STREAM GAUGING IN INDIA - PRACTICES AND PROBLEMS

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ABSTRACT

Streamflow is a very important phase of the hydrological cycle as far as its utilisation by mankind is concerned. At the same time this phase also creates disastrous situations for the surrounding areas. For better design, management and operation of various conservational and protectional projects an idea about the amount of water flowing through a particular section of stream is very essential. Stream flow measurement is thus a very important hydrological investigation activity. In this chapter the present status of stream gauging in India is discussed. The factors which have effected the use of certain methodologies and equipment at different stream gauging sites have been presented. A few problems which are faced while using these equipment have been brought into the state of stream gauging in India.

1. INTRODUCTION

Streamflow is that phase of the hydrological cycle in which water moves in confined and well defined channels over the surface of the earth. Streamflow is very useful to mankind in many ways. It supplies water for domestic, commercial, and industrial use; irrigation water for crops; dilution and transport for removal of waste; energy for hydroelectric power; transport channels for man and materials; and a medium of recreation. Records of streamflow are the basic data used in developing reliable surface water supplies because records provide information on the availability of streamflow and its variability in time and space. The records are therefore used in planning and design of surface water related projects and they are also used in management or operation of such projects after the projects have been built or activated. Streamflow, when it occurs in excess, can create a hazard - floods cause extensive damage and hardship. Records of flood events obtained at gauging stations serve as the basis for the design of bridges, culverts, dams, and flood control reservoirs, and for flood plane delineation and flood warning systems.

The streamflow at any location is affected by various climatological phenomenon and geographical factors prevailing in the region in general and on the upstream side in particular. These factors, affecting streamflow, varies tremendously and in all possible manner. Also, these variations in climatological and geographical factors, both in time and space domains, are not very easy to be quantified even with a low level of accuracy. It has therefore been a tall requirement with a low level of accuracy. It has therefore challenging working in the field of hydrology, to evolve a cause-effect relationship for the steamflow process. Nevertheless, research towards this goal, is a very active field in the subject of hydrology and the results obtained so far are very encouraging and promising. Hence an accurate streamflow simulation model would be an important agenda item for hydrologists, atleast for considerable time ahead.

It may be rightly argued that attempting such a cause-effect relationship would not only be cost ineffective but also extremely difficult, if not impossible. In such situation it becomes inevitable to physically observe streamflow as it flows past any given location. Though it seems to be an easy task but it is not at all so. Complete streamflow gauging gives information about the depth of flow, velocity at different points in the cross section and the total flow passing the section in an unit time. It is primarily a continuous process and so the gauging station is so instrumented and operated that a continuous record of stage and discharge is obtained. For some cases only a specific parameter is required to be gauged eg, obtaining the highest flood level at a particular location. This, for instance, may not warrant a complete gauging facility.

Making even a simple observation for discharge in a reasonably big river by conventional techniques is a very costly and time consuming process. Fortunately, discharge may also be estimated indirectly by knowing only the corresponding river stage. There exists a relationship between the discharge and the depth or stage of flow at any location. This stage discharge relationship, though not perfectly unique in all situations, provides a very easy way of converting discharge from the observed stages. However, direct discharge measurements are also required at certain intervals of time for developing this relationship between stage and discharge and to update this relationship because factors governing this relationship also vary considerably with time in most of the cases.

Therefore, the data obtained at the gauging station are regularly reviewed and analysed by engineering personnel. Discharge ratings are established, and gauge values are used to get the corresponding discharge

values at selected time intervals. The mean discharge for each day and extremes for the year are computed. The data is then prepared for publication and retrieval by the end user.

2. STREAM GAUGING IN INDIA

Before independence, there were very few gauge and discharge sites in India. Measurement of the flow was started in 1921 at all important points on the Indus and its tributaries.

The other river where regular measurements were being made was the Cauvery to regulate the flow between the states of Karnataka and Tamil Nadu. It was only in the second half of the century that observation sites were set up on a large scale.

