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HYDROLOGICAL STUDIES OF DOKRIANI GLACIER (PART III)

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Preface

Snow and glacier melt contribute a substantial part of the flow in the Himalayan rivers. However, very few studies on the hydrological aspects of glaciers were carried out in the country. Inacessibility to the glaciated region due to very rugged terrain, high altitude and harsh weather conditions have restricted such studies. Any data collected by any organisation in such environment is considered very valuable for hydrological studies on glaciers. National Institute of Hydrology has been participating in the expeditions to the Dokriani glacier in Garhwal Himalayas since 1992 with the objective of studying the hydrological aspects of glaciers. Scientists of the Mountain Hydrology Division in the institute are carrying out the hydrological investigations on the glacier. Inspite of harsh weather conditions and several difficulties of the field, detailed investigations are being made by the scientific team on the Dokriani glacier year after year. During 1995, a water level recorder was installed near the discharge measuring site on the glacier melt stream.

Air and water temperature, hourly stage, daily discharge and suspended sediment data have been collected at the discharge measuring site. During 1995, the period of data collection was longer than in earlier years and water yield from the glacier during June, July and August could be estimated. In this report the results of the analysis based on the investigations carried out during 1995 are reported. The work was carried out by Dr Pratap Singh, Scientist C, Shri Naresh Kumar, Senior Research Assistant, Sri S K Dhariwal, Research Assistant and Shri Dhanpal Singh, Tech Gr III under the guidance of Dr K. S. Ramasastri, Scientist F.

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Abstract

Discharge, suspended sediment, air temperature and water temperature data have been collected at the gauging site established by NIH on the Dokriani glacier melt stream in the Garhwal Himalayan region in the years of 1992, 1994 and 1995. The gauging site was established at about 800 m downstream of the snout of the glacier. To monitor the diurnal variation of glacier melt runoff , an automatic water level recorder was installed at the same gauging site in 1995. For this purpose a stilling well was constructed at the gauging site and it was connected with the glacier melt stream through a constructed drain. Automatic water level recorder recorded changes in the water level in the stilling well which were representative of the changes in the melt stream. Daily recording charts were used to obtain continuous recording of water level in the channel. Manual observations were also made both for water level and discharge at the gauging site during day time. It helped in developing a stage-discharge relationship and this relationship was used to convert water level into discharge. This discharge data was expected to give reliable information about the water yield from the glacier. Data on precipitation, air temperature, suspended sediment and melt water temperature were also collected. To collect meteorological data, a small meteorological observatory was set up near the gauging site. Additional equipment to record humidity, wind velocity and direction etc. are proposed to install in 1996. The data were collected from June to mid September, 1995. A glacier melt runoff study is to be carried out for this glacier after collecting data for few years.

Maximum melt rates were noted to be in the month of July and August during 1995. Rainfall was observed almost daily. The rain thus not only contributed to runoff but also helped in the generation and transport of suspended sediment. Rain free periods were therefore, selected to detemine the melt rate from the glacier. Maximum temperature for atmosphere as well as stream water was attained in the month of June and after that both temperatures have shown decreasing trend. Variability in atmospheric temperature was very high as compared to the water temperature. No specific correlation was found between streamflow and suspended sediment.

1.0 INTRODUCTION

The glacier contribution in the rivers originating from Himalaya starts in the month of June/July when seasonal snowcover is melted off. This flow, generally, continues till September or October depending upon the climatic conditions in that region. Snowmelt runoff and glacier melt runoff make these rivers perennial in nature. As such very limited detailed hydrological studies have been carried out for the Himalayan glaciers (Singh, 1991, 1992; Singh et al., 1993). The estimation of the melt rate of the glacier and total volume of water expected in the melt season is of vital use for water resources planning and management including flood forecasting, reservoir operation and design of hydraulic structure etc. In the regions where monsoon rain penetrates the high altitude valleys comprising glaciers and coincide with glacier melt run-off, the flow in the rivers is augmented suddenly that may cause havoc in the down stream. The hydrological data collected during 1995 expedition to the Dokriani glacier has been analysed and presented in this report.

Glacier melt runoff modelling studies require data on radiation, temperature, precipitation, humidity, wind velocity and direction, daily and hourly discharges etc. But for many glaciers even basic data like temperature, precipitation and discharge are also not available. The problems associated with higher rate of suspended sediment. their constitution and structure are of immediate concern in this region. The problems associated with Himalayan glacier inventory were discussed by Vohra (1980). Poor accessibility, difficult and rugged terrain and lack of proper logistics are the main reasons to limit the collection of hydrological data through systematic hydrologic investigations on the Himalayan glaciers. Due to successive expeditions organised during the last ten years by several government and academic organisations the data base has some what improved in the recent years. The details of the hydrological investigations carried out during 1995 and the results of the analysis are presented in this report.

2.0 SALIENT FEATURES OF DOKRIANI GLACIER

There is about 25 km foot trek to approach the Dokriani glacier. This trek starts from the Bhukki bus stand on the Uttarkashi - Gangotri Road and passes through thick and dense forest cover. The forest has some wild animals like Wolfs, Bears and Tigers. The trek is very difficult one and under rainy conditions it becomes very slippery and risky as well. In general one night halt is made in between at Tela camp to reach the glacier base camp. The snout of the glacier is about 1 km from the base camp.

The Dokriani glacier is a valley type of glacier located in Garhwal Himalayas. This glacier lies between latitudes 31°49' to 31°52' N and Longitudes 78°47' to 78°51' E. It is situated about 25 km ENE of Bhukki. It originates in the vicinity of Janoli (6633m) and Draupadi ka Danda (5716m) peaks. The melt stream originating from Dokriani glacier is known as Din Gad. It follows a narrow valley and meets Bhagirathi river near Bhukki village. Total drainage area of this glacier is about 23 km^2 out of which about 10.3 km^2 is glaciated.

