DATA OBSERVATION FOR SNOW MELT RUNOFF ASSESSMENT

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Abstract *The contribution of snow melt runoff to rivers is an extremely important element since it augments their discharges during the lean season when the water demands are also usually high. This also reduces the variability in the river flows thereby reducing the requirement of storage capacity for meeting the demand. For proper planning and management of water resources of such rivers, accurate assessment of snow melt contribution and its seasonal/periodic predictions are apriori. To achieve this end, systematic data observation and a comprehensive and reliable database is a must. Various numerical methods are available for estimation and prediction of snow melt runoff. They are based on either the temperature index or energy budget. In this paper, various parameters characterising the snowpack as well as those responsible for snow melt are described. Equipment installed at Batote and Chilla Top Observatories are also described.*

INTRODUCTION

Water resources planning, development and management is a complex task more accentuated in the Indian context where there is a large variability in spatial and temporal distribution of hydrological phenomena consequent on variation in river flows and rising water population, resulting in increased water demands. Planning and management of available water resources have to take care of these factors and to ensure water supply according to the pattern of water demands and their locations.

Most of the Himalayan rivers have considerable snowclad areas. The snow melt contribution in such rivers is a welcome phenomenon since it augments their flows in the lean season, thereby reducing the variation in water availability. This results in lesser requirements of storages. Besides it also facilitates water supply in summer months when the demands are substantially high.

For proper planning and management of Himalayan rivers it is necessary among other things to assess their snow melt contributions. The seasonal as well as periodic, say weekly, fortnightly and monthly forecasts of snow melt runoff can be of immense help in adopting optimal operational strategies, thereby achieving maximum benefits out of available water resources. This requires a good knowledge of snowpack, its water equivalent, extent of snowcover, depletion pattern and various atmospheric parameters causing snow melt. To achieve this, establishment of snow observatories fully equipped with data collection and recording system, identification of representative snow courses, and stream gauging stations at suitable locations in the watersheds/ catchments are required.

PHYSICS OF SNOWPACK

The formation of snowpack begins with the deposit of new fallen snow in the form of snow flakes. The density of snowpack is usually very low, which changes with time. The delicate crystals become coarse grains and the density of snowpack increases. This process of change from loose, dry and sub-freezing snowpack of low density into a coarse, granular and moist snowpack of high density is called ripening of the snowpack. When the liquid water holding capacity of the ripe snowpack is reached, it becomes ready to produce runoff. At this stage, the storage effect of the snowpack is transitory in nature. This results in temporary delay of liquid water in transit through the pack. There is no restriction that the snowpack would yield runoff only in spring season. Mid winter rainfall or snow melt may satisfy the cold content and liquid water holding capacity of the snowpack. When this condition is reached, any further input of liquid water would simply pass through the snowpack under gravity.

Changes that take place within the snowpack are caused by several physical processes, such as:

(i) heat exchange at the snow surface, (ii) percolation of melt or rain water through the snowpack, (iii) internal pressure due to the weight of the snow, (iv) wind (v) temperature and vapour pressure variation within the snowpack, and (vi) heat exchange at the ground surface.

PARAMETERS

Various factors affecting the process of the precipitation in the form of snow, its accumulation, its melt, and variation in runoff, to be used to develop snow melt runoff relationship, are: air temperature, solar radiation-relative humidity, precipitation, wind velocity, snow water equivalent, snow depth, snow density, aerial cover of snow, and discharge data on the draining stream.

DATA OBSERVATIONS

Snow hydrologic studies require data on the aerial cover of snow depth and density at various locations spread over the catchment area of the basin in addition to the hydrometeorological data mentioned above. In addition, the flow parameters, i.e. gauge and discharge, are also needed to develop the relationship between snow melt and runoff. The computer models that are in use at present require at least 6 hourly data. It may be mentioned that the catchment areas in which the data on snow hydrologic parameters are required to be collected are mostly located at high altitudes in difficult terrains with adverse climatic conditions.

This makes the manual collection of data extremely difficult. Accordingly, automated data observatories/stations are necessary. At present, a number of electronic sensors are available for automatic observation of various parameters.

These electronic sensors are connected to the recording system, which is capable of storing the sensed data for a long time.

