2.3 Design of Hydrometeorological Data Networks

Data on temporal and spatial characteristics of water resources of a region are obtained by a network of observational stations. Setting up a station requires investment for infrastructure equipment, logistics, and for operation and maintenance. Scientific planning is necessary for network design so that the desired results could be achieved with minimum cost.

Since the requirement of water resources data depends on their end use, it is difficult to formulate general rules on network design. While designing hydrologic networks, the decisions to be taken are:

i. the variables to be measured and the frequencies and duration of observations;
ii. the location of gauging stations;
iii. the instruments to be installed and methods of observation; and
iv. data observation and transmission system.

Since the hydrometeorological data networks are operated by a number of independent agencies, a good coordination among them is important. This will reduce the expenditure and improve data quality. Of particular importance is the coordination between hydromet, water quantity and quality data networks.

2.3.1 Classification of Observation Networks

Hydro-meteorological observation networks can be classified in many different ways. Based on spatial features, there are two types of networks:

a) areal networks, such as those for precipitation, and ground water levels, and
b) linear networks such as those for streamflow and river sediment.

Areal networks are established to get spatial characteristic of the variables over an area while the linear networks are created for rivers, canals, etc. On the basis of purpose, the networks can be classified in three categories: basic (to get the fundamental characteristics of the variables of interest), specific (to gather data for some specific purpose, e.g., a reservoir project), and temporary (which are in operation for a short period of time).

Another criterion for classification of hydro-meteorological networks could be the purpose for which the network is established. The purpose of a basic network is to provide a level of hydrological information at any location within its region of applicability that would preclude any gross mistake in water resources decision making (WMO, 1994). In the early stages of development of a network, the first step should be to set up a minimum network. Such a network should consist of the minimum number of stations required to initiate planning for utilization of water resources management in the region.
Depending on the purpose, the hydrological observation station could be classified into three types:

1) Primary stations: These are also termed as key gauging stations, principal stations or benchmark stations and are maintained on long term basis to generate representative flow series of the river system.

2) Secondary stations: These are essentially short duration stations which are operated only for short time period to establish the flow characteristics of the river.

3) Special purpose stations: These are also termed as specific purpose stations or project stations or temporary stations meant for projects and are discontinued when the purpose is served. The purpose could vary from design, management and operation of the project to monitoring and fulfillment of legal agreement between co-basin states. Many a times, the primary as well as the secondary stations also serve as special purpose stations.

The *Guide to Hydrological Practices* (2008) published by World Meteorological Organization (www.wmo.ch) contains useful guidelines to set up networks for various types of data, and observe and analyze the data. Bureau of Indian Standards (www.bis.org) have also published various standards for Indian conditions.

### 2.4 Precipitation Networks

The optimum density of a precipitation gauge network depends on the purpose for which the data are to be used. For example, measurements of precipitation for flood forecasting require denser networks as compared to that for rainfall-runoff modeling. WMO (2008) has recommended the following (Table 2.1) as minimum network densities for precipitation stations.

<table>
<thead>
<tr>
<th>Physiographic unit</th>
<th>Precipitation Non-recording</th>
<th>Precipitation Recording</th>
<th>Evaporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>900</td>
<td>9000</td>
<td>50000</td>
</tr>
<tr>
<td>Mountains</td>
<td>250</td>
<td>2500</td>
<td>50000</td>
</tr>
<tr>
<td>Interior plains</td>
<td>575</td>
<td>5750</td>
<td>5000</td>
</tr>
<tr>
<td>Hilly/undulating</td>
<td>575</td>
<td>5750</td>
<td>50000</td>
</tr>
<tr>
<td>Small islands</td>
<td>25</td>
<td>250</td>
<td>50000</td>
</tr>
<tr>
<td>Urban areas</td>
<td>-</td>
<td>10–20</td>
<td>-</td>
</tr>
<tr>
<td>Polar/arid</td>
<td>10000</td>
<td>100000</td>
<td>100000</td>
</tr>
</tbody>
</table>

The optimum network should make it possible to derive required information with desired accuracy. The optimum number of rain gauge stations (N) in a network is given by (BIS 1968):
\[ N = \left[ \frac{C_v}{p} \right]^2 \]  

where \( C_v \) = the coefficient of variation of the precipitation values of the existing rain gauge stations, and \( p \) = the allowable maximum percentage error in the estimate of basin mean rainfall. A typical value of \( p \) is 10 percent. Here, \( C_v \) is computed by

\[ C_v = \frac{100 \times s}{P_m} \]  