The elevation of glacier varies from about 3950 - 5800 m. The length of this glacier is about 5.5 km whereas its width varies from 0.1 to 2.0 km from snout to accumulation zone. The area- elevation curve of the glacier is given in figure 1. The middle part of

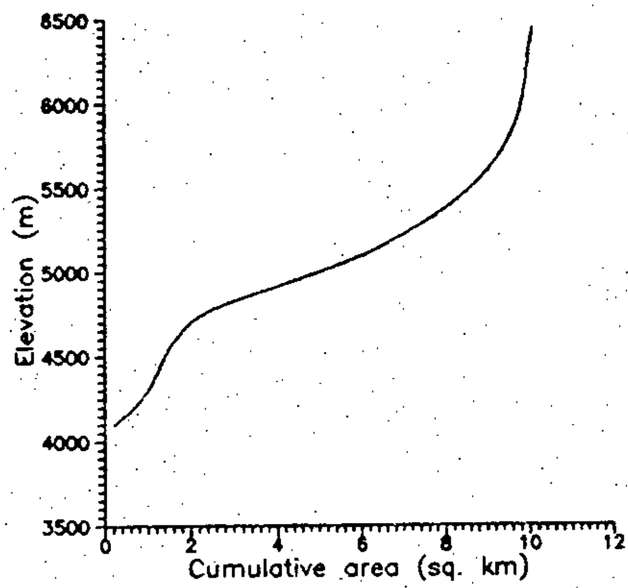


Figure 1: Area–elevation curve of the Dokriani glacier

the glacier is highly fractured and consists of crevasses, moulins, glacier table and ground moraines. The crevasses are found to be mainly of the transverse type which are wide and long. Sometimes longitudinal crevasses are also seen along the sides of the glacier.

The snout of glacier is situated at an elevation of about 4000 m and covered by huge boulders and debris. The lower portion of the glacier is almost covered by debris. The material of these moraines has been derived from the side of valley mainly by frosting. This glacier is bounded by two large lateral moraines which are about 200 m in height. Besides the above two lateral moraines, there are several other lateral moraines observed at different altitude. These different levels of moraines indicate the past extension of the glacier. The remnants of terminal moraines can be observed up to 2 km downstream of Gujar hut. These are partly covered by grass.

3. 0 HYDROLOGICAL INVESTIGATIONS ON THE MELT STREAM

3.1 Establishment of Gauging Site

Selection and establishment of the gauging site and observations of stream flow for mountainous rivers are difficult in comparison to the rivers flowing in the plain areas. The hydrological observations were made at the site which was established by NIH in 1992. The gauge site was selected after a survey of the melt stream starting from snout to about 2 km downstream was made. The melt stream was again surveyed during 1994 and 1995. During 1995 an officer of the Central Water Commission also joined the NIH team in the survey for identifying a suitable gauge- discharge site and after the survey the same gauge site which was established during 1992 and 1994 was found to be the ideal site. The selected gauging site was about 800 m downstream of the snout. A view of the gauging site is shown in Figure 2. The flow was not very much turbulent at this site and most of the boulders were removed from the channel. The site was about 1 km upstream of the confluence of the several small nallahs joining the main stream from southern side.

A temporary wooden bridge was made over the glacier melt stream (Figure 2). The cross-section area of the channel was determined with the help of this bridge. The float travelling length of not more than 8 m was available at the gauging site. A

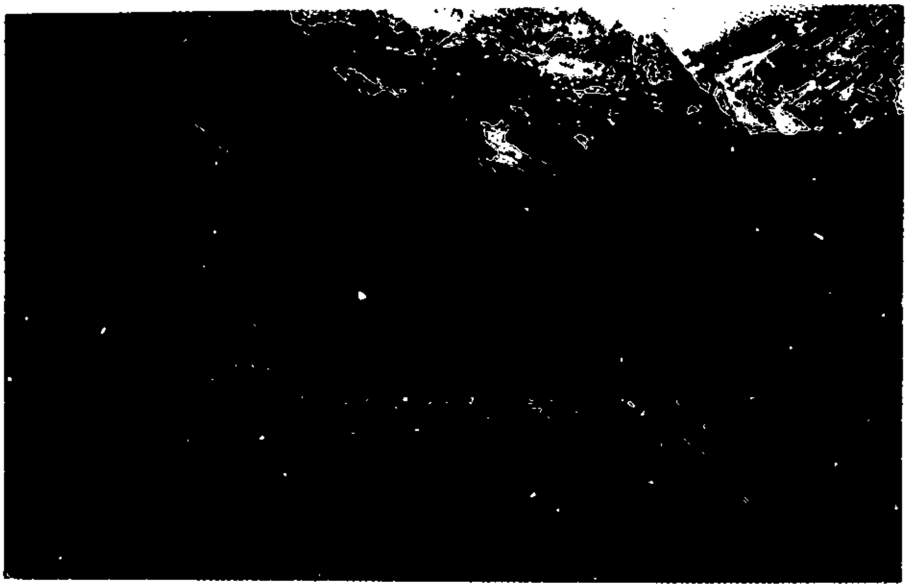


Figure 2 : View of the Discharge Measuring site on the Dokriani Glacier Melt Stream. with Glacier in the background

Figure 3 : Automatic Water Level Recorder near the Discharge measuring site on the Dokriani Glacier Melt Stream

