Dist WP 3 Recommended for Installer)

Range	1990 µS/cm
Resolution	1 µS/cm
Accuracy	±2% F.S.
Calibration	manual, 1 point, through trimmer
Temperature Compensation	automatic, 5 to 50°C (41 to 122°F)
Battery Type / Life	4 x 1.5V / approx. 150 hours of continuous use
Environment	0 to 50°C (32 to 122°F); RH max 95%
Dimensions	150 x 30 x 21 mm (5.9 x 1.2 x 0.8")
Weight	70 g (2.5 oz.)

APPENDIX - B

FLOW MEASUREMENT METHODS AND EXAMPLES

APPENDIX - B

FLOW MEASUREMENT METHODS AND EXAMPLES

B1 Stream flow measurements

Flow measurements in natural channels such as rivers are difficult for the following reasons:

- The cross-section of the river is not uniform and furthermore, it varies with depth as the water level changes.
- The flow velocity varies at different locations along the cross-section as well as depths
- If the river flows through sand deposits (such as in the case of alluvial rivers), the cross-section of the river will change with time.

In case of micro-hydropower schemes, the source streams are usually small tributaries or sub-tributaries of main rivers and are steep. Therefore, the flow depth may not be sufficient to cover an ordinary current meter, especially during the low flow seasons. However, for mini hydropower schemes that divert flows from larger rivers, it may be feasible to use current meter. Thus, as discussed earlier, if the river flow exceeds 2.5 m3/s, a current meter should be used for flow measurement (regardless of whether the scheme is in the micro or mini hydro range. General description and principles of the current meter were presented earlier. Flow measurement process using the current meter is discussed later..

Although, the float method is simple in principle, it requires subjective judgment for the determination of the velocity reduction factor. As the name denotes, in the float method objects such as twigs or plastic bottle partially filled with stones are placed on the surface of the stream where the cross sectional areas have been measured at certain intervals. Then, the velocity of the object (that floats on the surface) is measured as it passes through known cross sections. Although, the velocity and the cross section area are known it is not possible to calculate the flow by directly multiplying the measured velocity with the cross sectional area. This is because the velocity in the surface of the stream is higher than the average velocity. Therefore, a reduction factor has to be applied which depends on the roughness of the stream, vegetation growth, depth etc. and thus requires subjective judgment.

Therefore, accurate methods to measure flows in small rivers are to use conductivity meters and current meters for relatively larger flows.

B1.1 Flow Measurements using Conductivity Meter

Conductivity meters can be used in small, highly turbulent streams with rough, irregular channels and thus are suitable for flow measurements in micro-hydro Source Rivers. Table salt (Sodium Chloride, NaCl) is the most commonly used salt since it is inexpensive and widely available.

For accurate results, the following conditions have to be ensured:

- The salt solution poured upstream must be completely mixed throughout the river cross section before it arrives at the measurement location.

- The stream section should not have large stagnant pools.

- There should not be any inflows into or outflows from the stream between the point where the salt solution is poured and the measurement location. In other words the flow at the location where salt is poured must be equal to the flow that arrives at the measurement location.

- The conductivity meter probe should be submerged in fairly fast flowing section of the river.

The advantages of this method are that it is simple and fairly accurate (within ~ 7%) when used by trained personnel. It is also reliable for a wide range of flows and measurements can generally be taken within 30 minutes.

The conductivity meter shall be calibrated every six months by a standard laboratory. The laboratory shall issue a certificate of calibration with the date and other technical parameters.

B1.1.1 Measurement Procedure

The equipment required is as follows:

1. A conductivity meter covering a range of 0 – 10,000 micro-siemens (μS.)
2. A thermometer to measure the water temperature.
3. Some amount of salt (according to discharge).
4. A weighing machine (to weigh the salt).
5. One stop watch.
6. Graph Papers (mm type) and a Calculator.
7. One bucket.

B1.1.2 Discharge measurement

i) Prepare a salt solution in a bucket by mixing salt and river water and stir the solution with a clean stick until the salt is completely dissolved. Note that the weight of salt should be carefully measured (using a weighing machine) and recorded before placing it into the bucket. Also, once such a solution is prepared care must be taken not to spill any. 50 to 300 gm of salt may be required for each 100 liter per second of flow depending on the baseline conductivity of the flow. For higher baseline conductivity, more salt will be required. Since the river flow is initially unknown, it will have to be estimated in order to apply the above general rule.

ii) Turn on the conductivity meter and submerge the probe in a fast flowing section of the river at the intake area or nearby. Then record the baseline conductivity (i.e. natural conductivity of the river before the addition of the salt solution). Also set the stopwatch so that the time can be measured.

iii) Select a place upstream of the measurement location where the salt solution can be quickly dumped. Depending on the turbulence of the flow, this location should be between 50 m to 300 m upstream of the measurement site. If the flow is turbulent, upstream (i.e., presence of rapids, and falls) 50 m may be adequate, else the distance will have to be increased. The principle is that the cloud of salt solution needs to be completely dispersed in the stream water before it arrives at the place where conductivity measurement is taken. Similarly, it is necessary to ensure that there are no flow abstractions, additions, or stagnant pools between the measurement site and the upstream location where the salt solution is poured.

iv) Then send a helper with the salt solution bucket upstream at the chosen location (make sure that the solution is not spilled on the way). Signal the helper to pour the salt-water solution into the stream. The entire solution should be poured quickly and in one go. Slow pouring may cause fluctuations in the conductivity readings and hence less accurate results. Start the stopwatch and note down the readings on the conductivity meter as soon as there is an increase in the values from the base line conductivity. The common practice is to note down the readings in five seconds intervals. It is useful to have two persons to take the readings at the measurement site. One can read the conductivity values every 5 seconds intervals (using the stopwatch) and the other can record these values. Also, it is helpful to record the readings in pre-formatted table (see Table B1).

The conductivity readings should be taken continuously until the value diminishes back to the baseline conductivity of the stream. Note that sometimes, the conductivity values will remain above the baseline value by a few μS for a long time. If this is the case, then the conductivity readings can be stooped since the difference of a few percent in conductivity does not contribute significant additional flows.

v) Measure the temperature of the water in the stream if the conductivity meter does not have provision for temperature adjustment. Also, fill in other data such as weather, date, time etc. as shown in Table B1.

vi) Finally, plot the reading on the graph paper with time in seconds in the horizontal axis and conductivity in micro Siemens (μS) in vertical axis as shown Figure B1.1. If the result is not satisfactory, (i.e., a smooth shaped graph according to Figure B1.1, case e) repeat the measurement with more or less amount of salt depending on the outcome. Inaccurate graphs and their probable reasons are also presented in the figure. Therefore, based on the results obtained (i.e., graph) take remedial measures.

vii) After satisfactory results are obtained, take a second set of measurement to verify the first. Note that this will only require about half an hour of additional work at site and will be cost effective compared to coming back to site the second time for flow measurements.

The accuracy of the measurement depends on the calibration of the conductivity meter. The conductivity meter is calibrated by carefully determining the salt constant (k value) for the type of salt used under controlled laboratory conditions. This is discussed in the subsequent section. Note that packet salts (usually available in 1 kg sealed plastic bags) should be used rather than loose crystals. This is because packet salts are more homogenous and loose salt crystals can absorb water and thus lead to errors.

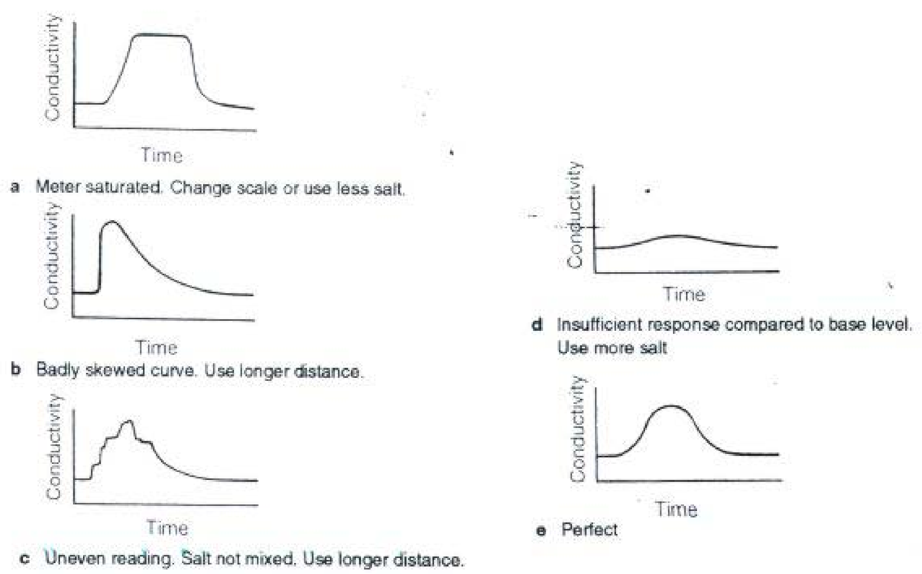


Figure B1.1: Conductivity graphs for various conditions

Once a satisfactory graph is obtained, the flow can be calculated as follows:

Stream Flow, Q = M x k/A

Where,

Q is the flow in lit/sec

M is mass of the dried salt in mg.

k is the salt constant and is dependent on the nature of salt and water temperature (if conductivity meter is not of temperature adjustment type). The units of k are (μS)/(mg/liter) or micro seimens per milligram per liter. Note that conductivity is the reciprocal of resistivity and,

micro Seimen (1 μS) = 1 $\text{ohm}^{-1} \times 10^{-6}$ and 1 Siemen = 1 ohm^{-1}. For determination of k –value, refer to section B1.3

A is the area of the curve after excluding the area due to base conductivity in (sec x μS). The units in the equation Q = Mk/A are checked below:

[mg x (μS /(mg/lit))/ (sec x μS) = lit/sec] Since the final units are lit/sec for the flow (Q), the units match.

Example 1: Flow calculation using conductivity meter results

Data obtained from a site using conductivity meter is presented in Table B1

Table B1: Flow measurement using conductivity meter

Water flow measurement by salt dilution method of ABC river
time: 7:40 am, Apr. 24, 2001 Weather: Clear & sunny
Salt used: 400 gram Water temp: 9.7 0c
Baseline Conductivity: 53 mS (i.e., conductivity in the river before pouring salt solution)
Salt constant k = 1.88

Time (sec)			05	10	15	20	25	30	35	40	45	50	55	60	Sum
water conductivity in µS	Minutes	1	53	56	60	64	70	77	85	93	103	114	126	139	1,040
		2	152	155	155	154	151	147	138	129	119	110	103	96	1,609
		3	90	85	80	75	71	67	64	62	60	58	56	56	824
		4	56	56	56	55	55	55	55	54	54	54	54	54	658
		5	53	53	53										159
		6													
		7													
		8													
		9													
		10													
TOTAL															4290

Area (A) under the curve = (4290 – 53 x 51) x 5= 7935 µS Sec.

Note that the "Area" here is the area under the graph of conductivity in µΣ in the vertical axis and time in seconds in the horizontal axis excluding the baseline conductivity (i.e., conductivity measure before pouring the salt solution upstream). Hence, the units of "Area" under the graph are µS Sec. The graph of the conductivity readings over time for this example is also presented in Figure B1.2.

In the calculation of area for this example, 4290 is the sum of the conductivity readings. 53 is the baseline conductivity and it is multiplied by 51 since there are 51 readings. Finally, (4290 – 53 x 51) is multiplied by 5, since the readings are taken in 5 seconds intervals. Thus, the area under the curve above the baseline conductivity is calculated. The graph of the above reading is also presented in Figure B1.2. Note that the shape of the graph is similar to that of the ideal case (Figure B1.1-.e).

Recall that, Q = Mk/A and from Table 10 k = 1.88, and M = 400 gram = 400,000 milligram

Q = 400,000 x 1.88 /7935 = 94.8 l/s, Or, Q = 95 l/s

Therefore the river flow is 95 l/s.

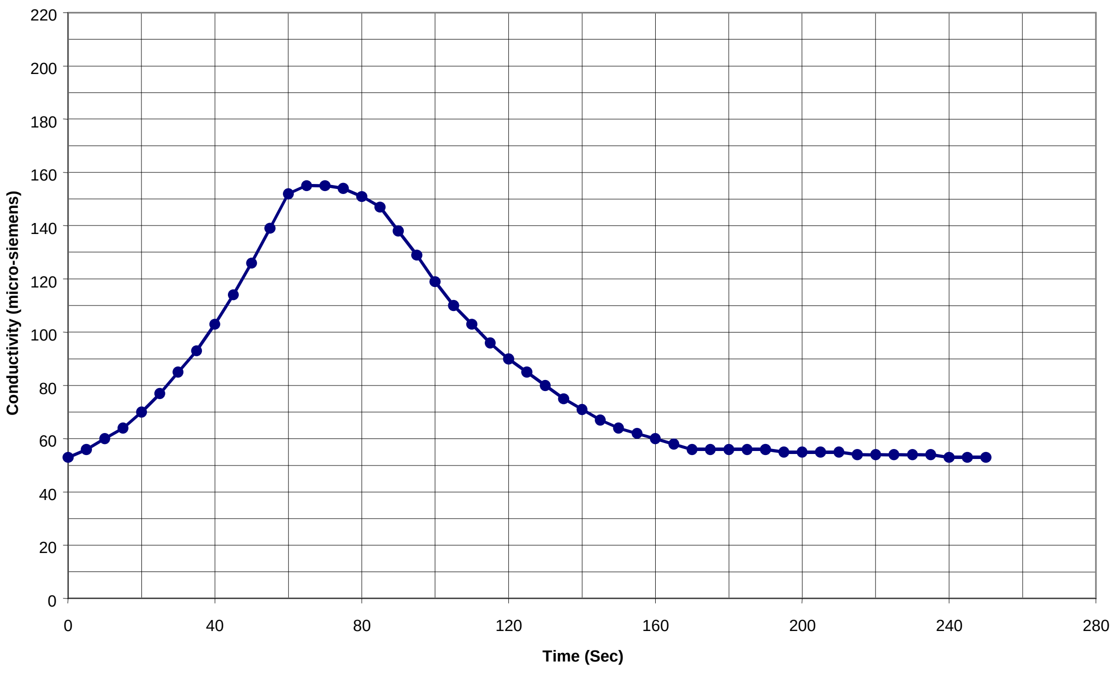


Figure B1.2: Graph of conductivity over time (Based on data from Table B1)

B.1.1.3 Determination of K-value

The following equipment is required to determine the K-value:

2. Conductivity meter
3. Weighing machine
4. Bucket (10 – 20 liter)
5. Graduated cylinder (1 liter)
6. Pipette
7. Stirring rod
8. Salt (of the type that will be used for flow measurement)

Once all equipment is ready, adopt the following procedure:

i) Pour about 10 liters of tap water in the bucket. Use the graduated cylinder to measure the exact volume of water.

ii) Using the weighing machine weigh about 20 gm of salt and note down the exact weight. Pour about 1.0 liter (1000 ml) of tap water in the graduated cylinder and note down the exact volume. Pour the salt in water and stir with a stirring rod until it is completely dissolved. Now the concentration of salt in the calibration solution is 20gm/1000 ml = 20mg/ml (assuming that exactly 20 gm of salt is added into 1000 ml of water).

iii) Measure the temperature and the base conductivity of the water in the bucket and note them in the field book.

iv) Take 10 ml of the above-calibrated solution (= 10 ml x 20 mg/ml = 200 mg of salt) in a pipette and inject it into the bucket. Stir the salt-water solution to ensure proper mixing and then note the conductivity reading. Note that once the salt-water has been completely mixed in the bucket, the readings will not fluctuate. Therefore, after adding the calibrated solution in the bucket it must be stirred well and measurements should be taken once there is no fluctuations. Note that in this case the concentration in the bucket is 200 mg/10.01 liters = 19.99 mg/ml. Note that the volume in the bucket is 10.01 liter since 10 liter of water was initially placed in the bucket and then 10 ml of salt solution was added. The volume of the salt solution should also be included in the total volume calculation since this could be significant as more and more salt solution is added.

v) Repeat step 4 about five times so that there are adequate data to calculate the salt constant.

vi) Now plot the conductivity values (μS) in the vertical axis and the cumulative salt concentration (mg/liter) in the horizontal axis. Then draw a best-fit line joining the five data points. Determine the slope of this line, i.e., rise in conductivity over rise in salt concentration which is the value for the salt constant (k value).