India is a very vast country having fresh water resources which is very unevenly distributed in time and space. The country's economy is in the developmental phase and therefore more and more area is coming under pressure of man's activities. Like other developmental projects, water resources developmental projects also are increasing manifold. In such circumstances there is an acute need of sustainable planning of water resources projects. Good planning may only be based on good quality of information about the movement of water in the space and time domain. Observation of parameters used in deriving useful information about the water movement has therefore become more and more necessary. Since streamgauging is very expensive and our economy not being so strong, it is not unnatural to have a very sparse gauging network in the country. Nevertheless, the awareness about the need of a better gauging network is building up and this task is being taken up by the central government as well as governments of different states.

Stream gauging on all the major rivers of the country is being undertaken by the Central Water Commission which is a central government agency. The Water Resources and Irrigation departments of the states are entrusted with the work of gauging all the minor rivers of the country. Both the Central Water Commission and state government agencies, are having their gauging sites on the medium sized rivers which are the main tributaries of the major rivers of the country.

At present a total of 224 gauge-discharge and 18 gauge-discharge-sediment sites have been established in the country. Table 1 shows the river basin wise and agency wise distribution of all the stream gauging sites existing as on April, 1988 (CWC, 1988).

Table 1 : Basin-wise hydrological and sediment observation stations of the Central Water Commission (CWC, 1988)

S.No.	River Basin	No. of stations G&D	GDS/WQ	Total
1.	Indus	8	10	18
2.	Ganga	113	114	227
3.	Brahamputra & Meghna	11	20	31
4.	Barak	9	10	19
5.	Godavari	29	20	49
6.	Krishna	23	25	48
7.	Cauvery	3	19	22
8.	Pennar	–	4	4
9.	East flowing rivers	8	10	18
10.	Mahanadi	4	13	17
11.	Brahmani & Baitarani	–	7	7
12.	Subarnarekha	–	3	3
13.	Sabarmati	1	–	1
14.	Mahi	–	5	5
15.	West flowing rivers of Kutch Saurastra & Luni	4	10	14
16.	Narmada	7	12	19
17.	Tapi	4	12	16
18.	West flowing rivers from Tapi to Tadri	–	3	3
19.	West flowing rivers from Tadri to Kanya Kumari	–	21	21
	Total	224	318	542

G&D : Gauge & Discharge Observations
GDS/WQ : Gauge, Discharge & Sediment/Water Quality

3. FACTORS INFLUENCING ADOPTION OF DIFFERENT STREAM GAUGING PRACTICES IN INDIA

Different types of stream gauging techniques are in practice in our country. Some of the factors which have influenced the practicising of different techniques being followed at different gauging sites are:

(a) Importance of the stream

Depending on whether the steam is a major, medium or a minor one or it is a small nalla or riverlet, the degree of sophistication in the instrumentation of gauging sites varies. The greater the importance of the river (which is directly proportional to the amount of water it carries) the higher is the sophistication. Sophistication here means that the equipment are automatic and recording type (i.e., manual work is reduced and the parameters may be observed continuously).

(b) Economical condition of the concerned agency

The degree of sophistication practiced depends very much or rather solely on the economic condition of the agency which is entrusted with the instrumentation of the gauging site. The Central Water Commission which is looking after stream gauging on all the major rivers is funded by the central government. The avaibalility of funds from the central government is adequate to introduce modern techniques into the system. On the other hand, the streams which are under the control of the Irrigation or Water Resources departments of the different state governments are generally instrumented very poorly. There are not enough funds available to introduce the latest available techniques.

(c) Awareness about the importance of hydrological data

The realisataion of the importance of hydrological data in general and streamflow data in particular is not uniform among all the organisations responsible for the water resources development of different regions/ states of the country. It has been noticed that some of the states have started off very nicely with respect to the installation and instrumentation of streamflow gauging sites whereas other states are either very feebly motivated or else are quite indifferent about the collection of streamflow data.

(d) Absence of indigenous manufacturing facilities

It is another very big factor influencing the type of equipment used for

instrumentation of the gauging sites in India. There are only a few automatic recording type equipment which is being manufactured and maintained indigenously. A major part of the countrymade equipment is of the conventional type which is either non-automatic or non-recording type. One of the major reasons for any controlling agency for not introducing sophisticated technology is that the required equipment has to be purchased from the developed world at an exhorbitantly high price and then paying for even more costlier maintanance facilities. As more and more modern equipments would be indigenously manufactured and maintained, use in their stream gauging sites around the country would be much faster owing to reduced costs and approachable maintenance facilities.

