# STANDARDS/MANUALS/ GUIDELINES FOR SMALL HYDRO DEVELOPMENT

## 1.12 General– Site Investigations

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## Standards/ Manuals/Guidelines series for Small Hydropower Development

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# PREAMBLE

There are series of standards, guidelines and manuals available on electrical, electromechanical aspect of moving machines and hydro power related issues from Bureau of Indian Standards (BIS), Rural Electrification Corporation Ltd (REC), Central Electricity Authority (CEA), Central Board of Irrigation & Power (CBIP), International Electromechanical Commission (IEC), International Electrical and Electronics Engineers (IEEE), American Society of Mechanical Engineers (ASME) and others. But most of these are developed keeping in view the large water resources/ hydropower projects. Use of the standards/guidelines/manuals is voluntary at the moment. Small scale hydropower projects are to be developed in a cost effective manner with quality and reliability. Therefore a need to develop and make available the standards and guidelines specifically developed for small scale projects was felt.

Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee initiated the exercise of developing standards/guidelines/manuals specifically for small scale hydropower projects under the sponsorship of Ministry of New and Renewable Energy, Government of India, in 2006. The available relevant standards / guidelines / manuals were revisited to suitably adopt them for small scale hydro projects. These have been prepared by experts in their respective fields. Wide consultations were held with all stake holders covering government agencies, government and private developers, equipment manufacturers, consultants, financial institutions, regulators and others through web, post and meetings. After taking into consideration the comments received and discussions held with the lead experts the standards/guidelines/manuals are now prepared and presented in this publication.

The experts have drawn some text and figures from existing standards, manuals, publications and reports. Attempts have been made to give suitable reference and credit. However, the possibility of some omission due to oversight cannot be ruled out. These can be incorporated in our subsequent editions.

These standards / manuals / guidelines are the first edition. We request users of these to send their views / comments on the contents and utilization to enable us to review these after about one year of its publication.

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# INVESTIGATIONS FOR SMALL HYDROPOWER PROJECTS

## 1.0 SCOPE

Small hydropower projects can be grouped under:

(i) Type-1: Run of river schemes.
(ii) Type-2: Schemes on canal and canal falls.
(iii) Type-3: Schemes utilizing the existing dam/barrage.

For Type 2 and Type 3 schemes, the availability of water is well established and data may be available with concerned authorities. The schemes can therefore be formulated on the basis of water available or water released from dam / barrage for the irrigation or any other purpose for which they were originally constructed and water being spilled from spillways of barrages/dams. However the field investigations for layout of power channel, penstocks, power house, switchyard, tailrace channel and other appurtenant works will be required, similar to type 1 schemes i.e. run of river schemes. Before undertaking the detailed investigations, a reconnaissance of the project site is required to be undertaken.

The following field investigations would be required for establishing the SHP schemes.

(1) Topographical surveys
(2) Geological mapping and exploration
(3) Hydrological investigation
(4) Sediment data of the stream
(5) Surveys for construction material
(6) Surveys for Power utilization/ evacuation facility
(7) Access to different components of the scheme.
(8) Investigations for environmental aspects
(9) Surveys for muck disposal area
(10) Infrastructural facilities

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## 2.1 Objectives of Investigations

(i) To assess the general suitability of site for small hydropower project.
(ii) To enable adequate and economical design.
(iii) To foresee and provide solution against difficulties that may arise due to ground and other local conditions.

Selection of a proper site for the project is the important task which can be done with the help of Survey of India topographical survey maps and reconnaissance survey of project area. The reconnaissance should involve visiting all possible locations, which are available for consideration and gathering information related to each site as much possible without detailed field explorations. The best topographic map with large scale available should be obtained for possible locations. Preliminary layout of different components of projects should be laid and the most technically feasible layout be selected.

Thereafter detailed field surveys are carried out for the selected layout. The run of river schemes are mostly located in hilly terrain at small streams or large rivers . The stability of slopes is important considerations for siting different structures. Unstable slopes are to be ignored and sites which are away from slip zones, easily accessible site for personnel and transporting the construction materials should be given more weightage.

# 3. RECONNAISSANCE OF SITE

The purpose of a site reconnaissance visit is to have an understanding of site characteristics, identification of problems as well as solutions, and inputs for selection of site for the various project structures.

Prior to undertaking a site reconnaissance visit, available data should be reviewed, preliminary conceptual designs prepared and laid out on available maps for guidance during the field visit. It is further recommended that an outline of the preliminary studies report be made at this time and a check list prepared before going into the field. This will help to identify important informations in order to search for them during the site visit.

The site visit provides an opportunity to obtain an appreciation of site topography, flow regime, geology and access for roads and transmission lines. From these on-site observations it is often possible to identify feasible locations for temporary facilities, head-works, desilting tank and powerhouse and to decide the side of the river best suited for routing of the waterways, preliminary access roads and transmission line (T.L.) routes. These locations, their elevations and co-ordinates can be determined with portable GPS equipment. GPS equipment capable of giving elevation and spatial measurement with accuracies of +/- 0.3m and 1.0 m respectively (or better) may be used. It is also recommended that the inspection team should preferably include three professionals: a hydrologist, an engineering geologist/geotechnical engineer and a hydropower engineer. It is also recommended that the team should include local representatives, astheir practical knowledge of the area could be valuable. This initial contact could also be an opportunity for developing the interest and support of local residents for the project. Typically, a field visit may require 1-3 days depending on the remoteness, size and complexity of the site.

The following generic checklist on site conditions is recommended for assistance in planning the reconnaissance visit.

- Climate
- Condition of main road to the project site, weight and width limitations on bridges.
- Access and site roads and suitable areas for structures, stock-pile, waste disposal.
- Routes for transmission / distribution lines.
- Visual assessment of foundation conditions and slope stability along waterways and at structure sites.
- Developable head.
- Availability of construction materials (sand, aggregates, number and impermeable fill, as required)
- Local services and skills available.
- High water marks in tail water and head pond areas.
- Location of important lateral water courses
- Population of villages within the probable service radius of the plant and types of industries, existing or planned.
- Location of buildings or other structures that may require relocation, etc.

A site reconnaissance relies mainly upon visual assessment of site conditions and therefore it is important that the findings be supported by photographs of key features. Finally, it is recommended that a site reconnaissance report be prepared outlining the observations and findings from site reconnaissance. At this stage a preliminary report is usually prepared combining the findings of office studies and site reconnaissance visit. If this report concludes that the project is likely to be viable then a feasibility study would be recommended and a scope of work prepared for detailed investigations. Projects deemed infeasible would usually be abandoned at this stage. The detailed surveys and investigations required to be carried out for technically feasible projects based on site reconnaissance are given in subsequent part of this guideline/standards.

## 4. TOPOGRAPHICAL SURVEYS

The scope of topo mapping should be decided following the field reconnaissance, when locations of major structures have been approximately decided. In general, the extent of mapping should be sufficient to cover all alternatives envisaged and to allow for reasonable realignments of structures, waterways, access roads and transmission line (T.L) routes.

The first activity in the topographic survey program be the establishment of a control network of reference points and benchmarks. The network should provide coverage of the complete hydro scheme from intake to tailrace channel including switchyards, laydown (stockpile) areas and site roads. While the initial use of this network is for control of topographic surveying, the same benchmarks will eventually be used for control of construction.. Once the benchmarks have been installed a first order survey should be carried out to establish elevations and coordinates at each control point. If possible, the control survey should be based on the survey of India benchmarks, for new run-of river schemes, or based on existing project grids for toe of dam or canal fall schemes.

The scope of topographic surveying as it applies to various components of a typical small hydro project are described below. The suggested scope attempts to be comprehensive; however, the scope can be tailored to fit the requirements of a particular project.