Note that if the conductivity meter is not of temperature compensating type then the calibration method presented above should be repeated at various temperatures and then the change in k value with change in temperature can be determined. If the procedure is repeated 3 – 4 times for temperatures between 5^oC to 20^oC, it should be adequate since this range should cover most of the cases at site.

An example is presented below to further illustrate the calibration of the conductivity meter.

Example 2.: Conductivity meter calibration

Concentration of calibration solution = 20 mg/ml

Volume of water in the bucket = 10 l

Baseline conductivity = 20 μs (i.e., conductivity before the calibration solution is poured in the bucket.

Conductivity readings are presented below in Table B2

Table B2: Conductivity reading

Incremental amount of calibration solution added		Cumulative amount of calibration solution		Salt concentration in Bucket (mg/l)	Conductivity readings (μS)
Volume (ml)	Weight (mg)	Volume (ml)	Weight (mg)		
0	0	0	0	0	20 (base line)
10	200	10	200	200/10.01 = 19.98	61
8	160	18	360	360/10.018 = 35.94	92
12	240	30	600	600/10.03 = 59.8	139
10	200	40	800	800/10.04 = 79.68	162
13	260	53	1,060	1060/10.053 = 105.44	190

Now plot the salt concentration in bucket (mg/l) I the horizontal axis and conductivity (μS) in the vertical axis and draw the best fit line as shown in Figure B1.3.

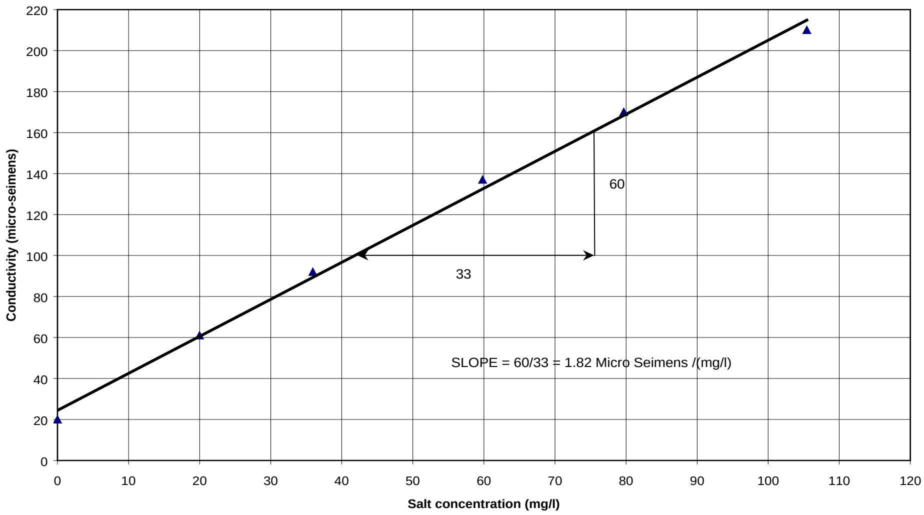


Figure B1.3: Conductivity meter calibration

As can be seen from Figure B1.3, the slope of the line is 1.82. Therefore the salt constant k = 1.82 μS/(mg/l).

B2 Flow Measurements using Current meter

B2.1 Flow measurement procedure

1. Selection of measurement location

As far as possible a straight portion of river with comparatively uniform flow section should be selected for flow measurement. A typical measurement location is shown in Photo B2.

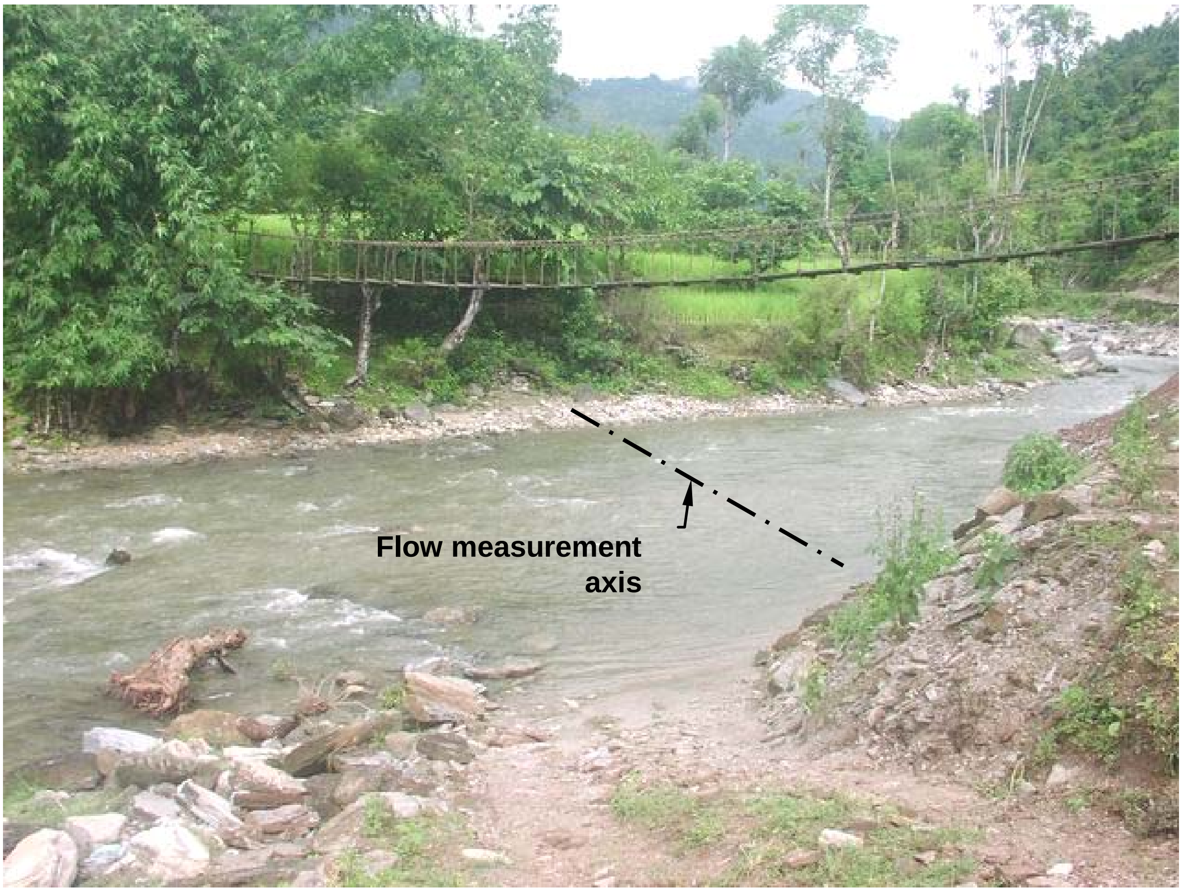


Photo B2: Appropriate flow measurement location

2. Segment division

The entire width of the river should be divided into equal segment width, w as shown in Figure B2. It is recommended that the river cross section be divided to a minimum of 6 segments so that measurement accuracy is increased. The segment width should generally be between 0.5 m to 1.0 m (such that there is minimum of 8 segments).

A typical river cross section for flow velocity measurement and flow calculation is shown in Figure B2 and notations used are as follows:

W= width of river

w= width of measurement segments (all equal)

d_1, d_2, d_3, ……= depths of flow of measurement segments

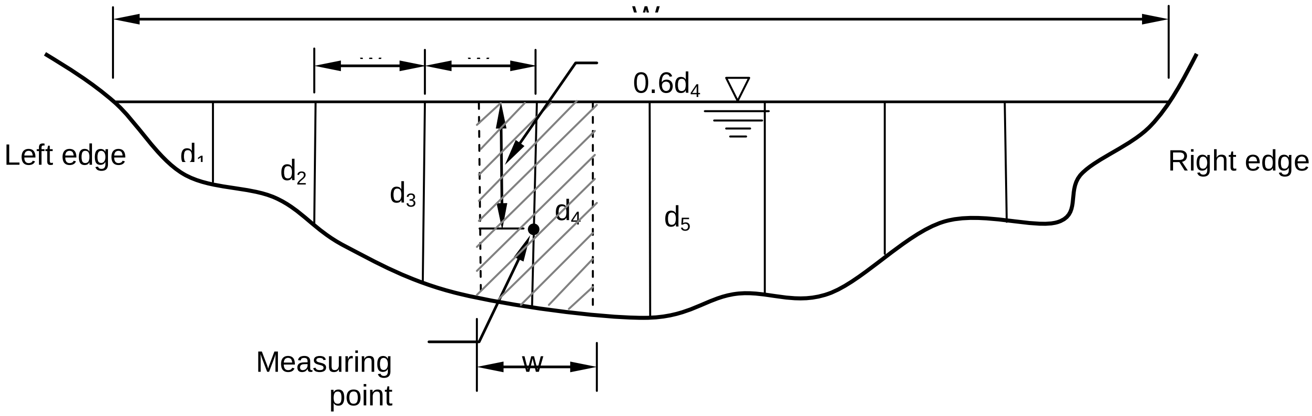


Figure B2: River cross section

3. Measurement

A current meter mounted on a graduated wading road should be placed at the end of each segment at a depth of 0.6 times the water depth from the surface (see Figure B2) and the readings should be recorded (e.g., d_1, d_2, d_3,).. Note that the cup or propeller of the current meter should be facing the upstream side of the wading road and care should be taken not to disturb flow during the measurement process, i.e., the recorder should stand downstream from the wading rod.

The number of revolution in 30seconds time should be recorded. Based on the type of current meter, the number of revolution can be counted either via a sound emitted (e.g., beep or click) through a headphone or via a mechanical/digital counter mounted on the current meter.

4. Parameter calculation

Frequency of the revolution is number of revolution per second and can be found by dividing the number of revolution recorded by the time period in seconds. Then flow velocity of the segment can be found from the correlation equation presented earlier and area of the segment can be found by multiplying segment width, w and segment depth (in Figure B2 d_4 in hatched area segment).

Then the flow through the hatched segment in Figure B2, is $w*d_4*v_4$ (v_4 flow velocity through the segment 4). Thus, calculating the flow of each segment and adding all flows will result in total river flow at the time of measurement. At least three sets of measurements should be taken during flow measurement to avoid error. If all measurements are within 5% range the average should be used as the estimated flow. If the deviation is larger than 5% the measurement should be repeated until the three sets of measurements are within the 5% range.

It should be noted that current meters displaying direct value of velocity is also available in the market. If such current meter is used, the velocity calculation will not be necessary.

A form for recording the measured data and flow calculation is presented in page below and an example of flow data recording and calculation is shown in Table B3.

Table B3: Data recording and flow calculation example[5]

[5] Data courtesy Sanima Hydropower (P.) Ltd., Kathmandu, Nepal

FLOW DATA RECORDING AND CALCULATION BY CURRENT METER

Instrument:		River width (W):	16 m
River:	Mai Khola	Segment width (w):	1.0 m
Location:	Danabari, Gunmune, Ilam	Revolution duaration (t):	40 s
Date:	10/21/2062	Last calibrated date:	

Segment	Distance	Depth (d)	Number of revolution (R)	Frequency of revolution (N)	Segment velocity (v)	Segment flow (q)
	m	m	r	rps	m/s	m3/s
1	1	0.11	35	0.88	0.23	0.03
2	2	0.2	60	1.50	0.40	0.08
3	3	0.35	68	1.70	0.45	0.16
4	**4**	**0.42**	**78**	**1.95**	**0.51**	**0.22**
5	5	0.52	83	2.08	0.55	0.28
6	6	0.55	89	2.23	0.59	0.32
7	7	0.55	96	2.40	0.63	0.35
8	8	0.6	98	2.45	0.65	0.39
9	9	0.59	100	2.50	0.66	0.39
10	10	0.65	101	2.53	0.67	0.43
11	11	0.6	98	2.45	0.65	0.39
12	12	0.5	100	2.50	0.66	0.33
13	13	0.57	84	2.10	0.55	0.32
14	14	0.55	82	2.05	0.54	0.30
15	15	0.3	52	1.30	0.35	0.10
16	16	0.18	45	1.13	0.30	0.05
					Total	**4.13**

Correlation equations:	v=a*N+b		
Correlation coefficients:	a	b	
	0.2503	0.0150	for N<0.84
	0.2610	0.0060	for N≥0.84

The segment velocity should be put in v column if current meter gives it directly.

Calculation of segment 4 flow is shown below.

Known;

Depth (d_4)	=0.42 m
Segment width (w)	=0.40 m
Revolution duration (t_4)	=40 s
Number of revolution (R_4)	=78

Correlation coefficient (provided by equipment supplier in the owner's handbook and confirmed through calibration)

(a, b) =(0.2503, 0.0150) for N<0.84

=(0.2610, 0.0060) for N≥0.84

Calculation;

Frequency of revolution (N_4)	$=R_4/t_4$
	=78/40 =1.95 rps
As N>0.84, formula for segment velocity (v_4)	$=0.2610*N_4+0.0060$
	=0.2610*1.95+0.0060
	=0.51 m/s
Segment flow (q_4)	$= w*d_4*v_4$
	=0.40*0.42*0.51
	=**0.22 m^3/s**

Similarly discharge of each segment is calculated and added to find the river flow of 4.13 m3/s.

B2.2 Calibration of current meter

Calibration of current meter shall be done at least once every six months by a standard laboratory for consistency and accuracy of flow measurement. During calibration wide range of velocities and sufficient number of measurements shall be taken as recommended by the manufacturer. The laboratory shall issue a certificate of calibration with the date and other technical parameters.

B3 Flow Verification Using Weirs

It is generally difficult to measure the flow diverted into the micro-hydropower scheme (such as design flow) using the conductivity meter. This is because the flow in the headrace canal is laminar (velocity is low) and therefore larger distances will be required between flow measurement and salt pouring locations. Therefore, for short headrace canal or headrace pipe the conductivity meter will not be practical. Similarly, although the flow in the tailrace canal is turbulent the distance may be too short to use the conductivity meter.

During the commissioning stage, the diverted flow into the micro-hydropower scheme will have to be measured to verify the power output at designed flow and to check efficiencies at various flows (i.e. a few percent above and under design flow). This flow verification process will be simple if a triangular weir is installed along the headrace, beginning, or end of settling basin and forebay or the tailrace canal.

B3.1 V-Notch weir

A V-shaped notch in a vertical thin plate, which is placed perpendicular to the sides and bottom of a straight channel, is defined as a V-notch sharp-crested weir. In the literature, the V notch is also referred to as the triangular weir, since the opening is triangular in shape (i.e. V shaped).