In which \( s \) is the standard deviation and \( P_m \) is the mean rainfall of the existing stations. Obviously, a decrease in the percentage error would mean an increase in the number of gauges required. Mukherjee and Kaur (1987) have proposed a modified form of eq. (2.1) by including the mean correlation (\( r \)) of precipitation over the area

\[ N = \left[ \frac{C_v}{p} \right]^2 (1 - r) \]  

WMO recommends that the precipitation (amount and form) should be measured with an accuracy of 3–7\% and rainfall intensity with 1 mm/hr at the 95 per cent confidence interval. Snow depth below 20 cm should be accuracy of less than 1 cm and depth above 20 cm should not have more than 10\% error. The recommended accuracy for evaporation range 2–5\% and for wind speed 0.5 m/sec.

**Example 2.1**: A catchment has 6 rain gauges and the annual rainfall at these has been measured as 750, 540, 465, 493, 421, and 780 mm. Find out the optimum number of rain gauges for the basin if the error of estimation is required to be kept below 10\%.

**Solution**: For the data given, mean = 574.83 mm and standard deviation = 152.59 mm. Thus

\[ C_v = \frac{100 \times 152.59}{574.83} = 26.54 \]

Hence, using eq. (2.1), the optimum number of rain gauges for the basin (\( N \)) is

\[ N = (26.54/10)^2 = 7.04 \]

This means that 7 rain gauge stations are required in the basin and the existing network of 6 rain gauges is slightly inadequate. It needs to be strengthened by adding one new gauge so that the estimate of rainfall depth has stipulated accuracy.

**2.5 Stream Gauging Networks**

A network of stream gauging stations is established in a river basin to provide data required by the hydrologists for planning, development and management of water resources of the basin. The collected data also enables to estimate the principal characteristics of the hydrological regime of
the basin.

Every major stream should be gauged near its mouth and its major tributaries should also be gauged as feasible. Naturally, gauging depends on the existing and likely development in the basin. According to WMO, the first gauging station is selected at the most upstream location where the drainage area is about 1300 km$^2$. The second station is located at a point in the downstream direction where the drainage area is approximately doubled. The WMO recommendations for a minimum density of stream gauging stations are given in Table 2.2.

Table 2.2 Recommended minimum densities of stations (area in km$^2$ per station) [Source: WMO (2008)].

<table>
<thead>
<tr>
<th>Physiographic unit</th>
<th>Streamflow</th>
<th>Sediments</th>
<th>Water quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>2750</td>
<td>18300</td>
<td>55000</td>
</tr>
<tr>
<td>Mountains</td>
<td>1000</td>
<td>6700</td>
<td>20000</td>
</tr>
<tr>
<td>Interior plains</td>
<td>1875</td>
<td>12500</td>
<td>37500</td>
</tr>
<tr>
<td>Hilly/undulating</td>
<td>1875</td>
<td>12500</td>
<td>47500</td>
</tr>
<tr>
<td>Small islands</td>
<td>300</td>
<td>2000</td>
<td>6000</td>
</tr>
<tr>
<td>Urban areas</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Polar/arid</td>
<td>20000</td>
<td>200000</td>
<td>200000</td>
</tr>
</tbody>
</table>

Stations are also established in the basin at the sites where significant changes in the volume of flow are noticed, for example downstream of the confluence of a major tributary or at the outflow point of a lake etc. In case a suitable location is not available downstream of the confluence, the sites can be located upstream of the confluence, preferably on the tributary. While establishing sites at the downstream of confluence, it should be ensured that no other small stream joins the main river before the station so that correct assessment of the contribution of the tributary to the main river is obtained.

The distance between two consequent stations on the same river may vary from about 50 km to several hundred kilometers, depending on many factors. The drainage area computed from origin up to two consecutive observation sites on a large river should preferably differ by more than ten percent so that the difference in quantities of flow at the two stations is significant. Sometimes stations are set up due to hydrological significance, say, to determine the flow contribution from a typical catchment.

A different approach is recommended for small independent rivers which flow directly into the sea (for example, the rivers in Western Ghats). In such cases, the first hydrological observation station is to be established on a stream that is typical of the region and further stations are added to the network to cover the area and obtain information about the variability. Stream in the area whose flows are low should not be avoided from the network. Absence of
stations from low flow streams may lead to wrong assessment of the surface water potential of the area if it has been evaluated just on the basis of the data from the high flow streams. Thus, great care is to be exercised to ensure that all distinct hydrological features are adequately covered by the gauging network.