4. COMMONLY FOLLOWED PRACTICES IN INDIA

There are three main parameters which are required in streamflow measurement. They are (i) bed profile at the gauging section, (ii) water level with respect to a fixed datum, and (iii) average velocity of the water flowing through the section. A general picture of the practices followed for the observation of these three parameters is given here.

(a) Bed Profile

Though bed profile at some sites may remain practically unchanged but in practice most of the sites experience a shift in the flow regime. For the former case, which is an ideal case, the bed profile details may be surveyed once or twice a year by the help of conventional methods. But in the case of shifting control, the details have to be surveyed quite frequently. In this case since the bed profile has to be surveyed during high flow periods also, the usual conventional procedures are no longer possible. In shallow waters the continuous observation of bed profile is made by wading rods operated from a boat or weight suspended from a cable. In other situations like very wide or deep rivers, a portable sonic sounder is used to provide a continuous strip chart record of the depth of the stream; that is, a profile of the cross section between the two ends. In India most of the gauging sites have conventional ways of finding the bed profile. Only at a very few sites, where moving boat facility is also available, sonic sounders are used.

(b) Stage Measurement

The stage of a stream is the height of the water surface above an established datum plane. The stage is usually expressed in meters and hundredths or thousandths of a meter. Records of stage are used with the

stage-discharge relation in computing records of stream discharge. The reliability of the discharge records is therefore dependent on the reliability of stage records as well as on the accuracy of the stage-discharge relation. A record of stage may be obtained by systematic observations by a non-recording gauge or by means of a water level recorder.

Non-recording stream gauging stations: In India most of the stage measuring sites have non-recording type of gauges that need a very low initial investment and maintenance costs. The disadvantage is that it requires an observer to record the observations. Usually at a non-recording gauge the readings are taken twice a day in normal times and at smaller intervals during times of floods.

Staff gauges are mostly used in India for a non-recording gauge site. Staff gauges are either vertical or inclined. Vertical staff gauges consist of porcelain enamelled iron sections, each 150mm wide, one meter long and graduated to every 10mm. An inclined gauge is usually a graduated heavy timber rod securely attached to a permanent foundation pier. Sometimes the existing rock outcrop also forms good material for inclined staff guages and thus require little dressing and proper graduation with good quality enamel. Inclined gauges built flush with the streambanks are less likely to be damaged by floods, floating ice, or drift than are projecting vertical gauges.

Recording Stream Gauging Stations: Stage is sensed for automatic recording by a float in a stilling well, or by a gaspurge system that transmits the pressure head of water in a stream to a manomenter. The latter system, which does not require a stilling well, is known as a bubble gauge. In India, bubble gauges have been installed at only a very few sites. Mostly the gauging sites which are on the main streams and looked after by the Central Water Commission, float type gauges are employed.

(c) Meausrement of Discharge

Streamflow, or discharge, is defined as the volume rate of flow of water and is expressed in cubic meters per second. Discharge measurements are made at each gauging station to determine the discharge rating for the site. At most of the sites on major Indian rivers which are under the Central Water Commission at least one discharge measurement is made every day in normal times.

Discharge measurements are made by several methods but the basic instruments most commonly used in making measurements is the current

meter. The observation of water velocity and depth are usually made by an observer while stationary at each of several observation points in a cross-section of a stream. In contrast to this conventional method is the relatively new moving boat method, the ultrasonic method and the electromagnetic method. On almost all the gauging sites, which are under state government agencies, current meter is used to measure the velocity. However, at some of these sites, even floats are employed to measure the velocity of flow. The Central Water Commission employs current meter on most of its sites alongwith moving boat method on some of these.

5. PROBLEMS IN STREAMFLOW MEASUREMENT

Streamflow measurement is a very tedious, expensive and difficult task to perform. Moreover, the final values obtained by different methods carry a certain degree of inaccuracy which may not be fully excluded due to various problems which are experienced during stream gauging. Some of the problems which are experienced are given here.