The line which bisects the angle of the notch should be vertical and at the same distance from both sides of the channel. The **V-notch sharp-crested weir** is one of the most precise discharge measuring devices suitable for a wide range of flow and is commonly used in hydraulic laboratories for flow measurements. For V notch weirs to be classified under the term "sharp-crested" or "thin-plate" the length of crest in the direction of flow should be equal to or less than two millimeters. The weir plate should be smooth and plane, especially on the upstream face, while the crest surface and the sides of the notch should have plane surfaces, which make sharp 90-degree intersections with the upstream weir face. The downstream edge of the notch should be beveled if the weir plate is thicker than two millimeters. The beveled surfaces should make an angle of not less than 60 degrees as shown in Figure B3.1.1 Note that thicker plates (3 mm to 4 mm) can be used if the edge is beveled as discussed above.

V notch weir should be located only in a rectangular approach canal. Owing to a lack of experimental data relating to the discharge coefficient over a sufficiently wide range of parameters (depth over width, canal width to V notch width, canal depth to V notch depth etc), only the 90 – degree V-notch should be used.

To obtain high accuracy, provision should be made for ventilating the nappe to ensure that the pressure on the sides and surfaces of the nappe is atmospheric. The downstream water level should be low enough to ensure that it does not interfere with the ventilation of the air pocket beneath the nappe. Hence locating a weir just upstream of a drop along the headrace canal can be an appropriate option.

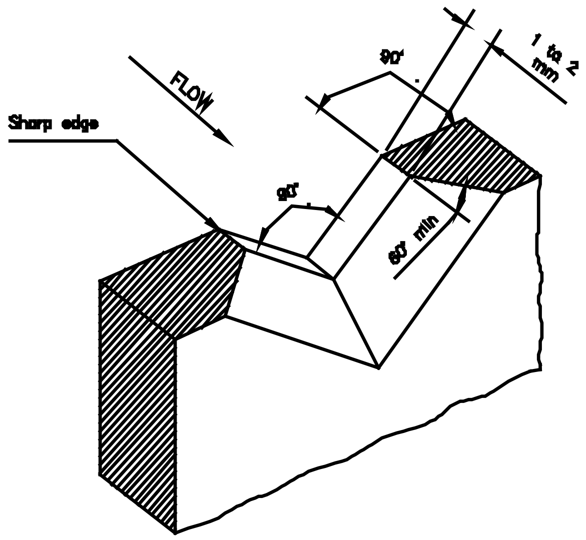


Figure B3.1.1: Enlarged view of V–Notch weir

The basic equation of discharge for a V notch weir is:

$Q = C \times (8/15) \times (2g)^{0.5} \tan(\theta/2)h^{5/2}$

where:

Q = discharge in m^3/s
h = head over the weir measured from the vertex of the notch (see Figure B3.1.2)
g = acceleration due to gravity = 9.81 m/s^2
θ = The angle of the notch and for a 90^o triangular weir $\theta = 90^o$ and,
Tan $(\theta/2) = \tan 45^o = 1$
C = coefficient of discharge. The value of C varies from 0.608 at h = 0.050 m to 0.590 at h = 0.381 m. Hence, a value of C=0.60 can be used for low head over the weir. Anther option is to have the weir coefficient independently verified by a laboratory.

For a 90^o V notch weir the above equation can be simplified as:

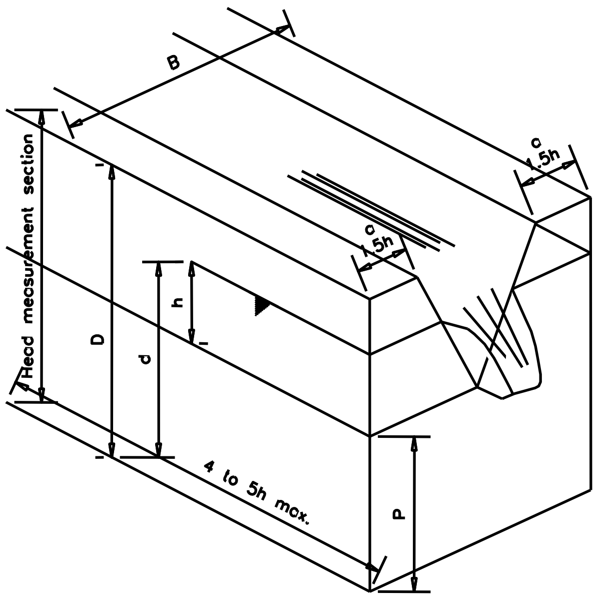
$Q = 0.6 \times (8/15) \times (2\times9.81)^{0.5} \times \tan45^o \times h^{5/2}$

Or $Q = 1.417\ h^{5/2}$

Therefore, for a sharp crested V notch (triangular) weir, the flow can be determined by measuring the head over weir and using the above equation. Note that measurement should not be done exactly at the weir but at a distance between 4 to 5 times h as shown in Figure B3.1.2. This is primarily due to two reasons as follows:

- Measurements exactly above the notch of the weir disturbs the flow and thus gives erroneous result

- The flow surface profile upstream gradually decreases as it approaches the notch. Thus the depth measured at the notch of the weir will be somewhat less than the actual depth required in the equation.



A V Notch weir located along a section of a headrace canal is presented in Figure B3.1.2.

Figure B3.1.2: V-Notch weir located on along a headrace canal

B3.1.1 Installation of a V notch weir in a micro-hydro scheme

If a provision is made to install a V-Notch weir in the micro-hydro scheme during the design phase, then flow verification during the commissioning phase will be simple. Furthermore, if the location of the weir is carefully thought of, then it can be installed at little additional cost. The following factors should be considered while sizing the V notch weir dimensions:

- As discussed earlier, the weir should be located just upstream of a drop along the headrace canal so that the downstream water level does not obstruct with the water level.

- There should not be significant leakage downstream of the weir since the flow measured at the weir will be used to partly determine the system efficiencies.

- Weir should be sized such that the minimum head over the weir is 50 mm with adequate free board (50 to 100 mm). Weir dimensions for various flow range are presented in Table B4

- A 3 mm weir with a notch profile according to Figure B3.1.2 should be appropriate. A thinner such as 2 mm thick weir would although be ideal it could get damaged during transportation, handling and simply due to corrosion.

- A removable weir, which is placed at the measurement location during flow verification phase or at other times as required should be designed. To allow these grooves should be made at the measurement structure to ensure the insertion of the weir. At other times, the weir can be stored close to the scheme. The floor should be level at the measurement location for about 5 times the head over the weir (required for design flow).

- Placing the weir will raise the water level upstream for some distance, and the walls of the waterways (canal, settling basin etc.) will have to be raised according to the water surface profile calculation. If this is not feasible (or too expensive) then wooden planks or plywood can also be placed along the walls during the measurement time.

Table B4: Recommended minimum dimensions for V- notch weirs

Design Flow (Q) l/s	h (mm)	D (mm)	a (mm)	p (mm)
20	182	600	275	370
40	240	800	360	480
60	282	900	425	575
80	317	700	475	640
100	346	1100	520	700
150	407	1300	490	820
200	457	1400	690	920

Note that in Table B4, h is the actual depth of water over the weir measured 4 to 5 times the distance upstream of the weir. The dimensions can be either determined based on Figure B3.1.2 or interpolated using Table B4 for intermediate flows between 20 l/s to 200 l/s. The 20 to 200 l/s flow rage should cover most of the micro-hydropower schemes. For flows beyond 200 l/s the flow should be divided in two parallel sections (i.e. 2 headrace or tail race canals etc.) and measured or a rectangular weir should be used. Note that except for the area around the V notch, the weir can be made in pieces such that they can be transported easily to site. Another option is to use wooden planks (plywood) at the sides and bottom of the notch (and use mild steel for only the periphery of the notch; for about 100 mm from the notch perimeter). However, the connection joints should face downstream and the upstream face should be smooth. Also, note that for large flows, the dimensions of the weir are also significantly high and therefore such a V notch weir along the headrace canal may not be practical as discussed earlier.

In section B3.1, it was mentioned that a weir coefficient 0.6 is appropriate for thin plate V notch weir if the head over weir is between 50 mm to 381 mm. Note that for flows of 150 l/s and 200 l/s the depths exceed 381 mm. This implies that the weir coefficient may be different than 0.6 for these flows. The procedure for computing the weir coefficient for large depths is complicated. However, for flows up to 200 l/s, the assumption of weir coefficient of 0.6 will not lead to significant error.

B3.2 Rectangular Weir

In the exceptional case that the design flow exceeds 200 l/s and two parallel flow measurement sections using V-notch weirs is not practical, a rectangular weir may be appropriate. The enlarged view of the crest and sides of a rectangular sharp crested weir is presented in Figure B3.2.1. Similar to sharp crested V-Notch weir, for rectangular weir the length of crest in the direction of flow should be equal to or less than two millimeters as can be seen in the figure. The weir plate should be smooth and plane, especially on the upstream face, while the crest surface and the sides of the notch should have plane surfaces, which make sharp 90-degree intersections with the upstream weir face. The downstream edge of the notch should be beveled if the weir plate is thicker than 2 mm. The beveled surfaces should make an angle of not less than 45^o as shown in Figure B3.2.1. Note that thicker plates (3 mm to 4 mm) can be used if the edge is beveled as discussed above.

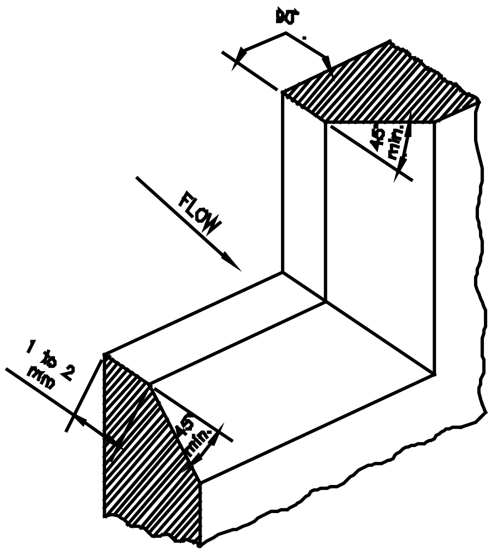


Figure B3.2.1: Enlarged view of crest and side of rectangular sharp-crested weir

Similar to the V notch weir, the rectangular weir should also be located along a rectangular approach canal as can be seen in Figure B3.2.2.

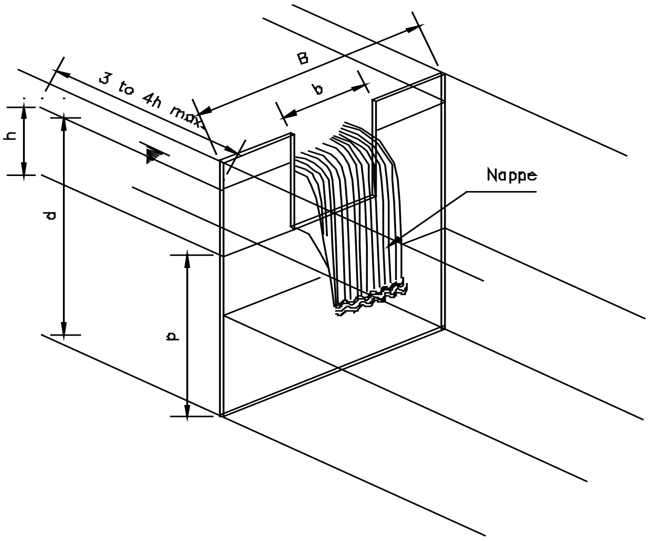


Figure B3.2.2: Rectangular Sharp Crested Weir

The basic equation of discharge for a rectangular weir is:

$Q = C \times 2.953 \times b \times h^{1.5}$

Where,

d = Depth of water from bed level to water surface in m
p = Height from bed level to the crest of the weir in m
h = Head over weir (d – p) in m
b = Width of the weir in m
C = Weir coefficient of discharge which is close to 0.6.

The exact value depends on the ratio of weir width over canal width (b/B), and h/p. Hence, ideally the weir coefficient should be independently verified by standard laboratory.

If installation of V notch weirs in two parallel sections is not practical (or is expensive), a standard rectangular weir with the following dimensions is recommended for use when the design flow exceeds 200 l/s (refer to Figure B3.2.2 for definition of parameters):

a	=	200 mm
b	=	1000 mm
p	=	200 mm
D	=	600 mm

Depth of weir, D -P = 400 mm

For the weir with the above dimensions, the weir constant varies between C = 0.630 to C = 0.648 for weir heads between 226 mm (200 l/s) to 350 mm (400 l/s) respectively. For intermediate weir head, the value of C should be interpolated based on the above values for C. Note that the maximum flow that can be measured with this rectangular weir is 400 l/s with 50 mm of freeboard. Similar to the V notch weir, head measurement for rectangular weir should not be done exactly at the weir but at a distance between 4 to 5 times h as shown in Figure B3.2.2

APPENDIX - C

FLOW ESTIMATION METHODS AND EXAMPLES

APPENDIX - C

FLOW ESTIMATION METHODS AND EXAMPLES

C1 Catchment area calculation

The Example below illustrates the process of determining catchment areas from topographical maps.

The catchment area shown in Figure C1.1 is of a tributary of Bhudka Khola, Khimadi VDC located in Seti zone. This catchment area map has been copied from Finnmap.

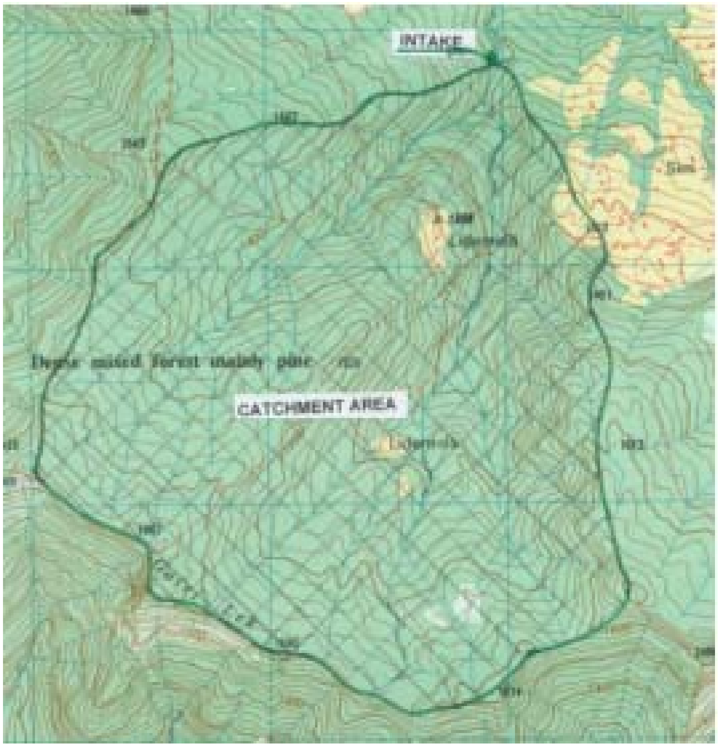


Figure C1.1: Catchment area of a MHP scheme (scale 1:25,000) and its location

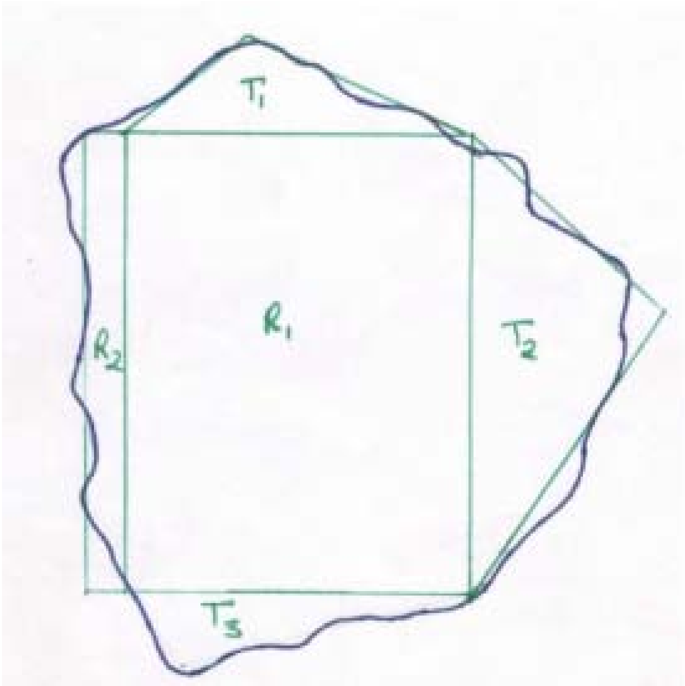


Figure C1.2 Catchment area calculation based on areas of rectangles and triangles

As can be seen in Figure C1.2, the catchment area has been divided into two rectangles (R1 & R2) and three triangles (T1, T2 & T3).