### 4.1 Reservoir Survey

A cross section survey should be carried out upstream of the diversion dam site to establish the limits of the head pond reservoir, extent of over bank flooding (if any) and reservoir area and volume. The survey should extend upstream to the point where the river bottom elevation and reservoir maximum flood level are the same. Spacing between cross sections should be between 2 to 5 times the width of the river channel, but not greater than 500m apart. Cross sections should extend to the maximum flood level (MFL) plus 1.0 m (plus 10.0 m for potentially unstable bank slopes especially in areas likely to affect village homes or fields). Current water levels and high water marks should be marked. Cross sections should be referenced to a control / centre line. If water flow is too fast or too deep for wading, the depth should be estimated visually or by sounding from a boat.

### 4.2 Diversion weir/barrage and Head works

Three to five cross sections should be taken through the dam centre line, upstream and downstream of the dam. Additional cross-section may be required to cover the river channel area in front of the head works. Surface mapping should be sufficient to cover barrage abutment and head regulator (intake) areas. L-section of the river should be taken covering upstream and downstream of proposed location of barrage.

### 4.3 River downstream of diversion weir/barrage

Survey of the river channel downstream of the dam is required to establish a head / discharge rating curve at the toe of the diversion dam. The survey should also be continued far enough downstream to establish an adequate drop between the desilting device and river for input to siting of the desilting device.

### 4.4 Water conductor survey

It is recommended that a control traverse be laid out along the route of the waterways. This traverse should be traced along the contour corresponding to the normal water level in the canals. Cross sections should extend (typically) 20m up hill and 10m down hill or as appropriate. Cross sections should be located at 100m intervals, at abrupt changes in topography and at gullies (nalas) crossing the waterway centre line. A minimum of three cross sections should also be taken at gully (nala) crossings sufficient to describe these features for design of cross drainage works. It is preferable that the control traverse be “closed” on a pre-established survey control point. This traverse will also be useful for tying in geological features, test pits, etc.

### 4.5 Structure Surveys

Structure surveys should provide coverage for the structure plan forms (footprints) with allowances for re-alignment, slope stabilization works or retaining walls, if required.

### 4.6 River downstream of tailrace outlet

A river cross section survey should be carried out below the tailrace outlet sufficient to permit establishment of a head / discharge rating curve at this location.

### 4.7 Access roads, T.L. routes and project infrastructure

Routes surveys along the access roads and T.L. routes should also be included. It is also desirable to survey project infrastructure sites such as: stockpile areas, camp and office areas, disposal areas and temporary (construction) roads. In some cases pre-existing quarries or commercial areas may be available for stockpiling, offices and the like. Surveys of such areas would not be required.

After selection of suitable site, detailed surveys are required to be carried out. A Survey of India bench mark should be located and based on this bench mark, a project bench mark should be installed in the project area. This is very important for the successful completion of project as well as to the life of project. The scale of survey, contour interval and other requirements for the surveys for different components of the project to be carried out are detailed below in Table 1.

**Table 1: Topographical Surveys for run of river schemes**

| S. No. | Feature | Survey Requirement | Scale | Contour Interval | Additional Requirement |
|---|---|---|---|---|---|
| 1. | L-section along the Stream | Bed level and water level of the stream along its center line from 1 km upstream of diversion structure to 0.5 km downstream of confluence of tailrace. | 1:10,000 | _ | (i) Date of survey<br>(ii) Water levels on date of survey along the stream |
| 2. | General layout | (1) Contour plan to cover all components of the project extending from 1.0 km upstream of diversion Structure to 0.5 km downstream of confluence of tailrace with the river. | 1:10,000/ 1:5,000 | 5m/ 2m | _ |

| S. No. | Feature | Survey Requirement | Scale | Contour Interval | Additional Requirement |
|---|---|---|---|---|---|
| | | (2) River cross sections at 500 m interval to cover both banks well above the highest flood marks and include water conductor for the reach where it is close to the river. | 1:500 | _ | (i) Date of survey (ii) Water level on date of survey (iii) Max. observed HFL on the basis of flood marks. |
| | | (3) Access road. | 1:5,000 | 2m | _ |
| 3. | Diversion Structure | (1) Contour plan to cover reach 200 m upstream to 200 m downstream of the proposed structure and extend at least 25 m above anticipated highest flood level (HFL). | 1:500 | 1-2 m | _ |
| | | (2) 5 cross section, 1 along the proposed axis and 2 on either side i.e. Upstream and downstream of the axis. | 1:200 | _ | (i) Date of survey (ii) Water level on the date of survey (iii) Max. Observed HFL on the basis of flood marks. |
| 4. | Water conductor system (channel, tunnel, desilting tank, spill channel, tail race channel) | (1) Contour plan along water conductor alignment extending 20 m towards the hill side and 10m towards the valley side. | 1:500 | 1 – 2m | _ |
| | | (2) 'L' section along the alignment of water conductor. | 1:500 | _ | _ |
| | | (3) Cross – section along the water conductor at 100 m intervals and at locations where cross drains are intercepted and also at locations where topography change abruptly. | 1:500 | _ | _ |

| S. No. | Feature | Survey Requirement | Scale | Contour Interval | Additional Requirement |
|---|---|---|---|---|---|
| | | (4) Three cross – sections of the cross drains – one on the alignment and one each on either side of the alignment. | 1:500 | _ | _ |
| | | (5) 'L' section along cross drains 100 m on either side of water conductor. | _ | _ | Date of survey<br>(i) Water level on date of survey<br>(ii) HFL based on flood marks to be indicated. |
| | | (6) Contour plan to cover sufficient area of the cross drains and its banks. | 1:500 | 1-2 m | _ |
| 5. | Forebay / balancing reservoir /surge tank | (1) Contour plan to cover entire area of forebay including its vicinity of 50m or more. | 1:500<br>or<br>1:200 | 2m<br>or<br>1m | _ |
| | | (2) Longitudinal section and 2-3 cross – sections. | 1:500 | _ | _ |
| 6. | Penstock | (1) Contour plan extending 30 m either side of the alignment. | 1:500 | 2m | _ |
| | | (2) 'L' sections along penstock alignment. | 1:500 | | _ |
| | | (3) Cross-section at 100m intervals along alignment and at all anchor block locations. | 1:500 | | _ |
| 7. | Powerhouse | (1) Contour plan to cover sufficient area to include different alternative layouts of powerhouse and switchyard and tailrace channel up to its confluence with the river. | 1:500<br>Or<br>1:200 | 2m<br>Or<br>1m | _ |
| | | (2) 'L' sections along the powerhouse and tailrace channel upto its confluence with | 1:500 | - | (i) Date of survey.<br>(ii) Water level at the point of |

| S. No. | Feature | Survey Requirement | Scale | Contour Interval | Additional Requirement |
|---|---|---|---|---|---|
| | | the river. | | | confluence of the tailrace with the river on the data of survey. (iii) Max. observed HFL on the basis of flood marks. |
| | | (3) Access road to powerhouse. | 1:500 | 2m | - |

*Note: The scale and contour interval may vary as per topography of the area to have clarity.*

For schemes on canal and canal falls, detailed field surveys are to be carried out after an initial reconnaissance survey to get information needs to be collected about the topographical features and constraints for locating the bypass channel and powerhouse adjacent to the fall structure. After study of these particulars the alignment should be identified in the first instance. Detailed field survey is to be carried out for the identified alignment and location, covering sufficient area to examine all possible shifts in locations to arrive at an optimum alignment and positioning of structures. The scale and particulars of the survey are included in Table 2 below.