(a) Depth Correction for Sounding Line and Weight

During current meter measurements with a cable suspension mechanism in deep swift water, the current meter and the sounding weight is carried downstream for a certain distance before the weight touches the bottom. This is often the case when the measurements are made from a bridge or a cable way which is at a vertical distance above the surface. In such a situation corrections have to be applied in order to determine the correct depth of water and the depth to which the current meter is to be lowered.

(b) Stilling Well Lag and Draw-down

During periods of rapid change of stage, water levels in the stilling well lag behind those in the stream because of head loss in the intake system. This phenomenon is known as stilling well lag and occurs on a rising or falling stage. Also the protruding end of the intake pipe causes a disturbance of flow past the pipe producing a reduction of the water level in the stilling well. This effect is known as draw-down. In our country rarely any corrections are applied for these two types of corrections. This might have allowed errors to have been introduced in the observed values of the stages at most of the sites.

(c) Rapidly Changing Discharge

At the stream-gauging station located in a reach where the slope is very flat, the stage-discharge relationship is generally affected by the super-imposed slope of the rising and falling limb of the passing flood wave. During the rising stage the velocity and the discharge are normally higher than those for the same stage during steady flow conditions. Similarly, during the falling stage the discharge is normally less for any given stage as compared to steady flow conditions. The steady state rating curve is generally developed by drawing a median curve through a scattered plot of stage-discharge measurement. This procedure may give a correct result only when all measurements are made during nearly steady flow conditions. Infact, the slope of the actual rating curve takes the shape of a loop during rapidly flowing discharge. For hydrological analysis it is general practice to develop and use the steady state rating curve for converting the observed stages into discharges, which are generally erroneous. In order to consider the unsteady state effects some auxillary station has to be installed and necessary corrections have to be applied. Such practices are normally very tedious, uneconomical and require trained technical personnel. In normal practice the hydrologists generally rely on the use of steady state rating curve and the error is left in the observation.

(d) Shifting Control

Shifts in control features occur especially in alluvial sand-bed streams. However, even in stable streams shifts occur, particularly at low flow because of weed growth in the channel, or due to debris in the control section. The stage discharge relation, for alluvial sand-bed streams, usually changes with time, either gradually or abruptly, due to scour and silting in the channel and because of moving sand dunes and bars. These variations cause the rating curve to vary with both time and the magnitude of flow, and observations and measurements have to be carried out in the best possible way.

(e) Extrapolation of Rating Curve

Extrapolation of rating curve in both directions is often required. If the point of zero flow has been obtained, the curve may be extrapolated between this point and the lowest discharge measurements without much error. But, if the point of zero flow is not available, it is not advisable to extrapolate far in this direction and this restriction poses the problem

of converting lower stages into corresponding discharges. In the upper part of the curve extrapolation is almost always necessary. Only in a few cases are discharge measurements available at about the highest observed peak . Though there some established methods for extrapolation of rating curves in the upper zone it is observed that in India in very few cases these are properly followed.

(f) Safety Measures in Streamflow Measurement

The safety record in streamflow measurements over the past 100 years has been a good one. Nevertheless, fatal accidents occur, notably during the times of floods. These accidents can be avoided if adequate safety measures are adopted.

6. CONCLUSIONS

In light of the present practices followed in India and the problems faced during stream gauging the following conclusions are drawn.

(a) Greater awareness about the importance of stream gauging has to be generated among technical personnel involved in water resources projects and decision makers responsible for the clearance of such projects.

(b) The stream gauging network in the country is very sparse and must be strengthened so as to improve the existing design and management procedures for water resources projects.

(c) Indigenous manufacturing industry in the field of instrumentation for stream gauging must be encouraged. This type of encouragement should be followed-up by strong research and developmental efforts in the field of hydrological instrumentation in general and stream gauging in particular. Alongwith the manufacturing activity, the maintenance aspect of the instruments must also be given due importance so that very cheap maintenance facilities must develop around the country for instruments already in use and for those which may follow.

(d) There is an urgent need to develop such automatic and self recording instruments which are capable of gauging the stream during unsteady, very high, very low or very swift flow conditions.

(e) Automation in stream gauging must consider difficult field situations, economics of the system and accuracy over the existing conventional and modern techniques.

(f) There is a need to appreciate that the development of instruments and subsequently the manufacturing activity can only take place if proper interaction by experts of different disciplines is forthcoming.

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