Area Calculations:

Map area in cm^2: R1 = 6 cm x 8 cm = 48 cm^2
R2 = 0.7 cm x 8 cm = 5.6 cm^2
T1 = 0.5 x 6 cm x1.6 = 4.8 cm^2
T2 = 0.5 x 8 cm x3.4 = 13.6 cm^2
T3 = 0.5 x 6 cm x1.3 = 3.9 cm^2

Total Area = 75.9 cm^2
Catchment area = area measured on map x reciprocal of scale
= 75.9 x $(25,000)^2$ = 47.44 x 109 cm^2
= 47.44 x109/$(100)^2$ = 4,744,000 m^2
= 4,744,000/$(1000)^2$ = 4.74 km^2

Therefore the catchment area calculated from the above method is 4.74 km^2.

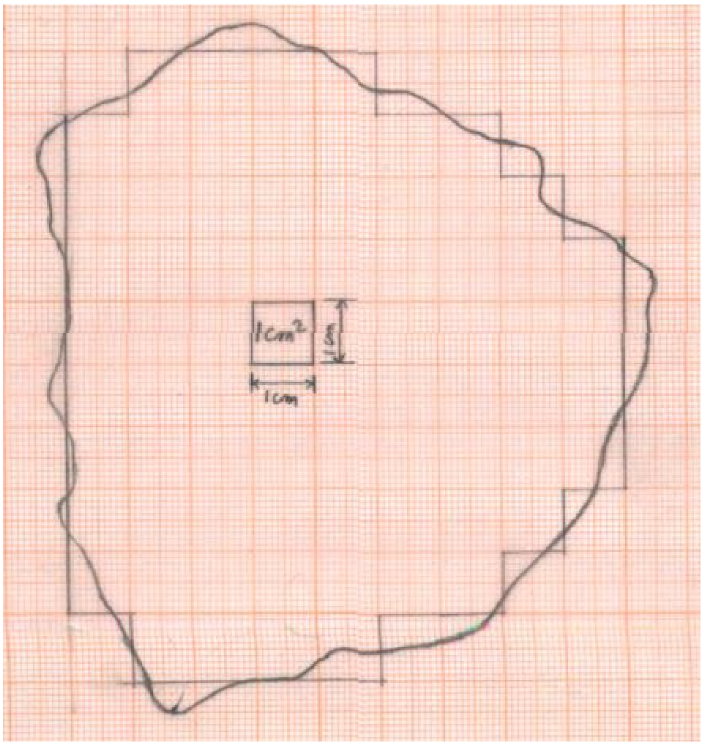


Figure C1.3: Catchment area calculation based on graphical method

In Figure C1.3, the catchment area is divided into 1 cm by 1cm squares (i..e. area = 1 cm^2) by tracing the area in the map on a transparent graph paper. As discussed earlier, near the catchment boundary, if the segment area exceeds 0.5 cm^2 then it is rounded to 1 cm^2 (i.e. it is included) else the portion is ignored.

Map area = 74 numbers of 1cm x 1cm squares
= 74 cm2x(25,000)2 = 46.25 x 109 cm2
= 46.25 x109/(100)2 = 4,625,000m2
= 4,635,000/(1000)2 = 4.63 km2

Hence from both methods the calculated catchment areas are close (within 3%).

C2 Estimation of Low-Flow

C2.1 WECS/Department of Hydrology and Meteorology (DHM) method

The procedure for estimating long term average monthly flows is as follows:

i) From available topographic maps, determine the total catchment area and the area below 5000 m elevation as discussed earlier.

ii) Read the values of monsoon wetness index (of the basin centre) from Figure C2.1.1 (Three maps, one from Department of Hydrology and Meteorology (DHM) and two from International Centre for Integrated Mountain Development (ICIMOD) using DHM data).

iii) In the following equation, input the required coefficients from Table C2.1.1 for each month and thus derive the average monthly flows.

$$Q_{\text{mean month}} = C \text{ x } (\text{Area of Basin})^{A1} \text{ x } (\text{Area below 5000 m} + 1)^{A2} \text{ x } (\text{Monsoon Wetness Index})^{A3}$$

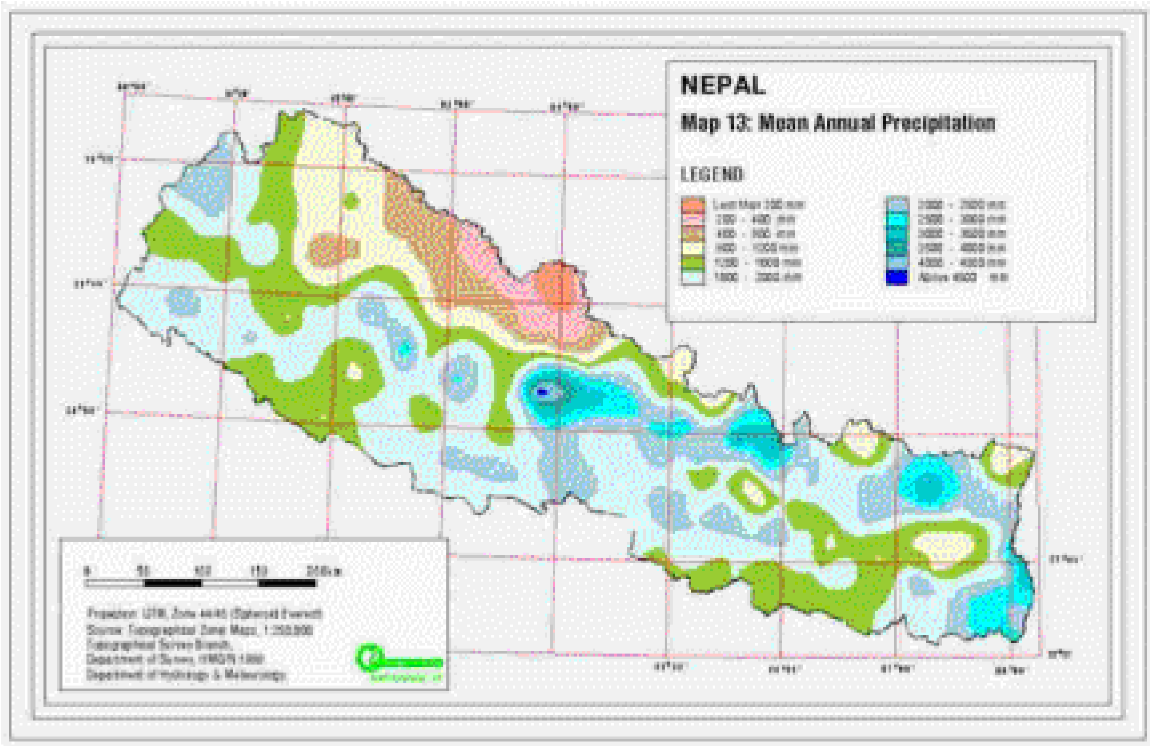
where, subscript month denotes one of the months from January to December. A power of 0 indicates that particular parameter does not enter into the equation for that month.

Table C2.1.1. Prediction coefficients for long term average monthly flows

Month	Constant coefficient C	Area of basin (km^2) A_1	Area of basin below 5000 m +1 (km^2) A_2	Monsoon Wetness Index A_3
January	0.01423	0	0.9777	0
February	0.01219	0	0.9766	0
March	0.009988	0	0.9948	0
April	0.007974	0	1.0435	0
May	0.008434	0	1.0898	0
June	0.006943	0.9968	0	0.2610
July	0.02123	0	1.0093	0.2523
August	0.02548	0	0.9963	0.2620
September	0.01677	0	0.9894	0.2878
October	0.009724	0	0.9880	0.2508
November	0.001760	0.9605	0	0.3910
December	0.001485	0.9536	0	0.3607

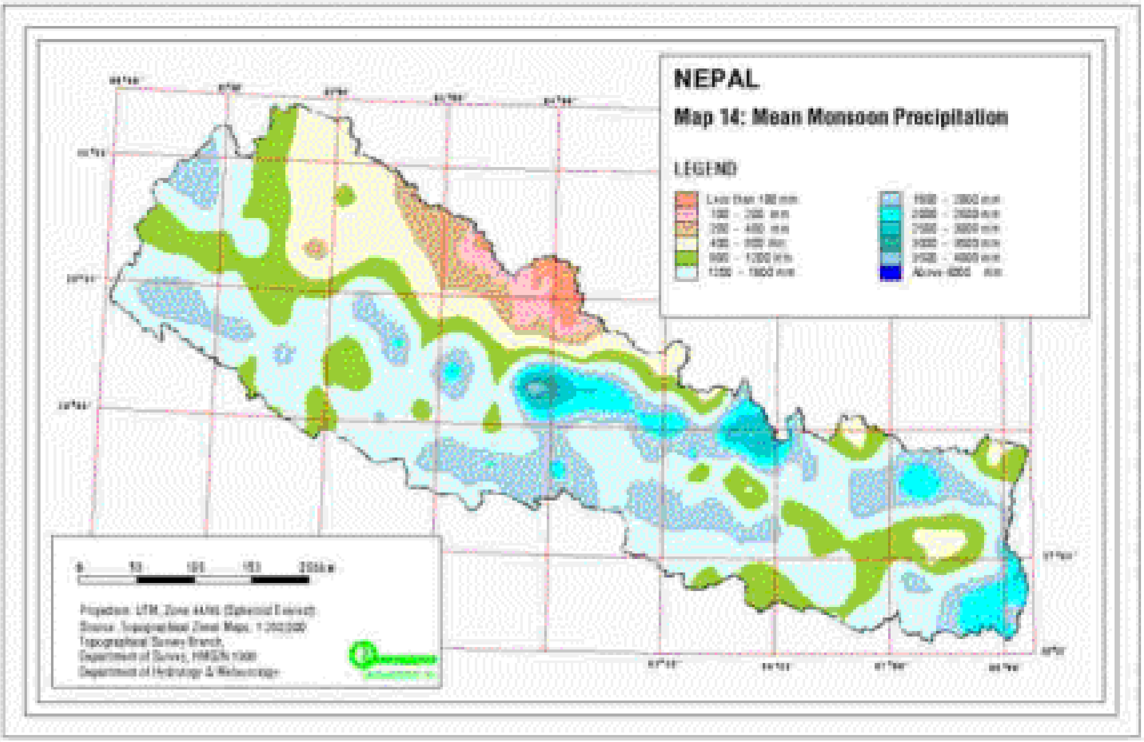
Note: units of flow are m^3/s, catchment areas are in km2 and monsson wetness index is in mm. Month

Source: DHM



Source: ICIMOD

Figure C2.1.1: Monsoon Wetness Index



Source: ICIMOD
Figure C2.1.1 (contd.): Monsoon Wetness Index

C2.2 Medium Irrigation Project (MIP) method

The MIP method for estimating mean monthly flows for a given catchments area is as follows:

i) Calculate the catchment area as discussed earlier and establish hydrological region the catchment lies from Figure C2.2.1

ii) The unit hydrographs also known as mean monthly hydrographs in litre per sec (lps)/km^2 of catchment area for the seven regions are presented in Table C2.2.1. Multiply these unit hydrograph values (for the region identified and appropriate month) with the catchment area to come up with an initial estimate of the monthly flows.

   The MIP method gives the non-dimensional hydrograph in tabular form and the unit hydrographs graphically. The non-dimensional hydrographs are derived by normalising the April flows of the unit hydrograph, i.e., the April flow of the unit hydrograph is made unity (1) and the flows for other months are multiplied by the April flow of the unit hydrograph. For example, in the unit hydrograph, if the April flow is 4.8 l/s per km^2 and the flow in June is 15 l/s per km^2, then the non-dimensional flows for April and June would be 1 and 3.13 respectively. Non-dimensional hydrographs for the seven regions are presented in Table C2.2.2. The non-dimensional hydrographs make the calculations easier if the flows during the low flow months have been measured.

iii) The flows calculated in step ii are regarded as initial estimates. This is because the accuracy of MIP method depends on actual flow measurement (at least one) during the low flow months.

In the low flow period from November to May, visit the site and make one flow measurement near the intake area. Ensure that there has been no heavy rainfall during the preceding few days and that the water level is not fluctuating rapidly. Note that the MIP method explicitly states that the flow measurement should be made in November to May but an extra month has been added here. This gives seven months for flow measurements (instead of six) and, therefore more studies and designs can be done in a year. However, the measurements done during May would be less accurate and should generally be avoided measurements during this month as far as possible.

iv) Divide the measured flow by the non-dimensional hydrograph value for the appropriate month and region. If the flow measurement was conducted at the beginning or the end of the month, it may be necessary to interpolate between the two relevant ordinates from Table 3. The result represents the mean April flow to be expected in those catchments. Note that the flow thus calculated takes the unit of the measured flow, e.g. if l/s is used for the measured flow, then the mean April flow will also be in l/s.

v) Ascertain if there are significant upstream abstractions such as irrigation off takes, attempt to quantify them and add this amount to the measured flow. The result will be the flow at the intake of the scheme in the absence of the upstream abstractions. It is important to add the upstream abstractions as well because the ratio of the measured flow over the flow according to the non-dimensional hydrograph (or unit hydrograph) for that month is used to refine the other monthly flows. Thus, if the upstream abstractions are not included then flows for other months will be under predicted.

vi) Take the April flow calculated in step iv and multiply it by each non-dimensional ordinate from Table C2.2.2. The result is the hydrograph of mean monthly flows.

Another approach is to divide the measured flow by the unit hydrograph for the appropriate month and region. Then determine the refined monthly flows for the 12 months by multiplying the unit hydrograph flow values with the above ratio (i.e., measure flow/mean monthly hydrograph for the appropriate month and region).

Note that in the exceptional case, if the catchments area lies in two different regions then calculate flows for each region with the portion of the catchments that lies in that region. Then add the monthly flows from each catchments area of the two regions. Similarly, if more than one measurement is done during different months (but between November to May), and then the process described above should be repeated for each of the measurement. The average values should be used as the mean monthly flows.