**Table 2: Topographical Surveys for schemes on canal falls**

| S. No. | Feature | Survey Requirement | Scale | Contour Interval | Additional Requirement |
|---|---|---|---|---|---|
| 1. | General layout | (1) Contour plan<br>(2) Longitudinal section | 1:1000<br>1:1000 | 0.5-2 m | Load availability, approach road routing to intake and powerhouse switchyard locations to be included. |
| 2. | Intake of the canal | (1) Contour plan<br>(2) Longitudinal section and 2 cross-sections | 1:200<br>1:200 | 0.5-2m | Longitudinal section to include canal and inlet area. |
| 3 | Widened canal bypass canal | (1) Contour plan<br>(2) Longitudinal section and cross-sections. | 1:200<br>1:200 | 0.5-2 m | - |
| 4 | Power house and switchyard | (1) contour Plan<br>(2) Longitudinal section and 2 cross-sections. | 1:200<br>1:200 | 0.5-2 m | - |
| 5 | Tailrace channel | (1) Contour plan<br>(2) Longitudinal section and cross-Sections. | 1:200<br>1:200 | 0.5-2 m | Longitudinal section to include outfall area (connecting to the canal) |
| 6 | Outfall into canal | (1) Contour Plan<br>(2) Longitudinal section | 1:200<br>1:200 | 0.5-2 m | Longitudinal section to include canal and |

| | | | | | |
|---|---|---|---|---|---|
| | | and 2 cross-sections. | | | outlet area. |

For Powerhouse located downstream of an existing Dam/Barrage, detailed field survey will be carried out after initial reconnaissance survey when the alignment of the water conductor system and the location of the powerhouse, tailrace and switchyard are identified taking into account topographical constraints. Detailed topographical survey shall be carried out for the identified alignment and locations. The survey shall cover sufficient area to enable examination of all possible shifts in alignment and locations to arrive at an optimum alignment and positioning of structures. Accurate drawings of existing structures which are linked with the planned small hydropower scheme should be obtained and used for necessary co-ordination. The scale and particulars of the survey are indicated in Table 3 below.

**Table 3: Topographical Surveys for Powerhouse located downstream of an existing Dam/Barrage**

| S. No. | Feature | Survey Requirement | Scale | Contour Interval | Additional Requirement |
|---|---|---|---|---|---|
| 1. | General layout | (1) Contour plan.<br>(2) Longitudinal section. | 1:1000<br>1:1000 | 1-2m | Approach road routing to intake, powerhouse and switchyard to be included. |
| 2. | Intake area | (1) Contour plan.<br>(2) Longitudinal section and cross-sections. | 1:200<br>1:1000 | 1-2m | - |
| 3 | Water conductor | (1) Contour plan<br>(2) Longitudinal section and cross-section. | 1:200<br>1:200 | 1-2m (1-2m in flat terrain or 5m in hilly terrain) | - |
| 4 | Powerhouse and switchyard | (1) Contour plan.<br>(2) Longitudinal section and cross-section. | 1:200<br>1:200 | 1-2m | - |
| 5 | Tailrace channel | (1) Contour plan.<br>(2) Longitudinal section and cross-section. | 1:200<br>1:200 | 1-2m | - |
| 6 | Outfall from tailrace | (1) Contour plan.<br>(2) Longitudinal section and cross-section. | 1:200<br>1:200 | 1-2m | - |

## 5.0 GEOLOGICAL INVESTIGATIONS

Geological investigation of a project site is the preparation of a geological map. Such a map is usually based on surface observations supplemented by information from laboratory test and analyses of collected samples. When the geology is complex or bedrock not exposed, subsurface investigation may be needed. However, such investigations are very costly and rarely justified for small hydro projects. For small hydro schemes much of the appraisal of site geologic conditions will be based on visual inspection of site features. This should be done by an experienced engineering geologist; preferably one familiar with geology of the area.

According to the specific geological conditions of the site, the scope of site investigations may vary considerably. A well thought out and flexible program should be established before subsurface investigations begin. Geological features likely to necessitate special attention are summarized below :

- Major geological features affecting the site, such as faults, fractured and shear zones and the contacts between the different types of rock.
- Areas of deeply weathered or heavily altered zones.
- Permeable strata, large open cracks, limestone caves or fissures and location of springs.
- Active processes showing evidence of erosion, slope-creep, screes, landslides, rockfalls and rockbursts.

The characteristics of these features should be elucidated and implications for design established. Where bedrock exposures are limited, geophysical methods of investigation may be required depending on the importance of the structure. Sampling and laboratory testing of soils and rocks is also required for classification of soil and rock masses.

Site investigations for small hydro normally include:

- Test pits are effective for inspection of foundation conditions and for soil/rock sampling.
- Trenches are used when a continuous exposure of bedrock along a given line or section is needed, for example: along the centre line of a dam.
- Auger borings often provide the simplest method of soil investigation and sampling. Borings are also used to gauge overburden thickness.
- Field permeability tests at dam site.

Core drilling, seismic refraction surveys and electric resistivity surveys can provide reliable information but are too costly to be used for most small scale hydropower investigations. The exception would be projects involving tunneling, where structure sites may require expensive stabilization works or where unusual geological features are encountered in structure foundations, shear zones, faults, etc.

Seismic zone of the site should be determined from the National Building Code of India.

The geological information should be presented in the form of a complete list of investigations performed with their results shown on maps and in charts. All relevant laboratory tests should likewise be documented. For sites in the Himalayas, preparation of micro-landslide zonation maps in particular along linear features such as waterways or access roads should be considered.

Based on the data obtained from the investigations and laboratory tests, assessments should be made of the foundation conditions for the various structures and soil/rock conditions evaluated if tunnels, shafts or deep excavations are involved. These assessments should include design criteria, recommendations on methods for excavation and support works, and for handling and depositing of excavated material or their suitability for use in construction. Finally, recommendations should be made on quarry sites and borrow areas, if required to supplement materials obtained from structure excavations.

SHP schemes involve small size structure as compared to large schemes. Exploration by trial pits or trenches for various features is sufficient to meet the requirement for small stream and tunnels. A judicious and careful geological assessment with limited geological exploration is essential for selecting appropriate alignment and sitting the various structures of the scheme. A preliminary survey of the alignment shall be carried out for obtaining a general idea of the regional and localized geology to identify the problem areas to firm up the layout. The problem areas should be studied from geotechnical aspects and layout firmed up with necessary modifications. Sub-soil exploration to find out C and phi value, bearing capacity at the foundation level need to be carried out at important structures viz barrage/dam, forebay tank, penstock alignment and power house, switchyard etc.

### 5.1 Diversion Structure

Geological explorations to be conducted with trial pits or dril holes as close to deepest bed level as possible and two trial pits/dril holes on each bank. One of three locations should be at proposed intake structure. Geological assessment of abutment conditions and the hill slopes of the abutment with a geological section indicating the dip and strike direction shall be made. This will be helpful in assessing the stability of the hill slopes of excavated abutment.

### 5.2 Water Conductor System

Few trial pits along the alignment of after conductor system at every 500 m, including vulnerable reaches should be taken for the geological assessment of the foundation strata along with permeability and other subsidence characteristics. Slope stability of excavated hill slopes for laying water conductor system is very important. For this, a geological section should be developed by surface observations at 200m Interval including at vulnerable / critical locations. If water conductor system comprises of tunnel reach, in addition to a geological section along the alignment, more detailed information on the nature and classification of rock mass, joint patterns encountered along the alignment, the strike & dip pattern needs to be collected with identification of reaches of shear zone and rock classification. The inlet & outlet portal of tunnel needs to be investigated for stability of excavated slope.

### 5.3 Forebay/Surge Tanks/Balancing Reservoir

A trial pit/drill holes at the location of forebay be taken to assess the foundation strata. The hill slope behind and below forebay may be assessed for stability. The foundation strata be assessed for permeability characteristics.

### 5.4 Penstocks

Penstock slope be investigated for slope stability by developing a geological section on the alignment based on detailed survey. Foundation strata at anchor block and saddle locations be assessed by trial pits at representative locations.

### 5.5 Powerhouse

Foundations strata at powerhouse be assessed by trial pits/drill holes. Powerhouse excavation slopes be assessed for slope stability by developing geological sections on the basis of detailed survey by the geologist.

For underground works, detailed geological investigations are required as per established Central Water Commission/Bureau of Indian Standard guidelines for large hydropower/river valley projects.

### 5.5.1 Schemes on canal falls

The stability of excavated slopes for intake channel and tailrace channel/bypass channel and powerhouse needs to be investigated by developing geological section and/or study of soil characteristics and ground water conditions. The foundation strata of the powerhouse, inlet and outlet structures shall be investigated by trial pits.