DATA OBSERVATION AND COLLECTION SYSTEM

Till now, no reports on comprehensive snow-hydrological studies based systematic data collection were available for any of the Himalayan river systems. A pilot project has been initiated in Chilla Khud watershed in Chenab basin for developing snow melt runoff relationships. This experimental watershed was selected mainly because of the following considerations:

(i) Easy accessibility of the catchment during snow season to facilitate the snow course surveys by observers;
(ii) Having predominantly north facing catchment so that the snowfall taking place during the snow season does not melt out simultaneously but keeps on accumulating to form a snowpack of considerable depth over the catchment before the melting process commences; and
(iii) Suitable gauge site for the draining stream.

For comprehensive data collection, two snow observatories, one each at Batote and Chilla Top, have been established.

Experimental Catchment

The experimental Chilla Khud watershed is predominantly north-facing and fan-shaped. Its catchment area is about 6.13 km^2. The draining stream originates at an elevation of about 2500 m. The highest and the lowest points in the watershed are at about 2575 m and 1290 m, respectively. The stream-gauging site is located near Landri village at an elevation of about 1468 m. The length of the stream up to the G and D site is about 2.63 km and the catchment area is about 5.775 km^2. This discharge is being measured with the help of a pigmy current meter by making an artificial small rectangular channel. The experimental catchment is shown in Fig. 1.

Snow Observatories

The observatories at Chilla Top and Batote are equipped with automatic sensors for data collection.

Easy Logger

It is a multichannel battery operated portable data recording system. It provides easy, fast and accurate collection, transfer and reporting of data. It can be operated in the temperature range of -30° to +50°C. It is easy to use, because it is menu-driven with understandable English commands. It is capable of scanning the data with an interval ranging from 1 min to 24 h, and also provides an option for selectable report interval at which the data are reported in the data storage pack mounted over this field unit.

Various instructions for scanning, reporting and mode of data are required to be fed in the field unit depending upon the purpose for which the observatory is set up. These instructions which shall control the sequence of operation of data observation and recording are fed through a handheld terminal, plugged into the easy logger.

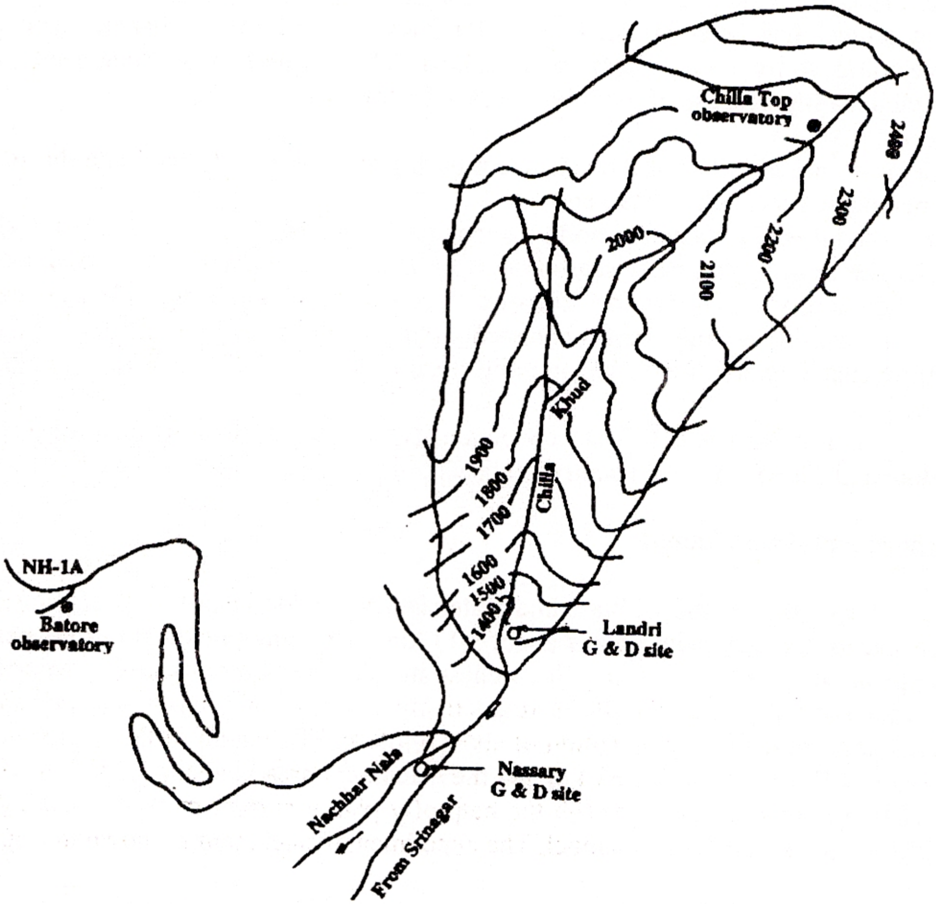

Fig. 1 Chilla khud watershed.