An existing gauging network needs periodic review. The developments that take place in the basin like construction of new water resources development projects may warrant addition or closure of the sites. Often the rivers are polluted by the discharge of affluents from industries. A need may also arise to establish stations to monitor the quality of water in the river.

Regarding the accuracy desired in measuring river water depth and discharge, WMO recommends that the water depth measurement should have accuracy of about 2%, velocity of flow 2–5%, and discharge about 5%. Suspended sediment concentration should be estimated with accuracy of 10%.

2.5.1 Network Design Process
Design of networks is not a one-time affair. Factors affecting network design go on evolving with time and thus the networks also require periodic review and adjustments. Design of networks to measure stream gauge and discharge involves the following steps:

1. Network design begins with collection of maps and background information about the area/region. Usually 1:250,000 scale topographical maps of the river basin showing basin boundaries will form the base map for the network design. Smaller scale maps are of limited use because it is difficult to identify the location of stations relative to key features. It is also important to use an updated map. Ideally, the following maps should also be collected:
   i. Existing precipitation and gauge-discharge gauging stations operated by various departments.
   ii. Location of existing and proposed water projects and command areas of irrigation projects.
   iii. Land use map, also showing forests, main industries and population centres.
   iv. Communications map showing roads, rails, power transmission lines, canals, etc.
   v. Map showing soil classification, geological formation and mining areas.
2. Define the objectives of the network: who will be the data users and what will the use of data? What is the required frequency?
3. Evaluate the existing network and find out how well it meets the objectives?
4. Review existing database to identify gaps, ascertain variability in catchment behaviour.
5. Identify gaps and over-design (if any) in the existing network; new stations may be proposed and existing stations deleted shifted.
6. Prioritise stations by following appropriate classification system.
7. Estimate average capital and recurrent costs of installing and maintaining different categories of stations and overall cost of operating and maintaining the network.
8. Decide on approximate location of sites and carryout site surveys.
9. Review revised network in relation to overall objectives and available budget; adjust it as necessary.

10. Prepare a realistic implementation plan which is achievable.

These steps and related topics are further elaborated in the following sections.

2.5.2 Criteria for Location of Stations
With particular reference to India, location of stream gauging stations is influenced by the following factors:

- Places where major rivers cross State borders;
- Locations of proposed dams/diversion/run-of-river schemes including diversions or off-takes/joining points for (proposed) inter-basin water transfers link canals;
- Locations whose data may be needed for flood forecasting;
- Conservation areas and areas of ecological interest;
- Areas of water supply shortages;
- Areas expected to have significant land use change, e.g., de-forestation or re-forestation;

2.5.3 Evaluation and Adequacy of Networks
To evaluate the networks, the existing network and proposed new stations should be marked on a 1:250,000 map. The catchment area for each river gauging station could be estimated from the basin maps (hard copy or in GIS). Scanning the network systematically, the following questions need to be considered for each station:

- What purpose will the station fulfill?
- Does a better location exist nearby?
- Have any developments (e.g. dam construction) taken place or are likely which could affect this station?
- How close are the nearest upstream and downstream gauging stations? Two stations should not be very close unless there are specific reasons.
- Does any other organisation operate a gauging station in the vicinity? If yes, could the data from that station serve the purpose expected from this station?

Based on the answers, stations which can be added, deleted or relocated are identified.

Financial Aspects
In addition to technical financial considerations are also important in network design because the stations cannot be established without adequate money, equipment cannot be purchased and operated, and staff cannot be hired. Hence, after the preliminary design of the network has been completed, the expenditure to establish stations and the cost of operating them should be estimated. These monetary requirements should match with the budget so that the proposed
network is sustainable. In case of deficit in the budget, the network should be re-aligned or additional budget should be arranged. Stations in the network may be prioritized to best attain the objectives, given the constraints. Table 2.3 gives a possible categorization of stations based on their relative importance.

Table 2.3: A possible categorization of stations based on their relative importance

<table>
<thead>
<tr>
<th>Category</th>
<th>Priority</th>
<th>Relative Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>High</td>
<td>Sites of major water resources project(s): existing or proposed; important rivers crossing state boundary, large basins that are still ungauged, heavily polluted river.</td>
</tr>
<tr>
<td>B</td>
<td>Medium</td>
<td>Sites of medium scale water resources projects: existing or proposed, medium size river crossing state boundary, operation of a medium project, area with (potential) water quality problems. All of these with an existing gauging site at some distance away.</td>
</tr>
<tr>
<td>C</td>
<td>Low</td>
<td>Minor irrigation project site, gauging station on small tributary, major river but with nearby gauging sites.</td>
</tr>
</tbody>
</table>

Prior to removing/shifting an existing station in the network, the main users and beneficiaries of the data should be consulted.