The regions in Tables C2.2.1 & C2.2.2 represent the following catchments:

Region	Catchments
1	Mountain catchments.
2	Hills to north of Mahabharats.
3	Pokhara, Nuwakot, Kathmandu, Sun Koshi tributaries.
4	Lower Tamur valley.
5	River draining Mahabharats.
6	Kankai Mai basin.
7	Rivers draining from Churia range to the Terai.

Table C2.2.1: Unit Hydrograph in liter/sec per km^2 of Catchments Area

Month	Region						
	1	2	3	4	5	6	7
January	24.00	7.39	13.00	8.23	15.97	15.02	3.30
February	18.00	5.61	9.02	6.02	12.01	11.99	2.20
March	13.00	4.39	6.62	4.42	8.98	9.40	1.40
April	10.00	3.30	4.8	3.20	6.60	7.40	1.00
May	26.00	3.99	9.02	7.01	6.01	19.02	3.50
June	60.00	23.79	15.02	12.00	18.01	44.99	6.00
July	145.00	59.99	64.99	22.05	73.99	179.97	14.00
August	250.00	89.99	120.00	87.26	92.00	249.97	35.00
September	165.00	66.69	99.98	66.91	66.00	200.02	24.00
October	80.00	30.00	50.02	22.05	43.03	44.99	12.00
November	41.00	13.00	24.00	16.00	30.03	25.01	7.50
December	31.00	10.00	18.00	11.01	21.98	19.02	5.00

Table C2.2.2: Non-dimensional Regional Hydrographs

Month	Region						
	1	2	3	4	5	6	7
January	2.40	2.24	2.71	2.59	2.42	2.03	3.30
February	1.80	1.70	1.88	1.88	1.82	1.62	2.20
March	1.30	1.33	1.38	1.38	1.36	1.27	1.40
April	1.00	1.00	1.00	1.00	1.00	1.00	1.00
May	2.60	1.21	1.88	2.19	0.91	2.57	3.50
June	6.00	7.27	3.13	3.75	2.73	6.08	6.00
July	14.50	18.18	13.54	6.89	11.21	24.32	14.00
August	25.00	27.27	25.00	27.27	13.94	33.78	35.00
September	16.50	20.91	20.83	20.91	10.00	27.03	24.00
October	8.00	9.09	10.42	6.89	6.52	6.08	12.00
November	4.10	3.94	5.00	5.00	4.55	3.38	7.50
December	3.10	3.03	3.75	3.44	3.33	2.57	5.00

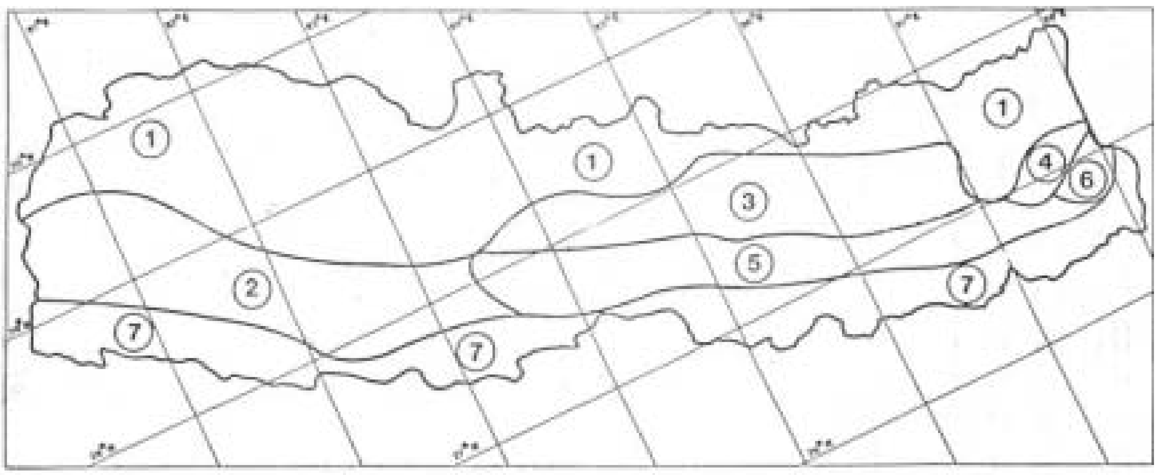


Figure C2.2.1: Hydrological regions of Nepal

Example C1: Average monthly flow estimation

Catchment name	Midim Khola
Catchment location	Intake near Taksar, Lamjung District
Hydrological region	3
Catchment area	111 km^2 The catchment area is circled in the map and lies between 4500 m to 900m elevation
Monsoon wetness index	2000

Figure C2.2.2 shows the catchment map.

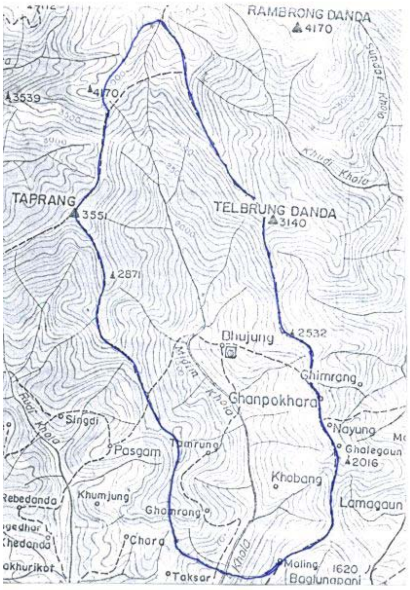


Figure C2.2.2: Catchment area of the Midim Khola for Example C1

WECS/DHM procedure

Using the following equation with the corresponding coefficients:

$Q_{mean\ month}$ = C x (Area of Basin)^{A1} x (Area below 5000 m + 1)^{A2} x (Monsoon Wetness Index)^{A3}
Average Monthly flow for January :
$Q_{mean\ January}$ = 0.01423 x $(111)^{0}$ x $(111 + 1)^{0.9777}$ x $(2000)^{0}$
$Q_{January}$ = 1.43 m^3/s.

Similarly, mean monthly flows for other months are calculated in Table C2.2.3

Table C2.2.3: Mean Monthly Flow Hydrograph According to WECS/DHM Method

Month	Long term average discharge (m^3/s)
January	1.43
February	1.22
March	1.09
April	1.10
May	1.44
June	5.52
July	16.91
August	20.54
September	15.92
October	6.92
November	3.17
December	2.06
Annual	6.44

MIP procedure

Low flow estimates for the above example using the MIP procedure is presented below. Note that the catchment area is 111 km^2 and it lies in region 3.

Table C2.2.4: First estimate of the mean monthly flow hydrograph

Month	Unit hydrograph in l/s per km^2 of catchment area (Region 3)	Predicted Mean monthly flow for catchment in l/s	Predicted mean monthly flow (m^3/s)
January	13.00	1,443	1.43
February	9.02	1,001	1.00
March	6.62	735	0.735
April	4.8	533	0.533
May	9.02	1,001	1.00
June	15.02	1,667	1.67
July	64.99	7,214	7.21
August	120.00	13,320	13.32
September	99.98	11,098	11.10
October	50.02	5,552	5.52
November	24.00	2,664	2.66
December	18.00	1,998	2.00
Annual			4.02

Table C2.2.5 presents a comparison between WECS/DHM method and the initial estimates of MIP method.

Table C2.2.5: Comparison between WECS/DHM method and the initial estimates of MIP method

Month	Initial estimates of mean monthly flows using MIP method (m^3/s)	Predicted mean monthly flows using WECS/DHM method (m^3/s)
January	1.43	1.43
February	1.00	1.22
March	0.74 (11 month exceedance flow)	1.09 (12 month exceedance flow)
April	0.53 (12 month exceedance flow)	1.10 (11 month exceedance flow)
May	1.00	1.44
June	1.67	5.52
July	7.21	16.91
August	13.32	20.54
September	11.10	15.92
October	5.52	6.92
November	2.66	3.17
December	2.00	2.06
Annual	4.02	6.44

As can be seen from Table C2.2.4, the 11 and 12 months exceedance low flows from the initial estimates using MIP methods are 0.74 m^3/s in March and 0.53 m^3/s in April, respectively. Similarly, in the WECS/DHM method, the 11 and 12 months exceedance low flows are 1.10 m^3/s in April and 1.09 m^3/s in March. Although, there is a significant difference in the 11 and 12 months exceedance flows for the first estimates using the MIP method, the values are very close in the WECS DHM method (also, in reverse order though insignificant). Therefore, if actual flow measurements were not done, then as discussed earlier the 11 month low flows (1.10 less 15% for seepage through the weir) derived from the WEC/DHM method could be used as the maximum design flow during the pre-feasibility study, since the catchments area exceeds 100 km^2. Later during the feasibility stage this low flow value would have to be verified by a spot measurement.

Now assume that the flow measurement during the month of March was 0.97 m^3/s. Then, the first estimate of the mean monthly flows would be refined as presented in Tables C2.2.6 and C2.2.7.

Since, hydrologically, both unit hydrograph and non-dimensional hydrograph are equivalent (once correlations are made with the measured value), both methods yield same values except for rounding off errors as can be seen from Tables C2.2.6 and C2.2.7.

Results

A comparison of the dry season mean monthly flows calculated by the WECS and MIP methods are presented in Table C2.2.8. The differences in flows from the two methods during the monsoon months are not significant since the design flow would be ensured in both cases (i.e., the concern is for low flow). In the above example WECS shows a slightly higher figure than MIP for the month of April. Note that by definition MIP shows the measured flow for at least one of the low flow months. Also, results obtained by WECS and MIP methods may vary for different catchments and MIP method may not always yield lower values than WECS.

Table C2.2.6: Mean monthly hydrograph based on flow measurements using non-dimensional hydrograph

Month	Non-dimensional hydrograph	Measured flow (m^3/s)	Ratio	Predicted April flow (m^3/s)	Predicted hydrograph (m^3/s)
January	2.71				2.71 x *0.7029* = 1.91
February	1.88				1.32
March	1.38	0.97	= 0.97/1.38 = *0.7029*		0.97
April	1.00			0.7209/1.00 = 0.7029	0.70
May	1.88				1.32
June	3.13				2.20
July	13.54				9.52
August	25.00				17.57
September	20.83				14.64
October	10.42				7.32
November	5.00				3.51
December	3.75				2.64

Note: Predicted hydrograph = Non dimensional hydrograph x predicted April flow

Table C2.2.7: Mean monthly hydrograph based on flow measurements using unit hydrograph

Month	First estimates of flows from unit hydrograph (last column in Table .5)	Measured flow (m^3/s)	Ratio	Predicted hydrograph (m^3/s)
January	1.43			1.43 x *1.3197* = 1.89
February	1.00			1.32
March	0.735	0.97	= 0.97/0.735 = *1.3197*	0.97
April	0.53			0.70
May	1.00			1.32
June	1.67			2.20
July	7.21			9.52
August	13.32			17.58
September	11.10			14.65
October	5.52			7.28
November	2.66			3.51
December	2.00			2.64

Note: Predicted hydrograph = flow estimates from unit hydrograph x ratio

Table C2.2.8: Comparison between WECS and DHM methods (for Example C1)

Month	WECS	MIP	Measured flow	% Difference (MIP taken as base value)
October	6.92	7.28		5
November	3.17	3.51		10
December	2.06	2.64		22
January	1.43	1.89		24
February	1.22	1.32		8
March	1.09	0.97	0.97	-12
April	1.10	0.70		-57
May	1.44	1.32		-9

As can be seen from the table above, the differences between the two methods vary between +5% to -57%. According to the WECS/DHM method, the 11 and 12 months exceedance flows are 1.10 m3/s in April 1.09 in March respectively. The 11 and 12 months low flows according to the MIP method are 0.97 in March and 0.70 in April, respectively.

As discussed earlier, the low flow based on MIP should be used since it is based on actual measurements. Note that WECS/DHM method is only useful during the pre-feasibility study phase for catchment areas exceeding 100 km2. Therefore, the maximum design flow in this example is:

0.85 x 11 month exceedance flow = 0.85 x 0.97 = 0.82. Hence, the proposed micro-hydro scheme should not be sized for design flow exceeding 820 l/s. Note that in practice design flows in micro-hydropower schemes rarely exceed 300 l/s. In this example, the low flow values are comparatively high since the catchment area is large (111 km^2).

As discussed earlier, the design flow adopted for mini hydro should be estimated using the MIP method but on the basis of the average of four spot measurements.

C3 POINTS TO BE CONSIDERED DURING FLOW MEASUREMENT AND ESTIMATION

Based on the presentation and discussions in the earlier sections, the following points to be considered are put forth.

- The 11-month exceedance flow with a 15% allowance for seepage and environmental release should be used as the maximum design flow. This allows for some flexibility in sizing of the scheme.

- Low flow of the source river at the intake should be determined during the pre-feasibility study stage and refined during the feasibility stage. Flow measurements at site should be done during both pre-feasibility and feasibility stage as far as practicable. However, there must be at least one actual flow measurement during the low flow periods (November to May) for any proposed micro-hydro schemes.

- During commissioning of the scheme, the diverted design flow should be measured in the system to verify that the installed capacity power output is feasible from the design flow. During the pre-feasibility/feasibility stage, provisions should be made for incorporating a triangular weir (removable) along the headrace canal, forebay or tailrace (and installed during the construction phase) so that the design flow can be measured during commissioning. Flow measurement should also be done at the intake during the commissioning stage so that 85% of the 11-month exceedance flow can be estimated.

- A "conductivity meter" should be used for the river flow measurement since it is more accurate than other methods and does not involve subjective judgement of the hydraulic/hydrological parameters. For the higher flow more than 2.5m3/sec, current meter is recommended.

- Both the weir (triangular and rectangular) and the conductivity meter should be calibrated by standard laboratories The weir constant (C) and the salt constant (k) would then be determined accurately.

- The Consultant/Inspector who verifies the low flow during commissioning should be different than the one that did the pre-feasibility/feasibility study (i.e., to minimise bias).

- The WECS/ DHM method should be used only if flow measurement is not possible during the pre-feasibility stage and the catchment area exceeds 100 km^2. At other times hydrological analysis should be based on the MIP method which is based on actual flow measurement.

- Since hydrological analysis such as flow verification is not an exact science and furthermore there will be some instrumentation errors, a maximum tolerance of $\pm$10%, should be allowed on the low flow predicted during the feasibility/detailed design stage and commissioning and POV stage for all sizes MH

- The Consultants/Inspectors who will be involved in power/flow verification of micro-hydropower schemes should be provided with both theoretical and field training on low flow prediction and verification. The theoretical part should cover the basic principles of low flow measurements including the WECS/DHM and the MIP methods as discussed in this document. The field training should involve measurement of the flow in a river using the conductivity meter (and its calibration process) as well as the design flow of an existing micro-hydropower plant using the weir method.

APPENDIX - D

GENERAL INSTRUCTION FOR POWEROUTPUT VERIFICATION

APPENDIX – D

GENERAL INSTRUCTION FOR POWEROUTPUT VERIFICATION

General Instructions and Data sheet for Power Output Verification for Micro Hydro Plant

D1. General Information

Name of the scheme: ……………………………………

Name of the stream:…………….

Location: Village………………… Ward No:………...

VDC: ……………… District:……….

Name of the owner/ Users' Committee Chairperson: ……………………………………..