Hand-held Terminal

The terminal is used for feeding the instructions to the Easy Logger. A set of commands has been provided to operate the observatory system. These are fed with the help of a terminal. The terminal gives two-line display and draws power from the battery of Easy logger. It is very handy and therefore convenient to carry to the site in a travel kit.

Data Storage Pack

This is a small pack and can be mounted on the Easy Logger. The Easy Logger receives data as per the set sequence/programme from the sensors and reports at the prefixed report interval which is recorded in the Data Storage Pack (DSP). DSP is primarily a device which is detachable, small and convenient to handle and is used for storing the data. DSP, after it is removed from the field unit, is brought to the office and the data stored in it can be retrieved on a personal computer through the Easy Reader. Meanwhile, another DSP is mounted on the Easy Logger in the field to collect the data at the observatory, uninterrupted. The DSPs are re-usable. Once the data stored in the DSP is retrieved and taken on a floppy, which becomes a permanent record, data in the DSP can be erased with the help of EPROM eraser. The DSPs are available in 16K, 32K, 64K, and 124K memory ranges.

Reader

It is used to retrieve and transfer the data recorded on DSP on a PC for further processing and analysis. Through a set of protocol commands it is made compatible with the PC.

Relative Humidity and Temperature Probe

At the observatory, temperature and relative humidity sensor has been installed. The relative humidity sensing element is composed of two thin film electrodes etched on a glass substrate over which a 1 μm polymer layer is applied. An upper electrode is vacuum evaporated onto the polymer layer. This electrode is approximately 0.01 μm thick. Moisture passes through the upper electrode and water molecules form bonds with the polymer molecules. This effect changes the capacitance of the sensing element.

Temperature is sensed with a three-wire, two element precision thermistor. The thermistor is a temperature-senstive resistor which decreases its resistance as the temperature increases. The thermistor is extremely sensitive and exhibits a large resistance change with respect to temperature. This sensor has a range for measurement of temperature form -50° to 80°C and 0-100% relative humidity. It gives very accurate results.

Pressure Transducer

The pressure transducer is being used at the observatory for the measurement of SWE. The pressure transducer consists of an active four-arm strain gauge diffused into the surface of a single crystal silicon diaphragm. Silicon has excellent mechanical properties, being perfectly elastic and gives a relatively high output at low strain levels. The basic sensor is built into a fully encapsulated solid state transducer. A small breather tube provides an atmospheric reference pressure to the diaphragm. The output of the pressure transducer which is in volts, changes with the variation of the head of water over it. This resultant change in voltage due to variation in the head is calibrated with the help of the requisite formula, in the units of depth (mm or cm). At the observatory site, the transducer is placed in a vertical pipe which has been connected with the necessary pipe fittings etc., to the snow pillow which is filled with liquid. As and when snowfall occurs, the liquid in the snow pillow is pressed downwards, which causes a rise in the level of water in the pipe containing the transducer. The change in level which is reported in terms of depth units with the help of the inserted depth calibration formula is recorded in the DSP at a predecided report interval.

Weathertronics Star Pyranometer

The pyranómeter is an instrument for measuring direct and diffuse solar radiation. The sensing element consists of twelve wedge-shaped sectors, alternating black and white. Six thermocouples are embedded in each sector, making a total of 72 thermocouples, which are connected in series.

When the sensor is exposed to solar radiation, a temperature differential exists between the black and white sectors, which causes the thermocouple junctions to output a voltage directly proportional to the intensity of the solar radiation. Diffuse radiation can also be measured by using a shadow ring.