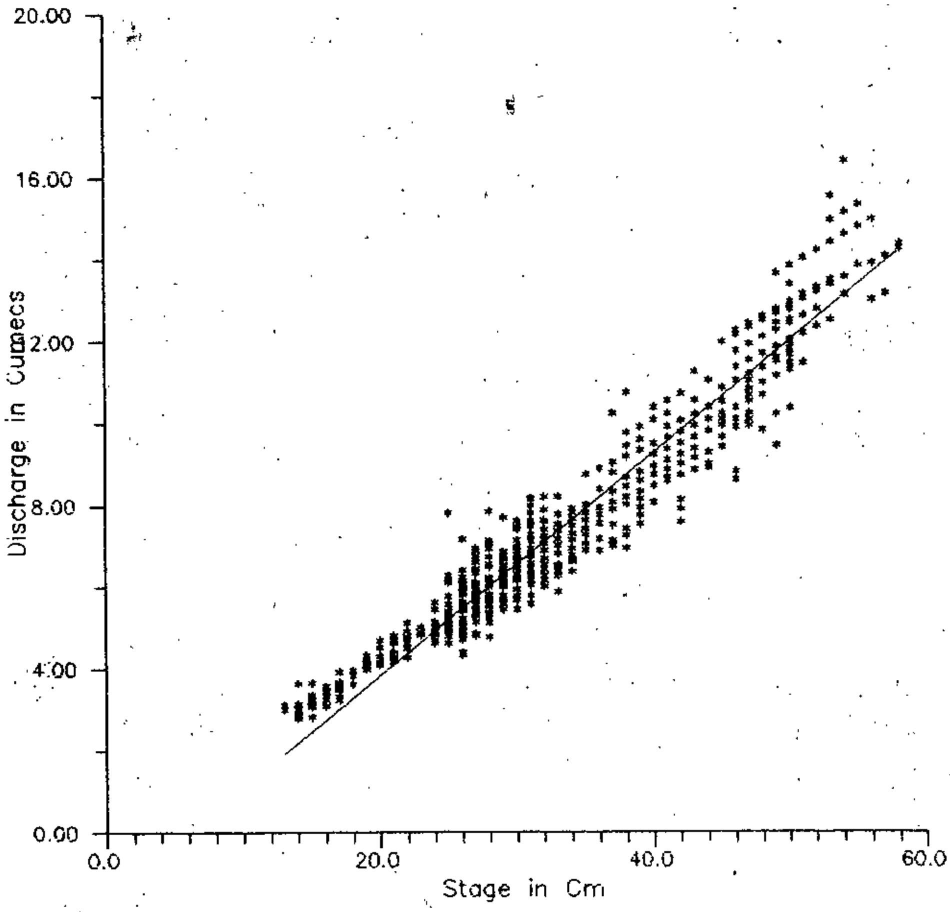


Figure 4 : Stage – Discharge Relationship for Dokriani Glacier – 1995 summer

graduated staff gauge was installed at the left bank of the stream for observations of water level fluctuations in the melt stream.

3 . 2 Measurement of Stream Flow

Velocity-area method was used to estimate flow in the melt stream. Wooden floats were used to compute the velocity of flow and time travelled by the floats was determined with the help of stop watch. For accuracy in velocity the readings were repeated at least three times and an average value was adopted for further computations.

3. 3 Automatic Recording of Water Level

Extensive streamflow observations at the glacier melt stream were made in 1995. A stilling well was constructed at the gauging site and an automatic water level recorder was installed for continuous monitoring of the flow. Daily charts were used for recording the water level fluctuations in the stream. The chart was changed daily at 0800 hrs(IST) Hourly manual observations were also made during day time. A view of location of the automatic water level recorder near the melt stream is shown in Figure 3.

3. 4 Stage - Discharge Relationship

Stage - discharge relationship was established for the gauging site. Later this relationship was used for determining flow only by recording the stage. The developed stage-discharge relationship is shown in Figure 4. However, time to time velocity was also ascertained for verification of flow computed using established relationship.

3. 5 Atmospheric and Melt Water Temperature

Hourly observations of atmospheric temperature and melt stream water temperature were made at the gauging site. The data was collected for the day period and mean daily values were computed using this data. The mean daily values of these records are shown in Figure 5. It is evident that maximum temperature for both atmosphere as well as stream water is attained in the month of June. After that both temperatures have shown decreasing trend. Variability in atmospheric temperature is very high as compared to the water temperature. Rainfall was observed almost daily at the base camp.

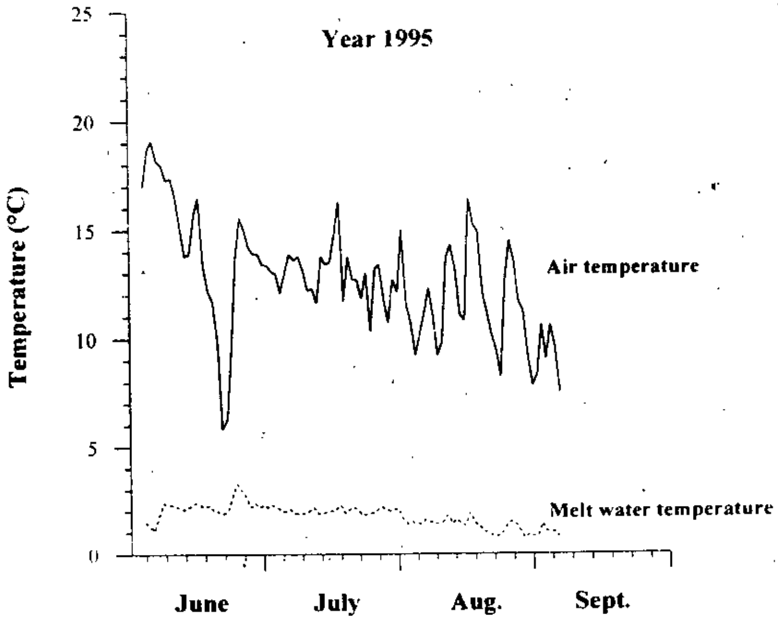


Figure 5: Mean daily air and melt water temperatures observed at the Dokriani glacier melt stream gauging site