### 5.5.2 Powerhouse located downstream of an existing dam/ barrage

The stability of water conductor system be ascertained by geological sections as in case of type 1 schemes. In case water conductor system comprises a tunnel a geological section along the tunnel alignment is to be developed as suggested for the tunnel reach of type 1. The assessment has also to be based on borehole logging data at the inlet portal, exit portal and reaches of low rock cover. Powerhouse foundation needs to be investigated by either trial pits or by bore holes where ever warranted. Geological assessment for approach channel and tail race needs to be made.

## 5.6 Requirement of Geological Field Investigations

It is desirable that a geological assessment of the geological features at the various locations of the scheme is made through a site visit by a well experienced geologist in consultation with the design engineers regarding technical aspects. The requirement of geological field investigations is given in Table 4.

**Table 4: Geological Field Investigations for Run of River Scheme**

| S. No. | Structure | No. of trial pits/ borehole | Location of trial pits | Depth of trial pits | Additional requirement |
|---|---|---|---|---|---|
| 1 | Diversion structure | | | | |
| | (i) conventional weir/trench weir/barrage | Trial pits 3 nos. | One trial pit at middle and two trial pits, on either abutment end. | 1.5 -2 m | Geological assessment of stability of rock slope on either abutment |
| | (ii) Low dam | Dril hole 3 nos. | One borehole at middle and one borehole at intake location. | Up to foundation level of dam | ---- |
| 2 | Water Conductor | | | | |
| | (i) Surface | Trial pits 3-5 nos. | Trial pits at every 500 m c/c and at critical locations. | 1.5-2 m | Geological assessment of stability of rock slopes along the alignment reach-wise. |
| | (ii) Tunnel | Dril hole 3 | Intake portal–1no. Outlet portal–1 no. | Up to | (1) Delineation |

| S. No. | Structure | No. of trial pits/ borehole | Location of trial pits | Depth of trial pits | Additional requirement |
|---|---|---|---|---|---|
| | | nos. | Low cover reach – 1 no. | tunnel grade | of shear zone<br>(2) Geological assessment along alignment<br>(3) Geophysical assessment |
| 3 | Forebay | Trial pits 2 nos. | One trial pit in forebay area and another trial pit at penstock intake location. | 1.5 – 2 m | Geological assessment of rock slope on hill side of forebay. |
| 4 | Penstock | Trial pits 2 nos. | Along the alignment of penstock preferably at anchor block locations. | 1.5 – 2 m | Geological assessment of penstock slope. |
| 5 | Powerhouse | Trial pits 1 no. | Powerhouse area | 1.5 – 2 m | Geological assessment of excavation slope. |
| 6 | Tailrace | Trial pits 1 no. | Along the alignment | 1.5 – 2 m | Geological assessment of excavation slope. |

**Table 5: Geological Field Investigations for canal falls based scheme**

| S. No. | Structure | No. of trial pits | Location of trial pits | Depth of trial pits | Additional requirement |
|---|---|---|---|---|---|
| 1 | Water Conductor | 4 | (1) At inlet – 1 no.<br>(2) Upstream of powerhouse - 1 no.<br>(3) Downstream of powerhouse – 1 no.<br>(4) At outlet – 1 no. | 1.5 -2 m | Geological assessment of stability of excavation slopes. |
| 2 | Powerhouse | 1 | Powerhouse area | 1.5-2 m | Geological assessment of excavation slopes and powerhouse foundation grade. |

**Table 6: Geological field investigations for existing dam/barrage based schemes**

| S. No. | Structure | No. of trial pits | Location of trial pits | Depth of trial pits | Additional requirement |
|---|---|---|---|---|---|
| 1 | Intake | Drilhole-1no. | Intake area | Up to foundation level of structure | Geological assessment of stability of excavation slopes. |
| 2 | Approach channel | 1no. | Approach channel location. | 1.5m to 2m | Geological assessment of the area. |
| 3 | Water conductor<br>(a) Open | Trial Pits-2-3no. | Along alignment | 1.5m to 2m | Geological assessment of stability of excavation slopes |
| | (b) Tunnel | drilhole-3no. | (1) Intake portal-1no.<br>(2) Outlet portal-1no.<br>(3) Low cover reach-1no. | Delineation of shear zones upto tunnel grade | Geological assessment along alignment. |
| 4 | Power house | Trial Pit-1no. | Powerhouse area | 1.5 to 2m | Geological assessment of stability of excavation slopes and powerhouse foundation grade. |
| 5 | Tailrace<br>(a) Open | Trial Pit-3 nos. | Along alignment | 1.5 to 2m | Geological assessment of excavation slopes. |
| | (b) Tunnel | Drilhole-3 nos. | At portal, along alignment and at low cover reach. | Upto tunnel grade | (1) Geological assessment along alignment.<br>(2) Delineation of shear zones. |

Subsurface Explorations are also required, if tunneling is involved. Generally for large hydro schemes this aspect is important but for small hydro schemes the need is rare. For small hydro projects, drilling and drifting gives a fare idea of subsurface geology.

Techniques of sampling and reporting on results of geological investigations are given in the Indian Standards IS 4453; IS 5529, IS 6929 and IS 7422.

## 6.0 HYDROLOGICAL INVESTIGATIONS

Acquiring reliable hydrological data for a reasonable length of time for assessing the pattern of stream flow at different times in representative years wet as well as dry, is the most essential requirement for a dependable formulation of hydro project. Besides the pattern of stream flows, other hydrologic inputs required for the design of project components are design flood, water quality and sediment transportation. The hydrological data cannot be acquired by just visiting the site and carrying out discharge measurements for a short while. It is necessary to acquire the long duration data.

It is necessary first to collect the minimum essential hydrological data and secondly, make analysis to establish a reliable flow quantity and other hydrological inputs.

### 6.1 Data Requirement

The following data are required for a hydro project.

- (a) Rainfall and snowfall
- (b) Climatological parameters like temperature, humidity, wind and cloudiness.
- (c) River gauges (level) and discharges.
- (d) Past flood discharges.
- (e) Sediment transportation load.
- (f) Water quality.

The rainfall, snowfall and other climatological data are available with the India Meteorological Department (IMD), Snow and Avalanche Study Establishment (SASE) and state revenue as well as agriculture departments. Most of the major rivers and their tributaries are being regularly gauged by the state governments and Central Water Commission (CWC). Such gauging includes water levels, discharges, flood discharges and sediment transportation. However such data is normally not available in respect of small hydro projects located on small streams which are often not gauged by any agency.

The streams across which small hydro schemes are proposed, lack in most cases any measured stream flow data. The entire catchment may not have even a single rain gauge station in many cases. In such situation, there is a need for establishing a gauging station near the proposed project site. The discharge measurements should preferably cover a minimum period of two lean seasons and one flood season.

### 6.2 Discharge Measuring Techniques

The discharge measuring methods in a stream or river are classified broadly as direct methods and indirect methods. The direct methods are (a) velocity-area method, (b) dilution method, (c) ultrasonic method and (d) electromagnetic method. The indirect methods are (a) use of structures such as notches, weirs and flumes (b) slope-area method and (c) stage discharge method.

Each method has its advantages and limitations and its choice is dependent on site conditions and the equipment as well as resources available to the gauging authority. The techniques are explained as follows:

### 6.2.1 Velocity area method (IS:1192/ISO:748)

In its simplest form, gauging by the velocity area method can be performed by measuring the area of river cross-section and the mean velocity of flow through it. The cross-sectional area is measured by means of soundings at a number of verticals on the cross-section, together with the measurement of the distance of these verticals from a reference point on the bank.