2.5.4 Site Selection Surveys

Once the objectives have been defined and the techniques for measurement/recoding water level and flow measurement have been finalized, the site selection process can begin. To select the most appropriate site for a station, site selection surveys are carried out. These surveys can be divided into four distinct phases:

1. Desk study,
2. Reconnaissance surveys,
3. Topographic surveys, and other surveys.

By now, the target location for the gauging station will have already been identified on a 1:250,000 or similar map in earlier steps. However, 1:250,000 is too small a scale for final site selection purposes. Large-scale topographic maps (1:50,000) should be checked to identify possible sites within the target zone. Reconnaissance surveys should be undertaken by an experienced hydrologist along with a person familiar with the area. As the hydraulic conditions and river characteristics vary considerably from non-monsoon to monsoon season, reconnaissance survey in both the seasons would facilitate correct decision on the suitability of the site. When the establishment of site cannot wait that long, the suitability of the site for hydrological observation could be decided after single inspection assisted by toposheet studies and other relevant field investigations including measurements of width and depth.
At sites of interest, ownership of the land and approach should be ascertained. The site shall be accessible in all seasons and all weather. It is important to use updated maps since most surveys were completed several decades ago and things may have undergone large changes. Recent situation can be obtained from remote sensing images or internet sites such as Google Earth.

Information on the historical high flood level should also be collected (by local enquiry and/or by examining the available landmarks) during the inspection. An all weather accessible site located in a straight uniform reach free from weeds, rock outcrop, pools and back water effect with stable non-overflowing banks with flow confined to single channel normal to the selected cross-section of measurement would be an ideal site for stream gauging.

On completion of the reconnaissance surveys, one or more locations are shortlisted for further consideration. After this, field surveys are carried out and the cross-section of the proposed site is surveyed. If artificial controls (e.g. a weir) are planned, it will be necessary to survey the river for some distance upstream and downstream to ascertain the impact on flows and water levels. It will also be important to understand what type of control exists and to make sure that the location will not be impacted by variable backwater effect of any structure.

2.5.5 General site selection guidelines

The following are the general site selection guidelines. Specific recommendations for different types of stations are mentioned subsequently. It is emphasized that an ideal location which satisfies all requirements can be found in very few real-life cases. In practice, it is often required to take measurements in non-ideal conditions.

1) The approach channel should be of uniform cross-section and free from irregularities and the flow shall have a regular velocity distribution. This can most readily be provided by having a long, straight approach channel. There should be straight, uniform, well defined approach channel upstream of the measuring section to ensure parallel and non-turbulent flow. For rivers less than 100 m wide, a straight approach of 4 times channel width should be preferred. For rivers more than 100 m wide, a straight approach channel of minimum 400 m is desirable. When adequate length of straight channel is not present, the straight length upstream should be at least twice that downstream.

2) Sites where high sediment deposition or scouring occurs or those which are subject to weed growth should be avoided, if possible.

3) Locations which are subject to high turbulence or wind effects should be avoided.

4) It needs to be ensured that there is no parallel by-pass channel, natural or man-made, on the surface or sub-surface, around the station.

5) The channel bed should be solid, relatively smooth and free from obstructions and debris.

6) The control shall be sensitive, such that a significant change in discharge, even for the lowest discharges, should result in a significant change in stage. Small errors in stage
readings during calibration at a non-sensitive station can result in large errors in the discharges indicated by the stage-discharge relationship.

7) The station should be located where the flood plain is at its narrowest and the out-of-bank flood flow is the minimum. It is often not possible to locate a gauging station so that all flood flows are contained within the river channel. At many locations, there is an elevation after which out-of-bank flow occurs.

8) The banks of the river should be high and steep and free from larger vegetation. Some vegetation is desirable since this helps maintain the stability of the banks.

9) River banks at the site should be well-defined, stable, and free from vegetation and other obstructions.

10) Downstream conditions should preferably be stable. Sites, which are influenced by downstream confluences with other rivers, river control structures, dams, tidal conditions or heavy weed growth, should be avoided. Such downstream conditions should be taken into account when designing the structure to assess the modular limit.

11) Factors such as unhindered access to the site in all seasons, availability of office accommodation, living space for the observers, electricity and other services should also be taken into account.