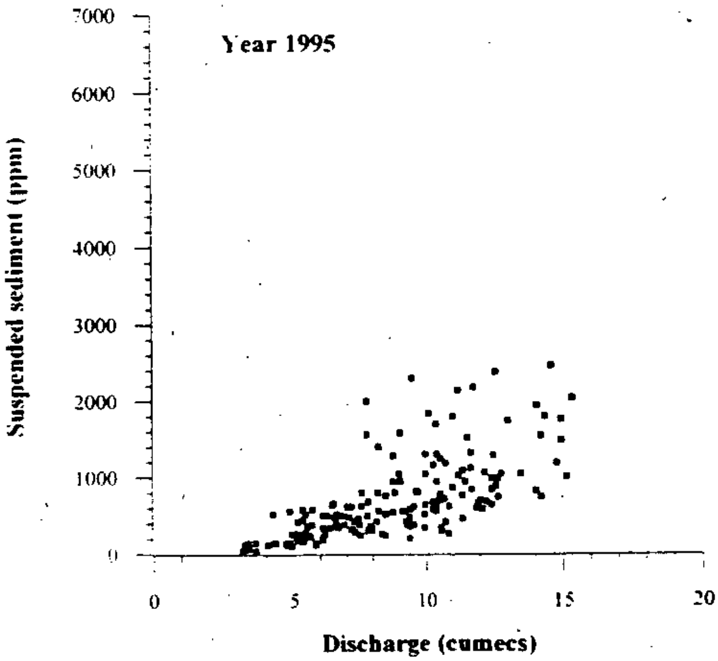


Figure 6: Changes in suspended sediment concentration with glacier melt runoff observed at gauging site

3.6 Suspended Sediment

Every day two or three samples were collected. At the same time flow was also measured. A known volume of water (500 ml) was collected from the stream and filtered using Whatman-40 ashless filter paper at the site. The filtered samples were properly packed in polyethylene bags marked with details of samples such as date and time of the sample collection etc.

The samples were analyzed in the Water Quality Laboratory of the institute at Roorkee. First empty silica crucibles were brought to their constant weight by heating and cooling system. The samples were placed in those crucibles and placed in the oven for more than 24 hrs. During this period, the temperature of the oven was maintained at 200 °C . The ashless filter paper was burnt completely in the high temperature. The crucibles were again weighed with samples of sediment . The net weight of sediment was determined by subtracting the weight of empty crucible from the total weight. Because the amount of sediment was very little, an electronic balance was used for weighing .

The changes in suspended sediment concentration with streamflow observed at the gauging site in 1995 field visit are given in Figure 6 . There is a high variation in the concentration due to rain events over the basin. Rain transports a lot of sediment into the stream from the valley sides. Landslides and rockslides also contribute in increasing the concentration and magnitude of suspended sediment in the stream. It results in no specific relationship between streamflow and concentration of suspended sediments.

Table 1: Monthly Water Yield from the Dokriani glacier basin and rainfall observed at the gauging site during 1994 and 1995

Year	Monthly water Yield (million cubic meter)			Rainfall (mm)		
	June	July	August	June	July	August
1994	8.29*	23.9	22.1	74*	510	476
1995	12.8+	25.1	24.0	174**	321	423