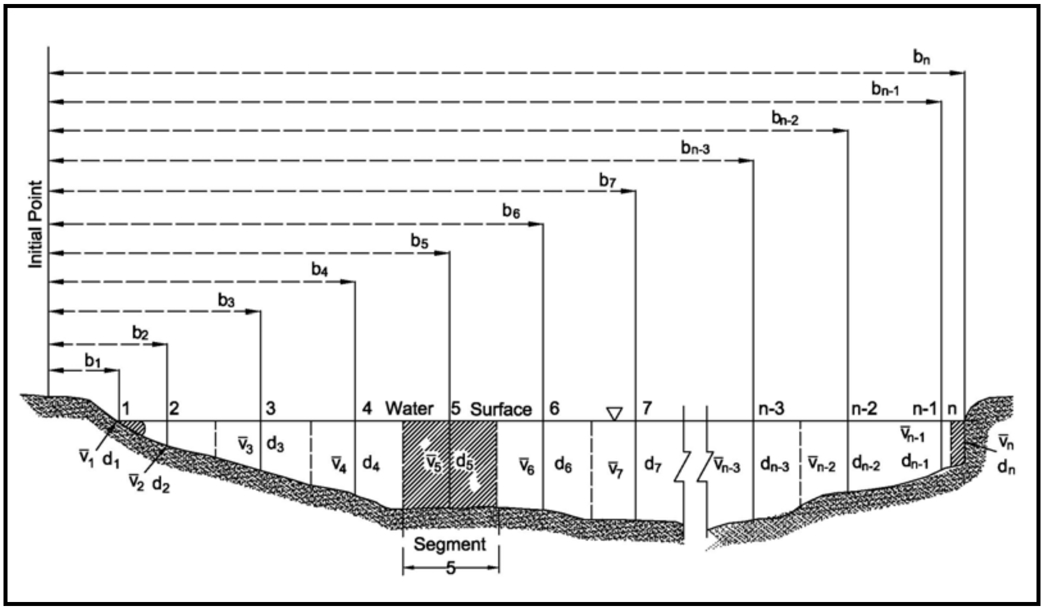



**Fig. 1: Typical cross section measurement of a river**

Fig. 1 shows the different verticals on a typical river cross section. The velocities can be measured usually by the current meter observations using any one of the following conventions:

- **One-point method:** In this, velocity is observed at a single point at 0.6 times of the depth from the surface.

  $$V = V_{0.6d}$$

- **Two-point method:** The velocity in this method is observed at two points at 0.2 and 0.8 of the depth from the surface and the average of the two readings is taken as the mean velocity at the vertical.

  $$V = (V_{0.2d} + V_{0.8d})/2$$

- **Three-point method:** The velocity is observed at three points at 0.2, 0.6 and 0.8 of the depth from the surface and average of the three readings is taken as mean velocity at the vertical.

  $$V = (V_{0.2d} + V_{0.6d} + V_{0.8d})/3$$

- **Five-point method:** The velocity is observed at five points at the surface, at 0.3, 0.6, 0.8 and at the bed surface of river and mean is calculated as follows:

$$V= (V_{surface}+3V_{0.2d}+3V_{0.6d}+2V_{0.8d}+V_{bedsurface})/10$$

- **Six-point method:** The velocity is observed at six points at the surface, at 0.2, 0.4 0.6,0.8 and at the bed surface of the river and the average velocity is calculated as follows:

$$V= (V_{surface}+2V_{0.2d}+2V_{0.4d}+2V_{0.6d}+2V_{0.8d}+V_{bedsurface})/10$$

Velocity may also be determined by floats or by measuring the slope of the flowing water, but it is generally accepted that the current meter has superiority in accuracy over other methods and its use is virtually universal. The other two mentioned methods still have a place in any broad river gauging programme or recourse to them may be necessary when the use of current meter is impracticable or where the need for accuracy is not so desired.

The accuracy of discharge measurement by the velocity-area method is better, if the conditions are as follows:

a) The channel is straight and its cross-section is well defined;
b) The conditions of flow do not change within the period of measurement;
c) The velocities at all points are parallel to one another and at right angles to the measuring cross-sections;
d) The velocity contours (iso-vels) are regular in the vertical and horizontal planes on which they are measured.

### 6.2.2 Dilution Method (IS:9163/ISO:9555-1)

In the dilution method, discharge is compacted by using a known quantity of concentrated chemical or dye solution in the stream and measuring its concentration. Chemical analysis or color comparison is used to determine the degree of dilution of the injected or mixed samples. Dilution method is a well established effective method of estimating the discharge for the rivers with boulders and non uniform siltation with rapids/steep slopes or when rivers are in extreme conditions of flood or draught. Hence this method of measurement becomes very useful for small streams and streams with lots of boulders, wood or other roughness elements.

There are two basic methods of dilution gauging:

1. Constant-rate injection method
2. Sudden injection method

In constant-rate injection method, a tracer with a known concentration ($C_1$) is injected at a known flow rate ($Q_T$) into the stream with concentration ($C_0$). When a sufficient mixing is achieved and an equilibrium concentration ($C_2$) exists downstream. Measure the stream concentration ($C_2$). Now, the stream flow (Q) is calculated as:

$$Q= (C_1 - C_2)\, Q_T/ (C_2 - C_0).$$

In the sudden injection method of dilution gauging, a quantity of tracer of volume (V1) and concentration (c1) is added to the river or stream, often by a simple, steady emptying of a flask of tracer solution, and at the sampling station downstream the passage of the entire tracer cloud is monitored to determine the relationship between concentration and time. The discharge is calculated from the following equation:

$$Q = V_1 * C_1 / \int_{t_1}^{t_2} (C_2 - C_0)\,dt ,$$

Where $C_2$ and $C_0$ are the concentrations of stream after and before mixing respectively.

The most commonly used tracers in this method are sodium chloride, Sodium dichromate, sodium nitrite Manganese sulphate and Fluorescein. The tracer must be neutral to sunlight and it should not contaminate the aquatic life.

### 6.2.3 Ultrasonic method (ISO 6416)

The ultrasonic technique, sometimes known as acoustic method of stream gauging is basically a velocity-area method, where the velocity at a known depth in river is measured by recording the time it takes for a beam of acoustic pulse to cross the river. It uses the principle that transit time of an acoustic signal along a known path is altered by the fluid velocity. The acoustic pulse is transmitted using a transducer. The transducers are located at the banks in such a way that the angle between the pulse path and the direction of flow is between 30° to 60°. It is necessary to stagger the transducers along the river bank so that there is a time difference between the pulses travelling downstream and those travelling upstream. The difference between the times of travel of the pulse in two different directions is directly related to the average velocity of the water at the depth of the transducer.

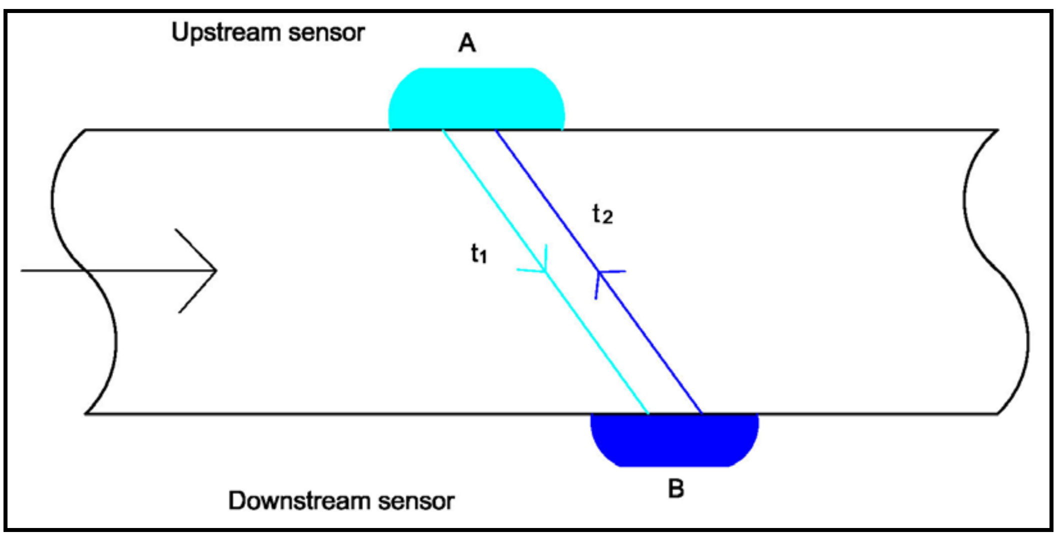



**Fig. 2: Ultrasonic method**

The average velocity of flow is calculated as:

$$V = \frac{L}{2\cos\theta}\left[\frac{1}{t_1} - \frac{1}{t_2}\right];$$

where L is the acoustic path length, $t_1$ and $t_2$ are the times of travel of pulse from A to B and B to A respectively and θ is the angle between the acoustic travel path and the river bank as shown in Fig. 2. The discharge can be calculated by multiplying the area of flow with the average velocity found from this method.