A crystal quartz glass dome admits energy between 0.3 and 3 μm and shields the sensing surface from the elements. The reflective outer surface and mass of the case keep the interior at ambient conditions. Levelling is accomplished by using the bull's eye level and three levelling legs.

The sensor has a range of wave lengths from 300 to 3000 nm. It is capable of measuring radiation with an accuracy of 1% for angle of incidence not exceeding 70 degrees to the sensor plane. It has a response time of 4 s.

Solar Panel Battery Charger

The data collection system is powered with the help of a pair of gel cell batteries. The battery supplies power throughout the period of operation and gets gradually discharged. To keep the battery voltage at the desired level it should be charged continuously. The charged is supplied to the batteries with the help of a solar panel, which is generally mounted at the top of the mast supporting the sensor viz. temperature and relative humidity sensor, pyranometer etc.

A solar panel battery charger has been installed at the observatory. It is a photovoltaic module designed to charge 12 V DC gel cell batteries which power the data collection system.

The solar panel consists of 36 semicrystalline silicon solar cells protected beneath a sheet of 1/8 in tempered low-iron glass, which is self-cleaning and impact resistant. It provides a constant battery charge voltage throughout the temperature range. It does not overcharge in hot weather nor undercharge in cold weather.

Snow Pillow

Snow pillows are used for measurement of snow water equivalent. Till recently, stainless steel snow pillows were being used for this purpose, but they have the problem of repair and affect the bridging resulting in erroneous response. Nowadays, the Hypalon snow pillows have come in vogue. The snow pillows laid at the Batote and Chilla Top Observatories are of this type. These snow pillows are hexagonal in shape with 6 ft sides.

The snow pillow after it is layed on levelled ground, is filled with antifreezing chemicals and water, and is connected to a vertical pipe containing a transducer in it. Whenever snow falls over the pillow, the water column in the vertical pipe rises. The variation of the water column in the vertical pipe is a function of the water content in the snow accumulated on the snow pillow. Accordingly, the variation of water column in the vertical pipe is caliberated in snow water equivalent which is sensed by the transducer and passed on to the Easy Logger for recording.

Snow Sampling Set

The data collected at the observatory site may not be representative of the whole catchment. Therefore, to have some sort of relationship between the data observed at the observatory site and in the rest of the catchment, snow data on the extent of aerial cover, depth and density, etc. are required to be observed at various locations.

This data is observed with the help of a snow sampling set. It comprises a set of four tubes which can be joined if required. This mechanism gives the amount of snow water equivalent directly as the scale provided with the balance is calibrated and graduated in terms of centimetres/inches of SWE. The tubes are connected depending upon the depth of snow at the location where observation is to be made.

First, the weight of the empty tube is taken and then it is driven into the snowpack up to the bottom. The tube gets filled in with the snow. Thereafter, it is withdrawn and weighed with the snow in it. The weighing mechanism which is calibrated in terms of SWE gives the SWE, directly based on the net weight.

Besides the above mentioned instruments, certain conventional instruments are also being used on the snow hydrology project. These are (i) psychrometer (for measuring relative humidity), (ii) pigmy current meter (for measuring discharge), (iii) manometer (for measuring SWE), (iv) ordinary rain gauge (for measuring rainfall), and (v) snow board (for measuring daily snowfall). The schematic diagram of the data observation system at the observatories is shown in Fig. 2.

Performance

The relative humidity and temperature at the observatory sites are also being measured manually with conventional equipment. The sensor data have been compared with manually observed data by plotting bar diagrams as shown in Fig. 3. It may be seen that the sensor data compare well with those manually observed.