* 19 days starting from 12. 06 . 1994

+ 27 days starting from 04. 06. 1995

** 18 days starting from 13.06.1995

4. 0 RESULTS AND DISCUSSIONS

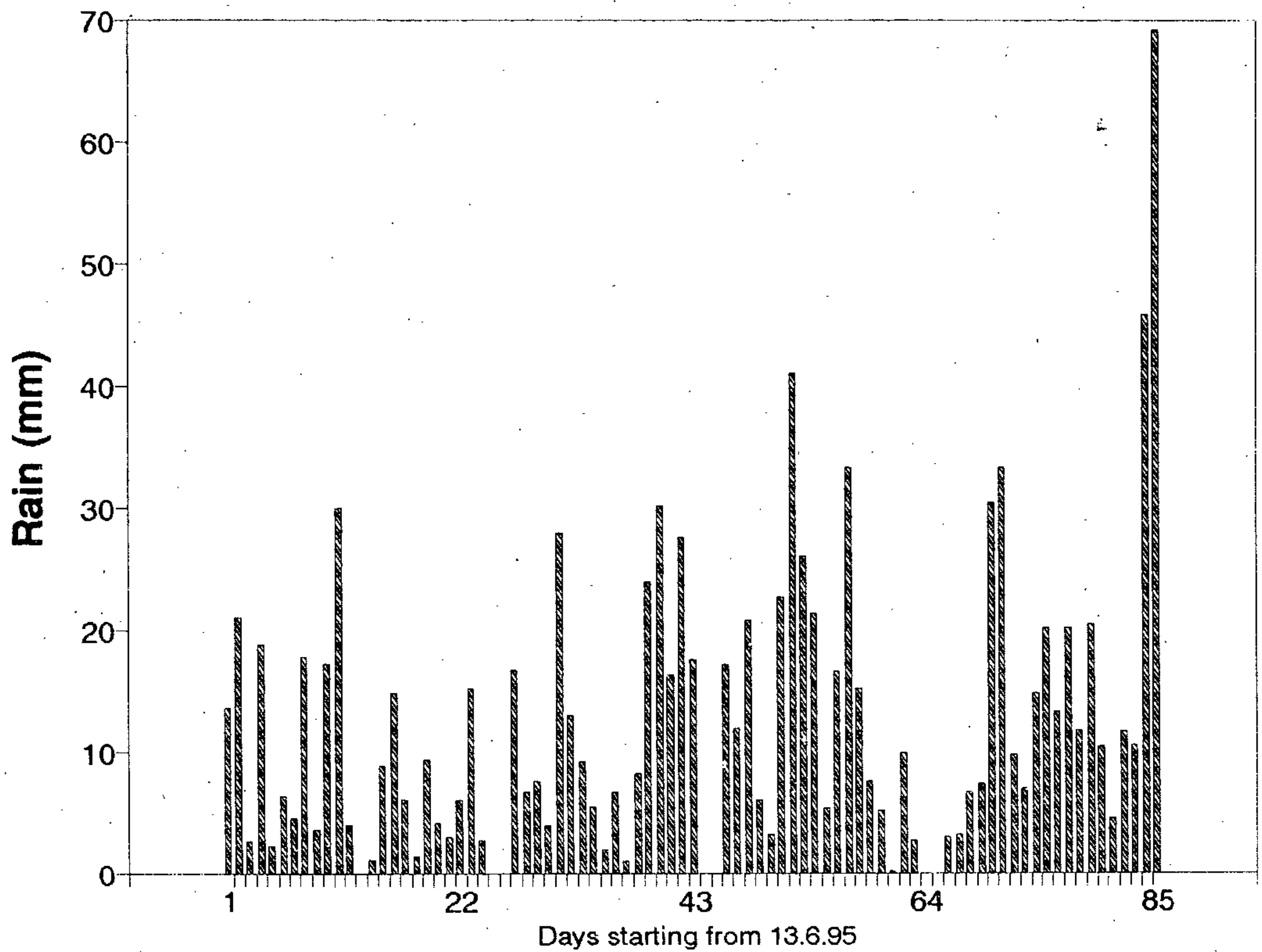
As mentioned above, the hydrological data collected for the months of June, July, August and September in 1995 made it possible to compute and compare water yield for different months in the glacier melt stream (Table 1). From the streamflow data, it can be noticed that a major part of the glacier melt runoff is received in the months of July and August. The water yield in the month of July has been observed to be slightly on the higher side. It is possible because of higher rain and temperature in July in comparison to August. It is found that maximum water yield in the melt stream is in the month of July and second to maximum in the month of August although all the water yield is not due to the melt alone as rainfall contributed a substantial part of runoff to the water yield.

It is also to be pointed out that, however, maximum air temperature has been recorded in the month of June in this region, but maximum flow is observed in the month of July. It can be explained by the extent of snow covered area of the glacier. In the month of June most of the glacier area is covered with snow and by virtue of higher albedo of snow, most of the radiation falling on the glacier surface is reflected back into the atmosphere and ultimately very less energy is used to generate the runoff. As the season advances, snowline moves up because snow over the glacier body melts away. Gradually snow cover area of the glacier decreases and glacier ice is exposed at the places where accumulated snow is completely melted. In the other words, ablation area of the glacier increases and accumulation area decreases as the snowline goes up and vice-versa when snowline moves down. The glacier ice has lower albedo and absorbs more energy in comparison to the snow surface. Obviously in the month of July and August temperature are lower but glacier physical conditions are more suitable to provide higher quantity of runoff. Temperature follows a decreasing trend due to initiation of cold climate in the region and melt rate of the glacier is also reduced which results in less flow in the melt stream.

Melt Discharge During Rain Free periods :

A close observation of rainfall and streamflow data indicates that most of the peaks in the streamflow are because of rainfall. To remove the effect of rainfall on the

Figure 7 : Rainfall Over Dokriani Glacier



discharge in the melt stream of the glacier, and to assess the contribution of the glacier melt only , rain free periods of durations of two or more days were selected (Figure 7). These periods were :

(i) 0800hr of 25th June to 0900hr of 26th June 1995
(ii) 0900hr of 08th July to 1000hr of 09th July 1995
(iii) 0800hr of 26th July to 0500hr of 28 July 1995
(iv) 0200hr of 15th August 1300hr of 16th August 1995

Hourly hydrographs for the above periods are shown in figures 8 to 11. It may be seen from these figures that the melt discharge is higher, 13 to 14 cumecs during July as compared to around 12 cumecs in August. The rates were low, less than 5 cumecs in June.

The delay characteristics of the rainfall contribution from the accumulation zone in comparison to the ablation zone makes regression analysis complex. It is expected that if Q, T and P data is available for four to five years, glacier melt runoff modelling studies may be carried out for this glacier. Such studies will consider melting processes and its transformation to the runoff using appropriate methodology. Keeping in view these aspects NIH is planning to make intensive observations of all the hydrological parameters for this glacier for 1996.

5.0 CONCLUSIONS

The following conclusions can be drawn from the study carried out on Dokriani glacier:

1. Maximum water yield from this glacier is observed in the month of July followed by the month of August. However, maximum air temperature has been recorded in the month of June.

2. The timing of peak runoff and recession rate changes as the glacier melt season advances. An early peak is noticed in July and August as compared with June . Recession is also faster in July and August in comparision to June. This is possible because of changes in storage characteristics of the glacier. Singh et al. (1995) used recession coefficients to explain the storage characteristics of the ablation and accumulation zones of the glacier.