### 6.2.4 Electromagnetic method (ISO:9213)

This method is based on the Faraday's law of electromagnetic induction. The motion of water flowing in a stream cuts the vertical component of the earth's magnetic field and an electromotive force (e.m.f.) is induced in the water (refer Fig. 3). This e.m.f. can be sensed by electrodes at each side of the river and is directly proportional to the average velocity of flow in the cross-section. Since the e.m.f. produced by the earth's magnetic field is too small to be distinguished from other direct potentials due to electrical interference from ambience the measurable potential is therefore induced in the electrodes by burying a large coil beneath the river bed through which an electric current is passed. The coil may be placed above the open channel also.

The e.m.f. generated (E) is given by the following equation:

$$E = HVb$$

Where,

H is the Magnetic field in tests, V is the average velocity and b is the width of the river section.

The discharge can be computed by multiplying the average velocity with the area of river section.

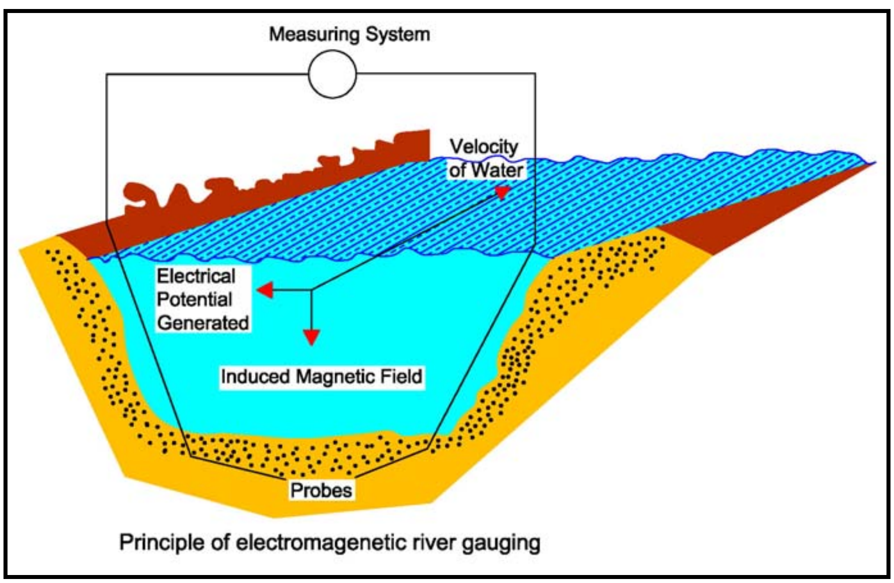



**Fig. 3: Electromagnetic method of discharge measurement**

### 6.2.5 Acoustic Doppler method (ISO/TR 24578:2012)

ADCP works on the principle of Doppler shift in frequency. It uses a transducer, which emits sound waves and receives its echoes from the suspended particles carried by the water stream and also from the banks and bed of the channel (Ref. Fig. 4). Doppler shift is the difference in frequency of the acoustic beam (sound wave) emitted by the transducer, and that of the beam received back by it. When the sound-reflecting particle moves away from the transducer, the sound it hears is Doppler shifted to a lower frequency proportional to the relative velocity between the transducer and the particle, and vice-versa when the particle moves towards the transducer. Since Doppler shift occurs twice during the forward and backward movement of the sound wave, the Doppler shift in the frequency is doubled, and is expressed as

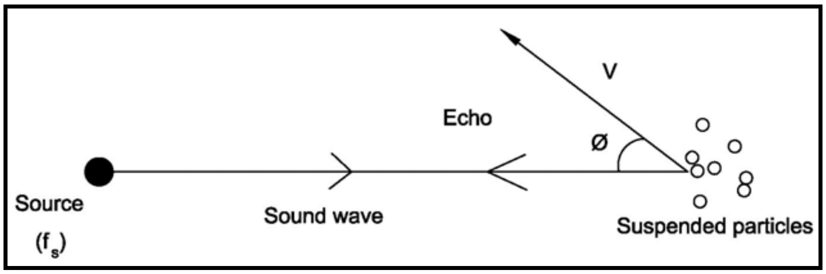



**Fig. 4: Illustration of the Doppler Shift Phenomenon**

$$f_d = 2f_s\,(v/c)$$

where,

$f_d$ is the total Doppler shift in frequency in Hz;
$f_s$ is the frequency of sound wave transmitted from stationary source in Hz;
v is the relative velocity between sound source and suspended particles in m/s; and,
c is the speed of sound in still water in m/s

The Doppler shift in frequency is caused by the radial velocity component of the suspended particles. Hence, the Doppler shift observed by ADCP resulting from the radial component of particle velocity can be given as

$$f_d = 2f_s\,(v/c)\cos\phi$$

where,

$\phi$ is the angle between the velocity vector and the line between the ADCP and suspended particles in water as shown in Fig. 1.

ADCPs can be classified into two categories depending on their beam orientation: horizontal-beam ADCP (H-ADCP); and, vertical-beam ADCP (V-ADCP).

### 6.2.6 Flow measuring structures: Notches, weirs and lumes (IS 12752, 13083, 14673, 14974, 15353, 14869, 6330 and 9108/ISO 3847, 1438-1, 8368, 4377, 4360, 4359, 8333)

The weir is one of the oldest structures used to measure the flow of water in open channels. A measuring weir is simply an overflow structure built perpendicular to an open channel axis to measure the discharge. A weir of a given shape (triangular, rectangular and trapezoidal) has a unique depth of water at the measuring station in the upstream for each discharge. The measuring structure should be rigid and placed at right angles to the direction of flow and should be installed in a stable and rigid section. A weir discharge measurement consists of measuring depth or head relative to the crest at the location 3–5 times of depth of water upstream, and then using a table or equation for the specific type weir to determine discharge. Fig. 5, 6 and 7 show triangular weir, rectangular weir and trapezoidal weir respectively.

For Triangular weir, $Q = \frac{15}{8}\sqrt{2g}\, C_d \tan\frac{\theta}{2} h^{5/2}$