12) Enough land should be available near the site to install various instruments.

13) Human interference (out of curiosity or with malafide intention) with hydrometric installations is a problem in India. This issue has to be given serious consideration during the site selection process. For example if a choice has to be made between two hydraulically similar sites, the final selection should be made in favour of the site which has fewer problems due to human interference and law and order.

14) Sites with a tendency for formation of vortices, reverse flow or dead water shall be avoided.

15) The measuring section should be away from obstructions (artificial and natural) and control structures, e.g., dams, weirs.

16) Channel at measuring section should be free from weed growth, accessible at all times of the year and under all flow conditions, and must be safe to gauge.

17) For a station to be sustainable, manpower and logistic support to operate and maintain the installation are necessary. Local manpower with desired qualification and interest is always helpful.

2.5.6 Criteria for Water Level Gauging Sites

Water level or river stage is the primary variable that is measured at stream gauging sites and most frequent measurements pertain to river stage. For stage monitoring, the following additional site selection guidelines apply.

1. Steep banks or sides are preferred; the location should be selected so that for manual observation the gauge posts are readable over the full water level range.
2. The stage measurement device should be installed as close to the edge of the stream as possible. Sections subject to high velocities should be avoided to the extent possible since drawdown effects can occur around the device.

3. To minimize the effects of turbulence and high velocities, water level measuring devices can be installed in a suitable stilling bay at the bank.

4. It is desirable to have access to the site and gauge posts at all times.

5. The site should not a tendency to collect floating debris which may hinder working of water level measurement device.

2.5.7 Criteria for Streamflow Measurement Sites

Current meter is a commonly used instrument and velocity area method is the preferred approach to measure river discharge. A stage and discharge measurement station should have appropriate conditions to install a stage measurement device and to measure discharge. The required features of a good discharge gauging site are as follows:

a. The measurement section should be clearly visible across its width and unobstructed by trees, aquatic growth or other obstacles.

b. There should be sufficient depth of flow across the whole cross-section:

c. Sites with mobile beds and bank shall be avoided. In some rivers, this is not possible and the site may be chosen so that the bed and bank changes are minimised.

d. Ideally, flow should be confined to a single channel. When this is not possible, each channel should be gauged separately to obtain the total flow.

e. The site shall be sufficiently far away from the disturbance caused by rapids and falls.

f. If the site is upstream of confluence of two rivers, it should be located sufficiently far upstream so that it is beyond backwater and any disturbance due to joining of two rivers.

g. Velocities should be well in excess of the minimum required speed of the current meter over the full flow range.

2.5.8 Criteria for Natural Control Sites

The factors that are important in selecting a good site with natural control are summarised below.

1. If possible a natural control should be selected where the relationship between stage and discharge is substantially consistent and stable.

2. The control should be sufficiently far upstream of another feature or control structure to avoid inconsistencies due to variable backwater effects. The channel should be stable.

3. The general course of the stream should be straight upstream and downstream of the site. Ideally the measuring reach should be straight for about 2 - 3 times the river width or a minimum of 400 m (whichever is less) both upstream and downstream of the site.

4. Stable (unchanging) controls should be available in the form of a bedrock outcrop or other stable riffle for low flows and a channel constriction for high flows; a fall or cascade, which remains un-submerged over the full range of stage is ideal.
5. A pool (deeper water) upstream of the control is helpful because it ensures the recording of stage at low flows and avoids/dampens high velocities at observing/recording, device during high flows.

2.5.9 Criteria for Artificial Control Sites
A variety of flow measurement structures are used and the choice depends on a variety of factors including objectives, flow range, afflux, size and nature of the channel, channel slope and sediment load, operation and maintenance, and cost. The applications and limitations of a structure will determine where its use is most appropriate. Each structure has its own specific site selection criteria. Some general criteria to be considered are described here.