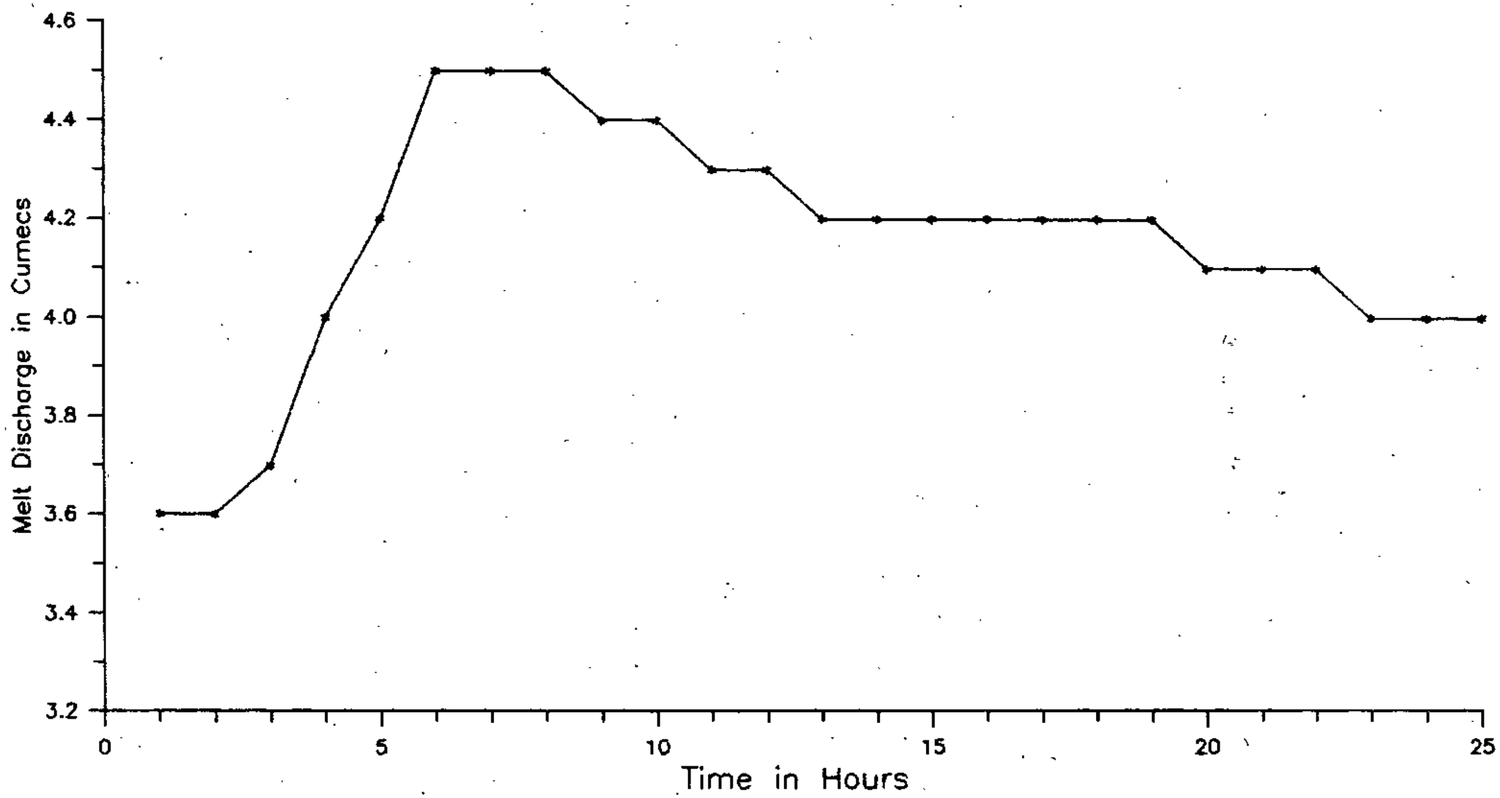


Figure 8 : Hydrograph of 25–26th June 1995 (starting 0800 of 25th) of Dokriani Glacier