where,

$C_d = 0.585$

For rectangular weir, $Q = \frac{15}{8}\sqrt{2g}\, C_d\, L h_e^{3/2}$

where,

$C_d = 0.6035 + 0.813\ h/P$

$h_e = h + 0.0012$ m

For Trapezoidal weir, $Q = 1.9 b\sqrt{h}$

For broad crested Weir, $Q = 1.71 b\sqrt{h}$

For sharp crested weir, $Q = 2.1 b\sqrt{h}$

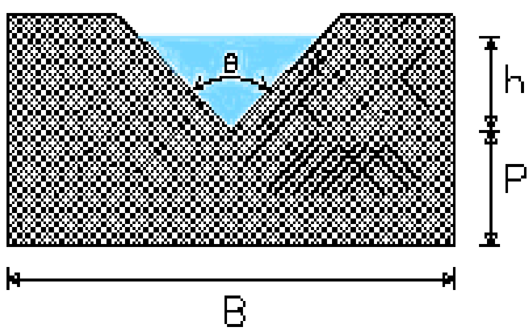



**Fig. 5: Triangular Weir**

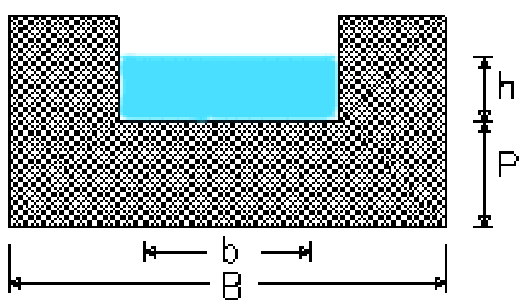



**Fig. 6: Rectangular Weir**

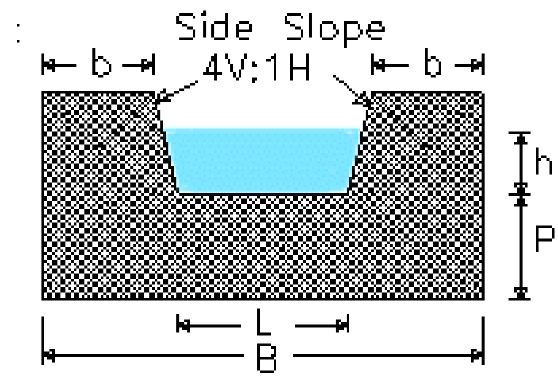



**Fig. 7: Trapezoidal Weir**

Broad-crested weirs also are used for flow measurement. These have a foundation or base which is relatively long in the direction of flow. A weir in the form of a relatively long raised channel control crest section is a broad-crested weir. The flow control section can have different shapes, such as rectangular, triangular or circular.

### 6.2.7 Slope area method (IS:2912 / ISO:1070)

In the slope area method, discharge is computed on the basis of uniform flow equation involving channel characteristics, water surface profiles and a roughness coefficient. It is suitable for use under special conditions when direct measurement of discharge by more accurate methods, such as the velocity-area method, is not possible. The slope-area method can be used with reasonable accuracy in stream having stable boundaries, bed and sides, in lined channels and in channels with relatively coarse material. This method is not suitable for use in streams very large channels, channels with very flat surface slopes and high sediment load or channels having significant curvature. In application of slope-area method, following Manning's equation is used.

$$Q = 1/n\ (AR^{2/3}S^{1/2}),$$

Where,

'n' is the Manning's coefficient, 'A' is the area of flow, 'R' is the hydraulic radius and 's' is the bed slope.

A measuring reach is chosen for which the mean area of the stream or river cross-section is determined and the surface slope of the flowing water in that reach is measured. The mean velocity is then established by using known empirical formula which relates the velocity to the hydraulic mean depth, and the surface slope is corrected for the kinetic energy of the flowing water and the characteristics of the bed and bed material. The discharge is computed as the product of the mean velocity and the mean area of the stream cross-section.

### 6.2.8 Stage discharge method (IS: 15119, 2914/ISO: 1100-2)

Discharge measurement by velocity-area method can also be achieved by producing a continuous measurement of a stage-discharge relation which correlates discharge to either the water level at a single section of the channel or to the water levels at each end of reach. In the former case a single-gauge station is employed but in the latter a twin-gauge station is necessary and a different procedure for establishing the stage discharge relation is used

The stage-discharge relation is determined from field measurements of stages and corresponding discharges and the calibration so established holds good only so long as no significant alteration takes place in characteristics of the reach. For design the weir/barrage the stage discharge curve is to be developed.

### 6.2.9 Discharge measuring instruments

Various instruments used in hydrometry may be listed as follows and some of them are shown in Fig. 8:

1. Gauges (Staff , needle, wire-weight, float) (IS: 4080)
2. Recorders (IS: 9116)
3. Floats (IS: 3911)
4. Current meters (IS: 3910, 3918, 13371)
5. Electromagnetic current meter (ISO: 9213)
6. Ultrasonic (acoustic) velocity meter (ISO: 6416)

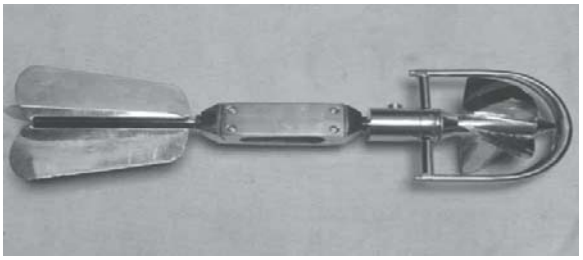
Gauges are the instruments of various types which give the stage readings in the units of length. A staff gauge is a graduated scale anchored in the water and read by observing the level of the water surface in contact with it. The gauge should be placed so that the water level can be read from the bank. Water-stage recorders consist of a group of instruments that produce a record of water surface elevation with respect to time. The output of recorders may be analogue or digital.

The float can be any buoyant object. It needs to be heavy enough so that its sufficient depth is below the water line. A float measures surface velocity hence mean velocity is obtained using a suitable correction factor (0.8 to 0.9).

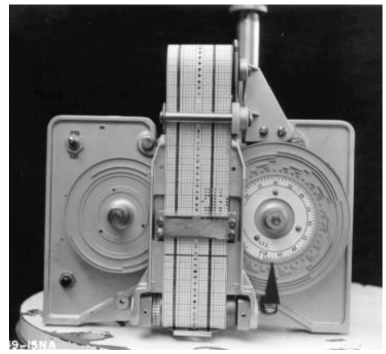
Current meters may be cup-type or propeller-type. A cup-type instrument with a vertical axis has the vanes to keep the front of the meter headed into the current, a rod for holding the meter, weights for sinking the meter when it is suspended on a cable, an electric device for signaling and/or counting the number of revolutions. A propeller type is a horizontal axis current meter. These meters have some advantages compared to the cup-type meters. They are less sensitive to velocity components not parallel to the meter axis. They are smaller and more suited for mounting in multiple units.

Electromagnetic current meters produce voltage proportional to the velocity. These current meters can also measure cross flow and are directional. Electromagnetic current meters, while still not as reliable as the anemometer type, have improved greatly in recent years.

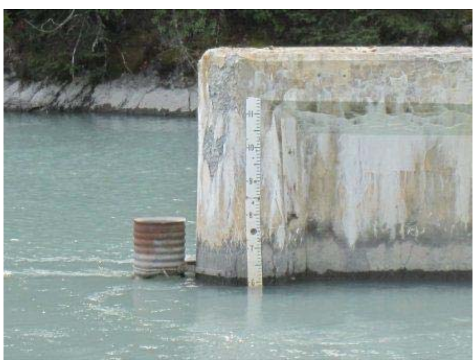
An acoustic flow meter is a non-mechanical, non-intrusive device which is capable of measuring discharge in open channels or pipes. These flow meters can provide continuous and reliable records of flow rates over a wide range of conditions including flow in both directions.



**Propeller current meter** **Cup-type current meter**

**Electromagnetic current meter** **Digital recorder**



**Staff gauge** **Wire-weight gauge**

**Fig. 8: Discharge Measuring Instruments**

## 6.3 Design Flood Level

Design flood levels are computed for the intake and power house sites for providing necessary protection work. Design flood is computed based on the guideline 1.3: project hydrology and installed capacity.

## 6.4 Sedimentation

The generation unit may suffer due to damage of underwater components on account of highly erosive action of incoming silt. Besides damaging runners and guide vanes, the erosive action of silt causes operation and maintenance problems.

The small diversion structure without storage, divert silt laden water into the water conductor. Some of the silt would get removed through trash racks and desilting arrangement provided before the fore bay. A desilting chamber is generally constructed to minimize the silt load. Samples should be taken for incoming silt to find out the sediment size/and sediment concentration required for design of barrage/weir and desilting tank.

## 7.0 CONSTRUCTION MATERIAL SURVEY

Concrete coarse and fine aggregates and possibly fill materials will be needed for construction of a hydropower plant. Coarse aggregates are usually derived from river boulders, cobbles or from a quarry site. Availability of required quantity and quality of construction material like aggregate, boulders, sand for construction works and its location shall be surveyed in project area or nearby area. For stones, suitable quarry and for fine aggregates suitable river stretch is to be identified. Material testing laboratory shall be required for testing the quality of material which may have to be established or samples may be sent for testing to some nearby reliable laboratory. Location (quarry) of good quality coarse aggregates as well as fine aggregate, stones, wood etc. be identified in the nearby area. Suitable query sources / stores for procuring manufactured items such as bricks, cement, steel and Gelatins etc. need to be assessed for procurement.