Design Power Output of the Plant: …….. kW

Design flow: ……….. lps Design Gross head: ………..m

Design Net Head: ………..m GPS Coordinates: X= Y=

D2 General instructions and Norms

D2.1 Preparation before the site visit:

1. Fill up the section A General Information in this data sheet.
2. Inform to the installer and owner/users' committee for site visit. Get confirmation from the installer and owner/users' committee to make plant ready for POV.
3. Collect equipment as per the equipment list given in this guideline and as per the site condition.
4. Where flow measurement by weir method is not feasible due reasons such as, no provision for weir installation made and new installation not feasible due to inappropriate site condition, take ultrasonic flow meter. The installation and the measurement by weir method require prior experience, which the inspecting team, should posses.
5. Note that the number of additional dump load kit depends on the size of the plant. Each dump load has a ballast heater of 18 kW and can measure power up to 17 kW. Therefore, number of kit required depends on the power to be measured.
6. Check that all the equipments are in working order and confirm that the measuring instruments: a) true RMS clamp-on power meter, b) digital clamp

meter, c) weir and or ultrasonic flow meter, d) conductivity meter, and e) pressure gauge meter have certificate of calibration where applicable.

7. Make sure that the equipments are packed for safe transportation.

8. The date of site visit for power output verification should be confirmed with the owner and the manufacturer prior to departure to the site.

D2.2 Preparation at Site:

1. Upon arrival at site, meet the owner/users' committee representative and installer's representative to plan for the power output verification test. Brief them on how the power output verification will be carried out.

2. Inspect the scheme with the parties to make preparations for the test and fix time for carrying out the tests. The best time would be in the morning hour, so that there is sufficient time for the test.

3. Set up the test equipment as per Fig 1: circuit diagram for test set up for MHP or Fig 2: circuit diagram for test set up for Pico set.

4. Fix the pressure transducer at the section of the penstock pipe connecting with the turbine manifold. Make sure that the transducer is connected with the digital pressure gauge.

5. For instruction on the setting up of weir for measurement of flow, refer to the flow measurement procedure given separately with this sheet.

D2.3 During the Test:

1. For safety during the test, do not allow other people to enter into the power house. Observe, basic safety rules while in the power house.

2. For plants up to 20 kW, a tolerance of $\pm$ 10% on the rated power is accepted, i.e. the minimum power required from a plant designed for 20 kW is 18 kW. For plants above 20 kW and up to 100 kW, the tolerance of $\pm$ 5% on the rated power is accepted, i.e. the minimum power that a 50 kW designed plant should generate is 47.5 kW.

3. At the completion of the test and filling up of power output measurement form make sure that all the parties sign in the certification form.

D3. Procedure for Power Output Measurement for MHP (5 -100 kW)

Method D3.1 uses two methods of measurement, one by using additional dump load and other by using true RMS meter and the measurement are taken simultaneously. The use of two methods allow cross verification. As confidence is developed on the use of true RMS power meter with their extensive uses with the ADL, then true RMS clamp-on power meter alone can be used for power measurement. D3.2 describes measurement by true RMS meter only.

D3.1 Using Additional Dump Load and True RMS Clamp-on Power Meter

Equipment List

1. Power measurement kit – 1 set for plant size up to 17 kW or more depending on the size of the plant.

   A set of power measurement kit consists of:

   - An additional dump load of 18 kW immersion heater fitted with 9 nos. of MCBs for step wise increase of loads and an analogue frequency meter
   - 20 liters plastic bucket fitted with a flow outlet – 1 no.
   - mm diameter plastic tube – about 10 m
   - phase 4 wire cable – 6 m

2. Digital clamp meter (with voltage measurement option) – 1 no.
3. AC/DC true RMS clamp-on power meter – 1 no.
4. Spare batteries for digital clamp meter and true RMS meter – 3 nos.
5. Power output verification datasheet – 2 nos.
6. Screw driver and wrenches – 1 set
7. Scientific calculator – 1 no.
8. Digital pressure gauge meter with standard pressure sensor – 1 set
9. Calibrated V notch weir for discharge up to 100 lps or rectangular weir for discharge above 100 lps, where the provision for installing a weir in the tailrace has been made during the construction of the scheme. Where such provision are not made, take ultrasonic water flow measurement meter – 1 no.
10. Salt dilution gauge meter – 1nos.

Measurement Procedures

Step 1: Close the turbine valve to stop the operation of the turbine.

Step 2: Switch off the main switch to the consumer supply.

Step 3: Disconnect the cable going to the consumer side and connect with the additional dump load: For up to 17 kW, use 1 kit; For above 17 kW and up to 34 kW, use 2 kit; For above 34 kW and up to 68 use 3 kit; For above 68 and up to 85 kW use, 4 kit; For above 85 kW and up to 102 kW use, 5 kit.

Note that when more than one kit is used, the kits should be connected in parallel.

Step 4: Fill up the additional dump load tank with water. Place the 20-litre bucket at a higher location. Using a plastic pipe connect the outlet of the bucket with the inlet of the ADL tank. Connect a water tube with the outlet of the ADL to discharge the hot water safely outside the power- house or tailrace. This arrangement allows a continuous supply of water to the ADL tank by gravity flow from a bucket using a pipe connection and the discharge of hot water from the ADL safely to the tailrace. Keep extra reserve of water in containers/buckets (about 100 liters) to pour into the 20-litre bucket once the water level goes down during the test.

Step 5: Open the turbine gate valve gradually so that the ballast voltmeter reads approximately 100 volt.

Step 6: Switch on the main switch connected with the ADL. Then, switch on the step switches on the additional dump load until the ballast volt is near to zero and the frequency is 50 Hz.

Step 7: If the frequency is lower than 50 Hz, while the ballast voltage is zero, increase the flow in the turbine so that frequency meter reads 50 Hz with ballast voltage at zero.

Step 8: If the ballast volt is more than zero, bring the ballast voltage to zero by decreasing the flow of water into the turbine, while doing so make sure to maintain the frequency at 50 Hz.

Step 9: Measure voltage, current, and frequency at the output terminal of the generator in all three phases and record the data in the record form.

Step 10: Note the corresponding weir height for flow measurement if a weir is installed at the tailrace. If the weir is not installed at the tailrace, use ultrasonic flow measurement device to measure the flow. And note the net head from the pressure gauge reading and the approximate position of valve opening (given by number of turns made by the valve handle).

Step 11: Now switch off the main switch to ADL to divert all generated power to main ballast load. Take the readings for voltage, current, frequency, power factor, KVA, kW in each phase by calibrated true RMS clamp-on power meter. Record these readings in the record form.

Step 12: Now further open the turbine valve so that the ballast voltage is 150 V. Then repeat the steps from 6-11.

Step 13: Repeat the steps 6-11 with ballast voltage near 180 V.

Step 14: For the concluding measurement:

- Keep the turbine valve full open. Switch on the main switch to the ADL.
- Check the ballast voltage and frequency, if the ballast voltage is greater than zero, increase the step load by 1 step at a time until the ballast voltage is zero and frequency is less than 50 Hz. When the ballast voltage is zero and frequency less than 50 Hz, switch off 1 step load in ADL so that a small power is diverted to ballast heater.
- Record voltage, current, frequency, for each phase. While doing this, measure corresponding head and flow.

Step 15: Now switch off the main switch to ADL to divert all generated power to main ballast load. Record voltage, current, frequency, power factor, KVA, kW in each phase in the record form by calibrated true RMS clamp-on power meter.

Step 16: Calculate the power for each phase and total power for different flow conditions.

While carrying out this test, it is important to keep adding water into the ADL tank to avoid excessive heating and evaporation of water.

D3.2 Procedure for Power Measurement by True RMS Clamp-on Power Meter

Use of true RMS meter (without the ADL) should be followed only after enough confidence has been developed in use of true RMS meter i.e. through the application of method D3.2

Equipment required

1. AC/DC True RMS Clamp-on Power Meter – 1 set
2. Spare battery – 3 nos.
3. Recording forms – no.
4. Scientific calculator -1
5. Digital pressure gauge meter with standard pressure sensor – 1 set
6. Calibrated weir, V-notch for flow up to 100 lps or rectangular notch for flow above 100 lps or ultrasonic flow measurement meter if provision for installation of weir is/can not be made – 1 set
7. Salt dilution gauge meter – 1 set

Measurement Procedures

Step 1: Switch on the true RMS meter outside the powerhouse (to avoid influence of magnetic field). Observe that the meter starts to calibrate itself automatically, and once it is done, it is then ready for measurement. Keep the meter switched on and take it to the powerhouse test area.

Step 2: Gradually open the turbine valve until ballast voltage is at 100 volt. Measure the voltage, current, power factor, kW and KVA and Hz for each phase at the generator output terminal using the true RMS meter. Measure corresponding net head from the pressure gauge reading and flow using either weir at the tailrace or ultrasound flow meter and record in the form.

Step 3: Further open the gate valve and increase the flow to the turbine so that the ballast voltage is at 150. Again, measure the voltage, current, power factor, kW and KVA and Hz for each phase at the generator output terminal and record in the form. Also, measure corresponding head and flow, and record in the form.

Step 4: Again further open the gate valve and increase the flow to the turbine so that the ballast voltage is near 180 V. Measure the voltage, current, power factor, kW and KVA and Hz for each phase and record in the form. Measure corresponding head and flow, and record in the form.

Step 5: Finally, open the turbine valve at full and measure the voltage, current, power factor, kW and KVA and Hz for each phase. Measure corresponding head and flow, and record in the form.

Step 6: Calculate total actual power output by adding up power at each phase at different flow conditions and fill up the power measurement form.

Step 7: Certify the amount of power output from the plant and sign by all parties

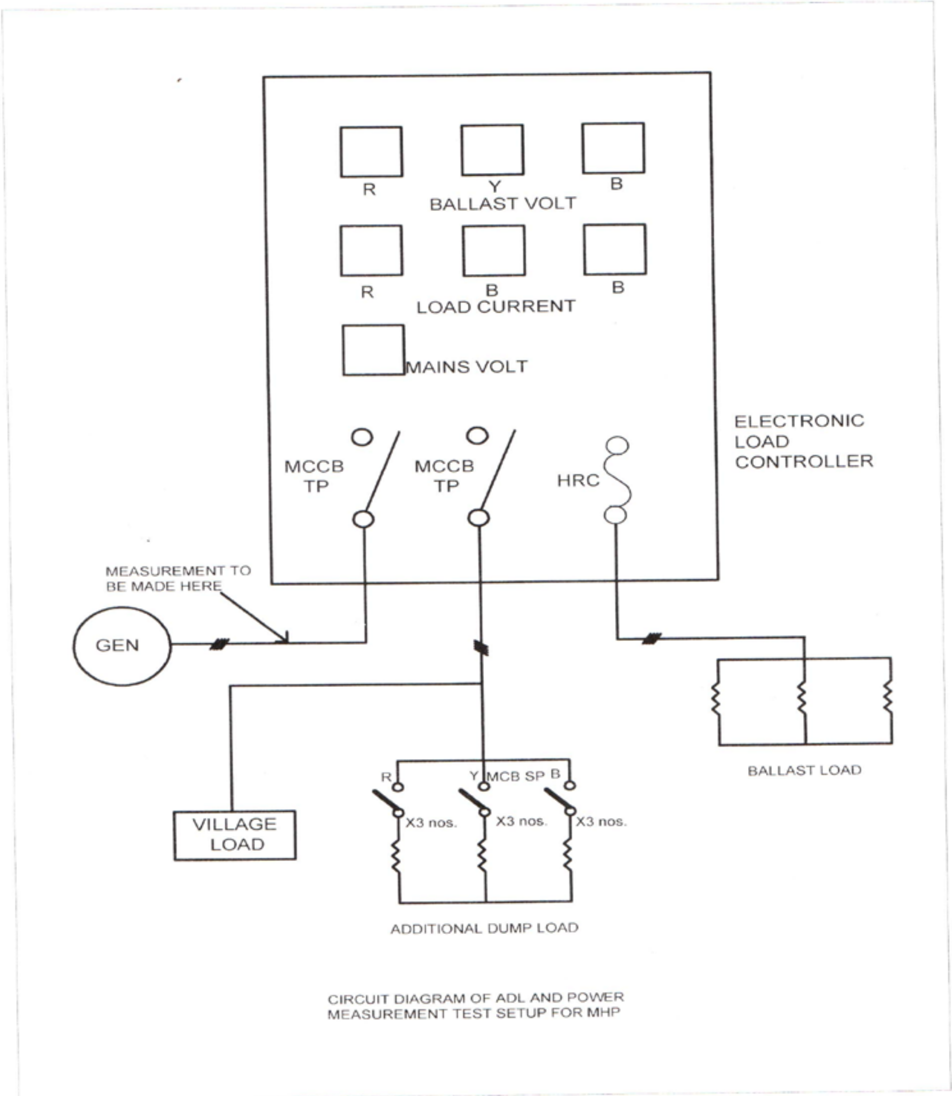


Figure 1: Power Measurement Test Set Up For MHP

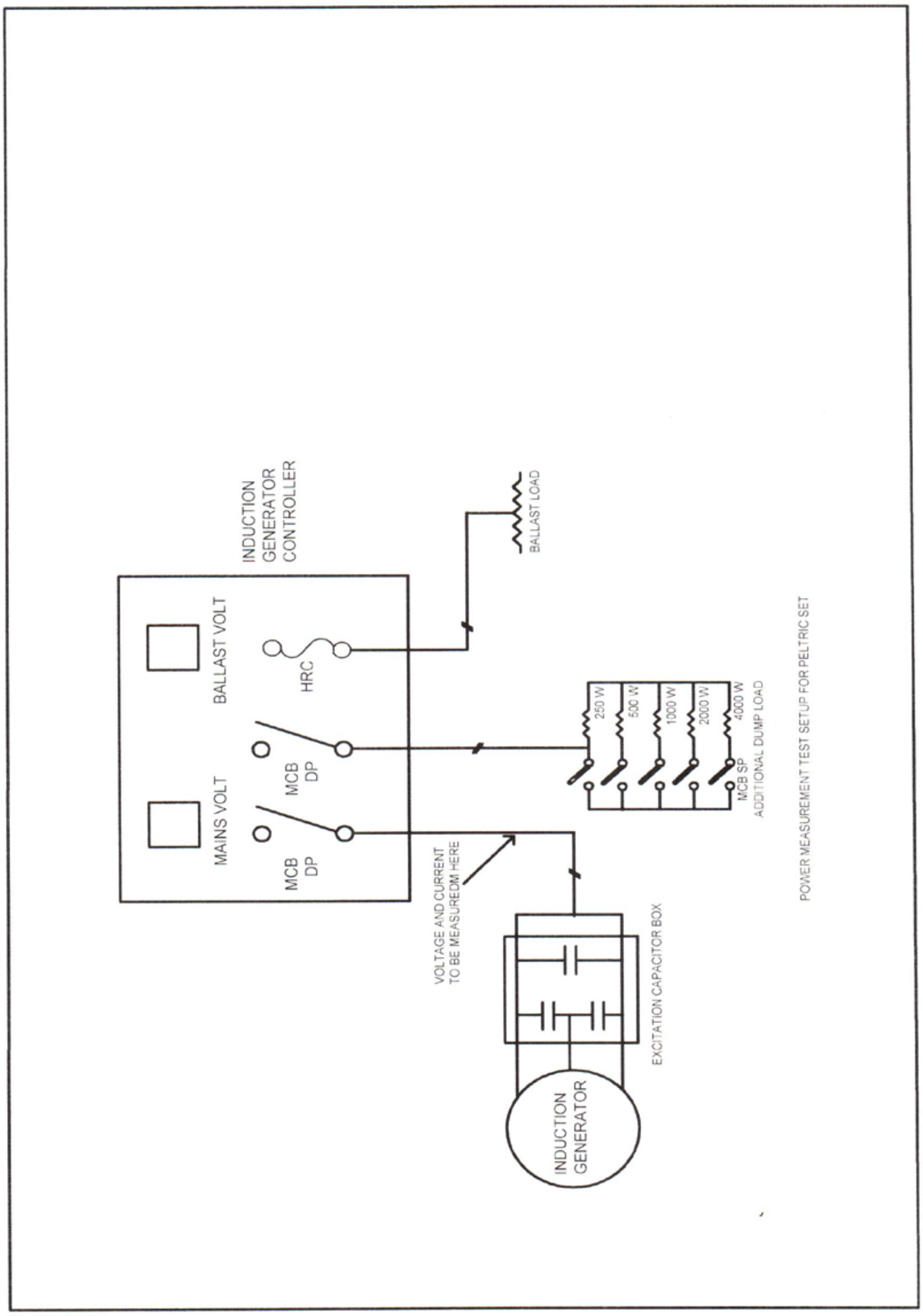


Figure: 2 Power Measurement Test Set Up for Pico Hydro Set

D4. Procedure for power output measurement for Pico Hydro (up to 5 kW) By Using Additional Dump Load

Equipment list

1. Air Heater dump load with 4 nos. of MCB to provide loads in the increasing steps of 250 W up to 7.75 kW maximum – 1 set
2. Digital clamp meter6 to measure current and voltage – 1 no.
3. Power output verification record forms.
4. Scientific calculator- 1 no.
5. Digital pressure gauge - 1 set
6. Stop watch – 1 no.
7. 40-litre bucket or container of similar capacity – 1 no.