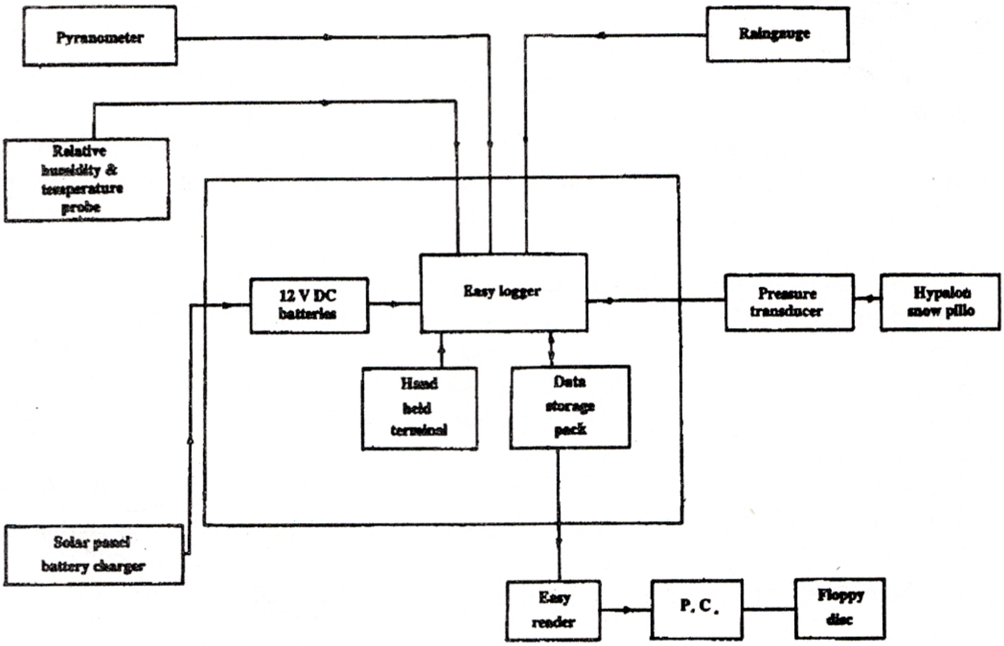

Fig. 2 Schematic diagram of the data observation system.

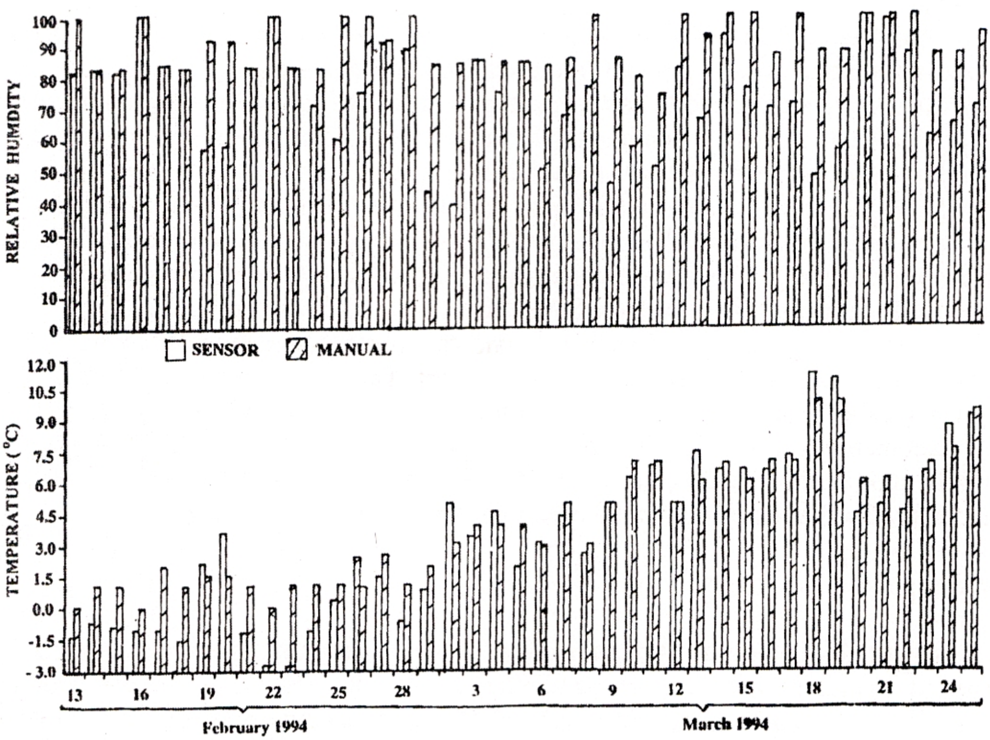

Fig. 3 Comparison of sensor and manually observed RH and temperature data.

The variations of solar radiation, temperature, discharge and snow water equivalent for the snow season are given in Fig. 4. The variation of daily average temperature compares well with snow water equivalent which represents the snow accumulation and ablation process. The trend of daily discharge also compares well with the snow water equivalent except where there has been rainfall in the catchment. There is also a general agreement between the trends of daily average solar radiation and temperature.