Part of site geotechnical investigation is to evaluate the suitability of these materials for concrete and embankment construction. A geological assessment of the type of rock material and its soundness by the engineering geologist is usually sufficient for small hydro projects. This opinion can be further supported by examination of structures that may have been built in the area using the same source materials. Two basic tests are recommended nonetheless:

(i) A "quick" test to assess the possibility of alkali aggregate reactivity (AAR) of proposed aggregates and project cement.
(ii) Sieve analyses to establish the gradation of fine aggregate and percentage of objectionable fines.

For larger stations a fuller range of tests should be considered to evaluate the following coarse aggregate properties.

(i) Specific gravity and absorption
(ii) Abrasion
(iii) Soundness

In special cases other tests may be recommended depending on the finding of initial tests.

Guidelines on the performance of these tests are given in the IS 2386 (Part III); IS 2386 (Part IV); IS 2386 (Part V) and IS 2386 (Part VII).

## 8.0 SURVEY FOR LOAD DEMAND AND POWER EVACUATION

### 8.1 Electrical Load Survey

Electric load survey will establish the demand that is needed, and what form is needed (mechanical effort, heat, or electricity?). Further a genuine willingness and ability to pay for the proposed new supply is to be established.

A biased opinion of energy demand reflecting the interests of only one group of villagers should be avoided. Often the most senior person in a household or village given his views, but his aspirations or needs may be different to those of his family members. Interviews must be conducted with all types and sectors of people.

For isolated SHP projects, electrical load survey of nearby villages up to 4 to 10 km distance from the location of proposed SHP station is required to assess the load requirement for planning the installed capacity. The following factors may be considered during the electrical load survey.

- (iv) Number of villages.
- (v) No. of houses holds
- (vi) Population.
- (vii) No. of projected connections.
- (viii) Average daily energy consumptions.
- (ix) Demand for street lighting.
- (x) No. of commercial establishment (shops, business activity) and energy demand for each establishment.
- (xi) No. of schools, health centers and other community services and their energy demand.
- (xii) No. of small industries with energy requirement for each.
- (xiii) Miscellaneous demand.
- (xiv) Current and projected demand for electrical energy of various types of consumption.

Following energy consumption and growth criteria may be considered.

### 8.1.1 Domestic

| | | |
|---|---|---|
| Average consumption | : | Minimum 30 kWh per month per consumer |
| Growth rate | : | (i) 10% the total household as new consumers per year<br>(ii) 5% per annum increase in consumption |

### 8.1.2 Street Lights

| | | |
|---|---|---|
| Average consumption | : | 150 kWh per annum per light point |
| Growth rate | : | 5% per annum increase in consumption |

### 8.1.3 Commercial

| | | |
|---|---|---|
| Average consumption | : | Minimum 30 kWh per month per consumer |
| Growth rate | : | (i) 2 consumer per year<br>(ii) 5% per annum increase in consumption |

### 8.1.4 Public Institutions

| | | |
|---|---|---|
| Average consumption | : | Minimum 100 kWh per month per consumer |
| Growth rate | : | 5% per annum increase in consumption |

#### 8.1..5 Industry

| | | |
|---|---|---|
| Average consumption | : | 500 kWh per month per industry |
| Growth rate | : | 1 consumer per year |

#### 8.1.6 Miscellaneous

| | | |
|---|---|---|
| First year | : | 10000 kWh per year or so |
| Growth rate | : | 10% per annum increase in consumption |

Based on above assumptions, load for first year can be estimated and increased for subsequent years up to 10$^{th}$ year. The transmission and distribution losses may be taken as 10% of the total consumptions to arrive at the installed capacity.

A topographical plan map showing route of transmission / distribution line from the power house to near by villages for supply of power need to be surveyed.

### 8.2 Grid connected Projects

The following surveys shall be carried out:

(i) Present position of power supply in the region, system loads. Details of major loads to be served, energy demand etc.
(ii) A plan showing route of transmission line for evacuation of power.
(iii) Study of near by grid substation where power is likely to be fed. The study shall cover the carrying capacity of sub-station and transmission line and also probability of expansive on account of the additional power that will be available from the project under which such study is being carried out.

## 9.0 ENVIRONMENTAL ASPECTS

A careful evaluation of impact of proposed scheme on the environment shall be carried out and necessary measures to be planned well in advance to mitigate the adverse effect. Following surveys would be required.

(i) Area to be used for project construction, staff colony and resettlement of local population.
(ii) Area of submergence.
(iii) Details of families likely to be displaced, and scheme of their rehabilitation.
(iv) Social/ cultural/religious consideration.
(v) Loss of any important mineral resources, if so, it's magnitude and estimated loss.
(vi) Loss of any monument/site of cultural, historical, religious or archaeological importance which fall in project area, its plan of relocation.
(vii) Any rare endangered species of flora and fauna in the project area and measures to salvage/rehabilitate them.
(viii) Wild life, if affected.
(ix) Potential loss to aquatic life such as fish, impact to their migratory behavior.
(x) Expected loss to trees and to make up the loss, identification of land for plantation.

(xi) Arrangement to meet fuel requirement of labour force during construction and afterwards.
(xii) Arrangement for restoration of land in construction area.

## 10.0 SOCIO-ECONOMIC SURVEYS

The following surveys will be carried out:

(i) Area of land required for physical components of project.
(ii) type of land i.e. agricultural, residential, details of crop, vegetation etc.
(iii) Ownership of land i.e. government, private, traditional population, encumbrances details etc.
(iv) Current land use in proposed area and surroundings.
(v) Possible land use change expected after project implementation.
(vi) Possible strategy for procurement of land i.e. government lease, direct purchase, negotiated settlement or compulsory acquisition etc., Detailed description of area falling under each category
(vii) Details of families affected( details as necessary)
 (a) Including those loosing home and livelihood.
 (b) Those deriving benefits (employment, electricity etc) from the project.
 (c) Those adversely affected by imposition of an external population on local cultures (i.e. women, tribals)
(viii) Assessment of positive and negative impact.
(ix) Assessment of cultural impact on population due to land acquisition for project.
(x) Assessment of need for rehabilitation and resettlement implementation.
(xi) Study of national and state legal frame work existing, the relevant provisions and applicability for the specific case as identified above.
(xii) Entitlement calculations for payment of compensation for various losses or replacement values.
(xiii) Existing and proposed mechanisms/ efforts for public consultations and disclosures of information/ statutory requirement, if any for above.
(ix) Expected public participation during the project implementation.
(xv) Grievances redressal mechanism legally available as well as socially acceptable.
(xvi) Remedies available through Lok Adalats, Village Pachayats, NGO's etc.
(xvii) Manpower locally available.

## 10.0 ACCESS TO THE DIFFERENT COMPONENT OF SCHEME

On the topographic plan, layout of existing roads shall be marked. The requirement of the new approach roads, bridges, culverts, shall be assessed for smooth construction work and later on maintenance of works and marked on the topographic plan.

## 12.0 INFRASTRUCTURAL FACILITIES

The detailed survey for the following infrastructural facilities be made and the locations are marked on the plan map as per project requirement.

(i) Access roads to the project and in the project area
(ii) Construction power requirement
(iii) Power supply facilities
(iv) Telecommunication facilities required during the construction and after completion of the project
(v) Colonies / residential buildings for the project staff
(vi) Workshop
(vii) Drinking water facilities
(viii) Drainage around the power house
(ix) Sewage and sanitation
(x) Other facilities as required

## 13.0 MUCK DISPOSAL

The quantities of muck to be generated during construction of various components of the project need to be estimated. Some quantities of usable muck will be used for various construction activities/ earth filling in the project area. The unused muck need to be disposed off at barren land which can be used as muck disposal area. The muck disposal area may be supported by constructing the toe walls to prevent muck entry to the river, wherever required. Muck disposal areas of suitable size should be shown on the general layout plan of the project and use of these locations is to be authorized by state forest department and or land owners.