Measurement Procedures

Step 1: Close the gate valve to stop the operation of the turbine.

Step 2: Switch off the main switch to the consumer supply.

Step 3: Disconnect the cable going to the consumer side and connect them with the additional air-heater dump-load.

Step 4: Open the turbine valve fully.

Step 5: Switch on the main switch connected with the additional dump load.

Step 6: Switch on the step switches so that the power to the system increases at the steps of 250 W up to 7.75 kW maximum (to be used depending on the size of the scheme) until the ballast voltage drops to zero. While doing so make sure that the generator voltage does not drop below 5% of generation voltage.

Step 7: Measure current and voltage after the capacitor bank (but prior to the IGC) with the clamp meter and record in the form.

Step 8: Calculate the power output using power equation, P = VXI (as under the condition i.e. when ballast voltage = 0, the power factor = 1). Fill up the power output verification form and get all the parties to sign in the certification form.

Remark: To keep the measurement process simple, there is no need for measurement of flow and head measurement except in the situation when the power output is severely less than the design power. In which case, measure head using pressure gauge and flow using V notch weir or bucket method whichever is convenient.

[6] The meter should be used after calibration at Nepal Standard. The meter should be calibrated once every year.

D5. Procedure for power output measurement for Pico Hydro (up to 5 kW) By True RMS clamp on power Meter

Equipment list

1. True RMS clamp on Power meter to measure current and voltage – 1 no.
2. Power output verification record forms.
3. Scientific calculator- 1 no.
4. Digital pressure gauge - 1 set
5. Stop watch – 1 no.
6. 40-litre bucket or container of similar capacity – 1 no.

Measurement Procedures

Step 1: Close the gate valve to stop the operation of the turbine.

Step 2: Switch off the main switch to the consumer supply.

Step 3: Open the turbine valve fully.

Step 4: Measure current and voltage after the capacitor bank (but prior to the IGC) with the True RMS clamp on power meter and record in the form.

Step 5: Calculate the power output using power equation, $P = V * I * \cos\phi$. Fill up the power output verification form and get all the parties to sign in the certification form.

Remark: To keep the measurement process simple, there is no need for measurement of flow and head measurement except in the situation when the power output is severely less than the design power. In which case, measure head using pressure gauge and flow using V notch weir or bucket method whichever is convenient.

D6 Flow verification using weirs

D6.1 Equipment required:

Find out the design flow of the scheme before leaving for site. If the design flow is less than 200 l/s, use a V notch weir. For higher flows, use a rectangular weir.

Or, if it is not possible to measure flows using weirs in schemes that have not made provisions for weir installation, another option is to use ultra-sonic measurement equipment.

D6.2 Measurement Procedure:

Step 1: If a provision has been made for installation of a weir during the construction, then install the prefabricated weir at that location. If such a provision has not been made, then select a location along the headrace or tailrace canal for the flow measurement. The criteria are that for a length of 2 m, the bed level of the canal should be almost horizontal (i.e., no drops, or steep invert) and the section should be uniform. If possible, the measurement location should be just upstream of a drop.

Step 2: Once the weir is placed at the measurement location, ensure that there is no leakage from the sides (i.e., flow is possible only through the opening of the weir). Also, the weir may raise the water level upstream (depending on the freeboard of the canal, ground profile and the location). If this is the case, then place wooden planks or other temporary protection works to ensure that there is no spillage upstream.

Step 3: Ensure that there is a free fall of water from the weir and that the downstream water level does not interfere with the free fall. If this is not possible, select another location. For schemes that have provisions for installation of weirs, most of the criteria should be met since these would have been considered during the design phase.

Step 4: Ensure that there is no leakage downstream of the weir (i.e., the same discharge is available for the turbine). If necessary, close other spillways (i.e., forebay etc.) downstream and seal other locations where seepage is observed.

Measure the depth of water upstream at a distance of about 4 times the water depth over the weir as shown in Figures 1 and 2 (Form 3 and 4) and fill the Form No. 5 – Appendix E, to record measurement data.

D7. Stream flow measurement using the conductivity meter

D7.1 Equipment required

The equipments required to measure river flows using a conductivity meter are as follows:

1. A conductivity meter covering a range of 0 – 10,000 micro-siemens (μS.)
2. A thermometer to measure the water temperature if the meter does not compensate for temperature.
3. Some pre-calibrated and packed salt (i.e., air tight) such as "Iyoo nune" which is available in 1 kg packet. Loose salt or salt that has been exposed to the atmosphere too long should not be used.
4. A weighing machine (to weigh the salt).
5. A stop watch.
6. Graph Papers (mm type) and a Calculator.
7. A 20 liter bucket

D7.2 Measurement procedure

The flow measurement procedure using the conductivity meter is as follows:

Step 1: Undertake a site visit is between Novembers to May. If the site visit is done at other time, the flow measurement cannot be used to determine the average monthly flows for other months.

Step 2: Ensure that there has been no heavy rainfall during the preceding two days and that the water level is not fluctuating rapidly. If there has been heavy rainfall or the water level is fluctuating rapidly, wait for two dry days at site before taking the flow measurement.

Step 3: Select a place at the intake or near the intake for the measurement location. Note that the flow past the measurement location should be the same as that in the intake.

Step 4: Select a place upstream of the measurement location where the salt solution can be quickly dumped. Depending on the turbulence of the flow this location should be between 50 m to 300 m upstream of the measurement site. If the flow is turbulent upstream (i.e., presence of rapids, and falls) 50 m may be adequate, else the distance will have to be increased. Also, ensure that there are no flow diversions, additions or stagnant pools between the measurement site and the upstream location where the salt solution is to be poured.

Step 5: Turn on the conductivity meter and submerge the probe in a fast flowing section of the river at the measurement location (intake area or nearby). Then record the baseline conductivity (i.e. natural conductivity of the river before the addition of the salt solution). Also set the stopwatch so that the time can be measured.

Step 6: Prepare 50 to 300 gram of salt for each 100 l/s of flow based on your visual estimate and the baseline conductivity. The exact weight of the salt should be measured using a weighing machine. If the baseline conductivity is low (i.e., less than or equal to 20 μS) 50 gram per 100 l/s of flow may be adequate. If the visual estimate of the flow is inaccurate, then this will be observed from the nature of the graph (discussed in step 12) and the process will have to be repeated using a different quantity of salt.

Step 7: Prepare a salt solution in a bucket by mixing the weighed salt and river water and stir the solution with a clean stick until the salt is completely dissolved.

Step 8: Then send a helper with the salt solution bucket upstream at the chosen location to pour the slat solution (make sure that the solution is not spilled on the way). Signal the helper to pour the salt-water solution into the stream. The entire solution should be poured quickly and in one go.

Step 9: Start the stopwatch and note down the readings on the conductivity meter at 5 seconds intervals as soon as there is an increase in the values from the base line conductivity. Record these readings and other relevant data using Form No. 6 of Appendix E.

Step 10: Take the conductivity readings continuously until the value diminishes back to the baseline conductivity of the stream. Note that sometimes, the conductivity values will remain above the baseline value by a few μS for a long time. If this is the case, then the conductivity readings can be stooped since the difference of a few percent in conductivity does not contribute significant additional flows.

Step 11: Measure the temperature of the water in the stream if the conductivity meter does not have provision for temperature adjustment.

Step 12: Finally, plot the reading on the graph paper with time in seconds in the horizontal axis and conductivity in micro Siemens (μS) in vertical axis. If the result is not satisfactory (i.e., a smooth shaped graph according to Figure B1.2 Appendix B, repeat the measurement with more or less amount of salt or distances depending on the outcome. Inaccurate graphs and their probable reasons are also presented in Figure B1.1 –Appendix B. Therefore, based on the results obtained (i.e., graph) take remedial measures.

Step 13: After satisfactory results are obtained take a second set of measurement to verify the first.

D7.3 Calculation:

Once a satisfactory graph is obtained, the flow can be calculated as follows:

Stream Flow, Q = M x k/A

Where,

Q is the flow in lit/sec

M is mass of the dried salt in milligram (i.e.10-6 kg).

k is the salt constant in (μS)/(milligram/litre). If the conductivity meter is not of temperature adjustment type, then use the k value for the measured river temperature. Refer to the B1.3 – Appendix B for the determination of the k value.

A is the area under the graph of conductivity versus time, after excluding the area due to base conductivity. The units for the area under the graph is sec x μS.

The area is determined as follows:

In Table B1- Appendix B, add the individual conductivity readings taken in 5 seconds intervals. Then the area under the graph excluding the base line conductivity becomes:

Area (A) = (total sum of the individual conductivity readings – nos. of readings taken x baseline conductivity)

D8. Procedures for Low Flow Prediction for Micro Hydro Power

The step-by-step procedures for both flow prediction and verification are presented here. For detailed calculations and examples, refer to Appendix C.

D8.1 Equipment Supplies and Data Required

1. A Finn map of the catchment area. If a Finn map of the area is not available then use district maps or trekking maps. Note that original maps should be used as far as practicable. In the event that a photocopied map is used, it must be ensured that the photocopy is done at the same scale, i.e., the map is neither enlarged nor reduced from the original.

2. One observation of flow measurement during the period November to May.

D8.2 Estimation Procedure

Step 1: Identify the intake and the catchment boundary on the map.

Step 2: Determine the catchment area by measuring the map area and then multiplying it by the square of the reciprocal of the map scale.

Step 3: If the catchment area is more than 100 km^2, use the WECS/DHM method to come up with the first estimate of the average monthly flows. On the other hand, if the catchment area is less than 100 km^2, the only option is to use the MIP method. Furthermore, note that the flow estimate from WECS/DHM method should be treated as preliminary estimates of monthly flow. The flows estimated using this method should always be verified by the MIP method for micro-hydro schemes, regardless of the size of the catchment. Guidelines for the WECS/DHM and MIP methods are presented in Appendix C.

Step 4: Undertake a site visit between November to May and measure the stream flow near the intake using a conductivity meter. The detailed procedure for measuring stream flow is presented in Appendix B.

Step 5: Based on the flow measurement, use the MIP method to obtain average monthly flows, i.e., refine the non-dimensional hydrographs for the appropriate region and month based on the flow measurement of step 4.

Step 6: Use 85% of the 11 month exceedance flow as the maximum design flow, i.e., the design flow can be less than 85% of the 11 month exceedance flow but this value should never be exceeded ($Q_{design} \leq 0.85$ x 11 month exceedance flow).

D9. Estimates of monthly average flows using WECS/DHM method

The procedure for estimating long term average monthly flows using the WECS/DHM method is as follows:

Step 1: Determine the total catchment area and the area below 5000 m elevation.

Step 2: Read the values of monsoon wetness index (of the basin centre) from Monsoon Index Map (Figure C2.1.1- Appendix C).

Step 3: In the following equation, input the required coefficients from Table 1 for each month and derive the average monthly flows.

$$Q_{mean\ month} = C \times (\text{Area of Basin})^{A1} \times (\text{Area below 5000 m} + 1)^{A2} \times (\text{Monsoon Wetness Index})^{A3}$$

Step 4: where subscript month denotes one of the months from January to December. A power of 0 indicates that particular parameter does not enter into the equation for that month.

Step 5: Use Form 8 Appendix E for calculation.

Table 1. Prediction coefficients for long term average monthly flows

Month	Constant coefficient C	Power, Area of basin (km^2) A_1	Power, Area of basin below 5000 m +1 (km^2) A_2	Power of Monsoon Wetness Index A_3
January	0.01423	0	0.9777	0
February	0.01219	0	0.9766	0
March	0.009988	0	0.9948	0
April	0.007974	0	1.0435	0
May	0.008434	0	1.0898	0
June	0.006943	0.9968	0	0.2610
July	0.02123	0	1.0093	0.2523
August	0.02548	0	0.9963	0.2620
September	0.01677	0	0.9894	0.2878
October	0.009724	0	0.9880	0.2508
November	0.001760	0.9605	0	0.3910
December	0.001485	0.9536	0	0.3607

Note: units of flow are m^3/s, catchment areas are in km^2 and monsoon wetness index is in mm.

D10. Estimates of monthly average flows using MIP method

The MIP method for estimating mean monthly flows for a given catchment is as follows:

Step 1: Calculate the catchment area and then establish in which of the seven hydrological region the catchment lies, from Figure C2.2.1 in – Appendix C.

Step 2: As discussed earlier make one site visit between November to May and measure the flow at the intake.

Step 3: Divide the measured flow by the non-dimensional hydrograph value for the appropriate month and region. If the flow measurement was conducted at the beginning or the end of the month, it may be necessary to interpolate between the two relevant ordinates from Table C2.2.1 Appendix C. The result represents the mean April flow to be expected in that catchment.

Step 4: If there are significant upstream abstractions such as irrigation off takes, attempt to quantify them and add this amount to the measured flow. The result will be the flow at the intake of the scheme in the absence of the upstream abstractions.

Step 5: Take the April flow calculated in step 3 and multiply it by each non-dimensional ordinate from Table 2. The result is the hydrograph of mean monthly flows.

Step 6: Use Form 6 in this Appendix for calculation.