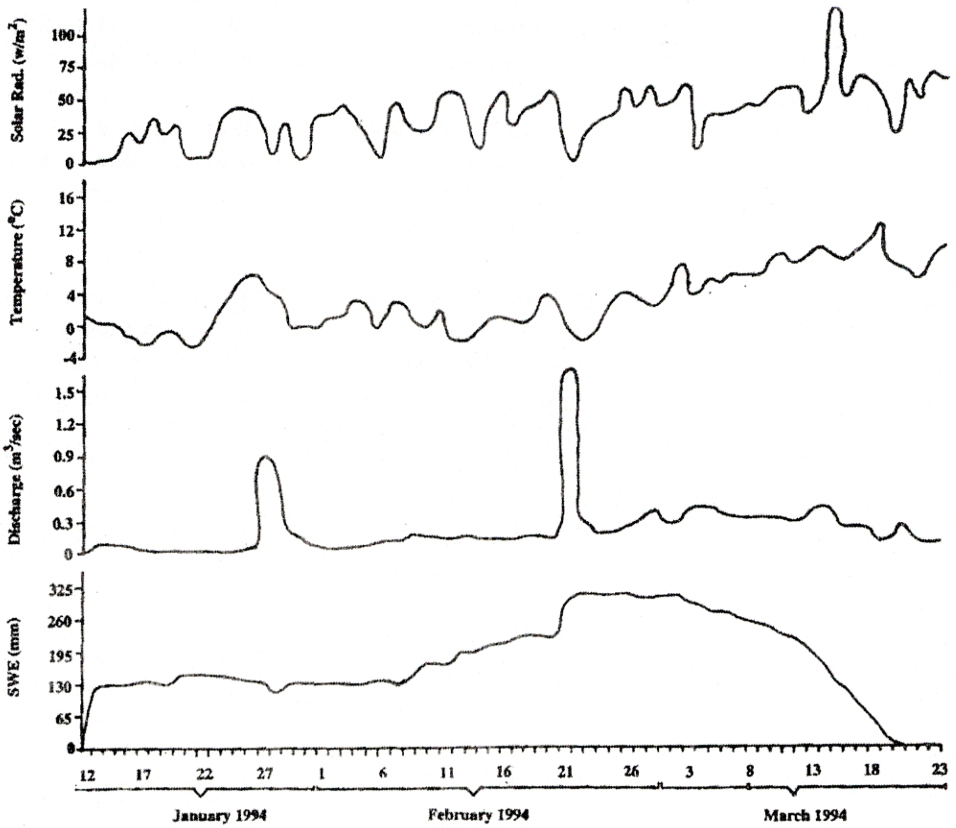

Fig. 4 Variations of SR, temperature, discharge and SWE during snowstorm.

CONCLUSIONS

Assessment of snow melt runoff, its seasonal and periodic predictions are of vital importance for planning and water management of a river basin having a considerable contribution from snow melt. For accurate assessment and prediction, a comprehensive and systematic reliable database is a must. This warrants the setting up of observatories at representative locations in the river basin for observation of various parameters which depict the characteristics of snowpack and influence melting process. Such observatories are likely to be set up in high altitudes with hostile climate, which are extremely difficult to approach. Hence, these observatories should essentially be equipped with automatic data collection system.

Various equipment that may be necessary for automatic data collection system have been described. The data collected by the automatic observation system have been examined and found to be consistent. The trends observed between temperature, snow water equivalent representing snowpack accumulation and ablation and stream discharge show that there is a good interrelationship between them. This provides logistics for the application of simpler numerical models, which are based on the temperature index. However, the data collected by the automated system have all the ingredients from which various parameters could be estimated for other models as well.

Thus, it may be concluded that an automatic data collection system could be established to create a comprehensive database in the river basin where snow runoff studies are to be carried out. From this database, the parameters of the intended model can be derived for assessing snowmelt runoff and prediction.

Acknowledgement The snow hydrologic study project in the pilot catchment was undertaken with the assistance of USAID, who supplied the required equipment that was installed at the observatories. The authors are highly grateful to USAID for the supply of equipment and to Dr. Arthur G. Crook for his guidance in the installation of equipment and valuable discussions on various aspects of snow melt.