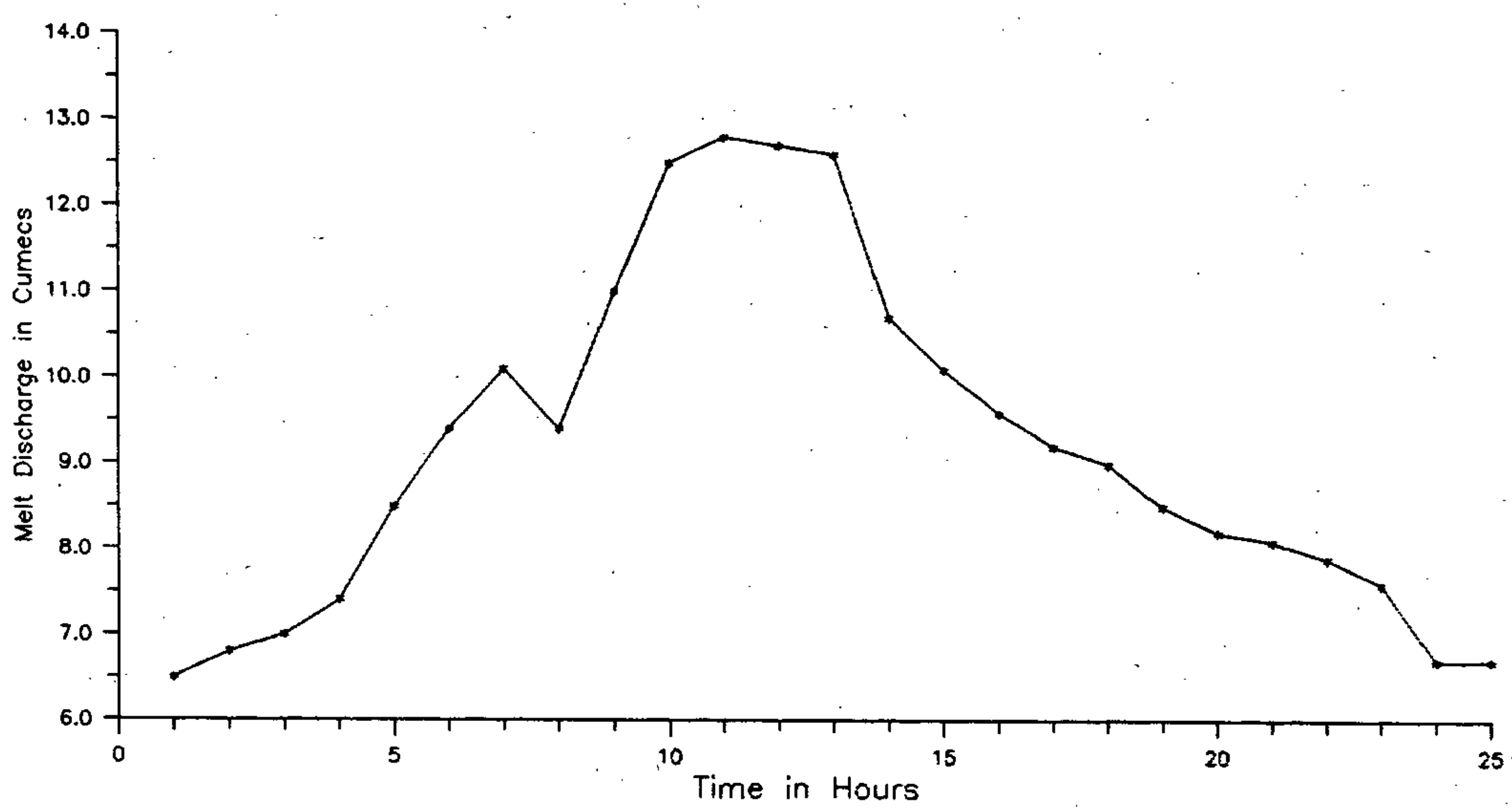


Figure 9 : Hydrograph of 7–8th July 1995 (starting 0900 of 7th) of Dokriani Glacier

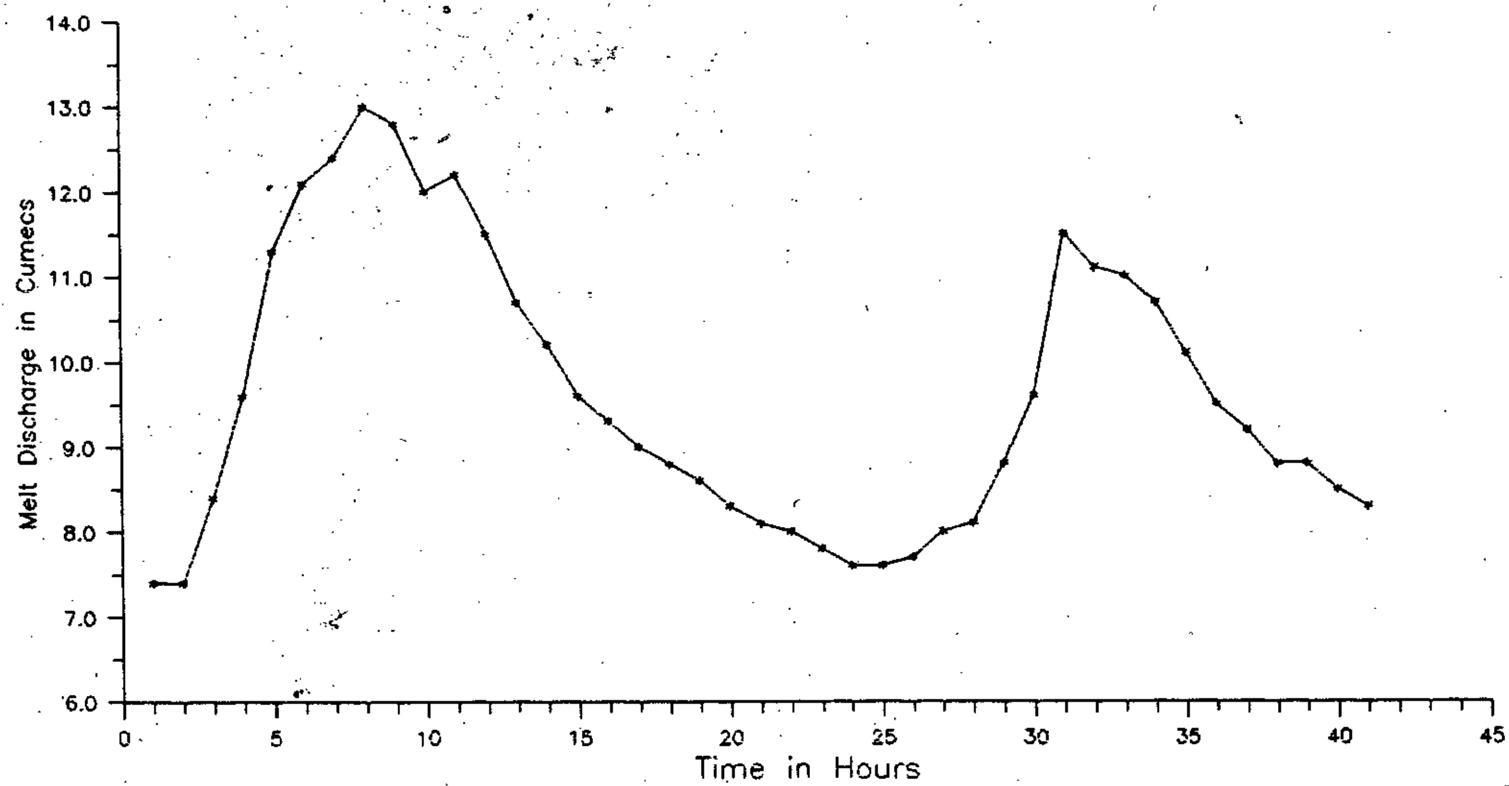


Figure 10 : Hydrograph of 26–27th July 1995 (starting 0800 of 26th) of Dokriani Glacier