Table 2

Month	Non-dimensional regional hydrographs						
	1	2	3	4	5	6	7
January	2.40	2.24	2.71	2.59	2.42	2.03	3.30
February	1.80	1.70	1.88	1.88	1.82	1.62	2.20
March	1.30	1.33	1.38	1.38	1.36	1.27	1.40
April	1.00	1.00	1.00	1.00	1.00	1.00	1.00
May	2.60	1.21	1.88	2.19	0.91	2.57	3.50
June	6.00	7.27	3.13	3.75	2.73	6.08	6.00
July	14.50	18.18	13.54	6.89	11.21	24.32	14.00
August	25.00	27.27	25.00	27.27	13.94	33.78	35.00
September	16.50	20.91	20.83	20.91	10.00	27.03	24.00
October	8.00	9.09	10.42	6.89	6.52	6.08	12.00
November	4.10	3.94	5.00	5.00	4.55	3.38	7.50
December	3.10	3.03	3.75	3.44	3.33	2.57	5.00

APPENDIX - E

FORMS AND FORMATS

Rural Energy Fund

Form No. 1, Power Output Verification Form for Micro Hydropower Plant

Government of Nepal
Ministry of Environment Science and Technology
Alternative Energy Promotion Centre

Energy sector Assistance Programme/
Rural Energy Development Programme

Name of the Scheme: ………………………………………………… Owner of the Plant: ……………..……………………………….
Location:Village………………………….……… VDC……………………….………..Ward No.…………..District:…………………………

Obs. No.	V_{RN} Volt	I_R Amp	p.f.	P_R kW	V_{YN} Volt	I_Y Amp	p.f.	P_Y kW	V_{BN} Volt	I_B Amp	p.f.	P_B kW	Total Power $P_R+P_Y+P_B$ kW	Freq Hz	Weir Height (cm)	Discharge lit./sec.	Pressure guage Kg/cm^2	Net Head (m)	Valve Position	Remark
1																				
2																				
3																				
4 5																				

Design Net Head: …..m Design Flow: ……lps Design Power:…..kW Minimum Power Required:

Actual Net Head: ……m Actual Flow: …....lps Actual Power:……kW

Stream Flow by the intake :………lps , Design Gross Head :………m, Actual Gross Head:……m.

I/We hereby ceritify that I/we have measured and verified power output from this micro hydro plant as per IREF power output verification guidelines. I/We hereby certify that the measured power output for the designed flow of this installation is ….. kW.

Signature of the Inspector and Date: Signature of Assistant Inspector and Date:

Name of the Inspector Name of the Assistant Inspector:

	Name	Signature and Date
Data Recorded By		
Owner's Representative as witness		
Installer's Representative as witness		
Date		

Rural Energy Fund

Form No. 2, Power Output Verification Form for Pico Hydro Plant

Government of Nepal
Ministry of Environment Science and Technology
Alternative Energy Promotion Centre

Energy sector Assistance Programme/
Rural Energy Development Programme

Name of the Scheme: ………………………………………………… Owner of the Plant: ………………..…………………………………….

Location:Village……………………….….….…. VDC……………………….……….. Ward No…………….District:………………………..

Obs. No.	V_{RN} Volt	I_R Amp	p.f.	P_R kW	Freq Hz	Weir Height (cm)	Discharge lit./sec.	Pressure guage Kg/cm^2	Net Head (m)	Valve Position	Remark
1											
2											
3											
4											
5											

Design Net Head: …..m Design Flow: ……lps Design Power:…..kW Minimum Power Required:

Actual Net Head: ……m Actual Flow: …....lps Actual Power:……kW

Stream Flow by the intake :………lps Design Gross Head :…………m, Actual Gross head:…….m

I/We hereby ceritify that I/we have measured and verified power output from this micro hydro plant as per IREF power output verification guidelines. I/We hereby certify that the measured power output for the designed flow of this installation is ….. kW.

Signature of the Inspector and Date: Signature of Assistant Inspector and Date:

Name of the Inspector Name of the Assistant Inspector:

	Name	Signature and Date
Data Recorded By		
Owner's Representative as witness		
Installer's Representative as witness		
Date		

Form No. - 3

Flow Calculation for 90^o Triangular (V-Notch) Weir

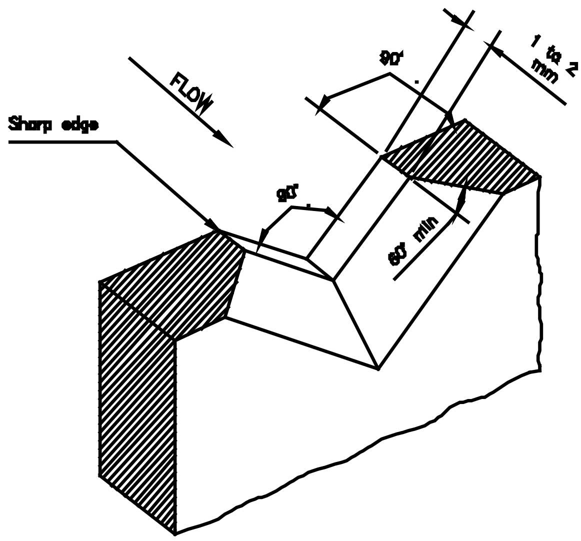


Figure No. 1

Weir coefficient of discharge C = ______ (as certified by laboratory test, use C= 0.6, if test results are not available and the weir is fabricated as specified in the Appendix B)

Depth of water from bed level to water surface (d): __________ (m)

Height from bed level to bottom of V notch (p): _____________ (m)

Head over weir (h): d – p = _______ m

Discharge, $Q = C \times 2.362 \times h^{5/2}$

$Q = (\_\_\_\_\_) \times 2.362 \times (\_\_\_\_\_)^{5/2} = \_\_\_\_\_\_\_\_\_$ m^3/s.

Form No. - 4

Flow Calculation for Rectangular Weir

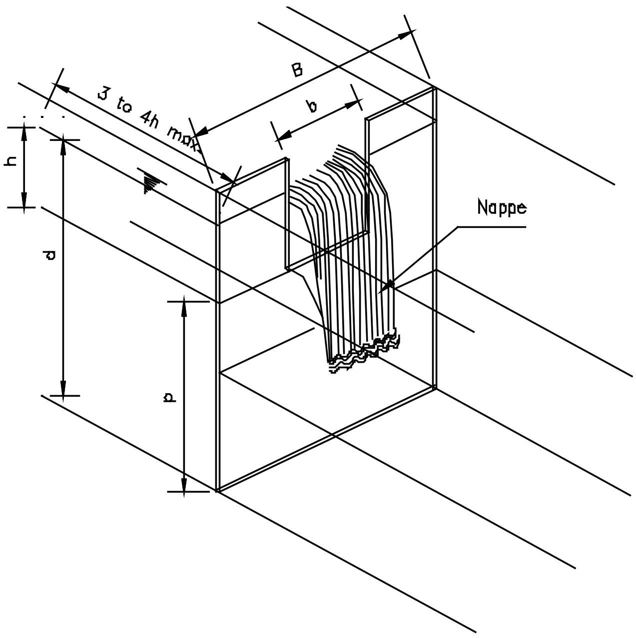


Figure No.2

Weir coefficient of discharge C = ______ (as certified by laboratory test, use C= 0.6, if test results are not available and the weir is fabricated as specified in Appendix B)

Depth of water from bed level to water surface (d): __________ (m)

Height from bed level to bottom of V notch (p): _____________ (m)

Head over weir (h):   d – p = _______ m

Width of weir (b):   = _______ m

Discharge, $Q = C \times 2.953 \times b \times h^{1.5}$

$Q = (\_\_\_\_\_) \times 2.953 \times (\_\_\_\_) \times (\_\_\_\_\_)^{1.5} = \_\_\_\_\_\_\_\_\_ \ m^3/s.$

Form No. - 5

Data Record Sheet for Flow Measurement by Weir Method

Name of the Scheme: ……………………………………………………………………

Location: VDC:…………………………….. Ward:…………

Recorded by:……………………………….Date:……………………………………………..

Type of Weir:

Weir coefficient C = Width of weir = B = ... m. (Rectangular)

S.No	Depth, bed level to water surface (d) m	Height, bed level to bottom of V/U notch (p) m	Head over weir (h) = (d)-(p) m	Discharge cum/sec	Discharge litre/sec	Remarks
1						@ Ballast Volt of 100 V
2						@ Ballast Volt of 150 V
3						@ Ballast Volt of 180 V
4						@ Ballast Volt of 220 V

Transfer the data on actual flow above to the power output verification certification form.

Name of the inspector:

Signature of the inspector:

Name of the Owner:

Signature of the Owner

Name of the civil contractor:

Signature of the civil contractor:

Form No. - 6

Flow calculation using conductivity meter results

River Name: Name of the Scheme:
Date: Location: VDC: Ward:
Time:
Weather:
Salt used (M): _______ gm water temp: ____ ^{0}c base level: ____ µS
Salt constant k = _______(µS)/(milligram/litre)

Time (sec)			05	10	15	20	25	30	35	40	45	50	55	60	Sum
water conductivity in µS	Minutes	1													
		2													
		3													
		4													
		5													
		6													
		7													
		8													
		9													
		10													
TOTAL															

Area(A)= ________ µS Sec

Q = Mk/A

Q =(___ x ____)/(_____) lps

Form No. - 7

FLOW DATA RECORDING AND CALCULATION BY CURRENT METER

Instrument:	River width (W):	m
River:	Segment width (w):	m
Location:	Revolution duaration (t):	s
Date:	Last calibrated date:	

Segment	Distance	Depth (d)	Number of revolution (R)	Frequency of revolution (N)	Segment velocity (v)	Segment flow (q)
	m	m	r	rps	m/s	m^3/s
					Total	

Correlation equations: v=a*N+b
Correlation coefficients: a b

The segment velocity should be put in v column if current meter gives it directly.

Measured and calculated by:

FORM No. - 8
Estimate of Monthly Average Flows – WECS/DHM Method

1. Total Catchment Area: …………………………… km^2
2. Catchment below 5000 m elevation: …………………………… km^2
3. Monsoon Wetness Index of Basin center: ………………… mm
   (From Figure C2.1.1 – Appendix C)

Using the equation below along with the information from above (1, 2, and 3) and the coefficient C, fill the last column to average monthly flows:

$Q_{mean\ month}$ = C x (Area of Basin)^{A1} x (Area below 5000 m + 1)^{A2} x (Monsoon Wetness Index)^{A3}

Month	Constant coefficient C	Power, Area of basin (km^2) A_1	Power, Area of basin below 5000 m +1 (km^2) A_2	Power of Monsoon Wetness Index A_3	Average Monthly Flows (m3/s) $Q_{mean\ month}$
January	0.01423	0	0.9777	0	
February	0.01219	0	0.9766	0	
March	0.009988	0	0.9948	0	
April	0.007974	0	1.0435	0	
May	0.008434	0	1.0898	0	
June	0.006943	0.9968	0	0.2610	
July	0.02123	0	1.0093	0.2523	
August	0.02548	0	0.9963	0.2620	
September	0.01677	0	0.9894	0.2878	
October	0.009724	0	0.9880	0.2508	
November	0.001760	0.9605	0	0.3910	
December	0.001485	0.9536	0	0.3607	

Note: units of flow are m^3/s, catchment areas are in km^2 and monsoon wetness index is in mm.

FORM No - 9
Estimate of Monthly Average Flows – MIP Method

1. Total Catchment Area: …………………………… km^2

2. Hydrological Region (1 – 7) : …………………
   (From Figure C2.2.1 – Appendix C)

3. Date of Flow Measurement at the Site (November – April): …………………

4. Measured Flow Value: …………………m^3/s

5. Upstream Diversion Estimate during measurement: …………………m^3/s

6. Total Flow Past Intake (4 + 5): …………………m^3/s

7. Expected Flow in April : …………………m^3/s
   (Total flow past intake (m^3/s)/Non Dimensional Hydrograph value for the month of measurement for the region identified in 'Step 2' above)

8. Multiply April Flow obtained in 'Step 7' by each non-dimensional ordinate of the region selected above 'Step 2' from Table below to obtain monthly flows:

Month	Non-dimensional regional hydrographs							
	1	2	3	4	5	6	7	
January	2.40	2.24	2.71	2.59	2.42	2.03	3.30	
February	1.80	1.70	1.88	1.88	1.82	1.62	2.20	
March	1.30	1.33	1.38	1.38	1.36	1.27	1.40	
April	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
May	2.60	1.21	1.88	2.19	0.91	2.57	3.50	
June	6.00	7.27	3.13	3.75	2.73	6.08	6.00	
July	14.50	18.18	13.54	6.89	11.21	24.32	14.00	
August	25.00	27.27	25.00	27.27	13.94	33.78	35.00	
September	16.50	20.91	20.83	20.91	10.00	27.03	24.00	
October	8.00	9.09	10.42	6.89	6.52	6.08	12.00	
November	4.10	3.94	5.00	5.00	4.55	3.38	7.50	
December	3.10	3.03	3.75	3.44	3.33	2.57	5.00	

Form No - 10 a
Household Connection verification Form
(To be obtained from REF before leaving to field for verification)

Name of the Project:……………………………………………..

Location: VDC:…………………………………..……, District:………………..

Design HH:……………Nos.

Design Capacity:………………….kW

S.N.	VDC	Ward No.	Cluster	Status of HH Connection			Remarks
				Pole No.	Proposed	Connected up to POT	
				Total			

We here by Certify that the above mentioned information is true.

Installer Company	Developer	VDC Representative
Signature:	Signature:	Signature:
Designation:	Designation:	Designation:
Name:-	Name:	Name:
Date:-	Date:	Date:

Form No 10 b
Household Connection verification Form
(To be filled at site during field verification)

Name of the Project:

Location: VDC:…………………………………….……, District:………………..

Design HH:……………Nos.

Design Capacity:………………….kW

S.N.	VDC	Ward No.	Cluster	Status of HH Connection				Remarks
				Pole No.	Proposed	Connected up to POT	Connected After POT	
					Total			

We here by Certify that the above mentioned information is true.

Installer Company:	PoV Team	User Committee	VDC/Wards Member
Signature:	Signature:	Signature:	Signature
Name:-	Name:-	Name:-	Name:
Designation:-	Designation:-	Designation:-	Designation:
Date:-	Date:-	Date:-	Date:

Form No. - 10 c
Household Connection verification Form
(To be filled at site during field verification)

Name of the Project:

Location: VDC:…………………………………….……, District:………………..

Design HH:……………Nos.

Design Capacity:………………….kW

S.N.	VDC	Ward No.	Cluster	Status of HH Connection				Remarks
				Pole No.	Proposed	Not Connected up to POV but Access Possible	Total Connected up to POV	
					Total			

We here by Certify that the above mentioned information is true.

Installer Company:	PoV Team	User Committee	VDC/Wards Member
Signature:	Signature:	Signature:	Signature
Name:-	Name:-	Name:-	Name:
Designation:-	Designation:-	Designation:-	Designation:
Date:-	Date:-	Date:-	Date:

Note: The reasons for Not Connection

Form No. - 10 d
Household Connection verification Form
(To be filled at site during field verification)

Name of the Project:

Location: VDC:………………………………….……, District:………………..

Design HH:……………Nos.

Design Capacity:………………….kW

S.N.	VDC	Ward No.	Cluster	Status of HH Connection				Remarks
				Pole No.	Proposed	Not Connected HH up to POV Access Not Possible	Total Connected up to POV	
					Total			

We here by Certify that the above mentioned information is true.

Installer Company:	PoV Team	User Committee	VDC/Wards Member
Signature:	Signature:	Signature:	Signature
Name:-	Name:-	Name:-	Name:
Designation:-	Designation:-	Designation:-	Designation:
Date:-	Date:-	Date:-	Date:

Note: The reasons for Not Connection