1) Generally the use of artificial controls should be limited to small but important rivers (< 100 m wide) and for special investigations in artificial channels.
2) Existing structures may be adapted for the purpose of flow measurement, wherever feasible.
3) The sensitivity of upstream area to increased levels should be assessed. For example, will the installation of the structure cause a potential, increased risk of flooding.
4) A minimum length of straight approach channel of five times the maximum width of the water surface is recommended for most structures, except for thin plate weirs where ten times the maximum channel width is recommended. However, research has shown that for triangular profile weirs accurate results can be obtained even if the weir is only twice the channel width from an upstream bend.
5) Thin plate weirs are particularly sensitive to upstream velocity distribution.
6) Like all controls, it is essential that the structure creates a sensitive stage-discharge relationship. In wider rivers, this can be a problem at low flows. Structures such as the triangular profile flat “v” weirs provide such sensitivity.
7) The discharge coefficients of many structures vary when the velocity head in the upstream approach channel becomes large in relation to the depth of flow. A dimensionless number which describes this is the Froude number (Fr). To prevent water surface instability in the approach channel the Froude number should generally not exceed 0.5.
8) The design of the structure should be such as to minimise upstream sediment deposition or downstream scouring. In rivers with high bed loads the use of structures which significantly reduce the stream velocity is not recommended.
9) On rivers which are navigable or those which are important fish migration routes the use of flow measurement structures should be avoided and some other form of flow measurement considered.

2.5.10 Bureau of Indian Standards (BIS) criteria for selection of river gauging sites
The ideal requirements for a good gauging site as enunciated in the standard IS 1192-1981 "Velocity - Area methods for measurement of flow of water in open channels" are given below. The accuracy of measurement of discharge by velocity area method is increased if the site is selected considering these aspects.

The site selected should comply, as far as possible, with the following essential requirements:

a) The reach of the open channel at the gauging site shall be straight and of uniform cross section and slope, as far as possible, in order to avoid irregularities in velocity distribution. The length of the reach need not be more than 1600 m and should not be less than 400 m. When the length of the straight channel is restricted, it is recommended for current meter measurements and the straight length upstream of the measuring cross section should be twice that on the downstream.

(Note: In case of artificial channel, the minimum length of straight reach should preferably be such as to give a drop in water level of 0.06 m. or the minimum length should be equal to four times the width of the channel, whichever is larger.)

b) The depth of water in the selected reach shall be sufficient to provide for the effective immersion of either the current meters or floats, whichever are to be used.

c) When near a confluence, the site, if located on a tributary shall be sufficiently upstream preferably beyond the backwater effect; and if located on the main stream, upstream or downstream of the confluence it shall be beyond the disturbances due to the tributary.

d) The site should be easily accessible at all times of the year.

In addition to the above requirements, the following points shall be taken into consideration as desirable requirements in the selection of the gauging site.

a. The flow should be confined in a single channel and there should be no overflow as far as possible. Where this is not possible, the site in which minimum number of channels exist and the flood plain has minimum width should be preferred.

b. Where these requirements cannot be met (for instance- when in alluvial rivers the river bed is changing during the period of measurement, or when, under flood conditions, the river is not confined to a single channel in embankments), a gauging site shall be chosen such that the bed change and/or overflow is minimum. Floodplain, if cannot be avoided, shall be of minimum width, as smooth as possible, with a distinct channel, and clear of bushes and trees. The flow in the over bank or floodplain section (s) shall be measured separately and added, treating the whole as a composite section.

c. The site shall be remote from any bend or natural or artificial obstruction if disturbances of the flow are likely to be caused thereby.

d. The orientation of the reach should be such that the direction of flow is as close as possible normal to that of the prevailing wind.

e. Sites at which there is a tendency for vortex formation should be avoided.
f. The site should, as far as possible, be free from trees and obstructions which may interfere with flow and clear vision during observation.
g. The site shall be free from aquatic growth which is likely to interfere with the measurement of depth and the current meter reading.
h. The site shall be away from the back water zone caused by any structure on the river.
i. The site should be sufficiently away from the disturbance caused by rapids and falls. etc.

2.5.11 World Meteorological Organisation (WMO) criteria for selection of site
The following are the WMO recommendations for selection of a site:
   I. The general course of the stream should be straight for about 100 m upstream and downstream from the site.
   II. No flow bypasses the site as subsurface flow.
   III. The stream bed is not subject to scour and fill.
   IV. The banks are permanent and high enough to contain floods.
   V. Unchanging natural controls are present in the form of a bedrock outcrop or other ruffle for low flow and a channel constriction for high flow.
   VI. Small pool is present upstream from the control at extremely low stages to ensure a recording of stage at extremely low flow and to avoid high velocities
   VII. A satisfactory reach for measuring discharge at all stages is available within reasonable proximity of the gauge site.

2.5.12 International Standards for Hydrometry
International Organization for Standardization (ISO) has published a large number of standards related to Hydrometry. A partial list is given in Table 2.4. For further details, their website (www.iso.org) may be referred. A brief description of the provisions of relevant ISO standards is given in Annexure A.