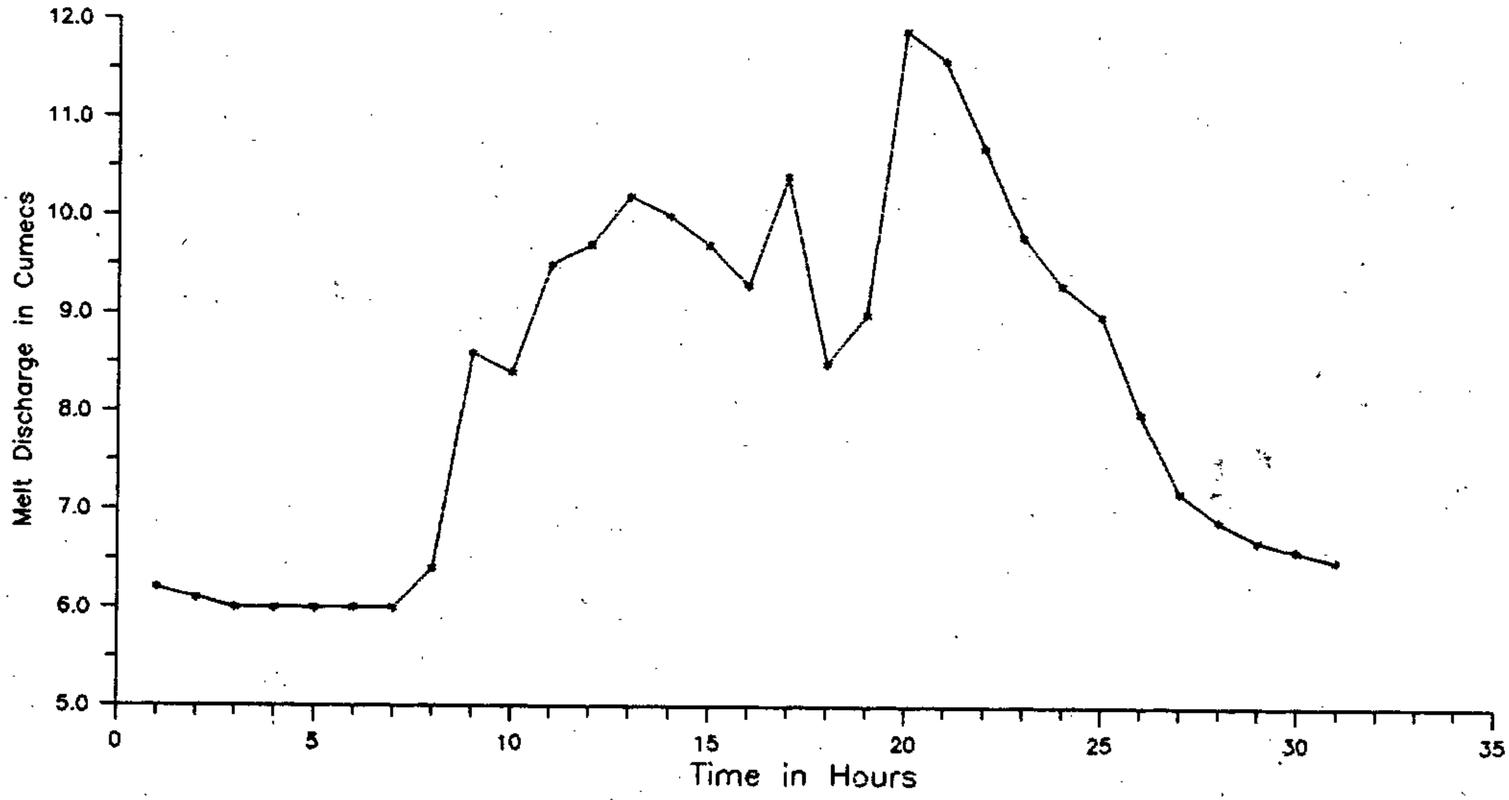


Figure 11 : Hydrograph of 15–16th August 1995 (starting 0200 of 15th) of Dokriani Glacier

3. Significant rainfall is observed in the months of July and August when maximum runoff is drained from the glacier. A close observation of rainfall and streamflow data indicates that most of the peaks in the streamflows are because of the rainfall.

4. Analysis of hourly hydrographs for the rain free periods indicated that the melt discharge is higher, 13 to 14 cumecs during July as compared to around 12 cumecs in August. The rates were low, less than 5 cumecs in June.

5. No relationship is noticed between streamflow and suspended sediment for this gauging site. Magnitude of rainfall affects the magnitude of suspended sediment at such places. Landslides also contribute in sediment concentration and magnitude in these streams.

6. After collecting Q,T and P data for two to three years or more, it is possible to carry out glacier melt runoff modelling studies for this glacier. A linear relationship between specific yield and mean daily temperature has been found by Singh et al. (1995) for rainfree period.

Acknowledgements :

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